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16. Abstract

Live tests of emergency evacuation of transport aircraft are becoming increasingly expensive as the planes grow to a size seating hundreds of passengers. Repeated tests, to cope with random variations, increase these costs, as well as risks of injuries to participants.

A method of simulating such repeated tests, by use of computer models based on statistics from measured components of the escape path, has been developed. The models utilize GPSS, a computer programming language, to represent various features of the escape process: passenger mix, seating and exit configuration, door-opening delay, time on the escape slide, and slide capacity.

Two particular configurations of aircraft have been simulated: the Boeing 720 124-Passenger Model and a 234-Passenger Model. On the former the total time for all passengers to get out averaged 89.23 seconds, with a standard deviation of 6.38 seconds for 20 randomized runs. On the latter the corresponding average and standard deviation were 74.09 and 2.29 seconds, respectively. There were larger exits throughout the latter model. Both models indicated under-utilization of the aft exit. Flow diagrams, GPSS block diagrams, and listings are included.

At this time the computer model is for research purposes and its use is not intended to replace the evacuation demonstrations required of aircraft manufacturers and airline operators.

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GPSS/360 COMPUTER MODELS TO SIMULATE AIRCRAFT PASSENGER EMERGENCY EVACUATIONS

I. Introduction

Computer methods are being applied to an increasing variety of problems. A recent application is simulating man and his motions to analyze environmental conditions and present or suggest more efficient ways to perform tasks. This paper describes use of the general purpose simulation system, known as GPSS,[1] in the unique situation of simulating you as a passenger aboard an airliner confronted by an emergency demanding quick evacuation of the aircraft.

The IBM Corporation developed this computer programing language originally to determine the most feasible arrangements of such facilities as grocery store cashiers, bank tellers, and fuel truck dockings to minimize length of lines and waiting times which add to costs in terms of time and convenience. The versatility of GPSS allows entries of statistical functions to control variables and at the same time to advance time parameters in various combinations to estimate overall aircraft escape times and permit detailed analyses of escape processes.

Some background information will give you a picture of the conditions surrounding this application. At present, aircraft manufacturers (Douglas, Boeing, etc.,) and the airlines must demonstrate by actual tests that a transport aircraft can be evacuated in 90 seconds using only half the available exits. These tests are performed in darkened emergency lighting conditions with a specified age and sex ratio of passengers. On the large capacity high density aircraft, these certification tests are frequently failed and must be repeated until they are passed. This process requires a large number of people—in the hundreds—and involves a great deal of money. The major failures are usually mechanical malfunctions while the human element performs at a more predictable level. An ultimate goal with GPSS is to very nearly simulate or model actual evacuations on the computer. At this time the computer model is for research purposes and its use is not intended to replace the evacuation demonstrations required of aircraft manufacturers and airline operators. The model must have the capability of being easily refined or changed, and have been tested in enough situations with good results that there is confidence that the model is sufficiently accurate to be usable. An advantage of such simulations is that there may not be a need to place human beings in conditions that can result, and have resulted, in personal injuries. Further refinements are being made to the computer program and its use is being validated. However, the GPSS model may be used as a research tool to obtain information on aircraft in the planning stages by constructing simulation models with various arrangements of exits and exit sizes.

The basic statistical information to be utilized by the computer is collected by research on each portion of the total evacuation process. These physical tests furnish information to make up and refine the models. Human tests like these can be kept small in size and repeated until a certain degree of confidence can be obtained for particular parameter values. This approach can be taken without a large facility and research budget, as would be encountered with continued large-scale testing. This means that at the FAA Aeronautical Center in Oklahoma City the 75 foot long mock-up[2] with lift, roll, and pitch capabilities, can be set up to test any physical portion of the evacuation route without the costs associated with a full scale facility. GPSS offers a means to then simulate a full load of passengers and test for total time to escape. In this paper two such models for escape are presented.

These models are based on many years of research on escape procedures. Actual evacuations have been studied by use of motion picture film from cameras at varying positions and angles,

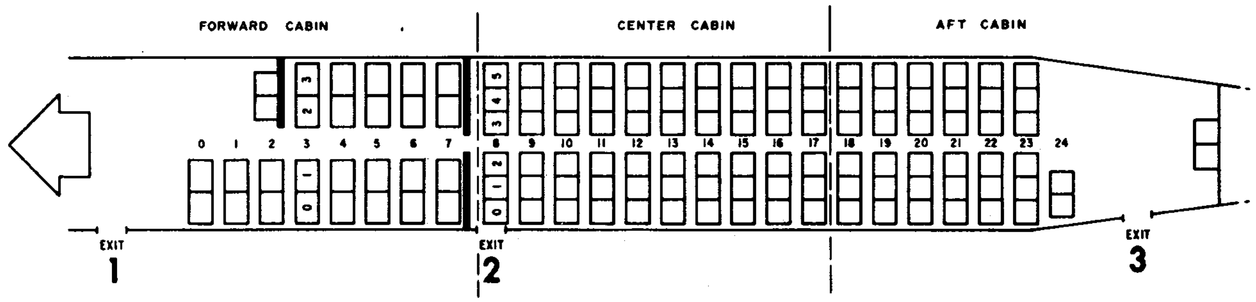

FIGURE 1. Seating configuration of Boeing 720 aircraft

inside and outside the aircraft. The seating configuration of one aircraft used for such tests at the FAA Aeronautical Center is shown in Figure 1. Passengers departing the forward and aft exits slide down a smooth inflated chute or slide to reach the ground. Passengers were considered as having evacuated the aircraft if they were on the ground, for passengers using exits 1 and 3, and if they were on the wing clear of exit 2 (window exit) for overwing exiting passengers.

Statistics were accumulated for the time passengers hesitated in the exit before jumping on the slide. The time on the slide for each passenger and the times between successive passengers arriving at the door were also computed. Distributions of these times were computed for four passenger categories: (a) males aged 12–60, (b) females aged 12–60, (c) children under 12 years of age, and (d) adults over 60 years of age.

II. The 124-Passenger Model and Results

Figure 2 is a general flow diagram of the 124-Passenger Model used to simulate the evacuation of passengers from an aircraft. Basically in this model 124 passengers are generated and seated according to the seating arrangement of the Boeing 720 aircraft. Characteristics such as age and sex are assigned to each passenger, for use in later tests, as their significance becomes better established. Gamma functions fit to empirical data by the Method of Moments[3] were used to determine time delays incurred by the passengers as they exit the aircraft. In some delay blocks the model references the functions directly; in others, the block references a variable which in turn references a function.

Appendix A is a detailed flow chart of the model; Appendix B is a list of functions used to provide the time delays in the model. Statistics such as total time for the evacuation of each exit, average utilization of each exit, and the distribution of time spent by each passenger in various facilities of the model were gathered and tabulated for analysis.

The details of operation of this model are spelled out block-by-block along the side of the flow chart in Appendix A. However, certain features are worthy of emphasis at this point. Following the generate block, there are 14 blocks devoted to producing the seating arrangement of passengers shown in Figure 1, and five more to designate three of the females as carrying infants. All passengers (model transactions) are held until this is complete, in block number 21. From block 22 through block 32, parameters have values assigned to distinguish the exits and slides to be used by the passengers from the forward, center, and aft cabin, respectively. Block 33 begins the EXIT routine for passengers to leave their respective seats, wait for their respective doors to open, and proceed with the escape. There is provision in blocks 37 through 41 for one-fourth of the passengers from the center cabin to use the forward exit, whenever it is available.

Block number 42 provides for a division of flow between each of the respective right and left exits, according to which has the longer queue. That is, when the length of the queue whose number is given by parameter 6 is equal to or greater than the length of the queue whose number is given by parameter 5, the EXIT1 routine between block 43 and block 55 is followed. Thus, the model uses the parameters and variables, etc., associated with the right doors and slides, and the results for these are stored in the savevalues of parameter 5, as shown at

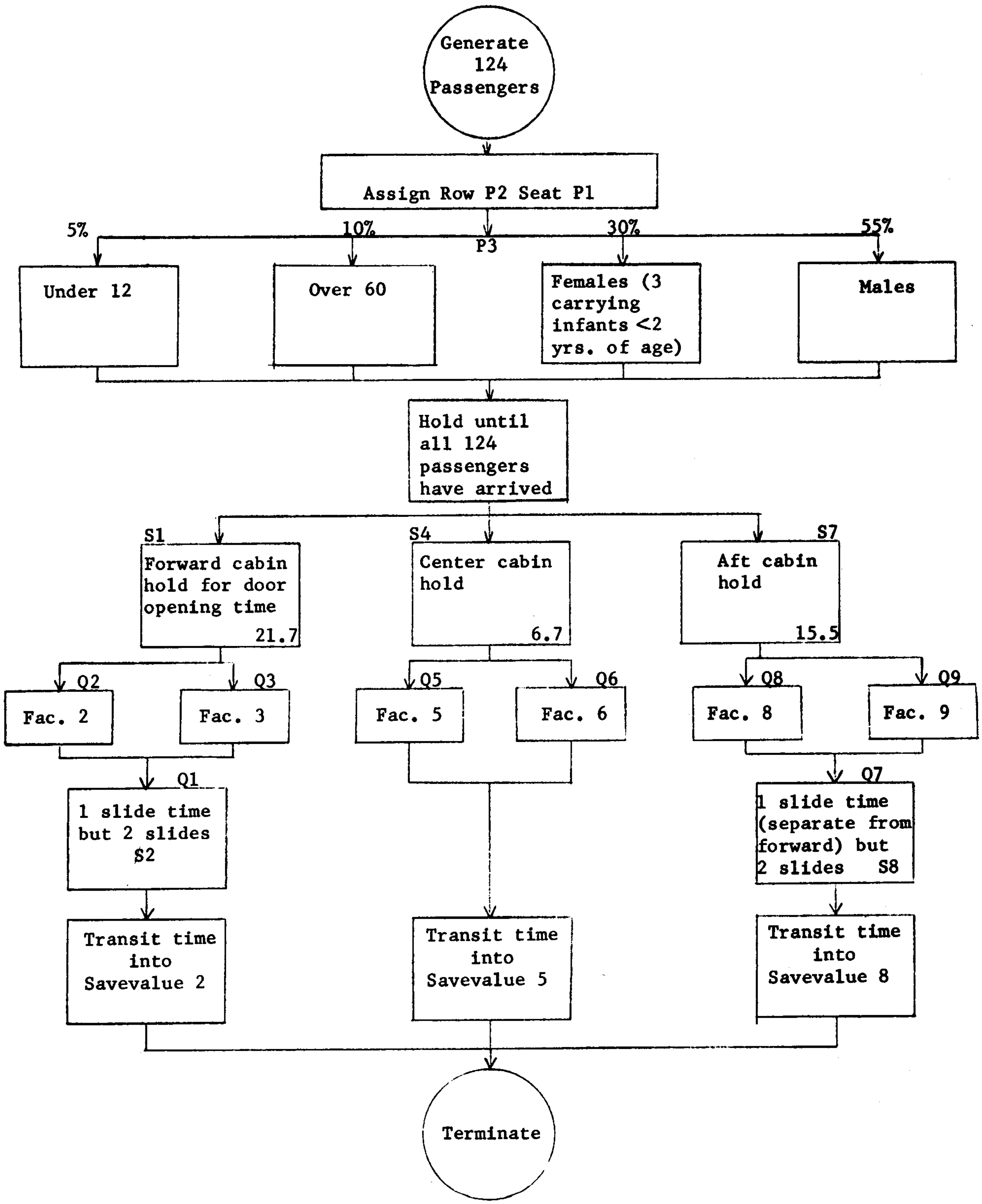

FIGURE 2. Flow diagram of 124-Passenger Model

block 54. If the left queue is shorter when a transaction (passenger) reaches block 42, a different but parallel series of events takes place starting in block 56 with the EXIT2 routine.

In order to simulate the condition of all the left doors blocked, and only the right doors available, parameter 6 is assigned the same values as parameter 5 for corresponding exits. The results of these runs are reported in Table 1. In this case all passengers take the EXIT1 routine, and the time values resulting apply to getting all the passengers out of the right doors. The maximum time to clear the aircraft is then the longest time for any of the three exits, as shown in the column on the far right in Table 1.

Perhaps it is worth noting that in this 124-Passenger Model, block 47 provides for center cabin passengers to go straight to the DEPART block number 53 after clearing the overwing exit. It will be seen this is changed in the 234-Passenger Model, to provide for both an overwing ramp time and a further slide time to reach the ground.

In Table 1 are summary statistics from 20 runs of the 124-Passenger Model. Means and standard deviations for the twenty runs are shown in the last two rows of the table. In 10 of the 20 runs the last passenger out had used the forward exit and in the remaining runs the last passenger out had used the overwing exit. On the average the last passenger departing by the aft exit was out 8.7 seconds before either of the other two exits were clear and 19.2 seconds before both of the other two exits were clear. The average utilization data is consistent with these results by showing a lower average utilization on the aft exit than either of the other two exits. This suggests that diversion of a few passengers from the overwing to the aft exit would tend to optimize utilization and shorten the average overall escape time.

III. The 234-Passenger Model and Results

The 234-Passenger Model is a further development of the Boeing 720 evacuation model for 124 Passengers. Essentially, two more parameters, P7 and P8 are added to make provision for overwing ramp time in P7, and time distribution tables are made available from cumulative times marked in P8. Only the passengers from the center cabin pass through the overwing ramp, but all passengers have their time marked in P8. This is readily verified by looking at the block listing, Figure 4, while the overall flow diagram is given in Figure 3.

Some features of the models are not fully used in a given application. However, it is

	FORWARD EXIT			OVERWING EXIT			AFT EXIT			TOTAL TIME FOR ALL PASSENGERS OUT
RUN	NUMBER OF PASSENGERS	TIME FOR LAST PERSON OUT	AVERAGE UTILIZATION	NUMBER OF PASSENGERS	TIME FOR LAST PERSON OUT	AVERAGE UTILIZATION	NUMBER OF PASSENGERS	TIME FOR LAST PERSON OUT	AVERAGE UTILIZATION	
1	38	82.2	.582	48	101.2	.932	38	69.2	.486	101.2
2	40	80.8	.663	46	86.9	.921	38	70.8	.581	86.9
3	39	81.2	.576	47	100.3	.932	38	71.9	.470	100.3
4	37	87.1	.650	49	97.8	.930	38	71.1	.497	97.8
5	41	82.3	.712	45	83.6	.918	38	73.0	.626	83.6
6	40	81.2	.704	46	82.9	.918	38	67.2	.524	82.9
7	38	83.2	.661	48	89.8	.924	38	73.4	.602	89.8
8	40	82.6	.719	46	78.1	.863	38	69.5	.581	82.6
9	44	88.9	.740	42	76.2	.780	38	65.4	.503	88.9
10	44	82.5	.720	42	73.7	.811	38	70.2	.606	82.5
11	45	93.0	.745	41	75.4	.737	38	67.8	.500	93.0
12	44	85.9	.738	42	70.8	.745	38	72.7	.593	85.9
13	38	77.2	.603	48	90.0	.924	38	75.1	.614	90.0
14	39	75.1	.566	47	90.3	.924	38	70.8	.585	90.3
15	39	80.3	.710	47	67.8	.759	38	70.4	.634	80.3
16	42	92.2	.744	44	75.2	.742	38	71.8	.529	92.2
17	42	97.3	.759	44	84.6	.799	38	70.4	.524	97.3
18	41	89.1	.730	45	77.5	.793	38	70.4	.553	89.1
19	35	78.9	.673	51	82.3	.917	38	68.8	.583	82.3
20	44	95.7	.756	42	73.8	.700	38	69.5	.482	95.7
$\bar{X}$	40.5	84.84	.6876	45.5	82.91	.8485	38.0	70.47	.5537	89.63
S	2.7	6.13	.0628	2.7	9.70	.0838	0.0	2.24	.0527	6.38

TABLE 1. Statistical data from 124-Passenger Model

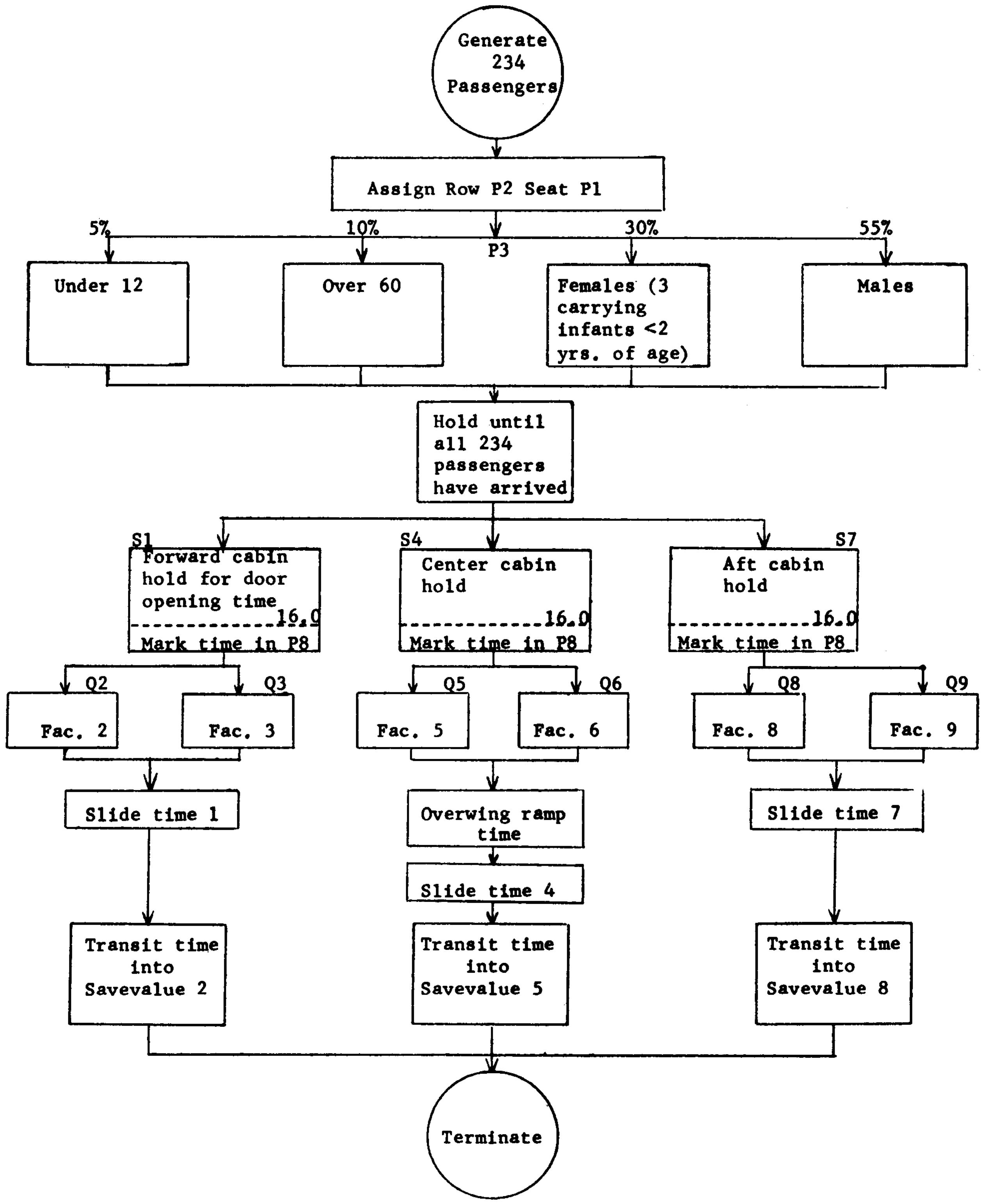

FIGURE 3. Flow diagram of 234-Passenger Model

```
      GENERATE   ,,,234,,8      GENERATE 234 PASSENGERS; 8 PARAMETERS EACH
      TEST LE    X2,20,CENTR    PUT 21 ROWS IN FORWARD CABIN, REST TO CENTER AND AFT CABINS
      ASSIGN     4,1            ASSIGN VALUES 1,2,2 TO PARAMETERS 4,5,6, RESPECTIVELY
      ASSIGN     5,2              OF PASSENGERS (TRANSACTIONS) IN FORWARD CABIN.  CENTER AND AFT
      ASSIGN     6,2              CABINS WILL HAVE 4,5,5 AND 7,8,8 IN THESE PARAMETERS
      TEST G     X2,4,ROW4      PUT 4 SEATS INTO FIRST 5 ROWS
      TEST G     X2,10,ROW5     PUT 5 SEATS INTO NEXT 6 ROWS
      TEST NE    X2,11,ROW3     PUT 3 SEATS INTO ROW 11
ROW5  TEST GE    X1,5,NXROW     PUT 5 SEATS INTO ROWS 12 - 20
      SAVEVALUE  1-,K5          ROW IS FULL - ZERO OUT SEAT COUNT
      TRANSFER   ,INCRW           AND GO TO INCREMENT ROW COUNT
ROW3  TEST GE    X1,3,NXROW     PUT 3 SEATS TO THE ROW
      SAVEVALUE  1-,K3          ZERO SEAT COUNT AND GO TO INCREMENT ROW
      TRANSFER   ,INCRW           COUNT
ROW4  TEST GE    X1,4,NXROW     PUT 4 SEATS TO THE ROW
      SAVEVALUE  1-,K4          ZERO SEAT COUNT AND GO TO INCREMENT ROW
      TRANSFER   ,INCRW           COUNT
CENTR TEST LE    X2,38,AFT      PUT ADDITIONAL ROWS UP TO 38 IN CENTER CABIN, REST
      ASSIGN     4,4              IN AFT CABIN
      ASSIGN     5,5
      ASSIGN     6,5
      ASSIGN     7,6            PASSENGERS USING RAMP HAVE 6 IN PARAMETER 7
      TRANSFER   ,ROW5          CENTER CABIN HAS 5 PASSENGERS TO THE ROW
AFT   ASSIGN     4,7            AFT CABIN PASSENGERS HAVE VALUES 7,8,8
      ASSIGN     5,8              ASSIGNED TO PARAMETERS 4,5,6, RESPECTIVELY
      ASSIGN     6,8
      TEST LE    X2,40,ROW5     ROWS 39 AND 40 HAVE 4 SEATS, THE REST HAVE 5
      TRANSFER   ,ROW4
INCRW SAVEVALUE  2+,K1          INCREMENT ROW COUNT SAVEVALUE 2 WHEN SEATS ARE FULL
NXROW TEST E     N2,K99,NXR1    99th PASSENGER ASSIGNED TO AFT CABIN
      ASSIGN     4,7              GROUP OF PARAMETER VALUES, 7,8,8 IN
      ASSIGN     5,8              PARAMETERS 4,5, AND 6, RESPECTIVELY
      ASSIGN     6,8
NXR1  ASSIGN     1,X1           LOAD SEAT NUMBER (SAVEVALUE 1) INTO EACH PARAMETER 1
      SAVEVALUE  1+,K1          INCREMENT SAVEVALUE 1 BY 1 FOR EACH NEW PASSENGER
      ASSIGN     2,X2           LOAD ROW NUMBER (SAVEVALUE 2) INTO EACH PARAMETER 2
      ASSIGN     3,FN10         ASSIGN AGE-SEX GROUP TO PARAMETER 3 OF EACH PASSENGER
      TEST E     P3,3,SEAT      SEND MALES TO SEATS WITHOUT INFANT
      TEST LE    X3,2,SEAT      SEND ALL BUT FIRST THREE FEMALES TO SEATS WITHOUT INFANTS
      SAVEVALUE  3+,K1          COUNT FIRST THREE FEMALES IN SAVEVALUE 3
      ASSIGN     3,5            USE 5 IN PARAMETER 3 TO INDICATE INFANT FOR FIRST 3
SEAT  TEST E     N2,K234        SEAT ALL PASSENGERS BEFORE STARTING ESCAPE THRU EXITS

EXIT  ENTER      P4             ENTER STORAGE AISLES AWAITING DOORS 1,4, and 7
      ADVANCE    FN9            OBTAIN DOOR TIME-DELAY FROM FN9, WHICH USES PARAMETER 4
      LEAVE      P4             LEAVE STORAGE 1,4, OR 7 FOR FORWARD, CENTER, OR AFT EXIT
EXIT1 QUEUE      P5             LINE UP FOR 2,5, OR 8 SLIDE, I.E., FORWARD, CENTER, OR AFT SLIDE
      SEIZE      P5             SEIZE CORRESPONDING FACILITY (EXIT 2,5, OR 8)
      MARK       8              PUT CLOCK-TIME OF EXIT-SEIZE INTO PARAMETER 8 OF THE TRANSACTION
      ADVANCE    V*5            USE VARIABLE 2,5, OR 8 FOR RESPECTIVE EXIT TIME
      RELEASE    P5             RELEASE FACILITY (EXIT) FOR NEXT TRANSACTION (PASSENGER)
      TEST E     P4,4,STR1      WING (CENTER) EXIT ONLY HAS ADDITIONAL RAMP TIME
      QUEUE      P7             RAMP QUEUE IS NUMBERED 6 FROM VALUE IN PARAMETER 7
      ENTER      P7             STORAGE NUMBER IS ALSO 6 FOR USING RAMP
      ADVANCE    FN6            RANDOM TIME IS DRAWN FROM FUNCTION 6 FOR RAMP DELAY
      LEAVE      P7             PASSENGERS LEAVE THE WING RAMP STORAGE
      DEPART     P7             PASSENGERS DEPART QUEUE FOR WING RAMP
STR1  QUEUE      P4             ENTER QUEUES 1,4, AND 7, SET UP FOR STORAGES 2,5, AND 8 IN PARAMETER 5
      ENTER      P5             TRANSACTIONS (PASSENGERS) ENTER RESPECTIVE SLIDES (STORAGES) PARAMETER 5
      ADVANCE    V*4            DELAY PASSENGERS ON SLIDES ACCORDING TO VARIABLES 1,4, OR 7 GIVEN BY PARAMETER 4
      LEAVE      P5             PASSENGERS LEAVE SLIDES
      DEPART     P4             QUEUE STATISTICS COMPLETED FOR SLIDES
      DEPART     P5             QUEUE STATISTICS COMPLETED FOR EXITS-PLUS-SLIDES
      TABULATE   P5             TABLE PROVIDED FOR QUEUE STATISTICS
      SAVEVALUE  P5,M1          PUT THE TOTAL TIME FOR EACH PASSENGER INTO THE SAVEVALUE GIVEN IN PARAMETER 5
TERM  TERMINATE  1              TERMINATE TRANSACTION REPRESENTING PASSENGER
```

FIGURE 4. Program listing of 234-Passenger Model

simpler in the overall model development process to leave the general groundwork in place, even though some of it may be bypassed in a particular run. For instance, both the 124-Passenger Model and the 234-Passenger Model were run using only three exits, to comply with the test condition of having half the exits blocked. Other variations can readily be run, using all doors, or various combinations of doors and door-opening times.

The data supplied herein for the 234-passenger test are obtained using three equal delay times of 16.0 seconds, for the three large, type A doors. This is in contrast to the 124-passenger test where the times to open the exits differed, to conform with historical data on those exits.

Another difference between the 124-passenger runs and those for 234-passengers, was the fixed allocation of passengers to each exit in the latter, while a probabilistic assignment of 25% of the passengers from the center cabin to the forward exit, was used in the former. This variability is indicated starting in block 37 of the 124-Passenger, Boeing 720 Model.

The two models are alike in that individual seat and row assignments are made and recorded in P1 and P2 for each passenger, and appropriate passengers are marked in P3 as carrying infants. However, no exit-time variation depending on these parameters was introduced into the currently reported runs. These parameter assignments remain to be exploited at a later date.

The larger, 234-passenger runs appeared to very nearly exhaust the capacity of our IBM 360/30 computer with 64K core. It was operating under the IBM Disk Operating System (DOS) and 54K of core was actually available for GPSS/360 system use. Reassignment of core within the GPSS program was necessary to provide for 234 transactions in the system simultaneously, since the 64K version of GPSS/360 normally provides for only 200 transactions. "REALLOCATE" cards were used to decrease the core storage earmarked for the other 15 GPSS entities, where they were not required for these models, in order to specifically reserve enough space for 234 transactions. The specification of only 6 or 8 parameters in the GENERATE block rather than the 12 otherwise provided for, helped in savings of core allocation also. However, further measures will apparently be required to extend the number of passengers as the maximum plane size and passenger loading density sought is continually increasing.

	FORWARD EXIT			OVERWING EXIT			AFT EXIT			TOTAL TIME FOR ALL PASSENGERS OUT
RUN	NUMBER OF PASSENGERS	TIME FOR LAST PERSON OUT	AVERAGE UTILIZATION	NUMBER OF PASSENGERS	TIME FOR LAST PERSON OUT	AVERAGE UTILIZATION	NUMBER OF PASSENGERS	TIME FOR LAST PERSON OUT	AVERAGE UTILIZATION	
1	98	73.8	.748	90	67.4	.610	46	44.0	.323	73.8
2	98	70.9	.712	90	74.4	.726	46	47.5	.357	74.4
3	98	70.2	.749	90	67.8	.665	46	47.9	.344	70.2
4	98	70.1	.696	90	74.3	.659	46	46.0	.346	74.3
5	98	74.6	.753	90	72.7	.685	46	45.1	.341	74.6
6	98	71.4	.751	90	70.1	.668	46	49.5	.416	71.4
7	98	75.9	.764	90	73.1	.689	46	45.1	.310	75.9
8	98	73.8	.764	90	72.6	.680	46	46.1	.354	73.8
9	98	76.5	.763	90	71.9	.643	46	46.5	.355	76.5
10	98	71.4	.674	90	79.9	.684	46	43.9	.277	79.9
11	98	71.7	.760	90	71.2	.694	46	46.4	.373	71.7
12	98	72.7	.748	90	73.5	.703	46	50.2	.369	73.5
13	98	76.0	.763	90	71.2	.662	46	46.4	.349	76.0
14	98	70.6	.698	90	75.5	.685	46	45.9	.330	75.5
15	98	71.2	.708	90	75.5	.699	46	49.7	.399	75.5
16	98	71.2	.746	90	68.8	.666	46	47.2	.374	71.2
17	98	75.3	.762	90	69.9	.641	46	51.8	.384	75.3
18	98	71.0	.749	90	70.5	.697	46	45.4	.358	71.0
19	98	73.5	.762	90	71.2	.663	46	48.0	.381	73.5
20	98	73.7	.762	90	72.9	.684	46	46.6	.353	73.7
$\bar{X}$	98.0	72.78	.7416	90.0	72.22	.6752	46.0	46.96	.3547	74.09
S	0.0	2.08	.0274	0.0	2.93	.0255	0.0	2.07	.0308	2.29

TABLE 2. Statistical data from 234-Passenger Model

The results of runs of the 234-Passenger Model given in Table 2 show that the last passenger departing the aircraft departed by the forward exit in 14 of 20 runs and by the overwing exit in 6 of 20 runs. Similarly as with the 124-Passenger Model the average utilization was less for the aft exit than for either of the other two exits for all the runs. On the average both forward and overwing exits were in use 24.0 seconds after the aft exit was clear and at least one was in use 27.1 seconds after the last passenger departed the aft exit.

It should be noted that a much larger number of passengers departed in a shorter time in the 234-Passenger Model than the 124-Passenger Model which can be attributed to the larger size exits which are characteristic of aircraft capable of carrying large passenger loads. In live tests we had found that the larger exit allowed approximately 2.6 times as many passengers to pass through it in the same amount of time. This factor of 2.6 was used in the appropriate functions in the 234-Passenger Model in the absence of completely measured distributions of times for the larger doors.

IV. Conclusion

The distributions of the total times for last passenger out for the 124-Passenger and 234-Passenger Models are shown in Figures 5 and 6, respectively. The shorter evacuation times shown in Figure 6 display the effect of the larger exits throughout the latter model. Both the models shown here readily permit different functions to be substituted for different door, slide, and population age-sex distributions. When sufficient data is available on these variables they will be included in the model in the form of separate functions for each category or classification of the variables.

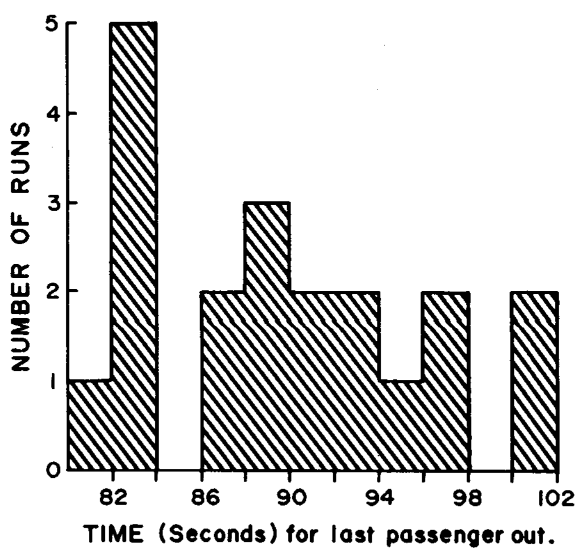

FIGURE 5. Total times for 124-Passenger Model

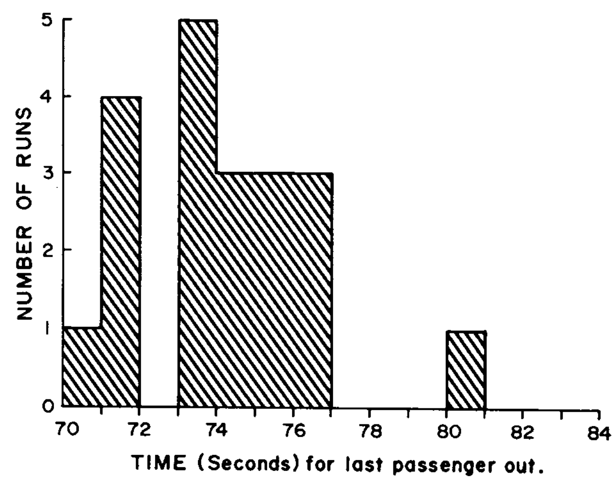

FIGURE 6. Total times for 234-Passenger Model

The two models described above (124-passenger and 234-passenger) are manifestly just two phases of a continuing model-development effort. There are additional features not described herein, for the sake of brevity. Such features include aids to interpretation, such as graphical as well as tabular representations of the various components of passenger flow. There are differing seat-configurations and door-configurations in combination, some involving very large numbers of passengers (i.e., over 400).

Test results obtained from wide-body jet and mock-up evacuations are continually being used as input data for constructing new models. The flexibility of the GPSS high-level language makes possible the development and utilization of many varied computer models in a relatively small span of time and expenditure of resources.

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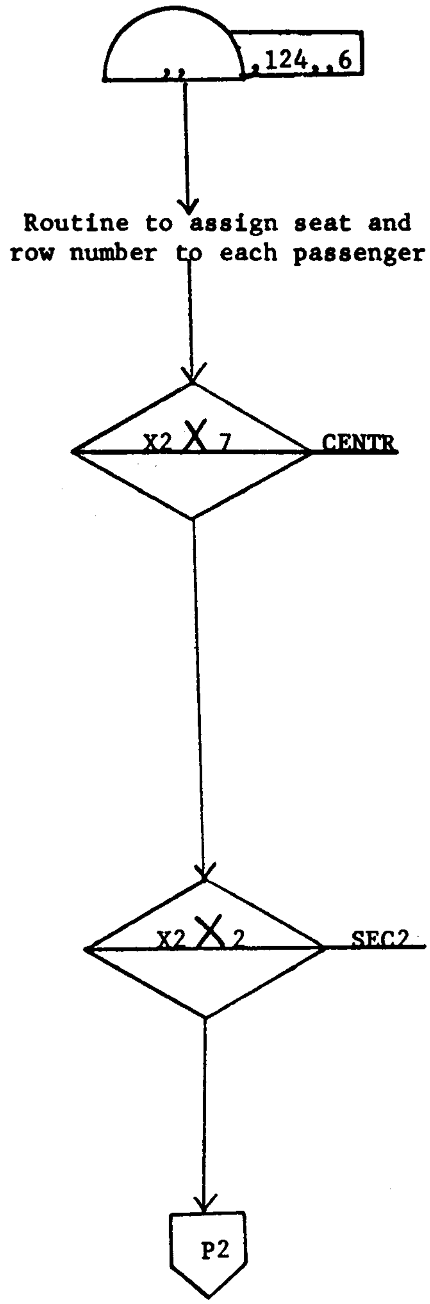
APPENDIX A

GPSS Aircraft Evacuation Model Flow Chart
Boeing 720 -- 124-Passenger Model

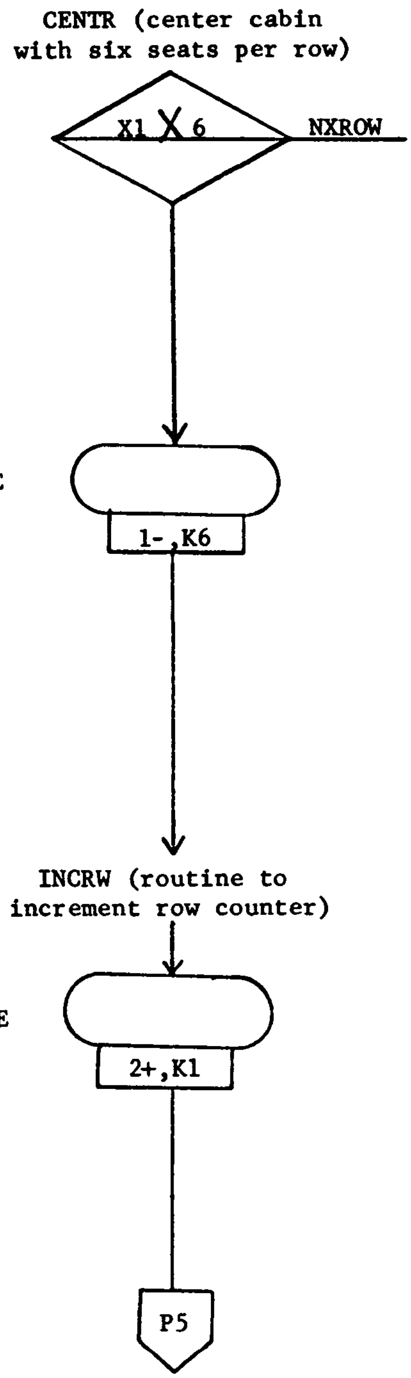
Block Number



1. GENERATE — Generate 124 passengers with 6 parameters each.

2. TEST LE — Savevalue 2 is used for a row counter with an initial value of zero. All passengers are routed thru this block until first eight rows are full, then remaining passengers go to CENTR (center cabin) routine.

3. TEST LE — All passengers routed thru this block until first 3 rows are filled, remaining go to SEC2 (section 2 of forward cabin).



10. TEST GE

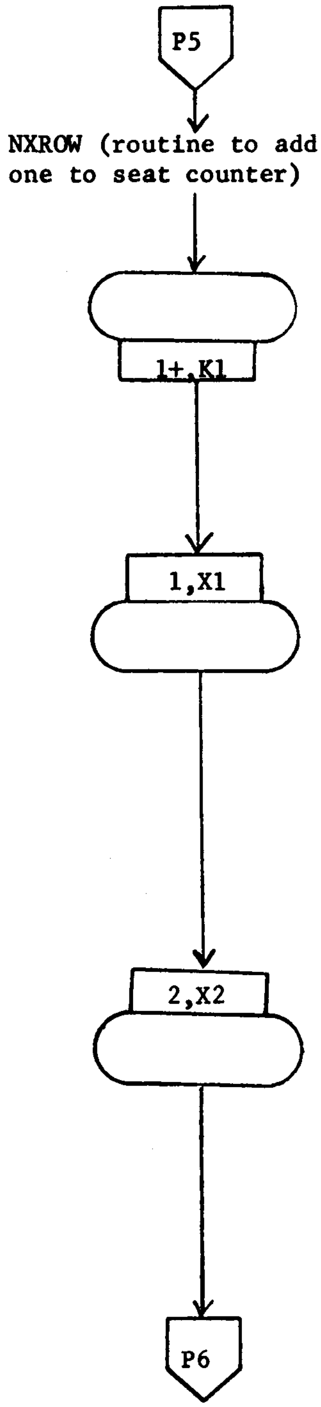
First six passengers in each row of center cabin are transferred to NXROW routine which increments seat number.

11. SAVEVALUE

As each of rows 8 thru 24 is filled, the first passenger of the next row is routed to this block and decrements savevalue 1, which contains the seat number for this passenger, back to seat zero.

12. SAVEVALUE

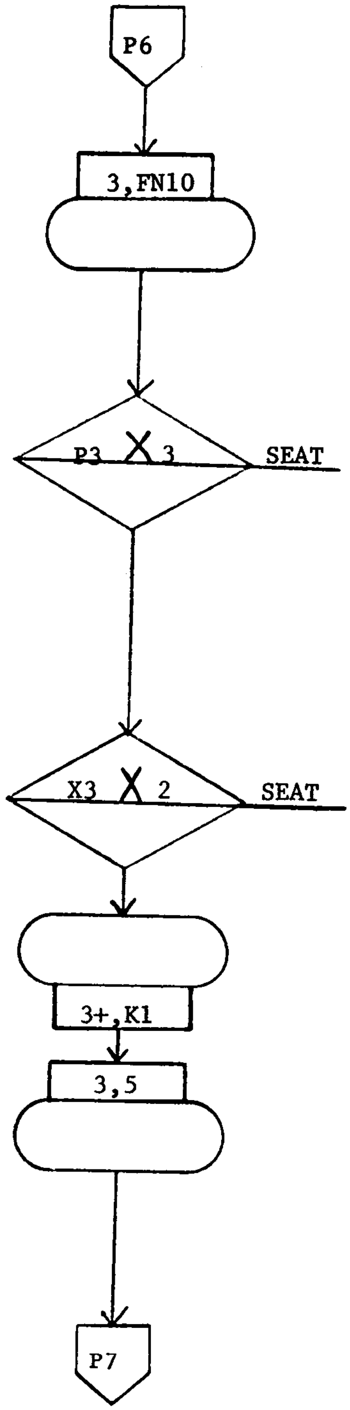
This block increments the row counter, savevalue 2, by one each time a row is filled.



13. SAVEVALUE — Increment seat counter by one.

14. ASSIGN — Put the value in savevalue 1 (seat counter) into the first parameter of each passenger.

15. ASSIGN — Put the value in savevalue 2 (row counter) into parameter 2 of each passenger.



16. ASSIGN

Place the value generated from function 10 (age-sex function) into parameter 3 of each passenger.

17. TEST E

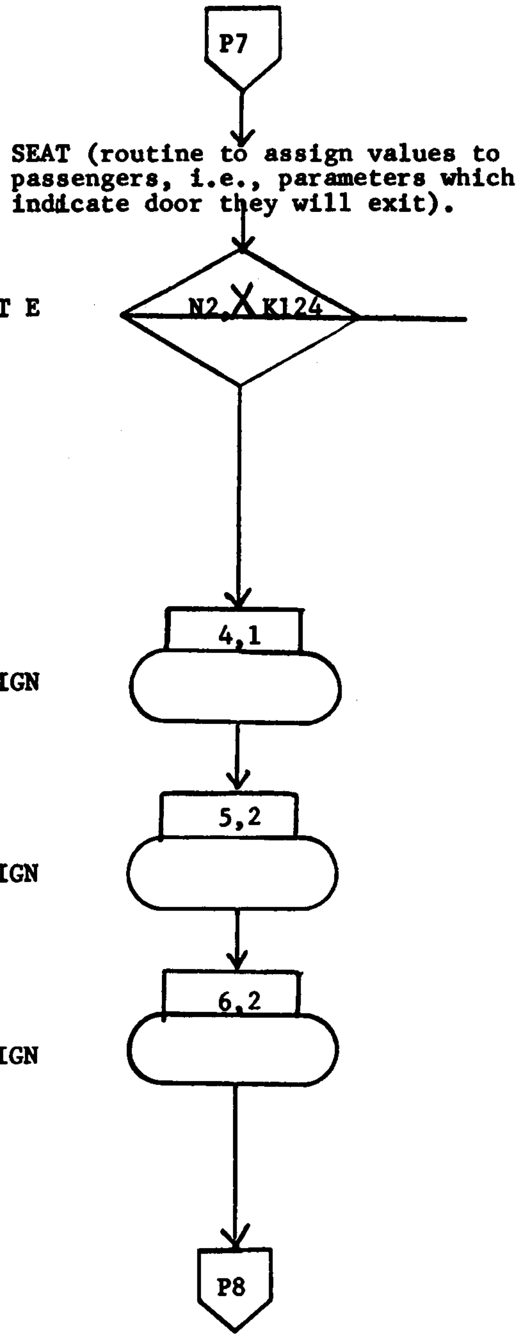
Female passengers will have a 3 in their third parameter, therefore; all females will be routed thru this block, remaining will go to SEAT (routine to seat the passengers).

18. TEST LE

19. SAVEVALUE

20. ASSIGN

First three female passengers will go thru these three blocks and the value 5 will be placed in their third parameter indicating that they are carrying a small child.



21. TEST E

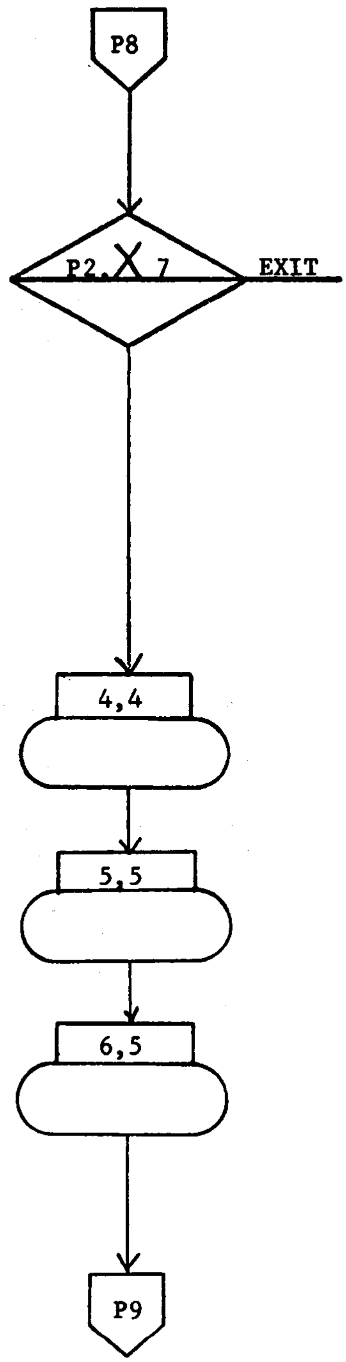
Hold all passengers in the model until 124 have entered block number 2.

22. ASSIGN

23. ASSIGN

24. ASSIGN

Parameter 4 indicates what cabin the passengers are in (forward, center, or aft). Parameter 5 and 6 indicate right and left doors, respectively, for each cabin. A 1 in parameter 4 indicates forward cabin and 2 in parameter 5 and 6 indicates all passengers in this cabin will exit right door. Left door is blocked for this model.



25. TEST G

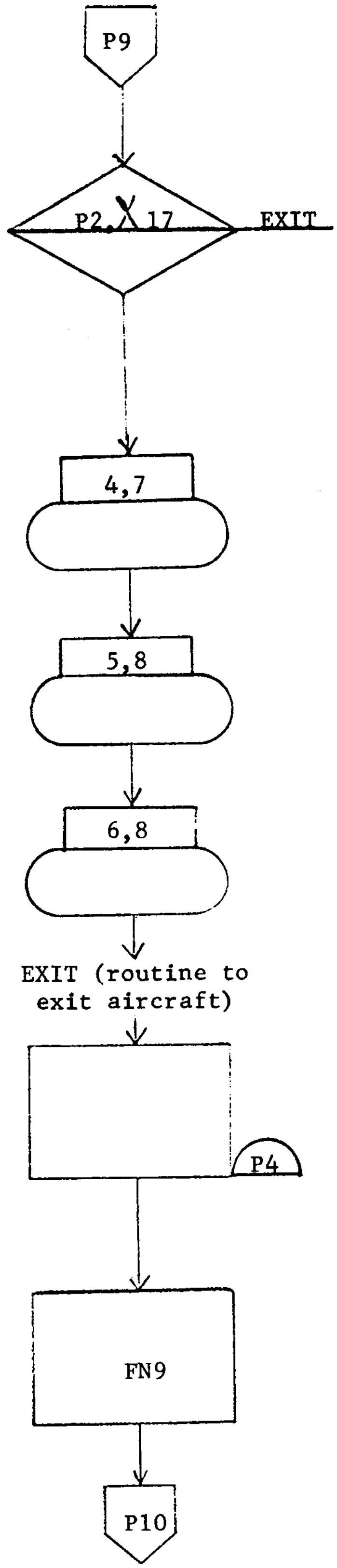
Forward cabin passengers go to EXIT at this point. All others go to next block to have the value in their parameters reassigned for respective cabins. Parameter two contains the row number.

26. ASSIGN

Parameters for center cabin passengers are assigned values 4, 5 and 5, respectively.

27. ASSIGN

28. ASSIGN



29. TEST G — Center cabin passengers go to EXIT. Aft cabin passengers go to next block to have their parameter values reassigned.

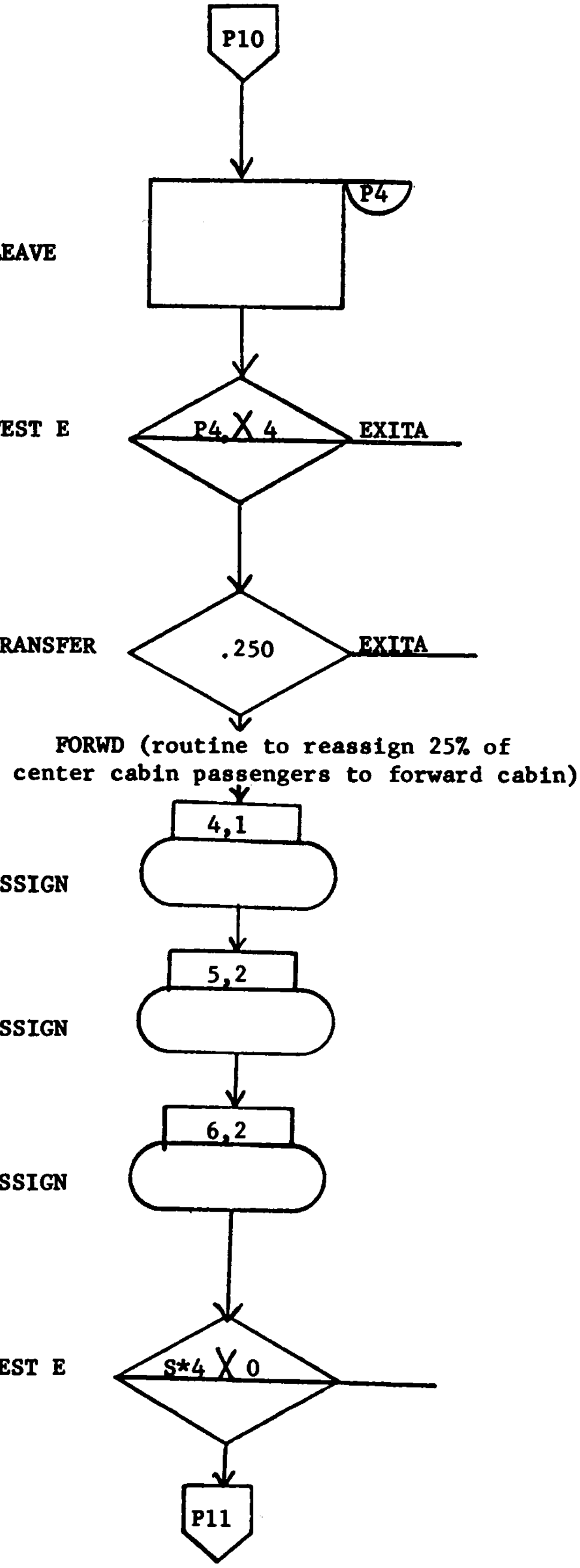
30. ASSIGN — Parameters for aft cabin passengers are assigned values 7, 8 and 8, respectively.

31. ASSIGN

32. ASSIGN

33. ENTER — Passengers enter a storage to wait for the door to open in respective cabins.

34. ADVANCE — The clock is advanced by the amount of time required to open the door in each cabin.



35. LEAVE

Passengers leave the storage thru this block after the doors are opened.

36. TEST E

Center cabin passengers go thru this series of blocks and 25% are routed to the forward cabin by reassigning their parameters 4, 5 and 6 to 1, 2 and 2, respectively. Remaining 75% go to EXITA.

37. TRANSFER

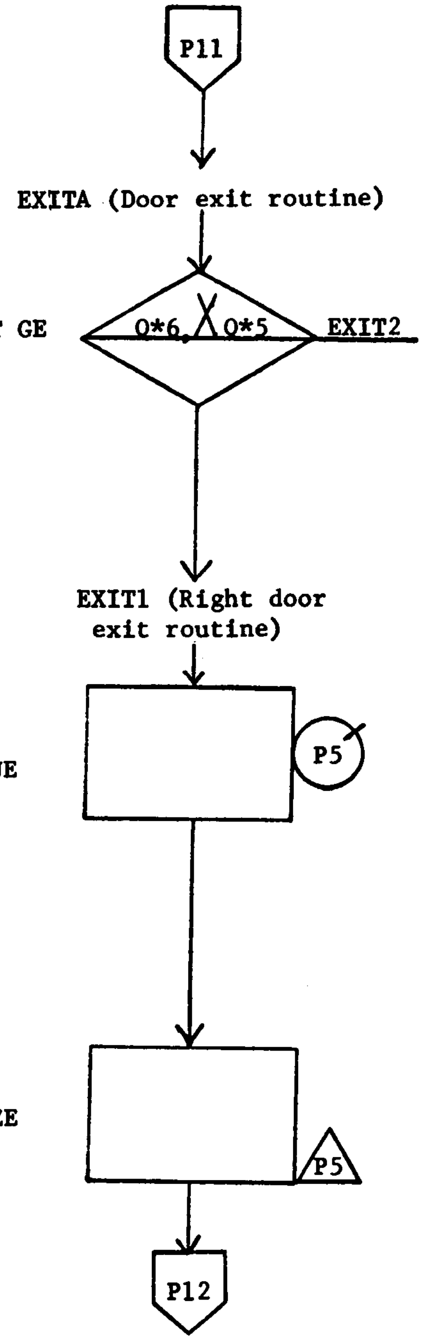
38. ASSIGN

39. ASSIGN

40. ASSIGN

41. TEST E

Hold all center cabin passengers that are routed to forward cabin until forward cabin door is open.



42. TEST GE

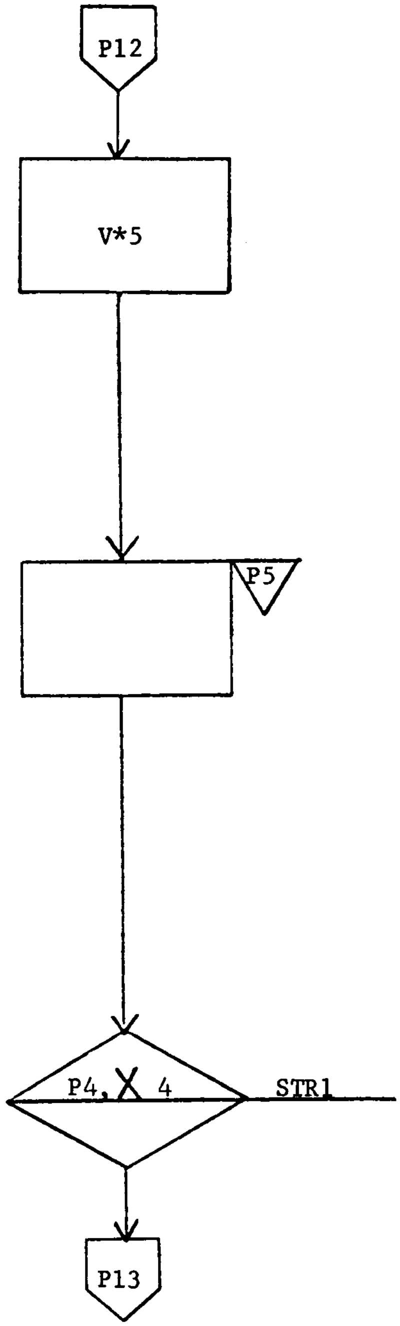
Each passenger checks to see whether right or left door is the busiest to determine which door to exit. If right door is busiest the passengers go to EXIT2, otherwise they go to EXIT1.

43. QUEUE

Each passenger gets into line to exit the door whose number is in parameter 5 of that passenger.

44. SEIZE

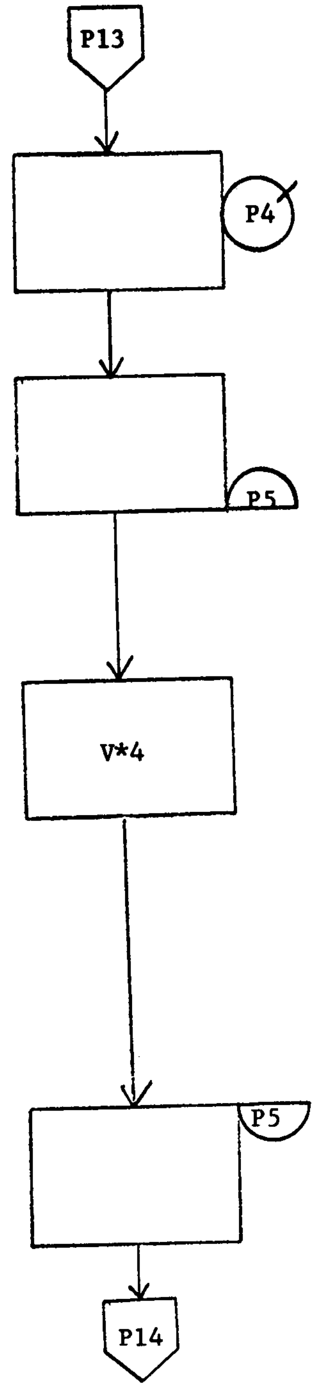
Passenger seizes the doorway.



45. ADVANCE — Advance the clock by the time the passenger spends in the door. This time is computed by a variable whose number is in parameter 5.

46. RELEASE — Exit the door.

47. TEST NE — Center cabin passengers go to routine to depart the model, others go to next block.

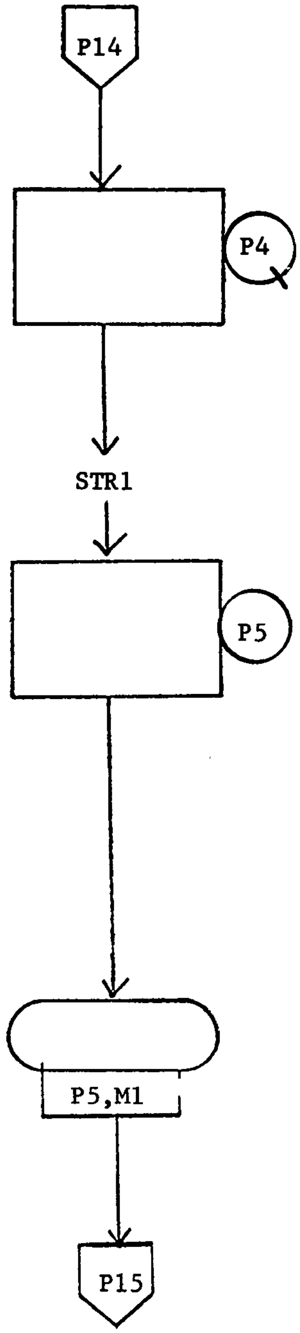


48. QUEUE — Forward and aft cabin passengers enter a queue for the slide. There is no slide for center cabin in this model.

49. ENTER — Passengers enter a storage containing the slide.

50. ADVANCE — Advance the clock by the amount of time the passenger is on the slide. That time is computed by a variable whose number is in parameter four.

51. LEAVE — Passengers leave the slide storage.



52. DEPART

Depart the queue around the slide whose number is in parameter 4.

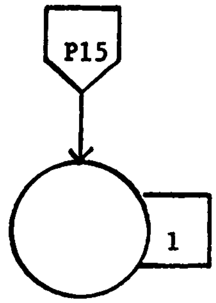
53. DEPART

Depart the queue entered before seizing the door.

54. SAVEVALUE

Store into the savevalue whose number is in parameter five the total time each passenger was in the model. At the end of the run the savevalue will contain the total time for the last passenger out each exit.

55. TERMINATE



Each passenger leaves the model thru this block.

56. EXIT2 (This routine is a duplicate of EXIT1 except it is for the left doors).

APPENDIX B

Functions Used in Aircraft Evacuation Models

FORWARD EXIT TIME — MEAN = 1.57 — SD = 0.76

1 FUNCTION RN1 C35

.00132	2	.01662	4	.06162	6
.13949	8	.24221	10	.35722	12
.47262	14	.57971	16	.67340	18
.75173	20	.81485	22	.86423	24
.90190	26	.93005	28	.95070	30
.96562	32	.97625	34	.98373	36
.98894	38	.99254	40	.99500	42
.99667	44	.99779	46	.99854	48
.99904	50	.99937	52	.99959	54
.99974	56	.99983	58	.99989	60
.99993	62	.99995	64	.99997	66
.99998	68	.99999	70		

WING EXIT TIME — MEAN = 1.70 — SD = 1.61

2 FUNCTION RN1 C35

.09200	2	.18634	4	.27422	6
.35437	8	.42675	10	.49172	12
.54981	14	.60161	16	.64770	18
.68864	20	.72497	22	.75717	24
.78568	26	.81091	28	.83322	30
.85294	32	.87036	34	.88574	36
.89932	38	.91130	40	.92187	42
.93119	44	.93941	46	.94665	48
.95304	50	.95866	52	.96362	54
.96798	56	.97182	58	.97521	60
.97819	62	.98081	64	.98312	66
.98515	68	.98694	70		

AFT EXIT TIME — MEAN = 1.34 — SD = 0.58

3 FUNCTION RN1 C28

.00071	2	.01493	4	.06878	6
.17177	8	.30973	10	.45851	12
.59727	14	.71393	16	.80463	18
.87100	20	.91727	22	.94826	24
.96835	26	.98101	28	.98880	30
.99350	32	.99627	34	.99789	36
.99882	38	.99935	40	.99964	42
.99980	44	.99989	46	.99994	48
.99997	50	.99998	52	.99999	54
1.0	56				

FORWARD SLIDE TIME MEAN = 1.73 SD = 0.45

4 FUNCTION RN1 C22

0.0	4	.00038	6	.00559	8
.03283	10	.10818	12	.24270	14
.41720	16	.59486	18	.74445	20
.85257	22	.92152	24	.96112	26
.98193	28	.99207	30	.99669	32
.99868	34	.99950	36	.99981	38
.99993	40	.99998	42	.99999	44
1.0	70				

AFT SLIDE TIME MEAN = 3.82 SD = 0.93

5 FUNCTION RN1 C31

0.0	10	.00005	12	.00028	14
.00119	16	.00389	18	.01032	20
.02322	22	.04572	24	.08053	26
.12925	28	.19179	30	.26625	32
.34927	34	.43660	36	.52382	38
.60701	40	.68311	42	.75013	44
.80718	46	.85424	48	.89195	50
.92139	52	.94381	54	.96051	56
.97268	58	.98139	60	.98750	62
.99172	64	.99458	66	.99650	68
.99777	70				

AGE-SEX DISTRIBUTIONS

10 FUNCTION RN1 D4

.049	1	.149	2	.449	3
.999	4				

DOOR OPENING TIME

9 FUNCTION P4 D3

1	217	4	67	7	155