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THE AIRPORT NETWORK FLOW SIMULATOR

Steven Gordon

U.S. DEPARTMENT OF TRANSPORTATION
Transportation Systems Center
Kendall Square
Cambridge MA 02142

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16. Abstract

The impact of investment at an individual airport is felt throughout the National Airport System by reduction of delays at other airports in the system. A GPSS model was constructed to simulate the propagation of delays through a nine-airport system. The model is largely based on, and calibrated to, scheduled air carrier itineraries through the system. It calculates statistics and costs for landing, takeoff, and gate arrival delays.

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PREFACE

As part of the FAA's program to rationalize its investment decisions, the Transportation Systems Center (TSC) has examined the relationship between airport investments and the level of service provided to the public by the National System of Airports. This report documents the preliminary design of one of the two models developed to translate airport capabilities and characteristics into levels of public service. The "Airport Network Flow Simulator" projects the impact of capability enhancements at individual airports on the performance of the airport system as a whole. A companion report, The Airport Performance Model,* determines the impact of investments at individual airports on the level and quality of service delivered to the public. Both models were developed under the sponsorship of the Federal Aviation Administration's Office of Aviation System Plans.

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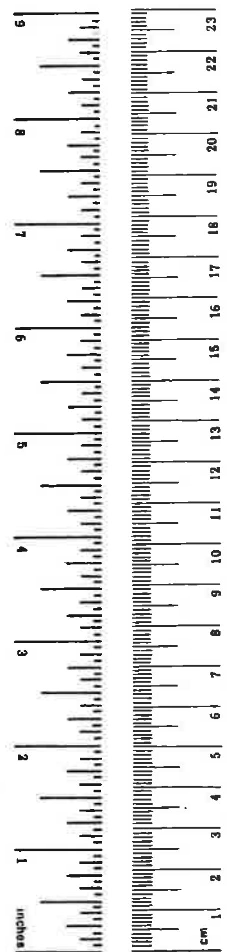
*David Hiatt, Steven Gordon, and James F. Oisen, The Airport Performance Model, Federal Aviation Administration, Washington DC 20591, FAA-ASP-75-5, April 1976.

METRIC CONVERSION FACTORS

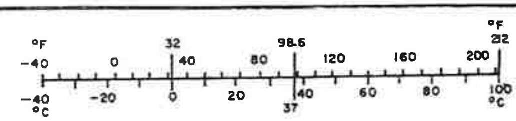
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1. INTRODUCTION

Since 1970, the Federal Government has spent over $280 million annually to subsidize airport improvements under the Airport Development Aid Program (ADAP). The FAA believes that this money has been spent wisely to increase the quality and quantity, and decrease the cost, of services offered to the air-traveling public. To substantiate this belief, and to create new rational guidelines for distributing ADAP funds, the FAA has sought to quantify the benefits attributable to ADAP-subsidized improvements. The greater part of this effort has been directed at assessing "airport specific" benefits – benefits obtained by flights operating at each of the improved airports. This report documents a complementary effort directed at assessing "system benefits" – benefits observed throughout the system when one airport is improved.

To the extent that there are system interactions in the National Airport System, they must manifest themselves through aircraft movements – the flows that characterize the network structure. Figure 1 illustrates how the performance of one airport can affect, through its impact on aircraft movement, the performance of the system. A hypothetical aircraft routed from LAX to BOS experiences delay on the LAX-ORD leg due to weather or traffic at

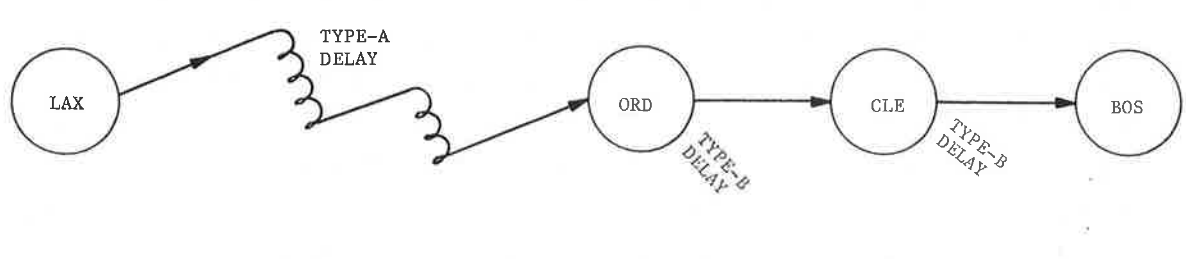

Figure 1. Difference Between Type-A and Type-B Delays

ORD. The flight arrives late at ORD and consequently departs late. If it cannot "make up" all delays on the ORD-CLE leg, it may also leave CLE late, even though the weather at CLE is clear and traffic is light. The delay experienced by the originating passengers at ORD and CLE is "propagated" from the original delay on the LAX-ORD flight leg. This propagated delay (hereafter called type-B to distinguish it from type-A, the primary delay – see Section 3.2 for a more detailed definition of these terms) would be eliminated if ORD's bad-weather capabilities were upgraded to the point of eliminating the type-A delay.

Although type-B delay does not impact airline direct operating costs – the aircraft and crew departing CLE late because of delays on the LAX-ORD flight leg need not experience additional delays at CLE – it quite significantly affects airline fleet utilization. If delays were not propagated, airlines could schedule their fleet tightly, allowing little excess time in the air and on the ground. But in reality, such a tight schedule would be disastrous once delays were encountered. A delay early in the day would result in the aircraft running late all day, causing many hours of passenger delay, and downgrading the airline's reputation for reliability. Passengers waiting for a late aircraft on a clear day at an uncongested airport are bound to blame the airline management for the type-B delay they experience. To avoid this blame, airlines generally include slack time in their schedules, a practice that decreases the utilization of their aircraft fleet.

Although experienced by most seasoned travelers, type-B delay has been summarily ignored by all past studies of the costs and benefits of delay reduction. By underrestimating total delays, these studies consequently have underestimated the relative benefits that can be achieved by delay-reducing equipment and procedures. They have also underestimated the relative importance of reducing delay at those airports serving predominantly continuing flights vis-a-vis those serving terminating flights. Considering the potential impact of type-B delays on passengers and airlines, this oversight should be corrected immediately.

To address this problem, TSC has developed the Airport Network Flow Simulator. This model simulates aircraft schedules and operations at and between the following nine major airports:

1. Atlanta
2. Logan (Boston)
3. O'Hare (Chicago)
4. Miami
5. La Guardia (New York)
6. JFK (New York)
7. San Francisco
8. National (Washington DC)
9. Los Angeles International

It computes type-A delays at these airports and type-B delays within the entire U.S. system that result from the propagation of the modeled type-A delays. It is sensitive to (accepts as input) the rate of operations at the nine airports, so that the effect of weather or airport improvements can be addressed. It is also sensitive to the aircraft schedules, so that the tradeoff between fleet utilization and type-B delay can be addressed.

Although it would have been desirable to validate the Airport Network Flow Simulator, and to apply it to the current system of airports and set of potential improvements, the scope of this study was limited to the model's development and calibration. Nevertheless, the calibrated model was run several times. Although the detailed outputs of the model will not be released until the model is validated, the preliminary runs have demonstrated the wisdom of modeling type-B delays. In particular they show:

1. If bad weather severely disrupts even one major commercial airport, type-A and type-B delays are on the same order of magnitude;
2. As type-A delay increases, type-B delay increases relative to type-A delay; and

3. The impact on type-B delay of changes in type-A delay is strongly dependent on the airport at which type-A delays are changed.

2. PROPAGATION OF DELAY A NETWORK EFFECT

Consider the plight of the passenger whose flight is delayed because its aircraft and crew have not arrived. His delay in the terminal, while waiting for the preceding flight to arrive, be refueled, and loaded with baggage, may exceed all other delays during the entire course of his flight. If he is lucky, the delay is short, or the airline substitutes a spare aircraft and crew for the delayed flight. If he is unlucky, the airline may induce him to remain at the airport by incrementally adjusting his estimated time of departure before finally canceling the flight. If the weather is good, and other flights at his airport operate on schedule, he may blame the delay, not understanding its cause, on the airline's management.

The airline is aware of the passenger's problem. It has deliberately scheduled more time than is necessary in the air and on the ground, enabling it to "make up" time lost on preceding flight legs, and thereby reducing the passenger's delay. In some situations, it substitutes spare aircraft for those delayed elsewhere. These precautions, however, cannot completely eliminate the passenger's delay.

Although most experienced air travelers can identify with this hypothetical passenger and most airlines are acutely aware of his existence, past studies of the costs and benefits of reducing delay have summarily ignored him. By treating the air transportation system as if it were composed of flights unrelated to one another in either time or space, the passenger's delay has been counted only from the time his aircraft is ready for boarding. By underestimating total delays, the benefits that can be achieved by delay-reducing equipment and procedures have been underestimated. Also underestimated has been the relative importance of reducing delay at those airports serving predominantly continuing flights as opposed to those serving terminating flights.

This study is therefore aimed at correcting this oversight by identifying and modeling the propagation of delays through the air transport network. In concludes that the costs of propagated delays generally of the same order of magnitude as the costs of delays measured in past studies (Reference 1). Furthermore, as delays increase, the propagations become increasingly important. When traffic increases, the costs of propagated delays alone can exceed the costs of traditionally measured delays. A methodology is developed to predict the volume of passengers the system can handle at a fixed level of service, assuming constant temporal and spatial patterns of travel, and accounting for the propagation of delays through the system. If the cost of increasing service capabilities at individual airports is known, the cost of increasing systems throughout can be computed using the methodology documented in this paper.

3. TYPES OF DELAY IN AN AIR TRANSPORT SYSTEM

3.1 DEFINITION OF DELAY

We define delay to be the time taken, exceeding some "minimal" standard, to perform some function. Since minimal standards may vary widely, the above definition is ambiguous. For example, airlines might measure their delays against the standard of the published schedule, and the Federal Aviation Administration against the schedule plus 30 minutes. Consequently, more definite standards must be defined for this study.

Choice of a standard, however, should not be critical in a comparative study. For example, one standard might show that a certain airport improvement changes a hypothetical scenario from one flight 10 minutes early, two on time, to three flights 10 minutes early. A stricter standard would show that the same improvement changes the scenario from one flight on time, two flights 10 minutes late, to three flights on time. Either standard shows that the airport improvement results in an absolute savings of 10 minutes for two flights. However, if performance may ever exceed the standard, care should be taken to count all resultant "negative delays." Failure to do so in the example above would show that the airport improvement results in no savings according to the first (relaxed) standard.

Care should also be taken in using standards that vary with changes in the operation of the system. The standard of the schedule is one such example. With this standard, increasing slack in the schedule will always reduce the measured delay. On the one hand, this would be inappropriate if fuel and crew cost and non-productive passenger time are the impacts of delay-reduction to be measured. On the other hand, this would be desired if the satisfaction of passenger expectations is the impact to be measured.

In the discussion below, we set standards according to the type of delay and the expected impacts such delays have upon the system.

3.2 TYPE-A AND TYPE-B DELAY

Two types of delay are defined: delays on a flight leg attributable to the lateness of a preceding flight leg, hereafter called "type-B"; and all other delays, hereafter called "type-A." Type-A delays occur, for example, when:

a. Loading baggage takes longer than expected

b. A flight, ready to take off, waits in a queue because of traffic.

c. A flight, ready for boarding, waits at the gate because of flow control.

d. A flight ready to dock waits for a free gate.

Type-A delays are those traditionally measured in studies of delay and congestion. Their major impacts have been identified as airline operating cost and nonproductive passenger time. Thus, we have selected a standard invariant to schedule — normal, uncongested, good-weather operation — to measure this type of delay. Since type-A delays generally result from congestion, particularly due to bad weather, negative delays should rarely occur. Furthermore, once incurred by a flight, type-A delays cannot be "made up" unless the flight proceeds faster after the delay than under normal, uncongested, good-weather conditions. If negative or "made up" delays are observed with regularity, the standard should probably be made stricter.

Type-B delay, the propagated delay, is experienced by a passenger who cannot board his desired flight on schedule because the aircraft and crew have been delayed on a previous flight leg. Type-B delay, since it impacts the passenger only insofar as his actual boarding time is later than his schedule boarding time, should be measured against the standard of the schedule. Since flights rarely depart before schedule, "negative delays" will not be a problem.

Figure 1 illustrates the difference between type-A and type-B delays for a hypothetical aircraft routing from Los Angeles to Boston. Due to weather or traffic at Chicago, the flight experiences type-A delay on the LAX-ORD leg. Passengers traveling from ORD to CLE or BOS experience type-B delay. Passengers traveling from CLE to BOS could also experience type-B delays if the flight cannot "make up" all the lost time before departing Cleveland.

Whereas type-A delay, if taken in the air, on the taxiway or even at the gate because of flow control, may increase fuel and crew costs and nonproductive passenger time, type-B delay directly affects only the enplaning passenger. The aircraft, crew, and on-board passenger, departing late because of late arrival, need not experience any additional delay.

Because airlines do not directly bear the cost of type-B delay, they might appear, incorrectly, to lack any incentives to reduce it. Such incentives do exist, because the passenger who experiences the delay may choose another flight, cancel his trip altogether, or, blaming the airline for the delay, choose another airline for his next trip. Therefore, type-B delay may result in a loss of airline revenue, particularly to airlines known for long or frequent type-B delays. An airline that schedules its aircraft and crew tightly runs the risk of having one delay at the start of the day propagate throughout the entire day, giving the airline a reputation for lateness. On the other hand, loose scheduling, while increasing passenger confidence in an airline's reliability, decreases aircraft and crew utilization, thus increasing cost. Consequently, type-B delay to the passenger can be traded-off against airline operating costs.

Type-B delay differs from type-A delay in that it can be eliminated by scheduling long groundtime between consecutive flights. If, for example, the aircraft whose route is illustrated in Figure 1 had 24 hours scheduled at ORD, it could experience long type-A delays on the LAX-ORD leg without propagating these delays through to passengers originating at ORD and CLE.

Type-B delay also can be eliminated if airlines keep a sufficiently large spare fleet and crew to substitute for aircraft and crew delayed on preceding flight legs. Reducing or eliminating type-B delay by this means is costly and generally is avoided, unless preceding flights have been canceled or diverted.

4. APPLICATIONS OF A MODEL THAT SIMULATES THE PROPAGATION OF DELAY

A model that simulates the propagation of delay can be used to answer many questions about the magnitude and impact of the propagated (type-B) delays. This section discusses how a model of type-B delays could be used to answer the following questions:

1. What is the magnitude of type-B delay? How does it compare in magnitude to type-A delay? Does the relative magnitude of type-B and type-A delay depend on the absolute magnitude of type-A delay?
2. Suppose type-A delay were reduced by a given amount at airport X. Does the reduction in type-B delay depend on X? If so, at which airports is a reduction in type-A delay more worthwhile?
3. How do airlines compute the cost of type-B delays?
4. How can a "system capacity" be defined?

4.1 MAGNITUDE OF TYPE-B DELAYS

A model that calculates type-B delays can be used to compare their magnitudes under differing circumstances. For example, the effects of the various weather patterns on type-A and type-B delays can be computed. Airport processing rates can be modified to simulate the effect of improving airport facilities. For example, bad weather airport processing rates can be increased to simulate the effect of adding an ILS or upgrading an existing ILS. Good weather airport processing rates can be increased to simulate the effect of a wake-vortex avoidance system at one or more of the congested airports. Schedules can be increased to simulate type-A and type-B delays that can be expected at traffic levels projected for future years. Airport processing rates can be decreased simultaneously at all airports to measure the impact of an increase in the percentage of wide-body aircraft in use.

Type-B delays do not vary directly with type-A delays. Schedules have been created so that small delays do not badly disrupt an aircraft's on-time performance down-range. However, long delays can work havoc on a tightly-constructed schedule. To investigate this hypothesized nonlinear relationship between type-A and type-B delays, it is necessary only to simulate very bad weather for different periods of time at several airports. As the period of bad weather is extended, type-A and the associated type-B delays are simultaneously increased. A graph such as that shown in Figure 2 can be constructed.

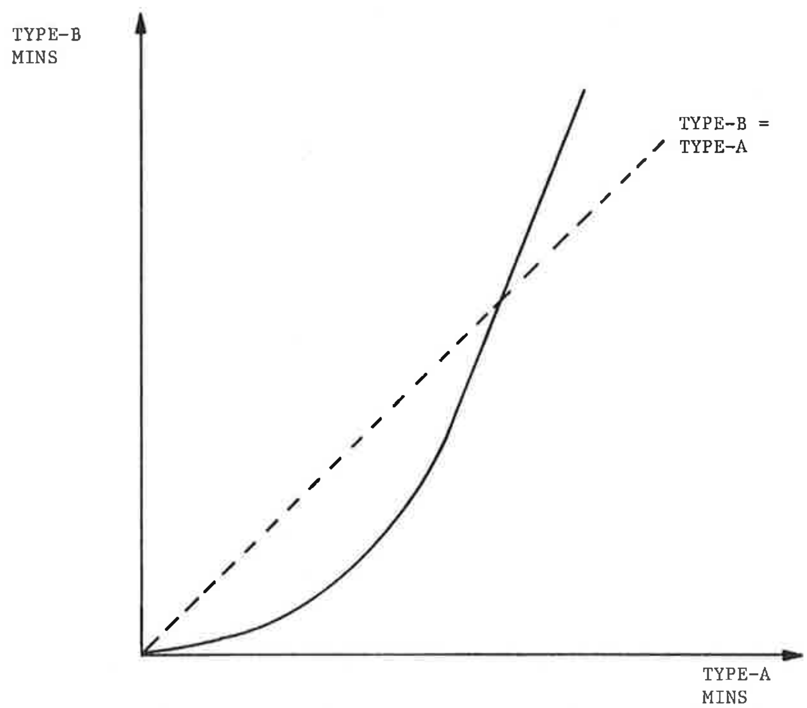

Figure 2. Type-A vs. Type-B Delays

4.2 DIFFERENTIAL REDUCTION OF SYSTEM DELAYS BY IMPROVEMENTS AT VARIOUS AIRPORTS

Since some airports serve primarily continuing flights, others, turn-around flights, and still others, the end-points of long flights, the amount of time aircraft are scheduled on the ground varies widely across all airports. Consequently, delays have a greater tendency to occur at some airports than at others. As a result, reducing type-A delay at an airport reduces type-B delay by differing amounts depending on the airport. Faced with alternatives of reducing delay at different airports on a limited budget, the most effective use of funds depends on the cost-effectiveness of reducing not only type-A but also type-B delay. Conceivably the money might be spent most effectively at those airports where the potential for reducing type-A delay is the least. In order to logically allocate a budget among requests for airport or F&E investments, a model is necessary to compute the expected reduction in type-A and type-B delays associated with such investments.

4.3 COST OF SYSTEM DELAY, AS INPUTTED BY AIRLINES

Let K_1 be the average scheduled flight time, K_2 the average minimum time an aircraft must remain on the ground between consecutive flights, and x the average slack time (exceeding K_2) that an aircraft is scheduled on the ground between consecutive flights. Then, with K_1, K_2, and x measured in hours, the average number of daily flights per aircraft, FPA, is:

$$FPA = 24/(K_1 + K_2 + x) \quad (1)$$

Let K_3 be the number of flights per day in the system. Equation (1) implies that the number of aircraft required, NAR, is:

$$NAR = K_3/FPA = K_3(K_1 + K_2 + x)/24 \quad (2)$$

Let K_4 be the daily cost of depreciation per aircraft (independent of whether or not it is used) or the opportunity cost of an aircraft, whichever is more. Then daily aircraft depreciation or opportunity costs, DADC, are:

$$DADC = K_4 * NAR = K_3 * K_4(K_1 + K_2 + x)/24 \quad (3)$$

Although type-A delay does not depend on how much excess ground time, x, is scheduled, type-B delay does. Figure 3 shows a hypothetical plot of the daily passenger-minutes of type-B delay as a function, f, of x.

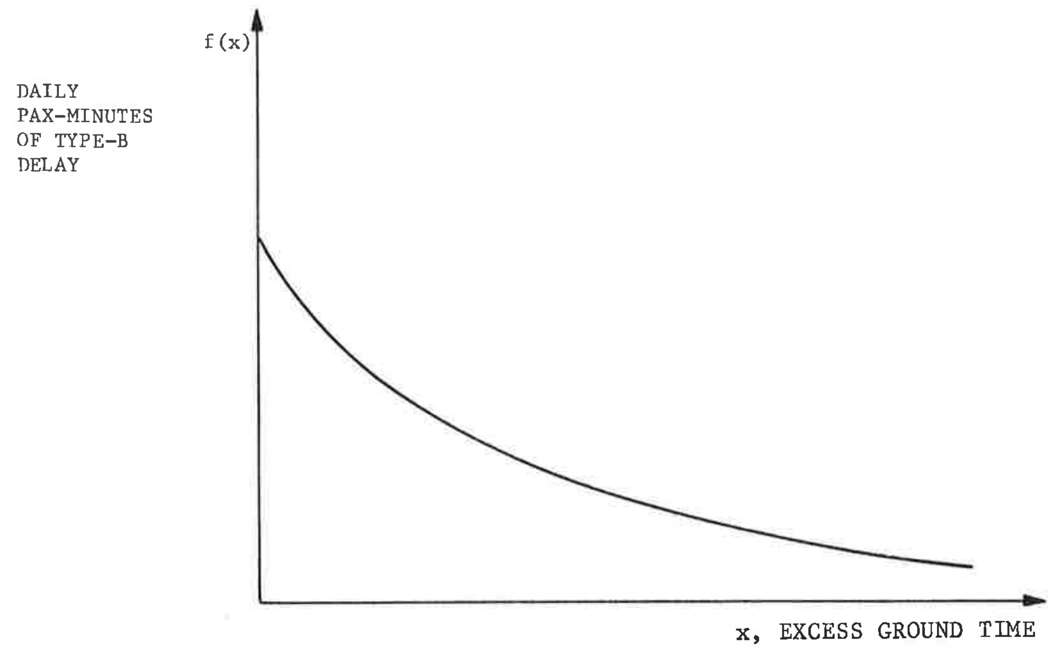

Figure 3. Type-B Delay as a Function of Excess Ground Time

Function f(x) is concave in x. The first extra minute of ground time reduces by 1 minute the propagation of delay caused by each flight that arrives 1 or more minutes late. By contrast, the second extra minute of ground time reduces by 1 additional minute the propagation of delay caused by each flight that arrives 2 or more minutes late, but reduces by less than 1 additional minute the propagation of delay caused by each flight arriving more than 1 but less than 2 minutes late. Therefore, the second minute of slack reduces propagation of delays less than the first minute of slack. This argument can be continued to show that $f''(x)>0$.

Let y be the value the airlines impute to a passenger-minute of type-B delay. Then the total daily airline cost, TC, for an average of x minutes scheduled slack ground time is:

$$TC = \left[K_3K_4\left(K_1 + K_2 + x\right)/24\right] + yf(x) \qquad (4)$$

If we assume, by definition that the airlines have minimized their imputed cost, then $\frac{\partial TC}{\partial x} = 0$, or

$$0 = \frac{K_3K_4}{24} + yf'(x) \qquad (5)$$

which implies

$$y = - K_3K_4/\left[24f'(x)\right] \qquad (6)$$

We can use equation 6 to uncover the airlines' imputed cost of a minute of type-B passenger delay. If the airlines keep x small, f'(x) is large and negative, implying y is small. On the other hand, if x is large, f'(x) is small and negative (approaching zero), implying y is large. This is to be expected. If the airlines impute a large cost to type-B delay, they will attempt to minimize it by scheduling long ground times. On the other hand, if they feel that type-B delays are not particularly significant, they will schedule short ground time so as to use their fleet at a maximum.

In order to compute y, we must first compute f(x) and find reasonable values for parameters K_3 and K_4. In order to uncover function f(x), we must use a model that simulates the propagation of delay through a network; K_3 and K_4 must be uncovered by other methods.

4.4 DEFINING "SYSTEM CAPACITY"

The capacity of a system of airports is not well-defined. A high level of operations can be accommodated within any system as long as we are not concerned about the level of service that is offered. The level of operations a system can accommodate is lowered if some minimal standards of level of service are set. For example, we might reasonably ask the question: What level of operations can the system accommodate if the average passenger is to be delayed no more than 10 minutes?

Unfortunately, the answer to this question does not conform to our concept of a system capacity. A high level of operations can exist in off-peak hours and to airports for which there is little demand without violating the constraints on level of service. However, the capacity so provided has little value. What we really mean by capacity is the limit of volume that could be handled were passengers to maintain the currently prevailing pattern of travel in both space and time, without exceeding minimal standards of level of service.

A model that maintains the current temporal and spacial patterns of travel, and computes type-A and type-B delays would be useful in computing a "system capacity." Total traffic volumes could be gradually increased until the delays exceed the standard limit. Capacities could then be defined as the level of operations at the point. Improvements at congested airports would increase the computed capacity. Improvements at airports that experience little delay when the total level of operations is at capacity would not significantly increase the system capacity.

5. THE AIRPORT NETWORK FLOW SIMULATION MODEL

This section documents the Airport Network Flow Simulator (ANFS), a model designed to capture the propagation of delays through an air transport network. The model is written in GPSS, a high-level simulation language for the IBM-360 computer. Appendixes A, B, and C contain, respectively, a user's manual, program listing, and technical documentation.

5.1 OVERVIEW

Figure 4 illustrates the functions of the ANFS model. Aircraft schedules, or statistical descriptions of such schedules, standard flight times between the modeled airports, and processing rates at the modeled airports comprise the inputs to the ANFS model. The model computes type-A delays associated with airport congestion and type-B delays resulting from the propagation of type-A delays through the system.

The ANFS model is composed of separable schedule and flight simulators. The two simulators are run in parallel, as illustrated in Figure 5. The schedule simulator reproduces aircraft schedules from statistical descriptions of such schedules. Actual schedules, if available, can be used in place of the schedule simulator. The flight simulator reproduces aircraft operations, including departure from a hanger, docking at a gate, preparation for passenger boarding, taxiing, taking off, flying, landing, passenger deboarding, preparation of the aircraft for the following flight, and return to the hanger at the end of the day.

The ANFS model steps through time, accumulating type-A delay any time an aircraft is forced to wait in a landing or takeoff queue or any time an aircraft must wait for a free gate (note that not all type-A delays are modeled). Type-B delay is accumulated any time an aircraft is scheduled to depart but is not ready to depart. As shown in Figure 5, type-A delays may exceed the difference between scheduled and actual arrival times if some delay

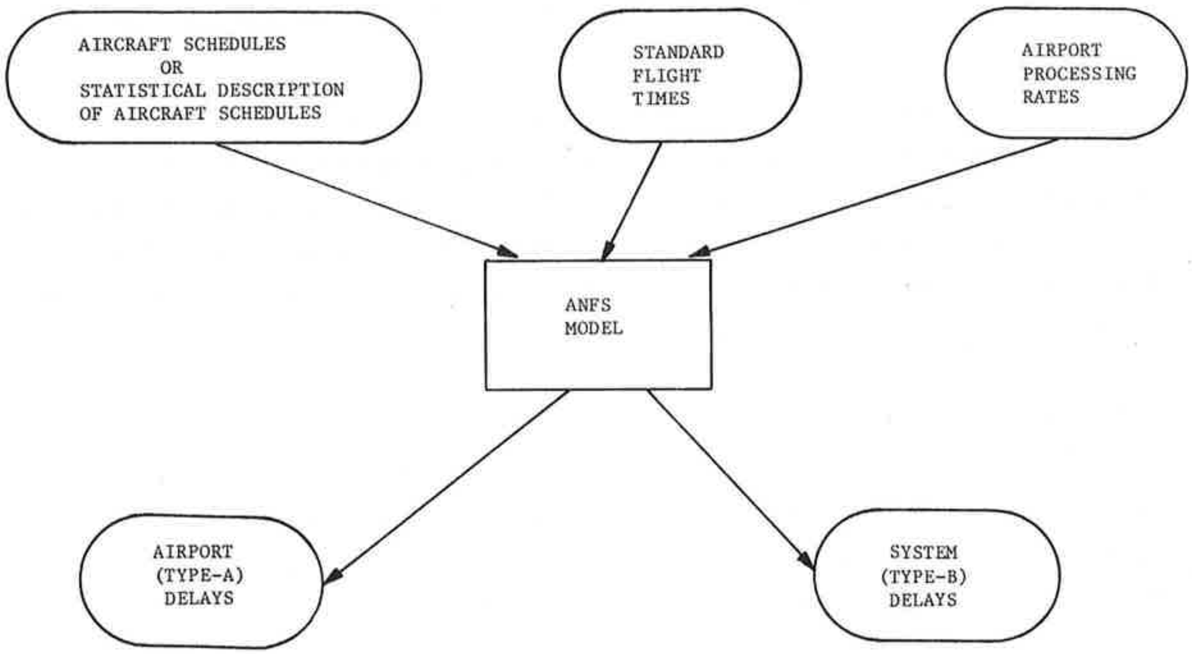

Figure 4. Overview of ANFS Model

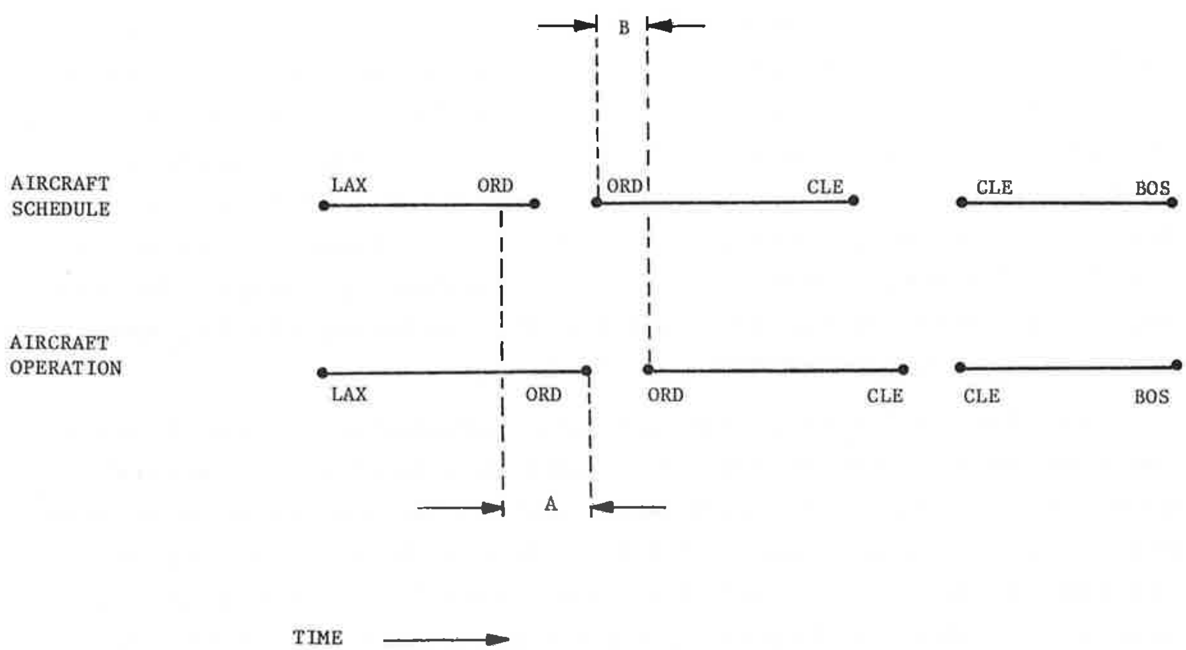

Figure 5. Airport Network Flow Simulator

is built into the schedules. Type-B delay depends solely on the divergence of the scheduled and actual departure times. In the example of Figure 5, the long scheduled ground time at CLE eliminates propagation of type-B delay beyond CLE, even though the aircraft arrives late.

Currently, the model is designed to consider only the propagation of delays originating at the nine major airports listed in Section 1. Type-A delays at all other airports are ignored. Figure 6 illustrates the scope of the simulation. "The System" is defined to include everything above the dotted line. Aircraft not originating at one of the nine airports enter the system from the circle at the lower left as flights from airports not modeled. Because they are assumed to arrive without delay until they attempt to land, that portion of their flight is not modeled. Once they are ready to land, they have entered the system, and their activity is modeled. The point where the arriving flights enter the system is illustrated by the break in the arrow of Figure 6. All flights between any of the nine airports and all activity at the nine airports are modeled. Aircraft that leave the system with delay and reenter it with delay are modeled within the system, as are all activities at the intermediate airports (except that no additional type-A delays are incurred). Aircraft leaving the nine airports without delay are modeled only until they have taken off, as represented by the broken arrow on the right of Figure 6. Aircraft leaving the nine airports with delay, never returning, or returning on schedule, are modeled outside the system only until they have completely caught up with their schedule. Then they are dropped from the system, as shown by the break in the arrow at the lower right in Figure 6.

It is anticipated that the scope of the model will be expanded in the near future. Limitations on the current model are due to storage restrictions pecular to GPSS. Implementation of the model in FORTRAN will relieve this constraint as well as reduce computation time, an important consideration as the scope of the model is expanded.

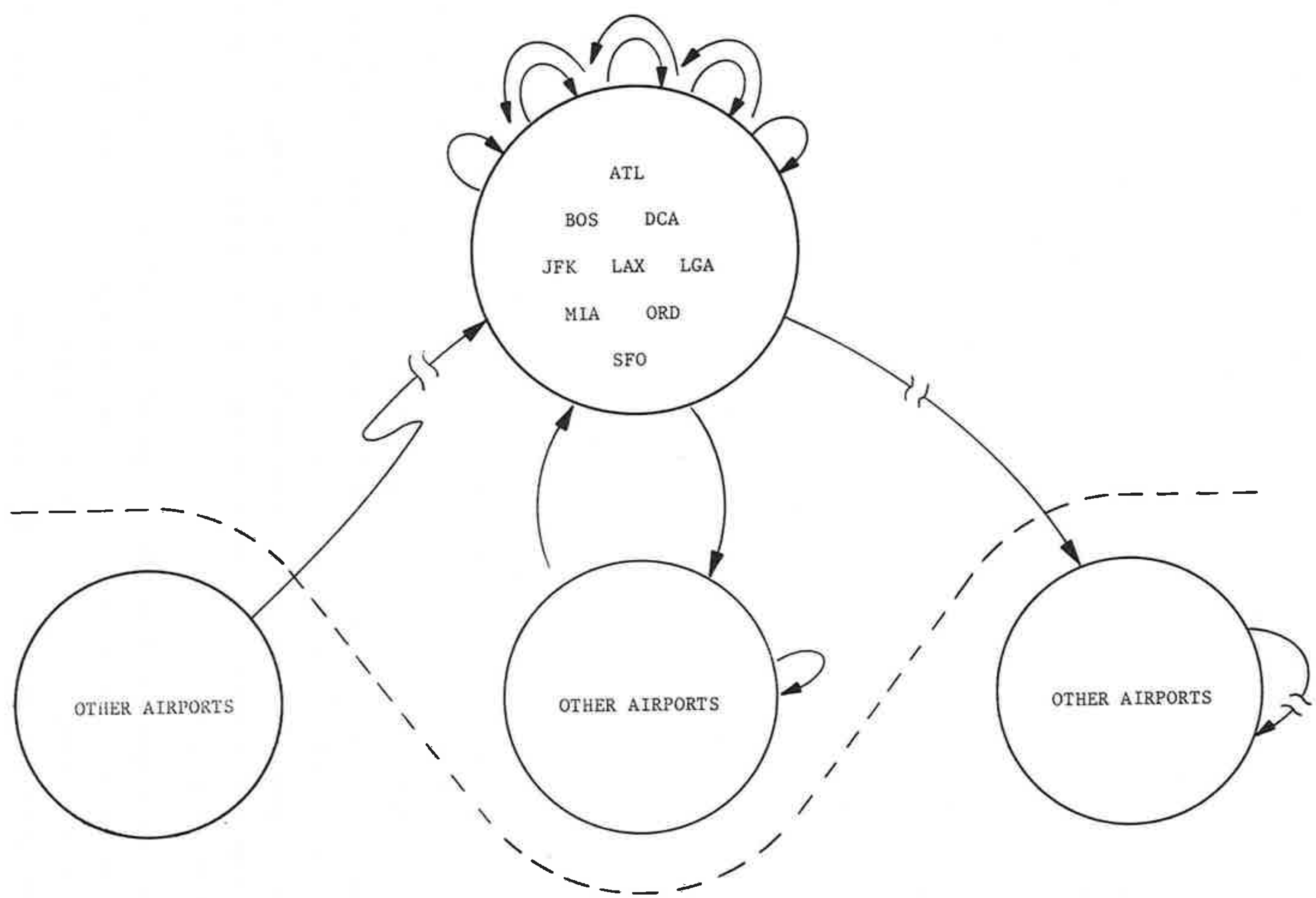

Figure 6. Current Scope of Simulation

5.2 THE SCHEDULE SIMULATOR

The schedule simulator reproduces aircraft schedules. It may be used instead of actual aircraft schedules when:

1. Schedules are desired for some date in the future having traffic volumes different than current volumes;
2. The model is used to investigate the impact on delay of changing certain parameters of the current schedule, such a slack built into air or ground time; or
3. Aircraft schedules are unavailable. Aircraft schedules may be unavailable to the modeler because they are unpublished. The Official Airline Guide (OAG) publishes flight itineraries, but little public information exists on the actual schedules of aircraft as they proceed from flight to flight.

5.2.1 Inputs to the Schedule Simulator

The following parameters are used by the schedule simulator to reproduce aircraft schedules (more details and technical documentation appear in Appendix B):

1. ASP1 (Hour) - For each hour of the day, the spacing (in seconds) of arrivals from outside the system
2. PNDES (Origin, Destination) - For each origin-destination pair, the fraction of flights leaving the origin that are destined for the given destination
3. ORAC (Airport) - For each airport, the number of aircraft that overnight daily
4. ARTIM (Origin, Destination) - For each OD pair, the standard (minimal) air time (in minutes)
5. TWO22 (Hour) - For each hour, the fraction of aircraft departing that will return the same day
6. POVTI (Hour) - For each hour, the fraction of aircraft arriving that will remain at the airport overnight

7. POVAP (Airport) - For each airport, the fraction of arrivals that remain at the airport overnight relative to (divided by) that fraction for the entire system (e.g., an average airport in the system)

8. PCOTI (Hour) - For each hour, the fraction of nonovernight arrivals that are continuing flights (same flight number)

9. PCOAP (Airport) - For each airport, the fraction of nonovernight arrivals that are continuing flights relative to (divided by) that fraction for the entire system

10. TINCO (Hour) - For each hour, the time scheduled at the gate for noncontinuing, nonovernight aircraft arriving that hour, relative to the average hour

11. APNCO (Airport) - For each airport, the average time scheduled at the gate for noncontinuing, nonovernight aircraft (in seconds)

12. TICO (Hour) - For each hour, the time schedule at the gate for continuing flights arriving that hour, relative to the average hour

13. APCO (Airport) - For each airport, the average time scheduled at the gate for continuing aircraft (in seconds)

14. NXHDP (Hour) - For each hour, the average time between departures from overnight hangers (in seconds).

ASP1 provides the hourly rate of arrival of flights from outside the system. PNDES and TWO22 are used to route the aircraft in the system, and AIRTM is used to find the air time for any flight route. ORAC, POVTI, POVAP, and NXHDP provide information about flights that overnight at one of the airports in the system; e.g., how many overnight at each airport, what time they arrive, and what time they leave. PCOTI and PCOAP are used to determine which aircraft continue with the same flight number and which change flight numbers before continuing. TINCO, APNCO, TICO and APCO contain information on how long aircraft are scheduled to remain on the ground between flight legs.

5.2.2 Operation of the Schedule Simulator

The operation of the schedule simulator is illustrated by the flow-charts shown in Figures 7, 8, and 9. Figure 7 charts the flow of the scheduler for aircraft entering the system from outside. Figures 7 and 8 show the operation of the scheduler for flights starting within the system. Figure 9 illustrates the operation of the scheduler for flights leaving the system with delay. In parentheses are the inputs to the associated step in the model's operation.

Flights are scheduled to enter the system at a rate, input by the user, that may vary every hour. A destination airport is selected, and the flight is scheduled to arrive 300 seconds after entering the system. Aircraft that remain at the airport overnight are scheduled to leave the gate for the hangar one-half hour after their scheduled arrival. Of the aircraft that arrive and leave, some fraction is assigned new flight numbers. All are then scheduled to depart, with those having the same flight numbers scheduled to remain on the ground for a shorter period than those having new flight numbers. A destination airport is selected and a scheduled arrival time computed based on the acheduled departure time, the minimal air time between the two airports, and some slack. If the destination lies outside of the system, the schedule of the aircraft terminates. Otherwise, the scheduler continues as with the previous flight leg, using the old destination airport as the origin for the new leg.

Aircraft starting the day inside the system are scheduled similarly to those entering from outside the system except for their departure. They are scheduled to leave the hangar and dock at a gate 1 hour before departure. Their release from the hangar is timed by the user's input. On the first simulated day, the number of hangered aircraft at each airport is input by the user. Otherwise, the number hangared at each airport on a given day is determined by the scheduler during the preceding day.

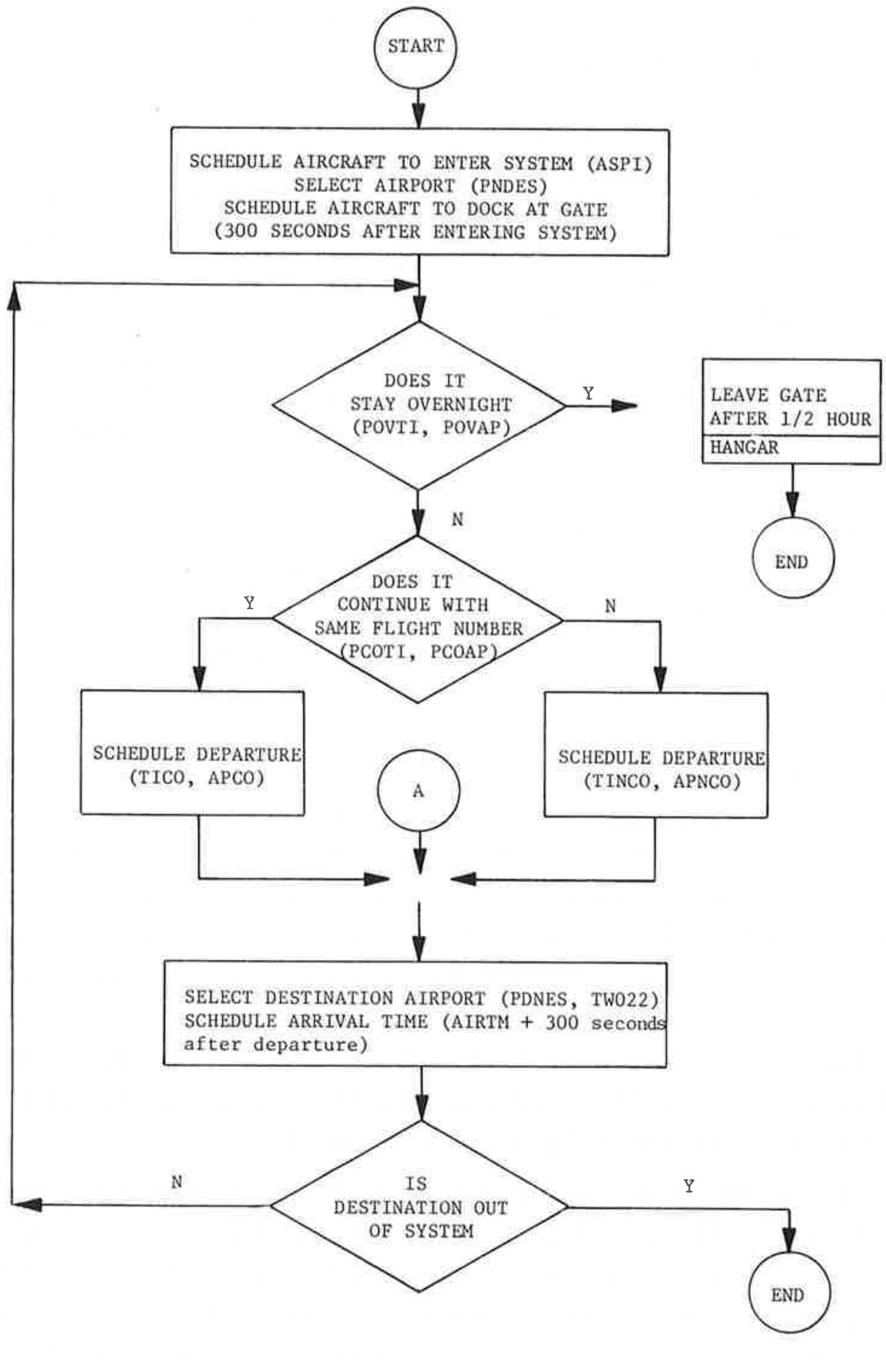

Figure 7. Schedule of Flights Entering System from Other Airports

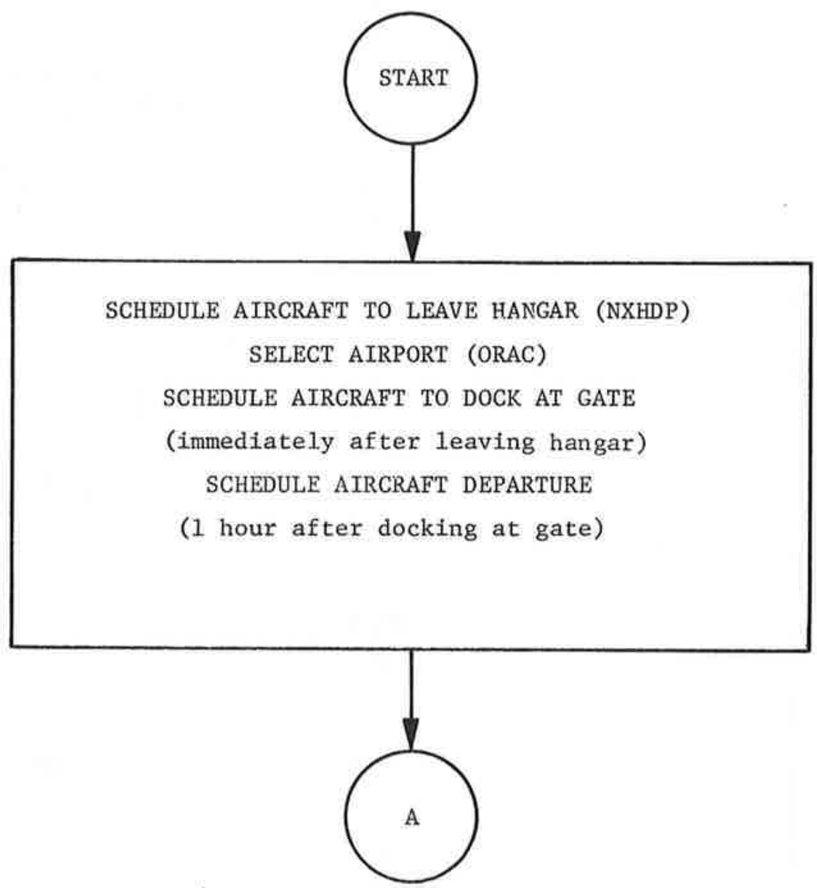

Figure 8. Schedule of Flights Starting Within System at Beginning of Day

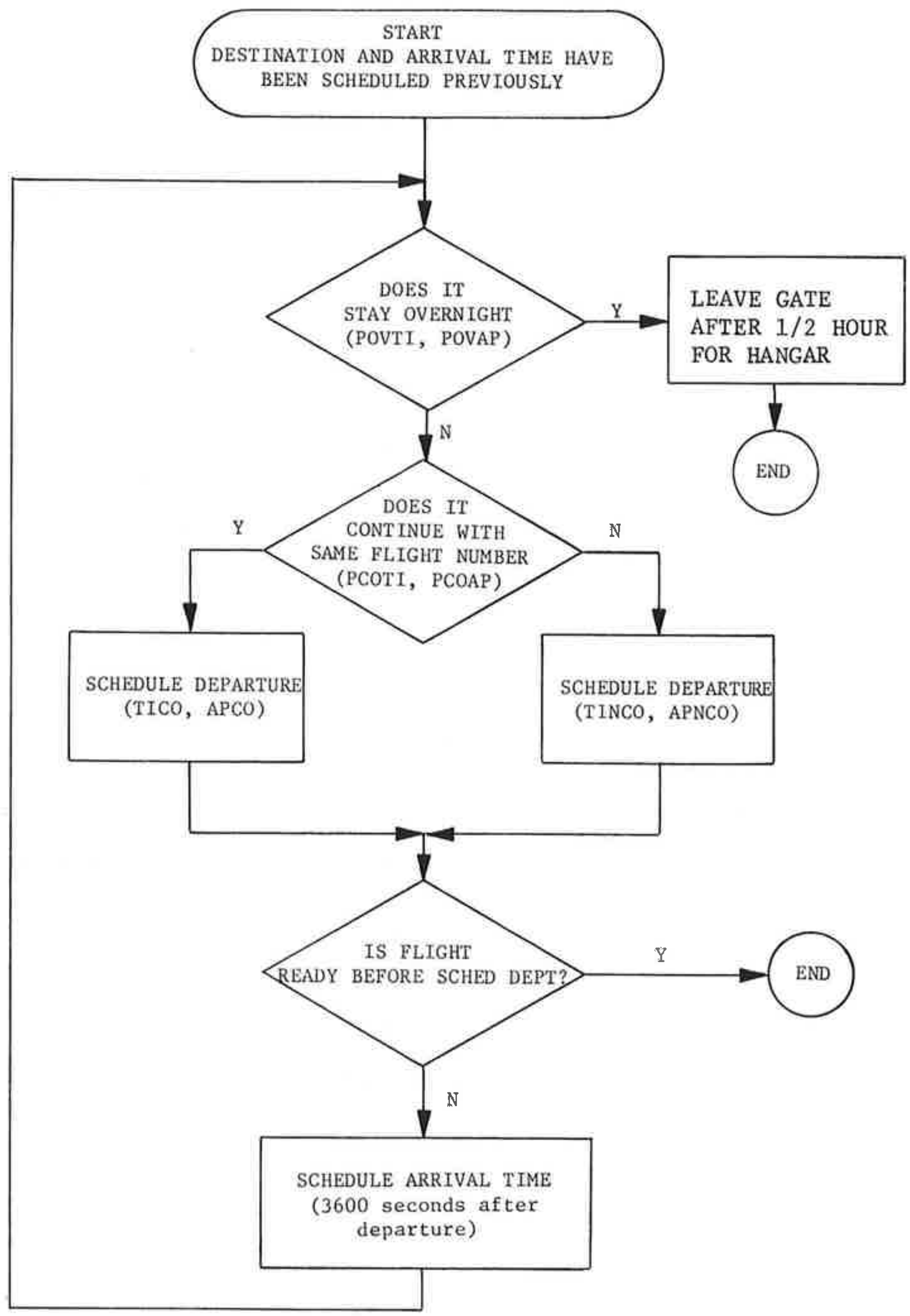

Figure 9. Schedule of Flights Leaving System with Delay

Once aircraft leave the system, the scheduler described above, one independent of the aircraft's actual operation, ceases. Flights that leave the system with delay activate a similar schedule simulator that interact with the flight simulator. It is similar to the independent schedule simulator except that:

1. Before every scheduled departure, the status of the flight is interrogated. If it is ready to depart, the actual and schedule simulator are simultaneously terminated for that aircraft.

2. The scheduled arrival airport is not computed. All airports outside of the system are assumed to be identical.

3. The scheduled arrival is assumed to occur 3600 seconds (1 hour) after the scheduled departure.

5.3 THE FLIGHT SIMULATOR

The flight simulator reproduces the airside activity at all of the airports in the system and the flights within the system. The flight simulator may be driven by an actual schedule or by a schedule created by the schedule simulator. The outputs of the flight simulator are statistics of activity on the system, including an O-D flight matrix and information on delays and queues, as well as statistics on type-B delay outside the system.

5.3.1 Inputs to the Flight Simulator

The following parameters are used by the flight simulator to reproduce aviation activity at and between airports in the system (for further detail, see Appendix B):

1. RWOT - Runway occupancy time (in seconds); the inverse of the airport processing rate, as a function of airport and time

2. ARTIM - For each OD pair, the standard (minimal) air time (in minutes)

3. GAFAC - For each airport, nonscheduled activity as a fraction of scheduled activity, to two decimal places

4. Aircraft Schedules - For each aircraft that enters the system, an itinerary of arrivals and departures, with times and airports, from time of system entry to time of system departure

5. Airport Gate Facilities - For each airport, the number of simultaneously useable aircraft gates.

RWOT provides the airport processing rate. This may vary with time to allow the user to simulate varying weather patterns. ARTIM provides the flight time between airports in the system in an uncongested environment. GAFEC inputs the general aviation and other nonscheduled activity that competes with the scheduled flights for use of the airport facilities. Aircraft schedules may be drawn from the schedule simulator or from actual schedules input by the user. Airport gate facilities must be input so that queues for gates may be simulated. Since the simulator does not differentiate among airlines, the number of gates input should be slightly lower than the number that exist to reflect the circumstance of one airline's flights waiting for a gate while other airlines have gates available.

5.3.2 Operation of the Flight Simulator

The operation of the flight simulator is illustrated by the flow charts of Figures 10 and 11. Figure 10 shows the operation of the simulator for aircraft activity within the system; Figure 11 shows its operation for aircraft activity outside the system.

Simulation of flights entering the system from outside begins at the moment that flight is scheduled to enter the system. Since type-A delays are assumed to be nonexistent outside the system, the flight always arrives on time. It queues for landing, waiting its turn as it and other aircraft are processed by the airport's runway system. It then lands, occupying the runway system for a period of time (the user-input, runway-occupancy time), forcing all aircraft that arrived later to wait in a queue for landing or takeoff. Aircraft are served on a first-come, first-served basis whether they wait in a landing or takeoff queue.

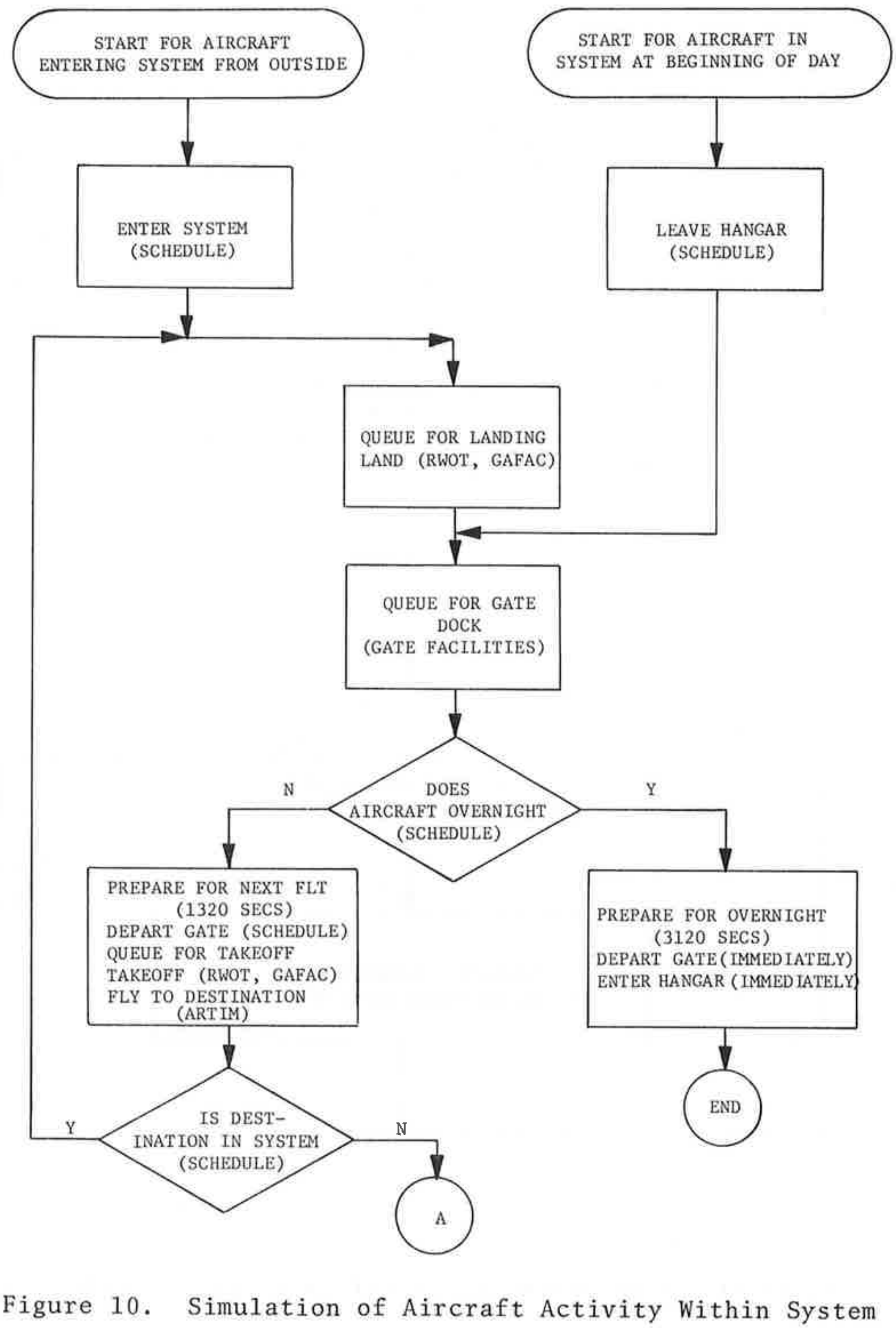

Figure 10. Simulation of Aircraft Activity Within System

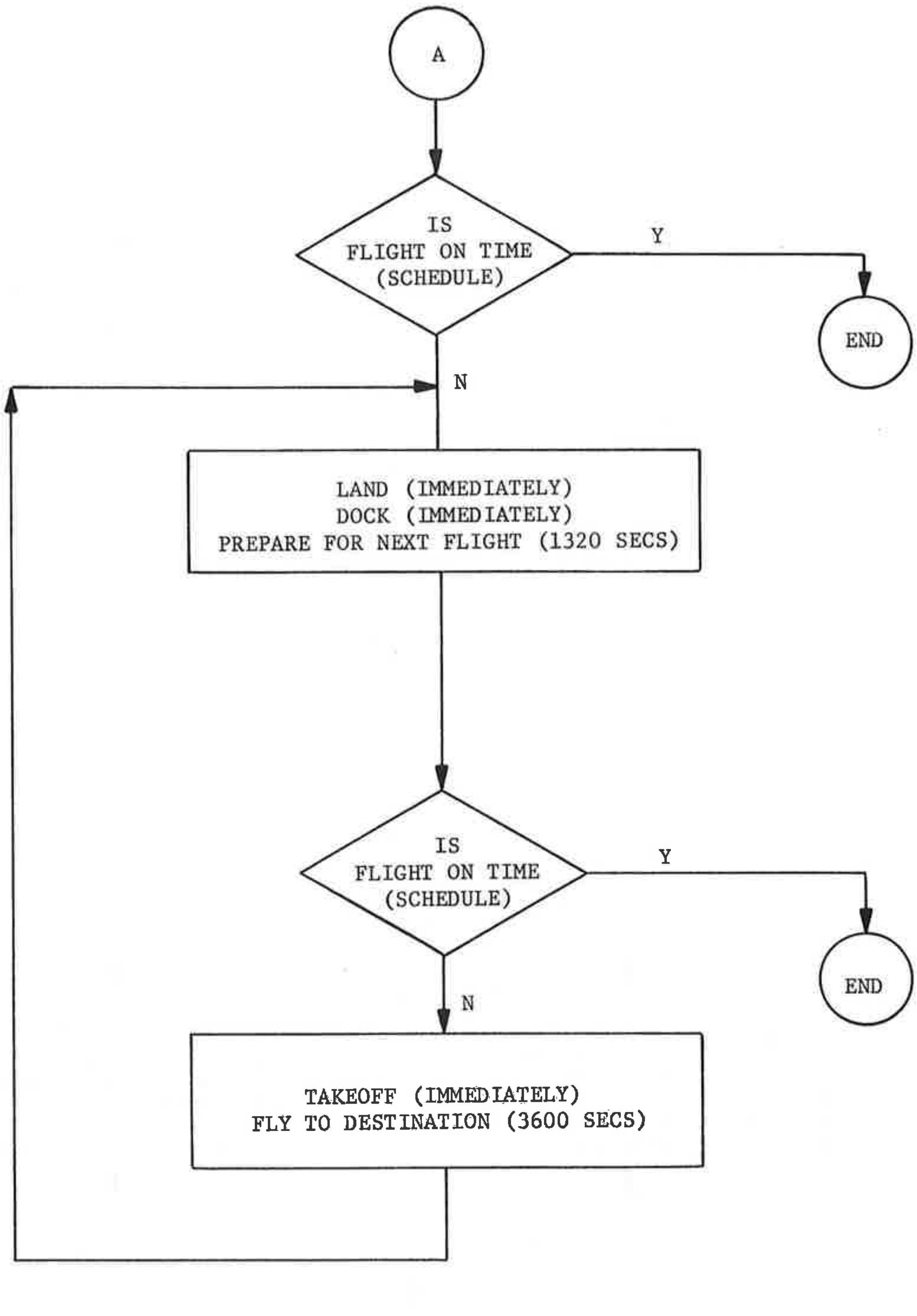

Figure 11. Simulation of Aircraft Activity Outside System

Simulation of aircraft that are in the system at the beginning of the day starts when the aircraft is scheduled to leave the hanger. It is assumed always to leave the hangar on schedule and to queue, with those aircraft that have loaded (from outside or inside the system) for a gate. From this point, all aircraft activity within the system is simulated identically.

When a gate becomes available the aircraft docks and passengers and luggage are deboarded. If the aircraft is to remain overnight, it remains at the gate 3120 seconds before departing for the hangar. Otherwise, it remains at the gate at least 1320 seconds to deplane and enplane passengers and luggage and to prepare the aircraft for the following flight leg. Then it departs the gate on schedule or as soon as it is ready, whichever is later. It queues for takeoff, takes off, and flies to its destination. If the destination is in the system, it queues for landing, and continues its activities from outside the system. Otherwise it may be simulated outside the system, as shown in Figure 11.

If the aircraft leaves the system on schedule, it will not incur any additional delay, so the simulation of its activity is terminated. If the aircraft leaves the system late, delay may propagate outside the system. The flight, however, will incur no new type-A delays. It lands immediately on arriving at its destination, docks at an available gate, and prepares for the following flight leg, deplaning and enplaning passengers and baggage, taking 1320 seconds. If it is ready to depart on schedule, the simulation of its activity ends. Otherwise, it takes off and flies to its destination, arriving 3600 seconds after departure. Simulation continues, as described above, until the aircraft "catches-up" to its schedule.

5.4 CALIBRATION OF THE MODEL

5.4.1 Calibration of the Schedule Simulator

The schedule simulator creates realistic aircraft schedules based on statistics that describe such schedules. Unfortunately, neither real aircraft schedules nor statistics to describe them are publically available. The Official Airline Guide (OAG), issued biweekly, publishes flight schedules. These differ from aircraft schedules in that information is lost regarding the link between consecutive flights having different flight numbers and using the same aircraft. This makes it impossible to trace the propagation of delay from one flight to the next.

The difference between flight and aircraft schedules is illustrated by the hypothetical example of Table 1. The schedule for aircraft #237 takes it from DFW, through LGA and DCA, to BNA. If the aircraft is delayed several hours landing at LGA, the delay may be propagated through to the LGA and DCA originating passengers. The flight schedule shows the two flights that constitute the aircraft schedule described above. If the flight schedule were used instead of the aircraft schedule to model type-B delays, propagation of landing delay at LGA would be overlooked since the flight following flight #89 is unknown.

In order to calibrate the model, aircraft schedules were created. These schedules are based on the OAG plus some simple rules to link consecutive flights having different flight numbers. The procedure used to create such linkages is described below.

At each of the nine modeled airports, for each airline and aircraft type, the arrivals and departures are listed. Arrivals and departures with the same flight number are automatically linked. The remaining arrivals and departures are linked so that the fewest number of aircraft are required (minimizing the aircraft fleet, as is reasonable), subject to the condition that widebody aircraft must be scheduled for at least 40 minutes and all other aircraft for at least 30 minutes on the ground. Frequently, this rule results in several plausible linkages. In that case, the linking was selected that maximized the minimum slack time. (Slack time is the difference between the scheduled departure and the scheduled arrival.) Since this rule uniquely specifies only one linkage – the one with the minimum slack time – it is possible that several ways exist to link the remaining arrivals and departures. In that case, the rule, "maximize the minimum slack time" is re-applied until all linkages have been specified.

TABLE 1. DIFFERENCE BETWEEN AIRCRAFT AND FLIGHT SCHEDULES

AIRCRAFT SCHEDULES

AIRLINE = XX   AIRCRAFT = 72S

TAIL NO.	FROM	DEPART	TO	ARRIVE	FLT. #
⋮	⋮	⋮	⋮	⋮	⋮
237	DFW	11:00	LGA	14:59	89
	LGA	17:45	DCA	18:44	115
	DCA	19:10	BNA	19:43	115
⋮	⋮	⋮	⋮	⋮	⋮

FLIGHT SCHEDULES

AIRLINE = XX   AIRCRAFT = 72S

FLT. #	FROM	DEPART	TO	ARRIVE
⋮	⋮	⋮	⋮	⋮
89	DFW	11:00	LGA	14:59
⋮	⋮	⋮	⋮	⋮
115	LGA	17:45	DCA	18:44
	DCA	19:10	BNA	19:43
⋮	⋮	⋮	⋮	⋮

Once linkages between arrivals and departures have been specified, aircraft schedules are simple to create. Flights arriving from outside the system start an aircraft schedule. These are followed by the flight to which they have been linked. This procedure continues until a flight's destination is outside the system or the aircraft remains on the ground overnight — it arrives before 8 a.m. GMT (3 a.m. EST) and departs after 8 a.m. GMT. Other aircraft schedules start at one of the nine modeled airports. When a flight arriving after 8 a.m. GMT is linked to a flight departing after 8 a.m. GMT, the first flight becomes the end of an aircraft schedule and the second flight the beginning of another. Typically, aircraft overnights arrive at about 11:00 p.m and depart at about 6 a.m. local time.

The following statistics were collected by airport and by airport and by hour of day:

1. Number of flights arriving from outside the system
2. Length of scheduled time between arrival and departure of consecutive flights with the same flight number
3. Length of scheduled time between arrival and departure of consecutive flight numbers
4. Number of flights departing after an overnight.

These statistics, summarized in Tables 2 to 7, were used to calibrate the inputs to the model so that realistic schedules could be simulated.

Since arrivals and departures outside the system are not linked, no record is kept in the aircraft schedule of the return of flights that had previously left the system. Consequently, data to calibrate function TWO22 were unavailable. Function TWO22 has been set reasonably, but has not been calibrated.

In calibrating the schedule simulator, 50 flights were found to be in the air at 3:00 a.m. EST. After the simulation of the first day, these flights would be correctly scheduled by the simulator. In order to correctly simulate arrivals on the first simulated day, flights in the air at 3:00 a.m. EST were treated as if arriving from outside the system. The spacing of arrivals of flights from outside the system was appropriately reduced for flights arriving in the first simulated day by means of function ASP2.

TABLE 2. BEGINNING OF AIRCRAFT SCHEDULES BY HOUR (EST)

HOUR	ARRIVALS FROM OUTSIDE SYSTEM	DEPARTURES FROM WITHIN SYSTEM
1	38	0
2	37	0
3	24	0
4	15	14
5	22	16
6	10	43
7	48	100
8	146	132
9	147	90
10	163	95
11	198	64
12	155	53
13	192	23
14	217	12
15	227	14
16	209	11
17	255	7
18	183	3
19	229	6
20	163	0
21	216	0
22	125	0
23	136	0
24	66	0

TABLE 3. SCHEDULED MINUTES BETWEEN ARRIVAL AND DEPARTURE, BY HOUR (EST)

HOUR OF LANDING	AIRCRAFT CONTINUING WITH SAME FLIGHT #	AIRCRAFT CONTINUING WITH NEW FLIGHT #
1	45	97
2	61	65
3	33	30
4	66	368
5	75	319
6	142	250
7	48	254
8	52	149
9	51	134
10	48	116
11	49	118
12	44	109
13	47	109
14	49	113
15	48	99
16	44	117
17	49	104
18	44	104
19	56	102
20	41	103
21	41	121
22	53	143
23	51	117
24	53	106

TABLE 4. SCHEDULED MINUTES BETWEEN ARRIVAL AND DEPARTURE BY AIRPORT

AIRPORT	AIRCRAFT CONTINUING WITH SAME FLIGHT #	AIRCRAFT CONTINUING WITH NEW FLIGHT #
ATL	56	111
BOS	53	105
DCA	30	99
JFK	76	167
LAX	43	146
LGA	34	84
MIA	56	122
ORD	50	98
SFO	46	163

TABLE 5. CONTINUANCE OF AIRCRAFT SCHEDULE BY HOUR OF ARRIVAL (EST)

LANDING	CONTINUING WITH SAME FLIGHT NO.	CONTINUING WITH NEW FLIGHT NO.	SCHEDULED OVERNIGHT
1	14	4	34
2	15	5	38
3	2	1	36
4	12	16	0
5	8	26	0
6	13	15	0
7	26	42	0
8	61	107	3
9	73	109	1
10	72	120	4
11	91	150	4
12	60	143	5
13	79	152	3
14	101	176	5
15	97	189	3
16	72	168	12
17	111	183	25
18	69	141	26
19	99	144	42
20	51	99	68
21	77	82	109
22	25	46	87
23	44	29	103
24	22	13	70

TABLE 6. CONTINUANCE OF AIRCRAFT SCHEDULE BY ARRIVAL AIRPORT

AIRPORT	CONTINUING WITH SAME FLIGHT NO.	CONTINUING WITH NEW FLIGHT NO.	SCHEDULED OVERNIGHT
ATL	318	193	55
BOS	46	219	76
DCA	116	184	54
JFK	82	243	80
LAX	194	297	92
LGA	56	220	62
MIA	20	192	77
ORD	405	431	112
SFO	87	207	78

TABLE 7. ORIGIN - DESTINATION MATRIX

	ATL	BOS	DCA	JFK	LAX	LGA	MIA	ORD	SFO	OTHER
ATL	-	4	12	9	9	12	19	16	2	486
BOS	5	-	19	15	3	27	4	19	3	246
DCA	15	20	-	5	0	23	8	26	0	253
JFK	10	16	3	-	15	0	16	15	9	324
LAX	9	2	0	18	-	0	3	29	76	455
LGA	13	26	22	0	0	-	10	31	0	232
MIA	17	4	8	15	2	11	-	8	1	225
ORD	18	19	25	14	27	32	9	-	20	766
SFO	4	2	0	10	71	0	1	22	-	263
OTHER	477	248	261	321	459	229	221	767	261	-

5.4.2 Calibration of the Flight Simulator

Only three sets of data were necessary to calibrate the flight simulator. Airport processing rates – or, equivalently, runway occupancy time – for good and bad weather were taken from Reference 2. The number of gates at each airport was obtained from the same source. The number of gates were reduced by about 10% to reflect airline ownership or rental of gates, a condition that may result in gate delays existing even when some gates are unused. Finally, the general aviation factor was obtained from the FAA Terminal Area Activity Statistics (Reference 3).

6. MODEL EXTENSIONS AND REFINEMENTS

The model documented in this report was designed to be a first step towards a more extensive model to simulate type-B delays and their relation to type-A delays. The current version of the model can be improved in numerous ways. We anticipate that those improvements relating to the efficiency of the computer code will be implemented in the near future. Other improvements, relating to the realism of the model, will be implemented only when the validity of the model is deemed insufficient for its anticipated use.

6.1 IMPROVEMENTS IN COMPUTERIZATION

6.1.1 Recoding in FORTRAN

GPSS is an interpretive language. As such, it is inefficient in its use of computer core and running time. In addition, input and output capabilities are quite restrictive, and man-machine interaction is imposisble to implement. Finally, input is cumbersome. The entire program must be input every time the data inputs are changed. Input of the data alone is much more convenient.

The problems with the current GPSS formulation of the model can be alleviated by recoding the model in FORTRAN. An event simulation technique would be used to mimic the GPSS formulation.

6.1.2 Separation of Schedule and Flight Simulators

Currently, the schedule and flight simulators operate in parallel. In order to validate the model, the flight simulator must be capable of running with an externally input schedule. Thus, it will be necessary eventually to code the flight simulator to run apart from the schedule simulator. It would also be desirable to operate the schedule simulator without the flight simulator. Schedules thus created could be input to the flight simulator under different simulated weather or airport capability. Currently, experimental designs to test the impact of airport improvements are difficult to implement, since every time the flight simulator is run, a different schedule is received from the schedule simulator. This extension is expected to require approximately 1 man-week of effort to implement in GPSS. If this extension is directly programmed into a new FORTRAN implementation, it is not expected to have any impact on the effort required to implement the FORTRAN code.

6.2 IMPROVEMENTS IN MODEL REALISM

6.2.1 Incorporation of Within-Hour Peaking

At present, the model distributes arrivals and departures at an airport uniformly. In the real world, peaking is observed at the hour and half-hour, with smaller peaks at the quarter-hour. Extension of the model to capture these peaking characteristics is expected to require 2 man-weeks for implementation, calibration, and validation.

6.2.2 Identification of Airline and Aircraft Type

The present model simulates the scheduling and flight of aircraft that are identical with respect to type and airline. This makes it particularly difficult to account for delays at gates (because gates are often not shared among airlines) and to account for the costs of delay (because different aircraft types have different operating costs and, as a result of differences in capacity, different costs for passenger delay). Association of a type and airline with each aircraft may alleviate these problems. On the other hand, it would be extremely difficult to simulate the scheduling process airlines use to mitigate conflict for aircraft gates. Therefore, greater validity may be achieved simply by treating the entire aircraft fleet as if it were a single airline and calibrating the number of "effective gates" at an airport so that gate delays are computed accurately, as is done currently. Similarly, since detailed statistics would have to be kept regarding the different scheduling characteristics of each aircraft type if different aircraft types were to be simulated, simulation of an "average" aircraft only, as is currently done, may be the sole plausible procedure.

Whether it is worth implementing this extension depends on the validity of the current model. It is estimated that this extension would require approximately 2 man-months to implement, calibrate, and validate if the model were coded in FORTRAN. It would be impossible to implement if the model were coded in GPSS.

6.2.3 Consideration of Time in Scheduling Aircraft Destination

Currently, an aircraft's time of departure from an airport depends on its time of arrival. This insures that the number of takeoffs in any given hour is in accordance with the scehdules at that airport. An aircraft's time of arrival, on the other hand, depends only on its time of departure and flight time. Thus arrivals are distributed throughout the day identically at all airports. This results in the simulated arrivals at such airports as DCA and LGA being spread more uniformly throughout the day than they actually are. Consequently, delays at these airports are probably underestimated. Similarly, simulated arrivals at airports such as ORD are spread less uniformly throughout the day than they actually are. This may result in an overestimate of the delays at ORD.

The validity of the schedule simulator would probably improve significantly if the assignment of aircraft destination depended on time of day. Incorporation of this improvement into the current model would require approximately 3 man-weeks to implement, calibrate, and validate.

6.2.4 Estimation of Cancellations and Diversions

The present model assumes that aircraft schedules cannot be dynamically adjusted. In reality, when delays become exceedingly long, airlines will frequently divert incoming flights and cancel departing flights that would otherwise leave after too long a delay. Therefore, the current model overestimates the extent of type-A and type-B delays and underestimates (at zero) cancellations and diversions that substitute for such delays.

Unfortunately, it is difficult to simulate how airlines dynamically alter their schedules to respond to long delays. At best, rules could be devised, based on observations of the real world, to determine when flights are diverted or canceled. However, the adjustment of airline schedules to such activity is probably more difficult to quantify.

The extension of the model to account for diversions and cancellations would require approximately 3 man-months to implement, calibrate, and validate. Airlines would have to be consulted, and data on past dynamic rescheduling practices would have to be obtained. Even so, the success of an effort to extend the model into this realm is not guaranteed.

REFERENCES

1. Congressional Air Transportation Study, Federal Aviation Administration, [Washington DC], January 1971, ASP-130.

2. R.A. Bales and J.F. Koetsch, Airport Surface Traffic Control Systems Deployment Analysis - Expanded, Federal Aviation Administration, Washington DC, March 1975, FAA-RD-75-51.

3. FAA Air Traffic Activity: Peak Day and Terminal Area Relationships, Calendar Year 1973, Federal Aviation Administration [Washington DC], February 1974.

APPENDIX A
AIRPORT NETWORK FLOW SIMULATOR USER MANUAL

A.1 INPUTS

A.1.1 Program Structure

The simulator consists of several parts which must appear in order. These parts can be found in the program listing located in Appendix C. Generally, the user need only change the initialization statements, the storage definition, the function definitions, or the report generator cards. These inputs are described in this section.

All GPSS cards have a common format. Column 1 is either blank or an asterisk (*). If an asterisk is found in Column 1, the rest of the card is treated as a comment, and may contain any characters formated in any way. If Column 1 is blank, the rest of the card is treated as a GPSS statement. Columns 2 through 6 may contain an alpha-numeric or numeric field that labels the GPSS statement. Column 7 must be blank. Columns 8 through 17 may contain GPSS command. Column 18 must be blank. Beginning in Column 19 are the parameters of the command separated by commas, with no intervening spaces. All characters following the first space are treated as comments. The one exception to this rule is the GPSS function follower statements, discussed in Section A.1.4 below.

A.1.2 Savevalue Initialization

Much of the data input to a GPSS program is in the form of savevalues. Savevalues are global variables to a GPSS program. Savevalues used in the simulator are documented by comment statements numbers 4 through 22 in the program listing. The savevalues themselves are initialized in statements 23 through 26. These statements contain the work "initial" beginning in column 8 and the initialization parameters beginning in column 19. The initialization parameters have the form "XNV" where N is the number of the savevalue and V is its initial value. Several savevalues can be initialized on the same card by inserting slashes between the initial parameters starting in column 19.

The user is most likely interested in modifying only two sets of parameters: cost parameters, savevalues 12 and 13; and overnight parameters, savevalue 2 and savevalues 42 through 51. Operating cost, in cents-per-minute, is the cost of operating a single aircraft. In statement 23 it is currently initialized to be 10. More realistically, it should be 1,000, as it costs approximately $10-per-minute to operate most jet aircraft. Passenger costs, in cents-per-minute, should be set equal to the cost to the passenger of one aircraft-minute of type B Delay. Passenger costs, now set to 10 in statement #23, should probably be more realistically set to 500.

Savevalues 42 through 50 contain the number of overnights at airports 3 through 11, respectively. Savevalues 2 to 51 contain the total number of overnights.

A.1.3 Storage

Each airport has a limit to the number of aircraft it can hold simultaneously (store) at the airport's gates. This number is input in statements 40 through 49 for airports 2 through 11, respectively. The label to the STORAGE card is the airport number; the parameter in column 19 is the number of gates at the airport. Note that airport 2 is shown as having 5000 gates. This is because airport 2 is a composite airport outside the system, and we do not wish to make any gate delays outside the system. Note also that the number of gates shown is about 10 percent less than the number that actually exist at the airports. The reason for this is that some aircraft and delayed even when some gates are empty, because airlines generally do not share gates.

A.1.4 Functions

A.1.4.1 Format - The FUNCTION statement has the same form as any other GPSS command. The parameters beginning in column 19 have the form "a, b, c," where "a" is the name of the independent variable, "b" denotes the type of function, and "c" is the finite number of points at where the function is explicitly defined. The symbol "b" may take on the values "L, D, C, M, and E." "L, D, and C" indicate that the function is scalar-valued, whereas "M and S" indicate that it is attribute-valued; by attribute-valued we mean that the dependent variable is a GPSS attribute (such as a savevalue, variable, or even another function). "L and M" signify "list independent variable," variables that take on the discrete values "1" through "C," where "C" is the third parameter in the FUNCTION statement. "D" indicates that the dependent variable takes on only a finite number of values and breaks (changes values) only as "C" descrete points, where "C" is the third parameter of the FUNCTION statement. The symbol "C" indicates that the dependent variable is continuous and linear between the "C" points explicitly defined.

Every FUNCTION statement is followed by one or more function-follower statements specifying the values of the dependent variable at the "c" points promised in the FUNCTION card. The format of the function-follower is "$x_1,y_1/x_2,y_2/\ldots\ldots/x_c,y_c$" starting in column 1, where y_i is the value of the dependent variable when the independent variable is x_i. The x_i must be in increasing order. For "L" or "M" functions, x_i must go from 1 to "c" and $f(x_i) = y_i$. The function f(x) is undefined for $x \neq x_i$. For "D" or "E" functions,

$$f(x) = y_i \text{ if } x_{i-1} < x < x_i,$$

$$f(x) = y_o \text{ if } x < x_1 \text{ and}$$

$$f(x) = y_c \text{ if } x > x_c \text{ .}$$

For "C" functions,

$$f(x) = \left(\frac{x - x_{i-1}}{x_i - x_{i-1}}\right)\left(y_i - y_{i-1}\right) + y_{i-1} \text{ if } x_{i-1} < x < x_i$$

$$f(x) = y_i \text{ if } x < x_1 \text{ and}$$

$$f(x) = y_c \text{ if } x > x_c.$$

A.1.4.2 ASP1, ASP2, and NXHDP - Functions ASP1, ASP2, and NXHDP originate aircraft schedules. They are all functions of VII, which is the hour of the day (1 through 24). ASP1 gives the number of seconds until the next arrival of an aircraft from outside the system, once the model has simulated at least a day's activity. Simulating the first day, flights that are in the air and within the system at the beginning of the day have not been previously simulated. In order to prime the model, they are treated as if they are arriving from outside the system. Consequently, as the first simulated day, flights arrive from outside the system at a faster rate than in succeeding days. The time between arrivals from outside the system is ASP1 — ASP2. NXHDP gives the number of seconds between hangar departures (equivalent to arrivals from within the system).

A.1.4.3 RWOT, WPTN(x), and OCCU(x) - RWOT, WPTN(x), and OCCU(x) are used to give the runway occupancy time as a function of airport and time of day. OCCU(x), a function of x9, the airport of interest, gives the runway occupancy time and weather x. In the program listing Appendix C, runway occupancy times for four categories of weather are given, but this list may be expanded. WPTN(X), a function of variable 15, the time of day, has as its value one of OOCU(x). For example, WPTN1 (weather pattern 1) has a value OCCU3 from second 1 to second 25200, OCCU4 from second 25201 to second 54000, and OCCU3 from second 54001 to second 86400. Finally, RWOT gives the value of one of WPTN(x̄) as a function of the airport of interest. OCCU(x) should not be changed except when calibrating the model. To change the modeled weather at airport x, change the dependent variable in RWOT corresponding to x to the new weather pattern FN&WPTN(y). If WPTN(y) does not exist, create it.

A.1.4.4 PNDES, DST(x), and TWO22 - PNDES, DST(x), and TOW22 give the destination of an aircraft once its origin is known. PNDES, based on P42, the origin airport, has as its value one of DST(x). Each DST(x) gives a destination airport as a function of a random variable. The DST(x) differ since each is used to find the destination for different origins, and consequently, each has different probability distributions for destination airports being chosen. If the destination selected is "1" (outside the system), some fraction of the aircraft, TWO22, a function of V63, the scheduled departure time, will return to the system later in the day, and hence is assigned a destination of "2."

A.1.4.5 POVTI and POVAP - POVTI and POVAP are used to find the probability that an arriving aircraft overnights at its destination. POVTI gives that probability as a function of V4, the hour of scheduled arrival (1 to 24). POVAP gives a scaling factor to apply to the probability POVTI as a function of R42, the destination airport. This reflects the fact that same airports are more likely than others to be points of overnighting vehicles. These parameters can be changed at will to change the schedule simulator.

A.1.4.6 PCOTI and PCOAP - PCOTI and PCOAP give the probability of an arriving aircraft that it does not overnight, continuing with the same flight number. PCOTI gives that probability as a function of V4, the hour of arrival (1 to 24). PCOAP shows how that probability should be scaled, as a function of arrival airport, to reflect the fact that some airports are generally serve terminating flights and others continuing flights. These parameters can be change at will to modify the schedule simulator.

A.1.4.7 TICO, TINCO, APCO, and APNCO - TICO, TINCO, APCO, and APNCO are used to determine how by arriving flights are scheduled to spend on the ground. APCO and APNCO give the number of seconds spent on the ground as a function of P42, arriving airport, for continuing (departing with the same flight number) and noncontinuing (departing with a new flight number), respectively. TICO and TINCO give a factor to adjust these values as a function of hour of arrival (1 to 24) for continuing and noncontinuing flights, respectively. These values can be adjusted at will to modify the schedule simulator.

A.1.4.8 GAFAC - GAFAC contains the fraction nonscheduled flights are of scheduled flights, as a function of savevalue 9, the airport of interest. It can be adjusted to modify the flight simulator but should reflect actual data.

A.1.5 Report Generation

Reports are generated by the START card, listed in Appendix C as statement 460. The letters "a,,b" starting in column 19 of the START card signify that output is to be generated every "b" simulated hours starting at hour "b" and ending at hour "a." The example of Appendix C generates output after simulated hours 4, 8, 12, 16, 20, and 24.

Standard GPSS output can be obtained by placing the END card (statement 490 of Appendix c) immediately after the START card. Specially formatted summary reports can be obtained when statements 461 to 488 are inserted between the START and END cards. When statement 489 is also included, as it is in the example of Appendix C, both the formatted and standard outputs will be provided.

A.2 OUTPUTS

Sample output is shown in the following pages. This section reviews the interpretation of each of the outputs. The summary statistics should be self-explanatory.

The gate utilization statistics show, for each airport, reading from left to right, the number of gates, the average (over time) number of aircraft using gates, the average gate utilization (rate of the preceding two columns), the number of arrivals at gates during the day, average number of seconds an aircraft spends at a gate, the current number of gates in use, and the maximum number of gates simultaneously in use.

The runway utilization statistics show, respectively, the average runway utilization and the number of OPS handled at the airport.

Floating-point and full word savevalue and logic switch output are used for debugging only. Their output can be suppressed to reduce volume.

Halfword matrix 1 shows the scheduled origin-destination table created by the schedule simulator. The row denotes the origin; the column denotes the destination.

The queue statistics give the information on each of the queues simulated. Queue 1 is the queue of flight leg originations waiting for delayed aircraft. It contains information on type-B delay in the system. Queues XXX through SFO are the landing queues at the respective airports. Queues 12 through 21 are the take-off queues for airports 2 through 11. Queues 22 through 21 are the queues for gate space at airports 2 through 11. The remaining outputs are used for debugging only.

A.3 SAMPLE OUTPUT

SUMMARY STATISTICS

	TYPE-A DELAY	TYPE-B DELAY	TOTAL DELAY
OCCURENCES	37.00	.00	37.00
MINUTES/OCCURENCE	.47	.00	.47
TOTAL MINUTES	17.22	.00	17.22
OPERATING COST ($)	1.72	.00	1.72
PASSENGER COST ($)	1.72	.00	1.72
TOTAL COST ($)	3.44	.00	3.44

	IN SYSTEM	OUTSIDE SYSTEM	TOTAL
FLIGHTS SIMULATED	208.00	.00	208.00
TYPE-A MINUTES/FLIGHT	.08	.00	.08
TYPE-B MINUTES/FLIGHT	.00	.00	.00

FACILITIES

FACILITY	NUMBER ENTRIES	AVERAGE TIME/TRAN	-AVERAGE TOTAL TIME	UTILIZATION AVAIL. TIME	DURING- UNAVAIL. TIME	CURRENT STATUS	PERCENT AVAILABILITY	TRANSACTION NUMBER SEIZING	PREEMPTING
ATL	35	40.314	.055				100.0		
BOS	31	44.484	.054				100.0	413	
DCA	32	53.531	.067				100.0		
JFK	38	49.053	.073				100.0		
LAX	50	37.860	.075				100.0		
LGA	29	58.483	.067				100.0		
MIA	28	38.179	.042				100.0		
ORD	56	24.786	.055				100.0		
SFO	27	53.037	.056				100.0		

STORAGES

STORAGE	CAPACITY	AVERAGE CONTENTS	ENTRIES	AVERAGE TIME/UNIT	-AVERAGE TOTAL TIME	UTILIZATION AVAIL. TIME	DURING- UNAVAIL. TIME	CURRENT STATUS	PERCENT AVAILABILITY	CURRENT CONTENTS	MAXIMUM CONTENTS
ATL	70	5.432	39	3509.872	.077				100.0	19	19
BOS	62	6.456	43	3807.860	.104				100.0	25	26
DCA	36	6.359	43	3726.767	.176				100.0	27	27
JFK	124	7.548	56	3396.482	.060				100.0	31	32
LAX	67	9.594	67	3608.435	.143				100.0	40	44
LGA	76	5.528	36	3869.833	.072				100.0	20	23
MIA	80	5.401	37	3733.000	.068				100.0	23	23
ORD	69	10.136	71	3597.648	.146				100.0	43	43
SFO	60	5.446	45	3049.866	.090				100.0	26	27

QUEUES

QUEUE	MAXIMUM CONTENTS	AVERAGE CONTENTS	TOTAL ENTRIES	ZERO ENTRIES	PERCENT ZEROS	AVERAGE TIME/TRANS	$AVERAGE TIME/TRANS	TABLE NUMBER	CURRENT CONTENTS
1	1	.000	183	183	100.0	.000	.000		
ATL	1	.001	20	17	84.9	2.000	13.333		
BOS	1	.000	18	17	94.4	.888	16.000		
DCA	3	.014	16	12	75.0	23.375	93.500		
JFK	1	.004	25	21	83.9	4.839	30.250		
LAX	1	.000	27	23	85.1	.481	3.250		
LGA	1	.000	16	15	93.7	1.562	25.000		
MIA	1	.001	14	11	78.5	2.928	13.666		
ORD	1	.000	28	27	96.4	.892	25.000		
SFO	1	.001	19	17	89.4	1.684	16.000		
13	1	.001	15	14	93.3	2.466	37.000		
14	1	.000	13	13	100.0	.000	.000		
15	1	.001	16	14	87.5	3.062	24.500		
16	1	.005	13	10	76.9	7.076	30.666		
17	1	.004	23	18	78.2	5.478	25.199		
18	1	.000	13	12	92.3	1.461	19.000		
19	1	.000	14	13	92.8	.142	2.000		
20	1	.000	28	27	96.4	.750	21.000		
21	1	.000	8	8	100.0	.000	.000		
23	1	.000	15	15	100.0	.000	.000		
24	1	.000	13	13	100.0	.000	.000		
25	1	.000	16	16	100.0	.000	.000		
26	1	.000	13	13	100.0	.000	.000		
27	1	.000	23	23	100.0	.000	.000		
28	1	.000	13	13	100.0	.000	.000		
29	1	.000	14	14	100.0	.000	.000		
30	1	.000	28	28	100.0	.000	.000		
31	1	.000	8	8	100.0	.000	.000		
32	30	.409	3260	2890	88.6	3.168	27.918		

$AVERAGE TIME/TRANS = AVERAGE TIME/TRANS EXCLUDING ZERO ENTRIES

FULLWORD SAVEVALUES

NUMBER	CONTENTS	NUMBER	CONTENTS	NUMBER	CONTENTS	NUMBER	CONTENTS	NUMBER	CONTENTS	NUMBER	CONTENTS
1	11	2	686	3	323	4	63	5	62	6	41810
7	46991	8	40450	9	4	12	10	13	10	14	3700
15	47	16	1722	17	172	18	172	19	344	26	3700
27	47	28	1722	29	172	30	172	31	344	32	20800
33	8	38	20800	39	8	41	170	52	31	53	46
54	27	55	37	56	48	57	39	58	54	59	69
60	41	61	391	63	196	64	188	65	26		

HALFWORD MATRICES

HALFWORD MATRIX 1

ROW/COLUMN	1	2	3	4	5	6	7	8	9	10
1	0	0	15	12	15	11	21	12	14	28
2	0	0	0	0	0	0	0	0	0	0
3	12	3	0	0	1	1	0	2	1	0
4	12	1	0	0	1	2	0	2	0	0
5	12	2	0	0	0	0	0	1	0	1
6	15	4	1	0	0	0	1	0	2	2
7	13	6	1	0	0	1	0	0	0	2
8	9	3	0	3	0	0	0	0	1	0
9	8	1	2	1	0	2	0	0	0	0
10	19	5	0	0	1	0	1	0	1	0
11	11	2	0	0	0	0	5	0	0	1

ROW/COLUMN	11
1	8
	ROWS 2-6, COLUMNS 11-11 ARE ZERO
7	4
	ROWS 8-9, COLUMNS 11-11 ARE ZERO
10	1
11	0

LOGIC SWITCHES

LOGIC SWITCH - SET (ON) STATUS

NUMBER	NUMBER	NUMBER	NUMBER	NUMBER	NUMBER	NUMBER	NUMBER	NUMBER	NUMBER	NUMBER	NUMBER	NUMBER	NUMBER	NUMBER
4	5	6	7	8	9	10	12	13	14	15	16	19	21	23
25	28	30	31	34	37	39	40	41	42	43	44	45	46	47
48	50	51	53	55	57	59	60	62	64	67	68	69	70	72
73	74	75	77	79	80	81	82	84	85	86	87	89	90	95
96	98	100	101	102	104	105	106	107	108	109	110	112	114	116
117	118	120	121	122	125	126	128	130	132	135	137	139	140	141
143	144	145	146	148	151	152	154	155	156	157	158	160	161	162
165	167	169	171	172	175	179	182	186	187	188	189	190	191	193
195	198	199	200	201	202	203	204	205	206	207	208	209	210	211
212	213	214	215	216	217	218	219	220	221	222	223	224	225	226
227	228	229	230	231	232	233	234	235	236	237	238	239	240	241
242	243	244	245	246	247	248	249	250	251	252	253	254	255	256
257	258	259	260	261	262	263	264	265	266	267	268	269	270	271
272	273	274	275	276	277	278	280	281	283	284	285	286	287	289
290	291	293	294	295	296	298	299	301	303	304	306	307	308	310
311	312	314	315	317	318	320	322	323						

FLOATING POINT SAVEVALUES

NUMBER	CONTENTS	NUMBER	CONTENTS	NUMBER	CONTENTS	NUMBER	CONTENTS	NUMBER	CONTENTS	NUMBER	CONTENTS
1	37.0	2	0.46531	3	17.21662	4	1.72166	5	1.72166	6	3.44332
13	37.0	14	0.46531	15	17.21662	16	1.72166	17	1.72166	18	3.44332
19	208.0	20	0.08277	25	208.0	26	0.08277				

BYTE SAVEVALUES

NUMBER	CONTENTS	NUMBER	CONTENTS	NUMBER	CONTENTS	NUMBER	CONTENTS	NUMBER	CONTENTS	NUMBER	CONTENTS
1	1										

APPENDIX B
AIRPORT NETWORK FLOW SIMULATOR — PROGRAM LISTING

```
                    * * *  G P S S   V  -  O S   V E R S I O N   * * *
                       *** IBM PROGRAM PRODUCT 5734-XS2 (V1M3) ***
                                                                            STATEMENT
                                                                             NUMBER
REALLOCATE BLO,180,FAC,15,STO,15,QUE,40,TAB,10,CHA,5,COM,89240                   1
REALLOCATE BSV,3,HSV,1,BVR,1,VAR,75,FUN,100,XAC,1500                             2
```

```
BLOCK
NUMBER  *LOC    OPERATION  A,B,C,D,E,F,G,H,I          COMMENTS                                    STATEMENT
                                                                                                   NUMBER
        *          FULLWORD SAVEVALUES
        *  1.   NUMBER OF AIRPORTS
        *  2.   NUMBER OF AIRCRAFT OVERNIGHTS
        *  3.   GREATEST AIRCRAFT TAIL NUMBER
        *  4.   POINTER TO TOP OF AIRCRAFT NUMBER STACK
        *  5.   POINTER TO BOTTOM OF AIRCRAFT NUMBER STACK
        *  6.   ACTUAL CLOCK FOR FLIGHTS OUTSIDE SYSTEM
        *  7.   SCHEDULE CLOCK FOR FLIGHTS OUTSIDE SYSTEM
        *  8.   HOUR OF ARRIVAL FOR COMPUTING SCHEDULE DEPARTURE TIME
        *  9.   AIRPORT IN USE FOR COMPUTING RUNWAY OCCUPANCY TIME
        *  10.  NUMBER OF FLIGHTS WITH TYPE-B DELAY OUTSIDE SYSTEM
        *  11.  TOTAL TYPE-B DELAY OUTSIDE SYSTEM
        *  12.  OPERATING COST, CENTS/MINUTE
        *  13.  PASSENGER COST, CENTS/MINUTE
        *  14-40.  OUTPUT VARIABLES
        *  41.  AIR TIME FROM NODE 1 TO NODE 1
        *  42.-51.  HANGER ENTRIES
        *  52.-61.  HANGER ENTRIES READY TO DEPART
        *  62 ON.  AIRCRAFT NUMBER STACK
                INITIAL    X1,11/X2,686/X3,2/X4,62/X5,62/X12,10/X13,10
                INITIAL    X41,170
                INITIAL    X42,55/X43,76/X44,54/X45,80/X46,92/X47,62/X48,77
                INITIAL    X49,112/X50,78/X51,686
        *        BYTE SAVEVALUES
        *  1.   ZERO IF C1 .GT. 72000, ONE OTHERWISE
                INITIAL    XB1,1
         XXX    EQU        2,F,S,Q
         ATL    EQU        3,F,S,Q
         BOS    EQU        4,F,S,Q
         DCA    EQU        5,F,S,Q
         JFK    EQU        6,F,S,Q
         LAX    EQU        7,F,S,Q
         LGA    EQU        8,F,S,Q
         MIA    EQU        9,F,S,Q
         ORD    EQU        10,F,S,Q
         SFO    EQU        11,F,S,Q
         2      STORAGE    5000
         3      STORAGE    70
         4      STORAGE    62
         5      STORAGE    36
         6      STORAGE    124
         7      STORAGE    67
         8      STORAGE    76
         9      STORAGE    60
         10     STORAGE    69
         11     STORAGE    60
         1      MATRIX     MH,11,11
        *SPACING OF ARRIVALS FROM NODE 1, IN SECONDS
         1      FVARIABLE  .002*RN1*(FN$ASP1-XB1*FN$ASP2)
        *RUNWAY OCCUPANCY TIME, IN SECONDS
         2      FVARIABLE  (FN$GAFAC+1)*FN$RWOT*(4000.+RN2-500.)/4000.
         3      FVARIABLE  1800.+(RN1-500.)/5.
         4      VARIABLE   X8/3600+1
         5      FVARIABLE  C1+300.
         6      FVARIABLE  100.*FN$GAFAC+.49
```

```
7       VARIABLE    C1+PF1-PF2
8       VARIABLE    PF1@86400
9       FVARIABLE   PF2+V43+300.
10      FVARIABLE   PF2-C1
11      VARIABLE    (V15-1)/3600+1
12      VARIABLE    X1-1+PH3
13      VARIABLE    2*X1-2+PH3
14      VARIABLE    (PH2@PH3)/PH2
15      VARIABLE    C1@86400
18      VARIABLE    X7@86400
19      VARIABLE    X6-X7
20      FVARIABLE   GC*PH2*GT*PH2/60.
21      VARIABLE    3*X1-2
22      VARIABLE    GC*PH2-G2*PH2
23      FVARIABLE   GC1-G21+X10
24      FVARIABLE   (GC1*GT1+X11)/60.
25      FVARIABLE   XL3/XL1
26      FVARIABLE   XL9/XL7
27      FVARIABLE   XL3*X12/100.
28      FVARIABLE   XL3*X13/100.
29      FVARIABLE   XL9*X13/100.
30      FVARIABLE   XL4+XL5
31      FVARIABLE   XL10+XL11
32      FVARIABLE   XL1+XL7
33      FVARIABLE   XL15/XL13
34      FVARIABLE   XL3+XL9
35      FVARIABLE   XL5+XL11
36      FVARIABLE   XL6+XL12
37      FVARIABLE   (N$FLT+N$TRMFT+N$TRMIS)/2.
38      FVARIABLE   XL3/XL19
39      FVARIABLE   GC1*GT1/(60.*XL19)
40      FVARIABLE   XL19+XL22
41      FVARIABLE   XL3/XL25
42      FVARIABLE   XL9/XL25
43      VARIABLE    60*FN$ARTIM
44      FVARIABLE   0.5+100.*XL*PH2
45      VARIABLE    13+PH2
46      FVARIABLE   X11/(60.*XL22)
47      VARIABLE    V14*(PH3-PH2)+PH2
48      VARIABLE    V14*(PH2-PH3)+PH3
49      VARIABLE    PF1@86400
50      VARIABLE    (X8-1)/3600+1
51      VARIABLE    C1+3600
52      VARIABLE    PF2-3600-C1
53      FVARIABLE   FN$POVTI*FN$POVAP
54      VARIABLE    PH2+41
55      VARIABLE    PH2+49
56      VARIABLE    PH2+51
57      FVARIABLE   FN$PCOTI*FN$PCOAP
58      FVARIABLE   FN$TINCO*FN$APNCO
59      FVARIABLE   FN$TILO*FN$APLO
60      VARIABLE    PH2+39
61      VARIABLE    PF1+1320
62      VARIABLE    PF1-PF2
63      VARIABLE    PF2@86400
*SPACING OF ARRIVALS FROM NODE 1, IN MINUTES, BY HOUR
ASP1  FUNCTION    V11,L24
1,95/2,97/3,150/4,240/5,164/6,360/7,75/8,25/9,24/10,22/11,18/12,23
13,19/14,17/15,16/16,17/17,14/18,20/19,16/20,22/21,17/22,29/23,26/24,55
```

```
 ASP2  FUNCTION   V11,D6
3,0/4,102/5,67/6,210/7,12/24,0
*RUNWAY OCCUPANCY TIME DEPENDS ON WEATHER PATTERN, WHICH IS FUNCTION
*     OF AIRPORT
 RWOT  FUNCTION   X9,M11
1,FN$WPTN1/2,FN$WPTN1/3,FN$WPTN2/4,FN$WPTN3/5,FN$WPTN2/6,FN$WPTN2
7,FN$WPTN3/8,FN$WPTN2/9,FN$WPTN2/10,FN$WPTN3/11,FN$WPTN2
*WEATHER PATTERNS - POINT TO RUNWAY OCCUPANCY TIME AS FUNCTION OF
*      HOUR OF DAY
 WPTN1 FUNCTION   V15,E2
43200,FN$OCCU1/86400,FN$OCCU2
 WPTN2 FUNCTION   V15,E2
43200,FN$OCCU1/86400,FN$OCCU1
 WPTN3 FUNCTION   V15,E2
43200,FN$OCCU1/86400,FN$OCCU1
*GOOD WEATHER RUNWAY OCCUPANCY TIMES AS FUNCTION OF AIRPORT,
*      IN SECONDS
 OCCU1 FUNCTION   X9,L11
1,0/2,0/3,36/4,42/5,50/6,46/7,34/8,53/9,36/10,23/11,49
*BAD WEATHER RUNWAY OCCUPANCY TIMES AS FUNCTION OF AIRPORT,
*      IN SECONDS
 OCCU2 FUNCTION   X9,L11
1,0/2,0/3,41/4,60/5,67/6,55/7,42/8,64/9,50/10,26/11,61
*POINTER TO DESTINATION ASSIGNMENT, AS FUNCTION OF ORIGIN
 PLDES FUNCTION   FH2,M11
1,FN$DST1/2,FN$DST1/3,FN$DST3/4,FN$DST4/5,FN$DST5/6,FN$DST6
7,FN$DST7/8,FN$DST8/9,FN$DST9/10,FN$DST10/11,FN$DST11
*FUNCTION DST'N' GIVES RANDOM DESTINATION ASSIGNMENT FOR FLIGHT
*      FROM ORIGIN 'N'
 DST1  FUNCTION   RN1,D9
.14829,3/.22436,4/.33051,5/.40283,6/.54358,7/.61457,8/.68325,9
.91931,10/1.0,11
 DST3  FUNCTION   RN1,D9
.84637,1/.85488,4/.87863,5/.89554,6/.91117,7
.93316,8/.96482,9/.99472,10/1.0,11
 DST4  FUNCTION   RN1,D9
.72434,1/.75754,3/.79472,5/.84018,6/.84751,7
.92522,8/.95695,9/.99267,10/1.0,11
 DST5  FUNCTION   RN1,D7
.73429,1/.77208,3/.82057,4/.84000,6/.90429,8/.92714,9/1.0,10
 DST6  FUNCTION   RN1,D8
.79141,1/.81472,3/.85278,4/.86258,5/.90307,7/.94110,9/.97660,10/1.0,11
 DST7  FUNCTION   RN1,D7
.77589,1/.79117,3/.79542,4/.82343,6/.82767,9/.87521,10/1.0,11
 DST8  FUNCTION   RN1,D6
.69012,1/.72754,3/.80689,4/.87425,5/.90589,9/1.0,10
 DST9  FUNCTION   RN1,D9
.76632,1/.82818,3/.84192,4/.86942,5/.92268,6
.95127,7/.96735,8/.99658,10/1.0,11
 DST10 FUNCTION   RN1,D9
.82287,1/.84112,3/.86151,4/.88889,5/.90446,6
.93451,7/.96833,8/.97740,9/1.0,11
 DST11 FUNCTION   RN1,D7
.70335,1/.71141,3/.71812,4/.74362,6/.94094,7/.94362,9/1.0,10
*AIRCRAFT ORIGIN AT START OF DAY, ASSIGNS RANDOMLY
 ORAC  FUNCTION   RN1,D9
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.080,3/.191,4/.270,5/.388,6/.520,7/.611,8/.723,9/.886,10/1.0,11
*O-D STANDARD AIR TIMES
 ARTIM FUNCTION    V47,M11
1,X41/2,X41/3,FN$ART3/4,FN$ART4/5,FN$ART5/6,FN$ART6/7,FN$ART7
8,FN$ART8/9,FN$ART9/10,FN$ART10/11,FN$ART11
 ART3  FUNCTION    V48,L2
1,147/2,147
 ART4  FUNCTION    V48,L3
1,150/2,150/3,155
 ART5  FUNCTION    V48,L4
1,126/2,126/3,100/4,70
 ART6  FUNCTION    V48,L5
1,138/2,138/3,130/4,45/5,60
 ART7  FUNCTION    V48,L6
1,250/2,250/3,227/4,300/5,210/6,290
 ART8  FUNCTION    V48,L7
1,138/2,138/3,130/4,45/5,60/6,7/7,340
 ART9  FUNCTION    V48,L8
1,183/2,183/3,100/4,160/5,130/6,155/7,310/8,155
 ART10 FUNCTION    V48,L9
1,145/2,145/3,90/4,120/5,97/6,105/7,255/8,105/9,156
 ART11 FUNCTION    V48,L10
1,255/2,255/3,244/4,305/5,280/6,310/7,64/8,310/9,296/10,230
*FRACTION OF FLIGHTS FROM NODE2 TO NODE2 TIMES 1000
 TRC22 FUNCTION    V63,C7
10801,0/21600,250/32400,200/43200,150/54000,100/64800,50/86400,0
*PROBABILITY OF OVERNIGHT ARRIVING THIS HOUR, TIMES 1000
 POVTI FUNCTION    V4,L24
1,654/2,655/3,923/4,0/5,0/6,0/7,0/8,018/9,5/10,20/11,16/12,24/13,13
14,18/15,10/16,48/17,78/18,110/19,147/20,312/21,407/22,551/23,585
24,667
*PROBABILITY OF OVERNIGHT AT THIS AIRPORT, RELATIVE TO AVERAGE
 POVAP FUNCTION    FN2,L11
1,0/2,0/3,.591/4,1.45/5,.933/6,1.25/7,.963/8,1.15/9,1.80/10,.720
11,1.33
*FRACTION OF NON-OVERNIGHT FLIGHTS ARRIVING THIS HOUR THAT CONTINUE,
*      TIMES 1000
 PCOTI FUNCTION    V4,L24
1,778/2,750/3,667/4,429/5,235/6,464/7,362/8,363/9,401/10,375/11,378
12,295/13,342/14,365/15,329/16,300/17,378/18,329/19,407/20,340/21,484
22,352/23,603/24,629
*PROBABILITY OF FLIGHT ARRIVING AT THIS AIRPORT CONTINUING,
*      RELATIVE TO AVERAGE
 PCOAP FUNCTION    FN2,L11
1,1/2,1/3,1.70/4,.462/5,1.05/6,.668/7,1.05/8,.538/9,.249/10,1.28
11,.785
*FOR NON-CONTINUING FLIGHTS, FRACTION OF AVERAGE GROUND TIME
*      SPENT BY AIRCRAFT ARRIVING THIS HOUR
 TINCO FUNCTION    V4,L24
1,.802/2,.597/3,.248/4,3.04/5,2.64/6,2.07/7,2.10/8,1.23/9,1.11
10,.959/11,.975/12,.901/13,.901/14,.934/15,.818/16,.967/17,.860
18,.860/19,.843/20,.851/21,1.00/22,1.18/23,.967/24,.876
*AVERAGE GROUND TIME FOR NON-CONTINUING FLIGHTS AT THIS AIRPORT
 APNCO FUNCTION    FN2,L11
1,7260/2,7260/3,6600/4,6300/5,5940/6,10020/7,8760/8,5040/9,7320
10,5880/11,9780
*FOR CONTINUING FLIGHTS, FRACTION OF AVERAGE GROUND TIME SPENT BY
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      *     AIRCRAFT ARRIVING THIS HOUR
       TICO  FUNCTION   V4,L24
      1,.918/2,1.24/3,.673/4,1.35/5,1.53/6,2.90/7,.980/8,1.06/9,1.04/10,.980
      11,1.00/12,.898/13,.959/14,1.00/15,.980/16,.898/17,1.00/18,.898
      19,.114/20,.839/21,.837/22,1.08/23,1.04/24,1.08
      *AVERAGE GROUND TIME FOR CONTINUING FLIGHTS AT THIS AIRPORT
       APCO  FUNCTION   PH2,L11
      1,2940/2,2940/3,3360/4,3180/5,1800/6,4560/7,2580/8,2040/9,3360
      10,3000/11,2760
      *TIME TO NEXT HANGER DEPARTURE
       NXHDP FUNCTION   V11,D24
      1,400/2,400/3,400/4,225/5,80/6,35/7,27/8,40/9,37/10,56/11,68/12,157
      13,300/14,257/15,327/16,400/17,400/18,400/19,400/20,400/21,400/
      22,400/23,400/24,400
       GAFAC FUNCTION   X9,L11
      1,.10/2,.10/3,.10/4,.10/5,.10/6,.10/7,.10/8,.10/9,.10/10,.10/11,.10
      *          HALFWORD PARAMETERS
      *  1.    AIRCRAFT TAIL NUMBER
      *  2.    FLIGHT ORIGIN
      *  3.    FLIGHT DESTINATION
      *          FULLWORD PARAMETERS
      *  1.    SCHEDULED ARRIVAL TIME
      *  2.    SCHEDULED DEPARTURE TIME
                 SIMULATE
 1               GENERATE   1,0,10800,1,,2PF,3PH  GENERATES A/C FROM OUTSIDE SYS
 2        OUTWT  ADVANCE    V1                    WAIT BEFORE GEN A/C FROM OUTSIDE
 3               TEST E     X4,X5,GETOP           IF STACK NOT EMPTY, GET TOP
 4               SAVEVALUE  3+,K1                 INC GREATEST A/C NO.
 5               ASSIGN     1,X3,PH               ASSIGN A/C NO.
 6               TEST GE    PH1,K999,OUTSP        IF NOT TOO MANY A/C, GEN FLT
 7               TERMINATE  500                   OTHERWISE, TERMINATE IN ERROR
 8        GETOP  ASSIGN     1,X*X4,PH             PH1 GETS FREE A/C NO.
 9               SAVEVALUE  4-,K1                 LOWER TOP OF STACK
10        OUTSP  SPLIT      1,OUTAC               START SCHED FOR NEW A/C
11               TRANSFER   ,OUTWT                SCHEDULE NEXT NEW A/C
12        OUTAC  ASSIGN     2,K1,PH               ASSIGN A/C ORIGIN
13               LOGIC R    PH1                   NOTE A/C IS NOT AVAILABLE
14               ASSIGN     1,V5,PF               SCHED ARR TIME = NOW+300.
15               ASSIGN     3,FN$PNDES,PH         ASSIGN DESTINATION
16               MSAVEVALUE 1+,1,PH3,1,MH         ADD TO O-D TABLE
17               SPLIT      1,LNDR                CREATE FLIGHT
18               TRANSFER   ,NEXT                 CONTINUE AS ALL OTHR A/C SCHEDS
19               GENERATE   86400,0,10800,,,2PF,3PH   GENERATES A/C FROM HANGER
20               ASSIGN     2,10,PH               INDEX FOR LOOP
21        HINIT  SAVEVALUE  V56,X*V54             # TO LEAVE HNGR = # THAT ENTRED
22               SAVEVALUE  V54,0                 INIT NO ENTERING HANGER
23               LOOP       2PH,HINIT             LOOP ON PH2 FOR ALL AIRPTS
24        HLV    TEST G     X61,0,HTRM            ANY MORE A/C TO LEAVE
25               SAVEVALUE  61-,1                 YES, REDUCE BY 1
26               ADVANCE    FN$NXHDP              ADVANCE TO LEAVING TIME
27               TEST E     X4,X5,GTTOP           IF STACK NOT EMPTY, GET TOP
28               SAVEVALUE  3+,1                  INC GREATEST A/C NO
29               ASSIGN     1,X3,PH               ASSIGN A/C NO
30               TEST GE    PH1,999,ACSP          IF NOT TOO MANY A/C, DEPT HNGR
31               TERMINATE  500                     OTHERWISE, TERMINATE IN ERROR
32        GTTOP  ASSIGN     1,X*X4,PH             PH1 GETS FREE A/C NO
33               SAVEVALUE  4-,1                  LOWER TOP OF STACK
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 34   ACSF   ASSIGN      2,FN$ORAC,PH          GET ORIGIN
 35          TEST G      X*V55,0,ACSP          IF NO A/C THERE, GET NEW ORIG
 36          SAVEVALUE   V55-,1                REDUCE NO THERE BY 1
 37          SPLIT       1,HGDPT               CREATE HANGER DEPARTURE
 38          TRANSFER    ,HLV                  GET NEXT A/C TO LEAVE HANGER
 39   HTRM   TERMINATE                         ALL A/C HAVE LEFT HANGR
 40   HGDPT  LOGIC S     PH1                   A/C IS AVAILABLE
 41          ENTER       PH2                   HOLD GATE
 42          ASSIGN      2,V51,PF              PF2 HAS HOUR OF SCHED DEPTURE
 43          TRANSFER    ,DEST                 CONTINUE AS ALL OTHR A/C SCHEDS
 44   NEXT   ASSIGN      2,PH3,PH              A/C ORIGIN = OLD DESTINATION
 45          SAVEVALUE   8,V49                 X8 HAS HOUR OF SCHED ARRIVAL
      ****   MSAVEVALUE  PH3+,V50,1,1,MH       TAB SCHED ARRIVALS
 46          TEST GE     RN1,V53,OVNT          IF OVERNIGHT, GO TO OVNT
 47          ASSIGN      2,PF1,PF              PF2 HAS HOUR OF SCHED ARRIVAL
 48          TEST G      RN1,V57,CONT          IF CONTINUING, GO TO CONT
 49          ASSIGN      2+,V58,PF             PF2 HAS HOUR OF SCHED DEPARTURE
 50          TRANSFER    ,SHRT                 IS GROUND TIME TOO SHORT
 51   CONT   ASSIGN      2+,V59,PF             PF2 HAS HOUR OF SCHED DEPARTURE
 52   SHRT   TEST L      PF2,V61,DEST          IF GROUND TIME IS OK, GET DEST
 53          ASSIGN      2,V61,PF               OTHERWISE, RECOMPUTE DEPT TIME
 54   DEST   TEST E      PH2,K2,NDX2           A/C WITH ORIG NOT = 2 GO TO NDX2
 55          TEST G      RN1,FN$TW022,NDA2       ELSE, SOME % GET DEST=2 @ NDA2
 56          ASSIGN      3,FN$DST1,PH            AND OTHERS GET DEST IN SYSTEM
 57          TRANSFER    ,ATM                    GET SCHED ARR TIME
 58   NDA2   ASSIGN      3,K2,PH               DEST = NODE 2
 59          TRANSFER    ,ATM                  GET SCHED ARR TIME
 60   NDX2   ASSIGN      3,FN$*NDES,PH         A/C DEST FOR ORIG NOT = 1,2
 61          TEST E      PH3,K1,ATM            IF DEST .NE. 1, GET SCHED AIR TM
 62          TEST G      RN1,FN$TW022,NDA2       ELSE, SOME % OF DEST=2, @ NDA2
 63   ATM    ASSIGN      1,V9,PF               SCHED ARRIVAL TIME
 64          ADVANCE     V10                   TIME TO SCHED DEPARTURE
      ****   MSAVEVALUE  PH2+,V11,2,1,MH       TAB SCHED DEPARTURES
 65          MSAVEVALUE  1+,PH2,PH3,1,MH       ADD TO O-D TABLE
 66          SPLIT       1,FLT                 CREATE FLIGHT
 67          TEST NE     PH3,K1,TERM           IF LAST IN SYS, TERM A/C SCHED
 68          TRANSFER    ,NEXT                 NEXT FLIGHT
 69   TERM   TERMINATE                         TERMINATE A/C SCHEDULE
 70   OVNT   SPLIT       1,HNGR                SCHEDULE HANGER VISIT
 71          TERMINATE                          END A/C SCHED IN SYSTEM
 72   HNGR   GATE LS     PH1                   HOLD UNTIL A/C AVAIL
 73          TEST GE     X4,999,ADSTK          IF STACK .LT. 999, ADD TO STACK
 74          TERMINATE   500                    ELSE, TERMINATE IN ERROR
 75   ADSTK  SAVEVALUE   4+,1                  ADD TO TOP OF STACK
 76          SAVEVALUE   X4,PH1                FILL IN FREE A/C NO.
 77          ADVANCE     1800                  WAIT HALF-HOUR TO DEBOARD
 78          SAVEVALUE   V60+,K1               ENTER HANGER
 79          SAVEVALUE   51+,1                 ADD TO TOT ENTERING HANGER
 80          LEAVE       PH2                   LEAVE GATE
 81          TERMINATE                          END OF DAY FOR A/C
 82   FLT    QUEUE       1                     QUEUE FOR AVAIL A/C
 83          GATE LS     PH1                   HOLD UNTIL A/C AVAIL
 84          LOGICR      PH1                   NEXT FLT MUST WAIT FOR A/C
 85          DEPART      1                     DEPART QUEUE FOR A/C
 86          LEAVE       PH2                   LEAVE GATE
      ****   MSAVEVALUE  PH2+,V11,4,1,MH       TAB DEPARTURES FROM GATE
 87          QUEUE       PH2                   QUEUE FOR RUNWAY
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 88            SAVEVALUE  9,PH2                   X9 HAS RUNWAY IN USE
 89            QUEUE      32,V6                   GA QUEUE
 90            SEIZE      PH2                     HOLD RUNWAY
       ****    MSAVEVALUE PH2+,V11,5,1,MH         TAB RUNWAY OPS
 91            DEPART     PH2                     DEPART RUNWAY QUEUE
 92            DEPART     32,V6                   GA QUEUE
 93            ADVANCE    V2                      USE RUNWAY
 94            RELEASE    PH2                     RELEASE RUNWAY
 95            TEST E     PH3,K1,FLYR             IF DEST=1, FREE AC NO
 96            TEST GE    X4,K999,STKAD           IF STACK .LT. 999, ADD TO STACK
 97            TERMINATE  500                     OTHERWISE, TERMINATE IN ERROR
 98    STKAD   SAVEVALUE  4+,K1                   ADD TO TOP OF STACK
 99            SAVEVALUE  X4,PH1                  FILL IN FREE A/C NO.
100            SAVEVALUE  6,V7                    X6 HAS ACTUAL ARRIVAL TIME
101            SAVEVALUE  7,PF1                   X7 HAS SCHEDULED ARRIVAL TIME
102    NLEG    SAVEVALUE  6+,1320                 TIME NEXT FLT READY TO DEPART
103            SAVEVALUE  8,V18                   X8 HAS HOUR OF SCHED ARRIVAL
104            ASSIGN     1,X7,PF                 PF1 HAS SCHEDULED ARRIVAL TIME
105            ASSIGN     2,1,PH                  ORIGIN IS NOW AIRPORT NO 1
106            TEST G     KN1,V53,TRMFT           IF OVERNIGHT, TERMINATE FLIGHT
107            TEST G     KN1,V57,CONS            IF FLT CONTINUES, GO TO CONS
108            SAVEVALUE  7+,V58                  X7 HAS SCHEDULED DEPARTURE TIME
109            TRANSFER   ,SHOR                   IS GROUND TIME TOO SHORT
110    CONS    SAVEVALUE  7+,V59                  X7 HAS HOUR OF SCHED DEPARTURE
111    SHOR    TEST L     X7,V61,ANYB             IF GROUND TIME OK, ANY B-DELAY
112            SAVEVALUE  7,V61                    OTHERWISE, RECOMPUTE DEPT TIME
113    ANYB    TEST L     X7,X6,TRMFT             IF SCHD DPT .GE. RDY DPT, TERM
114            SAVEVALUE  10+,K1                  ADD TO NO FLTS DELAYED
115            SAVEVALUE  11+,V19                 ADD TO DELAY
116            SAVEVALUE  6+,3600                 X6 HAS ACTUAL ARRIVAL TIME
117            SAVEVALUE  7+,3600                 X7 HAS SCHED ARRIVAL TIME
118            TRANSFER   ,NLEG                   NEXT LEG
119    TRMFT   TERMINATE                          TERMINATE FLIGHT
120    FLYR    ADVANCE    V62                     FLY TO DESTINATION
      *LNDR    MSAVEVALUE PH3+,V11,3,1,MH         TAB ARRIVALS AT THRESHHOLD
121    LNDR    QUEUE      V12                     QUEUE FOR RUNWAY
122            SAVEVALUE  9,PH3                   X9 HAS RUNWAY IN USE
123            QUEUE      32,V6                   GA QUEUE
124            SEIZE      PH3                     HOLD RUNWAY
       ****    MSAVEVALUE PH3+,V11,5,1,MH         TAB RUNWAY OPS
125            DEPART     V12                     DEPART RUNWAY QUEUE
126            DEPART     32,V6                   GA QUEUE
127            ADVANCE    V2                      USE RUNWAY
128            RELEASE    PH3                     RELEASE RUNWAY
129            QUEUE      V13                     QUEUE FOR GATE
130            ENTER      PH3                     HOLD GATE
131            DEPART     V13                     LEAVE QUEUE FOR GATE
132            ADVANCE    1320                    DEBOARD & PREPARE NEXT FLT
133            LOGICS     PH1                     MAKE A/C AVAIL
134    THIS    TERMINATE                          TERMINATE FLT IN SYSTEM
135            GENERATE   1,0,72000,1             MODIFIES XB1 AT 72000
136            SAVEVALUE  1,0,XB                  SETS XB1 TO ZERO
137            TERMINATE                           ENDS
138            GENERATE   3600,0,14400            HOURLY ACCUMULATOR
       ****    ASSIGN     2,K2,PH                 USE PH2 AS INDEX
      *TABG    MSAVEVALUE PH2+,V11,6,G*PH2,MH     TAB TAKEOFF QUEUE
       ****    ASSIGN     3,PH2,PH                SET PH3=PH2
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            ****   MSAVEVALUE PH2+,V11,7,Q*V12,MH    TAB LANDING QUEUE
            ****   TEST L     PH2,X1,BDLAY           IF PH2 .GE. NO OF A/PS, B-DELAY
            ****   ASSIGN     2+,K1,PH                 OTHERWISE, ADD 1 TO PH2
            ****   TRANSFER   ,TABG                    AND TAB QUEUES FOR NEXT A/P
   139             SAVEVALUE  1,0,,XL                INITIALIZE XL1
   140             SAVEVALUE  3,0,,XL                INITIALIZE XL3
   141             ASSIGN     2,K2,PH                USE PH2 AS INDEX
   142      NXTA   SAVEVALUE  1+,V22,XL              ADD DLYS TO NO OF TYPE-A
   143             SAVEVALUE  3+,V20,XL              ADD DLYS TO MINS OF TYPE-A
   144             TEST L     PH2,V21,BDLAY          IF LAST Q, GET B-DELAYS
   145             ASSIGN     2+,K1,PH               PH2 POINTS TO NEXT Q
   146             TRANSFER   ,NXTA                  ADD A-DELAYS FOR NEXT Q
   147      BDLAY  SAVEVALUE  7,V23,XL               XL7=NO B-DLYS
   148             SAVEVALUE  9,V24,XL               XL9=TOT MINS B-DLY
   149             SAVEVALUE  2,V25,XL               XL2=AVG A-DLY/OCCUR
   150             SAVEVALUE  8,V26,XL               XL8=AVG B-DLY/OCCUR
   151             SAVEVALUE  4,V27,XL               XL4=OP COST OF A-DLY
   152             SAVEVALUE  10,0,,XL               XL10=OP COST OF B-DLY
   153             SAVEVALUE  5,V28,XL               XL5=PAX COST OF A-DLY
   154             SAVEVALUE  11,V29,XL              XL11=PAX COST OF B-DLY
   155             SAVEVALUE  6,V30,XL               XL16=TOT COST OF A-DLY
   156             SAVEVALUE  12,V31,XL              XL13=TOT COST OF B-DLY
   157             SAVEVALUE  13,V32,XL              XL13=TOT OCCURENCES
   158             SAVEVALUE  15,V34,XL              XL15=TOT MINS DELAY
   159             SAVEVALUE  14,V33,XL              XL14=TOT MINS/OCCUR
   160             SAVEVALUE  16,XL4,XL              XL16=TOT OP COST
   161             SAVEVALUE  17,V35,XL              XL17=TOT PAX COST
   162             SAVEVALUE  18,V36,XL              XL18=TOT COST
   163             SAVEVALUE  19,V37,XL              XL19=FLTS IN SYST
   164             SAVEVALUE  20,V38,XL              XL20=A-DLY MINS/FLT IN SYS
   165             SAVEVALUE  21,V39,XL              XL21=B-DLY MINS/FLT IN SYS
   166             SAVEVALUE  22,X10,XL              XL22=FLTS OUTSIDE SYS
   167             SAVEVALUE  23,0,,XL               XL23=A-DLY MINS OUTSIDE SYS
   168             SAVEVALUE  24,V40,XL              XL24=B-DLY MINS OUTSIDE SYS
   169             SAVEVALUE  25,V40,XL              XL25=TOT FLTS SIMULATED
   170             SAVEVALUE  26,V41,XL              XL26=A-DLY MINS/FLT
   171             SAVEVALUE  27,V42,XL              VL27=B-DLY MINS/FLT
   172             ASSIGN     2,27,PH                PH2 IS INDEX FOR LOOP
   173      SIGNF  SAVEVALUE  V45,V44                X(13+PH2)=XL*PH2 TIMES 100,RNDED
   174             LOOP       2PH,SIGNF              REPEAT FOR ALL XL'S
   175             TERMINATE  1                      END HOURLY TRANSACTION
                   START      52,,4
                   REPORT
                   EJECT
                   SPACE      3
            *                          SUMMARY STATISTICS
                   SPACE      6
            *                                   TYPE-A           TYPE-B            TOTAL
            *.                                  DELAY            DELAY             DELAY
            5      TEXT       OCCURENCES                      #X14,2/2LXXXXXXX.XX#     #
            #X20,2/2LXXXXXXX.XX#     #X26,2/2LXXXXXXX.XX#
            5      TEXT       MINUTES/OCCURENCE               #X15,2/2LXXXXXXX.XX#     #
            #X21,2/2LXXXXXXX.XX#     #X27,2/2LXXXXXXX.XX#
            5      TEXT       TOTAL MINUTES                   #X16,2/2LXXXXXXX.XX#     #
            #X22,2/2LXXXXXXX.XX#     #X28,2/2LXXXXXXX.XX#
            5      TEXT       OPERATING COST ($)              #X17,2/2LXXXXXXX.XX#     #
            #X23,2/2LXXXXXXX.XX#     #X29,2/2LXXXXXXX.XX#
```

```
 5      TEXT        PASSENGER COST ($)          #X18,2/2LXXXXXXX.XX#     #
#X24,2/2LXXXXXXX.XX#      #X30,2/2LXXXXXXX.XX#
 5      TEXT        TOTAL COST ($)              #X19,2/2LXXXXXXX.XX#     #
#X25,2/2LXXXXXXX.XX#      #X31,2/2LXXXXXXX.XX#
        SPACE       6
*                             IN SYSTEM     OUTSIDE SYSTEM      TOTAL
 5      TEXT        FLIGHTS SIMULATED           #X32,2/2LXXXXXXX.XX#     #
#X35,2/2LXXXXXXX.XX#      #X38,2/2LXXXXXXX.XX#
 5      TEXT        TYPE-A MINUTES/FLIGHT       #X33,2/2LXXXXXXX.XX#     #
#X36,2/2LXXXXXXX.XX#      #X39,2/2LXXXXXXX.XX#
 5      TEXT        TYPE-B MINUTES/FLIGHT       #X34,2/2LXXXXXXX.XX#     #
#X37,2/2LXXXXXXX.XX#      #X40,2/2LXXXXXXX.XX#
        EJECT
        OUTPUT
        END
```

APPENDIX C
TECHNICAL DESCRIPTION

C.1 THE AIRCRAFT NUMBER STOCK

In order to compute type-B delay, the flight simulator must "hold" an outgoing flight leg if the aircraft scheduled to fly that let is not ready (e.g., has been previously delayed). The schedule simulator has previously specified which aircraft is to fly that flight leg by placing the aircraft's tail number in half-word parameter 1 of the flight-leg transaction starting at statement lable "FLT." The flight simulator indicates the readiness of the aircraft by setting the logic switch whose number equals the aircraft tail number. For example, when aircraft 222 is ready for its next flight leg, logic switch 222 is set.

In order to keep the number of logic switchs to a minimum (so as to conserve core) the greatest aircraft tail number had to be kept as low as possible. Since aircraft were continually entering and leaving the system, the only way to keep the greatest tail number to a minimum was to reassign to those aircraft entering the system the tail number of those aircraft that had previously left the system. Consequently, a list had to be kept of the tail numbers of aircraft that had left the system. This list was kept in a savevalue "stack" starting with savevalue number 64.

As an aircraft left the system, the tail number of that aircraft was added to the top of the stack. As an aircraft entered the system, its tail number was taken from off the top of the stack if the stack was nonempty. Otherwise, a tail number greater than any yet assigned would have been used. Savevalue 4 pointed to the top of the stack. Thus if savevalue 4 was 75, savevalue 75 would contain the tail number to be assigned to the next entering aircraft.

C.2 CREATING A REALISTIC AIRCRAFT SCHEDULE

C.2.1 Discussion

A realistic aircraft schedule was needed to calibrate the schedule simulator or be used directly with the flight simulator. This section describes how a realistic flight schedule was generated.

Program SELD reads the TSC-reduced OAG tape and selects all flight legs incident at one or two of the nine study airports. The selected records are given sequence numbers and written on a sequential output file, File B. They are implicitly sorted by airline by flight number. Program SELN5 reads the sequential output file created by SELD, File B, selects records of flight legs whose arrival airport is one of the nine study airports, truncates the records, and writes them to a sequential output file, File C. SELN5 is then modified by changing statement 035 + 01 to create a similar file, File D, of records of flight legs whose departure airport is one of the nine study airports. We would suggest that programs SELD and SELN5 be merged in the future to save processing time and cost.

Files C and D are then sorted by airline, by aircraft type, by arrival and departure airport (for Files C and D, respectively), and by arrival and departure time (for Files C and D, respectively), creating sorted Files G and F, respectively. Program MERG-F4 using subroutines PGPROC-F4 creates a new File E, which is a merger of Files F and G, except that each record of File F and G contains appendages BEF and AFT. Every record from F (denoting a flight leg departing from one of the nine study airports) has AFT = 0 and BEF equal to the sequence number from File G of the flight leg arriving at the airport and using the same aircraft. Similarly, each record from File G (demoting a flight leg arriving at one of the nine study airports) has BEF = 0 and AFT equal to the sequence number from File F of the flight leg immediately following it using the same aircraft. Since a flight incident on two study airports will appear in both Files F and G, it will have two records in File E, one with BEF $\neq$ 0 and one with AFT $\neq$ 0. File E is then sorted by sequence number and program FIXI.F4 is run. FIXI.F4 merges sequential records with the identical sequence number (refering to the same flight — one record from File F, the other from File G) into one record, having BEF and AFT both nonzero. The File E thus formed contains one record for each flight leg with BEF equal to the sequence number of the preceding flight leg and AFT equal to the sequence number of the following flight leg. BEF or AFT equaling zero indicates the record is for the first or last leg of the flight in the system.

Program FINI.DMD is then used to make File E an indexed sequential file. We suggest that in order to save processing time and cost, program FINI.DMD be changed so that DAIR, DGMT, AAIR, AGMT, and AFT be unkeyed. This simple modification alone should save several hundred dollars. More money can be saved by unkeying BEF and ICHK; however, program FINLET would also have to modified to accommodate this change.

Finally, program FILET is run to create aircraft schedules from the indexed sequential File E. Each record of the aircraft schedule file, File H, contains the airline identification, aircraft identification, and a string of flight leg fields which each field containing departure airport, departure time, arrival airport, arrival time, and flight number.

C.2.2 Realistic Aircraft Schedule Generation — Program Listings

C.2.2.1 Variable Definition -

ICT = Counter

DAIR = Departure Airport

AAIR = Arrival Airport

DGMT = Departure Time - GMT

AGMT = Arrival Time - GMT

ACT = Aircraft Type

ACD = Airline Code

FLN = Flight Number

EFM = Effective Month - First Day Flight was Scheduled

EFD = Effective Day - First Day Flight was Scheduled

DSM = Discontinued Month

DSD = Discontinued Day

DAY = 1 if Flight Active on 12/28/74;

= 0 Otherwise

C.2.2.2 <u>Program - SELD</u> - Reads the OAG; selects flights incident at one or more of the nine airports; writes sequenced file. (Selects only those flights active 12/28/74.)

```
      DIMENSION CHK(9)
      DATA CHK/'ORD','LGA','JFK','DCA','BOS','ATL','MIA','LAX','SFO'/
      ICT=0
      GO TO 40
999   ICT=ICT+1
40    READ(11,50,END=100,ERR=99)DAIR,DGMT,AAIR,
     & AGMT,ACT,ACD,FLN,DAY,EFM,EFD,DSM,DSD
50    FORMAT(4X,A3,6X,A4,4X,A3,7X,A4,1X,A3,1X,A2,A5,10X,A1,7X,A2,A2,
     & A2,A2)
      IF(EFM.NE.'12') GO TO 33
      IF(EFD.GT.'28') GO TO 40
33    IF(DSM.EQ.' ') GO TO 34
      IF(DSM.LT.'12') GO TO 40
      IF(DSD.LT.'28') GO TO 40
34    IF(DAY.EQ.'0') GO TO 40
35    DO 300 K=1,9
      IF(DAIR.NE.CHK(K)) GO TO 300
      WRITE(12,280)ICT,DAIR,DGMT,AAIR,AGMT,ACT,ACD,
     & FLN,DAY,EFM,EFD,DSM,DSD
280   FORMAT(I6,A3,A4,A3,A4,A3,A2,A5,A1,A2,A2,A2,A2)
      GO TO 999
300   CONTINUE
      DO 301 K=1,9
      IF(AAIR.NE.CHK(K)) GO TO 301
      WRITE(12,281)ICT,DAIR,DGMT,AAIR,AGMT,ACT,ACD,
     & FLN,DAY,EFM,EFD,DSM,DSD
281   FORMAT(I6,A3,A4,A3,A4,A3,A2,A5,A1,A2,A2,A2,A2)
      GO TO 999
301   CONTINUE
      GO TO 999
99    TYPE 10,ICT
10    FORMAT(1X,'ERROR ON RECORD ',I6)
100           END FILE 12
      TYPE 13,ICT
13    FORMAT(1X,I6,1X,'RECORDS HAVE BEEN WRITTEN')
      STOP
      END
```

C.2.2.3 <u>Program - SELN5</u> - Truncates records created by program SELD; applied once for arrival airport (AAIR) and once for departure airport (DAIR) by changing statement # (35+1) and name of output file.

```
          DIMENSION CHK(9)
          DATA CHK/'ORD','LGA','JFK','DCA','BOS','ATL','MIA','LAX','SFC'/
          ICT=Ø
999       ICT=ICT+1
4Ø        READ(23,5Ø,END=1ØØ,ERR=99)ISEQ,DAIR,DGMT,AAIR,
      &   AGMT,ACT,ACD,FLN
5Ø        FORMAT(I6,A3,A4,A3,A4,A3,A2,A5)
35        DO 3ØØ K=1,9
          IF(AAIR.NE.CHK(K)) GO TO 3ØØ
35Ø       WRITE(22,28Ø)ISEQ,DAIR,DGMT,AAIR,AGMT,ACT,ACD,
      &   FLN
28Ø       FORMAT(I6,A3,A4,A3;A4,A3,A2,A5)
          GO TO 999
3ØØ       CONTINUE
          GO TO 4Ø
99        TYPE 1Ø,ICT
1Ø        FORMAT(1X,'ERROR ON RECORD ',I6)
          GO TO 4Ø
1ØØ       END FILE 12
          TYPE 13,ICT
13        FORMAT(1X,I6,1X,'RECORDS HAVE BEEN WRITTEN')
          STOP
          END
```

C.2.2.4 Program MERG.F4 -

```
          DIMENSION F(7,2ØØ),G(7,2ØØ),FSEQ(2ØØ),GSEQ(2ØØ),FBEF(2ØØ),
     &    FAFT(2ØØ),GBEF(2ØØ),GAFT(2ØØ),IDF(2ØØ),IAF(2ØØ),
     &    IDG(2ØØ),IAG(2ØØ)
          INTEGER FSEQ,GSEQ,FBEF,FAFT,GBEF,GAFT,G1,FSUB,GSUB,
     &    FRECS,GRECS
C
          I=1
          FRECS=Ø
          GRECS=Ø
          G1=1
          IBEG=Ø
          IEND=Ø
5         CONTINUE
C         READ FIRST GROUP OF F RECORDS
          READ(22,5Ø)FSEQ(1),(F(J,1),J=1,7),FBEF(1),FAFT(1)
5Ø        FORMAT(I6,A3,A4,A3,A4,A3,A2,A5,2I6)
          REREAD 51,IDF(1),IAF(1)
51        FORMAT(9X,I4,3X,I4)
C         F(5,1) IS THE AIRCRAFT TYPE
          CACT1=F(5,1)
C         F(1,1) IS THE DEPARTURE AIRPORT
          CACT2=F(1,1)
C         F(6,1) IS THE AIRLINE CODE
          CACT3=F(6,1)
4Ø        CONTINUE
          DO 3ØØ I=2,2ØØ
          READ(22,5Ø,END=2Ø2)FSEQ(I),(F(J,I),J=1,7),FBEF(I),FAFT(I)
          REREAD 51,IDF(I),IAF(I)
          IF(F(5,I).NE.CACT1.OR.F(1,I).NE.CACT2)GO TO 2Ø1
          IF (F(6,I).NE.CACT3) GO TO 2Ø1
3ØØ       CONTINUE
C
2Ø2       CONTINUE
          N=I
          GO TO 351
2Ø1       CONTINUE
          N=I-1
C         TYPE 63,N
63        FORMAT(1X,I3,'=N')
351       CONTINUE
          IF (IBEG.NE.Ø) GO TO 365
C         READ FIRST OF A GROUP OF G RECORDS
          READ(24,5Ø,END=17Ø)GSEQ(G1),(G(I,G1),I=1,7),
     &    GBEF(G1),GAFT(G1)
          REREAD 51,IDG(G1),IAG(G1)
C         TYPE 87,G(4,1),IAG(1)
35Ø       CONTINUE
          DACT1=G(5,1)
36Ø       CONTINUE
          IAG(1)=IAG(1)+3Ø
          IF(DACT1.EQ.'D1Ø'.OR.DACT1.EQ.'L1Ø') IAG(1)=IAG(1)+4Ø
          IF(DACT1.EQ.'747') IAG(1)=IAG(1)+4Ø
C         TYPE 5ØØ5,IAG(1)
5ØØ5      FORMAT(1X,'IAG=',I4)
          ITIME=24ØØ
          DO 3ØØØ L=1,24
          IF(IAG(1).GE.ITIME) GO TO 3ØØ1
          ITIME=ITIME-1ØØ
3ØØØ      CONTINUE
3ØØ1      IF((IAG(1)-(ITIME+4Ø)).LT.Ø) GO TO 2333
          IFIXT=IAG(1)-6Ø
```

```
      IAG(1)=IFIXT+100
2333  IF(IAG(1).GT.2400) IAG(1)=IAG(1)-2400
365       CONTINUE
      IF(G(5,G1).NE.CACT1.OR.G(3,G1).NE.CACT2) GO TO 373
      IF(G(6,G1).NE.CACT3) GO TO 373
      JN=2
370   CONTINUE
      READ(24,50,END=374)GSEQ(JN),(G(I,JN),I=1,7),GBEF(JN),GAFT(JN)
      REREAD 51,IDG(JN),IAG(JN)
      DACT1=G(5,JN)
      IAG(JN)=IAG(JN)+30
      IF(DACT1.EQ.'D10'.OR.DACT1.EQ.'L10') IAG(JN)=IAG(JN)+40
      IF (DACT1.EQ.'747') IAG(JN)=IAG(JN)+40
C     TYPE 5027,IAG(JN)
5027  FORMAT(1X,'IAGJN=',I4)
      ITIME=2400
      DO 2000 L=1,24
      IF(IAG(JN).GE.ITIME) GO TO 2002
      ITIME=ITIME-100
2000  CONTINUE
2002  IF((IAG(JN)-(ITIME+60)).LT.0) GO TO 2001
      IFIXT=IAG(JN)-60
      IAG(JN)=IFIXT+100
2001  IF(IAG(JN).GT.2400) IAG(JN)=IAG(JN)-2400
C5561  TYPE 5562,IAG(JN)
5562  FORMAT(1X,'IAG2='I4)
      IF(G(5,JN).NE.CACT1.OR.G(3,JN).NE.CACT2) GO TO 375
      IF(G(6,JN).NE.CACT3) GO TO 375
      JN=JN+1
      GO TO 370
373   K=0
      GO TO 62
374   IF(IEND.EQ.1) GO TO 100
      IEND=1
375   CONTINUE
      K=JN-1
C     TYPE 61,K
61    FORMAT(1X,I3,'=K')
62    IF (N.EQ.K) GO TO 380
      IF (N.GT.K) GO TO 378
376   CONTINUE
C     N IS LESS THAN K - MORE G RECS
C     IRITA-THE LEAST VALUE OF K OR N,NO. OF READS IN SUBROUTINE
      KSUB=K-N
      GRECS=GRECS+KSUB
      IRITA=N
      IADDG=IRITA+KSUB+1
      IADDF=IRITA+1
      GO TO 385
378   CONTINUE
C     N GT K - MORE F RECS
      FSUB=N-K
      FRECS=FRECS+FSUB
      IRITA=K
      IADDF=IRITA+FSUB+1
      IADDG=IRITA+1
      GO TO 385
380   CONTINUE
C     EQUAL NUMBER OF READS
      N=K
      IRITA=N
```

```
        IADDF=IRITA+1
        IADDG=IRITA+1
385     CONTINUE
C       TYPE 65
65      FORMAT(1X,'BEFORE')
        IF(IRITA.EQ.0) GO TO 440
        CALL PGPROC(F,G,IRITA,FSEQ,GSEQ,FBEF,FAFT,GBEF,GAFT,IDF,IAG)
C       TYPE 66
66      FORMAT(1X,'AFTER')
        DO 400 J=1,IRITA
        WRITE(21,50)FSEQ(J),(F(I,J),I=1,7),FBEF(J),FAFT(J)
400     CONTINUE
        DO 401 J=1,IRITA
C       TYPE 88,(G(I,J),I=1,7)
88      FORMAT(A3,A4,A3,A4,A3,A2,A5)
        WRITE(21,50)GSEQ(J),(G(I,J),I=1,7),GBEF(J),GAFT(J)
401     CONTINUE
C       IF (N.GT.K) GO TO 420
C       IF (K.GT.N) GO TO 430
410     CONTINUE
C       N EQ K - EQUAL NO. OF F AND G RECS.
C       IADDF=IRITA+1
C       IADDG=IRITA+1
C       GO TO 440
C420    CONTINUE
CC      N GT K - MORE F RECS
C       IADDF=IRITA+FSUB+1
C       IADDG=IRITA+1
C       GO TO 440
C430    CONTINUE
CC      K GT N - MORE G RECS
C       IADDG=IRITA+GSUB+1
C       IADDF=IRITA+1
440     CONTINUE
        DO 445 J=1,7
445     F(J,1)=F(J,IADDF)
        FSEQ(1)=FSEQ(IADDF)
        FBEF(1)=FBEF(IADDF)
        FAFT(1)=FAFT(IADDF)
        CACT1=F(5,IADDF)
        CACT2=F(1,IADDF)
        CACT3=F(6,IADDF)
        IDF(1)=IDF(IADDF)
        IAF(1)=IAF(IADDF)
        DO 450 J=1,7
        G(J,1)=G(J,IADDG)
450     CONTINUE
        GSEQ(1)=GSEQ(IADDG)
        GBEF(1)=GBEF(IADDG)
        GAFT(1)=GAFT(IADDG)
        DACT1=G(5,IADDG)
        IDG(1)=IDG(IADDG)
        IAG(1)=IAG(IADDG)
        IBEG=1
        IF(G(5,1).NE.CACT1.OR.G(3,1).NE.CACT2) IBEG=0
        IF(G(6,1).NE.CACT3) IBEG=0
C       TYPE 87,G(4,1),IAG(1)
87      FORMAT(1X,A4,I4)
        GO TO 40
100     CONTINUE
        STOP

        END
```

C.2.2.5 Program PGPROC.F4 - Called from MERG.4

```
      SUBROUTINE PGPROC(F,G,IRITA,FSEQ,GSEQ,FBEF,FAFT,
     & GBEF,GAFT,IDF,IAG)
      DIMENSION F(7,IRITA),G(7,IRITA),FSEQ(IRITA),GSEQ(IRITA),
     & GBEF(IRITA),FBEF(IRITA),FAFT(IRITA),GAFT(IRITA),
     & IFHK(200),IGCHK(200),IDF(IRITA),IAG(IRITA)
      INTEGER FSEQ,GSEQ,FBEF,FAFT,GBEF,GAFT
C     TYPE 83
83    FORMAT(1X,'IN SUB')
      DO 59 I=1,IRITA
      IFHK(I)=0
      IGCHK(I)=0
59    CONTINUE
131   DO 20 I=1,IRITA
      DO 10 J=1,IRITA
C     IF (IRITA.EQ.1) TYPE 111,F(7,I),G(7,J)
111   FORMAT(5X,2(A5,2X))
      IF(F(7,I).NE.G(7,J)) GO TO 10
      IFHK(I)=1
      IGCHK(J)=1
      GAFT(J)=FSEQ(I)
      FBEF(I)=GSEQ(J)
10    CONTINUE
20    CONTINUE
C     TYPE 38
38    FORMAT(1X,'BEF NOAC')
      NOAC=100
      MINAC=100
      MING=1
      MINF=0
      INDF=1
      INDG=1
30    CONTINUE
C     TYPE 71,IFHK(INDF),INDF
71    FORMAT(1X,'IFHK=',I3,'INDF=',I2)
      IF(IFHK(INDF).EQ.1) GO TO 40
C     TYPE 72,IGCHK(INDG)
72    FORMAT(1X,'IGCHK=',I3)
      IF(IGCHK(INDG).EQ.1) GO TO 60
C     TYPE 54
54    FORMAT(1X,'BEF IDF')
      IF(IDF(INDF).GE.IAG(INDG)) GO TO 50
C     TYPE 73
73    FORMAT(1X,'AFT IDF')
      NOAC=NOAC-1
      IF(NOAC.GE.MINAC) GO TO 40
      MING=INDG
      MINF=INDF
      MINAC=NOAC
C     TYPE 37
37    FORMAT(1X,'BEF 40')
40    IF(INDF.EQ.IRITA) GO TO 70
      INDF=INDF+1
      GO TO 30
50    NOAC=NOAC+1
60    IF(INDG.EQ.IRITA) GO TO 70
C     TYPE 91,INDG,IRITA
91    FORMAT(1X,'INDG=',I3,'IRITA=',I3)
      INDG=INDG+1
      GO TO 30
70    INDF=MINF+1
      INDG=MING
```

```
        IF(INDF.GT.IRITA) INDF=1
80      IF(IFHK(INDF).EQ.1) GO TO 9Ø
85      IF(IGCHK(INDG).EQ.1) GO TO 1ØØ
        GAFT(INDG)=FSEQ(INDF)
        FBEF(INDF)=GSEQ(INDG)
        INDG=INDG+1
        IF(INDG.GT.IRITA) INDG=1
        IF(INDG.EQ.MING) GO TO 11Ø
9Ø      INDF=INDF+1
        IF(INDF.GT.IRITA) INDF=1
        IF(INDF.EQ.(MINF+1)) GO TO 85
        GO TO 8Ø
1ØØ     INDG=INDG+1
        IF(INDG.GT.IRITA) INDG=1
        IF(INDG.EQ.MING) GO TO 11Ø
        GO TO 85
11Ø     RETURN
        END
```

C.2.2.6 <u>Program FIX1.F4</u> -

```
      DIMENSION ISEQ(2),F(7,2),IBEF(2),IAFT(2)
40    READ(23,5Ø,END=1ØØ)ISEQ(1),(F(J,1),J=1,7),IBEF(1),
     & IAFT(1)
5Ø    FORMAT(I6,A3,A4,A3,A4,A3,A2,A5,2I6)
41    READ(23,5Ø,END=1ØØ)ISEQ(2),(F(J,2),J=1,7),IBEF(2),
     & IAFT(2)
      IF(ISEQ(1).EQ.ISEQ(2)) GO TO 5ØØ
      WRITE(3,5Ø)ISEQ(1),(F(J,1),J=1,7),IBEF(1),IAFT(1)
      ISEQ(1)=ISEQ(2)
      IBEF(1)=IBEF(2)
      IAFT(1)=IAFT(2)
      DO 6Ø J=1,7
      F(J,1)=F(J,2)
6Ø    CONTINUE
      GO TO 41
5ØØ   IBEF(1)=IBEF(2)
      WRITE(3,5Ø)ISEQ(1),(F(J,1),J=1,7),IBEF(1),IAFT(1)
      GO TO 4Ø
1ØØ   STOP
      END
```

C.2.2.7 <u>Program FINI.DMD</u> - Sets up R.A file.

```
✓ ATT SEQ INT LENGTH 5 KEYED
  ATT DAIR TEXT LENGTH 3 KEYED
  ATT DGMT INT LENGTH 4 KEYED
  ATT AAIR TEXT LENGTH 3 KEYED
  ATT AGMT INT LENGTH 4 KEYED
  ATT ACT TEXT LENGTH 3
  ATT ACD TEXT LENGTH 2
  ATT FLN TEXT LENGTH 5
✓ ATT BEF INT LENGTH 6 KEYED
  ATT AFT INT LENGTH 6 KEYED
  ATT ICHK INT LENGTH 6 KEYED
```

C.2.2.8 <u>Program FILET</u> - Creates file H.

```
O FINI, F ALL,
UPDATE ON, INI 1 RPT1, INI 2 TEST, CLEAR,
DPL START,
DEFINE INTEGER IREC ICAFT I M ITIME,
LET I EQ 0,
PT2: F BEF EQ 0, GETREC R2,
FF1: IF ICHK EQ 99999 THEN PT2,
IF BEF EQ 0 THEN PT1,
IF ITIME GT DGMT THEN PT5B,
IF ITIME LT 0800 THEN PT5,
PT9: IF AFT EQ 0 THEN PT3,
IF DGMT LT 0800 THEN PT4,
IF DGMT GT AGMT THEN PT4B,
PT6: CHANGE ICHK 99999, PRINT ON 2 ICHK FMT I5 END,
PRINT ON 1 DAIR DGMT AAIR AGMT FLN FMT 2(A3 P9999) A5 $ END,
LET ICAFT EQ AFT, PRINT ON 2 ICAFT AFT FMT 2I5 END,
LET ITIME EQ AGMT, PRINT ON 2 ITIME AGMT FMT 2I4 END,
F SEQ EQ ICAFT, PRINT ON 2 SEQ ICAFT FMT 2I5 END,
GOTO FF1,
PT1: CHANGE BEF 99999,
PT8: CHANGE ICHK 99999, PRINT ON 2 ICHK FMT I5 END,
PRINT ON 1 ACD ACT DAIR DGMT AAIR AGMT FLN FMT / A2 A3 2(A3 P9999) A5 $ END,
LET ICAFT EQ AFT, PRINT ON 2 ICAFT AFT FMT 2I5 END,
LET ITIME EQ AGMT, PRINT ON 2 ITIME AGMT FMT 2I4 END,
F SEQ EQ ICAFT, PRINT ON 2 SEQ ICAFT FMT 2I5 END,
GOTO FF1,
PT3: PRINT ON 1 DAIR DGMT AAIR AGMT FLN FMT 2(A3 P9999) A5 $ END,
CHANGE ICHK 99999, PRINT ON 2 ICHK FMT I5 END,
PT29: LET I EQ I+1, IF I EQ 2200 THEN R2,
GOTO PT2,
PT4: IF AGMT GT 0800 THEN K1,
IF DGMT GT AGMT THEN K1,
GOTO PT6,
PT4B: IF AGMT GT 0800 THEN K1,
IF DGMT LT 0800 THEN K1,
GOTO PT6,
K1: PRINT ON 1 DAIR DGMT AAIR AGMT FLN FMT 2(A3 P9999) A5 END,
PRINT ON 1 ACD ACT DAIR DGMT AAIR AGMT FLN FMT A2 A3 2(A3 P9999) A5 $ END,
LET ICAFT EQ AFT, PRINT ON 2 ICAFT AFT FMT 2I5 END,
CHANGE ICHK 99999, PRINT ON 2 ICHK FMT I5 END,
LET ITIME EQ AGMT, PRINT ON 2 ITIME AGMT FMT 2I4 END,
F SEQ EQ ICAFT, PRINT ON 2 SEQ ICAFT FMT 2I5 END,
GOTO FF1,
PT5B: IF DGMT GT 0800 THEN PT10,
IF ITIME LT 0800 THEN PT10,
GOTO PT9,
PT5: IF ITIME GT DGMT THEN PT10,
IF DGMT GT 0800 THEN PT10,
GOTO PT9,
PT10: PRINT ON 1 ACD ACT DAIR DGMT AAIR AGMT FLN FMT / A2 A3 2(A3 P9999) A5 $ END
CHANGE ICHK 99999, PRINT ON 2 ICHK FMT I5 END,
IF AFT EQ 0 THEN PT29,
IF DGMT LT 0800 THEN PT11,
IF DGMT GT AGMT THEN PT11B,
FF2: LET ICAFT EQ AFT, PRINT ON 2 ICAFT AFT FMT 2I5 END,
CHANGE ICHK 99999, PRINT ON 2 ICHK FMT I5 END,
LET ITIME EQ AGMT, PRINT ON 2 ITIME AGMT FMT 2I4 END,
F SEQ EQ ICAFT, PRINT ON 2 SEQ ICAFT FMT 2I5 END,
GOTO FF1,
PT11: IF AGMT GT 0800 THEN PT12,
IF DGMT GT AGMT THEN PT12,
```

```
GOTO TO FF2.
PT11B: IF DGMT LT 0800 THEN PT12.
IF AGMT GT 0800 THEN PT12.
GOTO FF2.
PT12: PRINT ON 1 ACD ACT DAIR DGMT AAIR AGMT FLN FMT / A2 A3 2(A3 P9999) A5 $
GOTO FF2.                                                                  END
R2: DPL END.
UPDATE OFF.
REL 1.
QUIT.
```

C.2.2.9 Program PRJN3 -

```
          L=0
          K=1
          I=0
          J=0
999       I=I+1
          READ(12,50,END=100,ERR=99)DAIR,DGMT,AAIR,AGMT,
     &    ACT,ACD,FLN
50        FORMAT(A3,A4,A3,A4,A3,A2,A5)
          IF(AAIR.NE.'BOS') GO TO 80
          IF(I.EQ.1) GO TO 75
          IF(J.EQ.52) GO TO 75
          WRITE(3,60)AGMT,DAIR,DGMT,ACT,ACD,FLN
60        FORMAT(15X,A4,18X,A3,18X,A4,17X,A3,16X,A2,17X,A5)
          J=J+1
          GO TO 999
75        WRITE(3,61)
61        FORMAT(1H1,42X,'OAG AIRLINE SCHEDULE FOR FRIDAY',
     &    ' DECEMBER 20,1974')
          WRITE(3,62)AAIR
62        FORMAT(1H-,57X,'ARRIVALS AT:',1X,A3)
          WRITE(3,63)AGMT,DAIR,DGMT,ACT,ACD,FLN
63        FORMAT(1H-,'ARRIVAL TIME:',1X,A4,2X,'ORIGIN AIRPORT:',
     &    1X,A3,2X,'DEPARTURE TIME:',1X,A4,2X,'AIRCRAFT TYPE:',1X,A3,
     &    2X,'AIRLINE CODE:',1X,A2,2X,'FLIGHT NUMBER:',1X,A5)
          J=0
          GO TO 999
80        IF(K.EQ.1) GO TO 81
          IF(L.EQ.52) GO TO 81
          WRITE(3,70)DGMT,AAIR,AGMT,ACT,ACD,FLN
70        FORMAT(17X,A4,23X,A3,16X,A4,17X,A3,16X,A2,17X,A5)
          L=L+1
          GO TO 999
81        WRITE(3,64)
64        FORMAT(1H1,42X,'OAG AIRLINE SCHEDULE FOR FRIDAY',
     &    ' DECEMBER 20,1974')
          WRITE(3,65)DAIR
65        FORMAT(1H-,55X,'DEPARTURES FROM:',1X,A3)
          WRITE(3,66)DGMT,AAIR,AGMT,ACT,ACD,FLN
66        FORMAT(1H-,'DEPARTURE TIME:',1X,A4,2X,'DESTINATION AIRPORT:',
     &    1X,A3,2X,'ARRIVAL TIME:',1X,A4,2X,'AIRCRAFT TYPE:'1X,A3,2X,
     &    'AIRLINE CODE:',1X,A2,2X,'FLIGHT NUMBER:',1X,A5)
          L=0
          K=K+1
          GO TO 999
99        TYPE 15,I
15        FORMAT(1X,'ERROR ON RECORD',I6)
          GO TO 999
100       TYPE 16,I
16        FORMAT(1X,I6,1X,'RECORDS HAVE BEEN WRITTEN')
          STOP
          END
```

C.2.2.10 <u>Program PRIN'</u> - Reads file created by program SELN5 and prints formatted output with major break on new airline or airport and minor break on aircraft type.

```
          CHK1=' '
          CHK2=' '
          CHK3=' '
          I=Ø
999       I=I+1
4Ø        READ(12,5Ø,END=1ØØ,ERR=99)DAIR,DGMT,AAIR,AGMT,ACT,
     &    ACD,FLN
5Ø        FORMAT(6X,A3,A4,A3,A4,A3,A2,A5)
          IF(I.EQ.1) GO TO 75
          IF(ACD.NE.CHK1) GO TO 75
          IF(AAIR.NE.CHK2) GO TO 75
          IF(ACT.NE.CHK3) GO TO 77
          WRITE(3,6Ø)AGMT,DAIR,DGMT,FLN
6Ø        FORMAT(33X,A4,22X,A3,23X,A4,21X,A5)
          GO TO 999
75        CHK1=ACD
          CHK2=AAIR
          WRITE(3,61)
61        FORMAT(1H1,42X,'OAG AIRLINE SCHEDULE FOR FRIDAY ',
     &    'SEPTEMBER 2Ø,1974')
77        CHK3=ACT
          WRITE(3,62)ACD,AAIR,ACT
62        FORMAT(1H-,32X,'AIRLINE CODE:',1X,A2,7X,
     &    'DESTINATION AIRPORT:',1X,A3,6X,'AIRCRAFT TYPE:',1X,A5)
          WRITE(3,63)AGMT,DAIR,DGMT,FLN
63        FORMAT(18X,'ARRIVAL TIME:',1X,A4,5X,'ORIGIN ',
     &    'AIRPORT:',1X,A3,6X,'DEPARTURE TIME:',1X,A4,5X,
     &    'FLIGHT NUMBER:',1X,A5)
          GO TO 999
99        TYPE 1Ø,I
1Ø        FORMAT(1X,'ERROR ON RECORD',1X,I6)
          GO TO 999
1ØØ       STOP
          END
```