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GPSS COMPUTER SIMULATION OF AIRCRAFT PASSENGER EMERGENCY EVACUA--ETC(U)
JUN 78 J D GARNER, R F CHANDLER, E A COOK

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GPSS COMPUTER SIMULATION OF AIRCRAFT PASSENGER EMERGENCY EVACUATIONS

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16. Abstract

The costs of civil air transport emergency evacuation demonstrations using human subjects have risen as seating capacities of these aircraft have increased. Repeated tests further increase the costs and also the risks of injuries to participants.

A method to simulate such evacuations, by use of a computer model based on statistics from measured components of the escape path, has been developed. This model uses the General Purpose Simulation System (GPSS) computer programing language to represent various features of the escape process; e.g., seating and exit configurations, passenger mix, door-opening delays, time on escape slides, slide capacity, and redirection of passengers to equalize escape lines.

Results of simulated evacuations from the DC-10, L-1011, and B-747 aircraft and a military aircraft are reported. These results have been compared with results of certification demonstrations from the DC-10, L-1011, and B-747. Comparisons of exit size substitutions were evaluated as a means of estimating differences in escape potential for exit design optimization.

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GPSS COMPUTER SIMULATION OF AIRCRAFT
PASSENGER EMERGENCY EVACUATIONS

I. Introduction.

The first two aircraft computer evacuation simulations using the General Purpose Simulation System (GPSS) language, developed by the IBM Corporation, were reported in September 1972 (1). The report contained the fundamental computer flow diagram of GPSS evacuations and results of simulated evacuations of 124 and 234 passengers from a narrow-bodied civil air transport.

Development and refinement of the model have progressed through the simulation of the DC-10 (with passenger complements of 355, 375, and 391), the L-1011 (356 and 411 passengers), the B-747 (527 passengers), and a military command post aircraft (114 passengers). Furthermore, a series of nine comparative evacuations was made on proposed exit design configurations of three Type A exits per side relative to one Type I and two Type A exits. The model has been enlarged to encompass redirection of passengers within the cabin to equalize evacuee lines to the exits. Such passenger redirection is significant on aircraft with different size exits or when natural flow rate variations occur from the same size exits.

Representative passenger flow rates for specific exits must be determined by the user of the evacuation simulation model. Selection of quantitative values that are representative of passenger movements along other segments of the evacuation path must also be made for input to the model. The utility and accuracy of the model will depend to a great extent on the realistic selection of these parameters. This report illustrates the ability of the model to predict the results of evacuation demonstrations and describes how the model can be used in preliminary design analysis to study the effects of alternative exit configurations.

The GPSS is composed of a vocabulary and operating mechanics unique to this system. It is a specialized system and thus is somewhat at a disadvantage because GPSS is not widely known or used, particularly within the engineering disciplines. To understand the simulation processes, a user must become familiar with the system as described in the IBM, Inc., User's Manual (2). The GPSS evacuation simulation model is one of two models available for analysis of an air carrier aircraft evacuation. The other model, initially supported by task assignment under the FAA Office of Aviation Medicine, was developed in Fortran computer language (3).

II. General Features of the GPSS Computer Simulation Model of Aircraft Passenger Emergency Evacuation.

Passenger Emergency Evacuation. The versatility of GPSS programing allows entries of statistical functions to control passenger movements and to advance time related to each event in order to estimate and analyze the escape process in detail. Basic statistical information to be provided by the computer is derived from experimental data on each segment of the evacuation process. Additional tests or actual evacuations may furnish data to maintain and update the model.

The GPSS model design simulates 5 exit pairs (10 exits) that represent the largest number of cabin exits on current civil air transports. However, only five exits are normally programed into the model, based on the assumption that half the exits may be unusable in an emergency. To simulate smaller aircraft with fewer exits and lower seating capacities, appropriate operational statements within the model can bypass program statements for nonapplicable exits while leaving the basic model intact. When this is done, less computer core is required during the computation.

To use the model, specific numbers of "passengers" are assigned to seating areas and are initially designated to leave by the nearest logical exit. Each passenger is assigned to a specific seat in a specific row with the number of seats per row according to the simulated aircraft configuration. A passenger mix of 5 percent under 12 yr of age and 10 percent over 60 yr of age, 30 percent female and 55 percent male, has been provided in the passenger distribution, but no differentiating values are available to use as factors influencing the evacuation rate. The seating instructions can assign a person, or a group, specific time delays that may represent interior cabin obstacles, physical incapacitation of a passenger, mothers with infants, etc., by reference to parameter functions. However, simulations have not yet used interior delays because of a lack of quantitative time values associated with these events. Moreover, available data indicate that evacuation times are determined by movement through exits following door preparation and slide deployment and thus delays inside the aircraft are not a limiting factor. This situation will probably change as more test data become available on adverse interior conditions; e.g., heavy smoke or debris in the exit pathway. Such data are limited. These factors must be carefully considered in selecting criteria for computer validation.

The simulated evacuation process begins with a time interval that includes door and slide preparation. During this time passengers form queues at exits. Specific door preparation times can be assigned for each exit, or all exits can be assigned the same time interval. When the exits are ready, passengers escape through these exits at rates determined by random selection from a distribution function designated for each exit or evacuation segment. The distribution function is calculated from a known escape rate and its standard deviation by the method of moments. An example of the forward Type I exit function is shown in Figure 1. This function is a cumulative probability distribution of time vs. frequency of occurrence. Numbers to the left of the decimal found between the slash marks (ranging from 0.0 to 1.0) represent frequency of occurrence of the event, and numbers to the right of the decimal are time increments of 20-ms intervals from 0.0 to 700. A plot of these two variables would follow the Gaussian cumulative distribution "S" curve except for the skewness reflecting evacuation data

```
    MEAN = 1.57    SD = 0.76                  FORWARD EXIT TIME FUNCTION
 1      FUNCTION    RN3,C32           FORWARD EXIT FUNCTION (TYPE I)
0,0/.00132,20/.01662,40/.06162,60/.13949,80/.24221,100/.35722,120
.47262,140
.57971,160/.67340,180/.75173,200/.81485,200/.86423,240/.90190,260/
.93005,280/.95070,300/.96562,320/.97625,340/.98373,360/.98894,380/
.99254,400/.99500,420/.99667,440/.99779,460/.99854,480/.99904,500/
.99937,520/.99959,540/.99974,560/.99983.580/.99989,600/1.0000,700
*   MEAN = 1.73    SD = .45                   FORWARD  SLIDE TIME
```

Figure 1. Example of the forward Type I exit function.

that elongates the top of the curve. Each evacuation pathway segment in the model references similar functions for random selection of passenger movement; i.e., time in each segment, until the passenger is on the ground.

The model limits the number of passengers allowed to occupy specific escape slides at one time to three on a single-lane slide, six on a double-lane slide, or to other numbers designated by the user. The length of an escape slide corresponds to the time-on-the-slide function in the model and, consequently, a delay could result in the rate at which passengers may enter the top of the slide.

The model has the capability to use differing mathematical routines, if needed, although none were used in this report. Such routines would be entered into the input listings along with the functions now used.

Transactions are accumulated in counting blocks that register passenger times, numbers of occupants using a facility (door, slide, etc.), and cumulative data during evacuations for each segment of the escape route. These data are then printed out in tabular or graphic form. The redirection of passengers in the cabin from longer waiting lines to an adjacent exit with shorter queues depends on the number programed for the shorter line to contain before transfers take place. The model assumes that passengers reach the shorter exit line before a gap in the escape line occurs. This exit reassignment is similar to volunteer passenger transfers that take place in evacuation demonstrations.

The time at which the last person reaches the ground at each exit is defined as the evacuation time, and the time at the exit with the longest evacuation time is defined as the total escape time. A number of runs on a particular configuration can be made to permit random selections to represent human performance variables on each run and to enable statistical statements of evacuation predictions. Runs of 10, 20, 40, 50, and 100 repeated model evacuations were examined to assess the number of runs needed to confidently display the built-in randomness. The optimum number of runs to allow adequate distribution appears to be between 20 and 40. For each configuration, 20 evacuations were made during the majority of the developmental simulations; this number appeared to provide satisfactory results.

Model Input Data Sources. A central source to obtain all evacuation data relating to transport aircraft does not exist. The aircraft manufacturers, airlines, FAA headquarters and field offices, the National Transportation Safety Board, and the Evacuation Research Unit at the Civil Aeromedical Institute (CAMI) each have limited information. The largest publication thus far is of data assembled by the Aerospace Industries Association (AIA) in their study of evacuations in 1967-68 (4). Assembly and publication of similar data since 1968 has not been accomplished but would be desirable to support the selection of quantitative data for computer inputs. This is especially true since most wide-bodied aircraft were evacuation certified during the early 1970's and are not included in the earlier AIA report.

Passenger flow rates through Type I (24 x 48 in) and Type A (42 x 72 in) exits, described in the Federal Aviation Regulations (25.807), and used in the GPSS model, were derived from the results of an evaluation performed by CAMI in Oklahoma City (5). Overall flow rates through Type I exits averaged 46.8 passengers/min or 1.28 s/passenger. The overall rate for the Type A exit averaged 126.2 passengers/min or 0.48 s/passenger. A ratio of 2.6 has been used for Type A exit escape rates and appears in the GPSS as 10/26. The computer derives the Type A flow rate by dividing the mean Type I flow rate, entered as parameter function 1 (1.57 s/passenger), by 2.6, which maintains the ratio. The resulting Type A flow rate is 0.60 s/passenger and remains in use in the GPSS program until a more representative rate is established for validation of the model.

Calculation of passenger flow rates during the evacuations can be performed either by using the total time from test start to the last out or by considering the time from the first passenger out until the last has evacuated.

Thus, the overall flow rate for an exit is defined by the following ratio:

$$\frac{\text{Time (s) from start signal to last passenger on ground}}{\text{No. passengers evacuated}} = \text{Average overall flow rate (s/passenger)}$$

Continuous flow rate is defined as:

$$\frac{\text{Time (s) from first passenger on ground to last passenger on ground}}{\text{No. passengers} - 1} = \text{Average continuous flow rate (s/passenger)}$$

GPSS General Format. Appendix A is a typical GPSS evacuation program showing the analysis of 527 passengers evacuating a B-747 aircraft through five Type A exits. The first entries in Appendix A, four statements of model operational instructions, are followed by seven Function entities. The Functions permit computations of discrete functional relationships between an independent variable and dependent values of the function. For the B-747 evacuation, these functions are probabilistic distributions from which random generators select values for exit flow rates, time for each passenger on an escape slide and the overwing ramp, age/sex passenger distributions, and door-opening and slide-delay times. Following the Functions are the Variable entities that permit the computation of arithmetical combinations of standard numerical attributes. These Variable expressions, called operands, are Fortran-type arithmetical operations with either a floating decimal (Fullword variables) or whole-number (Halfword) variables.

The Generate block initiates the evacuation model program by the entry of the 527 passengers and notes that 10 parameters may apply to each passenger during the course of the evacuation. From this point, each passenger is considered a transaction in the GPSS language. As each transaction moves through the program, it passes through blocks in which transactions are acted on according to programed instructions for each block. Blocks are numbered consecutively beginning with the Generate block, and a transaction continues from block to block through block 141 where transactions are terminated as evacuation from the aircraft is completed. Provisions are contained in the program to account for the statistics, contents, and transaction times occurring within each block. Instructions on which of these data are desired as printout information permit selection of evacuation segment information and graphic or tabular displays of the results.

As transactions move from blocks 2 through 42, passenger seating areas and nearest logical exit assignments are performed and parameter values are assigned to each block. The program arguments are presented by conditions of the argument. For instance, a transaction in an exit block will have instructions to test if there are six or less in the next block (on the slide block). If this condition is met, the transaction moves onto the slide at that exit.

III. Results.

Evacuation Simulations From Wide-Bodied Aircraft. Simulations of evacuations have been performed from the DC-10, L-1011, and B-747 wide-bodied-transport configurations. These transports were undergoing evacuation certifications during this period, thus giving the authors a chance to compare simulation results with the evacuation demonstration times.

Research tests and evacuation demonstrations show that passengers usually reach the exits before gaps occur in escape lines at exits because the delay to ready the door and slide allows passengers to gather at the exits ready to escape. Quantitative research data have shown an average rate of movement down the aisle by physically unimpaired passengers of 8 ft/s, by 10 elderly passengers of 3.6 ft/s, and by 21 blind passengers of 3.3 ft/s, all under the same test conditions (6). Rates of movement under adverse conditions have not been evaluated.

An example of a series of GPSS model simulations is shown in Table 1 that represents 20 evacuations of 527 passengers from a B-747 through five

Type A exits. The model provided for passenger reassignment in the cabin to equalize escape lines to exits. The different times shown in Table 1 for the last passenger out of each exit result from the selection of different points from the probabilistic distribution function for passenger flow rates and escape times on each evacuation. The total evacuation time for each run is determined by the exit having the longest escape time and represents the last passenger to be evacuated. The majority (all but 2) of 20 simulated evacuations show the last passenger out the overwing exit (Exit No. 3), which has a longer path to reach the ground via the overwing ramp.

TABLE 1. Results of 20 Computer Evacuations of 527 Passengers From a B-747 Aircraft

	Exit 1		Exit 2		Exit 3		Exit 4		Exit 5		
Run No.	Time Last Pax Out*	No. Pax	Time Last Pax Out*	No. Pax	Time Last Pax Out*	No. Pax	Time Last Pax Out*	No. Pax	Time Last Pax Out*	No. Pax	Total Evacuation Time*
1	78.5	110	80.6	105	80.3	110	77.8	104	75.7	98	80.6
2	75.7	108	77.2	101	83.0	99	81.1	110	80.9	109	83.0
3	76.3	104	77.9	105	82.7	103	81.6	107	79.2	108	82.7
4	79.4	102	79.6	111	80.8	109	77.5	101	72.5	104	80.8
5	78.4	107	81.9	110	87.5	102	78.4	103	77.1	105	87.5
6	78.6	105	78.2	101	81.7	106	80.0	110	77.7	105	81.7
7	82.7	106	80.1	111	86.9	109	78.7	102	76.0	99	86.9
8	75.6	106	74.3	110	81.5	99	79.8	102	77.7	110	81.5
9	78.8	102	80.0	107	85.0	105	81.7	104	79.3	109	85.0
10	78.4	104	77.4	103	82.3	104	81.4	112	77.9	104	82.3
11	78.4	102	79.9	103	81.7	101	80.5	106	83.3	115	83.3
12	84.5	108	83.1	114	87.3	104	81.4	95	80.5	106	87.3
13	82.5	115	83.7	105	86.0	107	79.6	101	77.5	99	86.0
14	79.4	101	79.4	106	81.2	116	77.0	106	78.1	98	81.2
15	80.7	109	81.1	109	87.8	103	80.9	102	79.7	104	87.8
16	80.5	101	80.6	106	82.2	109	78.6	110	77.6	101	82.2
17	84.1	108	80.9	106	87.0	108	76.0	99	80.9	106	87.0
18	80.4	105	81.9	105	85.6	107	81.3	103	80.3	107	85.6
19	80.3	108	82.5	107	87.0	103	80.6	105	81.4	104	87.0
20	78.2	103	76.8	105	80.7	101	80.3	112	79.0	106	80.7
MEAN	79.57	105.7	79.86	106.5	83.91	105.3	79.71	104.7	78.62	104.90	84.00
S.D.	2.48	3.54	2.35	3.44	2.71	4.22	1.70	4.48	2.39	4.37	2.64

*Time in seconds

Fourteen crewmembers and 527 passengers evacuated a B-747 in 66.2 s on a certification demonstration in 1974. In comparison, the computer model evacuation simulation with 527 passengers resulted in an average total evacuation time of 84 s (ranging from 80.16 to 87.8 s) (Table 1). The passenger flow rates of approximately 0.63 s/passenger through the exits in the actual demonstration were faster than the simulated evacuation flow rate of 0.80 s/passenger used in the computations. A highly motivated passenger group, an enthusiastic and efficient cabin crew, and rapid door preparation were apparently factors that contributed to the unexpectedly fast flow rates in the evacuation demonstration.

Table 2 lists results of a series of six simulated evacuations, each the average of 20 runs, on the L-1011 aircraft with 356 or 411 passengers. The objective of the runs was to comparatively evaluate a Type I exit vs. a Type A exit in the aft exit position in combination with three other Type A exits on the L-1011. Three of these simulations were comparable to aircraft evacuation demonstrations, the results of which are noted for comparison in Table 2.

TABLE 2. Evacuation Times and Conditions of GPSS Simulation of an L-1011 Evacuation (20 Computer Runs; Exit-Opening Time = 13 s)

No. Pax.	Exits Used A	Exits Used I	Intracabin Redirection Yes	Intracabin Redirection No	Average Total Evacuation Time (s)	Average Total Evacuation Time (Range (s)
356	3	1	-	N	93.5[1]	77.4 - 120.0
356	3	1	Y	-	84.9[2]	77.8 - 90.8
356	4	-	-	N	83.6	77.6 - 89.3
356	4	-	Y	-	79.6	76.7 - 83.9
411	4	-	-	N	83.6	77.6 - 89.3
411	4	-	Y	-	79.6[3]	76.7 - 83.9

[1]Total evacuation time for an actual demonstration was 101.1 s.
[2]Total evacuation time for an actual demonstration was 82 s.
[3]Total evacuation time for an actual demonstration was 89.7 s.

Table 3 consists of groups of 20 simulation runs and shows the total average escape times on a DC-10 with 391 passengers with two variables in the simulated conditions. Exit No. 2 (Type A) simulated a delayed exit-opening time of 50 s, with and without redirection of passengers in the cabin. The other variable shown is a blocked aft exit (Type A), with and without redirection.

TABLE 3. Evacuation Times and Conditions of GPSS Simulation of a DC-10 (20 Computer Runs; 391 Passengers)

Exits Used A	Exits Used I	Intracabin Redistribution Yes	Intracabin Redistribution No	Average Total Evacuation Time (s)	Average Total Evacuation Time Range (s)	Exit-Opening Time (s) 1	2	3	4
3	1	-	N	112.0	100.0 - 122.0	13	50	13	13
3	1	Y	-	92.5	88.9 - 96.6	13	50	13	13
3	1	Y	-	90.2	85.8 - 93.2	13	50	13	13
3	1	-	N	85.0	76.0 - 99.0	13	13	13	13
2	1	-	N	144.0	130.0 - 162.0	13	13	13	--*
2	1	Y	-	114.0	110.0 - 118.0	13	13	13	--*
3	1	Y	-	82.0	77.0 - 88.0	13	13	13	13
3	1	Y	-	90.2	85.8 - 93.2	13	13	13	13

*The aft Type A (Exit 4) was blocked.

Table 4 lists three sets of 20 evacuation simulations that compare evacuation times for: (1) 355 passengers through three Type A and either a Type I (24 x 48 in with a single slide) or a Type B (32 x 72 in with a double slide) exit in the forward position, and (2) 375 passengers through three Type A exits and a Type B exit in the forward position.

TABLE 4. Evacuation Times and Conditions of GPSS Simulation of a DC-10 to Compare Type I and Type B Exit Times (20 Computer Runs)

Exits Used I[1]	A	B[2]	No. Pax	Intracabin Redirection Yes	No	Average Total Evacuation Time (s)	Average Total Evacuation Time Range (s)
1	3	-	355	-	N	106.0	94.0 - 119.0
-	3	1	355	-	N	58.0	55.0 - 61.0
-	3	1	375	Y	-	73.4	67.9 - 79.4

[1]Single-lane slide used.
[2]Double-lane slide used.

Special Applications of the GPSS Evacuation Model. The GPSS model was used to simulate a unique evacuation of 114 passengers from a military command post aircraft. In lieu of flight attendants, military personnel working aboard the aircraft at other duties were assigned to prepare the exits for evacuation. The time required for them to reach the exits from their respective work stations was added to door/slide preparation time. Groups of 25 passengers were evacuated from each exit, one exit at a time, to obtain basic input data for statistical controls. The test results (Table 5) were applied to the flow rate determinations for computer functions. Results of simulated evacuations through five and nine Type A exits are shown in Table 6. The total evacuation times and number of passengers out each exit were averaged from 50 computer runs for each exit configuration.

TABLE 5. Evacuation Time-Path Data Obtained From Evacuations of 25 Passengers From a Military Command Post Aircraft

Test No.	Exit	Time to Exit (s)	No. Pax Out Exit	Time 4th Pax Out Exit (s)	Time 8th Pax Out Exit (s)	Time Last Pax Out Exit (s)
1	L-2	7.1	9	22.2	25.5	27.0
2	L-1	6.8	9	22.2	24.6	26.0
3	R-1	9.2	9	24.0	27.0	28.5
4	R-2	5.3	16	21.0	24.3	31.5
5	L-3	9.2	16	25.2	30.6	42.0
6	R-3	5.4	16	--	20.4	30.0
7	R-4	6.8	16	23.4	29.4	40.5
8	L-5	9.6	16	24.0	29.4	40.0
9	R-5	5.6	9	25.2	31.2	33.0

TABLE 6. GPSS Computer Model Evacuation Simulation Results: Escape by 114 Passengers From a Command Post Aircraft via 5 and 9 Exits

Exit No.	Total Evacuation Time (s)	Average No. Evacuees Through Exit
	5 Exits	
R-1	35.34	23.1
R-2	36.72	25.5
R-3	39.45	23.2
R-4	34.70	22.9
R-5	32.47	19.3
	9 Exits	
R-1	28.90	12.4
R-2	31.49	11.4
R-3	36.33	11.8
R-4	28.37	12.7
R-5	28.37	13.2
L-1	28.10	13.2
L-2	28.82	13.4
L-3	35.88	12.6
L-5	28.80	13.3

A second use of the GPSS evacuation model was as a new aircraft design tool. Two exit configurations and three passenger loads for each configuration were presented for exit optimization in a new civil air transport aircraft. The existing five-exit model program was adjusted to a three-exit program by bypassing operational statements for two nonessential exits. Three Type A exits, and one Type I and two Type A exits in combination, were evaluated, each with 208, 248, or 309 passengers. Table 7 displays the evacuation times for the exit combinations and load factors given. It can be seen that 30 percent less time was required for evacuation with the three Type A exits.

TABLE 7. Averages of Evacuation Times for Exit Combinations and Passenger Load Factors Proposed for a New Design Transport Aircraft (20 Computer Runs)

Exits Used I	Exits Used A	Average Evacuation Times (s) No. Pax 208	248	309
1	2	87.19	99.70	120.40
0	3	62.89	70.49	83.32

The chart listing the number of passengers using each exit demonstrates the effect of passenger transfers to exits with faster escape rates. The transfers are particularly evident with the smaller Type I exit in the forward position combined with two Type A exits when compared with the configuration of three Type A exits as shown in Table 8.

TABLE 8. Effect of Passenger Transfers Showing Average Number Out Each Exit (20 Computer Runs)

No. Pax	Exits: 3 Type A Forward	Overwing	Aft
208	68.65	71.22	68.13
248	82.48	83.10	83.42
309	102.48	104.04	102.48

No. Pax	1 Type I and 2 Type A Forward	Overwing	Aft
208	42.75	95.75	69.50
248	51.00	114.28	82.72
309	63.68	140.95	104.37

IV. Discussion.

The program of civil air transport evacuation simulation was undertaken to provide a better understanding of the factors that influence evacuation. Existing certification procedures for demonstrating the safe evacuation potential of an aircraft have proven costly and may result in injury to the participants. The present simulation model program is designed with the exit and slide segments of an evacuation as the major determining factors for total evacuation times. In addition, redistribution or reassignment of passengers to equalize waiting lines to escape contributes significantly to the total evacuation time and this is included in the program. The effects of adverse conditions, such as smoke, fallen ceiling panels, and debris in the aisles, on evacuation times have not been simulated because of the lack of available data for any specific condition.

The knowledge gained from the evacuation demonstrations and accident histories has provided a valuable source of information on which judgments for simulation can be based. Criteria must be determined for the simulation that will provide assurance of adequate escape potential from civil transport aircraft and detect factors inimical to escape and survival. The GPSS-language computer model has the potential to simulate much more sophisticated entities than are shown in this report. An example is the inclusion of the effects of crew effort on evacuation times. Graded on a scale from 1 to 10, a Factor could be entered that would directly influence passenger flow rates through an exit. Computer runs could be made with both easy and low effort (grade 1) to the most enthusiastic effort (grade 10) to evaluate the effects of crew effort. Of course, data would be required to establish the delay function of the Factor. Another example would relate to exit design evaluations to establish optimum distances between exits while considering exit capacities to provide optimization of a total aircraft exit configuration. Until encumbrances on passenger movement to exits override the limiting flow rates, modeling exit flow and escape slide patterns will provide adequate evacuation performance evaluations. Although some rudimentary information is available on interior cabin movement by individual passengers, group tests will be required to substantiate data for more precise simulations.

V. Conclusions.

1. The capability and potential of the GPSS evacuation model have reached the stage in development that allows it to closely simulate actual evacuations from current transport aircraft. With refined inputs, based on additional test results, the model may provide a valid means to certify evacuation systems or evaluate escape system designs while the aircraft are in the early planning stages.

2. A group knowledgeable in evacuation simulation should develop a program to provide the data and formulate simulation criteria for potential use as a certification and/or design tool.

3. All evacuation tests, research, and actual performance data should be assembled at one source and analyzed to obtain pertinent material for model input functions.

4. A final model should be refined and subjected to a rigorous validation process.

5. A practical, validated, evacuation simulation model should then be considered for acceptance as a certification and/or design tool.

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APPENDIX A

TYPICAL GPSS EVACUATION PROGRAM

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 1          GENERATE  ,,,527,,1C                                                        70
 2          TRANSFER  .200,,FWDA  FORWARD TYPE A EXIT EXPECTS 1/5                       71
 3          TRANSFER  .250,,MIDA  SECOND TYPE A EXIT EXPECTS 1/5                        72
 4          TRANSFER  .333,,AFTA  THIRD TYPE A EXIT EXPECTS 1/5                         73
 5          TRANSFER  .500,,AFT1  FOURTH TYPE A EXIT EXPECTS 1/5                        74
 6          TRANSFER  ,ADDL       FIFTH TYPE A EXIT EXPECTS 1/5                         75
 7    FWDA  ASSIGN    4,1                                                  CB160740    76
 8          ASSIGN    5,2               FIRST EXIT, SLIDE NBR ASSIGNED P5  CB160750    77
 9          ASSIGN    6,2               OPPOSITE SIDE E&S NBR ASSIGNED P6  CB160760    78
10          ASSIGN    9,21                                                 CB160770    79
11          ASSIGN    1C,22                                                CB160780    8C
12          ASSIGN    1,1                                                              81
13          TRANSFER  ,EXIT                                                CB160790    82
14    MIDA  ASSIGN    4,4                                                  CB160800    83
15          ASSIGN    5,5                                                  CB160810    84
16          ASSIGN    6,5                                                  CB160820    85
17          ASSIGN    9,24                                                 CB160830    86
18          ASSIGN    10,25                                                CB160840    87
19          ASSIGN    1,2                                                              88
20          TRANSFER  ,EXIT                                                CB160850    89
21    AFTA  ASSIGN    4,7                                                  CB160860    90
22          ASSIGN    5,4                                                  CB160870    91
23          ASSIGN    6,8                                                  CB160880    92
24          ASSIGN    7,6         OVERWING-RAMP PATH IS NUMBERED    6 IN P7 CB160890   93
25          ASSIGN    9,27                                                 CB160900    94
26          ASSIGN    10,28                                                CB160910    95
27          ASSIGN    1,3                                                              96
28          TRANSFER  ,EXIT                                                CB160920    97
29    AFT1  ASSIGN    4,10                                                 CB160930    98
30          ASSIGN    5,11                                                 CB160940    99
31          ASSIGN    6,11                                                 CB160950   100
32          ASSIGN    9,30                                                 CB160960   101
33          ASSIGN    1C,31                                                CB160970   102
34          ASSIGN    1,4                                                             103
35          TRANSFER  ,EXIT                                                CB160980   104
36    ADDL  ASSIGN    4,13                                                 CB160990   105
37          ASSIGN    5,14                                                 CB161000   106
38          ASSIGN    6,14                                                 CB161010   107
39          ASSIGN    9,33                                                 CB161020   108
40          ASSIGN    1C,34                                                CB161030   109
41          ASSIGN    1,5                                                             110
42          TRANSFER  ,EXIT                                                CB161040   111
43    EXIT  TEST GE   N2,114                                                          112
44    BEGIN ENTER     P4          ENTER AISLES AWAITING DOORS                         113
45          ADVANCE   FN2         DOOR-MECHANISM DELAY, USING P4 ALSO      CB161120   114
46          LEAVE     P4                                                   CB161130   115
47          QUEUE     P9                                                   CB161140   116
48          LINK      P1,FIFO,AAA                                                     117
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49   AAA    GATE NU    P5               HELD FOR EXIT REASSIGNMENT
50          UNLINK     P1,AAA,1
51          TEST GE    Q*3,K0,SEZ                                        CB161170
52          TEST NE    P9,21,NOONE                                       CB161180
53          TEST NE    P9,24,NOFOR                                       CB161190
54          TEST NE    P9,27,NOSEV                                       CB161200
55          TEST NE    P9,30,NOTEN                                       CB161210
56          TEST NE    P9,33,NOTHT
57   NOONE  TEST L     Q*V$SIDE2,K0,ONE4                                 CB161220
58          TRANSFER   ,ASGN2                                            CB161230
59   ONE4   TEST L     Q*V$SIDE4,K0,SEZ                                  CB161240
60          TRANSFER   ,ASGN4                                            CB161250
61   NOFOR  TEST L     Q*V$SIDE1,K0,FOR2                                 CB161260
62          TRANSFER   ,ASGN1                                            CB161270
63   FOR2   TEST L     Q*V$SIDE2,K0,FOR4                                 CB161280
64          TRANSFER   ,ASGN2                                            CB161290
65   FOR4   TEST L     Q*V$SIDE4,K0,SEZ                                  CB161300
66          TRANSFER   ,ASGN4                                            CB161310
67   NOSEV  TEST L     Q*V$SIDE1,K0,SEV2                                 CB161320
68          TRANSFER   ,ASGN1                                            CB161330
69   SEV2   TEST L     Q*V$SIDE2,K0,SEV3                                 CB161340
70          TRANSFER   ,ASGN2                                            CB161350
71   SEV3   TEST L     Q*V$SIDE3,K0,SEV4
72          TRANSFER   ,ASGN3                                            CB161370
73   SEV4   TEST L     Q*V$SIDE4,K0,SEZ
74          TRANSFER   ,ASGN4
75   NOTEN  TEST E     Q*V$SIDE1,K0,TEN2
76          TRANSFER   ,ASGN1                                            CB161390
77   TEN2   TEST L     Q*V$SIDE2,K0,TEN3
78          TRANSFER   ,ASGN2
79   TEN3   TEST L     Q*V$SIDE3,K0,SEZ                                  CB161400
80          TRANSFER   ,ASGN3                                            CB161410
81   NOTHT  TEST L     Q*V$SIDE1,K0,THT3
82          TRANSFER   ,ASGN1
83   THT3   TEST E     Q*V$SIDE3,K0,SEZ
84          TRANSFER   ,ASGN3
85   ASGN1  ASSIGN     4-,3             SEND PAX TO NEXT EXIT FORWARD    CB161420
86          ASSIGN     5-,3                                              CB161430
87          ASSIGN     6-,3                                              CB161440
88          DEPART     P9                                                CB161450
89          ASSIGN     9-,3                                              CB161460
90          QUEUE      P9                                                CB161470
91          QUEUE      P10                                               CB161480
92          DEPART     P10                                               CB161490
93          TRANSFER   ,SEZ                                              CB161500
94   ASGN2  ASSIGN     4+,3             SEND PAX TO NEXT EXIT AFT        CB161510
95          ASSIGN     5+,3                                              CB161520
96          ASSIGN     6+,3                                              CB161530
97          DEPART     P9                                                CB161540
98          ASSIGN     9+,3                                              CB161550
99          QUEUE      P9                                                CB161560
100         QUEUE      P10                                               CB161570
101         DEPART     P10                                               CB161580
102         TRANSFER   ,SEZ                                              CB161590
103  ASGN3  ASSIGN     4-,6                                              CB161600
104         ASSIGN     5-,6                                              CB161610
105         ASSIGN     6-,6                                              CB161620
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106         DEPART     P9                                                CB161630
107         ASSIGN     9-,6                                              CB161640
108         QUEUE      P9                                                CB161650
109         QUEUE      P10                                               CB161660
110         DEPART     P10                                               CB161670
111         TRANSFER   ,SEZ                                              CB161680
112   ASGN4 ASSIGN     4+,6                                              CB161690
113         ASSIGN     5+,6                                              CB161700
114         ASSIGN     6+,6                                              CB161710
115         DEPART     P9                                                CB161720
116         ASSIGN     9+,6                                              CB161730
117         QUEUE      P9                                                CB161740
118         QUEUE      P10                                               CB161750
119         DEPART     P10                                               CB161760
120         TRANSFER   ,SEZ                                              CB161770
121   SEZ   QUEUE      P5             BEGIN EXIT DELAY-INTERVALS         CB161780
122         SEIZE      P5                                                CB161790
123         DEPART     P9                                                CB161800
124         MARK       8                                                 CB161810
125         ADVANCE    V*5                                               CB161820
126         RELEASE    P5                                                CB161830
127         TEST E     P4,7,QUE4      PATH 7 INCLUDES OVERWING SEGMENT, 6 IN P7 CB161850
128         ASSIGN     7,6                                               CB161860
129         QUEUE      P7                                                CB161870
130         ENTER      P7             ENTER STORAGE FOR OVERWING RAMP    CB161880
131         ADVANCE    V*7                                               CB161890
132         LEAVE      P7                                                CB161900
133         DEPART     P7                                                CB161910
134   QUE4  QUEUE      P4                                                CB161920
135         ENTER      P5             ENTER STORAGE FOR SLIDE TIME       CB161930
136         ADVANCE    V*4                                               CB161940
137         LEAVE      P5                                                CB161950
138         DEPART     P4                                                CB161960
139         DEPART     P5                                                CB161970
140         SAVEVALUE  P5,M1          RECORD THE LATEST TOTAL TIME FOR EACH PATH CB161990
141   TERM  TERMINATE  1                                                 CB162000
      *                               STORAGE CAPACITIES LISTED NEXT     CB162010
```