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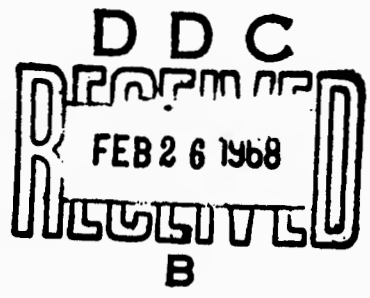
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**FINAL REPORT**

Contract Number FA67WA-1766

Project Number 530-011-01H

**NEW CONCEPTS FOR EMERGENCY  
EVACUATION OF  
TRANSPORT AIRCRAFT FOLLOWING  
SURVIVABLE ACCIDENTS**



**JANUARY 1968**

Prepared for

**DEPARTMENT OF TRANSPORTATION  
FEDERAL AVIATION ADMINISTRATION**

Aircraft Development Service

Washington, D.C., 20590

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**NORTH AMERICAN ROCKWELL CORPORATION  
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**LOS ANGELES DIVISION**

Los Angeles, California, 90009

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FINAL REPORT

Contract Number FA67WA-1766

Project Number 530-011-01H

Report Number ~~DS-68-2~~

ADS-68-2 ✓

NEW CONCEPTS FOR EMERGENCY EVACUATION OF  
TRANSPORT AIRCRAFT FOLLOWING SURVIVABLE ACCIDENTS

January 1968

Prepared by  
J. A. Roebuck, Jr.

This report has been prepared by North American Rockwell Corporation for the Aircraft Development Service, Federal Aviation Administration, under Contract No. FA67WA-1766. The contents of this report reflect the views of the contractor, who is responsible for the facts and the accuracy of the data presented herein, and do not necessarily reflect the official views or policy of the FAA. This report does not constitute a standard, specification or regulation.

NORTH AMERICAN ROCKWELL CORPORATION  
AEROSPACE AND SYSTEMS GROUP  
LOS ANGELES DIVISION

Los Angeles, California, 90009

## ABSTRACT

A systems analysis and creative engineering study has resulted in descriptions and theoretical evaluations of 51 new concepts concerning hardware and procedures for improving emergency evacuation of passengers from transport category aircraft following survivable accidents. The concepts are organized into 15 major concepts which are rank ordered in terms of 12 feasibility and economic factors for purposes of selection for experimental evaluation. The 15 major concepts are as follows: (1) application of automatic voice instructions and audio signal devices, (2) active, better distributed lighting mix for interiors and exteriors, (3) use of tactual sense displays, (4) situation displays for the crew, (5) improved interpersonal communication devices, (6) wide-spectrum passenger and crew education program and displays, (7) personal protective devices, (8) improved, general, on-board fire suppressant and prevention systems, (9) automatically and manually controlled cabin venting systems, (10) improved ground support complex, (11) better slide entry and egress devices, (12) better passenger containment and more versatile egress devices, (13) power assistance for doors and egress device deployment, (14) automatic passenger egress devices, (15) application of cargo handling concepts. Requirements for experimental evaluation are presented, with especial emphasis on the most favorably rated first five major concepts and their specific associated detail concepts.

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## INTRODUCTION

This report presents the procedures, results, conclusions, and recommendations of a study whose goal is to develop new concepts for emergency evacuation of passengers from transport aircraft following survivable accidents. The study was performed according to a plan prepared by North American Rockwell Corporation in response to a request for proposal from the Federal Aviation Agency, No. WAsR-6-0853, dated 1 July 1966, entitled "New Emergency Evacuation Concepts, Hitherto Unreported, for Air Transport Category Aircraft Following Survivable Accidents," (Project No. 530-011-01H).

The purpose of the study, as stated in the awarded contract, was to "develop a series of concepts which will provide a theoretical basis for the avoidance of fatalities in survivable aircraft accidents, especially those resulting from smoke, fire, fumes, or other toxic causes of human death in aircraft accidents. Each concept shall be:

- (a) New, original, and not a repetition of prior published concepts.
- (b) Described in sufficient detail to present a clear, accurate, and intelligible understanding to the reader.
- (c) Evaluated on a theoretical but realistically sound economic and operational basis.

"After consultation with, and approval by, the Federal Aviation Administration (FAA) Contracting Officer's Technical Representative (COTR), the contractor shall proceed with work on that concept or those concepts selected by the Government for full-scale experimentation. The Contractor shall detail the requirements of the selected concept or concepts for experimentation, in a manner which will enable the Government to publish a request for competitive proposals for such experimental work."

This report is submitted as the Final Report, contractually described as follows:

- "(a) The final Report shall contain a summary of all data used in developing the concepts; a description of the concepts developed under this contract; and the economic and operational evaluation of the selected concept or concepts, and recommendations of the Contractor.

- (b) An appendix to the report shall contain the data and requirements necessary for experimentation and evaluation of the selected concept or concepts."

As noted in the Table of Contents, the main body of the report discusses study procedures and general findings. Three appendices are presented, the first giving complete descriptive data and evaluation of some 51 detail concepts, and the second containing the requirements for experimental evaluation of the set of selected concepts. The final appendix is a fold-out diagram of the overall transport aircraft emergency evacuation system.

It will be noted that, in addition to description and evaluation of recent and proposed concepts for emergency evacuation, the report presents a structured summary of general requirements and considerations concerning aspects of the whole system of emergency evacuation of transport aircraft following survivable accidents. The primary emphasis in this report is the evacuation of large, fixed-wing transport aircraft, not of VTOL/STOL types. Also, priority has been given to on-board devices and procedures as contrasted with ground support or rescue systems.

However, it is expected that in the future there will need to be studies emphasizing evacuation schemes for VTOL/STOL-type aircraft and the further development of a quick-reacting, effective ground rescue system.

The study to develop new concepts followed closely the plan and schedule outlined in the North American Rockwell Corporation proposal. Briefly, this was to begin with assembling a group of senior specialists from a variety of disciplines, performing an analysis of historical records regarding the general subject, interviewing persons in the field, and inspecting mockups of transport aircraft currently being developed.

Following this initial phase was a period of concept development using creative engineering approaches to conceive solutions to problems identified in the first phase and then to evaluate these concepts in the light of economic, engineering, and operational requirements. The next phase was the selection and recommendation of concepts to the Federal Aviation Administration. Finally, the concepts jointly selected were discussed in further detail, and plans were prepared for experimental evaluation. Details of these procedures and the finding resulting from them are presented in the following sections.

## HISTORICAL ANALYSIS

The historical analysis phase encompassed review and analysis of recent trends in transport aircraft and other areas, with regard to provisions for emergency evacuation.

### LITERATURE REVIEW

A review of literature on emergency evacuation of transport aircraft, fire prevention and rescue systems, display and communication devices for emergency warning, and several other peripheral areas was conducted as part of the historical analysis. This was performed with the aid of the North American Rockwell Corporation Technical Information Center library personnel and other departments. The procedures employed included computerized searches of the corporate files on emergency egress, a search of patents using the Manufacturer's Aircraft Association services and corporate files, use of McDonnell Douglas Company files of Civil Aeronautics Board reports, and several other personal and public sources.

An important goal of this search was to establish the state-of-the-art, in order to be able to indicate whether any of the concepts to be developed had been previously described in prior publications, and if so, what type and distribution such publications might have had. This was in keeping with the spirit of one of the contractual statements listed in the Introduction of this report.

A document control and distribution system was set up to record acquisitions and distributions of documents to the various specialists according to the subject matter presented therein.

A preliminary list of references was collated and included with the Third Monthly Progress Report. The final list of all pertinent references is included in the Bibliography of this report. This list includes books, articles, and reports in one group; patents in another separate group. The former group is arranged alphabetically by author, sponsoring agency or publisher, and date. The latter is arranged chronologically by serial number.

The analysis activities were directed to identification of typical problem areas in emergency evacuations, typical sites and conditions of crashes, historical trends and extrapolations, and a search for technologies which could be used in improving emergency evacuation survivability. Although material of a statistical nature was reviewed, this was not a primary emphasis. It was felt that such activity was already being performed by several other agencies.

## INTERVIEWS AND MOCKUP INSPECTIONS

Personnel on the study team interviewed persons working in a variety of fields related to emergency evacuation, fire prevention and rescue, aircraft safety equipment manufacture, airline operations, aircraft design, lighting, and safety education. In connection with some interviews, mockups of the current large fixed-wing transport aircraft were inspected to gain firsthand knowledge of the cabin interior arrangements and exit systems.

These meetings, conversations, and inspections are briefly summarized in the following pages, combining the formats prepared for monthly progress reports.

### SUMMARY OF MEETINGS AND TELEPHONE CONVERSATIONS (MEETINGS ASTERISKED \*)

Agency Contacted,  
Time and Place of Meetings

Functions, Contacts, Purpose,  
and Subjects Discussed at Meetings

17 June through 17 July 1967

Radar Relay Div of Teledyne, Inc      Manufacturers of audio information display system (AID).

\*Nortronics Div of Northrop Corp      Manufacturers of Northrop Voice Interrup-  
Palos Verdes, Calif.                      tion Priority System (NORVIPS).

11 July 1967

Space Division of North American      G. E. Click - Nortronics - Palos Verdes,  
Rockwell Corporation, Downey,          Program Mgr - Nortronics Voice Warning  
Calif.    Systems.

Purpose: To obtain detailed technical data on the Nortronics Voice Warning and Instruction System and to discuss applications to emergency evacuation problems.

It appeared that the proposed use of NORVIPS (Northrop Voice Interruption Priority System) to passenger transport evacuation problems was a novel application. Several reports and references were obtained.

Agency Contacted,  
Time and Place of Meetings

Functions, Contacts, Purpose,  
and Subjects Discussed at Meetings

17 June through 17 July 1967

\*McDonnell Douglas Co Transport  
Aircraft Div, Long Beach, Calif.

J. A. Graves - member of Aircraft Industries Association Crashworthiness Committee, Manufacturers of Passenger Jet Transport Aircraft.

\*Pacific Inflatables Co

McDonnell Douglas - J. A. Graves, Advanced Design Interiors  
L. W. Teel - Chief Interiors Design  
H. C. Banas - Interiors Design

\*The Garrett Corporation  
13 July 1967  
McDonnell Douglas Co  
Long Beach, Calif.

Other Representatives:

R. Black - Remington Arms Co  
J. M. Johnson - Pacific Inflatables  
W. B. Palmer - The Garrett Corp

Purpose: To review activities of the Aircraft Industries Association Crashworthiness Committee work at McDonnell Douglas and to see a demonstration of Liquid (See Glossary-chemical light) installed on an inflatable slide.

Mr. Graves outlined the AIA Committee approach, after the slide demonstration. Their study effort parallels this FAA contract effort in some areas, but includes laboratory work and is more detailed in design and applications to current vehicles. Airport operations and ground support devices are not included.

\*Remington Arms Co  
13 July 1967  
Space Division of North  
American Rockwell Corporation  
Downey, Calif.

Manufacturers of Chemical Light

R. Black - Remington Arms Co  
J. M. Johnson - Pacific Inflatables Co

Purpose: To obtain detailed technical data on "chemical light," observe demonstration of samples, and discuss applications to emergency evacuation problems. This purpose was accomplished.

Agency Contacted,  
Time and Place of Meetings

Functions, Contacts, Purpose,  
and Subjects Discussed at Meetings

17 June through 17 July 1967

FAA Liaison Office  
Norton Air Force Base

To obtain access to crash survival statistics of military aircraft.

The Boeing Company  
Seattle, Wash.

Member of Aircraft Industries Association  
Crashworthiness Committee, Manufacturer  
of Passenger Jet Transport Aircraft.

Los Angeles Fire Dept  
Fire Prevention Bureau

Initiation of discussions concerning  
evacuation of large numbers of persons  
from burning buildings.

17 July through 17 August 1967

\*Los Angeles Fire Dept  
Fire Prevention Bureau

Battalion Chief, D. D. Smedley  
Captain J. Werner  
Captain F. W. Ray

19 July 1967  
Los Angeles Fire Dept  
Fire Prevention Bureau  
Los Angeles, Calif.

Purpose: To discuss current Fire Dept  
research and activities in areas of  
personnel control and safety requirements  
for emergency evacuation.

Chief Smedley discussed general require-  
ments for building design and personnel  
evacuation. As a result, the following  
concepts will be investigated further for  
aircraft application:

- (a) Use of chutes for multistory build-  
ings.
- (b) Compartmentation for various  
occupancy categories.
- (3) Airborne and ground use of fire  
control agents.

Ansul Chemical Co

To investigate use of "Light Water"  
systems for helicopter application of  
ground fire suppression techniques and  
possible use of onboard systems.

Agency Contacted,  
Time and Place of Meetings

Functions, Contacts, Purpose,  
and Subjects Discussed at Meetings

17 July through 17 August 1967

\*J. M. Tillman (consultant)  
United Air Lines  
San Francisco, Calif.

To discuss airline operations involving passenger evacuation and new developments in escape devices.

C. O. Miller (consultant)  
University of Southern California  
Los Angeles, Calif.

To verify arrangements for consulting services.

\*McDonnell Douglas Co  
Transport Aircraft Div  
Long Beach, Calif.

B. Altman, Human Factors Group  
J. A. Oden, Human Factors Group

24 July - 9 August 1967  
McDonnell Douglas Co  
Transport Aircraft Div  
Long Beach, Calif.

Purpose: To review Civil Aeronautics Board Accident reports.

Various NR Study Team members have contacted the preceding personnel during the time period indicated, in conducting a review of the Civil Aeronautics Board Accident Reports.

\*Federal Aviation Administration  
Dept of Transportation

H. D. Hoekstra, FAA, Washington, D.C.  
M. F. Collins, FAA, Washington, D.C.  
O. K. Stampley, FAA, Los Angeles, Calif.

27 July 1967  
Los Angeles Division of  
North American Rockwell  
Corporation  
Los Angeles, Calif.

Purpose: To review activity on the study with cognizant FAA personnel and discuss priorities of areas of investigation and applications of new concepts.

It was agreed that evacuation from fixed-wing aircraft should have priority over helicopter, STOL- VTOL-, and V/STOL-type evacuation considerations.

It was agreed that use of ground support vehicles and equipment at airports should be considered, but the primary emphasis should be on equipment and procedures carried on the aircraft.

Agency Contacted,  
Time and Place of Meetings

Functions, Contacts, Purpose  
and Subjects Discussed at Meetings

17 July through 17 August 1967

Suggestions for contacts with lighting equipment manufacturers were given to NR.

The discussion of newer applications of previously reported concepts should be included in NR reports of concepts, not arbitrarily ruled out.

The AIA Crashworthiness Committee studies are considered complementary to those of this study team, and a reasonable exchange of information is expected. However, North American Rockwell Corporation reports are to be approved by FAA before publication, as stated in the contract

An oral briefing with view-graph presentations on an informal basis with key Federal Aviation Administration personnel at Washington, D.C., was requested. This briefing was not specifically mentioned in the study contract. However, it was agreed that trip money and time for this meeting would be reserved to aid in selection of proposed concepts for which test plans are to be prepared. These test plans are a contractually required portion of the final report.

\*The Boeing Company  
Seattle,

31 July 1967  
The Boeing Company  
Seattle, Wash.

E. M. Santee, Supervisor, Passenger Accommodations, 707

Purpose: To discuss procedures, exits and devices for emergency evacuation, and to view 747 and supersonic transport mockups.

Proposed emergency evacuation procedures, exit sizes, and descent devices (including slides and stairs) were discussed with Mr. Santee, and the 747 and supersonic transport mockups were inspected. A film was also viewed of tests conducted on the Model 747 exit sizes and descent devices.

Agency Contacted,  
Time and Place of Meetings

Functions, Contacts, Purpose  
and Subjects Discussed at Meetings

17 July through 17 August 1967

1 August 1967  
United Air Lines  
Flight Safety Office  
San Francisco, Calif.

J. M. Tillman, Staff Representative,  
Flight Safety, UAL (consultant on this  
study)

Purpose: To discuss airline operations  
involving passenger evacuation, and new  
developments in escape devices.

Discussions with Mr. Tillman included  
sonic signals for exits, smoke visibility  
problems, accident reports, customer  
reactions, ditching safety devices, and  
radio communications.

A visit to Pacific Shenandoah Co in  
Redwood City, with Mr. Tillman, was in-  
cluded to view a metal mechanical folding  
stairway under development.

\*Goodyear Aerospace Corp  
Los Angeles, Calif.

E. B. Hollander, Western Regional Manager

3 August 1967  
Goodyear Aerospace Corp  
Los Angeles Office  
Los Angeles, Calif.

Purpose: To discuss new developments in  
inflatable structures.

Discussions with Mr. Hollander included  
inflatable structures generally, and  
specifically, fabrication of such struc-  
tures with Goodyear's "Airmat" material.

Configurations achievable in this material  
are "virtually limitless," and brochures  
were received on the company's use of  
this material on several applications.

Federal Aviation Administration  
Liaison Office  
Norton Air Force Base

To obtain access to crash survival  
statistics of military transport aircraft.

Agency Contacted  
Time and Place of Meetings

Functions, Contacts, Purpose  
and Subjects Discussed at Meetings

17 September through 17 October 1967

\*Luminex, Inc.  
(P.O. Box 696)  
Santa Barbara, Calif.

5 October 1967  
Space Division of North  
American Rockwell Corporation  
Downey, Calif.

Contact: D. Peebles, Luminex, Inc  
(Representing Dr. F. J. Kanoffsky)

Purpose: To demonstrate an application of a material which is normally invisible but which fluoresces under ultraviolet light. Rug samples which had been sprayed with the material were shown in normal and ultraviolet light (3,660 Angstrom units wavelength).

Possible applications to the passenger emergency evacuation problem were discussed. Light sources, various surface treatment methods, colors, areas, and compatible materials were discussed.

Luminex is in a position to support mock-up tests of this concept with easily applied spray lacquers and light sources.

Testing of rugs, wall materials, etc, for wear or visibility in smoke conditions has not been performed.

Conclusion: The fluorescent materials' normally invisible appearance is attractive to airline operators, and the system merits serious consideration.

## DEVELOPMENT OF CONCEPTS

Concepts were suggested as solutions to the observed specific problem areas known to the investigators and discovered during the extensive historical analysis activities. In addition, a system analysis of the whole emergency evacuation situation was performed to the depth considered feasible for the scope and size of the contract. Group meetings and other interpersonal discussions during and between interviews helped to elicit ideas which were recorded and then described and developed in more detail according to the available data.

The extensive range of experience of the multidisciplinary study team as well as the wide range of technology of the North American Rockwell Corporation was drawn upon in developing these concepts. For example, a concept for a two-directional flexible bellows joint for a fully enclosed tubular slide was based upon proven concepts used in spacesuit shoulder and wrist joints.

Also, from the space experience of Project Apollo, was the suggestion of use of lightweight ablative materials to prevent heat distortion of components critical to the evacuation process. Extensive military aircraft experience and system analysis background was drawn upon for several other concepts and approaches.

Some discussion and interpretation of the level of originality and degree of disclosure by publication seems appropriate here. In this study, for example, a concept was considered for development and reporting herein if it involved the application to passenger aircraft ground evacuation of a technique or system previously developed for use in another context, such as military combat aircraft, marine vessels, or public buildings. Also, a candidate for inclusion herein might have been mentioned briefly in a general article on aviation safety, but not described in detail or evaluated with respect to such items as probable costs, weight increase, passenger acceptability, or interference with other passenger evacuation systems or services.

Another item of concern in meeting the contractual requirements of this study was the effective date for establishment of priority of publication disclosure of these or similar concepts. In the (then) North American Aviation proposal submitted in response to the Federal Aviation Agency Request for Proposal No. WA5R-6-0853, the proposed reference date was July 1966. No specification was made of such priority dates during contractual negotiations. However, informal discussion with contracting agency personnel indicated that the primary concern was that concepts not antedate the baseline report, AM65-7, published in 1964. The general intent of the

study was recognized as the discovery and evaluation of useful and sound concepts not currently in use in commercial aircraft or generally known to Federal Aviation Agency personnel who would be in a position to recommend their use. Therefore, several important concepts which are discussed may not meet the previously mentioned requirements. In most cases, the related publications which help establish prior dates of disclosure have been referenced.

## SYSTEMS ANALYSIS

In this study, investigation concepts have been defined for the emergency evacuation of the airline passenger who finds himself in the hostile environment of the aircraft which has met disaster. This hostile environment may range from the relatively innocuous situation of a smoke-filled cabin resulting from a cigaret fire, to the massive destruction resulting from a crash landing. Each situation in this continuum is a somewhat unique occurrence with the common objectives of protecting the passenger against further injury and removing him in a minimum period of time.

Any concept devised to improve chances for survival with the environment of the damaged aircraft must be considered a part of the overall system.

The emergency evacuation of aircraft is a portion of the total aircraft transportation system. One method of depicting these relationships is shown schematically in figure 1. Abstracting from this overall system those elements dealing with the survivable aircraft crash provides us with a smaller system which may be considered as the emergency evacuation system. This is pictorially shown in figure 2. The system consists of people, machinery, and environments of several types.

Many types of classification are possible. Figure 2 shows the machinery of the aircraft and its associated evacuation safety hardware as central, with the ground support equipment complex as separate in the lower left.

The environmental considerations, on the right, include natural environments (above) and man-made or crash-induced environments (both internal and external) represented by fire, smoke, and fuel in the lower right.

A much more detailed schematic diagram of the aircraft emergency evacuation system elements and relationships is contained in the fold-out charts in appendix C at the end of this report. This system diagram treats the environment, the passenger (or crewmember), and the hardware and procedures for evacuation as the primary interfacing elements. These elements

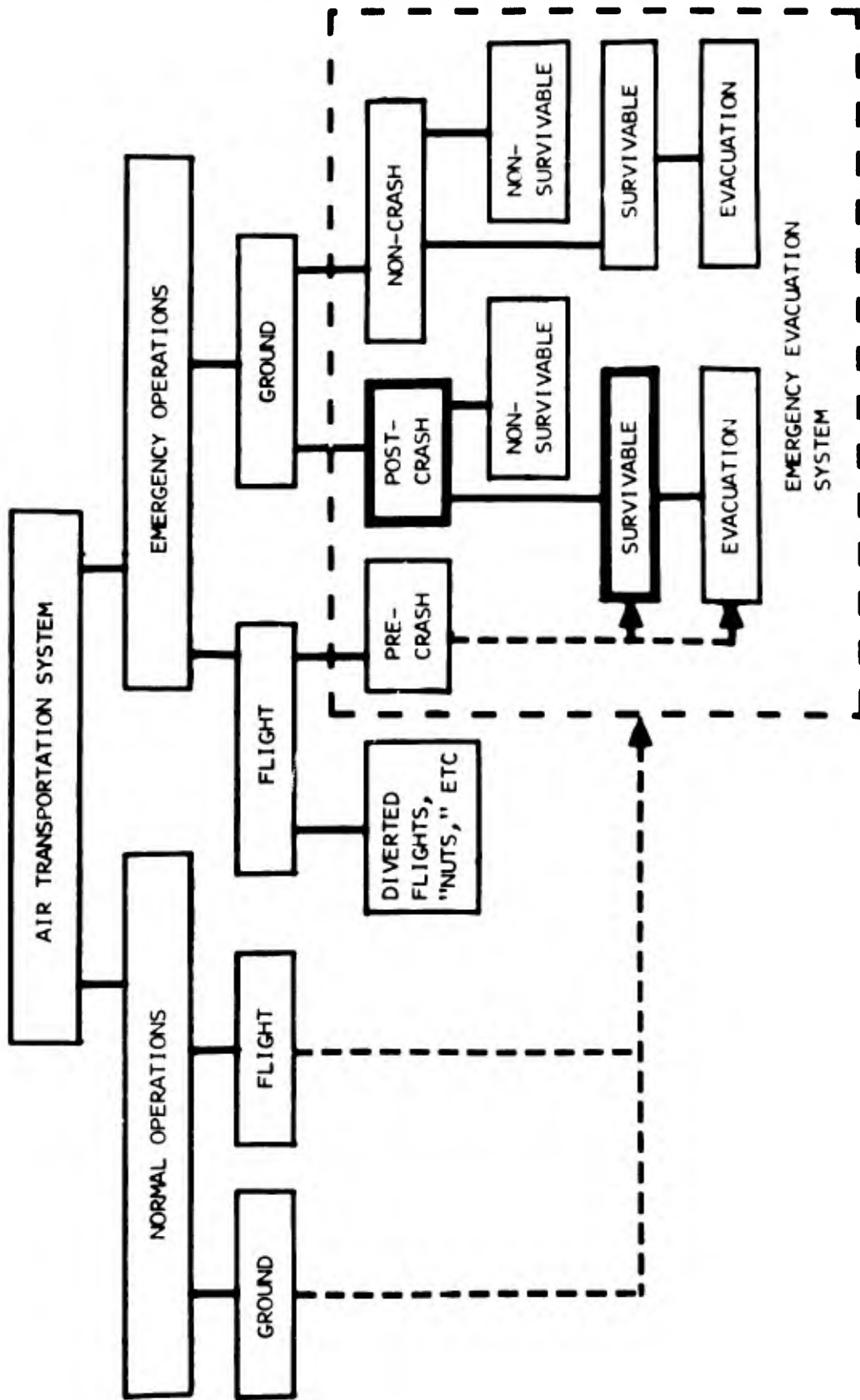


Figure 1. Relation of Emergency Evacuation System to Air Transportation System

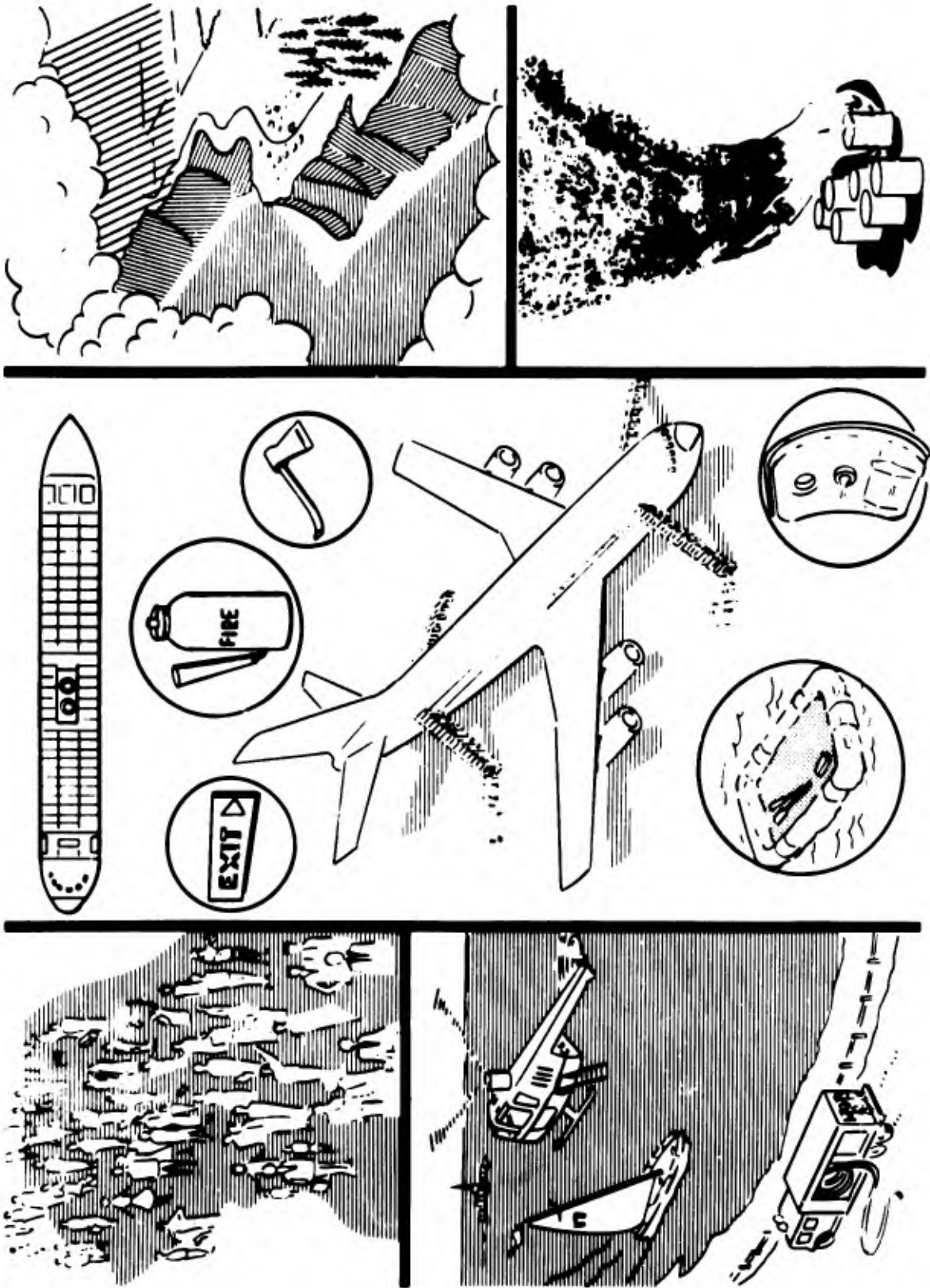


Figure 2. Emergency Evacuation System Elements

are further described in terms of those characteristics which must be taken into account in the development and testing of each new concept for improving passenger survival after the accident.

The system description formulated during the current contract was based upon previous experiences cited in various reports dealing with commercial aircraft accidents. No effort was made to completely exhaust the identification of parametric relationships. The criteria used in the format synthesis of this figure were somewhat arbitrary; this would be true for any method of system analysis. The descriptive method used for appendix C was selected to identify areas for which design criteria are necessary, to provide the designer with a checklist for concept development and feasibility testing, and to establish an abbreviated index of situations for which new concepts may be desired and against which candidate new concepts were evaluated.

A primary function of the system analysis/synthesis chart is the identification of parameters which can be simulated during the testing of the evacuation concepts reported elsewhere in this report. Selection of the most pertinent parameters and relationships will depend upon specific test objectives and the degree of simulation fidelity required. This latter aspect is related to incidence of occurrence for any situation. It is recommended that further effort be expended to quantify (in terms of relative importance) each of the parametric relationships prior to the finalization of any test plan. This would serve the purpose of insuring test program economy and providing the most realistic environment for the comparative evaluation of emergency evacuation concepts.

#### ENVIRONMENT CONSIDERATIONS

The environment to be considered includes the outside environment and the inside environment. The external environment requires little discussion, but greatly influences the ability of surviving passengers to vacate the endangered aircraft rapidly. The most important aspects are associated with those things which prevent or slow down the evacuation procedure, including the movement of passengers away from the immediate site of wreckage. Wreckage, debris, and fire are included as part of this external environment.

On the other hand, the internal environment can range from the condition associated with the undamaged vehicle to that of severe destruction. An analysis of the continuum between this range of conditions is required to determine what may ultimately be the best concepts to insure rapid and safe emergency evacuation. Whatever happens to change the internal environment

will also affect the emergency concepts incorporated (i.e., the compatibility of the concept with an environment, its availability, its resistance to damage, etc).

Examination of the internal environment continuum will ultimately dictate requirements for passenger protection against the hostile condition and the need for specific methods for escape. Passenger entrapment, for example, may be more serious than a slowdown of passenger removal due to an insufficient number of exits. The trapped passenger is unable to get out without assistance, appropriate tools, and sufficient time.

#### PASSENGER CONSIDERATIONS

Ability of the passenger to help himself is related to many of his own characteristics (e.g., strength, emotional attitude, degree of training, etc) and to evacuation concepts which are designed for compatibility with his prevailing state or condition. As in the case of the environment continuum, consideration must also be given to the continuum of passenger characteristics. Of primary importance is the requirement for insuring that the passenger can cope with the hostile environment - to insure that he can rely upon his inherent capabilities of sight, touch, motor activities, etc, and that he is protected until he can leave the aircraft.

Reference to several aircraft accident incidents indicates that passengers could have been evacuated safely except for the incidence of negative panic, lack of knowledge on the operation of emergency exits, and unawareness of exit locations. It is quite apparent that one of the most important parameters for insuring passenger survival after an accident is his adequate pre-education and the user of positive directions after the accident.

#### HARDWARE AND PROCEDURES FOR EVACUATION

Once a particular concept is selected on the basis of established requirements, it must be designed to perform efficiently. Figure 1 includes many of the parameters which must be considered in the design procedures. It must be compatible with the environment and the passenger and must meet the multitude of requirements for airline operational economies.

The need for emergency evacuation procedures is relatively rare, but, when required, any concept must be immediately available and should operate (or at least not become an impedance) under any constraint of the emergency environment. A concept which is usable only under a limited number of conditions is likely to be an extremely costly and inefficient inclusion to the aircraft.

## FORMAL CONCEPT DESCRIPTION PROCEDURES

Each candidate detail concept which could be identified as an apparent entity was given a serial number, a title, and author's name and added to a development status list in chronological order. The serial number had associated with it a letter code describing a tentative general category related to the emergency evacuation situation. This code letter was used to aid in filing the candidate detail concept descriptions and related materials by category. Each serial number had a data file folder prepared for it, in which were collected all pertinent background data.

A concept description sheet, or checklist format, was developed to record descriptive material in a uniform manner. This was to primarily emphasize the advantages of the concept and its useful areas of application. It also contained spaces for data on relative originality and "newness" of the ideas set forth. Following the concept description, a standard concept evaluation sheet, or checklist format, was prepared detailing advantages and disadvantages of each detail concept candidate.

A complete set of concept descriptions and concept evaluations is contained in appendix A, arranged in order of serial number.

The list of contents at the beginning of the appendix is essentially the same as the original list of candidate concepts, except for those items which were eliminated by combination with others or dropped because of preliminary evaluation procedures.

## SUMMARY DESCRIPTION OF NEW CONCEPTS

Following the evaluation procedures, these candidate concepts were reorganized and combined to form a set of 15 functionally related ideas called major concepts. These major concepts and brief descriptions of their supporting detail concepts are presented in table I. In table I, it may be seen that the major concepts are organized into three categories, dealing with, respectively:

- (a) Communications devices, systems, and procedures
- (b) Protection devices and systems - from fire, smoke, and toxic fumes, ditching hazards
- (c) Exit and egress devices.

TABLE I

NEW CONCEPTS  
(EMERGENCY EVACUATION OF TRANSPORT AIRCRAFT FOLLOWING SURVIVABLE ACCIDENTS)

No.	Major Concepts Title	Detail Concepts Title and Description	Ref. Serial No. App A
CATEGORY: COMMUNICATIONS DEVICES, SYSTEMS, AND PROCEDURES			
1	Automatic voice instruction and audio display devices	<p><u>Application of automatic voice instructions and warning system to passenger evacuation</u></p> <p>Speaker and tape system provide postcrash instructions for passengers. Instructions include life-vest donning, opening hatches and doors, location of emergency tools and life rafts, etc. Also useful for preflight briefing or precrash briefing to relieve crew for other duties. May be controlled by sensors or crew.</p>	2-C
		<p><u>Sonic indicators for exits - sensor/manual controlled</u></p> <p>Sound emitters activated along with emergency exit lamps to provide "fog horn" effect in dense smoke. Uses human sense mode not affected by visual obstruction. May be beeper, siren, klaxon, or voice speaker.</p>	26-C

TABLE I (CONTINUED)

NEW CONCEPTS

No.	Major Concepts	Detail Concepts	Ref. Serial No. App A
	Title	Title and Description	
2	Active, better-distributed lighting mix for interior and exterior	<u>Application of "chemical light" to aid emergency evacuation</u>	3-C
	(Location, type, and actuation of lighting tailored to specific uses in optimum manner.)	Aisles, exits and egress devices bordered by a specially configured package of long-lasting nontoxic chemical which gives off light on contact with air or by mixture of chemicals. Triggered by evacuation activity.	
		<u>Directional, active, sensor/manual-controlled floor/ceiling/wall lighting for exits</u>	24-C
		Progressive on-off lamps timed to give impression of movement, to catch passengers' attention and direct them to exits. Lamps controlled by sensors detecting heat, structural deformation, etc, and by crew, to indicate best exits, passenger distribution. Lamps located on floor, ceiling, and side wall for optimum visibility in various attitudes and smoke conditions.	
		<u>Floor level lighting for fire/smoke conditions</u>	28-C

TABLE I (CONTINUED)

NEW CONCEPTS

No.	Major Concepts Title	Detail Concepts Title and Description	Ref. Serial No. App A
2 (Continued)		Provides illumination sources near floor level for smoke conditions in upright aircraft attitude where passengers must crawl to get best breathing conditions. Battery-powered lamps activated when main power shut off.	
		<u>Ultraviolet light activation of egress signs</u>	52-C
		Provides emergency ultraviolet, collimated, indirect light source and special fluorescent spray lacquer, fabric, or other material normally invisible in incandescent light for egress markings on rugs, seats, walls, and exits. Provides improved exit-awareness and visibility. Permits lighting of large areas with markings visible only during emergency conditions. Minimum impact on interior decor.	
		<u>Additional exterior lighting</u> (Refer to Major Concept 5.)	(49-C)
3 Tactual sense displays		<u>Tactual indicators towards exit areas in aisleway, walls, and ceiling</u>	44-C
		Aisle rug, seat surfaces, wall, and ceiling provided with	

TABLE I (CONTINUED)

NEW CONCEPTS

No.	Major Concepts Title	Detail Concepts Title and Description	Ref. Serial No. App A
3 (Continued)		distinctive contrasting raised-surface beads, grid, arrows, or other texture indicating proximity of emergency exit. Standardized for all aircraft.	
		<u>Fan indication for exit</u>	27-C
		Battery-powered fans near exits provide tactual/heat-cold air movement indication in darkness or smoke. May help clear air to improve visibility.	
		<u>Seat bottom lift-up and warning device</u>	43-F
		Provides method of lifting seat bottom surface under passenger to stimulate passenger to action.	
4 Situation display systems for crew		Remote TV cameras high in tail, on sides of fuselage, or other locations to provide crew and attendants with view of outside to help select best escape path. Exterior support lighting, required for nighttime, is aid to post-egress activity. Situation display panels in front and rear of craft. Could also be adapted for in-flight checks, or for passenger entertainment.	

TABLE I (CONTINUED)

NEW CONCEPTS

No.	Major Concepts Title	Detail Concepts Title and Description	Ref. Serial No. App A
5	Improved interpersonal communications devices for crew and to passengers	<u>Flight Crew and attendants emergency communication equipment</u>  Miniaturized solid-state inter-communication equipment for personal wear by all flight crew-members permits assessment of situation and more effective direction of passengers to exits. Provides flip-up microphone and headset with long cord, bulkhead jacks, and control switches at intervals 8 to 12 feet apart on baggage rack. Provides high-power 6-inch PA speakers at 12-foot intervals, battery pack power.	40-A
		<u>Miniaturized and solid-state voice amplification device worn at take-off and landing</u>  Small device worn as necklace replaces bull horn. Battery-powered. Frees hands for use at exits.	48-A
6	Wide-spectrum passenger and crew education programs and displays	<u>Airport-located evacuation demonstration display/play area for passenger familiarization (Disneyland style)</u>  Suitable displays and mockups located in airport would provide unique opportunity for passengers both potential and actual to acquire	19-E

TABLE I (CONTINUED)

NEW CONCEPTS

No.	Major Concepts Title	Detail Concepts Title and Description	Ref. Serial No. App A
6 (Continued)		<p>a basic familiarity with emergency equipment and procedures not possible during preflight period in airplane. Would provide opportunity to actually operate and use equipment and to learn location and functions of equipment in a manner that facilitates learning.</p>	
		<p><u>Mobile classroom display and mock-up play area</u></p>	20-E
		<p>Provides mobile displays and mock-ups suitable for demonstration and exhibit of aircraft emergency equipment and evacuation procedures. Items could be utilized for public education as part of public relations efforts in a variety of situations including school classrooms, symposiums, exhibits, fairs, airline terminals, etc, to provide basic learn-by-doing experience for actual or potential airline passengers.</p>	
		<p><u>Television/film presentation pre-flight briefing</u></p>	21-E
		<p>As an alternative emergency information instructional method, television or movies could supplement or replace current instructional media. The use of such devices offers a dynamic and more impelling presentation of three-dimensional equipment</p>	

TABLE I (CONTINUED)

NEW CONCEPTS

No.	Major Concepts Title	Detail Concepts Title and Description	Ref. Serial No. App A
6 (Continued)		<p>aspects as well as demonstrations of equipment operation not available using standard techniques. In-flight entertainment equipment (TV or movies) could be used during preflight period or, if not feasible, TV or film presentations could be provided in terminal area prior to boarding. Other potential uses of in-flight entertainment equipment include, although less desirable, in-flight presentations on TV/movie or audio entertainment equipment.</p>	
		<p><u>Standardized passenger evacuation instructions</u></p>	23-E
		<p>To insure an adequate passenger education program, develop a standardized passenger instruction method jointly with airlines, manufacturers, and FAA. This includes form and content of all briefings, written material, and other potential media and techniques. Methodology would be systematically developed, evaluated, and maintained to insure a thorough, consistent, and effective educational program.</p>	

TABLE I (CONTINUED)

NEW CONCEPTS

No.	Major Concepts Title	Detail Concepts Title and Description	Ref. Serial No. App A
6 (Continued)		<u>Crawling procedure for fire/smoke conditions</u>	29-E
		Revise passenger evacuation information pamphlets to indicate need to keep head down near floor in presence of hot gases and smoke, and to crawl toward exits.	
		<u>Passenger volunteer emergency assistant program</u>	58-E
		Develop safety club concept to provide passenger assistants for emergency egress. Provide actual steward training in hatch, slide, etc, operation and award certificate for wallet, or pin for recognition by stewardess.	
		<u>Uniform crew training school program</u>	22-I
		Jointly sponsored and FAA-regulated training programs and facilities provided to all airlines to insure an acceptable level of crew training. Accomplished by centrally developed training facilities which could provide more better-qualified and specialized instructors; and better simulation facilities and training aids than individual (particularly, smaller) airlines can provide. Concept potentially offers greater	

TABLE I (CONTINUED)

NEW CONCEPTS

No.	Major Concepts Title	Detail Concepts Title and Description	Ref. Serial No. App A
6	(Continued)	training flexibility, thoroughness, and lowered costs as well as greater assurance of training adequacy.	

CATEGORY: PROTECTION  
DEVICES AND SYSTEMS -  
FROM FIRE, SMOKE, AND  
TOXIC FUMES AND  
DITCHING HAZARDS

7	Improved personal protective devices	<p><u>Personal smoke/fire protection hood/mask</u></p> <p>Each seat furnished with small package containing self-inflating plastic hood or simple bag, with a small (5-minute) air supply and a wetted (H<sub>2</sub>O) air filter included. Hood constructed of fire-resistant materials.</p>	6-A
		<p><u>Seat belt, upholstery escape harness</u></p> <p>Integrated seat belt, seat, and back cushions provide basis for passenger static line hookup for egress device or bosun chair (refer to detail concept serial No. 7-B). Also provides for support of life vest, smoke and fire protection hood, and air supply.</p>	31-A

TABLE I (CONTINUED)

NEW CONCEPTS

No.	Major Concepts Title	Detail Concepts Title and Description	Ref. Serial No. App A
7 (Continued)		<p><u>Simple smoke filter (moist cloth)</u></p> <p>Provides each seat with sealed plastic bag with quick-opening pull tab to contain moist cloth to cover nose and mouth. Provide elastic headband to hold on face, freeing hands.</p>	55-A
		<p><u>Inflatable antismoke tunnel in aisleway</u></p> <p>Provides interior-lighted, fabric tunnel erected and maintained in aisleway by low-pressure air which also keeps out smoke or fumes. Slit-flap openings permit entrance from each seat row, and egress to exits. For fire source at wall, ceiling, or end of cabin. Device stored under aisle rugs.</p>	34-B
		<p><u>Automatic/manual antismoke hood and fans in aisles</u></p> <p>Provides long fabric hood over aisleway unfolded from baggage rack or ceiling with integral fresh air supply. Passenger ducks under and proceeds to exit, with partial protection from smoke and fumes (around head, and shoulder area).</p>	35-B

TABLE I (CONTINUED)

NEW CONCEPTS

No.	Major Concepts	Detail Concepts	Ref. Serial No. App A
	Title	Title and Description	
8	Fire suppression systems (On-board components or complete systems. Exterior systems listed under major concept 10.)	<u>Onboard cabin interior foam fire suppression</u>	63-F
		Applies high-expansion foam fire suppressant to passenger compartment to protect passengers and provide additional egress time.	
		<u>Fire containment panels/curtains - inflatable and detachable</u>	32-II
		Provides transparent fire containment curtains, pop-out inflatable panels, and ceiling dropped sections to prevent spread of hot air and smoke throughout cabin. Integrates with fire suppressant systems, exits, and lighting systems.	
		<u>Freon fire suppression during evacuation</u>	60-F
		Flood cabin with freon to suppress fire during cabin emergency egress period and provide additional escape time.	
		<u>Onboard use of "Light Water" fire suppression system for passenger type aircraft</u>	62-F
		A system consisting of redundant storage containers, air or nitrogen pressurization systems, plumbing,	

TABLE I (CONTINUED)

NEW CONCEPTS

No.	Major Concepts Title	Detail Concepts Title and Description	Ref. Serial No. App A
8 (Continued)		and nozzle distribution systems for spraying "Light Water" onto all interior surfaces of passenger cabin.	
		<u>Passenger compartment manifold distribution system</u>	17-F
		Installation of a manifold system in overhead area of passenger compartments allows distribution of a foam fire-suppressant following a survivable crash landing. To reduce onboard weight, supply is delivered by ground-based vehicles to a distribution manifold connector on aircraft exterior surface. A dual manifold provides capability for pumping fire suppressant from either forward or aft sections of passenger compartment in case one end is destroyed or inaccessible.	
9	Smoke and fume removal ventilation systems	<u>Smoke and fume removal systems</u>	59-F
		A ventilation system in passenger cabin consisting of sealable port openings in ceiling and walls, battery-powered fans, or air bottles using jet pump principle to drain off hot air, and smoke, or fumes.	

TABLE I (CONTINUED)

NEW CONCEPTS

No.	Major Concepts Title	Detail Concepts Title and Description	Ref. Serial No. App A
10	Improved ground support complex	<u>Helicopter Fire Suppression and Rescue Vehicle</u>	4-G
		Heavy-duty helicopter fitted out with fire suppression and rescue equipment, located at each commercial airfield, crew on continuous standby.	
		<u>Ground rescue - vehicle</u>	51-G
		Provides standby crew and high-acceleration truck or ground effect machine with capability to foam, spray, or mist areas around aircraft which have crashed in vicinity of airport. Provides rescue ramps, power saws, etc, to assist egress, and give access to interior.	
		<u>Airport remote-control spray nozzle system</u>	5-G
		Water or foam sprayed on runway and aircraft, through pop-up nozzles spaced at intervals beside runway. Control of nozzles, their direction, and number is from tower.	

TABLE I (CONTINUED)

NEW CONCEPTS

No.	Major Concepts Title	Detail Concepts Title and Description	Ref. Serial No. App A
CATEGORY: EXITS AND EGRESS DEVICES			
11	Improved egress access	<u>Hinged combination overhead hatch and ladder above aisle</u>  Ladders attached to ceiling hatches located at intervals along center aisle - lowered by attendants or passengers. When hatch is opened, exiting passengers are aided by external handrails running length of fuselage.	1-B
		<u>Moving walkway passenger conveyor system</u>  Aisle moves - like an escalator - minimizing crowding but moving the passengers to rear or front exits smoothly and at a constant rate. Provides for nonambulatory, injured, or unconscious passengers in aisles.  Provides powered floor belt and hand-rail for assisting passengers into slide. No jump motion required. Can be extended to end to assist leaving slide. Requires large power source for short period (60 to 90 seconds).	9-B

TABLE I (CONTINUED)

NEW CONCEPTS

No.	Major Concepts Title	Detail Concepts Title and Description	Ref. Serial No. App A
11 (Continued)		<u>Separated exterior platform and slide entry configuration</u>	12-B
		Provides platform at floor level outside of Type I, Type A exits to aid egress through doorway before preparing to enter slide. Separates the two kinds of decisions, reducing hesitation, and aids lateral separation for double slides.	
		<u>Sitdown slide entrance</u>	41-B
		A stool- or chair-shaped slide entry device permitting smoother slide entry for older persons, or injured but ambulatory persons who hesitate to jump.	
		<u>Mechanical folding stairway</u>	14-B
		Replaces inflatable slide for emergency egress. Special, lightweight structure mounts under doorway. Spring or gas - power operated or manual crank-operated. Also usable for passenger loading.	
		<u>Collapsible seats to assist clear passage ways, and provide wider aisles near exits</u>	54-B
		Provides means for collapsing folding seats to afford greater	

TABLE I (CONTINUED)

NEW CONCEPTS

No.	Major Concepts Title	Detail Concepts Title and Description	Ref. Serial No. App A
11	(Continued)	passageway areas, access to special doors (refer to previous concept).	
		<u>Mechanical folding slide/walkway</u>	15-B
		Replaces inflatable slide with metal expanding structure platform and sides usable for slide at steep angles and for ramp at shallow angles. Spring, gas, or crank deployment. Converts from slide to stairway for normal passenger loading.	
		<u>Ablative coating for exit areas and devices</u>	46-B
		Provides lightweight coating around exit areas and on egress devices such as tunnels, which provides insulation, charring (rather than burning) which carries away heat. Prevents buckling of exit structure by heat of short-term fire.	
12	Better passenger containment, versatility of egress devices	<u>Divider-separated double slide configuration</u>	39-B
		Fabric divider erected in middle of double slide prevents inadvertent contact of arms, elbows, and knees. Permits and encourages simultaneous use of slide by two persons in place of waiting.	

TABLE I (CONTINUED)

NEW CONCEPTS

No.	Major Concepts Title	Detail Concepts Title and Description	Ref. Serial No. App A
12 (Continued)		<u>Fully enclosed inflatable slide and walkway</u>	8-B
		Passenger hesitation at interface between aircraft exit and slide is a problem. This may be minimized by covering slide to give a psychological improvement at interface. Provides for all-attitude egress, even upside down; protects passengers from radiant heat, smoke, and fire hose water jets.	
		<u>Stewardess protection guard gate at exit</u>	25-B
		Provide temporary barrier to guard area near exits to assure stewardess operating room to open exit. Opening door releases barrier.	
		<u>Combination inflatable slide/walkway and life raft</u>	13-B
		Design chute to serve two functions: slide/walkway on ground and life raft replacement on water.	
		<u>Spiral slide configuration</u>	16-B
		Potentially permits stronger slide structure with less gas volume by attachment to central inflatable post, putting more material in tension in place of bending.	

TABLE I (CONTINUED)

NEW CONCEPTS

No.	Major Concepts Title	Detail Concepts Title and Description	Ref. Serial No. App A
12	(Continued)	Psychological advantages of containment against falling overboard if chute is tubular. Passenger does not see whole length of slide.	
13	Power assist for doors	<p><u>Explosive hatch panel</u></p> <p>Structural deformation may jam doors and hatches hopelessly. Explosive panels surrounding each hatch and door, operated from a protected area in cabin and rear sections, could remove hatch panels in doors, preventing passenger deaths from fire and smoke. Replacing door puts aircraft back into service in case of minor accident.</p>	10-B
		<p><u>Power actuated door opening</u></p> <p>Equips doors with a gas-powered system for operating main door latching mechanism - and possibly deploying escape chutes - equipped with safety provisions to prevent inadvertent operation, e.g., an airspeed sensor to prevent operation in flight.</p>	11-B

TABLE I (CONTINUED)

NEW CONCEPTS

No.	Major Concepts Title	Detail Concepts Title and Description	Ref. Serial No. App A
14	Automatic egress devices	<u>Automatic passenger bosun chair conveyor system</u>  A portion of passenger seat becomes a unit of a conveyor system which, when activated, lifts passenger, carries him from cabin, and deposits him on ground much like a ski lift.	7-B
		<u>Escalator egress system</u>  Provides moving stairway and hand-rail as replacement for inflatable slide permitting upright passenger body position throughout egress. May reduce hesitation of jumping, slide egress bunching at ground. Powered by battery, electric motor, or gravity. Aids flow rate if used as stairway.	38-B
15	Cargo handling concepts	<u>Large cargo doors and swing tail for emergency egress</u>  Provide large cargo-type doors in sides, swing-nose and swing-tail clamshell doors operable in emergency to provide rapid egress. Panels swing down to provide slide or ladder to ground. (Seat backs	53-R

TABLE I (CONCLUDED)

NEW CONCEPTS

No.	Major Concepts Title	Detail Concepts Title and Description	Ref. Serial No. App A
15	(Continued)	collapse for side door egress or eject through side door.) (Adaptation of quick-change cargo passenger aircraft provisions.)	

The following sections of this report present a summary discussion and integration of the concepts developed. The discussion sequence follows that of table I, except that a separate discussion of ground support aids is presented, resulting in the following four subject areas:

- (a) Communication/display aids and educational aspects of emergency evacuation
- (b) Reduction of fire and toxic hazards during emergency evacuation
- (c) Mechanical egress aids to emergency evacuation
- (d) Evacuation ground support aids

COMMUNICATION/DISPLAY AIDS AND EDUCATIONAL ASPECTS OF EMERGENCY EVACUATION

The typical airline passenger is faced in an emergency evacuation situation with many frightening, dangerous, and confusing factors. He is generally ill equipped by training or experience and is many times physically or psychologically unable to quickly and correctly perform a successful evacuation. Consequently, he is likely to either fail to act or perform in an appropriate behavior because of inadequate information, training, or direction. These facts require that the various evacuation information/communication aids and educational programs be highly effective in training and directing passengers within the variety of emergency environments and conditions possible. Pertinent methods to solve these requirements include various visual displays and markings, auditory signals or instructions,

tactical displays, and communication equipment for informational assistance during the evacuation; and training and educational programs of passenger and crew prior to the emergency.

Emergency evacuation displays and lighting must be designed and utilized in aircraft based upon the following guidelines:

- (a) Displays and lighting should be chosen to provide effectiveness in various environmental conditions of fire, smoke, fumes, darkness, aircraft attitude, and structural damage.
- (b) Lighting is required to illuminate exits (interior and exterior), slides, aisleways, and equipment stowage or operation areas.
- (c) Displays are required for exit location (exterior and interior), exit direction, equipment location, and equipment operating controls.
- (d) Displays should be unambiguous, demanding, or redundant (quantity and sense modality) but not panic- or confusion-inducing.
- (e) Displays should provide passenger information as to emergency equipment and exit location prior to an emergency and particularly if required during preflight briefing.
- (f) Displays should be standardized within the constraints of unique aircraft requirements.
- (g) Emergency displays and lighting should have an independent power supply and be capable of being automatically actuated (if required) as well as manually.
- (h) If the displays or lighting are capable of redirecting passengers or employ alternate displays based upon signals from sensors, manual control should also be provided in addition to fail-safe automatic logic.

Current aircraft lighting and emergency displays have proven inadequate in various environmental conditions experienced during emergency evacuation. This is in part due to airline reluctance to utilize overly conspicuous emergency information and in part due to the ineffectivity of current techniques in severe environmental conditions. To overcome this problem, a more positive and realistic appraisal of the requirement for conspicuous and redundant lighting and display requirements is required. This would include basic improvement in the existing lighting (exterior and interior and present

markings and signs) as well as adoption of one or more proposed concepts to further increase effectiveness and flexibility of emergency displays and lighting systems.

For a better distributed, active, and flexible lighting and visual display mix, the following concepts are offered:

- (a) 3-C - application of chemical light to aid emergency evacuation
- (b) 24-C - directional active sensor controlled floor/ceiling/wall lighting for exits (figure 3)
- (c) 28-C - floor level lighting for fire/smoke conditions
- (d) 52-C - ultraviolet light activation of egress signs

Each of these concepts offers a solution to one or more basic problem areas experienced in emergency evacuations and airline operations as well as general improvement. A complete aircraft cabin lighting system can be imagined which uses the best advantages of all of them along with the currently provided emergency and normal lighting system elements. The emergency ceiling lighting mounted lamps now provided are probably adequate for relatively mild conditions where smoke is not a serious factor, as they will provide general illumination in the aisle area and overflow into the seat areas. However, they tend to leave several shadowed areas under the seats and along the sides of the upper cabin and ceiling. These areas could be used for application of large and conspicuous signs giving directions for exit locations. However, to avoid the cries of anguish from the interior decorators, these signs could be painted or provided in materials visible only with application of ultraviolet light from sources under the seats and in the baggage racks such that there is no direct ultraviolet light upon passengers.

The introduction of smoke tends to obscure and diffuse light from whatever surface is "up" or distant from the viewer. Thus, lights mounted near floor level would aid persons crawling along the aisleway when the aircraft is upright. Emergency lights on the walls and ceiling would aid in cases of a rolled or listing fuselage. This would apply to ultraviolet-activated fluorescent signs, incandescent or electroluminescent lamps, or chemical light. However, the chemical light is best for areas where some mechanical action, required only for emergency evacuation, can also be used to introduce the air or mix the chemicals during the deployment of the device. Examples are slides, exit areas, life rafts, personal smoke-protective hoods, or smoke-protective tunnels. The progressive signal-type lamps can be of relatively small size due to the attention-getting quality of apparent movement. They can be placed at strategically located areas or walls, ceiling, and floor or



Figure 3. Lighting and Tactual Display Concepts for Emergency Evacuation

seats to best serve the needs and fit the interior arrangement of panels, windows, etc. The light panel currently used by several jet aircraft at the junction of the hat rack and the side wall (just above the windows) is a good place for such lights. As noted in concept 24-C, the movement could be used with normal boarding and deplaning, perhaps at a slower rate, to assist in reinforcing the relation to passenger movement direction.

The problem of adequate control for such light direction indicators as well as sonic indicators and exit situation indicators may be solved by a rather simple set of logic circuits or what may be termed a small computer. This computer may be given signals by the stewardess or by seat pressure sensors as regards the location and number of seats occupied. Following a crash, sensors at the exits can sense heat, water pressure, structural damage, or overtorquing of handles by passengers. The logic circuits would then turn off warning lights regarding the exit. Interior sensors detecting excess heat or smoke in one compartment could activate direction signals outward from that compartment toward others. These ideas were originally described in candidate concepts 33-C and 42-F, but were later incorporated into this discussion because of their general nature.

Auditory devices offer needed informational redundancy, usefulness in severely degraded visual conditions, and the capability for more complete instructions. As such, they are both unique information sources and valid supplements to visual displays. The following two concepts provide capabilities for both auditory signals, locator aids, and voice instructions, automatically, in response to crash-induced conditions.

- (a) 2-C - application of automatic voice instructions and audio signal devices.
- (b) 26-C - sonic indicators for exits: sensor/manual controlled.

Another sense modality which is potentially useful in emergency evacuation is used in tactual displays. These offer redundancy to other types of information sources and can function as an alternate information source in situations where visual and auditory displays are not adequate. In one concept (44-G) they are useful without a need for power. Both of the following concepts and particularly the latter can fill a display sorely needed in the worst evacuation conditions which generally include severely degraded visual conditions caused by smoke or darkness.

- (a) 27-C - fan indicator for exit
- (b) 44-C - tactual indicators towards areas in aisleway

Besides providing fixed displays, consideration should be given to various situational display systems that not only provide basic evacuation information but are responsive to various conditions of the evacuation which require passenger redirection, avoidance of various exits or areas or the use of alternate equipment/procedures. These systems can provide appropriate displays or information to passengers or crew and even be combined with other automated emergency systems (automatic doors, slides, etc) to optimize evacuation and decrease the reliance on crew or spontaneous passenger leadership, decisions, and activations.

The following concepts are representative of this type of system:

- (a) 24-C - directional active sensor controlled floor/ceiling/wall lighting for exits.
- (b) 49-C - remote TV cameras and emergency exterior lighting to assess exterior hazards.

Most aircraft emergency evacuations are required without prewarning and are accomplished in conditions of confusion often with degraded vision and lack of complete knowledge of conditions. Consequently, great reliance is placed upon the crew to provide leadership in order to direct and assist passengers. This role is often hampered because of lack of communication capability among the crew or with the passengers. This results in less than optimally effective crew participation. Consequently, the need for an emergency communication system is apparent. This system must be independent of the normal power supply and operative with severe structural damage. In addition, if possible, it should be useful outside of the aircraft for directing and controlling operations. With these requirements in mind, the following two concepts are offered:

- (a) 40-A - flight crew and attendant emergency communication equipment
- (b) 48-A - miniaturized and solid-state voice amplification device

The predicted growth rate of air travel as well as the current volume indicate a basic need for not just an adequate, but for a very effective passenger education program. The current preflight briefing techniques are sorely inadequate and have been a subject of criticisms by various air safety experts as basically ineffective. To overcome this deficiency and to meet the emergency education needs of the public, a basic change in approach is required. The initial change is an acceptance of the responsibility to insure that the public is adequately informed of the emergency provisions instead of a reluctance to disturb the passengers. Having accepted this requirement, more effective presentation techniques and media should be investigated to

insure effective and thorough education of all passengers is accomplished. With this in mind, the following wide spectrum of passenger education concepts is offered:

- (a) 19-E - airport-located evacuation demonstration display/play area for passenger familiarization
- (b) 20-E - mobile classroom display and mockup play area
- (c) 21-E - television/film presentation preflight briefing
- (d) 23-E - standardized passenger evacuation instructions
- (e) 58-E - passenger volunteer emergency assistant program

These several concepts include suggestions for basic improvement in pre-flight briefing techniques in terms of presentation and media including TV/movies and prerecorded briefings to increase the effectivity. In addition, several concepts are intended to be part of general or specific public education as part of public relations or general safety propaganda as part of commercial aviation's public responsibility. Also, the concept of specially trained veteran travelers to provide the needed crew assistance during evacuation is included within a general education plan. Thus, passenger education is viewed as a continuing program of life-long learning intended to insure that the novices, the veteran passengers and even the potential passengers are aware of aircraft emergency equipment both in the general sense as it applies to all aircraft and in the unique sense as it applies to specific aircraft and emergency situations.

Although crew training has generally been excellent, some criticisms of specific airline training policies indicate a need to insure continuing and widespread increases in crew training quality. In the future, the potential growth in number of cabin attendants and the rising costs demand investigation of techniques to insure maximum cost-effectiveness compatible with thorough and complete training. In line with these requirements, concept 22-I (uniform crew training school program) was offered.

#### REDUCTION OF FIRE AND TOXIC HAZARDS DURING EMERGENCY EVACUATION

Current airline practices relative to reduction of propagation of cabin fires and passenger protection from postcrash fires is limited to the elimination or reduction of flammable materials within the cabin area. Essentially, development of onboard passenger protection requirements has concentrated upon the ability of the passenger to quickly evacuate the aircraft. This

capability is provided by the number and location of normal and emergency hatches, minimum aisle dimensions and the training of flight crewmembers in specific emergency procedures. Recent transport aircraft survivable accidents have experienced passenger fatalities due to inability to evacuate the cabin area prior to being overcome by fire, smoke, superheated air, or toxic products of combustion. It is the purpose of this section of the report to discuss these hazards and to identify concepts which are applicable to protection of aircraft passengers from fire and its byproducts. Of necessity, some of the concepts presented are directly applicable only to large transport type aircraft (of the order of 200 passengers). However, it is felt that specific concepts are appropriate to existing smaller type transport aircraft with required modifications. Areas of protection discussed are those which deal with (1) components and systems to protect the immediate passengers, (2) components and systems which will reduce fire and fire propagation within a cabin area, and (3) a means for removal of the hazardous products of fires.

#### THE TOXIC HAZARDS OF FIRES IN PASSENGER AIRCRAFT

Pesman (1953) has reviewed the hazards of fires in airplane crashes with particular emphasis on how they affect passenger escape time. He concluded that, "Because the escape times determined in this study for the hazards of skin burning, respiratory injury, and toxic gases do not differ greatly, protection must be provided against all three if a significant increase in escape time is to be made." The relative importance of these hazards is subject to debate (Pryor and Yuill, 1966), and varies with the accident. The following discussion is concerned primarily with problems of toxic hazards.

Smoke is extremely complex and many of its components are known to be toxic. Probably the most thoroughly investigated smoke is that from cigarettes, and over 300 different compounds have been identified in either the particulate phase or in the gas phase (Public Health Service, 1964). Identified compounds include acids, alcohols, aldehydes, ketones, aliphatic and aromatic hydrocarbons, phenols, nitrogen oxides, ammonia, carbon monoxide, carbon dioxide, hydrogen cyanide, and others. It is unlikely that a fire in an aircraft will produce smoke any less complex than this from tobacco.

Smoke has been defined by some (Pryor and Yuill, 1966) as the solid particulate phase alone. Most of the attention it has received has involved its effect on visibility and consequent psychological effects. While the toxic effect of the particulate phase has been recognized by Pryor and Yuill (1966), it would appear that this aspect has not received sufficient emphasis. In cigarette smoke, the great majority or 254 of the 300 or so compounds identified, reside in the particulate phase. It is to be expected that many

TABLE II. CONTAMINANTS PRODUCED BY COMBUSTION  
 Milligrams of contaminant produced by the combustion of 1 gram of material

	CO <sub>2</sub>	CO	HCL	SO <sub>2</sub>	Ben- zene	Unsat. Hydro- carbons (1)	NO <sub>2</sub>	HCN	CL <sub>2</sub>	Arsine	Phos- gene
Acrylic	63.82	26.04									
Latex foam	553.50	56.33	0.49	0.006	3.92	0.44					
Leather	247.50	3.53		0.006			0.04	.005	.045		
Mineral wool	340.2	46.37					0.10				
Mbdacrylic	46.62	26.69	1.38	0.001				2.52			
Polyurethane foam	445.5	15.45				63.05					
Plywood	246.63	42.15				9.59				1.3	
Simulated leather	75.82	33.94				5.92					
Vinyl foam	116.6	29.37			6.46	11.29					0.05
Wool	90	2.86	♂	0.013		0.72					

(1) Determined as acetylene

Table III  
SHORT-TERM EXPOSURE LIMITS FOR SMOKE CONSTITUENTS

Constituent	Parts Per Million	mg/m <sup>3</sup>	Remarks	Reference
Arsine (AsH <sub>3</sub> )	30	96	6 to 30 ppm can be inhaled for 1 hour without serious consequences.	1
Benzene (C <sub>6</sub> H <sub>6</sub> )	3,000	9,570	3,000 to 4,700 ppm can be inhaled for 1 hour without serious consequences.	1
Bromine (Br <sub>2</sub> )	4	26	Maximum allowable conc. for 30 to 60 minutes	1
Carbon dioxide (CO <sub>2</sub> )	50,000	90,000	Navy permits 1 hour emergency exposure to this level. 50,000 ppm provides signs of intoxication on 30 minutes exposure.	2
Carbon monoxide (CO)	1,500	1,717	NM emergency exposure limit for 10 minutes	3
Chlorine (Cl <sub>2</sub> )	4	12	Maximum allowable concentration for 30 to 60 minutes	1
Fluorine (F <sub>2</sub> )	3	5	NM emergency exposure limit for 10 minutes.	3
Hydrobromic acid (HBr)	30	99	By analogy to HCl and Cl <sub>2</sub>	3
Hydrochloric acid (HCl)	30	43	NM emergency exposure limit for 10 minutes	1
Hydrocyanic acid (HCN)	60	66	50 to 60 ppm for 1 hour has no serious consequences. 45 to 54 ppm for 30 to 60 minutes without immediate or late effects	4
Hydrofluoric acid (HF)	20	16	NM emergency exposure limit for 10 minutes.	3
Nitrogen dioxide (NO <sub>2</sub> )	30	56	NM emergency exposure limit for 10 minutes.	3
Phosgene (COCl <sub>2</sub> )	3.0	12	3.1 ppm is least amount causing immediate throat irritation; 4.0 causes immediate irritation of the eyes; 4.8 causes coughing; 25 ppm is dangerous for even short exposures.	1
Sulfur dioxide (SO <sub>2</sub> )	30	79	NM emergency exposure limit for 10 minutes.	3

References:

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- Smyth, H. F., Jr., "Military and Space Short-Term Inhalation Standards," Arch. Environ. Health 12:488-90, 1966
- Patty, F. A. (Editor), Industrial Hygiene and Toxicology, Second Revised Edition, Vol 2, 1963, Interscience Publishers, New York
- A.C.G.I.H. Committee on Threshold Limit Values "Documentation of Threshold Limit Values, Rev. Edition, 1966 American Conference of Governmental Industrial Hygienists, Cincinnati, Ohio.

TABLE IV. CRITICAL WEIGHTS AND SMOKE CONSTITUENTS

Material	Weight to Produce Critical Limit, Grams	Smoke Constituent Producing Critical Limit	Reference
Acrylic	66	Carbon monoxide	1
Latex foam	30	Carbon monoxide	1
Leather	267	Chlorine	1
Mineral wool	37	Carbon monoxide	1
Modacrylic	26	Hydrogen cyanide	1
Polyurethane foam	111	Carbon monoxide	1
Plywood	41	Carbon monoxide	1
Insulated leather	51	Carbon monoxide	1
Vinyl foam	58	Carbon monoxide	1
Wool	600	Carbon monoxide	1
DER*331 + CA**	0.2	Hydrobromic acid	2
DER 542 + MDA**	0.3	Hydrobromic acid	2
DER 542 + MNA**	0.6	Hydrochloric acid	2
DER X-3448 + MDA**	0.2	Hydrochloric acid	2
DER X-3448 + MNA**	0.6	Hydrochloric acid	2

References:

1. Marcy, J. F., "A Study At Air Transport Passenger Cabin Fires and Materials," FAA Report ADS-44, December 1965
2. Thrune, R. I., "Gases Released When Fire Resistant Epoxy Resins Are Burned," American Industrial Hygiene Association Journal, 24(5):475, 1963

\*Dow epoxy resin

\*\*Curing agent

of these compounds are absorbed on small carbon or other particles. Consequently, a small particle could deliver a high concentration of toxic material to a small part of a cell with which it comes in contact. Thus, the effect produced could be very much more than expected from chemical determinations of the concentration. Perhaps this accounts for the general opinion that smoke is a respiratory irritant regardless of what compounds are in the gas phase. It is entirely possible that some respiratory injury attributed to burning from inhalation of hot gases, is in fact a toxic injury delivered by smoke particles.

Marcy burned various materials found in commercial passenger aircraft and determined the chief components of the smoke (Marcy, 1965). Combustion of 0.5 to 17.3 grams of material was carried out at a temperature of 1,130° F and the concentration of the products determined in a volume of 270 liters of air. Table II was calculated from his data and shows the number of milligrams of each smoke component produced by the combustion of 1 gram of material.

For evaluation of these amounts, table III shows short-term exposure limits for a number of substances which may be expected to occur in hazardous amounts in smoke. This table attempts to specify the highest concentrations which people may safely inhale for short periods. It must be emphasized that these are not precise figures, but while exposure times of 10 minutes to one hour are listed, they may all be considered as concentrations which should not be exceeded during an aircraft fire. Inhalation of greater concentrations are apt to cause a variety of toxic injuries. While some of the figures appear conservative, it must be remembered that carbon dioxide, fear, and activity will increase the respiration rate thus increasing the dose absorbed by the body in a given time. In addition, as pointed out, it is probable that when materials are absorbed on particles they can exert a very much greater effect than when they are inhaled as a gas or vapor. The concentrations expressed as milligrams per cubic meter lend themselves to the evaluation of table II listing the number of milligrams of toxic smoke constituent produced by the combustion of 1 gram of material. It is of interest that in the Boeing 747, the internal volume of 17,640 cubic feet is to be divided among as many as 490 passengers. This yields 36 cubic feet per passenger or approximately 1 cubic meter.

Obviously, the weight of material which can be burned in a confined area will be limited by various toxic products depending on the material. Table IV lists the materials in table II plus others, and gives the smoke constituent which limits the amount of material which could be safely burned in 1 cubic meter of space, as well as the number of grams required to reach this limiting concentration in table III.

As can be seen from table IV, the most common smoke constituent to create a toxic hazard is carbon monoxide. While the list of materials is a short one, consideration of other data from a variety of sources strengthens the conclusion that this is the most hazardous component of smoke from the standpoint of toxicity.

Protection against smoke hazards may take various forms.

An obvious possibility is selection of materials to minimize the amount of smoke which may be produced. Thus, it has been noted on the Apollo project that a substantial number of candidate materials produce no visible smoke when heated to 400° F. In this connection, it must be recalled that smoke is not only a product of combustion, but is also a result of pyrolysis or decomposition by heat alone. In addition, it is well known that, during actual combustion, some materials burn with very little or no visible smoke whereas others produce copious amounts of very dense smokes. It is clear then that careful selection of materials can reduce or eliminate visible smoke. In addition, table II indicates the strong possibility for selection of materials to reduce the toxic hazard of the gas phase from combustion or pyrolysis of materials. Thus it is seen for example, that whereas 1 gram of latex foam produces over 56 mg of carbon monoxide, a gram of wool produces only about 3. While these materials would be used for different purposes and do not actually represent a choice, it is likely that extension of Marcy's tests (1965) will produce alternate possibilities which permit a real reduction in toxic hazard.

Another possibility for reducing smoke hazard is through the use of non-flammable covers or coatings. While this principle has been in use for some time (seat upholstery for example), there is an aspect of this practice which requires a word of caution. Thrune (1963) has investigated the products from combustion of certain halogenated Dow epoxy resins which might be used as fire resistant materials. These materials are listed in table IV where it is seen that very small amounts when burned can produce a critical amount of halogen acid. Thrune minimizes the hazard of these products on the grounds that their extremely irritant quality warns of their presence and allows one to avoid breathing them. This might be true in some types of installations, but aircraft passengers have little choice of what to breathe. Consequently, it must be obvious that the use of such materials would be very hazardous in airplanes.

Thrune mentions specifically that no phosgene or phosgene-type gases were released by any of these resins. In the Apollo program, however, carbonyl fluoride has been detected in large amounts from three fluorinated compounds being investigated for use because of their fire-resistant properties. Under certain conditions, however, this substance was not found indicating that the conditions for its formation are not well understood. It is of interest to

note that one fire-resistant compound was found to pyrolyze readily at 550° F to produce carbonyl fluoride and other extremely toxic materials. This temperature is not apt to start a fire in a passenger compartment if fire-resistant materials are chosen, but could produce a highly lethal pyrolysate from this material.

### Personnel Protective Devices

Protection of passengers may be accomplished by complete or partial isolation of the passenger from the fire, smoke, and its products. Specifically, the oral-nasal and eye areas of passengers must be protected to allow additional evacuation times. Application of this type of passenger protection to a representative survivable transport crash (Denver DC-8 accident) would undoubtedly have provided a greater evacuation margin of safety to the sixteen occupants who perished by asphyxiation.

Concepts dealing with passenger protection from fire and smoke may further be defined as devices for individual protection and devices for group protection. The following concepts (a), (b), and (c) are considered applicable to individual protection, while items (d) and (e) are concepts to protect groups or masses of passengers during evacuation procedures.

Concepts which are considered applicable to individual passenger protection include:

- (a) Provide each passenger with small moist cloth to cover the oral-nasal area for filtering or limiting the amount of fire by-products inspired into the lungs. Refer to appendix A, concept 55-A, for the detailed description of this concept. Such cloths already furnished on some airlines for washing the hands or face would be useful in their present small size. Enlarging them or adding other slight modifications could enhance their usefulness. For the occasional claustrophobe, who cannot stand something over his face, the wet cloth provides a useful alternate to the smoke hood described later. Despite its limitations as compared with the protective hood, the wet cloth principle is well recognized and could undoubtedly save many lives as compared with the present choice given air passengers.
- (b) Although not an original study contract concept, the protective passenger smoke hood (McFadden et al, 1967) has capability of providing oral-nasal and eye protection from smoke and heat. The silvered polyimide hood has a self-contained air supply to provide a

breathing mixture for up to 8 minutes. Simplicity of design and compactness are features which make the smoke hood highly desirable for large transport-type aircraft passenger compartments. With its resistance to both heat and toxic hazards, there seems little doubt but that this device approaches the ideal, suggested as necessary above by Pesman (1953). Refer to appendix A, concept 6-A, for detailed description and application of the FAA-developed passenger protection smoke hood.

- (c) A related concept which allows individual passenger protection from fire and smoke and a rapid means of passenger evacuation is also proposed. The seatbelt, upholstery escape harness concept employs the previously mentioned smoke hood with an integrated seat-harness and conveyor evacuation system. The concept includes an integrated seatbelt and seat pan and back harness which would allow the passenger to rapidly enclose himself in a harness system which would, in turn, be connected to an overhead conveyor system for cabin area evacuation. This evacuation arrangement would be utilized in conjunction with a smoke hood or moist cloth for passenger smoke protection. Refer to appendix A, concept 31-A, for a detailed description of this concept.

Concepts dealing with fire protection which treat the mass or larger segments of the passenger group essentially provide a means for extension of safe time for orderly evacuation with attendant fire and smoke protection capabilities.

- (d) One proposed concept defines an inflatable aisleway tunnel to provide a smoke-free passageway along the compartment aisle to hatch areas. The collapsible tunnel structure would be stored either beneath the compartment aisleway flooring or within the baggage racks and actuated subsequent to a crash landing. Pressurization of the tunnel section by a self-contained pressure source would inflate the assembly with a smoke and heat resistant tunnel structure. Passenger egress/ingress flaps would allow entrance and exit maneuvers without disturbing the integrity of the structure. Use of "chemical light" (appendix A, concept 3-C) for lighting and directional marking would enhance the passenger flow to exit hatches. Refer to appendix A, concept 34-B, for a detailed description of this concept.
- (e) A simplified modification of this concept applies a hood device to be lowered or positioned over the passenger compartment aisleway to provide a smoke- and heat-resistant barrier for passenger protection. The antismoke hood would be designed such that fans and a

metered supply of fresh air would provide a relatively smoke-free area around evacuating passenger heads. Refer to appendix A, concept 35-B, for a detailed description of this concept.

Another possible structural protection against fire and smoke hazard would be a system of vents in the top of the aircraft to permit escape of hot gases. Typically, heat and smoke accumulate in aircraft to the point where a near explosion or flash fire occurs. This is a general problem as noted by Bieberdorf and Yuill (1963). According to these authors, it is standard procedure in fighting building fires "to provide ventilation at a high point of the building, such as the roof, for the purpose of exhausting unburned gases and to help clear the air for the benefit of entering fireman." It is true that such vents could conceivably exert a chimney effect and increase the rate of burning. It would appear, however, that this could be avoided by judicious use of lower vents such as the windows for example so that air is not drawn over the fire. It would seem possible that such an arrangement could provide a very significant increase in time available for passenger escape.

Unpublished results from a recent FAA test indicate that a simple opening 1 foot square in the top of a simulated cabin did not have any appreciable effect on a fire propagation. Concept 59-F suggests that the use of fans or jet-pump aspirators could help evacuate the smoke and superheated air. It appears that, to be effective, a smoke removal system for the cabin must receive considerable detailed theoretical analysis, effort, and product design development, just as do the other air conditioning systems in the aircraft.

## FIRE SUPPRESSION DEVICES

Fire suppression concept evaluations are concerned with systems for passenger cabin fire suppression during aircraft evacuation. In efforts to provide the greatest amount of onboard fire suppression capability while maintaining reasonable weight limitations, concept investigations dealt with minimum weight onboard systems and also onboard systems utilized in conjunction with ground-based fire suppressant supplies.

A limiting factor in use of high expansion foams and chemicals is the requirement for pure air to complete chemical reactions and foam expansion. Prior tests have indicated insufficient foam generation where combined with smoke-laden air. Design of any aircraft high expansion foam system will have to seriously consider this limiting factor.

It is to be noted that all fire suppressants identified will require further analysis and testing with respect to the extinguishants toxicity levels and toxicities of their pyrolysis products.

1. Operational onboard fire suppressant system would employ a manifold distribution system throughout passenger cabin areas. The manifold system would terminate at external connectors to receive fire retardant foam chemicals from a ground-based supplier. These high expansion foams could be provided by high-speed ground vehicles (appendix A, concept 51-G), or airborne helicopter vehicles (appendix, 4-G). The onboard manifold system would require nozzles compatible with the type of foam being delivered and flexibility to accommodate a limited amount of fuselage distortion and breakup. It is also recommended that redundant manifolds be used with external servicing connections on alternate ends of the passenger compartments. Refer to appendix A, concept 17-F, for detail description of this concept.
2. Integral onboard fire suppressant system concepts include use of the following vapor-securig agents for fire retardation: (a) fluorocarbon surfactants - "Light Water," (b) Freon ( $CF_3Br$ ) and (c) high expansion foam. These systems would each require stowage vessels, pressurization sources, and distribution systems for passenger compartment incorporation. For greater system reliability, it is also required that multiple systems be used, complete with separate stowage, pressurization, and distribution features. Refer to appendix A, concepts 60-F, 62-F and 63-F for further detailed descriptions and evaluations.

## MECHANICAL EGRESS AIDS TO EVACUATION

In this subsection are grouped those concepts dealing with aircraft-installed devices which physically and directly assist in the process of moving the passengers out the exits. As in the case of fire suppression techniques, it is possible to have devices exterior to the aircraft to assist the egress process. These are considered in the next subsection dealing with the general subject of ground support aids.

The study revealed that noticeable progress has been made in the last few years in reducing difficulty and time for deployment of inflatable slides on type I exits. This has come about through improvements in air aspirators, in door mounting of the slides, and in reduction in inflated volume by the use of a configuration based on a center membrane instead of an inflatable center section. On some aircraft, there are provided special floor-level type I exits which have slides always mounted and ready to inflate automatically as the door is opened. This permits the first person to get to the ground in as little as 8 seconds from time of beginning to open the door. Of course, even 8 seconds is nearly 10 percent of the 90-second total time now required. However, on most airlines, the main passenger and service doors still require the stewardess to hook the slide to floor fittings prior to opening the door in an emergency evacuation situation.

This situation presents the suggestion that all doors having slides be arranged in such a manner that the slide is automatically deployed upon opening in an emergency situation. At present, there are not sufficient safeguards to permit this. The outside door attendant at the terminal has no way of knowing whether or not the slide is engaged. If he were to open the door he would get punched in the abdomen by an expanding slide and possibly dragged down the loading tube or knocked off of the boarding ladder. There is no apparent way to provide both normal and emergency operation with a single door control. However, a lever-type selector for normal or emergency operation, with clear inside and outside indications and warnings, might be arranged.

A study of passenger subject behavior during simulated emergency evacuations indicated that there is a major problem of traffic constriction at exits, even with larger "double width" types. It appears that part of this may be due to the actual reduced dimensions of the opening, and part due to the unfamiliar appearance of the slide, a lack of familiarity with methods of entering the slide, and in part due to fear of height or fear of injury from jumping. Also, problems of modesty may enter at this point. The present aircraft slide configurations force the passenger to consider all of these problems at once as he approaches the door.

Proposed solutions to the alleviation of these physical and psychological problems are included in the concepts discussed in this section. Major concept 11 deals with methods of improved egress access. Within it is included detail concept 12-B, which provides a floor level platform extending outside the exit to which the slide is attached. It is postulated that this will help speed movement through the doorway construction and, with a slightly wider platform outside the door, provide for easier decisions as to slide entry. Platforms of this nature deployed from overwing exits would provide for sure footing and lower chance of injury.

Detail concept 41-B provides a small stool and slide fairing. See figure 4 for an illustration of this concept. It could be applied inside the aircraft to standard slides or incorporated in the exterior platform previously mentioned.

Detail concept 9-B helps to assist passengers toward the exit and force a decision to jump or get dumped on to the slide. Alternately, they may sit down on the floor and be propelled to the slide.

In major concept 12, the ideas deal with methods of handling unusual aircraft attitudes and the occasional case of a person falling off a slide. Also, it is postulated that the enclosed appearance of a slide (detail concepts 8-B and 13-B) will give confidence that one will not fall off and will help reduce hesitation. It certainly should prevent the habitual reaction of withdrawal from rain, snow, heat, and other inclement weather which may be present in the open-slide configurations.

Other problems in inflatable slide use have to do with failure to deploy or puncturing or tearing of the fabric. Mechanical metal slides and stairs of various types are proposed to provide protection against this type of problem. However, this raises a problem in compatibility with the combination slide and raft. A separate inflation system for the metal slides is needed, or a method of armoring the inflatables is required. A great deal of work in design development, adapting these concepts to specific aircraft configurations, remains to be done.

A problem frequently mentioned as a cause of delays in emergency evacuations is narrow aisles. The width of aisles is certain to be a subject of continuous discussion among airlines, manufacturers, and regulatory agencies. The reasons, of course, are that more seats per row result in more paying passengers per flight, but the wider the fuselage, the greater the weight and drag. A possible solution proposed for this problem is detail concept 54-B. A proposed method of folding aisle seats is shown in figure 5B. It is estimated this method could add approximately 8 inches for one side folded,

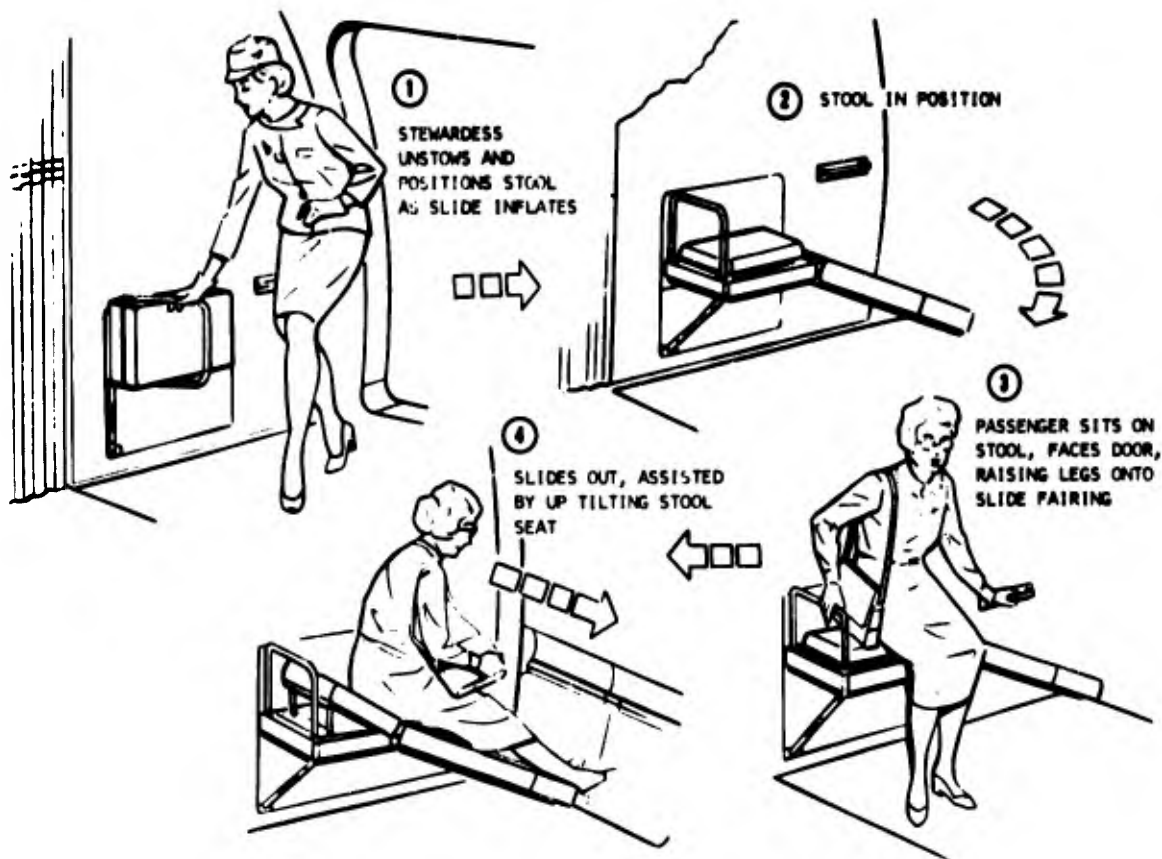


Figure 4. Device to Aid Sit-down Slide Entry

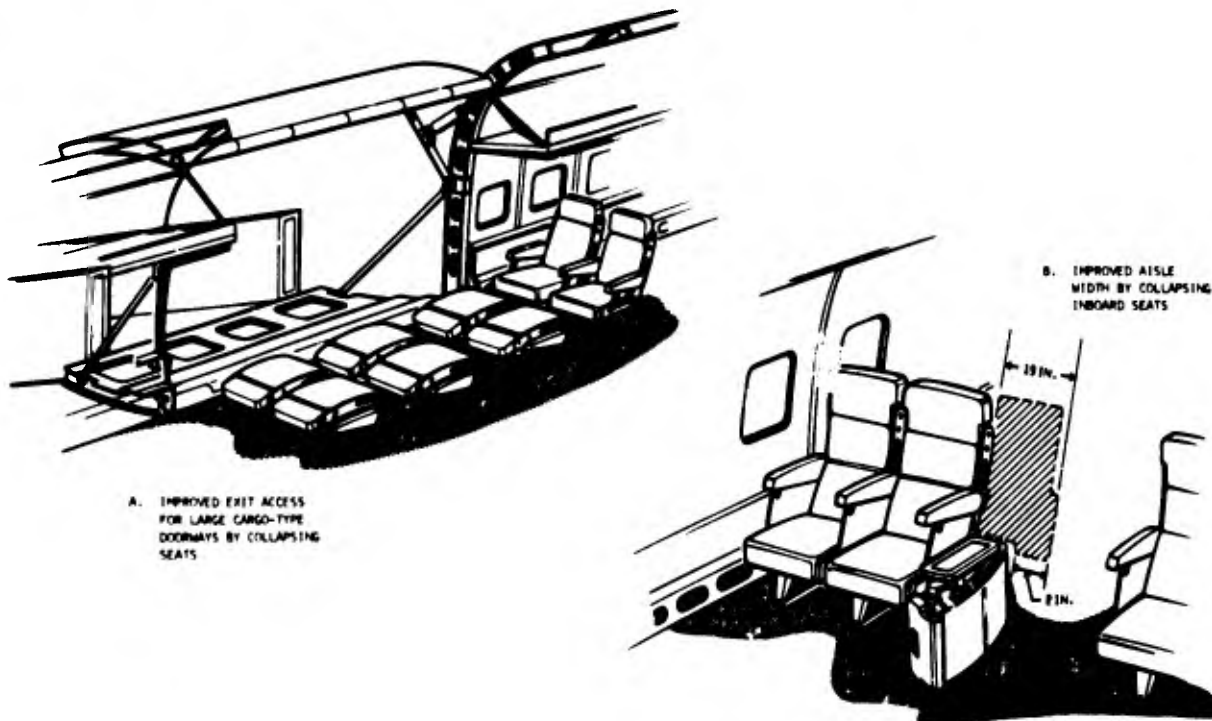


Figure 5. Foldable Seat Concepts for Emergency Evacuation

or 16 inches for both sides folded, approximately doubling the current minimum aisle width.

The large-scale solution to the egress problem is shown in figure 5A, which relates to the problem of congestion near exits. Here are combined two concepts, folding or collapsible seats and use of a large cargo-type door, part of which lifts upward and carries much of the interior lining with it. The collapsible seats are offered as a means to make such large doors more accessible without eliminating the seats adjacent to them for normal flight. All of the basic technology exists to design this capability into aircraft for it is essentially a QC (quick-change, cargo-to-passenger accommodation) except for the required increase in speed and simplicity of operation.

#### EXITS CREATED BY CRASH

Experience has shown that openings have been created in the fuselage by the crash conditions in many survivable accidents. In several cases, these openings have been a primary means of egress, being large, immediately available, obvious, and close to the ground, which eliminated the need for a slide or other egress device. Evacuation systems analysis and design should consider such chance opportunities just as much as the chance disadvantages of weather and terrain.

It has been shown that present structural analysis techniques can predict with reasonable reliability the places where large aircraft will break under given conditions of impact. Also, it is known that there is a reasonably limited envelope of survivable impact conditions. Examination of the key points on the periphery of this envelope should establish, with a practical degree of confidence, those areas of each aircraft which are especially susceptible.

These areas then can be considered in design of lighting displays, egress devices, seat location partitions, communications networks, electrical dead facing, fuel and fire suppressant line termination, and other devices or procedures which are part of the total emergency evacuation system.

For example, a strain sensor or light sensor could be installed nearby such an area to determine if a break has occurred. This could then operate lights around the area, illuminating and indicating an exit opportunity in that area, or voice instructions could be selected indicating actions which should be taken for the situation. Check valves or squibs could be installed on both sides of the potential break to shutoff or redirect liquids. Systems

sensitive to damage by strain of fuselage structure, such as life-raft boxes or circuitry, should be set apart from the suspected break.

#### EVACUATION GROUND SUPPORT AIDS

From an overall systems standpoint, the potential of aiding rescue of passengers by use of personnel and equipment on the ground remains one of the relatively untouched resources. To be sure, a great deal of money has been spent on firefighting trucks, fire crewmen, ambulances, and Coast Guard vessels with their attendant support equipment. However, it appears that the capabilities of the ground complex have not kept pace with the rapid changes in air transport design or the increased hazard associated with the survivable accident situation in a jet transport aircraft. As a result, a modern airport is likely to have foam-laying fire trucks which are fine for predicted aircraft emergency landings, but usually too late in reaching unpredicted accidents.

Consider the case of a 10,000-foot runway: A fire truck stationed at the runway midpoint with a standby crew would require 60 seconds at 60 miles per hour to reach the scene of an accident at either end of the runway. Adding time to man the vehicle, time to accelerate to top speed, and time to decelerate could easily raise the minimum time to 2 minutes, which is long past the 90-seconds maximum desired for passenger evacuation. Alternatives to this present, slow system must be found if ground support systems for emergency evacuation are to be effective.

Several possibilities are suggested:

1. Keep vehicles in motion, following all aircraft.
2. Provide more vehicles, stationed at more places on the airport.

These are expensive and perhaps not cost-effective answers. A review of the many problem areas associated with the ground rescue and firefighting equipment will show many areas not covered by present vehicle systems at all:

1. Aircraft falls a short distance (0.5 to 5 miles) outside airport runway area in terrain inaccessible to wheeled vehicles or into water or swampland, snow, or ice area.
2. Fog prevents location of aircraft by fire truck.
3. Access to the inside of the aircraft by fire and rescue crewman is limited to axes, which are defeated by tough, thick skins and window materials.

Clearly, a more generally capable ground support complex is needed for conditions in listed items. It is doubtful if one type of vehicle can answer the need. If we are to "think big" about moving people by air, then we surely need to "think big" about safety. The question arises, is such massive effort justified?

A general concept proposed herein is that of providing capability "where the action is," using appropriate technology and available personnel to the best of their ability.

A review of accident statistics with respect to flight phase has revealed the following significant statements:

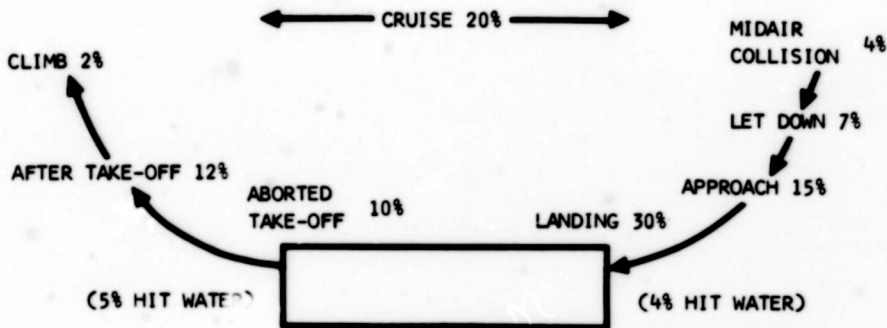
Figure 6 indicates 80 percent of the jet accidents from March 1953 to March 1967 occurred "at or near airports." A total of 9 percent hit water, either at takeoff or landing.

These data indicate that aircraft accidents typically do not occur hundreds of miles from civilization, in remote areas, but rather in the presence of people, equipment, and communication facilities which potentially could be of aid in the rescue efforts. It would appear that a well-balanced evacuation safety system effort should insure that the greater potential for survival would be placed in areas of the greatest potential for accidents. Otherwise, we will have an ironic situation, analogous to that of a house burning down across the street from a fire station. To solve the broad spectrum of problems presented requires attack along a broad front to build a capable complex of systems directed toward evacuation safety.

#### THE IMPROVED GROUND SUPPORT COMPLEX

The following is a set of suggested concepts which potentially could provide ground support capability proportionate to the accident potential.

1. To solve the general problem of inaccessible terrain, it is proposed to use a helicopter fire suppression and rescue system. Such a vehicle, properly equipped with sensors, is hampered only by severe, gusty weather conditions. It has proven effective in military systems and should be even more effective with large transports. Figure 7 illustrates this concept. It is more fully described in appendix A, concept 4-G.
2. To solve the problem of quick reaction within the airport complex, a series of concepts is offered. The most rapidly deployed is a



A RECENT SURVEY OF JET ACCIDENTS FROM 1953 TO MARCH 1967, IN WHICH A TOTAL OF 81 AIRCRAFT WERE INVOLVED AND 2593 LIVES WERE LOST, SHOWS THAT 80% OF THE ACCIDENTS OCCURRED AT OR NEAR AIRPORTS.

45% OF THE TOTAL OCCURRED IN THE APPROACH AND LANDING AREAS, AND IT REEMPHASISES THE NEED FOR A SAFETY CAMPAIGN IN THIS AREA.

22% OF THE TOTAL ACCIDENTS OCCURRED DURING TRAINING. (AIRLINE REPORT)

Figure 6. Approximate Locations of Jet Airliner Serious Accidents



Figure 7. Helicopter Fire Suppression and Rescue Vehicle

remotely controlled series of pop-up nozzles with underground high-pressure fire suppressant fluid plumbed to each one through valving under control of a station in the air traffic control tower (detail concept 5-G, appendix A). Figure 8 illustrates how these could be used to direct water, "Light Water" foam, or other fluid against a fire on an aircraft within the range of the turret nozzle. Being controlled from the tower, no extra standby crew at constant alert is needed. Remote TV cameras at the turrets could aid the tower operation in aiming the spray. Fog-penetrating ground radar or sonic picturization systems now under development would also aid in the problem of poor visibility from the tower. Such monitors, being relatively small and unobtrusive, could even be placed at points outside the geographic boundaries of the airport in the approach and takeoff areas.

3. Remotely controlled ground vehicles (detail concept 5-G-1, appendix A) are an alternative approach to plumbing the airport. The remote control feature should help reduce the requirement for standby fire crews. It is possible that such vehicles could be operated at higher accelerations (perhaps with rocket or catapult-assisted starts) than manned vehicles. They could potentially carry more fire suppressant than a manned vehicle, because of not carrying a crew and life-support gear, and could conceivably approach closer to a fire since there would be no danger to a human rescue crew. The vehicle could be fully sealed and coated with ablative materials for heat protection.
4. The remotely controlled ground vehicles envisioned do not have capability to mechanically assist the passengers out of the crashed aircraft. The alternative proposed herein is a special ground rescue vehicle which is provided with a five-man crew and swiveling, extendable ramps which can be raised or lowered to the height of a door or exit to aid passengers in egressing from the aircraft. The vehicle in operation might appear as shown in figure 9. It has multiple capabilities for protection of the passengers and crew from fire during the rescue operations. These include controllable nozzles which can direct a fire-suppressing agent against the fire, protective spray and foam-laying capabilities, spotlights and floodlights, two-way communications, and devices for opening a hole in the side of the fuselage. The basic vehicle concept is described in appendix A, concept 51-G. Alternative capabilities and attachments which could be provided to such a vehicle, and a listing of the appropriate interfaces with the aircraft are described in alternative concepts designated 51-G-1, 51-G-2, and 51-G-3 in



Figure 8. Remote Controlled Pop-up Nozzle Fire Suppression System at Airport

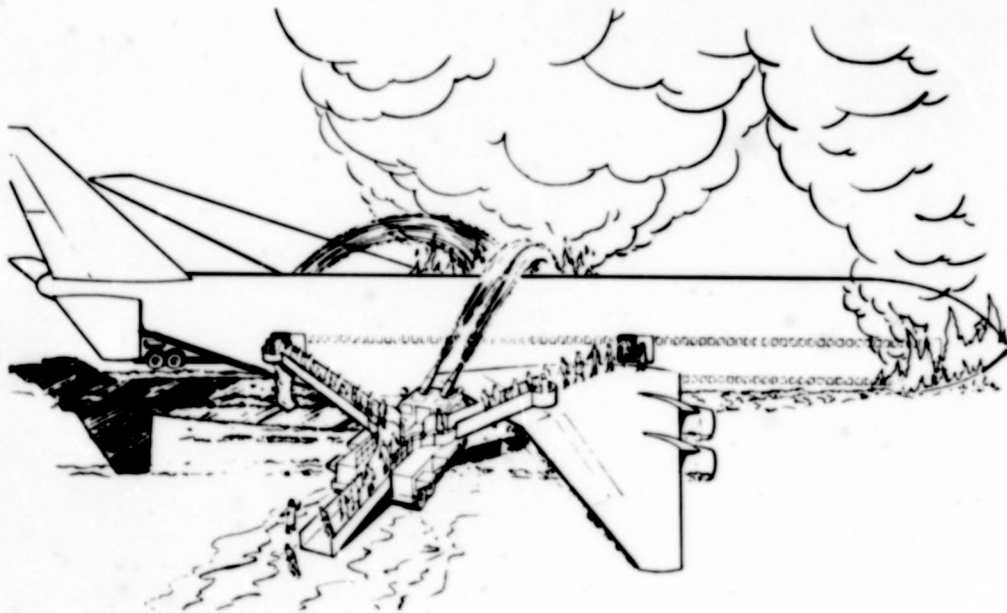


Figure 9. Ground Rescue Vehicle

appendix A. While this vehicle suffers from the inherent delay time mentioned previously, it does have tremendously increased potential for rescue operations as compared to present fire trucks when it does arrive. A review of survivable aircraft accidents indicates that there are many cases where evacuation and rescue attempts were still going on long after the first 90 seconds after the aircraft was halted on the airport grounds. For such cases, and where other evacuation provisions are inoperative due to structural damage, this type of vehicle answers a need.

5. A rescue force of civilian volunteers could be organized from among the personnel normally working or playing in the areas of greatest accident potential. For example, several survivable accident evacuations in water near airports or resort areas have been successfully carried out with the aid of small pleasure boats or fishing craft near the scene. It would seem that a similar capability could be provided on land by personnel operating delivery trucks, automotive repair garages, or other installations which may be "on the scene." An improved knowledge of firefighting and rescue techniques could be of considerable aid to such volunteer personnel, especially if they were equipped with a few items of effective firefighting equipment beyond the minimal requirements for their own vehicle or building safety. Given the knowledge and responsibility, such persons could provide that instant action necessary to help control fire and aid effective rescue in the first few precious seconds and minutes following a survivable accident.

#### FORMAL CONCEPT EVALUATION PROCEDURES

Following the concept description phase a concept evaluation sheet was prepared for each promising listed candidate concept. The evaluative statements and references from these sheets follow the appropriate concept descriptions in appendix A. These evaluations were based upon a number of preliminary evaluation procedures which are discussed herein.

The evaluation procedures led to the combination of several concept candidates and the complete elimination of others as inappropriate to this study or impractical in the light of apparent difficulties presented. The remaining concepts, now called detail concepts, were grouped (as shown in table I, previously presented) into functionally similar types, each of which was called a major concept. These major concepts were then rank-ordered and a selection was made from them for recommendation to the Federal Aviation Administration as regards suitability for experimental evaluation.

## GENERAL PROBLEMS IN EVALUATION OF EMERGENCY EVACUATION

The evaluation of the candidate detail concepts has proved to be one of the most difficult of the various activities performed in this study. It is difficult because it involves the weighing of tangibles and intangibles against each other. Because of the large number of concepts considered, it could have involved a very difficult and extensive collection of statistical and cost estimation data which, if, thoroughly investigated, could have required the full cost of the contract and considerably more. Therefore, the methods of concept evaluation had to be limited to largely qualitative considerations of feasibility and subjective estimates of relative costs of various items with respect to each other.

In considering methods for performing this evaluation, it was found that there was no commonly accepted, well-developed method or group of procedures related directly to this subject. Therefore, consideration was given to methods used in other areas. The evaluation process had actually begun with the systems analysis approach involving the identification of potential interface problems, which are formally organized and presented in relationships to each other in appendix C.

Failure mode effects analysis was one method considered. In using this method, one considers the elements and interactions of a system and attempts to estimate the probable areas where failures could occur and to determine the resulting effects. Another method considered was fault tree analysis. Here, one looks at failures which have occurred in a system and attempts to logically trace back through the system to find the primary cause or causes.

Formally carried out and documented, both of these methods would have required effort beyond the limited means of this contract. However, the general ideas were informally applied in the evaluation effort, and the results recorded on the concept evaluation sheets. For example, the general approach of failure mode effects analysis was applied in arriving at ratings on the portion of the concept evaluation sheet which contains headings for "Engineering/Operational Feasibility," "Psychological Evaluations," "Physiological Evaluations," and "Kinesiological Evaluations."

The kinds of information and considerations proposed to be included in these sections is briefly outlined in the following checklist:

#### CHECKLIST OF DETAIL EVALUATION CONSIDERATIONS

##### ENGINEERING/OPERATIONAL FEASIBILITY

1. DESIGN REQUIREMENTS DEFINITION - Is there available knowledge on how to write specifications for design of this kind of equipment?
2. DESIGN DATA/TEST DATA AVAILABILITY - Are there sufficient data on materials strength, wear, weight, volume, weather resistance, fire resistance, reliability, etc.
3. FABRICATION FEASIBILITY - Can it be made in a production shop? Are special tools or special skill required?
4. WEIGHT PENALTY - What will the installation finally weigh; is there a growth/interaction effect on structure?
5. DRAG PENALTY - Will there be aerodynamic protuberances, or disturbance of air flow?
6. POWER REQUIREMENTS - Is it active or passive? Is the use of electrical, hydraulic, gas, or chemical required? What type and quantity?
7. VOLUME PENALTY - Does it take up large amount of space? - Prime (customer) space? Interfere with standard installations?
8. COMPLEXITY/RELIABILITY - Do many, complicated parts suggest possible failure modes?
9. MAINTENANCE COST AND MAINTAINABILITY - Is frequent service required? Does it require new, expensive, or special tools? Is it easy to maintain? Costly replacement of expendables? Field site maintenance impossible or difficult?
10. FAILURE MODE SAFETY - What happens if it fails? Fail-safe? Are there still alternate escape modes?
11. REPARABILITY - If used inadvertently, can it be quickly reset for use? How long, what supplies are required?

## PSYCHOLOGICAL EVALUATION · HUMAN ENGINEERING:

### Senses

Visual - Detection, legibility, color, contrast, dark adaption, safety to eye.

Tactual - Detection, distinction, direction, masking by other factors, safety to touch, heat, cold, pain

Aural - Detection, distinction, safety to ear, direction, confusion, masking (talking, screams, yells, fire, hissing)

Olfactory - Detection, distinction, directive, masking (smoke, fumes)

Proprioceptive - Detection, distinction, direction

Kinaesthetic - Detection, distinction, direction

### Control/Display Compatibility

Direction of movement, population stereotypes of action, decision aids

### Behavior - Situational

Fear, panic, anger, aggressive action, confidence, passive action, habits

Motivation - Economic considerations. Does it induce: Fear of flying? or confidence in flying? Is it pleasant or unpleasant? Easy or hard?

## PHYSIOLOGICAL EVALUATION

Toxicity - Immediate - temporary injury, unconsciousness, pain, convulsion, shock, death

- Long-term - permanent injury, early death, pain, convulsion, shock

- Side effects - preventing effective action, tears, coughing, choking, weakness, blindness, numbness, nausea, pain, gagging, etc

### Thermal Tolerance

Heat - Pain, injury, shock, death, lung damage

Cold - Pain, exposure, freezing

## KINESIOLOGICAL EVALUATION

Strength - Can passengers, stewardesses operate devices?

Speed/Accuracy - Can devices be quickly operated and properly placed and operated? Can people accept speed, acceleration of device, jump, slide, fall, crawl, climb?

In another phase of the evaluation effort, the basic ideas underlying fault tree analysis were used to infer, from a list of past problems, what benefits the various concepts would have in preventing such problems in the future. These various procedures will be discussed in greater detail later.

As part of the study effort, it was required that a selection be made from among the concepts for further development of detail and for preparation of data and requirements for experimental evaluation. It was not considered essential that the exact ratio of costs and cost-effectiveness be determined for this purpose because the number of concepts which could be treated was relatively limited. The main purpose of the effort was to select a few concepts out of the larger group. For this activity, a simple ranking method was selected. This method is also discussed in greater detail later.

When it comes to justifying the use of any of these proposed concepts on a commercial transport airline operation, there will need to be developed detailed cost estimates for each particular design change. In applying such ideas as passenger education and training, there are costs and acceptability factors which are very difficult to assess, because they involve opinions which are influenced by day-to-day situations of an unpredictable nature. Also, they cannot easily be tested because the long-term effects of various educational media cannot be controlled. A historical approach is the only method of analysis for such activities.

## CONCEPT COMPATIBILITY

The subject of compatibility within the emergency evacuation system has been previously discussed in "Systems Analysis." For a systematic check of each candidate concept against each other one, a two-dimensional matrix was prepared. This chart is shown in two sections in table V.



COMPATIBILITY ANALYSIS CODE FOR TABLE V

- I = Incompatible
- A secondary concept which is not usable with the primary and which might even degrade use of the primary.
- D = Design Problem
- A secondary concept which may be functionally independent or functionally compatible, but which would suffer design problems, primarily in form, fit, and or method of application.
- C = Compatible
- A secondary concept which, if chosen on its own merits, will be applicable to the primary concept.
- R = Required
- A secondary concept which must also be selected if the primary concept is to operate or operate effectively.
- \* = Special situation
- Educational or procedural items which must take any selected concepts into account.
- E = Enhances
- Enhances or improves primary concept capability perhaps by alternate mode of use.
- B = Backup
- A secondary, independent system which probably indicates it would be desired as a backup to the primary.

## SOLUTIONS TO PAST PROBLEMS

Another method of evaluating each candidate detail concept was to compare its potential capabilities with a list of problems which have occurred in past accidents. This list was developed from records and reviews of both propeller-driven and jet aircraft experience concurrently with the systems analysis diagram in appendix C. With considerably more effort, additional detail and categories or problem areas could be identified for the emergency evacuation system. However, it is felt that a large proportion of the important considerations have been included in this list, sufficient to provide a reasonable basis for comparison among the various concepts. The list, shown in table VI, is based upon organization of categories similar to that of appendix C. No attempt was made to try to describe the probable cause of these particular problem areas. It is realized that many of them are a result of conditions leading up to the situation requiring emergency evacuation; others are a result of ensuing man-machine and man-environment interactions, and others are simply chance events. A further refinement would have been the incorporation of conditional probabilities, based upon past experience, to give an indication of the relative importance of each of these problem areas. Such level of detail investigation was beyond the limited resources of this contract.

In applying the list to concept evaluation, the analyst had to infer the probable causes, much as is required for accident investigation. This inference, being a matter of judgment, will often lead to difference of opinion. This is to be expected from past experience.

Each concept evaluation in appendix A lists a few significant problems to which the concept being evaluated would be especially pertinent. However, a more systematic, though less detailed, method of presentation was undertaken in tables VII, VIII, and IX. Here, the problems which are primarily related to the human elements, the aircraft elements, and the environmental elements are considered and each candidate detail concept are qualitatively rated according to four categories. These categories are as follows:

- S - Satisfactory as a partial or complete solution to at least some part of the problem consideration, or will work well with it.
- Q - Questionable as to the value of the concept in helping solve the problem - some positive and negative factors of incompatibilities to be considered.
- U - Unsatisfactory as a solution to, or will not work with, the problem considered, although it is a system or procedure closely related to the problem area.

(Blank) - No significant interaction is likely or expected between the concept and the problem. The concept does not apply to this kind of situation.

One may, if he desires, count the number of S, Q, and U entries to gain a rough figure of merit, but the result would mean very little unless the type of interactions being considered are comparable in some quantitative manner. This type of chart is more useful as a checklist for a designer in selecting groups of concepts for a given aircraft system which will apply to the majority of the critical problems.

It will be noted that table VIII, which is concerned with aircraft-related problems, also contains a group of problems called future problems. These will further be discussed under another heading.

Table IX is a chart of evaluations of concepts, similar to the foregoing, prepared for the examining effects of environmental system elements. Table IX reflects the concept that external environments influence signals to the passengers through sensors connected to the internal displays, through visual observations through the windows, through the sounds and heat conducted into the interior and by smoke, water, etc, which come in through openings.

It will be seen that many of the proposed concepts have essentially no interaction with the external environment, although their use may be influenced by exterior conditions through their effect on aircraft attitude or condition. The possible benefits of enclosed slides in protecting passengers from weather (precipitation, cold, etc) until they are committed to the slide have been previously mentioned. Most of the concepts apply to internal environment conditions, particularly fire and smoke, as this was a primary reason for this study.

Table VI

PAST PROBLEM AREAS - EMERGENCY EVACUATION

<u>Man-Passengers and Crew</u>	<u>Machine-Aircraft and Ground</u>	<u>Environment - External and Internal</u>
No start - just sit	Broken fuselage	Hail
Slow start	Door jammed	Snow
Don't unfasten belt	Narrow aisles	Sleet
Can't hear instructions	Exits bunched	Rain, spray
Wrong exit tried/used	Gear stowed	Fog
Don't know how to open exit (from inside)	Gear extended	Wind - high
Cannot see exit - smoke obscured	Fuselage on side, 45° to 135° roll	Hot
Cannot see exit - tears/ eye pain	Fuselage upside down, 135° to 180° roll	Cold
Death - hot air inhalation	Fuselage tipped, 0° to 45° roll	Darkness - external
Death - toxic fume inhalation	Fuselage bent or twisted	Deep water - calm - waves
Stand vs crawl	Debris in aisle	Shallow water - calm
Foreign language	Unusable for long time after false alarm (or minor accident)	waves
Injured - postcrash	High wing (above exits)	Mud, marsh
Dead crew - crash	Cockpit crumpled	Sand, dust
Unconscious - blow	Ventral exit blocked	Rocky
Unconscious - fumes	Slides do not inflate	Revetments, ditches
Elderly	Slides torn by heels of passengers	Cliffs
Children	Slide punctured	Sloping ground
Babies	Poor or illumination	Plowed
Crowding at door	Fuselage tilted, pitch up or down	Grassy
No internal means of communication	Truck - in collision	Bush
Stewardess could not get to exit - blocked by passengers	Fire truck late	Forest, jungle
Hesitation at exit	Fire truck could not fight interior fire	Buildings
Mentally incompetent		Concrete runway
Paraplegic		Fire - external
Blind		Smoke
Deaf		Fuel puddles
Dumb		Foam
		Noise (loud)
		Wreckage, debris
		Crowds

Table VI (Continued)

PAST PROBLEM AREAS - EMERGENCY EVACUATION

<u>Man-Passengers and Crew</u>	<u>Machine-Aircraft and Ground</u>	<u>Environment - External and Internal</u>
Noise - screams, yells, crying Personal belongings briefcases, purses Clothing, jewelry, shoes, glasses		

Table VII

EVALUATION OF CAPABILITY TO SOLVE HUMAN-RELATED PROBLEMS

Concept No. Problems	1 1 1 1 1 1 1 1 1 1 2 2 2 2 2 2																										
	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5		
1 No start	S					S														Q							
2 Slow start	S					S	S													Q					Q		
3 Don't unfasten belt	S						Q																				
4 Can't heat instr						U	S	Q													Q	Q	Q		Q		
5 Wrong exit used			Q	S	Q		S		U	Q	Q												Q	Q	S		
6 Don't know how to open exit	S	S				S			S	S											Q	Q	S	Q	S	S	
7 Can't see exit - smoke	Q	S	Q	Q	Q	S	Q	Q												Q					S		
8 Can't see exit - pain		Q		Q	S	S		Q																			
9 Death-hot air inhaled	Q		S	Q	S	Q														S							
10 Death-tox fumes inhaled	Q		Q	Q	S	Q														S							
11 Stand vs crawl	Q	S	Q					U													Q	Q	S	Q	S	Q	
12 Foreign language	U					S		Q	Q													Q	Q	Q	Q	S	
13 Injured-postcrash			S			S	Q													U		U			Q		
14 Crew killed in crash	Q	S				S	Q	S				U									U				Q	Q	
15 Unconscious-fumes			S				Q														U				Q		
16 Unconscious-fumes			S			S	S	Q													U				Q		
17 Elderly		Q	S			Q	S	Q	Q	Q	Q										U				Q		
18 Children		Q	S			S	Q	Q	Q	Q											U				Q	S	
19 Babies			S			S	Q	Q													U				Q		
20 Crowding at door	Q					S	U			Q	Q	Q	Q	Q							Q	Q	Q	S	Q	S	
21 No crew internal comm						Q		Q	Q																Q		
22 Stewardess not at exit	Q	S	S	S		Q		Q	Q	S										U		S	S	S	S	S	S
23 Hesitation at exit	S		S	Q		S	Q	U			S	Q	Q	Q	Q							Q	Q	S	S	S	Q
24 Slide egress bunching	Q	Q	S			S	Q	U			Q		Q	Q								Q	Q	Q	Q		
25 Mentally incompetent	U					S	Q	Q			S									U							
26 Injured - off wing			S																							Q	
27 Paraplegic	U		S			S	Q	Q			Q	S	U	Q	Q	Q									Q		
28 Abandon slide-grm			S			S	Q					Q	Q	S							S	Q	Q	Q	S	S	Q
29 Abandon slide-end			Q			S	Q				Q	S	S	S							S	Q	Q	Q	S	S	S
30 Blind	Q	Q	Q			S	Q			Q	Q	Q	Q	Q								Q	Q	Q	Q	Q	Q
31 Drunk passenger	Q		Q			Q	Q	U	Q	Q			U								U				Q	Q	Q
32 Deaf		S				Q																S	S	Q		S	
33 Dumb																											
34 Can't open exit (strength, skill)						S		S	S											Q			S	Q	Q		
35 Noise, screams, etc	Q					Q																				S	
36 Personal belongings						S																			Q		
37 Shoes, coats, debris	Q					S		U												Q				Q		S	

S = SATISFACTORY  
 Q = QUESTIONABLE  
 U = UNSATISFACTORY

Table VII

EVALUATION OF CAPABILITY TO SOLVE HUMAN-RELATED PROBLEMS (CONCLUDED)

	2	2	2	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5	5	6	6	6	6																	
	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3																		
1				S										S		S											Q		S								S	S																		
2			U	S										S		S											Q		S								S	S																		
3				S																							Q		S									Q	Q																	
4	Q	Q		S	Q	U								Q	S	Q													Q																											
5	Q	Q	U	S	S									S		Q	Q	Q	S	S																		Q																		
6																																																								
7																																																								
8	S	S	Q	S	S	S	S	Q																														S	S	Q	Q															
9	S	S		S	Q	Q	Q	Q																															Q	Q	S	S														
10			Q	S	S	S	S																				S												S	S	S	S														
11			Q	S	Q	Q	Q																																		S	S	S	S												
12			Q	S	U	S																																				Q	Q	S	S											
13	Q	Q		Q																																							Q	Q	S	S										
14	Q	Q	Q	Q		U								S	U													S	U	U	S	S												S	U	S	U									
15			Q	S		U	U							U	S	U													S	U	U	S														S	U	S	U							
16				Q	Q																								S	U	S	S															S	U	S	U						
17			Q	Q	Q		Q																						S	U	S	S																S	U	S	U					
18			Q	S		U	U	U	Q	S	U																		S	U	S																		S	U	S	U				
19	Q	Q	Q	Q	S				Q	Q	S																		S	U	S																			S	U	S	U			
20			U	Q					Q	Q	S																		S	U	S																				S	U	S	U		
21	U	U	U	U	S				Q	Q	S																		S	U	S																				S	U	S	U		
22					Q						S																			Q	Q																				S	U	S	U		
23	S	S	Q		U	S					S																		S	U	S																				S	U	S	U		
24			S	Q					S	Q	Q	S																	Q	Q	S																					S	U	S	U	
25			S						S	S	S	S																	Q	Q	S																					S	U	S	U	
26			S						S	U	Q	U																	S	U	S																					S	U	S	U	
27																													S	U	S																					S	U	S	U	
28	U	S							S	U	U	S	S	U															S	U	S																					S	U	S	U	
29									S	S																			S	U	S																					S	U	S	U	
30									S	S																			S	U	S																					S	U	S	U	
31	S	S	S	S					S	U																			S	U	S																					S	U	S	U	
32	Q	Q	U	Q					S																				Q	U	Q	Q																				S	U	S	U	
33	S																												Q	U	Q	Q																				S	U	S	U	
34																																																					S	U	S	U
35	Q								Q	Q																			S	Q																					S	U	S	U		
36			Q	S	S																																															S	U	S	U	
37			Q	S	S	S			Q																																											S	U	S	U	

S = SATISFACTORY  
 Q = QUESTIONABLE  
 U = UNSATISFACTORY

Table VIII

EVALUATION OF CAPABILITY TO SOLVE AIRCRAFT-RELATED PROBLEMS

Concept No. Problem	1 1 1 1 1 1 1 1 1 1 2 2 2 2 2 2																										
	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5		
1 Broken fuselage	Q	S	S				Q	S	U	Q	Q							Q		Q	Q	Q	Q	Q	Q		
2 Door jammed	Q	Q	Q	Q			U		U	S	Q							Q		Q	Q	Q	Q	Q	Q		
3 Narrow aisles	Q	Q					Q		Q									Q		Q	Q	Q	Q	Q	Q		
4 Exits bunched	Q	Q	Q	Q			S	Q		S	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q		
5 Gear stowed (land)							S				S	S	S	S	Q	Q											
6 Gear extended (land)							S				S	S	S	S	Q												
7 Fus on side 45-135° roll	Q	S	S	S			Q	Q	U	S	S	Q	Q	Q	Q	Q	Q	Q	Q		Q						
8 Fus ups dn 135-180° roll	Q	S	S	S			U	Q	U	S	S	Q	Q	Q	Q	Q	Q	Q	Q		Q						
9 Fus tipped 0-45° roll	Q	S	S	S			Q	Q	Q	S	S	Q	Q	Q	Q	Q	Q	Q	Q		Q						
10 Fus bent or twisted	Q	S	S				Q		Q	S	Q	Q	Q	Q	Q	Q	Q	Q	Q		Q						
11 Debris in aisle	S	S					S		Q										Q		Q	Q	Q	Q	Q		
12 Unusable long after alarm	Q	Q	Q	S			U	Q	S	Q	Q	Q							U								
13 High wing (above exits)	S		Q				S																				
14 Cockpit crumpled	S	S	S																								
15 Ventral exit blocked	S		Q				Q	U	Q	Q	Q	Q	Q	Q	Q									Q			
16 Slides do not inflate	S		S				S	U	U			U	S	S	S	Q					Q			Q			
17 Slides torn; heels, etc							S	U	Q			Q	S	S	S	Q											
18 Slides punctured							S	U	Q			Q	S	S	S	Q											
19 Poor/no illumination			S	S			Q	Q	Q	Q		Q				Q			Q						Q		
20 Fus pitched up or dn	Q						Q	S	Q			Q	S	Q	Q	Q	Q	Q	Q		Q			Q			
<u>Future Problems</u>																											
21 Hi pass. cap. (250-500)	S	S	S	S	S	Q	S	S	S	S	S	S	S	S	Q	S	Q	S	S	S	S	S	S	S	S	S	
22 Very high floor level	U		S	S		S	S	S	S		S	S	S	S	S	S	S	S	S		S				S		
23 Double deck	U		S	S		S	S	S	S		S	S	S	S	Q	S				S			S	S	S		
24 Interior stairwell			S			U															S	S		S	S		
25 Heavy door	S									S	S														S		
26 Very long cabin	S		S	S		S	S	S	S		S														S		
27 Very wide cabin	S					S	S																		S		
28 Very high ceiling	Q	Q				S																			S		
29 Long wing root	S					S	S				S	S	S	S	S				S						S		
30 Abrupt contour wings						S	S				S	S	S	S	S				S						S		

S - SATISFACTORY  
 Q - QUESTIONABLE  
 U - UNSATISFACTORY



Table IX

EVALUATION OF CAPABILITY TO SOLVE ENVIRONMENT-RELATED PROBLEMS

Problems	Concept No.	1 1 1 1 1 1 1 1 1 1 2 2 2 2 2 2																									
		1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	
<u>External Environ</u>																											
<u>Weather/Diurnal</u>																											
1 Hail		Q	S	Q	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
2 Snow		S	S	Q	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
3 Sleet		Q	S	Q	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
4 Rain, spray		Q	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
5 Fog		S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
6 Blowing dust		S	S	Q	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
7 Wind - high		Q	S	U	S	S	S	S	Q	S	S	S	S	Q	S	S	S	S	Q	S	S	S	S	S	S	S	S
8 Hot		S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
9 Cold		S	Q	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
10 Night, darkness		S	S	S	S	Q	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
<u>Terrain</u>																											
11 Deep water - calm		S	S	S	Q	S	Q	Q	S	S	U	U	U	U	S	S	S	S	S	S	S	S	S	S	S	S	S
12 - waves		S	S	S	Q	S	Q	Q	S	S	U	U	U	U	S	S	S	S	S	S	S	S	S	S	S	S	S
13 Shallow water - calm		S	S	S	Q	S	S	S	S	S	U	U	Q	S	S	S	S	S	S	S	S	S	S	S	S	S	S
14 - waves		S	S	S	Q	S	S	S	S	S	U	U	U	U	S	S	S	S	S	S	S	S	S	S	S	S	S
15 Mud, marsh		S	S	S	Q	S	S	S	S	Q	Q	Q	Q	S	S	S	S	S	S	S	S	S	S	S	S	S	S
16 Sand, dust		S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
17 Rocky		S	S	S	Q	S	S	S	S	S	Q	Q	Q	Q	S	S	S	S	S	S	S	S	S	S	S	S	S
18 Revetments, ditches		S	S	S	Q	Q	S	S	S	S	Q	Q	Q	Q	S	S	S	S	S	S	S	S	S	S	S	S	S
19 Cliffs		S	S	S	Q	Q	S	S	S	S	Q	Q	Q	Q	S	S	S	S	S	S	S	S	S	S	S	S	S
20 Sloping ground		S	S	S	Q	S	S	S	S	S	Q	Q	Q	Q	S	S	S	S	S	S	S	S	S	S	S	S	S
21 Plowed		S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
22 Grassy		S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
23 Bush		S	S	S	Q	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
24 Forest, jungle		S	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	S	S	S	S	S	S	S	S	S	S	S	S	S
25 Buildings		S	S	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	S	S	S	S	S	S	S	S	S	S	S	S	S
26 Concrete runway		S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
<u>Situation (external)</u>																											
27 Fire		Q	S	S	S	S	Q	S	S	S	S	S	S	S	Q	S	Q	S	S	S	S	S	S	S	S	S	S
28 Smoke		Q	S	S	S	S	Q	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
29 Fuel puddles		S	S	S	Q	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
30 Foam		S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
31 Noise (loud)		S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
32 Wreckage, debris		S	S	Q	Q	Q	S	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q
33 Gnd vehicle interf		S	S	Q	Q	Q	Q	Q	U	U	U	U	U	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q
<u>Internal Environ</u>																											
34 Fire		Q	S	U	S	Q	S	Q	S	S	S	S	S	S	S	Q	S	S	S	S	S	S	S	S	S	S	S
35 Smoke, fumes		Q	S	U	S	Q	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
36 Darkness		Q	S	S	Q	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
37 Foam		Q	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
38 Spray		S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
39 Water		S	Q	Q	S	S	S	Q	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
40 Debris		S	S	S	S	S	S	Q	S	S	S	S	S	S	Q	Q	Q	S	Q	S	Q	S	U	S	S	S	S
41 Noise		S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
42 Crowds of passengers		S	S	S	Q	S	Q	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S

S = SATISFACTORY  
 Q = QUESTIONABLE  
 U = UNSATISFACTORY



## SOLUTIONS TO FUTURE PROBLEMS

What has happened in the past is presumed to be some indication of what can happen in the future for which these new concepts are planned. However, it is also necessary to consider the possible and known changes in the system elements which may lead to new problems in the future. As can be expected, the majority of these new problems will fall into the category of machine elements. The range of types of humans and environments will remain essentially constant. These new problems will arise from the new aircraft types being produced and planned at this time, which will be significantly different in size, in exterior wing and engine configuration, or in interior cabin configuration. The magnitude of these changes is such as to require a careful reappraisal of the emergency evacuation requirements. For these considerations, the following can serve as a beginning list of the significant changes which may be expected to pose problems in either the "jumbo jets," the supersonic transports, or the stretched versions of current aircraft:

- Increased height of floor above ground level, with and without gear extended
- Double-deck configurations
- Stairways, straight and spiral
- Double aisles in cabin interior
- Larger, heavier doors
- Larger, heavier inflatable slides
- Longer cabins
- Wider cabins
- Higher cabins
- More exits to be checked and accounted for in emergencies
- Long wing roots in supersonic transports, necessitating more overwing exits
- Sharply contoured wing roots in supersonic transports, offering difficulties in footing

Fuel lines running from wing through fuselage adjacent to cabin area

Larger fuel capacities, capable of producing hotter, longer, more widespread fires

Very large passenger capacity

Increased number of stewardesses and stewards

To be sure, some of these items are also benefits if the inherent problems can be overcome, especially the larger doors. However, with the aircraft resting in a tilted or pitched attitude following a survivable accident there are increased problems, too. Certain simple geometrical relationships, when applied to the consideration of increased size, yield some significant problems. For example, as the length and width increase in given proportions, the volume increases as the cube of the length, depending on the limiting proportions. This means that such concepts as applying Freon or foam extinguishant must have a volume and, therefore, a weight increase out of proportion to the increased number of passengers, which increases as the product of the length and width.

Radiant energy such as light and sound decreases in intensity as the square of the distance from the source. This effectively prevents both visual and voice direct communication between one end of the aircraft and the other. Placing of galleys and coat racks near the doors also cuts off such communication.

With an aircraft in a 90-degree roll attitude or greater, the larger cabin suddenly becomes a potential for injury to the passengers as they unfasten their seatbelts and climb or fall to the opposite wall or ceiling as the case may be. While such unusual attitudes have been rare in past survivable accidents, anything is possible in an accident, and such conditions can still occur again. The multipurpose integrated escape harness described in concept 31-A could possibly be adapted to aid in lowering the passenger slowly to the lowest surface by including a rate-limited payout reel and cable attachment to the seat.

Solutions to some of the other problems listed have already been discussed in previous portions of the report, and further discussion and summary are not intended here.

In table VIII, one section is devoted to these future problems, and each of the candidate detail concepts is evaluated as to whether it is satisfactory, questionable, unsatisfactory, or not applicable as a solution to the listed potential future problem areas.

## REVISIONS TO CONCEPT LIST

Although the foregoing concept evaluation charts lists 63 candidate detail concepts, one can see by inspection of the table of contents in appendix A and of table I that not all concept numbers are included in these presentations, for the reasons cited below.

During the processes of detail description, evaluation, and presentation for the final report, the study team found several of the detail concepts should be combined or eliminated. Some concepts were found inappropriate to the originally planned method of presentation.

The general idea represented by the concept 30-J is fully discussed in the main text in sections on systems analysis and concept compatibility. Such a general idea was inconsistent with the other fairly specialized hardware systems or relatively specific programs called "detail concepts" or even the more general classification called "major concepts." Furthermore, it hardly could be called new or original, except in its application to the transport evacuation situation.

In a more restricted sense, the idea of using computers to aid in operation of signals at exits, or directing people to exits by using sensor inputs concerning the outside and inside environments, applies to a large number of the detail concepts and is inherently a part of some of them already. Therefore, this item (33-C) was eliminated from appendix A and is discussed only in the main text. Similarly, concept 42-F really represented a rather small detail which may be a useful component of many systems. By itself, it does nothing significant, although it may be a very clever or highly sophisticated piece of hardware, necessary for successful operation of another. A detailed discussion of the merits of various sensor devices is not a part of this study.

In a somewhat different sense, candidate concept 18-B, "Airmat" construction, represented only a significant capability of design and fabrication of a wide range of shapes for inflatable devices which may be used in some of the equipment items described in other detail concepts. As such, its merits must be weighed against those of other methods of fabrication.

Upon further consideration, some candidate concepts appeared to be so similar in nature or merely an extension of a basic capability over a different regime that a separate discussion was unnecessary. These were as follows:

Candidate concepts 9-B and 36-B were combined into one set of detail descriptions and evaluations: 9-B (conveyor belt egress assistance). Reconsideration of the two revealed that the basic concept was the same, the differences being mainly a matter of length and areas of application along the egress path from the seat to the ground.

A possible method of mechanically forming slide frameworks or other support structures for emergency escape is provided by forcing flat strips of metal through a die which forms them into a tube. The edges are locked together by a special interlocking set of fingers. However, this candidate detail (concept 50-B, rollup stowage of tubing) was omitted entirely from appendix A after further comparison with other proposed methods of mechanically forming supporting structures for slides. The concept did not appear to have sufficient potential to warrant full description and development.

Similar considerations applied to detail concept 61-B, which is another method of forming a slide. Its single advantage is that it forms the metal, mechanical beams after full deployment in place of the inflated tube construction used currently and, therefore, would not be subject to puncture. However, on weight and complexity considerations, it did not appear to offer significant improvements.

Concept 37-B (rotating plate slide egress system) also appeared too heavy and complex for serious consideration in view of the questionable improvements it offered.

Concept 47-F was included because it appears certain that very significant improvements in the area of noncombustible coatings for interior components would soon be available from the Apollo space program. However, considerable more testing of this material, known as LADICOTE, must be accomplished before it is used commercially. Also, this type of study was specifically mentioned in the proposal as being considered out of the scope of this study.

Two other detail candidate concepts dealt with areas of safety considered peripheral to the scope of this study and were deleted from further consideration in light of the limited funds available. These were concepts 56-B (emergency ground landing gear folding to reduce descent height) and 57-B (drogue chute to deploy tail cone and assure fuselage integrity).

In all, 12 candidate detail concepts were deleted. However, three more were added to the original 60 concepts described in an informal presentation to the Federal Aviation Administration on October 26, 1967. This resulted in a final total of 51 detail concepts in appendix A which were combined to form the 15 major concepts listed in table I.

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## SELECTION OF CONCEPTS FOR EXPERIMENTATION

### RANKING METHOD FOR SELECTION

In preparing recommendations to the Federal Aviation Administration regarding selections of major concepts for testing, a rank order evaluation method was chosen. The reason, as previously noted, was the assumption that a method was needed to make a relatively gross selection of a few from among the whole group, not to compare them to some standard set of values for total capability, or to some specific cost limitation or installation deadline.

Again, in deciding what factors should be considered for ranking the concepts, certain assumptions were made. Among these were the following:

1. Engineering design and fabrication of at least some of the detail concepts embodied in each major concept were feasible. This is considered a safe assumption because, while new in applications, nearly all of the hardware items are based upon established engineering principles or combinations and adaptations of existing devices.
2. Twelve evaluation factors were selected. They are listed in table X. Reasons and discussion concerning the basis for selection of these factors are given.

The first two items are clearly what the study is all about; either the aircraft emergency evacuation must be performed more quickly and easily, or the reasons for speed (primarily fire and smoke hazards) must be mitigated somewhat so that speed is not so essential. In ranking the various concepts, one must take a broad interpretation as to what could contribute to speed and ease of egress. It seems apparent that egress aid devices, such as improved slides, escalators, slide entry devices, have a lot to do with evacuation capability. However, the role of passenger education and lighting systems is not so definite. The assumption was made that those items which seem to have the greatest "on-the-scene," active, attention-getting capability would be most effective in insuring minimum lost motion and, therefore, most rapid egress.

In evaluating concepts using factor 1, the implicit assumption is that some relatively minor accident has occurred in which the fuselage is relatively intact and, therefore, all of the conceptual systems are able to function. In factor 3, this assumption is denied, and a "forced" ranking is used, assuming that a series of progressively worse impacts are sustained until each of the conceptual systems fails. No attempt was made at this time

Table X

EVALUATION FACTORS FOR RANKING CONCEPTS

1. Evacuation speed, ease
2. Extension of available time
3. Ability to withstand crash g loads
4. Fail-safe condition
5. Secondary injury potential
6. Public acceptance
7. Weight - minimum
8. Space requirement - minimum
9. Maintenance cost
10. Restowage capability - minimum time
11. Initial cost of installation
12. Reliability

to determine whether or not there was a cutoff g level below which none of the systems would be affected or another higher level, beyond human tolerances, beyond which failure of the systems would be immaterial to the problem of evacuation safety.

In actual fact, the exact limits of fuselage structural integrity, component reliability, and human tolerance are not well enough defined to insure that one can set arbitrary limits. However, for design goals and studies, such limits must be considered and selected.

The problem of comparing "education" with "ground support system" was resolved by assuming that "education" may be temporarily repressed by panic or shock in the case of an impact accident. Therefore, a ground support system, completely outside the airframe, would be less affected by g loads on the

aircraft. In ranking all major concepts, with respect to capability to extend time available for egress (factor 2), an arbitrary decision was made. It appears that there are some concepts which simply do not have any function, either by design or chance, which can be reasonably considered to affect available time for egress. Since these concepts were not designed to perform this function, it appears they should not all be penalized as the worst case. That is, if sufficiently rapid egress is made, there is no need for extension of available time. However, because they do not have some capability in this regard, it seemed that they should all be ranked lower than those which do. It was arbitrarily decided to rank these concepts at the rank of 10 for purposes of combining individual factor rank orders for an overall rank order based on all factors.

Inclusion of factor 4 is based upon the assumption that some failures can occur in almost any system either through actual malfunction or through misuse or lack of use because of "operator" ignorance. Such a definition can even apply to passive systems such as tactual displays. If such failures do occur on a potentially effective evacuation system, the question is, "Can the passenger readily revert to a more reliable, though perhaps less effective backup mode of egress without serious hindrance from the failed system"? The greater the potential hindrance of a system, the worse it was ranked (higher number).

Factor 5 is included because of the hazards possible when high-pressure bottles, explosives, or powered devices are used. Also, the potential for injury is greater where people are forced into a rapid motion without their being able to control it, as in the transition to and from an escalator or moving walkway.

Factor 6 (public acceptance) has to do with the positive and negative factors of public concern about safety, dignity of person, fear, lack of knowledge of an unfamiliar device, discomfort, and inconvenience. This also includes the ideas which airline operators and manufacturers have about public acceptance. The ranking here is very subjective, of course. It was assumed that unobtrusive items would be more acceptable, items of inconvenience less acceptable, and items directly implying or stating a possibility of accident least acceptable. Here, the manner in which such items are presented is crucial. It may be that the authors are somewhat optimistic in this case.

Weight is always very important in aircraft and may be the critical deciding condition in many cases. While actual design weight requirements for each conceptual system are unknown, it was assumed that those affecting the structure most would be the heaviest. Clearly ground support items have no effect. "Educational items" might include an onboard film or tape presentation, instruction cards, and pamphlets which do represent a slight weight

penalty. Tactual displays may also represent some additional weight though this should be very small with clever design. Communications systems are a little heavier because of battery requirements, wiring, control panels, and transducers.

As more machinery is required, weight will go up. The payoff may well be worth the penalty because of other factors such as reduced turnaround time (passenger loading and unloading), cargo handling capability of larger doors, or overall transportation system safety. However, in factor 7, only the estimated relative weights were considered, not their relative usefulness or cost effectiveness.

Factor 8 (space requirements) is similar to weight. Space is usually at a premium in transport aircraft, partly because the installation of large items requires structure and lining changes and partly because maximum passenger capacity and flexibility of arrangements are desired for revenue potential.

Factors 9, 10, and 11 are cost items. Since they all result in dollar expenditures, they could have been combined. However, the operational and financial problems associated with each are quite different. Maintenance cost (factor 9) implies that once installed, some systems require much more extensive expenditures than others (probably at inflated rates) throughout the life of the transportation system. This is quite a different kind of penalty from that of initial cost. The latter seems high to begin with but, if it can be amortized over the life of the system, the final unit cost per passenger mile may be acceptably small.

On the other hand, there are some things for which the cost is so huge that financing is extremely difficult or impossible to arrange and the apparent potential payoff unacceptably low. Items which require extensive research and development or expenditure of public funds, e.g., airport facilities development, may fall into this category at present. Future political changes, technology improvements, or a rise in accident rates may change the attitudes of the taxpayer or traveling public such that more massive attack on the problem of safety is desirable.

The problem of restowing deployed evacuation aids is in a different category, being related to factors of chance not necessarily associated with a really serious emergency danger. Experience has shown that the necessity for quick reactions in real emergencies has often led to full deployment of exits, slides, ropes, and other egress devices when later appraisal of the danger has shown there was no need.

The time lost in restowing the egress devices is, then, an additional expense both in labor and in non-revenue-producing delay. Such considerations work against concepts for evacuation devices which cut holes in basic structure and thus require extensive rework. A goal of 15 minutes maximum is being considered for incorporation into an Aeronautical Recommended Practice. The final factor (factor 12) is a reflection of miscellaneous mechanical, electrical, and chemical factors which may prevent a device from working properly. It is usually related to the relative complexity of the system and the arrangement of sequences and conditions required to operate it. This covers those aspects not previously mentioned in factors 1 through 11.

In considering these factors for a composite or overall ranking of each major concept, one may raise the point of relative importance. Because the rank magnitude is not a truly scalar quantity, it is difficult to assess such relative importance. However, for purposes of this study, it may seem that certain factors of safety and effectiveness outweigh cost. Figure 10 indicates a rank order chart in which weighting numbers are given to the various factors (in parentheses). A weighting of 3 was assigned to factor 1 because it was felt this was the single most important consideration in the emergency evacuation system, at least with the tacit understanding that fire, fumes, smoke, and the possibility of sinking are present in the situation. The possibility of extending stay time is considered next most important. However, it is not considered a complete substitute for speed of egress and, therefore, it is given a weight of 2. The remainder of those factors weighted with 2 are considered necessary to support factors 1 and 2 except for factor 6. Factor 6 is weighted with a magnitude of 2 in order to indicate that, if it is not acceptable, no one will procure and use the concept.

Another question which may arise is the validity of weighting all rank orders the same within a given factor. This is a reasonable question to ask. If it is known there is a sudden discontinuity in the relative value of the concepts or that the larger magnitude is many orders of magnitude greater than the smaller, some adjustments may be appropriate. Such items are difficult to assess without much more extensive study and statistical analysis than was contemplated for the scope of this study. However, in a few cases, it appears that total costs of a concept may at least relegate it to a lower rank because of the magnitude of the cost alone, in spite of other potential virtues. Cases in point are the wide-spectrum education concept and the ground support complex concepts. The procedure for developing an overall rank order for each concept will now be explained. A suggested step-by-step procedure is outlined in table XI.

MAJOR CONCEPT NUMBERS

1	14	8	10	6	6	4	10	10	3	6	3	3
2	15	9	6	10	2	5	6	6	6	3	7	7
3	11	7	3	3	1	9	3	3	2	5	2	2
4	1	10	7	7	3	8	2	2	1	4	1	6
5	2	6	2	4	4	3	1	1	5	1	5	4
6	3	4	1	5	5	1	5	7	4	9	4	1
7	8	5	5	9	9	2	7	5	7	2	12	5
8	9	(10)	8	1	7	12	4	4	12	7	11	11
9	4	(10)	9	2	8	11	12	8	11	10	13	12
10	6	(10)	4	8	10	13	13	9	9	13	9	13
11	7	(10)	11	11	12	6	11	11	8	11	8	8
12	13	(10)	12	12	11	7	9	13	13	12	6	9
13	12	(10)	13	13	13	10	8	12	15	14	15	10
14	5	(10)	15	15	14	15	15	15	14	15	14	15
15	10	(10)	14	14	15	14	14	14	10	8	10	14

BEST

RANK ORDER

WORST

:: RANK 10 ASSIGNED  
 ALL REMAINING  
 CONCEPTS  
 ::: WEIGHTING  
 FACTOR

EVAC SPEED    ::: 3  
 EXT TIME      2  
 "G"-SAFE     2  
 FAIL-SAFE     2  
 SEC INJURY    1  
 PUB ACCEPT.   2  
 WEIGHT        2  
 SPACE         1  
 MAINT &       1  
 RE-STOW      2  
 INIT. COST    1  
 RELIAB        1

EVALUATION FACTORS

Figure 10. Rank Order Chart For Major Concepts

Table XI

MAJOR CONCEPT RANK ORDER PROCEDURE

REQUIRED MATERIALS

1. List of major concepts (15) and detail background explanations
2. Rank order chart
3. Adding machine (if desired)

PROCEDURE

1. For each evaluation factor, select the major concept which best accomplishes the desired effect. Place its number in "best" row (No. 1 rank)
2. Select major concept which does poorest at achieving the desired effect. Place its number in "worst" row (No. 15 rank).
3. Rank remaining concepts from best to worst by placing their numbers in the remaining spaces.
4. Select weighting factor for each evaluation factor.
5. Record all rank positions (rank order number) for each concept.
6. Multiply rank position by weighting factor.
7. Add all resulting rank position numbers.
8. Arrange concepts in order from smallest sum to largest sum. This is in order - from best to worst - when all listed factors are considered.

An example of the ranking of one concept is given here. Consider concept 3. In the column of factor 1, it is ranked 6. In the column of factor 3 it is ranked 3. These rank order numbers are entered in column 3 of table XII, opposite their respective factor numbers.

Table XII

SAMPLE CALCULATIONS OF RANK ORDER FOR SELECTION OF CONCEPTS

(Col 1) Factor No.	(Col 2) Weight	(Col 3) Rank Order	(Col 4) (Col 2 x Col 3)
1	3	6	18
2	2	10	20
3	2	3	6
4	2	3	6
5	1	4	4
6	2	5	10
7	2	3	6
8	1	3	3
9	1	1	1
10	2	2	4
11	1	1	1
<u>12</u> Sum	<u>1</u>	<u>1</u> 42 Non-weighted Figure of Merit	<u>1</u> 80 Weighted Figure of Merit

The sum of numbers entered in column 3 is a figure of merit related to the average rank order of concept 3. Performing the same process on the other 15 concepts yields a figure of merit for each one. The smallest such figure has the least overall rank. The largest such figure has the worst, assuming that all factors are of equal weight. Now, if the weighting factors of column 2 are applied, each rank order number is multiplied by its respective weight

and entered in column 4. These numbers are then summed to obtain a new figure of merit for the specially weighted series. Performing the same process on the remaining 14 concepts yields a new series of figures of merit of larger magnitude in which, again, the smallest magnitude represents the best overall rating.

#### NORTH AMERICAN ROCKWELL CORPORATION RECOMMENDATIONS

Table XIII, columns 2 and 3 present the results of the previously described process as applied by the study team project engineer. There is a noticeable difference between two groups of concepts above and below the rank of 7. Those above have a minor impact on structural design of aircraft or airport systems. They have to do mainly with transfer of information (except for concept 7). Those below the rank of 7 have mainly to do with the transfer of mass, either that of the passengers or that of fire suppressant materials.

As the rank order numbers get larger, they have increasingly greater involvement with aircraft or airport structural design or equipment of an extensive nature. It is expected that such concepts would probably require extensive hardware development programs even to prepare for a test. It appears, then, that such programs, while potentially challenging and fruitful, would require a greater leadtime, more money, and more facilities than the first seven concepts. For these reasons, North American Rockwell Corporation recommends that concepts to be tested in the near future should be selected from among the first seven.

If the dissemination of the suggested detail concepts in this report leads safety equipment manufacturers to further improvements in slides, fire suppression systems, and venting systems, further large-scale tests could then be performed, using prototype hardware.

#### FEDERAL AVIATION ADMINISTRATION SELECTION OF CONCEPTS

The tentative results and the rank order evaluation were presented to Federal Aviation Administration representatives on 26 October 1967, at Washington, D.C. Subsequently, North American Rockwell Corporation received direction to concentrate on major concepts 1 through 5 and to prepare as many additional test plans as remaining funds would allow. After a careful review of publication costs and available time, it was concluded that there would hardly be sufficient resources to adequately cover major concepts 1 through 5 in the test plans. Therefore, no additional items were specifically discussed in the test requirements described in appendix B.

Table XIII

OVERALL RANK ORDER OF 15 MAJOR CONCEPTS

Rank No.	Equal Weight	NR* Weight A**	NR* Init. Cost Adjusted	
1	3	3	3	
2	6	6	7	Minor Impact on aircraft wt, structure, or GSE
3	2	2	2	
4	5	1	1	
5	1	4	5	
6	4	7	6	
7	7	5	4	
8	9	9	9	
9	10	10	8	
10	8	8	11	Major Impact on aircraft wt, structure, or GSE
11	11	11	12	
12	12	12	13	
13	13	13	15	
14	15	15	10	
15	14	14	14	

\* NR = North American Rockwell Corporation  
 \*\* Weight A = Applying weighting factors in Figure 10.

## PREPARATION OF DATA AND REQUIREMENTS FOR EXPERIMENTAL EVALUATION OF CONCEPTS

Appendix B has been prepared in response to the contract clause quoted in "Introduction," relating to requirements for experimental evaluation of selected concepts. As required by the study contract, a selection was made of certain concepts for which the contractor was to prepare data and requirements for experimental evaluation. The selection of concepts was recorded in a letter to North American Rockwell Corporation, dated 7 November 1967. It was indicated that the first five major concepts should be combined and given first priority. Also, it was requested that North American Rockwell Corporation prepare requirements for testing as many additional concepts as was permitted by the contract funds. Unfortunately, a careful review of requirements for completion of the many concept descriptions and evaluations for the final report indicated that only for the first five concepts could relatively specific requirements be prepared. However, it should be recognized that some procedures and requirements necessary for experimentation of this type are very general and such requirements can be considered applicable to all of the concepts dealing with hardware devices and specific procedures which have direct interfaces in the evacuation situation. In fact, it is not considered practical to attempt to layout a detailed, specific plan for experimentation related to these concepts. This is because of unknowns regarding available mockup devices, instrumentation availability, schedule limitations, cost trade-offs, and capabilities of the particular organizations which may be involved. Therefore, even the presented requirements which are specific to the selected concepts are in a relatively general form, suggesting approaches which should be followed rather than a step-by-step detail plan. The main purpose of these plans is to provide sufficient information for preparation of a Request For Proposal. This request should describe those requirements, peculiar to the general type of testing desired, which alert a contractor to a need to provide certain types of facilities and skills which may not be needed in other types of testing.

The diagram in figure 11, illustrates a simplified schematic diagram of this study and how it may relate to the next phases of work required to investigate the relative worth of these concepts and to develop them to the state where they can be incorporated into new regulations.

It will be noted that the upper right-hand corner of the diagram indicates that the phase titled "Preparation of Experimental Requirements" is divided into two portions. These are the general requirements and specific requirements previously mentioned which will each be separately described in appendix B.

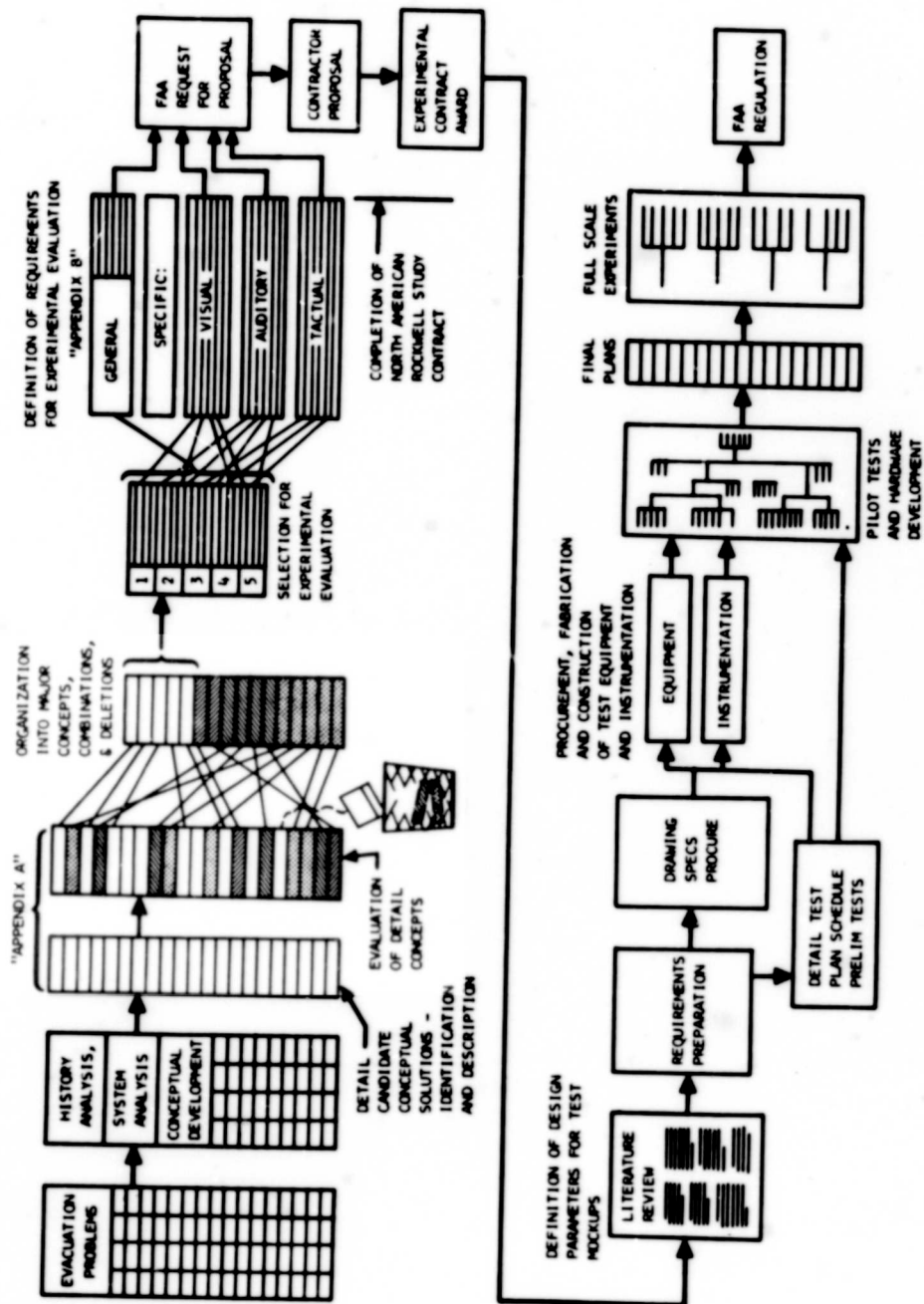


Figure 11. Schematic Flow Diagram of Concept Development and Evaluation

In the lower row are the activities considered necessary for a contractor selected to perform experimental evaluations. It may seem unnecessary and redundant to include a period of literature search in this work, which is primarily to be experimental. However, it is presumed that a normal contractor will not have been working recently on just exactly this type of experimentation, and thus will require some time to review, reorganize, and definitize his understanding and background knowledge of psychophysiological data in this field with respect to the specific test problems.

The next most significant feature of the depicted activity is the requirements for development tests and pilot tests to establish certain ranges of specific parameters which cannot be established from literature analysis.

Finally, when the test hardware has been developed and important variables established, a series of full-scale tests involving a large number of subjects representative of the airline population are performed to test the concepts in severe conditions of lighting, attitude, simulated fire and smoke, and/or water. The final phase is also considered to include all documentation and recommendations resulting from the test series. The test results and recommendations are presumed to be the basis for future regulations by the Federal Aviation Administration.

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## CONCLUSIONS

1. Although the subject of emergency evacuation of transport aircraft has had several review articles written about its various phases, the techniques of a thorough systems analysis have not previously been applied to the whole situation. In this study, a beginning to such systems analysis was made as an aid to identification of problem areas and potential solutions, and to help identify pertinent variables for preparation of experimental test requirements.
2. In developing improvements for emergency evacuation, it is essential that each one be selected and designed for compatibility with the other existing and planned components of the whole transportation system and the emergency evacuation systems. This consideration will result in economies of operation and installation by utilizing the capabilities of subsystems for both normal and emergency operations. It will help insure that there will be a minimum of interference between subsystems and a maximum of reinforcement.
3. As a result of this study, a group of some 63 candidate detail concepts were identified, described in appropriate detail, and evaluated as potential improvements in emergency evacuation of transport category aircraft following survivable accidents.
4. These concepts were classified, reviewed, and combined into a set of 15 major concepts:

### NEW EMERGENCY EVACUATION CONCEPTS

#### Communications Devices, Systems, and Procedures

1. Application of automatic voice instructions and audio signal devices.
2. Active, better-distributed lighting mix for interior and exterior.
3. Use of tactual sense displays.
4. Situation display systems for crew
5. Improved interpersonal communication devices for crew and to passengers.

6. Wide-spectrum passenger and crew education programs and displays.

Protection Devices and Systems - From Fire,  
Smoke, and Toxic Fumes, Ditching Hazards

7. Improved personal protective devices.
8. Improved, general, onboard fire suppressant and prevention systems.
9. Automatic and manual controlled cabin venting systems.
10. Improved ground support complex - quick-reacting, higher effectiveness in fire suppression and rescue.

Exits and Egress Devices

11. Better slide entry and egress devices.
  12. Better passenger containment and more versatile egress devices.
  13. Power assistance for doors, egress device employment.
  14. Automatic passenger removal devices (including inert passengers).
  15. Application of cargo handling concepts large doors, swing tail, mass transfer.
5. These 15 major concepts were rank ordered, first with respect to each of 12 evaluation factors, and then by a combined rank order procedure, considering all the factors together in a summation with various weighting factors. These rankings indicated that the concepts which appear most cost-effective and acceptable are those major concepts numbered 1 through 6. These major concepts are concerned with methods of communication of information, to passengers and crewmembers, concerning the situation inside and outside the aircraft before and during the emergency evacuation situation. That such information is a necessary key to success in emergency evacuation procedures has been amply demonstrated in simulated evacuation demonstrations and can be strongly inferred from reading of accident reports.
  6. The most serious problems of aircraft emergency evacuation arise in the presence of fire, smoke, and acrid toxic fumes. Therefore, considerable

attention has been given to concepts designed to prevent fire, confine it, reduce its rate of propagation, suppress it, ameliorate its general effects, and protect personnel from its effects, at least for a short time during evacuation. In this study, it was assumed that fires could not be absolutely prevented. Of these remaining methods, the use of some form of simple personal equipment which gives even short-term protection against toxic fume and hot-air inhalation appears to be the most efficient, and perhaps the safest on an overall system basis. Such items are included in major concept 7, and include a simple moist cloth, an antismoke hood, and an integrated survival harness combining several optional items such as a hood, cape, life vest, light, air supply, hook, and seat support harness assembly.

7. In general, all major concepts with numbers larger than 7 appeared to have an extensive impact on aircraft structural design, weight requirements, support equipment, fixed installations, and space requirements inside the aircraft. While detail design studies may indicate otherwise, the majority of these concepts appeared to be generally less effective in safety improvements per dollar of expenditure, and many of them are very high cost items. Nevertheless, many significant improvements in current aircraft designs and equipments may be realized by pursuit of some of these suggested goals.
8. The concepts selected for first priority in experimental evaluation were major concepts 1 through 5, consisting of some 15 detail concepts in the areas of visual displays, audio displays, and tactual displays.
9. The process of identification of a large number of potential concepts and the subsequent description and evaluation of each one precluded thorough detailed study of any one of them, even on a theoretical basis. Therefore, it will be necessary to perform some further detailed studies of the selected concept areas to establish human factors requirements both on a theoretical basis and a pilot scale experimental basis before extensive full-scale simulation can be performed.
10. In evaluation of these concepts, it is important that the experimental conditions be much more rigorous and representative of actual emergency evacuations in order to determine the real value of these proposed concepts. For many of them, it is highly likely that they will have no significant improvement on evacuation time under the mild conditions currently being used for demonstration of passenger aircraft emergency ground evacuation potential.

## RECOMMENDATIONS

1. A program of further study leading to detailed requirements of hardware design and systems installations in new and existing aircraft for proposed concepts dealing with methods of supplying more and better information to passengers should be initiated. This study would include a detail study of human engineering requirements; system circuits, weight, volume, and costs for installations; and a thorough analysis of probabilities of occurrence for each of the crash conditions identified herein.
2. A series of tests should be performed on representative aircraft mockups in simulated conditions of unusual attitude, unusual weather and terrain, and utilizing high-fidelity simulations of smoke and fire to evaluate the capability of the concepts proposed herein to assist in evacuation of transport aircraft. To support such tests, an indoor, weather-controlled, simulation facility should be constructed utilizing a large metal mockup fuselage section mounted so as to be capable of tilting to simulate a wide range of pitch up and down modes ( $\pm 30$  degrees), and roll angles ( $\pm 180$  degrees), and to be separable at several sections.
3. A wide-spectrum program of realistic safety and survival education should be initiated for children and adults. The program should include methods of evacuation from transport aircraft as well as from automobiles, buses, trains, boats, and public buildings. This program should include use of actual size hardware or mockups, audio-visual aids, and automatic tape recorded instructions.
4. A volunteer safety organization of knowledgeable airline travelers should be promoted to increase the likelihood of having trained personnel on board capable of assisting in evacuation procedures.
5. In addition to improving airport lighting, runways, and landing aids, attention should be given to fixed installations and more versatile vehicular equipment for firefighting and rescue in the areas of greatest accident potential. Both professional and amateur personnel should be coordinated into complementary groups of knowledgeable rescue aides.

## ACKNOWLEDGEMENTS

This report is the product of a multidisciplinary effort. The many specialists who contributed to it demonstrated a commendable professional interest and attention to the serious nature of the subject well beyond the expected level. The following is a list of the managerial and technical personnel who contributed directly to the preparation of the report. In addition, there were many helpful suggestions from personnel in both the Space Division and the Los Angeles Division of North American Rockwell Corporation.

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## GLOSSARY

The following are explanations of terms which may be unfamiliar to the reader because they are relatively new, or taken from outside the normal context of aircraft design and operations, or used in a special way in this report.

- Chemical light** - A trade name for a means for providing a phosphorescent glow in a given substrate material by use of a combination of chemicals. A particularly promising method, supplied by Remington Arms, uses ordinary air as one of the chemicals. A detailed explanation is contained in appendix A, concept 3-C.
- Light Water** - A registered trademark for a material used as a fire extinguishing agent. It is a clear slightly amber colored liquid which is an aqueous solution of two 3M fluorochemical surfactants and a polymer. It has the unique property of being able to float on the surface of hydrocarbon fuels, creating a film which prevents the escape of vapors and, consequently, prohibits ignition.
- Surfactant** - A chemical which provides a technique for changing the surface tension of a liquid usually water by acting on the surface.
- Foam** - A fire extinguishing material currently used in aircraft firefighting on the ground. It is formed by a mixture of air, water, and chemical foaming agent.
- Slide** - Any device upon which a person may sit on or jump into to slide down from an aircraft cabin to the ground.
- Airmat** - A registered trademark (Goodyear Aerospace Corporation) for a method of forming inflatable products to carefully controlled shapes by use of threads running between opposing airtight surfaces.
- Ablative** - Any material which sublimates, chars, or smokes in such a way as to carry away heat being applied to it, rather than supporting combustion and thus acts as an efficient insulator until the material is used up.
- Solid state** - Refers to a method of making or forming electronic components using semiconductors in place of vacuum tubes.

Such devices are generally smaller and more shock resistant than electronic tubes.

- TV - Television
- Freon - A trade name for any of several related chemical compounds used for refrigerants, cleaning electronic parts, and fire extinguishing. Refer to detail concept 60-F in appendix A for the properties and chemical formula for one particular Freon compound.
- PA - Public Address
- Bull horn - A portable means for amplifying speech, having a battery-powered speaker and microphone. The device is usually shaped like a short, wide-mouthed gun which the speaker holds up to his mouth to address his audience.

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PATENTS APPLICABLE TO TRANSPORT AIRCRAFT  
EMERGENCY CONCEPTS STUDY

OUT-OF-DATE PATENTS OF INTEREST (MORE THAN 17 YEARS OLD)

- 2,015,995 - "Fire Preventing and Extinguishing System for Aircraft", Egtvedt, 10 Oct 1935
- Covers automatic discharge of extinguishing fluid upon rupture, etc, of fuel lines.  
Might apply to 17-F
- 2,373,856 "Fire Detector", Smith, 28 Jan 1947
- Temperature and pressure isolated, two chambers, diaphragm closed, cooperatively making/breaking circuits.
- Could apply to any category requiring fire detector.
- 2,426,862 "Cargo Discharging Device", Cunningham, 2 Sep 1947
- Of interest in 7-B, 8-B, 9-B
- 2,445,157 "Emergency Aircraft Exit for Transport Aircraft", Bigelow, 30 Nov 1948
- Covers combination of latched overhead emergency door and rope ladder.
- Might apply to 1-B.
- 2,522,248 "Fire Detecting Switch", similar to 2,373,856, Bair, 12 Sep 1950
- Temperature and pressure isolated, two chambers, diaphragm closed, cooperatively making/breaking circuits.
- Could apply to any category requiring fire detector. See also 2,397,553.

CURRENT APPLICABLE PATENTS (1950 TO PRESENT)

- 2,701,827 "Apparatus for Detecting Incipient Fire and Explosion", Mathison, 30 Apr 1951
- Covers unit with means for response to "abnormal" pressure rate of rise.

- May Apply to 2-C, 17-F, 42-F.
- 2,765,131 "Inflatable Escape Chute Assembly", Boyle, 2 Aug 1956  
 Fluid (air) distended-inflated, three-tube chute assembly. See 2,936,056.
- 2,797,884 "Emergency Release for Pressure Cabin Door", Reed, 2 May 1957  
 A system of plungers, latches, bellcranks and cables to allow normal or emergency release of pressure doors for aircraft.  
 Might possibly apply to 1-B, 10-B, 11-B, 12-B.
- 2,901,055 "Escape Chute", Fairchilds et al, 25 Aug 1959  
 Covers extendable fabric-rope combination chute and "ladder" type with loops for holding base on ground.  
 May apply to 1-B, 39-B.
- 2,936,056 "Variable Length Inflatable Escape Chute", Heyniger, 10 May 1960  
 Covers means of extending Boyle chute (2,765,131) by selecting fasteners to turn back the end or release it at varying lengths.  
 Applies to 8-B, 12-B, 13-B, 39-B.
- 2,942,813 "Combined Speed Brake, Escape Hatch . . . ", English, 14 Feb 1958  
 Primarily covers cam-roller mechanism and unitary structural details of a combined purpose door.  
 Might apply to 1-B, 10-B, 11-B, 12-B.
- 3,018,867  
 (2,936,056) "Inflatable Escape Chute", Heyniger, 10 Jul 1960  
 Rolled, inflatable slide.  
 May apply to 8-B, 12-B, 13-B, 34-B, 50-B.
- 3,102,623 "Escape Slide", Schacht et al, 31 Mar 1960  
 Covers longitudinal extending strip and inflatable supporting structure plus attaching means.  
 May apply to 8-B, 12-B, 13-B, 16-B, 18-B.

- 3,144,224 "Escape Hatches for Passenger Airliner", Carroll, 28 Sep 1962  
Covers passageway through cabin ceiling to "dorsal" portion of fuselage with inside and/or outside operation of inside and outside two doors.  
Applies to 1-B.
- 3,201,169 "Safety Door for Vehicles", Scott, 12 Jul 1963  
Covers door structure, means for collapsing upper door structure into lower, means for jettisoning and control means.  
May apply to 1-B, 10-B, 11-B.
- 3,217,156 "Emergency Lighting System", Sherwood, 11 Feb 1963  
Covers combination rechargeable battery, light, structure and components to recharge battery, and actuate light upon primary power failure.  
May apply to 3-C, 52-C.
- 3,331,571 "Emergency Exit Arrangements in Aircraft", Lawrence et al, 22 Apr 1964 (G.B.)  
Covers arrangement of pressurized passage between inner and outer doors, door locking arrangement, and means of raising pressure and of operating each door.  
May apply to 1-B, (10-B), 11-B, 25-B.
- 3,339,690 "Evacuation Slide", Craig, 23 Oct 1965  
Covers fluid-drive extensible (telescoping) evacuation slide.  
Applies to 12-B, 15-B, 16-B, 37-B, 39-B.  
(Remotely associated with 8-B, 13-B, 50-B)

OTHER CURRENT PATENTS LISTED IN SEARCH BUT NOT REVIEWED

- Br. 887,449 "Escape Chute", Elliot Equip Ltd, 17 Jan 1962  
Fr. 1,163,036 "Escape Chute", Elliot Equip Ltd, 22 Sep 1958  
Fr. 1,473,484 "Emergency Oxygen Supply", Bowen, 1966

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## Appendix A

### DETAIL CONCEPT DESCRIPTIONS AND EVALUATIONS

#### DETAIL CONCEPT DESCRIPTION AND EVALUATION IDENTIFICATION NUMBERS

This appendix presents detail descriptions and evaluations of each detail concept. These concepts are arranged according to increased magnitude of a serial identification number which is placed on the upper corners of each page for rapid identification. These numbers were assigned chronologically and maintained for convenience of identification during the study. They include a letter code referring to a preliminary category of concept as noted in the following list:

- A - Personal equipment
- B - Escape hatches and descent devices - physical movement aids
- C - Exit awareness, lighting, signals
- D - Ditching equipment
- E - Passenger education and motivation procedures
- F - Fire and smoke suppression systems - airborne
- G - Ground fire suppression and rescue devices
- H - Interior configurations and fixtures
- I - Crew training program and devices
- J - Other miscellaneous proposed studies

Not all numbers from 1 through 63 are included in this presentation because of combinations and deletions during the course of the study. The rationale for such action is discussed in the main text of this report.

## DESCRIPTION OF TWO ACCIDENT CASES USED AS A BASIS FOR CONCEPT EVALUATION

Each passenger aircraft survivable accident is actually a unique situation. However, for purposes of realistically evaluating the proposed new concepts, it was felt that some specific cases should be referenced and discussed in formal evaluations contained in this appendix. The resulting comments give an indication of the possible benefits which could have resulted had the proposed concept been incorporated. Two specific cases were selected for consideration. These two cases had the following in common: (1) the problems of fire and smoke, considered to be a major cause of passenger fatalities; (2) the fuselage was relatively intact and few of the passengers were seriously injured as a direct result of impact; (3) the site of the accident was on or very near a major airport; (4) the crew and cabin attendants were potentially available to assist in evacuation; (5) the accident was unexpected (i.e., little or no advanced warning until impact).

In order for the reader to more fully understand the comments included in the latter part of each concept evaluation, these two cases are briefly described below, with emphasis on the comments related to passenger survival and evacuation.

### CASE 1 - DENVER DC-8

The following is abstracted from a report by the Federal Aviation Agency:<sup>1</sup>

Prior to the landing at Denver, an apparent malfunction of the plane's hydraulic system caused the captain to declare an "alert," and three pieces of firefighting equipment were stationed at the far end of the intended runway. The passengers were notified of the situation, but told to expect nothing more than a "hard" touchdown.

Apparently no emergency evacuation instructions were given to the passengers by any of the crewmembers prior to the landing. The plane touched down normally within 1,500 feet of the rear end of the runway and proceeded in a straight line for several hundred feet before it began to veer off to the right. As it skidded off the runway, it gradually yawed

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<sup>1</sup> Hasbrook, H. A., Garner, J. D. and Snow, C. C., "Evacuation Pattern Analysis of a Survivable Commercial Aircraft Crash." FAA Report 62-9, Federal Aviation Agency, Oklahoma City, Oklahoma, May 1962.

to the right, slid sideways across open ground, striking a panel truck and killing the driver. It came to rest on the sheer edge of an incompletd taxiway.

During the slide, the landing gears were torn off and, as the plane slid over the 2-foot-high edge of the concrete taxiway, three engines tore free and small fuel fires immediately erupted near and below the forward portion of the aircraft. Accelerative forces were very low and no impact injuries occurred. Soon after the aircraft came to rest, two major fires areas developed. One was near an engine in front of the right wing, but traveled to the forward right-hand portion of the fuselage.

The other major fire was concentrated at the left wing root, within which the number 1 engine had become lodged.

The three airport fire trucks reportedly reached the aircraft within 1 to 2 minutes after impact and were driven to an area near the right side of the aircraft, from which point the firemen vainly attempted to control the fire.

"However, prior to arrival of the fire trucks and immediately after the aircraft came to rest, the cockpit crew and the stewardesses in the forward (first class) cabin opened the forward, left-hand passenger door and deployed the evacuation chute; the chute was not inflated due to the short distance (approximately 4.5 feet) between the door sill and the ground. The service door on the opposite (right-hand) side of the cabin was not opened by the crew, because of the large fire near this exit.

"Evidence indicates that 26 of the 36 first class passengers and all five of the forward crewmembers utilized the left-hand passenger door for escape, despite the increasing magnitude of the fire at the left wing root, which eventually consumed a major portion of the aircraft before the fire was finally brought under control . . . .

"The two right-hand overwing exits were reportedly opened by several passengers, and were utilized by approximately nine of the first class passengers and 11 adults and a child from the forward part of the tourist cabin.

"Since the fire was quite intense at the left wing root, it is doubtful that the left-hand overwing exits were open.

"In the rear (tourist) section of the aircraft, one of the two stewardesses was sitting in the lounge; the other, wearing her shoulder harness and seatbelt, sat on a crew seat directly adjacent to the rear, left-hand, passenger door. As the aircraft slid sideways to a stop, paraphernalia (pillows, magazines, and other passenger comfort items) was

ejected from an upper storage locker on the right-hand side of the aircraft and deposited in a pile "knee deep" against the passenger door. Due to the debris piled up against the door, the stewardess did not attempt to open it; however, due to structural deformation of the fuselage under the door resulting from impact with the panel truck. . . , the door could not have been opened by the stewardess.

"The other stewardess (who had been sitting in the lounge) opened the rear, right-hand service door, placed the escape chute in position, inflated it, and then started assisting the tourist passengers through this exit. . .

"It is noteworthy that, as soon as the doors and exits were opened, dense smoke began to funnel back through the entire cabin, making sight and breathing extremely difficult. It is also noteworthy (according to survivor statements) that there was little or no hysteria; in fact, there apparently was a remarkable degree of calmness displayed by most, if not all of the occupants. . . .

"There were 36 passengers and five crewmembers in the forward cabin-cockpit area; three exits were available in this accident for evacuation of these 41 persons - a ratio of one exit for each 14 persons.

"Seventy-nine passengers and two crewmembers occupied the tourist compartment, for which there was only one exit (a service door) available for evacuation. All of the fatalities were in this rear compartment, whose ratio of exit to occupants was 1:81, as compared to 1:14 in the forward compartment.

"As noted before, as many as 12 to 14 persons in the tourist cabin apparently went forward and used the exits available in the first class cabin. If these 14 persons (including one infant in arms) did use the forward exits, the remaining 67 persons apparently attempted to use the only other exit available in the aircraft - in the rear - but only 51 were successful.

"In attempting to determine why all of these 67 tourist passengers were unable to evacuate the aircraft through this one exit, several major factors bear scrutiny: (1) The width of the aisle between the rows of triple seats in the tourist section was 15.5 inches, or approximately two-thirds of the 22-inch aisle width in the first class section. This narrow aisle width in the tourist cabin would require that the evacuating passengers stand in single file, while waiting to move toward the exit at the rear of the aircraft. (2) There were no overwing or window exits available within the tourist cabin. (3) A floor-to-ceiling partition separated the tourist cabin from the first class section, effectively blocking from the view of the tourist passenger any sight or sign of the overwing exits available in the

first class cabin, and (4) there was no placard or indication on the aft side of the partition to indicate the existence and availability of emergency exits in the first class cabin.

"During the routine CARI investigation of this accident, in cooperation with the Civil Aeronautics Board, it was determined that the persons, who had succumbed from carbon monoxide poisoning while attempting to evacuate the tourist section, died in . . . seats . . . (not those) for which they had been ticketed. It is of interest that these seats in which they died are predominantly spaced at random along the aisle. This indicates that these persons must have left their own seats and were attempting to move down the aisle toward the rear exit when they were overcome; it may be assumed that they collapsed into, or sat down in these seats to try to regain their senses and to await clearing of the aisle."

CASE 2 - SALT LAKE CITY, B-727

The following description is abstracted from a Civil Aeronautics Accident Investigation Report published in Aviation Week and Space Technology, June 27, 1966.

". . . A Boeing 727 crashed during an attempted landing at Salt Lake City Municipal Airport, Salt Lake City, Utah, at approximately 1752 MST on November 11, 1965. Of the 85 passengers and a crew of six aboard, there were 43 fatalities, including two passengers who succumbed in the hospital several days after the accident. The 48 survivors included all of the crewmembers.

"The flight . . . departed Denver at 1654. Shortly after 1748, the flight advised . . . 'Have the runway in sight now, we'll cancel the standby with you for traffic.' The high, straight-in approach continued under Visual Flight Rules (VFR). Impact occurred 335 feet short of the runway threshold, the main gear sheared, and the aircraft caught fire and slid approximately 2,838 feet on the nose gear and bottom fuselage surface, finally coming to rest approximately 150 feet off the east side of the runway . . .

"The accident occurred in darkness. . . .

"Injuries to Persons

<u>Injuries</u>	<u>Crew</u>	<u>Passengers</u>
Fatal	0	43
Nonfatal	6	29
None	0	13

"The aircraft was destroyed by impact and ground fire. The asphalt overrun, some runway lights and flush-mounted approach lights were damaged. . .

"The flight data recorder on this aircraft. . . was examined and there was no fire or mechanical damage found. . . . The flight record was read out for the last 15 minutes. . . During the last 1-1/2 minutes of the approach, the rate of descent exceeded 2,000 fpm and averaged in excess of 2,300 fpm in the last minute. At initial impact, a vertical acceleration of 4.7 g occurred, and the other three parameters apparently did not scribe for a 6-second time period. Although the acceleration peaks during the next several seconds reached total amplitudes of -1 to +6g, some aberrations did occur.

"The initial impact occurred 335 feet short of the threshold of Runway 34L at Salt Lake City Municipal Airport, and prior to contacting the threshold lights the right and left main landing gear began to separate from their attachment points. The aft lower portion of the fuselage contacted the runway, and the aircraft continued sliding on the fuselage and nose gear approximately 2,838 feet. During the skid, it veered to the right and came to rest 150 feet east of the runway on a heading of 123 degrees. The No. 1 engine separated and came to rest approximately 140 feet north of the aircraft.

"Examination of the wreckage revealed that the landing gear was down and locked, landing flaps and leading edge devices were fully extended, the spoilers were retracted. The horizontal stabilizer was set at 8-3/4 units noseup and sustained downward bending. There was no evidence of flight control difficulty prior to impact.

"Severe upward and rearward impact forces from the right main landing gear assembly produced a large impact hole and ruptured fuel lines and the No. 3 generator leads between fuselage station 1030 and 1130 on the right side. The fuel was ignited by sparks from the fuselage scraping on the runway and/or the severed generator leads. The hold and fire damage area extended circumferentially from the lower sill of the aft cargo compartment door to the top of the fuselage. The entire roof and cabin area forward of this was consumed by fire which was initially being supplied fuel under pressure by the operating boost pumps. All flight control cables, fuel supply lines from the No. 2 and 3 tanks, and the No. 3 generator leads which are routed through the cabin floor beams in the area of the impact hole were consumed by fire. Only a 5/8-inch stainless steel hydraulic pressure line remained intact. . . .

"There was no evidence of inflight fire. The survivors who were seated in the aft right portion of the cabin observed the fire initially enter the cabin from under seat 18E (right window seat) and erupt up the inside wall. Time estimates ranged from immediately to one or two seconds after impact.

"Two airport crash trucks arrived at the accident site within approximately 3-1/2 minutes. They were positioned on either side of the aircraft tail section where the flames seemed to originate. The fire was essentially contained within the fuselage, which materially reduced the effectiveness of the firefighting efforts. The flames persisted, and there was a temporary cessation of firefighting until the water supply could be replenished by additional personnel and equipment from the Salt Lake City Fire Department. These units had been simultaneously notified of the accident and arrived within approximately 10 minutes. The fire was finally brought under control about 1830.

### Survival Aspects

"This was a survivable accident. There were 91 persons aboard the aircraft and 50 were successful in evacuating, although many were severely burned and some sustained injuries during their egress. The remaining 41 occupants were overcome by dense smoke, intense heat, and flames, or a combination of these factors, before they were able to escape. There were no traumatic injuries which would preclude their escape. Two survivors died in the hospital several days after the accident bringing the total number of fatalities to 43 passengers.

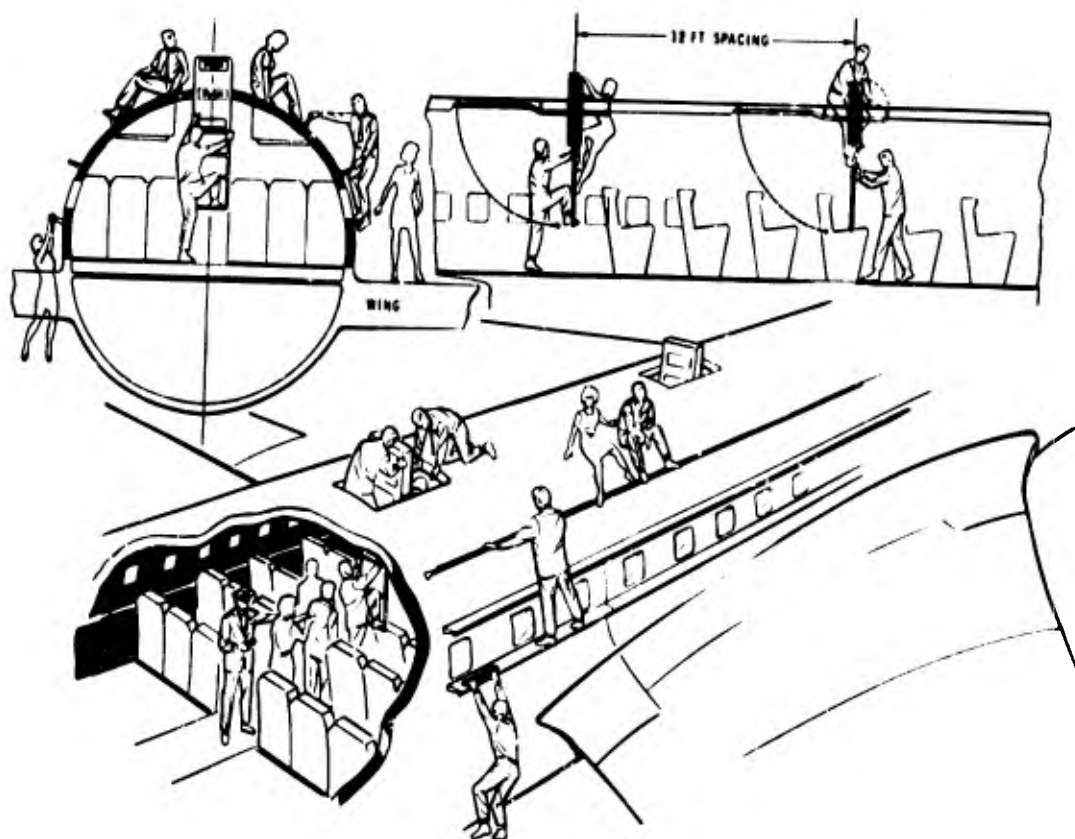
"All emergency exits were available and used. The sliding windows in the cockpit were actuated and used by the captain and first officer. The press of passengers crowding in the area of the main loading door hampered the attempts of the stewardess to open it. However, the second officer succeeded in opening it completely, inflating the slide, and the directing the evacuation of passengers through this exit. The galley door, on the right side between rows 8 and 9, and the overwing emergency exit windows on either side of rows 12 and 14 were all opened by passengers. The emergency slide at the galley door was not actuated until a UAL stewardess, who had been riding as a passenger, was able to instruct a man to activate it. Both were outside the aircraft at that time.

"When the aircraft came to a complete stop, the stewardess who was occupying the jumpseat on the aft passenger entry door opened this door to see if the ventral stairway could be used for egress. However, the nose-high attitude of the aircraft due to the extended nose gear and sheared main gear prevented the stairway from opening more than about 6-inches. Two men who were seated in the aft cabin area preceded her into the stairwell. When she attempted to return to another exit the flames and smoke had blocked them off. They huddled as far from the approaching fire as possible, and at the suggestion of the stewardess began pounding on the fuselage and yelling to the firemen outside. The stewardess

extended her arm through the narrow opening and succeeded in attracting the attention of firement outside. A hose was passed into the stairwell, and one of the men sprayed the surrounding area. All three persons were successfully rescued from the aircraft through the large hole which had burned through the aft cabin wall on the right side. Although there is no exact timetable for this unprecedented rescue, it is estimated that the time envelope from impact to discovery of the survivors was approximately 23 minutes and that rescue was completed between 25 and 30 minutes after the accident. . . .

"The impact of the crash did not produce any traumatic injuries which would have precluded the escape of every passenger. On the contrary, it was the speed with which the passengers progressed toward the exits that prevented the stewardess from reaching her assigned duty station for evacuation. Following the accident, the stewardesses recommended that they be seated near emergency exits for all takeoff and landings. This practice has been adopted by UAL as standard procedure on all B-727 flights. Inasmuch as all emergency exits were used during the evacuation it is not known how many additional lives, if any, might have been saved if the stewardess had been able to carry out her assignments."

### HINGED COMBINATION OVERHEAD HATCH AND LADDER ABOVE AISLE



#### CONCEPT DESCRIPTION

##### GENERAL DESCRIPTION OF CONCEPT

Pressure hatches spaced at approximately 12-foot intervals above center aisle are hinged near center and carry a ladder at one end recessed into ceiling to aid egress to "roof." A series of fences or rails parallel to fuselage permit descent to wing or ground.

##### AREAS OF IMPROVEMENT IN EMERGENCY EVACUATION OF AIRCRAFT

Provides additional openings with direct access to aisle to reduce total egress time from cabin enclosure. Readily visible from seat (improved exit awareness). Aids egress from flooding cabin in ditching and provides more high support surface on fuselage instead of wing.

## ESTIMATED QUANTITATIVE IMPROVEMENT IN SURVIVABILITY

Passenger flow rate: 30 passenger/exit/90 sec. Estimate 3 sec/passenger if both sides used; 6 sec/passenger for each side.

## HOW NEW IS THIS CONCEPT?

## Patents:

- 2,455,157, "Emergency Aircraft Exit for Transport Aircraft," Bigelow, 30 Nov 1948
- 2,797,894, "Emergency Release for Pressure Cabin Door," Peed, 2 May 1957
- 2,942,813, "Combined Speed Brake, Escape Hatch," English, 14 Feb 1958
- 3,144,224, "Escape Hatches for Passenger Airline," Carroll, 28 Sep 1962
- 3,201,169, "Safety Door for Vehicles," Scott, 12 July 1963
- 3,331,571, "Emergency Exit Arrangements in Aircraft," Lawrence et al, 22 Apr 1964

## HOW ORIGINAL IS THIS CONCEPT?

Adapted from military aircraft development or practice? Yes. Adapted from nonaircraft fields or practice? Yes. Overhead hatches for crew cabin used in many aircraft but not used in passenger cabin. Overhead hatches used in passenger and naval vessels.

## DETAIL DESCRIPTION OF SYSTEMS AND COMPONENTS

Refer to sketch.

CONCEPT EVALUATION

## ENGINEERING FEASIBILITY

Within current state-of-the-art? Yes - normal design and development cycle. Problems: Ceiling area commonly used for air ducts, other lines. Adds weight to aircraft structure - high stress area. Adds aerodynamic drag of fences, probably increases noise level. Mechanical complexity if fences are retracted.

## PSYCHOLOGICAL EVALUATION

Visibility

Good during passenger boarding and preflight preparation, non-smoke condition. During fire/smoke conditions:

- (a) Upright aircraft - very poor. Passengers should be on floor, facing down.
- (b) 90 degrees roll of aircraft - fair.
- (c) Overturned aircraft - good, but exit may be unusable if no clear space under fuselage.

Tactical

No contact in preflight boarding or preparation.

- (a) Upright aircraft - no contact.
- (b) 90 degrees roll - may be accessible but not certain.
- (c) Overturned aircraft - good but may be unusable if no clear space under fuselage (assuming ladder protrudes above main contour of ceiling panel).

Behavior

Inventor claims strong tendency by people to climb upward in panic condition. No evidence from public building experience to support this. May be especially useful in ditching condition as cabin fills up. Aisles blocked for walking to floor-level doorway exits.

## PHYSIOLOGICAL EVALUATION

Exposes passenger to heat and smoke while egressing and while preparing exit unless it is automatically deployed in normal upright cabin attitude. Heat and smoke may be concentrated in this area by chimney effect.

## KINESIOLOGICAL EVALUATION

Design of deployment initiation is critical here. Passengers must be able to reach and actuate from aisle.

Climbing is slower than jumping into slide and puts passenger farther from wing and ground as he exits aircraft in upright position. Hanging onto "fences" is hazardous for older persons and small children, or in pitching seas. Passengers carrying children would have serious problem.

## COMPATIBILITY

Premature deployment of ladders will interfere with access to floor-level exits by walking along aisleway. However, it may not seriously impede crawling passengers.

## EFFECTIVENESS OF SOLUTION IN TYPICAL ACCIDENT CASES

### Case 1 - Denver, DC-8

A small number of additional passengers might have been saved by virtue of an increased total number of exits. However, the smoke would have obscured the ceiling area and may have increased the egress hazard (through the hatch) by the "chimney effect" if the doors had been opened. The possible clearing of the cabin smoke through the ceiling vent may be offset by fanning flames internally through venting action of the hatch. Egress through the hatch to the upper surface of the fuselage would still require the passengers to climb down the side of the aircraft, exposing them to smoke, heat and flame, and serious injury in dropping to the ground.

APPLICATION OF AUTOMATIC VOICE INSTRUCTIONS AND  
WARNING SYSTEM TO PASSENGER EVACUATION

CONCEPT DESCRIPTION

GENERAL DESCRIPTION OF CONCEPT

This concept is based upon current voice warning systems (NORVIPS and FLAWS) currently being used in the military. These systems are modified and extended to provide automatic or manually initiated preflight briefings, pre-emergency instructions, and evacuation instructions. This concept utilizes sensors and logic to detect conditions and select and/or compose prerecorded messages and present them in a calm, firm, female voice to the passengers. This system relaxes the dependence on the crew for instructions and briefings; it presents the information in a more thorough, audible, and psychologically demanding manner; and it provides, particularly in conjunction with other emerging systems (power-actuated doors, warning systems, anticollision systems, computerized evacuation system, etc) a more sophisticated and reliable passenger evacuation system.

AREAS OF IMPROVEMENT IN EMERGENCY EVACUATION OF AIRCRAFT

- (a) The system improves the quality of instructions presented to the passengers by providing clear, concise, and thorough information. The presentation could include standardized briefing material including both general and unique aircraft configuration instructions. The presentation in a calm, firm, and professional voice is a major improvement over present stewardess preflight presentations as well as during the confusion of actual emergencies in terms of passenger reassurance and education.
- (b) The system also frees the crew for operation of emergency equipment and for passenger care during the important first few seconds following an accident. In addition, it provides the necessary leadership and instructions in situations of incapacitation of crewmembers.
- (c) Through a subsystem of sensors and logic, the system can assess conditions and provide pertinent voice instructions not always possible by the crew.
- (d) The system is combinable with other automatic emergency/malfunction systems which could ultimately provide a complete automated emergency evacuation system.

### ESTIMATED QUANTITATIVE IMPROVEMENT IN SURVIVABILITY

A 100 percent improvement is indicated in quality, meaningfulness, clarity, and audibility of passenger instruction.

### HOW NEW IS THIS CONCEPT?

Automatic voice warning systems have been in operational use for several years on military aircraft and weapon systems. However, the specific application to commercial airlines has not been implemented, nor has the extended concept developed here been proposed. The general concept, as detailed in the military specification, is not patentable; however, specific components of existing systems may be.

Publications: Department of the Navy, Reproducer, Set, Voice Warning, AN/ASA-19, Specification MIL-R-81000, Bureau of Naval Weapons, 18 February 1964

Patents related: 2,701,827, "Apparatus for Detecting Incipient Fire and Explosion," Mathison, 30 April 1951

### HOW ORIGINAL IS THIS CONCEPT?

The value and utility of voice warning systems have been fully validated in their military applications. However, these systems are limited to malfunction warnings as a supplement to standard malfunction lights. The concept discussed here is an extension which would include extensive briefing capability as well as augmented logic and message selection or construction capabilities.

There are three main automatic voice warning systems in operational use. These include NORVIPS (Northrop Nortronics Division), FLAWS (Teledyne Radar Relay Division), and AID (Teledyne Radar Relay Division).

The following chart indicates the present state-of-the-art for the operational systems. Expanded or more sophisticated systems are currently under development.

## COMPARISON OF VOICE WARNING SYSTEMS

	<u>NORVIPS</u>	<u>FLAWS</u>	<u>AID</u>
Number of inputs	50	40 (200)**	30
Number of message outputs	20	40* (80)**	20
Message length	15 sec min	-	0 to 18 sec
Response time	0.5 sec max	0.5 sec	0.3 sec max
Power required	17 to 29 volts dc	28 volts dc	22 to 32 volts dc
Weight	10.5 lb	7.5 lb (11)**	8.25 lb
Volume	391 sq in.	-	139.6 sq in.
Memory	Yes***	Yes	No

\*Also one preflight and prelanding checklist

\*\*Potential maximum

\*\*\*Separate unit - continuous in-flight performance recorder

Each of these systems is designed to operate in conjunction with or as a warning system. The voice message is actuated upon indication of an out-of-tolerance condition and repeated until acknowledged. Priority systems of simultaneous malfunctions are included to insure attendance to critical parameters first. The basic justification for the systems, and one that has been verified by operational experience, is the improvement in reaction time over reliance on visual or auditory tone warning display. Voice instructions are both alerting and instructional. For passenger evacuation use, the same reasoning is valid. An automatic voice system would increase the reaction time to the emergency situation as well as provide the necessary instructions.

Each of these systems has demonstrated good reliability and maintainability. In addition, their compact size and weight are ideally suited for commercial airline application.

## DETAILED DESCRIPTION OF SYSTEMS AND COMPONENTS

### Overall Description

The proposed automatic voice instructions and warning system has several purposes. It provides an automatic method of presentation of (1) preflight briefings, (2) preemergency instructions, and (3) emergency instructions.

The system is designed to operate independently and in conjunction with normal communication and other aircraft systems as well as be capable of reliable independent operation following a survivable crash. Thus, it is envisioned as being compartmentalized corresponding to aircraft structural design and having an independent emergency power source.

The system is capable of being initiated by the flight or cabin crew as a backup to automatic initiation or in the case of preflight or preemergency briefings as the normal mode. It will also be capable of being initiated by various sensors in cases of unexpected emergencies. The system sensors will provide signals to the logic subsystem which will select the appropriate message to be broadcast or to activate the sonic indicators.

The message will be presented in a firm and calm female voice instructing the passenger concerning appropriate equipment/procedures.

### System Components

Control panels will be provided in the flight deck and passenger sections. Controls and displays will be provided which permit the following:

- Manual selection of specific messages
- Message activation (on off)
- Message reset
- System test
- Manual override of automatic method
- Normal/emergency power source selection

A subsystem will be provided which includes sensor, logic, and memory capabilities. The sensors will function to detect conditions that require automatic activation of various messages. The logic will function in selecting and/or construction of messages and the establishment of message broadcast priority. An optional memory unit operating in conjunction with the

sensor/logic would provide a valuable postflight record of emergency events. The sensors would monitor the following types of parameters:

- Structural damage (breaking, twisting, deformation)
- G-load
- Vibration
- Heat
- Smoke
- Atmospheric toxicity
- Decompression
- Exit opening

On the basis of sensed parameters, the logic will select predetermined messages or combine words to construct appropriate message. On the basis of criticality, it will determine order and repetition of messages. Specific contents of the messages will require development and validation both in terms of content and presentation. The following represents preliminary conceptualization of messages or signals:

(a) Preflight briefing

These should be standardized general instructions and those specifically designed for a given aircraft configuration (refer to concept 23-E).

(b) Preemergency briefing

These should be standardized instructions for preparation for crash and/or evacuation.

(c) Emergency instructions

These should include standardized instructions for evacuation or other emergencies such as in-flight decompression, or fire presented in a sequential manner; and specific instructions or warnings automatically triggered by various sensor-monitored parameters necessitating a requirement for passengers reassurance or contingency actions, e.g., fire in specific area, blocked exit, opened exit, etc.

Although the system must be capable of operation independently following a crash, it also can interface or be integrated with other systems or potential systems. An interface must exist with both the normal emergency and entertainment communication systems. This is necessary to permit crew communication to passengers if required. The system must be capable of operation with

either the normal or an emergency power source because of the intent to use the system for normal preflight briefings and other uses not requiring use of the emergency batteries. If other automatic or semiautomatic emergency systems are utilized requiring identical sensors or a control panel, then they should be combined to minimize weight and cost, and to increase crew operability through a centralized control panel. Other potential uses of automatic voice warning systems such as for malfunction indication, collision avoidance, or automatic landings would for reasons of related sensors, common components, potential relationship, and most assuredly cost-effectiveness require integration into a centralized automatic voice warning and emergency system.

### CONCEPT EVALUATION

#### OVERALL SUMMARY RATINGS

Cost-effectiveness should be high for this concept, because of the overall improvement in effectiveness of passenger education and instruction. In addition, the cost-effectiveness of such a system would be greatly enhanced if the system were also used for such things as malfunction detection, collision avoidance, and automatic landing assists.

#### ENGINEERING FEASIBILITY

The basic concept and capability are within the state-of-the-art with actual components in operational use. The specific application to commercial aircraft would require minimum development of the concept. This would include increased message length capability as well as systematic development of message content and presentation. Another factor requiring development would be the logic of emergency message selection. The system has demonstrated reliability and maintenance capabilities and minimum weight, volume and power penalties.

#### PSYCHOLOGICAL EVALUATION

The adaptation of automatic voice instructions will significantly improve the effectiveness of passenger education. The presentation of the information in a professional manner for briefings would be an improvement over the current stewardess briefings which are often poorly delivered and received. In emergency situation, the presence of a calm but authoritative voice would both insure the passengers as well as increase the probability of correct behavior. Also, the systems will provide better assurance of being heard by the

passengers in an emergency situation in which noise, confusion, and the absence of effective crew leadership are possibilities. Finally, the auditory presentation is important due to the probability of darkness, smoke, and other factors that degrade reliance on visual cues for evacuation.

#### COMPATIBILITY WITH OTHER REQUIREMENTS

This concept is compatible with existing evacuation systems and procedures if utilized alone, as well as being adaptable for use with further automated systems of evacuation such as computerized exit openings and visual displays. In addition, the system would be partially successful with the development of a standardized passenger education program.

#### EFFECTIVENESS OF SOLUTION TO PROBLEM AREAS

This concept should improve:

- (a) Slow passenger starts
- (b) Utilization of wrong exits
- (c) Problems of degraded vision
- (d) Absence of crew instruction or leadership
- (e) Poor briefings

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APPLICATION OF CHEMICAL LIGHT  
TO AID EMERGENCY EVACUATION

CONCEPT DESCRIPTION

GENERAL DESCRIPTION OF CONCEPT

The concept involves the use of chemical luminescence for emergency signs; direction indicators; marking and identifying emergency equipment; and illuminating operating controls, evacuation areas, and emergency areas.

AREAS OF IMPROVEMENT IN EMERGENCY EVACUATION OF AIRCRAFT

The concept would improve exit awareness, safety of egress, passenger stability, and reliability of signs/exit devices.

ESTIMATED QUANTITATIVE IMPROVEMENT IN SURVIVABILITY

Reliability would be improved 100 percent.

HOW NEW IS THIS CONCEPT?

The concept and the devices have been developed by the Remington Arms Co., Inc., following basic research by their owning company, E. I. du Pont de Nemours & Co. Their product is known as "chemical light."

Previous publications:

Federal Aviation Agency, Minutes - FAA - Industry Conference on Crashworthiness and Passenger Standards for Transport Category Airplanes, Flight Standards Service, 29 and 30 March 1966.

HOW ORIGINAL IS THIS CONCEPT?

Current practice on certain aircraft, principally by United Air Lines, is to mark escape chutes with "chemical light" strips, both to outline the slide and to provide some exterior illumination. Other applications (including those suggested here) have been or are being evaluated or tested by the Remington Arms Co. and aircraft, airline, or military organizations.

## DETAIL DESCRIPTION OF SYSTEMS AND COMPONENTS

The following data were extracted from Remington Arms Co. data sheets:

A practical, new source of light is available in Remington's "chemical light." Its characteristics are so different that entirely new methods of making lighting devices had to be developed, and entirely new applications of light are possible. The basic "chemical light" element is a chemical in liquid form. The energizing means by which "chemical light" is turned on and off is air. The envelope in which "chemical light" is contained is nylon or glass.

- (a) Since "chemical light" needs only the addition of air to produce light, lighting systems and devices can be made which (1) can be completely isolated from other systems; (2) do not present the fire and explosion hazard associated with electrical systems; (3) have extra-long, maintenance-free standby life; and (4) are reliable, fail-safe, lightweight, and submersible. The activating air required can be contained in the lighting device, or can be obtained from the surrounding environment.
- (b) Since the "chemical light" envelope can be flexible nylon, lights can be provided as continuous wraparound tubing of any desired length, or as planes of light in any desired length-to-width ratio.

### Light Output and Other Properties

The light output is a function of ambient temperature, the humidity of the activating air, and the form in which the product is prepared. Brightness varies from 65 foot-lamberts downward (for comparison, a 600-volt electro-luminescent light has a brightness of about 20 foot-lamberts). Duration of useful light output ranges from 5 minutes to 4 hours. The light spectrum covers the entire visible range, with a peak in the vicinity of 500 nanometers wavelength (blue-green).

It requires approximately 35 cc of air at atmospheric pressure to completely oxidize the active chemical in one square inch of a "chemical light" panel. Light output ceases after complete oxidation.

Weight of "chemical light" devices:	One square inch of light area of a panel weighs approximately 1/2 gram.
Heat generation:	"Chemical light" is cold light, and it is not subject to spontaneous combustion.
Light stability:	"Chemical light" is not affected by exposure to visible light.

- Storage life: In its sealed container, and with storage temperature below 120°F, "chemical light" can be stored for about 2 years.
- Chemical compatibility: "chemical light" is compatible with inert materials such as saturated hydrocarbons, nylon, teflon, mylar.
- Toxicity of active ingredient: The amount of exposure to the active chemical which will occur with normal use of a "chemical light" device will have no harmful effect. However, if a large quantity of the active chemical contained in such a device is ingested, or placed on the skin or in the eyes, and allowed to remain for a long period of time, or if a concentration of its vapors is inhaled for a long period of time, mild temporary irritation may occur. Irritation can be avoided by washing out the chemical (or inhaling fresh air) immediately after such overexposure.
- Testing of Chemical Light devices: It is not necessary to turn on a "chemical light" device to determine whether it is in operating condition. A "passive" check can be made with ultraviolet light.

The characteristics which make "chemical light" useful in solving unusual lighting problems are the following:

- (a) Unlimited variety of shapes and sizes in flexible or rigid form
- (b) Requires no power supply
- (c) Isolated system; submersible
- (d) Long standby life
- (e) Lightweight and unbreakable

Applications considered:                    Lighting systems and devices for life jackets, life rafts, emergency exit path markers, outlining emergency exit doorways, and aircraft escape

Nighttime locating of rescue equipment.

#### CONCEPT EVALUATION

#### OVERALL SUMMARY RATINGS

Cost-effectiveness:                    Moderate

Price policy of manufacturer not established.

#### ENGINEERING FEASIBILITY

Requires moderate improvements in state-of-the-art for application, packaging, and production.

Restowage requires replacement of sealed bags. Check of capability to light is performed by ultraviolet lamp - inexpensive. Very lightweight for great deal of light. Short duration (15 minutes). Highly crashworthy. Fail-safe.

#### PSYCHOLOGICAL EVALUATION

Human engineering (vision) improved.

Behavioral psychology improved with vision and by selective application on signs, directional indicators, optical illusions on slide distance, etc.

#### PHYSIOLOGICAL EVALUATION

No toxic effect on personnel working with the material to date. If system uses own bottle air supply as in slide or raft, there is a negligibly small chance of even breathing the effluent gas.

## KINESIOLOGICAL EVALUATION

No effect.

## COMPATIBILITY WITH OTHER REQUIREMENTS

Compatible with other devices considered, including use as a backup to other (powered) lighting. Should be applied to exits and escape devices where a mechanical action is necessary to initiate device.

## EFFECTIVENESS OF SOLUTIONS IN SPECIFIC PROBLEM AREAS

Useful in behavioral and environmental problems especially associated with darkness. Would not be suitable for quick turnaround after use.

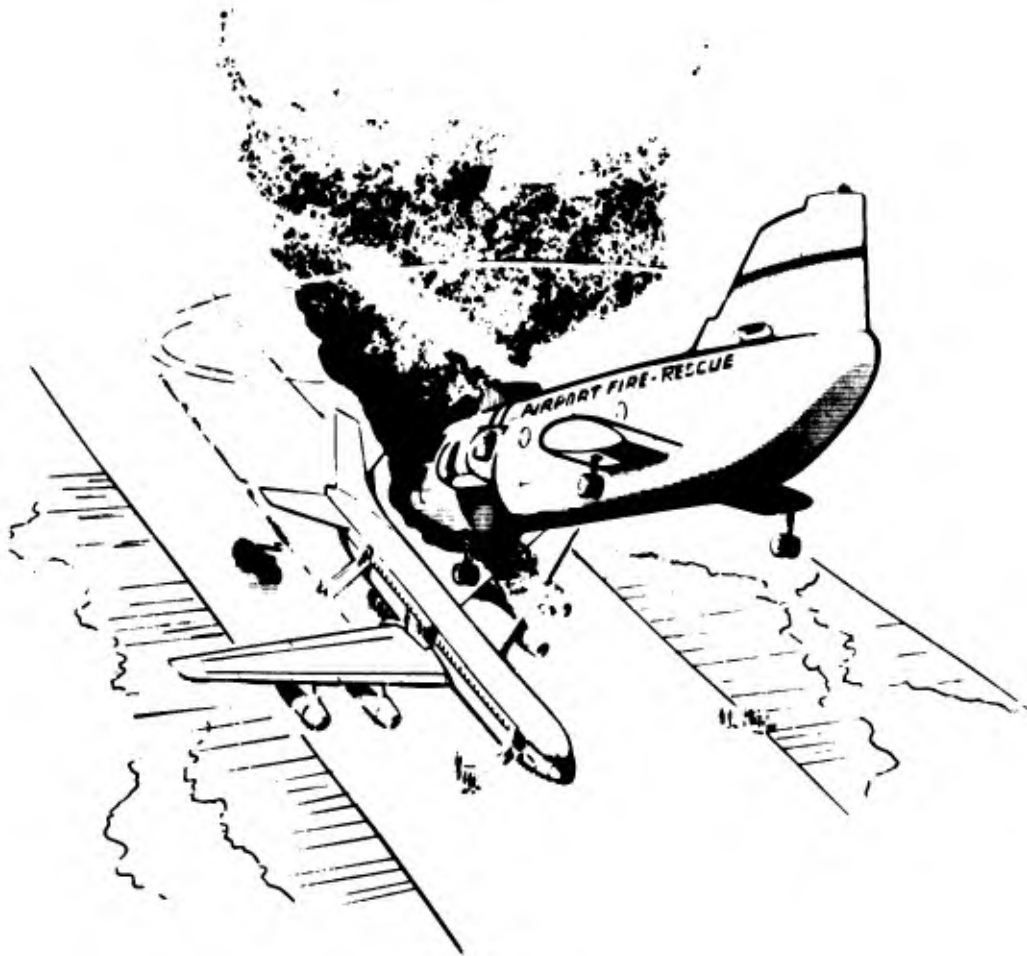
## EFFECTIVENESS OF SOLUTION IN TYPICAL ACCIDENT CASES

Case 1 - Denver, DC-8

The use of "chemical light" in this particular accident could have been of some assistance in speeding up passenger flow through the rear of the airplane; but, of perhaps greater significance, it could have been applied to exit notices which might have directed additional passengers to the overwing exits from the tourist cabin.

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## HELICOPTER FIRE SUPPRESSION AND RESCUE VEHICLE

CONCEPT DESCRIPTION

## GENERAL DESCRIPTION OF CONCEPT

The system consists of any current helicopter with a capability for carrying a fire suppressant system, trained fire and rescue personnel, and special rescue equipment. A corollary to this concept is the use of "Light Water" for the fire suppressant.

## AREAS OF IMPROVEMENT IN EMERGENCY EVACUATION OF AIRCRAFT

The complete rescue vehicle could shorten external fire control time, especially in areas beyond the immediate airport area, expedite opening of exits, and improve passenger safety after egress.

## ESTIMATED QUANTITATIVE IMPROVEMENT IN SURVIVABILITY

Preparation of exit: 30 to 50 percent  
 Passenger flow rate: 20 to 30 percent  
 Reduction in wrong exits tried: 10 percent

Provide fire- and smoke-free escape corridor.

## HOW NEW IS THIS CONCEPT?

Similar uses have been made of the helicopter, especially at military bases. Data on the "Light Water" system use are as follows:

## Previous publications:

1. Peterson, H. B., Jablonski, E. J., Neill, R. R., Gipe, R. L., and Tuve, R. L., "Full-Scale Fire Modeling Test Studies of 'Light Water' and Protein Type Foams." Naval Research Laboratory, Report 6573, 15 August 1967
2. Conley, D. W., "Post-Crash Fire-Fighting Studies on Transport Category Aircraft," FAA Report RD-65-50, May 1965

## Patents related:

3,258,423, "Method of Extinguishing Liquid Hydrocarbon Fires,"  
 Jablonski, E. J., and Tuve, R. L., 28 June 1966

## HOW ORIGINAL IS THIS CONCEPT?

Adapted from military aircraft developments or practice? Yes, reference George AFB and military operations in Vietnam.

Adapted from nonaircraft fields or practice? Yes, such as borate bombers.

## DETAIL DESCRIPTION OF SYSTEMS AND COMPONENTS

The fire and rescue helicopter would provide three major elements to the scene of the accident.

First, a fire suppressant system would serve primarily to reduce cabin heating and envelopment, provide "escape corridors," and might furnish additional fire control. The system would consist essentially of components

comparable to those which make up conventional firefighting equipment. The fire suppressant should be selected on the basis of its effectiveness with relation to weight and volume. One such suppressant would be "Light Water." The advisability of coupling a "Light Water" fire suppressant system to a helicopter for airborne delivery has been demonstrated by the Naval Research Laboratory and is currently in limited use at Naval Air Facilities. "Light Water" has approximately a 3:1 superiority over protein type foams for fire control. Combined with the fast reaction capabilities of helicopter rescue vehicles, the airborne "Light Water" system appears to offer the fastest response features for combating aircraft crash fires. The NRL report (Report No. 6573) demonstrated the ability of "Light Water" alone to be an effective fire suppressant agent. Prior work has coupled the liquid "Light Water" with a dry chemical agent, supposedly for fire knockdown and retention features. Their demonstration allows the weight of a "Light Water" system to be reduced by approximately one half.

A complete airborne system would only require:

- (a) A "Light Water" storage container (pressure vessel)
- (b) An air or nitrogen pressurization source
- (c) Nozzle and distribution system

Secondly, a trained crew of rescue personnel would be invaluable at the site to assist in locating and opening exits, assisting in the descent of passengers, clearing people from the immediate vicinity, announcing pertinent exit information, opening areas in the fuselage, etc. It is suggested that four to six men might be optimum for this type of rescue. They should be well-trained in emergency first aid, firefighting, aircraft rescue techniques, and in various aircraft configurations.

The third element would include the various items of rescue equipment. The helicopter should be equipped with communications equipment to the tower, the aircraft crew, and by loudspeaker to the evacuees. It should carry floodlights to illuminate the aircraft and immediate area, and could transmit TV status to the aircraft and tower. Included with the ground crew should be a bull horn, emergency lighting, fire bottles, power axes, blankets, a first aid kit, ground-to-air communication, and an auxiliary egress device. It is suggested that the latter be a telescoping ladder/slide device, such that it can be quickly adjusted to the appropriate height (within limits) used to climb up to open exits, then converted (if necessary) to a slide for passenger egress.

The helicopter and crew would be on standby and would respond to the first alarm, under tower direction. While response time may not be better

than ground crews on accidents in the airport boundaries, it could considerably improve response to premature touchdowns or aborted takeoffs. The system should, of course, be airborne whenever there is advance warning of an emergency condition. Upon reaching the aircraft, unless firefighting should prove to be the most urgent need, the helicopter would touch down, with the rescue personnel exiting with equipment in the manner of assault troops, and the helicopter would again rise to control the fire as previously described.

#### CONCEPT EVALUATION

##### OVERALL SUMMARY RATINGS

Cost-effectiveness: Low

Cost is probably twice as much as a conventional fire truck, with some overall improvement in effectiveness.

##### ENGINEERING FEASIBILITY

Within current state-of-the-art. The initial design activity would be in selecting the desired helicopter based on optimum weight and volume of systems, equipment, and crew size.

##### PSYCHOLOGICAL EVALUATION

With regard to the exterior of the aircraft, the helicopter should improve vision by fire suppression and by exterior lighting. In addition, use of the external voice communication may provide some motivation of passengers.

##### PHYSIOLOGICAL EVALUATION

Some reduction of heat inside the cabin may result from the fire suppressant, while a greater exterior improvement in heat and toxicity control would be possible.

##### KINESIOLOGICAL EVALUATION

May reduce requirements of strength and coordination, on the part of the aircraft occupants because of outside assistance.

#### COMPATIBILITY WITH OTHER REQUIREMENTS

The system is independent of and compatible with all other concepts. Since it is a ground-based, it should basically be considered to back up any onboard capabilities for passenger safety.

#### EFFECTIVENESS OF SOLUTIONS IN SPECIFIC PROBLEM AREAS

Under ideal conditions, the helicopter could improve any or all problems related to man. It could improve the machine problems related to blocked or jammed exits and reduce or eliminate the problems of darkness and fire. The principal disadvantages of the helicopter are that it may not improve the response time of a ground vehicle despite its higher cost and, in any case, may not be effective in the critical first 60 to 90 seconds. The helicopter would have a definite advantage over ground vehicles in accidents beyond the airport boundaries of course, and if the helicopter were airborne as a result of advance emergency warning, could probably reach a crashed aircraft in well under 90 seconds.

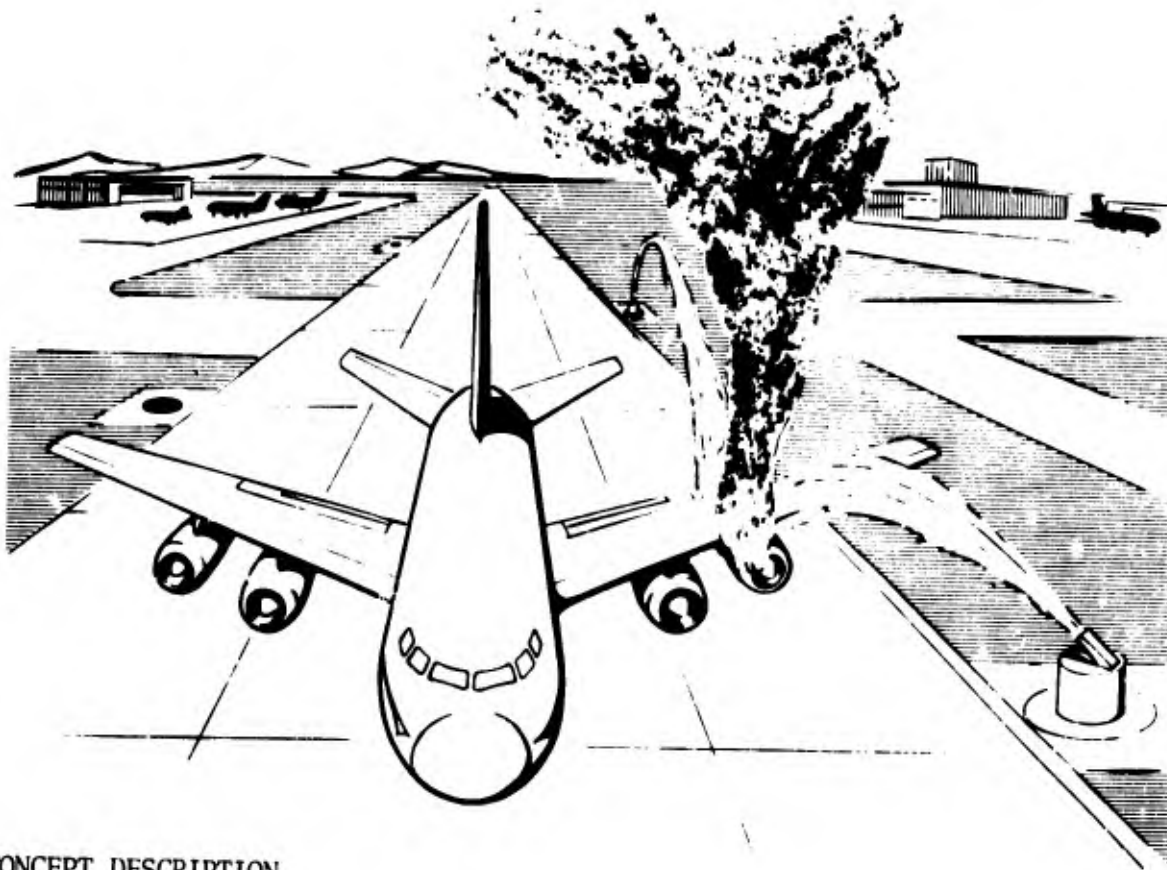
#### EFFECTIVENESS OF SOLUTION IN TYPICAL ACCIDENT CASES

##### Case 1 - Denver, DC-8

While there are many unknowns, it is estimated that the use of a helicopter in the United Air Lines DC-8 accident at Denver could have contributed to the savings of lives by providing a reduction in smoke and fire, and by improving passenger flow both by physical assistance at the exits and by verbal direction to passengers to use forward and auxiliary exits.

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## AIRPORT REMOTE CONTROL FIRE EXTINGUISHER SYSTEM



### CONCEPT DESCRIPTION

#### GENERAL DESCRIPTION OF CONCEPT

This concept consists of a fixed airport water spray system capable of actuation from the airport Air Traffic Control (ATC) tower in instances of postcrash aircraft fire. This concept description will explore two different configurations for such a system, the details of which will be elaborated in a later paragraph.

#### AREAS OF IMPROVEMENT IN EMERGENCY EVALUATION OF AIRCRAFT

This general system might serve to retard the progress of, or arrest, any postcrash aircraft fire - the initiation of which is usually external. Achievement of the former condition would greatly aid the subsequent efforts of the normal ground fire and rescue personnel, reduce the possibility of fire transfer to the cabin interior, and slow the temperature buildup on the fuselage exterior - all of which, while representing minimum results for system justification, would improve survivability factors. It is probable that

immediate external water application - possible with this system - provides the best first means for the elimination or retardation of hot gas generation within the cabin interior.

#### ESTIMATED QUANTITATIVE IMPROVEMENT IN SURVIVABILITY

Reduction of fire hazard certainly constitutes an improvement in survivability. Extension of escape time 60 to 200 seconds is possible, depending on conditions.

#### HOW NEW IS THIS CONCEPT?

No references previous to North American Rockwell Corporation proposal have been found.

#### HOW ORIGINAL IS THIS CONCEPT?

Fixed fire extinguishing systems in architecture are common.

#### DETAIL DESCRIPTION OF SYSTEMS AND COMPONENTS

The first fixed airport water spray system, shown in the sketch, consists of multiple, individual, water delivery stations each of which would be connected to a high-pressure water source by means of a remote controlled valve mechanism. All water delivery stations would be buried installations - to preclude addition of field obstacles - and would be positioned to provide effective coverage of all active runways and adjacent areas. Each water delivery station would be capable of remote activation on command of ATC tower personnel. The total airport system would accommodate the selective activation of one or more stations, simultaneously. After command, station activation would sequentially consist of (1) station hydraulic porting to the high-pressure water supply, (2) hydraulic powered erection of the "pop-up" water cannon - either direct or turbinized - and (3) water cannon porting at end of travel to commence nozzle delivery. The water cannon, in the use mode, would also provide capability for infinite directional positioning in both horizontal and vertical axes - also with remote control from the ATC tower command.

The second fixed airport water spray system consists of two parallel high-pressure water distribution lines - one located on each side of all active runways. Water delivery spray outlets would be oriented and spaced

along the distribution lines to deliver a continuous tunnel cascade of water along the entire runway length from threshold to overshoot ramp. Entire runway length coverage could be achieved with one continuous system or fragmented into a series of shorter, end-on-end subsystems. Remote system activation would be accomplished by the ATC tower personnel - the source of first knowledge for all field emergencies.

## CONCEPT EVALUATION

### OVERALL SUMMARY RATINGS

Cost-effectiveness: Low

An effective, high-capacity system would be an expensive capital investment, perhaps requiring bonds for funding in public works like the airport and surrounding territory. It would not be used very often so cost per accident is very high and its value is often indirect and uncertain as to magnitude.

### ENGINEERING FEASIBILITY

Within current state-of-the-art. Engineering and construction costs would be extensive. Maintenance costs should be relatively low compared to vehicular costs. Reliability should be fairly good if periodically checked out. Involves no weight addition to aircraft. Best advantage is quick, on-the-spot reaction to accidents in airport vicinity, but very limited in area covered, inflexible.

### PSYCHOLOGICAL EVALUATION

Human engineering: Requires special remote viewing displays to provide effective control of nozzle. Eliminates the factor of fear of fire danger in fire truck operation. Integral spotlights could aid exterior vision at night.

### PHYSIOLOGICAL EVALUATION

May help reduce heat and smoke production of fire at accident, thus reduce toxic products effects on passengers.

#### KINESIOLOGICAL EVALUATION

Requires good skill and coordination in aiming nozzle by remote control, but no problem of estimating speeds of closure or directions of travel is inherent in the system. No effect on passengers.

#### COMPATIBILITY WITH OTHER REQUIREMENTS

Basically compatible or noninterfering with all other concepts. Possible exception might be blinding of TV cameras on the aircraft in concept 49-C.

#### EFFECTIVENESS OF SOLUTIONS IN SPECIFIC PROBLEM AREAS

Provides quick reaction capability, 8 to 10 seconds, versus 2 to 10 minutes for conventional fire truck.

#### EFFECTIVENESS OF SOLUTION IN TYPICAL ACCIDENT CASES

##### Case 1 - Denver, DC-8

A rapid application of extinguishant to the flames in this accident could possibly have reduced the buildup of heavy, toxic smoke that apparently was the direct cause of death in many of the passengers.

##### Case 2 - Salt Lake City, B-727

This system would have been less effective than in the first case, due to the interior location of the fire.

### AIRPORT REMOTE CONTROL FIRE EXTINGUISHER VEHICLE



#### CONCEPT DESCRIPTION (ALTERNATE)

##### GENERAL DESCRIPTION OF CONCEPT

This concept consists of a compact, fire extinguisher vehicle which would be completely self-contained, capable of remote controlled deployment from the airport ATC tower personnel, and permit high-speed performance.

##### AREAS OF IMPROVEMENT IN EMERGENCY EVACUATION OF AIRCRAFT

Such a vehicle, one or more of which would be permanently stationed in proximity to the runways at all major airports, would serve the same functions as the fixed airport fire extinguisher installations described in concept 5-G; however, the mobility and flexibility of a vehicle may provide less costly and more efficient application. Whatever degradation that the vehicle suffers due to loss of time in transit might well be overcome by its specificity and accuracy of response. A notable disadvantage of a vehicular system would derive from its limited duration of operation; therefore, vehicle design sizing

should be based on estimations of effective, unsupported operational endurance for large aircraft similar to the Boeing 747.

#### ESTIMATED QUANTITATIVE IMPROVEMENT IN SURVIVABILITY

System potential for arresting or retarding aircraft fires before conventional equipment can be put in use is promising, 60 to 200 seconds extension of escape time, depending on conditions.

#### HOW NEW IS THIS CONCEPT?

No previous publication or patents.

#### HOW ORIGINAL IS THIS CONCEPT?

Prior utilization of this concept is unknown. (Note: System seems to be the reverse of an armored tank, flame thrower - but then, so are the functions.)

#### DETAILED DESCRIPTION OF SYSTEMS AND COMPONENTS

Description under first paragraph is sufficient.

#### CONCEPT EVALUATION

##### OVERALL SUMMARY RATINGS

Cost-effectiveness: Low (unfavorable)

Although well within the state-of-the-art, a large design and development program and small quantity production would entail a high cost per item, and capacity to rescue persons is quite limited.

##### ENGINEERING/OPERATIONAL FEASIBILITY

Within current state-of-the-art: Requires extensive design and development to apply automation techniques to this specialized vehicle. Checkout and maintenance would be expensive, requiring specialized skills. Reliability is

questionable, due to many complex systems. Several vehicles would be required so that one would be able to reach the scene of the accident quickly on a large airport.

Fail-safe if it has reliable destruct system. Adds no weight to aircraft. Requires no single-purpose crew, but requires a trained tower operator.

#### PSYCHOLOGICAL EVALUATION

Human engineering: Requires special remote viewing displays to provide effective control. Eliminates the factor of fear of fire danger in vehicle operator. Could aid vision by bringing powerful light to bear on scene at night.

#### PHYSIOLOGICAL EVALUATION

Eliminates any toxic hazards or heat hazards to vehicle operator. Helps control heat buildup in aircraft; helps open a path for escape.

#### KINESIOLOGICAL EVALUATION

Requires very good skill and coordination in remote control operator. No appreciable effect on passengers.

#### COMPATIBILITY WITH OTHER REQUIREMENTS

Could aid and work with ground rescue vehicle (concept 51-G), helicopter fire suppression and rescue vehicle (concept 4-G). Basically compatible with all others.

#### EFFECTIVENESS OF SOLUTIONS IN SPECIFIC PROBLEM AREAS

Provides means to reduce rate of heat buildup in cabin and spread of fire; helps reduce usable exit frequency; provides some protection for passengers exterior to fuselage by cooling area of egress.

## EFFECTIVENESS OF SOLUTION IN TYPICAL ACCIDENT CASES

Case 1 - Denver, DC-8

Presumably could have reduced number of deaths by controlling smoke level and spread of fire to some extent, assuming it arrived at the scene earlier than the actual fire trucks.

Case 2 - Salt Lake City, B-727

Some aid in reducing the rate of fire heat buildup, but probably not especially effective in case of interior fire source like this case.

PERSONAL SMOKE/FIRE PROTECTION  
HOOD/MASK



CONCEPT DESCRIPTION

GENERAL DESCRIPTION OF CONCEPT

This concept is a hood to provide protection from smoke and flames for exposed face and hair; it provides omnidirectional visibility, a self-contained air supply, flame protection, and extension of passenger escape time.

AREAS OF IMPROVEMENT IN EMERGENCY EVACUATION OF AIRCRAFT

Extension of escape time in the presence of toxic smoke.  
Flame protection for otherwise exposed face and hair.

## ESTIMATED QUANTITATIVE IMPROVEMENT IN SURVIVABILITY

Extension of safe time in smoke-filled cabin:	Up to 5 minutes
Passenger flow rate:	10 percent

## HOW NEW IS THIS CONCEPT?

Previous publications:

Wright, W., "FAA Will Tighten Aircraft Safety Rules," Aviation Week and Space Technology, 4 April 1966.

McFadden, E. B., Reynolds, H. I., and Funkhouser, G. E., "A Protective Passenger Smoke Hood," FAA Office of Aviation Medicine Report AM 67-4, April 1967.

Machine Design (picture report), May 1967.

Aviation Week and Space Technology, 19 June 1967.

Bioastronautics, "Fire/Smoke Protection Devices Studied," Report, 15 June 1967.

## HOW ORIGINAL IS THIS CONCEPT?

FAA-developed - fabricated by G. T. Schjeldahl Company, Northfield, Minnesota.

## DETAIL DESCRIPTION OF SYSTEMS AND COMPONENTS

The smoke/flame hood would include the following components: (1) transparent hood; (2) neck closure system, and (3) compressed air supply.

The hood portion of the system should be designed for omnidirectional donning to maintain simplicity and thus reduce the time required in preparation for evacuation. Since smoke will inhibit visibility, additional restriction to vision due to the hood should be avoided. The requirement for omnidirectional donning will also require omnidirectional vision.

In addition to providing a self-contained air supply, the hood should provide protection for the passenger from flame and heat. The clothing will provide some degree of heat protection, but this ends at the neck and the utilization of coats, blankets, or other items to provide head protection will only inhibit vision and thus reduce the evacuation flow.

Kapton, a high-temperature polyimide film has been used successfully by the FAA in the development of a protective hood which is manufactured by G. T. Schjeldahl Company. This material does not have a melting point, and only begins to char at temperatures exceeding 1,472<sup>o</sup> F. Coating the polyimide with a transparent layer of silver gives the hood an infrared reflectance of up to 90 percent. This material has proved to be resistant to fold damage and is stiff enough to resist deflection which could restrict the breathing. This material is, however, flexible enough to be responsive to changes in volume imposed by inspiration and expiration.

The hood is essentially a plastic bag, and closure is accomplished by a drawstring at the neck. This closure is not complete and provides a vent for the purging process. During the tests of the FAA-developed hood, the seal around the neck began to develop significant leakage in 4 to 6 minutes in response to the elevated tidal and minute volumes of hyperventilation. Maximal induced work reduced this time to 2-1/2 to 3 minutes.

It is desirable to provide the protection of the hood for a period of 2-1/2 to 8 minutes; therefore, a compressed air source must be provided. The initial flow rate from this source should be high in order to purge the hood of fumes or smoke. Thereafter, the flow rate should be reduced to only that required to replace the oxygen content used by the wearer and to compensate for leakage. This air supply should be attached to the hood so that it will be available to the donor for actuation and yet will not be in danger of entanglement with portions of the aircraft or with other passengers during the evacuation.

Packaging is an essential element of this concept. The size of the package should be as small as possible, and the enclosing component should be resistant to wear and yet easily opened under conditions of high stress.

Delivery of the package to the passenger is another factor in the concept which requires careful consideration. Since it would be impractical to distribute the hood to the passengers after an emergency, it must be available at the seat. Since the hood is a desirable safety device for other locations, close monitoring of its distribution and retrieval will be required. A compartmentation of the device at the seat with release only in an emergency may defeat its usefulness, since a centrally controlled release system is subject to failure in an emergency. Distribution upon entry and retrieval at exit may be feasible, but the availability of the package at the time of an emergency is dependent upon the passenger. A possible solution would be the placement of the package in the seatback pouch and absorption of the cost of missing hoods through a small increase in the fare.

### CONCEPT EVALUATION

#### OVERALL SUMMARY RATINGS

Cost-effectiveness: High

#### ENGINEERING FEASIBILITY

(Refer to AM 67-4.) Requires moderate improvement in state-of-the-art.

#### PSYCHOLOGICAL EVALUATION

The hood should increase the passenger's visual capabilities in the presence of smoke or toxic fumes since the eyes will not be irritated, and heavy clothing or blankets will not be used to protect the passenger's head from flame.

Acoustics would be impaired by the hood and may be a decisive factor in the maintenance of order and evacuation flow. A small short-range radio receiver could be incorporated to improve receipt of instructions from the crew. On the other hand, the hood could be considered as a muzzle for suppression of passenger noise and unwanted instruction.

Odors will be suppressed by the hood/compressed air system; thus, improvement in the evacuation flow should be expected.

Tactually, the hood will provide protection from convective and radiant heat.

From a behavioral standpoint, the passengers will be provided with a "crutch" in the donning of the hood which should have a calming effect and make them more receptive to following directions of the crew.

From a motivational psychology standpoint, the hood would also motivate certain passengers to follow directions and thus speed the evacuation flow of those who would otherwise be incapacitated with fear. A degree of regimentation could also develop due to the uniformity of protection and appearance.

#### PHYSIOLOGICAL EVALUATION

Toxicity:	A properly designed hood with an adequate air supply should virtually eliminate the danger from toxic fumes.
Heat and cold tolerance:	The infrared reflectance of the hood should increase the tolerance to heat from a fire. The exposed flesh areas other than the head will still be subject to heat and flame. Female passengers will be particularly susceptible with short skirts and sleeves. Male passengers will fare much better since only the hands and ankles will be exposed. Clothing provides some degree of protection to high radiant temperatures for a few minutes depending upon the characteristics of the weave and orientation of the fibers.

#### KINESIOLOGICAL EVALUATION

Strength:	Not applicable
Speed/Accuracy:	Improved evacuation flow
Coordination:	The evacuation should be more coordinated since each passenger will have equal protection for the head, and a certain feeling of harmony will be instilled.

#### COMPATIBILITY WITH OTHER REQUIREMENTS

Development of the smoke/fire protection hood/mask should be coordinated with the requirements for lighting, markings, and audio instructions and warning devices.

#### EFFECTIVENESS OF SOLUTIONS IN SPECIFIC PROBLEM AREAS

Effective protection against fire, smoke, fumes, and other environments for short duration.

#### EFFECTIVENESS OF SOLUTION IN TYPICAL ACCIDENT CASES

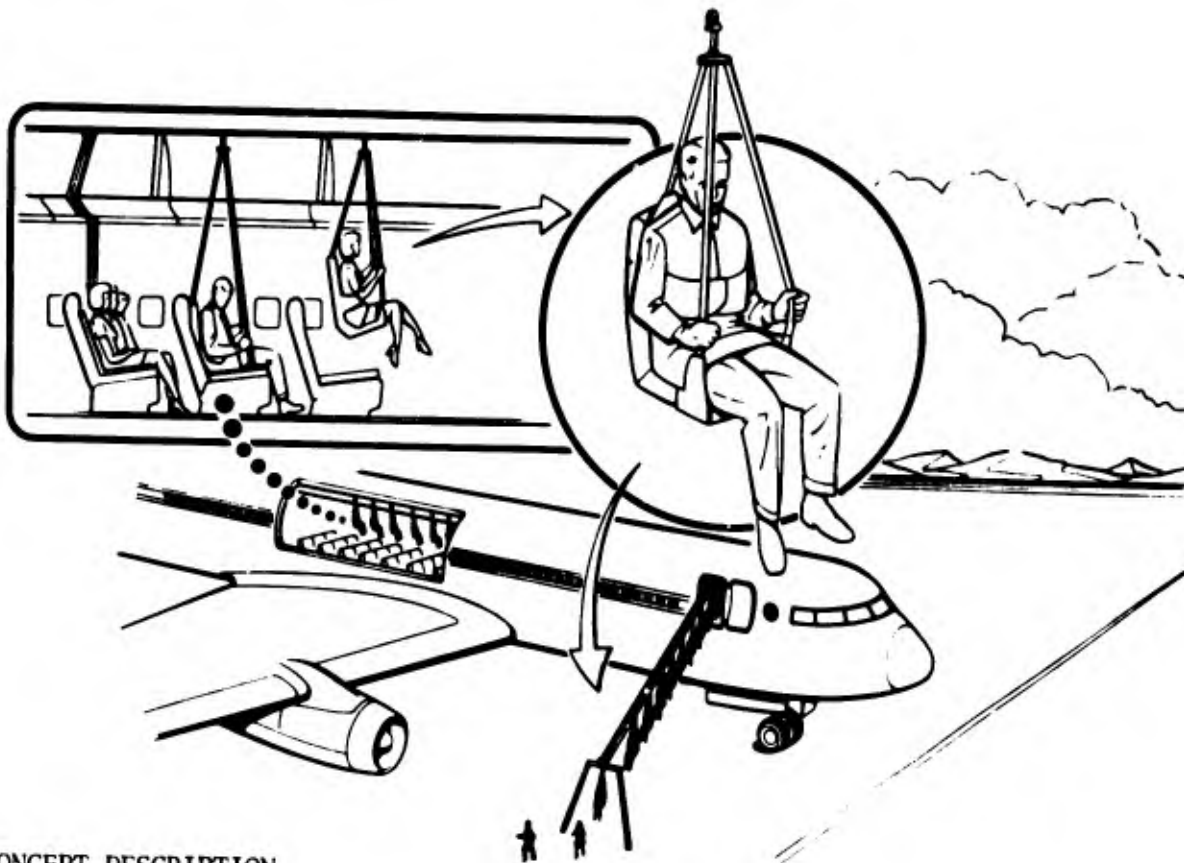
##### Case 1 - Denver, DC-8

The use of the hood would probably have provided the protection from toxic fumes required to allow the 16 fatalities who succumbed to carbon monoxide poisoning to reach the right-hand rear exit. The protection and visibility afforded by the hood could also have induced these passengers to seek another way out, namely through the first class section.

##### Case 2 - Salt Lake City, B-727

In the Salt Lake City accident, fire broke out almost instantly after impact. Evacuation, however, could not be initiated until the aircraft came to rest, following a skid of some 2,900 feet which consumed some 40 seconds to 1 minute of the required evacuation time. Thus, the 2-minute evacuation time was cut nearly in half. It is interesting to note that 43, or one-half of the 85 passengers aboard, failed to evacuate the aircraft and became fatalities. If passengers in this type of accident could have been protected from the immobilizing and incapacitating effects of inhalation of smoke, toxic gases, and flame, for only 1 to 2 additional minutes of evacuation time prior to the development of intolerable temperatures, it is probable that a very significant increase in survival could have been attained.

### AUTOMATIC PASSENGER BOSUN'S CHAIR CONVEYOR SYSTEM



#### CONCEPT DESCRIPTION

##### GENERAL DESCRIPTION OF CONCEPT

This system would pick up passengers in an emergency situation and convey them to the nearest exit. The system would include the seat pallets, the attaching fixtures to the overhead rails, and the overhead rails, and could include manually or computer-operated exit selection and passenger distribution.

##### AREAS OF IMPROVEMENT IN EMERGENCY EVACUATION OF AIRCRAFT

The system would optimize personnel evacuation in regard to time and in regard to incapacitated or "marginal" passengers. It would tend to eliminate the need for other exit devices, special warning audios, visuals, etc, and could be combined with water escape requirements, door/hatch designs, and personal or cabin smoke control systems or devices. The system is also capable of utilization for normal passenger loading/unloading.

## ESTIMATED QUANTITATIVE IMPROVEMENT IN SURVIVABILITY

Exit hesitation, 0 seconds (after door open): 100 percent improvement  
Wrong exits tried, 0 (with proper flow control): 100 percent improvement  
Passenger flow rate: 50 percent improvement

## HOW NEW IS THIS CONCEPT?

No similar concepts for passenger purposes on crashed aircraft were found. There are some similar elements in three out-of-date patents relating to passenger evacuation:

- (a) Patent No. 1,435,808, "Parachute Drop," Cornelius, 14 Jan 1922
- (b) Patent No. 1,859,542, "Life Preserving Mechanism for Airships," Truilz, 24 May 1932
- (c) Patent No. 2,426,862, "Cargo Discharging Device," Cunningham, 2 Sep 1947

## DETAIL DESCRIPTION OF SYSTEMS AND COMPONENTS

The system consists of a combined seat-cushion pallet, sling, or pallet support, and overhead attach point-traverse, plus associated operating, actuating, and control equipment. The pallet is designed to fit into a "stripped" passenger seat with minimum attachment necessary. The normal seatbelt would remain a part of the basic seating for security purposes; however, a low g strap would be included on the pallet primarily as required for children, elderly, or incapacitated passengers. The sling attachment would also permit hand gripping while passengers were in transit. The sling would be placed in a stowed position after takeoff by the stewardesses while remaining attached, and would be deployed again prior to landing, although the system would operate properly starting with the deployed position. The overhead track would include flexible switching-routing provisions as well as providing lifting, support, and motivating forces.

The system will be made inoperative under conditions of adverse fuselage attitude; however, design consideration will be given to using the system to "drag" passengers out in an inverted configuration. Emergency release from the pallet will be provided, as well as interlocks to the escape exits. In emergency use, the individual pallets will be routed to the most appropriate exit (based on fire, jamming, obstacle, water, and other conditions), then moved outside the aircraft for a distance of at least five and up to 15 feet

on the overhead track. At the termination of the track, simple mechanical trip and braking devices will let the seat descend to the ground safely while collecting the seat pallets like a paratrooper's static line.

A prime advantage in this system is that it would allow normal loading and unloading of passengers and thus improve turnaround time, especially at flight origination and termination points, but also when the system includes computer or manual seat-exit route selection. This scheme would permit use of a seating mockup in the waiting room of the terminal with passengers placed in the appropriate seats and loaded just prior to takeoff.

Principal disadvantages of the system lie in its increasing degradation with fuselage rotation off vertical, and its high cost of modification to existing aircraft. Weight increase is not considered to be an eliminating factor; that is, the combined pallet cushion (which replaces existing weight) and metal backing with a nylon sling would add less than 5 pounds per seat. The overhead track is a significant item but not considered excessive. Weight gained will be at least partially offset by elimination of conventional slides and other equipment.

#### CONCEPT EVALUATION

##### OVERALL SUMMARY RATINGS

New aircraft:           Moderate cost-effectiveness  
Existing aircraft:   Low cost-effectiveness (considering all situations)

##### ENGINEERING FEASIBILITY

Requires moderate improvement in state-of-the-art for optimized automatic routing and flow control. While individual capabilities exist, including computer programming, system integration of electromechanical elements would reflect advancement in design.

The solution to the problem of a broken or bent fuselage is difficult. A system of segmented overhead rails, with individual powered belts on each rail segment, could provide conveyance up to the point of a break. At this point, provisions for passenger release are required; then, passengers might best evacuate through a hole in the fuselage which could be expected if the fuselage is so distorted. Some accommodation of a fuselage distortion might be made with flexible structural joints.

Power requirements for such a system would be very high to effect rapid egress, especially with any appreciable upward incline. Present-day battery sources may be too heavy and large to store such power.

#### PSYCHOLOGICAL EVALUATION

Human engineering (vision, acoustics, odor, tactual): System is independent of passenger sensory condition.

Behavioral psychology: The system should improve passenger reactions by providing feeling of security in knowledge that they "are being taken care of."

#### PHYSIOLOGICAL EVALUATION:

The system has advantages in regard to toxicity, smoke, injury, etc, in that it will remove the passenger from the airplane despite his unconsciousness. However, a disadvantage is that the passenger is not at floor level and is consequently exposed to greater heat and fumes. Additional protection is required in accordance with concepts 6-A and 31-A.

#### KINESIOLOGICAL EVALUATION

Assuming design feasibility of automatic seatbelt release at the start of the procedure, and assuming doors open, the passenger is relieved of any kinesiological requirement except releasing a lap strap and a simple stepping or slipping out of the seat at ground level. This is far less demanding than the slide egress and can probably be expected to be ground-assisted.

#### COMPATIBILITY WITH OTHER REQUIREMENTS

The system is not compatible with the crawling procedure or aisleway equipments and would tend to eliminate all inflatable/mechanical slides or stairs, except as alternate modes. Also, lighting systems would be eliminated at least as essential items.

## EFFECTIVENESS OF SOLUTIONS IN SPECIFIC PROBLEM AREAS

This system primarily will serve to overcome all passenger incapacity problems, i.e., age, infirmity, injury, unconsciousness, etc. It should also solve the problems of visibility, wrong exit selection, and passenger crowding.

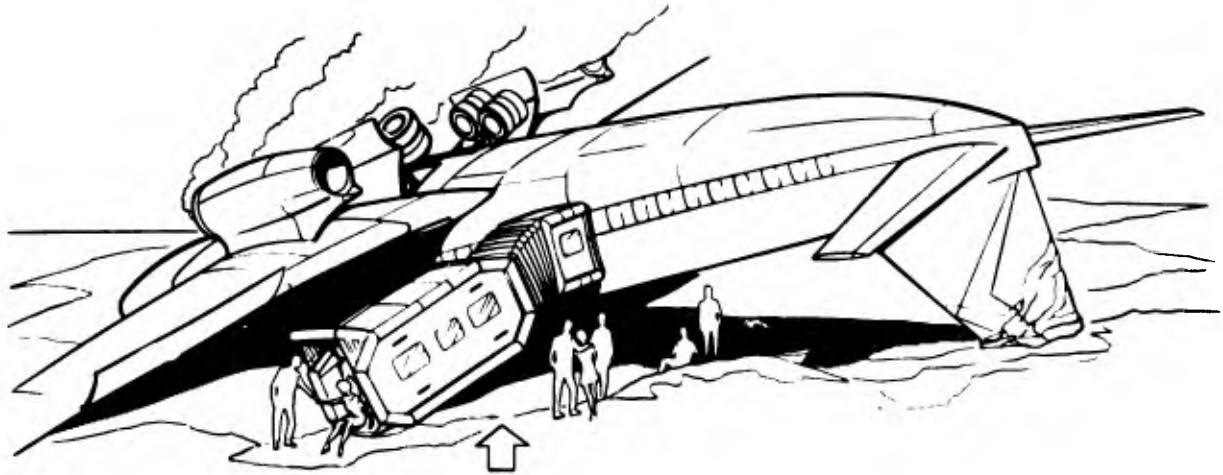
## EFFECTIVENESS OF SOLUTION IN TYPICAL ACCIDENT CASES

Case 1 - Denver, DC-8

Could have operated effectively to remove all passengers since aircraft fuselage remained intact. With use of breathing protection, all passengers might have been evacuated alive.

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## FULLY ENCLOSED INFLATABLE SLIDE AND WALKWAY

CONCEPT DESCRIPTION

## GENERAL DESCRIPTION OF CONCEPT

This concept is an inflatable device which, by its tubular shape and flexible joint section, is basically adaptable to allowing slide egress in a high or low, upright, tilted, or inverted position.

## AREAS OF IMPROVEMENT IN EMERGENCY EVACUATION OF AIRCRAFT

Improves safety of egress, preventing falls off slide or walkway and improves exit flow by reducing hesitancy of jumping due to fear of falling and aids the avoidance of smoke, radiant heat, or weather conditions.

## ESTIMATED QUANTITATIVE IMPROVEMENT IN SURVIVABILITY

Passenger flow rate: 10 percent

Safety: 2 percent

## HOW NEW IS THIS CONCEPT?

## Previous publications:

Radnofsky, M.I., "Space Suits," International Science and Technology, February 1967

Richardson, D.L., and Little, A.D., "Research to Advance Extravehicular Protective Technology," Aerospace Medical Research Laboratories, Aerospace Medical Division, Air Force Systems Command, Wright-Patterson AFB, Ohio, April 1967

## Patents related:

2,765,131, "Inflatable Escape Chute Assembly," Boyle, 2 Aug 1956

2,936,056, "Variable Length Inflatable Escape Chute," Heyniger, 10 May 1960

3,018,867, "Inflatable Escape Chute," Heyniger, 10 July 1960

3,102,623, "Escape Slide," Schacht et al, 31 Mar 1960

887,449 (British), "Escape Chute," Elliott Equipment Ltd, 17 Jan 1962

1,163,036 (French), "Escape Chute," 22 Sep 1958

## HOW ORIGINAL IS THIS CONCEPT?

Interior tubular chute idea for cargo, personnel in buildings, and in-flight escape has been used before.

This concept is an improvement over existing inflatable exterior slide devices for aircraft. Completely enclosed, exterior slides apparently have not been used before in such applications.

## DETAILED DESCRIPTION OF SYSTEMS AND COMPONENTS

This slide is an elongated box or tubular structure with an angled shape on the extended end to accommodate varying aircraft heights. A hinged flap panel is provided at the outer end, both at top and bottom, normally formed for angle outward. The weight of the slide folds the lower panel inward, forming a level deceleration platform at the bottom. The upper panel being flapped upward helps provide a higher opening at the top.

Windows of tough, flexible transparent plastic are formed in sides for light. Chemical light strips inside are provided to assist night egress. Emergency zipper or velcro detachments provide for a condition of incomplete inflation in which the device must be operated as a hand-held slide. A

relatively rigid section attached to the doorway is inherent in the bellows joint. It can be made long for overwing exits in order to extend to the wing edge, or it can be made short for non-overwing exits. This may help reduce the constriction at the doorway. (Refer to concept 12-B).

The device can be used even if the aircraft is upside down. It has enough vertical height to be used as a ramp walkway with ducking of head. The "floor" and ceiling panels can be made of Goodyear "Airmat" construction with capability to inflate to a 1- to 2-inch thick stiff surface by auxiliary inflation bottles in case of a very shallow angle of egress. The attached end is extended from the aircraft by a tubular, sliding cable-restrained bellows, capable of universal flexure (to about  $\pm 25$  degrees of arc) and torsion (to about  $\pm 30$  degrees of arc). The bellows articulation is similar to that of a shoulder joint in a space suit pressure garment.

A further development of this concept is covered in concept 13-B. The slide could profitably utilize "chemical light" (concept 3-C) and could use diverging strips in the interior to provide an optical illusion of a short descent distance.

#### CONCEPT EVALUATION

##### OVERALL SUMMARY RATINGS

Cost-effectiveness: High (Good)

Particularly useful for unusual aircraft rest attitude and high floor heights, inclement weather conditions.

##### ENGINEERING FEASIBILITY

Requires moderate improvement in state-of-the-art. Weight and bulk would represent a serious problem, but bulk and feasibility in stowage around the exit could be accommodated by good design.

##### PSYCHOLOGICAL EVALUATION

The device may improve vision around exit by reducing smoke influx.

There are also indications of an improvement in feeling of security, comfort, and stability by use of a fully enclosed slide, thus reducing psychological hesitation.

#### PHYSIOLOGICAL EVALUATION

The enclosed slide may reduce heat and smoke toxicity around the exit due to external fire sources.

#### KINESIOLOGICAL EVALUATION

Less coordination is required to enter and descent safely on an enclosed slide; provides dry floor, hand stabilization for overwing walkway section.

#### COMPATIBILITY WITH OTHER REQUIREMENTS

This type of slide would eliminate some other side exit slide devices.

#### EFFECTIVENESS OF SOLUTIONS IN SPECIFIC PROBLEM AREAS

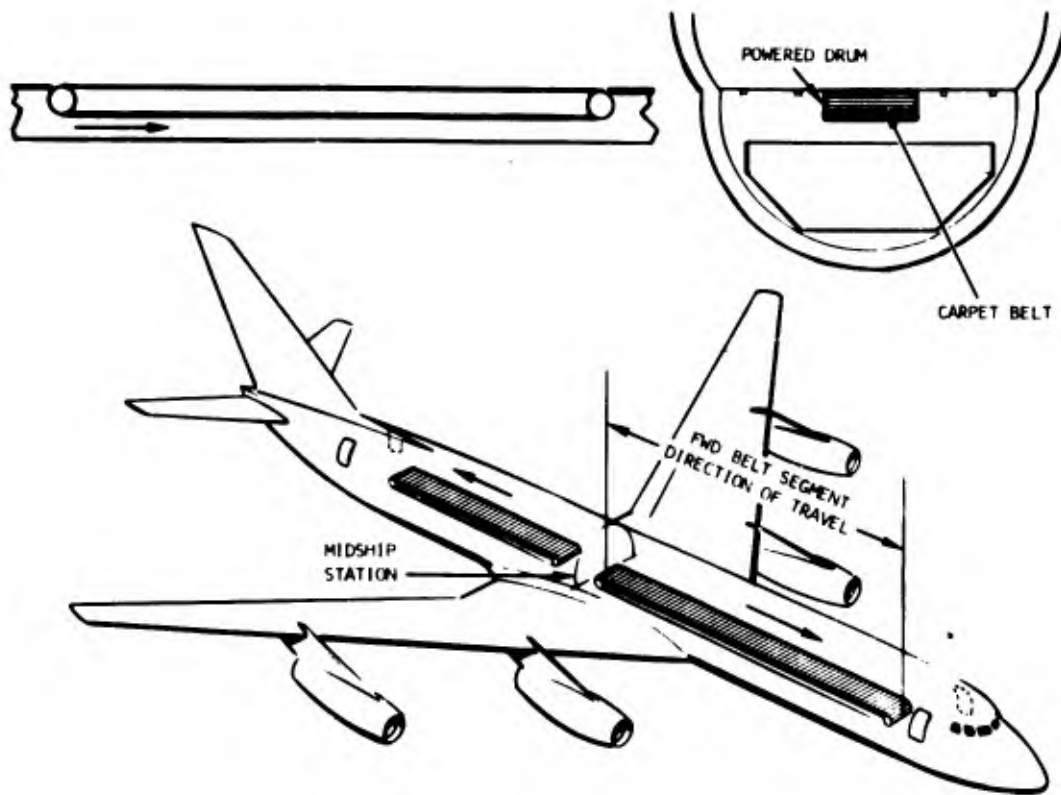
Improves egress rates of slow, infirm, and hesitant passengers especially at increased floor heights. Resolves problem of egress from inverted aircraft or fuselage in severe pitch up or down attitude. Increases safety of overwing egress, especially in wet weather.

#### EFFECTIVENESS OF SOLUTION IN TYPICAL ACCIDENT CASES:

##### Case 1 - Denver, DC-8

One major cause of fatalities in the Denver accident was inadequate egress speed. It is estimated that a 0.1-second improvement, times the 53 passengers who did exit would allow an additional 5.3 seconds exit time or approximately 3 to 4 more passengers to escape. The most advantageous feature of this concept (adaptability to various fuselage attitudes) was not required in this case.

## MOVING WALKWAY PASSENGER CONVEYOR SYSTEM

CONCEPT DESCRIPTION

## GENERAL DESCRIPTION OF CONCEPT

The conveyor aisleway concept consists of forward conveyor belt aisle segments which function to transport passengers to the type I exits. The system can also be extended to (1) assist passengers onto a slide and (2) assist them off of a slide to the ground.

## AREAS OF IMPROVEMENT IN EMERGENCY EVACUATION OF AIRCRAFT

The principal improvement of the device is in passenger evacuation time in that a steady flow of passengers would be delivered to the exits. Some improvement could also be expected from reduced preparation time.

## ESTIMATED QUANTITATIVE IMPROVEMENT IN SURVIVABILITY

Passenger flow rate: 20 percent

Reduction in wrong exits tried: 10 percent

A 5 to 10 percent improvement in prevention of death through inhalation of fumes is possible by carrying unconscious bodies out to exits where fresh air is available.

## HOW NEW IS THIS CONCEPT?

No specific data or patents have been noted; however, it is expected that various patents covering moving belt conveyors would be closely related, such as out-of-date patent 2,426,862, "Cargo Discharging Device," Cunningham, 2 Sep 1947.

## HOW ORIGINAL IS THIS CONCEPT?

Adapted from nonaircraft fields or practice; principally cargo movement devices and moving "sidewalks."

## DETAIL DESCRIPTION OF SYSTEMS AND COMPONENTS

The basic system consists of center-aisle conveyor belt segments rotated over powered drums. The conveyor segments would terminate at one or each end in the area of the type I or type II exit. The direction of travel for each segment would be variable and dependent upon the location of its best exit area. Operational system realization is unknown; however, it is anticipated that powered drums would be located between floor frame beam members with the aisleway conveyor passing over and under these members.

The function of the basic system is only to transport evacuees to an exit. The carpet belt sections would correspond to number of exits and direction of travel would vary with location of exits. System is physically capable of realization operationally, based upon today's technology and present design practice. (Floor beams at frame stations would not be affected, as carpet belt would pass over and under.)

Alternate No. 1 provides for the passengers sitting down on the conveyor belt, thus preparing them to get into the sitting position before they actually get to the exit. The belt would extend over the edge of the door

sill, thus pushing the passenger gently onto the slide. If the passenger does not sit on the belt, the system provides for standup conveyance of the passenger past the point of the exit and on to the slide area, and automatically dumps him onto the slide if he does not jump. A padded area at the end of the belt is needed to prevent injuries.

Alternate No. 2 is a separately powered conveyor belt which forms the slide surface. When the passenger slows at the end of the slide, the conveyor belt carries him to the end so that he may egress. This system aids greatly at shallow angles where the slide becomes a moving ramp or sidewalk. If the conveyor belt power fails, the system is still failsafe in that it may be walked over. A thin panel on the on the "floor" provides this capability. At shallow angles, a supporting assist rope or rail on the side would come into play.

The basic system would also provide for a tactual feel to the area where the exits are available; that is, by putting the hand on the floor and finding it moving in a certain direction, the passenger would be automatically directed to the proper area despite poor visibility.

The belt speed required to accommodate boarding at the seat row, and leave at the exit area without toppling passengers at either point, would be considerably slower than a walk (estimated at one-third normal speed). However, a 33 percent increase in passenger flow rate (added to normal walk) is very significant. The system might offer advantage if incorporated into aircraft with nose or tail exit openings and if, for present aircraft exits, erect escape posture (walking or running) were revised to prone, sitting, crawling, or kneeling position.

The conveyor belt system, or moving sidewalk, could also be used in connection with an escalator to the aircraft to help load passengers quickly and to space them.

## CONCEPT EVALUATION

### OVERALL SUMMARY RATINGS

Cost-effectiveness: Low (unfavorable)

Extensive effects on structural provisions and routing of tubing, wires, etc, as well as weight and power requirements and possibility of structural damage, work strongly against this concept.

#### ENGINEERING FEASIBILITY

Rerouting of wires and tubing in floor and ceiling will be required. Requires moderate improvement in state-of-the-art to adapt to minimum weight aircraft systems and to provide for some fuselage distortions.

A formidable problem arises with the difficulty and complexity of incorporating a programmed intelligence into the system which can determine the direction of travel for each conveyor segment based upon inputs of (1) number and location of nonusable exits, if any, and (2) location and condition of any fire.

Methods of preventing jam-up of debris, bodies, etc, in aisle and causing secondary injury will need much study. Considerable weight and significant power additions will be required. Structural damage will be a defeating factor in many crashes.

#### PSYCHOLOGICAL EVALUATION

Human engineering: Clear indication of movement would be required to assist boarding from seat rows.

Motivational psychology: Movement of floorway can be favorable selling point to help feeling of safety, "getting somewhere," unless a jam-up occurs at some point.

#### PHYSIOLOGICAL EVALUATION

Passengers who fall directly into aisle would be carried out to, hopefully, fresh air at exit area (or clear to the ground in a well-designed chute system using alternates 1 and 2). The use of conveyor belt conveyance for crawling helps feasibility of keeping head low to avoid hot air, by aiding egress speed in crawling position.

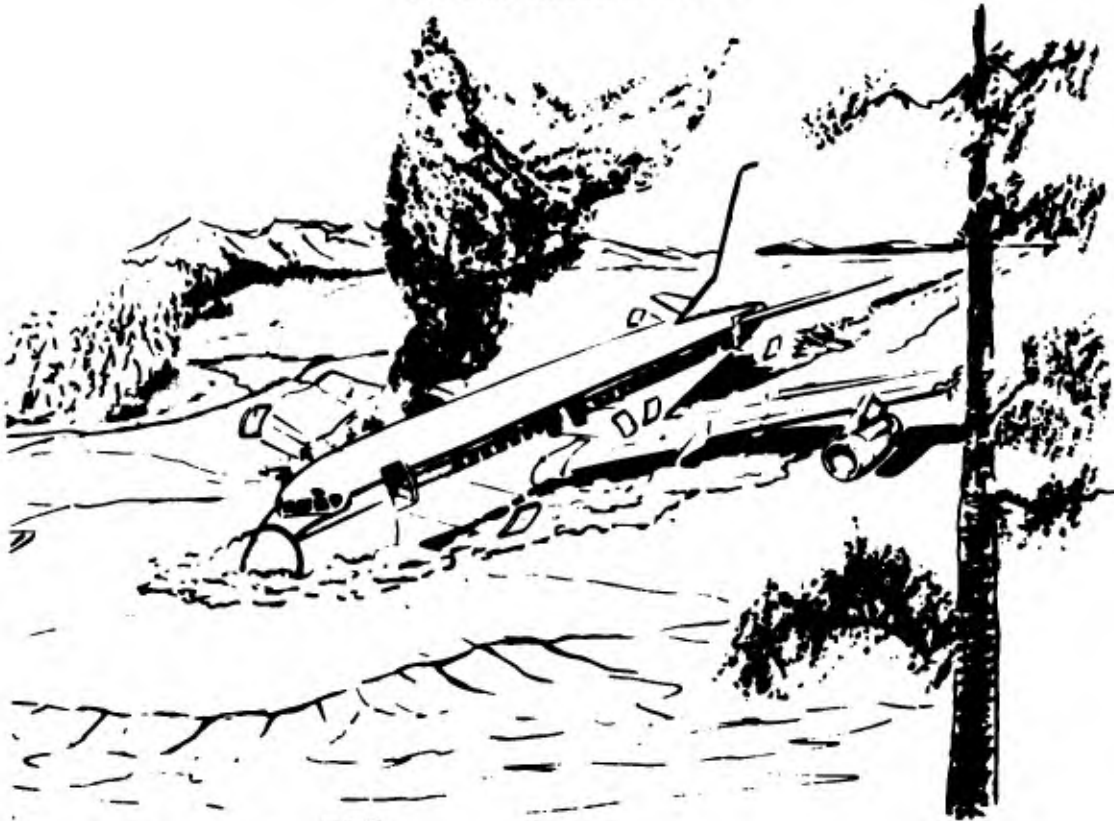
#### KINESIOLOGICAL EVALUATION

One problem is the physical difficulty of passengers negotiating a moving aisleway while boarding at the seat row and leaving at the exit area - especially at the conveyor speeds required for high survival assurance. The resolution of this problem in past pedestrian conveyor applications has always

been effected with a series of slaved, adjacent conveyors, each traveling at a speed which progressively approaches the terminal speed of the main conveyor. This solution is, of course, unavailable for aircraft application.

Also unavailable as a possible solution is the requirement that all passengers, under instruction or supervision of the crew, board the aisle conveyor prior to its actuation. The reality of present passenger density levels, which result from the conventional interior arrangement of six-abreast seating installed on 34-inch pitch, does not permit aisle occupation by more than 50 percent of the passenger load at one time.

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**EXPLOSIVE HATCH PANEL****CONCEPT DESCRIPTION****GENERAL DESCRIPTION OF CONCEPT**

Employs ordnance equipment in the form of linear shaped charges or other techniques to explosively release hatches.

**AREAS OF IMPROVEMENT IN EMERGENCY EVACUATION OF AIRCRAFT**

Permits remote operation of hatches, reduces time to operate hatches (especially damaged ones), permits positive safeguards against premature or improper opening, and contributes to reduced evacuation time.

**ESTIMATED QUANTITATIVE IMPROVEMENT IN SURVIVABILITY**

Preparation of exit:                      20 percent

## HOW NEW IS THIS CONCEPT?

## Previous publications:

Federal Aviation Agency, Minutes - FAA-Industry Conference on Crashworthiness and Passenger Standards for Transport Category Airplanes, Flight Standards Service, 29 and 30 March 1966

Machine Design, "Big Jets May Blast Away Escape Doors," 17 August 1967

Sipes, W. J., "Emergency Escape and Inflight Safety Systems," McCormick-Selph, 5th National Flight Safety, Survival and Personal Equipment Symposium, 26-28 September 1967

Bogland, J. L., "Explosive Release or Emergency Exit Hatches, Explosive Technology," Ducommun, Inc., 5th National Flight Safety, Survival and Personal Equipment Symposium, 25-26 September 1967

Brown, C. K., "Design and Application Parameters - Ordnance Actuated Aircraft Emergency Evacuation Systems," Space Ordnance Systems, Inc, El Segundo, Calif, 5th National Flight Safety, Survival and Personal Equipment Symposium, 25-26 September 1967

## Patents related:

2,797,884, "Emergency Release for Cabin Door," Peed, 2 May 1957  
 2,942,813, "Combined Speed Brake, Escape Hatch," English, 14 February 1958  
 3,201,169, "Safety Door for Vehicles," Scott, 12 July 1963  
 3,331,571, "Emergency Exit Arrangements in Aircraft," Lawrence, et al, 22 April 1964

## HOW ORIGINAL IS THIS CONCEPT?

Adapted from military aircraft developments or practice? Yes.  
 Adapted from nonaircraft fields or practice? Yes.  
 Other: Currently being reviewed by FAA and air carriers.

#### DETAILED DESCRIPTION OF SYSTEMS AND COMPONENTS

This system would consist of the explosive charges, an auto/manual control system, and associated safety circuits and devices. Provisions would be made for automatic actuation of the explosive with sensing of smoke and heat at established limits, assuming all safety switches were closed. Manual actuation would be made by any cabin crewmember after arming from the cockpit control. The charge should be designed so as to remove jammed or overstressed doors or hatches.

The safety circuit would include sensor switches to prevent actuation before landing gear closure or measured impact force, without inside/outside pressure equalization, in a submerged condition, or when airspeed is above landing or takeoff velocity.

Use of similar charges on the Gemini program and tests on military aircraft have demonstrated the effectiveness of such charges as well as the clean cutting action and safety of personnel in the immediate vicinity. Long-term usage of ordnance systems on military aircraft has proven design safety features.

#### CONCEPT EVALUATION

##### OVERALL SUMMARY RATINGS

Cost-effectiveness: Moderate

##### ENGINEERING FEASIBILITY

Within current state-of-the-art? Yes, reference Explosive Technology, subsidiary of Ducommun Inc, and others.

##### PSYCHOLOGICAL EVALUATION

Should reduce anxiety feelings relating to feelings of entrapment. However, fear of inadvertent explosion is a deterring factor.

##### KINESIOLOGICAL EVALUATION

Should eliminate requirements to force jammed doors.

10-B

10-B

COMPATIBILITY WITH OTHER REQUIREMENTS

Compatible with all other concepts; except is an alternate to concept 11-B.

## POWER-ACTUATED DOOR OPENING

CONCEPT DESCRIPTION

## GENERAL DESCRIPTION OF CONCEPT

Utilizes ordnance or pressurized gas thrusters to drive standard door opening mechanism.

## AREAS OF IMPROVEMENT IN EMERGENCY EVACUATION OF AIRCRAFT

Permits remote operation of hatches; reduces time to operate hatches (especially damaged ones); permits positive safeguards against premature or improper opening and contributes to reduced evacuation time.

## ESTIMATED QUANTITATIVE IMPROVEMENT IN SURVIVABILITY

Preparation of exit: 20 percent

## HOW NEW IS THIS CONCEPT?

Previous publications: Brown, C. K., "Design and Application Parameters - Ordnance Actuated Aircraft Emergency Evacuation Systems," Space Ordnance Systems, Inc, El Segundo, Calif 5th National Flight Safety, Survival and Personal Equipment Symposium, 25-26 September 1967

Patents related: 2,797,884, "Emergency Release for Cabin Door," Peed, 2 May 1957

2,942,813, "Combined Speed Brake, Escape Hatch," English, 14 February 1958

3,201,169, "Safety Door for Vehicles," Scott, 12 July 1963

3,331,571, "Emergency Exit Arrangements in Aircraft," Lawrence, et al, 22 April 1964

## HOW ORIGINAL IS THIS CONCEPT?

Adapted from military aircraft developments or practice? Yes.

Adapted from nonaircraft fields or practice? Yes.

## DETAILED DESCRIPTION OF SYSTEMS AND COMPONENTS

This system would consist of the explosive charges or inert gas cylinders, an auto/manual control system, and associated safety circuits and devices. Provisions would be made for automatic actuation of the explosive with sensing of smoke and heat at established limits, assuming all safety switches were closed. Manual actuation would be made by any cabin crewmember after arming from the cockpit control. The charge should be designed so as to release jammed or overstressed doors or hatches.

The safety circuit would include sensor switches to prevent actuation before landing gear closure or measured impact force, without inside/outside pressure equalization, in a submerged condition, or when airspeed is above landing or takeoff velocity.

Off-the-shelf devices now being marketed include ordnance squibs and lightweight cylinders over 3,000 psi. Similar concepts have been applied to the F-100, T-39, and XB-70 and nearly all other tactical aircraft, but not as yet to airlines.

CONCEPT EVALUATION

## OVERALL SUMMARY RATINGS

Cost-effectiveness: Moderate

The ability to improve hatch opening times and capabilities would justify relatively high initial costs.

## ENGINEERING FEASIBILITY

Within current state-of-the-art, but requires development for large aircraft application.

## PSYCHOLOGICAL EVALUATION

## Human engineering:

Design of thruster (pyro or gas) should be isolated from passengers to reduce sound pressure level extremes. Application to be used in conjunction with audio warning and alerting announcements.

## PHYSIOLOGICAL EVALUATION

Not applicable

## KINESIOLOGICAL EVALUATION

Eliminates need for stewardess to enlist aid of passengers to open a bulky door. Potentially increases speed of exit preparation.

## COMPATIBILITY WITH OTHER REQUIREMENTS

This concept appears compatible with other concepts. In all cases, it would support or improve evacuation times when applied with other concepts.

## EFFECTIVENESS OF SOLUTIONS IN SPECIFIC PROBLEM AREAS

This concept would decrease hatch opening time and thereby reduce congestion and crowding at exits. It would aid opening of jammed hatches, depending upon the amount of fuselage structural damage in the hatch vicinity.

## EFFECTIVENESS OF SOLUTION IN TYPICAL ACCIDENT CASES

Case 1 - Denver, DC-8

A power-actuated mechanism may have been able to overcome structural damage (due to pickup truck impact) and open the rear left-hand exit hatch, thus providing a larger exit than the service hatch utilized. The increased exit openings probably would have allowed total passenger evacuation prior to asphyxiation from smoke.

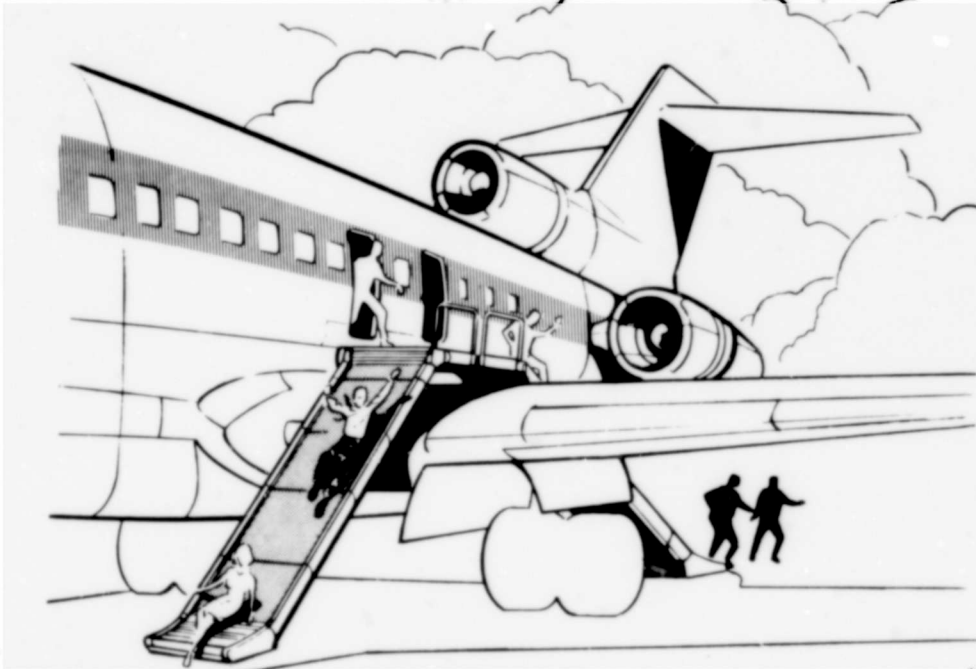
11-B

11-B

Case 2 - Salt Lake City, B-727

All hatches were opened, with exception of aft ventral entry which was jammed by ground position due to final aircraft nose-high resting attitude. Power-actuated hatch may have decreased opening time for main loading hatch which was delayed due to passenger crowding.

### SEPARATE EXTERIOR PLATFORM AND SLIDE ENTRY



#### CONCEPT DESCRIPTION

##### GENERAL DESCRIPTION OF CONCEPT

The separate exterior platform and slide entry concept consists of a horizontal platform - external to the exit opening - from which one or more descent slides may be deployed.

##### AREAS OF IMPROVEMENT IN EMERGENCY EVACUATION OF AIRCRAFT

The area of the emergency exit may be the traffic-flow bottleneck because of reasons other than those imposed by the dimensional limitations of the actual opening. It may be that the passenger cannot psychologically cope with the rapid sequence of events all occurring at the exit. For, simultaneously with passage through the opening, the passenger must immediately change his environmental reference and spatial attitude by leaving an understood solidity and jumping or falling into an unknown. This system might remove this psychological burden from the passenger - if indeed one exists - by permitting a more manageable order of events. In other words, the exit would remain

just that - an exit; subsequent entrance into the slide - perceived at better advantage and for a longer period when deployed from an external platform - might expedite total aircraft egress.

If emergency exits were wide enough to accommodate side-by-side egress, the provision of two or three slides from the external platform seems an obvious improvement.

#### ESTIMATED QUANTITATIVE IMPROVEMENT IN SURVIVABILITY

Expectancy for improvements in egress time appears promising, perhaps 10 to 20 percent increase in flow rate.

#### HOW ORIGINAL IS THIS CONCEPT?

External platforms as an escape route entry are, of course, common. The outside fire escape stairs on all older buildings make use of a "landing" at every stair access point.

Patents related: 2,942,813, "Combined Speed Brake, Escape Hatch,"  
English, 14 Feb 1958  
3,102,623, "Escape Slide," Schact et al, 31 Mar 1960

#### DETAIL DESCRIPTION OF SYSTEMS AND COMPONENTS

The external platform, here considered, would consist of a powered package stowable under the aircraft floor structure beneath each type I and II exit. Concurrent with exit opening, this package would be actuated for horizontal translation to the use position. Conventional inflatable slides would be automatically deployed from the platform package; the erection of guard rails, where needed, would also be automatic. Detailed system requirements of illumination, platform surface friction coefficients, etc, would derive from human factors considerations. See also concept 8-B.

#### CONCEPT EVALUATION

##### OVERALL SUMMARY RATINGS

Cost-effectiveness: Moderate-to-low

The high development and modification costs for retrofitting and installing in new aircraft combined with unknown actual improvements in passenger egress safety and times appear to limit the overall rating of this concept.

### ENGINEERING FEASIBILITY

The development of this concept is within the current state-of-the-art; however, design is required to modify and/or incorporate the mechanism into aircraft structures or into current slide designs.

### PSYCHOLOGICAL EVALUATION

Human engineering/motivational: The concept will continue a smooth flow of passengers through all exits before the decision to jump into a slide is required. This "guidance" will reduce passenger confusion in that directional decisions do not have to be made, only to follow directions indicated by the platform and slide configuration.

### PHYSIOLOGICAL EVALUATION

Not applicable

### KINESIOLOGICAL EVALUATION

Utilizes body momentum most effectively in getting through the floor level doorway construction. Provides additional room for preparing body for jump into slide. Also provides good flat support surface for overwing exits.

### COMPATIBILITY WITH OTHER CONCEPTS

This concept is compatible with all other concepts dealing with passenger handling and flow within the aircraft prior to hatch egress. Concepts defining hatch egress techniques are considered complementary to this concept. This includes all concepts on slides, materials, techniques, etc. The primary intent of this concept is to provide a means for continuous, smooth exit of passengers after they have exited over-the-wing hatches, main doors, or service doors.

## EFFECTIVENESS OF SOLUTIONS IN SPECIFIC PROBLEM AREAS

The separate exterior platform and slide entry concept would improve passenger survival in the following problem areas:

- (a) Passenger doesn't know how to egress from wing.
- (b) Can't see due to smoke and/or environment obscuring.
- (c) Hesitant to enter slide - platform allows stewardess assistance.
- (d) Gets passenger easily through restriction of doorway and provides more room for assistance outside doors.

## EFFECTIVENESS OF SOLUTION IN TYPICAL AIRCRAFT ACCIDENT

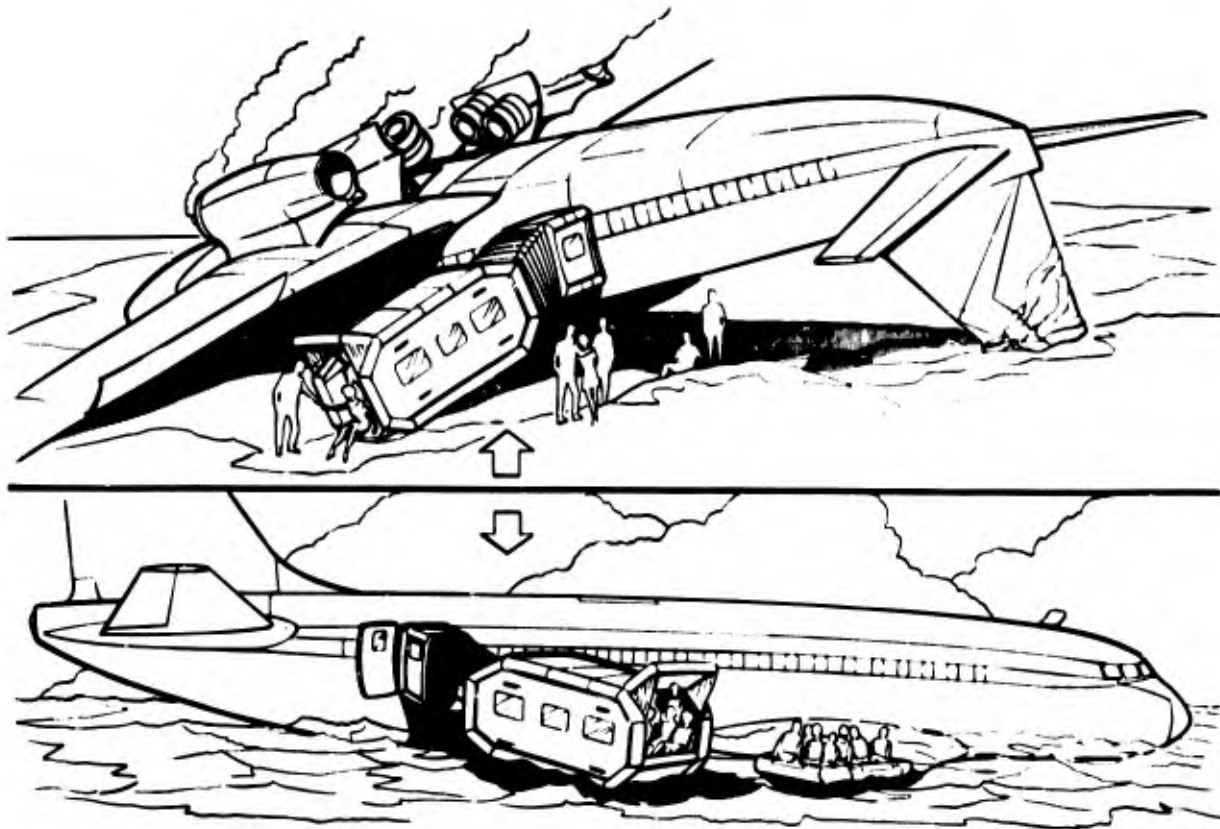
Case 1 - Denver, DC-8

Information is not available in the literature to indicate passenger injury, if any, due to over-the-wing egress. Twenty-one passengers left the aircraft via the right-hand wing exits. The service door egress might have been more effective with the exterior platform.

Case 2 - Salt Lake City, B-727

Information is not available in the literature to indicate the quantity of passengers exiting through over-the-wing exits. Application of this concept may have aided the reduction of passenger crowding at exits - a problem which was mentioned in reports.

## COMBINATION INFLATABLE SLIDE, WALKWAY, AND LIFE RAFT

CONCEPT DESCRIPTION

## GENERAL DESCRIPTION OF CONCEPT

This device is the same as the inflatable slide described under concept 8-B, with the addition of any provisions necessary to allow its use as a raft.

## AREAS OF IMPROVEMENT IN EMERGENCY EVACUATION OF AIRCRAFT

Same features as concept 8-B plus providing protection from sea, sun, and storms in its function as a fully enclosed raft. Also reduces total time for raft launching as one raft is already at each doorway.

## ESTIMATED QUANTITATIVE IMPROVEMENT IN SURVIVABILITY

Increases passenger flow rate up to 50 percent in ditching.

In addition to land usage figures of concept 8-B, the raft should increase survivability from exposure by a factor of 2 to 4 times, and provide a 50 percent improvement in detection from the air because of bulk of the raft.

#### HOW NEW IS THIS CONCEPT?

Previous publications:	None known besides the North American Rockwell Corporation proposal for this study.
Patents related:	Refer to concept 8-B. Also a McDonnell-Douglas patent is said to be in process.
2,765,131, "Inflatable, Three 3-Tube Chute Assembly,"	Boyle, 2 Aug 1956
2,936,056, "Variable Length Inflatable Escape Chute",	Heyniger, 10 May 1960
3,018,867, "Inflatable Escape Chute",	Heyniger, 10 June 1960
3,102,623, "Escape Slide",	Schact et al, 31 Mar 1960
Br. 887,449, "Escape Chute",	Elliott Equipment Ltd, 17 Jan 1962
Fr. 1,163,036, "Escape Chute",	22 Sep 1958

#### HOW ORIGINAL IS THIS CONCEPT?

Adapted from military and commercial aircraft developments or practice on existing inflatable slides and rafts.

Use of slide for raft has been tried before with varying degrees of success. Configuration shown here is original with this study.

#### DETAIL DESCRIPTION OF SYSTEMS AND COMPONENTS

Refer to concept 8-B. Because of its application as a raft, the device should be a bright fluorescent color, with exterior application of "chemical light" for darkness detection. It should also include various sea rescue design provisions and stowed equipment/consumables. The hinged inflatable flaps would be attached with a gusset panel to reduce water intake and could be strapped in an inward/upward position for improved sea-worthiness. A

detachable joint mechanism with check valves on inflation tubes would permit deployment as a raft. The weight of one raft per type I or type A door would be eliminated, thus reducing overall inflatables weight cost to overwater aircraft.

### CONCEPT EVALUATION

#### OVERALL SUMMARY RATINGS

Cost-effectiveness: Moderate

#### ENGINEERING FEASIBILITY

May require moderate improvement in state-of-the-art, especially in regard to construction details. Principal design problems are to reduce bulk and to develop feasible stowage and deployment means.

#### PSYCHOLOGICAL EVALUATION

Human Engineering:	By enclosing the main exits, the slide should improve vision and reduce fumes by reducing the influx of smoke.
Behavioral psychology:	The enclosed slide should improve feelings of safety and security and thus reduce hesitation in entering the slide.
Motivational psychology:	Passengers will be generally more inclined to enter an apparent "safe" area; however, some percentage may have feelings of entrapment and would prefer to enter an "open" area psychologically.

#### PHYSIOLOGICAL EVALUATION

Toxicity and heat from open flames around the aircraft could be considerably reduced by the extended and enclosed slide. For use as a life raft, the combination unit could reduce initial "dunking" of passengers trying to enter the raft as well as long term exposure to sea, wind and sun.

### KINESIOLOGICAL EVALUATION

Strength and coordination problems are reduced with a large, enclosed area for passengers to enter.

### COMPATIBILITY WITH OTHER REQUIREMENTS

This type of slide would eliminate or require design accommodation with some other slide/exit device concepts such as 7-B, 9-B, 14-B, 15-B, 16-B, 31-A, 36-B, 38-B, and 50-B. The concept is essentially the same as 8-B. The number and placement of existing life rafts would be modified.

### EFFECTIVENESS OF SOLUTIONS IN SPECIFIC PROBLEM AREAS

Improves egress rates of slow, infirm, or hesitant passengers especially at increased floor heights, inverted aircraft, or high pitch/roll attitudes. The combined raft/slide also reduces or eliminates the problem of getting passengers into the life raft by having to jump, especially with rough seas.

### EFFECTIVENESS OF SOLUTION IN TYPICAL ACCIDENT CASES

#### Case 1 - Denver, DC-8

There is no direct evidence at Denver that passenger hesitation was a factor; however, an estimated improvement of 0.1 second per person from all causes, times the 53 passengers who did exit, would equal an additional 5.3 seconds of available time. Consequently, six to eight more passengers could probably have escaped. The more advantageous features of this equipment (i.e., abnormal fuselage attitude and integral life raft) would not have been tested in this accident.

## MECHANICAL FOLDING STAIRWAY

### CONCEPT DESCRIPTION

#### GENERAL DESCRIPTION OF CONCEPT

A specially constructed, lightweight stairway for emergency egress and normal use is provided. It expands in width as well as length from a package either on the door or under the floor by the door.

#### AREAS OF IMPROVEMENT IN EMERGENCY EVACUATION OF AIRCRAFT

Reduced danger of puncture or heat damage and of problems related to jumping into or climbing off slides are the main features.

#### ESTIMATED QUANTITATIVE IMPROVEMENT IN SURVIVABILITY

Passenger flow rate: Normally comparable to inflatable slide except in case of puncture failures of inflatables.

#### HOW NEW IS THIS CONCEPT?

Previous publications: Many aircraft now have integral stairs, but these usually are slow in deployment and smaller than door width. Two-way expansion is recent, circa 1966-67.

Patents related: Patents of Shenandoah Pacific, Inc, Redwood City, Calif

#### HOW ORIGINAL IS THIS CONCEPT?

Idea stems from demonstrated capability of one concern (Shenandoah Pacific, Inc) to make cheap, lightweight structures which expand in two directions or three directions from a small package, possibly making stairs competitive with slides for emergency evacuation.

## DETAIL DESCRIPTION OF SYSTEMS AND COMPONENTS

A stairway is constructed of lightweight tubes, straps, and panels formed and joined in a trusslike structure which is foldable and collapsible into a small package which will fit within a doorway or under the floor at a doorway. It is powered by gas bottle or spring for deployment, then locks in place. It expands in both length and width to provide handrails and a wider descent path than the door width, permitting additional columns of persons on each side of the doorway. This additional width helps overcome the inherently slower rate of flow for a stair as compared to a slide. The design is constructed so that only those segments needed to reach the ground are deployed. The remainder stay stowed.

## CONCEPT EVALUATION

### OVERALL SUMMARY RATINGS

Cost-effectiveness: **Low**

Device probably will be heavier than inflatable slide and considerably more expensive. Advantages of nonpuncture, easier entry exit may not overcome basic speed and simplicity of inflatables of same size.

### ENGINEERING FEASIBILITY

Within current state-of-the-art: Demonstrated principles of certain proprietary designs can be applied to produce device adaptable to precision mass production, competitive weight and cost. Part is puncture- and leakproof. Not subject to heel abrasion, puncture, or tearing. Need for more parts implies questionable reliability.

### PSYCHOLOGICAL EVALUATION

Human engineering: Older passengers would find use of stair more acceptable from standpoint of ease of entry, knowledge of use.

Motivational psychology: Stairway is more common experience, more generally acceptable. No problem of modesty or discomfort for women.

### PHYSIOLOGICAL EVALUATION

No particular special considerations.

### KINESIOLOGICAL EVALUATION

Stairways are inherently slower than slides or ramps as to flow rate. Greater width and weight required to make flow rate comparable to slide. However, older persons could more readily enter and exit stairs.

### COMPATIBILITY WITH OTHER REQUIREMENTS

Not comparable with slide egress devices and aids. Not compatible with concept of combining with life raft unless additional inflatable bags are incorporated and stairs made to lie flat.

### EFFECTIVENESS OF SOLUTIONS IN SPECIFIC PROBLEM AREAS

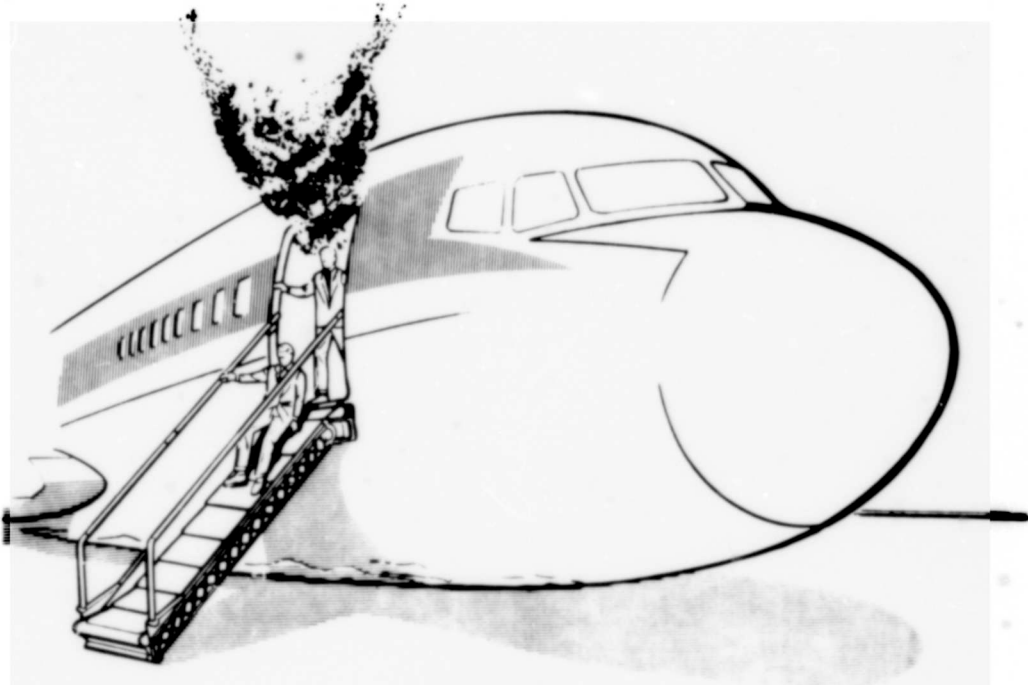
No solution to overturned aircraft or seriously unusual attitudes. Prevents problems of puncture, or tearing of slides. No aid to jammed door condition. Adaptable to gear up or down.

### EFFECTIVENESS OF SOLUTION IN TYPICAL ACCIDENT CASES

#### Case 1 - Denver, DC-8

Some slight advantage in flow rate of passengers may have been present with such a device in that a small stairway might be more encouraging than a noninflated slide.

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**MECHANICAL FOLDING SLIDE/WALKWAY****CONCEPT DESCRIPTION****GENERAL DESCRIPTION OF CONCEPT**

A specially constructed, lightweight, extendable truss structure is constructed to support stairs which can be folded down to form the surface of a slide or ramp for emergency evacuation.

**AREAS OF IMPROVEMENT IN EMERGENCY EVACUATION OF AIRCRAFT**

Improved safety of egress by elimination of problems of torn slide fabric or leaks. In gear-up landings, the surface forms a firm ramp which aids rate of flow in walking mode for shallow angles.

**ESTIMATED QUANTITATIVE IMPROVEMENT IN SURVIVABILITY**

Preparation of exit: Prevents loss of shape due to puncture or tear of inflatable device.

Passenger flow rate: Fastest rate of egress for shallow angles.  
Estimated as 10 percent over inflated slide.

#### HOW NEW IS THIS CONCEPT?

Previous publications: None

Patents related: Patents of Shenandoah Pacific, Inc, circa 1965-67

#### HOW ORIGINAL IS THIS CONCEPT?

Original in this context; no previous publications relating to emergency evacuation of aircraft.

#### DETAIL DESCRIPTION OF SYSTEMS AND COMPONENTS

This mechanical folding slide and walkway combination would consist of expandable pivoting structural segments which would be configured for unit and system structural integrity with integral side support rail construction. The complete system would be sized, powered, and designed to be stored in the collapsed condition under the type I and II exits. As previously indicated, the system would be designed for use as an "air stair" or evacuation slide at the operational option of the crew. Also, it could be used as a firm ramp at shallow angles from the floor to the ground.

The feasibility of this mechanical folding slide system would be greatly enhanced if this system were designed to provide crew-controlled functional duplication with optional service as an "air stair" (for normal operations) or a slide (for emergency operations). This functional duplication, however, may be applicable only to those short stage-length aircraft - such as the DC-9, 727, and 737 - utilized by the local service carriers as it is in this transport spectrum that the integral "air stair" finds widest usage.

#### CONCEPT EVALUATION

##### OVERALL SUMMARY RATINGS

Cost-effectiveness: **Low**

Primarily useful for limited types of accident situations. Requires additional development costs. However, usefully cost-effective for certain aircraft.

## ENGINEERING FEASIBILITY

Within current state-of-art, using Shenandoah Pacific demonstrated principles of mechanical expanding structures. Ease of restowage better than for inflatables. Leak-testing is no problem. Life expectancy of materials greater and maintenance costs less than for inflatables. Double usage for "air stair" overcomes most weight penalties. It is doubtful if a metal slide could provide any advantages, for most of the emergency evacuation criteria under consideration, over the current inflatable slides.

Replacing the door-mounted inflatable slide with such a system would add complexity, weight, and initial cost without providing (except in special cases) any improvements in egress time or facility. Furthermore, this system is not as adaptable to water ditching conditions as the inflatable slide although flotation devices could be incorporated in the design to accommodate this requirement. Increased number of parts and complexity may reduce reliability.

## PSYCHOLOGICAL EVALUATION

Human engineering: About same as other slides except for use as a ramp, which is more obvious, easier.

Some hesitation in entering a metal slide may be found due to possibility of injury on hard surfaces.

## PHYSIOLOGICAL EVALUATION

No particular applicable items.

## KINESIOLOGICAL EVALUATION

See note under "Psychological Evaluation." Use as both slide and ramp poses a problem in a surface smoothness design. Smooth ramp may be slippery for foot traffic especially when wet, and not offer significant speed increase.

## COMPATIBILITY WITH OTHER REQUIREMENTS

Not compatible with combination raft-slide concept.

## EFFECTIVENESS OF SOLUTIONS IN SPECIFIC PROBLEM AREAS

- (a) No problems of puncture, tear, or leakage.
- (b) Readily restowed after false alarm.

## EFFECTIVENESS OF SOLUTION IN TYPICAL ACCIDENT CASES

Case 1 - Denver, DC-8

May have overcome problem of noninflating slide. This slide was not inflated due to short distance from floor to ground 4.5 feet. This is too far for a comfortable stepdown, however. The ramp mode could have significantly speeded egress perhaps by 25 percent.

## SPIRAL SLIDE CONFIGURATION

CONCEPT DESCRIPTION

## GENERAL DESCRIPTION OF CONCEPT

This concept consists of an enclosed spiral escape chute which can be deployed at each type I and II exit as are the present inflatable escape slides.

## AREAS OF IMPROVEMENT IN EMERGENCY EVACUATION OF AIRCRAFT

Reduce fear of height for large aircraft evacuations. Permit lighter weight structure for inflatable slide or mechanical slide. Provide stiffer structure for wind resistance.

## ESTIMATED QUANTITATIVE IMPROVEMENT IN SURVIVABILITY

Preparation of exit: 5 percent  
Passenger flow rate: 5 percent

## HOW NEW IS THIS CONCEPT?

Previous publications: None found during review. New to aircraft applications

Patents related: 3,102,633, "Escape Slide", Schacht, et al, 31 Mar 1960  
3,339,690, "Evacuation Slide", Craig, 23 Oct 1965

## HOW ORIGINAL IS THIS CONCEPT?

Spiral slides have been used as fixed fire escape equipment in older institutional and public buildings as they occupy minimum ground area from multistoried buildings. Additionally, most of these spiral slides were closed chutes, fabricated of steel, and afforded faster escape and more protection from flame impingement than the open, exterior fire stairways in more common use.

## DETAIL DESCRIPTION OF SYSTEMS AND COMPONENTS

The spiral slide chute here considered would probably consist of a non-inflatable, low friction, sliding surface deployed and supported in the spiral chute configuration by a surrounding, inflated circular structure which would be structurally augmented with tension cable assemblies of predetermined length. The entire spiral slide chute assembly would be placed within a housing of minimum depth stowed - as do present air stair designs - under the aircraft floor beneath the type I exits. This housing would contain an integral power supply for the horizontal translation to the use position and would incorporate the stored gas required for automatic system inflation.

## CONCEPT EVALUATION

### OVERALL SUMMARY RATINGS

Cost-effectiveness: Low (unfavorable)

Possible benefits probably are not worth the cost of developing this device for aircraft evacuation.

### ENGINEERING FEASIBILITY:

Concept is probably within the current state-of-the-art, but will require some development to achieve correct shape. For a fully enclosed slide, the spiral offers some advantage in doubling use of floor material for ceiling material on next lower turn of spiral. Also, some improved load paths are possible using a central inflatable fabric in tension. However, design does not appear fail-safe.

### PSYCHOLOGICAL EVALUATION

Some reduction in fear of heights may be possible since the passenger cannot see the whole slide. However, fear of unknown at other end may also be detriment. Some dizziness may occur in passengers.

### PHYSIOLOGICAL EVALUATION

The egress route terminates closer to the aircraft than does the conventional slide chute, increasing possibility of burns.

#### KINESIOLOGICAL EVALUATION

There is some possibility of falling over sideways during the sliding process, but otherwise similar to present slides.

#### COMPATIBILITY WITH OTHER REQUIREMENTS

Not compatible with use as a life raft.

#### ESTIMATED COST

New development cycle for inflatable slide will be required. Overall weight saving uncertain.

#### EFFECTIVENESS OF SOLUTIONS IN SPECIFIC PROBLEM AREAS

Expected to be more stable in windy conditions primarily for very large new aircraft.

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PASSENGER COMPARTMENT MANIFOLD  
DISTRIBUTION SYSTEM

CONCEPT DESCRIPTION

GENERAL DESCRIPTION OF CONCEPT

Installation of a manifold system in the overhead area of passenger compartments will allow distribution of a foam fire suppressant following a survivable crash landing. To reduce onboard weight, the supply would be delivered by ground-based vehicles to a distribution manifold connector on the aircraft exterior surface. A dual manifold would provide capability for pumping fire suppressant from either the forward or aft sections of the passenger compartment in the event one end is destroyed or inaccessible.

AREAS OF IMPROVEMENT IN EMERGENCY EVACUATION OF AIRCRAFT

Increases time passenger compartment is habitable, assuming fire has not yet made cabin uninhabitable by the time ground vehicle arrives. Reduces fire and smoke in passenger compartment.

The capability of high expansion foam to effectively suppress fire and smoke from simulated aircraft passenger cabins has previously been demonstrated.

ESTIMATED QUANTITATIVE IMPROVEMENT

Passenger safety from heat, toxic gases and smoke: To 100 percent

Passenger orientation and visual perceptions: -50 percent

HOW NEW IS THIS CONCEPT?

Previous publications:

Wright, W., "FAA Will Tighten Aircraft Safety Rules," Aviation Week and Space Technology, 4 April 1966

O'Regan, J. F., "Experimental On-Board Aircraft Fire Suppression Equipment," Report No. 6573, National Fire Protection Association, May 1966

Heine, D., and Brenneman, J., "ALPA Cleveland Fire Test Results," presented at the Thirteenth ALPA Air Safety Forum, 4 and 5 October 1966

Aviation Week and Space Technology,  
"System Fills Jet Cabin With Foam," 13  
November 1967

#### HOW ORIGINAL IS THIS CONCEPT?

Extension of commercial studies and military application of foam fire suppressant systems.

#### DETAIL DESCRIPTION OF SYSTEMS AND COMPONENTS

The dual manifold would be located in the overhead area of aircraft passenger compartments. Location and spacing of nozzles would allow a dispersion pattern to cover maximum surface area of the compartment. Each segment of the dual manifold would originate at externally mounted disconnects on opposite ends of the passenger compartment. This feature would allow delivery of fire suppressant to the passenger compartment in the event one end is inaccessible. Delivery of fire suppressant to the crash site could be by two methods: modified fire truck, and/or helicopter. Investigation of reaction time comparisons between the two methods will be required with consideration given to analysis of (1) the types of emergency (i.e., prior knowledge or unexpected), and (2) accessibility of crash sites.

The manifolds should be lightweight and flexible to accommodate a maximum amount of fuselage distortion before rupturing. Design should include manifold reductions to limit flow to each nozzle in event of a manifold rupture. Nozzle design should incorporate a vane axial rotor to aid distribution of fire suppressant through centrifugal action.

The Bliss-Rockwood report identifies the following preliminary design guides for system requirements:

- (a) Foam system capable of flooding cabin in 30 seconds
- (b) System operation to be completely self-contained

- (c) Redundant systems
- (d) Sufficient foam to provide a volume 1-1/2 to two times the cabin volume.

It is emphasized that these criteria are preliminary and should be utilized only as an evaluation starting point. The components comprising the system include:

- (a) A pressurizable, storage container for the liquid foam or "Light Water" concentrate. The amount of foam concentrate is a function of the specific expansion ratio used. These may vary from 100:1 to 700:1. The higher the ratio, the lower the total system weight. However, the higher expansion ratio foams are not necessarily the most efficient in terms of foam life, insulating qualities, and fire suppression. The optimum ratio has yet to be determined. For comparison purposes, the following expansion ratio versus solution weights are referenced from the Bliss-Rockwood report for one cabin filling (6,500 cubic feet):

<u>Ratio</u>	<u>Gage of Solution</u>	<u>Weight of Solution (lb)</u>
100:1	488	4,065
300:1	163	1,355
500:1	98	813
700:1	70	581

#### CONCEPT EVALUATION

##### OVERALL SUMMARY RATINGS

Cost-effectiveness: Moderate

##### ENGINEERING/OPERATIONAL FEASIBILITY

Within the current state-of-the-art. Experimentation and development will be required, both for methods of distribution and for desirable agent.

Estimated weight of a 707 system is 1,200 to 1,500 pounds.

An undesirable feature of foam production systems is that they utilize atmospheric air for foam generation. The ALPA Cleveland fire tests demonstrated the undesirable effects of a smoke-filled environment for generating foam. In these tests, it was thought the ambient smoke prohibited complete generation of foam. Further tests are being conducted to evaluate this assumption.

#### PSYCHOLOGICAL EVALUATION

Human engineering:

Reduces vision, especially the foam system. Tactual effect of wetness from both systems, which might actually be welcome behaviorally in the presence of heat. There may be some fear of the foam because of loss of vision and feeling of claustrophobia.

#### PHYSIOLOGICAL EVALUATION

Should reduce toxicity by reducing fire and by particle assimilation; although this has not been evaluated, a tendency to gag has been noted.

#### KINESIOLOGICAL EVALUATION

No effects.

#### COMPATIBILITY WITH OTHER REQUIREMENTS

Essentially compatible with other concepts except competes with 60-F and may be incompatible with concepts using fans (27-C, 35-B, and 59-F), and lighting concepts (3-C, 24-G, and 28-G). Should require use of 6-A hood for breathing and vision or 55-A filter. The crawling procedure, 29-G, is questionable, also 34-B tunnel.

#### EFFECTIVENESS OF SOLUTIONS IN SPECIFIC PROBLEM AREAS

Reduce fire and resultant effects in cabin.

## EFFECTIVENESS OF SOLUTION IN TYPICAL ACCIDENT CASES

Case 1 - Denver, DC-8

Assuming some effectiveness in the reduction of smoke effects, the system could have provided some benefit.

Case 2 - Salt Lake City, B-727

Assuming that the system operates as proposed, a considerable reduction in fatalities should have ensued. Firemen were unable to enter vehicle as soon as they arrived, but plugging in the foam generator may have reduced heat, smoke, and resulting deaths until access was gained and passengers evacuated.

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**AIRPORT-LOCATED EVACUATION DEMONSTRATION DISPLAY/PLAY  
AREA FOR PASSENGER FAMILIARIZATION**



**CONCEPT DESCRIPTION**

**GENERAL DESCRIPTION OF CONCEPT**

The concept proposes the location of suitable displays and operable mock-ups in airport terminals to permit the familiarization of passengers by actual operation of equipment, presentation of types, location and purpose of equipment, and procedures for emergency evacuation. It is intended to supplement in-flight briefings in aircraft by providing opportunities for familiarization not possible after boarding the aircraft.

**AREAS OF IMPROVEMENT IN EMERGENCY EVACUATION OF AIRCRAFT**

A general improvement in passenger education can be expected. This is particularly true of items of equipment which the display permits them to use. The expected improvement is based upon the well-established training principle of the most effective training being that which allows actual physical participation.

### ESTIMATED QUANTITATIVE IMPROVEMENT IN SURVIVABILITY

A 100 percent improvement can be expected in equipment operation such as passenger opening of exits, inflation of slides as well as 20 percent improvement in location of exits and emergency equipment such as the life rafts.

### HOW NEW IS THIS CONCEPT?

The basic concept is not new but is extensively used by most effective training organizations.

### HOW ORIGINAL IS THE CONCEPT?

Displays and usable mockups as educational devices have been and are being used by police, schools, and other safety organizations as part of formal programs or informally at fairs, symposiums, etc, to educate the public. These types of training media are a significant part of any training program used by agencies such as military, industrial (including airlines), and educational institutions.

### DETAILED DESCRIPTION OF SYSTEM AND COMPONENTS

Various displays and operable mockups will be located in air terminals, in such a manner as to be readily available to waiting passengers and visitors. It would be designed and laid out to encourage and facilitate active utilization in order to maximize the educative value. Variety of techniques and media can be used and should be selected to fit terminal and airline requirements.

The basic approach is to provide opportunities to learn by doing and, if, this is not feasible, to select other techniques accordingly. Consequently, specific applications should be designed with this philosophy in mind.

The following list offers examples of types of techniques that can be used within the concept.

#### Aircraft emergency systems

- (a) Passive scaled-down mockup of aircraft showing exits, slides, equipment locations, etc
- (b) Films of evacuation demonstrations
- (c) Passive displays or films of ground rescue equipment

**Aircraft exits**

- (a) Usable mockups of various exit types
- (b) Passive exit location for specific aircraft
- (c) Films of exit usage

**Slides**

- (a) Passive slide permitting actual use
- (b) Small active display to demonstrate inflation
- (c) Passive display of location and evacuation configuration
- (d) Films of inflation and use

**Seatbelts/seats**

- (a) Mockup and display of seat indicating cushion usage for flotation and seat adjustments
- (b) Films of value of seatbelt/seat in withstanding g-loads
- (c) Display of impact posture
- (d) Display indicating requirements for removal of pockets, storage of loose equipment, etc

**Life raft**

- (a) Passive display of raft, emergency survival equipment, and stowage locations
- (b) Active model of life raft (miniature) to demonstrate inflation
- (c) Films depicting preparation, flotation, and boarding of life raft

**Life jacket**

- (a) Model/display indicating donning and operation (active) of life jacket
- (b) Films of use

**Oxygen mask**

- (a) Active oxygen mask
- (b) Display of use

**CONCEPT EVALUATION****OVERALL SUMMARY RATING**

Moderate cost-effectiveness can be expected from this concept if designed to reasonable costs and located and laid out to encourage passenger exposure.

### ENGINEERING FEASIBILITY

As the active equipment can be expected to flight configuration hardware, no apparent problems exist with operability. However, factors of safety and reliability must be assessed for each item. If the equipment is heavily used, this places an additional burden as well as requiring continuous maintenance to assure operability.

### PSYCHOLOGICAL EVALUATION

The concept, if properly developed, provides a unique opportunity for passengers to learn by doing. This learning is directly transferrable to aircraft. However, the success of the concept is a function of the techniques utilized as well as the layout. It is essential that display and mockup areas be readily available and freely accessible, as well as providing pertinent and meaningful information. Potential problems arise in presenting certain mockups such as exits and slides, because of the variety of configurations, operational procedures, and locations. Care must be exercised to insure that there is not negative or conflicting training imparted to the passengers. To insure the effectiveness of the concept, validation tests should be conducted.

All operable mockups should faithfully simulate actual equipment in terms of size, color, markings, weight, operating forces, etc, to insure good training.

### COMPATIBILITY WITH OTHER REQUIREMENTS

The concept is intended to be a valuable supplement to the preflight briefing given on the aircraft. As such, the only potential conflict is with the variety of equipment configurations which might confuse passengers. However, with careful consideration of this possible problem, this concept can be highly valuable in increasing passenger education.

### EFFECTIVENESS OF SOLUTION TO SPECIFIC PROBLEMS

This concept provides the opportunity for general passenger instruction as well as a unique opportunity for operational experience of vital evacuation equipment they maybe called upon to operate.

## MOBILE CLASSROOM DISPLAY AND MOCKUP PLAY AREA

### CONCEPT DESCRIPTION

#### GENERAL DESCRIPTION OF CONCEPT

The concept provides mobile displays and mockups suitable for demonstration and exhibit of aircraft emergency equipment and evacuation procedures. These items could be utilized for public education as part of public relations efforts in a variety of situations including school classrooms, symposiums, exhibits, fairs, airline terminals, etc, to provide basic learn-by-doing experience for actual or potential airline passengers.

#### AREAS OF IMPROVEMENT IN EMERGENCY EVACUATION OF AIRCRAFT

As a general approach to potential passenger education, this technique provides basic evacuation education capabilities.

#### ESTIMATED QUANTITATIVE IMPROVEMENT IN SURVIVABILITY

Difficult to evaluate improvement; however, general public instructions will provide basic awareness and knowledge of techniques.

#### HOW NEW IS THIS CONCEPT?

Entirely new and original in terms of airline use.

#### DETAILED DESCRIPTION OF SYSTEM AND COMPONENTS

This concept utilizes any or all of the techniques proposed in concept 19-E which may be adapted for mobile use. The intent of this concept is to adopt a more active public education of air safety equipment and procedures as part of the public relations effort. The goal is to provide basic education and assurance to actual and potential airline customers that emergency provisions are included within airline operations.

Mobile equipment would permit presentations at a variety of locations where maximum exposure is required. This includes smaller air terminals which cannot afford their own displays.

CONCEPT EVALUATION

## OVERALL SUMMARY RATING

By itself, the concept would represent a low cost-effectiveness investment. However, when viewed as part of airline public relations and/or FAA public responsibility, a more optimistic evaluation is possible.

## ENGINEERING FEASIBILITY

(Refer to concept 19-E.)

## PSYCHOLOGICAL EVALUATION

(Refer to concept 19-E.)

## COMPATIBILITY WITH OTHER REQUIREMENTS

(Refer to concept 19-E.)

## EFFECTIVENESS IN SOLUTION IN SPECIFIC PROBLEM AREAS

(Refer to concept 19-E.)

## TELEVISION/FILM PRESENTATION ON PREFLIGHT BRIEFING

CONCEPT DESCRIPTION

## GENERAL DESCRIPTION OF CONCEPT

This concept proposes the use of television or film techniques to supplement or replace conventional stewardess preflight briefings. More dynamic and professional, and, therefore, more compelling presentations can be developed utilizing these techniques. Methods of presentation can include (1) utilization of in-flight entertainment equipment (movie or TV) for the mandatory preflight briefing or in-flight as a supplement; or (2) presentation over equipment located in the immediate boarding/waiting area as preflight briefing supplement.

## AREAS OF IMPROVEMENT IN EMERGENCY EVACUATION OF AIRCRAFT

Criticism of current preflight briefing techniques includes:

- (a) Inadequate capability for instructions concerning equipment operation and location due to cramped area of aircraft.
- (b) Hurried or too routinely presented briefing.
- (c) Briefing lacks thoroughness and clarity.
- (d) Veteran passengers do not pay attention because of routineness of presentation.

All of these contribute to a lack of effectiveness of the preflight briefing. This technique can help overcome all of these basic problems and, thereby, increase passenger knowledge of exits, exit and slide operation, crash procedures, etc, which are vital to rapid and safe evacuation.

## ESTIMATED QUANTITATIVE IMPROVEMENT IN SURVIVABILITY

An overall estimate of 10 to 15 percent improvement can be expected; however, the major improvement can be expected in situations in which other than primary equipment and procedures are used. This would include blocked exits, incapacitated or otherwise unavailable crewmembers, etc, which require passenger awareness of alternatives without reliance on the crew for leadership and direction.

#### HOW NEW IS THIS CONCEPT?

The use and advantages of audio-visual techniques are widely known and applied in many similar situations for educative purposes. However, it has not been used for safety briefing for airline passengers.

#### HOW ORIGINAL IS THE CONCEPT?

The use of TV/film equipment for presentation of this type of information on commercial aircraft is not currently being done.

#### DETAILED DESCRIPTION OF SYSTEM AND COMPONENTS

For onboard presentation, the various in-flight entertainment systems that permit TV or film presentation can be utilized. A 5-minute (maximum) presentation can be given during the preflight period over these systems to either supplement or replace the present preflight briefing, or in-flight to supplement the preflight briefing.

If there is no onboard system, then suitable TV equipment could be located in the immediate waiting/boarding area to provide a preflight supplement to the normal preflight briefing.

This permits the presentation of the evacuation briefing material in a professional manner using either animation or movies depicting equipment and operations. A more compelling and interesting presentation is possible which will greatly increase the effectiveness on passengers by changing the presentation periodically and testing the validity of the presentations; a high effectiveness can be maintained.

These techniques allow the passengers to view equipment operation, evacuation procedures, and the hazards of evacuation in manner that is more meaningful and instructive than simple briefings or instruction cards. It provides instructions as detailed and close to actual participation in drills as possible. Consequently, the effect cannot but be that passengers will be better prepared.

The adoption of this concept could free the stewardess during the preflight period unless there is a foreign language problem which could be satisfied by subtitles or designing the film for stewardess talk-along.

A review of onboard systems that could utilize this technique includes only those which do not interfere with passenger or stewardess movement. Those aircraft utilizing single large screens in each compartment could be used only after everyone is seated so as not to interfere with movement. Those with individual TV or screens could be shown continuously and not interfere with movements. For best results, the presentation should be completed prior to beginning of taxiing for takeoff.

If the aircraft is not provided with appropriate equipment, then the presentation could be made in the immediate boarding/waiting area.

In general, this technique should be encouraged because of increase in effectiveness. However, it should only replace the in-flight briefing if it can be given on the aircraft in such a manner that all passengers are exposed to it during preflight without undue restrictions to normal boarding activities. If this is not possible, then the technique can function as a useful supplement to the preflight briefing by presentation in the aircraft in-flight or in the immediate waiting/boarding area in the terminal.

#### CONCEPT EVALUATION

##### OVERALL SUMMARY RATING

Favorable cost-effectiveness can be expected, particularly for aircraft with suitable onboard TV/Movie equipment. A somewhat lesser rating can be expected for terminal presentation.

##### ENGINEERING FEASIBILITY

Suitable equipment is already provided on aircraft or commercially available for terminal presentation.

##### PSYCHOLOGICAL EVALUATION

The advantages of well prepared audio/visual instructions over simple briefings, particularly the quality of those being given currently on commercial aircraft, are justified from past experience. A general increase in quantity and quality of passenger education can be expected. This assumes that presentation reflects careful consideration of the content and method of presentation of the material which should be validated by suitable passenger population tests and interviews.

#### COMPATIBILITY WITH OTHER REQUIREMENTS

The system is basically a method to insure that the standard preflight passenger briefing is given in a thorough and effective manner. As such, it does not introduce new or demanding requirements to aircraft or crew members; with the exception of those aircraft which do not have suitable equipment. The concept is particularly adaptable to standardized passenger instructions (concept 23-E) which must allow for general as well as specific instructions for each aircraft configuration.

For air terminal presentation, certain problems exist which could limit the effectiveness and consequently affect the decision to adopt the concept. These include the availability of a suitable area in which at least a majority of passengers wait until boarding and the environmental conditions which would permit an effective presentation, e.g., quietness, lighting, etc.

#### EFFECTIVENESS OF SOLUTION IN SPECIFIC PROBLEM AREAS

The technique offers a major improvement in passenger education presentation which should generally increase the capability for survival in all evacuation operations.

## UNIFORM CREW TRAINING PROGRAM

CONCEPT DESCRIPTION

## GENERAL DESCRIPTION OF CONCEPT

Jointly sponsored and FAA-regulated training programs and facilities are provided to all airlines to insure an acceptable level of crew training. This is accomplished by centrally developed training facilities which could be improved to provide more and better qualified and specialized instructors, and more effective simulation facilities and training aids than individual, particularly smaller, airlines can provide. This concept potentially offers greater training flexibility, thoroughness, and lowered costs as well as assurance of training adequacy.

## AREAS OF IMPROVEMENT IN EMERGENCY EVACUATION OF AIRCRAFT

Although the general level of cabin crew training is high, there are two factors that tend to degrade it. These include the high cost (estimated at \$25,000 per stewardess) and the increasing number of crew personnel. The proposal is intended to maintain the high level of training by lowering costs, insuring rigid standards, and making it available to all, especially smaller, airlines.

## ESTIMATED QUANTITATIVE IMPROVEMENT IN SURVIVABILITY

Because of the high level of crew training, only an overall improvement of 5 percent can be expected, and this would be reflected primarily by those airlines where less than the best training is offered.

## HOW NEW AND ORIGINAL IS THIS CONCEPT?

It is understood that this proposal has been offered previously without success.

#### DETAILED DESCRIPTION

The establishment of a uniform crew training program is envisioned within the following requirements and guidelines:

- (a) Training facilities including simulation and training will be centralized to insure high quality and cost-effectiveness by providing flexibility and maximum volume of use.
- (b) Provide a permanent corps of highly qualified and specialized instructors to insure the capability for quality and depth of training.
- (c) Initiate, develop, and maintain a standardized training program aimed at general as well as specific aircraft certification.
- (d) Develop and maintain detailed and specific training and testing criteria for certification.
- (e) The training program would be jointly sponsored by all airlines according to usage but regulated and maintained by the FAA.

#### CONCEPT EVALUATION

##### OVERALL SUMMARY RATING

No firm evaluation of this proposal is possible without a detailed evaluation of all factors to insure both advantages in costs and effectiveness.

##### ENGINEERING FEASIBILITY

To provide adequate training facilities within the scope of this concept without undue initial costs, present facilities must be used until optimum centralization would be possible to serve the large quantity of personnel involved with the training hardware required.

##### PSYCHOLOGICAL EVALUATION

The basic justifications for this concept include insuring better training standards and training instruction, and making more and better training equipment available to all cabin crews. This is certainly possible within the concept. However, a decrease in level of training could also result by

adopting the minimum level of the least effective participating airline or by reliance on mass training in an effort to increase cost-effectiveness by streamlining. Therefore, training quality must equal the best current programs if not better.

#### COMPATIBILITY WITH OTHER REQUIREMENTS

As the purpose of this training concept is limited to initial and recurrent emergency training, requirements for other aspects of crew training must be provided outside of the scope at this concept. Allowance must also be made for unique airline emergency equipment and procedures training requirements.

#### EFFECTIVENESS OF SOLUTIONS IN SPECIFIC PROBLEM AREAS

- (a) Guarantee crew familiarity with emergency equipment and procedures for each aircraft operated.
- (b) Assure minimum training variation between airlines, particularly smaller ones.
- (c) Decrease the prohibitive training costs in an effort to maintain and/or improve training quality.

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## STANDARDIZED PASSENGER EVACUATION INSTRUCTIONS

### CONCEPT DESCRIPTION

#### GENERAL DESCRIPTION OF CONCEPT

A standardized passenger instruction methodology, jointly developed by the FAA, airlines, and manufacturers, and designed to optimize the presentation of general and specific instructions and assist in transfer of training among commercial aircraft and airplanes, would improve passenger capabilities to react, perform, and utilize the proper emergency and evacuation techniques and equipment.

The standardization of instructions includes the forms, contents, and presentation techniques for all briefings, written materials, and other instructional media, which would be systematically developed, evaluated, and maintained to insure thorough, consistent, and effective passenger education.

#### AREAS OF IMPROVEMENT

The adoption of a standardized methodology would result in improvement in all facets of passenger evacuation behavior. Specifically, this would include:

- (a) Better utilization of emergency equipment because of more thorough understanding of equipment availability, purposes and uses.
- (b) Greater probability of passengers using correct and appropriate emergency procedures.
- (c) Decrease in effects of emotionality due to positive training.

#### ESTIMATED QUANTITATIVE IMPROVEMENTS IN SURVIVABILITY

An approximate 100 percent improvement in instruction effectivity could result in 20 percent greater survivability.

### HOW NEW AND ORIGINAL IS THIS CONCEPT?

Systematically developed instructions have been utilized by a variety of educational agencies with a consistent increase in educational effectiveness. This includes military agencies, schools, and industry.

### DETAILED DESCRIPTION

To insure effective and efficient passenger behavior during emergencies, an acceptable level of passenger education and training is a basic requirement. The importance of passenger education and education techniques is particularly important due to the lack of more formal training opportunities which optimally would include experience in use of actual equipment in simulated emergency conditions. Consequently, the content and presentation methods are critical in providing the passengers with the basic knowledge to increase the likelihood of correct passenger behavior so important to successful evacuations. To optimize passenger education, systematically developed and validated methodologies must be adopted.

The goals of a standardized passenger instruction methodology would be to provide consistent and thorough passenger instructions which would reliably provide the uninitiated traveler with basic survival information, insure transfer of training to different aircraft, increase the level of passenger knowledge with repeated exposures, minimize conflicting data among repeated exposures, provide unique aircraft or flight information, and in general be consistent with aircraft contingencies and emergency equipment and procedures.

The content of the standardized passenger education program would be developed by the combined effort of the Federal Aviation Administration, the airlines, and manufacturers to insure satisfaction of the specific goals of the effort and to promote unanimity and acceptance of the technique. The contents would include:

- (a) Basic information applicable to all aircraft
- (b) Unique information applicable to a specific aircraft
- (c) Unique information applicable to a specific flight, specific seat, or specific emergency duty

The education program would include information concerning emergency conditions, emergency equipment, and emergency procedures for at least the following items:

- (a) Decompression
- (b) Fire
- (c) Evacuation
- (d) Ditching
- (e) Takeoff and landing precautions
- (f) Crash procedures

The instructional presentation would permit utilization of many media consistent with good training requirements. The application of various audiovisual techniques to passenger education would be encouraged to:

- (a) Overcome passenger apathy to emergency instructions.
- (b) Permit the needed redundancy and repetition necessary for training.
- (c) Allow for specific airline creativity in presentation of the material in conjunction with other public relations effort.
- (d) Permit the use of a variety of media such as oral briefing, written material, TV/movies, audio, and promotional material to facilitate exposure to emergency information.
- (e) Allow for new and novel presentations of the information to increase seasoned-traveler interest.
- (f) Allow for combined media presentation.
- (g) Solve such problems of language and other passenger deficiencies as well as available preflight time on such flights as commuter or short hop flights.

To accomplish the purposes of the standardized passenger instruction concept, the methodology must utilize the systematic and scientific methods developed within training education and psychology. Thus would require the following steps:

- (a) Develop training requirements.
- (b) Evaluate media usefulness.
- (c) Develop prototype programs.
- (d) Validate programs by tests, interviews, etc.
- (e) Update and refine programs as required (continual iterative process involving all steps)

#### CONCEPT EVALUATION

##### OVERALL SUMMARY RATING

A high cost-effectiveness can be expected from this concept.

##### ENGINEERING FEASIBILITY

The only engineering requirements are those pertinent to the utilization of various media within the aircraft environment. These are discussed within other concepts.

##### PSYCHOLOGICAL EVALUATION

There have been many criticisms of the current preflight briefing techniques. This concept provides a solution to them.

##### COMPATIBILITY WITH OTHER REQUIREMENTS

The concept is basically an improvement over current techniques; as such, it presents no incompatibilities. In addition, it encourages utilization of various media and is compatible with them. (Refer to concepts, 2-C, 19-E, 20-E, 21-E, 23-E, 45-E, and 58-E.)

SOLUTION TO SPECIFIC PROBLEM AREAS

The basic improvement is in the quality and effectiveness of passenger education which will result in better utilization of equipment and proper procedures.

### DIRECTIONAL ACTIVE SENSOR/MANUAL-CONTROLLED FLOOR/CEILING/WALL LIGHTING FOR EXITS



#### CONCEPT DESCRIPTION

#### GENERAL DESCRIPTION OF CONCEPT

The system consists of progressive on-off lamps timed to give impression of movement, catch passenger attention, and direct them to exits. Lamps are controlled by sensors detecting heat, structural damage, etc, and by crew, to indicate best exits and hereby control passenger flow. Lamps would be located to promote optimum visibility under the variety of conditions expected in an emergency evacuation situation.

#### AREAS OF IMPROVEMENT IN EMERGENCY EVACUATION OF AIRCRAFT

- (a) Capability to redirect passengers by control of light motion for optimum flow.

- (b) Distribution of passengers to correct exits.
- (c) Increased exit and egress route visibility.

#### ESTIMATED QUANTITATIVE IMPROVEMENT IN SURVIVABILITY

A basic improvement as a result of displaying directional signals to the passengers could result in an improvement of flow rate as well as locating exits. The system is also significantly useful in redirecting passengers for optimum flow in cases of exit blockage or crowding. It is expected that a 10 percent increase is possible under normal conditions, and as much as 30 percent in situations requiring redirected flow.

#### HOW NEW IS THIS CONCEPT?

The use of progressive on-off lamps for directional displays is not new except in this application. In fact, it has been applied before. The most notable examples are in advertising street lights and in the current use as rear directional indicators on certain Ford Co. automobiles and runway landing lights. While specific uses may be patented the principle is not and, therefore, can be readily developed for use in aircraft.

Patents related:                   3,217,156, "Emergency Lighting System,"  
  Sherwood, 11 Feb 1963, (relates to  
  rechargeable battery power for emergency  
  lighting)

#### HOW ORIGINAL IS THIS CONCEPT?

As indicated, the system has had previous applications which indicate its usefulness for directional displays; only the application is original.

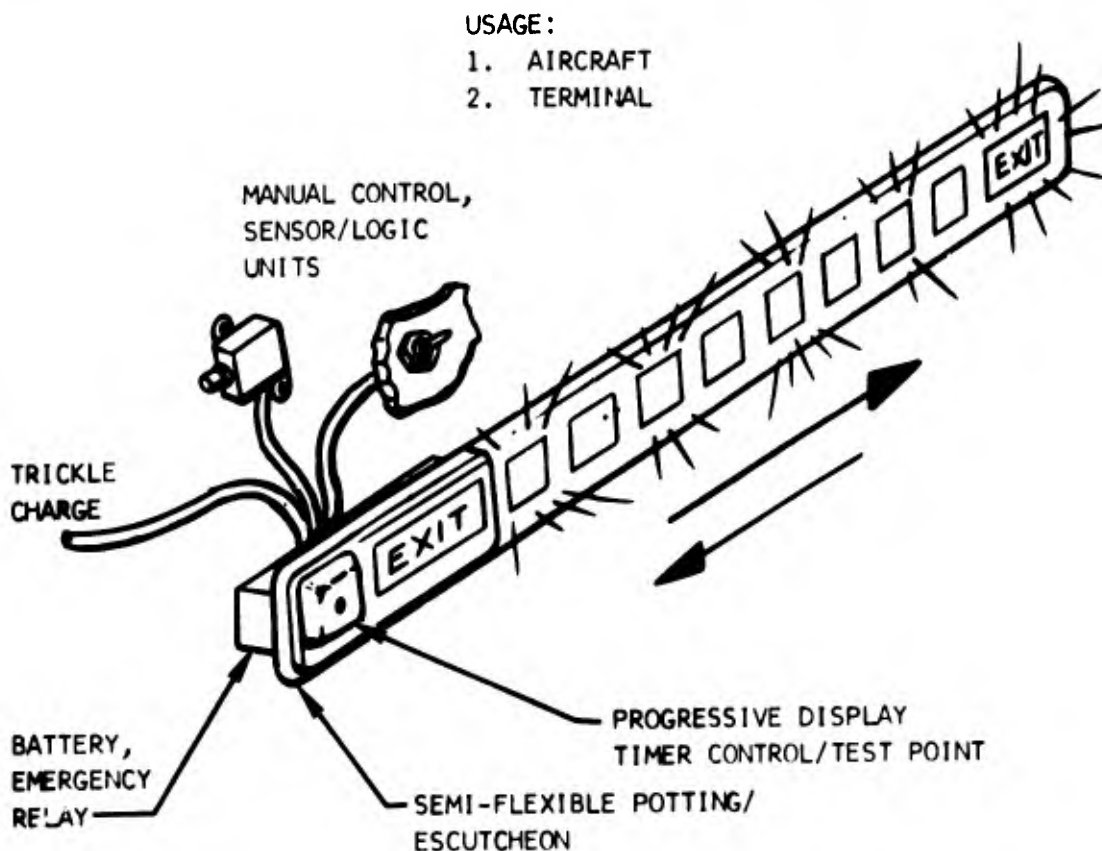
#### DETAILED DESCRIPTION OF THE SYSTEM AND COMPONENTS

The system would be provided with control panels located for access by the cabin crew. It would contain the following operational capabilities: on/off (each unit), directional control (each unit), test control, and manual override. This permits the crew to manually control the initiation of the system and control the direction of the signal for control of passenger flow as well as test the system or use it as part of the preflight briefing.

For automatic operation, the system will be equipped with sensors which detect conditions requiring evacuation (g-load or heat) and unusable exit conditions (heat, structural deformation). This would permit the system to activate on detection of excessive impact and fire and then to select proper motion direction as related to the heat or structural damage to primary exits.

The directional signals would be located on the walls, possibly along the molding or luggage racks, as well as on the ceiling and floor for conditions of poor visibility or aircraft attitude other than normal. Another use would be in terminals where the signals could function both to familiarize and direct boarding passengers. The directional signals can be composed of standard lamps or electroluminescent material. The latter would permit installation in a more inconspicuous manner until actuated. The lamps would momentarily illuminate progressively toward the preferred exit, thereby serving both as a directional indicator and exit locator aid. A conceptual design is illustrated.

The intensity and flash rate of the lamps would be such as to permit the preception of movement and to insure visibility in expected degraded visibility conditions. These magnitudes would be selected by laboratory test. It is suggested that a slower flash rate could be used for boarding and deplaning under normal conditions than would be used for the emergency conditions.



## CONCEPT EVALUATION

### OVERALL SUMMARY RATINGS

Favorable cost-effectiveness can be expected from this concept. This system provides an overall increase in exit display provisions as well as the addition of directional indicators which will provide a significant improvement to control of passenger flow under a variety of evacuation conditions. These two factors have been major problems in passenger egress behavior. The cost of the system is considered low for the potential benefits.

### ENGINEERING/OPERATIONAL FEASIBILITY

All of the components of the system are within the current state-of-the-art. Although no readily adaptable units are available, no foreseeable problems are evident as development difficulties. Maintenance and repair costs can be quite low if high-reliability solid-state timing and control devices are used. Fail-safe logic for circuitry would be greatest problem. Sensor reliability is also critical. A small effect on aircraft structure and interior decor is foreseen. Space requirements are negligible.

### PSYCHOLOGICAL EVALUATION

This system, as conceived, offers a significant increase in informational content both as to exit location and recommended direction for egress over current techniques. The selection of flash rate and intensity is important for effectiveness in potential evacuation conditions of reduced visibility caused by darkness, smoke, or flame illuminated areas. Electroluminescent displays would require careful evaluation in this regard. The capability for manual operation by the crew must be carefully considered to insure operability and ability for correct selection of displays and directions. This must include determination of control location, visibility of crew, and awareness of conditions (external fire or hidden structural damage) which can determine the capability to operate the system. For this reason, the proposed system should be primarily designed for automatic operation. Colors must be selected for preventing confusion with fires inside the aircraft.

### PHYSIOLOGICAL, KINESIOLOGICAL EVALUATION

No significant interaction.

### COMPATIBILITY WITH OTHER REQUIREMENTS

This system is compatible with existing systems, providing a basic improvement. The adoption of this technique, however, with the capability for manual control by crew changes the crew work requirements as would similar devices utilizing automatic/manual emergency systems. The utilization of this system with other visual display concepts would require evaluation to insure that the total system of displays is effective and unambiguous.

### EFFECTIVENESS OF SOLUTIONS IN SPECIFIC PROBLEM AREAS

Definite improvement can be expected for the following:

- (a) Quicker passenger starts
- (b) Use of proper exit
- (c) Decrease in crowding of exits
- (d) Better passenger flow
- (e) Better egress under reduced visibility, i.e., easier exit location

### EFFECTIVENESS OF CONCEPT IN TYPICAL ACCIDENTS

#### Case 1 - Denver, DC-8

Such attention-getting and directional exit indicators should have been able to more evenly divide the passenger group between the rear and front compartment exits, such that many more of the passengers would have survived by escaping sooner from the toxic smoke and hot air. In particular, these kinds of lights would have helped overcome the visual barrier of the divider between the first class and tourist sections, and drawn attention to the overwing exits.

## STEWARDESS PROTECTION GUARD GATE AT EXIT

CONCEPT DESCRIPTION

## GENERAL DESCRIPTION OF CONCEPT

A temporary barrier between passenger compartment and stewardess station prevents passenger crowding and interference with stewardess while she opens door and operates or prepares any necessary evacuation or survival equipment - may be a web strap net, an inflatable barrier, or a folding gate.

## AREAS OF IMPROVEMENT IN EMERGENCY EVACUATION OF AIRCRAFT

Preparation of exit prevents passenger crowding against exit, which would prevent or delay inward movement of the door during the opening sequence, or the slide egress system deployment. The concept can be designed to act as a smoke barrier, preventing or reducing toxic hazards.

## ESTIMATED QUANTITATIVE IMPROVEMENT IN SURVIVABILITY

This preparation of the exit may be the deciding factor between a successful opening or no opening, depending on speed with which passengers reach the exit and their state of panic. 0 percent to 100 percent exit capability. An overall average effect may be 10 percent improvement in exit preparation during emergency evacuations of all accidents.

## HOW NEW IS THIS CONCEPT?

Previous publications: None. Problem of passenger interference has been noted.

Patents related: 3,331,571, Lawrence, et al "Emergency Exit Arrangements for Aircraft,"  
22 Apr 1964

## HOW ORIGINAL IS THIS CONCEPT?

Concept used for public amusement parks and buildings to permit opening doors to let previous customers out. Suggested usage here is unique as far as is known.

#### DETAIL DESCRIPTION OF SYSTEMS AND COMPONENTS:

The problem of crowds jamming a door or preventing it from opening has been with us since the time of large community buildings. Of course, doors should open outward to prevent such happenings. However, because of the pressure-vessel nature of the aircraft vehicle, it is not safe to have doors open directly outward. Instead, they are often designed to first come inward a small amount in order to be able to turn and pass by the catch points. Furthermore, there must be time for someone to get at the door handle and open it to move it before the press of passengers becomes so great that it cannot be done.

A suggested method of doing this is to put a guard rail or gate across the area temporarily during the time that the stewardess is performing this function. It might be an inflatable device which can be punctured or pushed out of the way in case something happened that it was not removed by the stewardess. But it would provide a temporary constraint to the passengers to permit the stewardess, or an automatic opening device, time to get the door open and cleared and the slides or other devices ejected. These actions should, in fact, release the barrier. Otherwise a timer should permit passage.

Another possible use for such a barrier is to prevent intake of smoke and fumes at the doorway when the door is opened, such as happened in the Denver accident. The barrier should then act as a curtain with a slit, under tension, which closes after each person passes through. It should be transparent to admit light and allow persons inside to see the danger of smoke confronting them as well as the fact that people are egressing through the exit.

It should be provided with attention-getting signs indicating a need for passengers to wait until the exit is opened and slide prepared.

When retracted, the barrier must completely withdraw or roll up to prevent tripping people passing through the doorway area.

#### CONCEPT EVALUATION

##### OVERALL SUMMARY RATING

Cost-effectiveness: Good

Provides two kinds of protection for relatively small cost.

##### ENGINEERING FEASIBILITY

Within current state-of-art: Several techniques are available to accomplish desired results. Reliability and ease of operation are greatest problems, require careful design and verification testing.

## PSYCHOLOGICAL EVALUATION

Human engineering:	Aids stewardess in job.
Motivational psychology:	May be cause of panic to some, feeling of being "trapped" during wait until barrier is released.

## PHYSIOLOGICAL EVALUATION

Helps prevent exterior smoke from entering cabin. Provides protection for breathing.

## KINESIOLOGICAL EVALUATION

Strength:	Aids stewardess in performing functions
Speed, accuracy:	May delay getting help from stronger passenger if needed to open door.

## COMPATIBILITY WITH OTHER REQUIREMENTS

Creates problem for bosun's chair or conveyor belt concepts.

## EFFECTIVENESS OF SOLUTIONS IN SPECIFIC PROBLEM AREAS:

Prevents interference with stewardess during exit preparation. Prevents or reduces changes for cabin to immediately fill with smoke. Reduces breathing hazards for all ages. Improves interior visibility.

## EFFECTIVENESS OF SOLUTION IN TYPICAL ACCIDENT CASES

## Case 1 - Denver, DC-8

This item could have saved many lives by preventing or delaying the cabin from filling with smoke and hot air, which killed many passengers on their way to exits. However, stewardesses must be in proper place between exit and barrier during takeoff and landing, or ditching to make this concept effective.

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## SONIC INDICATORS FOR EXITS: SENSOR/MANUAL CONTROLLED

CONCEPT DESCRIPTION

## GENERAL DESCRIPTION OF CONCEPT

Sound emitters activated along with emergency exit visual displays to provide auditory location aids. This concept utilizes human sense not affected by reduced visibility in situations of smoke or darkness. Potential sound signals include beepers, siren klaxon horns, tones or voice. The system can be provided with manual activation and/or sensor activation capabilities.

## AREAS OF IMPROVEMENT IN EMERGENCY EVACUATION OF AIRCRAFT

Improvement will include:

- (a) Better exit location in reduced visibility
- (b) Increased motivation due to presence of demanding signal
- (c) Less confusion due to redundant information regarding exit location

## ESTIMATED QUANTITATIVE IMPROVEMENT IN SURVIVABILITY

System would provide better evacuation flow, particularly in situations of poor visibility (generally the most critical) which occurs in about 25 percent of cases.

## HOW NEW IS THIS CONCEPT?

Auditory signals have been used for both warning and location displays previously. One airline has performed demonstration of sonic devices for potential use as location aids on aircraft. Two systems were tested: a set of eight oscillating tones loudspeakers developed by the Huyck Systems Co of Long Island, N.Y., and a set of beeping devices. The Huyck system produces an oscillating tone varying in frequency from 700 to 1,700 cps and intensity from 70 to 90 db. The airline-applied beeping devices consisted of eight Sonarlert electronic audible signaling units which provided a 2,500 to 2,800 cps tone at 80 to 83 db at 24-volt dc power input. Four units were interrupted

at 60 pulses per minute and four at 75 per minute at an on-off ratio of: on 30 percent - off 70 percent.

The demonstration involved stewardesses in smoke-filled cabins. The results indicated the usefulness of auditory devices in locating exits. The preference for the tones was equally divided. The general conclusion was that they are useful, but require more development and evaluation.

Previous publications: **Unknown**

#### HOW ORIGINAL IS THIS CONCEPT?

The concept of auditory warning and location aids has been utilized previously. However, no clear cut selection criteria for different systems are available. To date, such systems are not operational on commercial aircraft.

#### DETAILED DESCRIPTION OF SYSTEM AND COMPONENTS

The system would be located at each exit to provide both an alerting signal to passengers to evacuate and a location aid in situations of reduced visibility.

The system can be activated by manual controls provided to the flight and cabin crews and/or by a g sensor that automatically actuates the signal independently or in combination with other automatic evacuation systems.

Auditory signals have certain characteristics which must be considered in specific applications. The environmental noise, the characteristics of auditory devices, and the purpose of the signal are all factors in proper selection. For use in commercial aircraft during emergency conditions as a location aid, consideration must be given to the wide range of sound to be expected. Consequently, the choice of signal must avoid masking, perceptual confusion, eliciting negative emotional reactions or just adding to the general confusion. As there are no established criteria for selection except the general requirements indicated, any or all of several devices are potential candidates. These include oscillating tones generated by klaxons,

horns, whistles, sirens, buzzers, bells, gongs, or combinations of tones. Selection should be a result of an evaluation program designed to determine effectivity, perceptibility, and noninterference with other auditory systems (communications). In addition, the system should not contribute to panic or confusion.

### CONCEPT EVALUATION

#### OVERALL SUMMARY RATING

The cost-effectiveness of a system that has been proven effective should be high considering the small cost per aircraft. However, due to the lack of complete results of tests and development, this assessment would be contingent upon satisfaction of this requirement.

#### ENGINEERING FEASIBILITY

All of the components of the system are developed items and consequently within the state-of-the-art. This assumes that current auditory signal devices meet the requirements for aircraft emergencies. This is apparently justified by preliminary demonstrations. Power, weight, volume, and installation requirements are minimal and, consequently, the system is a potential retrofit item as well as a candidate for new aircraft.

#### PSYCHOLOGICAL EVALUATION

Auditory devices have certain characteristics that are potential problems for utilization in aircraft evacuations. These include difficulty in detection in a noisy environment, and poor directional perception under certain conditions, adding to confusion or interfering with passenger and crew communication and eliciting detrimental emotional effects. Proper selection and testing should eliminate these problems, however.

On the positive side, an auditory device could significantly improve location of exits in conditions of reduced visibility which can be expected in many emergency evacuations.

#### COMPATIBILITY WITH OTHER REQUIREMENTS

The system is intended to provide redundancy to the visual displays located at the exits under normal conditions and function as the primary

mode in conditions of reduced visibility. Consequently, it is compatible with existing systems and is, in fact, an improvement. It is also compatible with other proposed sensor-operated emergency evacuation systems.

#### EFFECTIVENESS OF SOLUTION TO PROBLEM AREAS

The beneficial effects include:

- (a) Some decreases in failure to start evacuation
- (b) Use of correct exit
- (c) Location of exit under poor visibility
- (d) Increase passenger flow rate

All these have been major factors in loss of life in emergency evacuations.

## FAN INDICATION FOR EXIT

### GENERAL DESCRIPTION OF CONCEPT

This concept includes battery-powered fans located near exits intended to provide a tactual/cold-hot air movement indication in darkness and smoke as well as assist in the clearing of the air.

### AREAS OF IMPROVEMENT IN EMERGENCY EVACUATION OF AIRCRAFT

In situations of intense smoke or darkness, or where emergency illumination is inadequate, a tactual (air movement and/or temperature differential) indicator could provide the necessary cue for exit location. Also the system, if properly designed, could be effective in elimination of some smoke in the area of the exit, thus aiding evacuation and possibly eliminating some deaths by toxic inhalation.

### ESTIMATED QUANTITATIVE IMPROVEMENT SURVIVABILITY

Emergency evacuation conditions in which visibility conditions are degraded, and passengers and crew are not overcome by toxic inhalation, are relatively infrequent. However, they present critical problems for evacuation systems. Consequently, the increase in survivability of approximately 20 percent must be evaluated with the probability of the unique but critical conditions in which this concept would be effective.

### HOW NEW IS THIS CONCEPT?

The purposeful utilization of this concept is new; however, the use of air movement or temperature differences generated by open doors are commonly used by people escaping from smoke-filled buildings or other similar circumstances.

### HOW ORIGINAL IS THIS CONCEPT?

The purposeful utilization of this type of tactual cue for evacuation is quite original.

## DETAILED DESCRIPTION OF SYSTEM AND COMPONENTS

This system has two proposed configurations. The first is a simple overhead fan and the second includes external intake and exhaust fans for more complete smoke and fume removal. The first configuration is composed of a battery-operated overhead fan whose main purpose is to generate movement of air for exit location. The fan would be located above an exit and, once the exit was opened, could partially exhaust the area of the exit of smoke. The fan would be activated by sensor (automatically) or by the crew (manually.)

The second configuration would utilize a smoke and fume removal system such as envisioned in concept 59-F. This could include external air intake and cabin exhaust fans operated by batteries and activated by impact or smoke sensors or by the crew. These fans could be located at exit areas and thereby function as tactual indicators through the movement of air and the intake of fresh air. This system would provide the necessary tactual cue as well as remove the smoke and fumes from the exit area.

## CONCEPT EVALUATION

### OVERALL SUMMARY RATING

The cost-effectiveness of this system must be rated low (or unfavorable) because of the lack of validation of the basic feasibility of removal of smoke, especially the simple overhead fan configuration as well as the effectiveness of tactual stimulation of this sort.

### ENGINEERING FEASIBILITY

The effectiveness of removing large quantities of smoke that develop in current aircraft fires presents a difficult problem. The volume of air movement would have to be considerable and, if effective, could lead to further problems of providing fresh oxygen to the fire. Some preliminary evaluation of the effectivity of fans should be accomplished prior to any conclusions as to the engineering feasibility. The installation of such fans and the provision of exterior intakes and vents also present potential engineering problems as to the effects on aerodynamics and structural integrity. Another problem would be introduced by the vents becoming sources of flooding during ditching operations.

**PSYCHOLOGICAL EVALUATION**

The use of air movement and/or cold-heat air sensations for tactual perceptions is within human capabilities. The effects of fear and partial toxicity upon the sense organ thresholds have not been fully evaluated.

**COMPATIBILITY WITH OTHER REQUIREMENTS**

As the system is intended as a redundant exit location aid, it offers no incompatibility in this regard. Potential problems arise with ditching and fire suppression. The concept is also potentially combinable with concept 59-G.

**EFFECTIVENESS OF SOLUTIONS FOR SPECIFIC PROBLEMS**

These would include solution to problems of:

- (a) Inability to see exit.
- (b) Toxic inhalation death or incapacitation.

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## FLOOR LEVEL LIGHTING FOR FIRE/SMOKE CONDITIONS

CONCEPT DESCRIPTION

## GENERAL DESCRIPTION OF CONCEPT:

The concept includes utilization of emergency, battery-powered floor level illumination for smoke conditions in an upright aircraft in which passengers must crawl to get best breathing conditions. The floor lighting would also be useful as visual aids in situations of inverted or partially inverted aircraft attitude. The system can be activated either automatically or manually.

## AREAS OF IMPROVEMENT IN EMERGENCY EVACUATION OF AIRCRAFT

Improvement would include:

- (a) Faster exit location in smoke.
- (b) Faster egress in smoke.
- (c) Faster exit location in aircraft inverted attitude.

## ESTIMATED QUANTITATIVE IMPROVEMENT IN SURVIVABILITY

Conditions of smoke and aircraft attitude require the utilization of floor level lighting exit in approximately 20 percent of emergency evacuations. For these situations, it can be expected that this system would provide a 25 percent decrease in passenger egress time as well as saving lives otherwise lost because of severe degradation of visibility (smoke) or lack of visible display (inverted attitude).

## HOW NEW AND ORIGINAL IS THIS CONCEPT?

Floor level lighting has been used in many situations (theatre aisles, for example) primarily to assist safe movement in darkened areas without distributing the overall low illumination. One airline currently installs lights under seats. The floor level lighting has proven satisfactory in these situations, and should be especially useful in the aircraft environment of degraded visibility caused by smoke. Floor level illumination levels at exit areas have previously been specified by regulation. The uniqueness of this

concept lies in the emphasis on the illumination of aisleways as well as exit areas by sources placed as low as possible to best avoid their being obscured by smoke, which it is presumed will first rise to the ceiling areas as it is accompanied by heated air.

#### DETAILED DESCRIPTION OF SYSTEMS AND COMPONENTS

Two basic configurations are envisioned: (1) a floor level floodlighting, and (2) illuminated pathway markings. The first configuration would utilize fluorescent (concept 52-C) or incandescent lamps mounted under seats or low on walls to illuminate seat and main aisles to permit location of exits in cases where ceiling emergency lights are obscured by smoke. This configuration would be used with some other exit directional indicators such as fixed arrows, lines, or lettered signs.

The second configuration for floor level lighting would be visual directional indicators, passive or active (concept 24-C) utilizing incandescent or electroluminescent techniques. This technique would provide little general flood-lighting, but would indicate exit direction for crawling techniques or egress in inverted aircraft. Such lamps should be mounted at or below floor level, directing light upward.

Either system would be activated by sensors automatically or by manual activation by crew. They could also function as normal adjunct lighting for passenger boarding/deboarding.

Such use is desirable to provide an opportunity for passenger familiarization with the displays and their relationship to exits. For best safety, such lights should be on emergency power during takeoff and approach.

The lights would have battery power, connected to a trickle charge and relay which automatically energizes them in case of loss of main power.

#### OVERALL SUMMARY RATINGS

Moderate cost-effectiveness can be expected for adoption of this concept singularly. However, if it were included as part of a total illumination system, its cost-effectiveness would increase.

### ENGINEERING FEASIBILITY

The utilization of floodlighting requires no development outside of insuring proper illumination of floor and adoption of suitable adjunct directional aids. The use of electroluminescent or ultraviolet directional aids would require consideration of problems related to visibility, location, and, in the case of ultraviolet, energizing light source requirements.

### PSYCHOLOGICAL EVALUATION

The concept permits the utilization of a crawling technique in evacuation situations of heavy atmospheric toxicity, provides suitable lighting for inverted aircraft attitudes, as well as illuminating the floor which may be badly cluttered during an evacuation. As such, it is a valuable aid in a variety of emergency evacuations.

Some difficulties can be expected in development of suitable illumination levels in heavy smoke conditions. Extensive testing to establish requirements to various heights is required. There is also the basic question as to the willingness of passengers to utilize a crawling procedure for evacuation. It is mandatory that suitable exit directional aids (tactual, visual, or auditory) be provided along with the floodlighting to assist in egress. Electroluminescent displays may be insufficient in illumination level for use in smoke conditions.

### COMPATIBILITY WITH OTHER REQUIREMENTS

For the floodlighting configuration, suitable exit directional aids are required. Refer to concept 26-C, 27-C, 2-C, 3-C, 24-G, or 44-C. For the use of ultraviolet, refer to 52-C.

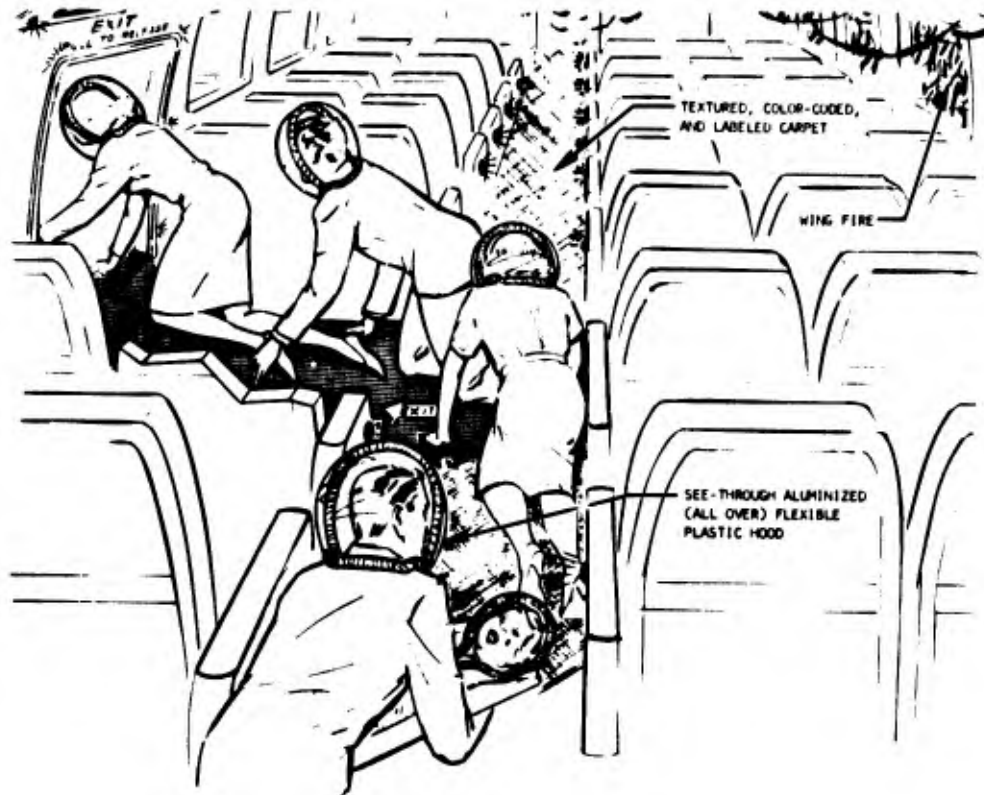
### EFFECTIVENESS OF SOLUTION IN SPECIFIC PROBLEM AREAS

This concept can furnish effective solution for the following problems:

- (a) Impaired vision due to smoke
- (b) Difficulty in using crawling procedure to avoid toxic inhalation
- (c) Lack of suitable illumination in inverted aircraft attitude
- (d) Difficulty of egress in cluttered aisles

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## CRAWLING PROCEDURE FOR SMOKE/FIRE CONDITIONS

CONCEPT DESCRIPTION

## GENERAL DESCRIPTION OF CONCEPT

Provide instructions to passengers to reach escape hatch by crawling to avoid breathing smoke and hot air. Aircraft crew training includes evacuation practices of the crawling procedure in darkness, including hatch operation.

## AREAS OF IMPROVEMENT IN EMERGENCY EVACUATION OF AIRCRAFT

Safety of egress; protection from inhalation of smoke and hot air in upper part of cabin.

## ESTIMATED QUANTITATIVE IMPROVEMENT IN SURVIVABILITY

20 percent improvement in survivability during evacuation in presence of hot air and toxic smoke.

## HOW NEW IS THIS CONCEPT?

Previous publications: Airline Pilots Association, "1966 Air Safety Forum - Crashworthiness," presentation to the Crashworthiness-Evacuation Conference, Washington, D.C., 29 and 30 March 1966. See also, SAFE Engineering, October/November 1967 (Discussed "braille" marks on floor, walls, and ceiling.)

Patents related: Not applicable

## HOW ORIGINAL IS THIS CONCEPT?

Mentioned in accident reports.

## DETAIL DESCRIPTION OF SYSTEMS AND COMPONENTS

- (a) Provide, with the evacuation direction plan pamphlet for each aircraft model, an instruction to passengers to keep heads down and crawl along escape aisles in presence of fire and smoke.
- (b) Provide emergency lights (g-operated?) at floor level on alternate seats. (Refer to concept 28-C.)
- (c) Provide tactual cues in the floor covering (concept 44-C) so that exits can be located in total darkness.
- (d) Give aircrews training in evacuation in total darkness - using crawling and floor cues. Include hatch operation and aircraft evacuation through the hatch.

CONCEPT EVALUATION

## OVERALL SUMMARY RATINGS

Cost-effectiveness: High

Requires only a change in passenger emergency evacuation instruction cards.

## ENGINEERING/OPERATIONAL FEASIBILITY

No engineering requirements; no maintenance or operational costs.

## PSYCHOLOGICAL EVALUATION

Aids visibility of floor markings and floor-mounted lights, but reduces direct vision of exits. In thick smoke, this is immaterial. Provides easy use of tactual displays on floor, ceiling, or whatever surface is "down."

## PHYSIOLOGICAL EVALUATION

Helps avoid hot air and smoke collected near "ceiling," or whatever surfaces are upward.

## KINESIOLOGICAL EVALUATION

Avoids stumbling over debris, possible impact injury. Slows down rate of travel along aisles due to increased separation. Awkward for older, infirm persons, especially women with long skirts. Creates problem in preparing to enter slide, as head is facing wrong direction. Difficult to carry small children, since arms are needed for locomotion. A squatting or bent-over walk is required for speed.

## COMPATIBILITY WITH OTHER REQUIREMENTS

Doubtful value for use with foam in cabin or Freon fire suppressants (concepts 17-F, 60-F, 63-F, and 51-G); complements tactual displays (concept 44-C), floor level (24-C), moving walkway (9-B). Requires change of attitude, and awkward transition for stand-up entry of slides and escalators (concept 38-B). A sitting position may be better for moving walkways.

## EFFECTIVENESS OF SOLUTIONS IN SPECIFIC PROBLEM AREAS

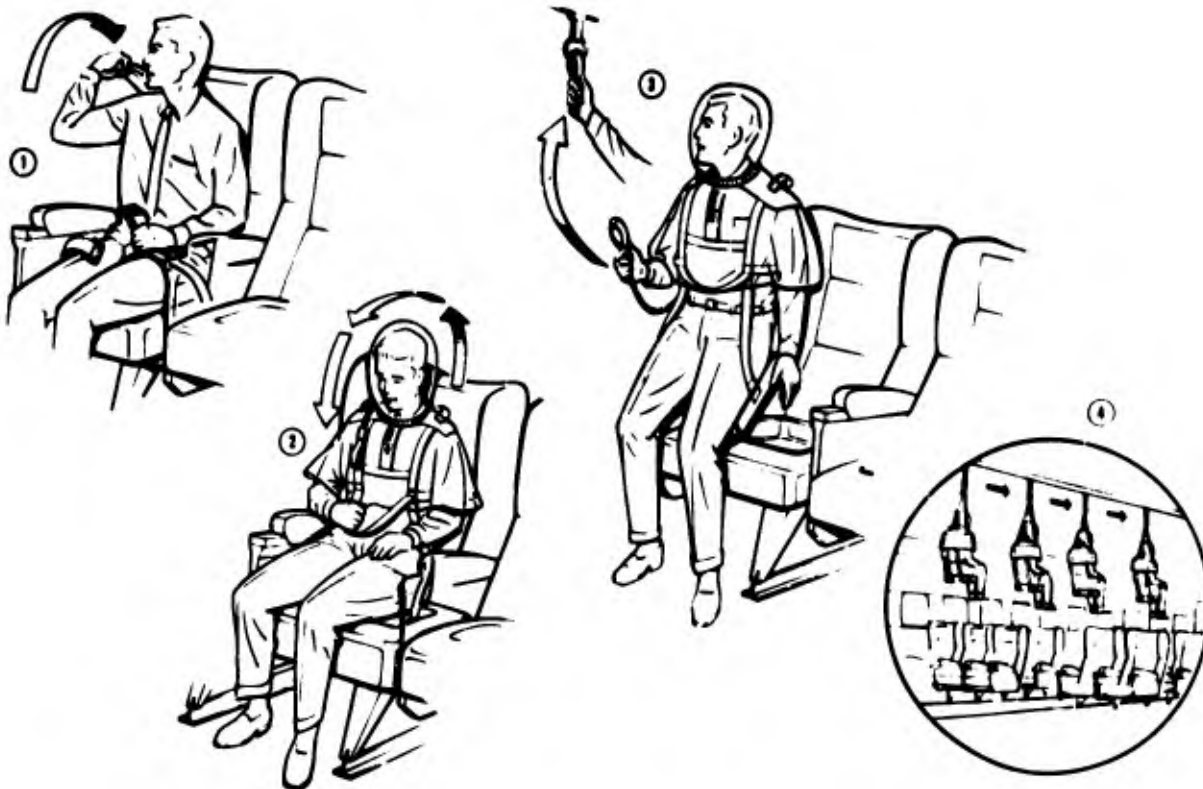
Helps avoid death due to inhalation of heated air and smoke particles.

## EFFECTIVENESS OF SOLUTION IN TYPICAL ACCIDENT CASES

Case 1 - Denver, DC-8

Successful escape of at least one passenger was attributed to this technique. It is presumed that more would have lived had they also used it.

## SEAT BELT, UPHOLSTERY ESCAPE HARNESS

CONCEPT DESCRIPTION

## GENERAL DESCRIPTION OF CONCEPT

An integrated seatbelt, seat, and back cushion arrangement which can be used to support the body by means of a cable hooked to an overhead carrying device and to which can be added a life vest, a smoke and fire protection hood, and a cape and air supply.

## AREA(S) OF IMPROVEMENT IN EMERGENCY EVACUATION OF AIRCRAFT

Improves safety of egress in fire and smoke by protective covering. Spaces passengers and carries them out rapidly if used in conjunction with automatic bosun chair concept. (Refer to concept 7-B.)

## ESTIMATED QUANTITATIVE IMPROVEMENT IN SURVIVABILITY

Potentially 100 percent protection from smoke or drowning during first few minutes after accident.

## HOW NEW IS THIS CONCEPT?

Previous publications: None related to passengers in commercial aircraft.

Patents related: None related to integration concept.

## HOW ORIGINAL IS THIS CONCEPT

Adapted from military aircraft developments or practice. Similar to military antiexposure suits with harness attaching to survival kits in seats, for fighter and bomber crews.

## DETAIL DESCRIPTION OF SYSTEMS AND COMPONENTS

The seat back cushion cover contains pockets for:

- (a) Antismoke and flame hood (at top), quickly deployed either automatically or manually. This may include a reflective material cape for upper body heat protection.
- (b) Life vest on sides which can be pulled out and wrapped around chest, then inflated for overwater accidents.
- (c) Air supply for breathing in antismoke hood.
- (d) A cable and hook arrangement which can be attached to an overhead powered hoist and conveyor system.
- (e) Additional belts/flaps for body support.

The seat cushion cover is connected to the back cushion cover by a cable system to provide a complete chair support when the cable hook is attached to an overhead conveyor.

A deployment strap disconnects these cushion covers from the seat by a manual release or automatic release mechanism.

**DESIGN CRITERIA:**

Based on a preliminary analysis of man-equipment-environment factors, a set of preliminary design criteria has been established. These include the following characteristics:

- Minimum weight
- Minimum bulk
- Flexible
- Minimum cost
- Immediate availability
- Provide some transient measure of respiratory protection
- Facilitate donning of antismoke hood
- Protect face upper torso
- Minimum interference with egress activities, mobility
- Easily, accurately, and reliably deployed
- Easily removed
- Readily replaced
- Producibile from available materials
- Allow visibility

**CONCEPT EVALUATION****OVERALL SUMMARY RATINGS**

Cost-effectiveness: Moderate

**ENGINEERING/OPERATIONAL FEASIBILITY:**

Within current state-of-the-art? Yes

Design requirements definitions of similar devices have been previously performed for military clothing and equipment such as flight clothing, survival gear packs, life vests, pressure suits, and chemical-biological warfare protective devices. Materials and fabrication techniques are available to design and fabricate such devices.

**Weight Penalty**

Estimated maximum additional weight: 5 pounds per passenger, including antismoke hood, breathing devices. No additional drag penalty will be associated.

### Volume Penalty

Minimal volume requirement is possible by use of seat cushion cover material as part of device. Hardware can be tucked into corners of seat.

### Complexity/Reliability

This consideration is a significant problem of design and development to insure all the functional parts work as intended. Several possible failure modes exist in deployment, strength of parts, and snagging of materials. A possibility of inadvertent deployment also exists.

### Maintenance

Wear and tear could be significant, and replacement costs would be much higher than for normal seat cushion because of the engineering development and fabrication costs of the cushions. However, detaching the cushion covers would be rapid and easy. Replacement could be more expensive than at present in that a separate safety inspection might be required to insure proper installation. However, the design could make the installation itself relatively rapid. A greater logistics problem may be introduced because complete, fabricated sets would need to be stocked, not just cloth and patterns.

### Failure Mode Effects

A problem of personal entanglement could occur with improper use. This could result in delay. If the potential safety features of the device are simply not used, the passenger would be in essentially the same condition as he is today. If some persons use the harness and others do not, there could be a problem of decisions at exits and in aisles, especially in the "bosun-chair" mode. (Refer to concept 7-B.)

### Restowage

Ease of restowage following use for actual or imagined emergencies may be improved by design, but potentially all seats of the aircraft will be affected and require individual attention as to color matching, cleaning requirements, repackaging, and reinstallation.

## PSYCHOLOGICAL EVALUATION

The method of use of the harness must be made as simple and obvious as possible. This may be difficult and require extensive human engineering effort, especially when considering persons of low educational background or different cultures.

### Behavioral Psychology

Some persons will find the operation of a harness system and a hood objectionable or frightening. They may panic if entanglement or nondeployment of any portion occurs. Another possible danger is overconfidence in ability to enter or stay too long in fire and smoke-filled areas.

### Motivation and Psychology

Opposing factors may operate here. Some passengers may object to being confined or covered at all. Others may feel more secure or "taken care of" by knowing that some protective covering between themselves and a potentially hazardous environment is available.

## PHYSIOLOGICAL EVALUATION

Aids in reduction of problems of visibility due to tears or facial pain from heat, potentially eliminates death or injury from hot air or toxic fume inhalation if rapidly deployed. Will not be of special help to babies unless problem carefully considered in design. Provides antiexposure covering against snow, rain, sleet, radiant heat.

Heat or cold tolerance is improved by additional insulation.

## KINESIOLOGICAL EVALUATION

### Speed Accuracy:

The manual deployment will require increased skills and coordination to effectively use the devices.

## COMPATIBILITY WITH OTHER REQUIREMENTS

Requires concept 6-A. Designed to go with concept 7-B.

31-A

31-A

EFFECTIVENESS OF SOLUTION IN TYPICAL ACCIDENT CASES

Case 1 - Denver, DC-8

Device could have provided protection against inhalation of smoke through use of concept 6-A.

FIRE CONTAINMENT PANELS/CURTAINS -  
INFLATABLE AND DETACHABLE

CONCEPT DESCRIPTION

GENERAL DESCRIPTION OF CONCEPT

Firewalls made from fireproof curtains, or drapes, and structural partitions will create barriers to prevent the propagation of fire and circulation of smoke, toxic gases, acrid fumes, and heat.

AREAS OF IMPROVEMENT IN EMERGENCY EVACUATION OF AIRCRAFT

Better visibility and atmospheric environment outside of affected compartment will improve conditions for passenger survival and reduce exit time.

ESTIMATED QUANTITATIVE IMPROVEMENT IN SURVIVABILITY

Reduction in wrong exits tried:	25 percent
Fire/smoke survival:	20 percent

HOW NEW IS THIS CONCEPT?

Previous publications: Federal Aviation Agency, Minutes - FAA-Industry Conference on Crashworthiness and Passenger Standards for Transport Category Airplanes, Flight Standards Service, 29 and 30 March 1966

Patents related: Possibly firewall doors used in hallways in buildings.

HOW ORIGINAL IS THIS CONCEPT?

Bulkheads with doors are used in ocean and submarine vessels to control water leakage and fire. Concept is similar to usage of firewall doors to close off hallways and prevent spreading of fire, smoke, hot gases, etc, in buildings - also fire curtains used in theaters.

## DETAIL DESCRIPTION OF SYSTEMS AND COMPONENTS

Future commercial aircraft should incorporate partitions (bulkheads) which divide the fuselage into passenger compartments. The partitions would form barriers to prevent the propagation of fire and the spreading or circulation of smoke, acrid fumes, heat, etc.

The number of partitions and size of compartments should be determined by several factors. An increase in the number of partitions would impede or diminish the spread of smoke and fire. However, the size of the compartment must be determined by the number of its passengers and the accessibility of an adequate number of emergency exits and/or doors to enable complete passenger evacuation from each compartment in the required minimum time.

An increase in passenger density will require an increase in the number and size of emergency openings. This weakens the fuselage structure and results in a weight penalty in providing the necessary strength. It is believed, with proper design, the incorporation of the bulkhead compartments will strengthen the overall fuselage and have a tendency to offset any weight penalty resulting from an increase in number and size of emergency exits. For multiple-deck aircraft, the structural partitions or bulkheads should help provide an efficient lightweight design.

It should be mentioned that the partition doorways located at each aisle should be provided with fireproof curtains. The design of the curtains should be such that passengers can pass through when they are drawn closed (vertical joints or slits). To provide emergency smoke barrier protection, it would be advisable to have the curtains closed during takeoff and landings since most accidents occur during these phases of flight. The passengers would have a tendency to become familiar with and use the emergency exits provided for their compartment. Strong visual signals directing them to usable exits will be required.

To augment the fire, smoke, and heat barrier concept, partial partitions should be located laterally across the upper ceiling of the fuselage. With proper design, they could also provide stowage provisions and help reduce the hazards of flying debris such as hand baggage and carry-on parcels, etc.

This concept has been discussed on a basis of requirements for future aircraft. However, the same concepts can be applied to existing airplanes. The partitions need not be structural members. Close-fitting fireproof curtains may prove adequate to do the job.

## CONCEPT EVALUATION

### OVERALL SUMMARY RATINGS

Cost-effectiveness: Moderate

Although the subject of many conflicting arguments, it would appear that this concept and its interconnection with others listed in this study could provide an increased overall level of safety at a reasonable cost.

### ENGINEERING FEASIBILITY

Within the current state-of-the-art. Requires the application of fire curtain design methods and upholstery techniques to cabin interior, and special design attention to closing devices, especially to prevent inadvertent closure and entrapment of passengers.

### PSYCHOLOGICAL EVALUATION

Human engineering: May improve passenger vision in other compartments to extent that smoke is reduced. However, visibility to other compartments is lost. Furthermore, the curtains may increase fear and feelings of claustrophobia in some persons. Strong indications of exit capability and obvious methods of egress are needed.

### PHYSIOLOGICAL EVALUATION

To the extent that the curtains reduce local fire and smoke, the passengers would benefit physiologically.

### KINESIOLOGICAL EVALUATION

No benefit kinesiologicaly and may require improved strength if it becomes necessary for the passengers to escape via the cabin aisle.

### COMPATIBILITY WITH OTHER REQUIREMENTS

Concept 1-B would require duplication in each compartment. Communication devices, such as 2-C, 40-A, and 48-A might be degraded. Situational

passenger control, i.e., 7-B, 9-B, 24-G, 53-L, 36-B, and 49-C, would be negated. In addition, increased exits and escape devices would be required.

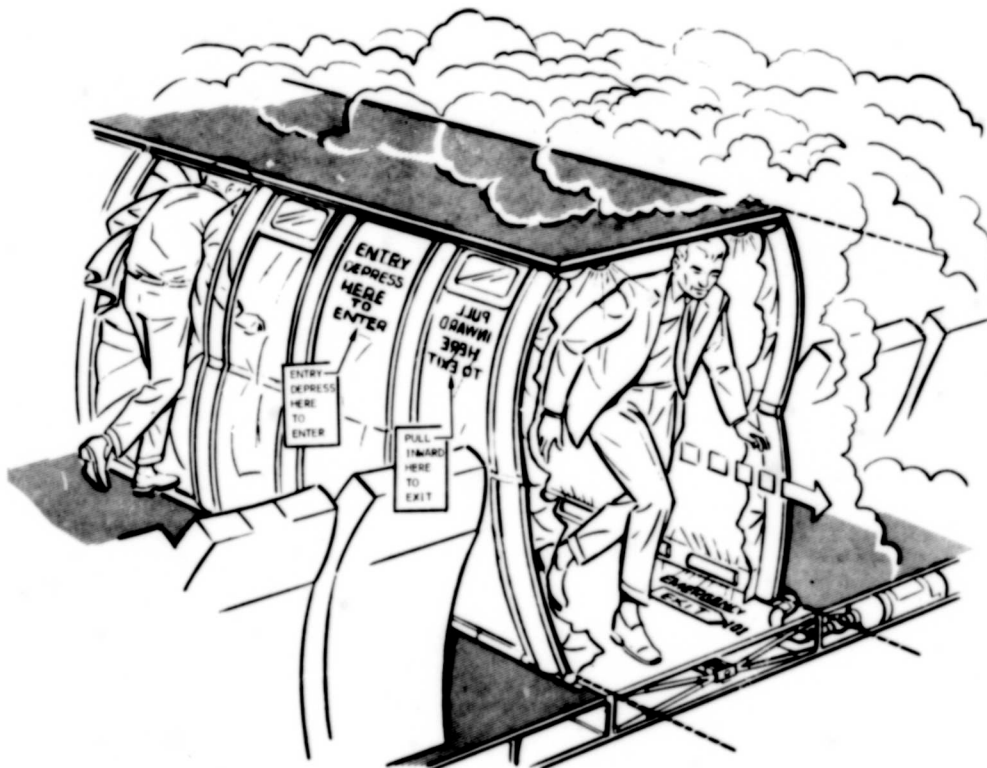
#### EFFECTIVENESS OF SOLUTIONS IN SPECIFIC PROBLEM AREAS

May improve smoke problems of man, i.e., visibility, tears, pain and inhalation. May improve structural integrity of fuselage if proper design accommodations are made. Should reduce spread of fire.

#### EFFECTIVENESS OF SOLUTION IN TYPICAL ACCIDENT CASES

##### Case 1 - Denver, DC-8

In this case, since apparently a few of the tourist passengers escaped through the first-class exits, additional lives could have been lost if the aisle had been blocked; even if the curtain had been operable, it could have constituted an additional psychological barrier (apparently the existing floor-to-ceiling partition constituted a visual and/or psychological barrier as it was). Furthermore, the firewall would not have reduced the influx of smoke which was entering the only available exit. However, a curtain placed very close to the exit area might have restricted smoke entry into the majority of the rear cabin where passengers were waiting to egress.

**INFLATABLE ANTISMOKE TUNNEL IN AISLEWAY****CONCEPT DESCRIPTION****GENERAL DESCRIPTION OF CONCEPT**

A tubular protective tunnel deployed in the aisleway by means of inflatable structure provides a smoke-free, lighted pathway to exits.

**AREAS OF IMPROVEMENT IN EMERGENCY EVACUATION OF AIRCRAFT**

Improved safety of egress. Protection of passengers from smoke, hot air, or fumes along pathway to exits does not depend on individual willingness or capability to put on a personal antismoke hood.

### ESTIMATED QUANTITATIVE IMPROVEMENT IN SURVIVABILITY

Potentially capable of 100 percent protection against smoke and fumes which erupt outside of aisleway after aircraft has stopped.

### HOW NEW IS THIS CONCEPT?

Previous publications: None related to smoke tunnel concept in public buildings.

Patents related: 3,018,867, "Inflatable Escape Chute," Heyniger, 10 July 1960

### HOW ORIGINAL IS THIS CONCEPT?

Original with this study as far as is known to study team.

### DETAIL DESCRIPTION OF SYSTEMS AND COMPONENTS

An inflatable structure stored under the floor rug or in the baggage rack or ceiling is deployed at time of crash by g-switch or heat sensors or manually by stewardess. It erects in the aisleway and provides a smoke barrier tunnelloid shelter for passengers who move into aisleway. It is partially or completely made of transparent, heat-resistant plastic and provided with "chemical light" illumination and directions or exit markings. It is supplied by low flow rate of bottled air to aid smoke and fume removal. Flaps are provided at each end and at each row of seats for passenger entry and egress. It may be made compatible with the conveyor belt concept by attaching it to both sides of the aisleway. Cross-aisle sections can also be installed for double-aisle configurations or for access to exits.

### CONCEPT EVALUATION

#### OVERALL SUMMARY RATINGS

Cost-effectiveness: Moderate

Considerable weight and design revision required, but potential for smoke protection is good. However, overall speed of egress may be slower.

### ENGINEERING FEASIBILITY

Within current state-of-the-art. Standard inflatable structure techniques and currently available materials can be used. Detail design development required. Significant weight increase required over current designs. Maintenance costs could be considerable. Restowage/repair costs would depend on design. Reliability fairly good if redundant sources provided. Volume requirements relatively small. Fail-safe if not inflated. Easy egress if punctured.

### PSYCHOLOGICAL EVALUATION

Human engineering: Requires some study for best method of entry/exit flap/seal methods.

Balance of interior-exterior lighting required. Some problem with claustrophobia in confined space, but transparency of materials, and lighting would help this.

### PHYSIOLOGICAL EVALUATION

Possibly provides excellent protection from smoke, hot air inhalation, and Freon gases, "Light Water," or foams used for fire suppression.

### KINESIOLOGICAL EVALUATION

Crowded conditions in tunnel would restrict movement. Time required to enter tunnel and reseal may slow down flow of passengers noticeably. However, omission of personal hood may save time, overall.

### COMPATIBILITY WITH OTHER REQUIREMENTS

Not compatible with bosun's chair concepts, or overhead hatch and aisleway combination. Similar in purpose to concept 35-B, differing mainly in stowage areas and degree of closure. Special design required to accommodate overturned fuselage.

**EFFECTIVENESS OF SOLUTIONS IN SPECIFIC PROBLEM AREAS**

Aids in getting to exit in smoke; prevents inhalation of smoke, fumes, and hot air for extension of escape time. Tends to throw debris out of aisleway if not too heavy. Flexible - accommodates some fuselage distortion. Difficult to use in overturned aircraft. May delay life raft launchings.

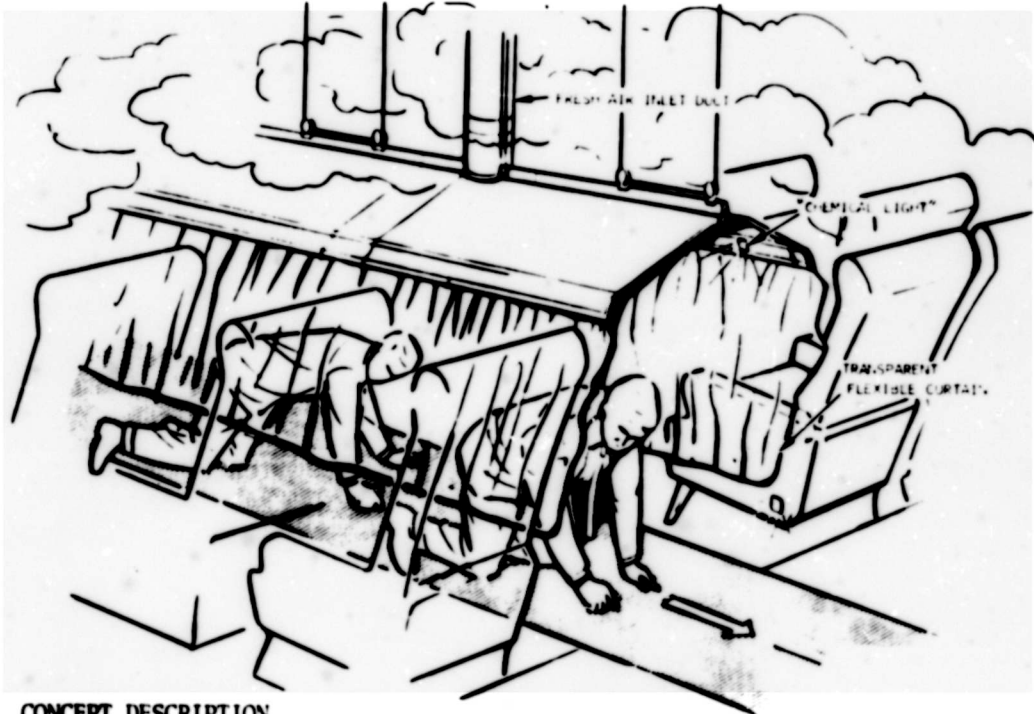
**EFFECTIVENESS OF SOLUTION IN TYPICAL ACCIDENT CASES****Case 1 - Denver, DC-8**

Potentially could have protected all passengers who died from smoke and hot air inhalation before reaching an exit from the rear compartment.

**Case 2 - Salt Lake City, B-727**

Some protection would have been afforded, but interior flame propagation may have been too rapid and hot for capacity of this concept. However, it would have worked well with a fire suppressant system such as Freon, "Light Water," or foam.

### AUTOMATIC, MANUAL ANTISMOKE HOOD AND FANS IN AISLES



#### CONCEPT DESCRIPTION

##### GENERAL DESCRIPTION OF CONCEPT

An antismoke hood is deployed over the aisleway to protect the heads of evacuating passengers and provide breathing space for evacuating smoke from local area.

##### AREAS OF IMPROVEMENT IN EMERGENCY EVALUATION OF AIRCRAFT

Improved safety of egress, protection from eye damage, protection from breathing smoke.

##### ESTIMATED QUANTITATIVE IMPROVEMENT IN SURVIVABILITY

100 percent complete protection from smoke inhalation if design concept is effective.

## HOW NEW IS THIS CONCEPT?

Previous publications: None

Patents related: None

## HOW ORIGINAL IS THIS CONCEPT?

Original concept: Reverse of cooking hood

## DETAIL DESCRIPTION OF SYSTEMS AND COMPONENTS

A hood device is made to drop from the ceiling or erect from baggage racks over the aisleway at height of approximately 5 feet. It is shaped to fit over heads of adult passengers and has side curtains down to shoulder level or, to permit crawling, they may extend lower. It is provided with a central air bottle source metering air in through a manifold at a low rate to help evacuate smoke from the hood area. It is provided with illumination and signs using "chemical light." (Refer to concept 3-C.) Windows are provided, or it may be all transparent except for heat-reflective silvering.

The operation of deploying the hood could be triggered manually by a crew-member or automatically by a crash. It could be inflatable device or a mechanically, actuated device. Its basic purpose within the cabin is similar to concept 6-A, but it does not require each passenger to put on a separate hood over his head. It assumes a flame/smoke-free aisleway.

CONCEPT EVALUATION

## OVERALL SUMMARY RATINGS

Cost-effectiveness: Moderate

Lacks versatility of adjustment to cabin roll attitudes, but saves individual passengers time of donning personal gear.

## ENGINEERING FEASIBILITY

Within current state-of-the-art. Could be designed and manufactured for fabrication from a variety of heat-resistant plastic and metal materials. The greatest problem is a supply of clear air to flush out smoke. Fans could

draw outside air from automatic vent in case of simple interior fire. Provision of air bottles sufficient to effectively flush smoke would require considerable weight and space, but is only sure method for outside/inside fire and smoke. A gravity-powered operation is simplest, but an inflatable device is possible. If the part fails to deploy, it would not be worse than at present. Design may permit quick restowage.

#### PSYCHOLOGICAL EVALUATION

Use of device would be natural and simple in upright fuselage.

#### PHYSIOLOGICAL EVALUATION

Helps prevent injury or death due to inhalation of toxic smoke products.

#### KINESIOLOGICAL EVALUATION

Use would be simple and natural, simply ducking under side curtains to get head into tunnel.

#### COMPATIBILITY WITH OTHER REQUIREMENTS

Incompatible or very difficult to make compatible with bosun's chair (concept 7-B) and overhead hatch and ladder (concept 1-B). Replaces inflatable antismoke tunnel (concept 34-B). Redundant to 6-A (personal smoke fire protection hood mask), 55-A (simple smoke filter), and some aspects of 31-A. Crawling procedure given in 29-E would not be needed for normal upright fuselage condition.

#### EFFECTIVENESS OF SOLUTIONS IN SPECIFIC PROBLEM AREAS

(Not useful for fuselage roll greater than 10 to 20 degrees.) Compatible with all other new concepts. May interfere with life raft access in ditching.

Could be interference if water fills cabin part way, or debris is piled high. May reduce ability to hear instructions by masking noise of fabric folding and by sound absorption or deflection. Some comments apply to concept 34-B.

## EFFECTIVENESS OF SOLUTION IN TYPICAL ACCIDENT CASES

Case 1 - Denver, DC-8

There is a strong indication this device, if it works as suggested, could have saved all passengers in this crash.

Case 2 - Salt Lake City, B-727

This device may have been able to save several more passengers, depending on the rate of spread and direction of the fire. Since fire was burning during most of the deceleration, the deployment of the device may have come too late to save all. Also, the massive fire may have overcome the relatively low capability of this device.

## ESCALATOR EGRESS SYSTEM

CONCEPT DESCRIPTION

## GENERAL DESCRIPTION OF CONCEPT

System 1. Battery-powered escalator from main hatches (doors)

System 2. Self gravity powered escalator from main hatches

## AREAS OF IMPROVEMENT IN EMERGENCY EVACUATION OF AIRCRAFT

Reduced time. Step on and step off is more acceptable than slide. Escalator motion assists rate of flow.

## ESTIMATED QUANTITATIVE IMPROVEMENT IN SURVIVABILITY

Passenger flow rate: 20 percent

## HOW NEW IS THIS CONCEPT?

Escalators have been in use in public buildings for many years. Not in use in present aircraft.

## HOW ORIGINAL IS THIS CONCEPT?

Adapted from nonaircraft fields or practice - public buildings. Application to emergency evacuation of aircraft is original.

## DETAIL DESCRIPTION OF SYSTEMS AND COMPONENTS

Escalator may be equipped with power drive or may be powered by the weight of passengers.

If unit is passenger-powered, a governor must be supplied. This can control the rate of descent so that, with one passenger or 10, the speed of descent is within safe limits.

Theoretical basis of usefulness depends on two factors: (1) People would be more familiar with escalators than slides and favorably disposed to quickly enter an escalator as compared with a slide, since a change in body attitude is not required. (2) Adding the speed of escalator movement to normal rapid stairway movement may permit a total increase in flow rate, even compared to a slide. Assume data show a wide stairway allows 100 persons per 80 seconds. Assuming a flow rate of 3 feet per second per file of persons, adding an escalator, moving 1 foot per second, permits a flow rate of 4 feet per second or a 33-1/3 percent increase, equivalent to 133 persons in 80 seconds.

Escalator structure is packaged in folded position using principle of Pacific Shenandoah Co. mechanisms, and extended from box beneath doorway by nitrogen gas bottle actuator. Battery-powered electrical motor actuates escalator downward motion to initiate action, overcome friction, and govern speed. Weight of passengers aids motion downward, reducing power requirement. The same (or similar) devices could be used to load/unload passengers with ground-powered motor. This could aid familiarization with equipment.

#### Alternate Concept

An additional conveyor belt section in the entryway serves as an additional aid and helps overcome the transition in speed. A handrail which could be nylon rope is necessary to aid stability of upper body.

#### CONCEPT EVALUATION

##### OVERALL SUMMARY RATINGS

Cost-effectiveness: Low

Weight and development costs are high and theoretical benefits not established as yet.

##### ENGINEERING FEASIBILITY

Requires moderate improvement in state-of-the-art. While known design techniques and experience with escalators indicate general feasibility, weight and development costs could be extensive. Maintenance and repair costs could also be significant. Design is relatively complex and may be less reliable than acceptable. However, it is not subject to deflation from heat, abrasion or heel punctures.

Failure to operate by moving the stairs would be fail-safe, and egress could still be accomplished. Failure to extend is more likely, but is less acceptable than failure to inflate in current inflatable slides, since the latter can be used in hand-held mode. Restowability should be easier than inflatable slides, but gas recharging portion of this activity is equivalent. The mechanism and surfaces could be adaptable to "chemical light" illumination.

#### PSYCHOLOGICAL EVALUATION

Human engineering: Conforms to known stereotype of western civilization. Not obvious to other cultures.

Motivational psychology: Some people may be afraid of escalators, in general, causing a hesitation. Trade-off with slide situation unknown to date. Warning signs at ends may be required.

#### PHYSIOLOGICAL EVALUATION

Not applicable

#### KINESIOLOGICAL EVALUATION

Requires good coordination and judgment of speeds to use most effectively, but is well within normal capability.

#### COMPATIBILITY WITH OTHER REQUIREMENTS

Not compatible with slides, combination life rafts and slides, bosun's chair. Can be compatible with conveyor belt system.

#### EFFECTIVENESS OF SOLUTIONS IN SPECIFIC PROBLEM AREAS

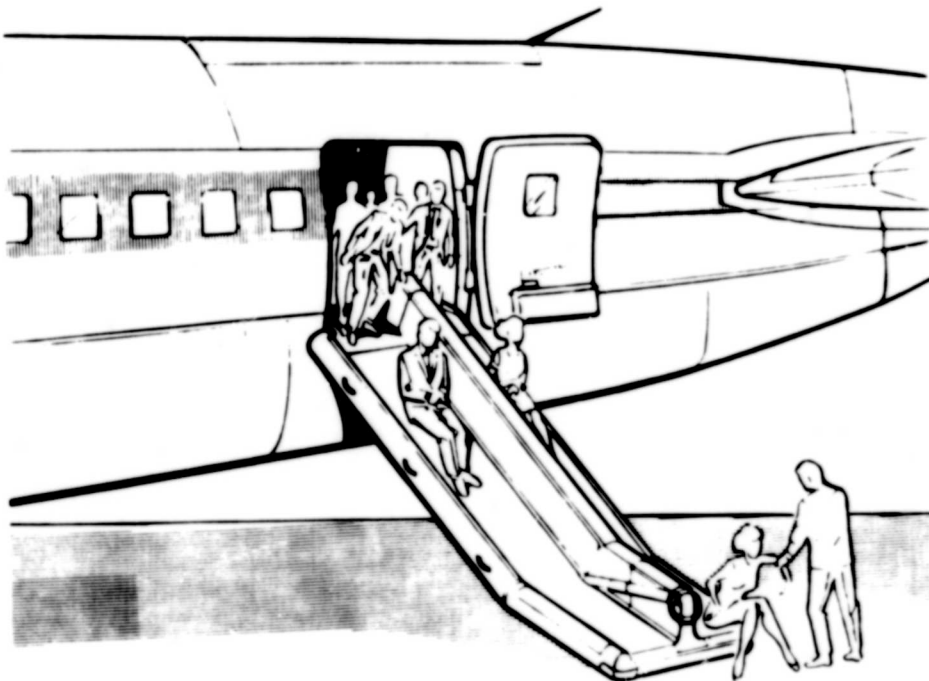
Not useful for overturned aircraft. Not useful for overwing exits.

EFFECTIVENESS OF SOLUTION IN TYPICAL ACCIDENT CASES

Case 1 - Denver, DC-8

Could have aided egress from rear passenger and service doors, helping to evacuate crowded rear compartments more quickly.

## DIVIDER-SEPARATED DOUBLE SLIDE CONFIGURATION

CONCEPT DESCRIPTION

## GENERAL DESCRIPTION OF CONCEPT

Provides an inflatable, semirigid separator fence on double inflatable slides at major exits such as the main entrances.

## AREAS OF IMPROVEMENT IN EMERGENCY EVACUATION OF AIRCRAFT

Reduced time of exit, and improved safety of exit.

The double slide configuration cuts the congestion by providing two adjacent slides, with an inflatable semirigid center divider which aids two persons to slide down side-by-side without hesitation, hitting each other, or tangling arms or legs. A higher point at the ground end helps pull body forward and helps raise oneself up off of the slide.

## ESTIMATED QUANTITATIVE IMPROVEMENT IN SURVIVABILITY

Passenger flow rate: Up to 10 percent

## HOW NEW IS THIS CONCEPT?

Previous publications: Unknown

Patents related - 2,765,131, "Inflatable Escape Chute Assembly," Boyle,  
2 Aug 1956  
2,901,055, "Escape Chute," Fairchilds, et al, 25  
Aug 1959  
2,936,056, "Variable Length Inflatable Escape Chute",  
Heyniger, 10 May 1960  
3,018,867, "Inflatable Escape Chute", Heyniger, 10  
June 1960  
3,102,623, "Escape Slide", Schact, et al, 31 Mar 1960  
Br. 887,449, "Escape Chute", Elliott Equip. Ltd., 17  
Jan 1962  
Fr. 1,163,036, "Escape Chute", 22 Sep 1958

## HOW ORIGINAL IS THIS CONCEPT?

Center divider concept is original with this study.

## DETAIL DESCRIPTION OF SYSTEMS AND COMPONENTS:

The double slide equipment would consist of a relatively recently developed double inflatable slide or two slides mounted side-by-side. Ideally, the two slides concept would include the feature of individual pressurizing equipment for each side, and thus provide for redundancy in the event of malfunction. However, a single control should be provided for ease and speed of operation. Although the slides will operate independently, they will be designed to mate at a center divider section. The center divider is desirable in order to prevent one passenger from blocking egress on both slides. The primary purpose is to prevent hesitation caused by one passenger waiting for another beside him to get well down the slide before jumping. This is hypothesized to encourage increased flowrate. A possible extra advantage is that the passengers could have a higher point (a hand-hold on the divider) to grasp in assisting themselves off of the slide. Provisions of "chemical light" (concept 3-C) along the top side of the dividers would be more efficient overall illumination, as the light can be direct downward.

The center divider would be inflatable and of similar construction to the other elements of the slide. It would be so designed as to improve longitudinal rigidity of long slide chutes. This divider section could take the shape of an I-beam using "Airmat" construction principal.

#### CONCEPT EVALUATION

##### OVERALL SUMMARY RATINGS

Cost-effectiveness: Moderate. Actual improvement in passenger flow rate is as yet untested.

##### ENGINEERING FEASIBILITY

Within current state-of-the-art. Requires engineering ingenuity in reduction of weight and bulk (especially for stowage provisions). All design and maintenance factors should be comparable to present inflatable slides, except weight and volume which may be two to three times as great.

##### PSYCHOLOGICAL EVALUATION

Human engineering: Should improve apparent safety and aid decision process.

Behavioral: Should reduce fear and improve confidence. However, where one member of side-by-side couple is hesitant and they jump together holding hands, the divider could cause a problem.

##### PHYSIOLOGICAL EVALUATION

Not applicable

##### KINESIOLOGICAL EVALUATION

Should reduce demands for accuracy and coordination on passengers, and aid in egress at lower end of slide.

### COMPATIBILITY WITH OTHER REQUIREMENTS

Excludes other slide or egress devices, i.e., concept 7-B, 8-B, 13-B, 14-B, 15-B, 16-B, 31-A, and 38-B except that the divider may be incorporated into some of them if they are of double width.

### EFFECTIVENESS OF SOLUTION IN SPECIFIC PROBLEM AREAS

Reduces passenger hesitation. Improves rate of passenger descent. May be problem in case of noninflation. A light elastic return strap set may need to be installed to permit use as a handheld slide.

### EFFECTIVENESS OF SOLUTION IN TYPICAL ACCIDENT CASES

#### Case 1 - Denver, DC-8

It is believed that the double slide could have resulted in some saving of life at Denver, since the basic fault behind the 16 fatalities was the inability to evacuate before being overcome, due to the slow rate of cabin evacuation. Any improvement in flow rate could have saved additional passengers.

EMERGENCY COMMUNICATION SYSTEM  
FOR EVACUATION CONDITIONS

CONCEPT DESCRIPTION

GENERAL DESCRIPTION OF CONCEPT

Provides a means of communication between pilot, stewardess, and passengers after complete aircraft power shutdown or failure. The concept is to provide a speaker-amplifier system, battery-powered, for emergency conditions.

AREAS OF IMPROVEMENT IN EMERGENCY EVACUATION OF AIRCRAFT

Through adequate communications, the following improvements can be accomplished:

Exit awareness

Passenger and crew preparation

Safe removal of injured personnel

Prevent delays in evacuation from insufficient knowledge by cockpit crew of cabin conditions

ESTIMATED QUANTITATIVE IMPROVEMENT IN SURVIVABILITY

Preparation of exit:	30 percent
Passenger flow rate:	30 percent
Reduction in wrong exits tried:	25-50 percent

HOW NEW IS THIS CONCEPT?

Previous publications:	Schmirler, C., "Crashworthiness and Evacuation as Viewed by the Stewardess," presented at the Thirteenth ALPHA Air Safety Forum, 4 and 5 October 1966 (Notes incidence of serious problem due to lack of communication.)
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Patents related:	Unknown
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### HOW ORIGINAL IS THIS CONCEPT?

This system has been conceived to provide communications for all modes of operation.

### DETAILED DESCRIPTION OF SYSTEMS AND COMPONENTS

This concept is to provide a method in which communications with the passengers can be successfully accomplished during aircraft power shutdown and when emergency evacuation procedures are underway. The concept incorporates the use of a series of 6-inch public address speakers to be housed in the aircraft ceiling, and spaced at 12-foot intervals. The system will contain amplification capabilities of a public address system (in the order of 125-watt amplifier at 3 percent distortion, 200-watt peak) for adequate power distribution to each series of speakers. The power requirements for the emergency system will be supplied through battery power packs, and function independently of regular aircraft power systems. For each passenger compartment on board, a separate speaker series, amplifier, and battery power pack system will be employed. There will be a limitation of four speakers per system, with a three-pole switch located at the amplifier to provide capabilities of communicating in the following modes: (1) stewardess to pilot, (2) stewardess to the respective compartment, and (3) to all other compartments. Each stewardess will be provided with a headset and mike with a 12-foot extension cord capability. Headset jacks will be installed along both sides of each outer bulkhead at 6-foot intervals; all bulkhead jacks will be commoned to feed into their amplifiers at each compartment communication center. This concept will provide the stewardesses with capabilities of maintaining a freehand state during emergency modes. At each station or compartment, there will also be an additional two-pole switch which will provide a power selection for either (1) aircraft power or (2) emergency battery power pack. This communication concept may be utilized as the regular flight communications requirement by providing aircraft power to the amplifiers and maintaining battery power as emergency reserve.

### CONCEPT EVALUATION

#### OVERALL SUMMARY RATINGS

Moderate initial cost; will provide high rate of effectiveness.

#### ENGINEERING/OPERATIONAL FEASIBILITY

Requires slight modifications over state-of-the-art, off-the-shelf equipment. Direct installation of entire system with low volume and weight costs to aircraft.

#### PSYCHOLOGICAL EVALUATION

This system can aid in decision-making by crew, using knowledge of conditions in other parts of aircraft, and helps to reduce panic and confusion.

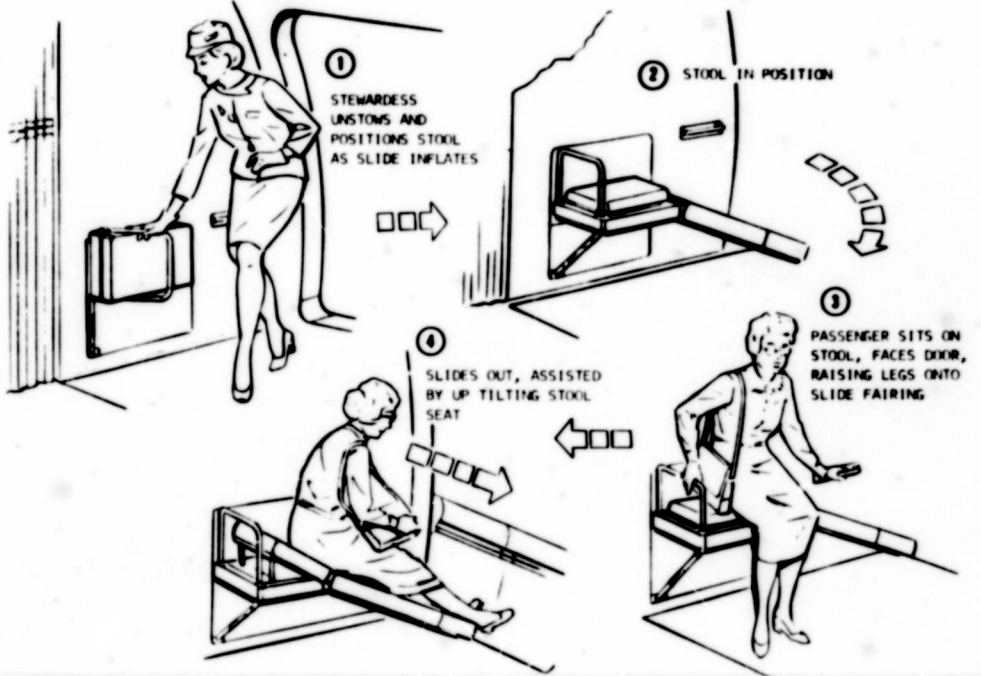
#### KINESIOLOGICAL EVALUATION

The system can be easily operated by the crewmembers, but is a limiting factor for movement from one place to another due to need of unplug and replug cord.

#### EFFECTIVENESS OF SOLUTIONS IN SPECIFIC PROBLEM AREAS

Can help prevent delays in evacuation by rapid communication of situation from cockpit to stewardess and vice versa. Provides a communication system that can be initiated after the loss of aircraft power. This system can be capable of providing clarity, and high voice amplification. Can prevent unnecessary evacuations due to strange noises from other end of aircraft.

## SITDOWN SLIDE ENTRANCE

CONCEPT DESCRIPTION

## GENERAL DESCRIPTION OF CONCEPT

Provide stool, ledge, ramp, or other device to permit passengers to sit down at chair level before entering slide to avoid hesitation of jumping into slide.

## AREAS OF IMPROVEMENT IN EMERGENCY EVACUATION OF AIRCRAFT

Reduces lost time due to elderly, or balky, hesitant passenger. Provides smoother, safer slide entry, with less danger of falling, bouncing, or tripping.

### ESTIMATED QUANTITATIVE IMPROVEMENT IN SURVIVABILITY

Passenger flow rate: 10 percent

Assuming one hesitant passenger in 15 takes 5 seconds, whereas others take only 2 seconds average, the 3-second loss results in 1.5 persons not accommodated of the 15 persons potential.

#### HOW NEW IS THIS CONCEPT?

No previous publications.

Patents related: None

#### HOW ORIGINAL IS THIS CONCEPT?

Original with this study. Not previously used in other areas.

### DETAIL DESCRIPTION OF SYSTEMS AND COMPONENTS

#### Basic Concept

A stool with a rotating seat is mounted adjacent to the exit by a bulkhead. Just below the seat of the stool is a bench-slide combination surface fairing into the surface of the slide. The passenger sits down on the seat, with his back against the bulkhead, rotates his body, swings his legs up onto the slide fairing and pushes off the stool seat onto the fairing, thence onto the slide. Rotation of the stool seat or pulling on an assist bar can trip an upset bar mechanism in the seat allowing it to tip the outer side downward and assist the passenger's downward and outward motion onto the slide.

#### Alternate Concept

A saddle-shaped stool surface and slide fairing is free-standing in front of exit. Passenger straddles stool, sits down onto it, and raises legs onto a slide fairing which leads him down into slide.

CONCEPT EVALUATION

## OVERALL SUMMARY RATINGS

Cost-effectiveness: Moderate

Primarily useful for elderly, infirm ambulatory passengers.

## ENGINEERING FEASIBILITY

Within current state-of-the-art. Detailed design and testing methods are applications of standard procedures. Adds weight to interior structure attachments. Requires extra space for storage. Approximately 1.5 cubic feet maximum. No power required to actuate once set up. Mechanism fairly simple.

Failure mode safety: Walk around or restow if will not stay up; not serious.

## PSYCHOLOGICAL EVALUATION

Human engineering: Operation appears to be natural, relatively obvious.

Motivational psychology: Straddling action may be distasteful, awkward for some.

## PHYSIOLOGICAL EVALUATION

Not applicable

## KINESIOLOGICAL EVALUATION

Requires fair coordination to be effective unless assisted by others. May require additional actions to erect or place in position. Aids infirm and elderly but may impede able-bodied.

## COMPATIBILITY WITH OTHER REQUIREMENTS

Not necessary, or incompatible with, passenger conveyor belts, escalator, bosun's chair or similar concepts where passengers are carried or are pre-positioned by other means. May cause additional constriction at exit if fail-safe, adequate design is not developed.

41-B

41-B

EFFECTIVENESS OF SOLUTIONS IN SPECIFIC PROBLEM AREAS

Aids slide entrance for elderly or infirm.

EFFECTIVENESS OF SOLUTION IN TYPICAL ACCIDENT CASES

Case 1 - Denver, DC-8

Insufficient detail information to assess value. Assumed not a significant solution to problems in this particular accident.

Case 2 - Salt Lake City, B-727

Not designed for major improvement in evacuation for this type of accident.

## SEAT BOTTOM FOLDUP OR WARNING

CONCEPT DESCRIPTION

## GENERAL DESCRIPTION OF CONCEPT

Concept involves (1) a folding seat bottom which would lift passenger into near erect position during folding, (2) warning devices, and/or inflatable seat cushions.

## AREAS OF IMPROVEMENT IN EMERGENCY EVACUATION OF AIRCRAFT

Reduced time of passenger egress. Concept is designed to aid in overcoming initial shock of crash, which in some persons results in a long delay before they begin to unfasten belt and get up. If seat bottom fold method used, it helps provide a wider access to emergency exits where seats are the closest obstacle.

## ESTIMATED QUANTITATIVE IMPROVEMENT IN SURVIVABILITY

Passenger flow rate: Passengers ready soon.

## HOW NEW IS THIS CONCEPT?

## Previous publications:

An aircraft passenger seat manufacturer has recently (Nov-Dec 1967) advertised a seat with a partially folding seat bottom to assist in obtaining access to aisles.

## Patents related:

May be some detailed patents on components.

## HOW ORIGINAL IS THIS CONCEPT?

Other applications not known, except for "practical jokers."

#### DETAIL DESCRIPTION OF SYSTEMS AND COMPONENTS

The concept would provide tactual and/or aural cue to prevent passengers from sitting "stunned" at the end of a crash. Each seat could have an attached vibrator, buzzer, or bumper device which would buzz, vibrate, or thump with sufficient energy and mass to make the seat cushion transmit a warning to the passenger thus serving to awaken or alert the passenger with the idea of expediting evacuation. The concept could consist of or include a shaped plastic envelope beneath the upholstery of each seat cushion. The seat cushion could be inflated automatically or from centralized/branch controls. The cushion could include a flapper valve to allow overpressure to escape with a warning noise. Development of an actual foldup seat would provide similar results but might present undue design complications.

#### CONCEPT EVALUATION

##### OVERALL SUMMARY RATINGS

Cost-effectiveness: *Low*

##### ENGINEERING FEASIBILITY

Within current state-of-the-art, insofar as warning devices or the plastic seat cushion are concerned. The foldup seat device may be prohibitive for design consideration. (Also, refer to concept 54-B.)

##### PSYCHOLOGICAL EVALUATION

Human engineering:	Provides tactual and audio indication of an emergency situation. May improve behavioral response by positive action of warning.
Motivational psychology:	Improves passenger motivation, especially for those passengers who are "dormant" or stunned psychologically.

##### PHYSIOLOGICAL EVALUATION

Does not affect passenger physiological situations, except as related to improving speed of egress.

#### KINESIOLOGICAL EVALUATION

The forces involved must not be such as to prevent seatbelt removal or such as to cause trapping of small children in the seat.

#### COMPATIBILITY WITH OTHER REQUIREMENTS

Compatible with all devices with the possible exception of concept 7-B (bosun chair). Could supplement other warning and motivational devices.

#### EFFECTIVENESS OF SOLUTIONS IN SPECIFIC PROBLEM AREAS

Improves the nonstarters or slow starters, and may tend to eliminate this problem. May complicate problems of elderly, incompetent, and injured.

#### EFFECTIVENESS OF SOLUTION IN TYPICAL ACCIDENT CASES

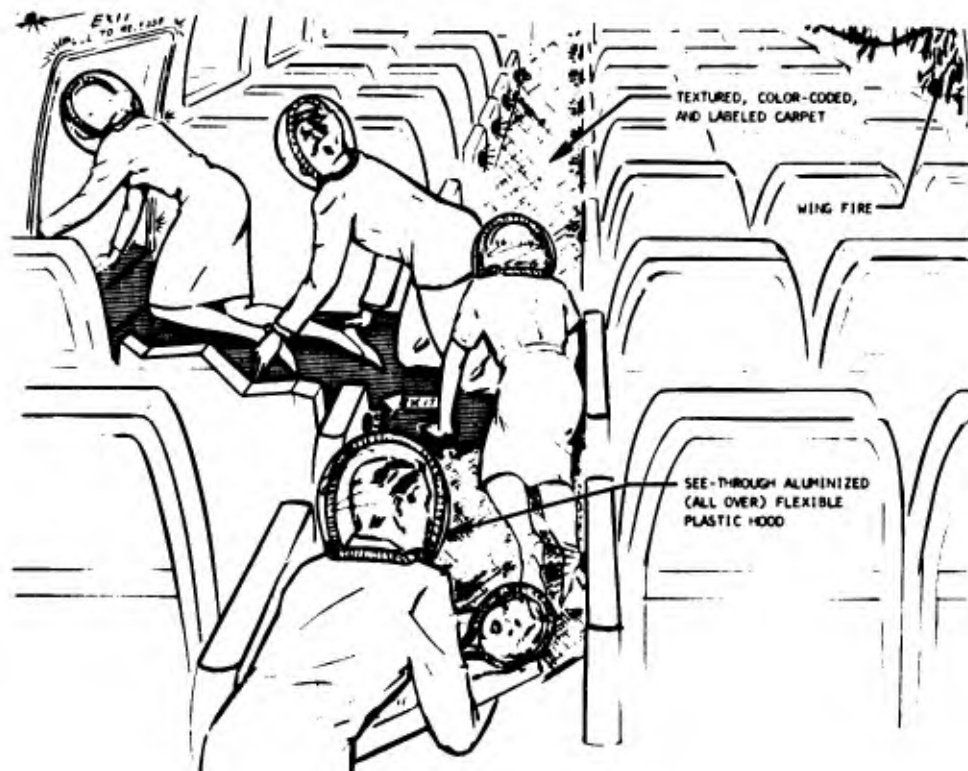
##### Case 1 - Denver, DC-8

From the available information, it does not appear that this concept would have aided evacuation of the Denver DC-8 accident. A possible exception to this conclusion is that maybe the audio warning would have made all tourist passengers move more rapidly. The available data on the evacuation indicate that the passengers who died had left their own seats and were enroute to the exit when they sat or slumped into aisle seats because of smoke fumes. It could be speculated that, even if the seats had motivated them to stand up again, it would probably have only increased their smoke inhalation.

##### Case 2 - Salt Lake City, B-727

Indications on this accident are that passengers reacted very quickly to evacuate the aircraft. Two men reached the ventral exit before the stewardess. Also from the board report, "the speed with which the passengers progressed toward the exits - prevented (the stewardess) from reaching (her) assigned duty station for evacuation."

## TACTUAL INDICATORS TOWARDS AREAS IN AISLEWAY

CONCEPT DESCRIPTION

This concept includes the provision, on aisle rugs, seat surfaces, walls, and ceilings, of distinctive tactual indicators to aid in locating exits in degraded visibility conditions.

## AREAS OF IMPROVEMENT IN EMERGENCY EVACUATION OF AIRCRAFT

The areas in improvement would be situations of reduced visibility caused by smoke, fume, or darkness and would include:

- (a) Capability to locate exit in smoke, fume, or darkness.
- (b) Faster egress in these conditions.
- (c) Fewer cases of toxic inhalation.

### ESTIMATED QUANTITATIVE IMPROVEMENT IN SURVIVABILITY

For those conditions in which degraded visibility is a problem for evacuation, a 50 percent improvement can be expected for properly developed system and trained passengers/crew.

### HOW NEW IS THIS CONCEPT?

This concept has been utilized for various situations where lack of visibility is a problem or where visual attention or access is limited.

From Aviation Week and Space Technology, 4 April 1966, page 38, "Dawson also called for better exit signs and emergency lighting, roughened texture on overhead racks, seat backs and headrests near exits, and special grill work on the floors around exits to give smoke-blinded passengers cues that they are near an exit."

### HOW ORIGINAL IS THIS CONCEPT?

This concept has been proposed by stewardesses, and other airline and air safety personnel. Material presented here is a further development of the concept.

### DETAILED DESCRIPTION OF SYSTEMS AND COMPONENTS

The tactual indicators are intended to provide a means whereby a passenger or crewman can locate emergency exits and/or equipment in conditions in which visual indication is not available. In addition, the indicators should be usable regardless of the aircraft attitude. Consequently, the indicators will be placed in a variety of locations to insure their usefulness. This would include potentially the floor (crawling egress procedures), the ceiling (inverted aircraft attitude), seat backs (normal egress), walls (locating exit controls), and edge of luggage rack (movement on top of seats). The indicators will be located to provide a continuous source of cues from any position to the exit or equipment. They will also be designed to indicate preferred direction or directions with differential indicators at the exit

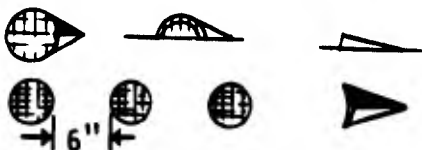
or equipment area. Candidates for use as tactual indicators include the following:

- (a) Wire, cord or other runners with periodic direction indicators (arrows)



Particularly useful on ceiling where the possibility of interference with egress is minimum. Technique allows continuous and therefore very rapid use.

- (b) Raised buttons or beads with pointed sides indicating direction or periodic arrow.



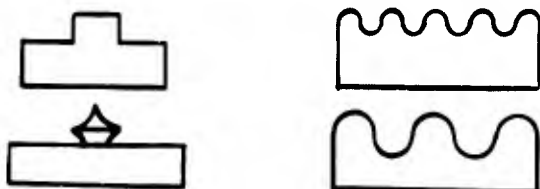
This technique is particularly useful on floor areas for crawling or where continuous hand contact can be maintained and where minimum disturbance of surface, carpet or upholstery is required

- (c) Series of directional arrows raised to provide a tactual utilization capability.



These are similar to technique (b). Potentially, they could be combined with ultraviolet indicators (concept 52-B). The specific configuration of the arrows as well as all tactual indicators should be system developed and evaluated to insure quick, reliable utilization.

- (d) Grids or other special tactual indicators.



These are useful in indicating arrival at exit or equipment location - also useful on top of seat to indicate aisle with exit. These would be selected shapes proven unambiguous.

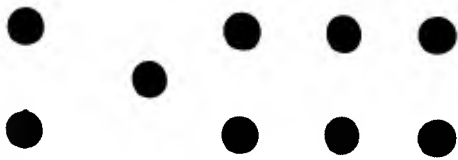
(e) Raised Numerical Indicators

This technique could be useful in indicating feet, steps, or seats to equipment or exit.

(1)



(2)



(f) Raised name, symbols, or abbreviation indicators

This technique could be useful to indicate what is at end of series of tactual indicators.

(1)



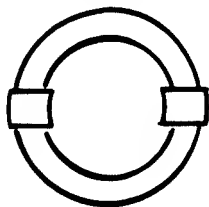
(2)

(first aid kit)



(3)

(life raft)



L  
I  
I

(g) Distinctive tactual control indicators

These would include distinctively shaped knobs, levers, etc, designed to insure location and proper selection of control for exits, slides, equipment stowage, etc.

The selected tactual indicators will be standardized for all aircraft and included in the passenger and crew training programs to insure proper utilization.

#### CONCEPT EVALUATION

##### OVERALL SUMMARY RATING

This concept has a very good cost-effectiveness rating both from the standpoint of very low cost and very high potential effectiveness in providing evacuation cues for conditions of severely restricted vision.

##### ENGINEERING FEASIBILITY

No difficulty is expected in manufacturing or installation of selected tactual indicators either as a retrofit or as an initial installation.

##### PSYCHOLOGICAL EVALUATION

The configuration and shape of the various tactual indicators suggested must be adequately verified to insure that they can be utilized quickly and are not confusing. In addition, the adoption of this concept must include adequate training to insure that the system is utilized by both passengers and crew.

##### COMPATIBILITY WITH OTHER REQUIREMENTS

The concept is designed to provide a backup and redundant system to the visual displays. As such, it must be laid out to be compatible with the normal visual system. Because the system is passive, it provides indications of normal egress patterns and potentially can be in conflict with more dynamic

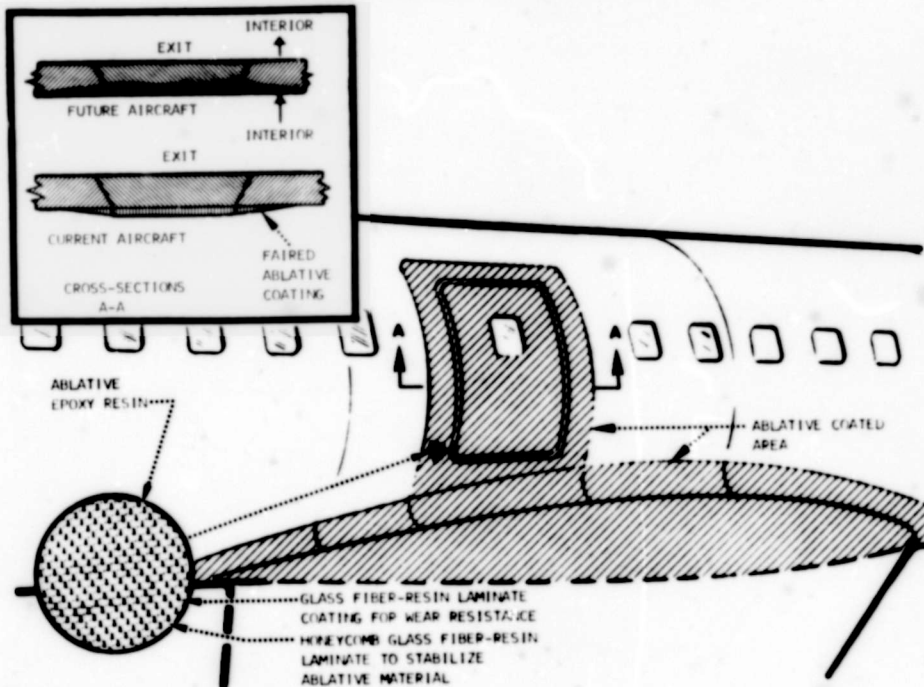
systems of passenger redirection, such as described in concept 24-G, or other passenger redirection methods either automatically or manually controlled. However, as the concept is basically intended for situations where visual cues are not available and thus passenger redirection can be expected to be limited, this system provides a major advancement.

#### EFFECTIVENESS OF SOLUTIONS IN SPECIFIC PROBLEM AREAS

The concept would help solve the following problems in degree of most to least:

- (a) Inability to see exits
- (b) Inability to locate equipment or controls
- (c) Loss of life through toxic inhalation because of slow evacuation
- (d) Slow evacuation

### ABLATIVE COATING FOR EXIT AREAS AND DEVICES



#### CONCEPT DESCRIPTION

##### GENERAL DESCRIPTION OF CONCEPT

Provide lightweight ablative coating (which insulates, chars, and off-gasses instead of supporting flame) on surfaces outside of cabin which are critical to survival in evacuation of aircraft when flame is burning outside. Includes wing-fuselage joints, engine firewall compartments, and auxiliary power unit (APU) compartment areas.

##### AREAS OF IMPROVEMENT IN EMERGENCY EVACUATION OF AIRCRAFT

Reduces flame propagation into cabin.

Prevents heat distortion of critical structure around exits which might cause jamming.

## ESTIMATED QUANTITATIVE IMPROVEMENT IN SURVIVABILITY

Preparation of exit: 0 to 100 percent

Highly dependent on crash fire conditions. Range 0 to 100 percent from fire; improved exit usage.

## HOW NEW IS THIS CONCEPT?

Previous publications:

Federal Aviation Agency, Minutes - FAA-Industry Conference on Crash-worthiness and Passenger Standards for Transport Category Airplanes, Flight Standards Service, 29 and 30 March 1966

Patents related:

AVCO patents on Apollo ablative coatings

## HOW ORIGINAL IS THIS CONCEPT?

Adapted from spacecraft usage, particularly Apollo command module heat shield. Application is original.

## DETAILED DESCRIPTION OF SYSTEMS AND COMPONENTS

Severe heating from exterior fires can distort exit structure and prevent opening at a later time, even if firemen have cleared a flame-free path to it. New, lightweight ablative coating materials applied to areas around and over the exits could form an insulative layer which also resists flame by charring and off-gassing, carrying heat away from structure. The Apollo heat shield is a composite material based on epoxy resin. Although relatively soft, such materials could be covered by a thin, glass-fiber laminate for wear resistance. The basic ablative material is stabilized by a glass fiber laminate honeycomb bonded to the skin surface. For a reasonable evacuation period (2 to 5 minutes), a layer only 1/4- to 3/8-inch thick could provide protection against fires of JP-4 or other fuels which burn cooler than spacecraft reentry temperatures of 4,000° to 5,000° F.

Similarly, areas at wing roots, in auxiliary power unit compartments, in electrical and pneumatic machinery compartments outside the pressurized area,

could also be so protected. Emergency egress devices such as escape tubes and slides could have a flexible ablative coating to protect them for a short time against flame damage.

### CONCEPT EVALUATION

#### OVERALL SUMMARY RATINGS

Cost-effectiveness: Low

Current state-of-the-art probably not directly adaptable to produce sufficiently lightweight material for aircraft.

#### ENGINEERING FEASIBILITY

Highly reliable, passive system - no moving parts. Feasibility of concept proven in space vehicles.

Requires moderate improvement in state-of-the-art to develop sufficiently lightweight material for large area coatings and to establish thickness requirements. Improved, less costly production techniques also required. A drag penalty will be associated with applications to present aircraft. Future aircraft could have dished-in area to accommodate coating. Maintenance and repair requires special equipment and supplies.

#### PSYCHOLOGICAL EVALUATIONS

Not applicable. Most passengers would be unaware of it.

#### PHYSIOLOGICAL EVALUATION

Toxicity: Combustion products could be highly toxic. Cannot be used internally for fire retarding.

Heat/cold tolerance: Provides longer time until structure heats up. Reduces or prevents burns on interior door handles and structure during egress.

## KINESIOLOGICAL EVALUATION

Strength: Increases weight of doors and hatches at exits; makes them more difficult to handle.

## COMPATIBILITY WITH OTHER REQUIREMENTS

Appears compatible with all other concepts. Especially complementary to ground rescue vehicle or helicopter in preventing heat damage to exit structure until exterior water, foam, spray, or air downwash can clear fire and smoke from exit.

## EFFECTIVENESS OF SOLUTIONS IN SPECIFIC PROBLEM AREAS

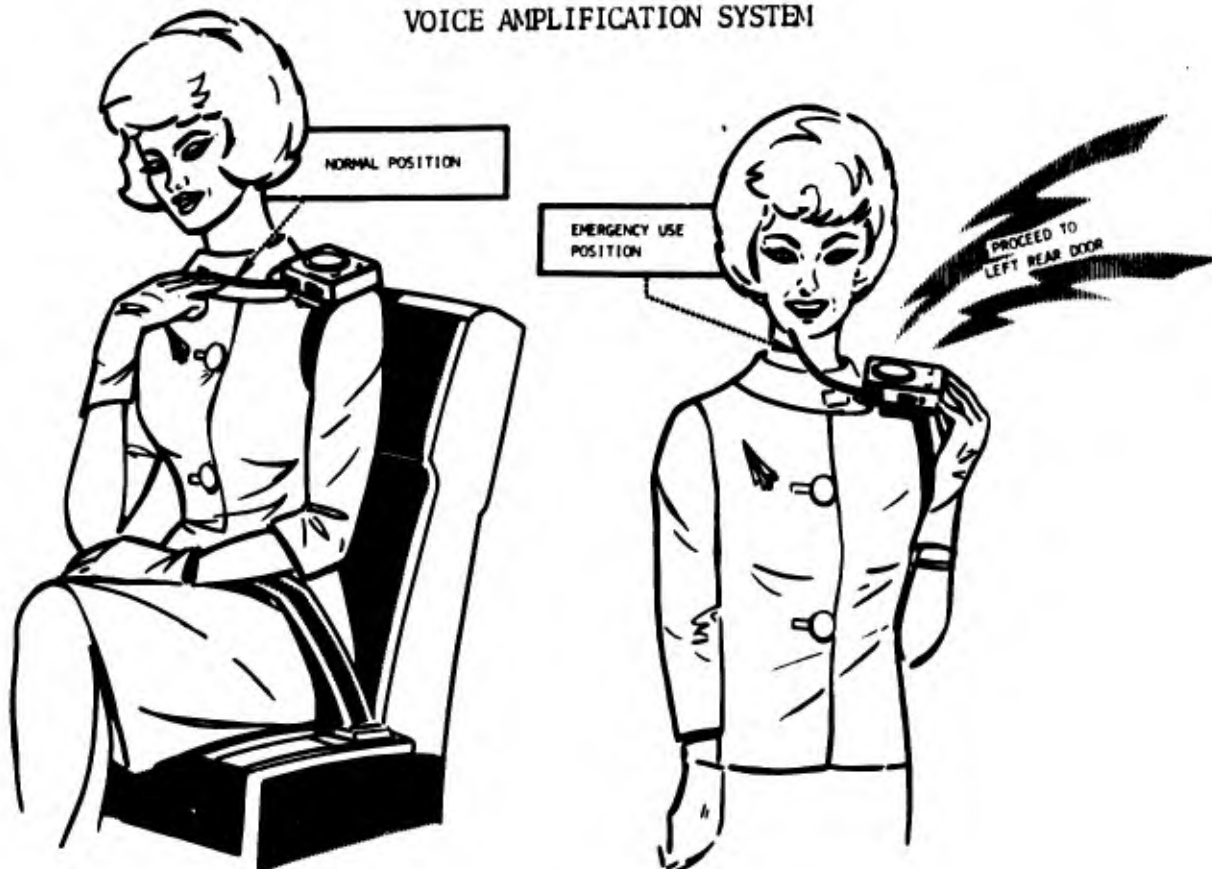
Reduces rate of heating interior air; reduces jamming of exits due to heat distortion.

## EFFECTIVENESS OF SOLUTION IN TYPICAL ACCIDENT CASES

Case 1 - Denver, DC-8

Not useful in this accident as far as known now. Smoke entered through open doorway.

MINIATURIZED SOLID-STATE  
VOICE AMPLIFICATION SYSTEM



CONCEPT DESCRIPTION

GENERAL DESCRIPTION OF CONCEPT

This unit will provide crewmembers with a means of communicating with the passengers independent of aircraft power, and at any time required. This unit will replace the bull horn, with a lightweight portable compact design suitable for being carried by each crewman on his person.

AREAS OF IMPROVEMENT IN EMERGENCY EVACUATION OF AIRCRAFT

- (a) Provide voice amplification to overcome general noise level and tell passengers about which exits to use, what to do about clothing in preparation to egress, and how to avoid smoke or fumes.
- (b) Unit can be used outside the aircraft as well as inside by crewmembers assembling evacuating personnel, directing raft ditching and preparation.

## ESTIMATED QUANTITATIVE IMPROVEMENT IN SURVIVABILITY

Preparation of exit:	50 percent
Passenger flow rate:	Up to 20 percent
Reduction in wrong exits tried:	50 to 75 percent

## HOW NEW IS THIS CONCEPT?

Previous publications:	Unknown
Patents related:	Miniaturized electrical devices too numerous to describe.

## HOW ORIGINAL IS THIS CONCEPT?

This unit has been conceived from current transistor radio designs and spacecraft communications to provide a more compact voice amplification system.

## DETAIL DESCRIPTION OF SYSTEMS AND COMPONENTS

This concept is to provide a compact, lightweight unit which may be worn by each crewman for communications with passengers during an aircraft power shutdown and when emergency evacuation procedures are under way. The unit will provide capabilities of performing outside the aircraft in continuous evacuation operations. This system will contain voice amplification capabilities in the order of the bull horn responses. The unit will be approximately 4 x 5 x 1-1/2 inches and contain transistor circuitry with a minimum 2-1/2-inch-diameter speaker and push-pull amplifier for quality sound. It will have a built-in 22-volt dc battery power supply, with service life of 15 (±1) hours. These units will be used for the direction of passengers to proper exits, precaution instructions, mode of evacuation (water or land), and placement of personnel in rescue vehicles or rafts. Each unit should be capable of passing all phases of environmental Military Specification 850C. The estimated weight is 0.75 pound.

The unique features of this device, which presumably make it a new item, differing from the currently used bull horn, are the small size and light weight which permit wearing it during takeoff and letdown or other periods of potential danger. Although several methods could be used to support it on the person of the crewman, the following are suggested

- (a) A soft collar, or necklace strap piece, worn around the neck supports the weight and helps position it.

- (b) A cloth pocket formed into the clothing, or a separately formed close-fitting bag with means to securely fasten the main part of the device to the clothing, withstands the required crash forces. The means may be a heavy-duty "lift-a-dot" type snap fastener on a strap which fits around the shoulder under the arm, around an epaulet or strap sewn on the jacket, or a heavy-duty safety pin type clip attaching to a specially reinforced clothing patch. The strap around the shoulder would be the most secure method and least dependent on clothing design.
- (c) A flexible, tubular microphone similar to Plantronics or General Electric designs can be extended upward from the main part of the device to the side of the mouth when in use. When not needed, it can be laid down parallel to the necklace around the neck, or otherwise bent back out of the way as shown in the sketch or perhaps around the speaker piece.

#### CONCEPT EVALUATION

##### OVERALL SUMMARY RATINGS

Low cost per unit with high rating in effectiveness.

##### ENGINEERING/OPERATIONAL FEASIBILITY

Within the present state-of-the-art, can be fabricated in a production shop. Battery-powered, low cost in replacing entire unit. Low volume and weight.

##### PSYCHOLOGICAL EVALUATION

Motivational: May help provide passengers with a confidence in crew-members' capability to communicate to them. The unit should help relieve stewardess uncertainty about ability to operate bull horn.

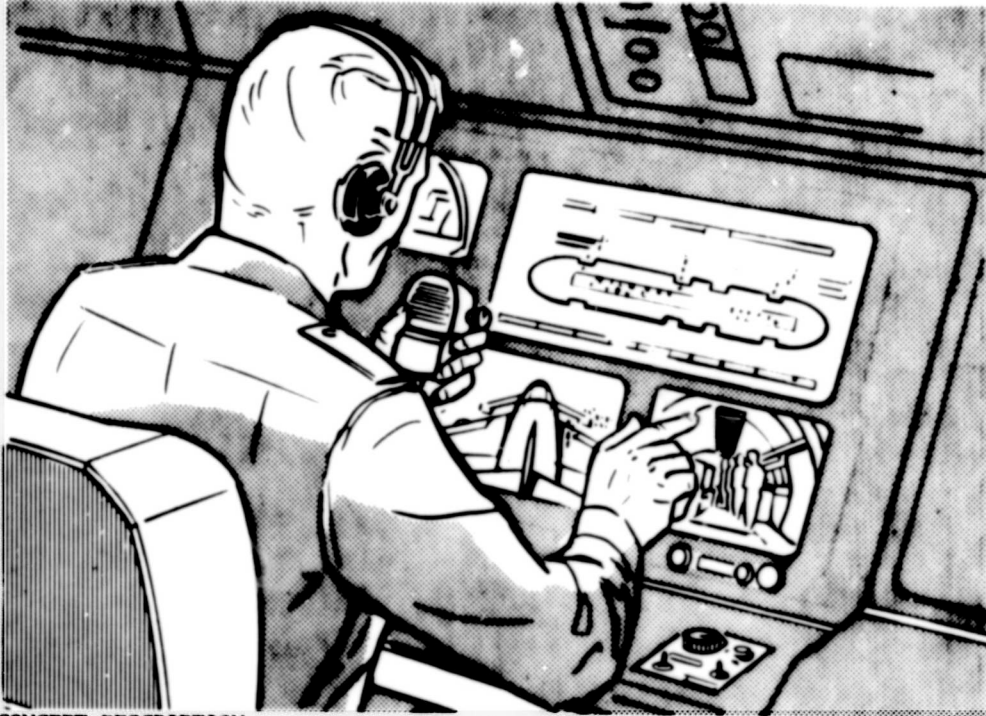
##### KINESIOLOGICAL EVALUATION

The unit appears to be more easily and quickly operated by crew than current devices. However, the item weight may be annoying, and may abrade clothing. Donning and doffing may be a nuisance problem.

## EFFECTIVENESS OF SOLUTIONS IN SPECIFIC PROBLEM AREAS

Provides an aid for advising/instructing passengers on board as well as outside the aircraft. Helps to distribute passengers evenly to exits, places stewardess in a command position, and aids in recovering injured personnel. Replaces standard bull horn and permits stewardess use of both hands to perform other tasks - open door, deploy slides, assist passengers.

REMOTE TV CAMERAS AND EMERGENCY EXTERIOR LIGHTING TO  
ASSESS EXTERIOR HAZARDS



CONCEPT DESCRIPTION

GENERAL DESCRIPTION OF CONCEPT

TV cameras in tail and sides of fuselage are connected to situation display panel in stewardess duty stations and flight crew compartment. May be supplemented by outside TV broadcast from ground vehicles.

AREA(S) OF IMPROVEMENT IN EMERGENCY EVACUATION OF AIRCRAFT

Improved exit awareness for flight crew/cabin attendants reduces lost time in opening wrong exits, reduces danger of fire coming in an exit opened into a hazardous area.

## ESTIMATED QUANTITATIVE IMPROVEMENT IN SURVIVABILITY (if applicable)

Passenger flow rate: 10 percent  
Reduction in wrong exits tried: 20 percent

## HOW NEW IS THIS CONCEPT?

Previous publications: None

No previous applications to commercial transport aircraft.

## HOW ORIGINAL IS THIS CONCEPT?

Adapted from nonaircraft fields or practice.

Remote TV used in many commercial applications and space applications, such as Surveyor moon probes.

## DETAIL DESCRIPTION OF SYSTEMS AND COMPONENTS

- (a) Remote fixed TV cameras mounted in strategic portions of aircraft viewing wings and exit areas.
- (b) Supporting exterior battery-powered floodlighting.
- (c) Situation display panel with TV screen or screens at stewardess and cockpit duty stations. Will permit selection of screens to be viewed.
- (d) Whole system must be highly rugged construction to withstand impact of aircraft.
- (e) Stewardess must have enhanced voice communication with passengers to make this effective and should have controls for exit lighting to indicate unsafe conditions. See concepts 40-A, 48A.
- (f) A TV reception capability in the aircraft could also be used to transmit TV pictures from a helicopter or other rescue vehicle on the outside, giving situation information to the crew inside.
- (g) The following figure illustrates the small size possible required for a television camera with application of space-age technology. The camera shown is capable of withstanding at least 6-G loads. It weighs approximately 4.5 pounds without lenses.



## PSYCHOLOGICAL EVALUATION

The system of outside lighting necessary for TV visibility would not only improve vision but human behavior under dark evacuation conditions. Intelligent communication of exits to be avoided could aid motivation of passengers and crew.

## PHYSIOLOGICAL EVALUATION

No specific aid other than directing passengers away from smoke/flame blocked exits.

## KINESIOLOGICAL EVALUATION

Strength, speed/accuracy, and coordination: No benefits or penalties

## COMPATIBILITY WITH OTHER REQUIREMENTS

Essentially compatible with all other rescue and evacuation means.

## EFFECTIVENESS OF SOLUTIONS IN SPECIFIC PROBLEM AREAS

There is generally good visibility of fire outside exits, except type I; consequently, there is only a limited improvement in this respect, unless smoke is blocking vision at the other exits. Similarly, the assist from lighting is possibly only a slight improvement over the light from a fire. In the absence of fire, the lights would, of course, be very helpful to a nighttime evacuation. It is questionable whether the system would have power and unbroken cabling after a crash. It is also questionable whether the lights and cameras could penetrate exterior smoke.

## EFFECTIVENESS OF SOLUTION IN TYPICAL ACCIDENT CASES

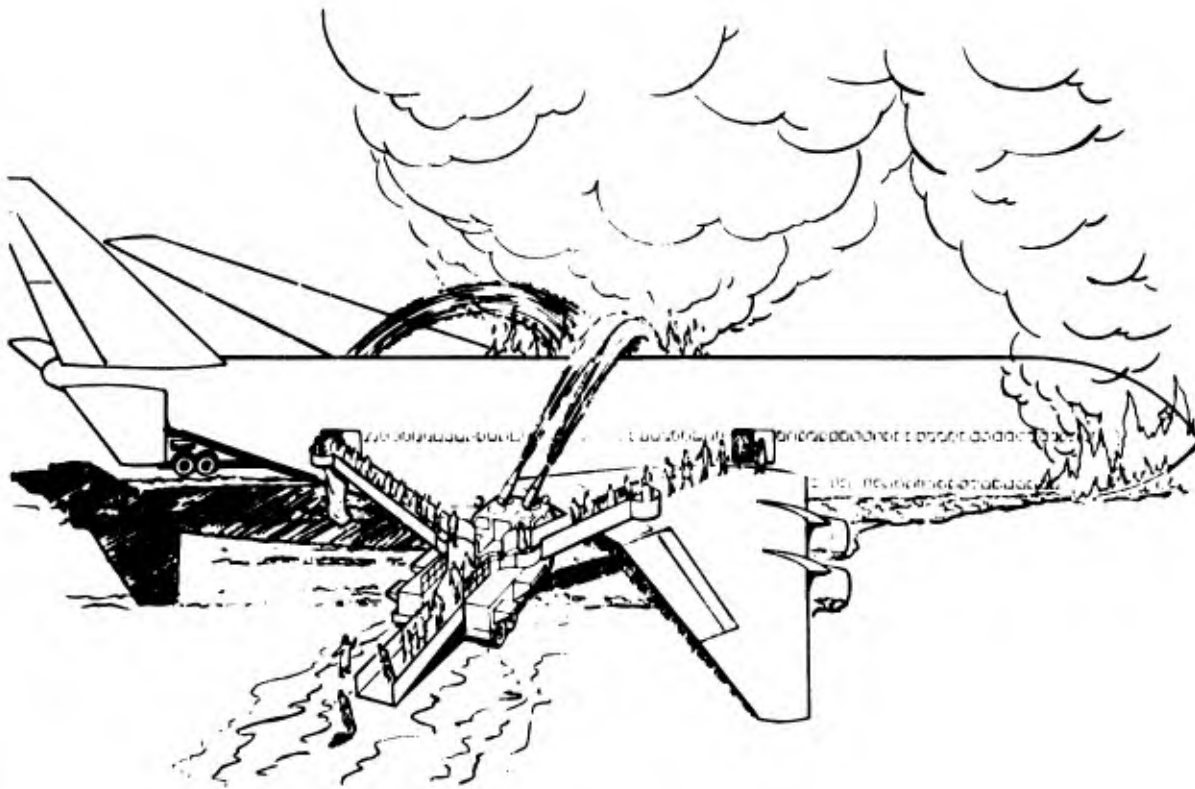
Case 1 - Denver, DC-8

It is conceivable that, if the crew had good visibility on their closed-circuit display, they could have noted a cessation of passenger flow from the

forward and overwing exits while passengers were exiting from the rear. In this case, assuming power and loudspeaker communication, they could have directed additional tourist passengers to the first class cabin and expedited evacuation.

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## GROUND RESCUE VEHICLE

CONCEPT DESCRIPTION

## GENERAL DESCRIPTION OF CONCEPT

The ground rescue vehicle (GRV) envisioned in this concept is a piece of heavy-duty airport-based emergency vehicular equipment, adapted to provide assistance in the rapid evacuation of transport category aircraft (or serve as a primary means of effecting evacuation and personnel rescue under certain contingencies), following a survivable accident or other emergency situation, at or in close proximity to an airport. This vehicle embodies a pair of adjustable/extendible ramps to provide a means for passenger and crew egress and descent, as well as protective devices, fire suppression equipment, communications, illumination and other emergency equipment, and a trained crew to assist in aircraft evacuation and perform rescue operations. Auxiliary devices, subsystems, or on-board aircraft devices which could be utilized or actuated in conjunction with an operational ground rescue vehicle to increase its versatility are described under concept 51-G-1, 51-G-2, and 51-G-3.

## AREAS OF IMPROVEMENT IN EMERGENCY EVACUATION OF AIRCRAFT

Total egress time may be greatly reduced if the ground rescue vehicle is immediately available (i.e., on standby or alert status adjacent to runway). Improved safety of egress within airport boundaries and proximity, considering relatively level terrain or area otherwise accessible by roads. The GRV may serve as a primary means of evacuation in the event of failure of standard evacuation slides (i.e., disconnected from aircraft, noninflatable, punctured, etc). The use of specifically trained rescue personnel enhances rapid and orderly evacuation. Adaptation of this concept is certainly not intended to replace the use of standard firefighting equipment, but rather to supplement it by primarily providing a means for effecting personnel rescue, and secondly, to assist in fire suppression in areas of evacuation.

## ESTIMATED QUANTITATIVE IMPROVEMENT IN SURVIVABILITY

Passenger flow rate increase would be variable, dependent on numerous circumstances. Potential decrease in passenger injury is possible by eliminating the necessity to jump from wing following use of overwing exits in gear-down condition, or jump from normal exit in the event of evacuation slide failure or malfunction.

## HOW NEW IS THIS CONCEPT?

Previous publications: North American Rockwell Corporation, "Technical Proposal to Provide New Emergency Evacuation Concepts, Hitherto Unreported, for Air Transport Category Aircraft Following Survivable Accidents," NA-66-869, dated 19 August 1966

Patents related: Unknown.

## HOW ORIGINAL IS THIS CONCEPT?

This concept is considered original. Military aircraft rescue techniques using specialized equipment and trained rescue personnel have been in existence for many years, but have customarily dealt with rescue of flight crews.

## DETAIL DESCRIPTION OF SYSTEMS AND COMPONENTS

This concept presents a method for rapid personnel egress from a disabled aircraft, following a survivable accident at or in close proximity to an airport, and involves the use of both equipment and rescue personnel, as well as a method of operation. As presented herein, the ground rescue vehicle (GRV) embodies a pair of side-mounted extendible ramps which normally stow aft along the vehicle body. These ramps are independently operated through mechanisms housed in the forward end of the vehicle bed, and through associated gearing and drive mechanisms in the side mounting housings. Ramp length adjustment (by telescoping) is provided as well as adjustments in azimuth and elevation. These ramps are of lightweight, but durable, construction so that if only one is extended laterally to its maximum range, there will be no tendency for the GRV to overturn. Support provided by the aircraft itself, when the ramps are in use, will preclude tendencies of the GRV to roll with the ramps loaded. Laterally deployed and hydraulically operated vehicle stabilizers are also provided beneath the ramps' side mounting housings, to afford a greater degree of vehicle stabilization, especially for use on unlevel terrain.

Side panels or railings will be required for the ramps, and the walkways are textured (such as with transverse ribs) to present nonslip surfaces under the most extreme degree of ramp elevation anticipated. A crosswalk connects the terminal points of the ramps and, from this crosswalk, a central sloping ramp extends aft through the bed of the GRV. Another ramp section, normally stowed within this area, is either telescoped or rotated aft to extend this central ramp to the ground, at a relatively shallow angle. These latter ramp sections are wider than the side ramps to accommodate the flow of egressing personnel. The outer ends of the side ramps incorporate a widened area to accommodate a member of the rescue crew, without restricting the passageway for egressing personnel.

Adequate tankage volume for water or other fire suppressant is provided on either side of the GRV aft ramp. The handrails of the extendible ramps are equipped with necessary plumbing (such as flexible looped lines to permit ramp telescoping, or telescoping plumbing lines may comprise the handrails), including nozzles at spaced intervals, so that a protective canopy of water fog (fine spray or mist) may be afforded egressing personnel, at the option of the ramp operator in the event of fire, smoke, heat, or toxic fumes. This feature could be expanded to provide a water fog over the entire exit pathway. Two or more standard gun-type nozzles are also provided on the cab roof of the GRV so that the GRV's crew may direct a water or fire suppressant spray toward the aircraft's emergency exits and/or the intervening area between such an exit and the ramp entrance (i.e., the wing surface between an overwing exit and the ramp entrance). Additionally, the GRV would also incorporate equipment for

suppressing fire on the ground and in the path of the vehicle or its extendible ramps. Spaced foam nozzles along the lower front and sides would permit the GRV to enter a spill fire area. For maximum protection of the crew and vehicle's controls and mechanisms, an ablative or insulating coating may be added over the cab exterior. This will permit close approach through flames and radiant heat. Air conditioning equipment may be provided in the GRV cab, or a trailing, extendible hose duct may be utilized with a blower to provide a source of fresh air for interior cooling and ventilation.

This concept envisions the use of GRV crews well trained in fire and crash rescue techniques (but not necessarily skilled personnel), equipped with modern insulative/reflective protective clothing as well as breathing apparatus. Furthermore, they would be familiar with various transport category aircraft configurations (i.e., exit types, number and locations, actuation methods, etc).

In order to achieve an optimum operational capability, the GRV should be staffed with a five-man crew: the vehicle operator, two ramp operators, and two rescue personnel. Ideally, the vehicle operator would be centrally located in the cab with the ramp operators on either side. In addition to the conventional side doors, an access door is provided in the rear of the cab, opening to the bed of the GRV. All primary ramp, water, and other controls are located in the GRV cab. Auxiliary controls are also provided at the outer end of each ramp (at the rescue crew's station), to provide for ramp adjustments as required by the situation, as well as actuation of the ramp's water spray facilities. A variety of standard fire-fighting/crash rescue hand and/or power tools may also be stowed in a locker at this ramp-end crew station.

In operation, the ramp operators would unlatch and rotate the side-mounted ramps to a generally forward direction while the GRV is enroute to the disabled aircraft. Upon approaching the aircraft, precise ramp orientation and extension may be rapidly achieved to meet the requirements of the situation. The function of the rescue personnel (one assigned to each side ramp) is to assist in the orderly, rapid evacuation of all passengers and crew. Each rescue operator would be stationed initially in the back of the GRV while enroute to the aircraft, then would enter his assigned ramp and occupy the crew station at its outer end during final ramp adjustment. He would verify general ramp-to-aircraft positioning and, by using the controls at the ramp-end crew station, would perform final discrete ramp adjustments if necessary. He would then take command of the evacuation at his particular station and, finally, enter the aircraft to ascertain that all passengers and flight crew have been evacuated.

Stabilization of the outer end of the ramp is necessary, either through support provided by a surface of the aircraft, or via temporary connection to the aircraft structure if the ramp end impinges on a curved, sloping or quasi-vertical surface (i.e., as below an exit door before the door has been opened). The latter may be effected by deployment of a pair of barbed plungers (i.e., similar to a harpoon) from the underside of the ramp into the aircraft structure; these barbs would be retractable so that plunger withdrawal may be accomplished for ramp disconnect from the aircraft.

Upon arrival at the aircraft, the vehicle operator would first secure the GRV, then deploy the aft central ramp to ground level. He would then exit the cab through the aft access door and station himself at the junction of the side ramps, to assist in funneling the two streams of egressing personnel into the wider central ramp to the ground. After the traffic flow pattern has been established, he would then descend the ramp and direct egressing passengers from the vicinity, to a less hazardous area; he would also assist descending passengers on the ramp, as required. The two cab ramp operators, upon securement of the GRV and upon completion of initial ramp adjustment and relinquishment of the ramp controls to the rescue operators on the ramp-end stations, would then operate the fire and smoke suppression equipment as required. They would also assist in the evacuation and rescue efforts, as dictated by the emergency, as well as assisting the ramp-stationed rescue operators in verification of evacuation completion.

In addition to the necessary floodlights or spotlights (at the crew stations at the outer ends of the ramps as well as on the vehicle itself) which may be required to illuminate the general rescue area, the GRV would be equipped with various communications equipment. A two-way communications system linking the GRV's cab with the airport control tower/control center would initially be utilized for the control tower to provide directional control to the GRV while enroute to the disabled aircraft. Subsequently, the GRV operator would apprise the control tower of the situation upon GRV arrival at the site of the emergency, and would be able to provide later advisories, as well as request additional equipment, medical aid, etc. A two-way communications system is also provided between the crew stations at the outer ends of the ramps and the GRV cab, for transmitting and receiving advisories, requests, instructions, etc. Additionally, a vehicle-mounted public address type system is provided, as well as individual, self-contained units (i.e., bull horns) at each rescue operator's station at the outer ends of the ramps, to provide evacuation and dispersal instructions to egressing passengers.

## CONCEPT EVALUATION

### OVERALL SUMMARY RATINGS

The cost effectiveness rating of a ground rescue vehicle (GRV), as depicted herein, and its 5-man crew may range from low to high because of the numerous circumstances to be considered and number of variables involved in operation of such a vehicle in relation to a survivable crash. Its cost-effectiveness rating will probably be at least equivalent to, and possibly substantially better than, the cost-effectiveness rating of standard airport-type fire-fighting equipment. An in-depth statistical analysis (not within the scope of this study) would be required to more accurately predict a reasonable cost-effectiveness ratio, as well as determine the probability of occurrence of numerous events which may occur in a survivable crash. A review of transport category aircraft accident statistics (both commercial and military) indicates that the great majority of survivable accidents occur on the runway, within the airport boundaries, or in close proximity to an airport. Admittedly, in some instances, a GRV may be of little value in an emergency (i.e., off-airport crash and not readily accessible, late arrival at crash site, etc) but, potentially, it can be a highly effective piece of equipment which may mean the difference between low fatalities (or none) and a relatively high percentage of fatalities in what would be deemed a "survivable crash." For example, it is felt that a single GRV, on alert status adjacent to the runway at the time of the Denver DC-8 crash on 11 July 1961, would have been able to effect total evacuation without a single fatality. This statement is based upon actually having been an eyewitness to the accident. The versatility of the GRV may be further increased and, consequently, its cost-effectiveness rating improved, through utilization of concept 51-G-1, 51-G-2, and/or 51-G-3 in conjunction with the GRV to provide an improved operational system.

### ENGINEERING FEASIBILITY

Development and production of a ground rescue vehicle are within the current state-of-the-art. All design and function requirements could be met utilizing existing technology and design techniques.

### PSYCHOLOGICAL EVALUATION

Human engineering:                      No significant interaction with passengers until exit doors are opened, then only relatively routine or normal functions required.

Motivational psychology: A greater feeling of security should be imparted to the passengers in the knowledge that modern equipment is available and prepared to deal with emergency situations.

#### PHYSIOLOGICAL EVALUATION

Operational use of the GRV would tend to provide increased protection and a rapid means of removal for passengers exposed to environmental hazards (fire, smoke, heat, toxic fumes, etc).

#### KINESIOLOGICAL EVALUATION

Adaptation of the GRV to a rescue operation would provide a simple method of effecting passenger evacuation and descent while tending to decrease the probability of passenger injury.

#### COMPATIBILITY WITH OTHER REQUIREMENTS

May not be as effective for off-airport accidents. Would generally be compatible with all aircraft attitudes, and all weather conditions if properly equipped. Can help reduce fire danger for all other egress devices.

#### EFFECTIVENESS OF SOLUTIONS IN SPECIFIC PROBLEM AREAS

Comparative tests have shown that ramps provide the most rapid means of escape because they permit simultaneous occupancy (King, B. G., et al, August 1954), thus utilizing "overlap" techniques, wherein passengers could egress in a steady flow and be spaced on an average of two to three feet apart during egress and descent. Evacuation by this method is approximately twice as fast as escaping by a standard aircraft-type slide, since use of the slide requires regulating the rate of passenger entry (even with maximum slide "overlap" techniques, one person jumps into the slide as the preceding reaches the ground). Improper handling of slides by ground crew, pile-up on slides, and congestion at the foot of slides are factors which cause undue delay and result in general inefficiency in escape procedures; use of ramps and trained rescue personnel, as provided by the GRV, would eliminate or greatly alleviate these conditions.

## EFFECTIVENESS OF SOLUTION IN TYPICAL ACCIDENT CASES

Case 1 - Denver, DC-8

A single ground rescue vehicle and crew could have been highly effective in effecting total evacuation of the rear passenger compartment, prior to the time that passengers would have been significantly endangered by fire, smoke, heat, and toxic products of combustion. Firefighting equipment alone was unsuited for use in evacuation of passengers.

## PASSENGER COMPARTMENT "SPRINKLER SYSTEM"

CONCEPT DESCRIPTION

## GENERAL DESCRIPTION OF CONCEPT

The passenger compartment "sprinkler system" envisioned in this concept is essentially an onboard built-in plumbing system, primarily adapted to be operated with an external water source. It is particularly well suited to be operated in conjunction with a ground rescue vehicle (reference concept 51-G), to comprise a more effective overall system, although other types of standard firefighting equipment could be utilized with equal effectiveness so far as the onboard plumbing system is concerned.

NOTE: This concept was originally proposed in conjunction with a ground rescue vehicle to provide a greater systems effectiveness (reference North American Rockwell Corporation Report NA-66-869, dated 19 August 1966, "Technical Proposal to Provide New Emergency Evacuation Concepts, Hitherto Unreported, for Air Transport Category Aircraft Following Survivable Accidents"). Another concept for an onboard (self-contained) fire suppression system has been generally expanded to include the broad scope of this concept as a passenger compartment manifold distribution system (reference concept 17-F). With the exception of the section entitled "Detail Description of Systems and Components," the remainder of the information on the concept description and evaluation is essentially summarized under the concept description and evaluation sections of concept 17-F. The following detail description is provided to present the more salient features of this concept, as originally conceived for an overall systems approach utilizing the ground rescue vehicle.

## DETAIL DESCRIPTION OF SYSTEMS AND COMPONENTS

This concept presents a method of utilizing an onboard aircraft system to materially aid in the suppression of smoke, fire, heat, and toxic fumes or products of combustion within the aircraft's passenger and crew compartments, following a survivable crash, and without the weight penalty of carrying the necessarily large quantities of fire suppressant on board the aircraft.

A built-in overhead plumbing system, with nozzles at spaced intervals, would essentially provide a "sprinkler system" capable of saturating the cabin environment with a water fog or mist. This plumbing system would have sufficient flexibility to accommodate some fuselage deformation without rupturing and, in addition, would incorporate pressure-sensing check valves, strategically located, so that fuselage breakup or extreme deformation would not destroy the total system capability, but isolate damaged sections. Plunger-operated, quick-disconnect fittings would be provided adjacent to each major emergency exit, readily accessible from the fuselage exterior, to utilize an external water supply; connection of such a water supply to any of the multiple quick disconnects provided would actuate the entire system.

Provisions on the ground rescue vehicle (GRV) to incorporate this concept would utilize flexible, high-pressure lines, routed along each side of the side ramps, and pressurized while the ramps are being positioned. A simple, rapid plug-in connection by the GRV's rescue operator on the ramp, through a spring-loaded access door in the fuselage, would instantaneously activate the system. It should be readily apparent that other types of vehicles or fire-fighting equipment could perform the same function, so long as these connections are quickly reachable and flow can be rapidly initiated. Provisions could be incorporated in the aircraft plumbing to utilize an onboard water supply as an interim measure, depending on the amount of water available (for example, either the water supply provided for lavatory usage and/or the large amount of water used for water injection during takeoff could be made available if an emergency occurred at this time).

#### CONCEPT EVALUATION

Refer to concept 17-F.

## EXTERNALLY ACTUATED BLOWOUT PANEL(S)

CONCEPT DESCRIPTION

## GENERAL DESCRIPTION OF CONCEPT

Since fuselage structural deformation or failure following a survivable accident may jam egress doors and overwing exits to the extent that they may be inoperable, it is highly desirable to provide an emergency backup method of providing openings in the fuselage for evacuation. The concept presented herein relates to the use of externally actuated blowout panels to provide these openings, either within the periphery of existing doors so as not to damage the surrounding airframe structure (as later explained), or through secondary structure adjacent to these doors or at other preselected locations in the fuselage. Another concept (10-B) relates generally to internally actuated explosive panels, to effect a similar end result, but is different in scope. This concept for external actuation of blowout panels is particularly well suited to be operated in conjunction with a ground rescue vehicle (reference concept 51-G), to comprise a more effective overall system. Although other types of standard firefighting equipment could be utilized with equal effectiveness to initiate external actuation of the system, a means for passenger descent is still required, from emergency exits where no descent devices would normally be provided.

## AREAS OF IMPROVEMENT IN EMERGENCY EVACUATION OF AIRCRAFT

Provides evacuation capability in case normal egress openings are inoperable or inaccessible. In the event that normal openings are operable and in use, affords the capability to provide additional openings to reduce total evacuation time.

## ESTIMATED QUANTITATIVE IMPROVEMENT IN SURVIVABILITY

Provides backup system to insure that evacuation openings will be available under various contingencies and thus prevent entrapment. Can provide additional emergency exits to increase total passenger egress flow rate, as well as improve cabin ventilation.

## HOW NEW IS THIS CONCEPT?

Previous publications:	Related article, "Big Jets May Blast Away Escape Doors," <u>Machine Design</u> , 17 August 1967
Patents Related:	2,797,884, "Emergency Release for Pressure Cabin Door," Peed, 2 July 1957
	3,201,169, "Safety Door for Vehicles," Scott, 17 August 1965

## HOW ORIGINAL IS THIS CONCEPT?

Some features of this concept are original; application of this concept to commercial aircraft is new. Adaptation of principle from military aircraft practices of providing for emergency ground release capability or jettisoning of hatches or canopies (usually by pyrotechnic charge to actuate a thruster). Similar instances of controlled explosive charges used in the Apollo Program to separate a structural joint or connection (final Command Module separation from Lunar Module - shaped charge severs tunnel structure).

## DETAIL DESCRIPTION OF SYSTEMS AND COMPONENTS

This concept presents a method for external actuation of blowout panels to provide emergency exits, if the normal exits are inoperable or inaccessible following a survivable crash, or to afford additional exits for egressing personnel. Both "destructive" and "nondestructive" type blowout panels may be provided, where the "nondestructive" type might be a panel within the envelope of the normal exit door, and would be utilized in a minor, apparent, or impending emergency if the door could not be rapidly opened by normal means. The design would be such that operation of the blowout panel would not damage the surrounding airframe structure, thus necessitating only replacement of the door. The "destructive" type blowout panel would be installed at selected locations within the fuselage, integrally fabricated with secondary structure, wherein actuation of the system would involve structural repair rather than simple replacement of an assembly; this would be utilized (as well as the "nondestructive" type) in an actual bona fide emergency where absolutely no consideration would be given to reparability of the airframe. These blowout panels could also be individual component-type assemblies (similar to the overwing exit hatches), which would normally be retained in place by structural fasteners or other devices to essentially be integrated with the structure; release and jettisoning of

these panels would be effected through a pyrotechnic device or system as described below.

The preferred design of the blowout panel would incorporate a linear shaped charge built into the structure, in a configuration so as to define an egress opening of suitable size. The design would preferably incorporate a peripheral backup structure of a configuration to insure that the controlled force of the charge as well as the debris is expelled outwardly, so as to present essentially no danger to the cabin occupants. External markings on the aircraft would indicate the locations of these blowout panels, as well as define their configuration.

The method of actuation of greatest versatility to any ground personnel would be by mechanical or electromechanical means, such as retrieving and pulling a stowed lanyard to actuate a pyrotechnic device or signal generator, which in turn would trigger the linear shaped charge to sever the panel from the airframe. Individual controls for each exit could be provided, or a single control at each of two or more locations (such as forward and aft fuselage sections on each side of the aircraft), where a manifolding technique would provide the capability of opening several exits by actuation of a single control.

Another method of actuation would be by electrical or electromechanical means, necessitating plug-in of an external electrical power supply. Necessary safeguards (shielding, mechanical or electrical interlocks, etc) would be provided to preclude inadvertent actuation. Provisions could be incorporated in the aircraft's electrical system to provide for on-board actuation by the flight crew, as an auxiliary or backup system, although external actuation is preferable. Electrical connectors (quick-disconnect type) would be strategically located adjacent to each major emergency exit, as well as other selected locations if necessary, readily accessible from the fuselage exterior through spring-loaded access doors; these locations would be appropriately marked for recognition purposes. The system could be wired so that all blowout panels, or selected panels only, could be actuated from any individual plug-in connection. Furthermore, system capability could be designed to accommodate some fuselage deformation or breakup without loss of the system.

Although several types of vehicles or firefighting equipment could perform the external actuation functions by providing a suitable electrical power supply, the ground rescue vehicle (GRV) described in concept 51-G is particularly well suited for this operation since it provides descent devices which would be required to complete the evacuation. These blowout panels would most likely be located where no onboard descent devices would normally be provided, or as in the case of a door-type blowout panel, the descent

slide would not usually be available unless the door itself were open. The necessary electrical umbilical cables and controls would be provided on each side ramp of the GRV, at the rescue operator's crew station, and a source of electrical power for this specific function would be provided in the basic vehicle.

### CONCEPT EVALUATION

#### OVERALL SUMMARY RATINGS

The cost-effectiveness rating of incorporating externally actuated blow-out panels in transport category aircraft will range from high to low, dependent upon the extent of implementation of this concept and the phasing in which such implementation is accomplished. Implementation of this total concept during production of new commercial transport aircraft would be relatively simple, resulting in a high cost effectiveness, and would be the optimum method of incorporation. Implementation of any portion of this concept subsequent to aircraft delivery (i.e., on aircraft currently in operation) would necessitate a retrofit program. Partial concept implementation, such as retrofitting only exit doors to provide blowout panels would result in a moderate cost-effectiveness rating, while an attempt to retrofit the entire system by including blowout panels in secondary fuselage structure as well as in exit doors would result in a low cost effectiveness and probably prohibitive costs.

#### ENGINEERING FEASIBILITY

All aspects of this concept are within the current state-of-the-art. All design and functional requirements could be met utilizing existing technology and design techniques.

#### PSYCHOLOGICAL EVALUATION

##### Human Engineering

No significant interaction with passengers until exit openings are provided through system activation, then only relatively routine or normal functions required, except that openings would probably be reduced in size, although still adequate to satisfy specification requirements.

### Motivational Psychology

A greater feeling of security should be imparted to some passengers in the knowledge that exit openings could be rapidly made available in an emergency, even under severe or adverse conditions. Other passengers would probably have a feeling of uneasiness and concern that the explosives might be inadvertently set off in flight or might backfire.

### PHYSIOLOGICAL EVALUATION

Implementation of this concept would tend to provide increased protection for passengers exposed to environmental hazards (fire, smoke, heat, toxic fumes, etc), by providing both an exit for passengers and a means for ventilating the cabin.

### KINESIOLOGICAL EVALUATION

No effects.

### COMPATIBILITY WITH OTHER REQUIREMENTS

This would be an independent system and would be compatible with other systems and requirements, although additional equipment may be required (i.e., descent means); well suited for operation with ground rescue vehicle (highly compatible).

### EFFECTIVENESS OF SOLUTIONS IN SPECIFIC PROBLEM AREAS

Provides capability for ground personnel (or flight crew) to actuate auxiliary emergency exits if exit doors and/or normal emergency exits (overwing) are inoperable or inaccessible. Improves total egress probability and may decrease total evacuation time; may also reduce cabin environmental problems by increasing ventilation capacity.

### EFFECTIVENESS OF SOLUTION IN TYPICAL ACCIDENT CASES

#### Case 1 - Denver, DC-8

Would have provided additional exits for egress, as well as ventilation of passenger cabin, with an estimated drastic reduction in fatalities (or possibly none).

51-G-2

51-G-2

Case 2 - Salt Lake City, B-727

Although all emergency exits were available and used (with the exception of the ventral stairwell), additional emergency exits provided by these blow-out panels would probably have resulted in a substantial decrease in fatalities.

## HOLE-CUTTING MECHANISM FOR EMERGENCY EXITS

CONCEPT DESCRIPTION

## GENERAL DESCRIPTION OF CONCEPT

The hole-cutting mechanism for emergency exits envisioned in this concept is an item of powered ground equipment adapted to rapidly cut and remove large portions in the fuselage structure of a transport-category aircraft following a survivable accident, in order to provide egress means for passengers, or entry for rescue or assistance by ground personnel. Use of this concept may provide auxiliary openings in fuselage structure, or primary openings if the normal egress means and emergency (overwing) exits are inoperative, inaccessible, or unusable because of aircraft attitude (i.e., exits blocked by debris, fuselage on side, etc). Although this mechanism may be mounted on a separate vehicle to provide an individual item of ground support equipment, or possibly on a modified firefighting vehicle, it is particularly well suited for operation in conjunction with a ground rescue vehicle (reference concept 51-G). In this manner, it will comprise a more effective overall system, since the ground rescue vehicle (GRV) inherently provides descent devices which are required to effect a complete evacuation system, as well as fire suppressant capabilities which could be utilized while the opening is being prepared and subsequently during evacuation.

## AREAS OF IMPROVEMENT IN EMERGENCY EVACUATION OF AIRCRAFT

Provides evacuation capability in the event that normal or emergency egress openings are inoperable, inaccessible, or unusable for any reason. If some of these openings are operable and in use, it affords the capability to provide additional openings to reduce total evacuation time.

## ESTIMATED QUANTITATIVE IMPROVEMENT IN SURVIVABILITY

Provides backup system to insure that evacuation openings can be made available under various contingencies and thus prevent entrapment. Can provide additional emergency exits to increase total passenger egress flow rate, as well as improve cabin ventilation, thereby enhancing survivability. Would be especially useful if the aircraft fuselage ended up in a rolled attitude, such that the exits on one side were blocked or otherwise unusable and the opposing exits were high so that passengers had to climb up the unlevel floor and/or over seats to egress.

## HOW NEW IS THIS CONCEPT?

Previous publications:                      Unknown, insofar as application to commercial aircraft is concerned.

Patents related:                            Unknown.

## HOW ORIGINAL IS THIS CONCEPT?

This concept is considered unique with respect to commercial aircraft application. Military aircraft rescue techniques using specialized equipment and trained rescue personnel have been in existence for many years. Similar type equipment, to cut into wreckage for flight crew rescue, have been considered in specialized applications.

## DETAIL DESCRIPTION OF SYSTEMS AND COMPONENTS

This concept presents a method for rapidly cutting suitable-sized openings in the fuselage structure of a transport-category aircraft following a survivable accident, with subsequent rapid removal and disposal of the cutout segment, to provide emergency exit openings and an unobstructed exit path. These openings may be rectangular or circular in geometric configuration, and of a size sufficient to permit rapid passenger egress. Although this cutting mechanism may be employed on any number of different vehicles, or may comprise a separate item of ground support equipment, it is particularly adaptable for operation with a ground rescue vehicle (GRV) (reference concept 51-G) to achieve optimum systems effectiveness, and is thus described.

The outer end of each GRV side ramp would include a vertically disposed rectangular frame, which is **gimbaled for self-centering when positioned** against a curved fuselage segment, subsequent to ramp connection and stabilization with respect to the fuselage. Four powered saw components are provided, one in each frame portion, which are track-guided and driven simultaneously on a noninterference basis (i.e., left unit, bottom to top; upper unit, left to right, etc). Controls for this entire unit would be provided at the rescue operator's station at the end of the GRV's side ramps. The side portions of this frame are formed as a shallow V, pivoted at the center so that the upper and lower saw components may engage the fuselage and perform their cutting functions simultaneously. The vertically operating saw components, throughout their vertical travel, would be continually driven forward to maintain contact with the curved surfaces of the fuselage.

These powered saw components would utilize high-speed metal cutting circular blades (or possibly a chain-saw type mechanism), and each of the four components would include a sensor mechanism to maintain a predetermined depth of cut. These cuts would be made essentially normal to the skin surface and of a depth sufficient to cut through the conventional stringer/frame aircraft fuselage construction. Also included in the four frame sections are holding devices which would be driven into the saw cut after passage of the powered saw component, to positively engage and hold the cutout fuselage segment upon completion of the sawing operation. Removal of this cutout fuselage segment would be accomplished by first withdrawal, then rotation, of the frame assembly, outward and away from the crew station at the end of the ramp, and above the ramp surface. Sufficient holding power during removal would insure that such low-strength materials as interior trim, lining, insulation, etc, would not inhibit segment removal.

Another version of a hole-cutting mechanism, which is less complex and consequently may be more reliable, as well as more rapid, would cut a circular rather than rectangular opening. Although smaller in size (i.e., such as approximately a 42-inch diameter opening as compared to approximately a 42 x 72-inch rectangular opening), it would still be considered adequate to provide a true "emergency" exit. This version would employ a circular hole or plug cutter, cylindrical in configuration with metal-cutting teeth on the forward edge, mounted on a central spindle or arbor. This arbor, the power unit, and associated drive equipment would be mounted in a frame above the ramp surface, capable of being driven a predetermined distance axially (for depth of cut), then withdrawn and rotated to one side, away from the rescue operator's station at the ramp end, to clear the passageway for egress.

Subsequent to ramp connection and stabilization with respect to the fuselage, this assembly would be driven forward so that the central spindle would first pierce the fuselage structure; radial or barbed devices would then lock the spindle to this structure so that subsequent withdrawal of the cutting assembly would remove the plug. The cylindrical saw would operate to cut through the structure, rapidly and efficiently. If the cutting teeth at the forward end of the cylinder are mounted on a rotating ring so that they may be disposed or flared slightly outwardly (to provide a clearance cut), then locked by a camming or overcenter action, they can be rotated inwardly upon completion of cutting to permit a thin, smooth-surfaced sleeve or bushing, stowed on the aft end of the cylindrical saw body, to be inserted as the saw is withdrawn; this would cover the rough-cut edges of the hole to prevent passenger injury during egress. Such a reversal of the saw teeth during or prior to removal will further assist in plug removal. This camming or flaring action of the ring-mounted cutting teeth may also be accomplished by the rotational direction of the cutting cylinder, or the tooth design and its interaction with the structure being cut.

## CONCEPT EVALUATION

### OVERALL SUMMARY RATINGS

The cost-effectiveness rating of incorporating this mechanism is variable. When utilized with a separate vehicle as an individual item of ground support equipment, its cost-effectiveness rating would be low, but would probably range from moderate to high when employed in conjunction with a ground rescue vehicle (GRV) (reference concept 51-G). It is considered that the circular hole cutting concept would result in improved cost-effectiveness, since it is considerably less complex and costly than the cutting mechanism described for rectangular openings and probably more reliable. Although the net result is a smaller opening, total overall evacuation time may be less because of the higher anticipated rate of preparing an opening.

### ENGINEERING FEASIBILITY

All aspects of this concept are within the current state-of-the-art. All design and functional requirements could be met utilizing existing technology and design techniques. Similar cutting techniques, as described for the circular hole cutter, are employed in oil-well drilling operations.

### PSYCHOLOGICAL EVALUATION

#### Human Engineering

No significant interaction with passengers until exit openings are provided through system activation; then only relatively routine or normal functions are required. Although openings will be smaller than normal entry/exit means, they would still be adequate for emergency egress and would satisfy specification requirements. A means to protect against passenger injury from the rough-cut edges of the opening is highly desirable. A passive means (such as the insert) may be more readily provided with the circular opening; the rectangular opening would be more difficult, with possibly only guidance and assistance provided by rescue personnel to minimize such injury.

#### Motivational Psychology

A greater feeling of security should be imparted to the passenger in the knowledge that exit openings could be rapidly made available in an emergency, even under severe or adverse conditions, such as fuselage rolled and normal or emergency exits not usable, etc.

### PHYSIOLOGICAL EVALUATION

Implementation of this concept would tend to provide increased protection for passengers exposed to environmental hazards (fire, smoke, heat, toxic fumes, etc), by providing both an exit for passengers and a means for ventilating the cabin.

### KINESIOLOGICAL EVALUATION

No effects.

### COMPATIBILITY WITH OTHER REQUIREMENTS

May not be as effective for off-airport accidents. Would generally be compatible with all aircraft attitudes.

### EFFECTIVENESS OF SOLUTIONS IN SPECIFIC PROBLEM AREAS

Affords capability to provide emergency exits under various contingencies (i.e., fuselage attitude, inoperable or unusable normal egress paths, etc).

### EFFECTIVENESS OF SOLUTION IN TYPICAL ACCIDENT CASES

#### Case 1 - Denver, DC-8

Would have been able to cut opening at left side of aft compartment where normal entry/exit door was jammed by structural deformation of the fuselage and internally blocked, with probable reduction in fatalities.

#### Case 2 - Salt Lake City, B-727

Could have provided additional emergency exits with a probable decrease in fatalities. Would have been highly effective in providing more rapid rescue capability for the two passengers and one crewmember who were trapped in the ventral stairwell for approximately 30 minutes.

## ULTRAVIOLET LIGHT ACTIVATION OF EGRESS SIGNS

CONCEPT DESCRIPTION

## GENERAL DESCRIPTION OF CONCEPT

Provide emergency ultraviolet light source and special fluorescent spray lacquer, fabric, or other material, normally invisible in incandescent light, for egress markings on rugs, seats, walls, and exits.

## AREAS OF IMPROVEMENT IN EMERGENCY EVACUATION OF AIRCRAFT

Improved exit awareness; visibility permits lighting of large areas with markings visible only during emergency conditions. Minimum impact on interior decor.

## ESTIMATED QUANTITATIVE IMPROVEMENT IN SURVIVABILITY

Preparation of exit.  
Passenger flow rate (indirectly).  
Reduction in wrong exits tried.

## HOW NEW IS THIS CONCEPT?

Previous publications: None known

Patents related: In preparation by Luminex, Inc.

## HOW ORIGINAL IS THIS CONCEPT?

Adapted from military aircraft developments or practice? Yes.

Adapted from nonaircraft fields or practice? Yes.

Other: Concept of supplying "package" of material and lights for aircraft emergency evacuation markings is original.

**DETAIL DESCRIPTION OF SYSTEMS AND COMPONENTS**

One manufacturer suggests providing:

- (a) Ultraviolet collimated light source. Collimated (indirect) light sources protect against eyeball glow which reduces visibility in darkness. Light must be rugged to withstand crash. Battery-powered; emergency-operated. Should be controllable by stewardess to demonstrate, at least at night.
- (b) Fluorescent material; could also be incorporated into rug fabric. Spray material could be under thin transparent plastic sheet or plate for wear resistance.
- (c) Spray-on method ideal for mockup test evaluation.
- (d) Lighting can be under seats or on side wall and baggage rack areas.

**CONCEPT EVALUATION****OVERALL SUMMARY RATINGS**

High cost-effectiveness

**ENGINEERING/OPERATIONAL FEASIBILITY**

Requires moderate improvement in wear resistance. Wearability testing required. Visibility in smoke test required.

**PSYCHOLOGICAL EVALUATION**

Human engineering (vision): Smoke scattering of light not tested. Eyeball glow may be prevented by light collimation; fluorescent light is of lower frequency than ultraviolet.

**PHYSIOLOGICAL EVALUATION**

Toxicity tests not performed. No apparent toxic effects.

## KINESIOLOGICAL EVALUATION

Not applicable

## COMPATIBILITY WITH OTHER REQUIREMENTS

Will not work with other strong white lights.

## EFFECTIVENESS OF SOLUTIONS IN SPECIFIC PROBLEM AREAS

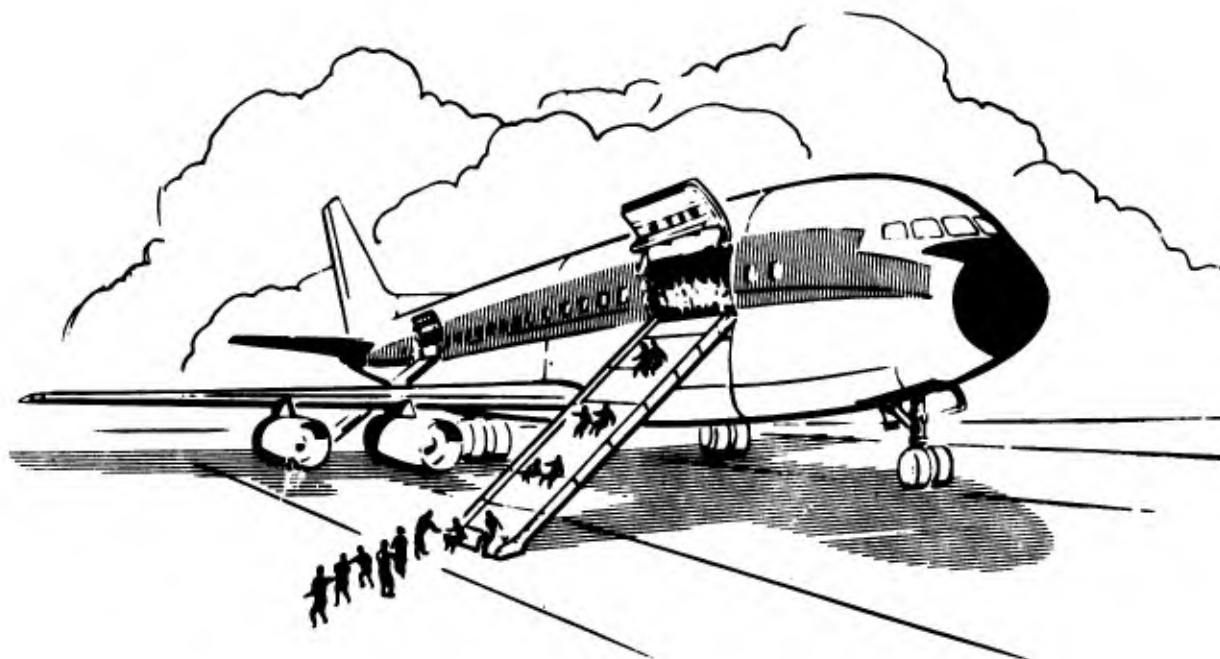
Applicable only to exit awareness and visibility. Requires adequate instructions for best advantage (what to look for).

## EFFECTIVENESS OF SOLUTION IN TYPICAL ACCIDENT CASES

Case 1 - Denver, DC-8

Presume it would have helped crawling passengers to see exit markings on rug, seats, and doors, and saved an additional two or three passengers by directing them to exits.

USE OF CARGO HANDLING CONCEPTS (LARGE DOORS,  
SWING-NOSE, SWING-TAIL)



CONCEPT DESCRIPTION

GENERAL DESCRIPTION OF CONCEPT

Provide large openings in nose, sides, and tail of passenger aircraft to facilitate the emergency evacuation of passengers. The feasibility of this concept is demonstrated by the fact that freight airplanes are in service which have large pressurized cabins with large doors, swing-nose, and swing-tail loading.

AREAS OF IMPROVEMENT IN EMERGENCY EVACUATION OF AIRCRAFT

- Reduces time for evacuation by up to 90 percent.
- Exits, if large enough will be obvious to all passengers.
- Improves interior light (during daytime) and ventilation.

## ESTIMATED QUANTITATIVE IMPROVEMENT IN SURVIVABILITY

Passenger flow rate: 90 percent  
 Reduction in wrong exits tried: 10 to 20 percent

## HOW NEW IS THIS CONCEPT?

Concept is new as applied to large passenger airplanes.

Previous publications: Aviation Week and Space Technology,  
 6 Apr 1959, 19 Nov 1962, 11 Jun 1962,  
 2 Sep 1963, and 31 Oct 1966

Patents related: Reference cargo doors, patents.

## HOW ORIGINAL IS THIS CONCEPT?

Is now the applied state-of-the-art for cargo and freight aircraft.

Could be adapted for passenger emergency unloading from currently flying freight aircraft. Using the same designs, large exit doors, swing tails, and swing noses could be provided for nominal weight penalty.

## DETAIL DESCRIPTION OF SYSTEMS AND COMPONENTS

Swing nose: The nose of the airplane immediately aft of the pilots' compartment is hinged so that the whole nose including the pilot's compartment swings to open the whole forward fuselage allowing a very large escape exit for passengers.

Swing tail: The tail immediately aft of the passenger cabin is hinged and swings aside opening up a large escape exit for passenger evacuation.

Ciamshell tail with ramp: The tail cone of the airplane opens in three pieces, the bottom piece serves as a ramp; the other two pieces move left and right leaving a large escape exit.

Large side doors - 8 x 15 feet: Large doors on the sides of the cabin hinged at the top or bottom open up large openings for passenger evacuation.

### CONCEPT EVALUATION

#### OVERALL SUMMARY RATINGS

Cost-effectiveness: High

These devices are considered an essential requirement for very large capacity aircraft.

#### ENGINEERING FEASIBILITY

Within current state-of-the-art. Requires application of cargo aircraft design to passenger aircraft with corresponding accommodation of seating arrangements.

#### PSYCHOLOGICAL EVALUATION

Human engineering: Improves ventilation, vision (less smoke, more daylight), and considerably improves personnel access to exit.

Behavioral psychology: May improve behavioral reaction to exit activity by visually creating a large exit.

Motivational psychology: May have some negative effect in the reduction of side (handhold) support during exit.

#### PHYSIOLOGICAL EVALUATION

Experimentation required to determine the extent to which large openings would improve ventilation, versus increasing cabin smoke, heat, and toxicity.

**KINESIOLOGICAL EVALUATION**

May make greater demands on crew or passengers to open exits, especially in the event of a malfunction. Should provide better exits, thus reducing coordination demands on passengers except as previously noted under motivational psychology.

**COMPATIBILITY WITH OTHER REQUIREMENTS**

Essentially compatible with all other devices except possibly explosive hatches which are a separate consideration. May have impact on slide and egress devices. Very suitable for use with concepts 7-B or 9-B.

**EFFECTIVENESS OF SOLUTIONS IN SPECIFIC PROBLEM AREAS**

Should facilitate exit for all passengers/crew, but especially disabled persons who need more space. If the swing-tail were not disabled, it should reduce the problem of rolled/tilted aircraft. Possible help for smoke and fumes problem, and could improve ground crew access.

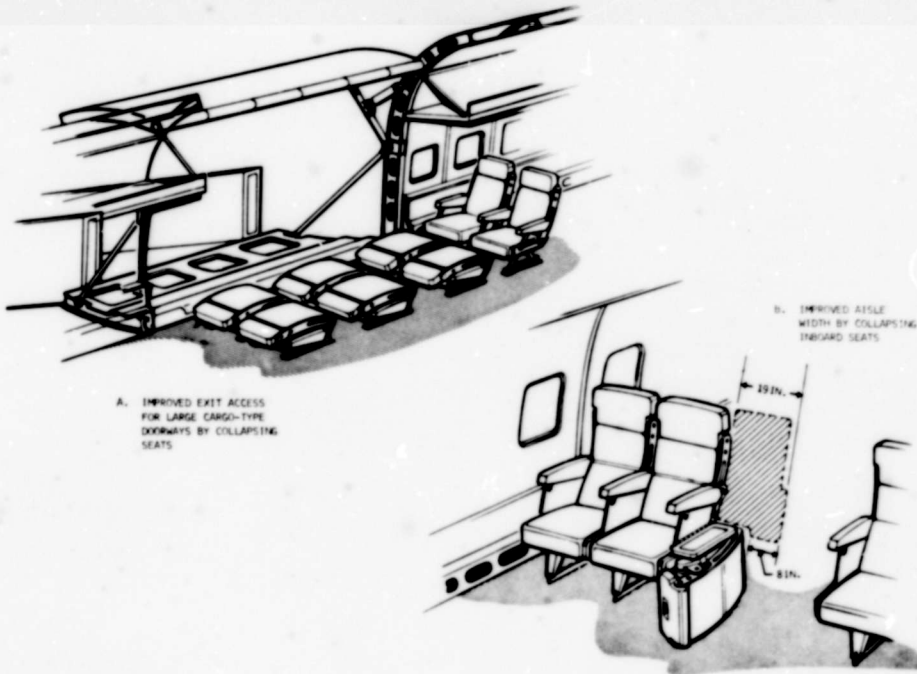
**EFFECTIVENESS OF SOLUTIONS IN TYPICAL ACCIDENT CASES****Case 1 - Denver, DC-8**

Either the large cargo door or the swing-tail would have been likely to save the lives of the remaining 16 passengers at Denver because of the large increase in exit rate.

**Case 2 - Salt Lake City, B-727**

The additional large exit areas could have enabled a large number if not all of the victims of the fire to escape. While the swing-tail may not be feasible with rear engine aircraft, one or two large doors would greatly accelerate evacuation time.

## FOLDABLE SEATS TO ASSIST EMERGENCY EXIT ACCESS AND CLEAR AISLEWAYS



### CONCEPT DESCRIPTION

#### GENERAL DESCRIPTION OF CONCEPT

This concept provides for increasing passenger accessibility to emergency window or escape hatches by reducing obstructions imposed by passenger seats. The concept includes the following:

- (a) Provides the capability for seats adjacent to emergency exits to translate downward and forward and drop back rests down to form relatively level platform.
- (b) Inboard (aisle) seats could also be foldable downward and outward to form increased aisle width along entire length of aisle.

## AREAS OF IMPROVEMENT IN EMERGENCY EVACUATION OF AIRCRAFT

Improve passenger access to emergency exits. Reduced congestion in aisles if aisle seats are folded.

Improve egress time.

## ESTIMATED QUANTITATIVE IMPROVEMENT IN SURVIVABILITY

Quantitative improvement would be safety of passengers preparing to exit and increase in number of passengers through an exit, estimated increase in flow rate 10 to 20 percent.

## HOW NEW IS THIS CONCEPT?

Foldable seats for quick-change cargo/passenger aircraft are at least 6 years old; however, for emergency egress, only the backs have been able to fold forward. Stewardess seats and theater seats have had foldup seat bottoms for 10 to 50 years. However, this extension of the concept is new with this study as far as is known by literature search to date.

Patents related: Unknown

## HOW ORIGINAL IS THIS CONCEPT?

Unknown previous application. Passenger survival dictates provisions for the easiest, safest, and quickest methods of egress. Small aisle width has been cited as unsafe.

It is believed this is an original approach to providing increased aisle width for emergency egress with minimum reduction in aircraft passenger revenue potential.

## DETAIL DESCRIPTION OF SYSTEMS AND COMPONENTS

Detail seat installation designs, employed by the various aircraft manufacturers, dictate a different design approach for each seat. Many designs currently incorporate a seat back foldability (break-forward) concept.

- (a) To provide a relatively level low-profile seat back platform for exit access requires two separate design requirements for seat assemblies:
- (1) To modify the two- or three-seat assemblies to provide capability for releasing the entire seat rack from its floor suspension and moving the seat rack forward and downward to obtain a minimum profile. Operation should be quickly performed by one person.
  - (2) To provide capability for folding the seat backs forward until level with the arm rests and locking them automatically in that position; or, alternately, folding the seat back rest backward until level and removing the arm rests as required. A type III overwing exit would not require the outboard arm rest to be removed, for example. This provides a lower profile, but a longer package and only can be used for one or two seat rows until the available space between seat attach points is used up.
- (b) To provide an increase of aisle width throughout the length of the airplane, or at least the tourist section. One aisle seat on each row could be made to fold into a box-table top area, or even to slide into and under the adjacent seat. An additional 15 to 25 inches would be very valuable. The seat could also be folded for normal in-flight use whenever the passenger manifest permitted, thus enhancing customer appeal by increased roominess and lounge-like appearance of tables.

Both of these capabilities could be provided in existing aircraft by retrofitting with new seats. The scope of such a change is indicated for type (a) folding seats (for exit access only) for representative aircraft models:

707-120B	Two seat racks with two seats each
707-320C	Two seat racks with three seats each
DC-8-61	Two seat racks with three seats each
Boeing SST	Four seat racks with two three-seat and two two-seat assemblies

CONCEPT EVALUATION

## OVERALL SUMMARY RATINGS

Cost-effectiveness: Moderate

Cost would be high; but, if comparing alternatives of folding seats versus one less seat per row, the cost might be worth the gain in revenue potential.

## ENGINEERING FEASIBILITY

Requires moderate improvement in state-of-the-art for minimum application of folding seats. Considerable design ingenuity would be required for an extensive application of the folding seat. Complexity would increase cost, weight, and maintenance, and probably reduce reliability. Brief case, hand bags, and loose debris must be positively eliminated from under such seats.

## PSYCHOLOGICAL EVALUATION

Human engineering: Improves visual attractiveness if seats are folded when passenger list permits. Passenger evacuation behavior pattern would be considerably improved if aisle width or emergency door access were improved to this extent. Many persons are not easily taught stowage of mechanical devices. Stewardess-actuated semiautomatic system seems almost a necessity.

## PHYSIOLOGICAL EVALUATION

No effect

## KINESIOLOGICAL EVALUATION

Potentially offers great benefit in speed and freedom of movement in cabin during emergency. May require added tires, exertion, and motor skill to stow seats in an emergency. However, if the stewardess, during preflight briefing, could explain a single method of stowing the seats, this problem might be avoided. An automatic system is preferred.

### COMPATIBILITY WITH OTHER REQUIREMENTS

Generally compatible with all other concepts. Especially helpful for cargo door concepts (53-B), if seats fold flat to form low-profile platform or if seat bottoms fold up to form effectively greater access aisles across ship.

### EFFECTIVENESS OF SOLUTIONS IN SPECIFIC PROBLEM AREAS

May compound problems of incapable passengers. Aisle blocking problems and exit access problems greatly reduced. Aisle debris may hinder folding, but extra width permits flexibility to walk, climb around.

### EFFECTIVENESS OF SOLUTION IN TYPICAL ACCIDENT CASES

#### Case 1 - Denver, DC-8

A significant factor in the 16 deaths at Denver according to one accident report was the narrow (15-inch) aisle width. A wider aisle may have improved passenger floor sufficiently to evacuate a high percentage of the 16.

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SIMPLE SMOKE FILTER  
(MOIST CLOTH)



CONCEPT DESCRIPTION

GENERAL DESCRIPTION OF CONCEPT

A moist cloth of several layers, large enough to cover the mouth and nose. The cloth should have elastic bands to fit around the head, and would be sealed in a plastic bag.

AREAS OF IMPROVEMENT IN EMERGENCY EVACUATION OF AIRCRAFT

It is believed that a wet cloth would be fairly effective in removing smoke particles and very soluble acid constituents which are quite irritating. Smoke particles are now known to be hazardous. (Bieberdorf, F. W., and Yuill, C. H., "An Investigation of the Hazards of Combustion Products in Building Fires," 14 October 1963, Southwest Research Institute, San Antonio, Texas). This is likely due to absorption of toxic gases on smoke particles, thus making it possible for the particles to deliver high concentrations of poisonous and irritating substances to the pulmonary tissue.

### ESTIMATED QUANTITATIVE IMPROVEMENT IN SURVIVABILITY

Passenger flow rate: Some improvement on account of ability of passengers to keep moving. Perhaps complete prevention of death due to hot air or smoke inhalation if evacuation exits are operable.

### HOW NEW IS THIS CONCEPT?

Previous publications: None known for this application.

Patents related: None known for this application

### HOW ORIGINAL IS THIS CONCEPT?

The concept of breathing through wet handkerchiefs or cloths during smoke exposure is very old. Provision of wet cloths by airlines for cleaning hands and face is an old concept. It is believed that making sure that every passenger can have one in an emergency and calling attention to this additional use is new.

### DETAIL DESCRIPTION OF SYSTEMS AND COMPONENTS

The presently used small wet, washing cloths could be adapted for, or developed into, the smoke filter. Possibly, the device could serve a dual purpose for economy. The cloth and attaching headband should be enclosed in a waterproof plastic sealer, with pull or tear opening. The container should contain simple instructions for use. The containers should be placed in all seat pouches.

### CONCEPT EVALUATION

#### OVERALL SUMMARY RATINGS

Cost-effectiveness: High, very favorable.

Low cost for what promises to be very effective. Experimentation is recommended to demonstrate.

#### ENGINEERING FEASIBILITY

Within current state-of-the-art.

#### PSYCHOLOGICAL EVALUATION

Human engineering: Odor problems greatly reduced.

Behavioral psychology: Improved when protection from smoke and fumes is available.

#### PHYSIOLOGICAL EVALUATION

Toxicity should be greatly reduced.

Heat tolerance, for ingested heat, should be improved.

#### KINESIOLOGICAL EVALUATION

No specific benefit, no penalty, unless the mask does not fit properly; then one hand may be required to hold it in place.

#### COMPATIBILITY WITH OTHER REQUIREMENTS

Compatible with all other concepts except 6-A (smoke hood) would probably not require use of the moist cloth.

#### EFFECTIVENESS OF SOLUTIONS IN SPECIFIC PROBLEM AREAS

Reduces or eliminates many man and environment problems which are psychologically or physiologically related to smoke, fire, and fumes.

## EFFECTIVENESS OF SOLUTION IN TYPICAL ACCIDENT CASES

Case 1 - Denver, DC-8

It is expected that possibly all of the victims of the Denver crash could have survived by use of this device. Experimentation should prove that at least an additional 60 seconds of safe breathing is possible in a smoke-filled cabin which would probably have been sufficient in this case for complete evacuation.

## PASSENGER VOLUNTEER EMERGENCY ASSISTANT PROGRAM

### CONCEPT DESCRIPTION

#### GENERAL DESCRIPTION OF CONCEPT

Initiate an approved FAA training program to qualify volunteer assistant flight attendants. The trained volunteer service will augment the flight attendant's efforts during an actual emergency evacuation.

#### AREAS OF IMPROVEMENT IN EMERGENCY EVACUATION OF AIRCRAFT

- Reduced egress time.
- Improve public training and preparation of passengers.
- Increased passenger assistance and guidance.

#### ESTIMATED QUANTITATIVE IMPROVEMENT IN SURVIVABILITY

- Preparation of exit: 25 percent extra exits available
- Passenger flow rate: 10 to 50 percent depending on conditions

#### HOW NEW IS THIS CONCEPT?

Adapted from nonaircraft fields or practice: ski patrol, Red Cross First Aid, Sierra Club, and other volunteer semiskilled personnel organizations.

#### DETAIL DESCRIPTION OF SYSTEMS AND COMPONENTS

Properly trained assistant flight attendants could help cope with emergency evacuations. Training should start soon to help future critical conditions as passenger density increases.

It is expected that many passengers who travel extensively via commercial aircraft will volunteer for the training. Candidates would be expected to pass minimum required written, oral, and physical standards. Upon successful completion of the training program, the trainee would receive a validated card and/or diploma. When the qualified flight assistant travels, he or she presents the validated card when purchasing a ticket and is assigned to a flight attendant. The attendant would assign the assistant to a specific seat and area of assistance in case of an emergency.

Possibly as an incentive, the assistant attendant could be allowed to purchase his ticket at a reduced rate. This may be desired from a legal point-of-view. Also, the airlines insurance company may possibly approve of the Emergency Assistant Program and be willing to defray some of the training expenses.

### CONCEPT EVALUATION

#### OVERALL SUMMARY RATINGS

Cost-effectiveness: High

Appears feasible, but is subject to chance factors of passenger population for effectiveness. "Best buy" in passenger education category.

#### ENGINEERING/OPERATIONAL FEASIBILITY

No design or fabrication involved. Cost of maintaining training of personnel cost of additional facilities to handle more personnel must be considered; number of volunteers not known. Estimated 1,000 men in USA is easily possible. A central office for clearing information and mailing is fixed cost.

#### PSYCHOLOGICAL EVALUATION

##### Human Engineering

Not applicable

##### Behavioral Pschyology

Prior training and clear responsibility would be advantage in emergency.

##### Motivational Psychology

Positive: Similar examples are ski patrols, posse, deputies, Sierra Club, volunteer fire departments. Adventure, prestige, knowledge, and authority are desirable.

Negative: Fear of "getting involved," inconvenience of training, lack of time may defeat. Airlines may object to "frightening best customers."

**PHYSIOLOGICAL EVALUATION**

Not applicable

**KINESIOLOGICAL EVALUATION**

Provides good use of able-bodied men in key positions to open doors, assist passengers.

**COMPATIBILITY WITH OTHER REQUIREMENTS**

Compatible with all other concepts.

**EFFECTIVENESS OF SOLUTIONS IN SPECIFIC PROBLEM AREAS**

Should help in passengers locating exits, opening exits, reducing delay at exits, reducing personal injury, panic, confusion. Aids slide egress on ground.

**EFFECTIVENESS OF SOLUTION IN TYPICAL ACCIDENT CASES****Case 1 - Denver, DC-8**

Trained assistant volunteers, familiar with the aircraft design, would have probably directed passengers from forward part of rear compartment into relatively clear first class, front compartments. This could have evacuated at least half of the rear compartment passengers before smoke overcame them.

## SMOKE AND FUME REMOVAL SYSTEM

CONCEPT DESCRIPTION

## GENERAL DESCRIPTION OF CONCEPT

The system could use existing cabin air vents in reverse flow to withdraw smoke and fume from cabin. Emergency batteries and fans could be used, or bottled nitrogen.

## AREAS OF IMPROVEMENT IN EMERGENCY EVACUATION OF AIRCRAFT

Improves safety and visibility of persons on the aircraft until evacuation could be completed. Prevents super heating of interior atmosphere, and may reduce spontaneous combustion or spread of fires.

## ESTIMATED QUANTITATIVE IMPROVEMENT IN SURVIVABILITY

Reduction in wrong exits tried: 10 percent

Survival time possibly up to 2 to 3 minutes depending on sources of fire.

## HOW NEW IS THIS CONCEPT?

Previous publications: None

Patents related: Component patents, probably none for this system per se.

## HOW ORIGINAL IS THIS CONCEPT?

Adapted from commercial aircraft developments or practice, i.e., cockpit in-flight smoke removal systems. A check of various commercial aircraft manufacturers indicates, however, that no work is being done on cabin smoke evacuation. Mr. John F. Marcy was contacted at FAA-NAFEC, and indicated that some testing had been done with small openings in simulated cabins with little effect on smoke. However, more sophisticated testing of an active smoke removal device is indicated, with measured results in reduction of heat, smoke, and toxicity.

**DETAIL DESCRIPTION OF SYSTEMS AND COMPONENTS**

Add emergency battery(ies) and fan(s) to draw smoke and fumes (increased flow) through cabin air conditioning inlets.

Add nitrogen bottle(s) adjacent to skin plug access plates. Plugs to be withdrawn, and nitrogen released through opening creating flow, using jet pump aspiration effect.

Since various aircraft cabin airflow systems differ greatly, more detailed description is not feasible. Considerable investigation of suitable methods must be done and tests with fire and smoke conditions must be made to establish overall desirability and to prevent undesirable "chimney" effects.

The following data on firefighting were taken from:

Bieberdorf, F. W., and Yuill, C. H., "An Investigation of the Hazards of Combustion Products in Building Fires, 14 October 1963," Southwest Research Institute, San Antonio, Texas; available from Division of Hospital and Medical Facilities, U.S. Department Health, Education, and Welfare.

"As the fire in a closed building grows in intensity, it 'burns' the oxygen at a more rapid rate. As this supply diminishes, the combustion becomes incomplete, and less of the carbon is consumed. Under such conditions dense smoke and voluminous quantities of carbon monoxide and other unburned gases could be expected. It is standard procedure in fighting such fires to provide ventilation at a high point of the building, such as the roof, for the purpose of exhausting unburned gases and to help clear the air for the benefit of entering firemen.

"The presence of unburned gases in this type of fire can be a severe hazard if not approached properly. To open a door or window of a burning building at a low level before venting the roof or upper story is to invite trouble. The rapid entry of a fresh supply of oxygen will mix with the unburned gases to form a highly combustible - often explosive - gaseous mixture. Firemen have been blown from a door for considerable distances by 'hot air' explosions."

**CONCEPT EVALUATION****OVERALL SUMMARY RATINGS**

Cost-effectiveness:                      Moderate

## ENGINEERING FEASIBILITY

Within the current state-of-the-art: The main problems are in designing for low weight penalty, assuring power, availability, and in maintaining reliability of the system after a crash.

## PSYCHOLOGICAL EVALUATION

Improves visibility and reduces noxious fumes.  
Improves behavioral response because of "clean" atmosphere.

## PHYSIOLOGICAL EVALUATION

Reduction in toxicity and related inhalation problems. If effective, will reduce heat and resulting pain or burns.

## KINESIOLOGICAL EVALUATION

No effect.

## COMPATIBILITY WITH OTHER REQUIREMENTS

Essentially compatible with other concepts, although there may be some conflict with the fire suppressant devices.

## EFFECTIVENESS OF SOLUTIONS IN SPECIFIC PROBLEM AREAS

Reduces problems of visibility, tears, eye/skin pain toxic fume inhalation, internal smoke, and fumes.

## EFFECTIVENESS OF SOLUTION IN TYPICAL ACCIDENT CASES

Case 1 - Denver, DC-8

An effective smoke removal system could have prolonged consciousness of the 16 passengers long enough to have permitted their evacuation.

## FREON FIRE SUPPRESSION DURING EVACUATION

CONCEPT DESCRIPTION

## GENERAL DESCRIPTION OF CONCEPT

The concept includes an installed system of stored Freon ( $\text{CF}_3\text{Br}$ ), and methods of dispensing it into the cabin area, to suppress incipient fire.

## AREAS OF IMPROVEMENT IN EMERGENCY EVACUATION OF AIRCRAFT

Reduces fire and smoke in cabin; expands passenger evacuation time; reduces fear, panic, and degraded human motor activity.

## ESTIMATED QUANTITATIVE IMPROVEMENT IN SURVIVABILITY

Passenger flow rate: 10 to 35 percent  
Reduction in wrong exits tried: 40 percent  
Increased time available: 30 to 40 percent

## HOW NEW IS THIS CONCEPT?

Previous publications: Refer to concept 17-F for publications on similar concepts.

Patents Related: 2,015,995, "Fire Preventing and Extinguishing System for Aircraft," (out of date) Egtvedt, 10 Oct 1935

2,701,827, "Apparatus for Detecting Incipient Fire and Explosion," Mathison, 30 Apr 1951

## HOW ORIGINAL IS THIS CONCEPT

Adapted from commercial developments.

## DETAIL DESCRIPTION OF SYSTEMS AND COMPONENTS

The use of Freon as a fire suppressant in the cabin could be accomplished by its storage in individual containers along the overhead storage rack, or

by a manifold system along such a storage rack. While there are sufficient data available, it is expected that the Freon would be released from a rupture device and expelled either by pressure assist or by gravity flow.

The principal problem would be in attaining the optimum fire suppression relative to safe toxic levels. Some of the relative advantages of Freon are as follows:

The following information is taken from Roth, E. M., "Space Cabin Atmospheres, Part II Fire and Blast Hazards," NASA SP-48., Washington, D.C., 1964.

The choice of an extinguishing agent is determined by the following factors:

Specific gravity  
Corrosive effects on vehicle structure  
Physiological toxicity  
Electrical conductivity  
Swelling of elastomers  
Effectiveness against unusual fires

- (a) Some extinguishants, listed in order of increasing specific gravity, are  $\text{CO}_2$ ,  $\text{CF}_3\text{Br}$ ,  $\text{CCl}_4$ ,  $\text{CH}_3\text{Br}$ ,  $\text{CH}_2\text{BrCl}$ ,  $\text{CF}_2\text{BrCF}_2\text{Br}$ , and  $\text{CF}_2\text{Br}_2$ .
- (b) Considering the corrosive effects on steel, brass, and aluminum, the extinguishants are listed as follows in the order least to worst:  $\text{CF}_3\text{Br}$ ,  $\text{CF}_3\text{Br}_2$ ,  $\text{CF}_2\text{Br}_2$ ,  $\text{CF}_2\text{BrCF}_2\text{Br}$ ,  $\text{CO}_2$ ,  $\text{CCl}_4$ ,  $\text{CH}_2\text{BrCl}$ ,  $\text{CH}_3\text{Br}$ .
- (c) Toxicity: According to Roth's sources, the approximate lethal concentrations for 15-minute exposure to rats are shown in the table. In addition, the concentration is given for the substances which, on heating to  $1,470^\circ\text{F}$ , kill the rats in 15 minutes.

	Natural Vapor (ppm)	Heated Vapor (ppm)
CF <sub>3</sub> Br	800,000	14,000
CO <sub>2</sub>	658,000	658,000
CF <sub>2</sub> ClBr	324,000	7,650
CF <sub>2</sub> BrCF <sub>2</sub> Br	126,000	1,600
CF <sub>2</sub> Br <sub>2</sub>	54,000	1,850
CH <sub>2</sub> BrCl	29,000	4,000
CCl <sub>4</sub>	28,000	300
CH <sub>3</sub> Br	5,900	9,600

- (d) All the foregoing compounds are electrically nonconducting.
- (e) Regarding swelling of elastomers, they may be listed from best to worst: CO<sub>2</sub>, CF<sub>3</sub>Br, CF<sub>2</sub>ClBr, CF<sub>2</sub>BrCF<sub>2</sub>Br, CCl<sub>4</sub>, CH<sub>2</sub>BrCl, CF<sub>2</sub>Br<sub>2</sub>.
- (f) The extinguishant concentrations required to put out ethyl alcohol fires are as follows: CF<sub>2</sub>BrCF<sub>2</sub>Br 53,000 ppm, CF<sub>2</sub>Br<sub>2</sub> 58,000, CH<sub>2</sub>BrCl 87,000, CH<sub>3</sub>Br 114,000, and CO<sub>2</sub> 141,000. No information on CF<sub>3</sub>Br.

"It has been recommended for aircraft that, in automatic systems, the halogenated compounds should be discharged within a maximum duration of 1 second and carbon dioxide within 1.25 to 1.35 seconds from 400 to 600 psi cylinders to attain the concentrations in table 28." These concentrations are as follows: expressed in ppm by volume CF<sub>3</sub>Br 60,000, CH<sub>2</sub>BrCl 110,000, and CO<sub>2</sub> 370,000.

From these considerations, it is seen that CF<sub>3</sub>Br, sold under the trade name of Freon 13B1, could possibly be used as suggested. Assuming the passengers were exposed to 60,000 ppm for only 90 seconds, it probably would have no ill effect. Rats and dogs have been exposed to 23,000 ppm 6 hours a day, 5 days a week, for 18 weeks without observable effects. (Industrial Hygiene and Toxicology, Vol. 2, p. 1328)

CONCEPT EVALUATION

## OVERALL SUMMARY RATINGS

Cost-effectiveness: Moderate

Appears to be a reasonable approach, effective for internal fires.

## ENGINEERING FEASIBILITY

Useful for protection against internal fires only. Adds weight to aircraft. Rough estimate is 150 pounds for 2-minute supply, Boeing 707 type. Special plumbing and control systems are required. Additional maintenance and inspection costs will be required. Test of compatibility of fabrics and other materials with Freon necessary. Has better potential "restowability" than foams (less damage and cleaning requirements for interiors.)

## PSYCHOLOGICAL EVALUATION

Human engineering: Odor of gas may be unpleasant, irritating, distressing. Will require explanation.

Behavioral psychology: Some danger of excessive fear, but normally not likely to be a problem. System unseen, unobtrusive "dry." No damage to clothes is desirable feature.

Motivational psychology: Some danger of excessive fear, but normally not likely to be a problem. System unseen, unobtrusive "dry." No damage to clothes is desirable feature.

## PHYSIOLOGICAL EVALUATION

Toxicity: (See concept description sheet.) Use of antismoke mask would defeat most objections to odor.

## KINESIOLOGICAL EVALUATION

No effect on strength, speed, coordination. May delete need for antismoke hood for internal fires, saving time of donning.

## COMPATIBILITY WITH OTHER REQUIREMENTS

Compatible with all concepts except as follows:

- (a) Concept 17-F is not needed for interior fire suppression if this concept is effective.
- (b) Compatibility with 59-F uncertain.

## EFFECTIVENESS OF SOLUTIONS IN SPECIFIC PROBLEM AREAS

Useful for internal fires only, not external fire and smoke. May be partially defeated in aircraft with broken fuselage. Reduces damage, repair cost of aircraft internal fire.

## EFFECTIVENESS OF SOLUTION IN TYPICAL ACCIDENT CASES

Case 1 - Denver, DC-8

Negligible benefit; smoke was from external source, admitted when cabin doors opened.

Case 2 - Salt Lake City, B-727

Probably would have reduced internal fire propagation to some extent, permitting many more (perhaps 20) passengers time to escape. Fire entered cabin "under seat 18E light window seat...immediately" or "1 to 2 seconds" after impact and was essentially contained within the fuselage.

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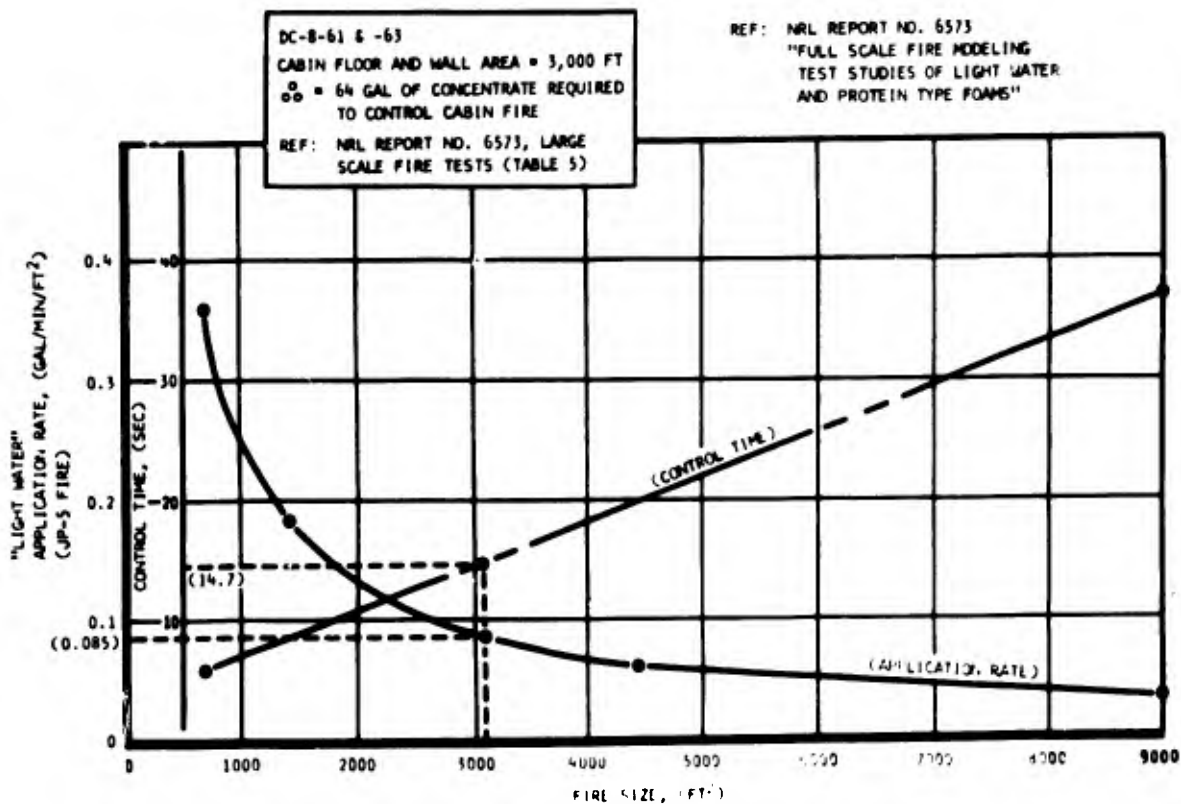
ONBOARD USE OF A "LIGHT WATER" FIRE SUPPRESSION  
SYSTEM FOR PASSENGER-TYPE AIRCRAFT

CONCEPT DESCRIPTION

GENERAL DESCRIPTION OF CONCEPT

To include a "Light Water" fire suppressant system in passenger-type aircraft, the system would be designed to completely cover all surface areas within the passenger cabin. To increase reliability of the system, it is proposed that overlapping redundant systems be provided. The onboard system would include:

- (a) Storage container for liquid concentrate (pressure vessel) based upon comparison analysis to aircraft fuel (JP-5) spill fires; approximately 64 gallons of "Light Water" would be required for large aircraft (DC-8-61 and -63) fire control.



- (b) Air or nitrogen pressurization system.
- (c) Nozzle distribution system.

#### AREAS OF IMPROVEMENT IN EMERGENCY EVACUATION OF AIRCRAFT

Protect passengers from internal fires.

#### ESTIMATING QUANTITATIVE IMPROVEMENT IN SURVIVABILITY

Unknown

#### HOW NEW IS THIS CONCEPT?

Previous publications:	Peterson, H. B., Jablonski, E. J., Neill, R. H., Gipe, R. L., and Tuve, R. L., <u>Full-Scale Fire Modeling Test Studies of "Light Water" and Protein Type Foams</u> , NRL Report 6573, 15 Aug 1967.
Patents related:	3,258,423, "Method of Extinguishing Liquid Hydrocarbon Fires," R.L. Tuve, E. J. Jablonski, 28 June 1966.

#### HOW ORIGINAL IS THIS CONCEPT?

Application to onboard use has not been investigated (reported in literature). Ability of "Light Water" to be effective without accompanying dry chemical (Ref NRL Report 6573) reduces airborne system weight requirements by approximately one-half.

#### DETAIL CONCEPT DESCRIPTION

The application of a "Light Water" fire suppression system to passenger-type aircraft will provide protection within the cabin area, from fire propagation. It would be expected that the passengers themselves would be "sprayed" with the "Light Water," thereby reducing the danger of fire in clothing. The ability of this technique to be applied to cabin interiors is unreported and unknown by the writer. The advantage of "Light Water" over

other types of suppressants for external fires indicates a possible application to onboard use. Also, it does not appear to be overly restricted by weight. Tests by Naval Research Lab indicate "Light Water" by itself to be an effective fire suppressant. Applying data from the NRI report (developed for JP-5 spill fires), an estimate is included in the attached figure of the quantity of "Light Water" required to control a fire within a KC-8-61 (or -63) type aircraft. Smaller, redundant "Light Water" systems should be located throughout the cabin area to insure complete coverage in the event of cabin breakup.

Components of a system would include:

- (a) Storage container for the "Light Water" concentrate solution. This would in effect be a pressure vessel to allow expulsion by a pressurizing source.
- (b) An air or nitrogen pressure source.
- (c) Ducting and nozzle system for distribution of the solution. A nozzle design which would distribute the solution in a hemispherical pattern would be required to saturate both floor and walls of the cabin.

#### CONCEPT EVALUATION

##### OVERALL SUMMARY RATINGS

Cost-effectiveness:                      Low - Moderate

##### ENGINEERING FEASIBILITY

Within current state-of-the-art? This concept is within the state-of-the-art. Equipment is available; however, specific aircraft requirements may necessitate design activities.

##### PSYCHOLOGICAL EVALUATION

Human engineering:                      "Light Water" spray may have adverse effects upon passenger vision and behavioral psychology.

## PHYSIOLOGICAL EVALUATION

Toxicity of "Light Water" has not been thoroughly examined, primarily with respect to the products of "Light Water" pyrolysis.

## KINESIOLOGICAL EVALUATION

Not applicable

## COMPATIBILITY WITH OTHER REQUIREMENTS

This concept does not appear to conflict with any other developed requirements.

## EFFECTIVENESS OF SOLUTION IN TYPICAL ACCIDENT CASES

Case 1 - Denver, DC-8

This concept does not appear to be applicable to the Denver DC-8 accident. Reports indicate no fatalities from flames. However, possible cabin area fires would have been eliminated, thereby reducing the amount of smoke and fumes.

Case 2 - Salt Lake, B-727

This concept would appear to have a high effect upon reducing fatality in this accident.

## ONBOARD CABIN INTERIOR FOAM FIRE SUPPRESSION

CONCEPT DESCRIPTION

## GENERAL DESCRIPTION OF CONCEPT

Installation of a manifold system in the overhead area of passenger compartments will allow distribution of a fire suppressant following a survivable crash landing. An onboard foam fire suppression system would require four major compartments or subsystems:

- (a) Storage container(s) for foam concentrate
- (b) Manifold distribution system
- (c) A pressurization system for expulsion of foam concentrate
- (d) Activating system

## AREAS OF IMPROVEMENT IN EMERGENCY EVACUATION OF AIRCRAFT

- (a) Increases time passenger compartment is habitable.
- (b) Reduces fire and smoke in passenger compartment.
- (c) Allows increased time for orderly preparation and cabin evacuation.
- (d) An on-board system is the only means of providing immediate passenger protection.

Foam Suppressant

The capability of high expansion foam to effectively suppress fire and smoke from simulated aircraft passenger cabins has previously been demonstrated. (Refer to following list of previous publications.)

## ESTIMATED QUANTITATIVE IMPROVEMENT

Passenger safety from heat, toxic gases, and smoke: To 100 percent.

## HOW NEW IS CONCEPT?

## Previous publications:

"Experimental On-board Aircraft Fire Suppression Equipment," NFPA Report MP66-2, By J. F. O'Regan, Bliss-Rockwood Div, E. W. Bliss Co, May 1966

"ALPA Cleveland Fire Test," by P. Heine, ALPA Reserve & Fire Comm, J. Brenneman, Fire Protection Engineer, IAL, 4 October 1966

Aviation Week and Space Technology,  
"System Fills Jet Cabin with Foam,"  
13 November 1967

## Patents related:

2,015,995, "Fire Preventing and Extinguishing System for Aircraft," Egtvedt, 10 Oct 1935

2,701,827, "Apparatus for Detecting Incipient Fire and Explosion," Mathison, 30 Apr 1951

## HOW ORIGINAL IS THIS CONCEPT?

Extension of commercial studies and military application of foam fire suppressant systems.

## DETAIL DESCRIPTION OF SYSTEMS AND COMPONENTS

The dual manifold would be located in the overhead area of aircraft passenger compartments. Location and spacing of nozzles would allow a dispersion pattern to cover maximum surface area of the compartment.

The manifolds should be lightweight and flexible to accommodate a maximum amount of fuselage distortion before rupturing. Design should include manifold reductions to limit flow to each nozzle in event of a manifold rupture. Nozzle design should incorporate a vane axial rotor to aid distribution of fire suppressant through centrifugal action.

The Bliss-Rockwood report identifies the following preliminary design guides for system requirements:

- (a) Foam system capable of flooding cabin in 30 seconds
- (b) System operation to be completely self-contained
- (c) Redundant systems
- (d) Sufficient foam to provide a volume 1-1/2 to two times the cabin volume

It is emphasized that these criteria are preliminary and should be utilized only as an evaluation starting point. The components comprising the system include:

- (a) A pressurizable, storage container for the liquid foam concentrate. The amount of foam concentrate is a function of the specific expansion ratio used. These may vary from 100:1 to 700:1. The higher the ratio, the lower the total system weight. However, the higher expansion ratio foams are not necessarily the most efficient in terms of foam life, insulating qualities, and fire suppression. The optimum ratio has yet to be determined. For comparison purposes, the following expansion ratio versus solution weights are referenced from the Bliss-Rockwood report for one cabin filling (6,500 cubic feet):

<u>Ratio</u>	<u>Gage of Solution</u>	<u>Wt of Solution (Lb)</u>
100:1	488	4,065
300:1	163	1,355
500:1	98	813
700:1	70	581

- (b) A storage container pressurization source, either compressed air or nitrogen. Information on the required foam delivery pressure is not available; therefore, the pressurization sources requirements cannot be defined. Passenger safety and aircraft weight and balance considerations will require the concentrate and pressure source containers to be located away from the immediate cabin area, possibly in the lower cargo bays.
- (c) A duct system will be required to distribute the concentrate to applicable cabin areas. (The distribution system will include a method of generating the foam.)

CONCEPT EVALUATION

## OVERALL SUMMARY RATING

Cost-effectiveness: Low

The high weight required to effectively fill the large jet transport cabin appears to be a prohibitive factor.

## ENGINEERING/OPERATIONAL FEASIBILITY

The possibility of application of such foams has been demonstrated. However, there are problems associated with weight and air supply needed for deployment. These include reduction of formation of bubble, and toxic hazards. A compressed air supply could be used to overcome the danger of contamination, but it would add to the cost, weight, and complexity. The restowage/refurbishing problem would be quite difficult for a minor fire or false alarm problem, as all the walls, rugs, seats, etc, would have to be wiped down or cleaned.

"A system for a Boeing 707 using cabin air for the foam and incorporating six to eight foam generators with their associated tankage and tubing would weigh 1,200 - 1,500 lbs." (Aviation Week and Space Technology, Nov 13, 1967, p 47)

## PSYCHOLOGICAL EVALUATION

Subjects who have participated in development demonstrations of the system report no ill effects, although there is a tendency to gag if the foam is ingested too rapidly. Hand motions suffice to push back the foam and break the bubbles closest to the mouth and nose. The use of the smoke-protective mask (Concept 6-A) may alleviate this problem. Announcements for preflight briefings and for emergencies would be necessary to help in passenger education.

Impairment of vision is a serious problem, requiring full application of tactual sense, audio warning systems, and well distributed directional lights.

### PHYSIOLOGICAL EVALUATION

"Routine examinations of personnel participating in system demonstrations and tests have revealed no harmful effects." (Aviation Week and Space Technology, Nov 13, 1967, p 47)

### KINESIOLOGICAL EVALUATION

Possibility of slipping on wetted surfaces or bumping against unseen obstacles in cabin is only apparent hazard if smoke-protective masks are used.

### COMPATIBILITY WITH OTHER REQUIREMENTS

The smoke-protective mask (concept 6-A) seems to be required to free hands and avoid gagging. Heavy reliance on special lighting (concept 24-C), tactual displays (concept 44-C), and on voice instructions (concept 40-A, 48-A, and 2-C) appears necessary. The fan indication (concept 27-C) might disperse foam too soon. Other fire suppressants might also cut down the foam, and should not be used at the same time.

### EFFECTIVENESS OF SOLUTIONS IN SPECIFIC PROBLEMS

This concept is designed to fight fires and reduce toxic hazards, thus prolonging safe stay-time in the fuselage.

### EFFECTIVENESS OF SOLUTION IN TYPICAL ACCIDENT CASES

#### Case 1 - Denver, DC-8

The foam, if generated from air bottles, may have prevented the heavy influx of smoke which apparently killed 16 passengers.

#### Case 2 - Salt Lake City, B-727

The foam could probably have greatly reduced the heat and toxic effects within the cabin, allowing many more persons to survive.

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## Appendix B

### REQUIREMENTS FOR EXPERIMENTAL EVALUATION OF SELECTED CONCEPTS FOR EMERGENCY EVACUATION OF TRANSPORT CATEGORY AIRCRAFT FOLLOWING SURVIVABLE ACCIDENTS

#### INTRODUCTION

New evacuation concepts for transport category aircraft, which offer significant potential benefit in removing both passengers and crew in a most efficient and safe manner following survivable emergencies, should be experimentally evaluated. Experimentation is necessary to accurately assess the improvements to be expected by incorporating the new concepts into present and future aircraft.

Presented herein are general and specific requirements for such experimental evaluation in the context of testing of emergency evacuation concepts using representative human subjects.

#### GENERAL REQUIREMENTS AND PHILOSOPHY

##### BASIC OBJECTIVES

- (a) To provide a meaningful measure of concepts improvement over existing techniques and procedures under representative environmental conditions.
- (b) To allow comparative analysis and evaluation of concepts, thus permitting selection of concepts on the basis of effectiveness and economy.
- (c) To identify possible modifications to the concepts which will increase their efficiency and performance.

A series of secondary specific objectives will be identified for a group of pilot, or preliminary, development tests as necessary to define test hardware configuration, ranges of variables to be tested and detailed instrumentation requirements. Specific hypotheses will be selected for each test of a specific concept or combination of concepts and conditions presented to subjects. Formulation of many of these hypotheses will depend upon the results of previous tests in the pilot test group.

## SCOPE OF ACTIVITIES

- (a) Development of test criteria, test configurations, and equipment
- (b) Experimentation with test hardware embodying principles described in new concepts using simulation of special environmental test conditions
- (c) Recording and documentation of results
- (d) Evaluation, correlation, and interpretation of test results
- (e) Generation of recommendations and material which can be used as a basis for improvements and specifications

These activities may be grouped in five phases in the chronological order shown.

## IDENTIFICATION OF VARIABLES

Through the systems approach, significant variables which may be operative during emergency evacuation of transport aircraft following survivable emergencies have been identified. Refer to appendix C, which identifies system elements and interfaces.

This same systems approach applied to test plan development allows the experimenter the flexibility to establish controls and combine significant variables, relative to a given concept evaluation, such that critical analysis of environment, aircraft configuration, evacuation concept technique, and procedure interactions may be ascertained in a systematic manner.

As a result of the analysis of the functional relationships significant to the possible conditions and requirements existing during emergency evacuation, two primary factors or dependent variables were identified as

- (a) Time - Measured as the rate of egress or the period during which passengers and crew are exposed to the hostile environment
- (b) Injuries - The incidence and type of injuries incurred as a result of evacuation technique or procedure inefficiency or failure.

As can be noted from appendix C, these two dependent variables are reflective to the numerous possible independent variables which may potentially be active within the context of any given accident. The unique

character of any specific emergency is primarily the result of the active existence or influence of these variables operative to differing extents or degrees in combination with each other.

#### GENERAL REQUIREMENTS FOR SELECTION OF VARIABLES

The basic requirements in the development of a test plan for the evaluation of new evacuation concepts are (1) that the test plan be realistic in terms of its feasibility within the scope and limitations of an experimental situation involving a mockup or test vehicle, and (2) that it employs volunteer subjects who impose basic constraints on the simulation of many potentially hazardous independent variables operative within an emergency environment. However, to a greater or lesser extent, nearly all of the independent variables specified in appendix C are capable of some degree of simulation. For example: irritants such as smoke and noxious odors in the form of tear gas or  $H_2S$  may be used to simulate toxic fumes; fire can be simulated through lighting techniques; characteristic populations can be specified; and emotional responses and injuries can be simulated in some passenger subjects through "stooges" and dummies. Various aircraft attitudes may be presented by gimbaling the test vehicle, and so on. The primary requirement is to select, from the numerous possible conditions which may exist, those which insure the adequate and valid testing of the concept(s) being analyzed. The number of possible conditions and combinations of conditions which can be simulated is enormous. There is a general lack of quantifiable data as to the weighting to be attributed to many specific independent variables relative to their effect upon time and injuries; therefore, specific test conditions will, to a large extent, be arbitrarily specified with selection based primarily upon recorded instances of occurrence or historical probability. Those independent variables for which an historical probability value cannot be derived and which appear to operate in a random manner may be included in the test, utilizing the method of randomization (using a table of random number for selection).

This approach is intrinsically more valid than arbitrary selection of all conditions because of the random nature in which many of these variables combine within the "real world" of aircraft emergencies. The final determination as to the method of variable selection, and of which specific variables will be utilized, will necessarily depend upon the availability of facilities, the nature of the concept being evaluated, and the feasibility of utilization relative to customer constraints.

The simpler tests and evaluation should be accomplished first in isolated environments under the most ideal conditions. The more complex experiments in which additional environmental, hostile, or distracting simulations are

combined should be investigated only after the isolated parameters have been determined.

It is possible that over 90 percent of the experiments and evaluations can be accomplished in the laboratory under controlled conditions, using only small numbers of test subjects in each test.

Full-system - large-scale simulations and tests should be scheduled only for final evaluations of complete concepts because of the magnitude of the experiments in terms of test subjects, test site, hardware requirements, test preparation, coordination, data recording, and documentation.

### SPECIFIC REQUIREMENTS FOR SELECTED CONCEPTS

#### SELECTED CONCEPTS

The remainder of this appendix is limited to the experimental evaluation of five major concepts. Sample test plans presented herein cover only those concepts; however, they may be used as formats for evaluating other concepts, since many of the techniques, test subject requirements, laboratories, and test sites would be common to all of the experiments. The five major concepts are as follows:

- (a) Automatic voice instruction and sonic display
- (b) Lighting improvements
- (c) Tactual displays
- (d) Communications equipment additions
- (e) Situation display

These major concepts encompass the following twelve specific detail concepts:

- (a) Application of "chemical lights" to aid emergency evacuation
- (b) Directional active sensor-controlled floor/ceiling/wall lighting for exits
- (c) Floor-level lighting for fire/smoke conditions
- (d) Remote TV cameras and emergency exterior lighting to assess exterior hazards

- (e) Ultraviolet light activation of egress signs
- (f) Fan indication for exit
- (g) Tactual indicators toward exit areas in aisleway, wall, and ceiling
- (h) Seat bottom lift-up and warning device
- (i) Application of automatic voice instructions and warning system to passenger evacuation
- (j) Sonic indicators for exits (sensor/manual controlled)
- (k) Flight crew and attendants' emergency communication equipment
- (l) Miniaturized and solid-state voice amplification device worn by crewmember at takeoff and landing

For purposes of experimental evaluation, these detail concepts can be classified into the following three categories:

- (a) Visual indicators (five)
- (b) Audio indicators (four)
- (c) Tactual indicators (three)

## TEST PROGRAM

### Purpose

The purpose of this test program is to evaluate the application of the selected concepts to the problem of emergency evacuation of transport aircraft to determine the relative values of the concepts with respect to each other and to other types of systems.

### Program Schedule

The program is planned in 10 general steps:

- (a) Contract negotiation and detailed planning
- (b) Research and correlation of existing data

- (c) Design, procurement, and fabrication of test specimens, equipment, instrumentation, simulators, models, mockups, and facilities
- (d) Planning and organization of tests and evaluations
- (e) Development experiments and evaluations
- (f) Pilot experiments and evaluations
- (g) Combined, full-scale experiments and evaluations
- (h) Data processing and data reduction
- (i) Data analysis
- (j) Final report

The methodology for evaluating the selected concepts is explained in further detail below.

LITERATURE ANALYSIS AND CORRELATION OF EXISTING DATA

This phase of the activity is a brief investigation of the existing data and knowledge regarding application of the selected concepts to the problem of motivating and directing people in emergency situations. The main purpose is to define preliminary criteria for test selection and range of variables.

Table B-1 may be used in analyzing the concepts to determine the parameters and environments which should be investigated with reference to each concept in the phase I evaluations.

- (a) Relative importance:

The following rating codes have been applied to the rating of the first five visual concepts:

<u>Relative Importance</u>	<u>Code</u>	<u>Relative Importance</u>	<u>Code</u>
Dangerous	A	Unknown	F
Fails unsafe	B	May be dangerous	G

Table B-I

## EXAMPLE TEST MATRIX FOR CONCEPT EVALUATION

Environment Impediment System	Concept (Visual Only Illustrated Here)				
	a	b	c	d	e
Impact	I,d,5	H,d,4	H,d,4	D,d,6	I,d,6
Smoke	H,d,2	C,b,2	C,d,2	J,d,5	D,e,3
Fire	H,d,4	D,d,4	D,d,4	J,d,3	D,b,3
Abnormal attitude of fuselage	I,d,3	I,d,3	I,d,3	h,d,3	I,d,3
Obstacles	I,d,3	I,d,3	I,d,3	I,b,3	D,d,3
Panic	I,d,4	G,b,1	G,d,1	J,d,1	I,b,1
Distortion of structure	H,d,4	H,d,4	H,d,4	J,d,6	I,b,4
Water immersion	D,c,2	G,c,6	G,c,6	I,d,6	D,e,6
High temperature	J,d,d	H,d,5	H,d,5	H,a,5	H,b,6
High illumination	H,d,d	H,d,5	H,d,5	J,d,3	D,e,6
Total darkness	J,d,4	J,d,4	J,d,4	J,d,3	J,b,4
Rain	I,d,4	I,d,4	I,d,4	I,d,3	I,b,6
Snow	I,d,4	I,d,4	I,d,4	I,d,3	I,b,6
Landing-gear-down landing	I,d,4	I,d,4	I,d,4	I,d,6	I,d,6
Fuselage on the ground	I,d,4	I,d,4	I,d,4	I,d,6	I,d,6

There are three ratings suggested for rating each concept: (a) relative importance, (b) priority of testing, and (c) method of evaluation.

<u>Relative Importance</u>	<u>Code</u>	<u>Relative Importance</u>	<u>Code</u>
Probably dangerous	C	Fails safe	H
Destroys capability	D	Not affected	I
Destroys capability of some other system	E	Improves effectiveness	J

The concepts which rate A through G in relative importance will be carefully screened to determine the following:

(b) Priority of testing:

Priority 1 - Concept should be tested early in the development testing.

Priority 2 - Concept should be tested in pilot tests.

Priority 3 - Concept may be tested during the development testing or pilot testing.

Priority 4 - Concept need not be tested in either development testing.

Priority 5 - Concept has doubtful value and may not be tested at all in any phase.

(c) Method of evaluation:

(1) Psychological

(2) Physiological

(3) Human factors

(4) Combination of 1, 2, and 3

(5) Physical measurements only

(6) Logic analysis without testing or experiments

The concepts which rate H, I, or J in relative importance by inspection need not be evaluated for that category during initial development tests, but may be evaluated in pilot tests or may be evaluated only as part of the combined full-scale tests.

The matrix has been filled in for concepts, using the first five visual concepts as an example.

#### DEVELOPMENT TESTS

From the matrix, the tests which will be conducted during the development tests, and the time schedule for conducting the tests can be planned as follows: for example, concept b will be evaluated for smoke, fire, panic, and water immersion. There will be psychological tests for smoke and panic, combined tests for fire, and logic analysis only for water immersion.

#### TEST LABORATORY REQUIREMENTS

One large laboratory room (100 x 40 feet) lightproof and fireproof

Two smaller laboratory rooms, lightproof heatproof, air conditioned

Laboratory rooms equipped for electrical power, water, gas, and compressed air

Shop facilities for fabricating wood and metal test specimens, mockups, and apparatus

#### PERSONNEL REQUIREMENTS

One test director, reporting to the project director

One assistant test director

One senior physicist, responsible for test equipment design requirements and evaluation of physical measurements test data

One senior psychologist, responsible for test design requirements and psychological evaluation of test data

One senior physiologist, responsible for test toxic products safety design requirements and evaluation of physiological implications of test data

One electrical engineer, responsible for design and operation of instrumentation and data acquisition

One mechanical design engineer, responsible for design of simulators, strength of mockups and mechanical devices

Laboratory technicians and shop support mechanics as required for fabricating and setting up test equipment and tests. Scientists and technicians can serve as test subjects during the initial and advanced development testing. In combined full-system testing, many more subjects will be employed.

#### EQUIPMENT REQUIREMENTS

Forty aircraft passenger seats

Aircraft cabin mockup (partial or complete)

Simulated walls, ceilings, and floor for mockup with lighting installed

Smoke generators (four)

Hot-air generators and infrared heat sources (four each)

Fire simulators (optical device) (four each)

#### INSTRUMENTATION REQUIREMENTS

Eight channel FM-FM tape recorder (two)

Use of closed-circuit TV equipment with low light intensity capability (eight systems)

Use of 16-millimeter motion picture equipment including lighting (16 cameras)

Transducers, microphones, heat, light, and sound detecting and measuring apparatus

#### MEASUREMENT REQUIREMENTS

The following parameters will be measured and recorded during the tests:

- (a) Time versus light intensity
- (b) Time versus heat radiation versus temperature
- (c) Smoke intensity versus time
- (d) Time required for subjects to accomplish phases or tasks

#### NUMBER OF TESTS OR EVALUATIONS

The number of tests required to investigate each condition will be governed by the degree of success of each test. A successful test is defined as one which complies with the test requirements in that the environmental conditions and the simulation of test parameters are met, and the test subject has completed the tasks defined. A minimum of five subjects is normally required to experience each test, or each phase, for the test or phase to be considered successful.

#### TEST METHOD

In this example, a minimum of three different types of lighting displays will be evaluated. A test subject will be placed in the middle of the test section in a rotatable chair. All lights will be extinguished and the chair will be rotated slowly until the subject is disoriented. An alarm will be sounded indicating emergency, lighting, and displays will be turned on, and the subject will proceed to the exit.

Closed-circuit, low light intensity TV will record the reactions and movements of the subject. Immediately after each test, the subject will record his own thoughts, comments, and reactions. After at least five subjects have experienced a particular test, the parameters will be changed. Light intensity, location of displays, color, frequency of blinking lights, arrangement of lights, size of lettering, and any other parameters which may be indicated as a result of the tests already completed will be investigated.

In addition to the basic parameters, impediments such as smoke, simulated fire, heat, noise, background light, blocked aisles, jammed exits, defective displays, or water rising in the cabin may be added.

As development tests proceed, each type of display or lighting method will be tested and evaluated individually so that the effectiveness of the basic types can be compared. Combinations of displays will be tested next, using the same method as used in the individual experiments, adding more parameters and impediments as the tests proceed.

### PILOT TESTS

For the pilot tests, equipment, mockups, and instrumentation will be improved and modified. Refinements will be added to the display equipment as a result of the findings during the development tests. Progressively, more parameters and environments will be introduced into the experimental procedures.

The test laboratory and personnel, equipment and instrumentation requirements will be enlarged to the extent that concepts, impediments, and environments will be added. Testing will be on a small scale as far as numbers of test subjects and size of test apparatus.

### MEASUREMENT REQUIREMENTS

The number and kinds of measurements per test will increase proportionally to the number of parameters and environments involved in each experiment.

### NUMBER OF TESTS

The number of combined pilot tests will be considerably less than the number of tests required in the development tests. The minimum number for each type and configuration will be five successes. A successful test is defined as a test in which the requirements are satisfied, the subject completes the required tasks, and all important simulators, specimens, and equipment function properly.

### TEST METHOD

The method for the pilot tests will be an extension of the method employed in the development tests. Many of the tests will involve only one test subject. Although the test environments and number of test parameters,

impediments, and concepts being evaluated will be greatly enlarged, the test method will consist of exposing the subjects to the concept or concepts being evaluated, and the environmental conditions specified, while the subjects perform the task of determining where the exit is, and find their way to the exit.

#### TEST CONFIGURATIONS

From the evacuation system diagram (appendix C), a matrix may be composed of simulated obstacles, environments, impediments, or conditions to be tested in conjunction with the concepts to be tested singularly and in combination. An example of such a matrix is shown in table B-II. The numbers of concepts and simulated conditions can be greatly expanded over those shown.

TABLE B-II  
CONCEPTS AND CONDITIONS

Simulated obstacle, environment, impediment or other parameter from appendix C	Concepts (Same as for Matrix Table B-I)				
	a	b	c	d	e plus...
Simulated fires	x	x	x	x	x
Smoke and tear gas	x	x	x	x	x
Radiated heat	x	x	x	x	x
Water rising in cabin					
Major structural damage					
Cabin broken in sections	x	x	x	x	x
Cabin sections pitched, rolled and yawed	x	x	x	x	x
Obstacles in cabin					
Bright daylight outside	x	x	x	x	x
Total darkness outside					
High wind condition	x	x	x	x	x
Dead calm condition					
Snow or rain	x	x	x	x	x

Many of these configurations may be too nearly identical, or superfluous.

The number of combinations or permutations of test configurations is obviously too great for even partial investigation. Selection of test configurations will be determined as the tests progress, and by noting trends in the data which indicate similarities or patterns in the test procedures.

The object of the pilot tests will be to define the test configuration ratios for the full-scale tests.

## FULL-SCALE TESTS

### INTRODUCTION

For an experimental study of the nature proposed here, it is necessary that data obtained be compared and analyzed relative to some standardized set of conditions from which an assessment of negative or positive effects may be made. In order to accomplish the objectives of the test plan, it is recommended that the experimental evaluation be presented in three phases.

#### Phase 1 - Subject Selection and Training

This phase consists of establishing existing emergency evacuation techniques and procedures used by the majority of commercial airlines. These standardized evacuation procedures will be integrated with the test vehicle configuration. Two groups of prospective test crewmembers, matched for experience and age, will be adequately trained in the utilization of the techniques and procedures within the experimental configuration. Group I will be trained in the use of existing techniques and procedures under standard training conditions. Group II will be similarly trained except that the new concepts will be integrated as part of the techniques and procedures training. Group I will form a control group from which differences will be assessed; Group II will form the experimental group.

#### Phase 2 - Test Subject Control Group Study

This evaluation phase will subject the control group to the test battery of emergency conditions. The objective of this test phase is to establish baseline data, i.e., to determine the elapsed evacuation time and incidence of injuries (or potentially injurious incidences) of N subjects from a given

configuration and emergency environment without the utilization of the new evacuation concepts. In addition to providing baseline data for the test program, this phase will also provide a realistic estimate of current evacuation techniques and egress time under other than "ideal" conditions.

### Phase 3 - Test Subject Experimental Group Study

Phase 3 of the test program will subject the experimental group and new evacuation concept(s) to the same emergency conditions to which the control group was exposed, and again record the elapsed evacuation time and incidence of injuries or other unusual events.

#### TEST SUBJECTS

The test subjects used in the evaluation of evacuation concepts will be representative of the normal flying population and in appropriate numbers for the configuration being evaluated. The subjects should be representative in terms of age, sex, height, and weight, flight experience, education and socioeconomic factors, physical infirmities (e.g., deafness, blindness, mental incompetence, etc). The subjects selected as crewmembers will also be representative in terms of flight experience and training.

#### TEST APPARATUS

As the pilot tests proceed, the detailed elements of the full-scale test apparatus will be defined. In general, the test apparatus will comprise the devices of the pilot tests with the addition of the full-scale mockup, which will necessitate larger quantities of simulation and instrumentation equipment to accommodate the larger scale of the experiments.

A complete full-scale airplane mockup, with seating for 250 passengers with all developed systems simulated, with actual equipment (not mockups) installed wherever possible, should be used.

### Test Laboratory Requirements

The laboratory requirements are the same as those for development and pilot tests, with the addition of a much larger test specimen consisting of a full-scale 250-passenger mockup and larger support facilities capable of accommodating as many as 250 test subjects per test.

## PERSONNEL REQUIREMENTS

The full-scale tests represent a culmination of the test program. All of the personnel working on development and pilot testing will participate in the full-scale tests.

In addition to people who primarily work in design, development, and pilot testing, the staff of the full-scale testing project will consist of the following:

- Project Director
- Assistant Project Director
- Engineering Assistant and Group Leader
- Instrumentation Assistant and Group Leader
- Simulation Assistant and Group Leader
- Plans and Operations Assistant
- Personnel Assistant
- Material and Facilities Assistant
- Flight Surgeon
- Registered Nurse

The following disciplines will be represented within these working groups:

- Anthropometry
- Electronic engineering
- Physiology
- Experimental psychology/human factors
- Mechanical engineering, structural engineering
- Lighting
- Vision
- Acoustics
- General human engineering
- Personal equipment
- Personnel instrumentation - telemetry, bioengineering
- Interior design of transport aircraft
- Airline operations

### Support Personnel

Within the organization, there will be available, as required, facilities and support personnel to accommodate the test program in the following areas:

- (a) A fire department to stand by during tests

- (b) A medical facility consisting of a medical doctor and at least three nurses, with first-aid facilities, to witness all tests
- (c) A photographic department for taking motion pictures and still photographs as necessary
- (d) Shop facilities for fabrication and modification of test equipment, simulators, and instrumentation apparatus.

#### EQUIPMENT REQUIREMENTS

Full-scale, 250-passenger airplane mockup, fireproof, and waterproof with 250 passenger seats installed. This mockup should have the capability of being divided into three sections so that structural failure of the cabin can be simulated. Walls, ceilings, floor lighting, communications, exits, etc, of the type used in the development and pilot tests will be installed. Provisions for introducing smoke, simulated fire, radiant heat, hot air, test gas, and water at various places in the cabin or outside. Exterior lighting should be controlled.

#### INSTRUMENTATION REQUIREMENTS

Since the full-scale test configurations are similar to the pilot configurations, but involve 250 test subjects, the amount of instrumentation equipment will necessarily be much greater. The instrumentation will consist of the type of equipment required to record the test parameters, and the movements and actions of the test subjects. This will include the following types of instrumentation:

Tape recorders (eight channels of FM sound track)

Closed-circuit low light intensity TV (minimum of eight cameras and video recorders)

16-millimeter motion picture cameras (16 cameras)

Heat, light, sound, and movement measuring devices such as microphones, thermocouples, calorimeters, photoelectric cells, and microswitches wired to recording oscillographs through suitable amplifiers and counters or digitizers

## MEASUREMENT REQUIREMENTS

The basic parameters to be measured in the full-scale tests are similar to those of the pilot tests:

- (a) Time versus light intensity
- (b) Time versus heat radiation versus temperature
- (c) Smoke intensity versus time
- (d) Time required for each subject to accomplish each task
- (e) Numbers of subjects versus time through each exit

## NUMBER OF TEST EVALUATIONS

The number of tests necessary to investigate all concepts is a function of the time allowed and the effort in terms of costs applied to the test program. It appears that a program of this nature, to be of value, must generate results which can be incorporated into specifications for hardware and into regulations for transport design and operation within a year after the beginning of the project. This means that sufficient development tests and pilot tests must be completed within 9 months so that an initial full-scale test series can be completed within a year. A full-scale test series should comprise at least 20 tests.

The initial number of tests will consist of a minimum of two tests for each total control group and two tests for each experimental group in each configuration with not more than five simulated configurations.

### Configuration 1

Wheels-up crash landing, moderate damage to the cabin, small fires outside the airplane block one-half the exits. Bright daylight.

### Configuration 2

Wheels-down crash landing, moderate damage to airplane, small fires outside block one-half the exits. Extreme darkness.

### Configuration 3

Wheels-up crash landing, airplane cabin in tilted position and cabin broken in two or more places, fires inside and outside airplane block escape through broken places and block some exits. The three sections should have different pitch, roll, and yaw attitudes: One section rolled 170 to 180 degrees, one rolled 45 degrees. Tilt angles 5 to 10 degrees pitch up and down. Extreme darkness.

### Configuration 4

Wheels-down crash landing, airplane cabin broken in two places and cabin tilted, fires block escape through broken places and some exits. Pitch attitudes 25-degree pitch-up, 15-degree pitch-down nose. One section rolled 90 degrees. Full, bright daylight.

### Configuration 5

Water landing, wheels-up, normal upright attitude. Water begins rising immediately in the cabin, small fires and some smoke. Water rises to a level of 2 feet in cabin within 90 seconds. Darkness. Baseline configurations will be repeated as required to confirm the test data.

### TEST METHOD

Simulations of developed concepts will be installed in the mockup airplane, although some systems will be inoperative in each test, depending on the damage simulated.

The 250 inexperienced test subjects chosen as representative of the typical passenger population will be briefed that they are taking part in an emergency evacuation test. They will be informed that the fires, heat and smoke are simulated and will not burn, but should be treated as genuine. They will not be told where the simulated fires or blocked exits will be. They will each be issued a dummy brief case or large handbag and pocket book and a simulated top coat to carry on to the airplane. Before boarding the airplane, each subject will don a vest with large identifying number on front and back.

Test subjects will be asked to leave the airplane as quickly as possible, while avoiding injury. They will be told to follow the instructions of the airplane crewmembers (the pilots, engineer, and stewardesses) and the loud speaker or visual displays as if they were airline passengers. These instructions will be presented in accordance with standard practice in commercial

transport aircraft, including an announcement by the stewardess and printed information on evacuation procedures placed on the backs of the seats. The latter will be especially prepared to include description of the specific concepts being tested.

Besides the test subjects, the crew consisting of three uniformed pilots and one uniformed engineer plus eight uniformed stewardesses and at least 20 experienced, trained observers will be on board the airplane at the start of the test.

#### TEST PROCEDURE:

Following the loading of test subjects (passengers), observers (technical personnel experienced in all phases of the testing), and crew (experienced airline crewmembers), the test will proceed as follows:

- (a) Engine start (simulated by sound track over loud speaker system)
- (b) Taxi to takeoff position (stewardess announcement and engine sounds over communication system)
- (c) Takeoff (noises simulated by sound track)
- (d) Five minutes of flight followed by crash noises (sound track)
- (e) Alarm sounds, and pilot instructs everyone to evacuate the airplane immediately. Lights go out, and automatic audio and visual equipment begins to function. Stewardesses proceed to the exits which are safe to use and with the help of passengers, open exits. Passengers are instructed by audio aids and crewmembers, to go to safe exits and leave the airplane.
- (f) Closed-circuit, low light TV cameras and sound recorders record events inside the cabin
- (g) Observers watch for signs of panic, or wrong or dangerous movements by test subjects, and compare the reactions of the test subjects to the various test conditions, impediments, or environments. Observers also note differences among the subjects' reactions in previous tests.
- (h) As soon as the test subject is clear of the airplane, he is taken to a debriefing room and asked to fill out a form containing basic

information such as name, identification number, seat number, which exit he left the airplane by, in addition to such questions as:

- (1) Could he have exited faster?
  - (2) Was he afraid of suffering injury during the procedure?
  - (3) Why did he take a certain path?
  - (4) Were the crewmembers helpful to him?
  - (5) Did he notice the moving lights; hear the signals?
  - (6) Did he see the fires?
  - (7) Did he feel the fires?
  - (8) Did the smoke bother him?
  - (9) How long does he estimate his exit required?
  - (10) Were the lights too bright?
  - (11) Did he hear the instructions?
  - (12) Were the instructions clear?
  - (13) Would he please write suggestions and comments?
- (i) The crewmembers and technical observers will assemble in a conference room where the sound and TV recordings will be played back, and the observers will report their findings for future analysis.

#### TEST DOCUMENTATION

Documentation for the test program will consist of written records, photographs, motion pictures, closed-circuit TV and sound recordings, notes, and tabulated data. This material will be compiled in report form and delivered to the customer periodically during the program as monthly progress reports, and within the months after completion of the project, in the form of a formal published FAA report.

Test data will be continually interpreted, charted, plotted, and graphed in usable form as the test program develops. Most of the data and measurements will require manual processing and interpretation as well as correlation. In the handling of all records, observations and test results, and in the planning of the tests, care will be taken to set up the measurement recordings and instrumentation in a manner that will produce data and records necessitating the least processing.

#### TEST REPORTS

Periodic progress reports covering all phases of the test program will be forwarded to the customer monthly. These reports will be a letter-type, consisting of the bond original and one reproducible vellum. Film records and tapes will consist of reproducible copies of edited data considered pertinent to the project.

Monthly reports will cover, but will not be limited to:

- (a) Schedule position
- (b) Progress since last report
- (c) Plans for the following 3 months
- (d) Changes or deviations in the test plan
- (e) Test data

A formal FAA test report covering a full-scale test series will be compiled periodically.

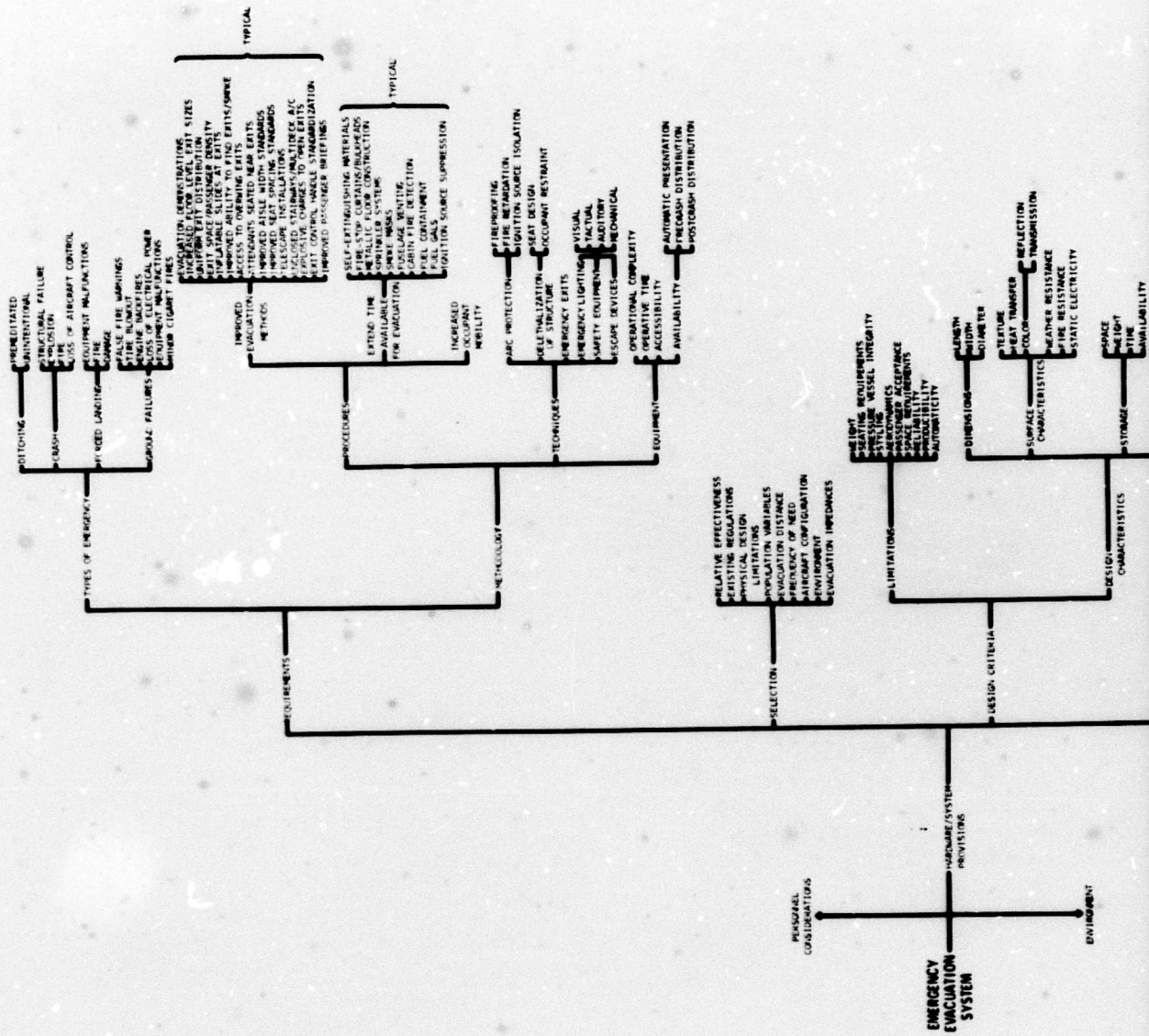
Appendix C

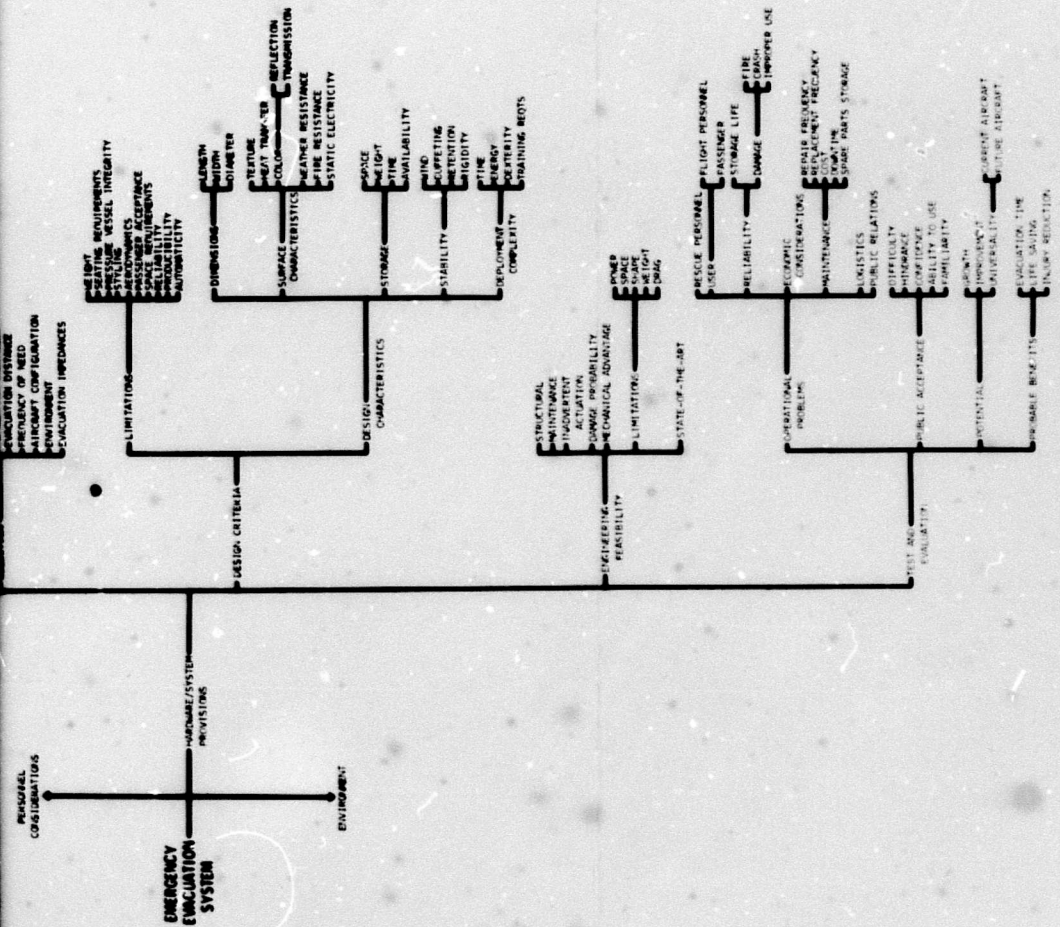
EMERGENCY EVACUATION SYSTEM DIAGRAM

The following three foldout pages constitute the complete emergency evacuation system diagram described in the main text. Each page represents approximately one-third of the total diagram and should be considered as connected to each other under the overall heading of Emergency Evacuation System.

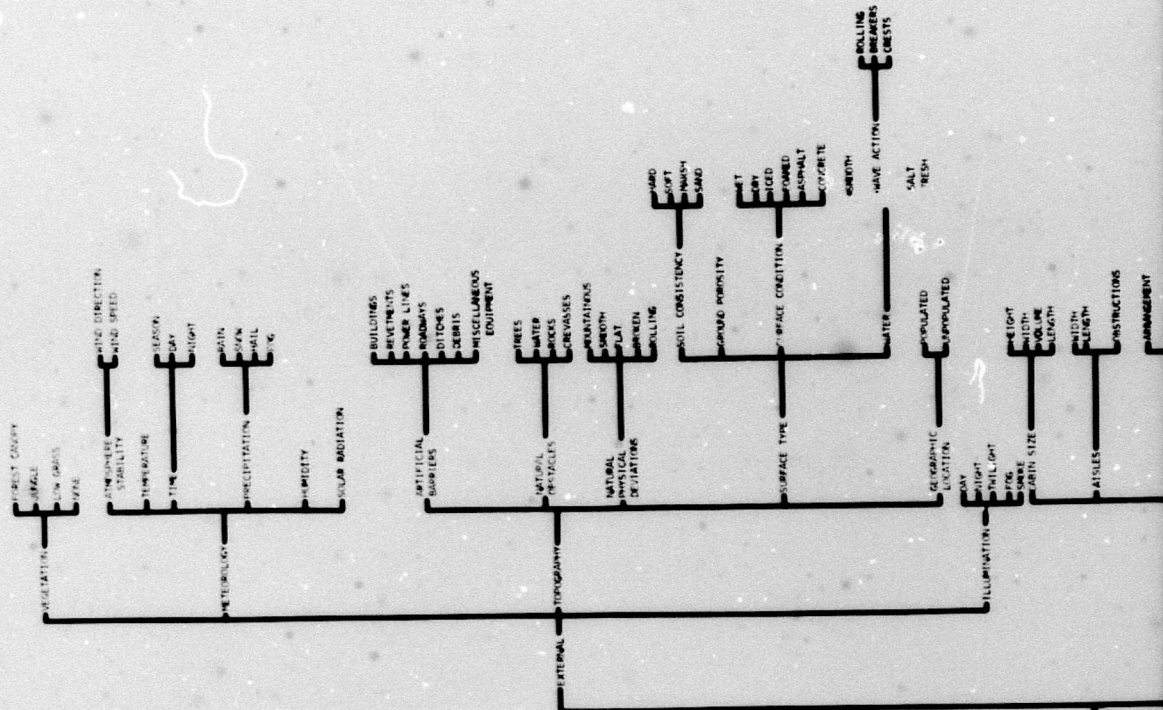








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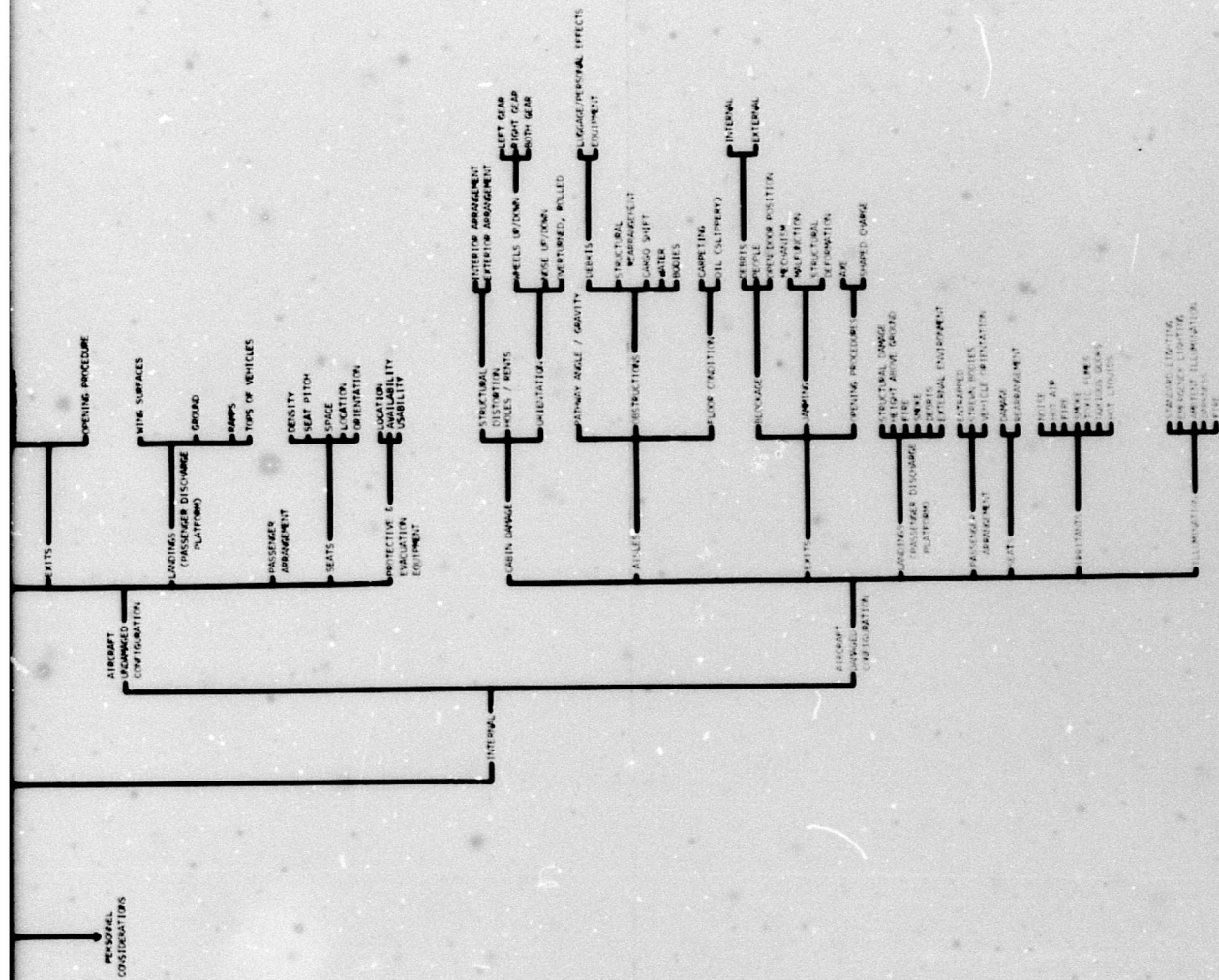


A

EMERGENCY EVACUATION SYSTEM

INCLUDE SYSTEM PROFILES

ENVIRONMENT



8