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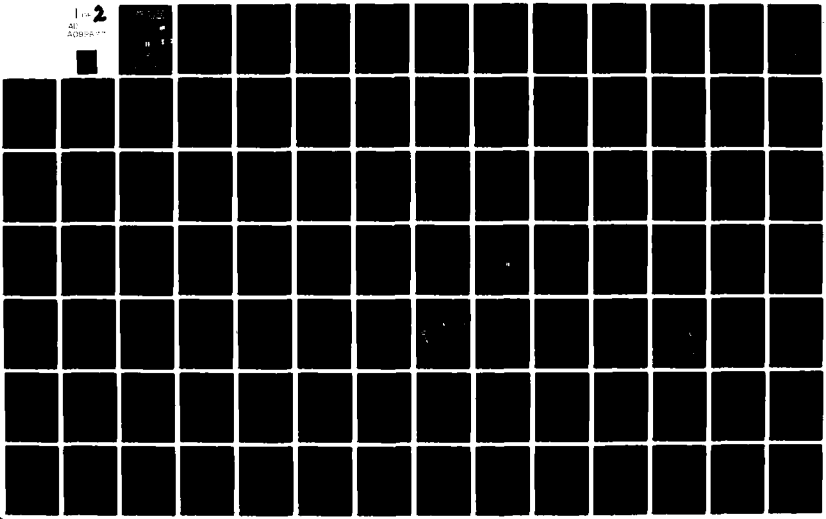
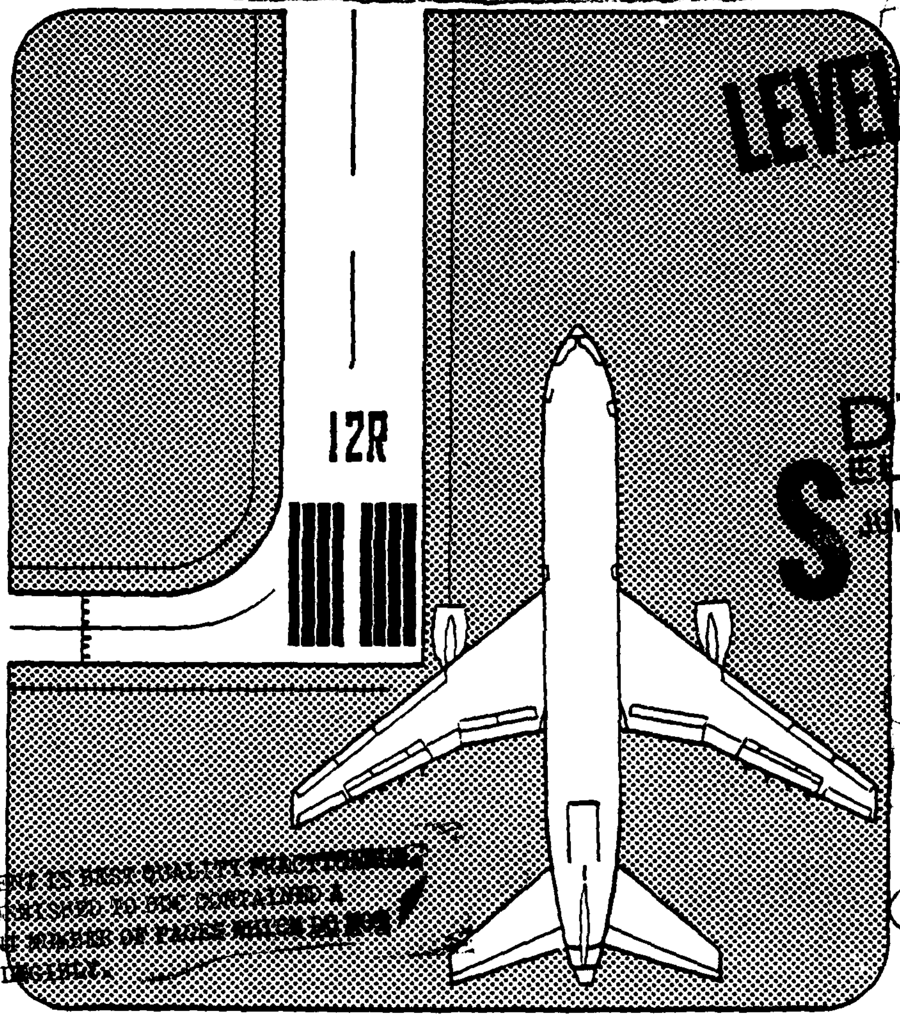


LAMBERT-ST. LOUIS INTERNATIONAL AIRPORT DATA PACKAGE ~~No.~~ 2.

AIRPORT IMPROVEMENT TASK FORCE DELAY STUDIES.



prepared for
DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
under contract
DOT- FA77WA -3961

Peat, Marwick, Mitchell & Co.

OCTOBER 1979

Telephone: (415) 347-9521

March 27, 1980

Mr. Christopher Quinn
Deputy Director
Air Transport Association
of America
9501 West Devon
Rosemont, Illinois 60018

Re: Suggested Values of Future Aviation Activity for Task Force Study of Lambert-St. Louis International Airport

Dear Chris:

This letter is in response to our commitment to suggest forecast aviation activity levels for the Task Force study.

We have reviewed recent historical activity and compared these data to the forecasts that were prepared by PMM&Co. in 1978.

Table 1 shows the annual data, which suggest that Lambert activity is growing faster than anticipated at the time of development of the 1978 forecasts. As I have stated previously, we do not believe that 1978 and 1979 activity should be considered as strong indicators of future activity, because of the low fare programs that were in effect and the onset of deregulation. Our best expectation is that the 1985 forecasts remain valid, within a reasonable percentage of error. Figure A is a sketch showing the same data graphically.

Table 2 depicts historical and forecast peak hour data. The same general observations can be made--the 1979 air carrier plus air taxi level of 53.9 is lower than our estimate of 60 for 1985 (6 class B, 44 class C, and 10 class D). This implies that the general aviation plus military activity in the peak hour will fall off rapidly between 1979 and 1985.

In line with the philosophy of the Experimental Design Subcommittee of the Task Force, we would suggest working variations in baseline, increased heavy, and reduced general aviation activity according to the values shown in Table 3, by analyzing 1979 data first and then testing high levels of activity, such as for the Stage III growth (2000), to determine the extent of delays in relation to demand. Should the Stage III levels indicate very high levels of delay, we would work with lower levels of demand, e.g., Stage II, to provide information on aircraft delays and to answer Task Force questions.

Please call me if you have any questions.

Sincerely yours,

Dan G. Haney
Manager

DGH/nw
Enclosures

cc: Mr. Leonard Griggs, St. Louis Airport Authority
Mr. Mel Fischer, FAA Central Region, Kansas City
Mr. C. F. Booth, American Airlines
Mr. Glenn Bales, FAA Tower, St. Louis
Dr. Steve Hockaday, PMM&CO.

bcc: TFD Correspondence File
TFD Project File, MO STL TF
D. van der Burch
G. Baskir

Table 1

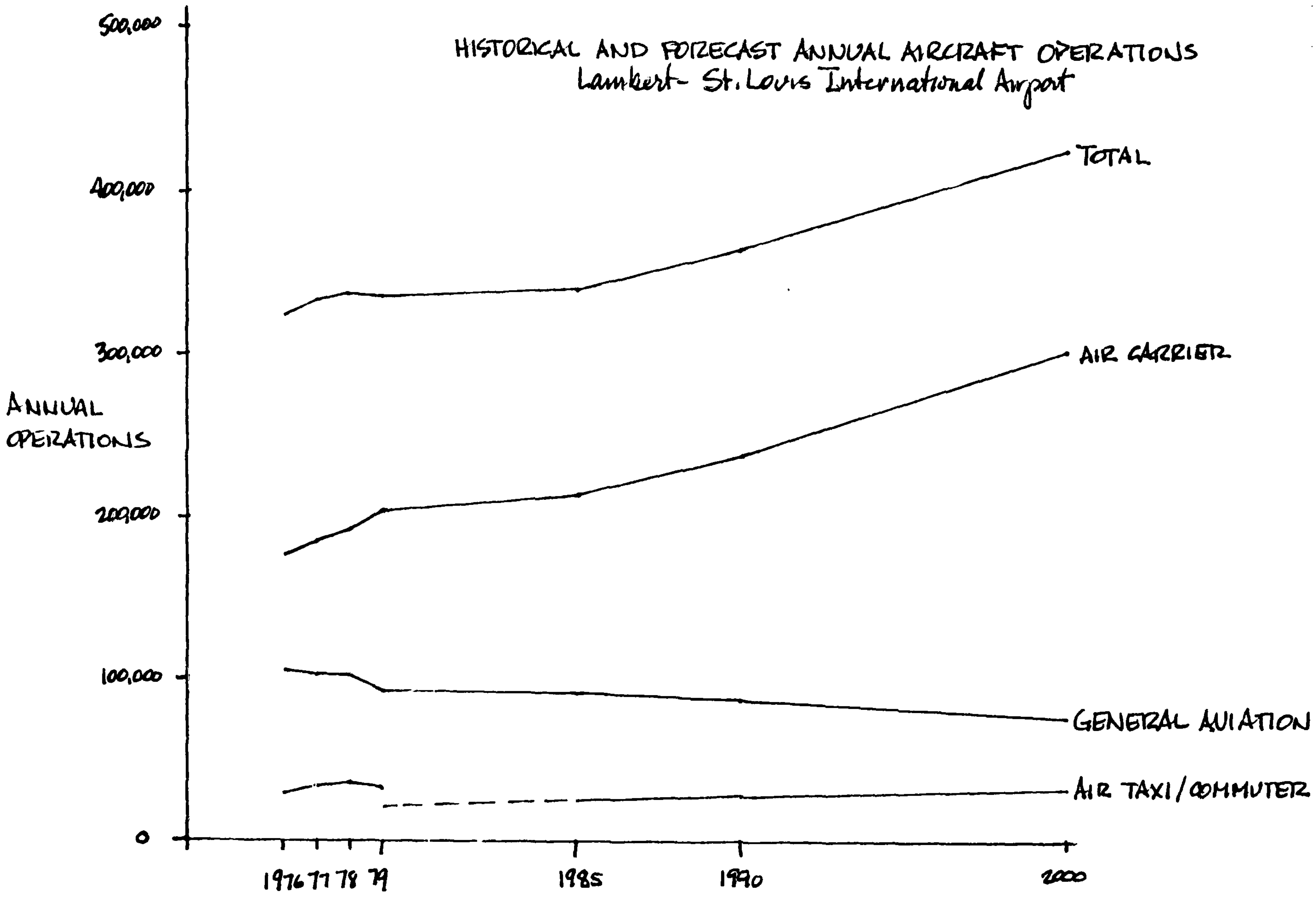
HISTORICAL AND FORECAST ANNUAL AIRCRAFT OPERATIONS
Lambert-St. Louis International Airport

	1976	1977	1978	1979	1985	1990	2000
Air Carrier	175,000	185,000	193,000	203,000	212,000	235,000	300,000
General Aviation	105,000	101,000	101,000	91,000	90,000	85,000	77,000
Air Taxi	29,000	36,000	38,000	35,000	25,000[a]	30,000[a]	34,000[a]
Military	12,000	11,000	9,000	8,000	12,000	12,000	12,000
Total	321,000	334,000	340,000	336,000	339,000	362,000	423,000

a. Forecasts are for *scheduled commuter services*. Nonscheduled air taxi operations are contained in the general aviation forecasts.

FIGURE A

HISTORICAL AND FORECAST ANNUAL AIRCRAFT OPERATIONS
Lambert- St. Louis International Airport



Source: PMM & Co

Table 2

PEAK HOUR OPERATIONS*
Lambert-St. Louis International Airport

	1976	1977	1979	1985	2000
Actual, PMS data					
AC and AT	42.5	47.4	53.9		
GA and MI	30.8	31.0	27.1		
Total	72.3	78.4	81.0		
PMM&CO. Forecast Report (VFR)					
A	7			4	3
B	25			19	20
C	39			44	46
D	2			10	27
Total	73			77	96

Note: The maximum number of operations during an hour, for two-week period in August 1979, was 99.

*Average peak hour operations in the peak month, (August) based on the hour of each day in which the peak total operations occur.

Table 3

SUGGESTED FORECAST VALUES
FAA TASK FORCE STUDY

	Stage I growth (Post 1985)	Stage II growth (Post 1990)	Stage III growth (2000)
A. Baseline			
Annual Operations			
Air Carrier	220,000	250,000	300,000
Commuter	27,000	32,000	34,000
Military	12,000	12,000	12,000
General Aviation	85,000	80,000	77,000
Total	344,000	374,000	423,000
Peak Hour Operations (VFR)			
A	4	3	3
B	21	21	20
C	47	47	46
D	13	22	27
Total	85	93	96
B. Increased Heavy Jets			
Annual Operations			
Air Carrier	212,000	215,000	277,000
Commuter	27,000	32,000	34,000
Military	12,000	12,000	12,000
General Aviation	85,000	80,000	77,000
Total	336,000	339,000	400,000
Peak Hour Operations (VFR)			
A	4	3	3
B	21	21	21
C	33	28	34
D	20	31	33
Total	78	83	91
C. Reduced general aviation			
Annual Operations			
Air Carrier	220,000	250,000	300,000
Commuter	27,000	32,000	34,000
Military	12,000	12,000	12,000
General Aviation	60,000	50,000	50,000
Total	319,000	344,000	396,000
Peak Hour Operations (VFR)			
A	2	2	2
B	16	13	13
C	47	47	47
D	13	22	22
Total	78	84	84

PEAT, MARWICK, MITCHELL & CO.
P. O. BOX 8007
SAN FRANCISCO INTERNATIONAL AIRPORT
SAN FRANCISCO, CALIFORNIA 94128

Telephone: (415) 347-9521

October 24, 1979

Mr. Michael M. Scott, ATF-4
Federal Aviation Administration
800 Independence Avenue, S.W.
Washington, D.C. 20591

Re: Lambert-St. Louis International Airport Data Package No. 2

Dear Mike:

Attached is Lambert-St. Louis International Airport Data Package No. 2. The package contains the results of the model calibration runs performed to date for Lambert-St. Louis International Airport and responds to comments made by the Task Force at the last meeting. The contents of the data package are:

- Attachment A, discussion materials on the Airfield Simulation Model, to be used for a Task Force "mini-course" on the model.
- Attachment B, examples of Model applications and experiments at other Task Forces.
- Attachment C, the calibration results at Lambert-St. Louis International Airport.
- Attachment D, a discussion of the potential experimental design process at Lambert-St. Louis International Airport.
- Attachment E, responses to questions raised by Glenn Bales.
- Attachment F, a list of model limitations.

- o Attachment G, extracted from the NAFEC Scenario.

This material should be reviewed by the Task Force members prior to the next meeting on October 31, 1979.

Sincerely,

Stephen L. M. Hockaday
Manager

SLMH/dch
Enclosures

Attachment A

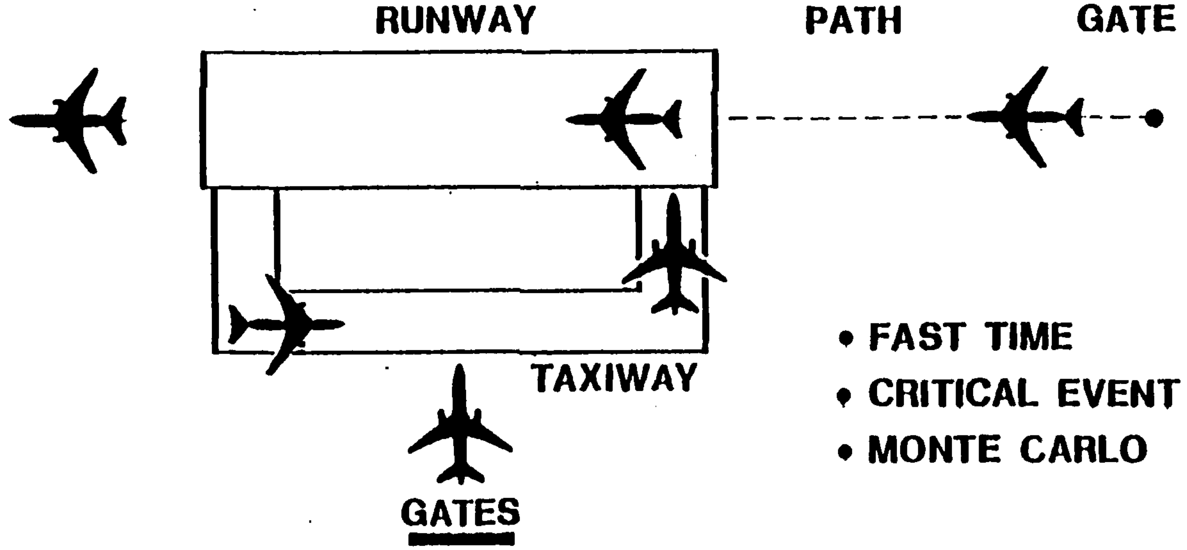
Airfield Simulation Model Discussion Materials

Lambert-St. Louis International Airport
Airport Improvement Task Force Delay Studies

Peat, Marwick, Mitchell & Co.
San Francisco, California

October 1979

SIMULATION MODEL



- FAST TIME
- CRITICAL EVENT
- MONTE CARLO

MODEL OVERVIEW

The model overview section of this user manual generally describes simulation model logic and sets forth a typical procedure for applying the simulation model.

Description of Simulation Model Logic

The PMM&Co. airfield simulation model contains a set of logic statements that describes the significant movements performed by aircraft on the airfield and in the adjacent airspace. The simulation model operates by tracing the path of each aircraft through space and time on the airfield and adjacent airspace. The airfield is represented by a series of links and nodes depicting the paths that an aircraft could follow. The traces of the paths of all aircraft are made by continually advancing clock time and recording the new location of the aircraft. The records of aircraft movement are then processed by the model to produce desired outputs including delays, travel times, and flow rates.

The PMM&Co. airfield simulation model is a critical events model that employs Monte Carlo sampling techniques. Variable time increments are used as the time flow mechanism; clock time is advanced by the amount necessary to cause the next most imminent (i.e., critical) event to take place. Running time for the model, therefore, depends on the levels of aircraft demand (and the size of the airfield) for any particular application.

The use of Monte Carlo sampling techniques permits the day-to-day variations encountered in real life to be simulated by the model. Certain of the model parameters are stochastic (time variant and random) in nature. For example, arrival aircraft approach speeds will vary from day to day for any given aircraft depending on such factors as payload, wind, and pilot technique. Analysis has shown that the distribution of these variations can be approximated by the normal distribution. Hence, the model assigns arrival aircraft approach speeds by sampling values from a normal distribution with mean and standard deviation specified by the user. Other stochastic model parameters are:

- Arrival/arrival separations
- Departure/arrival separations
- Arrival/departure separations
- Departure/departure separations

- Arrival runway occupancy time
- Touch-and-go runway occupancy time
- Departure runway occupancy time
- Exit taxiway choice
- Gate service time
- Arrival aircraft deviation from schedule

Because of the modular structure of the model, analysis of the total airfield or its individual components can be performed by manipulation of the model inputs. This approach is more flexible and efficient than having separate submodels for the individual components and a composite model for the total airfield.

During the various stages of model development, sensitivity analyses were performed to identify those parameters that have a significant impact on airfield capacity and aircraft delay. One sensitivity test was conducted to determine the impact of arrival runway occupancy times on runway capacity and aircraft delays. The tests dynamically considered the arrival aircraft's approach speed, touchdown speed, touchdown distance from threshold, and deceleration characteristics; runway conditions; and exit taxiway location and geometry. It was concluded that runway occupancy times calculated in this manner produce essentially the same values of runway capacity and aircraft delays when compared with values calculated using Monte Carlo sampling from empirical distributions of runway occupancy times.

Another sensitivity analysis considered aircraft taxiing velocities. Extensive field data show that taxiing velocities do not vary significantly by aircraft type. However, the analysis also shows that taxiing velocities are sensitive to the location of the taxiways with respect to the terminal building and runways. Consequently, taxiing velocities are assigned with respect to taxiway location, rather than by aircraft type.

In the following paragraphs, further details of simulation model logic are described as follows:

- Movement of aircraft--description of the progress of an aircraft through the airfield system.
- Runway and airspace operations--description of ATC algorithms that separate pairs of aircraft on the runways and in the airspace.

- Taxiing operations—description of model logic that processes aircraft on taxiways.

- Gate operations—description of model logic that processes aircraft in the apron-gate area.

Movement of Aircraft

Arrival aircraft commence at the appropriate arrival fixes in accordance with generated demand inputs. Depending on the arrival demand, aircraft may be vectored or put in holding patterns before merging on the common approach path to the runway. For each arrival aircraft, approach speeds are assigned from an empirical distribution according to the class of the aircraft. For each arrival pair, interarrival times, final approach speeds, and wake turbulence characteristics are checked so that sufficient separation exists on the common approach path. (The length of the common approach path is specified by the user.) As each aircraft arrives over the threshold, an exit taxiway and associated runway occupancy time are assigned to the aircraft. These assignments are based on empirical distributions which take into account such factors as exit location and type, aircraft class, of the runway, and weather.

The aircraft's routing to the gate or basing area is established in the following manner. As an air carrier aircraft exits the runway, a check is made on the availability of a gate of the correct size belonging to the airline under consideration. In the event a gate is not available, the aircraft is routed to a holding area where further checks on gate availability are made. In the case of general aviation or military aircraft, the aircraft's route to the basing area is assigned on the basis of the exit taxiway used and the location of the basing area.

Once an aircraft's route to the gate or basing area has been established, the aircraft is moved along its route from link-to link on the airfield network. Checks are made at each link to determine whether the next link on the route is available or occupied by another aircraft. If the next link is occupied, the aircraft is not moved until the link is vacated. Thus, the travel time is increased for the particular aircraft, and delay is incurred.

When the aircraft reaches its gate, a gate occupancy time is assigned from empirical distributions and is added to the gate arrival time. This information, when compared with the scheduled departure time, determines the earliest time when the aircraft could leave the gate. The empirical distributions for gate occupancy time may reflect the typical bunching of the schedules of air carrier departures. When an aircraft is ready to leave the gate, a check is made to ensure that the ramp area is clear for push-back. The route to the departure runway is determined by the aircraft's basing area or gate location, the aircraft class, and the departure runways in use at that particular time.

In the case of general aviation or military aircraft, when the aircraft reaches the basing area, it is assumed to be parked and to have left the system. This assumption is necessary because of the unstructured nature of general aviation or military operations on the apron. The flow of aircraft from the basing area is generated from the demand inputs by producing an expected departure time from the basing area for each general aviation aircraft. The route to the departure runway is established by the location of the basing area and the departure runways in use.

When an aircraft reaches the threshold of the departure runway, compliance with ATC procedures is checked and confirmed before the aircraft is cleared for takeoff. The following checks are made:

- Has the previous dependent arrival cleared the runway?
- Is there sufficient separation from the next incoming dependent arrival?
- Is there sufficient separation from the previous dependent departure?

If all of these checks are positive, the aircraft is cleared for takeoff.

Runway and Airspace Operations

An ATC algorithm allows the specification of separations between aircraft on the same runway and on dependent runways. These separations are defined for an arrival following an arrival, a departure following an arrival, a departure following a departure, and an arrival following a departure. For arrivals or departures on each runway, the model checks that sufficient separation exists between the aircraft under consideration and any other aircraft operation on the same runway or any dependent runway. In determining the time separation between a pair of successive arrival aircraft at the runway threshold, the model takes into account:

1. The required air traffic control separation for the aircraft pair.

2. The final approach velocity of each aircraft.

   a. If the trail aircraft is faster than the lead aircraft, the required arrival separation is assured at the runway threshold.

   b. If the trail aircraft is slower than the lead aircraft, the required arrival separations set up at the beginning of the common approach path. The amount of time the trail aircraft falls behind is included in the time separation over threshold for the aircraft pair.

3. Runway occupancy. Only one aircraft is permitted to occupy the runway at any given time.

The model determines a time separation between a pair of successive departure aircraft which takes into account the required air traffic control separation by aircraft pair. The model will permit a departure to roll on a runway (thus interleaving arrivals and departures) when all of the following conditions have been fulfilled:

1. The previous arrival aircraft has exited.

2. When the departure begins to roll, the next arrival is far enough from the threshold for the departure to clear the runway before the arrival is over its threshold.

3. Sufficient separation from the previous departure exists.

For pairs of intersecting runways, the user must also input arrival-departure separations so the model checks that the arrival aircraft has cleared the intersection before a departure that is being cleared on the intersecting runway.

Several special ATC features are incorporated into the simulation model logic. One ATC feature included in the model increases arrival aircraft spacings on final approach to allow departure queues to be dissipated. The length of the departure queue (number of aircraft) at which the interarrival spacing is increased and the desired interarrival spacing (minutes) must be specified.

Another ATC feature included in the model searches departure runways for congestion before assigning a departure runway to an aircraft leaving its gate. A runway is selected that minimizes delay. If runway congestion is too heavy, the aircraft is held on the gate until the congestion reduces.

Taxiing Operations. The normal operation of the model moves aircraft from link to link on a predetermined path which is defined in terms of a series of links. The model performs a check to ensure that the next link on the path is not occupied by another aircraft before moving on to the link. It is assumed in the logic that the taxiway is used by aircraft moving in the same direction at all times, unless the user specifies to the contrary.

Taxiways on which aircraft may taxi in both directions are defined as two-way taxiways. These taxiways, which are defined by the user, may occur at several places on the airfield and are often found between pier fingers at a terminal building. The model checks aircraft movements to determine if the aircraft is about to enter a two-way path. In the event that an aircraft is about to enter a two-way path, the model then checks along the path to determine if there are other aircraft on the path that may be moving toward a potential conflict. If a potential conflict exists, the aircraft for which the check is being made is delayed until the conflict condition no longer exists.

If an aircraft is about to taxi across an active runway, the model performs certain checks in accordance with ATC procedures to determine if it is safe for the aircraft to cross. Priority is always given to aircraft operating on the runway.

Gate Operations. Once a gate is assigned to an arriving air carrier aircraft, the model moves the aircraft from link to link on the network to the gate, observing a first-come-first-served rule in the event of conflicts (except for taxiways crossing active runways). For those airfields having terminal buildings with pier fingers, a "two-way path" will often serve the gates between any two pier fingers. Thus, prior to entering the two-way path, the model will check for aircraft moving either toward or away from a particular gate on the path. In the event an aircraft is moving on the path toward a gate (i.e., away from the arrival aircraft for which the check is being performed), the model permits the arrival aircraft to taxi on the path toward its gate in "platoon fashion" similar to real-life operations. If an aircraft is taxiing from the gate or is in the process of pushing back, the arrival aircraft is held until the departing aircraft is clear of the two-way path.

When the model detects that an aircraft is ready to push back from the gate, a check is performed to see if the aircraft will push back onto a two-way path. If it will push back onto a two-way path, the model then checks for aircraft on the two-way path and permits "platooning" in a similar fashion as described for arrivals. If there is an aircraft taxiing toward the area which the departing aircraft will occupy during push-back, the aircraft is delayed on the gate until the arrival aircraft has cleared the area in question.

Procedure for Application of Model

The following is a typical procedure for applying the simulation model to evaluate aspects of airfield operations:

- Establish the conditions under which the application will be performed.

- Visit site to obtain first-hand familiarization with airfield operations.

- Assemble input data from (a) discussions with ATC, airport sponsor, and airline personnel; (b) historical data; and (c) field data collection as necessary. The preprocessors models should be used to prepare demand and routing data in machine compatible format.

- Coordinate input data with ATC, airport sponsor, and airline personnel.

- Load input data and use output options that permit input data to be reviewed before execution. Correct as necessary.

- Perform trial model run using one random number seed, with all diagnostic print options functioning, to check that the model is operating correctly for the input data that is being used. Correct as necessary.

- After confidence in model inputs has been established, suppress diagnostic print options before making the model runs for evaluation of airfield improvements.

- Determine level of output detail required for evaluation and specify appropriate print options.

- Perform model runs.
- Use postprocessor models as required to develop detailed statistical information on aircraft delays.

INPUT DEFINITION

Introduction

The airfield simulation model was developed to be applicable to the range of airfield configurations currently in existence and to those configurations that are likely to evolve in the future. Consequently, the model does not contain any airport-specific or aircraft-class-specific data; all data are input.

Thus, the model may be applied to airfields ranging from a nontower general aviation field to an airfield with the complexity of Chicago O'Hare International Airport. It should be noted, however, that simulation model application is relatively expensive because of the model's complexity and the volume of input data required to run it. Therefore, the model is most often applied at airports with more complex airfield layouts that experience significant aircraft delays.

By manipulating the input data, it is possible to simulate the occurrence of unusual events. For example, the impact of a disabled aircraft on the runway can be simulated by specifying that the runway use be changed in the middle of the model run. Further examples include the simulation of the impact of a change in weather conditions or the effect of a storm passing through the area. These impacts may be simulated by changing aircraft separation runway uses, and aircraft operating characteristics in the middle of the simulation model run.

Description of Inputs

The input data required for the operation of the model are identified below. Guidance on preparing input data is given later in this section and in the detailed example which illustrates the development of input data for a typical airport.

Logistics

- Title: a brief description of the model application.

- Random number seeds: each random number seed represents a daily set of variations of events. (The number of random number seeds is selected to achieve stochastic convergence of results.)

- Start and finish times: the times when the run is to start and finish.

- Print options: several options are available concerning level of detail of output, debugging statements, etc.

- Airline names: the two letter codes for each airline included in the demand data (include dummy code for general aviation or military aircraft).

- Processing options: several options are available concerning the way input data are processed. e.g., print input data only.

- Truncation limits: applies to the limits of the normal distribution used in the Monte Carlo sampling technique. Defined in terms of a number of standard deviations.

Airfield Physical Characteristics

- Airfield network: a description of the airfield in terms of a network of links and nodes.

- Runway identification: the number of runways and their identifiers.

- Departure runway end links: the taxiway link(s) that can be occupied by aircraft prior to crossing an active runway.

- Runway crossing links: the taxiway link(s) that can be occupied by aircraft prior to crossing an active runway, together with clearance times to the crossing taxiway for arriving and departing aircraft.

- Exit taxiway location: the distance from the threshold of each exit taxiway, by runway.

- Holding areas: those sections of taxiways or apron that are used for storing arrival aircraft that are awaiting a gate.

- Airline gates: the gates belonging to each airline.

- Fixes: approach and departure fix identification.

ATC Procedures

- Aircraft separations: mean and standard deviation of minimum separations for each aircraft pair class for arrival-arrival, departure-arrival, departure-departure, and arrival-departure sequences (for each runway and for pairs of dependent runways).
- Route data: link sequence for all exit taxiway/gate and gate/departure runway combinations. Also link sequence for exit taxiway/holding area and holding area/gate combinations.
- Two-way path data: link sequence for those sections of taxiway used by aircraft that may be traveling in either direction.
- Common approach path(s): Length of the common approach to each runway by aircraft class.
- Vectoring delays: level of airborne delay (by fix) to arrival aircraft at which holding delays start to occur.
- Departure runway queue control: queue lengths (by runway) above which aircraft will be diverted to a different departure runway.
- Gate hold control: queue lengths (by runway) above which gate holds will be instigated.
- Departure airspace constraints: mean and standard deviation of effect of departure airspace constraints on delays, and percentage of departures affected.
- Interarrival gap control: departure queue lengths above which interarrival spacings will be increased to release departures.

Aircraft Operational Characteristics

- Exit taxiway utilization: distribution of exit taxiway usage by aircraft class.
- Arrival runway occupancy times: distance from the threshold versus time data for arrival aircraft by aircraft class.

- Touch-and-go runway occupancy times: mean and standard deviation by aircraft class.
- Departure runway occupancy times: mean and standard deviation by aircraft class.
- Taxi speeds: aircraft taxiing speeds for each of six taxiway link-types.
- Approach speeds: mean and standard deviation by aircraft class.
- Gate service times: mean and standard deviation by aircraft class.
- Airspace travel times: undelayed travel times from approach fix to threshold and from threshold to departure fix by aircraft class.
- Lateness distribution: distribution of deviations from scheduled arrival times to be used in conjunction with an airline schedule (if applicable).
- Demand: detailed list of aircraft, including scheduled arrival and departure times, aircraft class, desired arrival and departure runway and fixes, flight type, preferred gate assignment for air carrier aircraft, and basing area for general aviation.

Four classes of aircraft are used as model inputs. In general, any definition of aircraft classes is possible subject to the constraint that:

class 1 aircraft are larger than class 2,
class 2 aircraft are larger than class 3, and
class 3 aircraft are larger than class 4.

This condition is necessary for the gate logic where it is assumed that an aircraft can use a gate for its class number or of a lower class number.

Five flight types are recognized by the model. They are:

Flight Type Number	Description
1	Originating
2	Terminating
3	Through
4	Turnaround
5	Touch-and-go

Guidance on Input Data Preparation

At the beginning of each run, the model assumes that there are no aircraft on the airfield. Aircraft are generated at various locations on the airfield and in the adjacent airspace according to the demand schedule. To obtain relevant data for the time period being simulated, it is recommended that preloading be used. Preloading may be accomplished in one of two ways:

1. Start the simulation run approximately one hour ahead of the period of interest, using appropriate demand levels for that hour, or

2. Include in the demand schedule the aircraft that may be parked at the various airline gates at the beginning of the period of interest.

The first alternative is normally preferred if the period of interest being simulated is relatively short, i.e., one or two hours. If the period being simulated is greater than two hours then the second alternative may be used.

Random Number Seeds

Tests on the convergence of the model's stochastic parameters have indicated that it is normally desirable to use at least ten random number seeds when making a model run. Ten random number seeds, in effect, simulate the day-to-day variations of aircraft operations on ten days, for the period of the day under consideration.

Airfield Geometry

The geometry of the airfield is entered as a network of links and nodes. An example of a network is illustrated in Figure A-1. The airfield is divided into a series of numbered links with link lengths being no shorter than the length of the largest aircraft that frequently uses the airport. The link lengths should be selected such that the predominant classes of aircraft at the airport can occupy the link with approximately an aircraft length between one aircraft and an aircraft on an adjacent link. Link lengths typically vary from 200 to 400 feet at air carrier airports.

The following notes are of value in developing an airfield network:

1. Runways are treated as a single link (i.e., they may only be occupied by one aircraft at any one time).

2. Normally, a runway should only have one departure end link.

3. Exit taxiways should not be defined as a departure end link.

4. Even if identifiable holding areas (or penalty boxes) do not physically exist on the airport, some provision should be made for holding areas on the airfield in the network. This would account for the ability to hold aircraft on taxiways. If no holding areas are specified and all gates are occupied, the model will prematurely terminate execution.

5. For those taxiway intersections where the paths of taxiing aircraft cross, it is necessary to define a link that represents the intersection. See detailed example for further information.

Airline Gates

When identifying the gates belonging to a particular airline, the gates should typically be listed in ascending order by aircraft size (i.e., list gates for aircraft class 4 first). This prevents smaller aircraft from being reassigned to a class 1 gate in the event the smaller aircraft's preferred gate is occupied. However, if a class 1 gate is the only gate available, it will be assigned to the smaller aircraft.

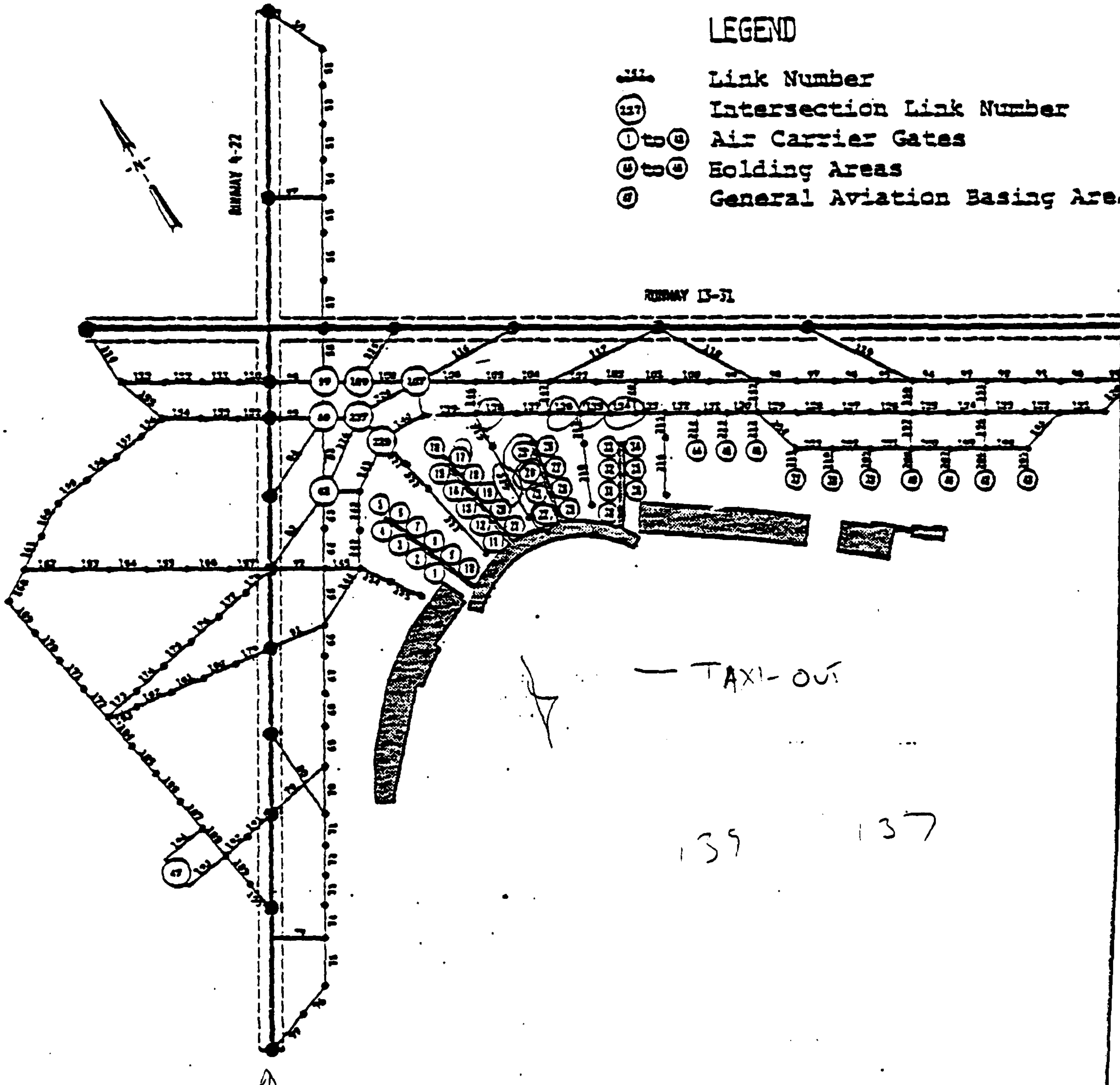


Figure A-1

TYPICAL AIRFIELD NETWORK

Route Data

Routing data requirements for the airfield simulation model consist of defining the typical paths aircraft use between the runways and the apron areas. More specifically, routes have to be defined for each exit taxiway/gate (or basing area) combination and for each gate (or basing area)/departure runway combination. In addition, if holding areas or penalty boxes are frequently used, routes have to be defined to and from these locations. A routing data preprocessor model has been developed which minimizes the effort involved in identifying the large number of routes that are typically used at a large air carrier airport. Input to the preprocessor model defines typical routes in a similar fashion to that required for the airfield simulation model. However, the logic of the preprocessor model is such that once a particular sequence of links has been defined on a route, it is only necessary to specify the start and end links of that sequence should they occur in subsequent routes. This considerably reduces the amount of work required to identify the routes and prepare the input data for the airfield simulation model. The output from the preprocessor model is formatted such that it is directly usable as input to the airfield simulation model.

Two-Way Path Data

For those sections of taxiways that are identified as two-way paths, it is necessary to enter two-way path data for both directions. This does not apply to two-way paths between pier fingers which typically can only be accessed from one end or from the gates along the two-way path.

Demand

The model requires the following input data concerning aircraft demand on the airfield system.

a. Aircraft identifier (e.g., flight number for air carrier aircraft)

b. Aircraft class

c. Flight type

d. Arrival time

e. Departure time

f. Arrival fix and runway

g. Departure fix and runway

h. Preferred gate assignment (for air carrier aircraft or basing area (for general aviation and military aircraft).

At air carrier airports, one of the best sources of demand information is the Official Airline Guide (OAG), which is available in hard-copy and magnetic tape format. The OAG data contain data items a, b, c, d, and e listed above. PMM&Co. has developed a demand schedule preprocessor model which extracts these items from the OAG data and combines them with data on items e and f listed above (which may be obtained from the ARTS Data Model) and gate assignment data to provide demand data for scheduled air carrier and air taxi operations. Demand data for general aviation, military, and other nonscheduled aircraft are combined with these data to provide inputs to the airfield simulation model.

In the event the preprocessor and the ARTS Data Model are not used to assist in the preparation of the demand data, the data may be developed manually.

Array Sizes

Because of core requirements, it was necessary to specify the sizes of various arrays in the development of the model program. The maximum number of parameter values for each of the model inputs is specified below (where appropriate):

- Random number seeds: the maximum number of random number seeds is 10
- Start and finish times: maximum length of run is 16 hours
- Airline names: the maximum number of airlines is 20
- Airfield network: maximum number of links is 600 (i.e., largest link number is 600)
- Runway identification: maximum number of active runways is 5

- Departure runway end links: one link per departure runway
- Runway crossing links: maximum number of crossing points is 10
- Exit taxiway location: maximum number of exit taxiways is 40
- Holding areas: maximum number of holding areas is 10
- Airline gates: maximum number of gates is 20 per airline
- Fixes: maximum number of approach and departure fixes is 10 (total)
- Aircraft separations: separations are defined by aircraft class pair; maximum number of aircraft class pairs is 16
- Route data: maximum number of routes is 1,400; maximum number of links on each path is 60
- Two-way path data: maximum number of two-way paths is 20; maximum number of links on each path is 25

Short Form

Once a baseline set of input data has been developed and checked out for a particular airfield, model runs to demonstrate the sensitivity of aircraft delays to small or large changes in certain input parameters can easily be carried out. For example, a small change in delay (e.g., on the order of 5%) may result from a change in gate push-back times due to revised airline procedures. However, the addition of a runway may result in large changes in delay (e.g., on the order of 30% to 50%).

A short form of the model can be applied for those applications that only require analysis of a component of the airfield. For example, the model may be applied to evaluate the impact of increased demand on runway and terminal airspace delays.

To evaluate this impact, it is only necessary to develop a set of runway and airspace delay values corresponding to various demand levels. Delays for taxiways and gates are not required. Therefore, the short form of the simulation model can be used that does not model operations on the taxiways and gates.

The short form of the simulation model is arranged to model runway and airspace operations in a very simple and efficient manner. A dummy gate is located at each exit from the runways, and a single dummy gate is connected to the departure runways. The complex handling of taxiing and gate operations is completely eliminated in this manner, and the short form focuses on the runway and airspace components in a simple, yet realistic, manner.

The efficient use of the short form of the model can yield substantial cost savings because many time-consuming simulation movements are eliminated and both core storage and computer running time are reduced. The short form is easy to apply because it uses a sub-set of the inputs required for the long form of the model.

Similar efficiencies are also attained via use of the preprocessor models to develop demand data and via the use of the postprocessor models to reduce detailed output to a form suitable for review by management and nontechnical personnel.

Data Forms

Several data forms have been developed to assist the user in assembling model input data. Samples of these forms are given in a later section of this manual.

OUTPUT DEFINITION

The primary outputs from the delay model are aircraft delays, travel times, and flow rates. In addition, the locations of aircraft delays are shown and departure runway queuing statistics are produced. The model outputs may be obtained in two levels of detail.

Summary Output

The summary output, which is automatically produced by the program together with a listing of the output data, contains the following information for each hour of the model run.

- Flow rates on runways, taxiways, and gates by aircraft class for arrival and departure aircraft.

- Delays (in minutes) for arrival and departure aircraft. For arrival aircraft, air delays are broken down into holding and vectoring delays by approach fix and by runway, while ground delays are identified as taxi-in, runway crossing, and gate delays. For departure aircraft, ground delays are broken down into gate, taxi-out, runway crossing, and runway delays; departure gate delays (gate holds) and runway delays are broken down by cause (i.e., runway congestion and airspace congestion).

- Travel times (in minutes) for arrival and departure aircraft are given by fix, runway, and aircraft class.

- In addition to the summary information noted above, delays are provided for individual arrival and departure aircraft and for the location of those delays (i.e., by link number). It is not meaningful to provide these data as average values over a number of random number seeds. Therefore, individual aircraft delays and link delays are provided for the last random number seed specified in the input data.

Figure A-2 shows a typical summary output for a one-hour period.

MODEL USER MANUAL EXAMPLE

* * * A V E R A G E   F L O W   R A T E S * * *

IN THE HOUR FROM 16, 0, 0 TO 17, 0, 0

A. RUNWAYS

RWY NO.	ARRIVAL TOTAL	D	C	B	A	TOUCH-AND-GO TOTAL	D	C	B	A	DEPARTURE TOTAL	D	C	B	A
1	29	0.00	.28	.48	.24	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
2	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	29	0.00	.21	.41	.38
TOTAL	29	0.00	.28	.48	.24	0	0.00	0.00	0.00	0.00	29	0.00	.21	.41	.38

	D	C	B	A	TOTAL
GRAND TOTAL FLOW	0	14	26	18	58

B. TAXIWAYS

STARTED TO TAXI-IN TOTAL	D	C	B	A	STARTED TO TAXI-OUT TOTAL	D	C	B	A
29	0.00	.28	.48	.24	33	.03	.18	.42	.36

INTERSECTION LINK NO.	ARRIVAL TOTAL	D	C	B	A	DEPARTURE TOTAL	D	C	B	A
83	4	0.00	0.00	0.00	1.00	0	0.00	0.00	0.00	0.00
110	2	0.00	0.00	1.00	0.00	0	0.00	0.00	0.00	0.00
152	1	0.00	0.00	1.00	0.00	0	0.00	0.00	0.00	0.00
191	0	0.00	0.00	0.00	0.00	10	0.00	0.00	.20	.80
TOTAL	7	0.00	0.00	.43	.57	10	0.00	0.00	.20	.80

C. GATES

	ARRIVED ON GATE TOTAL	D	C	B	A	DEPARTED FROM GATE TOTAL	D	C	B	A
AC	23	0.00	.39	.57	.09	23	.04	.26	.52	.17
GA	4	0.00	0.00	0.00	1.00	10	0.00	0.00	.20	.80
TOTAL	27	0.00	.30	.48	.22	33	.03	.18	.42	.36

Figure A-2

EXAMPLE OF SUMMARY OUTPUT

MODEL USER MANUAL EXAMPLE

* * * A V E R A G E   D E L A Y   S U M M A R Y * * *

IN THE HOUR FROM16. 0. 0 TO 17. 0. 0

RUNWAY NUMBER	AVERAGE ARRIVAL AIR DELAY	AVERAGE DEPARTURE RUNWAY DELAY
1	1.45	0.00
2	0.00	.25
WEIGHTED AVERAGE	1.45	.25

RUNWAY NUMBER	AVERAGE ARRIVAL HOLDING DELAY	AVERAGE ARRIVAL VECTORING DELAY	AVERAGE ARRIVAL AIR DELAY
1	.07	1.18	1.45
2	0.00	0.00	0.00
WEIGHTED AVERAGE	.07	1.38	1.45

FIX NUMBER	HOLDING DELAY	VECTORING DELAY	DEPARTURE RUNWAY DELAY	DEPARTURE RUNWAY CONG.	DEPARTURE AIRSPACE CONG.
1	0.00	1.95	0.00	0.00	0.00
2	0.00	1.24	0.00	0.00	0.00
3	.29	.71	0.00	0.00	0.00
4	0.00	1.59	0.00	0.00	0.00
5	0.00	0.00	.27	0.00	0.00
7	0.00	0.00	.44	0.00	0.00
8	0.00	0.00	.12	0.00	0.00
9	0.00	0.00	.20	0.00	0.00
10	0.00	0.00	.22	0.00	0.00

AVERAGE TAXI-IN DELAY		AVERAGE GATE DELAY			AVERAGE TAXI-OUT DELAY	
RUNWAY CROSSING	ARRIVAL TAXI-IN	ARRIVAL	DEPARTURE RUNWAY CONG.	DEPARTURE AIRSPACE CONG.	RUNWAY CROSSING	DEPARTURE TAXI-OUT
.05	.02	0.00	0.00	0.00	.05	.19

ARRIVAL AIRFIELD DELAY = 1.52   DEPARTURE AIRFIELD DELAY = .44

Figure A-2 (cont.)

*** A V E R A G E   T R A V E L   T I M E   S U M M A R Y ***

IN THE HOUR FROM16, 0, 0 TO 17, 0, 0

FIX	RUNWAY	CLASS	ARRIVAL TIME FIX TO THRESH	ARRIVAL TIME THRESH TO GATE	DEPARTURE TIME GATE TO ROLL	DEPARTURE TIME ROLL TO FIX
1	1	2	19.32	5.51	0.00	0.00
1	1	3	18.66	4.99	0.00	0.00
2	1	2	13.90	5.10	0.00	0.00
2	1	3	14.39	5.25	0.00	0.00
3	1	2	10.06	4.96	0.00	0.00
3	1	3	8.68	5.82	0.00	0.00
4	1	4	4.32	4.28	0.00	0.00
5	2	2	0.00	0.00	7.39	11.57
5	2	3	0.00	0.00	5.83	10.90
6	2	1	0.00	0.00	8.30	12.00
6	2	2	0.00	0.00	5.64	12.00
6	2	3	0.00	0.00	6.41	12.00
7	2	2	0.00	0.00	7.63	16.26
7	2	3	0.00	0.00	3.95	15.81
8	2	2	0.00	0.00	10.29	18.40
8	2	3	0.00	0.00	6.12	18.56
9	2	2	0.00	0.00	6.82	18.87
9	2	3	0.00	0.00	5.20	14.65
10	2	4	0.00	0.00	3.55	2.95
	WEIGHTED AVERAGE		11.94	5.02	5.19	10.05

Figure A-2 (cont.)

*** INDIVIDUAL AIRCRAFT OUTPUT ***

A. ARRIVALS

AIRCRAFT NUMBER	HOLD AT FIX	FIX TO THRESH	TOTAL AIR	TAXI-IN RUNWAY CROSSING	ARRIVAL TAXI-IN	HOLD AREA	TOTAL GROUND	TOTAL ARRIVAL
20 UNDEL TT	******	8.08	8.08	******	5.93	******	5.93	14.00
DELAYS	0.00	0.00	0.00	1.54	0.00	0.00	1.54	1.54
TOTAL TT	0.00	8.08	8.08	1.54	5.93	0.00	7.47	15.55
22 UNDEL TT	******	2.73	2.73	******	4.84	******	4.84	7.57
DELAYS	0.00	3.35	3.35	1.06	0.00	0.00	1.06	4.41
TOTAL TT	0.00	6.07	6.07	1.06	4.84	0.00	5.91	11.98
24 UNDEL TT	******	2.73	2.73	******	3.53	******	3.53	6.26
DELAYS	0.00	.25	.25	0.00	0.00	0.00	0.00	.25
TOTAL TT	0.00	2.98	2.98	0.00	3.53	0.00	3.53	6.51
25 UNDEL TT	******	8.08	8.08	******	4.98	******	3.53	6.26
DELAYS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]
[illegible] TT	0.00	8.08	8.08	0.00	3.53	0.00	[illegible]	[illegible]
[illegible]	[illegible]	12.97	12.97	******	[illegible]	[illegible]	[illegible]	3.96
TOTAL TT	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.00	6.14	23.07
58 UNDEL TT	******	12.97	12.97	******	5.69	******	5.69	18.66
DELAYS	0.00	3.27	3.27	0.00	0.00	0.00	0.00	3.27
TOTAL TT	0.00	16.24	16.24	0.00	5.69	0.00	5.69	21.93

B. DEPARTURES

AIRCRAFT NUMBER	GATE HOLD RUNWAY CONGESTION	GATE HOLD AIRSPACE CONGESTION	TAXI-OUT RUNWAY CROSSING	DEPARTURE TAXI-OUT	DEPARTURE RUNWAY	TOTAL DEPARTURE
2 UNDEL TT	******	******	******	8.30	12.00	20.30
DELAYS	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL TT	0.00	0.00	0.00	8.30	12.00	20.30
3 UNDEL TT	******	******	******	8.30	15.60	23.90
DELAYS	0.00	0.00	0.00	0.00	.63	.63
TOTAL TT	0.00	0.00	0.00	8.30	16.23	24.53
4 UNDEL TT	******	******	******	6.96	14.40	21.36
DELAYS	0.00	0.00	0.00	0.00	1.00	1.00
TOTAL TT	0.00	0.00	0.00	6.96	15.40	22.37
5 UNDEL TT	******	******	******	6.96	14.40	21.36
DELAYS	0.00	0.00	0.00	0.00	0.00	0.00
[illegible] TT	0.00	0.00	0.00	6.96	14.40	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	0.00	[illegible]	[illegible]
30 UNDEL TT	[illegible]	[illegible]	[illegible]	[illegible]	14.40	16.59
DELAYS	0.00	0.00	[illegible]	0.00	0.00	.10
TOTAL TT	0.00	0.00	.10	2.19	14.40	16.69
58 UNDEL TT	******	******	******	2.19	2.73	4.92
DELAYS	0.00	0.00	0.00	0.00	.27	.27
TOTAL TT	0.00	0.00	0.00	2.19	3.00	5.19

Figure A-2 (cont.)

* * * L I N K   D E L A Y S * * *

LINK NUMBER	TAXI-IN DELAY	TAXI-OUT DELAY	GATE DELAY
8	0.00	3.33	0.00
47	0.00	.50	0.00
58	.22	0.00	0.00
69	0.00	.13	0.00
75	0.00	.02	0.00
76	0.00	.79	0.00
77	0.00	6.50	0.00
85	.24	0.00	0.00
115	.09	0.00	0.00
116	.17	0.00	0.00
143	0.00	.10	0.00
191	0.00	.91	0.00
192	0.00	.21	0.00
229	0.00	.20	0.00

Figure A-2 (cont.)

Detailed Output

The detailed output is a time-ordered record of the movements of individual aircraft as they move from link to link in the network. The information contained in the detailed output for each individual aircraft movement includes the following:

- Aircraft identification number
- Aircraft state
- Aircraft class
- Gate assignment (where applicable)
- Time over threshold (for arrival)
- Gate service time (where applicable)
- Gate departure time
- Simulation clock time
- Location of aircraft

All times are given in hours, minutes, and seconds except for times included in error messages and diagnostics which are given in minutes.

In addition to this detailed information, the number of aircraft in the queue for a departure runway is printed out each time an aircraft joins the queue and each time an aircraft is given clearance for takeoff. The information contained in this detailed output permits the user to follow the movement of individual aircraft and identify the cause(s) of the delay that an aircraft may experience.

As the model processes aircraft through the system, it assigns a "state" to the aircraft depending on its location and the type of process being performed. These states are as follows:

Aircraft State	Description
0	Has not arrived
1	Being vectored or in holding pattern
2	Has landed and is taxiing to gate or holding area
3	Parked at gate
4	Taxiing to departure runway
5	Has left system, e.g., taken off
6	Pushing back from gate
7	In holding area
8	Leaving holding area after securing gate

Because this detailed output is voluminous, it is only normally requested for a single random number seed. However, a processing option is available which produces a tape of all of these data (for several random number seeds if required). The tape can then be used with postprocessors to produce a detailed statistical analysis of the data, with delays classified by airline, aircraft type, and location. In addition, distributions of delays and queuing information may be obtained for varying time periods (e.g., 15 minutes, 1 hour).

Figure A-3 shows a typical detailed output obtained directly from the simulation model. In this figure, for example, the progress of aircraft number 14 may be tracked; the aircraft leaves link 73 at 16.10.0, travels over links 74, 75, 76 and departs Runway 4 at 16.10.42. A diagnostic is printed when aircraft number 4 reaches the takeoff queue (in this case the queue length is one) showing that a check is made to see if the queue length is long enough to require arrival aircraft spacing to be increased. A further example shows aircraft number 26, which is a general aviation departure from the basing area (link 47), at time 16.10.0. Aircraft number 26 is seen to move from the basing area, on links 193 and 192 to link 191 (a runway crossing link), where it is delayed 0.38 minutes.

```
 ID           BK  FLIGHT A/C   GATE   BK   STATE    ARR. TIM    SERVICE    DEP. TI     CLOCK      LINK NO
                  TYPE   CLASS                                  TIME                   TIME
 12            7   1      2       0     0    0      0, 0, 0     0, 0, 0    16,10, 0    16,10, 0      0
 12            7   1      2       7     0    3      0, 0, 0     0, 0, 0    16,10, 0    16,10, 0      0
SUBTRACE PUSHUK CHECKING PUSHBACK INTO A TWO-WAY   SECTION
N=  12 ID=   1 K5=   7 K6=   2 K7=   6 J= 230 LKOCC (J)=    0
 26           47   1      4       0     0    0      0, 0, 0     0, 0, 0    16,10, 0    16,10, 0      0
 26           47   1      4      47     0    3      0, 0, 0     0, 0, 0    16,10, 0    16,10, 0      0
 14           40   1      3      40   888    4      0, 0, 0     0, 0, 0    16, 5, 0    16,10, 0     73
 13           32   1      3      32   651    4      0, 0, 0     0, 0, 0    16, 5, 0    16,10, 1    144
 15           13   1      2      13   237    4      0, 0, 0     0, 0, 0    16, 5, 0    16,10, 2    143
 11           39   1      3      39   829    4      0, 0, 0     0, 0, 0    16,10, 0    16,10, 6    209

SUBTRACE OUT       11       829        39       39
 26           44   1      4      47   999    6      0, 0, 0     0, 0, 0    16,10, 0    16,10, 6    193

SUBTRACE OUT       26       999        47       48
 16           43   1      4      43   990    4      0, 0, 0     0, 0, 0    16, 5, 0    16,10, 6     70
 25          270   4      3      38  3765    2     16, 7, 0     0,31,23    16,50, 0    16,10, 8     97
 13           32   1      3      32   652    4      0, 0, 0     0, 0, 0    16, 5, 0    16,10, 8     66
 14           40   1      3      40   889    4      0, 0, 0     0, 0, 0    16, 5, 0    16,10,10     78
 11           39   1      3      39   829    4      0, 0, 0     0, 0, 0    16,10, 0    16,10,11    209
 26           44   1      4      47   999    4      0, 0, 0     0, 0, 0    16,10, 0    16,10,14    193
 16           43   1      4      43   991    4      0, 0, 0     0, 0, 0    16, 5, 0    16,10,15     71
 25          270   4      3      38  3766    2     16, 7, 0     0,31,23    16,50, 0    16,10,16     96
 13           32   1      3      32   653    4      0, 0, 0     0, 0, 0    16, 5, 0    16,10,17     67
 14           40   1      3      40   890    4      0, 0, 0     0, 0, 0    16, 5, 0    16,10,19     75
 15           13   1      2      13   238    4      0, 0, 0     0, 0, 0    16, 5, 0    16,10,21    144
 11           39   1      3      39   830    4      0, 0, 0     0, 0, 0    16,10, 0    16,10,23    202
 25          270   4      3      38  3767    2     16, 7, 0     0,31,23    16,50, 0    16,10,26     95
 16           43   1      4      43   992    4      0, 0, 0     0, 0, 0    16, 5, 0    16,10,28     72
 13           32   1      3      32   654    4      0, 0, 0     0, 0, 0    16, 5, 0    16,10,28     68
 26           44   1      4      47  1000    4      0, 0, 0     0, 0, 0    16,10, 0    16,10,25    192
 15           13   1      2      13   239    4      0, 0, 0     0, 0, 0    16, 5, 0    16,10,28     66
 14           40   1      3      40   891    4      0, 0, 0     0, 0, 0    16, 5, 0    16,10,31     76
 13           32   1      3      32   655    4      0, 0, 0     0, 0, 0    16, 5, 0    16,10,34     69
 11           39   1      3      39   831    4      0, 0, 0     0, 0, 0    16,10, 0    16,10,34    203
 16           43   1      4      43   993    4      0, 0, 0     0, 0, 0    16, 5, 0    16,10,34     73
 15           13   1      2      13   240    4      0, 0, 0     0, 0, 0    16, 5, 0    16,10,36     67
 26           44   1      4      47  1001    4      0, 0, 0     0, 0, 0    16,10, 0    16,10,37    191

SUBTRACE RUNCRSDELAY=    ,38 N=    26 EVTM(N) = 970,62 NXTLND =     0
THAR (NXTLND)=   0,00 K2=   191 ALINK (K2) =    ,19 TIME = 970,62 IRUN=     2 ISUB =    4
 25          270   4      3      38  3768    2     16, 7, 0     0,31,23    16,50, 0    16,10,39    150
 14           40   1      3      40   892    4      0, 0, 0     0, 0, 0    16, 5, 0    16,10,42     77
SUBTRACE MOVE CHECKING THE LOGIC TO DECREASE TAKOFF QUEUE
   14970,710   77   77  892   77   12
I=    IL=    76LKOCC(L)=      0
 14           40   1      3      40   892    5      0, 0, 0     0, 0, 0    16, 5, 0    16,10,42  TAKEOFF RUNWAY    4
 16           43   1      4      43   994    4      0, 0, 0     0, 0, 0    16, 5, 0    16,10,44     74
 15           13   1      2      13   241    4      0, 0, 0     0, 0, 0    16, 5, 0    16,10,45     68
 13           32   1      3      32   656    4      0, 0, 0     0, 0, 0    16, 5, 0    16,10,48     70
 11           39   1      3      39   832    4      0, 0, 0     0, 0, 0    16,10, 0    16,10,49    204
SUBTRACE PAVCHK
IFLAG =  1 I=  9 ID=  5 N=  11 K =   3K3 =  832J8=   131J=   131 LKOCC(J) =    0
```

Figure A-3

EXAMPLE OF DETAILED OUTPU

AIRCRAFT MOVEMENT LOGIC
PMM&CO. AIRFIELD SIMULATION MODEL

Movement of Aircraft	Subroutine
Arrival aircraft commence at the appropriate arrival fixes in accordance with generated demand inputs. Depending on the arrival demand, aircraft may be vectored or put in holding patterns before merging on the common approach path to the runway. For each arrival aircraft, approach speeds are assigned from an empirical distribution according to the class of the aircraft.	ARRIVE
For each arrival pair, interarrival times, final approach speeds, and wake turbulence characteristics are checked so that sufficient separation exists on the common approach path. (The length of the common approach path is specified by the user.)	ATC
An ATC algorithm allows the specification of separations between aircraft on the same runway and on dependent runways. These separations are defined for an arrival following an arrival, a departure following an arrival, a departure following a departure, and an arrival following a departure. For arrivals, the model checks that sufficient separation exists between the aircraft under consideration and any other aircraft operation on the same runway or any dependent runway. In determining the time separation between a pair of successive arrival aircraft at the runway threshold, the model takes into account: 1. The required air traffic control separation for the aircraft pair. 2. The final approach velocity of each aircraft. a. If the trail aircraft is faster than the lead aircraft, the required arrival separation is assured at the runway threshold. b. If the trail aircraft is slower than the lead aircraft, the required arrival separations are set up at the beginning of the common approach path. The amount of time the trail aircraft falls behind is included in the time separation over threshold for the aircraft pair. 3. Runway occupancy. Only one aircraft is permitted to occupy the runway at any given time.	ATC
As each aircraft arrives over the threshold, an exit taxiway and associated runway occupancy time are assigned to the aircraft. These assignments are based on empirical distributions which take into account such factors as exit location and type, aircraft class, runway, and weather.	ARRIVE

The aircraft's routing to the gate or basing area is established in the following manner. As an air carrier aircraft exits the runway, a check is made on the availability of a gate of the correct size belonging to the airline under consideration. In the event a gate is not available, the aircraft is routed to a holding area where further checks on gate availability are made. In the case of general aviation or military aircraft, the aircraft's route to the basing area is assigned on the basis of the exit taxiway used and the location of the basing area. GATE ROUTE

Once an aircraft's route to the gate or basing area has been established, the aircraft is moved along its route from link-to-link on the airfield network. Checks are made at each link to determine whether the next link on the route is available or occupied by another aircraft. If the next link is occupied, the aircraft is not moved until the link is vacated. Thus, the travel time is increased for the particular aircraft, and delay is incurred. MOVE

The normal operation of the model moves aircraft from link to link on a predetermined path which is defined in terms of a series of links. The model performs a check to ensure that the next link on the path is not occupied by another aircraft before moving on to the link. It is assumed in the logic that the taxiway is used by aircraft moving in the same direction at all times, unless the user specifies to the contrary. MOVE

Taxiways on which aircraft may taxi in both directions are defined as two-way taxiways. These taxiways, which are defined by the user, may occur at several places on the airfield and are often found between pier fingers at a terminal building. The model checks aircraft movements to determine if the aircraft is about to enter a two-way path. In the event that an aircraft is about to enter a two-way path, the model then checks along the path to determine if there are other aircraft on the path that may be moving toward a potential conflict. If a potential conflict exists, the aircraft for which the check is being made is delayed until the conflict condition no longer exists. PAVCHK

If an aircraft is about to taxi across an active runway, the model performs certain checks in accordance with ATC procedures to determine if it is safe for the aircraft to cross. Priority is always given to aircraft operating on the runway. RUNCRS

Once a gate is assigned to an arriving air carrier aircraft, the model moves the aircraft from link to link on the network to the gate, observing a first-come-first-served rule in the event of conflicts (except for taxiways crossing active runways). For those airfields having terminal buildings with pier fingers, a "two-way path" will often serve the gates between any two pier fingers. Thus, prior to entering the two-way path, the model will check for aircraft moving either toward or away from a particular gate on the path. In the event an aircraft is moving on the path toward a gate (i.e., away from the arrival aircraft for which the check is being performed), the model permits the arrival MOVE PAVCHK aircraft to taxi on the path toward its gate in "platoon fashion" similar to real-life operations. If an aircraft is taxiing from the gate or is in the process of pushing back, the arrival aircraft is held until the departing aircraft is clear of the two-way path.

When the aircraft reaches its gate, a gate occupancy time is assigned from empirical distributions and is added to the gate arrival time. This information, when compared with the scheduled departure time, determines the earliest time when the aircraft could leave the gate. MOVE

When the model detects that an aircraft is ready to push back from the gate, a check is performed to see if the aircraft will push back onto a two-way path. If it will push back onto a two-way path, the model then checks for aircraft on the two-way path and permits "platooning" in a similar fashion as described for arrivals. If there is an aircraft taxiing toward the area which the departing aircraft will occupy during push-back, the aircraft is delayed on the gate until the arrival aircraft has cleared the area in question. PUSHBK

The route to the departure runway is determined by the aircraft's basing area or gate location, the aircraft class, and the departure runways in use at that particular time. ROUTE

In the case of general aviation or military aircraft, when the aircraft reaches the basing area, it is assumed to be parked and to have left the system. This assumption is necessary because of the unstructured nature of general aviation or military operations on the apron. The flow of aircraft from the basing area is generated from the demand inputs by producing an expected departure time from the basing area for each general aviation aircraft. The route to the departure runway is established by the location of the basing area and the departure runways in use. MOVE

When an aircraft reaches the threshold of the departure runway, compliance with ATC procedures is checked and confirmed before the aircraft is cleared for takeoff. TAKOFF

The model determines a time separation between a pair of successive departure aircraft which takes into account the required air traffic control separation by aircraft pair. The model will permit a departure to roll on a runway (thus interleaving arrivals and departures) when all of the following conditions have been fulfilled: ATC

1. The previous arrival aircraft has exited.

2. When the departure begins to roll, the next arrival is far enough from the threshold for the departure to clear the runway before the arrival is over its threshold.

3. Sufficient separation from the previous departure exists.

For pairs of intersecting runways, the user must also input arrival-departure separations so the model checks that the arrival aircraft has cleared the intersection before a departure is cleared on the intersecting runway. ATC

Several special ATC features are incorporated into the simulation model logic. One ATC feature included in the model increases arrival aircraft spacings on final approach to allow departure queues to be dissipated. The length of the departure queue (number of aircraft) at which the interarrival spacing is increased and the desired interarrival spacing (minutes) must be specified. MOVE

Once all ATC standards have been met, the aircraft departs and is cleared from the system. TAKOFF

Attachment B

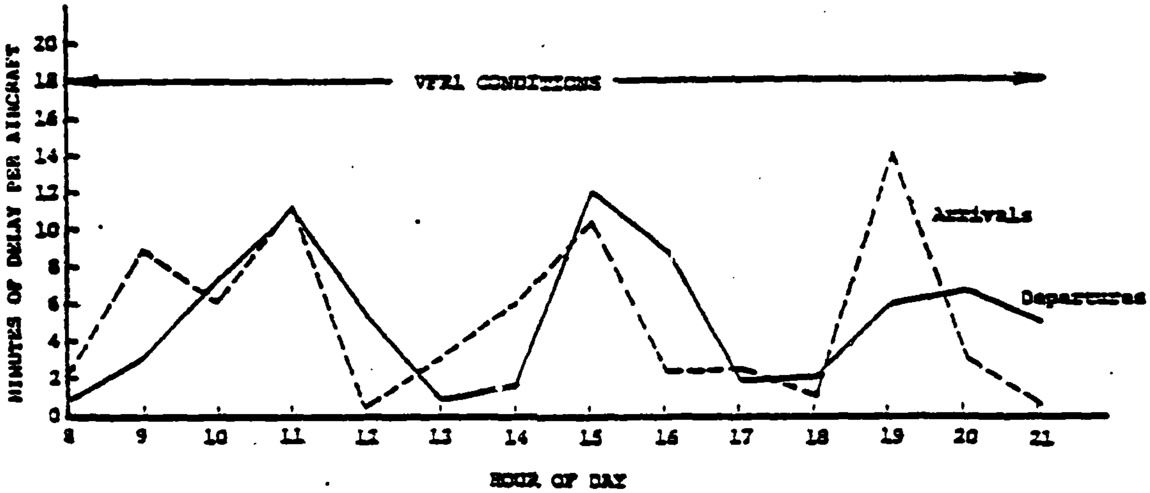
Task Force Applications

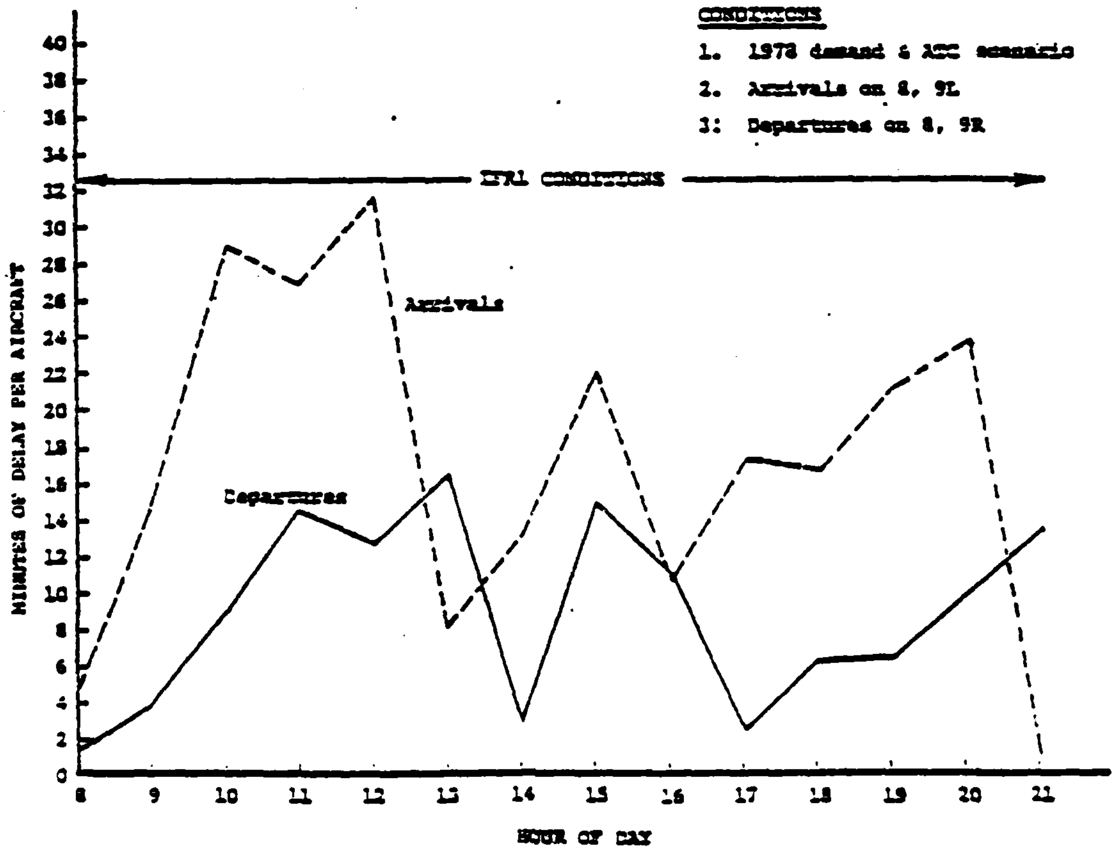
Lambert-St. Louis International Airport
Airport Improvement Task Force Delay Studies

Peat, Marwick, Mitchell & Co.
San Francisco, California

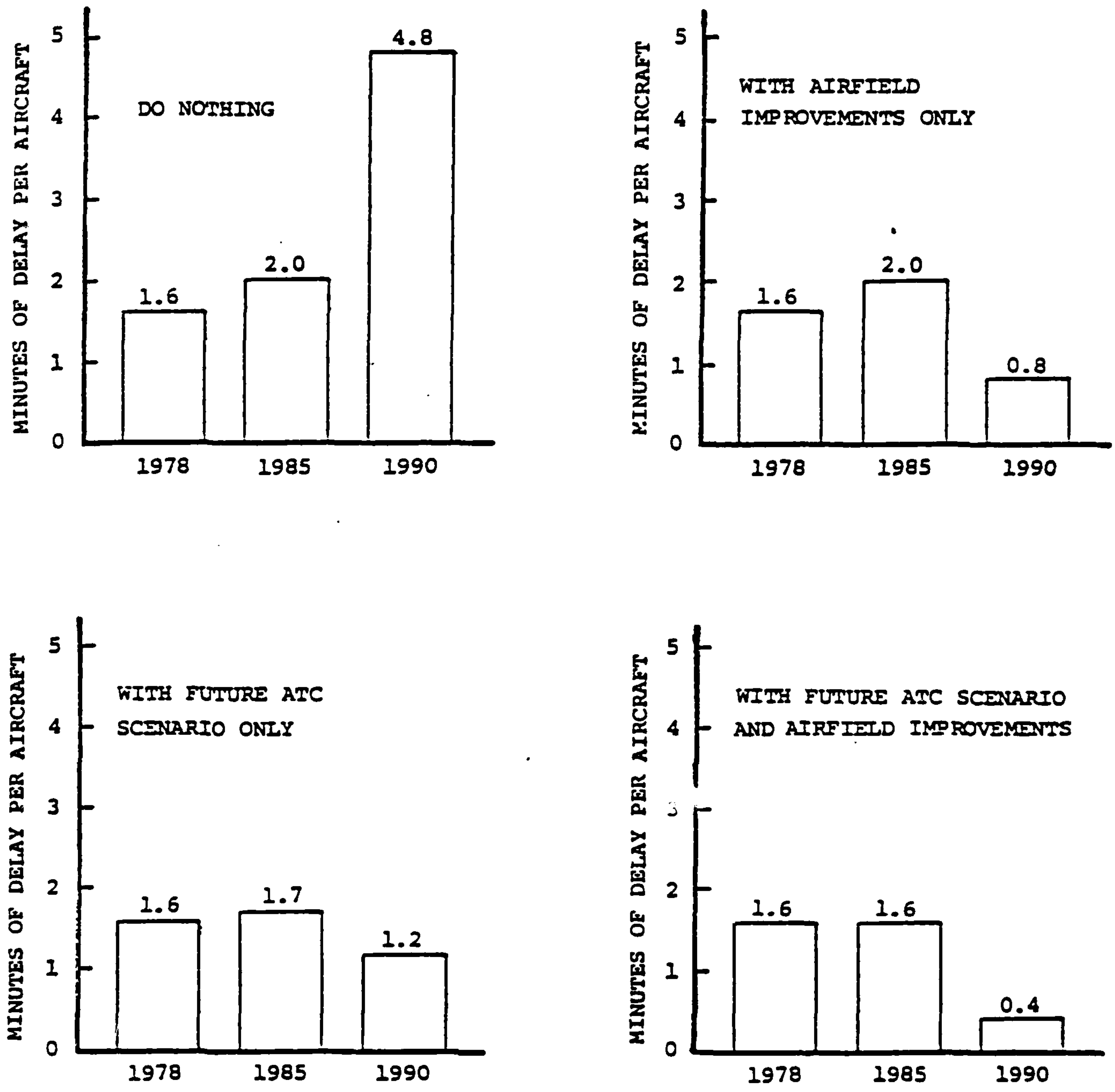
October 1979

ATLANTA — HOURLY RUNWAY DELAYS





Source: PMM&Co. estimates based
on Task Force inputs.



Source: PMM&Co. estimates based on Task Force inputs.

Figure 5

ANNUAL DELAYS

Stapleton International Airport

PMM&Co. December 1978

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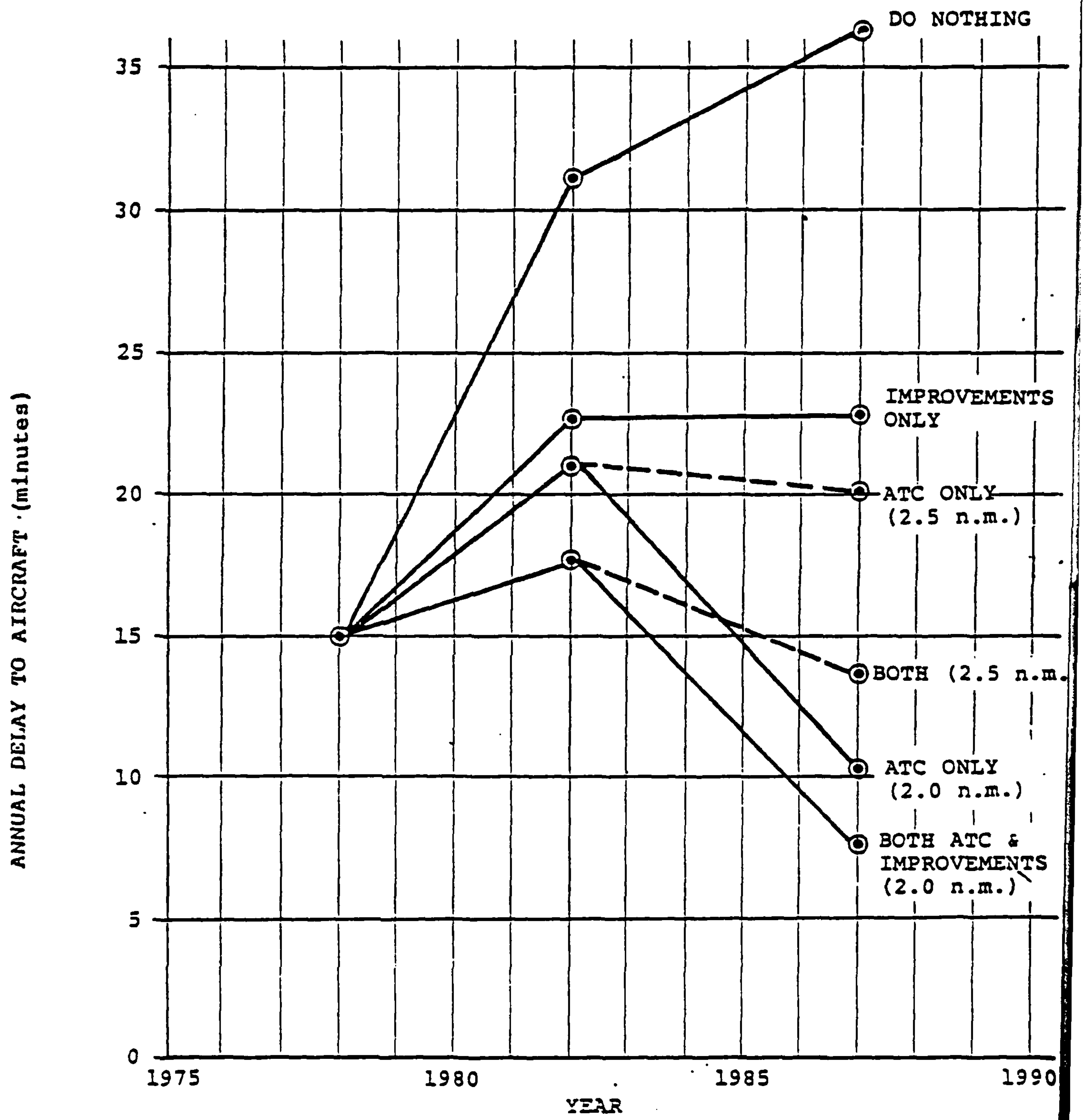
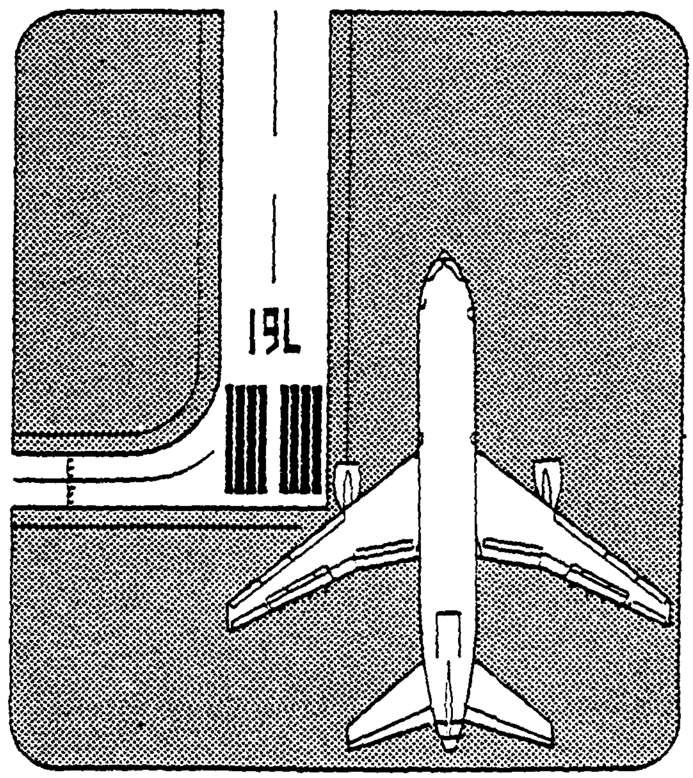


Figure C-4
ANNUAL DELAYS
John F. Kennedy International Airport
PMM & CO. June 1979

SAN FRANCISCO INTERNATIONAL AIRPORT

DATA PACKAGE NO. 5

AIRPORT IMPROVEMENT TASK FORCE DELAY STUDIES



prepared for
DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
under contract
DOT FA77WA- 3961

PMM&Co. Peat, Marwick, Mitchell & Co.

APRIL 1979

PEAT, MARWICK, MITCHELL & CO.
P. O. BOX 8007
SAN FRANCISCO INTERNATIONAL AIRPORT
SAN FRANCISCO, CALIFORNIA 94128

Telephone: (415) 347-9521

April 18, 1979

Mr. Michael M. Scott, ATF-4
Federal Aviation Administration
800 Independence Avenue, S.W.
Washington, D.C. 20591

Re: San Francisco Data Package No. 5

Dear Mike:

Enclosed is Data Package No. 5 for San Francisco International Airport. The package contains improvement benefit descriptions (Attachment A) and results of the Stage 2 annual delay experiments (Attachment B).

These data should be reviewed by the San Francisco Task Force during the April 18, 1979, Task Force meeting.

Sincerely,

Stephen L. M. Hockaday
Manager

SLMH/nbe
Enclosure

cc: Mr. J. R. Dupree (ALG-312) (w/o enclosure)
Mr. Royal Mink (AWE-4) (hand deliver)

Attachment A

IMPROVEMENT BENEFIT DESCRIPTIONS

SAN FRANCISCO INTERNATIONAL AIRPORT

Airport Improvement Task Force Delay Studies

Peat, Marwick, Mitchell & Co.
San Francisco, California

April 18, 1979

Baseline Delays

Several delay experiments were designed to establish baseline delays for the years 1977 and 1982. To estimate baseline aircraft delays in the future, it was necessary to establish the most likely level of demand and the most likely future ATC scenario. Demand was forecasted to increase by 12% from 1977 to 1982. The future ATC scenarios define reduced longitudinal separations between aircraft associated with implementation of E&D products. The following delays were obtained for VFR weather.

			VFR Peak-Hour[a] Runway Delays (minutes)		Average Daily[b] Runway Delays (minutes)	
Experiment #	Demand	ATC Scenario	Arrival	Departure	Arrival	Departure
Baseline (1)	1977	1977	0.9	2.7	0.5	1.6
Baseline (19)	1982	1982	1.6	5.4	0.7	2.5
Baseline (6)	1977	1977	2.5	5.9	0.9	2.9
Baseline (22)	1982	1982	1.9	5.4	0.8	2.6

a. Peak-hour for arrivals and departures are not necessarily the same hour.

b. Averaged over 15 hours from 0600-2100.

Runway delays in the first configuration increase by over 60% for arrivals and 100% for departures in the peak hour. The second configuration benefits from improvements in place in 1982 (primarily, 10L/10R simultaneous departures and the extension of 1R/19L).

For similar runway uses--IFR weather, much higher delays were obtained:

			IFR Peak-Hour Runway Delays (minutes)		Average Daily Runway Delays (minutes)	
Experiment #	Demand	ATC Scenario	Arrival	Departure	Arrival	Departure
Baseline (3)	1977	1977	60+	10.7	53.5	3.2
Baseline (20)	1982	1982	60+	27.6	60+	15.9
Baseline (5)	1977	1977	60+	4.4	55.3	1.3
Baseline (21)	1982	1982	60+	14.6	60+	3.5

Delay Reduction With ATC Equipment and Procedural Changes

Of the ATC equipment and procedural changes examined, the most significant delay reductions were associated with those which provided for simultaneous 10L/10R departures in VFR weather conditions (along with the extension of Taxiway K to improve access to 10L). In addition, the installation of VASI on 19R with the extension of 1L/19R was considered in the delay analysis.

10L/10R Departures, Extend Taxiway K. Current ATC procedures normally allow for only a single departure stream from Runways 10L and 10R even in VFR weather. Access to 10L is also restricted by departures from 10R.

The improvement option defined by the Task Force assumes that aircraft can depart from 10L and 10R simultaneously (providing neither is a heavy aircraft). Improved taxiway access is also assumed.

Two experiments demonstrate the delay savings associated with the improvement options:

			VFR Peak-Hour Runway Delays (minutes)		Average Daily Runway Delays (minutes)	
Experiment #	Demand	ATC Scenario	Arrival	Departure	Arrival	Departure
Baseline (6)	1977	1977	2.5	5.9	0.9	2.9
Improvement (12)	1977	1977	2.6	2.5	0.9	1.6

The ability to allow simultaneous departures on 10L/10R can substantially reduce departure runway delays--from almost 6 minutes to 2-1/2 minutes in the peak hour. Arrival runway delays are not significantly affected.

VASI on 19R, extend 1L/19R. Currently runway 1L/19R is only 7,000 feet long, and there is no glide slope information available for 19R. Consequently, use of 19R by arrivals is restricted.

One potential improvement assessed by the Task Force calls for extending 1L/19R to at least 8,500 feet, and installing a 3-bar VASI system on 19R. This would permit more arrivals to use 19R, allow for a more balanced use of Runways 19L and 19R, and improve controller flexibility.

Two experiments demonstrate delay savings in VFR weather conditions:

Experiment #	Demand	ATC Scenario	VFR Peak-Hour Runway Delays (minutes) Arrival	Departure	Average Daily Runway Delays (minutes) Arrival	Departure
Baseline (6)	1977	1977	2.5	5.9	0.9	2.9
Improvement (11)	1977	1977	1.2	6.3	0.6	3.1

This improvement reduces arrival runway delays in the peak demand hour by 50%. Departure delays increase slightly due to smaller gaps between arrivals.

Delay Reduction With Physical Improvements

Physical Improvements considered by the Task Force included the extension of Taxiways L and V, and using Taxiways L and C as utility runways.

Extention of Taxiways L and V. Currently, when operating arrivals and departures on runways 19L/19R, departure access to 19L raises considerable problems. Two or more queued departures on 19R prohibit taxiing aircraft access to 19L. Also, departures waiting to begin roll on 19L interfere with the approach glide slope control for arrivals, and occupy an active runway twice.

An improvement assessed by the Task Force involved the extension of taxiways L and V to the departure end of 19L. Such an extension permits better access for departures. It also permits smaller spacings between departures and arrivals since departures do not interfere with the arrival glide slope.

Two experiments assessed the benefits in IFR2 weather conditions:

Experiment #	Demand	ATC Scenario	IFR2 Peak-Hour Runway Delays (minutes) Arrival	Departure	Average Daily Runway Delays (minutes) Arrival	Departure
Baseline (9)	1977	1977	36.8	60+	12.4	48.0
Improvement (10)	1977	1977	36.4	38.5	12.7	20.4

The improvement dramatically reduces departure delays from over 60 minutes in the peak hour to under 40 minutes. Arrival delays are not significantly affected.

Utility Runways on Taxiways L and C

From a strictly operational point of view, under certain conditions, taxiways could be used as utility runways. Task Force experiments evaluated two such conditions.

Runway 1R is occasionally closed for repair. When it is, taxiway L could be used as a utility runway for light aircraft (ignoring environmental factors). Two experiments measured this benefit.

When operating straight 28 operations only one arrival stream might be permitted. Using taxiway C as a utility runway would allow light aircraft to be diverted from the runways to the taxiway. Two additional experiments evaluated this:

	VFR Peak-Hour Runway Delays (minutes)		Average Daily Runway Delays (minutes)	
	Arrival	Departure	Arrival	Departure
Taxiway L				
Baseline (14)	1.0	4.2	0.7	2.4
Improvement (13)	0.7	3.6	0.3	1.7
Taxiway C				
Baseline (15)	16.9	3.8	7.7	3.1
Improvement (18)	5.0	3.9	1.8	2.1

The use of taxiway L reduces arrival and departure runway delays. The use of Taxiway C as a utility runway under the conditions defined substantially reduced arrival delays. This is due primarily to the increase in arrival streams from one to two.

Delay Reductions due to Demand Management

The Task Force considered the delay impacts of demand management.

Two experiments demonstrated the impacts on delay of diverting all general aviation demand (11% of the total demand) in IFR weather conditions:

Experiment #	Demand	ATC Scenario	IFR Peak-Hour Runway Delays (minutes) Arrival	IFR Peak-Hour Runway Delays (minutes) Departure	Average Daily Runway Delays (minutes) Arrival	Average Daily Runway Delays (minutes) Departure
Baseline (20)	1982	1982	60+	60+	60+	31.3
Improvement (20A)	1982	1982	51.7	34.1	24.4	19.3

Substantial decreases in delays would occur with all general aviation (excluding air taxi's) diverted to other airports. IFR peak-hour delays drop from over 60 minutes for all operations to 51.7 minutes for arrivals and 34.1 minutes for departures.

Attachment B

RESULTS OF STAGE 2 ANNUAL DELAY MODEL EXPERIMENTS

San Francisco International Airport

Airport Improvement Task Force Delay Studies

Peat, Marwick, Mitchell & Co.
San Francisco, California

April 1979

Annual Delays

Average annual delays to aircraft were computed by PMM&Co. using the FAA annual delay model. The delays were computed for 1977, 1982, and 1987 using different near-term improvement packages, different future ATC scenarios, and different operating assumptions.

The total annual demand was forecasted to increase from 349,011 operations in 1977, to 390,800 in 1982, and 421,200 in 1987. The mix changed as follows:

	Percent			
Year	A	B	C	D
1977	6%	16%	60%	18%
1982	6	18	57	19
1987	5	17	53	25

The results of the experiments are summarized in Table 1. Average annual delays are given for each of the eleven experiments. In addition, average peak-hour delays are given for the most commonly occurring runway use (arrivals on Runways 28L and 28R, and departures on Runways 1L, 1R, and 28R) in VFR and IFR weather. These results are also shown graphically in Figure 1.

As shown in Table 1 and Figure 1, under the do-nothing (1977) ATC scenario, annual delays increased 26% from 2.1 minutes in 1977, to 3.6 minutes in 1982, and 5.6 minutes in 1987.

Review of the detailed computer output for the 1977 delay results showed that about 40% of the total annual delays took place in VFR weather (which occurs more than 92% of the year) and about 60% took place in IFR weather (which occurs less than 8% of the year).

Delays increase by about 70% in 1982 if no improvements are made and with no ATC scenario change. If both the 1982 near-term improvements package at the 1982 ATC scenario were implemented, delays would change very little from 1977 (even though demand has increased).

By 1987, the amount of average annual delay per aircraft is highly dependent on which near-term improvements are implemented and which ATC scenarios occur.

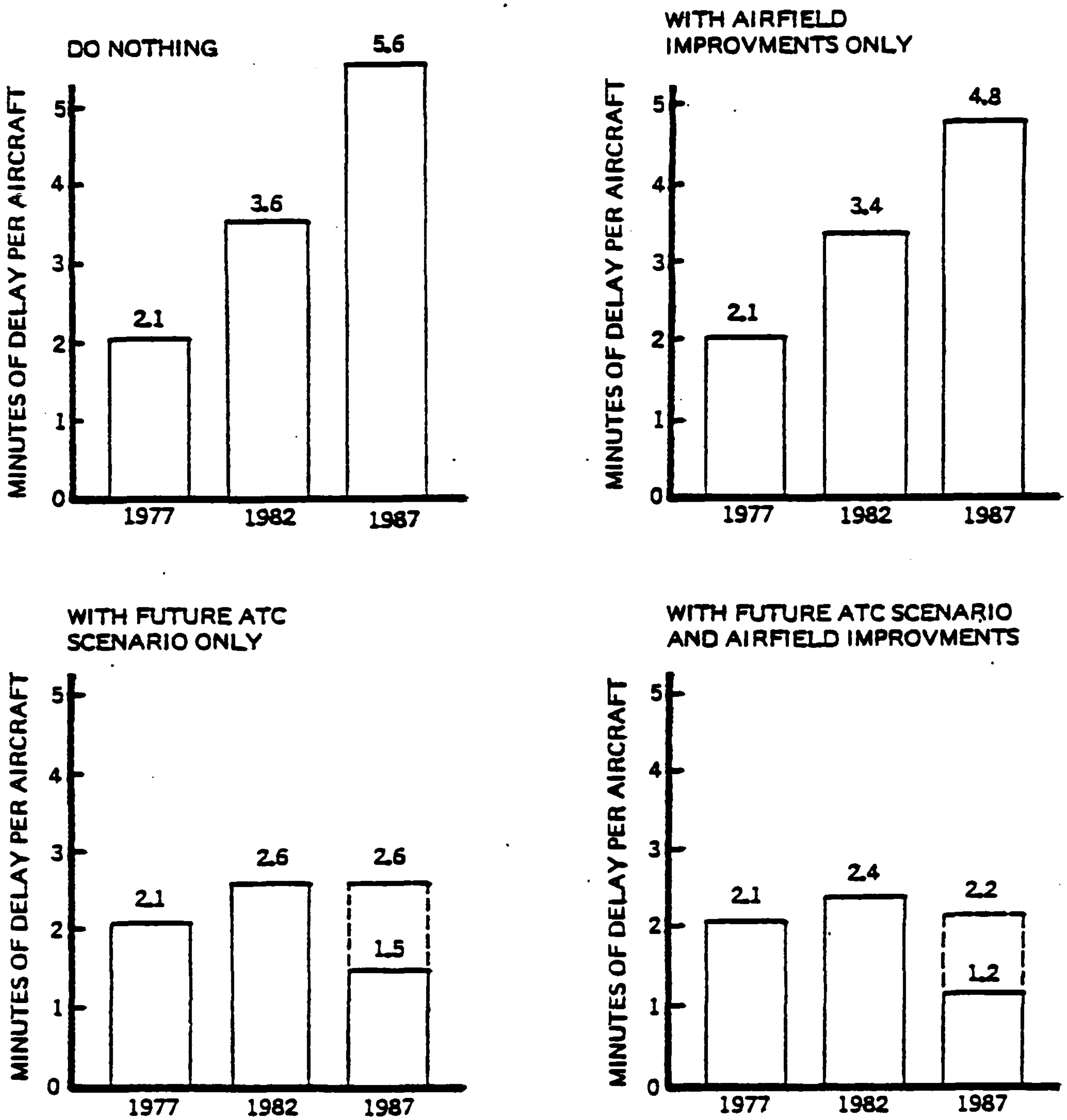
In both the 1987 improvement package and the 1987 ATC scenario are implemented, average annual delays are estimated to be as low as 1.2 minutes--a savings of about 4.4 minutes per aircraft when compared with the do-nothing scenario (if 2 mile separations are achieved; 3.4 minutes if 2-1/2 mile separations are achieved).

Table 1

SUMMARY OF ANNUAL DELAY MODEL EXPERIMENTS
San Francisco International Airport

Experiment No.	Demand	ATC Scenario	Airfield Improvements	Annual Delay (hours)	Average Aircraft Delay (minutes)	Average Peak-Hour Delays (arrivals on 28R, 28L departures on 1R, 1L, 28L) VFR	IFR
16	1977	1977	1977	12,267	2.1	1.2	60.2
17[a]	1977	1977	1977	10,021	1.7	1.2	60.2
24	1982	1977	1977	23,639	3.6	1.5	71.4
25	1982	1977	1982	22,430	3.4	1.7	81.3
26	1982	1982	1982	15,813	2.4	1.5	63.7
27	1982	1982	1977	16,847	2.6	1.8	70.2
28[a]	1982	1982	1982	10,104	1.6	1.5	63.7
29	1987	1977	1977	39,018	5.6	1.9	82.1
30	1987	1977	1987	33,748	4.8	1.8	82.1
31	1987	1987	1987	8,253	1.2	1.3	8.0
31A[b]	1987	1987	1987	15,638	2.2	1.6	58.4
32	1987	1987	1977	10,707	1.5	1.4	12.0
32A[b]	1987	1987	1977	18,161	2.6	1.6	61.0
33[a]	1987	1987	1987	6,069	0.9	1.3	8.0

a. These experiments are designed to evaluate the effects of noise abatement procedures.
b. These experiments assumed 2-1/2 mile separations instead of 2 miles.



Source: PMM & Co. estimates based on Task Force inputs.

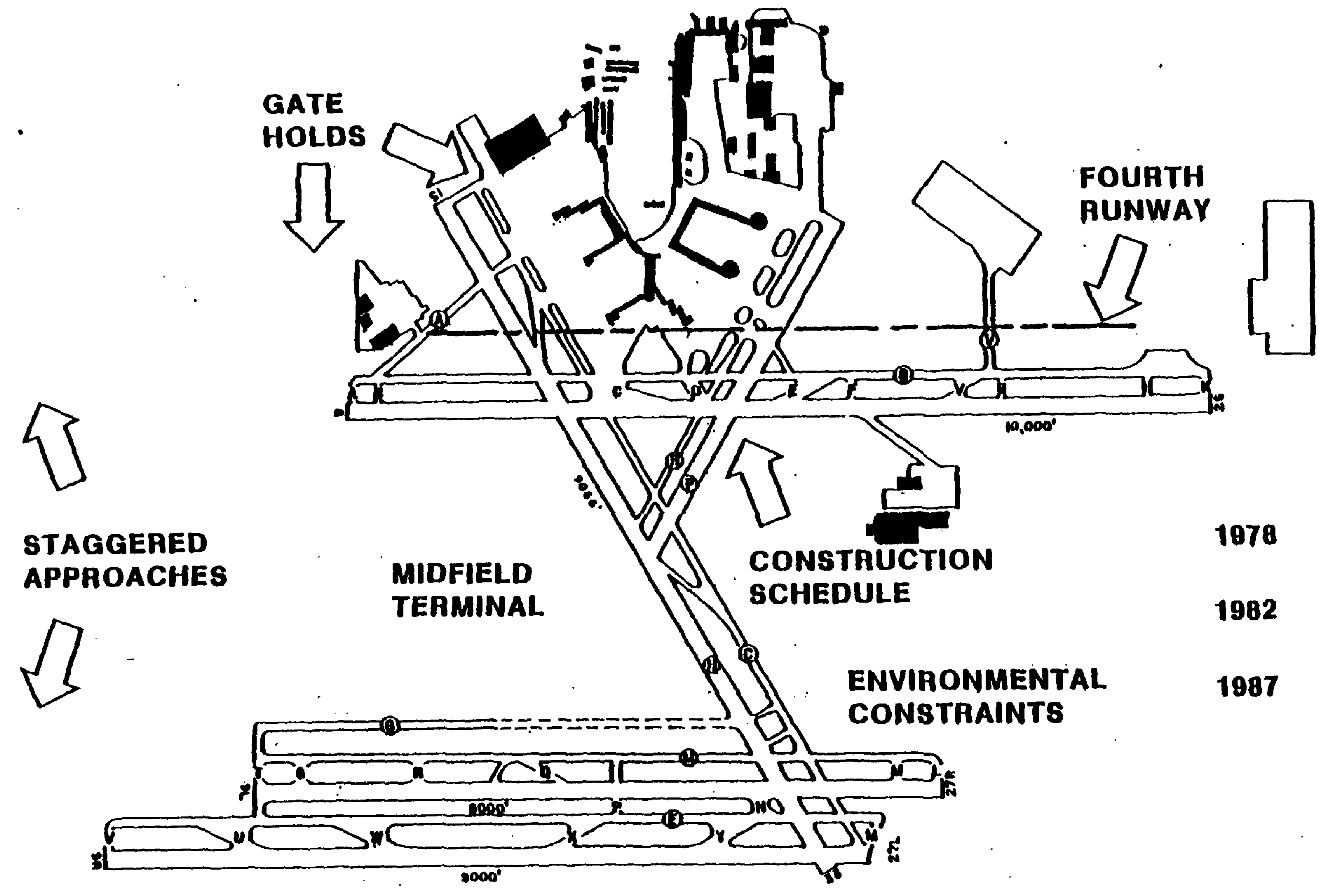
——— Assumes 2½ mile seperations

Figure 1
ANNUAL DELAYS
San Francisco International Airport
PMM & Co. April 1979

The operational constraints imposed by the noise abatement procedures has the following affects (assuming ATC scenarios improve as appropriate).

Year	Noise Abatement Policy Delay Level	Delay Level With No Operating Constraints
1977	2.1	1.7
1982	2.4	1.6
1987	1.2	0.9

The average delay (total delay) to aircraft in delay for the noise abatement procedures is 0.4 (140,000) minutes in 1977, 0.8 (310,000) minutes in 1982 and 0.3 (125,000) minutes in 1987.



ATLANTA DELAY EXPERIMENTS

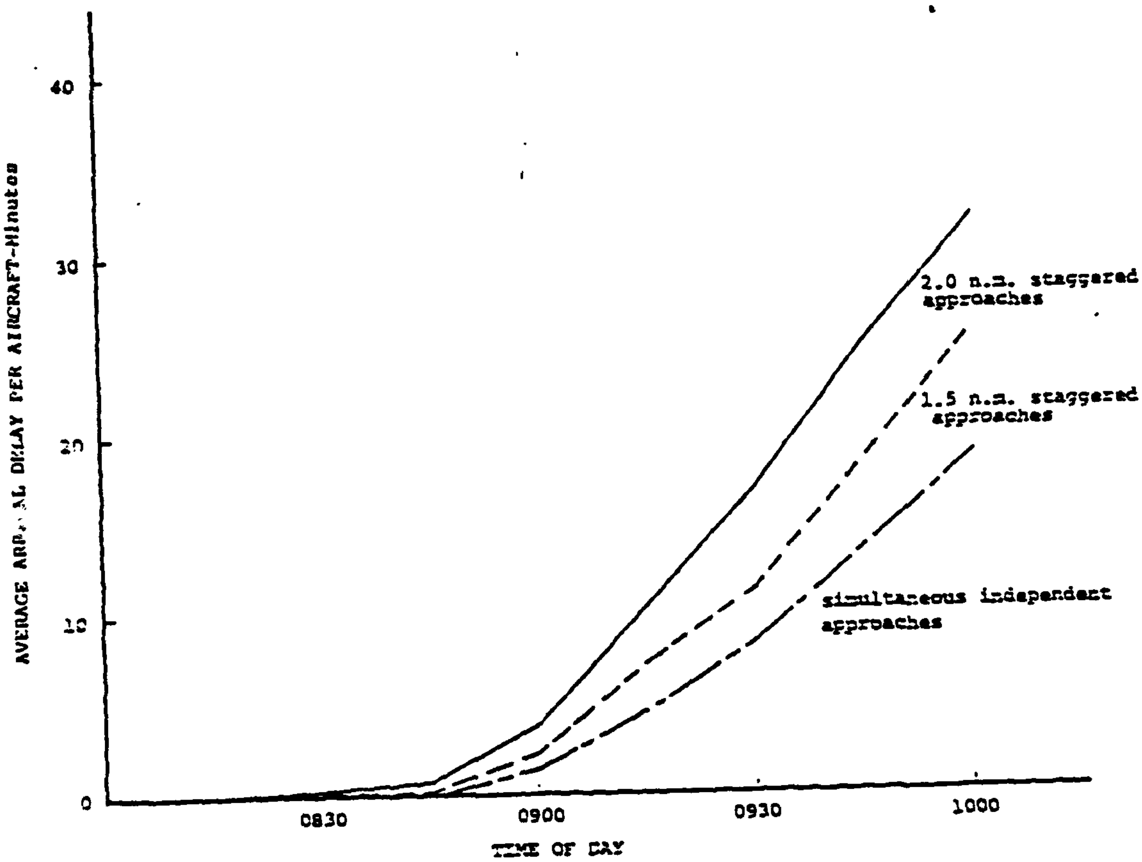


Figure 4

STAGGERED APPROACH PROCEDURES
Atlanta International Airport
PMM&Co. December 1978

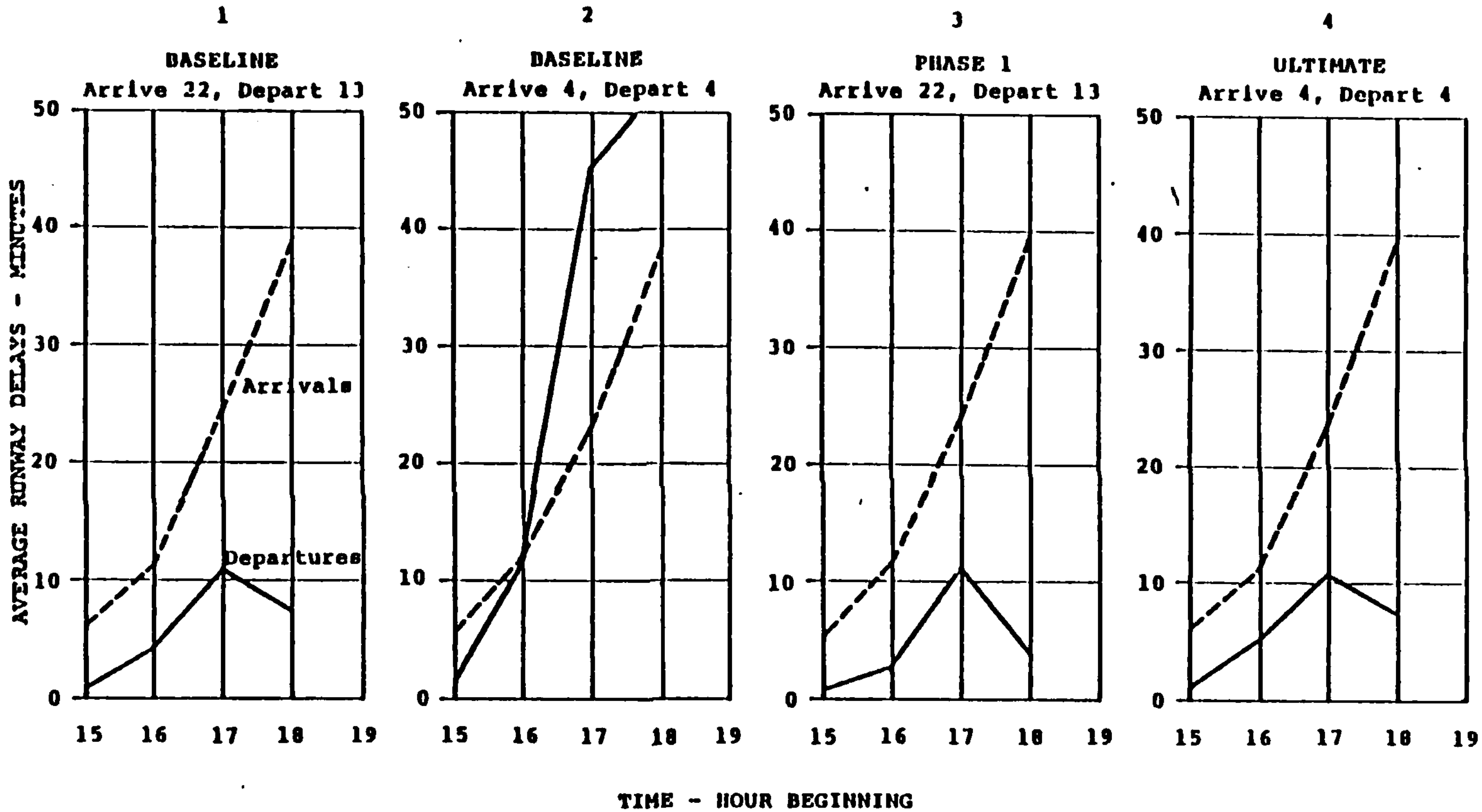


Figure B-1
WEST-TAXIWAY EXPERIMENTS
LaGuardia Airport
PNM & Co. July 1979

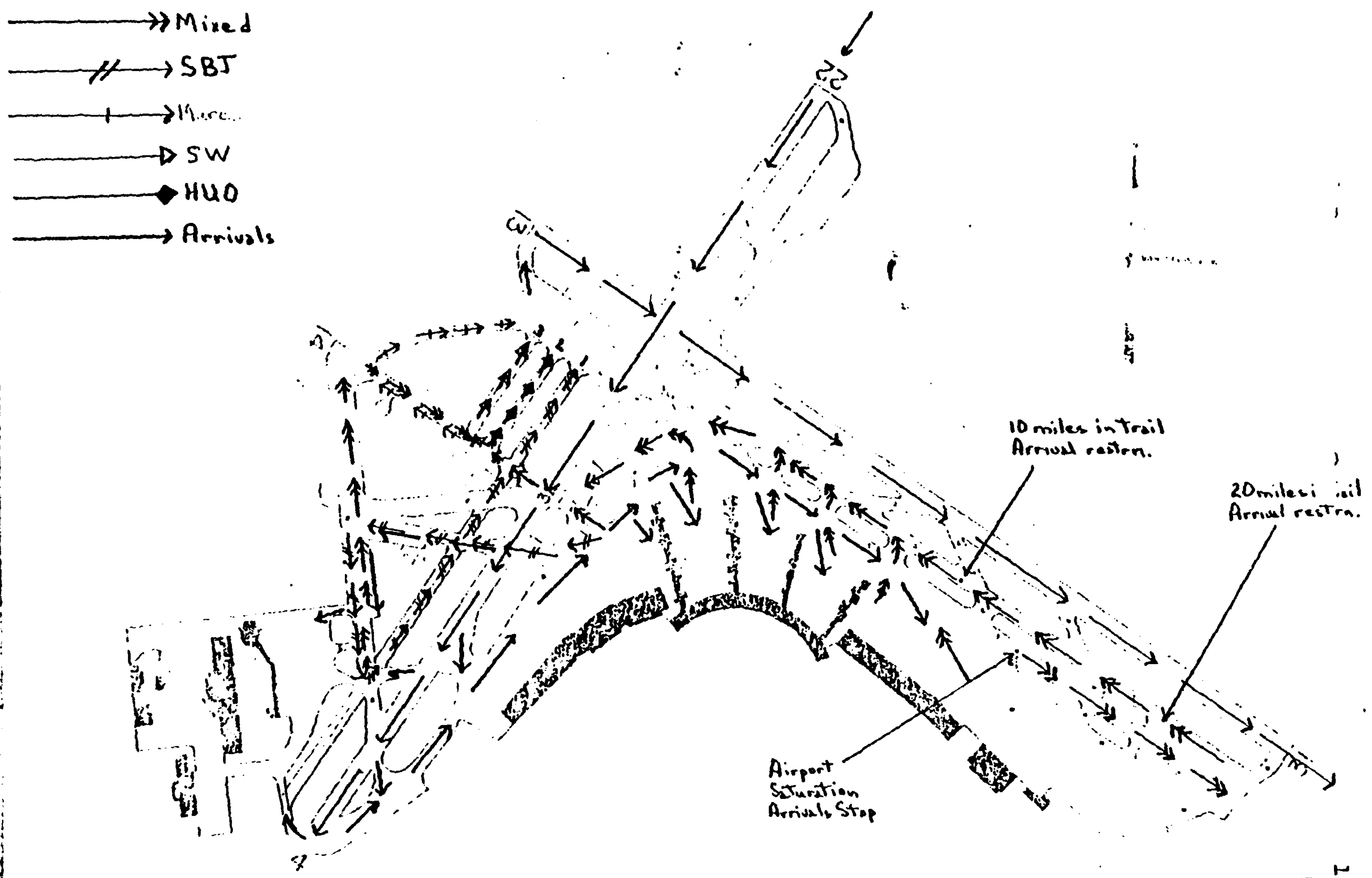

Mixed
SBJ
SW
HUD
Arrivals
22
3
10 miles in trail
Arrival restrn.
Arrival restrn.
Airport
Saturation
Arrivals Stop

Figure 3

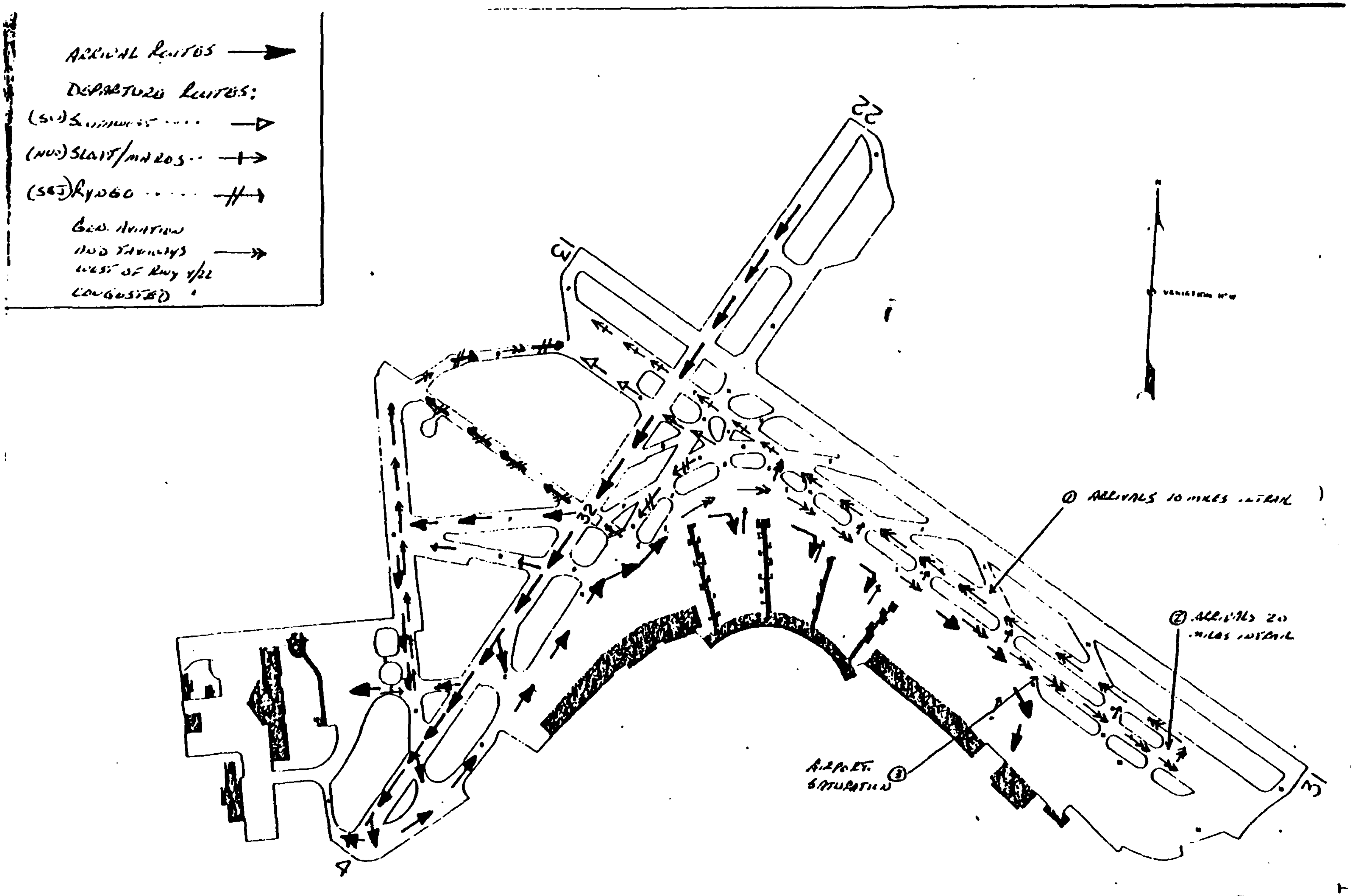
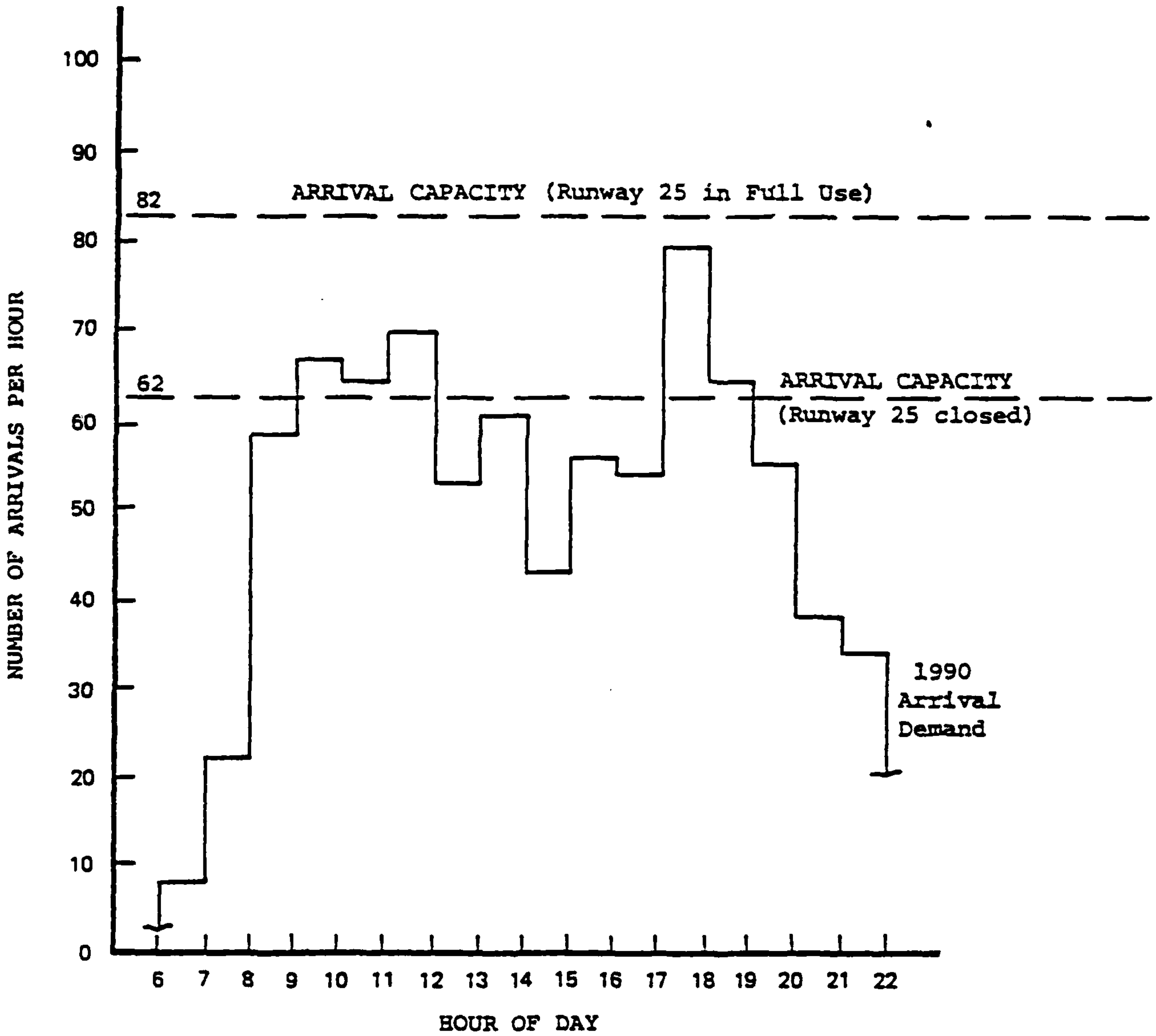


Figure #1

LGA AIRPORT LAYOU

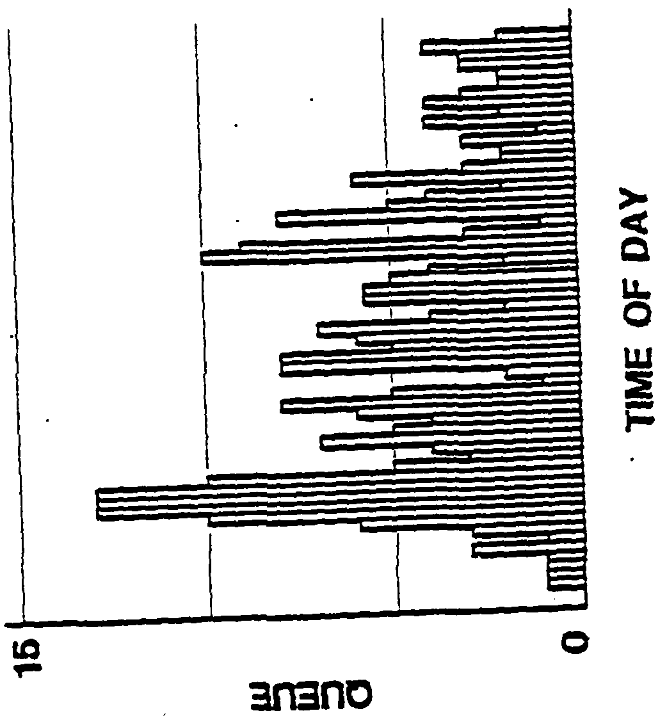


Source: PMM&Co. estimates based on Task Force inputs.

Figure 4

IMPACT OF CLOSURE OF RUNWAY 25
Stapleton International Airport
PMM&Co. December 1978

SFO DEPARTURE QUEUE



Attachment C

Lambert-St. Louis International Airport Calibration Results

Lambert-St. Louis International Airport
Airport Improvement Task Force Delay Studies

Peat, Marwick, Mitchell & Co.
San Francisco, California

October 1979

CALIBRATION RESULTS
Lambert-St. Louis International Airport

	1630-1730*	1730-1830*
Arrival flow rates		
Field data	30	32
Calibrated model	31	31
Departure flow rates		
Field data	45	41
Calibrated model	46	40
Average-fix-to-threshold travel times		
Field data	16.5	17.5
Calibrated model	17.2	16.9
Average threshold-to-car travel times		
Field data	2.4	2.4
Calibrated model	2.4	2.5
Average gate-to-roll travel times		
Field data	9.2	7.4
Calibrated model	8.5	8.4

* The calibration period is from 1630 to 1830 on March 21, 1979.
The operating configuration included arrivals and departures on 12L/R.

Attachment D

Potential Experimental Design Process

Lambert-St. Louis International Airport
Airport Improvement Task Force Delay Studies

Peat, Marwick, Mitchell & Co.
San Francisco, California

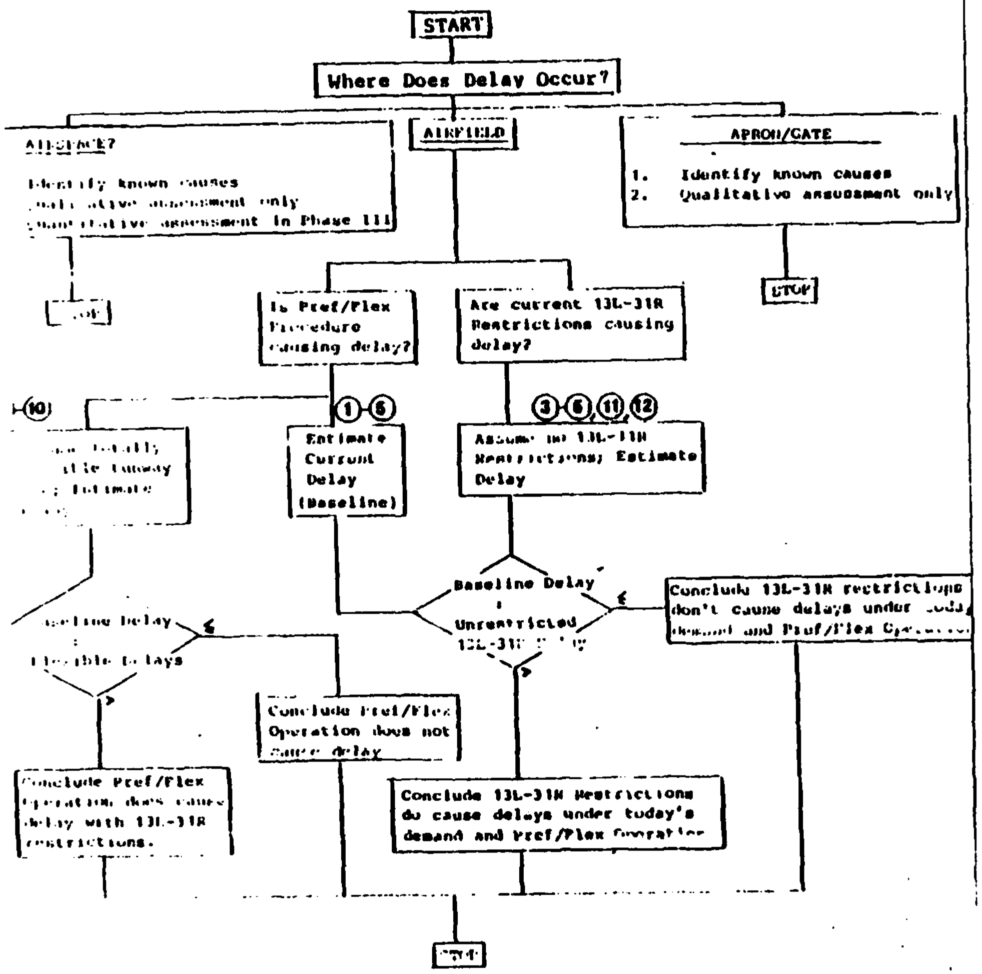
October 1979

EXHIBIT 1

Dallas/Fort Worth Airport

Recommended Approach
Objective 1

Objective 1: Identify causes of delay associated with terminal airspace, airfield, and apron/gate area operations.



(x) Experiment Numbers Keyed To Design Matrix

EXHIBIT 2

Dallas/Fort Worth Airport

Experiment Design Matrix
Objective 1

Air Traffic Control Equipment and

		1979 Schedule			
		Pref/Flex		Flex	
		'79 Airfield		'79 Airfield	
	Wx	13R-31L Restr.	No Restr.	13R-31L Restr.	No Restr.
1	VFR	(1)	(11)	(6)	
	IFR	(2)	(12)	(7)	
2	VFR		•		
	IFR		•		
3	VFR		(3)		(8)
	IFR				
4	VFR		(4)		(9)

Proposed Experimental Design Process to be discussed by C. F. Booth of American Airlines at the next Task Force Meeting.

Attachment E

Responses to Questions Raised by Glenn Bales

Lambert-St. Louis International Airport
Airport Improvement Task Force Delay Studies

Peat, Marwick, Mitchell & Co.
San Francisco, California

October 1979

Questions Raised by Glenn Bales

II. NAFEC Technical Plan

<u>Question</u>: Is the Airfield Simulation Model sensitive to the flight directions of aircraft?

<u>Response</u>: Yes, the model is sensitve to flight directiions through the aircraft separation inputs. Specific runway and fix separation requirements can be input to the model. Thus, by inputting different separations for different runway-fix combinations, different directions can be modelled. For example, the crossover departure environment at Los Angeles International Airport is simulated using this approach.

<u>Question</u>: Is the Airfield Simulation Model sensitive to air-space constraints including sector capacity?

<u>Response</u>: Yes, using the same methodology as described above. Here, different separations for different sectors are input. Sector capacity problems have been simulated for LaGuardia Airport and John F. Kennedy International Airport by implementing this technique.

<u>Question</u>: Is the Airfield Simulation Model sensitive to the interactions of parallel runway operations?

<u>Response</u>: Yes, through the same separation specification techniques as done in flight directives. Besides simulating normal close parallel operations at Atlanta, Denver, Los Angeles, New York, and San Francisco, previous task forces at Atlanta, Denver, and New York have evaluated staggered approaches to close parallel runways.

<u>Question</u>: Is the Airport Simulation Model sensitive to the impact of satellite operations?

<u>Response</u>: Yes, using this same separation input as simulated in sector capacity problems. Interactions between New York airports have been simulated.

<u>Question</u>: Is the Airport Simulation Model sensitive to run-way crossing delays?

<u>Response</u>: Yes, through the use of the runway crossing data inputs.

If an aircraft is about to taxi across an active runway, the model performs certain checks in accordance with ATC procedures to determine if it is safe for the aircraft to cross. Priority is always given to aircraft operating on the runway. If delays to taxiing aircraft become too large, the model increases arrival aircraft spacings on final approach to allow taxiing aircraft to cross. The length of delay to the taxiing aircraft at which the interarrival spacing is increased and the desired interarrival spacing (minutes) must be specified.

Question: Can apron/gate operations be simulated?

Response: Yes, provided that the following additional data from the Task Force is supplied:

- o Specific airline gate assignments
- o Gate locations and sizing
- o Aircraft service times

This data should be readily available and has been supplied at other task force efforts.

III. Data Package No. 1

a. Question: What function do the random seeds serve?

Response: Each seed simulates a single days airfield operation given the inputs into the model. The output is averaged across all random seeds. Thus, if 10 seeds are input, the output is an average of 10 days of variation in operation.

b. Question: What is the calibration period and how was it selected?

Response: The calibration period is a two-hour period from 1630 hours to 1830 hours. Data for longer calibration periods was not collected due to time and cost limitations.

c. Question: Why are three standard deviations used?

Response: Three standard deviations were originally selected by the Model Validation Group and may be changed by the Task Force.

d. Question: Why do departure-departure separations vary from those used in the capacity study?

Response: These new values were developed by FAA headquarters.

e. Question: Will the model be calibrated for IFR conditions?

Response: No, due to time and cost constraints. However, delay analyses will be performed in IFR in conformance with the experimental design.

f. Question: Why are arrival occupancy times different from those used in the capacity study?

Response: Those values were observed in the field data collection process and can be changed by the Task Force.

g. Question: What constitutes departure runway occupancy and how is it used?

Response: Departure runway occupancy is defined to be the time from the beginning of departure roll to lift-off and 6,000 feet down the runway. This input defines runway occupancy for the purposes of determining the time that the runway is considered to be occupied. Other runway operations must satisfy separate separation requirements as input into the model.

h. Question: Why are gate service times "not applicable to calibration"?

Response: The field data collection process for calibration only traced aircraft to apron areas and not to specific gates. Therefore, gate operations are not simulated during the calibration. However, gate service times can be included during experiments.

P. M. M. & CO.

Attachment F

Model Limitations

Lambert-St. Louis International Airport
Airport Improvement Task Force Delay Studies

Peat, Marwick, Mitchell & Co.
San Francisco, California

October 1979

LIMITATIONS OF AIRFIELD SIMULATION MODEL

- 30 Airlines
- Fixed Taxiway Routes
- 5 Active Runways
- No Dynamic Reallocation of Arrival Aircraft
- 1400 Taxiway Routes
- 10 Runways Crossing Links
- Limited Dynamic Reallocation of Aircraft to Gates
- 40 Exit Taxiways
- 30 Gates Per Airline

Attachment G

Extracts from NAFEC Scenario

Lambert-St. Louis International Airport
Airport Improvement Task Force Delay Studies

Peat, Marwick, Mitchell & Co.
San Francisco, California

October 1979

Data Report, Support to St. Louis Task Force Airport Capacity and Delay Studies, Ground/Airborne Scenarios. NAFEC Project No. 012-101-200.

The purpose of this report is to provide the St. Louis Task Force Study Team with the most frequently used arrival and departure operational traffic scenarios for the Lambert - St. Louis International Airport (STL).

This report is presented in three parts. The first part is a physical description of the STL Airport and its ground operations. The second part is an overview of the approach control procedures. The third part describes the selected airborne and ground scenarios.

This report presents scenarios for arrivals and departures for the following selected runway configurations:

Configuration No. 1	Arrive	30L and 30R
	Depart	30L and 30R
Configuration No. 2	Arrive	12L and 12R
	Depart	12L and 12R

Selection of these configurations was made based upon frequency of use of various runway configurations. Discussion in this report is limited to only the above listed configurations.

A. Airport Environment

The Lambert-St. Louis International Airport has two northwest/southeast runways, 12L/R, 30L/R, and two diagonal runways 6/24 and 17/35. Configuration of the runway layout resembles the letter "A" and is bowl shaped, with elevation of the approach end of runway on the south side of the airport being 18 to 35 feet higher than the opposite ends of the runways. The distance between the northwest/southeast runways is 1125 feet (1300' between centerlines). Runways 12R, 30L and 24 are equipped with Instrument Landing Systems (ILS) and runway 6 is served by a localizer back course approach. Runway 24 has the lowest approach minimums (200 and 1/2).

The passenger terminal is located south of runway 12R/30L, between runways 6/25 and 17/35, and has 43 gates. Two general aviation facilities are available: Midcoast Aviation - located south of runway 12R/30L, east of runway 17/35 and Rockwell Aviation - located north of runway 12/L30R east of runway 17/35. Missouri National Guard Aircraft and facilities are located on the west end of the passenger terminal ramp. The McDonnell Douglas aircraft and production line is located on the north side of the airport, paralleling runway 6/24 (Figure 1).

The control tower (Figure 3) is designed to provide a maximum of seven operational positions (2 local controllers, 2 ground controllers, flight data, clearance delivery and tower coordinator). The predominant traffic flow utilizes SE/NW parallel runways and under normal traffic conditions, permits consolidation of the local controllers, ground controllers, and flight data with clearance delivery. The tower coordinator serves as the primary focal point for interface between the tower and TRACON. TRACON position override is available at the local control positions for an immediate exchange of information.

Control of ground traffic is hampered in some areas of the east terminal and cargo ramps due to restricted visibility from the tower. Formal noise abatement programs have not been established at St. Louis, however an informal program has been implemented that is applicable to all turbojet aircraft departing runway 12L/R between the hours of 2200 and 0600 local.

A number of physical improvements are scheduled to be constructed between April 1, 1979 and the end of the year. The scheduled improvements (Figure 4) are as follows:

a. By-pass taxiway approximately 600 feet west of 30L threshold from taxiway A to taxiway F.

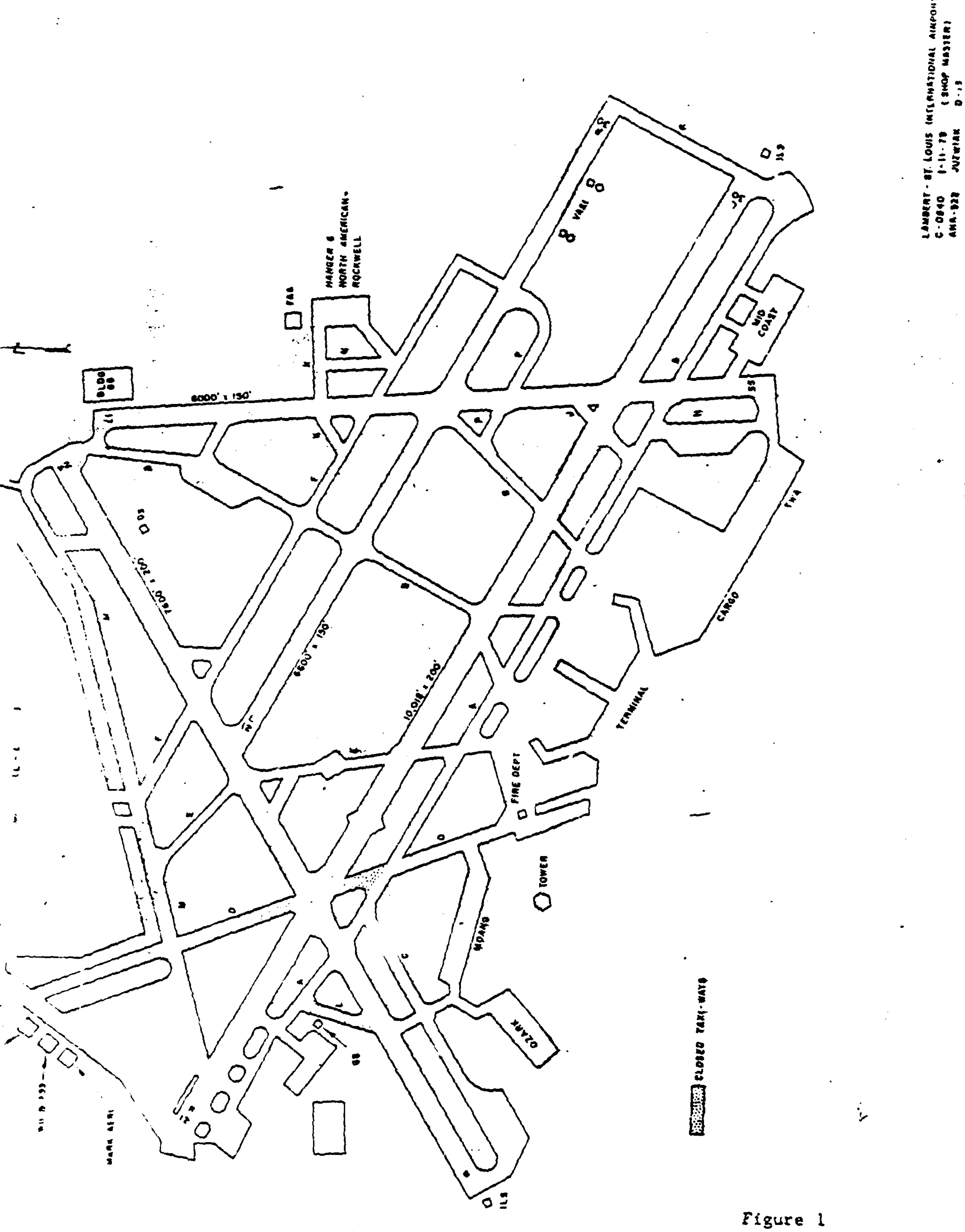
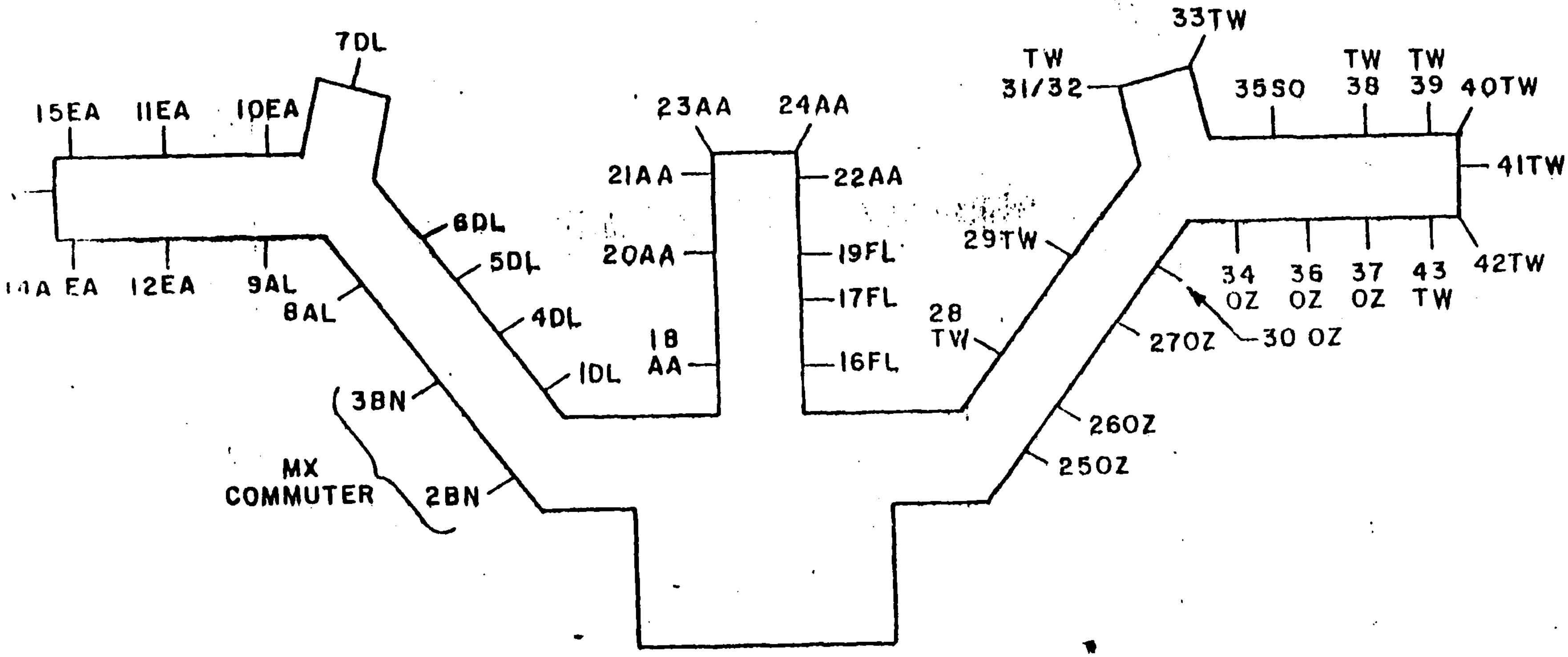
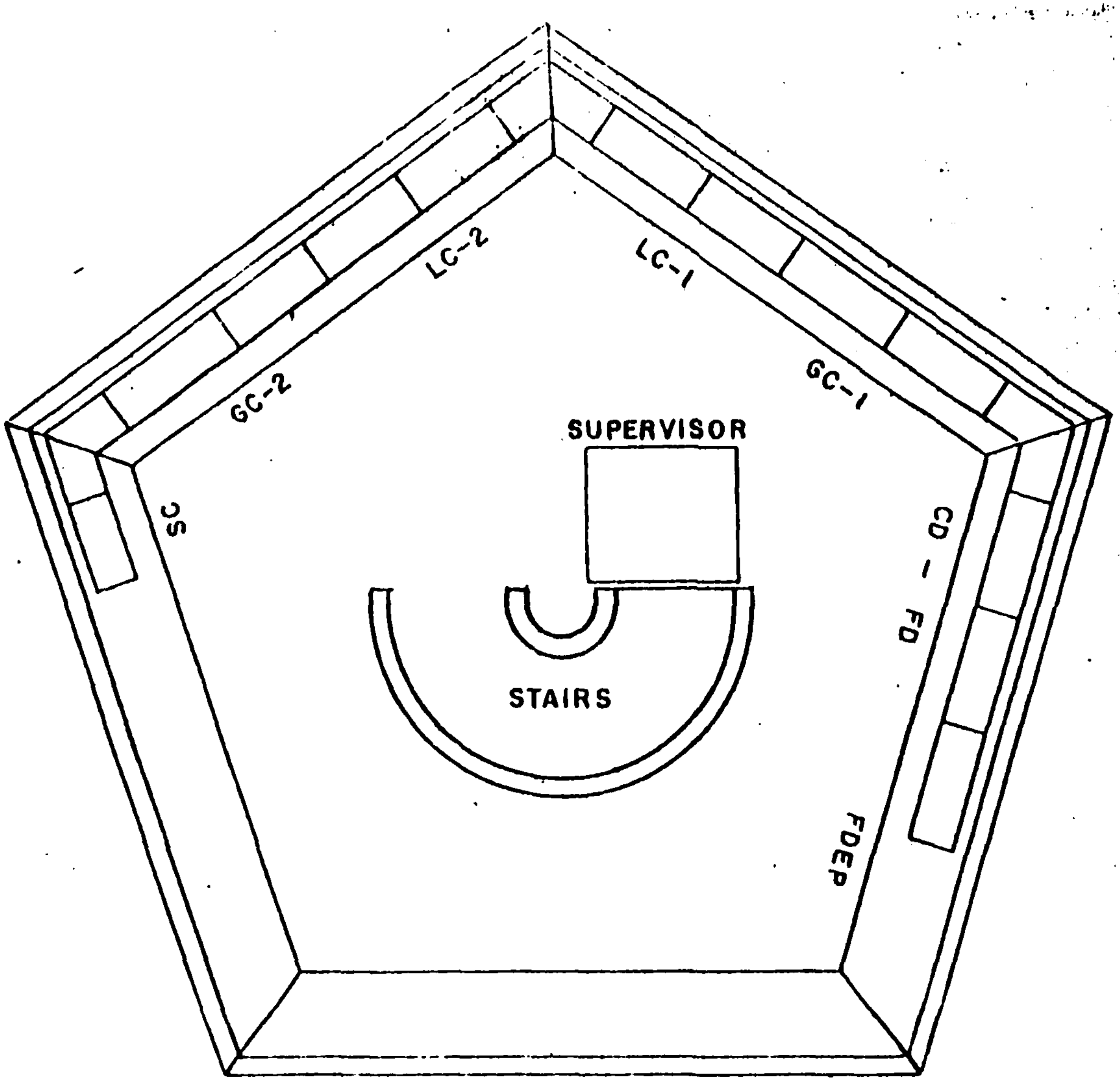

LAMBERT - ST. LOUIS INTERNATIONAL AIRPORT
C-0840 1-11-79 (SHOP MASTER)
HANGER 6
NORTH AMERICAN-ROCKWELL
FAA
BLDG 88
6000' x 150'
7600' x 200'
6600' x 150'
10,018' x 200'
MID COAST
TWA
CARGO
TERMINAL
FIRE DEPT
TOWER
OZARK
CLOSED TAXI-WAYS
ILS

Figure 1


7DL
15EA
11EA
10EA
23AA
24AA
33TW
TW 31/32
35SO
TW 38
TW 39
40TW
41TW
21AA
22AA
6DL
5DL
20AA
19FL
17FL
29TW
42TW
34 OZ
36 OZ
37 OZ
43 TW
12EA
9AL
8AL
4DL
18 AA
16FL
28 TW
27OZ
30 OZ
1DL
3BN
MX COMMUTER
2BN
26OZ
25OZ



LC - LOCAL CONTROL
GC - GROUND CONTROL
FD - FLIGHT DATA
CD - CLEARANCE DELIVERY

Figure 3

d. [illegible], parallel [illegible] west of runway 6/24 between taxiway F and taxiway A.

e. By-pass taxiway [illegible] feet west of runway 30R threshold. (Taxiway P to 30R)

f. Designation of general aviation runway or taxiway pavement (taxiway F and/or P). This runway would be used during daylight VFR only and for departure only during arrivals on [illegible].

g. Runway 30L exit taxiway 400 feet east of runway 6/24

h. Increase fillet radius on exit taxiways from runway 12R/30L

i. Increase separation from taxiway A to runway 12R, west of runway 6/24

j. Two one-way traffic lanes for taxiway A between runway 6/24 and 17/35

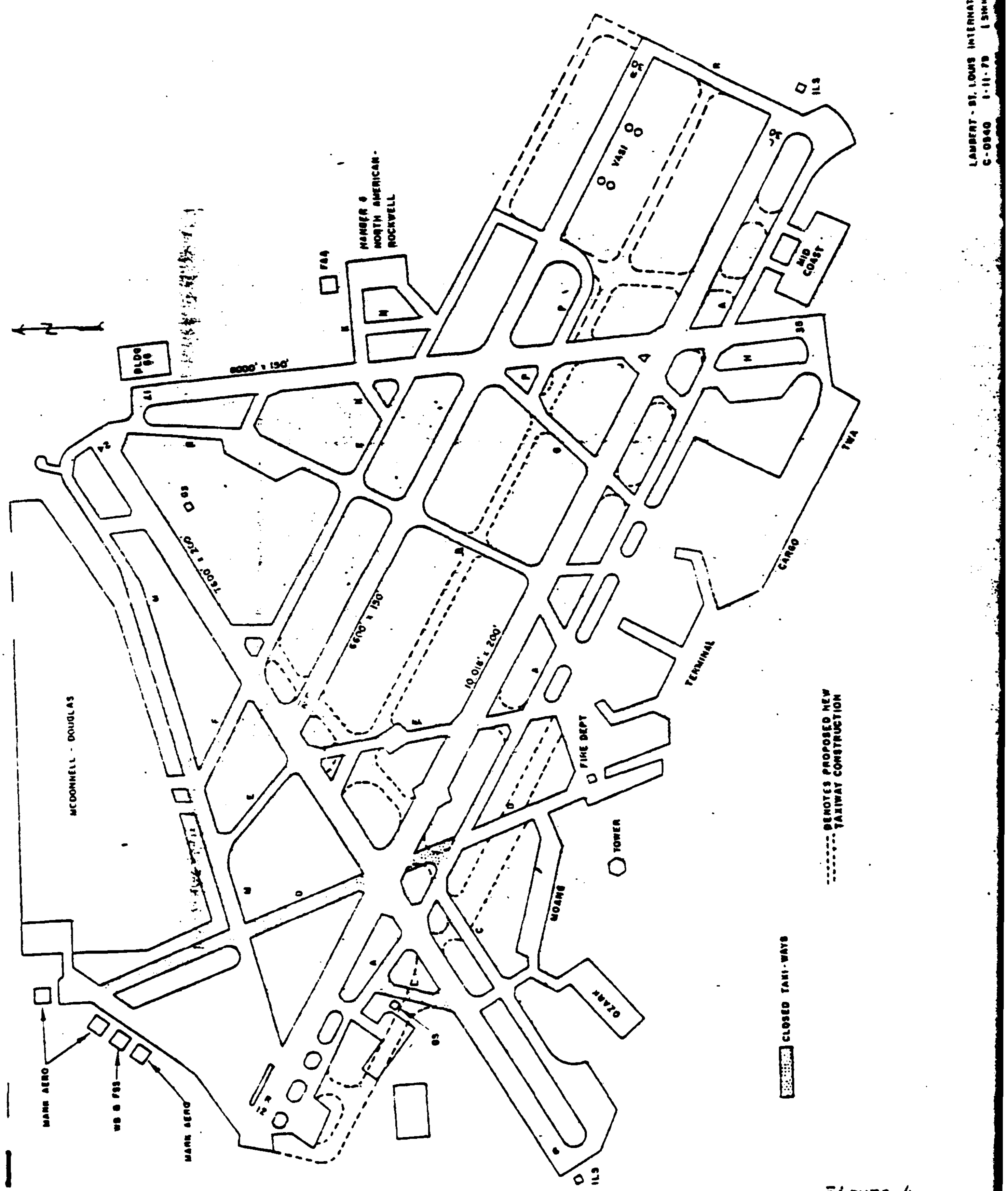
Additional improvements are planned as follows:

a. Runway 12L/30R constructed to 9100 feet

b. Runway 12R/30L constructed to 11,000 feet

c. [illegible] for runway [illegible]

d. CAT [illegible] ILS for runway 30R



MCDONNELL - DOUGLAS
TOWER
FIRE DEPT
TERMINAL
CARGO
TWA
MID COAST
OZARK
HANGER &
NORTH AMERICAN-
ROCKWELL
FAA
VASI
ILS
MARK AERO
MARK AERO
10,018' x 200'
6000' x 150'
DENOTES PROPOSED NEW
TAXIWAY CONSTRUCTION
CLOSED TAXI-WAYS

Figure 4

B. Approach Control

St. Louis Approach Control has been delegated airspace for the control of IFR traffic within a 32 nmi radius of the St. Louis ASR from the surface up to and including 12,000 feet (Figure 5). There are nine satellite airports under the St. Louis jurisdiction:

- Civic Memorial
- Bi-State Parks
- Weiss
- Spirit of St. Louis
- Arrowhead
- Creve Coeur
- St. Charles Municipal
- St. Charles Smart
- Washington Memorial

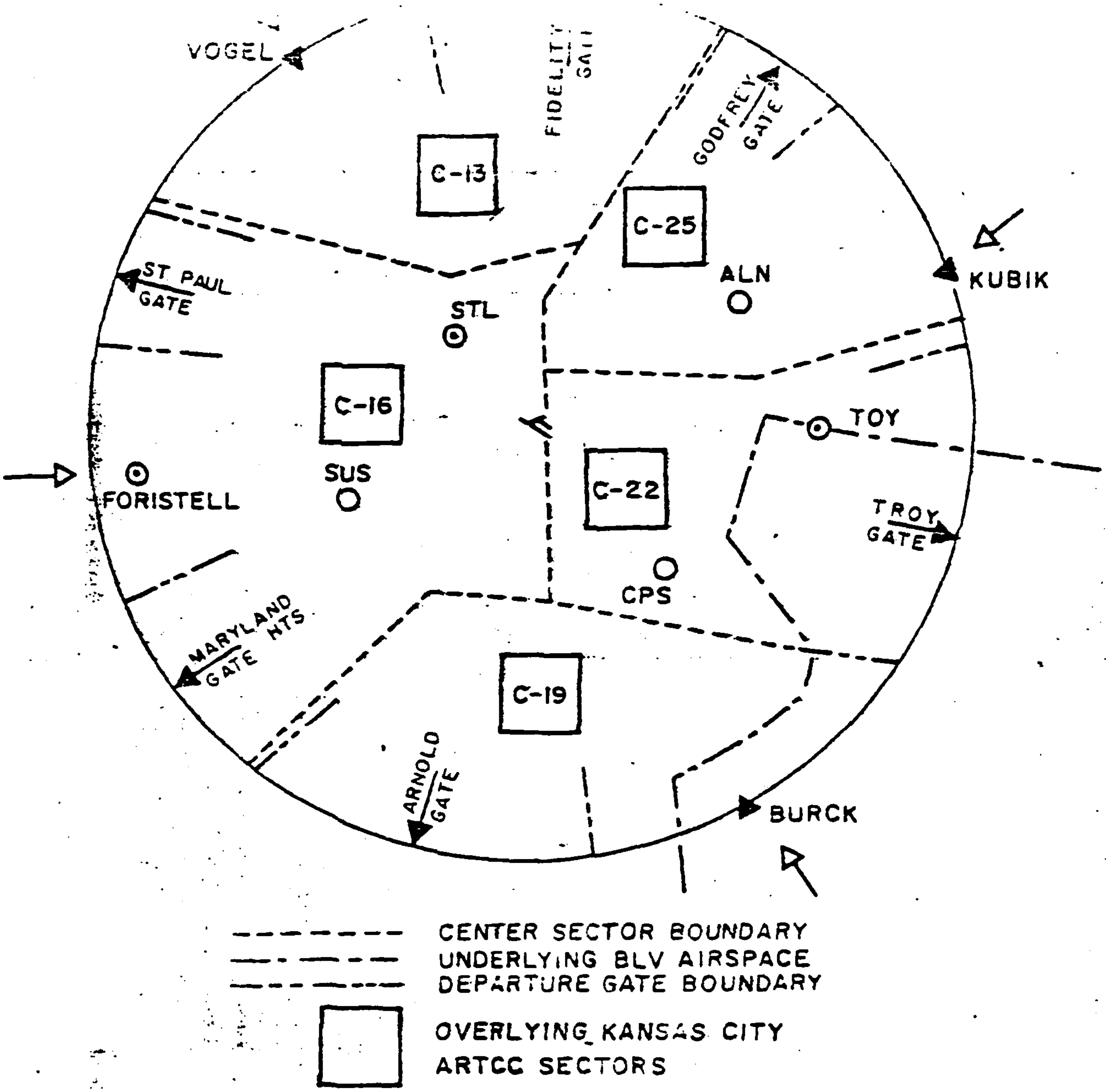
Eight of the nine satellite airports are located beneath the floor and within the lateral limits of the St. Louis Terminal Control Area (Group 2).

The St. Louis delegated airspace is functionally subdivided to balance workloads, reduce complexity and to meet user demands. Subdivisions are normally northeast/southwest of runway 12R/30L extended centerlines, below the floor of the TCA and/or 5000' whichever is lower, and above 5000' through 12,000 feet.

Turbojet and turboprop arrival aircraft above 6000 feet are routed via one of four corner posts (Figure 5), thence along a predefined corridor to an approach or descent quadrant. Propeller driven aircraft arriving St. Louis below 5000 feet are vectored by Low Altitude Control and normally given an approach to a secondary runway. Low Altitude Control also accommodates the satellite operations, which includes practice approaches at satellite airports.

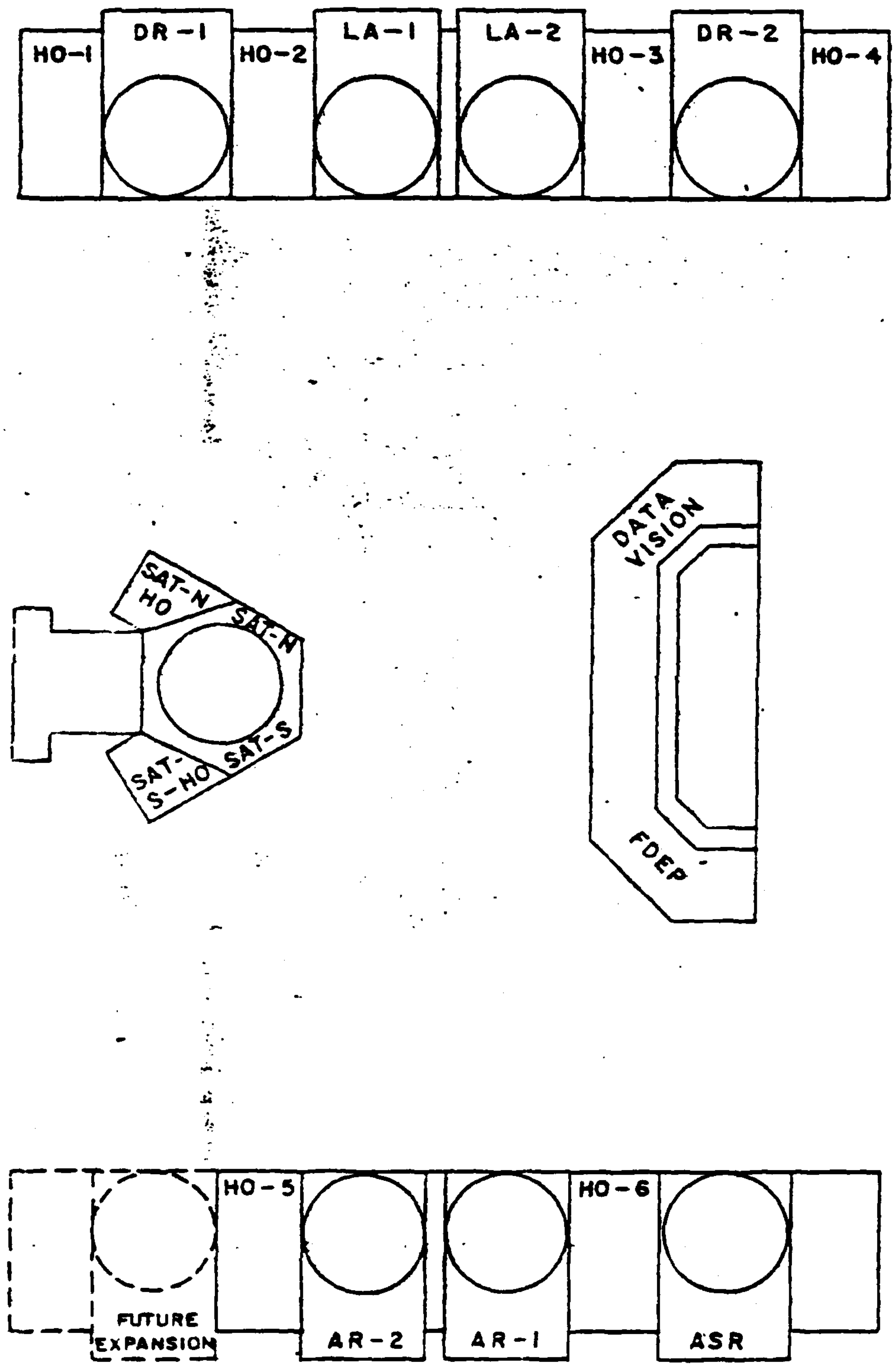
Departing aircraft are vectored through departure gates (Figure 5) that are appropriate for the direction of flight. As in the case of arrivals, turbojet and turboprop aircraft remain above the floor of the TCA until exiting the lateral limits. The concept being applied is the segregation of high and low performance aircraft as much as practical.

Scott Air Force Base is located approximately 28 nmi southeast of Lambert-St. Louis International Airport. Traffic entering or exiting the Scott AFB approach area on a course from approximately 240 degrees clockwise to 020 degrees is handled by the low altitude function of St. Louis approach control. Radar handoffs are exchanged and communications transferred prior to reaching the common boundary. Pre-determined routes and altitudes are utilized for efficiency.



ST. LOUIS APPROACH CONTROL AIRSPACE
AT & BELOW 12,000FT. MSL; 32 MILES
RADIUS STL ASR ANTENNA

Figure 5



AR-1 NORTH ARRIVAL
AR-2 SOUTH ARRIVAL
DR-1 NORTH DEPARTURE
DR-2 SOUTH DEPARTURE
LA-1 LOW ALTITUDE NORTH
LA-2 LOW ALTITUDE SOUTH
SAT-N NORTH SATELLITE
SAT-S SOUTH SATELLITE
HO HAND OFF

C. Selected Ground/Airborne Scenarios

Configuration No. 1: Arrivals and departures via runway 30L/R

Traffic arriving over the four corner posts (Vogel, Kubik, Burck and Foristell) is vectored by the arrival controller to a common point approximately ten miles southeast of the airport (Figure 7) using predefined arrival corridors. After landing, aircraft are taxied to the appropriate ramps via taxi patterns illustrated in Figure 8. Departures are taxied into position via patterns illustrated in Figure 9 and after departure are vectored by the Departure Controller to appropriate departure gates as specified in the Kansas City Center/St. Louis Tower Letter of Agreement (Figure 7).

Configuration No. 2: Arrivals and departures via runway 12L/R corner posts and departure gates are the same as in Configuration No. 1. Airborne procedures are illustrated in Figure 10 while taxi patterns are illustrated in Figure 11 (arrivals) and Figure 12 (departures).

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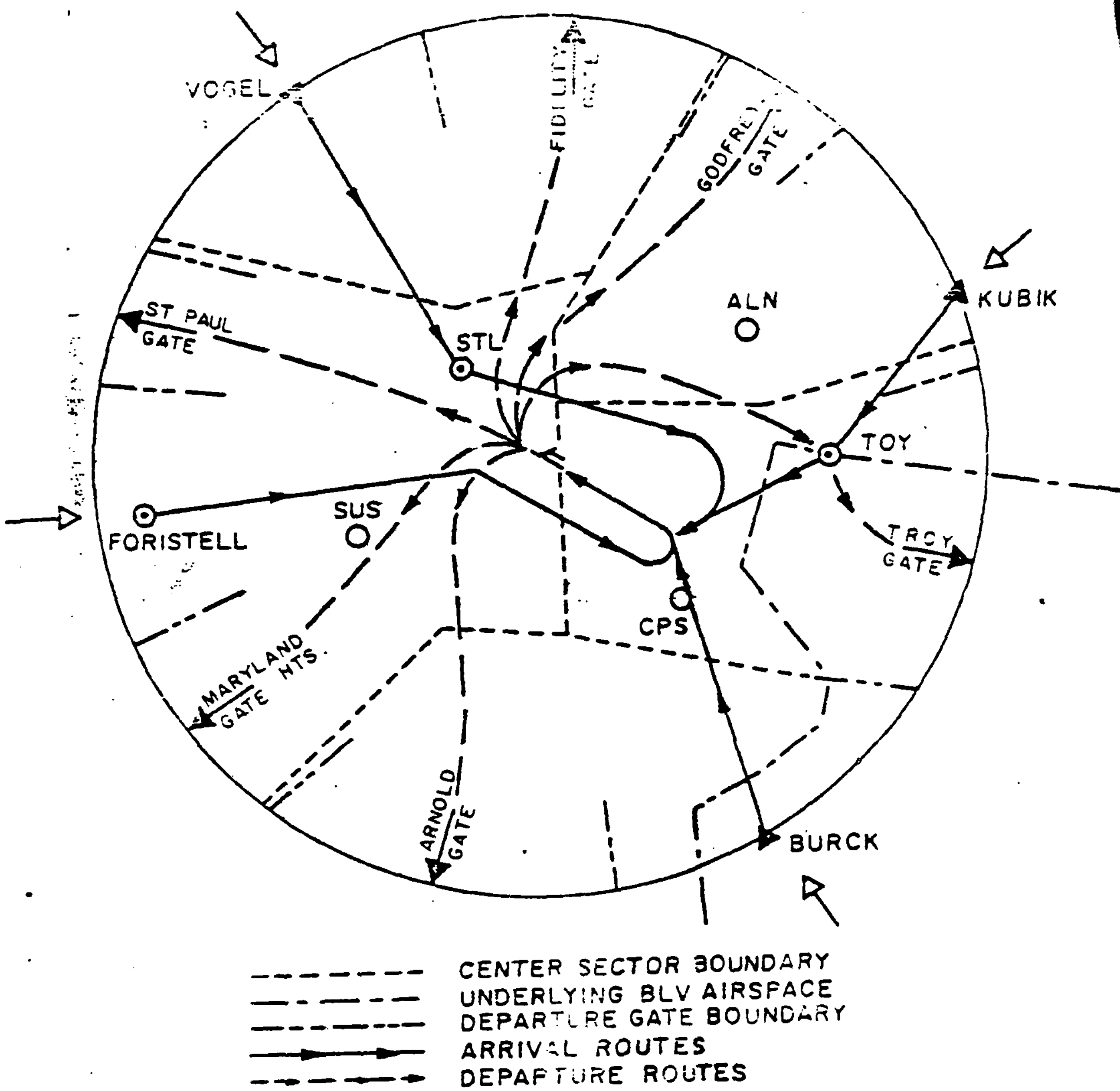


Configuration No. 1 Airborne

Figure 7

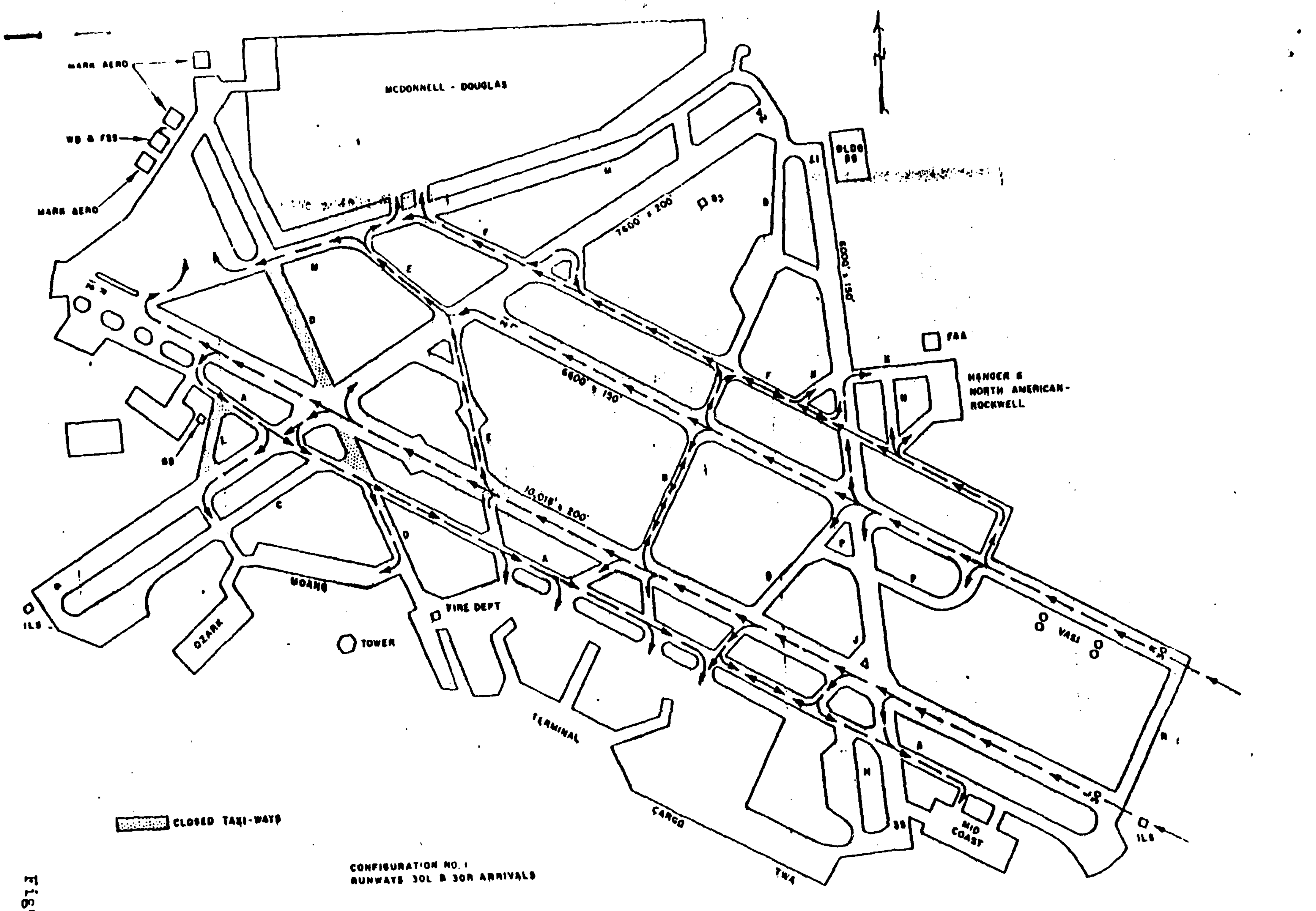
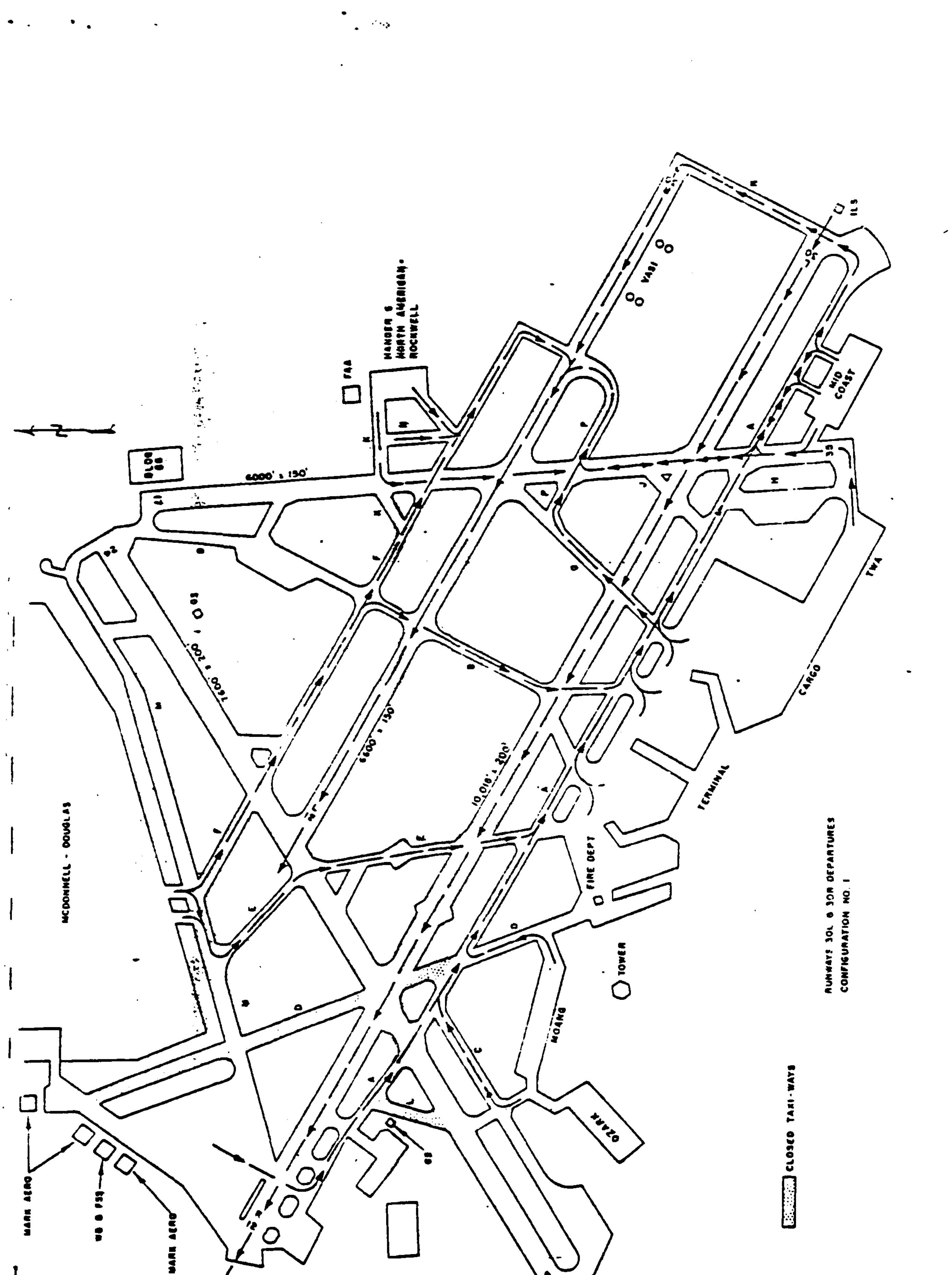
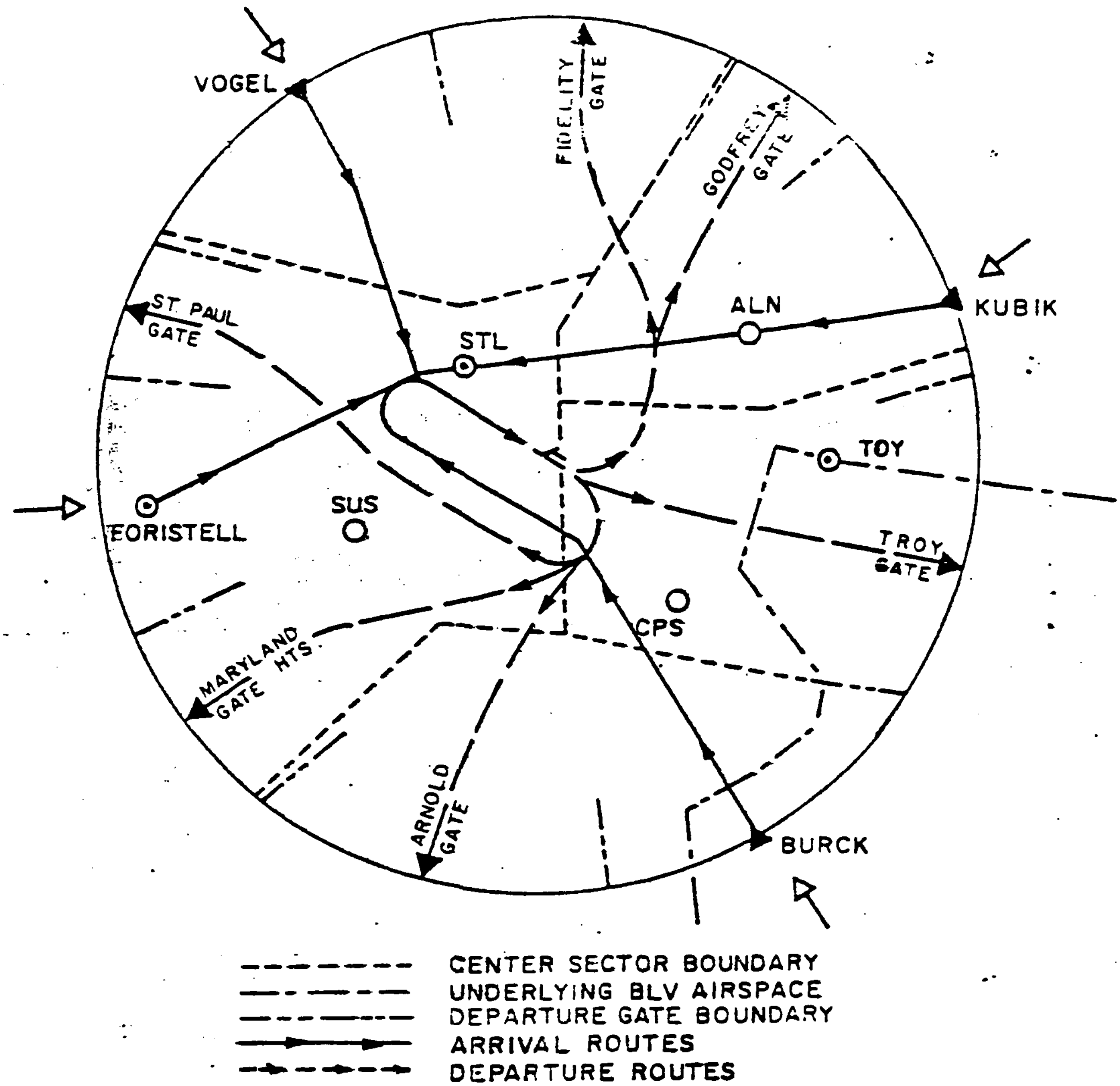

MCDONNELL - DOUGLAS
MARK AERO
WB & FSS
MARK AERO
BLDG 59
7600' x 200'
6000' x 150'
6600' x 150'
10,018' x 200'
FAA
HANGER 6
NORTH AMERICAN-
ROCKWELL
VASI
ILS
ILS
MOANS
OZARK
FIRE DEPT
TOWER
TERMINAL
CARGO
TWA
MID
COAST
CLOSED TAXI-WAYS
CONFIGURATION NO. 1
RUNWAYS 30L & 30R ARRIVALS
LAMBERT - ST. LOUIS INTERNATIONAL AIRPORT
C-0940 1-11-79 (SHOP MASTER)

Figure 8



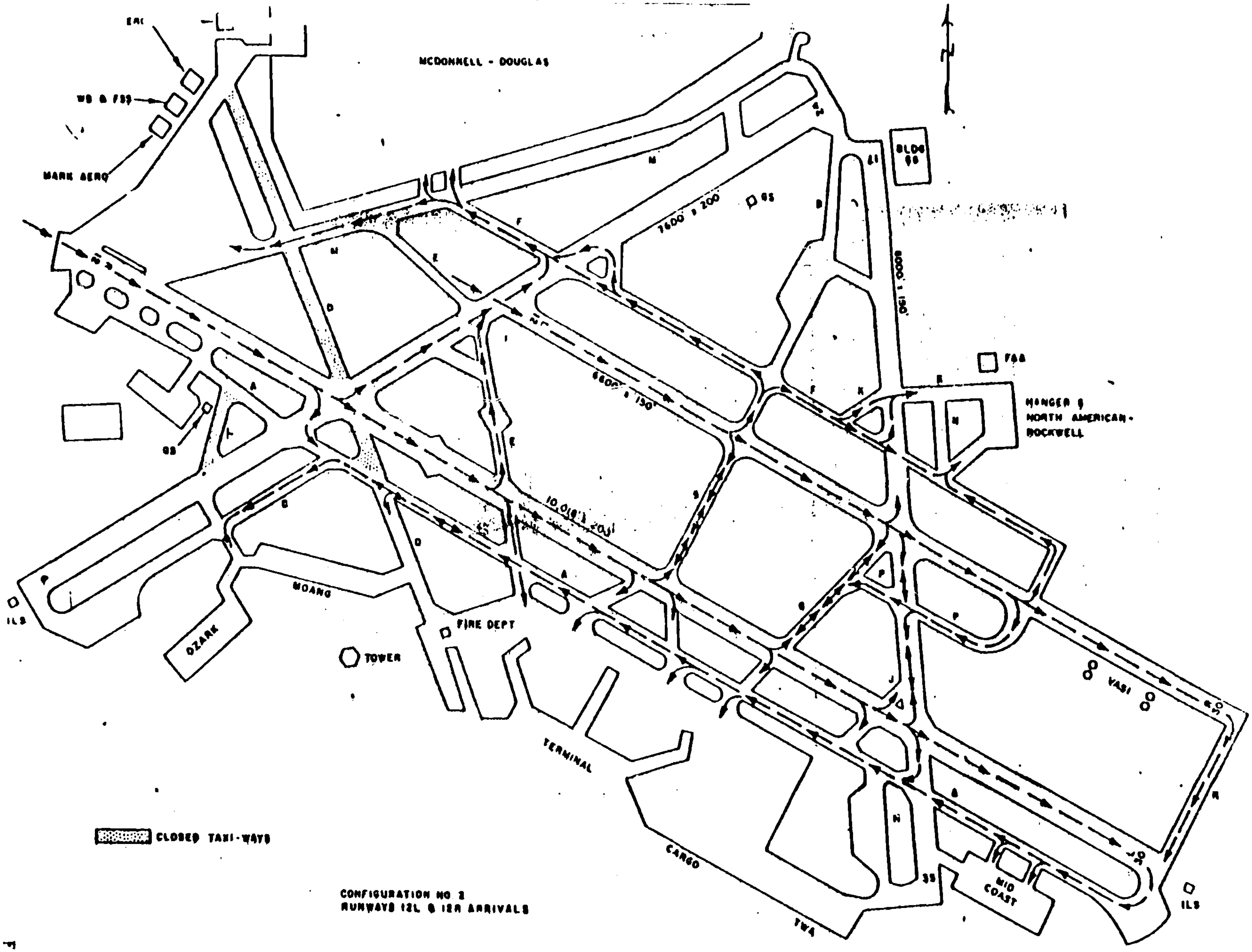
MCDONNELL - DOUGLAS
HANGER 6
NORTH AMERICAN-
ROCKWELL
FAA
BLDG 68
6000' x 150'
7600' x 200'
6600' x 150'
10,018' x 200'
VASI
ILS
MID COAST
TWA
CARGO
TERMINAL
FIRE DEPT
TOWER
OZARK
MARK AERO
WB & FSS
MARK AERO
RUNWAYS 30L & 30R DEPARTURES
CONFIGURATION NO. 1
CLOSED TAXI-WAYS

Figure 9



Configuration No.2 Airborne

Figure 10



CONFIGURATION NO 2
RUNWAYS 12L & 12R ARRIVALS

LAMBERT - ST. LOUIS INTERNATIONAL

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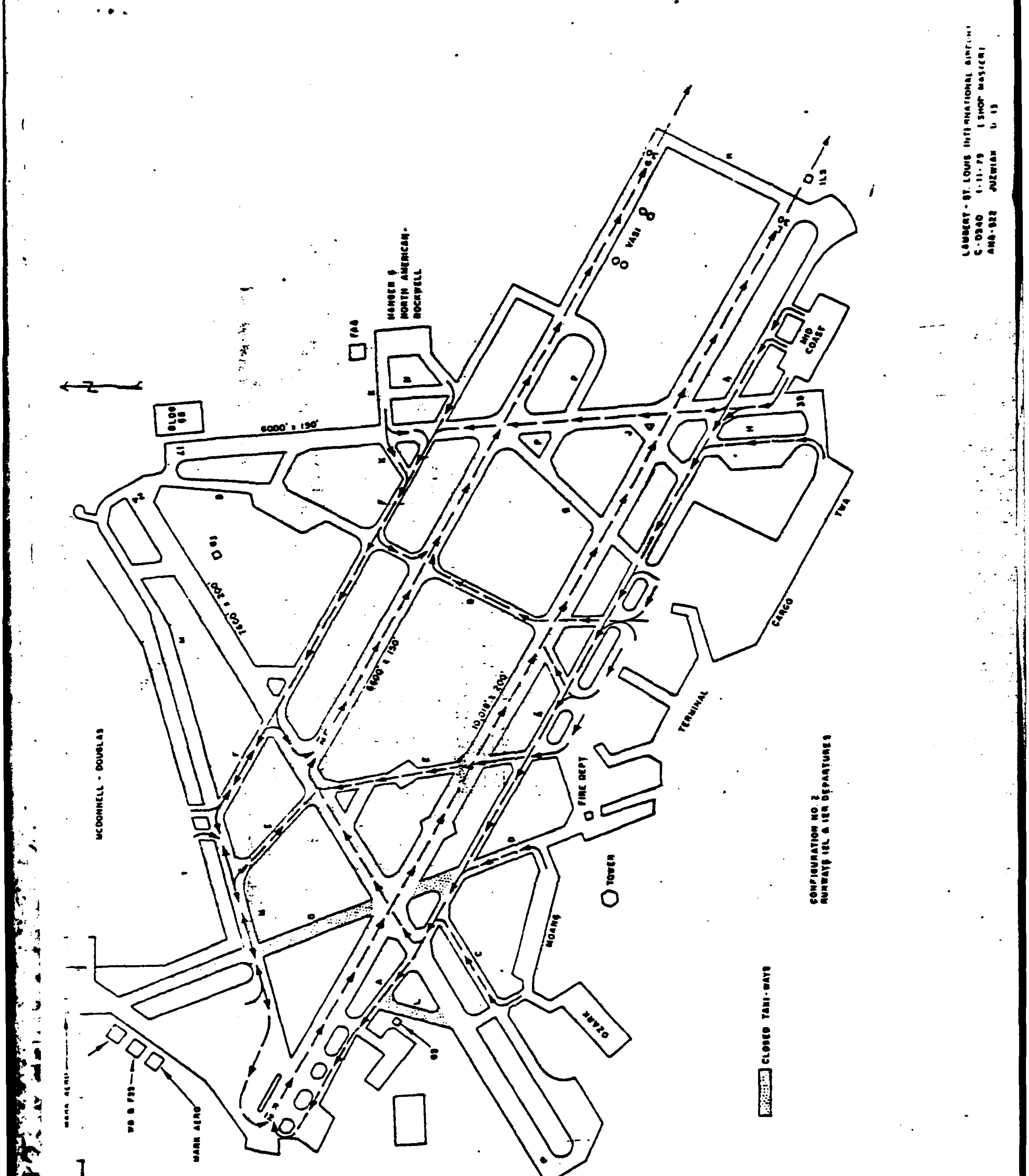

McDONNELL - DOUGLAS
TERMINAL
CARGO
TWA
TOWER
FIRE DEPT
OZARK
MID COAST
FAA
NORTH AMERICAN-
ROCKWELL
VASI
ILS
6000' x 150'
10,018' x 200'
CONFIGURATION NO 2
RUNWAYS 12L & 12R DEPARTURES
CLOSED TAXI-WAYS

Figure 12

DATE
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-8