Chapter 2

EVACUATION DEMONSTRATIONS FOR CERTIFICATION

Evacuation Demonstrations for Certification

Beginning in 1965, the Federal Aviation Administration (FAA) required each air carrier operating under Part 121 of the Federal Aviation Regulations to perform full-scale evacuation demonstrations under simulated emergency conditions prior to receiving operating certification for new aircraft or seating configurations.[1] The air carrier demonstration was designed to evaluate crew training and the adequacy of evacuation procedures.[2] FAA initially imposed a 120-second egress time limit for evacuating all passengers and crew. See box 2-A on evacuation regulation chronology.

FAA attributed a 1967 change in maximum egress time to 90 seconds to advances in slide technology that had occurred since the initial standard was released. g In 1982, after study of actual and demonstrated emergency evacuations, FAA allowed certificate holders, under specified conditions, to use the results of a successful demonstration conducted by either the manufacturer or another airline rather than conduct a new test.[4]

The stated goal of requiring the full-scale demonstrations is to provide a benchmark by which FAA can consistently evaluate evacuation capability using various seating and exit configurations.[5] FAA claims that a consistent measure of success is achieved by requiring all manufacturers to strive for the same 90-second limit. According to FAA, the demonstration . . . is not an acceptable evacuation performance standard.“G That is, manufacturers must also comply with specific equipment and minimum configuration requirements in addition to successfully demonstrating complete evacuation within 90 seconds. Performance standards, on the other hand, are expressed using objective performance goals alone--no specific design or operating criteria are established.

In addition to the 90-second time limit, FAA full-scale evacuation demonstration criteria include the following:

- The demonstration must be conducted during the[6] dark of night or with the dark of night simulated--the airplane’s emergency lighting system can provide the only illumination of exit paths and slides;
- A specified mix of passengers “in normal health” must be used--for example, at least 30 percent must be females and at least 5 percent must be over 60 years of age;
- The passengers may not have participated in a demonstration in the previous 6 months; and
- Not more than 50 percent of the emergency exits may be used.

In a 1989 advisory circular (AC), FAA provided guidance to manufacturers on how to determine whether analysis and tests might be used in place of full-scale demonstration.[7] The AC also provided guidelines for set-up and conduct of the demonstration. Among other things, the AC identified two equivalent age-sex distributions, shown in table 2-1. Under the 1989 FAA guidelines, manufacturers may replace participants in the highest age category (i.e., the one most susceptible to injury) with greater numbers of persons aged 51 to 60 years and need not use minors.

1 29 *Federal Register 18291* (Dec. 24, 1964).
2 Anthony J. Broderick, associate administrator for regulation and certification, Federal Aviation Administration, testimony at hearings before the House Committee on Government Operations, Subcommittee on Government Activities and Transportation, Apr. 11, 1991.
3 31 *Federal Register* 10276 (July 29, 1966).
4 Walter S. Coleman, director, operations, Air Transport Association, “Emergency Evacuations, Career *Training*, and Passenger Briefings, ” paper presented at the FAA Technical Conference on Emergency Evacuation of Transport Category Airplanes, Sept. 3-6, 1985, Seattle, WA, p. 3.
5 54 *Federal Register 26692* (June 23, 1989).

6 Ibid.
7 U.S. Department of Transportation, Federal Aviation Administration, Advisory Circular 25.803-1, Nov. 13, 1989.

Box 2-A–Chronology of Changes to Evacuation Regulations

June 1965	Amendment 121-2 required all transport-category aircraft operators to conduct demonstrations, to be completed in less than 120 seconds, for all previously built and new aircraft.
October 1%7	Amendment 25-15 required manufacturers to conduct a 90-second demonstration, and required that aircraft be equipped with automatically deployed egress assist devices. [1]
	Amendment 121-30 revised the operators' demonstration time limit from 120 seconds to 90 seconds, and required *retrofit* of automatically deployed egress assist devices within 2 years for all previously built aircraft.
December 1978	Amendments 25-46 and 121-149 revised requirements to permit manufacturers and operators to concurrently demonstrate compliance with evacuation certification requirements, and allowed evacuation certification to be substantiated by a combination of analysis and tests at the discretion of the FAA Administrator.
January 1982	Amendment 121-176 required, if an aircraft is certified to FAR 25.803 per Amendment 25-46, the airline operator to demonstrate crew proficiency by showing that crew members can open half the exits and achieve usable slides within 15 seconds.
March 1990	Amendment 121-124 established criteria for passengers seated in exit rows.

1 Egress assist devices include slides, slide raft combinations, and overwing escape routes. At certain exits, slides must be automatically erected as well.

KEY: FAR = Federal Aviation Regulations, Title 14, Chapter 1 of the CodC of Federal Regulations.

SOURCES: Federal Aviation Administration Advisory Circular No. 25-803-1. Nov. 13, 1989; and Aviation Rulemaking Advisory Committee, Emergency Evacuation Subcommittee, Performance Standards Working Group, "Emergency Evacuation Requirements and Methods That Would Eliminate or Minimize the Potential for Injury to Full-Scale Evacuation Demonstration Participants, " unpublished report, January 1993.

LIMITATIONS OF FULL-SCALE DEMONSTRATIONS

Full-scale demonstrations of evacuation systems are both hazardous and costly. Intended to serve as a benchmark for functional ability of emergency equipment and procedures, the test is not useful for system optimization.

The emergency evacuation scenario used in fill-scale demonstrations does not represent most accident conditions, where impact forces and fire effects frequently impair passengers' abilities to escape the aircraft. Participants in demonstrations know they face no such danger in their efforts to quickly exit the aircraft, so panic is not present. However, the test still exposes participants to a range of injuries, from bumps and bruises to serious, permanent injury. During seven full-scale demonstrations conducted by manufacturers between 1972 and 1980, 166 of 2,571 total participants received injuries, or 6.5 percent. Of the 3,761 participants in 12 demonstrations conducted between

Table 2-l-Equivalent Passenger Age-Sex Distributions for Evacuation Certification Participants, 1989 Federal Aviation Administration Advisory Circular

Passenger distribution 1:

Age	Percent of total	Percent of females
21-50	80	30
51-59	15	40
>60	5	30

Passenger distribution 2:

Age	Percent of total	Percent of females
18-50	75	30
51-60	25	40

NOTE: Minors are precluded from participating in evacuation demonstrations under many state child labor laws. Distribution 2 eliminates the need for participants older than age 60, who are most susceptible to injury. In August 1993, relying on Civil Aeromedical Institute and industry data on the relative evacuation rates of different age and sex mixtures, FM amended the age/sex distribution requirement for evacuation demonstration participants as follows: (1) at least 40 percent of the passenger load must be female; (2) at least 35 percent must be over 50 years of age; (3) at least 15 percent must be female and over 50 years of age.

SOURCE: U.S. Department of Transportation, Federal Aviation Administration, Advisory Circular 25.803-1, Nov. 13, 1989, and 58 *Federal Register 45230* (Aug. 26, 1993).

1981 and 1991, 212 received injuries (5.6 percent),8

The cost of conducting full-scale evacuation demonstrations, including test set-up, payments to volunteers, analysis, and so forth, reaches upward of $2 million for wide-body transports.[9] The cost of evacuation demonstration is insignificant compared to overall program and airplane construction; manufacturers assert it is the hazard of serious injury, not test costs, that generated their interest in modifying the existing certification criteria and developing alternative testing and assessment methods.

Since FAA first imposed the evacuation test on airlines and airframe manufacturers, there have been only two major changes. First, improvements in slide technology prompted FAA to reduce the maximum evacuation time in 1967. Second, Federal and State occupational safety and healh laws proscribe the use of children under 18 years of age in the demonstrations. [10]

As with other safety standards, the demonstration for certification relates to a minimum level of safety; airline economics dictate that manufacturers strive for maximum seating capability, not optimal safety for a given number of passenger seats. Both cost and the potential for injury make manufacturers reluctant to conduct any more than the minimum number of tests required of the industry.

The utility of FAA's "benchmark" for evacuation capability hinges on the comparability of test conditions and test results. The benchmark enables FAA to determine only if an aircraft achieves the same minimum level of performance as other aircraft before it; the benchmark does not permit quantitative assessment of overall safety or the relative performance of elements within the aircraft's evacuation system. The subjective nature of some of the test criteria (e.g., the maximum level of illumination possible to simulate the dark of night) introduces variability. Controlling variability is a key factor in the statistical validity of any test, as discussed below.

Test and Data Validity

In order to assess the validity of a test or its data, one must judge both the quality of the test procedure and the measurement methodology. The identification of major variables and how they affect the outcome of a test lends credibility to the process, as does the repeatability of results. Achieving consistent test conditions is fundamental to limiting variability. FAA and industry use the benchmark of 90 seconds to gauge whether different cabin seating and exit configurations provide a minimum level of aircraft evacuation safety. Human performance, a dominant variable in successful evacuations under real or imagined emergency situations, is not easily controlled. The following factors may greatly affect the outcome of an actual emergency evacuation performance:

- cabin and flight crew capabilities (e.g., training, experience, and physical/mental condition);
- aircraft integrity and evacuation technologies;
- passenger demographics, percent of seats occupied, and amount and mix of carry-on luggage;
- ambient lighting; and,
- actual accident conditions.

One potential problem with the test procedure is that the mix of test participants required by FAA is often not representative of the flying public on a given flight. In general, passenger demographics vary from region to region and seasonally. Tests conducted using passenger loads with higher percentages of women and

8 Aviation Rulemaking Advisory Committee, Emergency Evacuation Subcommittee, Performance Standards Working Group, "Emergency Evacuation Requirements and Compliance Methods That Would Eliminate or Minimize the Potential for Injury to Full-Scale Evacuation Demonstration Participants, " unpublished report, January 1993, p. 10.

9 Webster C. Heath, manager, Technical Liaison, Industry Regulatory Affairs, Douglas Aircraft Co., personal communication, July 8, 1992.

10 William H. Shook, senior principal technical specialist, Douglas Aircraft Co., personal communication, Dec. 16, 1992.

elderly persons, or with children and persons with disabilities, would likely generate longer average evacuation times. See box 2-B on FAA tests with persons with disabilities and figure A-1 in the appendix.

An unrealistic passenger mix, combined with the absence of surprise, trauma, fright, and panic, produces optimistic indications of an aircraft's evacuation safety capability.[11] However, industry and many others are understandably loathe to subject demonstration participants to the presence of fire, smoke, and additional debris, for fear of increasing the likelihood of injury. On the other hand, any changes to the certification process designed to reduce the risk of injury require analysis of the comparability of results.

In addition, without the benefit of repeated trials, one cannot be confident that a single certification test result truly represents an aircraft evacuation system's capability. Neither a margin of error or confidence level can be determined (see figure A-2 in the appendix). By comparison, use of anthropomorphic dummies allows auto manufacturers to conduct realistic crash response tests repeatedly and with high validity, without threat to human safety, and to determine performance relative to government standards.[12] FAA and the aviation community struggle to achieve agreement on whether the value of but one full-scale evacuation demonstration for certification warrants the risk. A formal vehicle for this discussion was the Emergency Evacuation Subcommittee established by the FAA Aviation Rulemaking Advisory Committee (ARAC).[13] The following section describes the subcommittee's progress and potential changes to the demonstration requirement.

DEVELOPMENT OF ALTERNATIVES

In February 1991, ARAC formed a subcommittee to address a slate of regulatory reforms in the evacuation area--reforms recommended during the conferences and workshops of the mid-1980s--and charged it with giving advice and recommendations to the FAA Flight Standards and Aircraft Certification offices on regulatory standards for evacuation and passenger safety. In turn, the subcommittee chartered a working group to address the potential for using performance standards in place of or in addition to design criteria for certification.[14] The Performance Standards Working Group (PSWG--members are drawn from the various elements of the aviation community) is charged with making a recommendation concerning whether new or revised standards for emergency evacuation can and should be stated in terms of safety performance rather than as specific design requirements. The working group must consider two questions:

- Can standards stated in terms of safety performance replace, supplement, or be an alternative to any or all of the current combination of design and performance standards that now address emergency evacuation found in Federal Aviation Regulations Parts 25 and 121?
- If a performance standard is recommended, how can FAA evaluate a minor change to an approved configuration, or a new configuration that differs in either a minor or a major way from an approved configuration?

In November 1991, PSWG expanded its mission to include making a recommendation to the Emergency Evacuation Subcommittee con-

11 S.M. Vanstone, Vice chairman, Aircraft Designs and Operations Committee, International Federation of Air Line Pilots Association (IFALPA), "Emergency Evacuation and Cabin Safety, " paper presented at the FAA Public Technical Conference on Emergency Evacuation of Transport Airplanes, Sept. 3-6, 1985, Seattle, WA, p. 1.

12 Jeffry H. Marcus, manager, Protection and Survival Laboratory, Civil Aeromedical Institute, personal communication, Jan. 13, 1992.

13 Created February 5, 1991, ARAC is comprised of FAA officials and representatives from 58 aviation groups.

14 As part of the 1993 renewal of ARAC's charter, the subcommittees were redesigned as interest areas (e. g., Emergency Evacuation Issues) and working groups now report directly to ARAC. Steve Erickson, assistant chair, Aviation Rulemaking Advisory Committee, Emergency Evacuation Issues, personal communication, Aug. 16, 1993.

Box 2-B–Evacuation of Persons With Disabilities

Because the need for assistance in emergency situations has limited the access of nonambulatory persons to commercial air transportation, in the early 1970s, the Federal Aviation Administration (FAA) commissioned the Civil Aeromedical Institute (CAMI) to study aircraft evacuation using passengers with disabilities.[1]

CAMI testing showed that, when occupying window seats, passengers with disabilities spent 50 percent of the total time required for egress in moving from their seats to the aisle. The data suggested that persons with disabilities should be seated along the aisle. However, this may compromise the safety of the passengers in the outboard seats. CAMI's evacuation trials also showed that total evacuation times were shorter when nonambulatory passengers were seated away from the exits. Other observations from the study included:

- Aide width and seat row pitch affect the ability ofother passengers to assist nonambulatory persons.
- Passengers with disabilities may need to be reoriented before entering the slides.

The desire to ensure accessibility to all forms of transportation led to a 1982 Civil Aeronautics Board ruling that all passengers, regardless of impairment, should be given reasonable access to air travel and the opportunity to use ordinary, unaltered airline services.[2] While it may be technically feasible to derive optimum seating conjurations for different percentages of passengers with disabilities, political and ethical considerations likely preclude the implementation of any such plans.

Rule changes adopted in 1991, and revised in 1992, limit seating adjacent to exits to those passengers who are proficient in the English language and do not have mobility, sensory (e.g., hearing and vision), or cognitive (e.g., schizophrenia) impairments.

1 J.G. Blethrow et al., Civil Aeromedical Institute, *Emergency Escape of Handicapped Air Travelers,* FAA-AM-77-11 (Washington, DC: Federal Aviation Administration, July 1977), pp. 1-2.

2 Mary Edwards and Elwyn Edwards, *The Aircraft Cabin: Managing the Human Factors* (Hants, England: Gover Technical Publishing Co., 1990), pp. 45-46.

cerning new or revised emergency evacuation requirements and compliance methods that would eliminate or minimize the potential for injury to fill-scale demonstration participants. PSWG released its report on methods of reducing risk of injury to participants in emergency evacuation demonstrations for certification in January 1993. Table 2-2 lists the working group's conclusions and recommendations.

Despite months of effort to reach consensus, the report failed to satisfy the group as a whole.[15] Three letters of dissent, submitted with the working group's report, described dissatisfaction with the process and report conclusions. Key concerns were the perceived failure of the group to ". . . undertake a systematic analysis of the procedures used in conducting full scale evacuation demonstrations, " and the loss of valuable crew performance information incurred by eliminating the requirement for full-scale demonstrations.[16] The Air Line Pilots Association expressed concern that the absence

[15] ARAC was intended to speed the rulemaking process by including constituents at the front end of regulation development (i.e., before notice of proposed rulemaking and request for comments are released). However, the length of time required by the Performance Standards Working Group to address its first mission caused some concern on the part of the subcommittee's chairman and members of Congress that the process is itself unwieldy.

[16] Association of Flight Attendants "Comments on Performance Standards Working Group Report, " unpublished report, Jan. 15, 1993, p. 1.

Table 2-2-Conclusions and Recommendations of the Performance Standards Working Group, 1992 Report

Conclusions:

- The nature of the full-scale evacuation demonstration, as currently defined in FAR 25.803(c), is such that injuries can occur.
- The full-scale evacuation demonstration can be a useful tool for comparing the evacuation capability of a new, unique airplane configuration with the current FAR 25.803 standard.
- The full-scale evacuation demonstration test conditions can and should be revised to minimize the potential for injuries to test participants.
- Steps must be taken to ensure that testing with humans is strictly limited and controlled. Only after all alternative means of obtaining necessary data have been deliberated should limited exposure of test subjects to the evacuation demonstration test conditions of FAR 25.803(c) be considered.
- Full-scale evacuation demonstrations should be conducted for only those airplane configurations where regulatory authority-approved test data are not available to support analysis.

Research recommendations:

- CAMI, or another source FAA deems appropriate, carry out a study to determine which age and sex group(s) are least susceptible to injury and develop an appropriate age and sex mix for full-scale demonstration tests while maintaining the validity of the 90-second criterion.
- Initiate a research program to develop a new, two-part emergency evacuation test protocol for escape slide testing and airplane flow rate tests without the use of escape slides.
- Institute a high-priority research and development program to develop long-term revisions to the evacuation demonstration test protocol so as to further minimize injuries to test participants.
- Develop a system or process for FAA to collect data on injuries sustained during emergency evacuation demonstration testing.
- Establish an FAA escape slide research and development program designed to further minimize injuries.

KEY: **CAMI = FAA's Civil Aeromedical Institute; FAA= Federal Aviation Administration; FAR = Federal Aviation Regulations, Title 14, Chapter I of the Code of Federal Regulations.**

SOURCE: **Aviation Rulemaking Advisory Committee, Emergency Evacuation Subcommittee, Performance Standards Working Group, "Emergency Evacuation Requirements and Compliance Methods that Would Eliminate or Minimize the Potential for Injury to Full Scale Evacuation Demonstration Participants," unpublished report, January 1993.**

of data on injury rates for alternatives to the two extremes of certification (analysis only or fill-scale demonstrations) made the working group report biased toward FAA approval based solely on analysis.[17]

Analysis

Injuries sustained over the years by demonstration participants became the basis for the 1978 rule change[18] providing that the demonstration requirement may be waived if the Administrator finds that a combination of analysis and component testing[19] will provide data equivalent to that obtainable through full-scale demonstration.[20] In 1982, Boeing Aircraft presented to FAA an analysis approach that relied on a timeline summation of evacuation activities from exit preparation to the arrival of the last evacuee on the ground. All segments of the timeline were derived using data from FAA-witnessed tests and tests verifiable from video or film records .21 Boeing's model approach is outlined in figure A-3. The time of exit flow is equal to the time elapsed between the first evacuee and last evacuee reaching the ground; this time is a function of the anticipated number of passengers and crew and the flow rate permitted by exits.[22] Critical to the analysis (and evacuation performance) is the balanced loading of passengers with respect to exit size and location. To address the issue of passenger management (flow control), Boeing includes a discussion of passenger distribution; exit performance capability, both preparation and egress; and crew member performance elements (e.g., time of travel to duty position).[23]

The Douglas Aircraft Company adopted a similar approach for predicting evacuation performance, using data from prior demonstrations and component tests, along with "industry-accepted averages, " to estimate total evacuation time. Douglas Aircraft Company staff believe the analytical model is more credible than a full-scale demonstration, which is affected by numerous human factors.[24] Industry in general supports testing of component performance, emergency procedures, and crew training to avoid exposing crew and demonstration volunteers to the risk of injury, but there is some political sensitivity to certification by analysis, as discussed in box 2-C.

Demonstrations With Platforms

One suggestion for reducing the likelihood of injury to demonstration participants entails replacing the slides with level platforms or gently sloped ramps. Slide performance data would thus be obtained with more controlled demonstrations that present fewer risks to participants.

On December 11 and 12, 1992, for its second attempt to certificate the MD-11 for 410 passenger seats, McDonnell Douglas adopted such a phased approach.[25] McDonnell Douglas first developed the analytic methodology to equate the existing 90-second test with slides to a ramp-based test of an unknown time limit. To fill in data gaps, McDonnell Douglas conducted component tests to establish average opening times for doors with and without slides, and the flow rates (passengers per minute) through doors without slides.

McDonnell Douglas completed 10 tests with 100 persons each to establish rates for Type A

17 Ricky R. Davidson, chairman, Air Line Pilots Association, Accident Survival Committee, letter to Jay Anema, chairman, Performance Standards Working Group, Jan. 19, 1993.

18 See FAR amendments 25-46 and 121-149.

19 Component tests and partial demonstrations examine the performance of isolated elements within the evacuation system.

20 George Veryioglou, engineer, Airframe Systems Technology, Boeing Commercial Airplane Group, "Emergency Evacuation System Certification via Analysis and Tests, " paper presented at the FAA Technical Conference on Emergency Evacuation of Transport Airplanes, Sept. 3-6, 1985, Seattle, WA, p. 5.

21 Ibid., p. 10.

22 Ibid., p. 11.

23 Ibid., pp. 11-12.

24 Douglas Aircraft Co., "MD-11 Evacuation Demonstration: Analysis and Changes Overview With Analytic Model, " paper submitted to the Federal Aviation Administration, n.d., p. 6.

25 According to McDonnell Douglas staff, the California Occupational Safety and Health Agency would not allow the manufacturer to repeat the full-scale demonstration with slides in total darkness.

Box 2-C–Political Sensitivity to Use of Analysis in Evacuation Certification

In 1984, Boeing proposed to deactivate one of five pairs of overwing exits on inservice passenger 747s.[1] Maximum passenger density would be reduced to 440 from 550, commensurate with the new number of Type A exit pairs.[2] However, the distance between doors would exceed 60 feet. (Existing regulations did not specify the maximum distance between exit doors.) The Federal Aviation Administration (FAA) Transport Aircraft Certification Office (Northwest Mountain Region) approved Boeing's request based on analysis.

Flight attendant unions protested the decisions and certification process, and called on Congress to intervene on grounds of diminished safety.[3] A June 1985 hearing conducted by the House Committee on Public Works, Subcommittee on investigations and Oversight brought public attention to both the potential impact of allowing large distances between exits and the unscrutinized process in which the deactivation was approved. At the hearing, FAA Administrator Donald Engen announced his disapproval of sealing off the overwing exits. Subsequently, Admiral Engen appointed an Emergency Evacuation Task Force to examine the issue and reassess related emergency evacuation regulations.[4]

In October 1987, FAA published a notice of proposed rulemaking relating to new standard limits on transport category airplanes for the distance between any passenger seat and the nearest exit and the distance between exits.[5] Under the rule, type certification for the new 747-400 with only eight exits would not be approved, and operation within the United States of oreign-owned 747s having eight exits would not be allowed.[6] In 1989, FAA issued a final rule prohibiting airplane manufacturers and air carriers from increasing the distance between emergency exits beyond 60 feet.[7] Boeing maintains the rule was specifically applied to the 747 but not the Lockheed L-1011, which also had distances greater than 60 feet between exits.[8] Mathematical analysis of evacuation times for the different configurations (i.e., 440 passenger seats with 8 exits or 550 passenger seats with 10 exits) would yield the same results because flow rates and door opening times were insensitive to variations in internal configurations.

1 At the time, Boeing offered the 747 in various configurations, including a passenger model with 10 Type A main deck exits; convertible and combi 747s with 10, 8, or 6 main deck Type A exits; and the special performance 747, with 8 such exits. George Veryiglou, senior manager, 747/767 Payload Systems, Boeing Commercial Airplane Group, personal communication, Jan. 25, 1993.

2 14 CFR 25.807 rates each Type A exit pair at 110 passengers.

3 U.S. Congress, Office of Technology Assessment, *Safe Skies for Tomorrow: Aviation Safety in a Competitive Environment*, OTA-SET-381 (Washington, DC: U.S. Government Printing Office, July 1988), p. 57, available from OTA's Science, Education, and Transportation Program.

4 Scott Imus, director of staff for Congressman James L, Oberstar, "Keynote Address." *Proceedings of the Flight Safety Foundation/Federal Aviation Administration International Aircraft Occupant Safety Conference and Workshop*, DOT/FAA/OV-89-2 (Washington, DC: U.S. Department of Transportation, August 1989), p. 12.

5 NPRM 87-10,52 *Federal Register* 39190 (Oct. 20,1987).

6 Off&of Technology Assessment, op. cit., footnote 3, p. 57.

7 14 CFR 121.310, Amendment 121-205, 54 *Federal Register* 26696 (June 23, 1989).

8 Veyioglou, op. cit. footnote 1. The L-1011 is still operated under Part 121 with these distances.

and Type I doors. Based on the test results, McDonnell Douglas proposed a maximum time limit of 62 seconds for the modified certification demonstration.[26] Additionally, after three evacuations using different procedures and flight attendant stations, McDonnell Douglas staff concluded that the cabin could be effectively managed with 9 (the minimum number required by FAA) instead of 10 flight attendants.

The evacuation test was completed in 56 seconds; a time margin analysis like that espoused by the Working Group for future certifications by analysis yielded 51 seconds, well above the

26 Shook, Op. cit., footnote 10.

10 percent factor.[27] The entire testing program resulted in only four minima1 injuries, although past experience suggested one or two fractures would occur.[28] FAA held the test to be sufficient for certification. Boeing and Airbus will likely adopt use of component tests and analysis when possible. However, this approach tells little about the system effects of new slide configurations, a major factor in evacuation performance and one that has often changed.[29]

Limitations to Analysis

The analytical models provide only estimates of flow rates under ideal conditions; the models do not take into account the effects of passenger motivation or the presence of fire, smoke, and injuries. The results of the October 1991 evacuation test for the MD-1 1 evacuation certification, in which test conditions were appreciably harsher,[30] illustrate this limitation. In addition, flow control is difficult to analyze mathematically because the calculations are insensitive to architectural changes within the cabin or differences in passengers' decision-making abilities.[31] Another concern over relying on analysis and component tests for certification is that, without full-scale demonstrations, it will be difficult to acquire information on passenger management strategies.

Industry asserts that its mathematical analysis methods are valid and that demonstrations using volunteers are no longer necessary. Boeing and McDonnell Douglas provided OTA incomplete data to perform a statistical analysis of the parameters used in their models.

Other Alternatives

In addition to the combination of analysis and component testing, the use of "professional" demonstration participants has been suggested (i.e., reduce the chance of injury by replacing the "naive" volunteers required for full-scale demonstrations with trained professionals).

The Civil Aeromedical Institute employs two different test protocols for its evacuation studies. In the first, participants repeat evacuation drills several times to gain experience before experimental variables are changed. Experimentation begins after no significant difference in evacuation times is reached. The second protocol entails exposing participants to the same combination of experimental variables in different orders to average the experience factor between subjects[32] (Latin square or counterbalanced experiment design).

Begging the question of whether or not the certification test represents reality, a ". . . systems test with naive subjects allows the evaluation of design factors such as cabin lighting, tactile clues for exit locations, etc., whose influence would be lost or minimized with experienced test subjects. "[33] Tests with young participants with similar athletic abilities could minimize the risk of injury but provide only optimistic estimates of evacuation performance. The comparability of test results with those of earlier demonstrations would be suspect.

Continuing research and technology development have been integral to improving the overall evacuation capability of an aircraft as well as developing new methods of assessing evacuation performance for certification purposes. The next chapter describes the major research and technology issues and programs related to evacuation performance.

27 The time margin analysis sums over all exits the difference between maximum allowable egress time (e.g., 90 seconds) and that achieved during the demonstration. The PSWG-recommended margin of 10 percent of the maximum equaled 6.2 seconds for the December 12, 1992, McDonnell Douglas evacuation test.

28 Shook, op. cit., footnote 10.

29 George Veryioglou, senior manager, 747/767 Payload Systems, Boeing Commercial Airplane Group, personal communication, Dec. 14, 1992.

30 FAA interpretation of the simulated dark of night requirement resulted in a pitch-black environment outside the aircraft; even the light from video monitors used for data collection was shielded from passengers' view. Additionally, a combination of cabin crews from different countries was used, contributing to poor coordination of flight attendant actions.

31 Shook, op. cit., footnote 10.

32 Marcus, op. cit., footnote 12.

33 Ibid.