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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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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			No.	Intracabin Redirection		Average Total Evacuation Time	Average Total Evacuation Time
I[1]	A	B[2]	Pax	Yes	No	(s)	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
2          TRANSFER   .200,,FWDA   FORWARD TYPE A EXIT EXPECTS 1/5
3          TRANSFER   .250,,MIDA   SECOND TYPE A EXIT EXPECTS 1/5
4          TRANSFER   .333,,AFTA   THIRD TYPE A EXIT EXPECTS 1/5
5          TRANSFER   .500,,AFT1   FOURTH TYPE A EXIT EXPECTS 1/5
6          TRANSFER   ,ADDL        FIFTH TYPE A EXIT EXPECTS 1/5
7    FWDA  ASSIGN     4,1                                                    CB160740
8          ASSIGN     5,2                FIRST EXIT, SLIDE NBR ASSIGNED P5   CB160750
9          ASSIGN     6,2                OPPOSITE SIDE E&S NBR ASSIGNED P6   CB160760
10         ASSIGN     9,21                                                   CB160770
11         ASSIGN     1C,22                                                  CB160780
12         ASSIGN     1,1
13         TRANSFER   ,EXIT                                                  CB160790
14   MIDA  ASSIGN     4,4                                                    CB160800
15         ASSIGN     5,5                                                    CB160810
16         ASSIGN     6,5                                                    CB160820
17         ASSIGN     9,24                                                   CB160830
18         ASSIGN     1C,25                                                  CB160840
19         ASSIGN     1,2
20         TRANSFER   ,EXIT                                                  CB160850
21   AFTA  ASSIGN     4,7                                                    CB160860
22         ASSIGN     5,8                                                    CB160870
23         ASSIGN     6,8                                                    CB160880
24         ASSIGN     7,6          OVERWING-RAMP PATH IS NUMBERED   6 IN P7  CB160890
25         ASSIGN     9,27                                                   CB160900
26         ASSIGN     10,28                                                  CB160910
27         ASSIGN     1,3
28         TRANSFER   ,EXIT                                                  CB160920
29   AFT1  ASSIGN     4,10                                                   CB160930
30         ASSIGN     5,11                                                   CB160940
31         ASSIGN     6,11                                                   CB160950
32         ASSIGN     9,30                                                   CB160960
33         ASSIGN     1C,31                                                  CB160970
34         ASSIGN     1,4
35         TRANSFER   ,EXIT                                                  CB160980
36   ADDL  ASSIGN     4,13                                                   CB160990
37         ASSIGN     5,14                                                   CB161000
38         ASSIGN     6,14                                                   CB161010
39         ASSIGN     9,33                                                   CB161020
40         ASSIGN     1C,34                                                  CB161030
41         ASSIGN     1,5
42         TRANSFER   ,EXIT                                                  CB161040
43   EXIT  TEST GE    N2,114
44   BEGIN ENTER      P4           ENTER AISLES AWAITING DOORS
45         ADVANCE    FN2          DOOR-MECHANISM DELAY, USING P4 ALSO      CB161120
46         LEAVE      P4                                                     CB161130
47         QUEUE      P9                                                     CB161140
48         LINK       P1,FIFO,AAA
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49    AAA    GATE NU    P5               HOLD FOR EXIT REASSIGNMENT
50           UNLINK     P1,AAA,1
51           TEST GE    Q*9,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$SIDE2,K0,ONE4                            CB161220
58           TRANSFER   ,ASGN2                                       CB161230
59    ONE4   TEST E     Q*V$SIDE4,K0,SEZ                             CB161240
60           TRANSFER   ,ASGN4                                       CB161250
61    NOFOR  TEST L     Q*V$SIDE1,K0,FOR2                            CB161260
62           TRANSFER   ,ASGN1                                       CB161270
63    FOR2   TEST E     Q*V$SIDE2,K0,FOR4                            CB161280
64           TRANSFER   ,ASGN2                                       CB161290
65    FOR4   TEST E     Q*V$SIDE4,K0,SEZ                             CB161300
66           TRANSFER   ,ASGN4                                       CB161310
67    NOSEV  TEST E     Q*V$SIDE1,K0,SEV2                            CB161320
68           TRANSFER   ,ASGN1                                       CB161330
69    SEV2   TEST E     Q*V$SIDE2,K0,SEV3                            CB161340
70           TRANSFER   ,ASGN2                                       CB161350
71    SEV3   TEST E     Q*V$SIDE3,K0,SEV4
72           TRANSFER   ,ASGN3                                       CB161370
73    SEV4   TEST E     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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