REPORT NO. DOT-TSC-FAA-72-39

A REVIEW OF AIRPORT GROUND TRAFFIC MODELS INCLUDING AN EVALUATION OF THE ASTS COMPUTER PROGRAM

B. Paul Bushueff Jr.
Transportation Systems Center
Kendall Square
Cambridge, MA. 02142

PRELIMINARY MEMORANDUM

DECEMBER 1972

APPROVED FOR FEDERAL AVIATION ADMINISTRATION ONLY. TRANSMITTAL OF THIS DOCUMENT OUTSIDE THE FAA DEPARTMENT OF TRANSPORTATION MUST HAVE PRIOR APPROVAL OF THE TSC CONTROL AND SIMULATION BRANCH.

Prepared for
DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
Systems Research and Development Services
Washington, DC 20591

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle A REVIEW OF AIRPORT GROUND TRAFFIC MODELS INCLUDING AN EVALUATION OF THE ASTS COMPUTER PROGRAM		5. Report Date December 1972 6. Performing Organization Code
7. Author(s) B. Paul Bushueff Jr.		8. Performing Organization Report No. DOT-TSC-FAA-72-39
9. Performing Organization Name and Address Department of Transportation Transportation Systems Center Kendall Square Cambridge, MA. 02142		10. Work Unit No. 11. Contract or Grant No.
12. Sponsoring Agency Name and Address Department of Transportation Federal Aviation Administration System Research and Development Serv. Washington, D.C. 20591		13. Type of Report and Period Covered Preliminary Memorandum 14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

This report covers an evaluation of Airport Ground Traffic models for the purpose of simulating an Autonomous Local Intersection Controller. All known models were reviewed and a detailed study was performed on the two in-house models the ASTS and ROSS programs.

Included in the report is the results of attempting to run and verify the ASTS computer program using real data gathered at Logan International Airport. A discussion of ASTS program operation and useability is included.

February 1973

17. Key Words Airport Traffic model, Airport models, ground traffic models, Airport simulation, ASTS, Computer simulation of Airports	18. Distribution Statement APPROVED FOR FEDERAL AVIATION ADMINISTRATION ONLY. TRANSMITTAL OF THIS DOCUMENT OUTSIDE THE FAA DEPARTMENT OF TRANSPORTATION MUST HAVE PRIOR APPROVAL OF THE TSC CONTROL AND SIMULATION BRANCH.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	142	

PREFACE

The review encompassed by this report, was prepared by the Transportation Systems Center as part of a larger Airport Surface Traffic Surveillance task under the sponsorship of the Federal Aviation Administration (SRDS). The review of all airport ground models was to locate a computer program to use as a test and evaluation tool for the design, development and implementation of an autonomous local intersection controller on a segment of the airport surface. The purpose of attempting to model traffic at Logan Airport with the ASTS computer was to verify the program's operation and to assess the practicality of using such a model for the Intersection Controller task.

The collection of data at Logan Airport was conducted by Robert C. Abelman of Kentron, Hawaii Ltd. and section seven of this report contains his results. He also performed much of the preparation and testing of the ASTS program and provided much input in the program evaluation. The plotting program discussed in Appendix I-F was designed and developed by Mary Kiersted of Tufts University.

TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

Section Page

TABLE OF CONTENTS (CONTINUED)

LIST OF ILLUSTRATIONS

LIST OF TABLES

1.0 INTRODUCTION

Airport modelling has become a popular method of studying and evaluating proposed airport designs. Modelling has been applied to the problems of relocating runways, determining the increased operations gained by parallel runways, finding the saturation points of proposed and existing airports, defining the hardware requirements of controllers, and many other areas of interest. The fast computation ability of digital computers has provided for an inexpensive method of predicting results prior to installation.

With the inception of the Airport Ground Traffic Control (AGTC) program at TSC, a task was initiated to review all the airport traffic models in existence and to evaluate them in light of using one for the purpose of modelling the traffic in, around and through a "Local Intersection Controller". Included in this survey were the two in-house programs, the ASTS and ROSS models.

To gain further insight into the feasibility of airport modelling and to evaluate the recently delivered ASTS program, a task was initiated to attempt to model an existing airport under existing traffic conditions. The reason for picking a real airport under real conditions was to determine how accurately the computer program could model an existing situation that could be measured. Also, whether or not a model could be finely tuned to a specific airport to consider a model calibrated enough to predict a future situation that does not exist today. Due to proximity and time constraints, Logan Airport was selected as the airport to be modelled. Thus, this report encompasses the airport traffic model review including a detailed comparison of the two in-house models. The ASTS program is evaluated operationally and as a simulation tool in light of the attempt to model Logan Airport. Also enclosed is a description of a data collection task undertaken at Logan Airport for the purpose of collecting some rough data to input to the model and for calibrating against the model.

2.0 SUMMARY

As many airports reach the saturation point due to runway usage, gate assignment, traffic routing, limited visibility operation, noise abatement requirements, etc., new methods and equipment are required. To cost-effectively evaluate proposed solutions requires the use of digital computers and detailed airport traffic models. However, care must be taken in the design and/or selection of an airport model. Some important considerations might be:

Time vs. event model - An event to event type model is the most efficient and accurate modelling method. However, real-time graphics require a time approach to provide continuity of motion on the display.

Modelling Capabilities - The program must be able to accurately model airport traffic. The model must be calibrated to fit the airport activity rather than the activity be modified to fit the model.

Degree of Detail - The program must have sufficient detail in the areas of interest to warrant its use. Gross performance modelling might be suitable for one situation but not for another.

Output Capability - The output requirements determine the effectiveness and usefulness of the model as here lies the liaison between the computer model, the user, and the real world.

Calibration Capabilities - A model should be tested and evaluated against a real world existing situation not against a contrived and immeasurable situation. The degree of confidence in a program is enhanced by the model's ability to predict existing conditions.

In reviewing the different ground traffic models known to TSC, the GPS Limited, "Heathrow Model", and the Peat, Marwick, Mitchell, "Maddison Model", best meet the considerations mentioned above. However, these two models as well as the others reviewed were gross performance models covering all major traffic activity suitable for major architectural modification analyses and capacity predictions. Thus, they could not be considered as-is candidates for study of a local autonomous intersection controller due to lack of detail and lack of suitable output. The intersection controller study requires a program to model the control hardware as well as the intersection control logic. Capability is required to determine performance changes based on the relocation of detector loops and control lights and to measure the effects of loop or light failures. This study would require a special program to handle the necessary detail which in turn could be linked, if desired, to a gross performance simulation model.

As well as the Maddison Model and the Heathrow Model, two Government-owned models exist, ASTS developed by IBM and ROSS developed by Bolt, Beranek and Newman. As they stand now neither is suitable for the intersection controller study or can meet the qualifications of a general airport model. However, each contains features in spite of limitations that are worthy of recognition.

The ASTS program is an attempt at a general airport model that covers all major areas of interest in excellent detail. However, as it is still in a developmental stage certain limitations exist:

a. The program is not fully debugged.

b. Routing is by fixed path without regard for congestion and other delays.

c. There is a lack of good output for calibration purposes.

d. Certain input restrictions limit accurate modelling ability.

The ROSS program on the other hand has a tremendous graphics capability for study of man/machine interfaces and should not be considered a general airport traffic model. The ROSS program concerns itself with the general motion of the aircraft and does not consider gates, gate assignment, service vehicles, ramp areas, hangar traffic, etc.

3.0 AIRPORT GROUND TRAFFIC MODEL REVIEW

3.1 BACKGROUND

In order to determine the feasibility of using simulation techniques for the problems of Airport Ground Traffic Control, a survey was made of all traffic models known to TSC. After having determined what an airport model might consist of (see Section 3.2), all models were reviewed and evaluated (see Section 3.3). The review and evaluation were conducted with the intention of using one of the simulations, if one was found to be suitable, to model the Local Intersection Controller at the medium sized airport selected as test site. The use of the computer program was to evaluate control strategies at the intersection chosen and to determine the overall performance change as a result of the intersection controller. The airports under consideration were Detroit, Logan and Pittsburgh.

3.2 AN AIRPORT GROUND TRAFFIC MODEL

An airport ground traffic model concerns itself with aircraft from the time they approach the outer marker on landing, to the gate, to the hangar, and vice versa. Exterior to the core of the model is a flight generator which sets up the take-off and landing schedule. On the other end is the statistical data gathering which goes on throughout the simulation.

To best explain the major elements and operations of a typical traffic model might be to describe how it might handle the movement of an aricraft through the taxiway network.

As a plane comes on final approach, it tries to reserve the runway. If this is not possible, due to another aircraft on the runway or failure to meet the flight separation criteria, the plane will make a missed approach and try again. When an aircraft can reserve the runway, all intersections are locked, thus prohibiting other planes from crossing the runway. As the plane lands and passes the intersections, it frees that intersection for another reservation. The plane will turn off the active runway according to any of several criteria:

a. ability to meet the turn off speed for that turn off

b. turn off occupancy

c. proximity to gate

d. aircraft type or any other arbitrary restriction

The aircraft now off the active runway will start trying to reserve its gate or gate group previously assigned to it, based on its predicted E.T.A. (estimated time of arrival) at the gate. This attempted gate reservation, if unsuccessful, will continue as the plane taxis on some fixed route, based on runway exit and desired gate, obeying whatever headway controls and taxiway speeds that are in effect. Aircraft require reservations to pass through intersections based on any of the following intersection logics:

1. first come, first served
2. flow priority
3. platooning

If the aircraft, as it moves through the taxiways, is still unable to reserve its desired gate, it may be given an alternate within the same gate group. If neither of the previous conditions are existing, the plane may be sent to a holding area if one is available; otherwise, the plane will come to a stop on or near the ramp throat. Ramp areas are divided into sectors each of which can hold a certain number of aircraft, based on the size of the planes.

A service time is required for through flights. This time factor is required for fueling, passenger embarking and disembarking, and repairs depending on aircraft type. This has an effect on gate utilization and aircraft delays. Each aircraft using a gate also requires service vehicles from the airline pools. Should not enough be available for that type of plane, further delays may be encountered depending upon E.T.D. (estimated time of departure).

When a plane's scheduled departure time arrives, if it has met all service time requirements, it requests ramp area room for pushback. If room is available, the plane will move out from the gate and select the fixed route to the active runway assigned to it and the reverse process continues until the plane is airborne and leaves the simulation area. Thus, for a traffic model to operate in the above way requires the following major elements:

Major Elements of a Ground Simulation Model

a. Flight Schedule Generator
b. Runway Control
c. Intersection Control
d. Headway Control
e. Gate Reservation
f. Ramp Space Control and Allocation
g. Gate Usage
h. Service Time (passengers, fuel, maintenance)
i. Traffic Elements
    - Airplane (different classes or types)
    - Service Vehicles
    - Port Authority Vehicles
j. Traffic Patterns
    - Runway to Gate
    - Runway to Gate to Runway
    - Gate to Hangar
    - Hangar to Gate
    - Gate to Runway
k. Route Structure
l. Route Control (taxi speeds, etc.)

m. Output Statistics

- Queue Lengths
- Delay Times
- Runway, Taxiway Utilization
- Number of Stops
- Travel Times
- Gate Utilization
- Etc.

3.3 TRAFFIC MODEL EVALUATION

The following traffic models were reviewed:

3.3.1 In-House Models (not calibrated)

a. Bolt, Beranek and Newman (ROSS Model)
b. IBM (ASTS Model)

3.3.2 Out-Of-House Models (not calibrated)

a. Computer Science Corp. (STRACS Model)
b. Tippets, Abbet, McCarthy and Stratton (AGOS Model)
c. United Aircraft Model
d. R. Dixon Speas (ASM-2 Model)
e. United Airlines Model

3.3.3 Out-Of-House Models (calibrated)

a. G.P.S. Limited/Howard, Needles, Tammen, Bergendoff (GPS Model)
b. Hodgins, Thompson, Ball and Associates (Willis Model)
c. Peat, Marwick, Mitchell (Maddison Model)

Each model was reviewed against the following selection criteria:

3.3.4 Model Selection Criteria

a. Reasonableness of Model
   1. Accurate Modelling Ability of Airport Activity
   2. Ease of Modification to Install Candidate Intersection Control Logic
   3. Type of Input Required
   4. Method of Modelling (time vs. event)

b. Suitability of Model
   1. Output Parameters Available
   2. Detail of Model - To Study Local Intersection Controller
   3. Ramp Area Detail (if ramp area intersection chosen)

c. Time Deadline (3 to 6 months to complete local intersection controller simulation)

d. Willingness of Program Owner to do Local Intersection Controller Simulation

e. Calibration

f. Cost

g. Future Capability of TSC

Calibration as noted above can be defined as follows:

3.3.5 Calibration Criteria of a Model

a. Model an Existing Airport

b. Simulate with Real Data (i.e., typical existing traffic load)

c. Model Existing Control Rules and Strategies of the Airport

d. Comparison of Predicted Results with Measured Results
   - Delay Times (taxiing, runway, gate)
   - Travel Times (gate to runway and vice versa)

- Activity Spots on Network
- Present Results to Airport Personnel (pilots, ground controllers, airport managers, airlines)

Thus, with the above criteria in mind a brief review of each model is presented here. The cost estimates are included only to indicate comparative sample usage costs and have been approximated.

3.3.6 ASTS Model -- IBM Federal Systems Division

This model was developed under a DOT/TSC contract with a completion date of January 1972. The program is a GPSS model that runs on a 360/50 or better. A graphics capability in the form of an IBM 2250 CRT can be used to stop the simulation and look at statistical data to that point and to modify the input data. This feature should be extremely useful for tuning the model to a specific airport. ASTS models all major activity areas on the airport surface including gates, ramps, intersections, taxiways, runways, etc., under whatever control strategies specified.

Approximately two months would be required to generate and model the specified airport, at a cost of $15-20K. The model has not been calibrated although all major modules have been checked to assure proper operation. This model with calibration greatly enhances our in-house capability.

3.3.7 ROSS Model -- Bolt, Beranek and Newman

The ground oriented modifications to an air traffic control model were performed under a TSC contract. The completion date was February 1972. The ROSS model has a sophisticated graphics capability for the main-in-the-loop control. The program contains a more detailed modelling of the aircraft taxiing dynamics than other models, although it is not clear at this time whether or not this degree of detail is necessary. Another feature of the model is the method in which the program has been developed. It has been written with the idea that the user will program in the control strategies and routing procedures.

ROSS cannot be considered fully automated as there is no gate reservation scheme, ramp utilization scheme, or statistical data reporting feature. However, to complete the automation process and calibrate the model for Detroit would require only a small effort on the order of $10-15K and two months of time.

The program is time oriented and runs on a PDP-10 requiring 28K words of memory.

3.3.8 GSP Model -- Howard, Needles, Tammen and Bergendoff/GPS Limited

The GPS model is an event model written mainly in Fortran. Because of its event-to-event update procedure, the program operates more efficiently than a time oriented model (e.g., ROSS). Sufficient detail is modelled to make it suitable for our purpose.

One unique feature of this model is the capability of measuring ground controller workload. This output is indicated in the form of the number of radio telephone communications that would be required by the controller for any intersections, ramps, etc. Other items that make the GPS approach different from the other models reviewed are in the form of inputs to the model. Two fixed routes, a primary and a secondary path, may be specified for each origin and destination point, the shortest time path being chosen at event time. Two flight schedules are generated, one for arrivals and one for departures; thus, no through flights are considered directly. The model has been used to simulate the existing Heathrow Airport and the results compared against measured data; therefore, the model can be considered calibrated. No cost can be ascertained until the airport and logic is chosen; however, $20-25K would not be an unreasonable figure to assume.

3.3.9 Maddison Model -- Peat, Marwick, Mitchell & Co.

The Maddison model is a critical events model written in Fortran. The detail is more than adequate to model intersection control. Features of this program include modelling of the pushback time according to aircraft type and gate geometry. Runway exits can be specified according to gate location. A deficiency may be that headway control is handled by dividing up the taxiways into small segments, each segment being approximately the length of an aircraft. Therefore, non-dynamic headway is provided by allowing one aircraft per link.

The Maddison model is the most extensively calibrated simulation. Peat, Marwick, Mitchell & Co. have used it to model ground traffic at San Francisco, Los Angeles and Honolulu Airports. To model Detroit and run the logic tests would require an estimate of 3-4 man/months of work at a cost of $20-25K.

3.3.10 Willis Model -- Hodgins, Thomas, Ball Associates

Although the Willis model was developed to simulate activity at New Orleans Airport, this GPSS model cannot be considered a general airport ground traffic model. To model a different airport would not just require changing the input to the program, but would necessitate rebuilding and writing a whole new model. Also, the present model does not use the queue function of GPSS and, therefore, queue lengths on taxiway segments and intersections cannot be obtained directly. As the traffic into and out of these intersection areas does not approximate a Poisson distribution, queue lengths cannot be obtained indirectly.

The cost for HTB to build an airport model for Detroit would be approximately $24-27K and 8 man/months of effort.

3.3.11 AMS-II Model -- R. Dixon Speas

The ASM-II model is written in Simscript and can simulate a 24-hour period in one minute on a 360/85. R. Dixon Speas' approach has the following advantages and several major disadvantages.

The program has the feature of being able to use a plotter to verify the airport geometry. There is considerable detail on the modelling of gate activity. Both a pre-planned and a random take-off and landing schedule can be employed to provide the traffic sample. An initial program can be run to build the matrix of fixed routes. Also, a 16 mm movie can be made of a simulated time period although it is very costly ($5000 for a ten-minute film).

The disadvantages of the Dixon Speas model are few but are of concern. Headway control is provided by requiring that each aircraft occupy a fixed amount of taxiway. This procedure might break down when aircraft of different types are following each other (e.g., GA following jumbo jet). The turn offs off the runway are selected as the plane comes over the threshold. The touchdown point is constant with a varying deceleration rate. There does not appear to be any way to force the exit according to airline type. The cost for the use of the model is approximately $20K. Also, the model has not been calibrated against real data although it has been used for Philadelphia and Phoenix airports.

3.3.12 AGOS Model -- Tippets, Abbett, McCarthy, Stratton

The AGOS model is a GPSS model similar in operation to the ASTS model; however, there are several disadvantages to this model.

A disadvantage is the method of headway control which is similar to the Dixon Speas model. Only one taxi speed is assumed for all types of aircraft depending on proximity to the terminal area. Gate to hangar traffic is not modelled nor do service vehicles occupy ramp area.

Although AGOS has a "best path" algorithm, it has not been developed fully and could prove to be a detriment to the modelling effort. Although the model has been used for Dallas-Fort Worth, Marguetia (Venezuela) airports, the model has never been calibrated.

The estimated cost for modelling Detroit Airport is $30,000. The cost for data gathering is $20,000 and for a ten-minute motion picture, $25,000.

3.3.13 STRACS Model --

Computer Sciences Corp.

This GPSS model was developed just to model Kennedy Airport and therefore could not be considered a general airport model. Also, no attempt was made to calibrate the simulation.

United Aircraft Model

This model does not have sufficient detail of ground movement to warrant consideration.

United Airlines Model

This model does not have sufficient detail; therefore, it does not warrant consideration at this time.

Having reviewed all the models, a preliminary summary is presented to indicate how TSC rated the different programs with respect to the selection criteria noted earlier.

PRELIMINARY MODEL EVALUATION*

Model	Reasonableness of Model	Suitability of Model	Time Deadline	Willingness to Work	Calibration	Cost
ASTS	2	2	1	1	2	1/15-20K
ROSS	2	2	1	1	3	1/10-15K
Maddison	1	2	3Δ	1	1	2/20-25K
GPS	1	1	2Δ	1	1	
Willis	3	4	3Δ	1	2	4/24-27K
STRACS	4	4	3Δ	4	2	
AGOS	2	2	3Δ	1	2	4/$32K
ASM-2	2	2	3Δ	1	2	2/18K
UAC	θ	4				
UAL	θ	4				

*Scale

1 = Excellent   2 = Very Good   3 = Fair   4 = Poor

Δ Due to an assumed contract procurement time of 3 months   θ Not Applicable

4.0 DETAILED REVIEW OF TSC'S IN-HOUSE MODELS

4.1 BACKGROUND

After an initial review of all traffic models available, a detailed study on the two government owned models, the ASTS and the ROSS programs, appeared warranted. Their conceptual and structural differences make them complement each other. The ROSS program with excellent graphics is suited for man/machine interface studies and the ASTS is more suited to batch simulation.

The approach taken was to discuss each major requirement of a traffic model and to compare and contrast each.

4.2 ASTS VS. ROSS

4.2.1 Aircraft Generation

ASTS - A fixed schedule can be input that will contain the airplane's scheduled arrival and departure times, gate, landing and take-off runways. Also, a percentage mix can be input to have ASTS generate the schedule.

Modifications - None at present.

ROSS - At present, scenarios in conjunction with route procedures are used to specify aircraft generation.

Modifications - Upgrade to ASTS level.

4.2.2 Runway Control

ASTS - Runways are controlled by an intersection and runway reservation scheme according to minimum spacing and runway occupancy. They can be used for landings, take-offs, or dual operation. Also, runways can be dependent on other runways, weather, usage, etc.

ROSS - Runway control has the following priority constraints: landings over take-offs and take-offs over taxiing aircraft crossing the active runway. Only one aircraft can be on the runway at any one time.

Modifications - Upgrade to include dependency groups and other usage criteria.

4.2.3 Runway Turnoff

ASTS - Variable touchdowns occur with a constant deceleration rate that could change to reflect weather. When a plane meets the velocity and turning radius criteria, the plane will turn off the runway.

Modifications - Have planes be able to turn off the runway according to which gate group they are going to and have a nominal touchdown distance and standard deviation for each runway.

ROSS - Planes have variable touchdown and deceleration rates and turn off when a certain velocity is reached.

Modifications - Incorporate turning radius of turn into criteria and input capability to select turn-off based on gate group destination.

4.2.4 Taxiway Routing

ASTS - Fixed routes are input during initialization for each exit-gate group configuration that might occur. The route is obtained when a plane turns off the runway based on the exit taken and the destination gate group.

Modifications - Create a shortest path generator to develop an alternate route strategy based upon look ahead and projected arrival times. Seldom can a fixed path be prescribed.

ROSS - Route procedures can be written to take a plane from exit to a gate; however, there is no method of using fixed routes.

Modifications - A procedure should be established to input the fixed routes and then use them to route a plane from exit to gate and vice-versa.

4.2.5 Taxiing Dynamics

Headway Control

ASTS - Headway parameters are input for each aircraft type following another. Headway is maintained by instantaneous velocity jumps to reflect the taxi velocity of the link or the leading aircraft. A plane dynamically accelerates or decelerates to keep the proper minimum headway.

ROSS - Headway control is maintained by one headway parameter input for all aircraft. A plane dynamically accelerates or decelerates to keep the proper minimum headway.

Turn Control

ASTS - Time to make a turn is calculated based on the geometry of the turn and the aircraft characteristics.

ROSS - Turning control is handled dynamically based on aircraft characteristics and turn angle.

4.2.6 Velocity Specification

ASTS - Velocities are input for each link of the taxiway network independent of aircraft type.

Modifications - None

ROSS - One velocity is input for the entire network.

Modifications - Input velocities for each link, length of link, or proximity to the terminal area.

4.2.7 Intersection Control

ASTS - There are three possible logics allowed for each intersection: (1) first come, first serve, (2) flow priority, and (3) platooning (with or without flow priority). Each can operate with or without intersection blockage allowed.

Modifications - None at present.

ROSS - First come, first serve is the only logic available.

Modifications - Incorporate flow priority and platooning into the intersection control procedure.

4.2.8 Apron/Gate Control

ASTS - Gates, gate groups, and ramp definitions are input to the model. Aircraft try to reserve and fill these entities. If a plane cannot obtain his desired gate, another gate within the gate group is selected. If no gates are available, the plane will be sent to a holding area or will stop on the apron as space permits. Each airport requires a certain number of service vehicles from the service vehicle pool of each airline for a specified length of time depending on aircraft type. Delays may be encountered if not enough vehicles are available. When an aircraft is ready to depart, a certain amount of ramp area is required for a pushback. The time required for pushback depends on aircraft type and gate geometry.

Modifications - None at present.

ROSS - There is no gate reservation or ramp utilization. Service vehicles, therefore, are not considered.

Modifications - Upgrade to the ASTS level.

4.2.9 Output Data Capabilities

ASTS - GPSS is the simulation language; therefore, most raw data is automatically collected. A formatted aircraft log is output at the end of the runs.

Modifications - Extract the raw data and format it into a neat package of useful data easily readable by a layman, and add new output parameters suitable for calibration.

ROSS - The capability is available to write data out to the terminal, printer, or disk, formatted or in raw form by means of the route procedure language.

Modifications - Put in data gathering statements and write data reduction routines to process and format the raw data.

4.2.10 Graphics Capabilities

ASTS - An IBM 2250 CRT display can be employed to do the following:

a. watch aircraft move around the network

b. look at input data and modify input data (including airport geometry)

c. look at statistical output at snap intervals

d. obtain line and bar graphs of key parameters

Modifications - The program should be adapted to support other graphics terminals that do not require hard wire connections over a short distance (2000 ft.) (e.g., Imlac, 2260, etc.).

ROSS - Tremendous man-in-the-loop capabilities exist through the PDP-10, 516, Sanders display hook-up. Planes move through the display area in a realistic manner, and a person at the teletype can interact with the simulation by means of route procedure commands. At present, two types of aircraft I.D. exist: a carot and two alphanumerics and an aircraft symbol. This graphics capability could be of great use to study the man/machine interface.

Modifications - A zoom feature for a specific portion of the airport and a flight strip table might be added to the graphics capability.

4.2.11 Machine Requirements

ASTS - 350K bytes on a 360/50 or better under O.S. and using GPSS V.

ROSS - PDP-10 and 26K words.

Simulation Times

It is difficult to ascertain comparable figures as machines vary greatly.

ASTS - 10:1 - simulation time to cpu time running batch processing on a 360/50. 2:1 with graphics.

ROSS - 20:1 - on TSC's PDP-10 without graphics. 3:1 with graphics.

4.3 COST ESTIMATES FOR MODELLING AN AIRPORT

Approximate cost estimates to incorporate the changes recommended above and to model a medium sized airport to evaluate intersection logics are presented here:

IBM (ASTS)	Cost
4.3.1 Gather and verify data at an airport	
a. medium sized airport (Logan)	$ 30,000
b. large airport (O'Hare)	$ 45,000
4.3.2 Set up program	
a. set up airport	
b. modify program to gather data on r/t communication workload	
c. tune model	
d. set up for production runs	$ 25,000
4.3.3 Modify output format	$ 5,000
4.3.4 Modify graphics for a 2260 display	$ 15,000
TOTAL	$ 90,000

BB&N (ROSS)

4.3.5 Upgrade program	
a. upgrade to ASTS level	
b. put in data gathering routines	
c. put in data reduction routines	$ 15,000
4.3.6 Gather data for an airport	$ 40,000
4.3.7 Tune model to a specific airport for production runs	$ 10,000
TOTAL	$ 65,000

4.4 SUMMARY OF DIFFERENCES

The ASTS program should be considered a completely automated system with no man-in-the-loop capability. Future interactive capability would require new software to handle the interactive graphics and the manual control commands. Such is not a feasible alternative, as running the program would require a large IBM computer 360/50 or better with appropriate graphic displays which is not available to TSC at this time.

Therefore, the ASTS program should be considered as a general airport traffic model requiring only major changes made to the output capability:

a. Format output data at snap intervals and at the end of the run. (Obtain hard copy output of statistical data available on the 2250 CRT.)

b. Provide support for other types of displays that can be used remotely and are readily available.

The ROSS program cannot be considered a general airport traffic model at this time as many features have yet to be incorporated into the program. However, with TSC's PDP-10, 516, Sanders display laboratory, the ROSS program allows user interaction and the graphic capability to study the man/machine interface provided thorough and realistic modelling of an airport is not required. The major modifications that must be made to make the ROSS program a general airport traffic model are as follows:

1. Develop fixed routing with look ahead capability
2. Upgrade runway control to include runway dependency and other runway usage criteria
3. Allow velocities to be varied over the different taxiway links
4. Allow for flow priority and platooning at intersections
5. Include modelling of apron, gate, and service vehicle control
6. Input data gathering statements to generate raw data and write data reduction routines to process the raw data and print out formatted critical activity statistics

Therefore, each model has capabilities but must be considered for separate purposes at present. The ASTS is a general traffic model applicable to any airport but does not contain the man-in-the-loop capability. The ROSS program cannot be considered a general model but does possess significant graphic and user interaction capability.

Thus, further program development should reflect future uses and any decision on which model to develop should be dictated by those future requirements. Some of the decision criteria that must be weighed are:

a. Scope of the modelling effort required for the local autonomous controller task
b. Future use for an airport traffic model
    i. man-in-the-loop capability
    ii. man/machine interface
    iii. control logic evaluations (e.g., taxiway direction, intersection control, runway dependency, etc.)

    - iv. aircraft type interaction
    - v. capacity predictions and capacity handling capabilities
    - vi. ground controller workload studies
    - vii. architectural design
    - viii. gate allocation and usage
    - ix. support facility location and interaction
    - x. etc.
- c. Present program capabilities
- d. Future program capabilities
- e. Future in-house problem solving capabilities
- f. On-going modelling capabilities
- g. Operational considerations
    - i. in-house vs. out-of-house computer
    - ii. in-house vs. out-of-house displays
    - iii. real-time vs. batch processing
    - iv. external hardware availability
    - v. model modifications (internal manpower requirements)
    - vi. general modelling adaptability
- h. Funding requirements
- i. Time requirements

The overriding criteria as to which model to choose is whether or not the man-in-the-loop capability is required. This condition necessitates the use of the ROSS program. Should the man-in-the-loop capability not be required, the ASTS would provide us with the most flexible batch process simulation capability.

5.0 ASTS OPERATIONAL EVALUATION

5.1 BACKGROUND

Having made a cursory study of several airport models the ASTS program appeared the most promising for the local intersection controller simulation. The method chosen was to model an existing airport, use an existing runway combination, and simulate airport activity with a typical two-hour peak period traffic load. The subject to be studied was Logan Airport between 4-6 PM, using the 33L and R runway combination.

The reason for selecting Logan Airport was twofold. First, the proximity was appropriate for ease of data collection. Second, Logan Airport was a possible test site for the local intersection controller project. The selection of 33L and 33R runway configuration was chosen as traffic out to 33L must cross through the possible test site for a local autonomous controller, namely the runway 9 and Charly taxiway intersection. Also, there were no intersecting runways in use. The reasons for selecting the 4-6 PM time frame were:

a. to stabilize the traffic control pattern

b. to provide enough traffic to generate some congestion and some delays

c. to test the program under relatively severe loading conditions

Attempting to model a real airport and use a typical traffic sample forced one to tailor the model to an existing situation rather than construct a fictitious airport tailored to the restrictions of the model. In doing so, the strong points and weaknesses appeared. The purpose and method of operation became readily apparent as well as the reasons for using GPSS. In attempting to debut and calibrate the program numerous errors were discovered and many corrected. The output from a simulation proves to be very important as that is one's only source of model verification. Thus, this ASTS Operational Evaluation contains the following:

1. method of operation
2. GPSS
3. major features of the ASTS program
4. limitations of the ASTS program (including a discussion of errors found and those corrected)
5. output capability of the ASTS program
6. calibrating the ASTS program

5.2 METHOD OF OPERATION

The ASTS program was coded in a combination of software languages. The model, which simulates the activity on the airport surface, was written in GPSS.

The interface program serves several purposes and is coded in both Fortran and Assembly languages. The input data is read in by the interface program and the GPSS storages, matrices, and save-values are initialized. Once the input data has been read, GPSS is initialized. This will start the model executing.

Certain functions, such as updating the aircraft position or the handling of graphic requests, are also performed in the interface program through calls from the model using Fortran "help blocks". The output consists of the standard GPSS output and an aircraft log generated by the interface program. The functional flow of the program between the interface and the model can be seen in Appendix A.1.

5.3 GPSS

The simulation language chosen for the ASTS program is GPSS V. This language is a high level user language that is well suited to event simulation. Though not as operationally efficient as other languages, it is easier to code and modify. GPSS also provides a complete statistical output package as is described in the

IBM GPSS V manuals. GPSS is also compatible with other languages such as Fortran through the use of GPSS "help blocks".

Therefore, the ASTS program generates transactions which are the aircraft and advances them from event to event recording pertinent data to appear in the standard GPSS output. This is accomplished by means of facilities (i.e., runways, intersections, gates, etc.), storages (i.e., ramps, gate groups, aprons, taxiways, links, etc.), user chains (i.e., planes waiting for gates, planes waiting for runways, etc.), and queues (i.e., at intersections, waiting to take off, waiting to land, etc.). For example, a transaction (aircraft) will be advanced (in time and position) to an event, such as entering a facility (runway), and then be advanced to the next event, such as leaving a facility (runway).

GPSS also provides the user with the facility to save the output from a simulation run and compare this to the output from another run.

5.4 MAJOR FEATURES OF THE ASTS PROGRAM

In attempting to model an existing airport under real conditions with the ASTS airport model, the strengths and weaknesses come out clearly. The following is a list of what the model performs:

5.4.1 Models Airport Activity Including the Movement of Aircraft In:

a. gates

b. runways

c. taxiways

d. intersections

e. ramps

f. holding aprons

g. taking off

h. landing

i. runway turn offs
j. service vehicles

5.4.2 Considers delays to and from Hangars that might occur:

a. landing
b. taking off
c. taxiing
d. at intersections
e. at gates
f. etc.

5.4.3 Generates a take off and landing schedule from:

a. a time line schedule
b. a percentage mix of airlines and aircraft types

5.4.4 Has output capability in the form of:

a. standard GPSS output
b. the printing of an aircraft log
c. graphic output including a dynamic display of aircraft movement with the use of a 2250

Thus, the ASTS program in the light of being a developmental program is an elaborate airport simulation encompassing most important areas of airport surface activity. As with any program, when treated for the first time, the ASTS has certain areas which could use some reinforcement and improvement. Also, there are some major limitations and minor logic problems that require correction. The following is a list of limitations of the model.

5.5 LIMITATIONS OF THE ASTS PROGRAM

The following is a partial list of what TSC considers to be minor limitations of the program that still exist after the corrections and changes that TSC has made (see Appendix A.2). These items are only listed here as they required only minor efforts to correct or are of a questionable nature.

a. Airport log requires better formatting and debugging.

b. Only one ramp is allowed for each gate.

c. Taxiways and links must be straight.

d. Turnoffs are determined only by aircraft type, velocity, and radius of turn; not by destination.

e. The intersection control logic is incorrect, allowing planes to be terminated and the intersection remaining locked.

f. Ramps must be large enough for planes to free the entering intersection (plane length plus intersection clear distance).

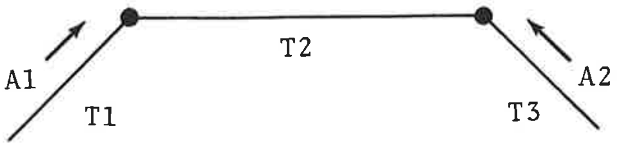
g. The users manual requires some improvement to eliminate the inconsistencies and confusion it might cause (see Appendix A.3 for changes to the users manual prepared by TSC).

Though the above mentioned limitations are not considered serious enough to fault the major logic development, there are several major flaws which could severely handicap the user of the ASTS program when attempting to model a real airport using typical traffic loads. Due to their seriousness they are noted and discussed here.

1. The ASTS program cannot be considered fully debugged and tested. There are numerous minor programming errors and logic errors as well as several major limitations that have been discovered but due to time and lack of computing facilities only a limited amount of testing and correcting could be performed. Therefore, due to the complexity and scope of the model, the fact that the model is not fully debugged could prove to be a major limitation of the program as it exists today.

2. Intersecting runways cannot be modelled with the ASTS program. When selecting a runway combination, avoid any group that has intersecting runways as, for example, the parallel 4's in use with 9 at Logan Airport. This constraint is due to the rule that intersections must be numbered sequentially on runways. This is a major limitation of the ASTS program as most major airports have intersecting runways that are used conjunctively.

3. The program does not provide for a plane to look beyond the link ahead to determine whether or not the link can be travelled in his direction. This may result in nose to nose conditions occurring. Due to the restricted definitions of taxiways often what is really one taxiway and could only have travel in one direction at one time must be broken up into several taxiways. Thus, when a situation (as depicted below) where



plane A1 and A2 are allowed to enter their respective taxiways T1 and T3 occurs, a nose condition develops on T2. The probable solution would be to change the definition of taxiways.

4. The routing input to the program may not be quite accurate, and less efficient than real life due to the model's single fixed-route structure. Some sort of alternative routing scheme must be developed to permit planes to alter their course to reflect traffic conditions ahead.

5. The ASTS program lacks any well formatted output. This requirement becomes very important when trying to calibrate and tune a model for a specific airport. Some

important parameters that would be required at output time would be:

a. gate to runway travel times
b. touchdown to gate travel times
c. turnoff usage
d. length of time on runway (for takeoffs and landings)
e. link travel times

5.6 OUTPUT CAPABILITY OF THE ASTS PROGRAM

There are three major types of output obtained from the ASTS program. The primary output is that produced by GPSS. A secondary output is generated by the interface program and consists only of an airplane log. The third mode of output available is that produced at the graphics terminal, namely the IBM 2250, and its generation is handled through the interface program. A brief discussion of each follows.

The standard GPSS output produces statistical data on: (1) facilities (e.g., gates, runways); (2) storages (e.g., links, aprons); (3) queues (e.g., at intersections, landings); (4) user chains (e.g. planes waiting for place in front to move, service vehicles waiting for plane to get to gate); (5) tables (e.g., time between departures).

As well as statistical data, all the program matrices and all variables, called save-values, are printed out. However, the statistical as well as the matrix data is unlabelled and the units not given. Therefore, understanding of this output requires knowledge of the GPSS output feature, noting all pertinent ASTS documentation, and checking the program code for an understanding and appreciation of this output. This lack of formatting could be improved through the use of the GPSS output editor. However, attempts to use the output editor with the program resulted in a system error, D13.

These statistics and matrices have been of great value in debugging the program but of only little value for calibration of the model against a real airport. For this reason, TSC has added two matrices, TRNEX and ALTIM. TRNEX is a matrix that contains the number of turnoffs by turnoff for each aircraft type. This has proved valuable in getting planes to turn off the runway at the correct turnoff. The other matrix, ALTIM, gives the average travel time from touchdown to gate and from gate to takeoff by airlines and the total number of planes that are included in the average. This is a useful overall calibration tool as these parameters are of primary concern in ground traffic movement and congestion.

The second type of output is the aircraft log produced at the end of a run by the interface program. This log, as can be seen in Appendix A.5 has printing errors and the most formatted of the output is not readily understandable. The Users Manual also fails to document the log.

The remaining form of output is that generated by the interface program and produced at the graphics terminal.

The graphics terminal required is an IBM 2250 display station. This terminal is extremely costly to rent or purchase, and must be hard wired over a short distance to the central processor. Thus, only limited observations could be made on its usefulness.

With a 2250 display the ASTS program can be run on-line. This means that the simulation can be started from the 2250 by reviewing and selecting a case from a case library. The simulation can proceed to a snap interval at which time statistics including bar and line graphs can be displayed. The input matrices can be reviewed and altered while the simulation is running, a static display of airport geometry can be displayed as well as a dynamic display of the aircraft movement. The aircraft are identified either by aircraft class (one alpha character on the screen) or by inbound and outbound (an asterisk or an ampersand on the screen).

The dynamic display could be useful for debugging but is heavily dependent on the aircraft update time. If the update time is made very small the simulation is slowed way down. There are also zoom features on the 2250 to blow up a specific portion of the airport map. One can also modify the airport geometry using the light pen. However, due to the number of changes that must be added to the input matrices to support the changed geometry, only the simplest changes, such as changing the lengths of two abutting links would be practical on the 2250. After simulating a period of time the simulation can be stopped and the output saved to compare to another run.

Most likely the greatest advantage of a 2250 would be to tune the model to an airport by simulating a period of time and then modifying the input and resuming simulation to determine the effect of the change.

Although the graphics capability does exist and can be informative, this would require fairly extensive practice with the 2250 and the ASTS and a thorough knowledge of the operation of the model and of the input. Thus, the graphics feature should not be considered as a useful operative tool at a user level.

As far as the selection of graphic terminals, the 2250 is far from ideal. Unless a 2250 was available on an in-house system the user would prefer that the software be changed to support a less expensive terminal that can communicate remotely over telephone lines.

Due to the complicated form of input TSC felt a need for new form of output to verify the input. For this purpose a Plotting program was written to read the input data and plot a detailed airport map. All the runways, taxiways, links and intersections are labeled for ease of verification. Also, a suitable airport map has been created, for debugging and calibrating the ASTS program (see Appendix A.6 for a description of the program and a sample map).

The only means of understanding the results of simulation, of calibrating a model, or of verifying its operation lies in the output available. Therefore, more work is required to bring the ASTS program output up to an adequate level. The major need is in formatting of present output and adding new reporting for calibration.

5.7 CALIBRATING THE ASTS PROGRAM

In attempting to calibrate the model to Logan Airport numerous problems arose (see also Appendix B.4 - ASTS INPUT RESTRICTIONS):

a. Planes would not turn off realistically -- this was fixed by adjusting the turning radius and velocity function as well as creating new plane types with phony deceleration characteristics to reflect the fact that international flights preferred the north taxiway turnoff due to the proximity of the gates.

b. Planes reserved the runways too soon and held them too long after turnoff. This was avoided by decreasing the turnoff taxiway to one aircraft length plus the intersection clear distance.

c. Nose to nose conditions developed on taxiways due to the lack of a look ahead capability. This was avoided by putting in incorrect routing that made nose to nose conditions not possible.

d. Planes were terminated for having inadequate minimum spacing -- this was a result of poor logic control of intersections resulting in all intersections being defined as "no intersection blockage allowed".

e. Planes in gates were still holding intersections causing major traffic tie-ups. This was corrected by lengthening the ramps to the largest aircraft length plus the intersection clear distance.

Although many changes were made the model never could be considered calibrated. All the planes did however land and takeoff successfully. Some of the calibration problems that still exist are discussed in Appendix A.3.

6.0 MODELING APPLICATIONS OF ASTS PROGRAM (IN LIGHT OF THE LOGAN SIMULATION)

6.1 BACKGROUND

The purpose of attempting to model a real airport with a real traffic load was not only to test out the ASTS program's suitability for the local intersection control simulation and determine calibration capabilities of the program, but also to determine the applicability of the ASTS simulation to modelling airports in general. The questions to be asked are:

a. What are the applications of the program?

b. What are the limitations?

c. What improvements might be made to expand the applications?

d. How useful is the model?

6.2 APPLICATIONS

The ASTS program can be used to model airports with relatively simple geometry and traffic patterns that adhere to the limitations noted below. The gate logic appears operable and the service vehicle support feature functioning although no attempts were made to verify the logic. Runway control does operate with planes entering and leaving the system according to the timeline schedule. Delays were occurring where expected; however, due to time constraints only limited calibration attempts were made to reduce the unusually high departure delay times (see Section 5 for further discussion of calibration attempts). Due to the general nature of this GPSS model and no real graphic capability to observe real time dynamic motion of aircraft, the ability to model a detailed situation may be extremely difficult without adding major routines to the model. Thus, as the model should be used to evaluate gross airport performance ASTS would not be useful for modelling a local intersection controller including the loops, lights, logic, etc. The model would not provide enough detail to accurately gauge performance on that area nor would the model be helpful for evaluating intersection logics or equipment placement except for determining its impact on the rest of the airport system. The same could be said of using the ASTS program for studying gate assignment or the sharing of service vehicles. However, the ASTS program could be interfaced with another program to study such situations in detail.

Therefore the present use of the program would be in gathering gross statistical data on a specific airport configuration under varying control strategies.

6.3 LIMITATIONS

The limitations beyond those mentioned in Section 5: poor output, not completely debugged, sequential intersection numbering on runways, no alternate routing, lack of a look ahead capability, are those applying to the specific situation at hand. Due to the general nature of the model, specific modelling tasks may require additional programming.

6.4 IMPROVEMENTS

In order to improve the ASTS program and to expand its applicability would require major changes to the program. The most prominent changes that could be made are as follows:

a. fully debug and test the program

b. incorporate an alternate path routine to handle rerouting due to future delay

c. prepare a well formatted output package

d. change the runway logic to allow for intersecting runways

e. redefine taxiways to avoid nose to nose conditions from developing

These items should greatly increase the usefulness of the ASTS program.

6.5 USEFULNESS

At present the ASTS program could not be considered a useful tool for modelling airport activity. Due to the major limitations that still exist, an initial effort would be required to clear up those difficulties. But considering the program in its proper perspective, that it is a developmental program, the ASTS program is a well conceived and well written model with a tremendous nucleus for future development.

7.0 DOCUMENTATION OF DATA COLLECTION

7.1 BACKGROUND

For the testing and calibration of the ASTS program a significant amount of raw data must be collected and reduced. Presented here is the data requirements for the ASTS program, the reduced data used, and a brief discussion of data modifications required for ASTS operation. All numbers presented are reasonable estimates for Logan Airport but have not been evaluated as to their statistical quality.

7.2 DATA COLLECTION REQUIREMENTS

The Data requirements can be separated into two major catagories: those elements to satisfy input requirements for program operation and those elements gathered for the purpose of validation and calibration. Diagrams below contain a list of the two types of data gathered. Noted on the right halves of the diagrams are the possible sources from which to obtain the information. Much of the information which is airport independent can be obtained from numerous reports that have been written on airport ground traffic (See Bibliography, Page 7-22). Other information is airport unique but can be obtained from airport maps and airport regulations. The remaining data plus checks of unobserved data were made by visual observations at Logan Airport.

7.3 DATA COLLECTION PROCEDURE

The data that required field observations fall into three major categories: runway area data, taxiway area data, and terminal area data. A discussion of each task follows:

ASTS INPUT DATA REQUIREMENTS

DATA	DATA SOURCES*
RUNWAYS:	
X,Y, width, orientation, grade rise	Map
Use - lanking/takeoffs	0
Direction - one way/two way	0
Dependency	0,RPTS
Gate Runway Preference	0
TAXIWAYS:	
X,Y, width, links	Map
Direction - one way/two way	0
Max speed	0,RPTS
HANGERS:	
X,Y	Map
TERMINAL BUILDINGS:	
X,Y	Map
INTERSECTIONS:	
X,Y, type	Map
Blockage	0,map
Control - FCFS/priorities/ Platooning	0
GATES:	
X,Y, associated apron	Map
Type, docking time, undocking Time, apron-to-gate time, Ramp-to-gate time	
Gate Group Association	0,map
APRONS:	
X,Y, area	Map, 0
Gate Group Association, Link Association, Capacity	0

---

*List of Abbreviations:
Map - Airport Map
0 - Field Observations
To - Terminal Observations
RPTS- Other airport surveys and reports
A/C CHAR - Books on aircraft characteristics

ASTS INPUT DATA REQUIREMENTS CONT.

DATA	DATA SOURCES
TURNOFFS:	
Radius Curvature (vs. velocity function)	0 (see manual)
AIRCRAFT CHARACTERISTICS:	
Length, Area, Weight, Seat capacity turn Radius vs. velocity Fcn, # of service vehicles Required, service time touch own velocities, Liftoff velocities, Acceleration, deceleration Landing distance, Takeoff distance, Approach time	A/C Char, 0, RPTS
AIRCRAFT SPACING:	
VFR - stopped and moving	0,RPTS
IFR - stopped and moving	0,RPTS
ROUTING:	
Inbound/outbound	0
SCHEDULE:	
TOA/TOD	Time-line schedules, 0
Runway use	0
Gate use	To
SERVICE VEHICLES:	
#/airline	0
Time to gate/airline	0
Miscellaneous:	
Nominal touchdown points by runway	0
Gate time tolerance	0
Reaction time to cross a runway	0
Intersection clear distance	0

CALIBRATION DATA REQUIREMENTS

DATA	DATA SOURCE
Turnoff Usage	0 (observation)
Total Travel Times	0
Inbound Travel Times/Airline	0
Outbound Travel Times/Airline	0
Link Travel Times	0
Gate Delay Times	0
Taxiing Delay Times	0
Runway Delay Times	0
Gate Utilization	0
Service Vehicle Times and #	0
Routing Usage	0
Queues Lengths at Ramps, Intersections, and Runways	0
Apron Usage and Delays	0

7.3.1 Runway Area Data

The runway System includes runway usage, runway interdependancy, aircraft performance on landings and takeoffs, and scheduling. The aircraft schedule or time line schedule is a major task that must be compiled prior to field observation. The sources used were The Official Airline Guide, television monitors or bulletin boards at the terminals, and airline schedules to compile a master schedule containing:

a. time of arrival or departure

b. airline

c. flight number

d. plane-type

e. gate

General aviation traffic must be observed over several study periods to get a feel for the number and frequency of flights to insert in the time-line schedule, as these are unscheduled flights. (Table A-2 contains the timeline schedule generated for field verification).

The runway area data collection task is contained in Appendix B.1.

7.3.2 Taxiway Area Data

The taxiway system includes taxiways, runway turnoffs, and routing. Taxiing speeds, direction of travel, transit times, and locations of congestion (for queue assignment) must be determined.

Appendix B.2 contains the taxiway area data collection task.

7.3.3 Terminal Area Data

The terminal area includes gates, gate-groups, gate-group aprons, and ramps. The data collector must determine the division of gates into groups and the association of each group with an apron and a ramp.

Each gate must be assigned an airline and a gate-type. Finally, from suitable vantage points (windows in the terminal or the tower), the following transit times must be measured:

a. Apron to gate times (by gate-group)

b. Ramp to gate times (by gate-group)

c. Docking times (by gate-type)

d. Undocking times (by gate-type)

e. Service vehicle reaction times (by airline)

Appendix B.3 contains the terminal area data collection task.

7.3.4 Summary of Data Collected

In April/May 1972, personnel from DOT/TSC gathered data at Logan Airport to test the ASTS Program. The numbers gathered are summarized as follows:

DATA COLLECTED AT LOGAN AIRPORT

PROGRAM INPUT

MAP Coordinates, Widths, and Lengths -- See Scale Map, Fig. 7-1.

RUNWAYS

Use:	33L	Landing and takeoffs
	33R	Landings (GA)
	27	Takeoffs (GA)
	4L	Takeoffs (GA)

Direction: All Runways One Way

Dependency: Parallel Runways -- None
Crossing Runways -- 100%

Gate-Runway Preference None

TAXIWAYS

Direction: See Routing Maps (Pg. 7-18 thru 7-20 refer to Map: Fig. 7-2 thru 7-4)

Speeds: See Taxiway Data Sheet

TAXIWAY VELOCITIES *

Taxiway No. (for ASTS)	Name	Location	Velocities (Kts)
1	ALG Hangar Ramp	hanger to O t/w	6-9
2	Outer t/w	T1 to	17-24
3		33 Lend to O t/w	15-20
4		O t/w to I t/w	15-20
5	TWA Hangar Ramp	hangar to I t/w	6-9
6	Inner t/w	hangar to N t/w	15-26
7	Outer t/w	hangar to N t/w	17-24
8	North t/w	33L to O t/w	18-30
9	North t/w	O t/w to I t/w	18-30
10	TWA Ramp	ramp to I t/w	3-5
11	North t/w	33R to 33L	30-34
12	Tango t/w	33L to O t/w	13-20
13	Tango t/w	O t/w to I t/w	13-20
14	Inner t/w	F t/w to O/N Int.	15-26
15	Inner t/w	F t/w to I/N Int.	15-26
16	Juliet t/w	33L to F t/w	17-24
17	Foxtrot t/w	33L to J/F Int.	36-47
18	Fortrot t/w	J/F Int. to I t/w	22-24
19	NEA Ramp	ramp to I t/w	6-9
20	Inner t/w	F t/w to C t/w	15-26
21	UAL Ramp	ramp to I t/w	6-9

---

* gathered for only those taxiways used with 33L operations

Taxiway No. (for ASTS)	Name	Location	Velocities (Kts)
22	Charlie t/w	I t/w to O t/w	18-23
23	Charlie t/w	O t/w to D t/w	18-23
24	Charlie t/w	D t/w to 33L t/o Apron	20-24
25	33L t/o apron	C t/w to 33L	10-15
26	R 9	E t/w to C t/w	16-23
27	Echo t/w	R 9 to O t/w	16-23
28	ALG Ramp	ramp to I t/w	6-9
29	Sierra t/w	O t/w to ALG Ramp	16-23
30	Echo t/w	O t/w to I t/w	24-26
31	Sierra (inbound) t/w	I t/w to EAL Ramp	17-18
32	Sierra (outbound) t/w	t 33 to I t/w	17-18
33	Sierra (outbound) t/w	S (in) t/w to S (out) t/w	17-18
34	EAL Ramp	ramp to S t/w	6-9
35	GA Ramp	ramp to S t/w	6-9
36	Inner t/w	C t/w to S t/w	23-28
37	Inner t/w	S t/w to E t/w	23-38
38	North t/w	33 R turnoff	

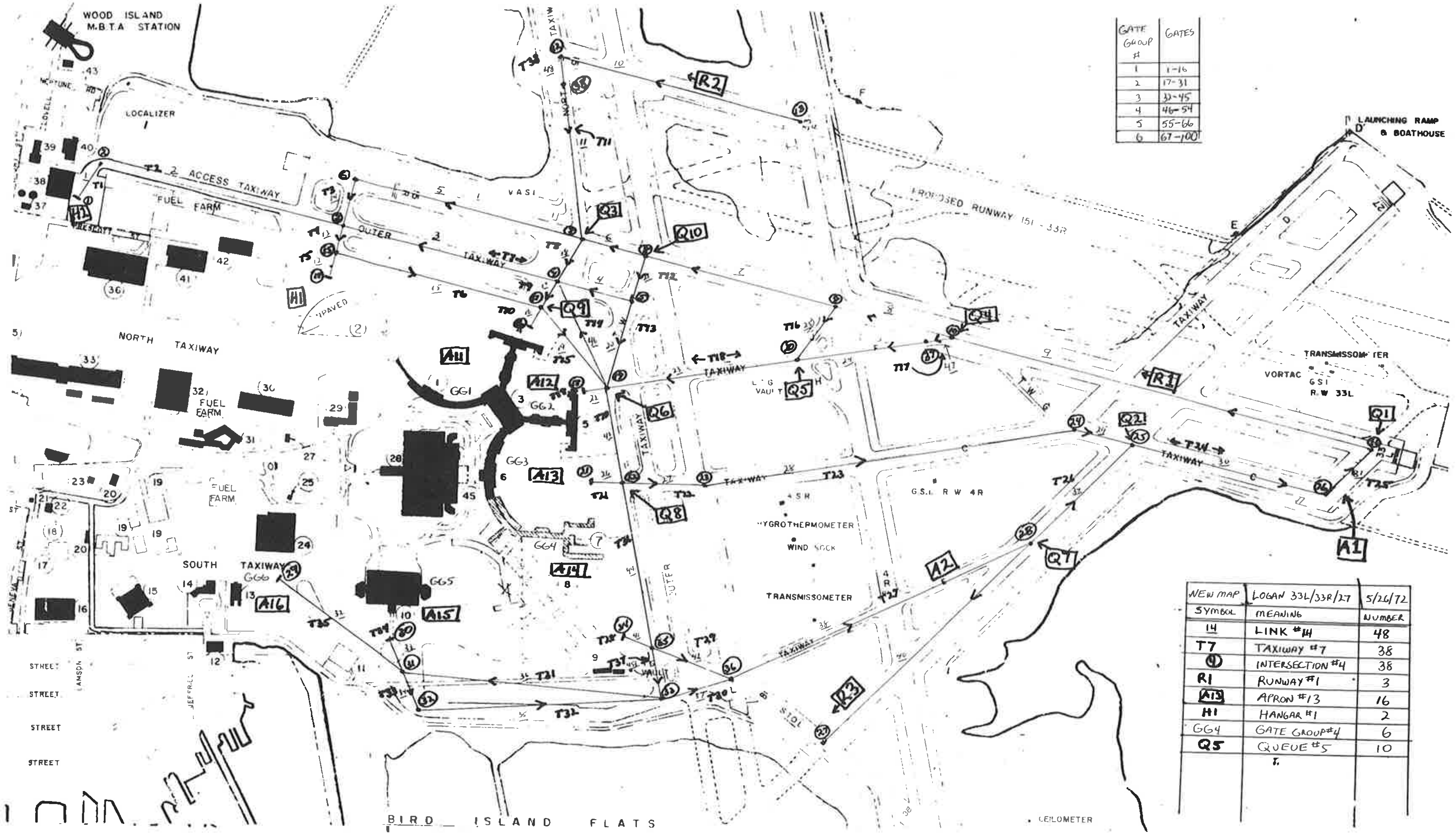
INTERSECTIONS

Blockage:	Allowed at all Intersections Except Those With Runways
Control:	All FC/FS

GATES

Types -- 1: "Accordion" Ramps
2: Regular Commercial Mobile Stairs
3: Apron Parking (GA)

Gate-Group Association: See Map 2, (Appendix B.3, Figure A-10)



GATE GROUP #	GATES
1	1-16
2	17-31
3	32-45
4	46-54
5	55-66
6	67-100

NEW MAP	LOGAN 33L/33R/27	5/26/72
SYMBOL	MEANING	NUMBER
14	LINK #14	48
T7	TAXIWAY #7	38
④	INTERSECTION #4	38
R1	RUNWAY #1	3
A13	APRON #13	16
H1	HANGAR #1	2
GG4	GATE GROUP #4	6
Q5	QUEUE #5	10

Figure 7-1. Map of Logan Airport showing Numbering Convention of Simulation Elements

AVERAGE TIMES

ROUGH DATA

GATE GROUP	APRON TO GATE TIME (SEC)	RAMP TO GATE TIME (SEC)
1. INT'L	30	110
2. TWA Area	30	50
3. NEA Area	30	50
4. UAL Area	30	70
5. ALG Area	30	60
6. EAL Area	30	75

GATE TYPE	DOCKING TIME (SECS)	UNDOCKING TIME (SECS)
1	40	70
2	30	70
3	20	30

APRONS

APPROXIMATE CAPACITIES

INT'L/TWA	FOUR DC-8's
NEA	TWO DC-8's
UAL/AAL	THREE DC-8's
ALG/MDH	THREE DC-8's
EAL	FOUR DC-8's

EQUIVALENCIES (APPROX.):

ONE DC-8 = 2/3 747 = 1 1/2 727

TURNOFFS

Usage primarily dependent on pilot decision, based on gate destination. Internationals usually went to

North Taxiway. TWA usually turned off at TANGO. Most 727 size planes (and smaller) turned off at FOXTROT.

ROUTING

See Routing Maps (See diagrams Fig. 7-2 - 7-4)

SCHEDULE

See Time-Line Schedule (Table A-2) from Official Airline Guide.

SERVICE VEHICLES

All airlines observed to have more than enough service vehicles.

Time for service vehicles to reach gate average around 60 secs for all airlines.

AIRCRAFT SPACING

Numbers Refer to Feet Between Planes
All Numbers Approximate

Following Plane	Front Plane						
	747	DC-8	707	DC-9	C580	Twin Otter	GA
747	360	180	180	180	180	180	240
DC-8	300	240	240	240	240	240	300
707	300	240	240	240	240	240	300
DC-9	360	180	180	150	150	150	240
C580	480	180	180	150	120	120	120
Twin-Otter	480	180	150	120	120	120	120
GA	1000	480	480	400	300	300	180

Plane Characteristics (By Type)

	Type	Length (Ft)	Capacity (Seats)	Weight (Lbs)	Area (Sq ft)	T.D. Vel.	Nominal Decel.	Liftoff Vel.	Nominal Accel.
1.	747	230	490	710000	75000	139	4	140	6
2.	707/30	153	189	327000	42000	126	4	140	7
3.	707/10	145	181	257000	35000	144	4	140	7
4.	DC8/20	151	179	276000	45000	131	4	140	7
5.	DC8/60	187	259	325000	52000	133	4	140	7
6.	720	137	160	257000	40000	129	4	140	7
7.	C880	129	120	185000	35000	126	4	140	7
8.	VC10	159	109	314000	47000	130	4	140	7
9.	DC9/10	104	90	77700	27000	125	5	135	7
10.	DC9/30	119	115	98000	28000	125	5	135	7
11.	727/10	133	131	170000	34000	122	5	135	7
12.	727/20	153	163	183000	37000	130	5	135	7
13.	737	100	125	116000	26000	109	5	130	7
14.	BACIII	94	89	87500	23000	110	5	130	8
15.	C580	81	56	55000	22000	73	5	120	6
16.	FH227	84	52	43500	21000	98	6	120	8
17.	Twin-Otter	51	20	12500	12000	64	6	100	8
18.	DC3	75	40	45000	20000	80	6	100	7
19.	Piper Nav.	33	9	6500	4500	80	6	100	8
20.	Cessna	26	6	2800	3700	80	6	100	8

Type	Service Vehicles Reqd.	Nominal Landing Dist.	Nominal takeoff Dist.	Service Time (Secs)
747	5	5200	5500	2700
707/30	4	2500	5000	2100
707/10	4	2800	5000	2100
DC8/20	4	3000	5000	2400
DC8/60	4	3000	5000	2100
720	4	2800	5000	2100
C880	4	3000	5000	2100
VC10	4	3000	5000	2100
DC9/10	4	2000	4300	1800
DC9/30	4	2000	4300	1800
727/10	4	1900	4200	2100
727/20	4	2000	4200	2100
737	4	2000	4500	1800
BACIII	4	1500	3500	1800
C580	4	1500	4000	1200
FH227	3	1500	3200	1200
Twin-Otter	2	1000	1200	1200
DC3	2	1500	1500	1200
Piper Nav.	1	1200	1000	1200
Cessna	1	1200	1000	1200

PROGRAM CALIBRATION DATA

A. TOTAL TRAVEL TIMES:

turnoff to gate group and gate group to TKO (in minutes and seconds)

Gate Group	In-Bound	Out-bound
1	2:30	11:20
2	2:50	10:00
3	2:50	9:10
4	3:30	6:20
5&6	5:40	6:50

B. TURNOFF USAGE:

in percentages

PLTYP (S)	Fox	Jul	Tan	N.T.	End33L
1-8	0	10	40	50	0
9-10	40	40	15	5	0
11-12	30	15	50	5	0
13	50	0	50	0	0
14-20	100	0	0	0	0

plus GA landing on other runways
The plane types correspond to the plane characteristics chart

C. DELAYS:

Inbound delays (once on ground) less than one minute.
Outbond delays (in rush hour) between four and six minutes.

D. QUEUES:

Length of 33L takeoff queue between 2 and 4 normally and between 4 and 8 in rush hour (maximum of 10 observed).

Length of queue to cross 33L at North Taxiway up to 3.

Some queue development at intersection of Inner Taxiway and Charlie.

No noticable problems at the intersection of 9 and Charlie.

E. TIME OF LANDING RUNWAY OCCUPANCY:

PLTYPS	Time (sec)
1-8	35-40
9-13	29-32
14-20	24-28

F. TIME OF TAKEOFF RUNWAY OCCUPANCY:

PLTYPS	TIME (sec)
1-8	29-31
9-13	26-28
14-20	16-20

G. RUNWAYS DISTANCES:

Average touchdown point (33L) -- 1900 feet

PLTYPS	Landing Roll (ft)	Takeoff Roll (ft)
1-8	4600	4800
9-13	3250	4200
14-20	1500	3000

7.3.5 Conclusions

Using the raw data as mentioned above certain restrictions and modifications were required for ASTS program operation. Appendix B.4 contains a list of operational Data input considerations.

In conclusion to the data requirements the user's best guarantees of efficient data collection are:

a. Well-planned program
b. Well-organized data sheets
c. Well-trained collectors (with a good knowledge of airport operation and airplane types).
d. A good working relationship with Airport management.

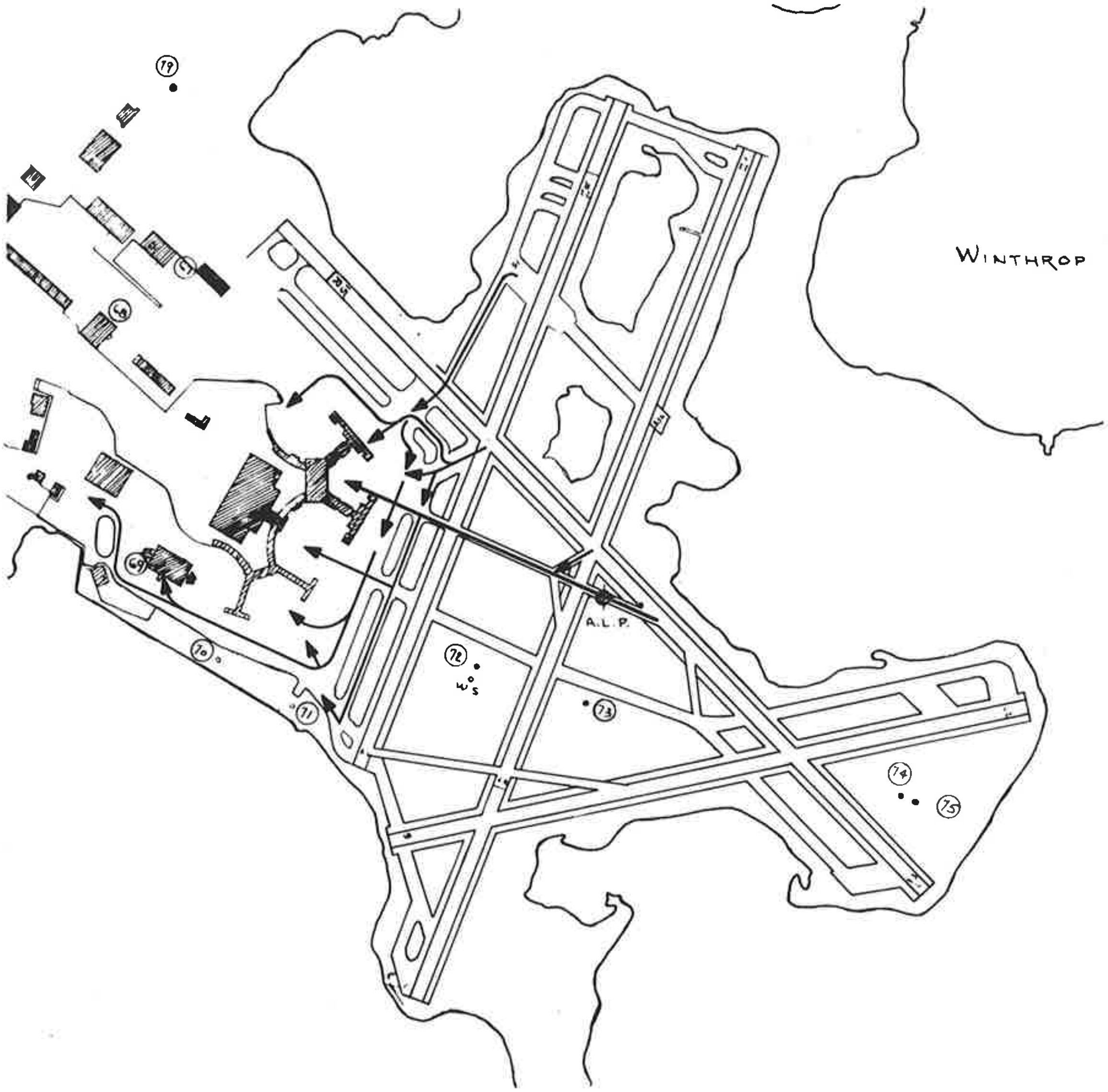


Figure 7-2 Map of Logan Airport Inbound Routes for Runway 33-L Operation

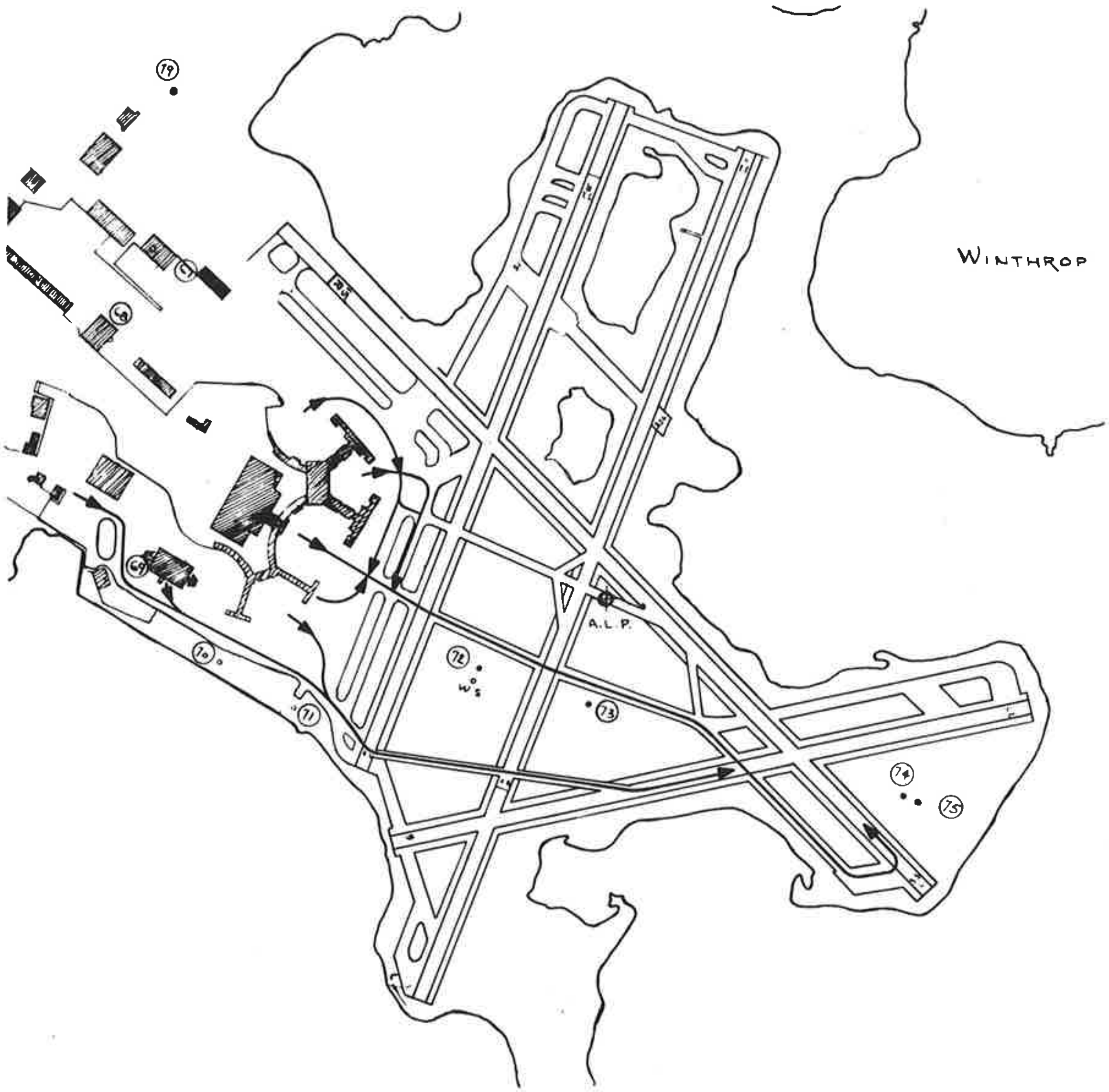


Figure 7-3 Map of Logan Airport Outbound Routes for Runway 33-L Operation

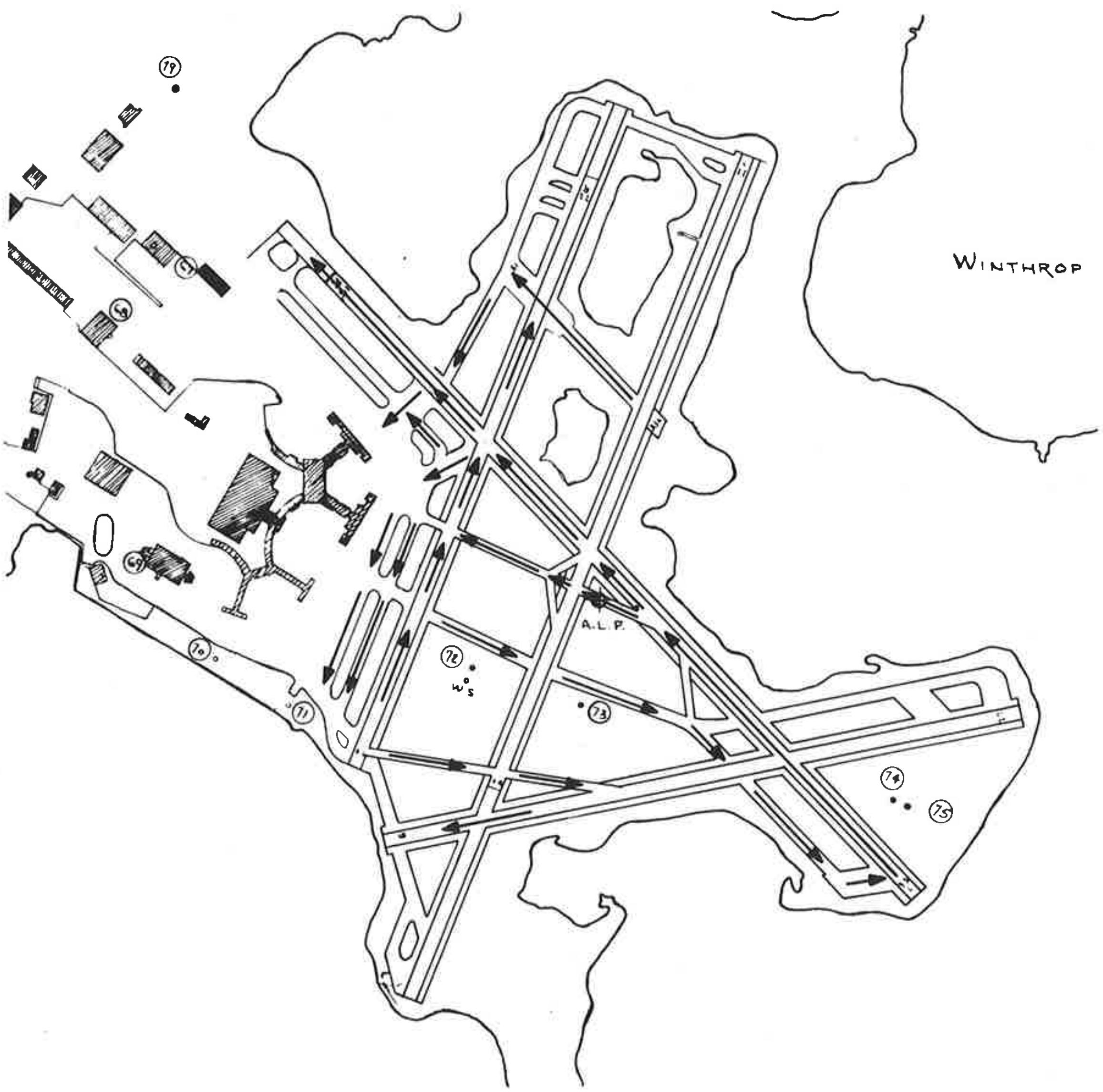


Figure 7-4 Map of Logan Airport Directional Flow for 33-L Operation

BIBLIOGRAPHY

Baran, G., Approach Airspace and Runway Capacity, Boeing Co., 1970.

Maddison, Donald, A Model of the Airfield Surface System, University of California, Berkeley, 1970.

Tippetts-Abbett-McCathy-Stratton, Aircraft Ground Operations Simulation, 1969.

Tippetts-Abbett-McCathy-Stratton, Evaluation of Airfield Performance by Simulation, 1971.

. . . ., Airport Surface Traffic Simulator User's Guide, International Business Machines, Gaithersburg, MD., 1972.

. . . ., Official Airline Guide, A Reuben H. Donnelley Publication.

. . . ., A Study of Heathrow Airport, London England.

Jane's - All the World's Aircraft 1971-1972

Various Airline Timetables.

8.0 CONCLUSIONS

Having reviewed all known airport ground traffic models, two stand out as being the most developed and the most tested. They are the Maddison Model and the GPS Model. Each contain all the major features required in a general airport simulation. The two in-house models although not tested to any great extent have much to offer. The ASTS program is a complete general simulation model with still some debugging and changes to be made. The ROSS program possesses a great man-in-the-loop modelling capability. However, none of the airport models contain sufficient detail to be readily adaptable to studying the complex autonomous controller problem. To model a control situation with discrete sensors and traffic lights would require major additional programming. The existing models do not contain the means nor the sensitivity to describe and monitor such a situation. For this reason, they must all be classified as general in nature suitable for studying gross performance.

Having attempted to model a real airport with the ASTS program an appreciation is gained into the requirements an airport imposes on a computer model. The limitations and features of the ASTS program became quite apparent. Including the numerous logic and coding errors that were discovered, calibration problems arose that prohibited the model from operating completely successfully. Therefore, one could not consider the ASTS program usable for airport modelling unless its use was confined to a small and limited situation.

In order to model Logan Airport data collection was performed on a limited basis. It became quite obvious that the key to successful results is a careful and well thought out data collection plan. Also discovered in modelling an airport was the lack of any means of verifying much of the complex input required for the ASTS program. Therefore, the ASTS plotting program developed by TSC proved to be a valuable means of checking the otherwise buried input data.

Thus, in spite of the limited success of the ASTS program, the ability to perform general airport modelling is an attainable goal and in fact has been reached by some of the other simulations. The ASTS program should be properly classified as a program in a developmental stage with an excellent nucleus for further expansion and improvement.

APPENDIX A

APPENDIX A.1 PATH OF AIRCRAFT THROUGH ASTS

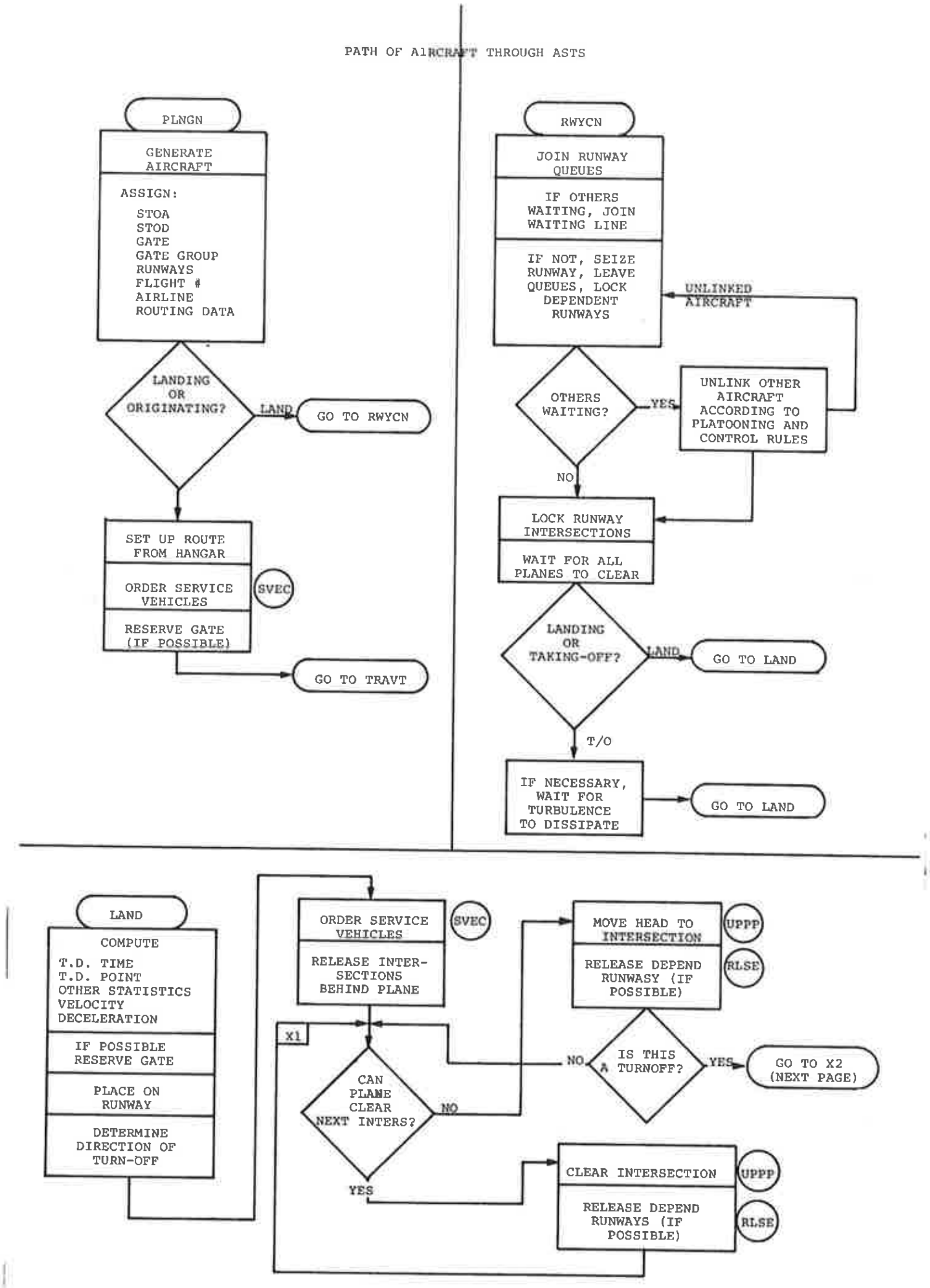


Figure A-1 ASTS Program Flow Chart (Sheet 1 of 4)

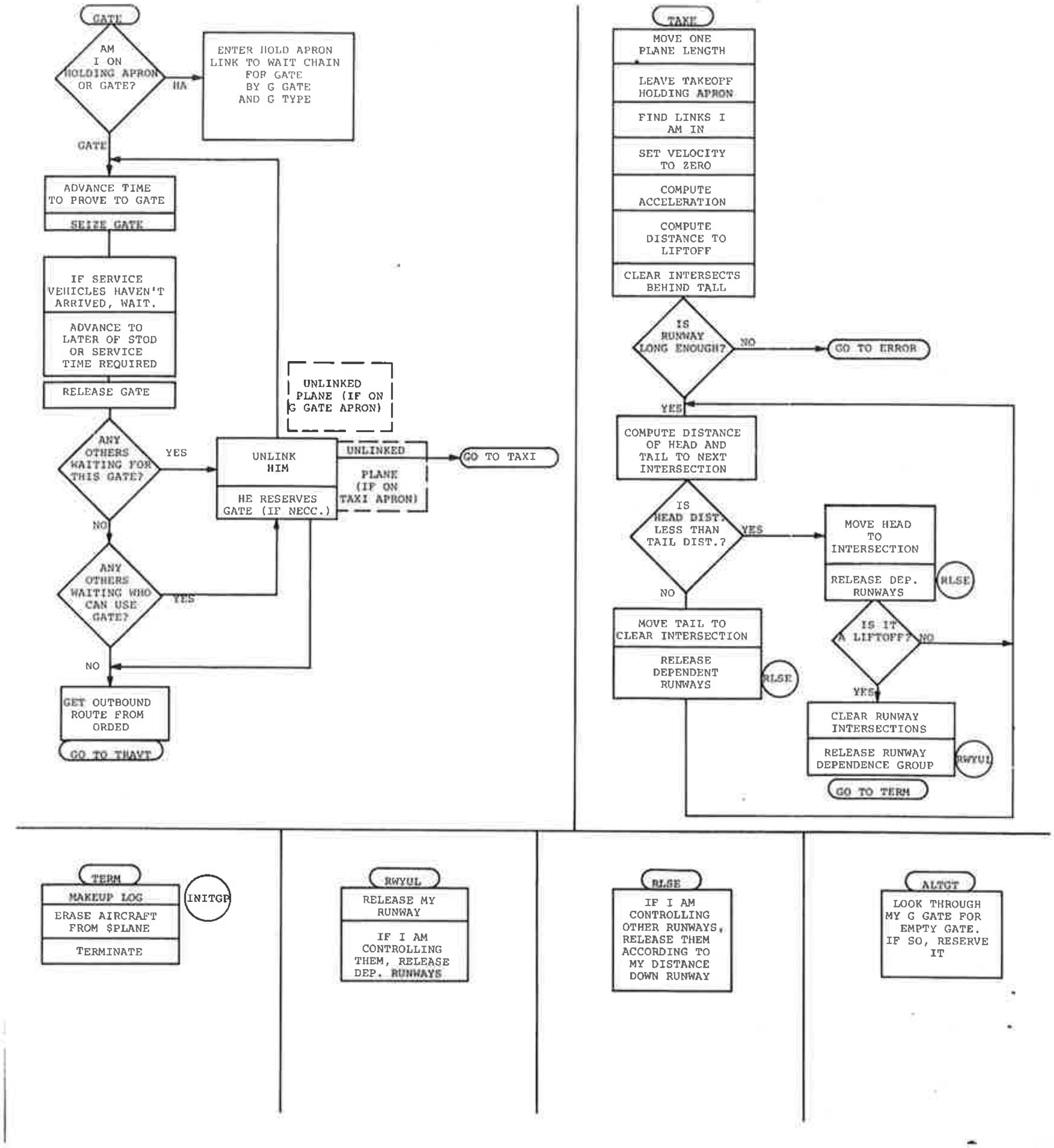


Figure A-1 ASTS Program Flow Chart (Sheet 2 of 4)

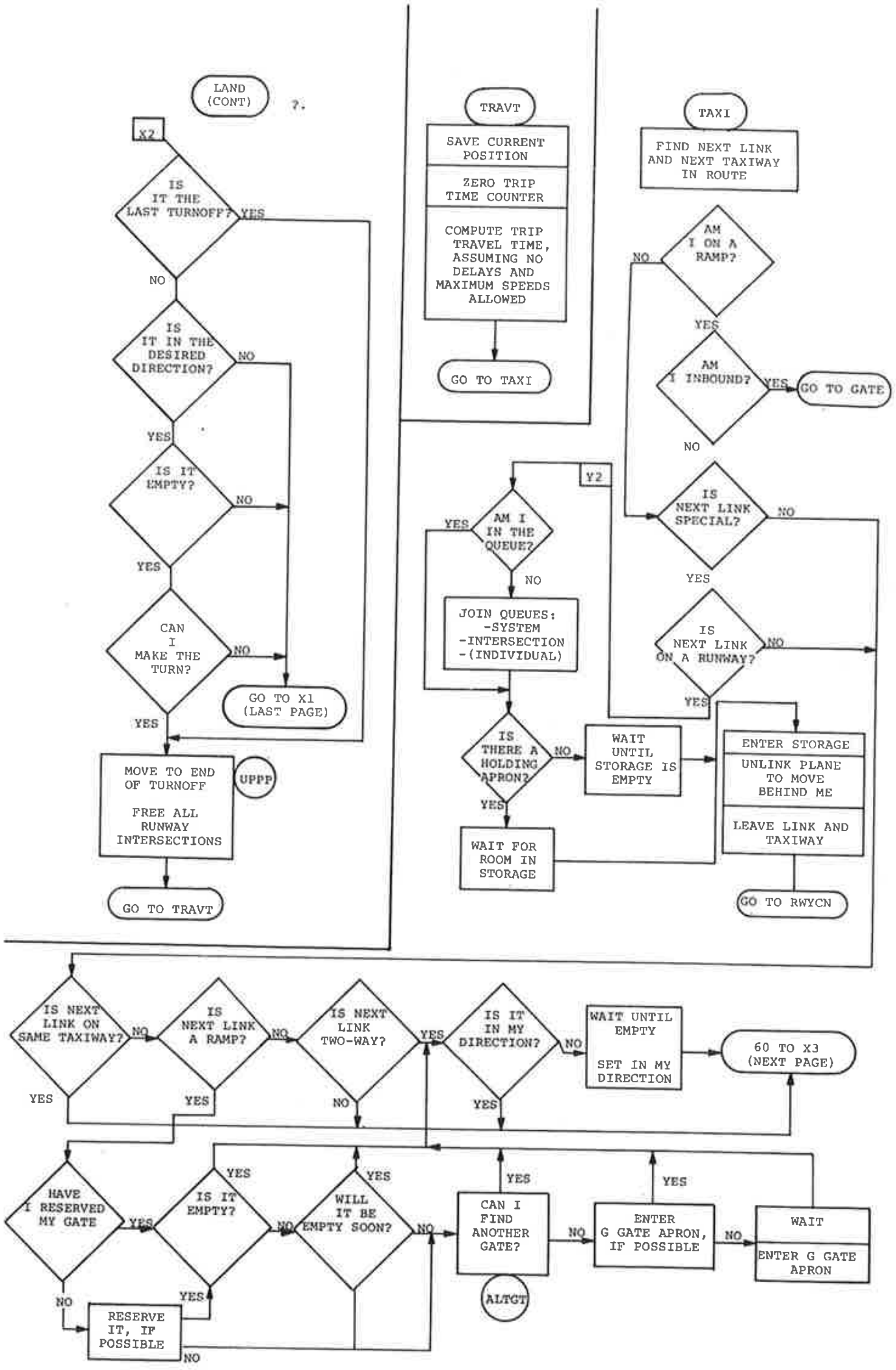


Figure A-1 ASTS Program Flow Chart (Sheet 3 of 4)

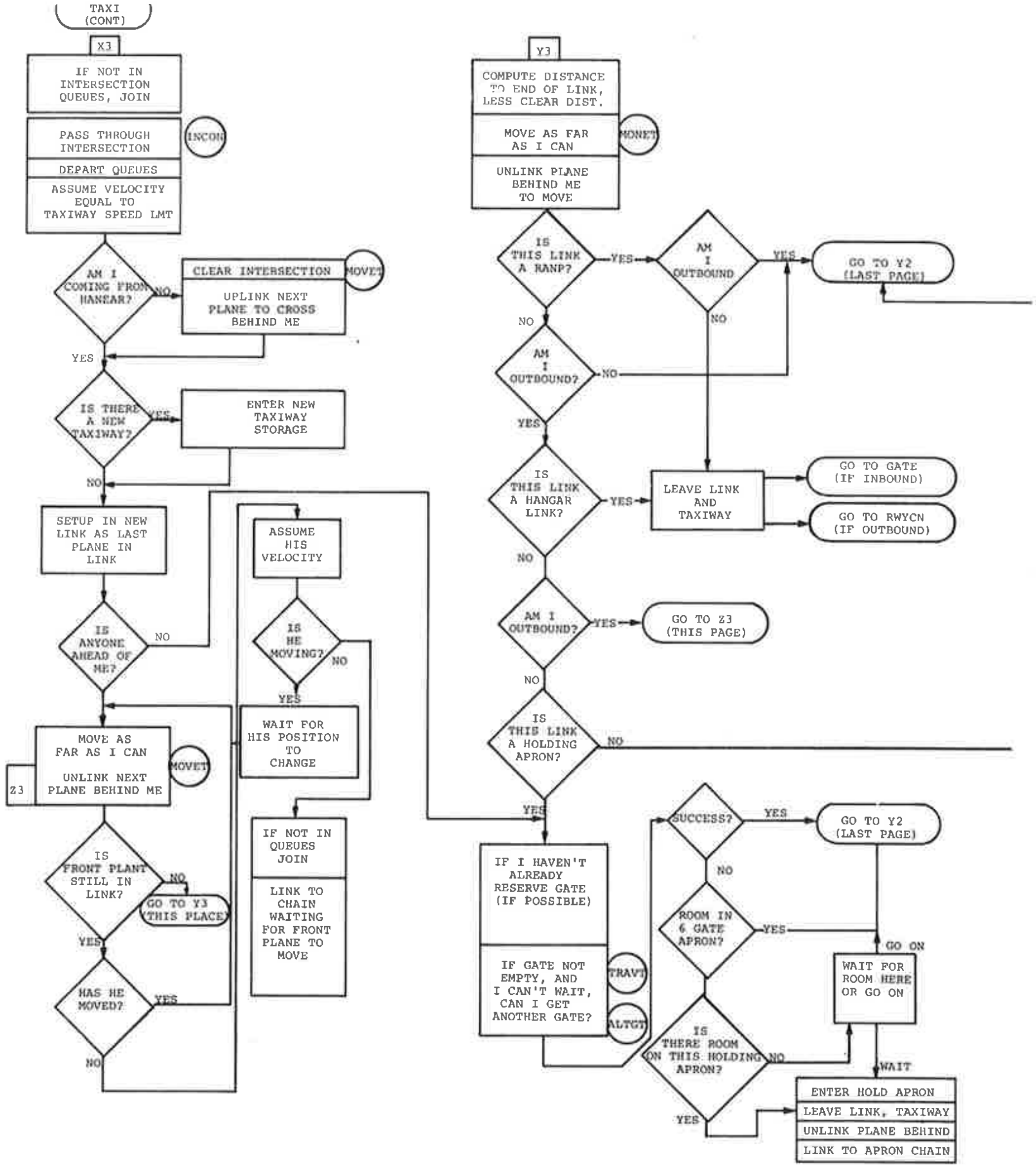


Figure A-1 ASTS Program Flow Chart (Sheet 4 of 4)

APPENDIX A.2 ERRORS FOUND AND CORRECTED

1. Facility numbers incorrect for intersections (interface program corrected by TSC).

2. Planes can decellerate to zero on runways and turnoff links (correction suggested by IBM).

3. References to spacing matrices incorrect (corrected by TSC).

4. Spacing control for planes going through intersections causing failure (failure avoided by IBM suggestion but logic still not acceptable).

5. Intersection matrix defined too small in the interface program. The second input card for each intersection read incorrectly, therefore, no intersection logic but first come, first serve used (correction suggested by TSC).

6. When a plane turns off an active runway it only checks the turnoff matrix to be sure the preceding plane for that turnoff is out of that link. However, the plane does not check the link matrix to see if a plane might be trying to cross the runway and is sitting in the turnoff link.

7. The variable in the model source for an infinite slope did not agree with the number in the interface program (correction provided by IBM).

8. The turnoff function relating velocity to radius of turn was upside down, forcing all planes to turn off at the first turnoff regardless of speed.

9. There was only one average touchdown point for all runways. This caused planes to shoot off the short runway, unable to turn off, and leaving the runway frozen. Changes were made to have an average touchdown point for each runway.

APPENDIX A.3 CALIBRATION PROBLEM AREAS DISCOVERED BUT NOT CORRECTED

1. The length of time planes are on runways appears to be too long. Although realistic deceleration times are used, the time for final approach is only 10 seconds, the exit ramps are as short as possible and the planes are turning off at approximately the correct turnoff. The runway usage is fully saturated causing the long delays. Attempts were made to platoon the runway which improved the situation somewhat. Also, the last link before the takeoff runway was expanded in order that the outbound planes could get into the runway queue sooner. Unless the planes are taken off on time, traffic backs up in the taxiways eventually backing up into the runway.

2. Planes, on the most part, are taking off as scheduled; however, a group appears to be attempting to depart 54 minutes before their scheduled E.T.D. This appears to indicate a problem in the time line schedule generator or in the part of the model which selects departures based upon their future departure times.

3. Under a platooning logic for 33L, aircraft are slow in touchdown to gate travel times but fast in gate to departure travel times. The problem could be in the taxiway velocities input, but this should not be the case.

4. Under a first come, first serve logic planes are getting delayed on landings and therefore are even more delayed on departures. One cause may be the length of time planes are reserving the runway. Remember the model logic does not allow for a controller sneaking a plane in or out as is often the case. Another cause may lie in the traffic congestion in the turnoff areas due to taxi routing logic problems.

APPENDIX A.4 UPDATES TO ASTS USER'S GUIDE*

The control cards for savevalue inputs are:

$WEATHER
$TIMES
$PCTSCHE
$GEOMETR
$GENERAL
$DYGRAPH
$AIRCRAF

The control cards for storage inputs are:

$TAXILEN
$APRNCAP
$SERVICE
$GGRPCAP

The control cards for interface input are:

$GRAPHD
$INTIMES
$CONTROL
$RWYNAME
$BUILDIN
$XYMAX
$HEADER

Data Card - Content

The content of matrix, save value, and storage data cards is described in Section 2.0.

---

*These Updates were prepared by William Barker of TSC.

7.4 GPSS Entities

7.4.1 Matrices - An 'X' beside a row number means this item must be input.

MATRIX	APRON
No.	4
Type	Full Word
No. Cols	35
No. Rows	5

Purpose: To describe aprons

Each column represents an apron.

Row	Use
X1	X coordinate of apron for display, feet
X2	Y coordinate of apron for display, feet
3	Number of planes on the apron
X4	XXYYY: where XX is the column of ORDEI for leaving storage and YYY is the intersection the plane is at upon leaving
X5	GPSS storage number corresponding to this apron

Notes:

1. This first ten columns of APRON are reserved as takeoff holding aprons for runways. Column N corresponds to runway N.

2. The X, Y coordinates are for the center of the box which will contain the apron contenst on the display.

MATRIX	GATES
No.	8
Type	HW
No. Cols	100
No. Rows	4

Purpose: To describe gates

Each column is a specific gate.

Row	Use
X1	Gate group
X2	Type
3	Current plane
4	Reserve plane

Notes:

The GTYPE and GGATE matrices must be filled in first.

MATRIX	GGATE
No.	5
Type	FW
No. Cols	20
No. Rows	9

Purpose: Describe Gate Group

Each column is a gate group.

Row	Use
X1	X coordinate for display (feet)
X2	Y coordinate for display (feet)
X3	Number of gates (must be sequential)
4	Number gates currently in use
X5	Apron associated with this group
X6	Ramp number (negative if gate group at x2 end)
X7	Time to move from apron to gate (sec)
X8	Time to move from ramp to gate (sec)
X9	First gate in group

Notes:

Every gate group must have an apron.

MATRIX	GPR
No.	9
Type	HW
No. Cols	20
No. Rows	10

Purpose: Show gate/runway preference for landings

Each column is a gate group.

Each row is a runway in the ascending preference, i.e., least prefered to most prefered.
Turn left indicated by minus, turn right by plus
Runway B is denoted by runway +100

All data in this matrix must be input.

MATRIX	IFRSM
No.	10
Type	HW
No. Cols	10
No. Rows	10

Purpose: Show IFR moving spacing

Each column is the aircraft class (1-10) of the second plane.

Each row is the aircraft class (1-10) of the lead plane.
Each element is the minimum spacing between the two aircraft classes in feet.
Spacing is the distance from the tail of the lead plane to the nose of the following plane.
All data in this matrix must be input.

108 Rev. 1, 5/22/72, WGB

MATRIX	ORDEI
No.	12
Type	HW
No. Cols	50
No. Rows	20

Purpose: Origin/Destination inbound route selector

Each column corresponds to a hanger, a taxiway holding apron or a landing runway turnoff, all of which are possible origins for inbound routes. Each row corresponds to a gate group, row I to gate group I. Gate groups are the destinations of inbounds routes.

The entries in ORDEI gives the column in the ROUTE matrix for the route connecting the appropriate origin/destination pair.

All data in this matrix must be input.

Notes:

1. TRNOF and GGATE matrices must be completed first.

MATRIX	LINK
No.	11
Type	HW
No. Cols	100
No. Rows	10

Purpose: To describe the links

Each column is a link.

Row	Use
X1	Intersection value of lower x value
X2	Intersection value of higher x value
X3	Type of link: 0 Standard Taxiway 1 Standard Runway 3 Ramp ± 4 xx Link with taxiway holding apron xx = column of apron matrix + go on if apron full - wait if apron full 6 xxx link connecting to a hanger xxx is intersection hanger is at
X4	Length of link, feet
X5	Link Direction 0: x1 $\rightarrow$ X2, 1:X2 $\rightarrow$ X1, ±2 two-directional; +: $x_1 \rightarrow X_2$, -:X2 $\rightarrow$ X1
6	Speed of last plane in link
7	Number of planes currently in link
8	Number of planes in the queue
9	Length of queues, feet
10	Column number in PLANE matrix of last plane in the link

NOTES:

1. Links must be sequentially ordered from the lower X_1 end within each runway and taxiway.

MATRIX	ROUTE
No.	15
Type	HW
No. Cols	100
No. Rows	5

If an element is negative, it points to another column in the matrix to continue the route.

Row	Use
1	First link of route
2	First link to be used of next taxiway
3	First link to be used of next taxiway
4	First link to be used of next taxiway
5	First link to be used of next taxiway

The last link of an outbound vehicle would be the first link it will use on the runway or the link connecting the hanger.

The last link of an inbound route is the ramp.

For inbound routes from landing runway turnoffs, the first link is the first link to be traveled <u>after</u> the turnoff, i.e., the link which is the turnoff is not the first link of the route.

For inbound routes from hangers, the first link is the link connecting to the hanger.

For outbound routes from gate groups, the first link is the ramp.

All data must be input.

MATRIX	TAXIW
No.	3
Type	FW
No. Cols	40
No. Rows	9

Purpose: Define taxiways

Each column is a taxiway.

Row	Use
X1	x_1 coordinate (ft)
X2	y1 coordinate (ft)
X3	x_2 coordinate (ft)
X4	y_2 coordinate (ft)
X5	width (ft) (for display purposes)
X6	first link from $x_1 y_1$
X7	number of links
X8	speed limit (kts)
9	2 way counter

Notes:

1. Each turnoff and ramp are separate taxiways which contain a single link.

2. Runways which are used as taxiways must be entered as both runways and taxiways.

3. Taxiways must be straight lines.

4. Number of taxiways must be entered in save value GTNUM.

5. Length of each taxiway is a storage input through $TAXILEN control card.

126 Rev. 1, 4/25/72, WGB

MATRIX	TLSCH
No.	3
Type	HW
No. Cols	120
No. Rows	6

Purpose: Timeline Schedule

Each column represents an aircraft to be generated.

Row	Use
1	Time of arrival (HHMM) at outer marker or hangar
2	Time of departure (HHMM) at gate
3	XXYY, XX Column of ORDEO for turnaround, terminating planes for route away from gate group
4	XXYY XX Column of ORDEI for originating plane for route from hanger YY Column in PLTYP matrix
5	Gate number
6	100* takeoff runway + landing runway 100: originates no landing runway: terminates

All data must be input.

MATRIX	TRNOF
No.	16
Type	HW
No. Cols	50

Purpose: Contains turnoff data for runways

Each column is a turnoff.

Row	Use
X1	Link number of runway from which turnoff is entered
X2	Turning radius + right - left
X3	Col in ORDEI
X4	Link number of turnoff
X5	=0 available, =1 not available
6	
7	=1 occupied, =0 not occupied

Notes:

1. Each turnoff is a separate taxiway with a single link.

2. Turnoffs must be in order in which they are encountered by an arriving aircraft.

MATRIX	VFRSS
No.	21
Type	HW
No. Cols	10
No. Rows	10

Purpose: VFR stopped spacing

Similar to IFRSM

Note: This matrix is currently not used in the model and need not be input. The minimum spacings between stopped aircraft are those values in the matrix IFRSS regardless of the setting of the IFR/VFR flag.

Group	Name	No.	Input	Use
TIME	TIPUP	30	X	Individual aircraft update time (sec) - default is 5 sec.
	TSPUP	31	X	Dynamic display simulated update time (sec) default is 6 sec.
	TSNAP	32	X	Snap interval (min) - default is 15 min.
	TSLT	33	X	Initial simulated local time (HHMM)
	TCSLT	34		Current simulated local time (HHMM)
	TMAX	35	X	Maximum simulation time (min) - default is 60 min.
	TBTU	36	X	Multiplication factor for basic time unit - default is 10
	TOLT	37	X	Gate time tolerance (sec) - default is 15 sec.
	TSAM	38		Sample time for graph (sec)
DYGPH	TGGUP	75	X	Growing graph factor of TSPUP - default is 1
	DYAH	76	X	100 percent value of A (sec) - default is 1
	DYOH	77	X	100 percent value of O - default is 1
	DYTH	78	X	100 percent value of T - default is 1
	DYGH	79	X	100 percent value of G (sec) - default is 1
	DYAA	80		Current longest delayed aircraft in air

133, Rev. 1, 4/25/72, WGB

Group	Name	No.	Input	Use
	DYGA	82		Current longest delayed aircraft on ground
	DYGL	83		Current longest delayed aircraft location
	DYGI	84		Current longest delayed aircraft entity
SCHED*	NTLCL	51	X	Number of columns in time line schedule
	TLCOL	52	X	Current column in time line schedule
	PCOR	53	X	% plane for % schedule originating this airport
	PCTR	54	X	% plane for % schedule terminating this airport
	PCMT	55	X	Mean time between generation for % schedule in seconds

* used only when generating a schedule from a mix

133, Rev. 1, 4/25/72, WGB

Group	Name	No.	Input	Use
AIRC	GARLN	57	X	Number of airlines
	DELAY	58	X	Reaction delay time crossing an intersection (sec) - default is 2 sec.
	INCTL	59	X	Intersection clear distance no opposing traffic (ft) - default is 100 ft.
	PLANC	60		Pointer to next free column of plane matrix
WEATH	WINDV*	63		Wind velocity (knots)
	WINDD*	64		Wind direction clockwise degrees from North
	WSTA	65	X	Acceleration/braking degradation as a function of condition
	WTEMP*	66		Temperature F°
	WBPRS*	67		Barometric pressure in tenths of inches
	SIORV	68	X	IFR = 0 VFR = 1
MISC	COPY1	70		USEDIN reserving a gate
	COPY2	71		USEDIN reserving a gate
	TERMC	72		Termination count

Fullword savevalues 1-10 K01-WRK10 are work locations

* not currently used in model calculations.

7.4.3 Facilities

1-10	Runway
11-110	Intersection
111-210	Gate
211-260	Turnoff

7.4.4 Storages

120 storages are reserved in the ASTS model. Storage capacities must be input for those storages which are used. Storage capacities for each of the categories described below are entered as if they were entries to a half work matrix, that is, a field length of 6 is used and all entries must be right justified.

7.4.4.1 Taxiways

Storages 1-40 are reserved for taxiways. The length in feet of each taxiway must be entered as the capacity of the GPSS storage associated with a taxiway. In addition, a value of 999999 must be entered as the capacity of a dummy taxiway which is the next taxiway after the last actual taxiway. The number of actual taxiways (not including the last dummy taxiway) must be entered as save value GTNUM. The control card is $TAXILEN. An example follows.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	2
$	T	A	X	I	L	E	N													
			1	0	0				2	0	0	9	9	9	9	9	9			

In the above example there are two actual taxiways. The length of taxiway 1 is 100 ft., and the length of taxiway 2 is 200 ft. (The value of save value GTNUM to be entered by the user would be 2.) Note that following the entry for taxiway 2, the last taxiway, there is an entry of 999999 for the dummy taxiway.

7.4.4.2 Gate Groups

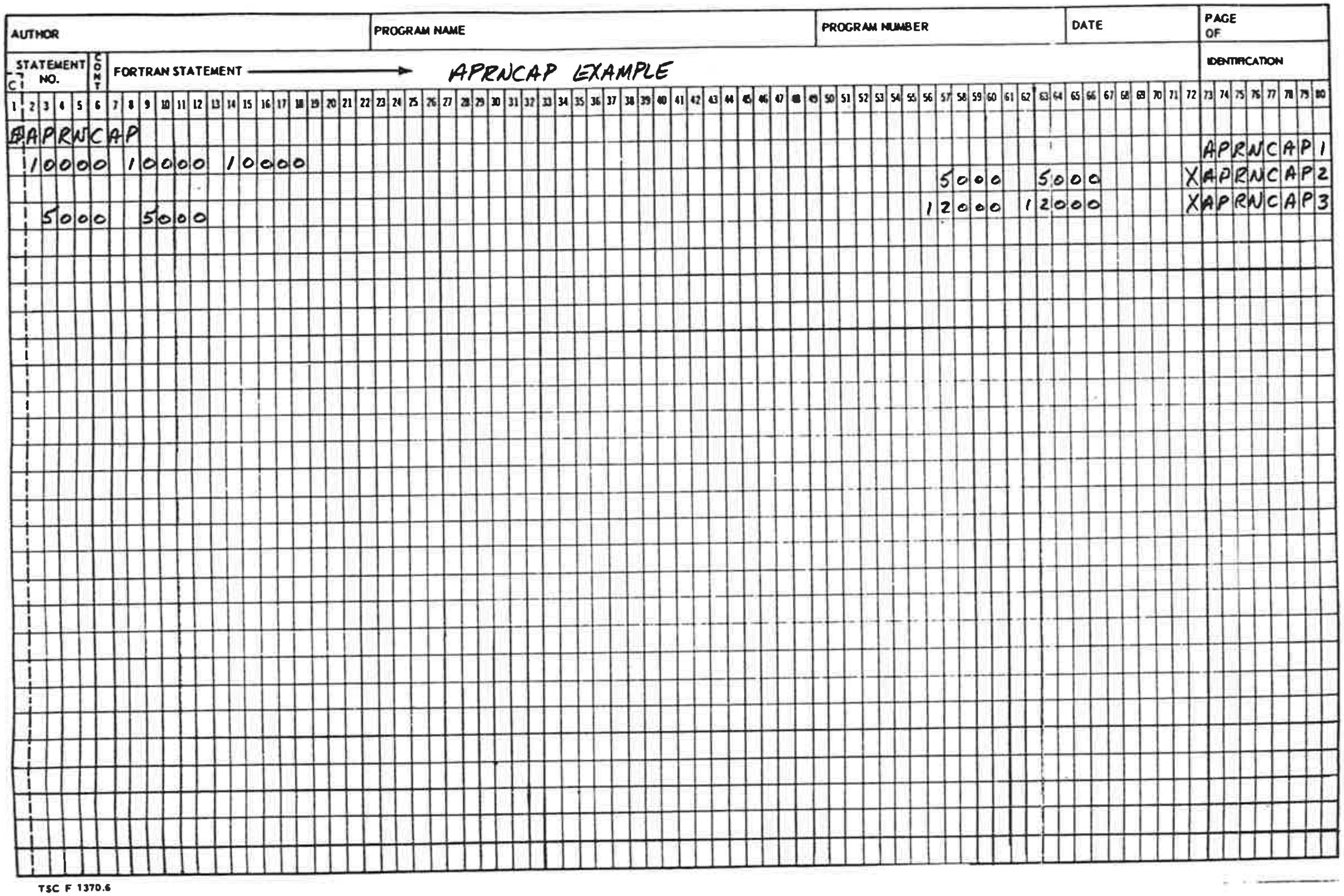
There are 20 storages (storages 41-60) reserved for the specification of gate group capacities. The capacity of a gate group is the number of gates in the gate group. The control card is $GGRPCAP. For example:

```
$GGRPCAP
     6    7
```

In the above example, gate group 1 has 6 gates, and gate group 2 has 7 gates.

7.4.4.3 Aprons

There are 40 storages reserved for the three types of aprons in the ASTS. Storages 61-80 are the gate group holding aprons, storages 81-90 are the taxiway holding aprons, and storages 91-100 are the runway takeoff holding aprons. All capacities are expressed in square feet. The storage capacity of all 40 storages must be input sequentially starting with storage number 61 with blanks inserted as the capacities of those storages which are not used. The control card is $APRNCAP. See Figure A-2 for an example.



AUTHOR

PROGRAM NAME

PROGRAM NUMBER

DATE

PAGE
OF

STATEMENT NO. | C | CONT | FORTRAN STATEMENT → APRNCAP EXAMPLE | IDENTIFICATION

```
0APRNCAP
 10000 10000 10000                                                      APRNCAP1
                                                        5000  5000     XAPRNCAP2
  5000  5000                                           12000 12000     XAPRNCAP3
```

Figure A2. Sample Control Card

In the example, there are three gate group holding aprons each with a capacity of 10,000 square feet. There are four taxiway holding aprons each with a capacity of 5,000 square feet entered as a the capacities of storages 81-84. Finally there are two takeoff holding aprons each with a capacity of 12,000 square feet.

7.4.4.4 Service Vehicle Pools

Each airline has a service vehicle pool assigned to it. The number of vehicles in each of these pools is input as a storage capacity for each pool. Service vehicle pools are storages 101-120. The control card is $SERVICE. Note the following example:

```
          $SERVICE
              10    20
```

In this example, airline number 1 has 10 service vehicles in its pool. Airline number 2 has 20 service vehicles in its pool of vehicles.

7.4.5 Queues

1-10	Each Takeoff Runway
11-20	Each Landing Runway
21-30	Each Runway Dependence Group
31	All Takeoffs
32	All Landings
33	All Intersections
34	All Gate Groups
41-60	Each Gate Group
61-70	Selected Intersections

SCHGN may be run using the standard GPSS execute JCL with a steplib dsname of ASTS.LOAD. The following cards must be included after the DINPUT1 DD* card. The INITIAL statements in the set-up below are an example. The user must supply his own INITIAL cards for his own case.

```
           SIMULATE       1
TLSCH      EQU            3, MH
TLSCH      MATRIX         MH,6,120
SCHPC      EQU            6,MH
SCHPC      MATRIX         MH,11,21
SCHPT      EQU            22,MH
SCHPT      MATRIX         MH,20,20
GGATE      EQU            5,MX
GGATE      MATRIX         MX,9,20
GATES      EQU            8,MH
GATES      MATRIX         MH,7,100
GTYPE      EQU            18,MH
GTYPE      MATRIX         MH,4,10
           INITIAL        MH6(1,1),1015/MH6(2,2),1320/MH6(3,1),10
           INITIAL        MH6(4-6,1),3
           INITIAL        MH6(1,2),1/MH6(2,2),1/MH6(3,2),20/MH6(4,2),20
           INITIAL        MH6(5,2),30/MH6(6,2),10/MH6(7,2),2/MH6(8,2),101
           INITIAL        MH6(9,2),1/MH6(10,2),2/MH6(11,2),3
           INITIAL        MH6(1,3),3/MH6(2,3)2/MH6(3,3),35/MH6(4,3),20
           INITIAL        MH6(5,3),30/MH6(6,3),15/MH6(7,3),2/MH6(8,3),201
```

```
INITIAL       MH6(9,3),4/MH6(10,3)5/MH6(11,3),6
INITIAL       MH6(1,4),7/MH6(2,4),3/MH6(3,4),45/MH6(4,4),20
INITIAL       MH6(5,4),30/MH6(6,4),12/MH6(7,4),2/MH6(8,4),101
INITIAL       MH6(9,4),7/MH6(10,4),8/MH6(11,4),9
INITIAL       MH22(1,1),25/MH22(2,1),30/MH22(3,1),45
INITIAL       MH22(1,2),40/MH22(3,2),60
INITIAL       MH22(1,3),30/MH22(2,3),15/MH22(3,3),55
INITIAL       MH8(1,1-4),1/MH8(1,5-8),2/MH8(1,9-12),3
```

APPENDIX A.5 ASTS AIRCRAFT LOG

```
1                                        A S T S   F L I G H T   L O G

0RUN NO.-TS0219LT     RUN NAME-LOGAN(33L/33R/27)NEW     SIMULATED LOCAL TIME11/22/71   0 0     DATE06/22/72

 USER NAME B.P.BUSHUEFF
0 FLIGHTS ARE PRINTED IN THE LOG IN THE SEQUENCE IN WHICH THEY LEAVE THE SYSTEM EITHER AT LIFTOFF OR WHEN THEY ENTER A HANGER

 UNLESS OTHERWISE NOTED ALL DELTA TIMES ARE IN MINUTES. THE TIME OF DAY IS BASED ON A 24 HOUR CLOCK

 THE FOLLOWING ABREVIATIONS ARE USED.
          A/O/T A - THIS IS A TURNAROUND FLIGHT   0- ORIGINATES AT THIS AIRPORT   T - TERMINATES AT THIS AIRPORT
          TOA     - TIME OF ARRIVAL
          IN      - INBOUND FROM A RUNWAY OR A HANGER TO A GATE
          OUT     - OUTBOUND FROM A GATE TO A RUNWAY OR HANGER
0 THIS RUN WAS ONLINE
0                         *                        *                        *                      . *

 FLIGHT A/O TYPE  AIR-    SCHED ACTUAL IN-RUNWAY  IN-TAXI  GATE                OUT-TAXI OUT-RUNWAY  LIFT   TOTAL
    NO. /T        LINE     TCA    TCA  NO. TIME     DELAY   NO.     LEFT DELAY    DELAY NO. DELAY ON  OFF  DELAY
0   24  0         NFAST    348    348         0         0    35      356    0         0 33R     4 10  406      4
0   14  0  *      PAN AM   340    340         0         0    12      356    0         0 33R     2 12  406      2
0    2  0      0  FASTRN   330    330         0         0    20      400    0         0 33R     0  6  406      0
0    7  0  3   0  EASTRN   334    334         0         0    21      400    0         1 33R     0  6  406      1
0    1  A    K      G      330    331        93         5    67      404    0         0         0  6  409      5
0    8  A    K      G      335    336         6         4    68      408    0         0         0  6  413      4
0    9  0  DC-9   NEAST    335    335         0         1    33      406    0         0 33R     6 12  417      7
0   29  0  727    UNITED   350    350         0         0    45      406    0         0 33R     5 12  418      5
0   32  A          Y  J    353    358  33R   72         0    55      406    0         0 33R     5 12  418      9
0    4  A   =              332    333  33R  129         0    61      411    0         0 33R     0 12  418      0
0   15  A  3   0    G      340    341         4         1    69      422    0         0         0  6  427      1
0   16  0  727    AMERCN   340    340         0         2     6      413    0         0 33R     6 12  427      8
0   13  0      0           339    339         0         4    53      415    0         7 33R     6  6  434     17
0    5  0         BRANFF   333    333         0         1    49      416    0         7 33R     6 12  435     14
0    6  A                  334    337  33R   82         0    65      414    0         7 33R     7 12  435     15
0   26  0         UNITED   349    349         0         0    44      416    0         7 33R     7 12  435     14
0   10  0  -&     NWEST    336    336         0         3    25      419    0         4 33R     7 12  436     14
0   21  A    K      G      345    346         9         2    70      432    0         0         0  6  437      2
0   27  A    K      G      350    351         6         2    71      437    0         0         0  6  442      2
0   12  0         NEAST    337    337         0         4    32      422    0         2 33R    16 12  445     22
0   23  0       K BRANFF   346    346         0         0    48      422    0         1 33R    16 10  445     17
0   18  A                  343    344  33R   92         0    57      421    0         1 33R    16 12  445     17
0    3  0  -&     DELTA    330    330         0         0    36      426    0         0 33R    14 12  446     14
0   17  0  727    AMERCN   342    342         0         1     7      425    0         0 33R    13 12  446     14
0   25  A                  349    352  33R   96         0    62      431    0         0 33R    17 12  455     19
0   11  0         PAN AM   336    336         0         1    16      431    0         0 33R    17 12  455     18
0   19  0         PAN AM   343    343         0         1    14      431    0         1 33R    16 12  455     18
0   22  A  -&              345    350  33R   80         0    58      433    0         0 33R    16 12  456     20
0   28  0  DC-9   NFAST    350    350         0         0    34      435    0         0 33R    16 12  456     16
0   41  A    K      G      414    415        11         1    73      457    0         1         0  6  503      2
0   31  A         UNITED   351    355  33R   97         0    33      436    0         0 33R    24 12  505     27
0   40  A  -&     NWEST    410    424  33R   84         0    24      436    0         0 33R    24 12  506     36
0   44  A  -&     UNITED   418    430  33R   77         0    38      436    0         1 33R    24 12  506     36
0   20  A   *              344    347  33R  109         0    59      441    0         0 33R    19 12  506     20
0   37  A         NWEST    405    412  33R  101         0    23      448    0         1 33R    12 12  507     19
0   45  A    K      G      418    419         9         2    74      505    0         0         0  6  510      2
0   39  A      0    G      410    420  33R  119         0    72      448    0         0 33R    20  6  516     28
0   30  0      0           350    350         0         0    54      450    0         0 33R    20  6  516     20
0   33  A         NWEST    355    401  33R   78         0    28      451    0         0 33R    20 12  516     25
0   35  A  727    AMERCN   400    408  33R   37         0     4      450    0         0 33R    19 12  517     25
0   36  A                  400    410  33R   60         0    60      451    0         0 33R    19 12  517     27
0   47  A  3   0    G      420    421         1         3    75      514    0         0         0  6  519      3
0   34  A  727    UNITED   359    404  33R  104         0    42      501    0         0 33R    20 12  526     23
0   38  A         NWEST    405    415  33R   94         0    29      501    0         0 33R    20 12  526     29
```

Figure A-3 Sample of ASTS Flight Log Printout

APPENDIX A.6 PLOTTING OF INPUT DATA

1. Introduction

The first task to running the ASTS program is to prepare the lengthy and elaborate input deck. Due to the complexity of it and the lack of any way to verify the data, a program was developed at TSC to read in parts of the data that will not be checked by ASTS and prepare an elaborate airport map on a Calcomp plotter. This map contains pertinent numbering information such as links, taxiways, intersections, and runways placed according to the input deck on the airport layout. As well as being a useful tool to verify input, the map provides an excellent reference map for debugging purposes.

Fig. A-4 contains the map generated from the ASTS program input; Table A-1 contains instructions on use of the plotting program; and Fig. A-5 contains a sample input deck.

2. Plotting Program

Using the ASTS data, the plotting program produces a detailed airport map useful in verifying the data or debugging if necessary. The program draws an X-Y axis, draws and labels runways, taxiways, and links, draws and numbers all intersections and queues, and includes a legend specifying title, author, data and scale. This enables the user to make a graphic evaluation without the need for the IBM 2250 display. The program is written for use on the PDP-10 with the Calcomp plotter and may require modification for use on another machine.

The main program reads in data, stores it in matrices and calls up certain subroutines which perform the actual plotting. The user must include the following subroutines for execution of the program.

Subroutine	Function
ASTSMP.C4	(Main Program)
PL.F4	(Plotting Runways, Taxiways, etc.)
L1.F4	(Labelling Runways)
L2.F4	(Labelling Taxiways)
L3.F4	(Labelling Links)

Subroutine	Function
BD.F4	(Drawing Building Lines)
AXSS.F4	(Drawing Axes)
TITL.F4	(Constructing a Legend)
INTS.F4	(Drawing Intersections)

It is also necessary to include the following data files, with control cards (e.g., $GEOMETR) preceding each file.

File	Data Included
$GEOMETR	Gives number of taxiways, intersections, links, and runways to be plotted
$EXTRA	Gives date, number of building, DPL (desired plot length), position of legend (xtitl, ytitl), and scale factor, and position of title (XHD, YHD)
$INTS	Gives x, y position for each intersection and a queue number if the intersection has one
$LINK	Gives intersection numbers on either end of a link, coordinates are later obtained from the intersection matrix
$RUNWG	Gives the midpoints of the end of each runway, and each runway width
$TAXIW	Gives the midpoints of the ends of each taxiway, and each taxiway width
$XY max	Gives maximum x and y values
$RWYNAME	Gives the name of each runway and its x-y position
$HEADER	Gives the title and author to be included in legend
$BUILDING	Gives end points of building lines
$DUMMY	A single card signifying the end of the data

To store the data, a series of IF statements are set up containing words corresponding to the control cards in the data files. When the words are matched control is transferred to a particular section of the main program where parameters of runways, taxiways, links, intersections, and building are read in through DO LOOPS. For this reason, the $GEOMETR card must come first in the data file, followed by the $EXTRA card, since these cards dictate the number of times a loop must be performed. Also, since the $DUMMY card indicates the end of the data, it must be placed last. When this card is reached, the data arrays have all been initialized, and are ready to be referenced by the various plotting subroutines.

The plotting subroutines also perform all necessary scaling. DPL is the desired plot length (i.e., the length of the final product along the y axis) while SF is a scale factor indicating the ratio of the number of inches given to the Calcomp routines to plot, to every inch actually plotted. SF will vary according to the plotting machine. YM gives the number of real inches/ plot inch and hence 12/YM gives a ratio of plot inches/real feet. Then all values are scaled VALUE*12/YM to yield plot inches. Also, since the character size and character movement (to the left or right, up or down) were determined arbitrarily in the original run with plot size (DPL*SF) set at 58, proportions are set up in the CS's and CM's to adjust to any plot size, keeping the same ratios of widths, lengths, etc.

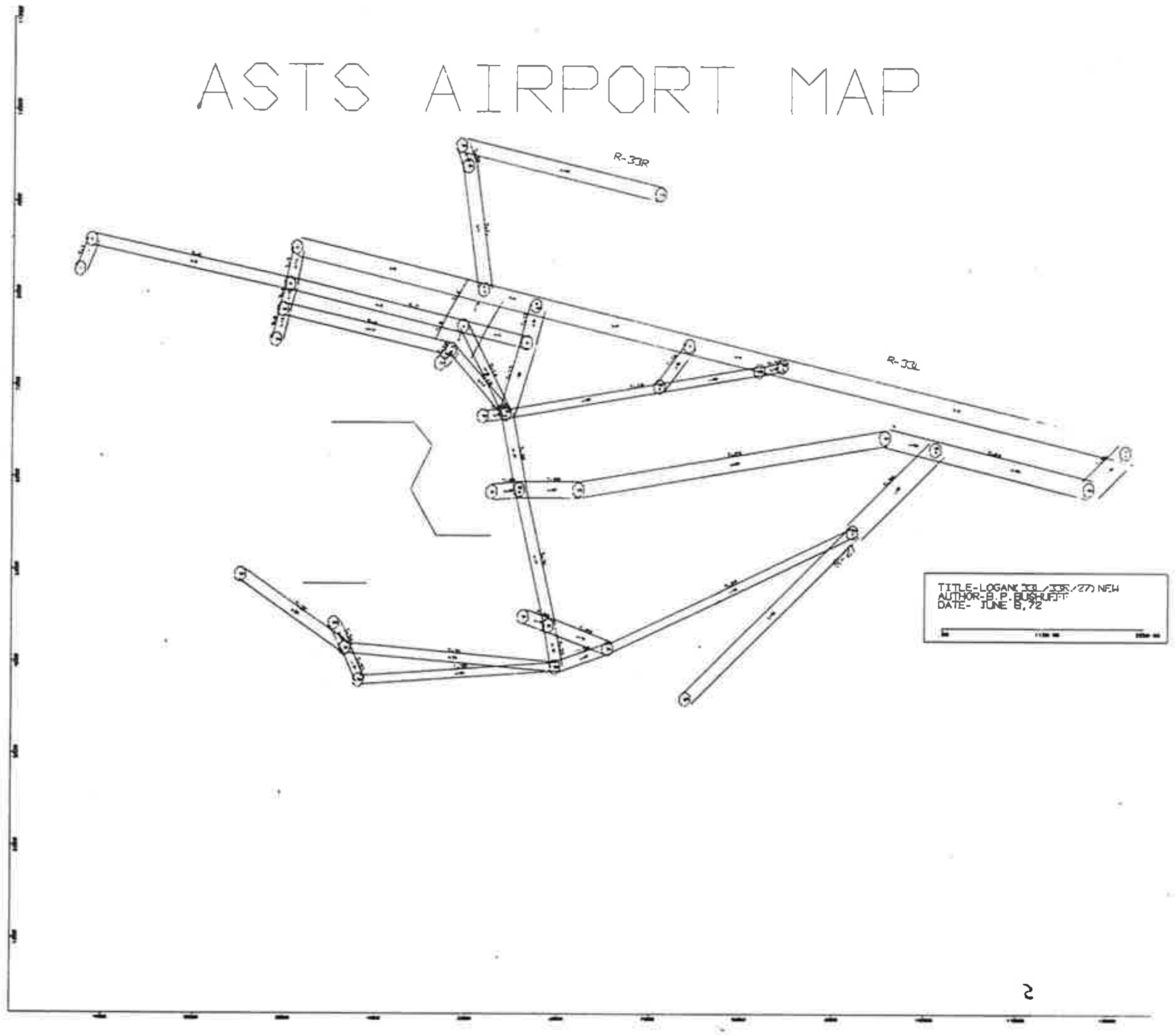


Figure A-4 ASTS Airport Map (Calcomp Plot)

TABLE A-1

Instructions on Use of Plotting Program

Two control cards must be prepared:

$EXTRA

and

$DUMMY

In addition, a data card which will follow the $EXTRA card must be prepared as follows:

Data		Card Cols.
Date		1-10
No. of Buildings		11-20
Desired Plot Length		21-30
Legend Position	x	31-40
	y	41-50
Scale Factor		51-60
Title Position	x	61-65
	y	66-70

The $EXTRA and following data card and the $GEOM and accompanying data cards should be placed at the beginning of the input deck. The $DUMMY card must be placed at the end of the input deck. (See Fig. A-5 for a sample input deck.) The input deck then must be converted from EBCDIC cards to BCD tapes to be translated to ASCHII on the PDP-10. The file created should be called FOR20.DAT.

To load and execute the program, the routines listed on Pg. A-35 must be included.

```
$GEOMETR
     2     6   100    38    38    48     3     2     2     6  1400      GEOMETR1
   700                                                                 XGEOMETR2
$EXTRA
 JUNE 8,72         6        10     10000      5000         2 150010000
$CONTROL
OFFLN
$HEADER
LOGAN(33L/33R/27)NEW
B.P.BUSHUEFF
$BUILDING
      3500      6600      4400      6600
      4400      6600      4600      6350
      4375      5875      4600      6350
      4375      5875      4650      5375
      4650      5375      5250      5375
      3200      4850      3900      4850
$XYMAX
     12500     13000
$TIMES
    10   600     1  0330           200    10     5
$DYGRAPH
     1   100   500  1000    50
$AIRCRAF
    13     1    50
$APRNCAP
208000104000156000156000208000500000     0     0     0     0     0
     0     0     0     0     0     0     0     0     0     0     0     X
     0     0     0     0     0     0     0     099999000000999999      XAPRNCAP3
     0     0     0     0     0     0     0                             X
$GGRPCAP
    16    15    14     9    12    34
$SERVICE
   100   100   100   100   100   100   100   100   100   100   100      SERVICE1




      3675      4150      3625      3800       100        34         1  SOUTHT33
        20                                                            X     T33
      3550      4425      3675      4150       125        33         1  GG5  T34
        10                                                            X     T34
      2525      4950      3675      4150       125        32         1  GG6  T35
        15                                                            X     T35
      5575      5875      5900      4400       125        44         1  INNERT36
        25                                                            X     T36
      5900      4400      5975      3950       125        45         1  INNERT37
        25                                                            X     T37
      4925      9625      5000      9400       150        48         1  NORTHT38
        25
$DUMMY
$STOP
```

Figure A-5 Sample Input Card Deck for Plotting Program

APPENDIX B

APPENDIX B.1 JOB 1: RUNWAY OBSERVATIONS

Job 1: RUNWAY OBSERVATIONS

Equipment: Radio (tuned to ground controller frequency on "Air" band)
Binoculars
Accurate clock or watch
Time-line schedule
Airplane diagrams
Map 1 (airport)
Runway data sheets

Task:
(1) Note exact TOAs and TODs for all flights
(2) Note runway used
(3) Note general aviation traffic, including runway use, TOA, TOD, and plane-type
(4) Note unscheduled commercial avaiation
(5) Note touchdown points, tunoffs, lift-off points, and times on runway
(6) Takeoff delays and queues
(7) Average time in takeoff holding apron

Personnel: One or two

Time: (1) - (4) -- chosen period of study
(5) -- anytime proper runways are used

Location: Tower

RUNWAY DATA SHEET DESCRIPTION

The following page contains a sample runway data sheet. A well filled-in runway data sheet(s) will produce the following input data:

a. Average touchdown distance ($GRTD)

b. Standard deviation about $GRTD ($GRTOS)

c. Average landing roll (by plane-type)

d. Average takeoff roll (by plane-type)

e. Average turnoff used (by plane-type and by airline).

f. Average time on runways (by plane-type and by airline)

The airport map (see Map 1, page A-45) should be set up so that approximate landing and takeoff points can be referred to easily. The procedure for landing should be:

1. Start stopwatch at touchdown
2. Note touchdown point
3. Stop stopwatch at turnoff
4. Note turnoff used

The procedure for takeoffs should be:

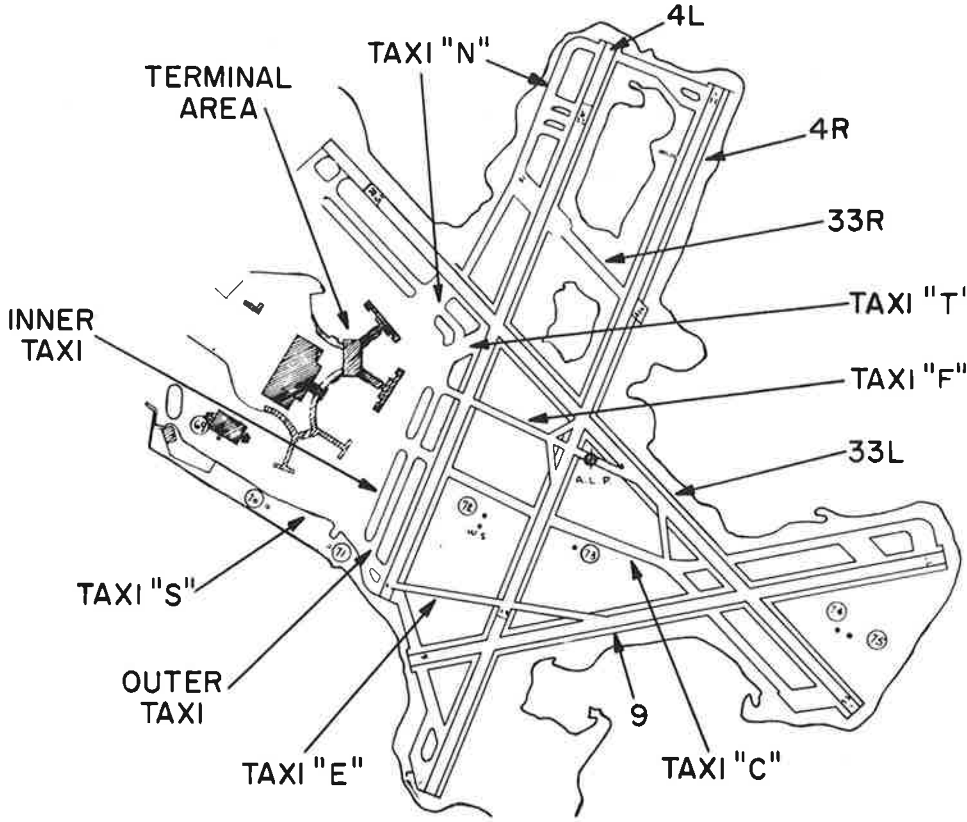
a. Start stopwatch at beginning of roll

b. Stop stopwatch at liftoff

c. Note liftoff point

From the observation station (ideally, the tower), note the TOA and TOD of every flight and the runway used. Be sure to note on another sheet the TOAs and TODs of GA. The radio should aid in the identification of flights, as the airplane diagrams (see Fig. A-11, PLTYP Diagrams, pg A-61) should aid in the identification of plane-types. The day chosen for these observations should not be a holiday or weekend. It might be possible to obtain old flight strips from the tower to supplement your observed data, but the latter is much more valuable.

MAP I



TOUCHDOWN AND TAKEOFF POINTS ON 33L

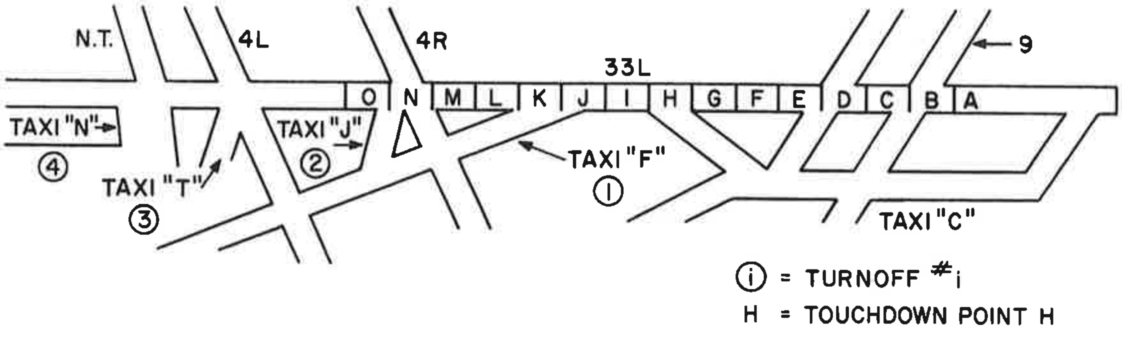


Figure A-6 Map of Logan Airport Data Reference Points

RUNWAY DATA: LOGAN

NAME: ____________

DATE: ____________

TIME: ____________

OBSERVATION POINT: ____________

All times in seconds.

AIRLINE	PLTYP	TOUCHDOWN POINT	TIME TO TURNOFF	TURNOFF NUMBER	TAKEOFF POINT	TAKEOFF TIME	TOTAL TRAVEL TIME
EAL	DC9				K	30	
EAL	DC9	A	32	3			
AAL	DC8	A	45	3			
ALG	727				A	27	
TWA	707				I	24	
NEA	727				H	20	
GA	TO				F	22	
ALG	BAC III	B	24	1			
EAL	DC9	B	20	1			
MOH	DC9	D	35	3			
TWA	727	B	22	3			
TWA	DC8				L	36	
BOAC	VC10	A	55	4			
AL6	DC9				L	29	
PAA	DC8				G	58	
UAL	727	A	30	2			
AF	DC8	F	45	4			

Figure A-7 Runway Data Sheet

TABLE A-2

TIME-LINE SCHEDULE

LOGAN (4pm-6pm)

	ARRIVING					DEPARTING				
SCHEDULED FLIGHT TIME	A/L	FLT.	GATE	PLTYP	ACTUAL ARRIVAL TIME	A/L	FLT.	GATE	PLTYP	ACTUAL DEPART. TIME
0400	EAL	874	60	DC9	Early	COMM	71	21	Piper Navaho	40230
						EAL	SH	65	DC9	40140
						COMM	643	20	TO	40105
0405	NEA	329	23	DC9	40020	EAL	SH		DC9	41255
	NEA	308	29	DC9	41645	TWA	811		880	41122
0410	NEA	42	24	727	40650	UAL	231	32	727	42155
0415	Air Canada	757	1(?)	DC9	42555	NEA	107	25	727	43530
						EX	386	53	TO	42930
						MOH	485	48	BAC-111	42515
						ALG	837	49	DC9	43425
0418	AAL	690	38	727	41700					
0420	NAL	4	37	727	43000	EAL	867	57	727	43830
0425	NEA	252	26	727	42420	NAL	65	36	727	44215

TABLE A-2 (Continued)

	ARRIVING					DEPARTING				
SCHEDULED FLIGHT TIME	A/L	FLT.	GATE	PLTYP	ACTUAL ARRIVAL TIME	A/L	FLT.	GATE	PLTYP	ACTUAL DEPART. TIME
0429	AL6	968	46	DC9	45310	UAL	163	34	DC8	4404
0430						AAL	35	39	727	4505
						EAL	SH	62	DC9	4463
						EAL	129	58	727	4525
						TWA	571	(?)	DC9	4472
0435	EAL	SH	65	DC9	44120	TWA	287	(?)	727	4452
0435	MOH	446	51	FH 227	43320					
0437	AAL	548	40	727	43930					
0440	UAL	92	32	DC8	45845	NEA	329	23	DC9	4571
	Prov Town	216	20	UNK	(?)	EAL	551	59	727	4543
	TWA	66	(?)	747	43700					
0444	AL6	880	49	DC9	44425					
0445	NEA	62	30	DC9	45450					
	AL6	638	47	C580	50430					

TABLE A-2 (Continued)

	ARRIVING					DEPARTING				
SCHEDULED FLIGHT TIME	A/L	FLT.	GATE	PLTYP	ACTUAL ARRIVAL TIME	A/L	FLT.	GATE	PLTYP	ACTUAL DEPART. TIME
0450						UAL	301	35	737	5132
						NEA	961	28	DC9	4595
						NEA	252	26	727	5030
						EAL	503	60	DC9	5012
						TWA	437	(?)	880	5083
0451	EAL	SH	62	DC9	45620					
0454	TWA	32	(?)	707	51655					
0455	TWA	542	(?)	727	45930					
0456	MOH	444	52	FH 227	50920					
0500	NEA	319	23	DC9	50030	UAL	205	33	DC8	5242
	NEA	58	27	727	50535	NEA	343	29	DC9	5173
	AIR N.E.	632	21	DC3	51410	NWO	287	55	727	5223
						MOH	433	51	FH 227	5130
						AAL	43	45	707	5152
						AAL	42	42	707	

TABLE A-2 (Continued)

	ARRIVING					DEPARTING				
SCHEDULED FLIGHT TIME	A/L	FLT.	GATE	PLTYP	ACTUAL ARRIVAL TIME	A/L	FLT.	GATE	PLTYP	ACTUAL DEPART. TIME
0500						EAL	SH	65	DC9	505
0502	AAL	164	41	707	50215	EAL	SH		DC9	510
0505						Air Canada	754	1(?)	DC9	5350
0510	NEA	12	25	727	50730	NEA	62	30	DC9	538
	AL6	858	51	DC9	51815	AAL	509	44	727	533
	ALG	860			51110	Prov Town	417	20	UNK	544
0515						NAL	71	37	727	5373
0520	NEA	76	28	727	52025					
	Bar Harbor	26	20	Cessna	52130					
	AAL	578	39	727	52730					
0523	AAL	12	43	707	53145					
0525	EAL	178	56	727	52510					
0526	UAL	426	33	720	55025					

TABLE A-2 (Continued)

	ARRIVING					DEPARTING				
SCHEDULED FLIGHT TIME	A/L	FLT.	GATE	PLTYP	ACTUAL ARRIVAL TIME	A/L	FLT.	GATE	PLTYP	ACTUAL DEPART. TIME
0530	Down East	45	21	Piper Navaro	54855	NEA	58	27	727	54420
	Air Canada	331	1(?)	VV	52305	NEA	47	24	727	55610
						MOH	450	52	FH 227	54440
						AL6	869	46	DC9	5580
						AAL	557	38	727	54120
						AAL	511	40	727	5400
						EAL	SH	62	DC9	53300
						Air N.E.	641	21	DC3	53850
0535						AL6	671	47	C580	5540
						AL6	861	49	DC9	55230
0538	EAL	SH	65	DC9	53355					
						NEA	319	23	DC9	5500
						Bar Harbor	37	20	Cessna	5463

TABLE A-2 (Continued)

	ARRIVING					DEPARTING				
SCHEDULED FLIGHT TIME	A/L	FLT.	GATE	PLTYP	ACTUAL ARRIVAL TIME	A/L	FLT.	GATE	PLTYP	ACTUAL DEPART. TIME
0541	EAL	116	57	727	60935					
0544	AL6	836	47	DC9	55930					
0545	NEA	373	26	DC9	54640	EX	344	54	TO	55720
						TWA	145	(?)	727	60100
0550	EAL	SH	62	DC9	55430	UAL	93	32	DC8	55850
						NEA	12	25	727	60310
0555	NEA	310	29	DC9	55300	TWA	33	(?)	707	62500
	EX	377	54	TO	55315					
	MOH	564	52	BAC-111	55750					
0600						TWA	65	(?)	747	62115
						EAL	SH	65	DC9	60540
						Down East	46	21	PN	55145
0605	NEA	150	30	DC9	60805					
	Pilgrim	162	21	TO	60720					
					46 Air					55 Aircraft
										101 Total Aircraft

APPENDIX B.2 JOB 2: TAXIWAY OBSERVATIONS

Job 2:	TAXIWAY OBSERVATIONS
Equipment:	Stopwatches Binoculars Taxiway data sheet Map 1. Figure A-6, (several copies) Map 2. Figure A-10 General Observation Sheet
Task:	(1) Fill in Taxiway Data Sheet (2) Note routing on Map(s) (3) Time various delays and travel times (4) Note queues (5) Reaction time to cross intersection (6) Clearance distance (7) Average wait for intersection
Personnel:	One or two
Time:	Chosen period of study
Location:	Tower

TAXIWAY DATA SHEET DESCRIPTION

A maximum taxiing speed for each taxiway must be input to the simulation. Also total travel times must be collected for calibration purposes. Taxiway lengths can be determined from the airport map, taxiway transit times, however, must be observed. A sample data sheet is contained on the following page.

Note that the first column contains the taxiway and the next two columns the end points of the segment measured.

TAXIWAY DATA

NAME:
DATE:
TIME:

All times in seconds.

NAME	FROM	TO	TIME(1)	TIME(2)	TIME(3)	DIST	SPEED
T(E)&9	E x 4L	9 x C	119 / 112	135 / 159	135	4200	16-23
T(C)	G x OT	9 x C	112 / 142	122	120	4350	18-23
T(C)	9 x C	C x Hold Apron	51	43	47	1725	20-24
T(F)	F x 33L	F x OT	63 / 65	68	46	2825	25-27
South Taxi	Eastern Ramp	Inner Taxi				2525	
North Taxi	33R	33L	32	29	31	1625	30-34
Inner Taxi	T(F)	T(C)	33	20	26	850	15-26
Inner Taxi	T(C)	South Taxi	49 / 50	31 / 35	37	1950	23-38
Outer Taxi	T(F)	T(C)	28 / 32	24	42	875	12-22
UAL Ramp	Apron	Inner Taxi	21	30	26	300	6-9
TWA Ramp	Apron	Inner Taxi	23	21	25	150	3-5
TRNOF FOXTROT	33L	4R	16	12	14	950	36-47
TRNOF JULIAN	33L	T(F)	15	21	18	600	17-24
TRNOF TANGO	33L	Inner Taxiway	38	59	48	1250	13-20
T(F)	Fx4R	OT	51	48	59	1875	22-24
South Taxi	IT	Old South Term	42	40	41	1200	17-18

Figure A-8 Taxiway Data Sheet

APPENDIX B.3 JOB 3: TERMINAL AREA DATA

Job 3: TERMINAL AREA DATA

Equipment:
- Stopwatch
- Gate-Group Data Sheet
- $TLSCH
- Map 1. Runway Data Sheet, Figure A-6
- Map 2. Terminal Area Map, Figure A-10
- General Observation Sheet

Task:
- (1) Divide terminal area into gates and gate groups
- (2) Note plane types using gates
- (3) No. of service vehicles required for each plane type
- (4) Gather the following times:
  - a. apron to gate travel times
  - b. ramp to gate travel times
  - c. docking and undocking times
  - d. service time required for each plane type
  - e. service vehicle reaction time
  - f. service vehicle delays
  - g. average plane time in gate and in gate group aprons
  - h. sq. ft. occupied by each plane type

Personnel: Two or three

Time: Anytime

Location: Tower terminal buildings

TERMINAL AREA DATA SHEET DESCRIPTION

The terminal area must be divided up into gate groups.

The division of gates into these groups necessitates some thought. The choices are limited by the requirement for one ramp per gate-group. Within this limitation, it was bound to be helpful to put all the gates of an air line in the same group (provided that they were in the same area), since the ASTS program assumed that gates within a group are interchangable to some extent.

The following page contains the gate group data sheet. Note that gate assignments, gate usage, and terminal area travel times are to be obtained from this sheet. The first column contains the gate group number and the second column contains the associated gates (refer to Figure A-10 for the selected gate layout). The travel times as noted here are defined in the A.S.T.S. Users Manual for the ASTS program.

GATE GROUP DATA

All times in seconds.

GG #	ASSOC GATES	PLANE-TYPES SEEN IN GG	APRON-GATE TIMES(SEC)	RAMP-GATE TIMES(SEC)	DOCKING TIMES(SEC)	UNDOCKING TIMES (SEC)
1	1-8					
2	9-12					
3	13-16					
4	17-19					
5	20-21					
6	22-24			50		
7	25-31			29 35		
8	32-35			32 78		
9	36-37			49 37		
10	38-44			40 38 50 38		
11	45			125		
12	46-52			96 51		
13	53-54					
14	55-60					

Figure A-9 Gate Group Data Sheet

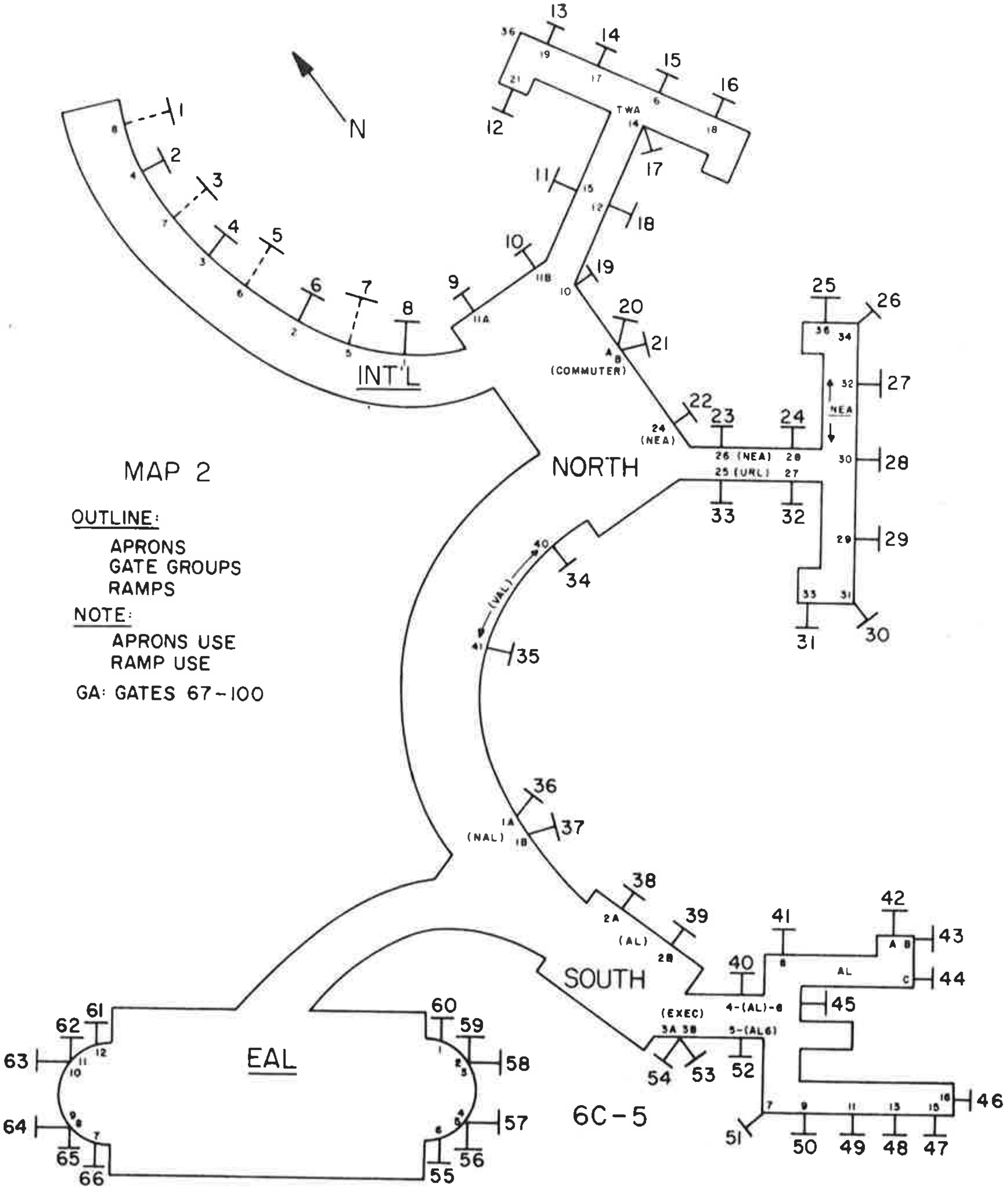
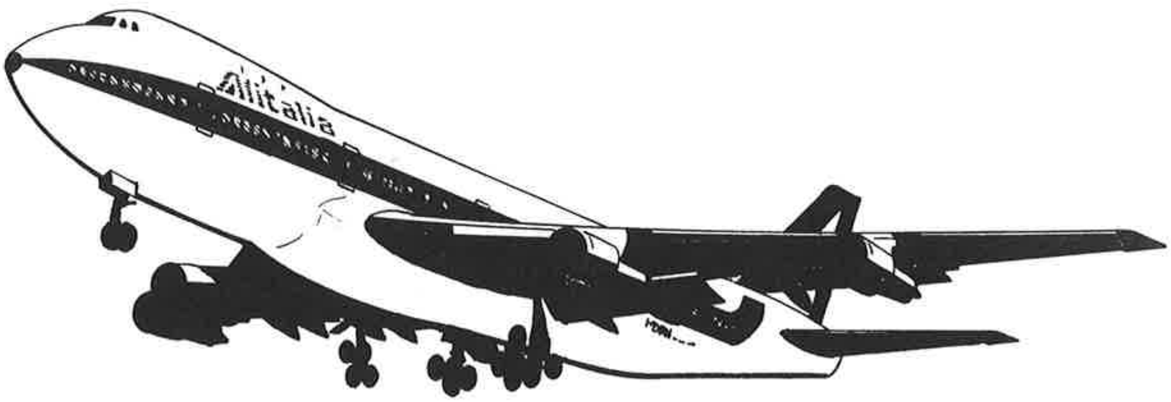
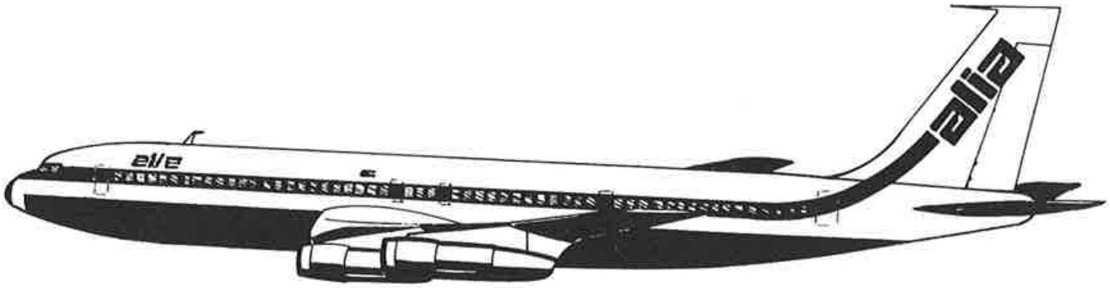


Figure A-10 Terminal Area Map



Boeing Model 747-51



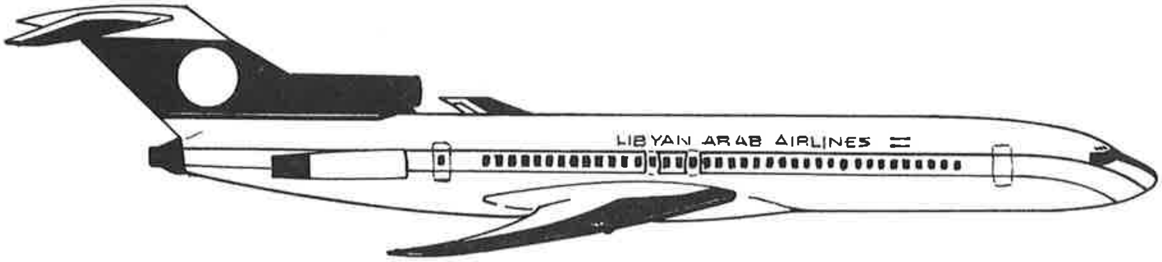
Boeing Model 707-311C

Figure A-11 PLTYP Diagrams (Sheet 1 of 4)

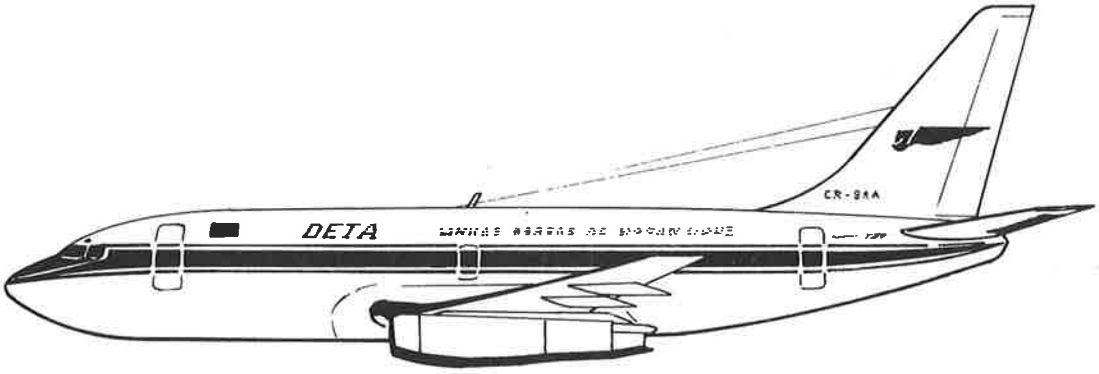
McDonnell Douglas DC-8 Super 62

McDonnell Douglas DC-9

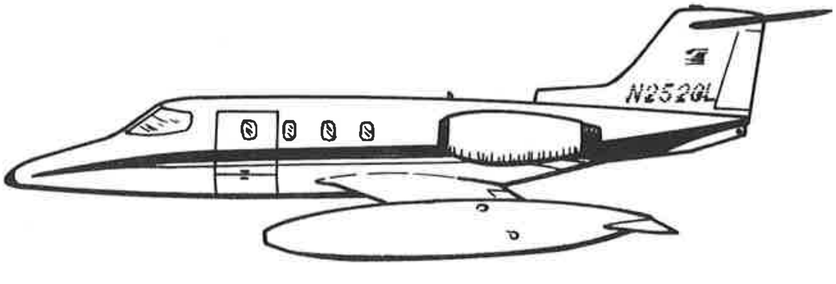
Figure A-11 PLTYP Diagrams (Sheet 2 of 4)



Boeing 727

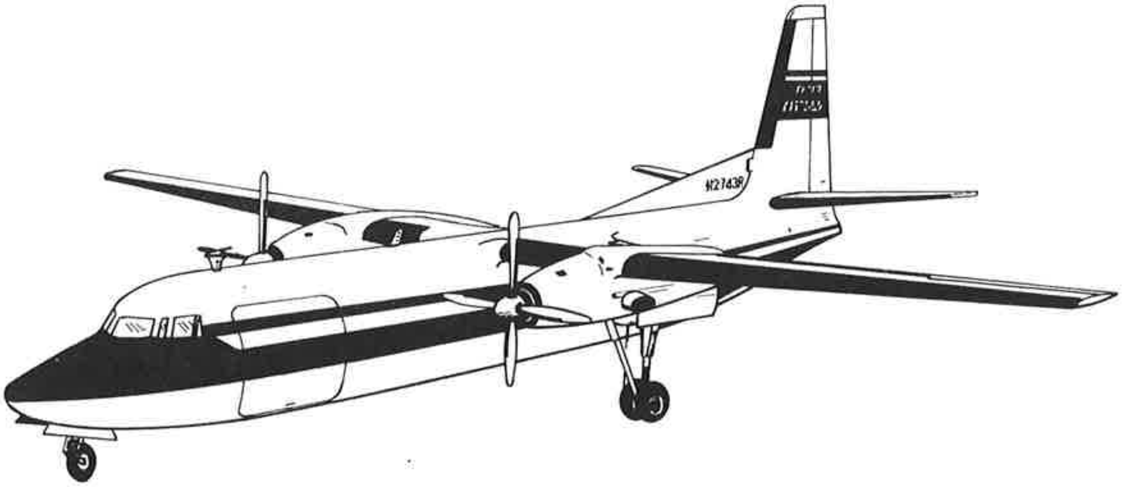


Boeing Model 737-2426

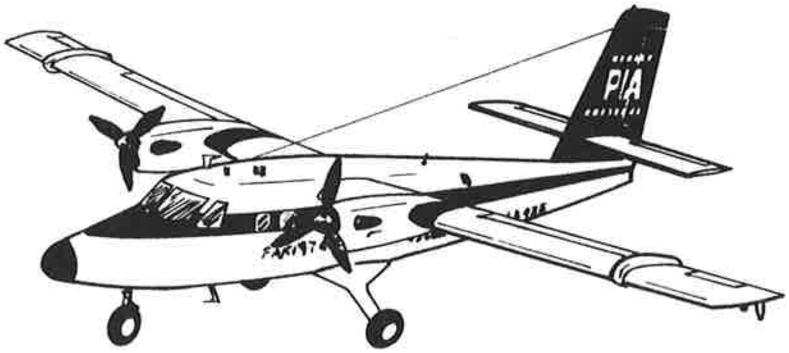


Gates Learjet

Figure A-11 PLTYP Diagrams (Sheet 3 of 4)



Fairchild Hiller FH227B



DHC-6 Twin Otter

Cessna Skyhawk

Figure A-11 PLTYP Diagrams (Sheet 4 of 4)

APPENDIX B.4 ASTS INPUT RESTRICTIONS

DATA INPUT REQUIREMENTS

Due to the vague language of the ASTS User's Guide, first-time users of ASTS might waste much time editing input data. Therefore, the following rules might help eliminate some confusion:

a. Before labelling the airport map, refer to page 4 of the User's Guide.

b. In rule 3 on that page, "high speed turns" refers to turnoffs.

c. In rule 2 on that page, "XL end" refers to the lower X-value (left-hand) end.

d. $APRON -- be sure the first ten columns are take-off apron or blanks. Other aprons begin at column 11.

e. $APRNCAP -- put in capacities from storage 61 (gate-group 1 holding apron) to storage 100 (runway 10 take-off apron), leaving in zeros to mark unused storage space.

f. $GGATE -- row 5: Lowest possible number for gate-group aprons is 11.

g. $GTYPE -- rows 3 and 4 refer to plane type, not class.

h. $LINK -- maximum of 99 allowed.

i. $ROUTE -- for inbound from runways, do not input link of turnoff. Elsewhere, input only first links traveled on of each route (see column 11 of $ROUTE matrix, Diagram 3.4).

j. $TAXIW -- maximum of 39 allowed.

k. $TAXILEN -- for "i" taxiways (i<40), input "999999" as length of "i+1" taxiway (row i+1).

l. $TLSCH -- aircraft can be brought into the system and taken out of the system only through runways or hangers.

m. $TRNOF -- turning radius is used in Function 2. It may be necessary to update the function in order to make aircraft turnoff at the proper places.

n. Don't forget to input the halfword save-values ($GEOMETR, $TIMES, $DYGRAPH, $PCTSCHE, $AIRCRAF, and (optional) $WEATHER), found on pages 132-134 of the User's Guide.

o. For graphic purposes, input these interface matrices: $XYMAX, $BUILDING, $HEADER, $CONTROL, and $RWYNAME (described on pages 25-26 of the <u>User's Guide.</u>

p. Refer to page 19 of the <u>User's Guide</u> for general information on input cards

MODIFICATIONS TO INPUT DECK

In the debugging of the ASTS model, it became necessary to place many restrictions on the input data. The following changes are required for the smooth running of the program:

$APRONCAP -- Make the capacity of takeoff holding aprons arbitrarily large so that they can contain most planes waiting to takeoff.

$GATES -- Make gate grouping as efficient as possible
$GGATE since many delays can develop near ramps.

$IFRSM
$IFRSS -- Don't make these distances too large - large
$UFRSM spacings tie up too much taxiway/link capacity
$UFRSS

$WAKE -- Keep these delays low
$INTS Allow no blockage at any intersection
$LINK -- It may be necessary to "invent" new links
$TAXIW -- taxiways, and routes in order to avoid head-
$ROUTE -- to-head conditions.

$PLTYP	--	Accelerations/decelerations will probably have to be made smaller than those observed in order to give proper runway times and turn-off usage.
$RUNWY	--	May have to make all runways independent

In addition, it is necessary to number runway intersections sequentially from left to right (in addition to numbering runway links sequentially).