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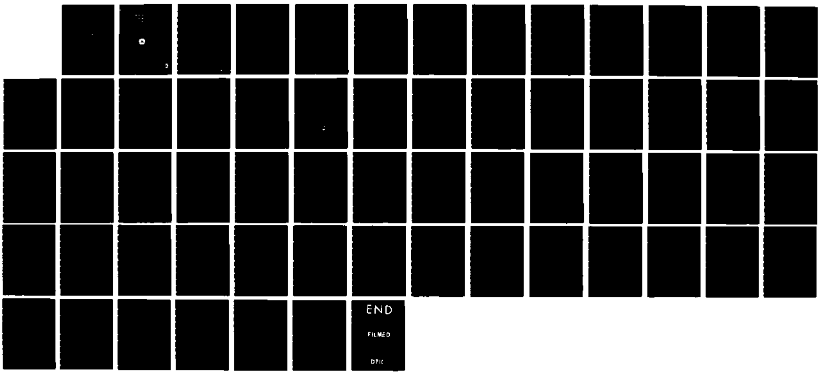


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Report No. FAA-ED-18-7

AD-A157 065

ENGINEERING AND DEVELOPMENT PROGRAM PLAN
AIRCRAFT CABIN FIRE SAFETY

DEPARTMENT OF TRANSPORTATION • UNITED STATES OF AMERICA •

JUNE 1980

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16. Abstract

This plan is designed to improve the survivability and safety of passengers and crew during postcrash or in-flight transport aircraft cabin fire. Four major tasks are identified to accomplish the goal: (1) Cabin Fire Hazard Characterization, (2) Materials Management (including test method development and evaluation/development of new materials), (3) Survival and Evacuation, and (4) Fire Management and Suppression. The program emphasizes the evaluation and development of improved materials and fire management and supression, which involve the potential for near-term products. The specific projects include seat cushion fire blocking layers, hand-held extinguishers, cargo compartment fire safety, and in-flight smoke ventilation. Of a long-term nature is the development of improved small-scale fire test methods for cabin materials that can be related to real fire behavior. Although of generally acknowledged importance, this endeavor is comprised of areas where basic knowledge is lacking, thus requiring research and development and involving high technological risk. Examples include mathematical and physical fire modeling of fire dynamics, toxicity of irritant gases and combustion mixtures, and measurement/prediction of flame spread. Work related to evacuation includes heat resistant evacuation slides (completed), emergency lighting and protective breathing devices. New material applications which will be evaluated and developed include low-weight and practical interior panels with improved fire performance and burnthrough resistant windows and door curtains. A total cabin postcrash fire protection system will be designed if shown to be effective and feasible during prototype testing. The ultimate product of the program is improved regulatory or advisory material pertaining to cabin fire safety.

17. Key Words
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Aircraft Fire
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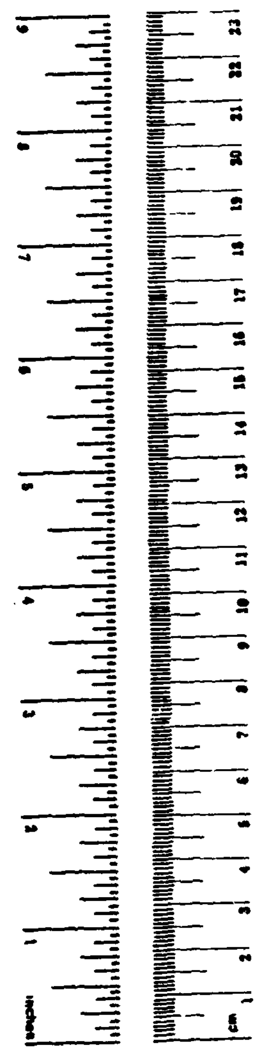
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

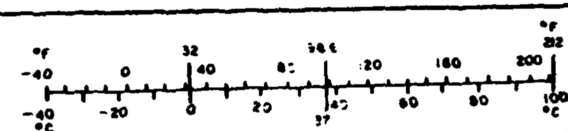
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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PROBLEM.

It is estimated that 39 percent of the fatalities in United States impact survivable transport aircraft accidents are a result of the effects of fire. Fire created by aircraft crashes invariably involves spilled fuel and, in many cases, cabin interior lining and furnishing materials. The role of interior materials in postcrash cabin fire survivability is controversial because of the apparent overwhelming dangers from the fuel fire itself. Federal Aviation Administration (FAA) flammability regulations (FAR 25.853, effective May 1972) specify that cabin materials cease burning on their own when subjected to a Bunsen burner test. However, these materials will ignite and burn when exposed to the severe heating conditions of a fuel fire, and will produce heat, smoke, and numerous toxic gases that may prevent the safe evacuation of cabin occupants. Although the FAA has issued, in 1974 and 1975, regulatory proposals on smoke and toxicity, they were eventually withdrawn primarily because of the inability to relate results from existing test methods to the various cabin hazards confronting occupants by a real fire. The effect of many of these hazards, individually or even more so in combination, on the ability of a cabin occupant to successfully evacuate an airplane is unknown.

A much smaller number of fatal accidents have occurred in U.S. manufactured aircraft operated by foreign carriers as a result of accidental fire erupting inside the fuselage while the aircraft was in flight, however, resulting in over 500 fatalities. Reported factors in these accidents were an inability to control the fire by application of hand-held extinguishers, ineffective emergency smoke ventilation measures, and lack of fire containment within the compartment of the fire origin. As a consequence, since FY-1981 increasingly more emphasis has been placed within the FAA's cabin fire safety program on in-flight fire safety.

PROGRAM OBJECTIVES.

The overall objective of the Aircraft Cabin Fire Safety Program is to characterize the transport aircraft cabin hazards created by an external fuel fire, or an in-flight fire, especially the contribution of interior materials, and increase the survivability and safety of occupants in the event of a cabin fire by developing relevant fire test methods and criteria for interior materials, examining and fostering the use of improved materials, and examining and recommending effective fire management and suppression systems and evacuation aids.

CRITICAL ISSUES.

As the Aircraft Cabin Fire Safety Program proceeds, certain critical issues must be considered. Three of these issues are as follows.

a. It is necessary to determine whether interior materials are a significant fire hazard relative to a postcrash fuel fire, or whether advanced materials provide a significant safety benefit in comparison to inservice materials. If either case is not true, resources should be redirected to support other measures for the improvement of cabin fire safety; e.g., fire management and suppression, evacuation aids, and antimisting fuel.

b. Heat, smoke, and toxic gases are measured during large- and full-scale tests, however, it is very difficult to predict with confidence the effect of these measured hazards on the ability of an occupant to survive and escape. Although this program plan provides for the development of a human survival model, such a model can obviously never be satisfactorily validated. Therefore, because of this difficulty in quantitating human hazard and survival, test data will usually be subject to some degree of interpretation.

c. Small-scale test methods for interior materials are extremely simplified compared to the complexities of the fire dynamics and hazards of a postcrash cabin fire. Therefore, it is uncertain if a determination can be made as to what test methods, test conditions, and data or scientific treatment of data best relate to the hazards created by interior materials during a cabin fire and, thus, could form the basis for materials selection. If this determination cannot be made with confidence, more emphasis will have to be placed on large-scale tests and, perhaps, modeling experiments to determine the safety benefit of alternate materials in order to encourage or require the usage of safer materials.

PROGRAM TECHNICAL APPROACH.

Figure ES-1 outlines the five major program tasks, the various projects and activities within each task, and their functional relationships. The technical approach recognizes that safety improvements are possible once the characteristics of postcrash cabin fire hazards are measured (top block) and understood (left block, human survival limits). Once the nature of the problem is reasonably well understood, three approaches are available for improving fire safety: (1) management of materials, (2) management of fire, and (3) management of people. The emphasis of the present program has been placed on improved materials (center block, right) and in-flight fire management and suppression (right block, top), which involve reasonable technological risk and the potential for near term products. The specific projects include seat cushion fire blocking layers, hand-held extinguishers, cargo compartment fire safety and in-flight smoke ventilation. Of a more long-term nature is the development of small-scale fire test methods for cabin materials that can be related to real fire behavior (center block, left). Although of generally acknowledged importance, this endeavor consists of elements where basic knowledge is lacking, requiring applied research and development (e.g., toxicity, fire dynamics (modeling), flame spread) and thus involving high technological risks. Management of people is addressed under the survival and evacuation task (left block). Planned projects include development of a human survival model, including the effects of irritant gases on escape impairment; heat resistant evacuation slides (completed); emergency lighting cost/design impact; and protective breathing devices. Other improved materials projects include low-weight and practical advanced panels with improved fire performance; and burn through resistant windows and door curtains. Under postcrash fire management and suppression (right block, bottom), a total cabin protection system will be designed, if shown to be effective and feasible. Utilmately, the described tasks will lead to improved requirements (bottom block).

ESTIMATED COMPLETION DATES.

Completion dates for those major projects and activities which can be estimated at this time are presented below:

a. Develop heat resistant evacuation slide requirements. Completed

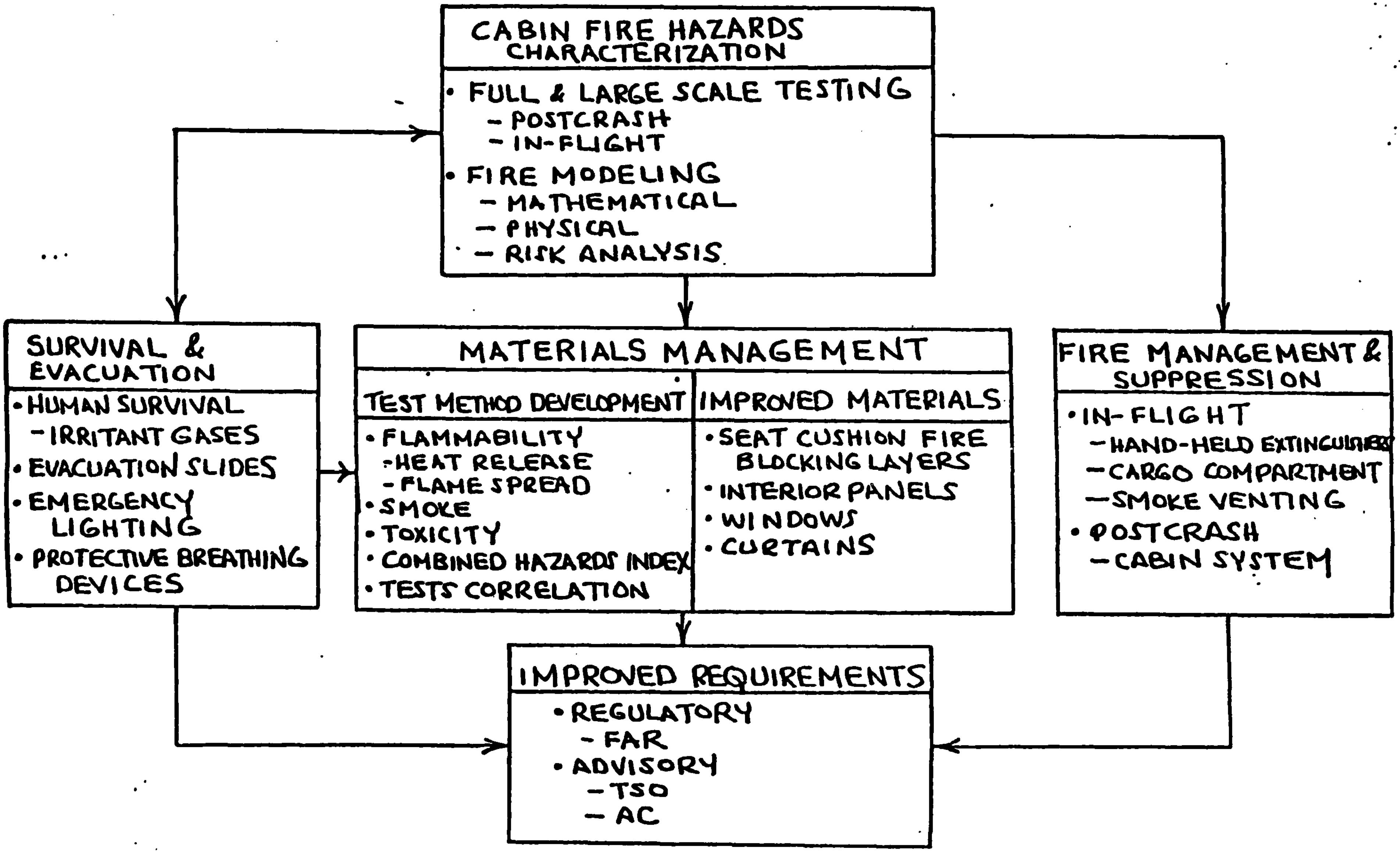

FIGURE ES-1. AIRCRAFT CABIN FIRE SAFETY PROGRAM FUNCTIONAL RLEATIONS AND WORKFLOW

b. Establish cabin hazards (C-133) created by wide-body type of materials.	Completed
c. Evaluate advanced emergency lighting concepts.	Completed
d. Combined Hazard Index contract.	Completed
e. Recommend improved seat cushion replacements for urethane foams, including cost estimates and evaluation test method.	Completed
f. Develop improved test method for cargo liners and derive improved class D cargo compartment design criteria.	3/83
g. Determine emergency lighting cost/design impact.	3/83
h. Upgrade/expand hand-held fire extinguishers advisory circular. Transport	Completed
General Aviation.	5/83
i. Derive small-scale test method for interior materials (preliminary).	8/83
j. Structure risk analysis model.	9/83
k. Complete study of water/foam sprinkler system.	9/83
l. Establish reduction in cabin hazards (C-133) through usage of advanced materials.	9/83
m. Develop realistic artificial smoke generator device and acceptable performance levels for flight test evaluation of emergency smoke ventilation procedures.	11/83
n. Complete development of mathematical cabin fire model to calculate postcrash fire growth.	9/85
o. Complete Technical Center pressure modeling studies.	3/85
p. Recommend small-scale test methods and criteria for interior materials.	9/84

1. INTRODUCTION.

1.1 CABIN FIRE PROBLEM.

A commercial aircraft is capable of transporting hundreds of passengers over long distances in a relatively short period of time. Thousands of gallons of flammable fuel are stored in the integral wind fuel tanks and consumed in flight while propelling the aircraft to its final destination. The passengers and crew are confined within a densely populated environment—the aircraft cabin—that is furnished and lined with a great variety and large quantity of complex synthetic (plastic) and natural polymeric materials. The potential dangers arising from an accidental fire seem evident from this brief description; however, the nature of these dangers and the means for their minimization have been and still are a subject of intense debate and controversy and, rightfully, are the central issues of this program plan.

An examination of transport aircraft accident statistics in the United States (U.S.) indicates that all fatalities which can be attributable to fire are the result of crash accidents during approach, takeoff, or landing (reference 1). The fire originates in most cases from the ignition of jet fuel released from fuel tanks damaged during the crash impact. It is estimated that about 15 percent of all fatalities in transport accidents are a result of the effects of fire; the remaining fatalities are, of course, due to impact. Normalizing the number of fire fatalities by the total number of fatalities in survivable accidents—those accidents in which one or more of the occupants survive the impact—produces a greater proportion of fire fatalities than exists in terms of all accidents. For example, an analysis of 29 impact survivable accidents for the period 1964 to 1977 indicated that 453 of 1162 fatalities (39 percent) were attributed to fire (reference 2). In summary, on the basis of accident analyses alone, it is evident that a very significant portion of the fatalities in survivable accidents is caused by fire, and that aircraft fire safety must be addressed in the context of the postcrash external fuel fire because all fire fatalities in U.S. air carrier accidents occur in this type of accident.

A much smaller number of fatal accidents have occurred in U.S. manufactured aircraft operated by foreign carriers as a result of accidental fire erupting inside the fuselage while the aricraft was in-flight. These in-flight fatal fires consist of a Varig 707 in 1974 (reference 3), a Pakistani 707 in 1979, and a Saudia L-1011 in 1980 (reference 3), combining for a total of over 500 fatalities. Reported factors in either the Varig or Saudia accidents were an inability to control the fire by application of hand-held extinguishers (both), ineffective emergency smoke ventilation measures (Varig 7070), and lack of fire containment within the compartment of the fire origin (lavatory in Varig 707 and class D cargo compartment in Saudia L-1011). As a consequence of these accidents, particularly the Saudia L-1011 which resulted in 301 fire fatalities since FY-1981, increasingly more emphasis has been placed within the FAA's Cabin Fire Safety Program on in-flight fire safety.

FAA flammability regulations for interior materials were initially promulgated in 1947 and essentially required that materials experience slow burning in a horizontal orientation. These regulations have been upgraded periodically to assure that the "best" state-of-the-art materials are incorporated into the cabin design. The latest flammability regulations (FAR 25.853), adopted in May 1972, specify that all large usage materials be "self-extinguishing" in a vertical orientation when subjected to a small ignition flame (reference 4). The test method used to show compliance with the "self-extinguishing" requirement is often referred to as the vertical Bunsen burner test (reference 5). This test method reduces the probability of ignition by a small flame (thus, the in-flight fire safety benefit) and possibly the rate of flame-spread beyond the ignition source. However, under the intense conditions created by an external fuel fire, any organic material will pyrolyze, ignite, and propagate flame, and will emit heat, smoke, combustibles, and toxic gases, endangering the safe evacuation of occupants. The exact role of interior materials as a factor affecting survivability will depend on such governing factors as fuselage integrity and fuel fire size, evacuation rate, location of fires(s), ambient wind conditions, door opening locations and type of aircraft. Aside from these real world effects which cannot be accurately simulated in the laboratory, it is apparent that the major deficiencies of the Bunsen burner test are that it does not provide for (1) exposure to an intense ignition source or (2) the measurement and consideration of flame spread and production of heat, smoke, combustibles and toxic gases.

The FAA issued proposed regulatory notices in 1974 on toxicity (reference 6) and in 1975 on smoke (reference 7) for the purpose of including these factors, in addition to the then existent flammability requirements, during the certification testing of interior materials. Public responses to these notices were primarily negative. Opposition was based on such generally valid arguments as inadequate test methodology development, extreme expense of compliance for a questionable safety benefit, and the independent "piecemeal" nature of these regulatory endeavors in conjunction with a flammability retrofit proposal (reference 8). The latter argument was of concern because of the apparent interrelationship which exists between flammability and smoke and toxicity. These regulatory proposals on toxicity, smoke, and flammability (retrofit) were withdrawn by FAA and a Special Aviation Fire and Explosion Reduction (SAFER) Advisory Committee was created to advise FAA with regard to future aircraft fire safety research and regulation (reference 9).

This document is a comprehensive program plan to improve various facets of postcrash and in-flight cabin fire safety. It emphasizes the conduct of reliable full- and large-scale fire tests to characterize and better understand the nature of the problem and to evaluate the effectiveness of proposed improvements. High priority has been placed on projects primarily composed of test and evaluation involving reasonable technological risk, with the potential for near-term products. Examples of these safety areas include heat resistant evacuation slides, seat cushion fire blocking layers, improved hand-held extinguisher requirements, cargo compartment fire safety and in-flight emergency smoke ventilation. Of a more long-term nature is the development of small-scale fire test methods for cabin materials that can be related to real fire behavior. Although of generally aknowledged importance, this endeavor consists of elements where basic knowledge is lacking, requiring applied research and development (e.g., toxicity, fire dynamics (modeling), flame spread), and thus moving high technological risks.

1.2 PROGRAM OBJECTIVES.

The overall objective of the Aircraft Cabin Fire Safety Program is to characterize the transport cabin hazards created by a postcrash external fuel fire, or an in-flight fire, especially the contribution of interior materials, and increase the survivability and safety of occupants in the event of a cabin fire by developing relevant fire test methods and criteria for interior materials, examining and fostering the use of improved materials, and examining and recommending effective fire management and suppression systems, and evacuation aids.

Specific objectives of the program are to:

a. Determine, by conducting full-scale tests for specific scenarios, the cabin hazards created by an external fuel fire and the contribution of interior materials to the overall cabin hazard.

b. Develop and determine the validity and utility of physical and mathematical fire modeling as an alternate or supplement to full-scale tests for the purpose of predicting or measuring cabin fire spread and hazard development.

c. Develop small-scale tests that measure the important hazards of burning cabin materials and correlate with full-scale or model cabin hazard data obtained for a postcrash scenario consisting of a large external fuel fire adjacent to a fuselage opening.

d. Develop and validate a methodology for combining small-scale test measurements of flammability, smoke, and toxicity into a unified hazard index (Combined Hazard Index or CHI).

e. Determine escape impairment limits for major irritant gaseous combustion products and develop a "state-of-the-art" human survival model for predicting the "theoretical escape time" of humans exposed to cabin fire hazards.

f. Examine and recommend cabin fire management and suppression systems and evacuation aids, including emergency lighting and protective breathing devices, that improve the survivability of cabin occupants.

g. Evaluate the effectiveness of current requirements and design practices for class D and class C cargo compartment fire protection and develop/recommend improvements where needed.

h. Identify those inservice cabin materials wherein economic and practical alternate materials are currently available or under development, and foster the replacement of these materials by demonstrating safety benefits during realistic fire tests. Examples include cabin panels (sidewall, ceiling, stowage bins) and windows.

i. Related to item h above, evaluate and specify for near-term application fire blocking layers for polyurethane seat cushions.

j. Update and expand FAA requirements for hand-held fire extinguishers in transport aircraft and develop requirements for general aviation.

k. Develop methods of risk analysis related to cabin fire safety.

l. Recommend test methods and criteria, and reflective coatings, to improve the radiative heat resistance of emergency evacuation slides.

m. Develop standard flight test procedures and criteria to evaluate the effectiveness of emergency in-flight smoke ventilation measures.

and optimum escape paths for occupants. These modeling techniques have been applied to bedrooms, mobile homes, hotel corridors, and shopping malls. These techniques have resulted in such improvements as flammability requirements for corridor carpet to prevent a room fire from igniting the carpet as heat and smoke flow into the corridor under the door soffit.

The FAA has supported modeling applications to cabin fire safety problems since 1974 in the case of mathematical modeling and 1977 in the case of physical modeling. The aviation applications are different from buildings in a number of important respects. First, the geometries are long and narrow in large aircraft. Second, while building fires are generally slowly developing enclosed fires like a mattress, a postcrash aircraft fire can involve a large external pool fire of aviation kerosene with the potential for causing rapid growth of an interior fire. Third, while a building enclosure fire can afford reasonable time for escape, provided occupants are quickly notified and use safe egress paths, an in-flight fire affords no opportunity for escape so long as the aircraft is airborne. Additionally, wind effects are of great importance in postcrash fuel fires. Finally, the passenger density of an aircraft is large in comparison to a typical building.

While the aircraft fire scenario is significantly different from a building scenario, progress in modeling aircraft fires also will yield techniques useful for buses and trains which are also long and narrow with high passenger densities.

2.1.2.3 Work to Date.

The modeling work sponsored by the FAA has involved in-house work on physical modeling and contractual work and interagency agreements for development and use of mathematical models. Contractual work has also been the source of the development of an adequate data base to evaluate a more realistic use of pressure modeling.

a. The accomplishments to date in physical modeling include:

(1) Definition of radiative flux through a fuselage doorway from a large external pool fire, and development of theoretical relationship for prediction thereof (reference 15).

(2) Development of sizing criteria for fires used in the C-133 wide-body tests (reference 15).

(3) Characterization of the effects of wind and door openings on hazard development in a fuselage from an external fuel fire (references 16, 17, and 18).

(4) A comparison of performance of a conventional stretched acrylic window with that of an advanced epoxy-polycarbonate window (reference 19).

(5) An evaluation of fire blocking curtains that could prevent flames from an external fuel fire from penetrating an open fuselage doorway (reference 20).

(6) Construction of a pressure modeling facility at the FAA Technical Center with the capability of testing wide-body jet models.

cases, this requires large computer programs because of the complexity of fire physics. Use of mathematical models for fire prediction is similar to theoretical aerodynamics both in the equations and predictive goals.

2.1.2.1 Objectives.

The general objectives of the fire modeling effort are as follows:

a. Develop and use reliable physical fire modeling techniques that allow rapid, inexpensive, and wide-ranging postcrash cabin fire tests to: (1) evaluate the effects of different fuselage material systems on flammability; (2) examine the effects of varying the overall scenario such as fuel fire size, wind direction with respect to the fuselage, number and location of door openings, and height of openings from an externally burning fuel layer; (3) determine the scenario for full-scale tests that would be most productive of useful data; and (4) provide an intermediate test scale between full-scale and lab-scale to determine which flammability parameters are scale-induced and which are configurational in nature.

b. Develop mathematical fire models of varying degrees of complexity and application to predict environmental conditions in the fuselage resulting from material properties, configuration, ventilation, and injection or production of noxious or harmful gas-state products. The objectives are inclusive of those in 2.1.2.1a but also include end products such as computer codes and selection nomographs for use in advisory material and design aids. These models include the following in ascending order of complexity:

1. Global models such as perfect stirrers and thermodynamics models to compute ventilation effects and fuel loads.

2. One-dimensional differential models such as the thermochemical models used to predict burning rates of char-forming materials.

3. Integral models such as those used to predict flame spread upwards on vertical surfaces.

4. Two-dimensional zone models such as DACFIR which predicts fire development within the fuselage and employs a large computer program.

5. Two-dimensional field models such as UNDSAFE which computes fire phenomena within a cabin on a point-by-point basis from a complex computer program.

2.1.2.2 Background.

Both physical and mathematical modeling of fire have been employed in nonaviation fields for over a decade. The majority of this work has been aimed at three scenarios; the room, the room and corridor, and an assembly of rooms. The issues are the development of a fire in a room to the point of flashover as a function of fire load and ventilation, the propagation of fire and toxic products from a room to a corridor, and the growth of fire from room to room with consequent movement of combustion products through corridors, shafts, and stairwells. The goal here is sound selection criteria for selection of furnishings and construction materials and information on escape criteria such as time for nonsurvivable conditions to develop in a building, time for fire detectors to activate at various locations,

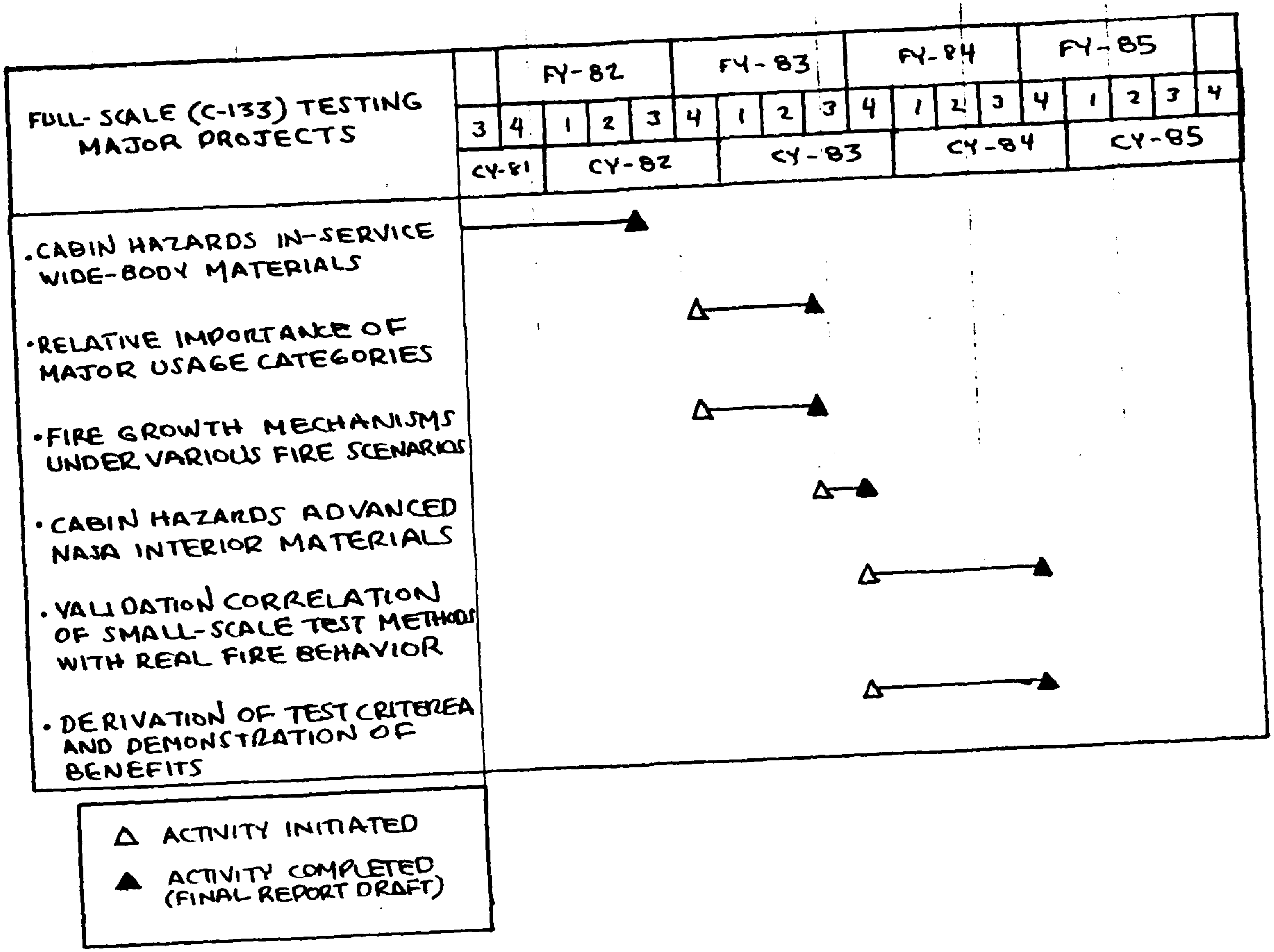

FIGURE 4. FULL-SCALE (C-133) PROJECTS MILESTONES

4. Derivation of test criteria and demonstration of the benefits therefrom under various fire scenarios.

The latter two efforts will be accomplished in FY-84.

2.1.1.8 Full-Scale Fire Test Facility.

A full-scale fire test facility housing the C-133 and other test articles became operational at the Technical Center in July 1980. The facility is composed of a test bay and an operations wing. The test bay is 180-feet long, 75-feet wide, and 45-feet high, and is designed to withstand the environment produced by a 20-foot square fuel fire at its center. The operations wing contains a test control and computer area, offices, a mechanical room, and shop/storage area. The new facility has significantly improved the capability of the C-133 test program for the following reasons:

a. By providing an environment isolated from random ambient wind fluctuations which destroy test repeatability (tests were previously conducted outdoors at approximately 0600 on those days when meteorological predictions indicate zero ambient wind).

b. By allowing for the conduct of tests on a regularly scheduled basis, independent of the weather, particularly the cancellation effects of wind and rain.

c. By permitting testing during the cold winter months (C-133 outdoor tests were terminated for 3 months during the winter).

2.1.1.9 Major Project Milestones.

Major project milestones are paragraphed in figure 4.

2.1.2 Fire Modeling.

Full-scale fire tests are inherently capable of yielding data that accurately represent the growth of hazards that can occur during an aircraft accident or incident. Nevertheless, full-scale fire tests are expensive in that manpower and material requirements are high. Furthermore, although results from a specific full-scale test configuration can be definitive (e.g., C-133 in the FAA full-scale fire test facility), the specific configuration will generally lack the flexibility for extensive change of scenario (e.g., C-133 cannot be totally immersed in a wind since the full-scale fire test facility is not a wind tunnel). Thus, while the C-133 has been and will continue to be the centerpiece of the FAA Cabin Fire Safety Program, additional approaches have been developed to generate a broad enough data bank to represent the full range of fire incident and accident possibilities within reasonable resource constraints.

These approaches are for the most part in the areas of physical fire modeling and mathematical fire modeling. Physical fire modeling (reference 14) involves testing of small-scale fuselages at ambient pressure (Froude modeling) or at elevated pressures (pressure modeling). Employment of physical modeling techniques is a technical approach similar to the use of wind tunnels in the evaluation of the performance of prototype aircraft. Mathematical modeling of fire involves prediction of fire behavior from solution of governing theoretical equations. In most

2.1.1.6.2 Background.

Are currently used cabin interior materials the safest available in the context of a survivable postcrash fire environment? What incremental safety benefit is attainable by replacing current materials with the "best" advanced materials under development by NASA and industry? These questions must be answered in order to rationally evaluate regulatory strategies and help guide the direction of future research relevant to cabin fire safety. The SAFER R&D Review Subgroup of the Compartment Interior Materials Technical Group recommended that tests be conducted in the C-133 with the interior lined and furnished with advanced materials in order to determine the incremental safety benefit afforded by these "best" materials.

2.1.1.6.3 Technical Approach.

The technical approach will be identical to that planned for the evaluation of "typical" wide-body materials, as described in section 2.1.1.3, except that the "best" advanced materials will be tested. This project will rely heavily on expertise provided by the NASA Ames Research Center under an interagency agreement to select and fabricate materials. With regard to advanced panel design, NASA has elected to upgrade the decorative film and resin components to polyetheretherketone (PEEK) and polyimide, respectively. The interior components will be fabricated from flat sheets and panels in order to assure identical geometrics between advanced and inservice configurations. Considering recent work accomplished at the Technical Center, demonstrating the effectiveness of seat foam fire blocking layers, the follwoing comparative tests will be performed:

1. Inservice seats with advanced panels versus inservice panels.

2. Completely inservice configuration versus completely advanced configuration.

3. Seats protected by fire blocking layers with advanced panels versus inservice panels.

A draft report will be issued in September 1983.

2.1.1.7 Studies to Correlate Small-Scale and Large-Scale Fire Test Results.

The C-133 test article provides for the measurement and observation of the behavior of interior materials under the most realistic conditions that can now be attained experimentally. For this reason, the C-133 test article will provide crucial information and data for the development of small-scale test methods and criteria for cabin materials (major usage categories) during the following efforts:

1. Determination of the relative importance of each major usage category on fire growth and hazard development.

2. Examination of fire growth mechanisms under various fire scenarios.

3. Validation of small-scale test methods exhibiting the highest correlation with cabin fire behavior based on 1/4-scale modeling of flashover (see section 2.1.2.5.1).

ceiling, sidewall, stowage bin, seats, and flooring. If it can be established that one or more of the above categories do not materially contribute to the growth of a fire, this would indicate that current flammability requirements are adequate for these materials and that improvements should focus only on those materials found to contribute significantly to fire growth.

2.1.1.4.3 Technical Approach.

Basically, consecutive tests will be conducted in the C-133 test article under a fixed fire condition with a different usage category material removed from the test section in each test. Thus, the first test will consist of all materials except ceiling panels; the second test, all materials except stowage bins; etc. By comparing fire and hazard growth between the five tests, the relative importance of each usage category will be established. The number of fire conditions examined will depend upon the availability of test materials.

A draft report will be issued in June 1983 (combined with fire scenario study, Paragraph 2.1.1.5).

2.1.1.5 Fire Scenario Effects.

2.1.1.5.1 Objective.

The objective of this project is to study the mechanisms of fire development in a cabin under different fire scenarios.

2.1.1.5.2 Background.

Based on past C-133 fire tests, certain impressions exist with regard to the controlling mechanisms for cabin fire growth from ignition to an untenable condition. However, these impressions were formed by tests performed under a single fire scenario; i.e., an external fuel fire adjacent to a door opening. Therefore, it is desirable to perform C-133 fire tests under additional fire scenarios to determine if the controlling mechanisms are common to various scenarios.

2.1.1.5.3 Technical Approach.

Tests will be conducted in the C-133 test article with a full complement of interior materials installed in the test section under a number of fire scenarios. At least three scenarios are planned: in-flight fire (closed fuselage with simulated ventilation), external fuel fire adjacent to a fuselage opening, and external fuel fire with fuselage burnthrough. Based on analyses of extensive hazard (temperature, smoke, gases) measurements in conjunction with video coverage, an attempt will be made to delineate the controlling mechanisms for fire growth under different fire conditions and seek commonalities.

2.1.1.6 Cabin Hazards Within an Interior Furnished with Advanced NASA Materials.

2.1.1.6.1 Objective.

The primary objective of this project is to determine the incremental increase in postcrash cabin fire safety that can be provided by the "best" advanced interior materials in comparison to typical inservice wide-body materials.

2.1.1.3.2 Background.

Significant controversy exists over the importance and role of cabin materials in effecting occupant survivability during a postcrash cabin fire originating from an external fuel fire. An unpublished cursory in-house study indicated that approximately 1/3 of commercial aircraft fire fatalities are attributable to interior materials. Conversely, it has been argued that there is no evidence of fire fatalities ever having resulted from burning wide-body type of interior materials. The SAFER Technical Group on Compartment Interior Materials recommended that top priority be given to this project in order to "determine whether a problem exists with interior materials."

2.1.1.3.3 Technical Approach.

A 20-foot length of the C-133 test article will be completely furnished and lined with "typical" wide-body materials (e.g., seats, carpeting, ceiling and sidewall panels, and overhead stowage bins) and subjected to an external fuel fire. C-133 experiments without interior materials indicate that the cabin hazards resulting from quiescent fuel fire are survivable at an aft fuselage station for at least 5 minutes. Also, the magnitude of thermal radiation and flame penetration at the fuselage opening adjacent to the fire increases when a simulated ambient wind is used against the fire; consequently, the burning of the interior will vary accordingly. By simply comparing the cabin hazards at the same aft station with and without interior materials, the importance of interior materials can be determined for the test conditions studied. This work was completed (reference 13) and the following summarizes the most important findings:

a. Burning cabin interior materials can be the primary factor affecting occupant survivability in certain types of postcrash fires despite the presence of a large fuel fire.

b. Uncontrolled postcrash fires in an intact fuselage will produce a flash-over condition which will be followed by a loss in survivability throughout the cabin.

c. The only fire hazards of significance, measured before the onset of flash-over, were the irritant gases, HF and HCl, and smoke produced by burning composite panels and, possibly, seats.

2.1.1.4 Relative Importance of Major Usage Categories.

2.1.1.4.1 Objective.

The objective of this project is to determine the relative importance of each of the major interior material usage categories (ceiling, stowage bin, sidewall, seats, and flooring) on cabin fire hazard development.

2.1.1.4.2 Background.

Past full-scale cabin fire tests in the C-133 test article exhibit significant stratification of fire hazards and most extensive fire involvement and damage in the upper cabin. It may be that materials located in the upper cabin are more important and should have more stringent requirements than materials located in the lower cabin. Interior materials can be divided into five broad categories:

replacements for current materials (e.g., seat foams cushion fire blocking layers and windows, section 2.2.2). The degree of success and progress during planned studies and developments by various organizations (FAA, NASA, SAFER, and industry) will determine the exact areas of C-133 utilization beyond the following firm plans of:

a. Defining cabin hazards within a bare interior.

b. Defining cabin hazards within an interior furnished with "typical" wide-body materials.

c. Determining the relative importance of each of the major usage categories (ceiling, stowage bin, sidewall, seats and flooring) on cabin fire hazard development.

d. Studying the mechanisms of fire development under different fire scernarios.

e. Defining cabin hazards within an interior furnished with advanced NASA materials.

f. Studying the correlation between small-scale and large-scale test results.

2.1.1.2 Cabin Hazards Within a Bare Interior.

This completed project consisted of conducting a large series of tests with the test article devoid of interior materials. The purpose was to develop a realistic and repeatable external fuel fire source, determine the cabin hazards exclusively resulting from the fuel fire, and determine the fire conditions that interior materials would be exposed to. A final FAA report was published in December 1979 (reference 12). The following summarizes the most important findings:

a. Ambient wind is the most important factor influencing the cabin hazards.

b. Significant vertical profiles (stratification) of heat, smoke, and toxic gases occur inside the cabin.

c. Heat and smoke individually are more hazardous than carbon monoxide in a cabin environment dominated by burning fuel.

d. Oxygen depletion without interior materials is insignificant when the cabin is ventilated.

2.1.1.3 Cabin Hazards Within an Interior Furnished with "Typical" Wide-Body Materials.

2.1.1.3.1 Objective.

The objective of this project is to determine the contribution of burning interior materials, relative to a postcrash external fuel fire, to the overall cabin fire hazard. A secondary objective is to study the relative importance of various fire hazards, including heat, smoke, and toxic gases on occupant survivability.

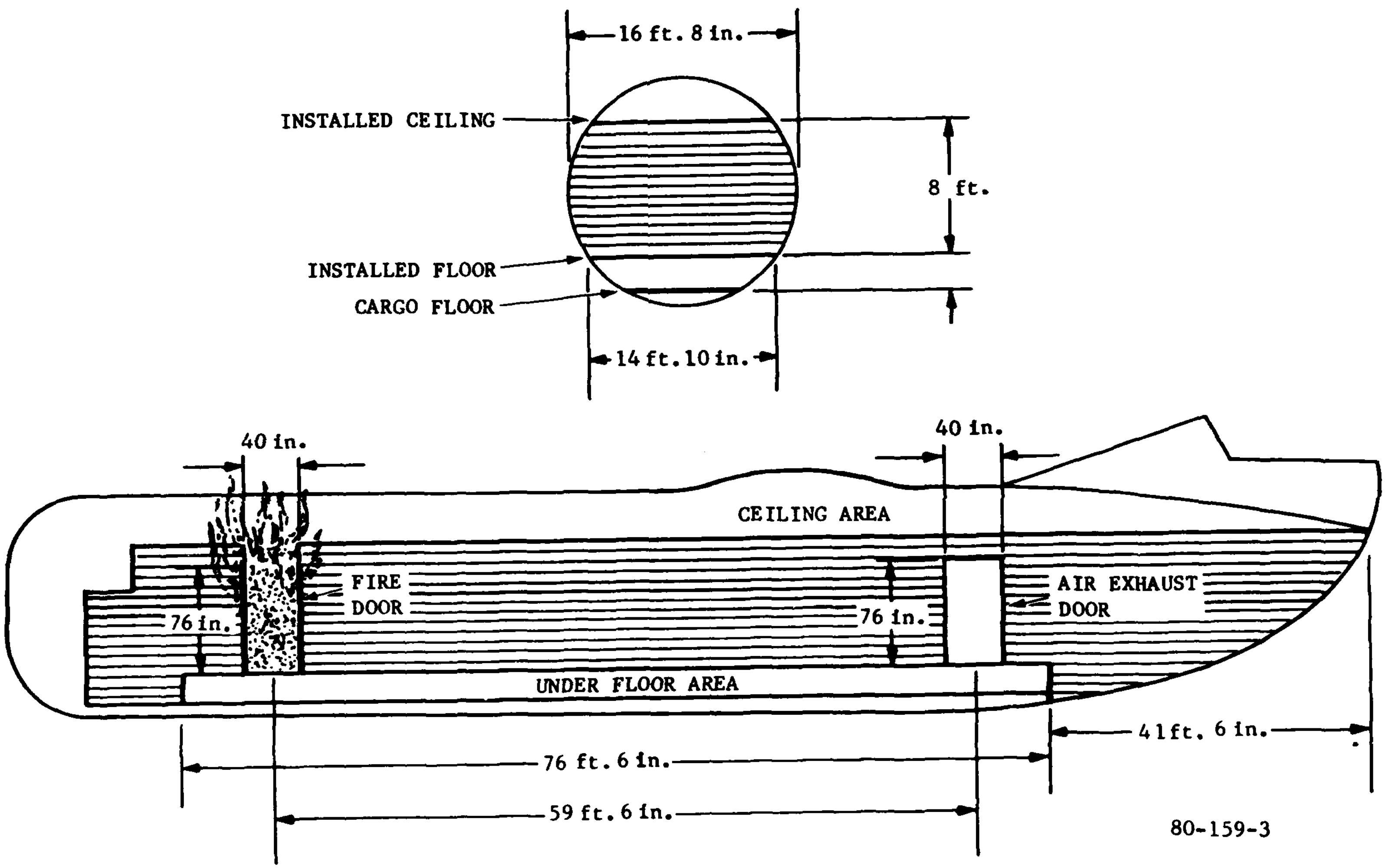

FIGURE 3. WIDE-BODY CABIN FIRE TEST ARTICLE

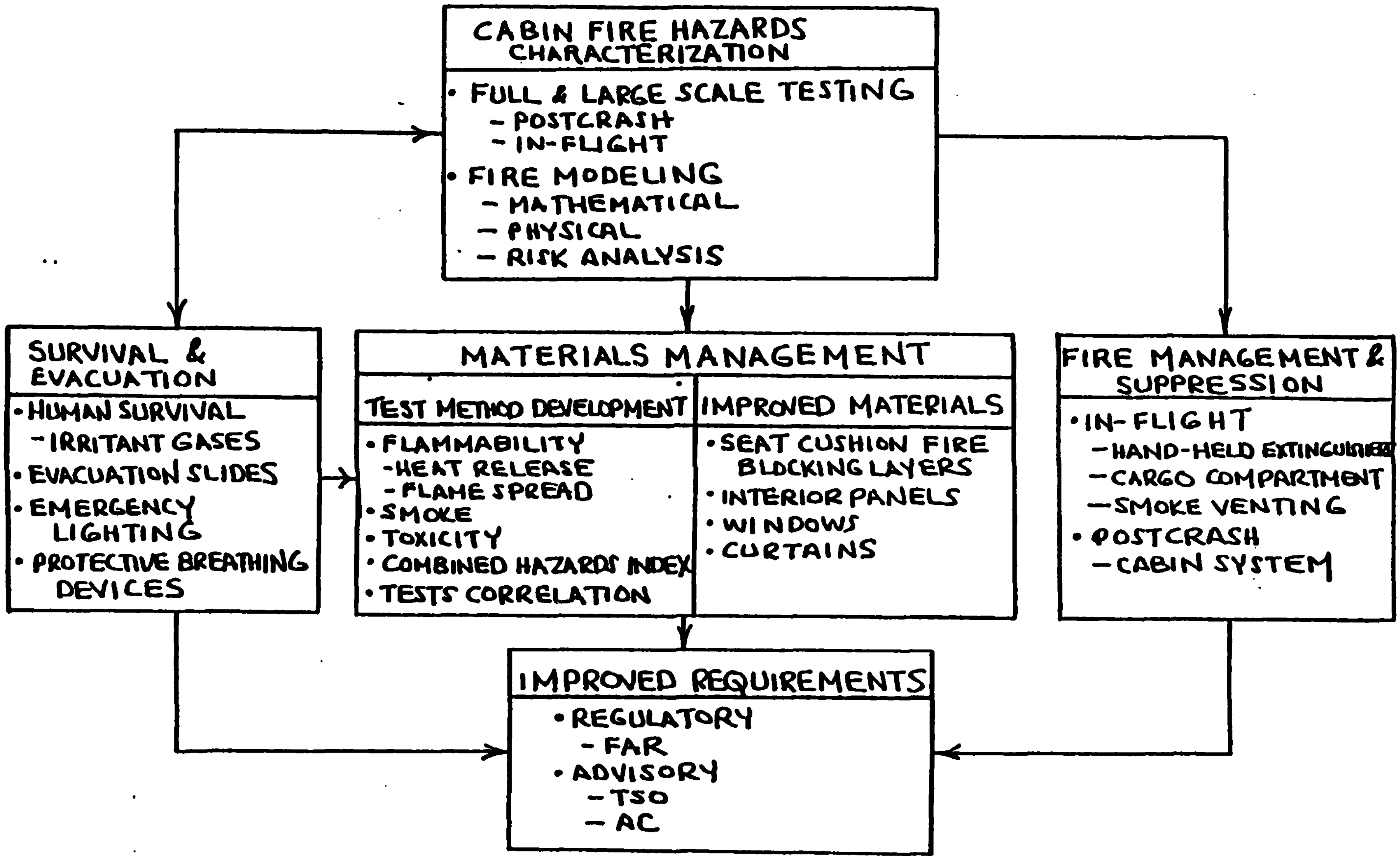

FIGURE 2. AIRCRAFT CABIN FIRE SAFETY PROGRAM FUNCTIONAL RELATIONS AND WORKFLOW

Currently, the greatest emphasis is being placed on fire and materials management. Figure 2 outlines the Aircraft Cabin Fire Safety Program tasks and projects, its functional relationships, and work flow. The plan is based on five essential tasks:

1. Cabin Fire Hazards Characterization.
2. Materials Management (improved test methods and advanced materials).
3. Survival and Evacuation.
4. Fire Management and Suppression.
5. Improved Requirements.

Each task is composed of individual projects as described in sections 2.1 to 2.5.

2. AIRCRAFT CABIN FIRE SAFETY PROGRAM DESCRIPTION.

2.1 CABIN FIRE HAZARDS CHARACTERIZATION.

Before major progress can be made in improving cabin fire safety, it is essential that the cabin hazards created by an external fuel fire be reasonably well understood. Detailed information on fire spread and rate of hazard buildup cannot be derived from examining a burned-out aircraft cabin at the site of an accident. The most appropriate means available for gathering this information is by conducting a series of controllable and well instrumented experiments in a full-scale cabin simulator or cabin model. The broad purpose of these experiments is to measure the temporal and spatial distribution of various cabin fire hazards and determine the influence of various configurational and environmental factors.

2.1.1 Full-scale (C-133) Experiments.

A full-scale, wide-body cabin type of test article has been constructed at the Technical Center from a surplus C-133 aircraft and a large number of external fuel fire experiments have been performed over the past several years. A detailed description of the test article is contained in references 11 or 12, and a drawing of the C-133 test article is shown in figure 3. The postcrash fire scenario that is used in the C-133 was selected to assure the greatest probability of the maximum contribution of interior materials, relative to the external fuel fire, to the overall cabin hazard. An 8- by 10-foot external fuel fire is positioned adjacent to a fuselage opening the size of a type A door near the front of the airplane. A similar opening on the same side of the fuselage exists in the back. Measurement and sampling probes are located throughout the cabin to determine the spatial and temporal distribution of hazards. Instrumentation is currently used for measurement of temperature, heat flux, smoke density, and various gases either continuously or from periodic batch samples. The gases which are analyzed presently include CO, CO_2, O_2, HCN, HF, HCl, and total yields of other selected species. White rats are used to determine the incapacitating and lethal nature of the C-133 environment.

2.1.1.1 Major Projects.

The C-133 test article could be properly utilized for any of a variety of studies described under subsequent tasks in sections 2.2 to 2.5. Several such examples include the evaluation of advanced fire management and suppression systems/concepts (section 2.4) and advanced material systems which are candidate cost/effective

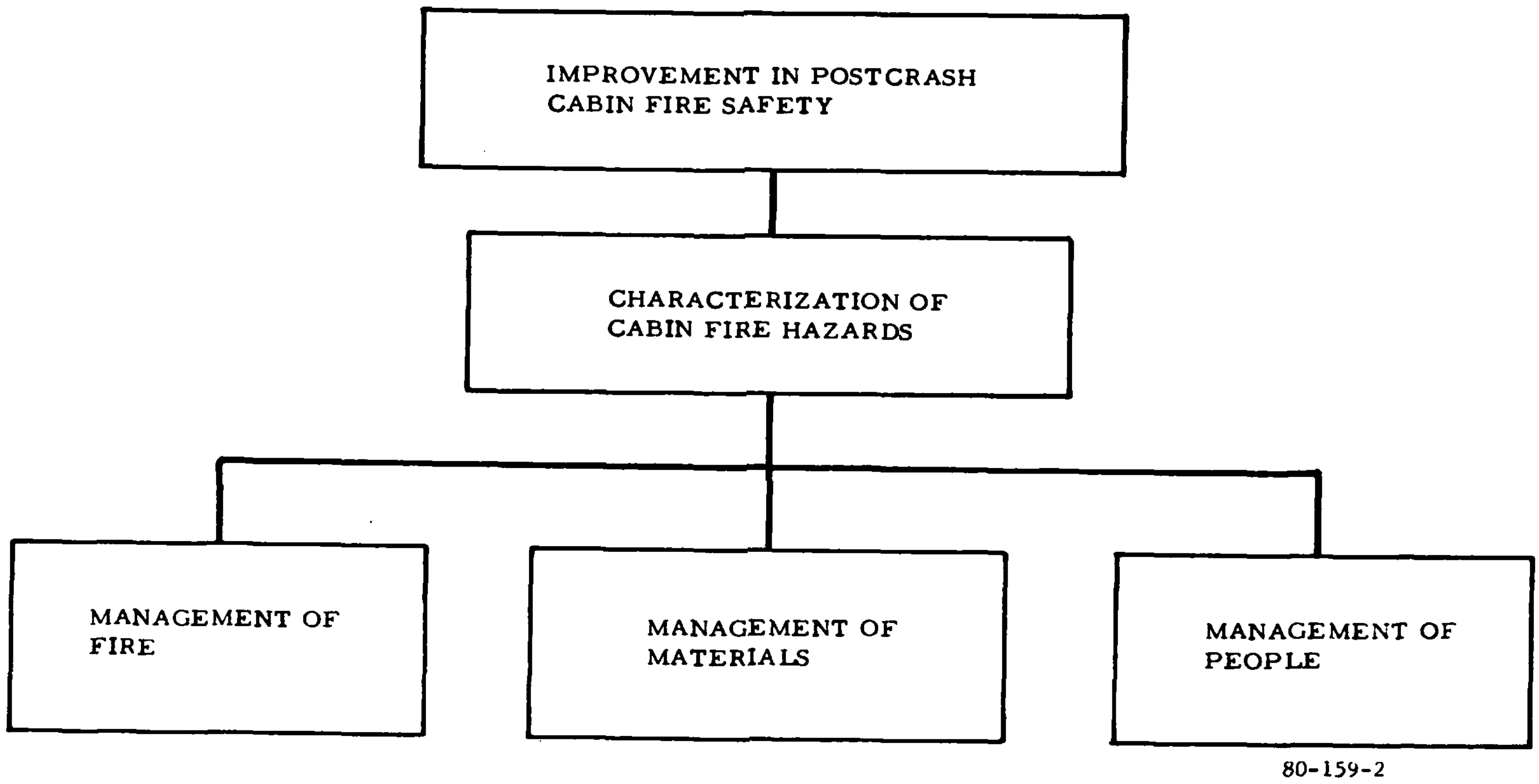

FIGURE 1. AIRCRAFT CABIN FIRE SAFETY PROGRAM GENERAL TECHNICAL APPROACH

other considerations are demonstrated safety benefit, cost/benefit analysis, compatability of new materials with existing processing equipment, durability, strength, asthetics, and servicing requirements.

e. The mathematical modeling of enclosure fires, such as within a furnished aircraft cabin, is in an infant state of development. Before cabin fire models can be applied to CHI methodologies currently under development and cost/benefit analyses, considerable research and development (R&D) must be performed. Overall program planning will proceed on the assumption that very limited cabin fire computer models will be available in the near future. Although physical fire modeling has been applied in the areas of home fires and corridor fires, this technology requires considerable effort in development and validation for the aircraft fire problem.

f. Technological breakthroughs may be required to make substantive improvements in aircraft cabin fire safety solely by changing the nature of interior materials. Other safety concepts must be periodically reexamined in light of current advances in materials testing and evaluation R&D; namely concepts of fire management and people management (crew training, passenger education and personal protection devices).

g. It is difficult to predict consistent evacuation responses of passengers in crashes which create external/internal fire, dense smoke, and toxic combustion products. Variables such as passenger group panic and impairment of judgment during evacuation from toxic products cannot be effectively and safely incorporated into a research protocol. The effects of visibility and emergency lighting improvement will be evaluated through comparative testing under conditions not hazardous to human subjects.

1.4 GENERAL TECHNICAL APPROACH.

The general technical approach is illustrated in figure 1 and recognizes that the ultimate goal of the program is to improve postcrash and in-flight cabin fire safety. Safety improvements are possible once the characteristics of cabin fire hazards are measured and understood. This information is obtained by performing well-instrumented and controllable series of full-scale and physical modeling tests. The present emphasis at the Technical Center is to conduct this type of testing. Once the nature of the problem is reasonably well understood, three approaches are available for improving fire safety: (1) management of interior materials, (2) management of fire, and (3) management of people. The present program is mainly concerned with producing fire safety products with near-term application and developing test methods and criteria for managing the selection of interior materials.

1.5 PROGRAM STRUCTURE.

The Aircraft Cabin Fire Safety Program plan is structured to provide concurrent development in four areas:

a. Characterization of Cabin Fire Hazards
b. Management of Materials
c. Management of Fire
d. Management of People

1.3 CRITICAL ISSUES.

As the Aircraft Cabin Fire Safety Program proceeds, related critical issues must be identified and addressed. Several of these issues are discussed below:

a. Although unlikely, it is possible that planned full-scale cabin fire tests will indicate that, compared to the fuel fire, interior materials do not contribute to postcrash survivability. If this is clearly the indication, then the resources now devoted toward testing and evaluating cabin materials in the context of a postcrash fire should be redirected toward fire management and suppression, evacuation aids, and antimisting fuel.

b. If currently used interior materials have an effect on postcrash fire survivability, it remains to be seen if advanced organic material systems can provide a significant incremental safety benefit. If a safety benefit can clearly be derived, the program should proceed as planned in this document. However, if an exhaustive evaluation of alternate organic material systems does not reveal a significant safety benefit, then the program should be redirected as described in the above paragraph.

c. A major problem exists with regard to the interpretation of the effect of heat, smoke, and toxic gases measured during large and full-scale tests on human survival and escape potential. Reliable information on human tolerance and survival limits for irritant gases are nonexistent; although research is planned in this program plan to begin to gather this information, it will probably not become available for at least several years. The combined effect of various hazards on human survival and escape has received very little attention by researchers. At this time it is even uncertain as to what major hazards are present during a postcrash cabin fire. The quantitative effect of smoke obscuration on survival needs to be determined. Because of these technical deficiencies within the next several years, it will be necessary to interpret large and full-scale fire test data in terms of relative measurements or on the basis of crude survival models. This will result in test data that is interpretative, and may make the decisions described in the preceding paragraphs somewhat subjective.

d. Small-scale fire test data, whether for flammability, smoke, or toxicity, are usually obtained for single, small test specimens under steady-state test conditions, and the test results are strongly dependent on the actual test conditions used. Real fires are dynamic in nature and involve a complex system of materials. It is generally accepted that standardized small-scale fire tests do not directly relate with full-scale tests or real fires. Fundamental questions about combustion processes and fire dynamics must be answered before relevant small-scale test methodologies can be developed. Although numerous standardized flammability tests are available, as well as at least one standardized smoke test (reference 10)—all with disclaimer statements pertaining to real fire relevancy—no standardized toxicity tests are in existence. Also, although FAA has under development a CHI test methodology, its great dependency on mathematical fire modeling and the transformation of numerous hazard measurements to human escape time make its near-term application very unlikely. There is a recognized and generally accepted credibility gap in small-scale fire tests for interior materials. It should be recognized that cabin interior material selection by industry is based on many aspects besides these small-scale fire tests. Some

(7) Establishment of a Froude modeling facility at the FAA Technical Center that currently houses a half-scale model of the C-133; a fifth-scale model of the full-scale fire test building; and a 1-foot diameter Froude model used to provide experimental data for the mathematical modeling effort at Harvard University.

(8) Establishment of a 32-foot square modeling pad at the Technical Center burn site where the one-quarter scale model of the C-133 is tested under varying wind conditions.

(9) A pressure modeling study of upward burning on vertically burning aircraft materials, wherein it was demonstrated that materials that passed the vertical Bunsen burner test could still burn in a full-scale scenario (reference 21).

(10) A pressure modeling study of fire spread on aircraft ceiling materials which also provided algorithms for prediction of thermal radiation to aircraft seats from the hot ceiling smoke layer (reference 22).

b. The accomplishments to date in the mathematical modeling area include:

(1) Development of a zone model for aircraft cabin fires that includes subroutines for flame spread across aircraft materials (reference 23). This current version, called DACFIR 3, will be the centerpiece of future refinements to and applications of the zone model (University of Dayton Research Institute).

(2) Application of UNDSAFE field model to an aircraft (reference 24). This application for the first time demonstrated how seat geometry could affect fire development in an aircraft (Notre Dame).

(3) Development of a mathematical model for flame ingestion from an external pool into a fuseage opening (Harvard). This model relies on data from specialized tests at the FAA Technical Center (reference 25).

(4) Development of an integral model for flame spread up a vertical surface (Factory Mutual Research Corporation, reference 26).

(5) Analysis of burning rates of aircraft seats and carpets and of seats with fire blocking layers using thermochemical modeling (Jet Propulsion Laboratory, references 27 and 28).

(6) Development of nomographs for dosages of extinguishing agents in ventilated aircraft compartments by means of perfect stirrer theory (FAA Technical Center, reference 29).

(7) Development of a computer code for prediction of radiation from smoke layers (Factory Mutual Research Corporation, reference 22)).

(8) Procurement and installation of VAX-750 computer for data acquisition in pressure modeling and for maintaining existing codes such as DACFIR in an active working state to support fire safety projects (FAA Technical Center).

(9) Convening a workshop and conference at the FAA Technical Center for technology transfer on state-of-the-art computer models (reference 30).

(10) Participation in Ad Hoc Steering Committee on Mathematical Fire Modeling with the National Bureau of Standards to aid in identification and prioritization of efforts of fire modeling on a national basis.

2.1.2.4 State-of-the-Art.

Fire modeling involves approaches ranging from Froude modeling of externally burning pool fires; wherein the heat transfer from an externally burning fuel fire to the skin of an adjacent fuselage is measured, to the complex numerical field models, which in principle have the generality and potential of treating the entire postcrash fire development sequence in great detail. Techniques of intermediate complexity are found within these two extremes. The current state-of-the-art is such that the simpler techniques are generally very reliable when applied to appropriate and limited problems while the most complex techniques are still faced with significant development problems (reference 31). For instance, the DACFIR zone model contains a flame spread routine that can be updated as technology dictates while the more complex UNDSAFE generally is based on specified volume release rates of heat within an enclosure rather than incorporating a self-propagating material-based fire. In general, Froude modeling techniques are useful when one is dealing with a fire source that is not growing and when looking at material exposure parameters. Pressure modeling has the capability for treating more complicated scenarios that involve flame spread and fire growth, but there are difficulties primarily related to burning of laminated and char-forming materials (reference 32). The simplest mathematical technique, the perfect stirrer, has shown excellent predictive capability in the limited case of extinguishing agent dispersal overtime. The most complex mathematical technique, the field model, is successful when the fire scenario is deliberately simplified to a steady burning fire in an enclosure. Nevertheless, the majority of the modeling techniques are useful when applied to that scenario for which their technical framework is most suitable. For instance, in an in-flight fire in which the fire can be treated as a constant size and where cabin ventilation is from ceiling to floor, the field model can be expected to yield highly accurate results while the zone model may be invalid. Conversely, the zone model is far superior at this time in any practical treatment of the postcrash fire. The current approach of the FAA in utilization of modeling technology is attempting to match a given technique to the scenario for which it is best suited.

2.1.2.5 Technical Approach.

The modeling efforts will be used primarily for two purposes. First, specific and limited modeling techniques will be used to support immediate project requirements and program requirements as need dictates. Second, the DACFIR model will be upgraded as technology allows so that it can be a reliable tool for aircraft interior design and material selection. This use of DACFIR is essential so that the impact of material lab-scale performance data on full-scale fire behavior can be demonstrated. Running batteries of full-scale tests to evaluate every proposed interior material fixture is simply too expensive an alternative.

2.1.2.5.1 Froude Modeling.

The one-quarter scale model at the burn site will continue to be used for quick-reaction evaluation of materials exposed to pool fires of twice the fuselage diameter in a wind environment. The 1-foot diameter model in the Froude facility will continue to be used for experimental verification of prediction of pool fire interaction with doorways so that DACFIR can be upgraded. A new one-quarter scale model in the Froude facility will be used to investigate flashover on aircraft ceiling materials to provide an intermediate step between C-133 scenario studies and lab-scale test in the correlation effort. The fifth-scale model of the full-cale fire test facility will continue to serve as a device for planning test configurations and facility changes in full-scale facility.

The half-scale model of the C-133 in the Froude facility will be used as a verification tool for mathematical modeling techniques.

2.1.2.5.2 Pressure Modeling.

The major components of the pressure modeling facility are complete. These include a control room, a building to house the compressor, and a bunker to house the pressure test vessel. All are tied together via underground conduit. The compressor is a nonlubricated, three-stage compressor with an output of 120 standard cubic feet per minute at 1,000 psi (pounds per square inch). Adjacent to the compressor building is a 1,000 psi storage tank for dehumidification and cooling of compressed air. The pressure test vessel itself is a 600-psi chamber with quick opening door on the front. All these high pressure air units are now tied together with appropriate high pressure piping, fittings, and control devices.

Work in FY-83 will involve installing instrumentation and control equipment to make the facility operational and fabrication of the first generation of models for fire testing. Prior to becoming operational for pressure modeling tests, the test vessel and storage tank will be used to provide ventilation air for the B-707 test bed in the smoke evacuation work.

The pressure test vessel is 5-feet in diameter and 18-feet long and will house 2-foot diameter models (one-tenth scale of a wide-body jet). The pressure modeling facility because of its size is unique in the free world. It will be used in its first operational year to support the data base on the correlation of test methods, particularly in the area of flame spread in varying orientations and on varying materials. All data will be recorded on the VAX-750 computer, which will also regulate the vent valves at the high speeds involved in pressure modeling.

2.1.2.5.3 Upgrading DACFIR.

The DACFIR computer code needs three modifications to reach a useful stature for the postcrash fire. First, the pool fire interaction with the fuselage opening now being codified at Harvard University must be added to the DACFIR program. Second, the submodels on creeping and upward flame spread being formulated at the National Bureau of Standards and at Factory Mutual Research Corporation must replace the existing flame spread subroutines in DACFIR. Finally, flame over or flashover criteria must be added to the DACFIR code as well as a means of predicting the time to incapacitation based on on a Combined Hazard Index (reference 13). In this way, DACFIR predictions can be verified against C-133 test data on a global rather than piecemeal basis.

2.1.2.5.4 Specific Mathematical Models.

Specific modeling techniques will be used as needed to support project requirements. For instance, work currently with UNDSAFE was motivated by needs to support the test program on test methodology for in-flight smoke ventilation on the B-707 test bed. Development of the stirrer technique for extinguisher dispersal was partially motivated by analytical requirements for support of the project on hand-held extinguishers in general aviation aircraft.

Thermochemical modeling is currently being used to support the C-133 effort on fire blocking layers. A DACFIR type model is being employed for theoretical support of the cargo compartment liner work being done on the DC-10 fuselage section.

2.1.2.6 Major Milestones.

Major milestones are presented in figure 5. The major milestones listed are limited to use of Froude modeling and pressure modeling in the correlation work leading to test methods and criteria and to the upgrading of DACFIR which is also pivotal in the development of acceptable test methods and criteria. Other modeling efforts that support specific projects like cargo compartment liners and in-flight smoke evacuation have their milestones dictated by constraints imposed by those specific projects.

2.1.2.7 Risk Analysis.

An interagency agreement with the National Bureau of Standards Center for Fire Research will result in the development and implementation of an analytic model to assess the public risk associated with various aircraft fire scenarios, and to assess the benefits and costs associated with candiate strategies for the mitigation of such public risk. The model will use and integrate the results of existing and planned research projects addressing various aspects of the aircraft fire problem, will identify information and data gaps in current research projects, and will provide the decision making framework for both definition of research priorities and for the development of recommendations for regulatory or other action.

The model will deal with the problems inherent in risk assessment relative to the occurrence of low probability events which have potentially catastrophic consequences. A multi-year project is planned. During the first year effort, ending in September 1983, the framework will be developed for the generic model to assess all fire scenarios of interest and all mitigating strategies; however, the bulk of the first year effort will focus on a benefit-cost analysis of the use of seat blocking materials to inhibit the spread of fire. Three scenarios will be modeled, namely, survivable post-crash cabin fires, in-flight fires and ramp fires.

2.2 MATERIALS MANAGEMENT.

2.2.1 Laboratory Test Methodology Development.

In order to impart some degree of fire safety to an aircraft cabin interior, materials are screened using small-scale fire tests. These tests fall into three categories: flammability, smoke, and toxicity.

FAA restrictions on cabin materials are limited to a flammability requirement contained in FAR 25.853 (reference 4). Fire researchers usually discuss the flammability of a material in terms of its tendency to resist ignition, propagate flame, generate heat, produce a combustible product or flashover. Flammability measurements in most test methods simply involve operator determination of ignition and/or flaming time, flame spread rate, burn length or temperature.

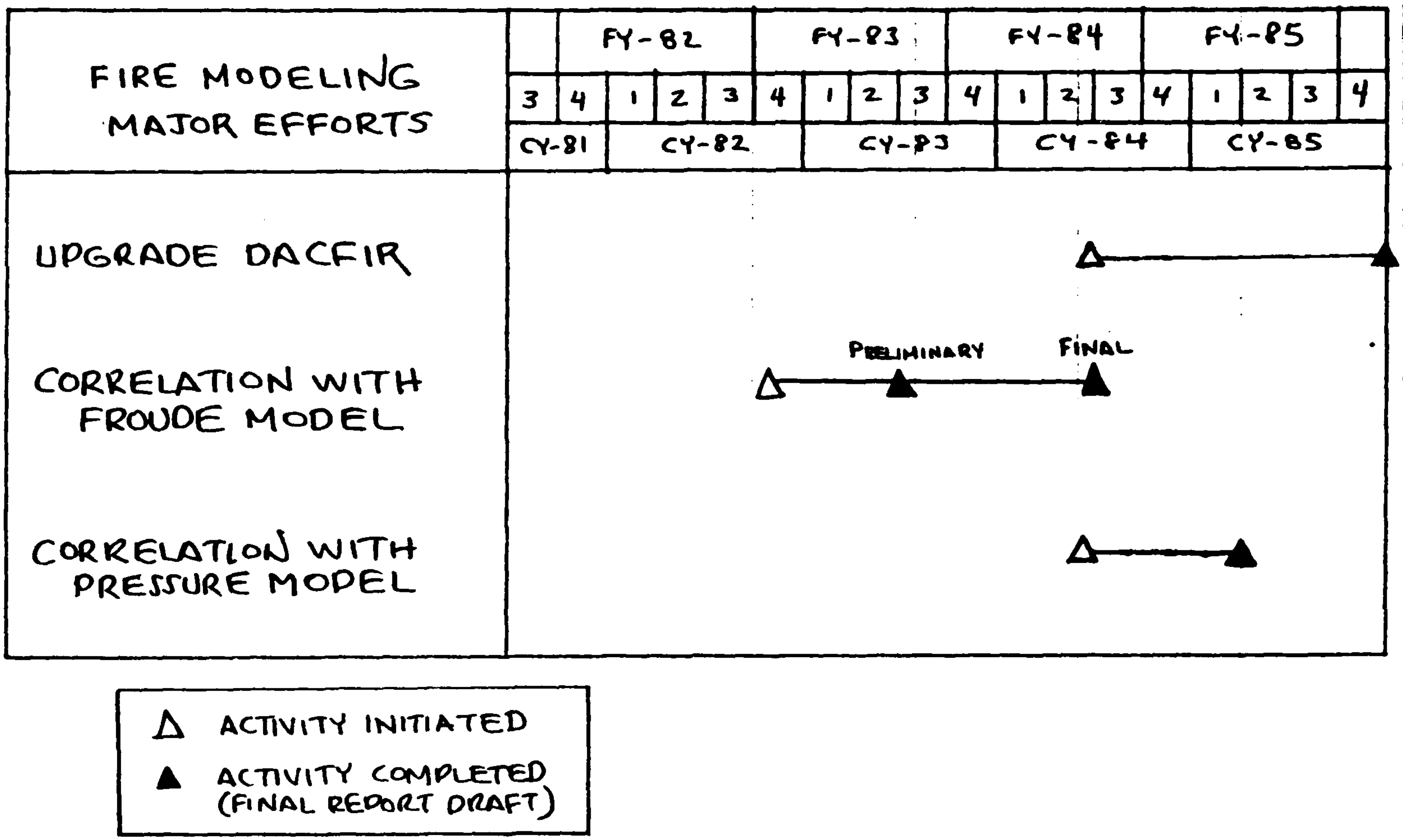

FIGURE 5. FIRE MODELING MILESTONES

Smoke refers to the light or visibility obscuring nature of the sooty and condensable products of combustion. The percentage transmission of a collimated beam of light is the usual method of measuring smoke density.

Toxicity includes the incapacitating and lethal nature of the products of combustion. The classical means of measuring toxicity is by, for example, what is called an LD_{50} (the dose or weight of a combusted material that is lethal to 50 percent of an exposed population of animals). Other more contemporary measurements include time of incapacitation, which some people believe is related to escape potential, and the amounts of toxic and irritant gases produced during combustion. Accurate gas measurements involve complex sampling and analytical procedures.

In summary, standardized flammability and smoke tests are relatively simple and can be performed by properly trained and experienced technicians. Toxicity tests on the other hand are far more complex and in an earlier stage of development, and usually require the services of professionals, although some animal tests can be systematized to a level which will allow technicians to perform the experiments.

2.2.1.1 Objective.

The ultimate objective of the test methodology development task is to determine what test or series of tests, test conditions, and data or scientific treatment of data best relate to the fire hazards of burning cabin materials in a postcrash external fuel fire environment. In effect, proposals for new small-scale test methodologies must be supported by large- and full-scale fire test data to demonstrate relevancy to the real fire condition.

2.2.1.2 Major Areas and Basic Approach.

The major areas under the test methodology development task are as follows:

a. Flammability
b. Smoke
c. Toxicity
d. Combined Hazard Index
e. Correlation Study of Small-Scale Tests with Large-Scale Tests

The priorities attached to each area are impacted by the current understanding of the nature of the cabin fire problem. Based on recent full-scale fire tests in the C-133 test article under primarily a single fire scenario (large external fuel fire adjacent to large fuselage opening), the occurrence of flashover appears to be the most critical factor leading to the loss in survivability during a cabin fire. Accordingly, during the development and correlation of small-scale test methods, the greatest emphasis will be placed on flammability considerations, such as ease of ignition, flame spread and heat release rate. Before the onset of flashover in the C-133 test article, the only hazards detected of any consequence were elevated temperature, smoke, and irritant gases. Flammability tests will address elevated temperature and smoke tests are available for examining this factor. It is unclear, at this time, as to the significance of the irritant gases, because of the unknown effects of the levels measured on escape impairment or on the accuracy of the data. Until these uncertainties can be resolved, it is believed that the most effective means of minimizing toxic (as well as heat and smoke) hazards is by taking measures to delay the onset of flashover (by using appropriate test methods for material evaluation).

2.2.1.3 Flammability.

2.2.1.3.1 Current Status.

The Technical Center has operational a number of widely-used test methods that will be evaluated under the small-scale/large-scale test correlation study (see section 2.2.1.7). These tests include the vertical Bunsen burner test prescribed in FAR 26.853, ASTM E-162 Radiant Panel test, thermogravimetric analyzer (TGA), ASTM D-2863 Limiting Oxygen Index (LOI) test, and OSU test chamber. A published report studied the relationship between these five flammability tests by comparing data obtained for 20 aircraft materials (reference 33). Except for heat release between the radiant panel test and OSU test chamber, there was very little correlation between the various tests.

The lack of correlation between flammability tests, as exemplified in the above study, has led many test organizations to seek more meaningful and realistic test methods. The OSU test chamber seems to fit into this category for the following reasons: heat and smoke emission rates are measured, these measurements are recorded with time, sample exposure radiation level can be varied, and samples can be tested in either a horizontal or vertical orientation. ASTM is attempting to standardize the OSU test chamber, and the Technical Center will participate in associated round-robin studies sponsored by ASTM. In FY-82, the Technical Center evaluated the OSU chamber as a screening test for candidate fire-blocking layer materials.

It is generally recognized that an accurate and realistic measurement of flame spread rate cannot be provided at this time by existing fire test methods. Flame spread rate is a crucial measurement implicitly related to fire hazard because it provides an indication of the rapidity by which a fire will spread and, therefore, the quantity and area of materials that will be producing hazardous combustion products.

2.2.1.3.2 Technical Approach.

2.2.1.3.2.1 OSU Chamber.

The OSU test chamber was recognized by the SAFER Compartment Interior Materials Technical Group as the most meaningful, realistic, small-scale test available with regard to testing materials for cabin fire hazards. This technical group recommended the development and evaluation of the OSU chamber as a test method for combined flammability, smoke, and gas criteria. The Technical Center has instrumented the OSU chamber for multihazard emission rate measurements and computerized data acquisition. In FY-83, the multihazard OSU chamber will be developed and evaluated as follows:

(1) characterization of typical aircraft materials for heat, smoke, and toxic gas emissions.

(2) repeatability of data.

(3) examination of the effect of incident heat flux on the completeness of combustion (CO_2/CO ratio) and the nature of toxic combustion products (e.g., HCN/NO_x, ratio).

(4) evaluation and comparison of rate of heat release measurements by oxygen depletion and compensated thermopile.

(5) evaluation of accuracy of hydrogen cyanide continuous gas analyzer.

(6) degree of correlation with cabin model flashover measurements.

2.2.1.3.2.2 Bunsen Burner Test.

The SAFER Compartment Interior Materials Technical Group recommended retention of the vertical Bunsen burner test as well as its modification for materials that melt away from the ignition flame. An ASTM task group with Technical Center participation was formed to modify the test method for materials that melt and drip away from the flame. However, after examining two approaches at a number of participating laboratories, the task group concluded that the requested modification was not feasible.

2.2.1.3.2.3 Flame Spread Rate.

Flame spread is an extremely complex process which is affected by many physical, geometrical, and chemical parameters, such as surface orientation, direction of flame spread, specimen size, initial fuel temperature, external radiant flux, surface roughness, flow velocity of environment, composition of material, composition of atmosphere, etc. A large number of test methods have evolved over the past 30 years to measure the rates of flame spread. Many of these tests were developed without allowing for the numerous factors influencing the flame spread rate. Efforts have been largely fragmented and the test methods developed yield results that are generally not consistent and do not adequately reflect behavior in actual fires. The flame spread tests have been conducted mostly with building materials and home furnishing materials. The construction of aircraft materials is vastly different from that of home furnishings and building materials. Composite material is used in an aircraft cabin to reduce the weight. Flame spread over a composite material is a very complex process which is controlled not only by the material properties but also by the material construction.

There is a need to develop an acceptable test method to measure the flame spread rate over aircraft cabin materials. This will be accomplished by an interagency agreement with the National Bureau of Standards. A 2-year endeavor is underway, scheduled for completion in September 1983. The following tasks are planned:

(1) Creeping Flame Spread. The driving force behind flame spread is radiation from the enclosure feedback effect or from the initiating fire. For lateral and downward spread on walls and for horizontal spread on floors, or creeping flame spread, radiation from external sources determines the rate of spread. This rate can reach very rapid or "flash" fire speeds which depend on the material, flux level, and exposure heating time. The creeping spread will be studied for a set of aircraft materials exposed to radiant heating. Existing test apparatuses will be adapted and used to measure the rate of spread (V_f) and to establish data which would lead to a prediction of V_f from a simple analytical formula.

(2) Wind-Aided Flame Spread. For upward spread on vertical surfaces or under ceilings, the spread rate is controlled primarily by the material's own flame heat transfer as well as by the external conditions. This wind-aided spread will be studied for the same set of materials, also under external radiative heating.

However the rate of spread will not directly be measured since it is very rapid and may not necessarily achieve steady state. Instead, a procedure will be carried out in which data is taken on rate of burning, energy release, flame length, and flame heat transfer. The data will be used as input variables in a formula intended to predict upward flame spread. With the establishment of this prediction model, its results will then be compared to results from specially designed or available flame spread experiments. The goal is to validate and simplify this procedure so that a test procedure could be practically conducted and interpreted by a straightforward analysis such that the hazard of "wind-aided" spread is quantified for a material.

2.2.1.3.2.4 Flashover.

The occurrence of a flashover corresponds to that point in time when human survival is no longer possible. Flashover is accompanied by significant increases in heat, smoke, and toxic gas concentrations beyond survivable proportions. In each of the full-scale C-133 fire tests, a flashover occurred. During the correlation of study in FY-83, it will be determined if a flash fire cell developed at NBS by partial FAA funding (reference 34) adequately characterizes the propensity of aircraft materials to flashover under postcrash cabin fire conditions.

2.2.1.4 Smoke.

There are no major efforts currently envisioned for developing new smoke test methods for or conducting smoke emission studies on cabin materials. The Technical Center operates a standard NBS smoke chamber, a modified NBS smoke chamber with high flux heater and sample weight loss monitor, and the OSU test chamber. These test methods are available and believed to be adequate for characterizing the smoke emission characteristics of cabin materials during planned correlation studies. A published report demonstrates the importance of heat flux level and the presence or not of a flaming ignition source on smoke density for a series of cabin materials (reference 35).

2.2.1.5 Toxicity.

How can the toxic threat during a postcrash cabin fire be minimized by the screening selection of interior materials using a small-scale test(s) procedure? What is the toxic threat and how can it be measured in the laboratory? What is an appropriate small-scale test(s) procedure? These questions are the driving functions behind research in combustion toxicology today.

There are no standardized small-scale toxicity test methods, although various tests have been developed and numerous materials evaluated over the past 10 years. A list of recommended research areas requiring long-term activity was compiled by the SAFER Ad Hoc Committee on Toxicology and implies that many fundamental problems still exist despite the existence of various tests developed by many different organizations (reference 36).

2.2.1.5.1 Current Status.

FAA research and testing in combustion toxicology and toxic gas analysis has been conducted at both CAMI and the Technical Center. Five years ago, a cooperative program between CAMI and the Technical Center was completed. This program involved the development of a combustion tube furnace (CTF) test method, which was used to evaluate 75 aircraft cabin materials on the basis of animal toxicity at CAMI (reference 37) and the measured yields of nine specific toxic gases at the Technical Center (reference 38). A subsequent report prepared at the Technical Center described for this study the correlation of animal toxicity with toxic gas yields (reference 39). On a statistical basis, this report demonstrated that the animal toxicity could be described almost entirely by the yields of several systemic poisons (CO, HCN, and H_2S), but that the overall effect of the irritant gases measured was actually to decrease toxicity (i.e., prolong time of incapacitation apparently by inhibiting breathing and thereby reducing the intake of systemic toxicants). In recent years, activity at CAMI has been on the development of an NBS toxicity test protocol and the measurement of the incapacitating and lethal effects of irritant gases on rats, and at the Technical Center it has been on the measurement of toxic gases within the C-133 full-scale cabin fire environment.

2.2.1.5.2 Future Studies.

From recent full-scale cabin fire tests in the C-133 test article, it is evident that the primary toxic threat of burning aircraft materials is associated with the occurrence of flashover. Therefore, until subsequent full-scale test data indicates otherwise, efforts to minimize the toxic hazards associated with a cabin fire will concentrate on delaying the onset or eliminating the occurrence of flashover. It is believed that this direction can best be achieved during materials evaluation by using flammability type of test methods, which measure factors such as ignitability, flame spread rate and rate of heat release.

Before the onset of flashover experienced in the C-133 cabin fire tests, concentrations of hydrogen fluoride (HF) and hydrogen chloride (HCl), produced by the interior panel decorative finish and possibly seat component were measured in the 100's of parts-per-million (ppm) range (reference 13). The validity of these measurements is now being examined. Moreover, the effects of irritant gases on escape impairment in nonhuman primates is being determined at SouthWest Research Institute under FAA-sponsored research (see section 2.3.2.2.1.1). Thus, the potential impact of the presence of irritant gases before the occurrence of flashover on interior materials design cannot be determined until establishment (1) of the validity of the C-133 measurements and (2) of the dose-response relationship for HC and HF on escape impairment in nonhuman primates. Perhaps more importantly, the primate study is also designed to compare primate and rat responses to selected irritant gases, and will thereby shed some light on the relevancy of the rodent models which are predominantly used in combustion toxicology studies.

Until hard data is obtained by the irritants/primate study, knowledge of and appreciation of the limitations of combustion toxicology can best be served as follows:

(1) By obtaining consistent data at one laboratory on a series of materials evaluated using popular combustion toxicology test methodologies (e.g., NBS protocol, CAMI combustion tube furnace, etc.).

(2) By examining the nature of combustion products produced by a series of materials subjected to commonly used furnaces and heaters employed in combustion toxicology (e.g., Potts furnace, radiant heater, etc.).

It is proposed that this work be performed at CAMI or under outside contract.

2.2.1.6 Combined Hazard Index.

2.2.1.6.1 Objective.

The objective is to develop a small-scale test methodology for determining a single index which combines the hazards of flammability, smoke, and toxicity for a material under postcrash cabin fire conditions.

2.2.1.6.2 Background.

The FAA's issuance of three separate proposed regulatory notices for flammability, smoke, and toxicity was criticized as a "piecemeal" attempt at improving cabin fire safety (reference 40). It was argued that these factors were interrelated, and that any new regulation pertaining to any one factor would require expensive design changes at its adoption and also again on each occasion that new regulations went into effect for the other factors. With this criticism in mind, the FAA issued a request for proposal (RFP) for the design, development, and verification of a CHI test methodology. The recipient of the contract was the Douglas Aircraft Company (DAC).

2.2.1.6.3 Technical Approach.

The approach selected by DAC was to utilize a single test method - the OSU test chamber - to measure heat, smoke and toxic gas emission rates as a function of time. A mathematical enclosure fire model computes the distribution of hazards within DAC's Cabin Fire Simulator (CFS), which is their large-scale cabin fire test article. The hazards are combined by computing their contribution to the theoretical escape time at some selected CFS location. It is assumed that the various hazards have an additive effect on escape time, and acute escape time limits for the various hazards are based primarily on extrapolated data. The OSU test method data acquisition and the mathematical model are computerized, which helps make the computation of a CHI an automated process. The accuracy of the OSU/mathematical model predictions is determined by comparison with test data obtained in the CFS.

The CHI study was completed (reference 41) and the test methodology will be evaluated during the planned correlation study (see section 2.2.1.7.1). Although the CHI concept was thought to have great promise when initially conceived, there are a number of major shortcomings which are a reflection of the state-of-the-art of fire testing hazard analysis:

(1) Lack of consideration of flashover or flame spread,

(2) simple (unvalidated and highly assumptive human survival and fire models, and

(3) inability to realistically consider the visibility obscuration effects of smoke.

2.2.1.7 Test Methods and Criteria.

Perhaps the most difficult undertaking and that which has the greatest potential impact on interior design is the development of improved test methods and criteria for cabin materials. Our understanding of the nature of the problem and the controlling parameters, as studied and measured in the C-133 test article, is a continuing process and has the greatest bearing on the approach taken. From past C-133 fire tests, it is clear that the dominant factor behind loss in survivability during a cabin fire is the occurrence of flashover. Also, the presence of irritant gases before the onset of flashover must be verified and their effect on escape impairment remains to be determined. Accordingly, a two-phase effort is planned as follows:

(1) correlate test methods with cabin model flashover (FY-83), and

(2) validate modeling results, factor in irritant gases and derive test criteria. (FY-84)

2.2.1.7.1 Correlation with Cabin Model Flashover.

The major thrust of this effort is to determine the degree of correlation of candidate small-scale fire test methods for interior materials with the incidence of flashover in a 1/4-scale cabin model. Design of the modeling experiments is the most critical aspect. The important model design features and goals are as follows:

(1) An ignition source and model design which will consistently create flashover using contemporary panel lining materials in a reasonable time framework.

(2) Fabrication and evaluation of aircraft quality panel materials of various cloth facing (fiberglas, Kevlar®, graphite) and resin (epoxy, phenolic) combinations. Note: Tedlar®, decorative finish and Nomex® materials will not be altered.

(3) Adequate resolution of the onset of flashover in the model for the various panel configurations.

Measurements obtained with candidate fire test methods for the panel materials will be correlated with the modeling results to determine which test methods for the panel materials will be correlated with the modeling results to determine which test methods and measurements produce the greatest agreement. The small-scale test methods will include but not be limited to the following:

(1) OSU chamber

(2) Radiant panel test (ASTM E-162)

(3) Flame spread rate (NBS)

(4) Bunsen burner test (FAR 25.853)

(5) Flash fire cell

(6) Limiting oxygen index (ASTM D-2863)

(7) Smoke density chamber (NFPA 258)

Smoke production predictions will also be correlated during phase 1. Test method correlation will be completed in August 1983.

2.2.1.7.2 Modeling Validation, Irritant Gases and Test Criteria.

Phase 2 will consist of three primary tasks: (1) validation of modeling results, (2) factoring in the effect of irritant gases, and (3) deriving test criteria. Model validation will be accomplished in the C-133 test article under realistic postcrash cabin fire conditions. In order to factor in the effect of irritant gases, the primate escape impairment threshold values for HF and HCl must be available. Completion of this work is scheduled for March 1984. Rational test criteria (material acceptance limits) will be derived by (1) demonstrating benefits in the C-133 test article and (2) taking into account the viability of panel improvements utilizing contemporary fabrication processes (see section 2.2.2.2.1). The final product of the two-phase effort will be improved fire test methods and criteria for major usage category cabin materials in September 1984.

2.2.2 Improved Materials.

The evaluation of improved materials or redesigned components for a transport cabin interior is basically driven by three discrete events: (1) accidents, (2) breakthroughs in material technology, and (3) new applications revealed by realistic fire tests. Currently, efforts of varying scope are underway or planned for the following applications: (1) seat cushion fire blocking layers, (2) cabin panels, (3) windows, and (4) curtains (for sealing off inadvertently opened doors).

2.2.2.1 Seat Cushion Fire Blocking Layers

2.2.2.1.1 Objective.

The objective of this project is to evaluate and develop practical fire blocking layers for protection of urethane seat cushions.

2.2.2.1.2 Background.

The flammable nature of foamed plastics, in general, has focused attention on protecting or replacing urethane foam in such widespread residential applications as household insulation, upholstery furniture, and mattresses. In transport aircraft, the large number of passenger seats constitute the major application for flexible urethane foam. Accordingly, the Special Aviation Fire and Explosion Reduction (SAFER) Advisory Committee, convened by the Federal Aviation Administration (FAA) to "examine the factors effecting the ability of aircraft cabin occupants to survive the postcrash environment and the range of solutions available," made the following recommendation: "Develop for aircraft seats, fire blocking layers (e.g., fire barriers) for polyurethane foam cushioning material, in order to retard fire spread" (reference 42).

2.2.2.1.3 Technical Approach.

A three-phase effort will consist of the following: (1) evaluation of effectiveness against cabin fires, (2) development of materials with due consideration to weight/cost and service performance, and (3) development of a small-scale test method.

Phase 1. Tests will be performed in the C-133 test article to demonstrate he benefit of candidate blocking layer materials against postcrash, in-flight, nd ramp fires. This work was completed and demonstrates that commercially vailable blocking layers can (1) increase the time available for evacuation uring an impact-survivable postcrash fire, and (2) prevent ramp and in-flight ires when the seat cushion is the primary target of the ignition source reference 43).

Phase 2. Through an interagency agreement with NASA Ames, the following tasks ill be accomplished:

(1) Examine candidate blocking layer configurations with potential weight avings for fire protection effectiveness.

(2) Perform mechanical tests of promising blocking layer configurations for ervice wear and comfort.

(3) Develop a computer program to determine the weight and cost impact on the .S. fleet of any blocking layer material.

This work was completed and the summary draft report is under revision. he major accomplishments included the identification of practical and effective ightweight aluminized fabrics for blocking layer application, and the discovery confirmed by FAA) that untreated foam, at a weight savings, can be used with a ire blocking layer without impacting effectiveness.

Test are being performed at CAMI to determine the impact of blocking layer aterials on buoyancy requirements specified in Technical Standards Order (TSO) 72B.

Phase 3. A small-scale test method will be developed for measuring the effectiveness of candidate blocking layer materials. FAA, NASA, and the ariframe anufacturers participated in an evaluation of their respective test procedures gainst large-scale fire tests for ten cushion configurations. The testing aspect of this work was completed, and the initial data analysis indicates that the standard FAA burner applied to a seat mockup could serve as a certification test, while several test methods have promise for screening purposes.

The fire blocking layer project was essentially completed in October 1982, although some report revisions and minor testing are still being accomplished.

2.2.2.2 Interior Panels.

2.2.2.2.1 Objective.

The objective of this project is to develop a generic type of an aircraft interior panel or panels which exhibit reduced flammability, smoke and toxicity at a minimum weight of the panel. The panel must also exhibt equivalent or better performance in terms of mechanical properties and durability when compared to baseline panels.

2.2.2.2.2 Background.

The interior of a jet transport is lined with a composite panel material composed essentially of decorative film finish, facing, honeycomb core, and backfacing.

:cause the compartment is designed to contain a fire by oxygen deprivation. In ›ntrast, a class C cargo compartment is designed with a detection/suppression ˊstem for fire extinguishment and control. Therefore, it is not clear if the ıtegrity (burnthrough resistance) of the cargo liners in a class C compartmen· are ; critical to fire safety as in a class D compartment.

.4.2.3.2.3 Technical Approach.

realistic class C cargo compartment test article will be outfitted in the :eviously stripped cargo compartments of an accident DC-10 aircraft. The test :ticle will be instrumented to measure and/or observe fire growth, heat and smoke ıildup, detection, extinguishing agent discharge, liner integrity, smoke leakage ıto the main cabin and heat exposure of critical components located in the space :tween the liner and cabin flooring A series of tests will be conducted to ıbject the cargo compartment liners to the most severe fire exposure conditions ıthin the realm of realism. The following variables will be studied: (1) cargo ıner resistance (barely compliant, exceeds, far exceeds current requriements ›ecified in FAR 25.853 and 25.855); and (2) fire source (high versus low elevaıon, smouldering (smokey) versus flaming (hot), slow versus rapid detector/ ‹tinguishing personnel).

: is estimated that a 12-month testing period would be required.

.5 FUTURE WORK.

ıis aircraft cabin fire safety program plan is a detailed document through FY-84 › improve various aspects of postcrash and in-flight fire safety. Extensive ‹pertise and facilities have been developed which can be readily applied to ther road fire safety areas in the post-FY-84 period:

a. In-flight fires originating in the galley and lavatory.
b. Hazards related to the emergency oxygen system.
c. Electrical fires and testing requirements for wiring insulation.
d. General aviation fire safety, including adequacy of current aterial flammability requirements.
e. Problems associated with the increased usage of graphite-einforced composites.
f. The need for flammability requirements for airline furnished tems (blankets, pillows and headrest covers).
g. Development of an automated aircraft fire command and emergency ystem (ACES).
h. Sustaining engineering to maintain state-of-the-art of fire echnology in cabin design.

. FUNDING REQUIREMENTS.

ɔntract funding required to meet the objectives set forth in this program plan are dentified in table 1. Allocation of funds by major tasks reflects the emphasis in he first several years of the program on cabin fire characterization (understandng and defining problem) and modeling development: in subsequent years, the rogram is more product oriented, consequently, the increased funding for materials anagement and fire management and suppression.

2.4.2.3.1.1 Objective.

The objectives of this project are to: (1) determine the characteristics of class D cargo compartment fires, with particular attention given to the adequacy of current design practices and regulatory requirements in containing the fire; and, (2) wheneever necessary, develop design features and cargo liner test requirements, which can be incorporated into improved regulations needed to safely contain likely fires in class D cargo compartments.

2.4.2.3.1.2 Background.

On August 19, 1980, a Saudi Arabian Airlines Lockheed L-1011, with 301 crewmembers and passengers onboard, experienced a fatal in-flight fire in the aft portion of the cabin. The investigation conducted on behalf of the Saudi Arabian Government concluded that the fire originated in the C-3 cargo compartment, which is a class D compartment.

As a consequence fo the L-1011 accident, the National Transportation Safety Board issued recommendations A-81-12 and A-81-13 to FAA calling essentially for a reevaluation of the class D certification in the L-1011 C-3 cargo compartment, with a view toward requiring design changes, if necessary, and reviewing the certification of all baggage/cargo compartments with a class D certification to insure that the intent of FAR 25.857 is satisfied.

2.4.2.3.1.3 Technical Approach.

The technical approach will be comprised of (1) a data survey, (2) a mathematical modeling analysis, and (3) an experimental effort. The bulk of the work will be the experimental effort, performed in a simulated C-3 compartment test article. It will consist essentially of; (1) describing the environmental conditions created by typical realistic fire sources, and (2) determining the effectiveness of class D compartment designs as a means of safely containing cargo fires. If warranted by the above findings, a more realistic and severe test procedure will be developed for cargo liners. Also, a number of cargo containers will be purchased and tested to determine the adequacy of present container fire safety requirements; i.e., flammability regulations contained in FAR 25.853(b-Z). Preparation of a draft report is scheduled for March 1983.

2.4.2.3.2 Class C.

2.4.2.3.2.1 Objective.

The objectives of this project are as follows: (1) evalute the adequacy current cargo liner fire test requirements contained in FAR 25.853 and 25.855 for class C cargo compartments and, if found to be inadequate, recommend new test requirements; and (2) broadly assess current class C cargo compartment design practices and regulatory requirements with the aim at identifying needed R&D.

2.4.2.3.2.2 Background.

Recent class D cargo compartment fire tests have indicated that current flammability requirements for cargo liners, contained in FAR 25.853 and 25.855, do not predict the burnthrough resistance of ceiling liners subjected to a realistic cargo fire. For a class D cargo compartment the integrity of the liners are critical

In recent years, there has been an increasing use of hand-held extinguishers in general aviation, even though the FAA does not require nor provide guidance material for their selection. The extinguishing requirements for general aviation (short range, hidden fires) and unique design parameters, compared to transport aircraft (single occupant, small volume, unknown ventilation), point to the need for a separate document covering hand-held extinguisher usage in general aviation.

2.4.2.2.3 Technical Approach.

Transport. A two-phase program will be conducted. The initial phase will essentially involve a comprehensive literature search and coordination/ contact with various user, standards, and manufacturing organizations. The second-phase will involve a test program at the Technical Center focusing in on such items as agent firefighting effectiveness, ventilation effects, neat agent safe concentration requirements, cabin volume considerations, and agent decomposition.

The effort on hand-held extinguisher usage in transport aricraft was completed, resulting in the following major accomplishments:

a. Demonstration of the effectiveness of Halon 1211 over other extinguishants in controlling volatile liquid spill fires in seating (FAA issued a General Notice recommending installation of two Halon 1211 extinguishers in each transport cabin).

b. Publication of state-of-the-art review study on hand-held extinguisher usage in civil aviation (reference 55).

c. Demonstration of safety of Halon 1211 extinguishment of in-flight fires, in terms of neat agent and agent decomposition concentration profiles (reference 56).

d. Development of criteria in the form of nomograms, for safe agent discharge quantities (container size) in habitable compartments with known ventilation rates (reference 57). These nomograms were incorporated into proposed upgraded AC 20-42B.

General Aviation. Guidance on the use of hand-held extinguishers will be studied in a unique new Technical Center facility. The building 204, Airflow Facility was extended in front to accommodate a confiscated Cessna 210 airplane obtained from Drug Enforcement Agency authorities. The fuselage with operable and remotely controlled engine is now mounted in the facility and will be extensively instrumented for gas/temperature/visibility measurements. The testing will be directed toward; (1) identifying any unique problems associated with the discharge of common extinguishants in close quarters, and (2) developing a simple means of measuring the ventilation rate in order to determine the allowable safe quantity of agent discharge (container size) by employing the nomograms developed for transport aircraft.

Preparation of a draft report is scheduled for May 1983.

2.4.2.3 Cargo Compartment Fire Safety.

2.4.2.3.1 Class D.

2.4.2.1.1 Objective.

The objective of this project is to develop standardized flight test procedures for the evaluation of emergency in-flight smoke removal measures during aircraft certification.

2.4.2.1.2 Background.

An FAA Multiple Expert Opinion Team (MEOT) was convened to examine industry means of demonstrating compliance to FAR 25.831, 25.855, and 25.857, related to exclusion of hazardous quantitites of smoke generated by a fire from any compartment occupied by the crew or passengers. The MEOT discovered major differences between airframe companies and between the regions with regard to the flight test procedures utilized or approved to demonstrate compliance with the above FAR's. Moreover, it was found that quantitative measurements were not made of the amount of smoke generated, nor of the effectiveness of the smoke removal procedure. Subsequently, industry recommended R&D to develop standard smoke generator systems and smoke measuring devices, and required smoke generation rates, acceptable transmissivity limits and require measurement locations.

2.4.2.1.3 Technical Approach.

The project will develop standardized flight test procedures and equipment/ instrumentation, including smoke generator devices and rates, initial density (transmissivity) levels, transmissivity measurement devices, measurement locations, and acceptable smoke clearing rates. The work will be accomplished in a 707 fuselage which was purchased for this purpose. A high pressure air supply system will be used to overpressurize the fuselage to a pressure differential equivalent to flight conditions at altitude. The air supply system will be used to generate ventilation flows in the fuselage. Artificial smoke will be generated to simulate a hot fire burning through the cabin floor from a cargo compartment (highly buoyant), or the relatively cool smoke produced by an undected smouldering fire in a galley or lavatory trash receptacle (highly diffuse). In order to simulate hot smoke, artificial smoke will be mixed with helium to give it buoyancy.

Preparation of a draft report is scheduled for November 1983.

2.4.2.2 Hand-Held Fire Extinguishers.

2.4.2.2.1 Objective.

The purpose of this project is to update and expand Advisory Circular (AC) 20-42, "Hand Fire Extinguishers in Transport Category Airplanes and Rotorcraft." Requirements for general aviation will also be included.

2.4.2.2.2 Background.

Since AC 20-42 was issued in 1965, there have been significant changes in the civil fleet in aircraft cabin size, configuration, materials, and operating environment, all of which bear on fire protection. Over the same period, new service experience has accumulated and there have been new developments in extinguisher agents and design. AC 20-42 is widely used, and experience indicates it should be updated and expanded to increase its usefulness and more effectively cover all aspects of evaluating and selecting hand-held extinguishers.

Each system or concept will fall into any one of three categories. First, the cost/benefit ratio will be estimated for those systems or concepts which appear feasible and beneficial. Second, those systems or concepts which are not feasible or have an extremely poor cost/benefit ratio will be identified as such with supportive documentation. Third, those systems or concepts will be identified which appear promising but require an experimental effort to determine feasibility or estimate cost/benefit. For those systems or concepts falling within the third category, the contractor will identify in detail the nature of the experimental work required to resolve any uncertainties. An estimate will be made of the probability of "success" for each concept or system. A final report has been drafted by IITRI.

2.4.1.2.2 Phase II.

The second phase will be an experimental study to determine the feasibility and cost/benefit of those promising concepts identified in the third category under phase I. The extent of the study as indicated in phase I and in-house commitments to other projects will dictate whether this work is performed in-house or by contract. All feasible systems and concepts will be rated in terms of estimated cost/benefit ratio.

At this time, an on-board foam/water sprinkler system will be developed and evaluated by in-house personnel. The objective is to develop a configuration of specially designed foam/water sprinkler nozzles, positioned strategically in the wall, ceiling and floor areas, so as to be capable of completely saturating any flammable class A materials without significantly impairing passenger evacuation. Developmental experiments are required to determine the optimum foam/water solution concentration, flow rate and pump pressure required to obtain the most rapid control and extinguishment of a "standardized" class A fire load. The effectiveness of the final system design will be demonstrated in a DC-7 cabin interior, fully instrumented to measure thermal profiles and cabin gas concentrations, during a series of extinguishment tests. Preparation of a draft report is scheduled for September 1983.

2.4.1.2.3 Phase III.

The third and final phase will be a study to design the best rated system(s) for installation in a real airplane. Emphasis will be placed on gathering hard data on initial and recurring costs. An accurate cost/benefit value for the best rated fire protection system(s) will be determined for comparison with cost/benefit values for advanced material systems.

2.4.1.2.4 Milestones.

The following are estimates for the duration of each phase of the study:

a. Phase I - Completed (Report Drafted)
b. Phase II - 6 to 9 Months per System
c. Phase III - 9 to 12 Months

2.4.2 In-Flight Fire Safety.

2.4.2.1 In-Flight Smoke Removal.

fire alarms automatically detect the existence of fires. Similar concepts are utilized in transport aircraft for in-flight fire protection. Fire detection systems mounted in the engine nacelle and APU's provide for the detection of an engine or APU fire; Halon 1301 or other agents are used for extinguishment. Some cargo compartments are protected by fire detectors, suppression systems, and airflow shutoff devices. The lavatory waste paper disposal compartment is fire hardened and, in some instances, protected with a small self-actuated, Halon 1301 bottle. Portable fire extinguishers operated by crew members can be used to extinguish small, in-flight fires. The fundamental questions are whether fire management and suppression concepts can be applied to the design of a cabin for the improvement of postcrash cabin fire safety, and whether state-of-the-art improvements are in order for a number of in-flight fire safety areas.

2.4.1 Postcrash Fire Safety.

2.4.1.1 Current Status.

The most recent large-scale experimental studies related to onboard postcrash cabin fire protection were performed at the Technical Center in the areas of compartmentation and Halon 1301 fire suppression. An examination of various compartmentation concepts, including class dividers, curtains and headliners, demonstrated that the effectiveness of the concept depended on the degree of airflow blockage between sections. Also, an effective compartmentation concept sometimes had an adverse effect on the hazard level in both the fire and protected areas (reference 53). Based on this limited study, the conclusion was that compartmentation was not a promising approach because of the usually nonexistent or questionable benefit, and unknown effect on evacuation. In a later study, it was demonstrated that an onboard Halon 1301 system could effectively and safely extinguish fires wholly contained within the cabin environment. However, this system displayed limited effectiveness and was not safe against an external fuel fire adjacent to a door opening because of significant agent decomposition caused by the incompletely extinguished fuel fire flames (reference 54). Thus, it appeared that the application of Halon 1301 could have a counterproductive effect on postcrash cabin fire safety. The Technical Center in-house activity in cabin fire management and suppression temporarily ceased in 1977 upon the completion of these projects.

2.4.1.2 Technical Approach.

The complexity of the postcrash cabin fire safety problem and the potential loss of life demands that the viability of cabin fire management and suppression be throughly examined. A three-phase study is planned.

2.4.1.2.1 Phase I.

The first phase is a contractual study by the Illinois Institute of Technology Research Institute (IITRI) to examine the feasibility of all known systems and concepts. These include but are not limited to:

- a. Fuselage and window burnthrough resistance
- b. Door hardening
- c. Smoke ventilation
- d. Foam/water sprinkler system
- e. Advanced fire extinguishing agents
- f. Compartmentation concepts compatible with rapid evacuation

(1) Completed full-scale tests of real inflated slides exposed to a large pool fire at a fixed distance, which (a) illustrated when and how slides fail from radiative heating and (b) demonstrated the prolonged inflation time provided by an aluminized coating (reference 48).

(2) Developed a small-scale test method for measuring the radiative heat resistance of slide fabrics (reference 49). This test method was shown to produce data that correlated with full-scale test results.

(3) Formalized the small-scale test into a test methodology incorporated into a revised TSO for evacuation slides and being developed into an ASTM standard.

(4) Evaluated candidate aluminized coatings against service performance requirements and identified suitable coatings (reference 50).

(5) Sponsored workshop on advanced evacuation slide/raft technology (reference 51).

It should be recognized that the majority of production evacuation slides and slide/rafts now contain aluminized pressure holding members. As such Technical Center activity is minimal in this area, consisting of the laboratory evaluation of new materials and supporting ASTM standardization and TSO acceptance.

2.3.5 Protective Breathing Devices.

The evaluation and development of protective breathing devices for passengers and crewmembers is performed at CAMI. The status of and current plans for these activities follows:

a. Protective breathing devices for crewmember use only. CAMI has developed a quantitative test procedure for examining mask and goggle leakage of environmental contaminants. In the absence of an FAA requirement regarding mask/goggle leakage, or the existance of a suitable industry laboratory, CAMI will continue to evaluate new designs which are submitted by industry. It is anticipated that the number of requested examinations of mask/goggle/regulator combinations for female flight deck crewmembers will increase in the future because of the increase in female crewmembers.

b. Protective breathing devices for passenger use. CAMI has recently completed a project to examine the feasibility of modifying present diluter-type emergency oxygen masks to provide smoke and contaminants protection or modifying smoke hoods to provide emergency oxygen in the event of cabin depressurization. The former concept was shown to be feasible while the latter was not (reference 52). The oxygen mask modification consists essentially of a rebreather bag, which imparts protection against in-flight fire smoke or contaminant release, but would not be useful against an unannounced postcrash cabin fire. The next step is to determine the cost effectiveness of the rebreather bag mask design.

2.4 FIRE MANAGEMENT AND SUPPRESSION.

In building construction, fire protection is achieved by the application of fire management and suppression concepts. For example, ceiling mounted water sprinkler systems automatically suppress fires; firewalls localize and contain fires until controlled by firefighters; fire escapes provide protected avenues for escape; and small-scale and outdoor tests was that a substantial increase in the inflation time of pressurized slide fabric samples was provided by a thin coating of aluminum paint. However, it was recommended that a more comprehensive program be conducted to collect the additional technical data necessary to support possible future rulemaking related to testing slide materials exposed to thermal radiation.

2.3.4.3 Technical Approach.

The project effort is divided into four tasks:

2.3.4.2.1 - Task 1.

A laboratory test suitable for regulatory purposes will be designed and developed. An important feature of the new test method will be an expedient and leak-free means of pressurizing the sample. Additional numbers of the test method will be fabricated at the Technical Center and delivered to major airframe and slide manufacturers to allow for the consistent evaluation of new materials and coatings.

2.3.4.3.2 - Task 2.

A contract has been awarded to a slide manufacturer to develop a reflective coating for possibly retrofitting inservice slides and slide/rafts. The contractor will select an optimum coating based on an examination of radiative heat resistance, weight, methods of application and integrity after long-term creasing when packed. The contractor will determine time and cost of a fleet retrofit.

2.3.4.3.3 - Task 3.

In order to encourage the use of superior materials in the manufacture of slides for future transports, the slide manufacturers and material suppliers will be solicited for candidate advance materials for evaluation of the Technical Center. Several real slides constructed of the most promising materials will be evaluated under full-scale pool fire conditions.

2.3.4.3.4 - Task 4.

At various stages during the project, real evacuation slides or slide/rafts will be subjected to the thermal radiation produced by a large fuel fire. The initial tests will involve testing a series of inservice slides to establish the failure mode under the most realistic conditions possible and to provide full-scale data for comparison with laboratory data from the new test method. Later, real slides protected with the optimum coating selected under task 2 will be tested to demonstrate the effectiveness of the coating in prolonging the usable time of the slide. Finally, similar tests will be conducted on slides fabricated from the best advanced material. Based on laboratory and full-scale examinations of various evacuation slide materials, heat resistance acceptance criteria that are both beneficial and practical will be determined.

2.3.4.4 Accomplishments.

The evacuation slide heat resistance project was completed in late 1980. The accomplishments of this project are as follows:

created by a cabin fire. At CAMI, the evacuation time of human subjects subjected to theatrical smoke was approximately 20 percent better when seat-mounted lighting was employed as compared to conventional interior lighting (reference 46).

At the Technical Center, a number of visual indicators proved successful in improving visibility in cabin smoke produced by burning jet fuel or burning interior materials (reference 47). These findings prompted a contractual study to examine the cost and design impact of emergency lighting systems in transport aircraft, designed to improve visibility in smoke. The major elements of the study include the following:

(a) two systems be specified in detail with regard to illumination level, hardware and design constraints;

(b) the cost of each system be broken down into detailed categories, including but not limited to cost per fixture, cost for a given aircraft model, weight penalties, and power requirements;

(c) specifications and costs be accomplished for a representative commercial fleet (10 models);

(d) cost be estimated for (1) retrofit during a major overhaul, (2) retrofit within a scheduled period of 2 years, and (3) installation in production aircraft.

A draft report is scheduled for March 1983.

2.3.4 Evacuation Sides.

2.3.4.1 Objective.

The primary objectives of this project are as follows:

a. Design and develop a laboratory test method relevant to full-scale postcrash fire conditions and suitable for materials qualification testing in airworthiness certification.

b. Develop a practical and lightweight coating for retrofitting inservice evacuation slides that will significantly increase their resistance to thermal radiation.

c. Examine and foster the development of advanced materials that are resistant to thermal radiation and suitable for use in the fabrication of evacuation slides.

d. Determine heat resistance acceptance criteria for slide materials.

2.3.4.2 Background.

The NTSB investigation of the Continental DC-10 accident at Los Angeles indicated that the slide/raft at 1R failed because of radiant heat from the fuel fire (reference 43). The early indication of this occurrence prompted the Technical Center to conduct a preliminary assessment of the fire protection characteristics of various escape slide materials (reference 48). The outstanding finding indicated in both

The primary application of these results will be to upgrade the human survival model described in section 2.3.2.2.2.

2.3.2.2.2 Human Survival Model.

Full-scale fire tests such as those conducted in the C-133 test article provide data on the variation of temperature and gas concentrations with time. This data are widely interpretative because of the absence of a theoretical human survival model. A study is required to develop a state-of-the-art human survival model that would periodically be upgraded as more data, such as from the study outlined above, becomes available. The model should provide for the best treatment available of the following:

a. Time-dependent heat and gas profiles.

b. Combinations of heat, gases, and oxygen depletion.

Although hypothetical in nature, the model would provide for consistent comparisons between large groups of data in terms of a single and most relevant parameter - human survival - rather than "abstract" measurements of temperature and gas concentrations.

A human survival model was developed and applied successfully to the analysis of full-scale cabin fire test data (reference 42). However, the model is based on simplifying assumptions (hazards are additive, oxygen depletion is ignored, hyperbolic dose-response relationship) and, in many cases, best estimates for tolerance limits (irritant gases). In this respect, efforts should be made to validate and upgrade the model, as outlined in section 2.3.2.2.1.4.

2.3.3 Emergency Lighting.

2.3.3.1 Objective.

The objective of this project is to evaluate emergency exit signs and lights that will enhance the evacuation rate of airline occupants from the smoke-filled cabin environment created by a survivable postcrash cabin fire.

2.3.3.2 Background.

A National Transportation Safety Board (NTSB) study examined a number of survivable accidents in which evacuation was carried out at night or in the presence of smoke (reference 45). It was concluded that inadequate cabin illumination hindered the ability of passengers to move through the cabin and locate emergency exits. Numerous advanced emergency lighting and exit sign concepts have been evaluated at CAMI using white theatrical smoke within a cabin simulator. Subsequently, it became desirable to evaluate these advanced concepts under realistic black smoke conditions more typical of a postcrash cabin fire, and to define a "dense smoke" concentration for their evaluation.

2.3.3.3 Technical Approach.

Studies have been completed at CAMI and the FAA Technical Center which demonstrates the potential benefits of lower-level emergency lighting concepts in improving visibility and shortening evacuation times in the smoke environment decorative film finish on panels and possibly fire retardants and vinyls used in seating. These gases cause irritation at relatively low concentrations; however, their lethal concentration is very high. The actual levels measured during cabin fire tests are inbetween these extremes. Thus, the effect of irritant gases on escape impairment is unknown and must be established in order to determine if design changes for panels and seating are in order.

2.3.2.2.1.3 Technical Approach.

A contractual study has been awarded to Southwest Research Institute (SWRI) to determine the threshold concentration for escape impairment caused by exposure to irritant gases found in significant concentrations during a cabin fire. The outstanding ingredients of this study are as follows:

(1) The test animal will be a juvenile baboon.

(2) A shuttlebox arrangement will be employed to examine escape impairment.

(3) The irritant gases to be studied are HCl and acrolein.

(4) The systemic poison CO will be examined initially.

(5) A complementary analysis will be performed for the same gases and a similar escape impairment paradigm using rodents.

(6) The escape impairment paradigm will be designed to avoid a "state change" in the animals behavior.

In addition to the basic requirement of determining escape thresholds for irritant gases detected in cabin fire tests, the study has been expanded to address the relevancy to animal models (rodents) and behavioral tasks employed in combustion toxicology. In conjunction with the latter, CAMI will derive the dose-response relationship for incapacitation in rodents exposed to HCl dnd acrolein (singly, in air).

2.3.2.2.1.4 Additional Work.

A follow-on study is planned to determine escape impairment for HF and NO_2 (or SO_2). The former is required to determine if the decorative film used in contemporary panel design becomes a factor effecting escape from a cabin fire. If the initial primate study is successful, an opportunity exists for studying a number of important toxicological effects which have been grossly ignored in the past because of the lack of a suitable methodology. These effects include the following:

(1) gas mixtures, including irritants and systemic poisons, either alone or together,

(2) elevated temperature and toxic gas(es),

(3) oxygen depletion, and

(4) oxygen depletion and systemic poisons.

d. Numerous toxic and irritant gases, posing a life hazard.

In order to understand the nature of the postcrash cabin fire problem and the role of cabin materials, it is essential that quantitative human tolerance limits for acute exposure to each of these hazards and hazard elements be available.

Survival in an environment comprised of the various hazards identified above is strongly time-dependent (classical dose-response relationship) and, therefore, closely linked with evacuation. The overriding consideration in aircraft cabin fire safety is the provision for the most rapid evacuation rate of passengers and crew members. Emergency lighting systems in a smoke-filled cabin and heat resistant evacuation slides are projects within this program plan that have a direct bearing on evacuation. Also, protective breathing devices for passengers and crew members may be useful under certain conditions.

2.3.1 Major Activities.

The major activities under the survival and evacuation task are as follows:

a. Human Survival Limitations

b. Emergency Lighting

c. Evacuation Slides

d. Protective Breathing Devices

2.3.2 Human Survival Limitations.

2.3.2.1 Current Status.

FAA experimental studies related to human survival are performed at CAMI. In response to the R&D request entitled "Physiological Criteria for Humans Exposed to Cabin Fires," CAMI has derived a temperature-time tolerance limit; developed equations for predicting incapacitation times, individually or in combination, for the systemic toxic gases CO, HCN and H S; and summarized human tolerance limits to oxygen depletion. However, the incapacitating effects of irritant gases such as HF, HCl, SO_2, etc., were not readily assessible from information within the literature.

2.3.2.2 Future Studies.

2.3.2.2.1 Escape Impairment In Nonhuman Primates Exposed to Irritant Gases.

2.3.2.2.1.1 Objective.

The objective of this project is to determine the threshold concentration for escape impairment in nonhuman primates exposed to irritant gases produced by a cabin fire.

2.3.2.2.1.2 Background.

The irritant gases HCl and HF are produced in significant concentrations before flashover during cabin fire tests (reference 42). The source of these gases is the

Preliminary comparative tests of acrylic and epoxy/polycarbonate window panes were completed at the Technical Center using the 1/4-scale fuselage model. An improvement of at least 1-1/2 minutes was observed.

2.2.2.3.3 Technical Approach. A 20-foot long by 8-foot high fuselage section of a DC-10 aircraft will be cut into units comprising two adjacent windows and mounted in a jig for insertion into the doorway of the C-133 aircraft fuselage where it will be exposed to a large free-burning jet-fuel fire. Each unit will contain an inservice and advanced window assembly for direct comparison under identical fire exposure conditions. The advanced window assemblies will be composed of a stretched acrylic outer pane and an advanced epoxy EX-112 inner pane. Each unit will be instrumented to determine the survival time and failure mode of the window panes and their mounting system. Additionally, comparisons will be made between the window panes in terms of flame penetration (burn through), heat transmission and the potential ignition of adjacent interior materials. The following comparisons will be made:

(1) Failure times of advanced versus inservice window assemblies.

(2) Burnthrough resistance of window panes, framing and sidewall insulation,

(3) Burnthrough times of honeycomb versus aluminum sidewall panels,

A draft report will be issued in March 1983.

2.2.2.4 Door Curtains.

It is possible that in a crash accident an external fuel fire can spread to and envelope an inadvertently opened emergency exit door. Closure of the doorway be prevented by flame penetration into the interior or by the fact that in certain designs the door cannot be readily closed once opened. Using a surplus DC-7 fuselage, commercially available thermally resistant fabrics will be fastened to a door opening subjected to a large fuel fire. In this manner the feasibility of a door curtain as a fire barrier will be determined. A draft letter report will be prepared in January 1983.

2.3 SURVIVAL AND EVACUATION.

FAA regulations require that the design of a transport cabin allows for the evacuation of a full complement of passengers through 1/2 of the emergency exit openings within 90 seconds. The actual evacuation time in a real accident is usually greater than the 90-second requirement (FAR 25.803) because of psychological factors such as panic, inaction, and group behavior and various fire-related hazards. The major fire-related hazards are as follows:

a. Smoke and numerous irritant gases, causing loss of visibility and eye irritation and lachrymation.

b. Heat, causing thermal stress.

c. Oxygen depletion, posing a life hazard in a ventilation restricted environment.

Similar designs are employed by the three major wide-body aircraft manufacturers, and used in production standard body aircraft designs as well as retrofit kits for inservice aircraft. The majoar surface area of a cabin interior, including sidewall, storage bin, ceiling and partition is made essentially from composite panels. Panel materials also comprise the upper cabin areas where fire growth and involvment is greatest. These considerations clearly indicate the panels used in cabin interiors are the most important materials system from a fire safety viewpoint. The incremental improvements which are possible will be established in planned C-133 fire tests in FY-83 (see section 2.1.1.6).

2.2.2.2.3 Technical Approach.

The technical approach will consist of the following four phases:

Phase 1. Design properties. The design panel properties in terms of fire safety, weight, and functionality will be established.

Phase 2. Selection of candidates. This component phase will involve the selection of resins, reinforcements (fabrics) and decorativee systems that will meet the desired properties. It will be assured that the processing parameters are reasonable for production conditions.

Phase 3. Laboratory and Small-Scale Testing. Laminate and sandwich panel prototypes will be evaluated for acoustical properties, environmental resistance, mechanical properties, corrosion, and fire safety.

Phase 4. Panel Manufacturing. The best candidate materials from phase 3 will be used to manufacture large sandwich panels. This phase will be directed toward evaluating the ability to fabricate large sandwich panels in a production environment. Also, these panels will be evaluated in the C-133 test article under various fire scenarios for the purpose of deriving test criteria consistent with optimum fire safety and weight/practicality (see section 2.2.1.7.2).

This project will be accomplished under an interagency agreement with NASA. The planned completion date (draft report) is September 1984.

2.2.2.3 Windows.

2.2.2.3.1 Objective. The objective of this project is to determine the improvement in burnthrough resistance of fire resistant epoxy windows developed by NASA compared to inservice acrylic windows.

2.2.2.3.2 Background. Aircraft occupants cannot survive direct exposure to the heat and flames of a large pool fire. However, if the occupants are inside the airplane and the fuselage is intact, then the aircraft structure will protect the passengers for a finite period of time until melting and burnthrough occurs. In a wide-body airplane accident, the investigation revealed that the acrylic windows were the least resistant part of the airplane to fuel fire burnthrough (reference 44). Therefore, the replacement of these inservice windows with a more fire resistant design will improve the overall fire burnthrough resistance of wide-body airplanes.

TABLE 1. CONTRACT FUNDING REQUIREMENTS - CABIN FIRE SAFETY PROGRAM

Major Tasks	FY-80	FY-81	FY-82	FY-83	FY-84
1. Cabin Fire Hazards Characterization	1348	1138	516	190	790
2. Materials Management	205	494	32	740	965
3. Survival and Evacuation	280	357	0	90	0
4. Fire Management and Suppression	150	173	257	195	450
Total	1983	2162	805	1215	2205

Note: Numbers represent thousand dollars.

4. PROGRAM MANAGEMENT

4.1 GENERAL.

The overall conduct of this program will be accomplished by the Fire Safety Branch, ACT-350, FAA Technical Center. The Fire Safety Branch contains the following four subelements of activity supervised by a "project manager" reporting directly to the Technical Center Program Manager (TPM):

a. Full-scale and small-scale testing; cargo compartment fire safety, seat cushion fireblocking layers.
b. Modeling; hand-held extinguishers; in-flight smoke venting; lighting.
c. Chemical analysis and toxicity.
d. Fire management and suppression; windows.

Each project or activity under the four major tasks described in this program plan is assigned to a project manager, or to the TPM for some contractual efforts, who is then responsible for its accomplishment. Projects or activities related generally to medical or human aspects of cabin fire safety, such as toxicity, human survival limits, and protective breathing devices, are usually performed by appropriate groups within the FAA's Civil Aeromedical Institute (CAMI).

4.2 COORDINATION WITH NASA.

The Aircraft Cabin Fire Safety Program is complemented by NASA's Research and Technology Program. An agreement as to the responsibilities of each agency is contained within a memorandum of understanding which is updated annually. Coordination is maintained primarily through interagency meetings and informal communications between the responsible individuals within FAA and NASA. The major thrust of the NASA program is the development and evaluation of advanced panels, seats, and thermoplastic for aircraft cabin interiors that are superior to inservice materials from the standpoint of flammability, smoke, and toxicity. In addition to fire safety performance, advanced materials are examined in terms of functionality, durability, aesthetics, weight, cost, and adaptability to aircraft production methods. In recent years, NASA has also emphasized fire modeling research and the development of burnthrough restraint materials.

A number of crucial interagency agreements exist or are planned with NASA: (1) fire blocking layer material optimization; (2) fabrication of advanced materials for full-scale testing to determine safety benefits; and (3) development of practical and low weight panel systems with improved fire performance characteristics.

4.3 PARTICIPATION ON TECHNICAL OR ADVISORY COMMITTEES.

Individuals working in the program participate on various fire safety and aircraft safety technical committees to assure maximum integration and benefit from related activities. These committees include the following:

a. NBS Ad Hoc Committee on Mathematical Fire Modeling

b. ASTM E-5 Committee on Fire Standards and F-7 Committee on Aerospace Industry Methods

c. NFPA Aviation Committee

d. SAE S-9 Cabin Safety Provisions

e. SAE A-20C Aircraft Lighting, Interior

The FAA program adheres to the major recommendations of the SAFER Advisory Committee.

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