A SIMULATION MODEL OF EASTERN AIRLINE'S
MOBILE LOUNGE SYSTEM
AT ATLANTA HARTSFIELD INTERNATIONAL AIRPORT

by

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I. INTRODUCTION

A. PURPOSE

In response to the interest expressed by EAL, their increased operational activities, and their renewed customer service efforts, we have undertaken a rigorous analysis of the Mobile Lounge System at Atlanta Hartsfield International Airport. This increasingly more complex interactive system has rendered the present scheduling methods less effective and the need for a better management tool has arisen. Therefore, we have designed and developed a computer simulation model that will aid in achieving better feasible solutions.

Our primary objective in simulating Eastern Airline's Mobile Lounge System is two-fold:

1. Create a flexible and well documented model that will determine the immediate scheduling requirements of the system.
2. Utilize this model to determine the equipment required to maintain an adequate and desirable service level in the system.

B. BACKGROUND

1. History

Before May 1, 1976, Eastern Airline's Mobile Lounge System at Atlanta Hartsfield International Airport (Figures 1a, 1b) con-

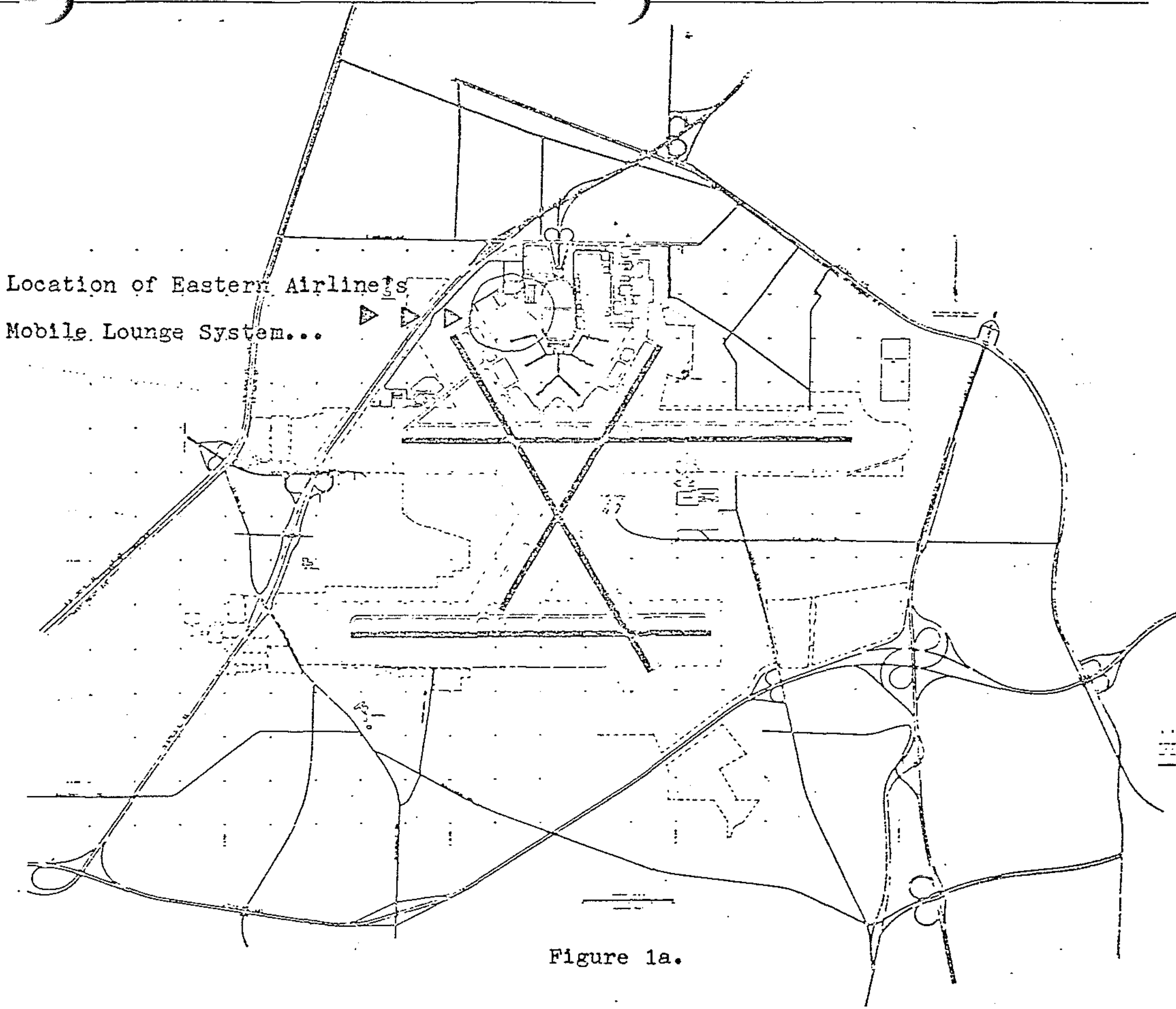

Figure 1a.

EXISTING AIRPORT LAYOUT PLAN

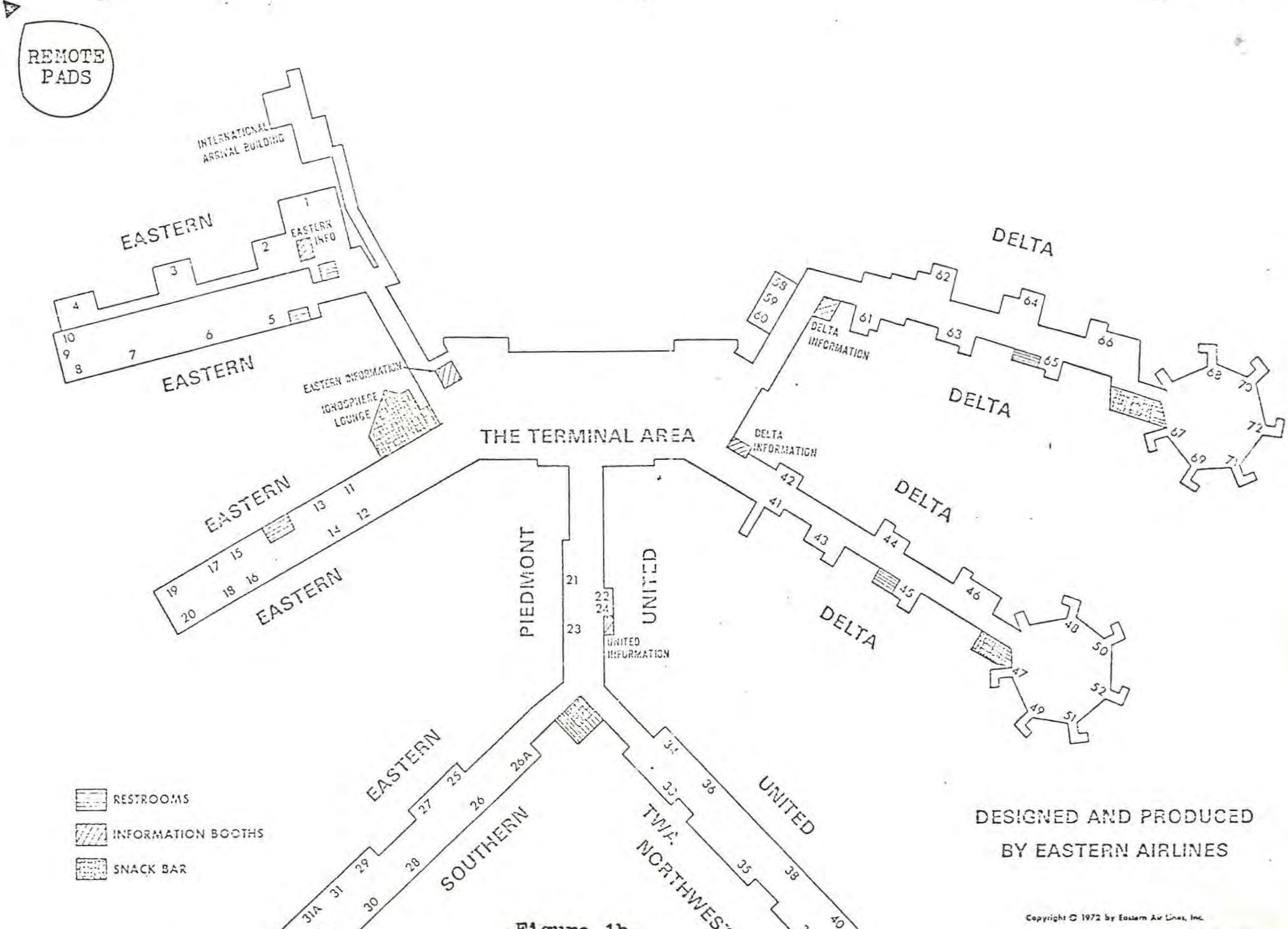

Figure 1b.

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sisted of two active mobile lounges and one reserve mobile lounge, ferrying passengers to and from a remote terminal (Figure 2) into which aircraft implaned and deplaned. This remote terminal consists of ten aircraft pads, three of which handle daily scheduled flights, while the rest were utilized as the need arose.

On May 1, 1976, thirty-two flights were added, bringing Eastern Airline's daily scheduled flights to a total of two hundred and forty (240 arrivals and 240 departures). A permanent addition of ten scheduled flights occurred on December 8, 1976, continuing their progressive domination and expansion in the Atlanta market before they relocate to the new midfield terminal (presently under construction) in 1981.

2. Problem Areas

On site investigation has turned up the following list of major problem areas that affect the outcome of any decision regarding the Mobile Lounge System.

a. Presently, there are no guidelines other than experience for augmenting the Mobile Lounge System, which has not had any physical improvement since its inception in 1971.

b. The increase in passengers and flights affecting the Mobile Lounge System are difficult, if not impossible, to reliably predict.

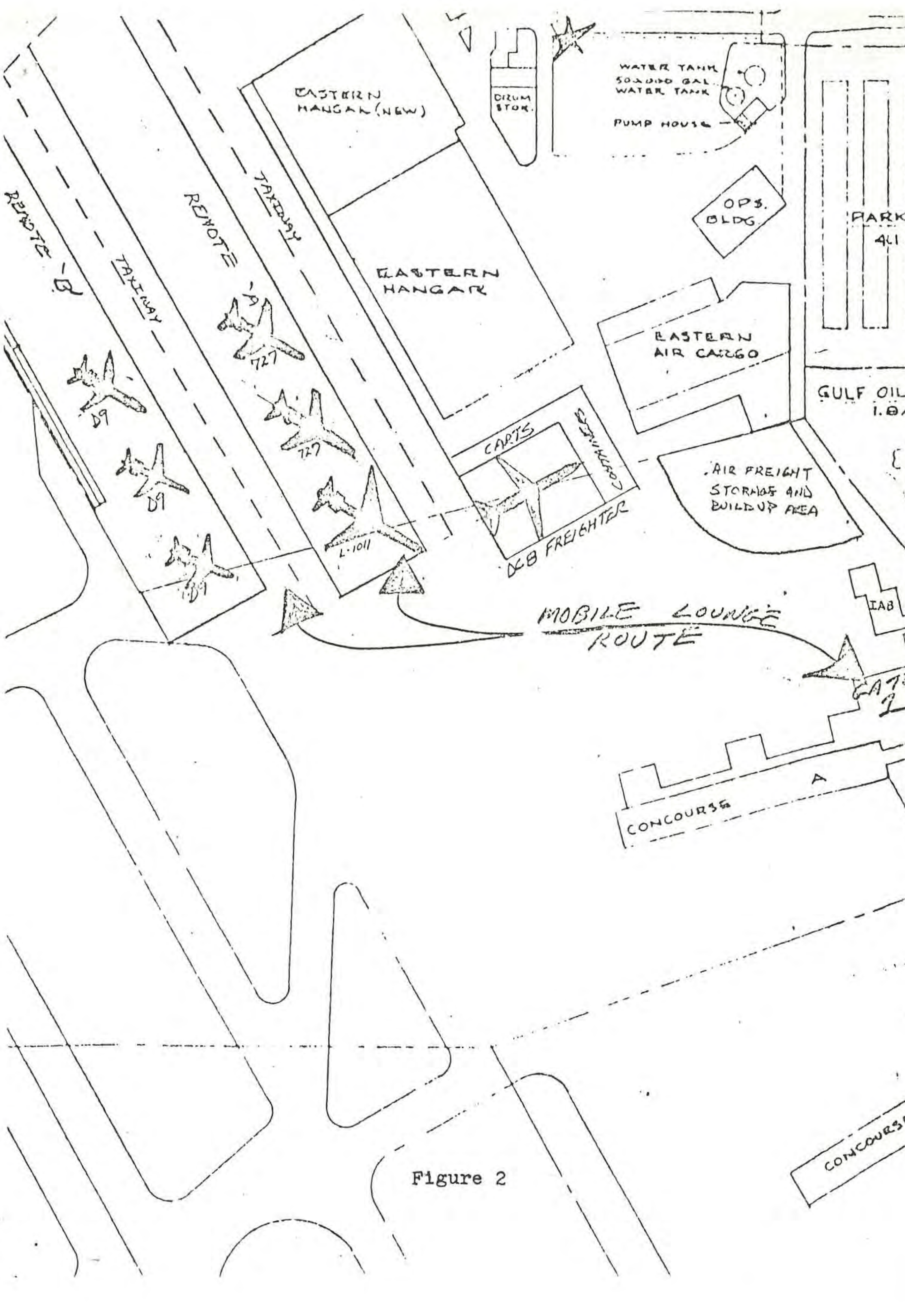

EASTERN HANGAR (NEW)
DRUM STOR.
WATER TANK
500,000 GAL WATER TANK
PUMP HOUSE
OPS. BLDG.
PARK
EASTERN HANGAR
EASTERN AIR CARGO
GULF OIL
REMOTE 'B'
TAXIWAY
REMOTE 'A'
TAXIWAY
727
727
D9
D9
D9
L-1011
CARTS
CONTAINERS
DC8 FREIGHTER
AIR FREIGHT STORAGE AND BUILDUP AREA
MOBILE LOUNGE ROUTE
IAB
GATE 2
A
CONCOURSE
CONCOURSE

Figure 2

c. Flight scheduling is presently based on two operating mobile lounges as a direct result of their frequent break-downs.

d. There are five positions for mobile lounges at Gate 1, only three of which are accessible due to interference caused by the International Arrivals Building (which houses Customs, Immigration, and Plant Quarantine Service processing of EAL's international passengers entering through remote).

e. Additional interference is caused by the deplaning of passengers at the IAB, and by the arrivals and departures of L-1011 aircraft at Gate 2 (adjoining Gate 1), which effectively block passage of mobile lounges.

f. No standards are available on the service level of the mobile lounge in this system.

g. The order lead time for a mobile lounge is at least eight (8) months (since they are custom made), and the present estimated cost per unit is half a million dollars ($500,000).

C. PROBLEM STATEMENT

Provide a flexible and well documented tool that will determine the impact on the operational characteristics of the Mobile Lounge System, using these primary variables:

1. Number of Passengers
2. Arrival and Departure Times
3. Number of Mobile Lounges

That is, given a predetermined number of passengers, what is the minimum acceptable level of separation between arrivals and/or departures, and what should the effective number of mobile lounges be in order to support the operation and provide adequate customer service?

D. VALUE OF MODEL

1. Application

Application of the model will enable the user to systematically examine critical factors that affect the operation of the Mobile Lounge System, such as scheduling, system utilization, and capital improvement alternatives.

This model is designed primarily for use at the Atlanta Hartsfield International Airport, although it can be readily applied with some alterations at any other station utilizing a similar transportation system.

2. Flexibility of Application

The flexibility of our model is demonstrated by the major alternatives it can examine to provide an acceptable level of service, determined by the variable equipment and schedule requirements which are outlined below:

a. Extra mobile lounge only

b. Extra mobile lounge requiring partial or complete removal of the International Arrivals Building

c. Fixed mobile lounges vs. variable aircraft schedule

d. Variable mobile lounges vs. fixed aircraft schedule

e. Fixed aircraft types vs. variable aircraft types

f. Fixed load factors vs. variable load factors

g. Alternate mobile lounge routes

h. Combination of the above

i. What point in time for any alternative?

j. Do nothing

3. Benefits

Primary benefits in the application of our model will be:

a. Improved scheduling ... from being able to better predict the impact on the operation of the system due to changing non-deterministic conditions inputed by the user, as opposed to subjective estimates based on past experience utilizing less effective methods.

b. Improved customer satisfaction ... due to less passenger delays as a direct result of improved scheduling.

c. Improved decision making involving capital improvements ... as a direct result of an objective analysis of the elements of the system, their utilization, and their effective projected operation under simulated conditions of growth.

d. Reduction in operating cost ... by implementation of corrective measures generated in advance by the simulation model.

e. Convenience to the user ... from better information and ease of application resulting in less man hours spent in scheduling.

f. Competitive advantage ... due to better decision making policies.

II. METHOD OF APPROACH

A. INTRODUCTION

In this section we will discuss our method of approach, including our reasons for selecting the technique utilized, the assumptions and constraints imposed by the nature of the problem, and the advantages, disadvantages, and limitations of our technique.

1. Why simulation?

The subjective analysis of various techniques, and their pros and cons regarding validity and feasibility of application, allowed for the acceptance of the simulation approach as a viable alternative with the following advantages and disadvantages:

a. Advantages

i. Provides a simpler method of solution to large complex systems, such as EAL's Mobile Lounge System, as other analytical methods are extremely complex and arduous in their mathematical formulation.

ii. Allows us to test out the operational feasibility and effectiveness of a complex system by varying input parameters, reflecting changing conditions and demands.

iii. Sensitivity analysis can be performed to predict the impact of various decisions before their actual implementation.

iv. In conjunction with financial analysis, we can estimate the economic feasibility of large complex service systems with long time frames.

b. Disadvantages

i. Inherent risk of oversimplification of the model utilized, resulting in possibly infeasible solutions.

ii. Development of a good simulation model is often expensive and time consuming.

2. Why did we reject other methods?

Two other methods that had some applicability were considered and rejected for the reasons outlined below:

a. Queueing Theory Approach - Several aspects of the Mobile Lounge System such as the stochastic arrival and departure of aircraft and the customer service requirements indicated that queueing theory was applicable. Since it gave the analyst more effective information, the queueing model seemed to be desirable, but the complexity of the mathematical formulation of the system, and the otherwise selective piecemeal use of the model rendered its use either impractical or infeasible.

b. Network Theory Approach - During the initial stages of analysis, a network theory approach was considered, as the extensive activities in the model envisioned at the time (Figure 3) could be simulated through the use of GERT (Graphical Evaluation Review Technique). The probabilistic nature of the occurence of arcs and nodes depicting interference

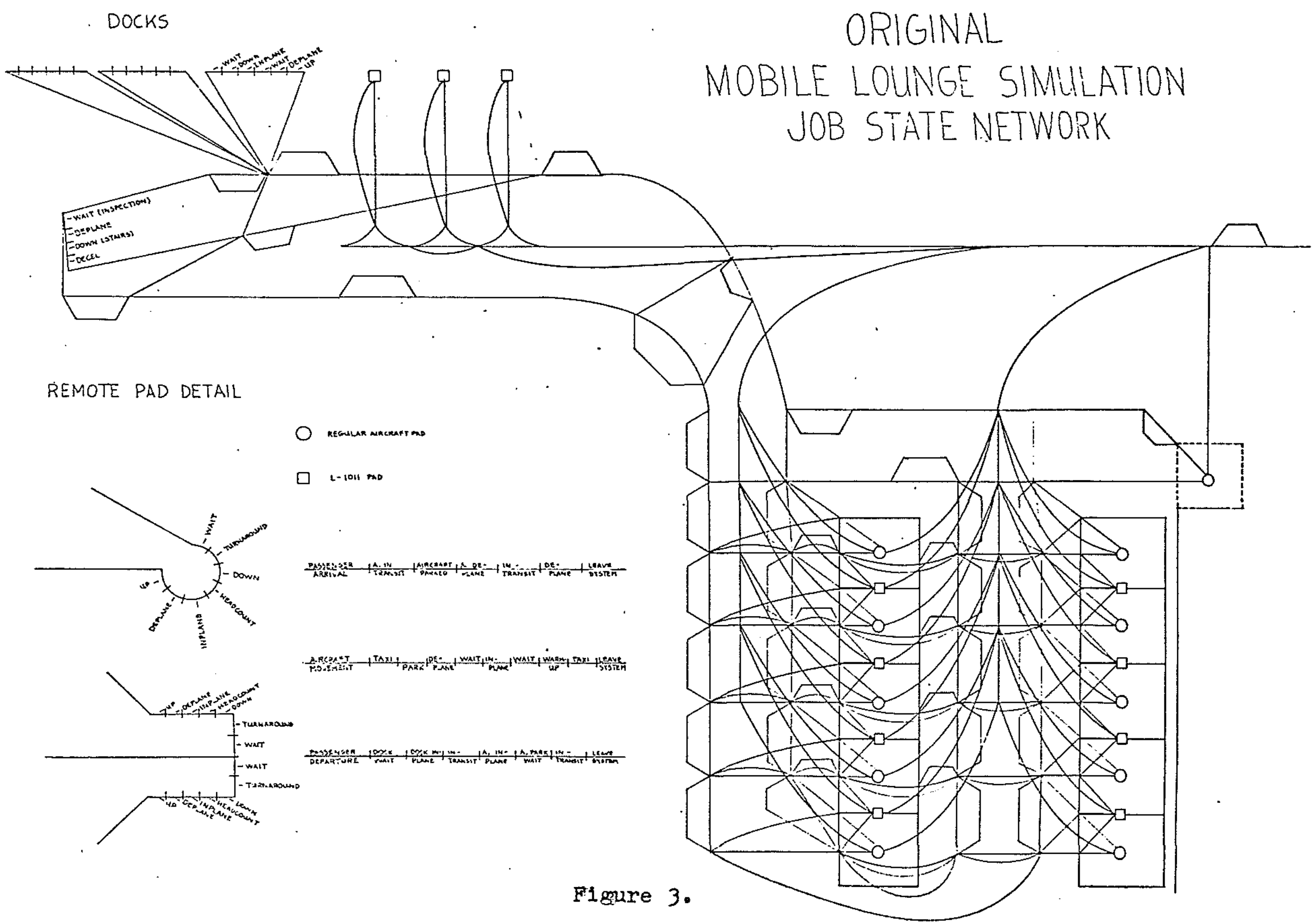

ORIGINAL
MOBILE LOUNGE SIMULATION
JOB STATE NETWORK
DOCKS
WAIT
DOWN
INPLANE
WAIT
DEPLANE
UP
WAIT (INSPECTION)
DEPLANE
DOWN (STAIRS)
DECEL
REMOTE PAD DETAIL
REGULAR AIRCRAFT PAD
L-1011 PAD
WAIT
TURNAROUND
DOWN
HEADCOUNT
INPLANE
DEPLANE
UP
TURNAROUND
WAIT
WAIT
TURNAROUND
PASSENGER ARRIVAL
A. IN TRANSIT
AIRCRAFT PARKED
A. DE-PLANE
IN-TRANSIT
DE-PLANE
LEAVE SYSTEM
AIRCRAFT MOVEMENT
TAXI
PARK
DE-PLANE
WAIT
IN-PLANE
WAIT
WARM UP
TAXI
LEAVE SYSTEM
PASSENGER DEPARTURE
DOCK WAIT
DOCK IN-PLANE
IN-TRANSIT
A. IN-PLANE
A. PARK WAIT
IN-TRANSIT
LEAVE SYSTEM

Figure 3.

and the random decision making elements of the mobile lounge driver, in combination with a shortest path algorithm, were the prime features of this approach. Further analysis and consultation with EAL management drastically simplified our model while still meeting the problem solving requirements, rendering this network approach unnecessary.

B. PLANNING: PHASES AND TASKS

In fulfilling the requirements of the problem at hand, we organized the design project into five phases in order to facilitate our analysis.

1. Definition - Onsite inspections and numerous discussions with involved personnel enabled us to identify and determine the causes of problems in the operation of the Mobile Lounge System.

2. Investigation - Preliminary analysis of the Mobile Lounge System enabled us to determine the information and data requirements for the simulation model. Substantial data was collected to familiarize ourselves with the operational characteristics of the system. This information let to the model formulation, as well as the statistical analysis required for the development of a pertinent model.

3. Synthesis - Preliminary analysis enabled us to conceptualize solution approaches and the structure of alternatives, resulting in our selection of the next event simulation model as the most feasible and applicable technique.

4. Design - Having selected the appropriate technique that will achieve our objectives, we introduced realism into the deterministic model by utilizing a stochastic simulation process. Our design process is summarized in Figure 4.

5. Implementation - The creation of a User's Manual facilitating

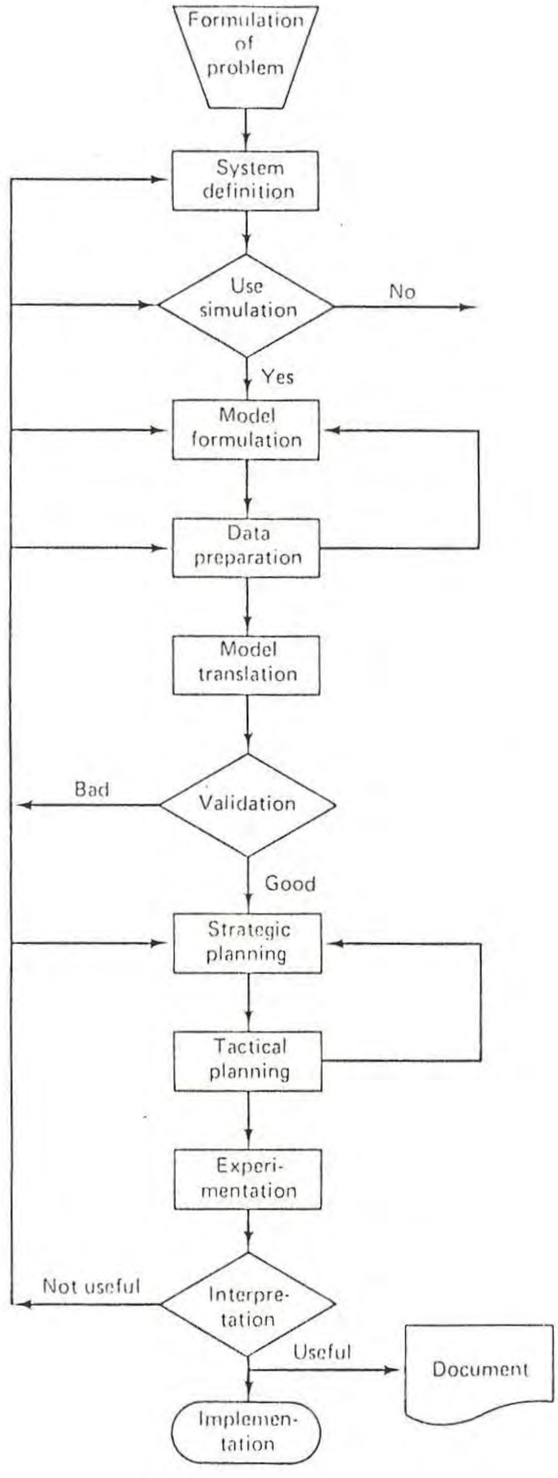

Formulation of problem
System definition
Use simulation
No
Yes
Model formulation
Data preparation
Model translation
Bad
Validation
Good
Strategic planning
Tactical planning
Experi-mentation
Not useful
Interpre-tation
Useful
Document
Implemen-tation

Figure 4.

the use of the simulation program, and the successful completion of our project in meeting the required objectives will serve as guidelines for effective scheduling and possible procurement of another mobile lounge. As a direct result, future policy decisions beyond the scope of this project can be evaluated.

C. MODEL

A description of the model in question is summarized on the following pages. Our general system flowchart (Figure 5) details the primary activities in the system that incorporates reality in our simulation. Some fixed (a noticeable amount of variability presently exists) pertinent policies and practices incorporated into our model include the following:

1. Dispatch of two mobile lounges for variable passenger loads (i.e., when seventy or greater), where one begins loading twenty minutes prior to the scheduled departure time (T-20), and the other at five minutes prior to scheduled departure time (T-5).

2. If mobile lounge is unavailable at T-20 with a flight carrying seventy or more passengers, the dispatcher waits until T-2 before a decision is made to utilize only one mobile lounge for transport.

3. The same mobile lounge will be utilized for both trips to a particular aircraft when seventy or more passengers are expected.

4. A mobile lounge will be considered available for the dispatcher's use when:

a. Mobile lounge is empty and functional at Gate 1 or Remote.

b. The sum of the passengers just unloaded from an incoming

GENERAL FLOW CHART

SEQUENCE OF EVENTS

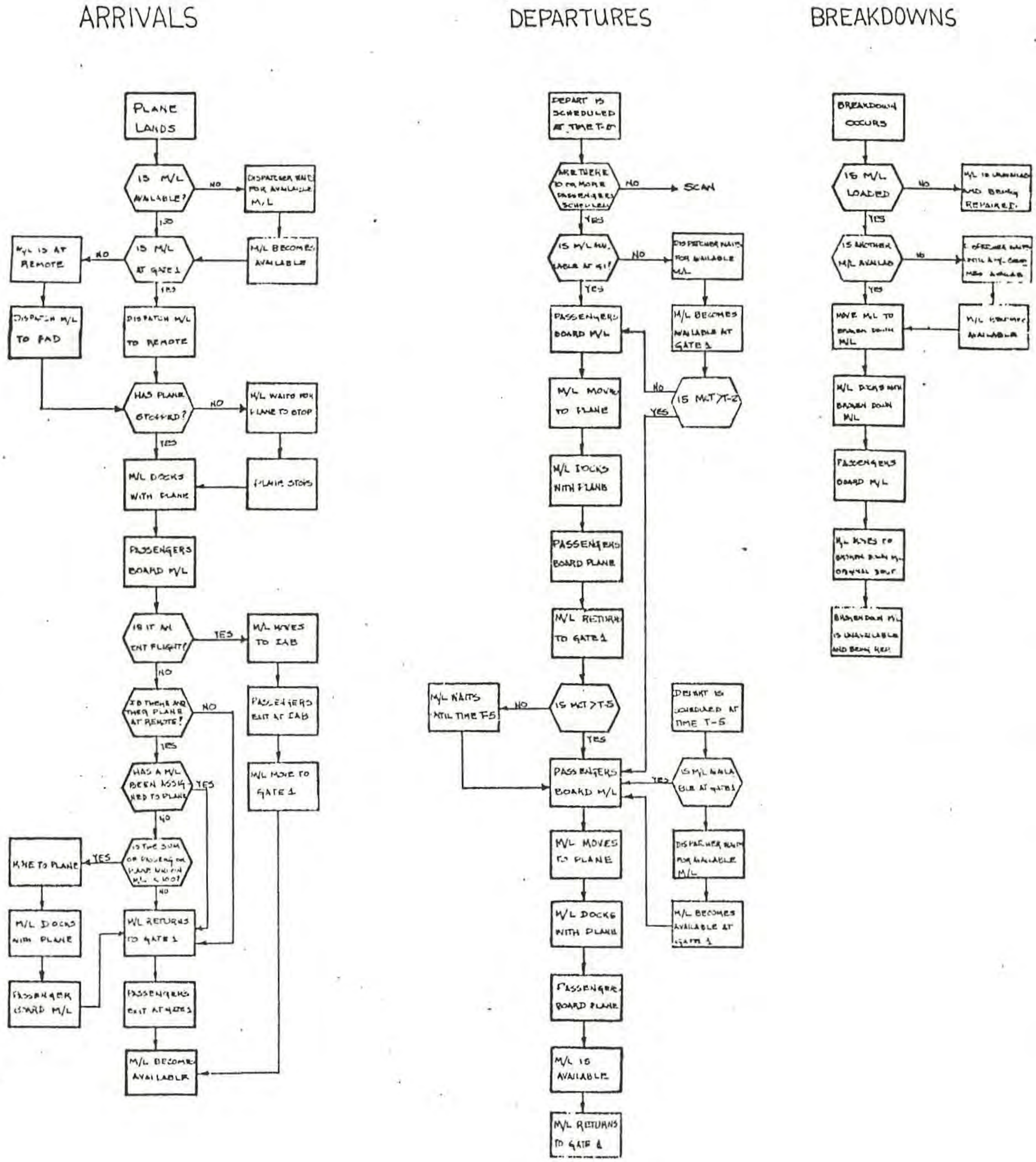


Figure 5.

flight and from another prospective passenger load already awaiting transport into the terminal does not exceed one hundred.

c. International flights are excluded from condition b.

5. International flights will be served by only one mobile lounge.

6. When a mobile lounge transporting passengers breaks down, another mobile lounge, when available, takes these passengers to their appropriate destination.

7. Two mobile lounges will not service one aircraft.

The general system flowchart and its activities are processed in our simulation program utilizing the schemes shown in Figure 6 (General Flow Chart For Simulation Program Showing Most Important Subroutines And Order Of Processing), Figure 7 (Mobile Lounge Job States), Table 1 (Description Of Mobile Lounge System Job States), and Figure 8 (Aircraft Job States).

D. LIMITATIONS AND ASSUMPTIONS

As with any simulation model, there are certain limitations and assumptions that need to be understood before any decision is made to utilize the results.

1. Since people are an integral part of the system, the so-called "Hawthorne Effect" may affect the results of our data collection - i.e., the fact that mobile lounge drivers are being observed may modify their behaviour.

2. Simulation is not absolutely precise, and we cannot measure the degree of imprecision. Analysis of the sensitivity of the model to changing parameter values can only partially overcome this difficulty.

3. Simulation results are usually numerical, hence, the danger of attributing a greater degree of validity to the numbers than is justified

GENERAL FLOW CHART FOR SIMULATION PROGRAM SHOWING MOST IMPORTANT SUBROUTINES AND ORDER OF PROCESSING

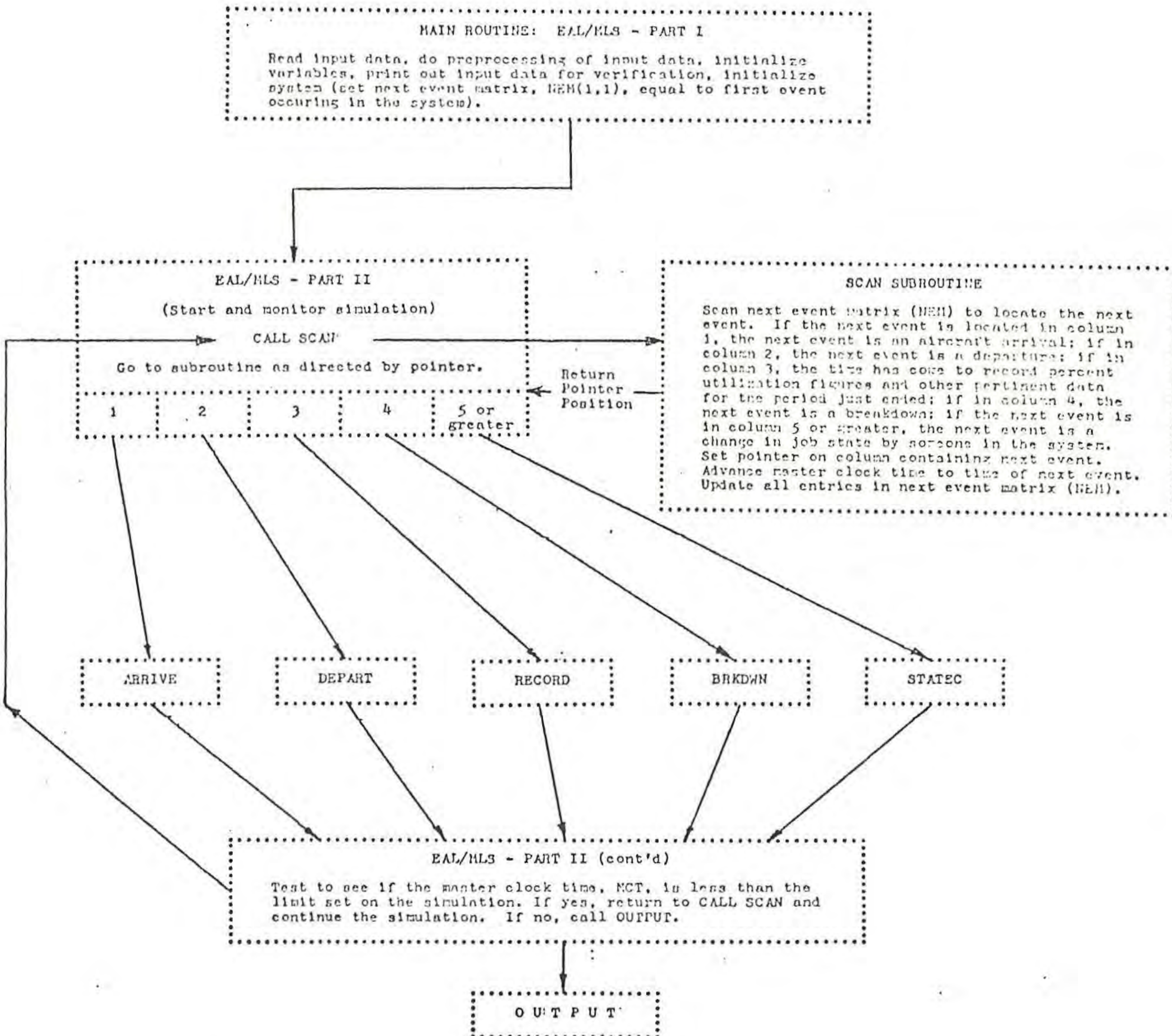


Figure 6.

MOBILE LOUNGE

JOB STATES

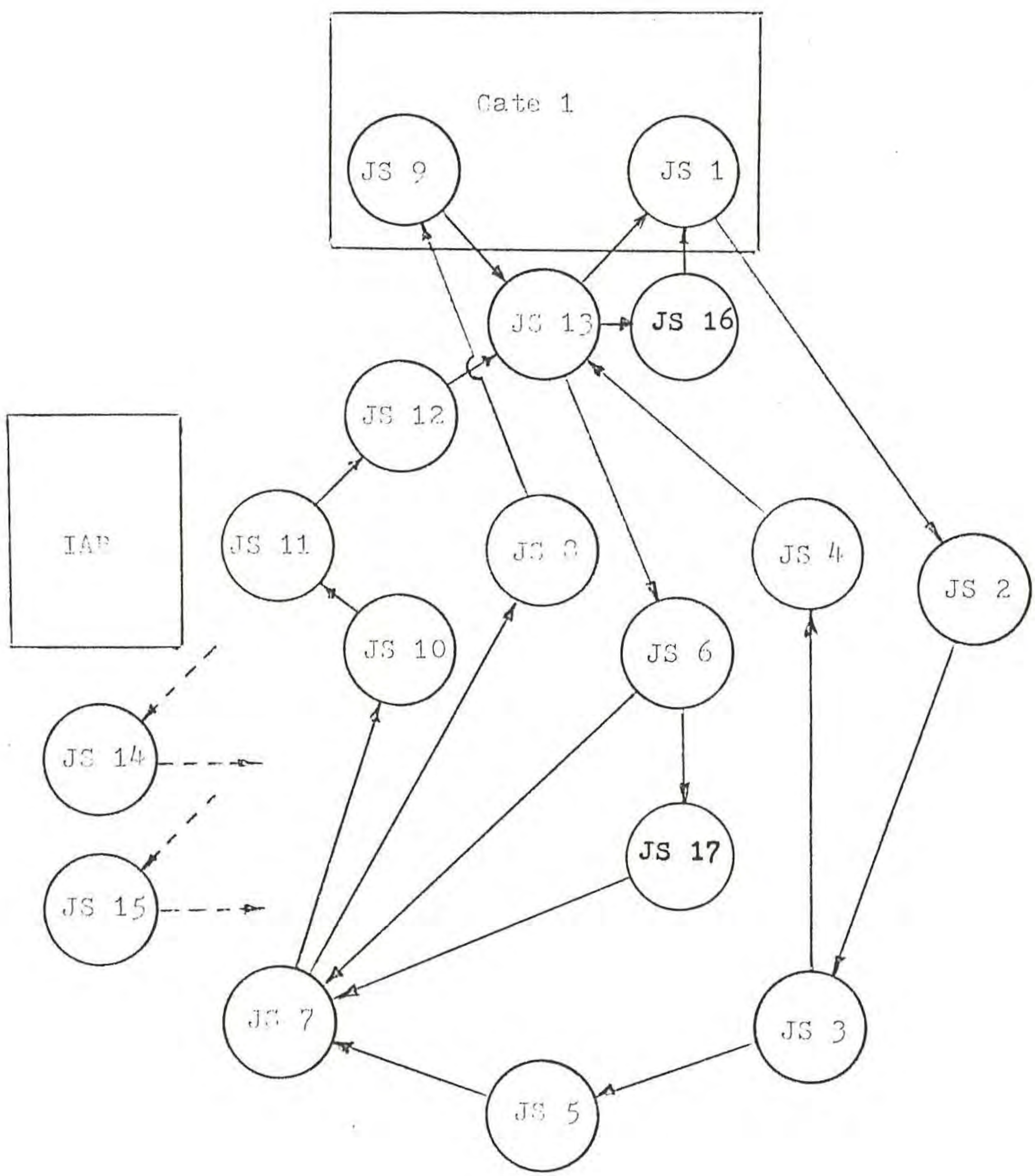


Figure 7

TABLE 1.

DESCRIPTION OF MOBILE LOUNGE JOB STATES

Job State Number	Description
1	Load Mobile Lounge at Gate 1.
2	Mobile Lounge travels to plane.
3	Load Plane.
4	Mobile Lounge returns empty to Gate 1.
5	Mobile Lounge travels between planes.
6	Mobile Lounge travels empty to Remote area to pick up passengers.
7	Unload plane.
8	Mobile Lounge returns with passengers to Gate 1.
9	Unload Mobile Lounge at Gate 1.
10	Mobile Lounge returns from an international flight.
11	Unload Mobile Lounge at IAB.
12	Mobile Lounge returns to Gate 1 from IAB.
13	Mobile Lounge idle at Gate 1.
14	Mobile Lounge breakdown occurs.
15	Unload passengers from breakdown

TABLE 1 (Cont'd)

16	Mobile Lounge waits for departure (passengers $\leq$ 70)
17	Mobile Lounge waits for arrival at Remote
19	Travel to breakdown Mobile Lounge

AIRCRAFT JOB STATES

18. Aircraft ground time.

20. Aircraft ready for unloading.

21. Taxi time (in transit between ON and IN time).

22. Late aircraft departure.

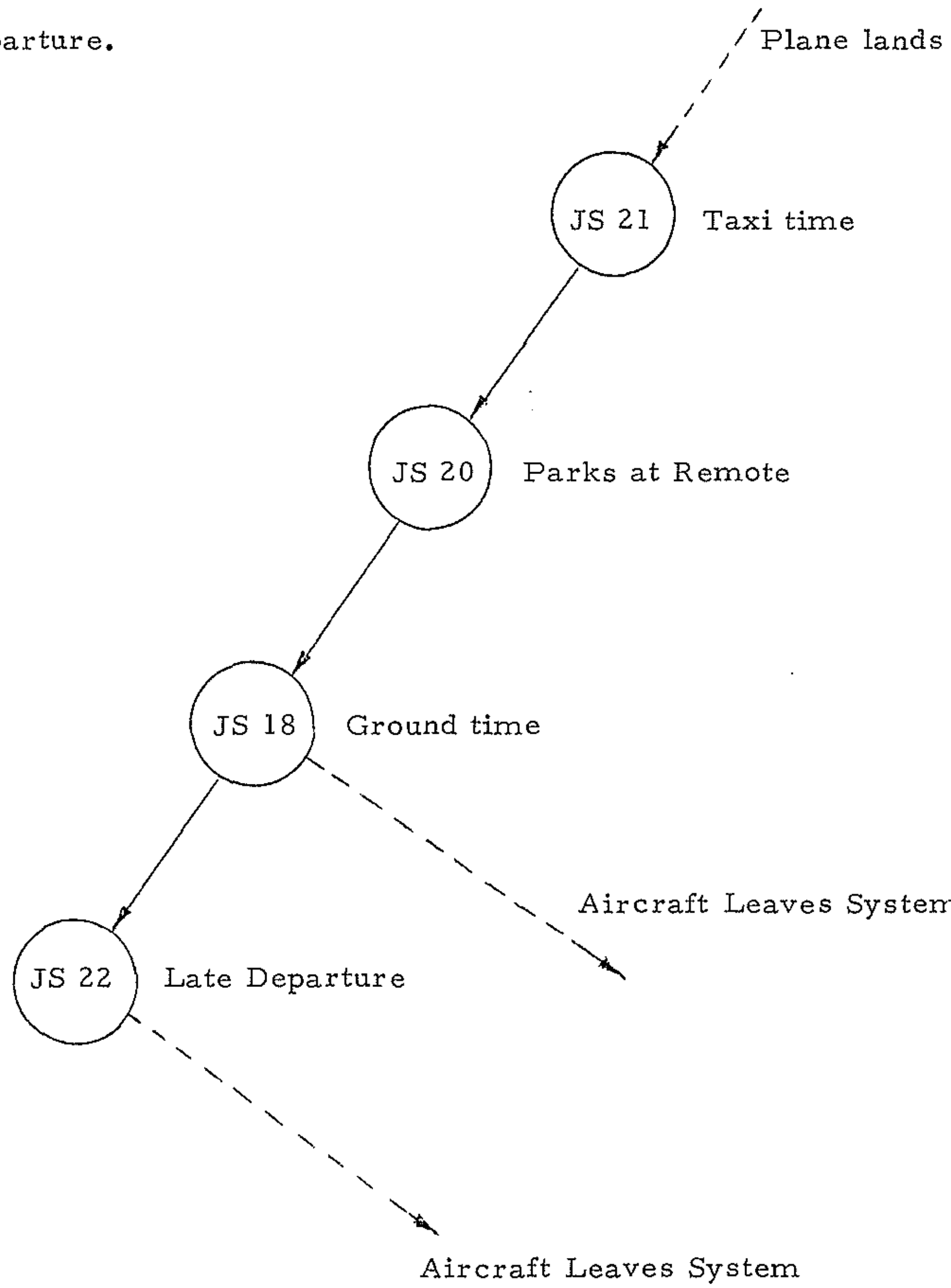


Figure 8.

arises.

4. The simulation model is primarily based on the normal day-to-day activities of the Mobile Lounge System. Exceptions and anomalies are not included, and are left to the user to provide, i.e., charter flights, aircraft breakdowns (flight returns), etc.

5. Our model reflects the operation of the Mobile Lounge System as it exists today.

6. Other complex decisions made by the dispatcher, ramp service manager, and the operations manager are not reflected in our model due to the difficulty in modeling rational human behaviour.

7. Time study data will incorporate the effects of any possible delays into our model, whether dependent or independent from other activities in the system, such as interference.

8. The simulation must be allowed to achieve steady state, that is, enough data must be generated to reduce "sample error" and provide adequate and confident results. In our model, a simulation run of one week is sufficient.

In essence, our simulation model uses only the critical elements necessary to perform in a relatively objective manner and at the same time provide results that upon analysis will enable the user to make appropriate and effective decisions and recommendations.

E. PERFORMANCE MEASURES

In the analysis of each alternative and the use of the stochastic elements in our simulation model of Eastern Airline's Mobile Lounge System, one can assign a fixed or variable penalty cost to our criteria for evaluating performance measures: passenger delay minutes. For our purposes, we have divided the major causes of delay into two categories, mobile lounge delays and flight delays, the duration of which can be incorporated into the time elements of our model.

1. Mobile Lounge delays
   a. Travel time
      i. Passenger inplane/deplane at Remote.
      ii. Passenger inplane/deplane at Gate 1.
      iii. Interference.
      iv. Aircraft position at Remote.
      v. Breakdown time (recoverability).
   b. Schedule changes
      i. Early arrival
      ii. Late arrival
2. Flight delays
   a. Arrival deviations
      i. Stacking (ATC delays).
      ii. Arrival time.
      iii. Unscheduled aircraft arrivals.
   b. Departure deviations
      i. Service time.
      ii. Late arrival.
      iii. Departure time

iv. Aircraft maintenance at Remote.

III. USE OF MODEL

A. USER'S MANUAL

Our simulation program is characterized by special procedures or techniques which enable the user to monitor the process (Figure 9) and to incorporate changing conditions in the Mobile Lounge System for management problem solving. In order to facilitate the understanding of the simulation procedure shown in Figure 6, and for purposes of training and instruction, we have developed a User's Manual which is attached directly to the simulation program for easy reference (see attached printout). In conjunction with the User's Manual, our program package and documentation is frought with explicit comment cards depicting the "English Version" of the FORTRAN used.

B. INFORMATION REQUIRED

Our simulation model requires the use of several important time distributions necessary to maintain the validity of its results. These distributions and some others outlined below greatly enhance the realism of our simulation model. Refer to Appendices A and B for further information.

1. Aircraft Data
   a. Scheduled arrival distribution
   b. Scheduled departure distribution
   c. Unscheduled arrival distribution
   d. Unscheduled departure distribution
2. Passenger data
   a. Quantity of arrivals distribution
   b. Quantity of departures distribution

```
MASTER                          SUMMARY OF JOB STATE CHANGES PROCESSED THROUGH NEXT EVENT MATRIX                       PAGE  1
CLOCK
TIME                            COLUMN  COLUMN  COLUMN  COLUMN  COLUMN  COLUMN  COLUMN  COLUMN  COLUMN  COLUMN
                                  1       2       3       4       5       6       7       8       9       10

 59700  SECONDS REMAINING -     120    3300   999999      0       0   999999     300     180    1200  999999
 AFTER  JOB NUMBER---------       0       0       0     101     102     103     120     121     122       0
 SCAN   JOB STATE NUMBER---       0       0       0       1       4      17      18      21      18       0
-------------------------------------------------------------------------------------------------------------------
        LOAD    TRAVL   UNLD    TRAVL   TRAVL   TRAVL   UNLD    TRAVL   UNLD    TRAVL   UNLD    TRAVL   IDLE
        ML      TO      ML      FRM     BTWN    TO      PLANE   FRM     ML      IAB     IAB     FMIAB
        101       0       0     102       0       0       0       0       0       0       0       0       0
          0       0       0       0       0       0       0       0       0       0       0       0       0
          0       0       0       0       0       0       0       0       0       0       0       0       0
          0       0       0       0       0       0       0       0       0       0       0       0       0

        BROKN   UNLD    WAIT    GBFOR   PLANE   TRAVL   UNLD    PLANE   LATE
        ML      BRKML   FOR 1     7     DEPR    BRKON   PLANE   TAXI    DEPRT
          0       0       0     103     120       0       0     121       0
          0       0       0       0     122       0       0       0       0
          0       0       0       0       0       0       0       0       0
          0       0       0       0       0       0       0       0       0
-------------------------------------------------------------------------------------------------------------------
        MOBILE LOUNGE           ML  1   ML  2   ML  3 -
        ACTIVITIES

                                122     120     121

                                  0       0       0

        COLUMN SELECTED IN NEM =  5            JOB NUMBER = 102            PRESENT JOB STATE =  4
-------------------------------------------------------------------------------------------------------------------

 59700  SECONDS REMAINING -     120    3300   999999      0     300   999999     300     180    1200  999999
 BEFORE JOB NUMBER---------       0       0       0     101     102     103     120     121     122       0
 SCAN   JOB STATE NUMBER---       0       0       0       1       1      17      18      21      18       0
-------------------------------------------------------------------------------------------------------------------
        LOAD    TRAVL   UNLD    TRAVL   TRAVL   TRAVL   UNLD    TRAVL   UNLD    TRAVL   UNLD    TRAVL   IDLE
        ML      TO      ML      FRM     BTWN    TO      PLANE   FRM     ML      IAB     IAB     FMIAB
        101       0       0       0       0       0       0       0       0       0       0       0       0
        102       0       0       0       0       0       0       0       0       0       0       0       0
          0       0       0       0       0       0       0       0       0       0       0       0       0
          0       0       0       0       0       0       0       0       0       0       0       0       0

        BROKN   UNLD    WAIT    GBFOR   PLANE   TRAVL   UNLD    PLANE   LATE
        ML      BRKML   FOR 1     7     DEPR    BRKON   PLANE   TAXI    DEPRT
          0       0       0     103     120       0       0     121       0
          0       0       0       0     122       0       0       0       0
          0       0       0       0       0       0       0       0       0
          0       0       0       0       0       0       0       0       0
-------------------------------------------------------------------------------------------------------------------
```

Figure 9

3. Maintenance data

   a. Mobile lounge

      i. Breakdown frequency

      ii. Maintenance duration distribution

   b. Aircraft

      i. Breakdown frequency

      ii. Maintenance duration distribution

4. Delay data

   a. Pushout delay

      i. Frequency

      ii. Duration

   b. Other (i. e., customs agent and mobile lounge driver inavailability)

      i. Frequency

      ii. Duration

   c. Taxi time distribution

The user is reminded here of the need to determine when another distribution is required to improve the simulation results, and of the cost incurred in developing the new distribution.

C. OUTPUT POSSIBLE

All output will include titles and descriptions in a format for all input/output data. Refer to Figure 10 (Example output - 3 mobile lounges) and to Figure 11 (Example output - 4 mobile lounges), and also to the attached computer printouts for more detail.

Figure 10

OUTPUT FOR THE MOBILE LOUNGES

MOBILE LOUNGE NUMBER	NUMBER OF FLIGHTS SERVICED	TOTAL TIME SPENT IN EACH JOB STATE 1	2	3	4	5	6	7	8
101	13	1935	2430	4005	1520	133	1525	1410	925
102	14	1290	1620	2670	950	133	2135	1880	1295
103	12	1505	1890	3115	950	266	1220	1410	740
TOTAL TIME		4730	5940	9790	3420	532	4880	4700	2960
AVERAGE TIME		248.95	312.63	515.26	213.75	133.00	305.00	235.00	185.00

	TOTAL TIME SPENT IN EACH JOB STATE 9	10	11	12	13	14	15	16	17	19
101	300	144	165	174	35157	0	0	4500	117	0
102	420	144	165	174	38229	0	0	5400	0	0
103	240	288	330	348	37281	0	0	4500	77	0
TOTAL TIME	960	576	660	696	110667	0	0	14400	194	0
AVERAGE TIME	60.00	144.00	165.00	174.00	3353.55	0.00	0.00	900.00	97.00	0.00

FLIGHT JOB NUMBER	MOBILE LOUNGE	PASSENGER TIME START	END	TOTAL TIME SPENT IN EACH JOB STATE FOR EACH FLIGHT 1	2	3	4	5	6	7
104	101	30525	31005	0	0	0	0	0	305	235
105	102	30525	31069	0	0	0	0	0	305	235
106	103	34200	35130	215	270	445	190	0	0	0
107	101	33300	35350	430	540	890	380	0	0	0
108	102	35445	35925	0	0	0	0	0	305	235
109	103	35745	36289	0	0	0	0	0	305	235
110	101	39300	40230	215	270	445	190	0	0	0
111	102	39600	40530	215	270	445	190	0	0	0
112	103	39885	40365	0	0	0	0	0	305	235
113	101	43500	44730	215	270	445	190	0	0	0
114	102	49005	49485	0	0	0	0	0	305	235
115	103	49545	50025	0	0	0	0	0	305	235
116	101	53340	54270	215	270	445	190	0	0	0
117	102	54000	54930	215	270	445	190	0	0	0
118	103	53745	54225	0	0	0	0	0	305	235
119	101	55425	55959	0	0	0	0	0	305	235
120	102	57400	58530	215	270	445	190	0	0	0
121	103	58400	59730	215	270	445	190	0	0	0
122	101	54445	56955	0	0	0	0	0	305	235
123	102	59325	59805	0	0	0	0	0	305	235
124	101	59355	59465	0	0	0	0	0	305	235
125	102	63000	63930	215	270	445	0	0	0	0
126	103	62100	64150	430	540	890	190	0	0	0

1. Input Data

    a. Predetermined aircraft schedules

    b. All initial matrices

    c. Other input variables and parameters:

        i. Load factors

        ii. Types of aircraft

        iii. Number of mobile lounges

        iv. Stochastic distribution parameters

        v. Other

2. Basic Values and Parameters Calculated by Program Before Processing Begins.

    a. Random number generator and expected values

    b. Stochastic distributions' expected values

    c. Basic parameter values

    d. Other

3. Printout to Verify Processing of Data

    a. Next Event Matrix and Unit Matrix (periodically)

    b. Other

4. Output Statistics

    a. Summary of job duration in each job state for different jobs.

    b. Percent of total job time spent in each job state

        i. Average figures for all jobs

        ii. Specific figures for the maximum job

        iii. Delay figures for each job

    c. Frequency distributions on delay minutes per time of day

(1) AVERAGE IS COMPUTED ONLY OVER THOSE JOBS THAT USED THAT STATE.
(2) THE MAX TIME ANY JOB SPENT IN THAT STATE.

OUTPUT FOR THE MOBILE LOUNGES

MOBILE LOUNGE NUMBER	NUMBER OF FLIGHTS SERVICED	TOTAL TIME SPENT IN EACH JOB STATE 1	2	3	4	5	6	7	8
101	11	1290	1620	2670	1140	0	1830	1410	1110
102	10	860	1080	1780	760	0	1830	1410	555
103	9	1075	1350	2225	950	0	1525	1175	925
104	9	1505	1690	3115	1330	0	915	705	370
TOTAL TIME		4730	5940	9790	4180	0	6100	4700	2960
AVERAGE TIME		248.95	312.63	515.25	220.00	0.00	305.00	235.00	185.00

	TOTAL TIME SPENT IN EACH JOB STATE 9	10	11	12	13	14	15	16	17	19
101	360	0	0	0	39410	0	0	3600	0	0
102	180	432	495	522	43001	0	0	3600	0	0
103	300	0	0	0	36480	0	0	2700	0	0
104	120	144	165	174	39227	0	0	4500	0	0
TOTAL TIME	960	576	660	696	158118	0	0	14400	0	0
AVERAGE TIME	60.00	144.00	165.00	174.00	4054.31	0.00	0.00	900.00	0.00	0.00

FLIGHT JOB NUMBER	MOBILE LOUNGE	PASSENGER TIME START	END	TOTAL TIME SPENT IN EACH JOB STATE FOR EACH FLIGHT 1	2	3	4	5	6	7
105	101	30525	31005	0	0	0	0	0	305	235
106	102	30525	31069	0	0	0	0	0	305	235
107	103	34200	35130	215	270	445	190	0	0	0
108	104	33300	35350	430	540	890	380	0	0	0
109	101	35445	35925	0	0	0	0	0	305	235
110	102	35745	36289	0	0	0	0	0	305	235
111	103	39300	40230	215	270	445	190	0	0	0
112	104	39500	40530	215	270	445	190	0	0	0
113	101	39385	40355	0	0	0	0	0	305	235

MOBILE LOUNGE NUMBER	PASSENGER TIME	SCHEDULED TIME	ACTUAL TIME	DELAY FOR FLIGHT	NUMBER OF PASSENGERS
0	0	0	0	0	0
105	480	31020	31005	-15	100
106	544	31020	31243	223	56
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Figure 11

d. Frequency distributions on time required to complete jobs

e. Detailed output for each mobile lounge

i. Number of jobs completed

ii. Mean job time

iii. Mean delay minutes

iv. Mean job time per time period

v. Mean delay minutes per time period

vi. Maximum job time per time period

vii. Maximum delay minutes per time period

viii. Total delay minutes per day

f. Display of percent utilizations for each mobile lounge in the system

g. Histogram showing demand on system vs. time

h. Table or listing showing maximum values per time period achieved for ...

i. Aircraft type(s) and load factor(s) being processed at one time

ii. Number of jobs being processed at one time

iii. Number of flights being delayed at one time

iv. Number of passengers being delayed at one time

v. Number of mobile lounges in use at one time

5. Feasibility Output

a. Fixed costs of passenger delay minutes

b. Variable costs of passenger delay minutes

c. Total system delay costs, projected annually

d. Utilization figures

e. Average job cycle times per time period

f. Maximum service level

   i. Limits on flights in

   ii. Limits on passengers

   iii. Limits on schedule changes effects

   iv. Service graphs vs. delay costs per day

   v. Service graphs vs. passengers per day

   vi. Service graphs vs. aircraft per day

6. Other

IV. RECOMMENDATIONS

In order to maintain our simulation model relevant with the current operation of the Mobile Lounge System, certain areas need to be systematically upgraded. These refinements are necessary to enhance the confidence in, and the validity of, the results for use in the management decision making process. Further discussion on this subject can be found in Appendix A, Section IV.

In order to justify schedule changes or capital improvements in the Mobile Lounge System, the following should be developed before a decision is made:

1. Establish different cost structures under which passenger delay minute costs may be determined.

2. Establish a standard of service level in order to quantify the true cost of passenger delay minutes.

3. Comparison of actual performance and costs with simulated performance and costs.

   a. Comparison of service levels measured in passenger delay minutes.

   b. The costs of delay minutes should be weighted differently for arrivals and departures.

   c. Comparison of costs of proposed improvement and new service level with the present costs, incurred over time.

4. Accurate assessment of the costs of operating the Mobile Lounge System (including maintenance) and the cost and policy implications of any proposed alternative.

5. Determine the impact of various dispatching and utilization policies to establish and maintain the best, feasible and uniform set of policies and standards for the operation of the Mobile Lounge System.

6. Test the impact of a variable aircraft schedule to determine optimum separation of flights, in order to even out or reduce the demand on the Mobile Lounge System at any given time.

7. Repeat the above with various capital improvement alternatives to determine the best tradeoff between improved customer service, reduced operating costs, and utilization of the investment involved.

8. Utilize the services of the members of our design project team when implementing the simulation program into your General Electric computer.

9. Utilize knowledgeable and experienced information and computer services personnel when initially installing the simulation program.

APPENDIX A

STATISTICAL ANALYSIS

I. INFORMATION REQUIRED

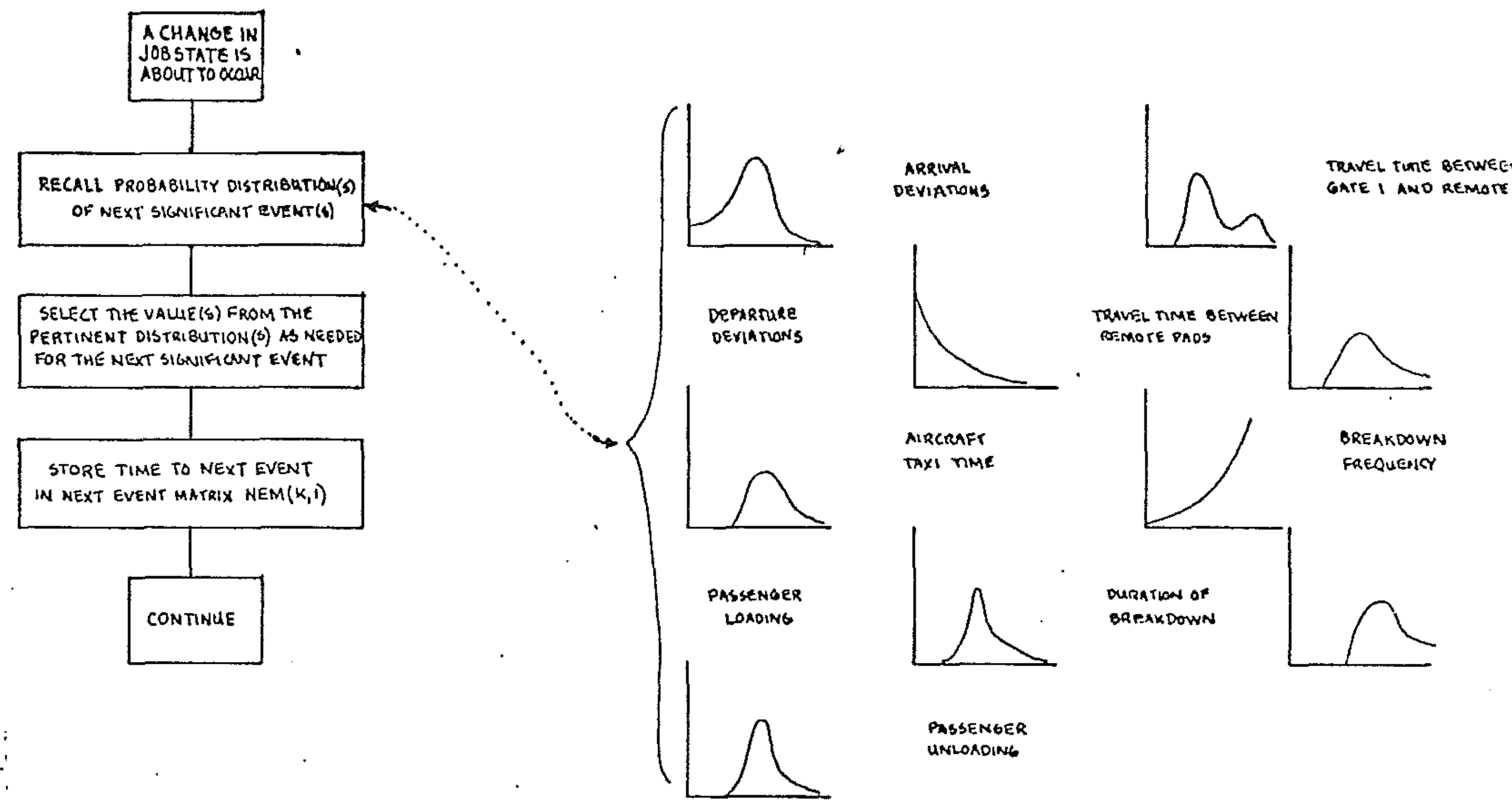
Certain events in our model which in nature have varying time and frequency conditions, will be processed through a stochastic subroutine simulating reality. These time and frequency distributions can be developed from time studies and other recorded data, because (a) the use of raw empirical data implies that all one is doing is simulating the past, (b) it is generally more efficient of computer time and storage requirements to use a calculated probability distribution, and (c) it is much easier to change the parameters of the probability distribution to perform sensitivity analysis. Refer to Figure A-1 for an outline of the mechanism involved in the stochastic subroutine.

As indicated previously, certain time study data and other recorded information will be required to process events throughout our stochastic simulation model. These are:

A. Gate 1 - Formulation of a time function and distribution incorporating passenger loading/unloading times and dispatching delays at Gate 1 in this general format:

$G1(i) = f(P)_i + \Delta_i$ --

Where: - $f(P)_i$ is a time function of the passenger loading/unloading times at Gate 1



MECHANISM OF STOCHASTIC SUBROUTINE

Figure A-1

- Δ_i is a time distribution incorporating dispatching delays at Gate 1

- G1(i) is the total gate time function for departures (i = 1) beginning from T-20 or T-5 when the dispatcher announces the departure of a flight (mobile lounge) or for arrivals (i = 2) which involve only the unloading of passengers from a mobile lounge (job states 1 and 9 respectively).

B. Travel Time - All our travel times can be generated through cumulative or other approximating travel time distributions and the random number generator, for job states 2, 4, 5, 6, 8, 10 and 12.

C. Remote Pad - Formulation of a time function and distribution incorporating passenger loading/unloading times and service delays at Remote in this general format:

$R1(j) = f(P)_j + \Delta_j$ --

Where: - $f(P)_j$ is a time function of the passenger loading and unloading times at Remote.

- Δ_j is a time distribution incorporating dispatching delays due to activities in Remote.

- Rl(j) is the total Remote Pad time function for the duration of loading passengers into aircraft (j = 1) or unloading passengers into mobile lounge (j = 2), for job states 3 and 7, respectively.

D. IAB - Formulation of a time function and distribution incorporating passenger unloading at the IAB and other delays due to customs inspection of mobile lounge, etc. in this general format, for job state 11:

$IAB = f(P) + \Delta$

E. Breakdown - Formulation of a time function and distribution incorporating the duration of mobile lounge breakdown and the transfer time of passengers between mobile lounges, for job states 14 and 15, respectively, in this general format:

$BK(k) = f(P)_k + \Delta_k$ --

Where:
- $f(P)_k$ is a function of the passenger transfer times between mobile lounges.
- Δ_k is a time distribution of the duration of mobile lounge breakdown time for mobile lounge K
- BK(k) is the total duration of breakdown ($k = 1$, $f(P)_k = 0$, for job state 14) or the total duration of passenger transfer times ($K = 2$, $\Delta_k = 0$, for job state 15)

F. Arrival/Departure Deviations - Formulation of a time function and distribution incorporating time deviations from the scheduled arrival or departure times in this general format:

$DEV(l) = \Delta_l$

Where:
- Δ_l is the deviate generation function that will adjust the scheduled arrival ($l = 0$) or departure ($l = 1$) times

II. TIME STUDIES

Through observation and analysis of the Mobile Lounge System, we were able to identify the primary events that were to be incorporated into our model. Therefore, in transforming these primary events into distinguishable elements to facilitate time study data collection and analysis, we tested and developed various forms, resulting in a "Mobile Lounge Time Study Sheet" (Figure A-2).

The ease in recording the various possible outcomes that may occur, demonstrates the flexibility of the "Mobile Lounge Time Study Sheet". For example, a departure and an international arrival can be recorded in sequence in one column, with adequate slots for flight data information such as flight numbers and number of passengers per flight.

Note also that the numerical index in the margin facilitates analysis when used in conjunction with the "Time Study Values" sheet (Figure A-3), which shows how to calculate the various job state time elements (Table A-1). It is from these time elements that the stochastic distributions will be developed and synthesized. The "Passenger Time Study Values" sheet (Figure A-4) simply isolates any passenger related data into a separate form.

MOBILE LOUNGE TIME STUDY SHEET

MOBILE LOUNGE NO.													
FLIGHT NO.													
NO. OF PASSENGERS													
NO. OF M/L PRESENTLY OPERATING													
SCHEDULED DEPARTURE TIME													
1. RAMP AGENT NOTIFIES DISPATCHER													
2. DISPATCHER ANNOUNCES DEPARTURE													
3. PASSENGERS BEGIN BOARDING M/L													
4. PASSENGERS FINISH BOARDING M/L													
5. DRIVER CLOSES DOORS OF M/L													
6. DRIVER OPENS DOORS OF M/L													
7. PASSENGERS FINISH BOARDING FLIGHT													
8. DRIVER CLOSES DOORS OF M/L													
9. DRIVER OPENS DOORS OF M/L AT G/1													
SCHEDULED ARRIVAL TIME													
SECOND FLIGHT NO.													
NO. OF PASSENGERS													
10. DISPATCHER NOTIFIED OF ARRIVAL													
11. DRIVER CLOSES DOORS OF M/L													
12. M/L WAITS FOR AIRCRAFT TO STOP													
13. END OF WAIT													
14. DRIVER OPENS DOORS OF M/L													
15. PASSENGERS BEGIN BOARDING M/L													
16. PASSENGERS FINISH BOARDING M/L													
17. DRIVER CLOSES DOORS OF M/L													
18. DRIVER OPENS DOORS OF M/L AT IAB													
19. PASSENGERS FINISH LEAVING M/L													
20. DRIVER OPENS DOORS OF M/L AT G/1													
21. PASSENGERS FINISH LEAVING M/L													

DATE: ______________________

TIMER: ______________________

TIME STUDY VALUES

JS#	STATEMENTS								
1.	5 - 2	.....	.....	.....	.....	.....	.....	.....	.....
2.	6 - 5	.....	.....	.....	.....	.....	.....	.....	.....
3.	8 - 6	.....	.....	.....	.....	.....	.....	.....	.....
4.	9 - 8	.....	.....	.....	.....	.....	.....	.....	.....
5.	(14- 8)-(13-12)	.....	.....	.....	.....	.....	.....	.....	.....
6.	(14-11)-(13-12)	.....	.....	.....	.....	.....	.....	.....	.....
7.	17 - 14	.....	.....	.....	.....	.....	.....	.....	.....
8.	20 - 17	.....	.....	.....	.....	.....	.....	.....	.....
9.	21 - 20	.....	.....	.....	.....	.....	.....	.....	.....
10.	18 - 17	.....	.....	.....	.....	.....	.....	.....	.....
11.	19 - 18	.....	.....	.....	.....	.....	.....	.....	.....
12.	20 - 19	.....	.....	.....	.....	.....	.....	.....	.....
16.	2 - 1	.....	.....	.....	.....	.....	.....	.....	.....
17.	13 - 12	.....	.....	.....	.....	.....	.....	.....	.....
DURATION:		.....	.....	.....	.....	.....	.....	.....	.....
FLIGHT NO.:		.....	.....	.....	.....	.....	.....	.....	.....
DATE-SHIFT:		.....	.....	.....	.....	.....	.....	.....	.....

TABLE A-1

Job State #	Job State Description
1.	Load M/L for departure at Gate 1
2.	Travel to departing flight
3.	Unload M/L for departure at Remote
4.	Travel empty to Gate 1
5.	Travel between aircraft at Remote
6.	Travel to arriving flight
7.	Unload arrival at Remote
8.	Travel loaded to Gate 1
9.	Unload M/L for arrival at Gate 1
10.	Travel from Remote to IAB
11.	Unload M/L at IAB
12.	Travel to Gate 1 from IAB
13.	Idle at Gate 1
14.	M/L breakdown
15.	Unload disabled M/L
16.	M/L waits for departure (passengers $\geq$ 70)
17.	M/L waits for arrival at Remote
18.	Aircraft ground time
19.	Other M/L travels to disabled M/L if loaded
20.	Aircraft ready for unloading
21.	Aircraft taxi time
22.	Late aircraft departure

PASSENGER TIME STUDY VALUES

FLIGHT NO.:	.....	.....	.....	.....	.....	.....	.....
NO. OF PASSENGERS:	.....	.....	.....	.....	.....	.....	.....
LOAD AT GATE 1 (DEP):	.....	.....	.....	.....	.....	.....	.....
UNLOAD AT GATE 1 (ARR):	.....	.....	.....	.....	.....	.....	.....
DURATION AT GATE 1:	.....	.....	.....	.....	.....	.....	.....
RATE PER PASSENGER (G/1):	.....	.....	.....	.....	.....	.....	.....
LOAD AT REMOTE (DEP):	.....	.....	.....	.....	.....	.....	.....
UNLOAD AT REMOTE (ARR):	.....	.....	.....	.....	.....	.....	.....
DURATION AT REMOTE:	.....	.....	.....	.....	.....	.....	.....
RATE PER PASSENGER (REM):	.....	.....	.....	.....	.....	.....	.....
UNLOAD AT IAB:	.....	.....	.....	.....	.....	.....	.....
RATE PER PASSENGER (IAB):	.....	.....	.....	.....	.....	.....	.....
DATE-SHIFT:	.....	.....	.....	.....	.....	.....	.....

We would like to point out here that a representative sample of data must be collected from both shifts, under various conditions, as well as different days of the week. The wide variation in operating policies, and the complexity of events that will affect the system must be realistically captured in the data collection process.

III. ANALYSIS OF TIME STUDIES

In order to make a reasonable estimate of the distribution of the time element that we have collected, we summarized our data in a frequency histogram (Figure A-5). Our approach was to compare visually the observed frequency histogram with those of several theoretical distributions, as it served to suggest what distributions we wanted to try. Having identified one or more theoretical distributions - such as normal, poisson, gamma, etc. - that may fit our data, we then determined the distribution parameters so as to proceed with statistical testing and development of our model. The following two examples highlight the procedures used in duplicating the job state distribution characteristics.

A. Job State #2

This time element in our simulation model consists of the mobile lounge travel time from Gate 1 to a departing flight in Remote. The frequency histogram in Figure A-5 depicts the nature of the time distribution of this job state according to our time study data. The first approach we took consisted of creating a cumulative probability distribution (Figure A-6). Nevertheless, we discarded this approach for the following reasons: (1) the use of this raw data implies that all one is doing is simulating the past, that is, the

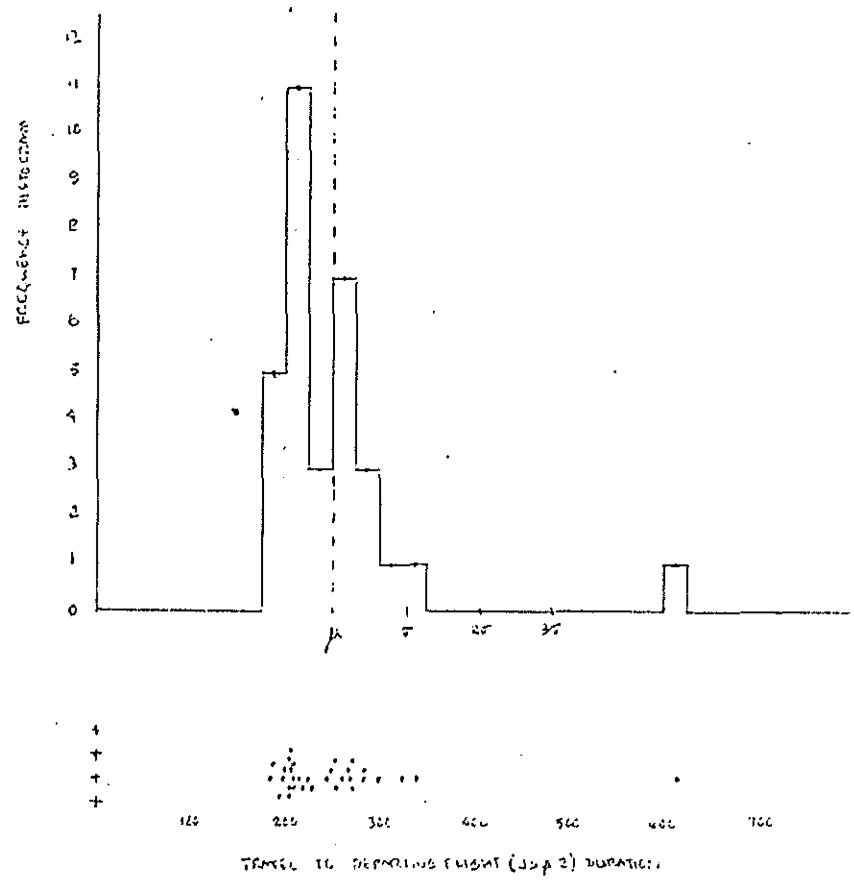
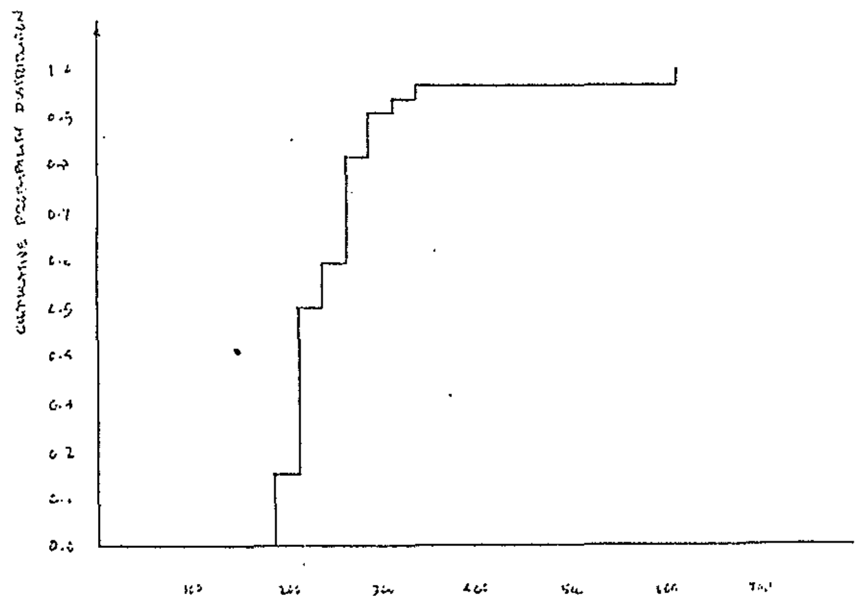


Figure A-5



μ = 256.26

σ = 77.131

Figure A-6

only events possible are those that actually occurred; (2) it is generally more efficient of computer time and storage requirements to use a theoretical probability distribution; (3) it is much easier to change the parameters of a theoretical distribution generator to perform sensitivity tests or to ask "what if" questions.

Therefore, we decided to capture the characteristics of this distribution via a gamma random deviate generator of the form

$$f(x) = \frac{X^{\alpha-1} e^{-x/\beta}}{\beta^{\alpha}(\alpha-1)!}$$

Where $\alpha = \frac{\mu^2}{\sigma^2}$, $\beta = \frac{\sigma^2}{\mu}$

Note that the mean μ and the variance σ^2 can be calculated from raw data by using:

$$\mu = \frac{\sum_{i=1}^{n} x_i}{n}$$

$$\sigma^2 = \frac{\sum_{i=1}^{n} (x_i - \mu)^2}{n-1}$$

For this particular job state the following values were obtained

$\mu = 250.28$ $\alpha = 10.36645$

$\sigma = 77.734$ $\beta = 24.14327$

And a frequency histogram may be seen in Figure A-7, which was truncated at our smallest observed value (TRUNC1 = 185.0).

```
INPUT DATA FILE [illegible]
INPUT NUMBER OF [illegible] STEP INTERVAL [illegible]
INPUT [illegible]
INPUT TOTAL NO. OF DATA POINTS [illegible]

SAMPLE MEAN [illegible]
SAMPLE [illegible]
STD. [illegible] 51.6[illegible]
MEDIAN [illegible]
MODAL CLASS INTERVAL IS 210 TO 225
MODE = 271.2[illegible]
RANGE = [illegible]
MINIMUM = [illegible]
MIDPOINT[illegible] 2[illegible].67
MIDPOINT[illegible] VARIANCE = [illegible].67
STD. DEV. = 51.8537

          0    15    30    45    60    75    90   105   120
```

Interval	Midpoint	Count
0–15	7.5	0
15–30	22.5	0
30–45	37.5	0
45–60	52.5	0
60–75	67.5	0
75–90	82.5	0
90–105	97.5	0
105–120	112.5	0
120–135	127.5	0
135–150	142.5	0
150–165	157.5	0
165–180	172.5	0
180–195	187.5	61
195–210	202.5	101
210–225	217.5	113
225–240	232.5	109
240–255	247.5	99
255–270	262.5	73
270–285	277.5	73
285–300	292.5	84
300–315	307.5	70
315–330	322.5	60
330–345	337.5	37
345–360	352.5	25
360–375	367.5	22
375–390	382.5	15
390–405	397.5	12
405–420	412.5	17
420–435	427.5	5
435–450	442.5	7
450–465	457.5	2
465–480	472.5	2
480–495	487.5	1
495–510	502.5	0
510–525	517.5	0
525–540	532.5	0
540–555	547.5	1
555–570	562.5	0
570–585	577.5	0
585–600	592.5	0
600–615	607.5	0
615–630	622.5	0
630–645	637.5	0
645–660	652.5	0
660–675	667.5	0
675–690	682.5	0
690–705	697.5	0

```
PROGRAM JS2          74/74    OPT=1                      FTN 4.6+428

      PROGRAM JS2(INPUT,OUTPUT,DATAA,TAPE5=INPUT,TAPE6=OUTPUT,
     XTAPE3=DATAA)
      DIMENSION RGAMM(1000),WORK(1000)
      ISEED1 = 987654321
      DO 30 I=1,1000
    1 TIME = GGTMAJ(ISEED1,10.3645,24.14327,1,WORK,RGAMM)
      IF(TIME - 185.0) 1,1,2
    2 WRITE(3,10) TIME
   10 FORMAT(1X,F10.3)
   30 CONTINUE
      ENDFILE 3
      REWIND 3
      STOP
      END
```

Figure A-7

B. Job State #3

This time element in our simulation model consists of the duration of loading time of departing passengers at Remote. Due to the interaction of the number of passengers, delay incurred that is not due to passengers, and the variable time elements of each, we chose regresssion analysis in order to estimate this job state time element.

Figure A-8 shows a plot of the total load duration (passenger load time plus delay time) of job state #3. The least squares linear regression technique on this data resulted in the equation

$$y = mx + b = 5.88x + 86.62$$

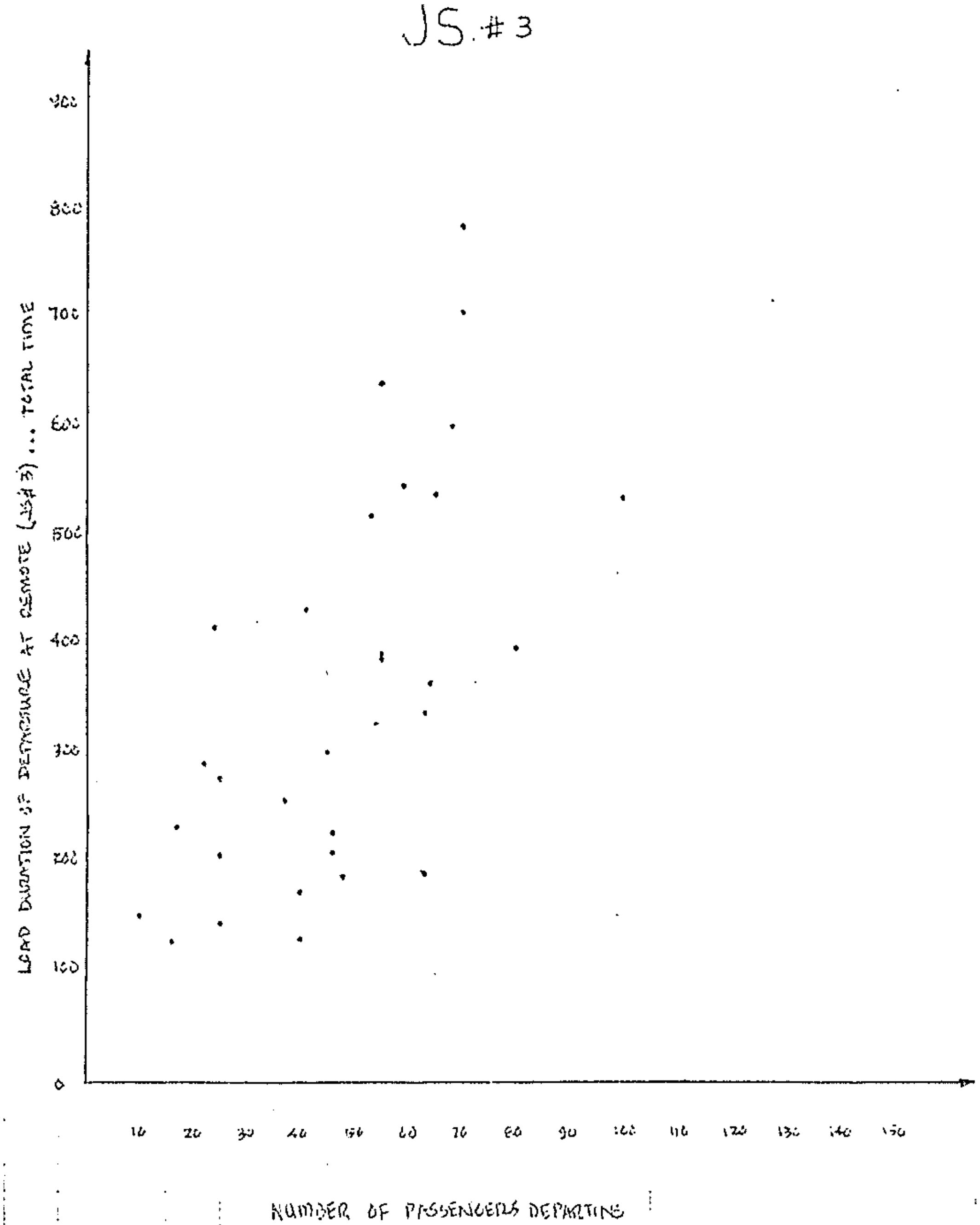
with a correlation coefficient of

$$\rho = 0.683$$

and a standard deviation

$$\sigma_y = 180.63 ,$$

which indicated some degree of relationship between the number of passengers and the total time, though not precisely linear.



$\sigma_x = 20.98$

$\sigma_y = 180.63$

$m = 5.88$

$b = 86.62$

$\rho = 0.683$

$y = mx + b = 5.88x + 86.62$

Figure A-8

To better determine the amount and source of variability, a separate plot of passenger loading time alone, without delays, is found in Figure A-9. The least squares linear regression technique on this element alone gave excellent results, as in the equation

$$y = mx + b = 5.35x - 35.36$$

with a correlation coefficient of

$$\rho = 0.905$$

and a standard deviation

$$\sigma_y = 124.17$$

which indicates a very high linear relationship between the number of passengers and their loading time. Both equations are plotted on Figure A-10.

Therefore, it only remained to compare how a composite function compared with a linear regression on the total time.

In Figure A-11, a plot of the delay not due to passengers shows the random nature of its occurence, so a

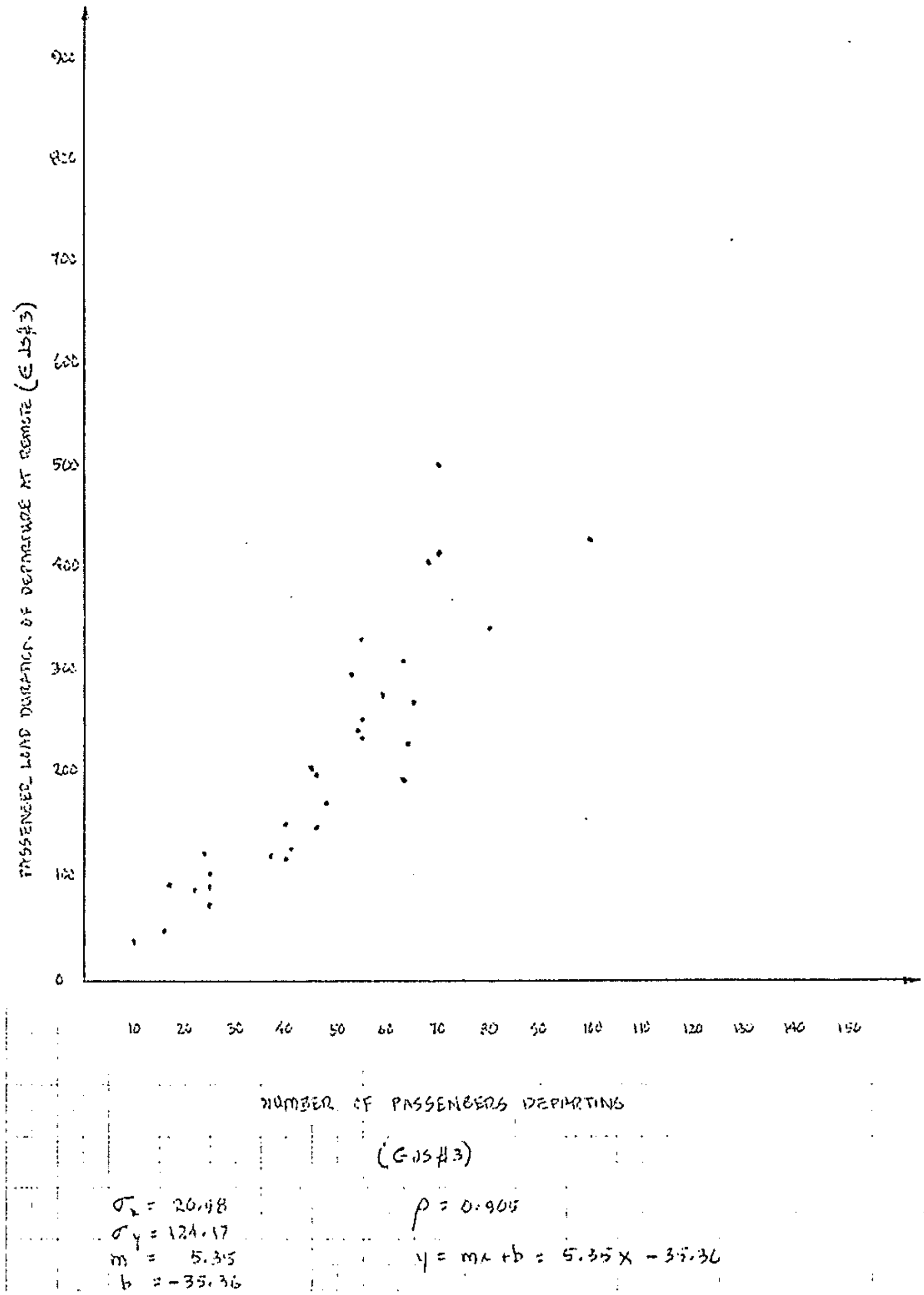
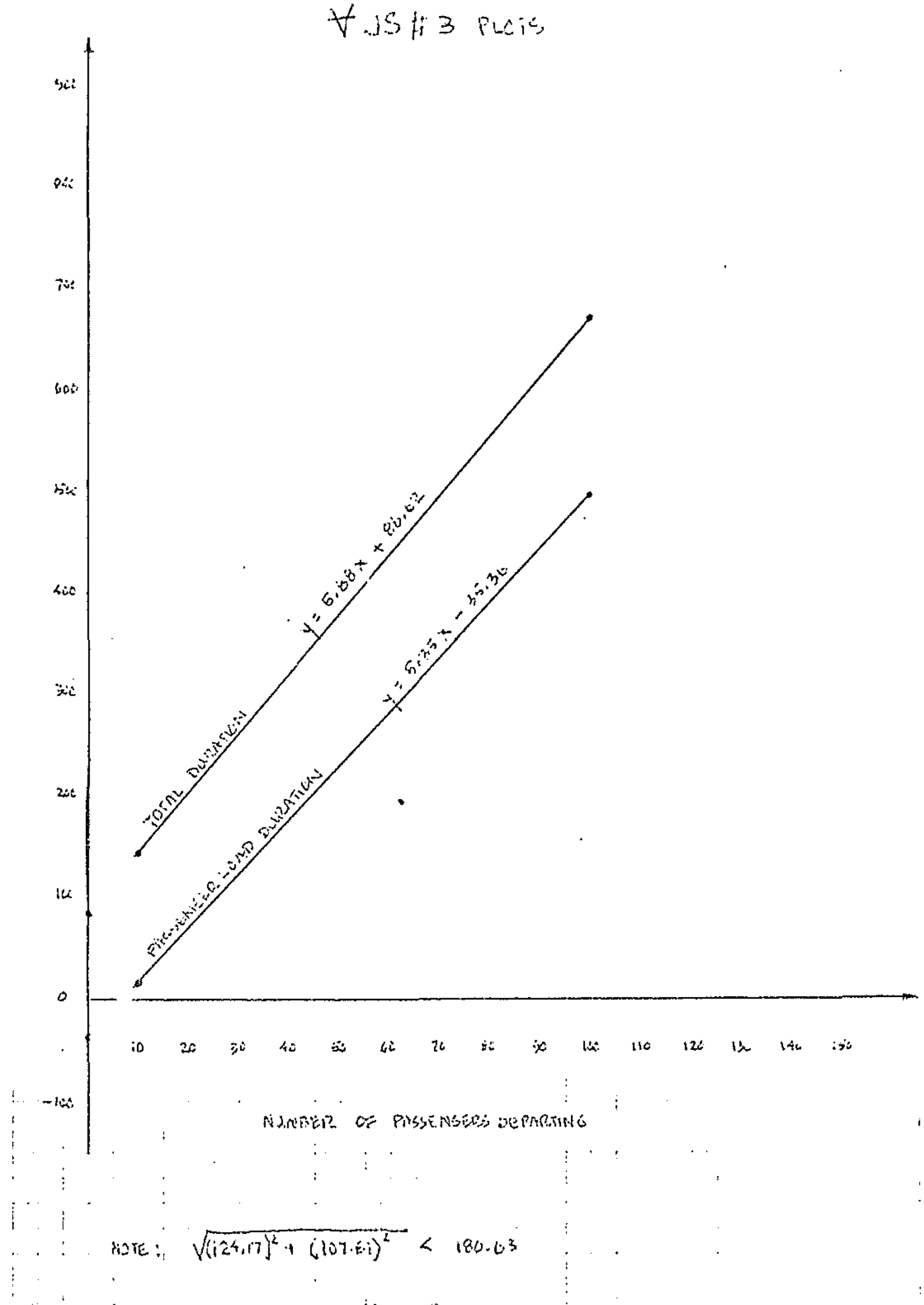

0
100
200
300
400
500
600
700
800
900
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
NUMBER OF PASSENGERS DEPARTING
σ_x = 20.98
σ_y = 124.17
m = 5.35
b = -35.36
ρ = 0.905
y = mx + b = 5.35x - 35.36

Figure A-9



TOTAL DURATION
PASSENGER LOAD DURATION
NUMBER OF PASSENGERS DEPARTING

Figure A-10

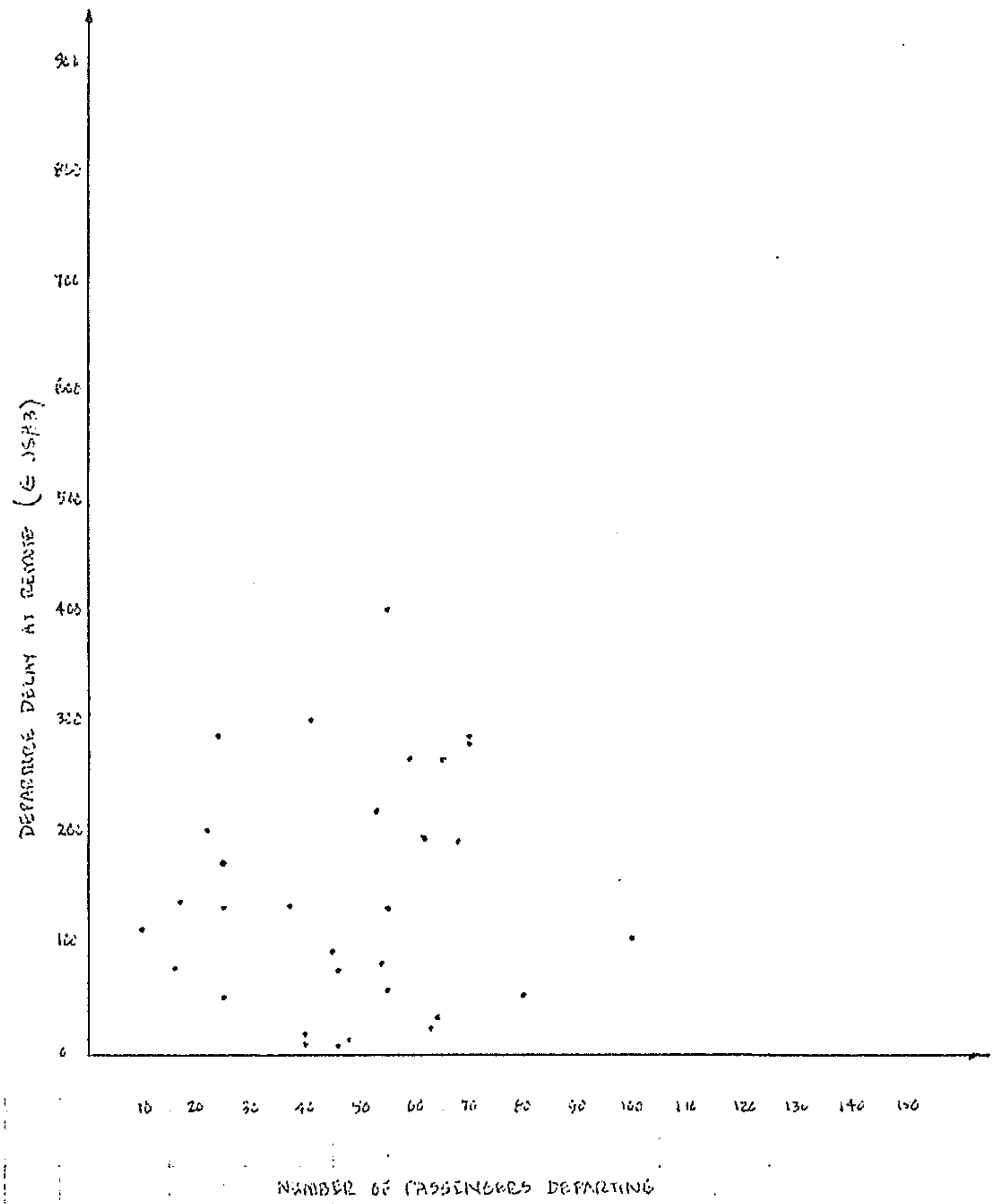


Figure A-11

frequency histogram (Figure A-12) gave a better indication of the delay occurence at Remote in this job state. We chose to duplicate this distribution utilizing a gamma random deviate generator with these parameters:

$$\mu = 143.53 \qquad \alpha = 1.77242$$

$$\sigma = 107.81 \qquad \beta = 80.97953$$

Note that the composite form $R(j) = f(P)_j + \Delta_j$ was chosen because it gave more accurate and tighter results, that is,

$$\left[(124.17)^2 + (107.81)^2\right]^{1/2} < 180.63$$

A random error component ϵ was also included in our linear regression analysis, to account for the variation in passenger load time, assumed to be distributed normal (0, 1). Therefore, our linear regression equation is of the form

$$y = mx + b + \epsilon = 5.35x - 35.36 + 124.17[N(0,1)]$$

where $\epsilon \sim N(0,1) = \sigma_y[N(0,1)]$.

Here again we chose to truncate our distribution at our

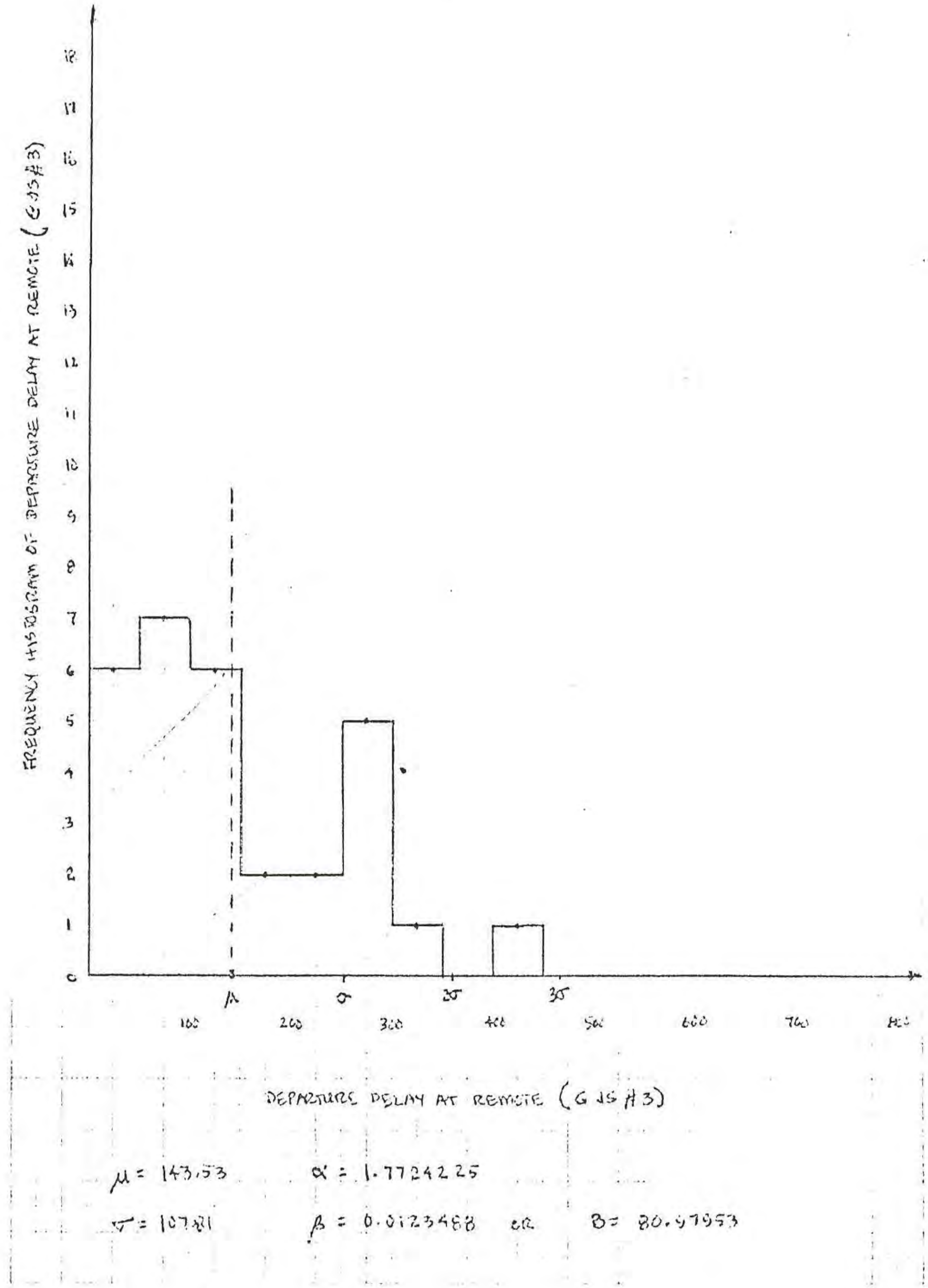

FREQUENCY HISTOGRAM OF DEPARTURE DELAY AT REMOTE (G 15 #3)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
μ
σ
2σ
3σ
100
200
300
400
500
600
700
800
DEPARTURE DELAY AT REMOTE (G 15 #3)
μ = 143.53
σ = 107.81
α = 1.7724225
β = 0.0123488 OR B = 80.97953

Figure A-12

smallest observed value (TRUNC3 = 130.0).

See Figures A-13 and A-14 for the frequency histogram of the computer results of the delay distribution, and the end result of the total job state random time generator.

C. Software Used

By this time, it has become apparent that we used several proven computer routines that were available to us at the Office of Computing Services on Georgia Tech Campus.

Some documentation of these library (IMSLIP, MSFLIB) subroutines (GGTMAJ, GGNOF, NRML) are provided for the reader's convenience, by courtesy of Control Data Corporation, as we used their Cyber 70 Model 74-28/CDC 6400. (See Appendix B). Other questions in this area can be directed to:

Dwighd D. Delgado
16000 Terrace Road
Apt. 1906
Cleveland, Ohio
44112

or

Eddie L. Holcomb
131 Hillandale
Toccoa, Georgia
30577

or

Jerry W. Segers
Department Manager
Office of Computing Services
Georgia Tech
Atlanta, Georgia
30332

```
INPUT DATA FILE NAME
INPUT ENDPOINTS OF ENTIRE INTERVAL,A & B
INPUT UNIT LENGTH OF CLASS INTERVALS, U
INPUT TOTAL NO. OF DATA POINTS, N

SAMPLE MEAN= 145.623
SAMPLE VARIANCE= 11667.3
STD. DEVIATION= 108.016
MEDIAN= 122.716
MODAL CLASS INTERVAL IS  50  TO  75
MODE= 51.3231
RANGE= 790.484
MIDRANGE= 395.645
MIDPOINT*FREQUENCY BASED MEAN= 143.925
MIDPOINT*FREQUENCY BASED VARIANCE= 10960.
STD. DEV.= 104.69

              0    15    30    45    60    75    90   105   120   135

    0     -
   12.5   -*******************( 58 )
   25     -
   37.5   -******************************************( 126 )
   50     -
   62.5   -*******************************************( 129 )
   75     -
   87.5   -*******************************( 93 )
  100     -
  112.5   -**********************************( 104 )
  125     -
  137.5   -*******************************( 95 )
  150     -
  162.5   -******************************( 91 )
  175     -
  187.5   -*****************( 53 )
  200     -
  212.5   -******************( 56 )
  225     -
  237.5   -************( 37 )
  250     -
  262.5   -************( 36 )
  275     -
  287.5   -**********( 32 )
  300     -
  312.5   -*******( 23 )
  325     -
  337.5   -*****( 17 )
  350     -
  362.5   -****( 14 )
  375     -
  387.5   -**( 6 )
  400     -
  412.5   -*( 4 )
  425     -
  437.5   -***( 9 )
  450     -
  462.5   -*( 5 )
  475     -
  487.5   -*( 4 )
  500     -
  512.5   -( 2 )
  525     -

  537.5   -( 2 )
  550     -
  562.5   -( 1 )
  575     -
  587.5   -( 0 )
  600     -
  612.5   -( 1 )
  625     -
  637.5   -( 0 )
  650     -
  662.5   -( 0 )
  675     -
  687.5   -( 0 )
  700     -
```

```
PROGRAM GAMMA        74/74    OPT=1

      PROGRAM GAMMA(INPUT,OUTPUT,DATAA,TAPE5=INPUT
     XTAPE3=DATAA)
      DIMENSION RGAMM(1000),WORK(1000)
      ISEED1 = 987654321
      DO 30 I=1,1000
    1 DELAYT = GGTMAJ(ISEED1,1.77242,80.97953,1,WO
      IF(DELAYT) 1,1,2
    2 WRITE(3,10) DELAYT
   10 FORMAT(5X,F10.3)
   30 CONTINUE
      ENDFILE 3
      REWIND 3
      STOP
      END
```

Figure A-13

NOPASS	RANDOM	DELAYT	PLOADT
10	-.7775	214.77	136.37
11	1.7055	99.68	335.43
12	.9522	31.27	179.35
13	.1553	133.10	186.57
14	-.2139	258.54	259.02
15	-.6508	339.18	303.45
16	.3424	236.91	373.66
17	-.1268	123.67	163.53
18	.6353	227.73	374.26
19	.8120	82.20	251.50
20	1.2675	85.72	313.74
21	-.3333	277.16	306.56
22	1.0763	35.97	251.95
23	.9375	149.36	360.56
24	-1.1595	292.59	241.34
25	-2.4318	474.57	271.11
26	1.3562	75.87	343.31
27	-1.2073	120.38	139.56
28	-.3409	254.74	221.38
29	.3264	59.82	294.54
30	-.6215	103.51	156.48
31	.9017	15.90	233.63
32	.1552	230.73	445.34
33	1.0358	135.53	411.54
34	-.1161	57.11	133.23
35	1.3530	129.20	443.39
36	.2420	116.63	304.71
37	-.0318	99.17	151.28
38	.7111	48.93	297.14
39	-.2511	215.93	356.45
40	.1875	341.14	543.06
41	-.3397	316.34	458.14
42	.2981	14.55	240.91
43	-.3544	156.84	337.53
44	-.7383	92.51	133.63
45	.5665	74.56	350.23
46	-1.1965	255.58	320.39
47	-.5263	154.50	305.24
48	.9346	146.82	484.31
49	.3333	57.04	393.71
50	.5557	144.55	445.68
51	-1.3324	302.47	372.15
52	.7654	50.34	388.22
53	.6598	104.91	434.63
54	-.4956	373.15	554.65
55	1.2780	74.40	491.98
56	.7177	77.58	430.94
57	.7119	249.71	637.59
58	-.2353	161.82	407.54
59	1.5444	88.34	563.33
60	.1563	113.75	413.79
61	-2.1010	151.00	181.11
62	.3328	71.11	367.79
63	-1.7239	129.59	275.56
64	-.3349	355.67	621.11
65	-.6076	313.17	555.07
66	1.2739	134.65	533.74
67	-1.9951	63.40	171.17
68	-1.0263	119.61	316.62
69	-1.0039	209.49	393.70
70	-.3748	165.89	462.49
71	-1.1795	172.49	370.65
72	-.9181	34.17	233.43
73	-.7963	57.28	313.59
74	.2470	50.44	446.02
75	.3781	125.48	605.15
76	.2201	166.85	567.42
77	-.7875	60.69	434.99
78	.7325	130.96	603.65
79	.5927	91.87	542.75
80	-.1307	134.51	410.33
81	1.0529	239.93	749.01
82	1.5984	40.74	642.54
83	1.3350	37.46	611.85
84	.0495	142.39	562.37
85	-1.3779	476.28	652.43
86	-.2475	55.27	474.11
87	-.5465	75.41	437.02
88	1.2917	157.70	754.16
89	.4340	21.50	520.58
90	-.2217	197.47	605.03
91	-1.0071	293.84	626.32
92	.9672	307.18	844.12
93	1.4043	105.23	754.45
94	.0558	287.14	754.07
95	-.1103	208.45	[illegible]
96	.3760	109.47	636.85
97	-.2557	65.48	523.30
98	.1018	94.71	681.34
99	.1612	208.06	821.75
100	-1.0548	95.47	464.08

FOR Y = M * X + L, THE VALUES ARE ...

M = 4.37   B = 155.28   K = .74

PROGRAM JS3   74/74   CPT=1   FTN 4.6+428

```
      PROGRAM JS3(INPUT,OUTPUT,DATAB,TAPE5=INPUT,TAPE6=OUTPUT,
     XTAPE3=DATAB)
      DIMENSION RGAMMS(1000),WORK(2)
      ISEED = 123456789
      ISEED1 = 987654321
      SUMX=SUMX2=SUMY=SUMY2=SUMXY=0.0
      N = 0.0
      WRITE(3,4)
    4 FORMAT(1H,5X,"NOPASS",6X,"RANDOM",6X,"DELAYT",6X,"PLOADT",
     X//)
      DO 30 NOPASS=10,100
    5 RANDOM = GGNOF(ISEED)
      PLOADT = 5.39*NOPASS -35.36 + 124.17*RANDOM
      DELAYT = GGTMAC(ISEED1,1.77242,80.57953,1,WORK,RGAMMS)
      PLOADT = PLOADT + DELAYT
      IF(PLOADT -130.0) 5,8,8
    8 WRITE(3,10) NOPASS,RANDOM,DELAYT,PLOADT
   10 FORMAT(7X,I3,6X,F8.4,4X,F8.2,4X,F8.2)
      X = NOPASS
      Y = PLOADT
      SUMXY = SUMXY + X*Y
      SUMX = SUMX + X
      SUMX2 = SUMX2 + X**2
      SUMY = SUMY +Y
      SUMY2 = SUMY2 + Y**2
      N = N + 1
   30 CONTINUE
      AN = N
      A = SUMXY - SUMY*SUMX/AN
      B = SUMX2 - (SUMX**2)/AN
      C = SUMY2 - (SUMY**2)/AN
      EM = A/B
      R = A/SQRT(B*C)
      BEE = (SUMY - EM*SUMX)/AN
      WRITE(3,40)
   40 FORMAT(//,5X," FOR Y = M * X + B, THE VALUES ARE ...")
      WRITE(3,50) EM,BEE,R
   50 FORMAT(/,5X,"M = ",F6.2,5X,"B = ",F6.2,5X,"R = ",F6.2)
      ENDFILE 3
      REWIND 3
      STOP
      END
```

Figure A-14

IV. REFINEMENTS

In order to upgrade the performance of our simulation model and to maintain and/or improve its relevance with the current operation of the Mobile Lounge System, three main areas come to mind:

A. Data Collection

More and constant data gathering, not only to improve the statistical fit of the theoretical distributions with actual data, but also to capture the seasonal characteristics (i.e., Christmas) of the system, would greatly improve the accuracy of our simulation model.

B. Computations

As more data is collected, the need may arise to compare various theoretical distributions and their performance with actual distribution data for each individual time element. For example, comparison between the gamma and the normal generator and their frequency histogram results may render one distribution function more desirable than another under various conditions.

C. Other

There are several improvement opportunities available in our simulation model that would also enhance the reliability of scheduling aircraft into Remote. These areas primarily consist of departure and arrival deviations, which are subject to change according to time of day, day of week, etc.

Another area involves the duration and the breakdown frequency of the mobile lounges, as these are subject to change as time passes, and as to how effective preventative maintenance can be.

There are also other job states which can be added to the model to "predict" the performance of the system. These may include four mobile lounges, relocation of IAB under Gate 1, etc.

APPENDIX B

This appendix contains some documentation of the computer library routines used in our simulation program. They are:

I. IMSLIB

a. GGEXP - generates exponential deviates

b. GGNOF - generates normal (0, 1) deviates

c. GGPOSR - generates poisson deviates

d. GGTMAJ - generates gamma deviates

e. GGUB - basic uniform random number generator

II. MSFLIB

a. NRML - generates normal (μ, σ^2) deviates

Similar computer library routines are available in the General Electric Computer Software.

IMSL LIB3-0005
Revised
November, 1975

L I B R A R Y 3

Reference Manual

This manual contains a detailed discussion of IMSL Library 3, an extensive collection of mathematical and statistical subroutines written in FORTRAN, for the CDC 6000/7000 Series, and CYBER 70/170 Series machines. The discussion includes subroutine descriptions as well as recommendations for use and implementation into the user's library environment.

V O L U M E I

C H A P T E R S A - I

Product: IMSL Library 3, Edition 5, 1975
(FORTRAN) CDC 6000/7000,
CYBER 70/170 Series

INTRODUCTION

IMSL Library 3 is a set of computational subroutines written in FORTRAN and tested on the CDC 6600. All subroutines in the library adhere to a common set of conventions, developed by IMSL. This implies consistency across the set.

Abilities residing in Library 3 have the following attributes:

1. Testing was performed in the KRONOS environment.
2. For each routine which has error detecting capability, the user is protected by default. That is, if a user chooses to ignore error possibilities, he is warned. To prevent the appearance of this warning, he must revise the routine by omitting all FORTRAN statements between statement number 9000 and the RETURN statement.
3. Each ability conforms to established conventions, in coding and documentation.
4. Each ability was designed by individuals at the doctoral level, and documented to be used by technical personnel in fields of engineering, medicine, agriculture,..., and in research activities.
5. Accuracy of results, clarity of documentation, and efficiency of coding were given first priority in development.
6. No attempt has been made to teach mathematics or statistics in this manual. Users are guided to correct abilities for specific problems. Periodicals and books are referenced for details of algorithmic development.
7. Often, tests for applicability of the algorithm are applied; the user is warned if the algorithm fails. Pitfalls to be avoided in usage are noted.
8. All information pertaining to library usage is available in this manual. All information pertaining to the usage of one ability is in one place. Documentation is a combination of printed matter and machine listings.
9. Machine readable documentation permits browsing and debugging. It is pictured in the manual and distributed with the source programs. For more difficult usage problems, users may refer to printed information in the manual.
10. Designers and implementers (or IMSL personnel responsible for the code) are noted in the documentation, for user reference.
11. Symmetric, band, band symmetric, and Hermitian matrix abilities utilize memory saving storage techniques.
12. With the exception of the Utility Functions Chapter abilities, all IMSL library abilities are input-output free.
13. Most routines have documented examples of input and results.

IMSL makes no warrants pertinent to its programs other than those stated above. IMSL is the sole owner of the programs in the IMSL Library and is solely responsible for their operation. IMSL is the sole source of technical information regarding these programs, and a mechanism for contacting IMSL for such information is given under the title "USER-IMSL INTERACTION" later in this introduction.

```
      SUBROUTINE GGEXP  (ISEED,XM,N,R)
C
C-GGEXP---------S-------LIBRARY 3----------------------------------------
C
C   FUNCTION            - GENERATES EXPONENTIAL DEVIATES WITH MEAN XM
C                           AND STANDARD DEVIATION XM.
C                           THE DISTRIBUTION FUNCTION IS P=1-EXP(-X/XM).
C                           WHERE X IS GREATER THAN OR EQUAL TO ZERO.
C                           THIS ROUTINE USES UNIFORM (0,1) DEVIATES
C                           IN VECTOR R, GENERATED BY GGUB, AND
C                           TRANSFORMS USING
C                                      -1
C                              X = P     (Y).
C   USAGE               - CALL GGEXP(ISEED,XM,N,R)
C   PARAMETERS   ISEED  - INPUT. AN INTEGER VALUE IN THE EXCLUSIVE
C                           RANGE (1,2147483647). ISEED IS USED TO
C                           INITIATE THE GENERATION, AND ON EXIT, HAS
C                           BEEN REPLACED BY A NEW ISEED FOR SUBSEQUENT
C                           USE.
C                XM     - INPUT MEAN VALUE.
C                N      - INPUT NUMBER OF DEVIATES TO BE GENERATED.
C                R      - OUTPUT VECTOR CONTAINING THE EXPONENTIAL
C                           DEVIATES. R MUST BE AT LEAST N IN LENGTH.
C   PRECISION           - SINGLE
C   REQD. IMSL ROUTINES - GGUB
C   LANGUAGE            - FORTRAN
C-----------------------------------------------------------------------
```

```
      FUNCTION    GGNOF   (ISEED)
C
C-GGNOF----------S-------LIBRARY 3------------------------------------
C
C   FUNCTION            - GENERATE ONE NORMAL (0,1) PSEUDO RANDOM
C                           NUMBER BY INVERTING THE NORMAL PROBABILITY
C                           DISTRIBUTION.  GGUB (CODED INTERNALLY)
C                           PROVIDES THE UNIFORM PSEUDO RANDOM DEVIATE.
C   USAGE               - FUNCTION GGNOF(ISEED)
C   PARAMETERS   GGNOF  - RESULTANT NORMAL (0,1) DEVIATE.
C                ISEED  - INPUT.  AN INTEGER VALUE IN THE EXCLUSIVE
C                           RANGE (1,2147483647).  ISEED IS REPLACED BY
C                           A NEW ISEED TO BE USED IN SUBSEQUENT CALLS.
C   PRECISION           - SINGLE
C   REQD. IMSL ROUTINES - MERFI,UERTST
C   LANGUAGE            - FORTRAN
C---------------------------------------------------------------------
```

FUNCTION GGNOF (ISEED)

Purpose

Generate one pseudo random normal (0,1) deviate.

Algorithm

Given ISEED, IMSL routine GGUBF is used (coded internally) to generate a uniform (0,1) pseudo random deviate. Then the inverse normal routine MDNRIS is called to transform this deviate to a normal deviate with mean zero and unit variance.

```
      SUBROUTINE GGPOSH (RLAM,ISEED,N,K,IER)
C
C-GGPOSH---------S--------LIBRARY 3-------------------------------------
C
C   FUNCTION            - GENERATE POISSON RANDOM DEVIATES
C   USAGE               - CALL GGPOSH(RLAM,ISEED,N,K,IER)
C   PARAMETERS   RLAM   - INPUT POISSON PARAMETER. RLAM MUST BE
C                           GREATER THAN 0.
C                ISEED  - AN INTEGER VALUE IN THE EXCLUSIVE RANGE
C                           (1,2147483647). ISEED IS USED TO INITIATE
C                           THE GENERATION, AND ON EXIT, HAS BEEN
C                           REPLACED BY A NEW ISEED FOR SUBSEQUENT USE.
C                           (INPUT)
C                N      - THE NUMBER OF RANDOM NUMBERS TO BE GENERATED.
C                           (INPUT)
C                K      - RESULTANT VECTOR OF LENGTH N.
C                IER    - ERROR PARAMETER.
C                         TERMINAL ERROR =128+N.
C                           N = 1 INDICATES THAT RLAM WAS SPECIFIED
C                             LESS THAN OR EQUAL TO ZERO.
C   PRECISION           - SINGLE
C   REQD. IMSL ROUTINES - GGUB,UERTST
C   LANGUAGE            - FORTRAN
C-----------------------------------------------------------------------
```

CALL GGPOSH(RLAM,ISEED,N,K,IER)

Purpose

GGPOSH generates N Poisson random deviates.

Algorithm

The resultant K_i, where i=1,2,...,N, is a number j such that $r_1 r_2 \ldots r_j$ is greater than $e^{-\lambda}$. $r_1, r_2, \ldots, r_j$ are uniform random numbers generated by GGUB; λ is stored in RLAM.

See reference: Schaffer, Henry E., "Algorithm 369, generator of random numbers satisfying the Poisson distribution", Comm. ACM, 13(1) 1970, 49.

Programming Notes

Subroutine GGPOSH should be used to generate Poisson deviates when RLAM is changed frequently and when N, the number of deviates requested, is small. In other cases, subroutine GGPOSR should be used.

Example

Using a starting ISEED=123457, and generating 1000 Poisson (λ) deviates, R_i, the mean ($\hat{\mu}$) and variance ($\hat{\sigma}^2$) were computed. The expected values for the estimators corresponding to $\hat{\mu}$ and $\hat{\sigma}^2$ are both λ.

$$\hat{\mu}=\sum_i R_i/1000$$

$$\hat{\sigma}^2=\sum_i (R_i-\hat{\mu})^2/999.$$

λ	$\hat{\mu}$	$\hat{\sigma}^2$	$\sigma_{\hat{\mu}}$
0.5	.556 .462 .506	.529 .459 .520	0.02
3.5	3.571 3.488 3.430	3.378 3.225 3.599	0.06
6.5	6.508 6.460 6.547	6.201 6.600 6.704	0.08
9.5	9.485 9.526 9.600	9.336 9.642 9.722	0.10

```
      SUBROUTINE GGPOSR (RLAM,ISEED,N,K,IER)
C
C-GGPOSR--------S-------LIBRARY 3---------------------------------------
C
C   FUNCTION            - GENERATE POISSON RANDOM DEVIATES
C   USAGE               - CALL GGPOSR(RLAM,ISEED,N,K,IER)
C   PARAMETERS   RLAM   - INPUT POISSON PARAMETER. RLAM MUST BE
C                           IN THE RANGE (0.,670.) INCLUSIVE.
C                ISEED  - INPUT.  AN INTEGER VALUE IN THE EXCLUSIVE
C                           RANGE (1,2147483647). ISEED IS USED TO
C                           INITIATE THE GENERATION, AND ON EXIT, HAS
C                           BEEN REPLACED BY A NEW ISEED FOR SUBSEQUENT
C                           USE.
C                N      - INPUT.  THE NUMBER OF RANDOM NUMBERS TO BE
C                           GENERATED.
C                K      - RESULTANT VECTOR OF LENGTH N.
C                IER    - ERROR PARAMETER.
C                         TERMINAL ERROR = 128+N.
C                           N = 1 INDICATES THAT RLAM WAS SPECIFIED
C                             LESS THAN ZERO OR GREATER THAN 670.
C   PRECISION           - SINGLE
C   REQD. IMSL ROUTINES - GGUB,UERTST
C   LANGUAGE            - FORTRAN
C-----------------------------------------------------------------------
```

CALL GGPOSR(RLAM,ISEED,N,K,IER)

Purpose

GGPOSR generates N Poisson random deviates.

Algorithm

The resultant K_i where i=1,2,...,N, is the smallest number, m, such that r is less than or equal to $\sum_{j=0}^{m} e^{-\lambda}\lambda^j/j!$ where r is a uniform random number generated by GGUB; λ is stored in RLAM.

See reference: Snow, Richard H., "Algorithm 342, generator of random numbers satisfying the Poisson distribution", Comm. ACM, 11(12) 1968, 819.

Programming Notes

Subroutine GGPOSR should be used to generate Poisson deviates when RLAM is not changed frequently or when N, the number of deviates requested is large. In other cases GGPOSH should be used.

For large generated uniform numbers and large λ, it is possible that a calculated term of the Poisson sum will not add, given a particular machine precision, to the current sum. In this case, which occurs with very small probability, the Poisson deviate is set to the sum of its count prior to the occurrence and a uniform deviate in the range [0.5, 1.5]λ.

Example

Using a starting ISEED=123457, and generating 1000 Poisson (λ) deviates, R_i, the mean $(\hat{\mu})$ and variance $(\hat{\sigma}^2)$ were computed. The expected values for the estimators corresponding to $\hat{\mu}$ and $\hat{\sigma}^2$ are both λ.

$$\hat{\mu}=\sum_i R_i/1000$$

$$\hat{\sigma}^2=\sum_i (R_i-\hat{\mu})^2/999.$$

λ	$\hat{\mu}$	$\hat{\sigma}^2$	$\sigma_{\hat{\mu}}$
0.5	.534	.511	0.02
	.521	.534	
	.473	.492	
3.5	3.548	3.651	0.06
	3.506	3.631	
	3.458	3.344	
6.5	6.560	6.887	0.08
	6.515	6.812	
	6.450	6.233	
9.5	9.587	9.799	0.10
	9.529	9.932	
	9.445	9.025	

```
      SUBROUTINE GGTMAJ (ISEED,A,B,N,W,R)                               GGTJ0010
C                                                                       GGTJ0020
C-GGTMAJ--------S-------LIBRARY 3---------------------------------------GGTJ0030
C                                                                       GGTJ0040
C   FUNCTION            - GENERATE GAMMA RANDOM DEVIATES. (REJECTION    GGTJ0050
C                           METHOD)                                     GGTJ0060
C   USAGE               - CALL GGTMAJ(ISEED,A,B,N,W,R)                  GGTJ0070
C   PARAMETERS   ISEED  - INPUT.  AN INTEGER VALUE IN THE EXCLUSIVE     GGTJ0080
C                           RANGE (1,2147483647). ISEED IS USED TO      GGTJ0090
C                           INITIATE THE GENERATION, AND ON EXIT, HAS   GGTJ0100
C                           BEEN REPLACED BY A NEW ISEED FOR SUBSEQUENT GGTJ0110
C                           USE.                                        GGTJ0120
C                A      - INPUT. FIRST GAMMA PARAMETER. A MUST BE       GGTJ0130
C                           GREATER THAN ZERO (SHAPE PARAMETER).        GGTJ0140
C                           AND SHOULD BE GREATER THAN 0.1              GGTJ0150
C                B      - INPUT. SECOND GAMMA PARAMETER (SCALE          GGTJ0160
C                           PARAMETER). BETA MUST BE GREATER THAN ZERO. GGTJ0170
C                N      - INPUT. NUMBER OF DEVIATES TO BE GENERATED     GGTJ0180
C                W      - WORKING STORAGE VECTOR OF LENGTH M, WHERE M   GGTJ0190
C                           IS THE GREATEST INTEGER IN A+1. ON OUTPUT, WGGTJ0200
C                           CONTAINS THE NEGATIVE OF LOGARITHMS OF      GGTJ0210
C                           RANDOM UNIFORM DEVIATES.                    GGTJ0220
C                R      - OUTPUT VECTOR OF LENGTH N CONTAINING THE      GGTJ0230
C                           GAMMA DEVIATES.                             GGTJ0240
C   PRECISION           - SINGLE                                        GGTJ0250
C   REQD. IMSL ROUTINES - GGBTA,GGUB                                    GGTJ0260
C   LANGUAGE            - FORTRAN                                       GGTJ0270
C-----------------------------------------------------------------------GGTJ0280
```

CALL GGTMAJ(ISEED,A,B,N,W,R)

Purpose

GGTMAJ generates an N-vector of gamma (A,B) deviates which are distributed as: $Kx^{A-1}\exp(-x/B)$; x,A,B all positive. $K=1/(\Gamma(A)B^{A})$

Algorithm

A rejection technique due to Johnk is used.

See references: (1) Johnk, M.D., "Erzung von betaverteiler und gammaverteiler zufallzahlen", Metrika, 8(2) 1964. (2) Phillips, Don T., and Beightler, Charles S., "Procedures for generating gamma variates with non-integer parameter sets", Journal of Statistical Computation and Simulation, 1, 1972, 197-208.

Programming Notes

This algorithm requires calculations which could cause under or overflows. Their detection prior to calculations is too expensive. Results should be acceptable if they occur.

Example

Using two different seeds, the following table of statistics was produced. Considering these results and those given in routine GGTMA1, it is felt that this generator is to be preferred over GGTMA1, especially for A larger than 1. Reference 2 above notes that tests imply a preference for GGTMA1 for small A (in the (.1, 1) range). See the GGTMA1 document (Example). This method (Johnk) requires more time than GGTMA1, but test results seem to allow more reliance on the generated deviates' distributional form.

Timing statistics: As noted in the comparison given in GGTMA1, when 1000 deviates were produced (IBM 370/155) on one call, GGTMAJ required .65 ms per deviate when A=B=1. 1.10 ms per deviate was required when A=B=3.

TEST OF GGTMAJ GAMMA GENERATOR

B=2.0

* MEANS REJECTION AT THE 5 PERCENT LEVEL IS IN ORDER

** MEANS REJECTION AT THE 1 PERCENT LEVEL IS IN ORDER

(2) IMPLIES THAT THE MEAN IS NOT WITHIN THE TWO STANDARD DEVIATION CONFIDENCE BOUND

A	N=10	N=50	N=100
.2	.43 / .41	.55 / .29	.45 / .29
	.25 / .25	1.29 / .40	1.20 / .47
	.34 / .33	.89 / .88	.93 / .22
.35	.37 / .26	.58 / .79	.53 / .81
	.27 / .29	.42 / 2.80	.74 / 2.45
	.61 / .96	.38 / .85	.52 / .37
.5	.43 / .91	.99 / 1.07	.87 / 1.01
	.54 / 1.66	1.47 / 1.42	1.70 / 1.19
	.76 / 1.00	.38 / .20	.42 / .12
.7	1.18 / 1.51	1.54 / 1.52	1.27 / 1.56
	.63 / 2.46	2.53 / 3.04	2.63 / 2.76
	.61 / .92	.56 / .66	.25 / *
.85	1.16 / 1.80	1.82 / 1.73	1.79 / 1.68
	1.08 / .90	2.71 / 2.93	2.87 / 2.63
	1.00 / .15	.39 / .97	* / .41
1.0	1.78 / 2.30	2.52 / 2.14	2.28 / 1.90
	5.53 / 9.50	7.44 / 3.88	6.50 / 4.59
	.88 / .97	.06 / .52	.51 / .37
1.2	1.82 / 2.41	2.13 / 2.23	2.43 / 2.62
	3.66 / 3.77	3.64 / 4.21	4.76 / 5.24
	.95 / .88	.87 / .86	.96 / .52
1.7	3.47 / 4.53	3.61 / 3.14	3.35 / 3.67
	6.56 / 6.52	4.87 / 6.29	7.00 / 9.68
	.91 / .10	.37 / .50	.88 / .45
2.3	4.81 / 3.38	5.28 / 5.05	4.65 / 5.24(2)
	4.42 / 5.49	10.30 / 8.61	8.87 /13.60
	.26 / .10	.08 / .10	.97 / *
2.7	5.48 / 6.90	5.63 / 6.67(2)	5.60 / 5.30
	5.56 /25.61	11.75 /14.63	12.09 /11.96
	.95 / .64	.40 / *	.90 / .29
3.6	7.61 / 7.82	6.66 / 7.27	7.52 / 8.24(2)
	4.38 /10.40	13.44 /13.88	15.06 /22.80
	.44 / .72	.43 / .95	.24 / .16
4.0	8.35 / 8.16	7.92 / 6.96(2)	7.30 / 8.09
	15.16 / 8.69	13.96 /12.35	15.76 /14.56
	.98 / .82	.66 / .55	* / .63
4.6	10.25 /10.04	9.92 / 9.48	9.11 / 9.61
	31.14 /21.57	18.19 /20.12	20.92 /15.91
	.80 / .96	.40 / .73	.44 / .62

5.4	9.87	/10.79	11.88	/12.70(2)	10.91	/10.82
	11.46	/20.66	22.33	/31.73	26.81	/19.05
	1.00	/ .43	.26	/ .06	.33	/ .90
6.1	12.06	/12.09	12.44	/12.43	12.39	/11.41
	40.05	/44.13	28.81	/22.93	26.69	/19.10
	.83	/ .81	.95	/ .66	.41	/ .38
6.8	15.82	/14.96	13.37	/12.88	13.91	/13.17
	24.90	/23.85	25.21	/25.93	40.75	/25.09
	.26	/ .60	.97	/ .23	.71	/ .83
7.0	11.62	/13.84	14.40	/14.49	13.73	/13.51
	22.86	/30.82	32.31	/38.45	21.36	/34.61
	.82	/ 1.00	.98	/ .96	.99	/ .30
10.0	19.19	/17.75	21.96(2)	/19.99	20.85	/20.03
	19.45	/19.78	52.02	/36.56	37.73	/35.31
	1.00	/ .75	*	/ .60	.38	/ .95
15.0	30.12	/34.32	29.49	/28.81	29.35	/31.24
	86.33	/83.14	59.33	/56.54	60.27	/80.99
	.93	/ .21	.94	/ .86	.11	/ .36
20.0	33.52(2)	/37.98	40.02	/40.87	39.70	/40.61
	84.03	/65.40	107.29	/85.45	71.18	/90.56
	.53	/ .97	1.0	/ .37	1.0	/ .59
25.0	49.64	/51.74	51.25	/51.00	50.08	/51.00
	89.12	/58.43	117.76	/108.32	141.85	/115.44
	.99	/ .77	.68	/ .43	.41	/ .54

FOR EACH A, THE THREE RESULT LINES ARE AS FOLLOWS.

LINE 1 (.43,...) IS THE MEAN OF THE N DEVIATES. ITS EXPECTED VALUE IS AB. A PARENTHETICAL TWO (2) FOLLOWING THE MEAN IMPLIES THAT THE STATISTIC IS OUTSIDE THE TWO STANDARD DEVIATION LIMIT.

LINE 2 (.25,...) IS THE VARIANCE (SUM OF SQUARES OF DEVIATIONS FROM THE MEAN DIVIDED BY N) OF THE N DEVIATES. ITS EXPECTED VALUE IS AB**2.

LINE 3 IS THE PROBABILITY (KOLMOGOROV SMIRNOV TEST, ASYMPTOTIC) OF REJECTING THE HYPOTHESIS, THAT THE DEVIATES ARE GAMMA (A,B), IN ERROR.

EXAMPLES: FOR A=20, N=10, THE MEAN (THE TOTAL SEQUENCE BEGAN WITH SEED 123457) OF 33.52 IS OUTSIDE THE TWO STANDARD DEVIATION LIMIT. FOR A=2.3, AND N=100 (SECOND SEED), ONE WOULD REJECT THE NULL HYPOTHESIS AT THE FIVE PERCENT LEVEL).

```
      SUBROUTINE GGUB   (ISEED,N,R)
C
C-GGUB-----------S--------LIBRARY 3-------------------------------------
C
C   FUNCTION            - BASIC UNIFORM (0,1) PSEUDO-RANDOM NUMBER
C                           GENERATOR
C   USAGE               - CALL GGUB(ISEED,N,R)
C   PARAMETERS   ISEED  - INPUT.  AN INTEGER VALUE IN THE EXCLUSIVE
C                           RANGE (1,2147483647).  ISEED IS REPLACED BY
C                           A NEW ISEED TO BE USED IN SUBSEQUENT CALLS.
C                N      - INPUT.  THE NUMBER OF DEVIATES TO BE GENERATED
C                           ON THIS CALL.
C                R(N)   - OUTPUT VECTOR OF LENGTH N, CONTAINING THE
C                           FLOATING POINT (0,1) DEVIATES.
C   PRECISION           - SINGLE
C   LANGUAGE            - FORTRAN
C-----------------------------------------------------------------------
```

CALL GGUB (ISEED,N,R)

Purpose

GGUB generates N pseudo-random uniform floating point numbers in the interval (0,1).

Algorithm

Let S=ISEED. Then deviates R_i are generated by

S_0 = ISEED

$S_i = 7^5 S_{i-1} \pmod{2^{31}-1}$

$R_i = 2^{-31} S_i$.

This generator is reported in the following references.

1. Lewis, P. A. W., Goodman, A. S., and Miller, J. M., "Psuedo-random number generator for the System/360", IBM Systems Journal, No. 2, 1969.

2. Learmonth, G. P. and Lewis, P. A. W., Naval Postgraduate School Random Number Generator Package LLRANDOM, NPS55LW73061A, Naval Postgraduate School, Monterey, California, June, 197

3. Learmonth, G. P., and Lewis, P. A. W., Statistical Tests of Some Widely Used and Recently Proposed Uniform Random Number Generators, NPS55LW73111A, Naval Postgraduate School, Montere California, November, 1973.

Programming Notes

The generator discussed in reference (2) has been reprogrammed in FORTRAN, and resides as generator GGU3 in assembly language form in the IBM Library. Extensive tests (reference 3) show that this generator is adequate for most purposes.

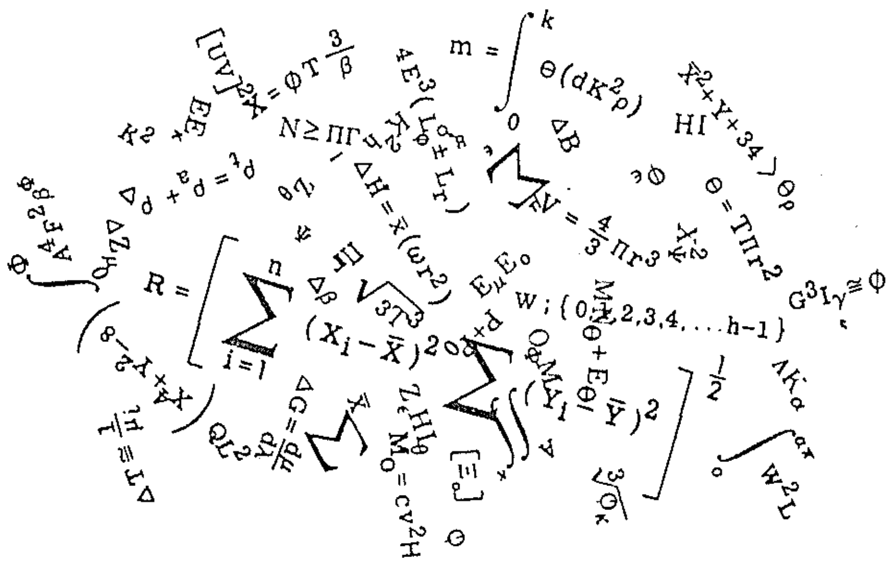
IMSL calls GGUB or its function counterpart GGUBF as its basic generator.

Example

Timing twenty calls to GGUB (IBM 370/155) with N=1000 resulted in a per deviate time of 48.5 microseconds. This can be compared with a 10.15 microsecond per deviate time when calling the assembly language version GGU3 (in the IBM Library).

Input:	Output:
ISEED = 123457	ISEED = 801129707
N = 100	R(1) = .96622
	R(100)= .373055

MATH SCIENCE LIBRARY



CONTROL DATA PROPRIETARY PRODUCT

VOLUME 7 PROBABILITY STATISTICS AND TIME SERIES

CONTROL DATA

SUBJECT: FORTRAN IV Subroutine NRML

PURPOSE: Generates pseudo-random numbers having a normal distribution.

METHOD:

The variable

$$X = \left[-2 \ln u_1\right]^{\frac{1}{2}} \quad \cos 2\pi u_2$$

has the exact standard normal distribution when the u_i are uniformly distributed between 0 and 1. The pseudo-random variates u_1 and u_2 are obtained from two different multiplicative congruential generators. The pseudo-random variate, y, with mean μ and variance σ^2 is then given by

$$y = \sigma X + \mu .$$

USAGE:

DIMENSIØN X(N*M)

CALL NRML (N, M, I, XMN, SIG, IU, IV, X, IP)

INPUT

N	Total number of random numbers which will be generated
M	Total number of variables in data array X
I	The random numbers will be stored as variable I in array X
XMN	Mean value for normal distribution
SIG	Standard deviation for normal distribution
IU	Start multiplier for one of the multiplicative congruential generators -- must be odd

IV	Start multiplier for the other generator -- must be odd
IP	Print indicator -- if IP > 0, the random numbers will be printed

OUTPUT

IU	Final value of multiplier
IV	Final value of multiplier
X	Array containing random numbers stored as variable I (The first number is in location X(I), the second in location X(I + M), the third in location X(I + 2M), etc.)

SUBROUTINES CALLED: None

ERROR RETURN: None

RESTRICTIONS: None

PRECISION: Single

EQUIPMENT: CDC 6600

LANGUAGE: FORTRAN IV

STORAGE: 110 words

Georgia Tech Box 31521
Atlanta, Georgia 30332
7 March 1977

Mr. Dan Blix
Manager - Industrial Engineering
EASTERN AIRLINES
47 Perimeter Center NE, Suite 103
Atlanta, Georgia 30346

Dear Sir,

We have completed the basic requirements of our project: "A Simulation Model of Eastern Airline's Mobile Lounge System at Atlanta Hartsfield International Airport". Enclosed you will find your copy of the report, and a computer printout which includes the User's Manual and the simulation program itself.

Application of the simulation model will enable the user to systematically examine critical factors that affect the operation of the Mobile Lounge System, such as scheduling, system utilization, and capital improvement alternatives.

The primary benefits to be reaped from the proper use of this simulation program are outlined below:

1. Improved scheduling
2. Improved decision making involving capital improvements
3. Improved customer satisfaction
4. Reduction in operating cost
5. Convenience to user
6. Competitive advantage

Nevertheless, the primary drawback is that the input information utilized in our simulation program must be regularly upgraded and improved to maintain the relevancy of our model to the current operation of the Mobile Lounge System.

I take this opportunity to remind you of our meeting on Friday March 11th at 1:15 P.M. to discuss the features of the simulation program and its future, along with comments, observations, and other recommendations.

The potential impact on the operations of the Mobile Lounge System and the Atlanta Station are astounding, with far reaching implications.

Sincerely yours,

Dwighd D. Delgado

Dwighd D. Delgado

GENERAL ELECTRIC

GENERAL ELECTRIC COMPANY, NELA PARK, CLEVELAND, OHIO 44112
Phone (216)266-3353

MINIATURE
LAMP PRODUCTS
DEPARTMENT

February 21, 1978

Mr. George Harrell
300 N. Washington Street
Alexandria, Virginia 22314

Dear George:

I wanted to make sure that you had a copy of the Mobile Lounge Simulation Project Report that we had started over a year ago. As you can see, we completed a basic package that is capable of doing quite a few things for you.

Who can I contact for permission to publish an article on this project? I am sure that Eastern Airlines would like to review the article before publication.

By the way, I am working for General Electric Miniature Lamp Engineering as a Specialist - Materials and Production Control. One of the items I am responsible for is the manufacture of some of your Quartz Halogen aircraft lights in our Pilot Plant.

If you ever drop by in Cleveland, I'll show you around.

Very truly yours,

Dwighd D. Delgado

Dwighd D. Delgado

Encl.
DDD/bw

GENERAL ELECTRIC

MINIATURE
LAMP PRODUCTS
DEPARTMENT

GENERAL ELECTRIC COMPANY, NELA PARK, CLEVELAND, OHIO 44112
Phone (216) 266-3353

January 21, 1980

John C. Devore, P. E.
Industrial Engineering
25 Technology Park/Atlanta
Norcross, Georgia 30092

Gentlemen:

Enclosed you will find a copy of the report titled "A Simulation Model of Eastern Airline's Mobile Lounge System at Atlanta International Airport."

I am submitting this report for your consideration and for publication since the applied methodology may be useful to other engineers' in our profession. I also believe that the quality of work involved meets the Industrial Engineering magazine standards for professionalism in practice.

I would like to point out that this project was undertaken and completed by a group of undergraduate Industrial Engineering students at Georgia Tech prior to graduation.

If you need assistance in editing, additional background information, etc., do not hesitate to call.

Thank you,

Very truly yours,

Dwighd D. Delgado

Dwighd D. Delgado

DDD/bw
Enclosure
cc: Mr. Steward Kelley
AIIE Chapter Development Manual

GENERAL ELECTRIC

MINIATURE
LAMP PRODUCTS
DEPARTMENT

GENERAL ELECTRIC COMPANY, 1814 EAST 45TH STREET CLEVELAND, OHIO 44103
Phone (216) 266- 4837

EUCLID LAMP PLANT

April 15, 1981

Program Chairman, Charles J. Shub
Computer Science
111 Votey Building
University of Vermont
Burlington, Vermont 05401

Dear Mr. Shub:

Please find enclosed a copy of the report "A Simulation Model of Eastern Airline's Mobile Lounge System at Atlanta International Airport".

This report is being submitted for your consideration at the 1981 Winter Simulation Conference since the applied methodolgy may be useful to other engineers' in our profession.

Very truly yours,

Dwighd D. Delgado

Dwighd D. Delgado

DD:cf

Enclosure

WSC 81

1981 WINTER SIMULATION CONFERENCE
December 9-11, 1981
Peachtree Plaza
Atlanta, Georgia

November 4, 1981

Dear Participant:

It is less than six weeks until the Winter Simulation conference. By now, the proceedings have been put to bed, and the program has reached its final form. By now you should have received your complete preliminary program with registration materials in the centerfold.

The proceedings will be available at the conference, so your presentation may, if you wish, not exactly mirror the printed paper word or word and picture for picture.

An important facet of the program is the participants complimentary breakfast, scheduled at 8:00 a.m. as follows:

Wednesday:	Grady Room
Thursday:	French Room
Friday:	French Room

Please plan to attend so that you may meet with your session chairman and any other participants in your session and to clear up any last minute details. Please feel free to call on me either here in Vermont or at the Conference itself if you have any questions.

I am looking foreward to seeing you in Atlanta.

Sincerely,

Charles M. Shub
Program Chairman