Description of document: Curriculum and Presentation Slides for the National Transportation Safety Board (NTSB) training class Survival Factors in Aviation Accidents (AS302) 2004

Requested date: 2021

Denied date: 12-October-2022

Appealed date 13-October-2022

Released 04-November-2022

Posted date: 12-December-2022

Source of document: FOIA Request
National Transportation Safety Board
Attention: FOIA Requester Service Center, CIO-40
490 L'Enfant Plaza, S.W.
Washington, DC 20594-2000
Fax: (240) 752-6257
NTSB's FOIA Online Submission Website

National Transportation Safety Board
Office of the Managing Director
Washington, DC 20594

November 4, 2022

RE: Freedom of Information Act (FOIA)
Appeal No. FOIA-2023-00002-A
Request No. FOIA-2021-00391

The National Transportation Safety Board (NTSB) has reviewed your FOIA appeal, received on October 13, 2022, in which you dispute the agency's response to the above request. On October 12, 2022, the FOIA Office informed you that there are no records responsive to your request for the curriculum and presentation slides for the NTSB training class Survival Factors in Aviation Accidents (AS302) and in your appeal, you state that the search for records was inadequate. During a November 3, 2022, telephone call with the Office of General Counsel, you agreed to narrow your request to the course curriculum and the full set of presentation slides for a single session. After conducting another search for records, we have uncovered the course curriculum and a complete set of presentation slides for the 2004 session of AS302. Thus, I am granting your appeal. Enclosed are 679 pages containing the releasable portions of the records that the NTSB has identified as responsive to your clarified request.

We are withholding 12 pages under 5 U.S.C. § 552(b)(5) ("Exemption 5") because they are draft versions of the 2004 course curriculum. FOIA Exemption 5 exempts from disclosure "inter-agency or intra-agency memorandums or letters that would not be available by law to a party ... in litigation with the agency." 5 U.S.C. § 552(b)(5). Exemption 5 encompasses the traditional discovery privileges, including the deliberative process privilege, which "protects agency documents that are both predecisional and deliberative." *Judicial Watch, Inc. v. Food & Drug Admin.*, 449 F.3d 141, 151 (D.C. Cir. 2006). As a result, the agency may withhold preliminary records that reflect the Board's internal deliberative process. *See, e.g., NLRB v. Sears, Roebuck & Co.*, 421 U.S. 132, 148-51 (1975); *Ancient Coin Collectors Guild v. Dep't of State*, 641 F.3d 504, 506 (D.C. Cir. 2011). *See also Wadhwa v. Dep't of Veterans Affairs*, 707 Fed. App'x. 61, 63 (3d Cir. 2017) (draft reports and internal communications generated as part of agency decision making may be properly withheld under Exemption 5). Therefore, the draft versions of the curriculum do not reflect final agency determinations, but instead represents the agency's deliberations in developing the course agenda.

This constitutes the NTSB's final action on your appeal. Pursuant to 5 U.S.C. § 552(a)(4)(B), my decision is reviewable in the district court of the United States where you reside, where you have your principal place of business, where records are located, or in the District of Columbia.

Sincerely,

Dana L Schulze

Dana L. Schulze
Managing Director

Encl.

AS320: Survival Factors in Aviation Accidents

Course Agenda

MONDAY – October 18, 2004

8:30 – 8:45	**COURSE OVERVIEW** Nora Marshall – NTSB Survival Factors
8:45 – 9:30	**INTRODUCTION TO CRASHWORTHINESS** Lisa Jones – NASA Langley
9:30 – 9:40	**BREAK**
9:40 – 10:30	**INTRODUCTION TO CRASHWORTHINESS (continued)**
10:30 – 10:40	**BREAK**
10:40 – 11:30	**CRASHWORTHINESS OF METAL VS. COMPOSITE AIRPLANES** Lisa Jones – NASA Langley
11:30 – 12:30	**LUNCH**
12:30 – 1:30	**AIRCRAFT SEATS AND RESTRAINT SYSTEMS** Rick DeWeese – FAA, Civil Aerospace Medical Institute
1:30 – 1:40	**BREAK**
1:40 – 2:00	**AIRCRAFT SEATS AND RESTRAINT SYSTEMS (continued)**
2:00 – 2:30	**GUIDANCE FOR SEAT AND RESTRAINT SYSTEMS DOCUMENTATION** Cindy Keegan & Mark George – NTSB Survival Factors
2:30 – 2:40	**BREAK**
2:40 – 3:30	**SEATS AND RESTRAINT SYSTEMS DOCUMENTATION EXERCISE** Rick DeWeese and NTSB Survival Factors Staff
3:30 – 3:40	**BREAK**
3:40 – 4:30	**DOCUMENTATION EXERCISE (continued) & INSTRUCTOR FEEDBACK**

TUESDAY – October 19, 2004

8:30 – 9:30	**TURBULENCE: INTERIOR & INJURY DOCUMENTATION** Kelli Jones – Cabin Safety Consultants, Inc.
9:30 – 9:40	**BREAK**
9:40 – 10:15	**TURBULENCE: INTERIOR & INJURY DOCUMENTATION (continued)**
10:15 – 10:45	**SURVIVAL FACTORS INTERVIEWS** Nora Marshall – NTSB Survival Factors

10:45 – 10:55	**BREAK**
10:55 – 11:45	**SURVIVAL FACTORS INTERVIEWS (continued)**
11:45 – 12:45	**LUNCH**
12:45 – 1:50	**COGNITIVE INTERVIEWING** Ron Fisher, Ph.D. – Florida International University
1:50 – 2:00	**BREAK**
2:00 – 3:10	**INTERVIEWING EXERCISE** Ron Fisher and NTSB Survival Factors Staff
3:10 – 3:20	**BREAK**
3:20 – 4:30	**INTERVIEWING EXERCISE (continued)/EXERCISE REVIEW**

WEDNESDAY – October 20, 2004

8:30 – 9:30	**EVACUATION SLIDES AND SLIDE/RAFTS** Michael Kret – Air Cruisers Company
9:30 – 9:40	**BREAK**
9:40 – 10:15	**EVACUATION SLIDE DOCUMENTATION EXERCISE (1/2 class)** Michael Kret and NTSB Survival Factors Staff
10:15 – 10:50	**WATER SURVIVAL EQUIPMENT/CASE STUDIES (1/2 class)** Mark George & Cindy Keegan – NTSB Survival Factors
10:50 – 11:00	**BREAK**
11:00 – 12:00	**EVACUATIONS AND EVACUATION SYSTEMS** Jason Fedok – NTSB Survival Factors
12:00 – 1:00	**LUNCH**
1:00 – 2:00	**EVACUATIONS AND EVACUATION SYSTEMS (continued)**
2:00 – 2:10	**BREAK**
2:10 – 3:00	**EVACUATIONS AND EVACUATION SYSTEMS (continued)**
3:00 – 3:30	**DITCHINGS/WATER CONTACT** Nora Marshall – NTSB Survival Factors
3:30 – 4:30	**TWA 800 PRESENTATION & TOUR** NTSB Academy staff

THURSDAY – October 21, 2004

8:30 – 9:45	**FIRE INVESTIGATIONS** David Blake – FAA Technical Center
9:45 – 9:55	**BREAK**
9:55 – 11:30	**CREWMEMBER EMERGENCY TRAINING, FLIGHT ATTENDANT MANUALS AND CASE STUDIES** Jay Livesey & Connie Reimer – FAA
11:30 – 12:30	**LUNCH**
12:30 – 1:00	**CREWMEMBER EMERGENCY TRAINING BREAKOUT SESSIONS** Jay Livesey, Connie Reimer & NTSB Survival Factors Staff
1:00 – 1:10	**BREAK**
1:10 – 2:20	**AIRPORT SAFETY AND CERTIFICATION** Ben Castellano – FAA Airports Safety and Operations Division
2:20 – 2:30	**BREAK**
2:30 – 3:30	**AIRPORTS/ARFF ACCIDENT CASE STUDIES** Courtney Liedler – NTSB Survival Factors
3:30 – 3:40	**BREAK**
3:40 – 4:30	**COURSE WRAP-UP AND EVALUATION**

Airport Safety and Certification

Ben Castellano

Manager, Airport Safety & Operations Division

(202) 267-8728

Internet: ben.castellano@faa.gov

Airports Website - http://www.faa.gov/arp

Overview of the US Airport System

- **Airports in the US are generally owned and operated by:**
  - **Local governments**
  - **State governments**
  - **Port Authorities**
  - **Airport Authorities**

Overview (cont'd)

- **Total Civil Landing Areas 19,581**

Private-use	**14,295 (4500 heliports)**
Open-to-Public	**5,286 (100 heliports)**
Airports - scheduled service	**600**

Airport Activity

Total Passengers

2003	Atlanta Hartsfield	79 million
	Chicago O'Hare	69 million
	Los Angeles Int'l	55 million

Total Operations

2003	Chicago O'Hare	931,000
	Atlanta	912,000
	Dallas-Ft. Worth	776,000

Airport Certification

- 1972 – Congress authorized the FAA to certificate certain airports
- Major amendment in 1988
- 1996 – Congress authorized the FAA to certificate airports that had air carrier service with aircraft with more than 9 passenger seats.

Airport Certification

Airports served by passenger aircraft with more than 9 seats in scheduled service or more than 31 seats in unscheduled (charter) service require a AIRPORT OPERATING CERTIFICATE under 14 CFR Part 139

– 570 civil airports

– 35 FAA inspectors

AIRPORT CERTIFICATION

Airports must develop an AIRPORT CERTIFICATION MANUAL explaining how they will comply with Part 139

The MANUAL must be approved by the FAA

Periodic Inspections by FAA

AIRPORT CERTIFICATION

FACILITIES AND PROCEDURES INSPECTED

- Pavement Conditions
- Safety Areas
- Lighting, Marking, Signs
- Hazardous Materials
- Traffic & Wind Indicators
- Ground Vehicles/Driver Training

AIRPORT CERTIFICATION

Aircraft Rescue & Firefighting

Bird & Wildlife Hazards

Self-inspection Procedures

Airport Condition Assessment/Reporting

Control of Hazards from Construction

Emergency Plan

Snow Removal Plan

AIRPORT CERTIFICATION

ICAO Requirement in 2003 that all countries that were signatories of ICAO were to have in place an aerodrome certification program. Such program was to be based on the ICAO Standards and Recommended Practices (SARPS).

Part 139 meets most of the ICAO standards and “differences” have been filed with ICAO where we do not meet the SARPS.

AIRPORT CERTIFICATION

Significant Accidents Occurring on Airports

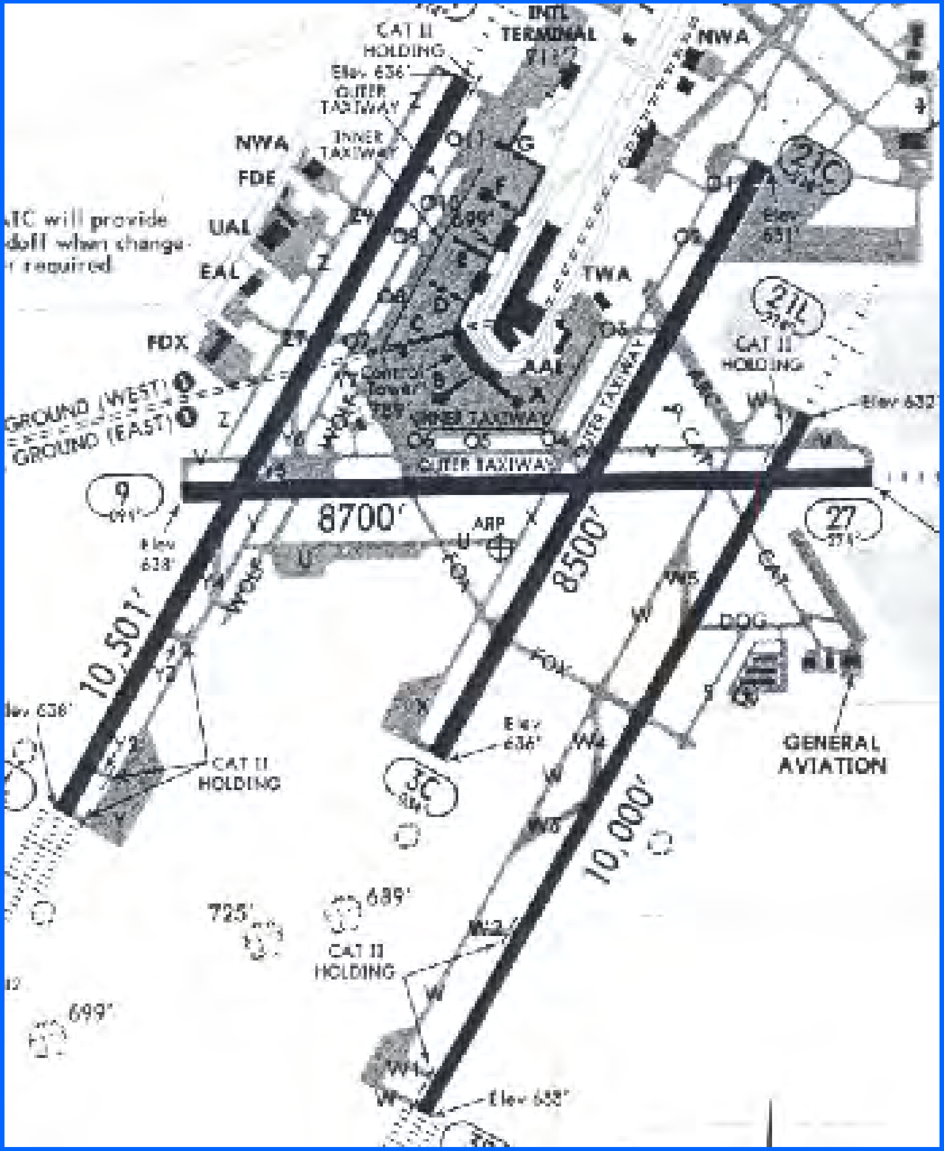
AIRPORT CERTIFICATION

- **Detroit Accident – December 1990**
- **Sikorsky Accident – April 27, 1994**
- **Quincy Accident – November 19, 1996**
- **Little Rock Accident – June 1, 1999**

Detroit Accident

- Dec 3, 1990
- NW DC-9 & NW B-727
- DC-9 8 dead 10 serious
- B-727 0 dead 0 serious
- DC-9 taxied onto Rnwy while 727 was departing

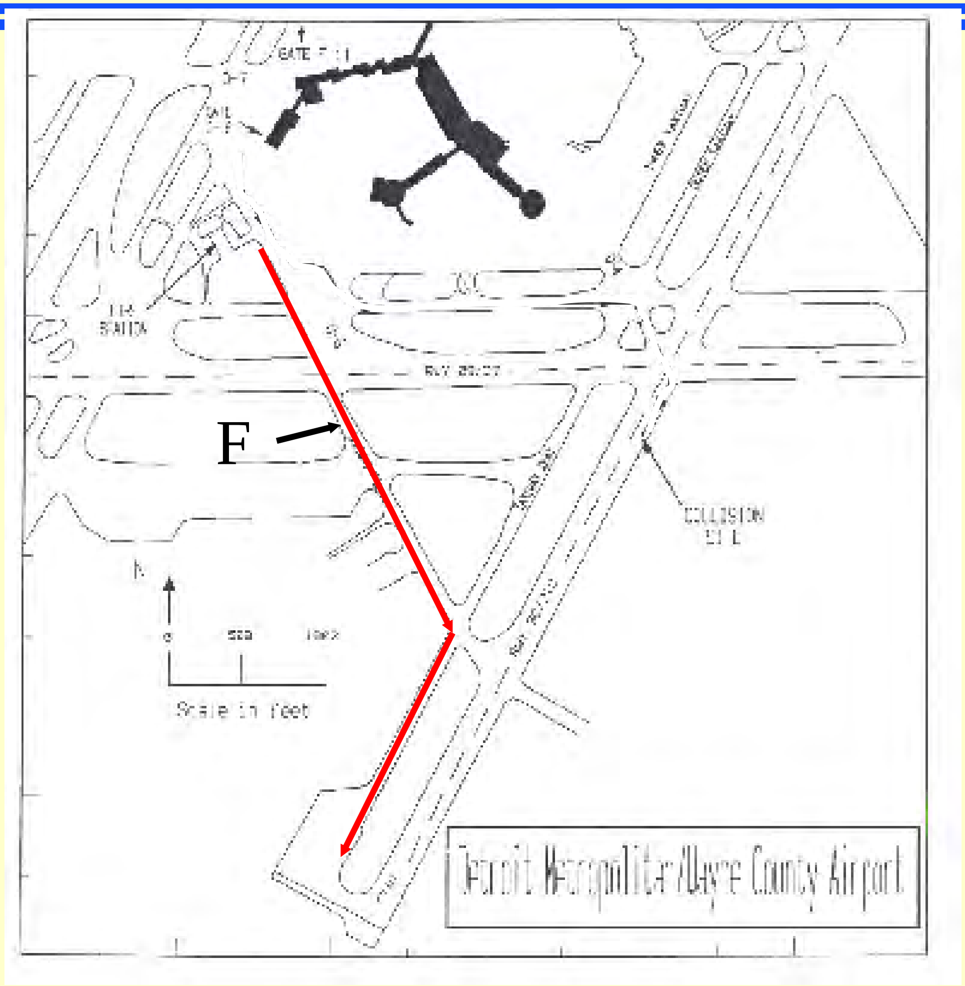
Detroit Airport as it existed in 1990



Detroit Accident

DC-9 cleared out Oscar 6 to cross Runway 9/27 to Foxtrot. Foxtrot to Xray. Right turn onto Xray to Runway 3C

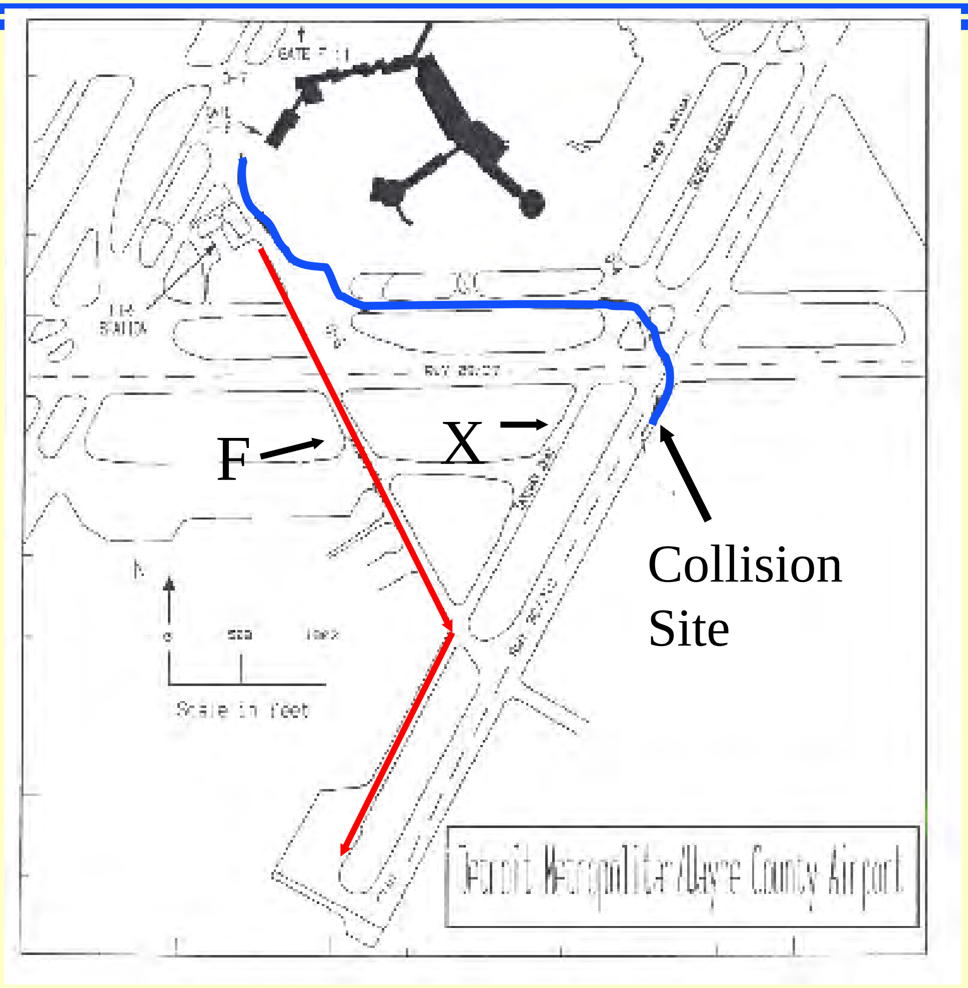
Visibility was deteriorating as they began taxiing.

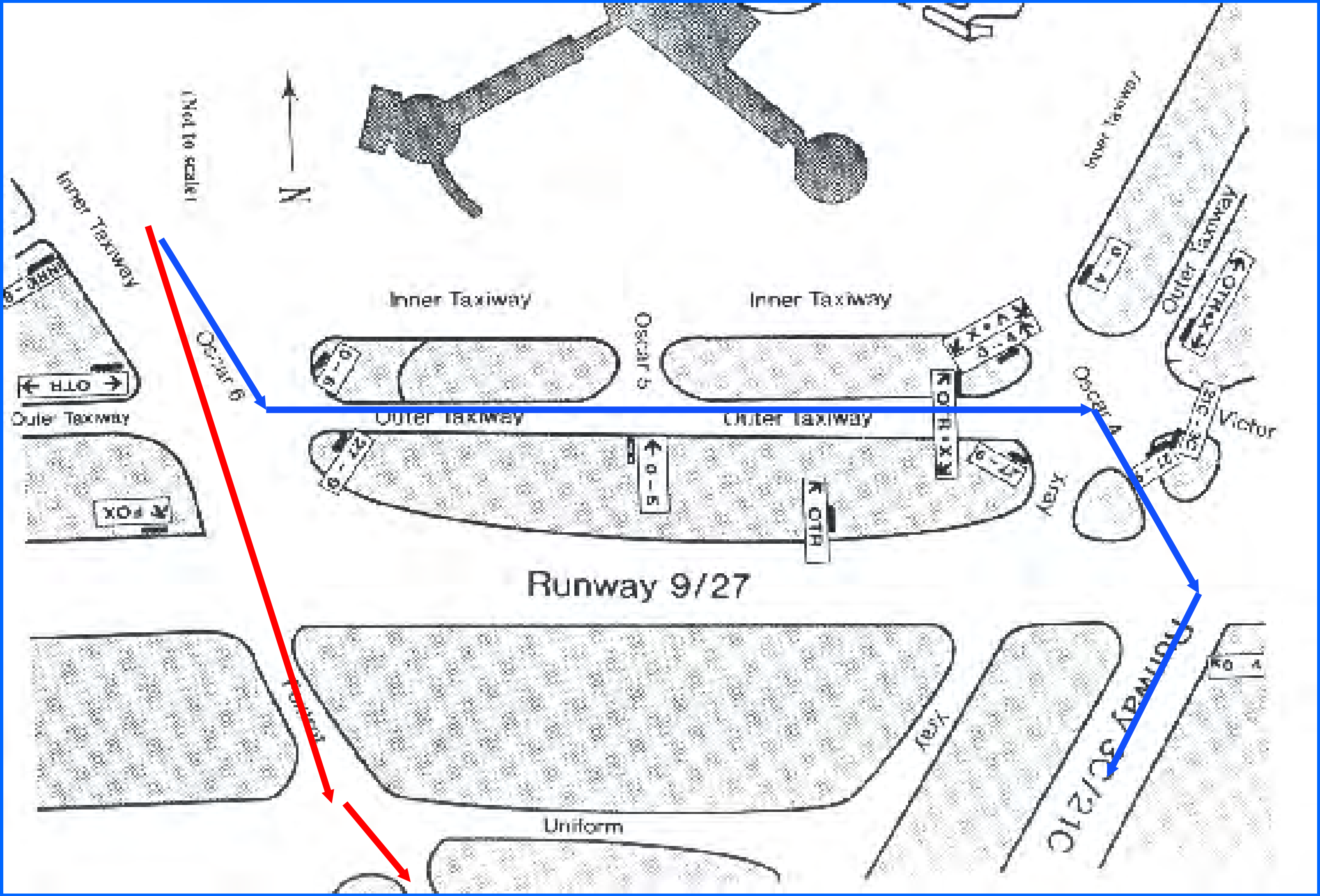


Detroit Accident

Actual route had the DC-9 taxiing the outer to Oscar 4. Was told to make a right turn onto Taxiway Xray.

Ended going Xray and turned onto Rnwy 3C





(Not to scale)
N
Inner Taxiway
Inner Taxiway
Inner Taxiway
Inner Taxiway
Oscar 6
Oscar 5
Oscar 4
Outer Taxiway
Outer Taxiway
Outer Taxiway
Outer Taxiway
OTH
FOX
Victor
Xray
Xray
Runway 9/27
Runway 3C/21C
Uniform

Detroit Accident

- **Impact on the Airport Industry:**
  - **New Sign Standards Developed**
    - **Airports required to meet the new standards**
    - **Sign Plans to be developed and approved**
  - **Markings Better Define**
    - **More specificity**
    - **Beads a requirement on certain markings**
    - **Hold Lines more definitive**

Sikorsky Accident

- April 27, 1994
- Navajo Chieftain Aircraft
- 1 Pilot/8 passengers
- All but 1passenger died
- Aircraft crashed into a blast fence at the end of the runway

Sikorsky Accident

Accident at 10:55 pm

Tower closed at 10:30 pm

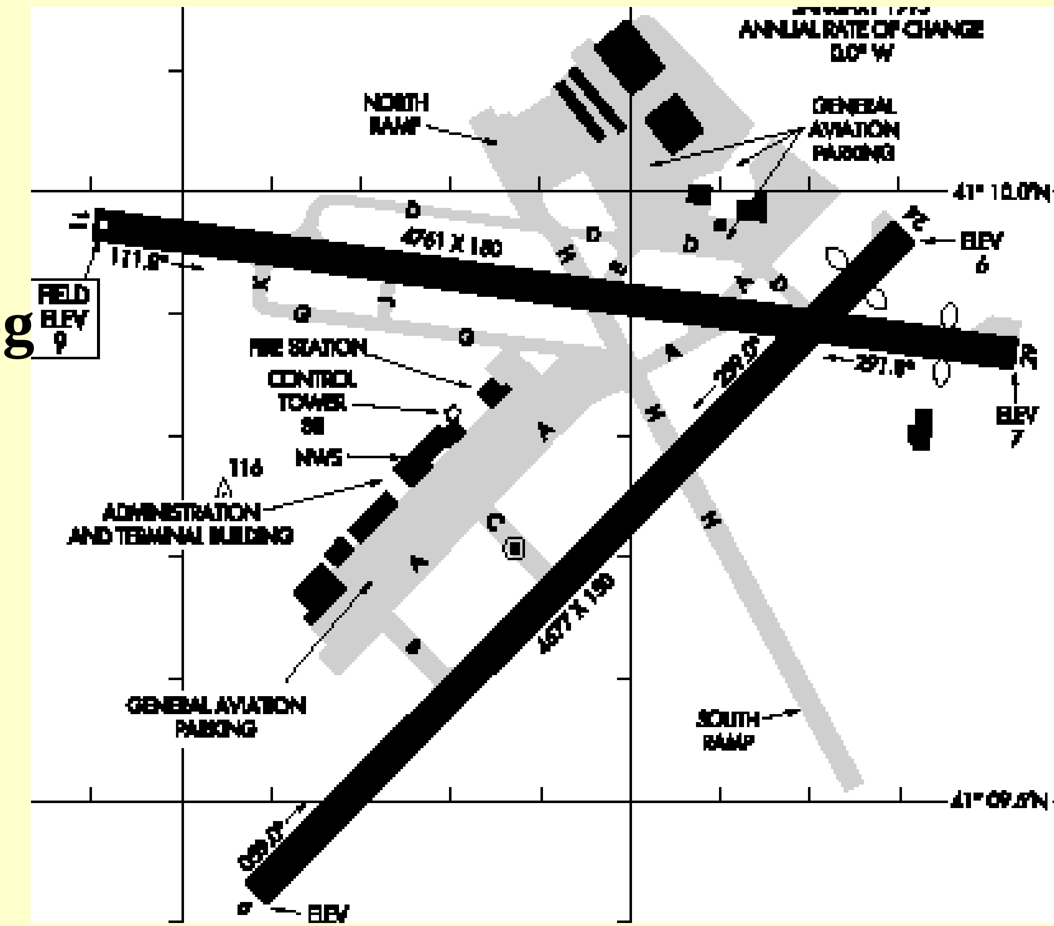
Weather marginal with fog

Landed Runway 6 – PIR

Highway 113 off Rnwy 24

No safety area on 24 end

Blast fence & Chain Link fence



Sikorsky Accident

- Impact on the Airport Industry:
  - Emphasis on Runway Safety Areas
  - Blast fences & frangibility

Quincy Accident

- **November 19, 1996**
- **United Express (Beech 1900) landing runway 13**
  - **10 passengers & 2 crew**
- **King Air taking off on runway 4**
  - **2 pilots**

Accident occurred 5 pm

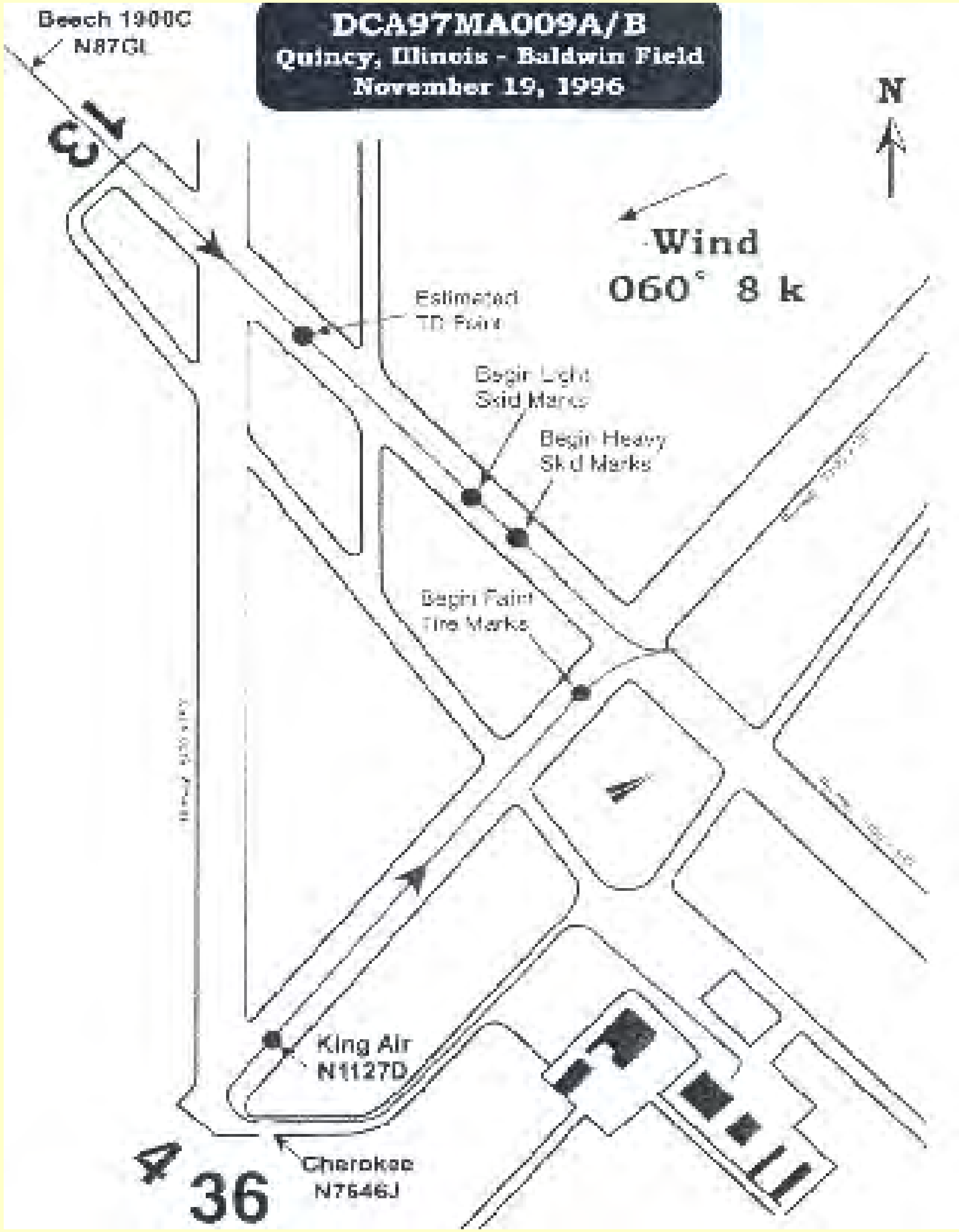
VMC – 12 mile visibility

United Express landing on 13

Announced intentions several times prior to touchdown

King Air on runway 4 for takeoff

Little to no radio communications from King Air



Sikorsky Accident

- Impact on the Airport Industry:
  - Certification of airports with scheduled air carrier service with aircraft with more than 9 and less than 31 passenger seats.

Little Rock Accident

- June 1, 1999
- American Airlines Flt 1420 – an MD-82
- 1 Flight crew (Captain) & 10 psgrs died
- Heavy rain and severe thunderstorms

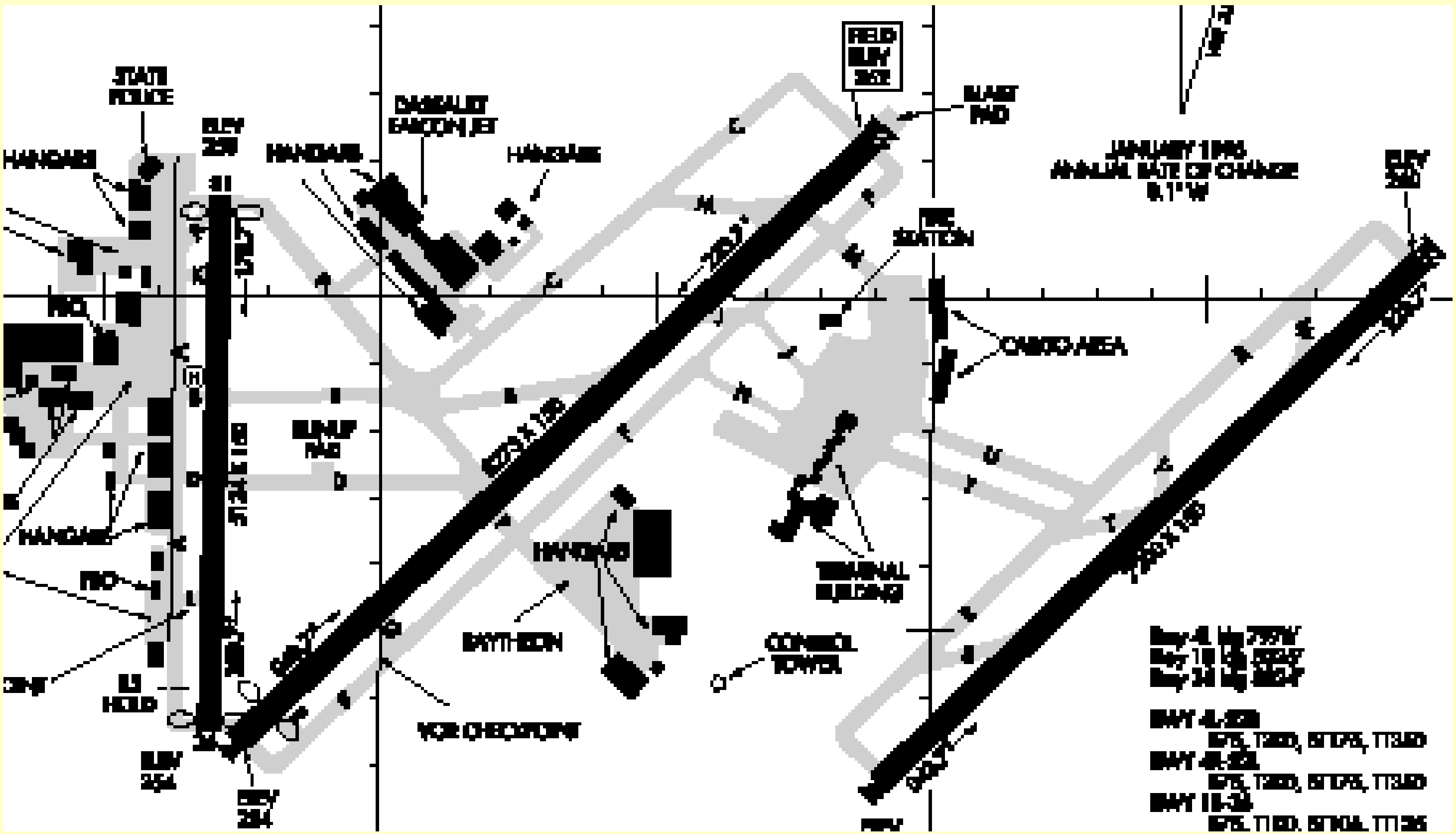
Little Rock Accident

Weather – major factor

Flight was delayed

Touchdown 2000 feet from threshold

Little Rock Accident



Little Rock Accident

Little Rock Accident

Impact on the Airport Industry:

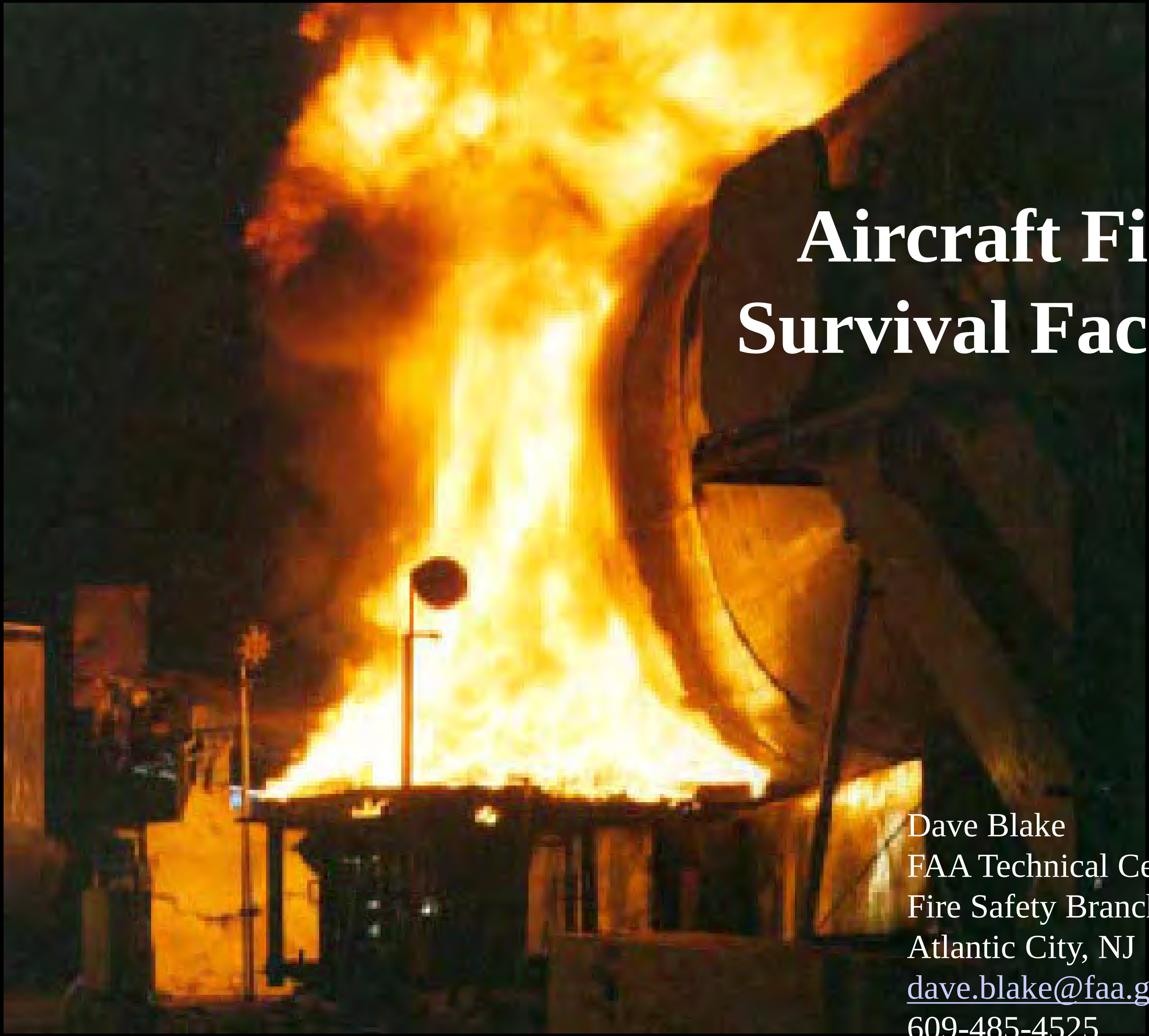
Renewed Emphasis on RSA

EMAS (Engineered Materials Arresting systems)

AIRPORT CERTIFICATION

Major Component of the Airport Certification Program

Daily Inspections by Qualified Airport Personnel



Aircraft Fire Survival Factors

Dave Blake
FAA Technical Center
Fire Safety Branch
Atlantic City, NJ
dave.blake@faa.gov
609-485-4525


FAA William J. Hughes Technical Center
Atlantic City, NJ

Full Scale Aircraft Fire Test Facility


FedEx

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www.fire.tc.faa.gov

The Federal Aviation Administration

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Fire Safety Branch

AAR-440

Reports | Handbook | Conference | Information | Search | Tech Center

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Cabin Safety

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What's New

Date	Section	Description
9/21/04	Reports	Added report DOT/FAA/AR-04/11.
8/23/04	Reports	Added report DOT/FAA/AR-04/8.
7/22/04	Materials	Added presentations, minutes and attendee list from the July meeting.
7/19/04	Systems: Fuel Tank Protection: Downloads	Updated Fuel Air Ratio Calculator.
7/15/04	Systems	Added PDF versions for larger presentations from the June meeting.
7/13/04	Systems: Fuel Tank Protection: Fuel Tank Flammability	Updated the Flammability Section
7/12/04	Systems	Added presentations, minutes and attendee list from the June meeting.
7/9/04	Reports	Added report DOT/FAA/AR-04/26.
7/8/04	Reports	Added report DOT/FAA/AR-03/58.
7/8/04	Systems: Fuel Tank Protection: Fuel Tank Inerting	Updated the Inerting Section
6/29/04	Reports	Added report DOT/FAA/TN-04/21.
6/3/04	Handbook	Updated Appendix G
5/24/04	Materials	Agenda for July meeting posted.
5/24/04	Reports	Added report DOT/FAA/AR-TN04/4.
5/13/04	Systems	Agenda for June meeting posted.
5/4/04	Systems: Fuel Tank Protection - Presentations	Added new presentation.
4/26/04	Materials	Fixed registration link; now points to correct file.
4/26/04	Reports	Added report DOT/FAA/AR-04/1.
4/19/04	Materials	Attendee list from March meeting posted.

Just Released

Final Rule:
Improved Flammability Standards for Thermal/Acoustic Insulation Materials Used in Transport Category Airplanes

Click here for the PDF file.

New Announcements

The Fourth Triennial International Fire & Cabin Safety Research Conference will be held November 15-18, 2004, in Lisbon, Portugal.

Click here for information.

Conference Program Now Available

Highlights

1997 Highlights
1998 Highlights
1999 Highlights

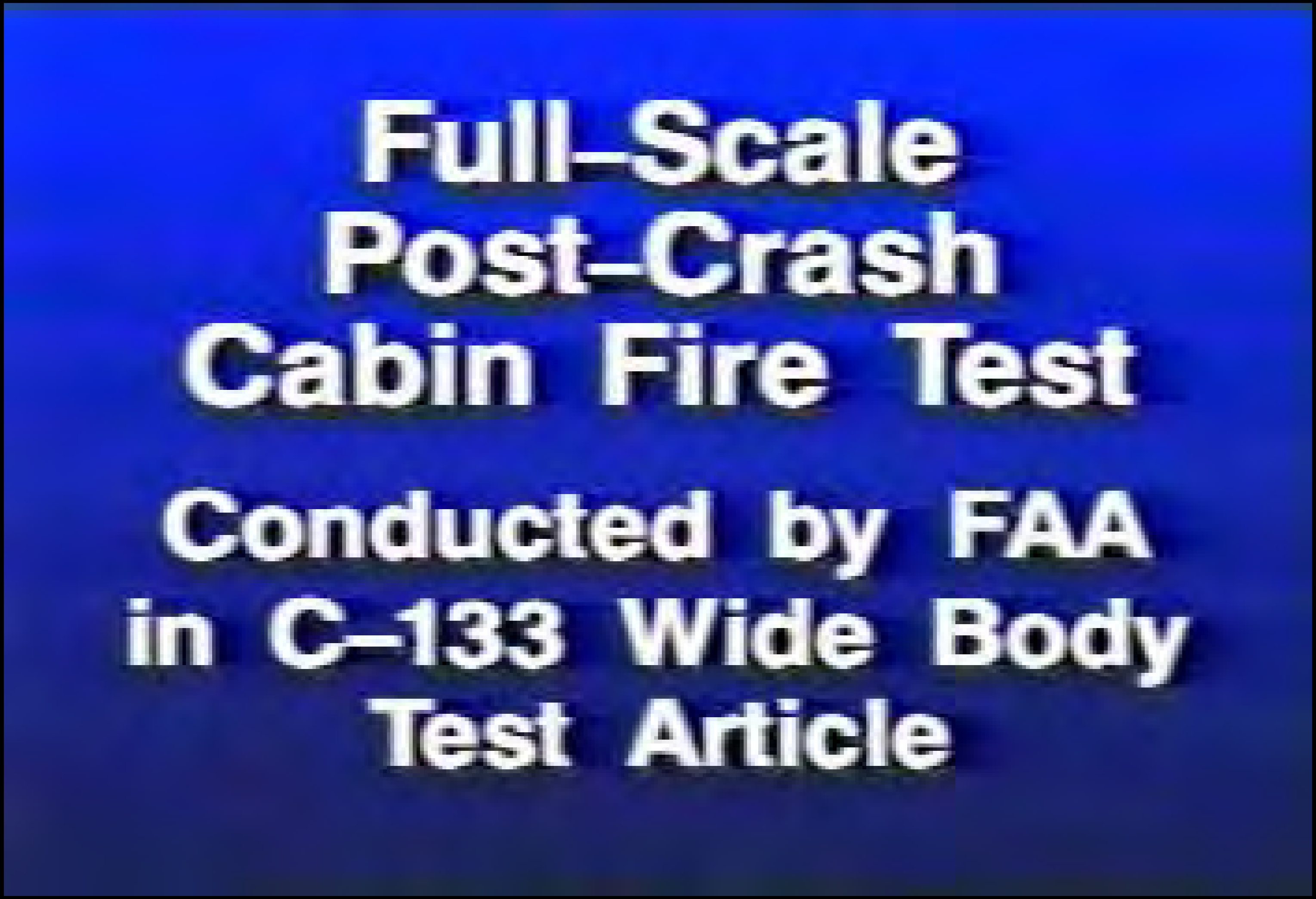
Internet

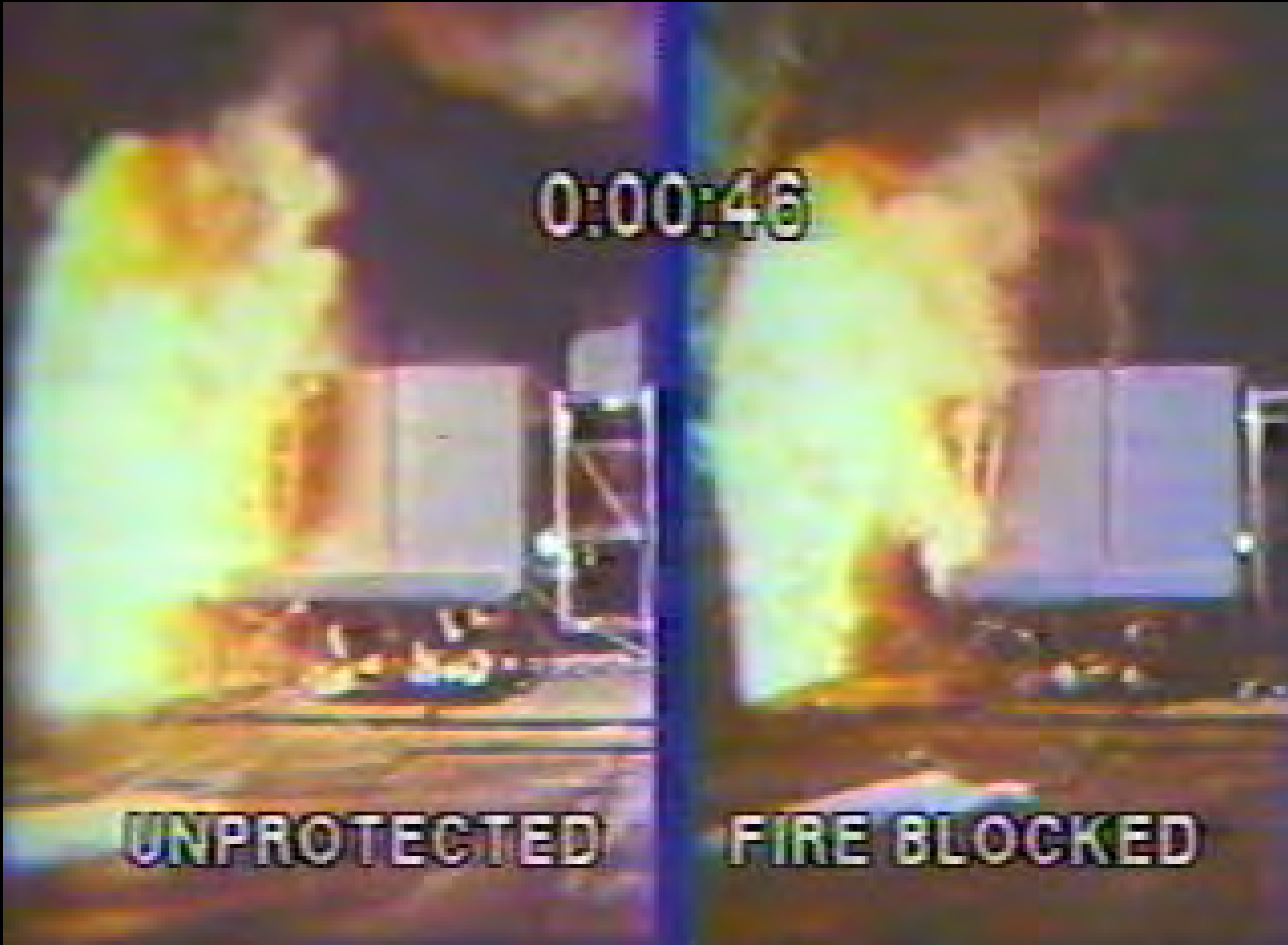
Swiss Air MD-11 9/2/98

Arced Wires

Insulation Blanket/Duct Fire

Aircraft Cabin Flashover





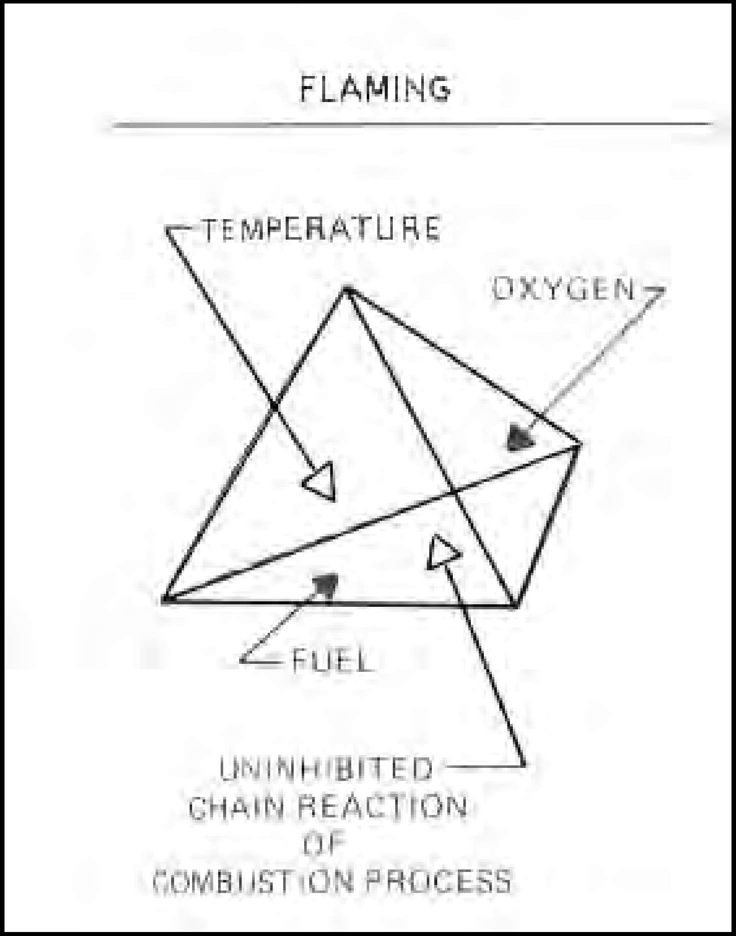
0:00:46
UNPROTECTED
FIRE BLOCKED

Flight Attendant Firefighting

Halon 1211

Bromochlorodifluoromethane

CF_2BrCl

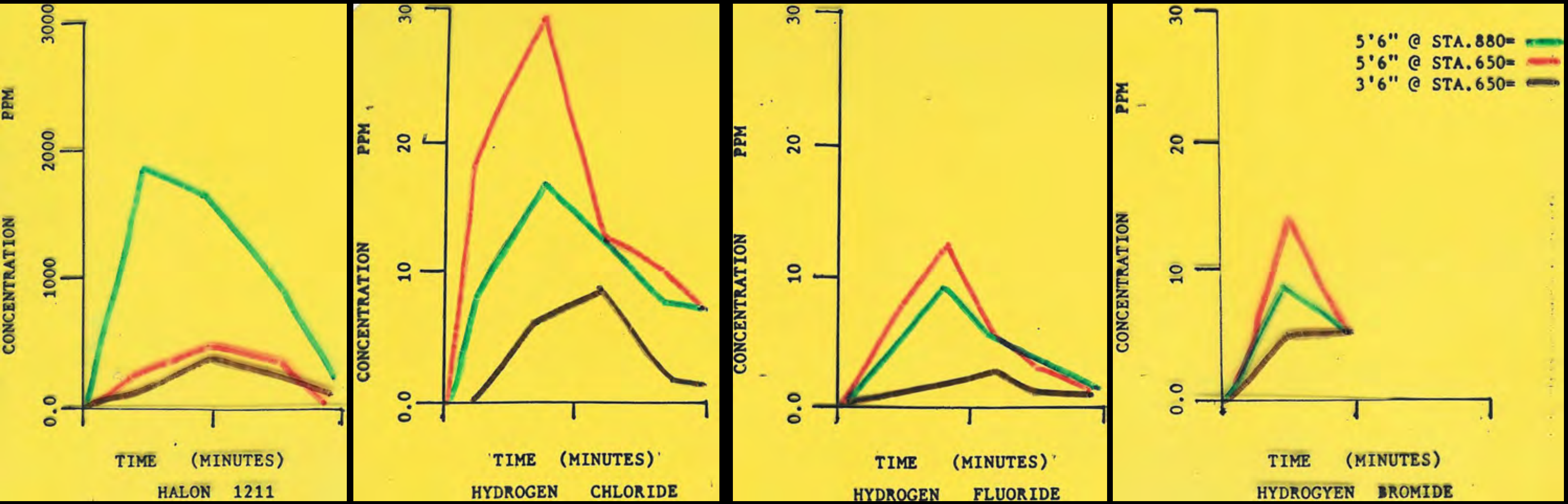


Fire Tetrahedron

Halon 1211

Bromochlorodifluoromethane

CF2BrCl



Delta L-1011

Goose Bay, Canada
March 17, 1991

Boeing 757

Copenhagen, Denmark
November 15, 2000

American MD-80

Dulles Airport
November 29, 2000




NTSB Safety Recommendations to the FAA. A-01-83 thru -87. January 2002

U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

Subject: IN-FLIGHT FIRES | **Date:** 1/8/04 | **AC No:** 120-80
Initiated by: AFS-210

1. WHAT IS THE PURPOSE OF THIS ADVISORY CIRCULAR (AC)?

a. General. The National Transportation Safety Board (NTSB) conducted a review of commercial aviation accidents involving in-flight fires. The scope of the review was limited to transport category airplanes operated by U.S. and foreign air carriers during the period 1983 to 2000. That review prompted the NTSB to issue a number of safety recommendations to the FAA, including A-01-83 through A-01-87 (see Appendix 1). The NTSB recommended that an Advisory Circular (AC) be developed and issued by the FAA to address a number of issues linked to in-flight fires. The FAA agrees with the safety intent of those recommendations and has developed the guidance material that follows. Specifically, this AC:

- Discusses the dangers of in-flight fires, with particular emphasis on hidden fires that may not be visible or easily accessed by the crew. It discusses the importance of recognizing and quickly assessing the conditions that may be associated with hidden fires and the importance of taking immediate action to gain access to fires that are located behind interior panels.

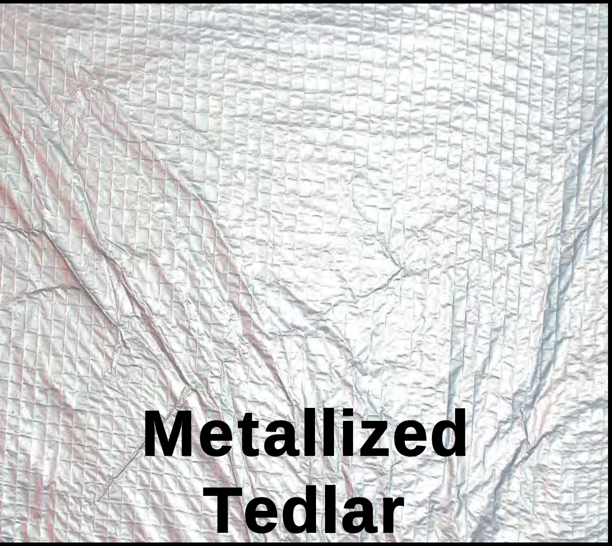
- Provides guidance on how to deal with in-flight fires, emphasizing the importance of crewmembers taking immediate and aggressive action in response to signs of an in-flight fire while stressing the effectiveness of Halon extinguishing agents.

- Discusses the importance of appropriate crewmember training in dealing with hidden fires, the effective application of fire extinguishing agents behind interior panels, and the urgency of the crew's action in dealing with such fires.

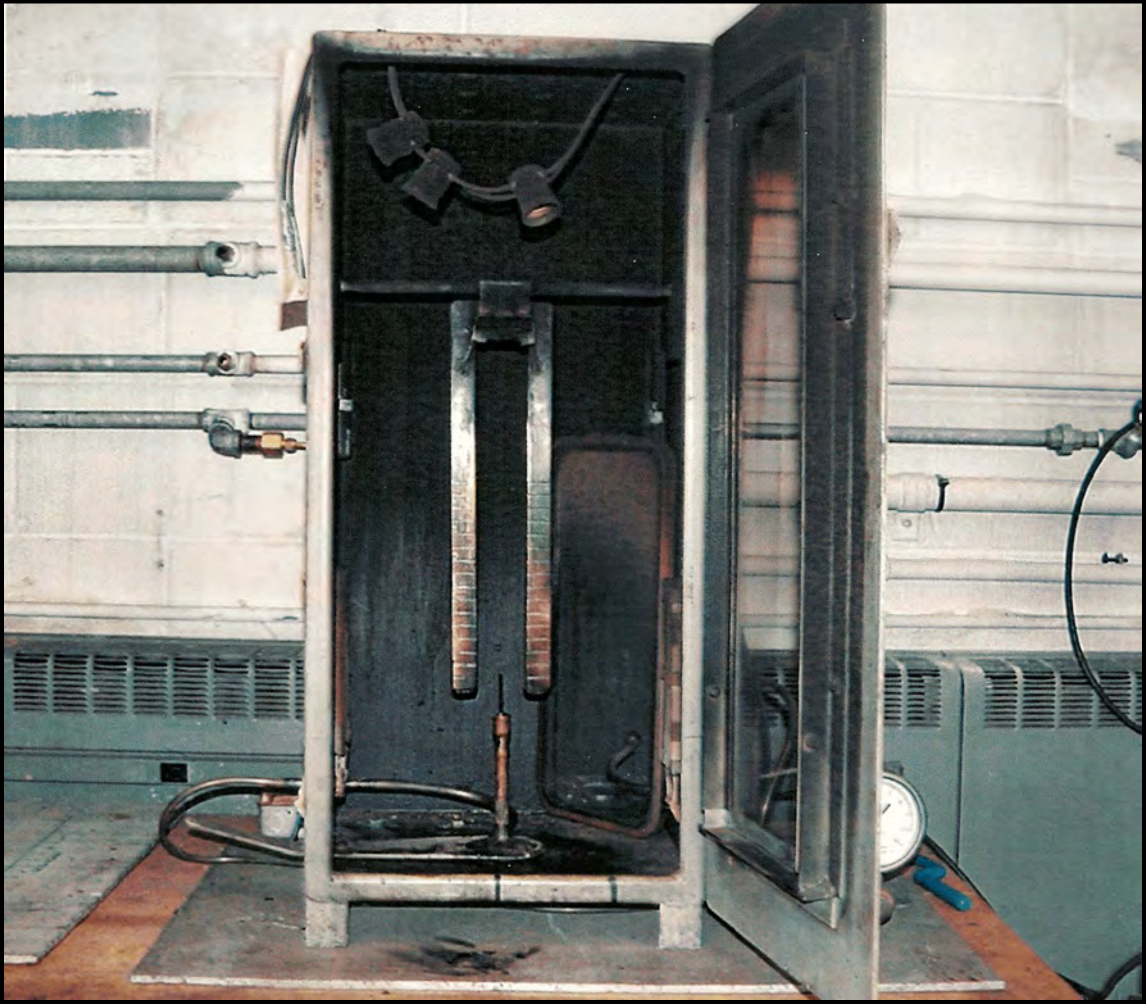
- Complements guidance previously developed for crewmembers concerning the proper use of cabin fire extinguishers (AC 20-42C, Hand Fire Extinguishers for Use in Aircraft, and National Fire Protection Association (NFPA) 408, Standard for Aircraft Hand Portable Fire Extinguishers) and the most effective means of extinguishing fires that are readily accessible.

- Includes information from research conducted by the FAA's Technical Center. As additional information becomes available, it will be published in future revisions to this AC.

Insulation Blankets

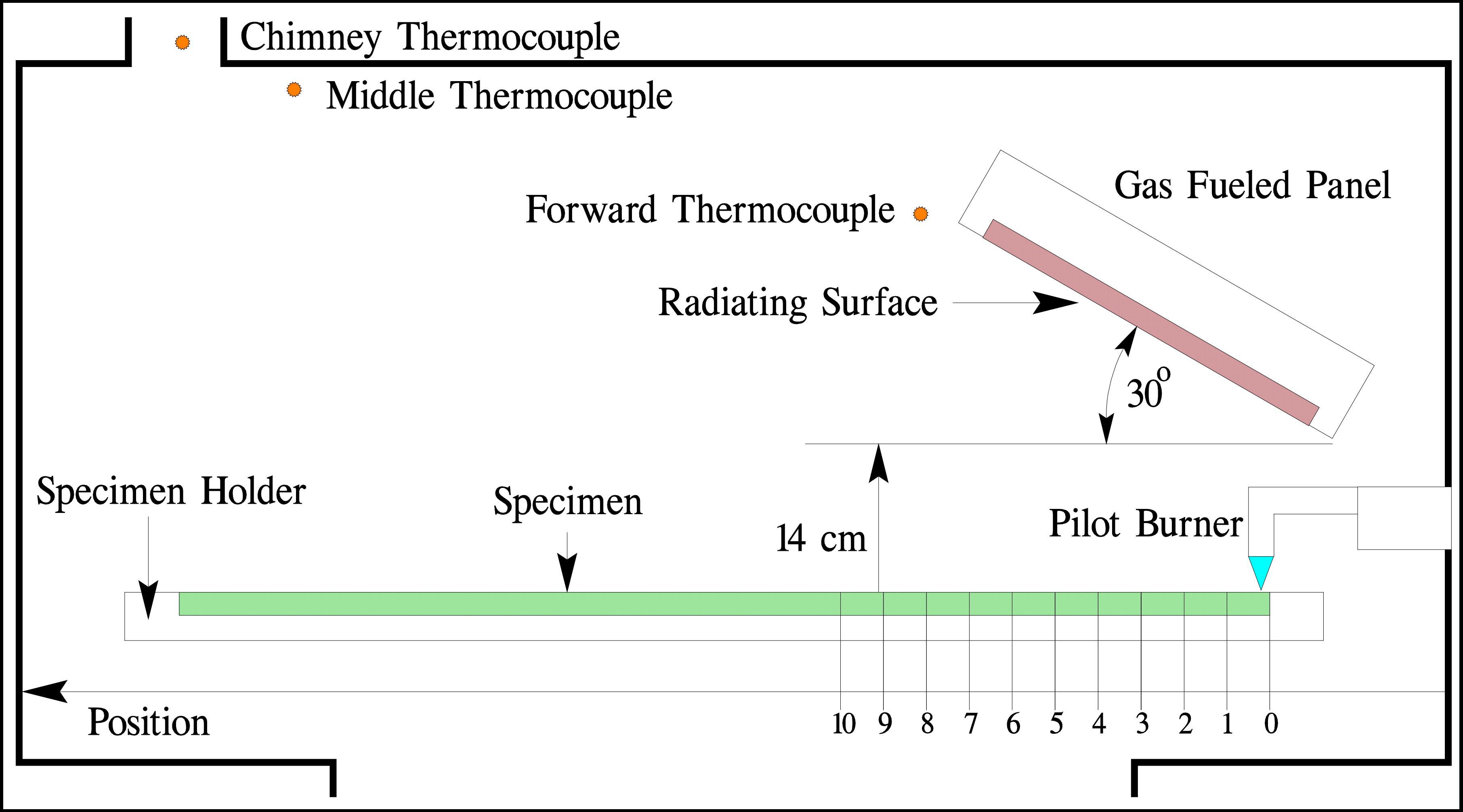


Vertical Bunsen Burner Test



Thermal/Acoustic Insulation Radiant Panel Flame Propagation Test

Schematic of Radiant Panel Test Apparatus



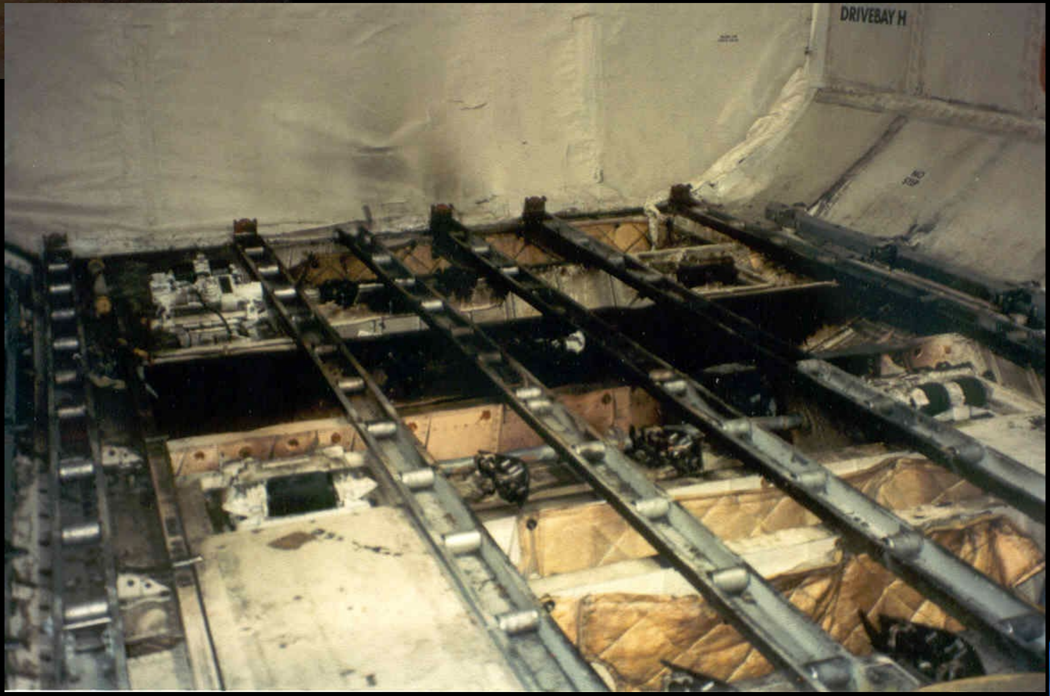
Polyimide (Kapton)

Metallized PET (Mylar)

Airworthiness Directive

- Adopted May 26, 2000
- Requires Replacement of Metallized PET Blankets
  - Only Film Ignited with Electrical Arc
  - Significant Flame Spread
- Replacement Materials Must Meet Radiant Panel Fire Test Criteria
  - No Flame Spread Beyond Two Inches
  - No Flaming After Pilot Burner Removal
- Five Years to Complete (by June 30, 2005)


LANCHILE


DRIVEBAY H


FRAGILE

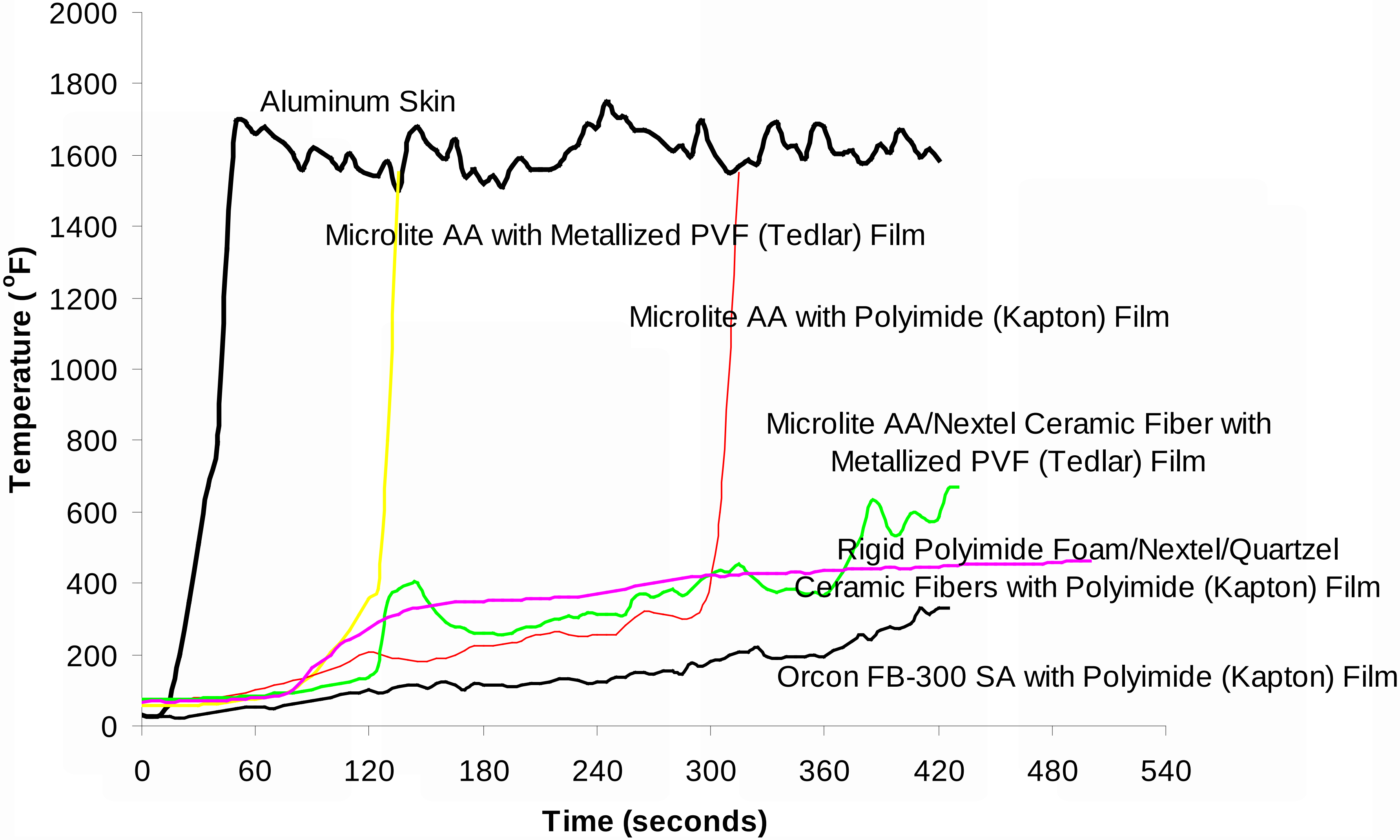

STA 680
LBL 20


NO
STEP
NO
STEP

Contaminated Insulation LAN Chile 767

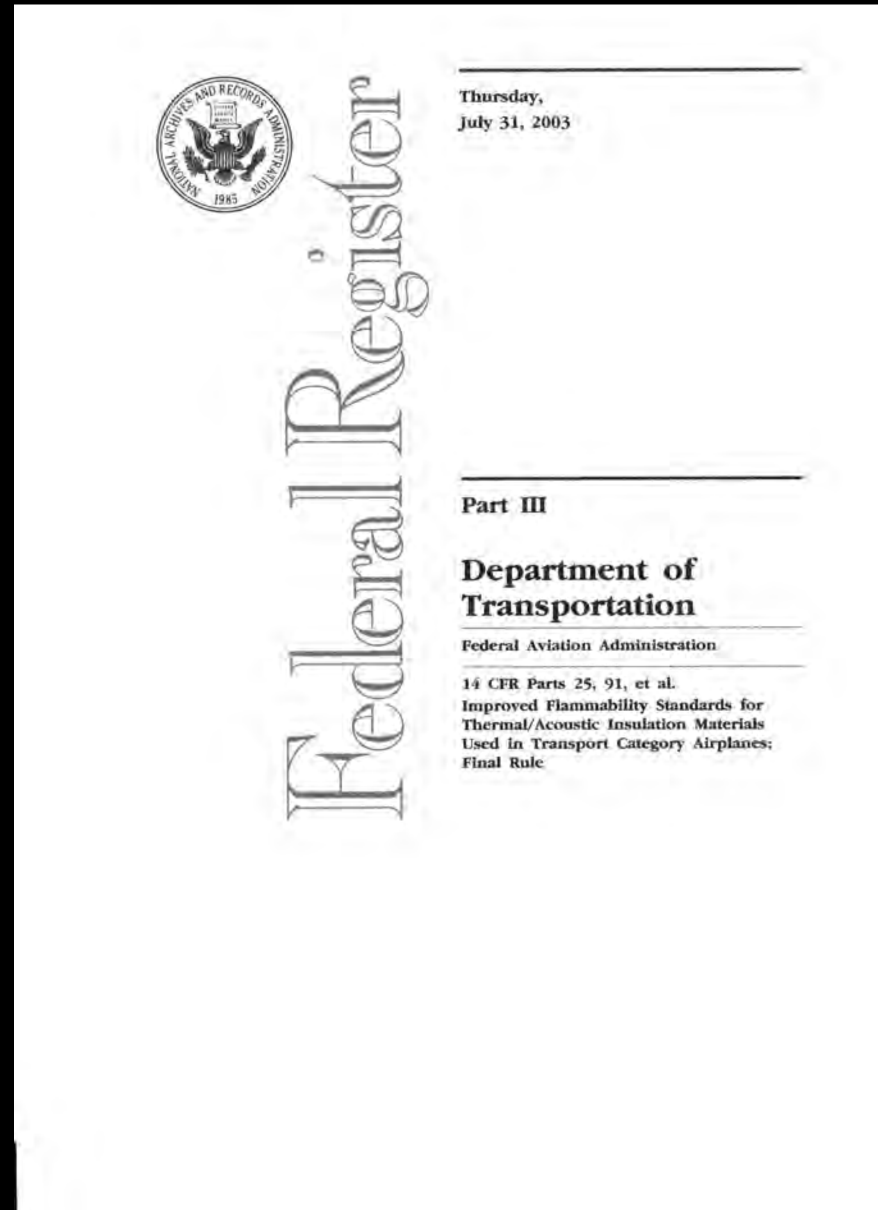
Fuselage Burnthrough

Full-Scale Test Results Using Various Materials



All Part 121 airplanes manufactured after Sept 2, 2005 must have thermal/ acoustic insulation that meets the new radiant panel flame propagation test. Test criteria is that the flame may not propagate outside of a 2” diameter circle.

All Part 121 airplanes manufactured after Sept 2, 2007 must have thermal/ acoustic insulation in the lower half of the fuselage that meets the new flame penetration resistance test. Test criteria is that the heat flux that passes through the insulation material not exceed 2.0 BTU/ft2-sec during the 4 minute test.


Federal Register

Thursday,
July 31, 2003

Part III

Department of Transportation

Federal Aviation Administration

14 CFR Parts 25, 91, et al.
Improved Flammability Standards for Thermal/Acoustic Insulation Materials Used in Transport Category Airplanes; Final Rule

Insulation Flame Penetration Test

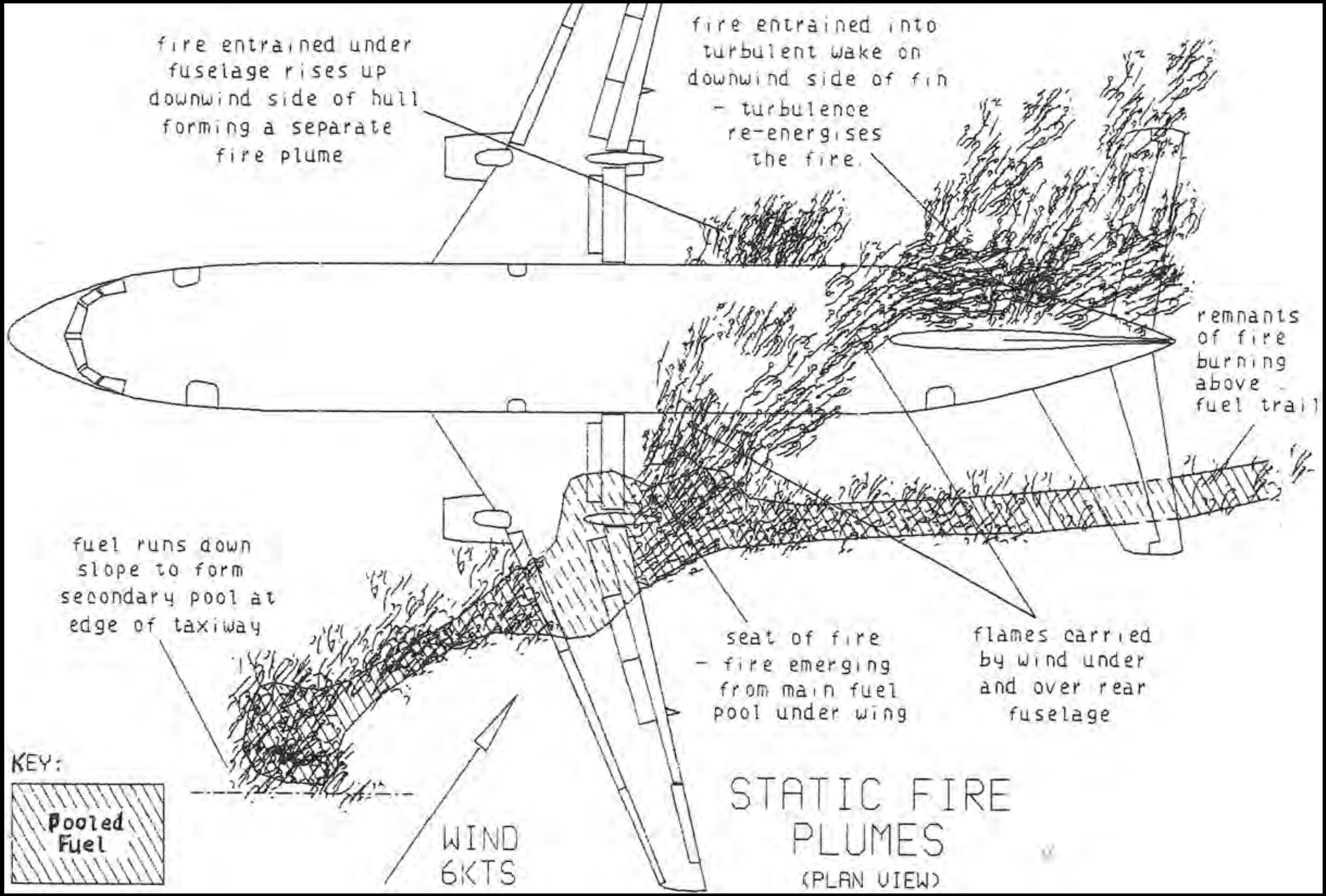
Insulation Flame Penetration Test

Manchester Accident

Date:	August 22, 1985
Location:	Manchester, England
Aircraft Type:	737-236
Carrier:	British Airtours
Number of Occupants:	137 (131 Passengers, 6 Crew)
Number of Fatalities:	55 (53 Passengers, 2 Crew)
Fire Origin:	External Fuel Fire (Postcrash)

Manchester Accident

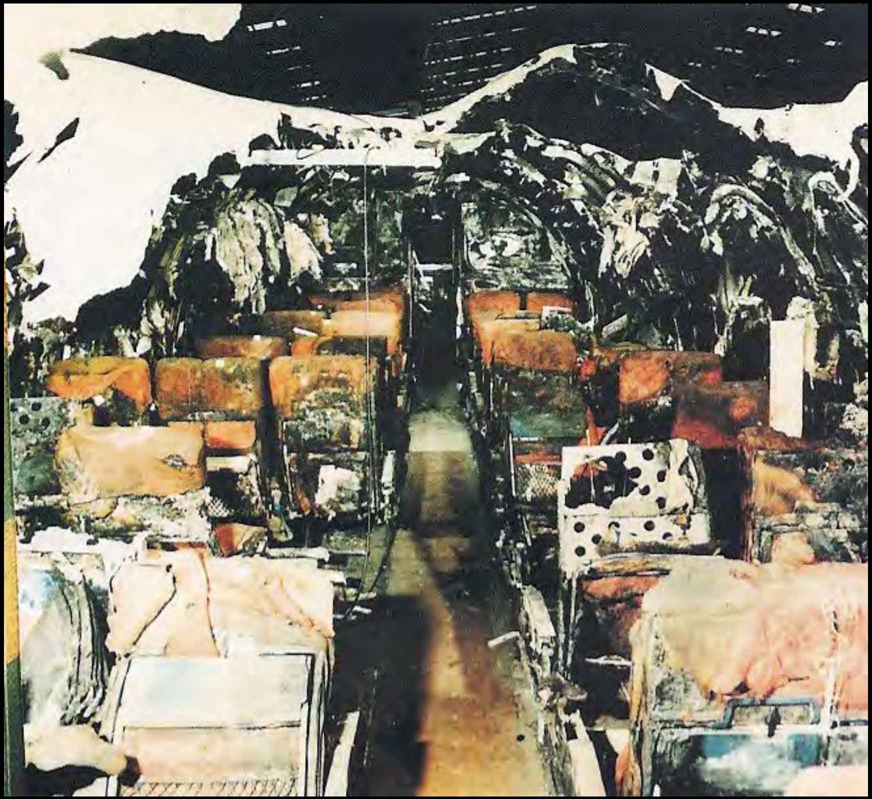
Manchester Accident



Manchester Accident

Manchester Accident

Manchester Accident



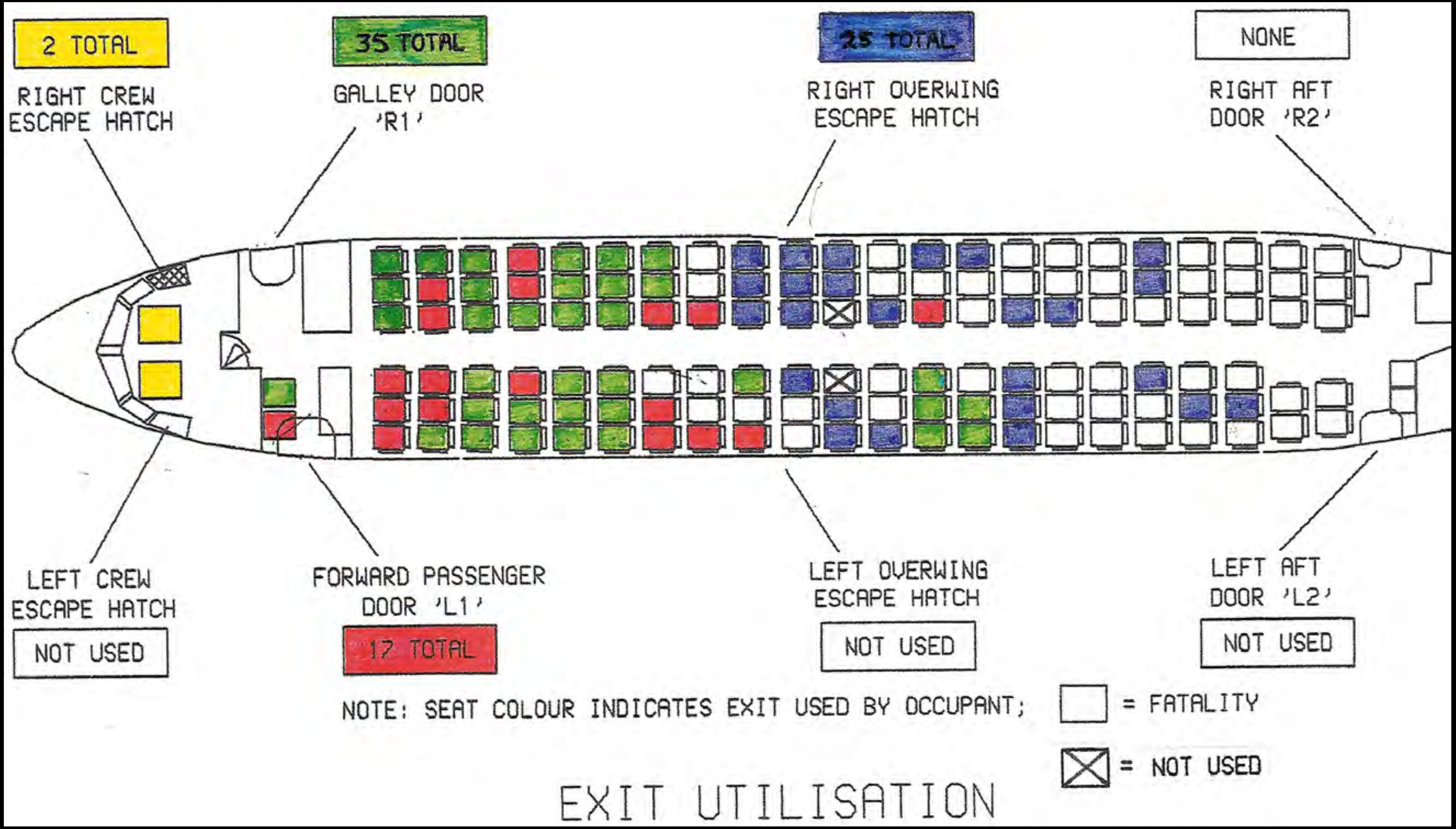
Cabin Interior

View Looking Forward

Cabin Interior

View Looking Aft

Manchester Accident
Exit Utilization



TWA L-1011 New York 7/30/92

Role of FAA Cabin Safety Inspectors (CSIs)

Role of the CSIs

- Parallel to FAA's other Aviation Safety Inspectors
- Serve as resource and technical authority on cabin safety requirements
- Ensure safe and effective performance of flight attendant's duties and responsibilities
- Ensure assigned operators comply with applicable FAR's, FAA policy and guidance as well as approved programs

CSI's
Duties & Responsibilities

- Technical Administration
- Certification
- Surveillance
- Investigation

Duties & Responsibilities Technical:

- Serve as technical advisor to Principal Operations Inspector
- Participate in special projects to improve cabin safety policies and procedures
- Administer FAA policy and guidance to assigned operators
- Ensure operator training facilities are adequately staffed, and conduct flight attendant training as required by FAR and FAA approved program

Duties & Responsibilities Certification:

- Review and recommend approval of manuals and revisions related to assigned cabin safety programs
- Perform initial certification of new operators in all cabin safety related areas
- Participate in the evaluation of new aircraft type for both manufacturers and operators

Duties & Responsibilities Surveillance:

- Monitor and evaluate training programs to ensure compliance with FAR's and approved programs
- Evaluate and approve cabin simulators, training devices, and other related equipment
- Observe flight attendant work activities by conducting cabin enroute inspections
- Conduct inspection of training and flight attendant duty time/rest requirement records

Duties & Responsibilities Investigation:

- Conduct investigations of public complaints and congressional inquires
- Initiate enforcement action, both operator and passenger, by preparing reports and recommendations on disposition
- Participate in cabin safety related incident and accident investigations of operators

Cabin Safety Website

www.faa.gov/avr/afs/cabinsafety/

Questions ?

Flight Attendant Manuals

Approved vs Accepted

- Approved: FAA regulation requires approval of a document
- Accepted: FAA regulation does not require the operator to have the document approved
  - ✈ *Document generally refers to programs, manuals or checklists*

Flight Attendant Manual

- Preparation
- Content/Consistency
- Distribution and Availability
- Revisions
- Accessible
- Current

Reference: 14 CFR 121.133, 121.135, 121.137

Flight Attendant Manual

- Preparation
- Content
- Distribution and Availability
- Revisions
- Current
- Accessible

Reference: CFR 121.133, 121.135, 121.137

Case Study Manual

- Location: Hartsfield International Airport, Atlanta, GA
- Date: June 8, 1995
- Airplane: DC-9-32
- Operator: Valujet Airlines, Flight 597

NTSB Accident ATL-95-MA-106

Accident Summary

- No. 2 engine experienced an uncontained failure during takeoff
- Takeoff was aborted
- Engine fragments penetrated the cabin, struck a fuel line, and started a fire
- Airplane destroyed by fire

Flight 597 Evacuation

- Pax evacuated via the forward exits as well as 4 overwing exits
- 7 pax minor injuries
- FA in aft jumpseat sustained wounds to left leg and second degree burns to her legs and left arm


Valuje

NTSB Findings

- Flight Attendant training program and manual developed by a contractor
- Paperwork used for initial training did not include tailcone exit drills
- Several errors were noted in the flight attendant manual
- Instructors used manual as guide for training which resulted in several inconsistencies

Responses

- In September 1995
  - 2 CSIs were assigned to the Southern Region
  - ValuJet revised their entire FA manual
  - ValuJet acquired and received FAA approval for a DC-9 tailcone mockup (August)
  - ValuJet completed hands-on training on tailcone exit mock-up

Reference Material

- Air Transportation Operations Inspector's Handbook, Order 8400.10, Vol. 3, Ch. 15, Sec. 6: Preparation of Flight Attendant Manual job aid (http://www.faa.gov/avr/afs/faa/8400/)
- NTSB Accident: ATL-95-MA-106

Flight Attendant Training and Qualification Programs

Types of Training

- Basic Indoctrination
- Initial
- Transition
- Emergency
- Differences
- Recurrent and Requalification

Initiating Approval Process

- Operator initiated
  - ✈ Informs FAA of plans to establish new training or change existing training
- FAA initiated
  - ✈ Based on training techniques, aviation technology, aircraft operational history, operator performance or regulatory changes.

Approval Process
Five Phases

- Phase I : Initiating the approval process
- Phase II: Requesting initial approval
- Phase III: Analysis and evaluation
- Phase IV: Training conducted under initial approval
- Phase V: Granting of final approval

Initial Approval:

- A conditional approval to train flight attendants pending FAA evaluation of training effectiveness.
- Granted by an initial approval letter specifying an expiration date.

Final Approval:

- FAA grants approval to continue training flight attendants in accordance with training program
- Granted by final approval letter and does not have an expiration date

Emergency Training

- Emergency equipment
- Emergency situation
- Emergency drill
- Additional emergency drill requirements

14 CFR 121.417

Cabin Mockups & Door Trainers

- Hands on emergency drill training should be conducted in an approved mockup, training device or static aircraft
- Must be representative of an actual aircraft
  - Forces must closely duplicate normal and emergency conditions with slide (raft) installed
  - Mechanisms and instructions to operate the exits

Case Study
Training Device

- Location: LaGuardia Airport, Flushing, NY
- Date: March 26, 2003
- Airplane: Boeing 717-200
- Operator: AirTran Airways, Flight 356

NTSB Accident NYC03FA067

Accident Summary

- Burning smell in the cabin
- Due to electrical system failure the aircraft received minor damage on landing
- Captain ordered emergency evacuation

Flight 356 Evacuation

- Forward door and window exits worked normally
- Tailcone jettisoned, however, escape slide did not successfully deploy or inflate
- 1 passenger received serious injury
- 22 passengers received minor injuries
- No injuries to crewmembers and 55 passengers

NTSB Findings

- Manual inaccuracies regarding the operation of the slide pack
- Tailcone trainer not representative of actual aircraft

Photos

AirTran DC-9/B-717 tailcone training device at the time of the accident.

Tailcone area of an actual B-717 airplane.

FAR 121.417

- Each crewmember must operate each type of emergency equipment in the normal and emergency modes including the actions and forces necessary in the deployment of evacuation slides

Operator Response

- AirTran conducted differences training
- Obtained and received FAA approval for DC-9 and B-717 door trainers

Case Study
Overpressurized Airplane

- Location: Miami International Airport, FL
- Date: November 20, 2000
- Airplane: Airbus A300-605R
- Operator: American Airlines, Flight 1291

Emergency Evacuation

- 133 people onboard
- Purser opened 1L and was forcibly ejected and killed
- 3 passengers sustained serious injuries
- 18 passengers and 1 flight service director sustained minor injuries

NTSB Recommendations

- Review crew training manuals and programs to ensure procedures address signs and dangers of opening exits in overpressurized airplanes
- Require cabin crew training manuals and programs to contain procedures to follow during an emergency evacuation when the airplane is overpressurized

FAA Response

- Issued guidance via Notice and Handbook
- Recommend that air carriers review training programs and manuals to include:
  - ✈ information about the signs of an overpressurized airplane on the ground
  - ✈ dangers of opening emergency exit doors while the airplane is overpressurized

FAA Response

- Air carriers should develop procedures to be followed in the event of an emergency evacuation in an overpressurized airplane
  - ✈ incorporate these procedures in their crewmember training and manuals

NTSB Safety Recommendation

- Dangers of inflight fires
- How to deal with inflight fires
- Appropriate crewmember training
- Means of extinguishing fires
- Information regarding research

FAA Response

- Issued AC 120-80, Inflight Fires
  - ✈Provides framework for defense against inflight fires
- Issued Notice 8400.70, Availability of AC 120-80, Inflight Fires
  - ✈Recommends use of AC to improve crew training

Reference Material

- Air Transportation Operations Inspector's Handbook, Order 8400.10, Vol. 3, Ch. 14, Sec. 2: Flight Attendant Training Program job aid (http://www.faa.gov/avr/afs/faa/8400/)
- FAA Advisory Circular 120-80, Inflight Fires
- NTSB Safety Recommendation A-01-83 through –87, dated January 4, 2002.
- NTSB Accident: MIA01FA029
- NTSB Accident: NYC03FA067

Evacuation Issues

Jason T. Fedok
Survival Factors Investigator

Why Look at Survival Factors?

- “Everyone dies in airplane crashes.”

ValuJet Flight 592 May 11, 1996

110/110 Fatal

TWA Flight 800 July 17, 1996

230/230 Fatal

National Transportation Safety Board

USAir Flight 427 September 8, 1994

132/132 Fatal

SwissAir Flight 111 September 2, 1998

229/229 Fatal

National Transportation Safety Board

EgyptAir Flight 990 October 31, 1999

217/217 Fatal

Alaska Airlines Flight 261 January 31, 2000

88/88 Fatal

National Transportation Safety Board

Air France Flight 4590 July 25, 2000

109/109 Fatal

American Airlines Flight 587
November 13, 2001

251/251 Fatal

Video

United Airlines
Flight 232
July 19, 1989

185/296
Survived

USAir Flight 5050 September 20, 1989

61/63 *Survived*

USAir Flight 1493   February 1, 1991

67/101 *Survived*

USAir Flight 1016 July 2, 1994

20/57 *Survived*

American Airlines Flight 1420
June 1, 1999

134/145 *Survived*

Why Look at Survival Factors?

- “Everyone dies in airplane crashes.”
- Not true!
- Disproportionate media attention for large, mass fatality accidents
- Flying public does not realize that many accidents are survivable

What Is An "Accident?"

- 49 Code of Federal Regulations §830.2
  - Intention of flight
  - Any person suffers death or serious injury
  - Aircraft receives substantial damage
- What's a "serious" injury?
- What's "substantial damage?"

What Is A "Reportable Event?"

- 49 Code of Federal Regulations §830.5
- About a dozen criteria
- From survival factors perspective:
  - (4) In-flight Fire
  - (7) For large multiengine aircraft (>12,500 lbs takeoff weight):
    - (iv) An evacuation in which an emergency egress system is utilized

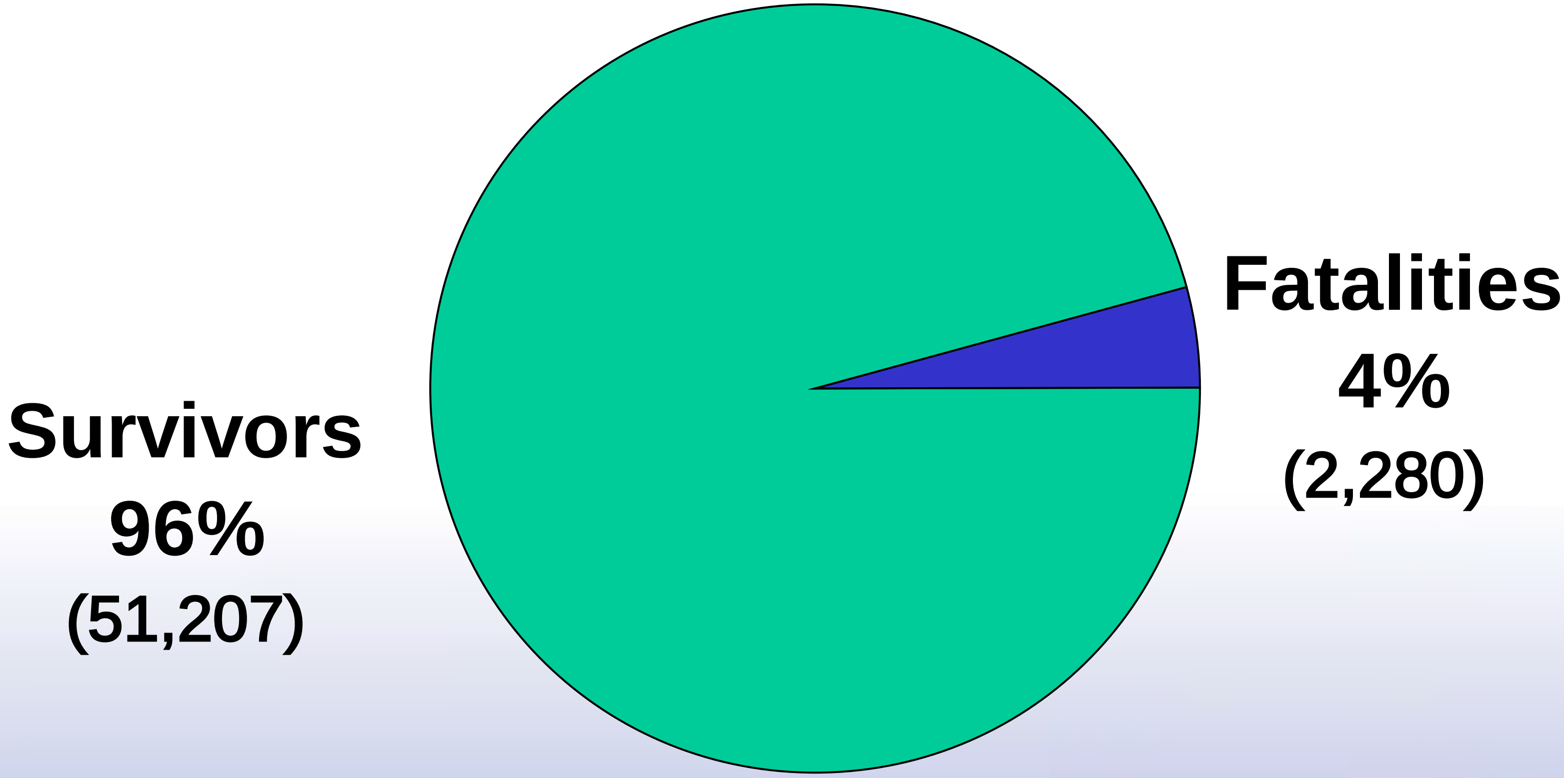
Why Look at Survival Factors?

- Not only are many accidents survivable, but…
- The most recent review (1983-2000) of survivability data indicate that most occupants survive accidents in the U.S.
- Many improvements in occupant protection are a result of survival factors investigations

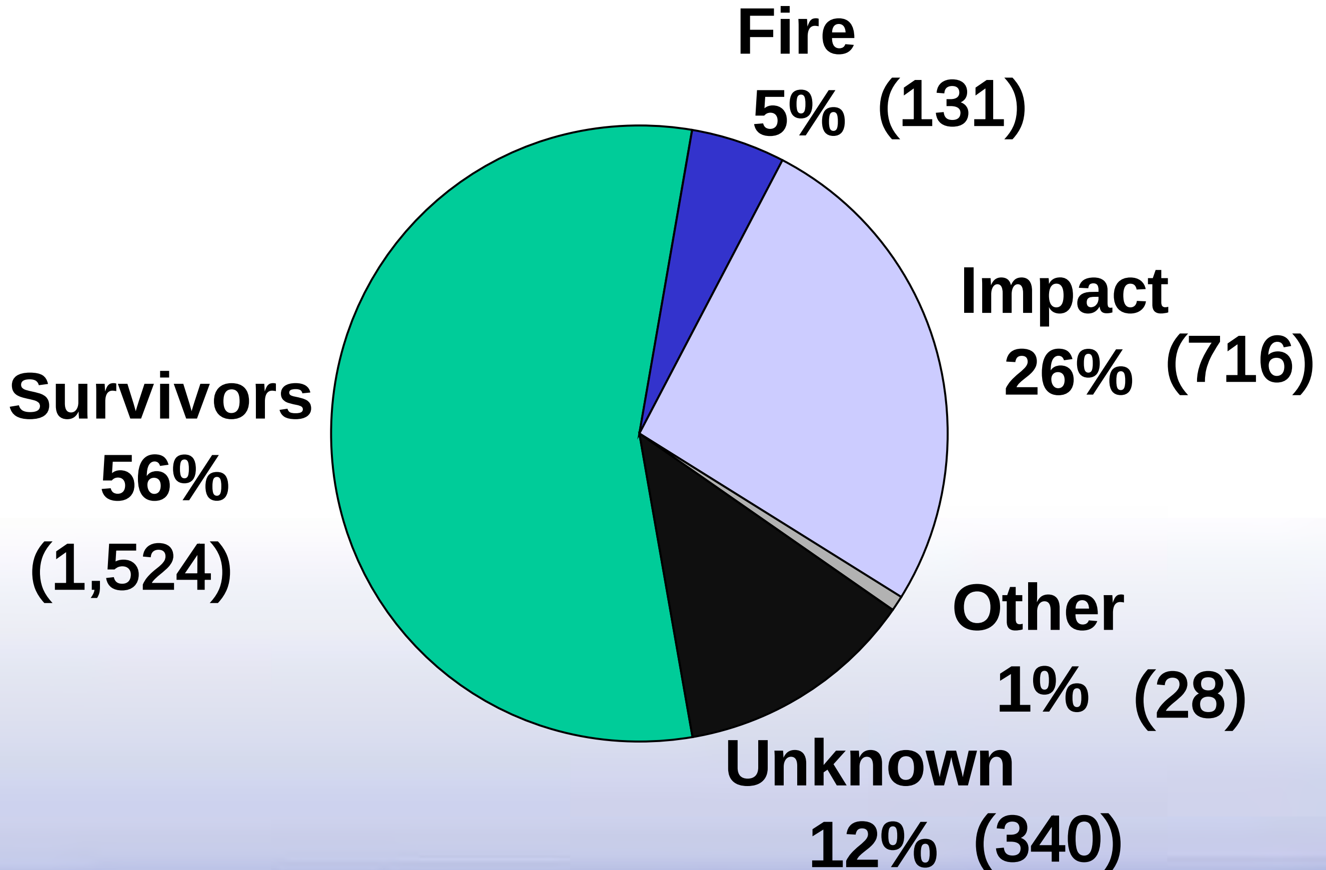
What Percentage of Occupants Survive All U.S. Part 121 Accidents?

- A. 43%
- B. 55%
- C. 76%
- D. 96%

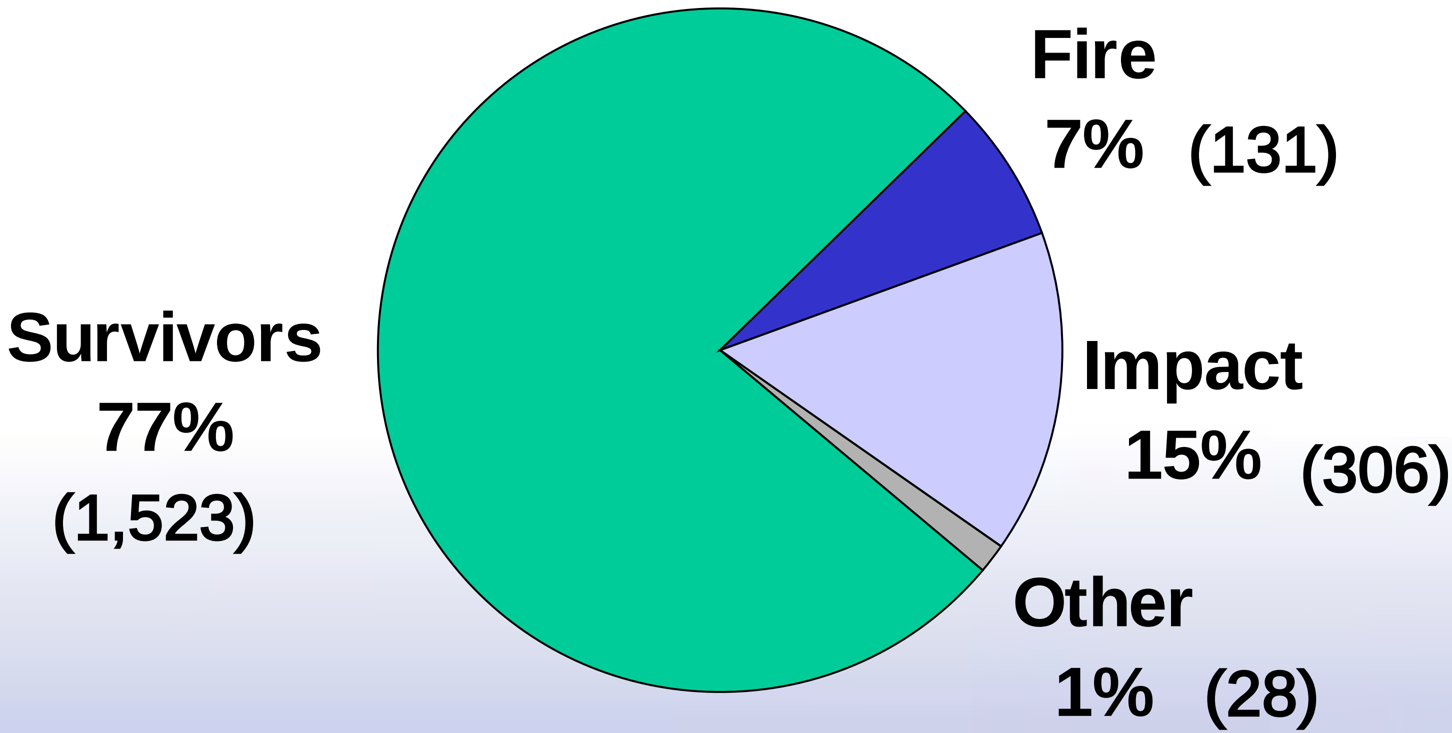
Occupant Survival for All U.S. Part 121 Accidents 1983-2000 (568)



Occupant Survival for Serious Part 121 Accidents (26)



Occupant Survival for Survivable-Serious Part 121 Accidents (19)



Survivable Accident

- Forces transmitted to occupants through the seat and restraint system cannot exceed the limits of human tolerance
- Structure in the occupants' immediate environment must remain substantially intact to the extent that a livable volume is provided throughout the crash

Why Look at Survival Factors?

- Probable Cause
  - Rarely involved with Probable Cause of accident
  - We look at cause of injury and explain injuries in context of accident
  - In some cases (i.e. turbulence) if you prevent a serious injury, you will prevent an accident

Evacuation Investigations

- Notification
  - Often to field office
    - Determination made whether to investigate
    - May involve AS-60
- When will AS-60 investigate evacuations?
  - Slide or slide/raft failures
  - Injuries
  - Other unique circumstances

Evacuation Investigations

- Initial Report
  - Often wrong!
- Make contact with airline/FAA/airport personnel
  - Any problems with slides? If so, quarantine!
- Have pictures taken prior to airplane movement (if possible)
- Respond to scene (if necessary)
  - SF Group Vs. SF Specialist

Evacuation Investigations

- Do interviews ASAP (F/As, ARFF, passengers, maintenance personnel, etc.)
- Document airplane
  - Doors, slide/rafts, evacuation systems, emergency equipment
- Document emergency response
- Document injuries
  - Passenger questionnaires

Evacuation Study (2000)

- Often asked how often evacuation occur in the U.S. and how many people are injured
- Study was first of its kind
- Examined all Part 121 evacuations for a 16-month period

Evacuation Study (2000)

- Injury Results
  - 46 evacuations; 2,846 occupants
  - 2,614 uninjured (92%)
  - 170 minor injuries (6%)
  - 11 serious/fatal injuries (2%)
- w/o Little Rock
  - 105 minor (.03%), 6 serious (.002%)

AAL Flight 1420
Little Rock, AR
June 1, 1999

AAL 1420 Little Rock, AR

- MD-82
- 2 flight crew, 4 F/As, 139 passengers
- Landed during Level 6 thunderstorm
- Departed end of runway, over a rock embankment, an struck approach lighting structure
- Airplane broke apart, immediate post-crash fire
- Captain and 10 passengers killed

Animation

Initial Reports

- Seats failed
- Overhead bins fell
- Flight attendants “panicked”
- Emergency lights failed
- ARFF slow to respond


American

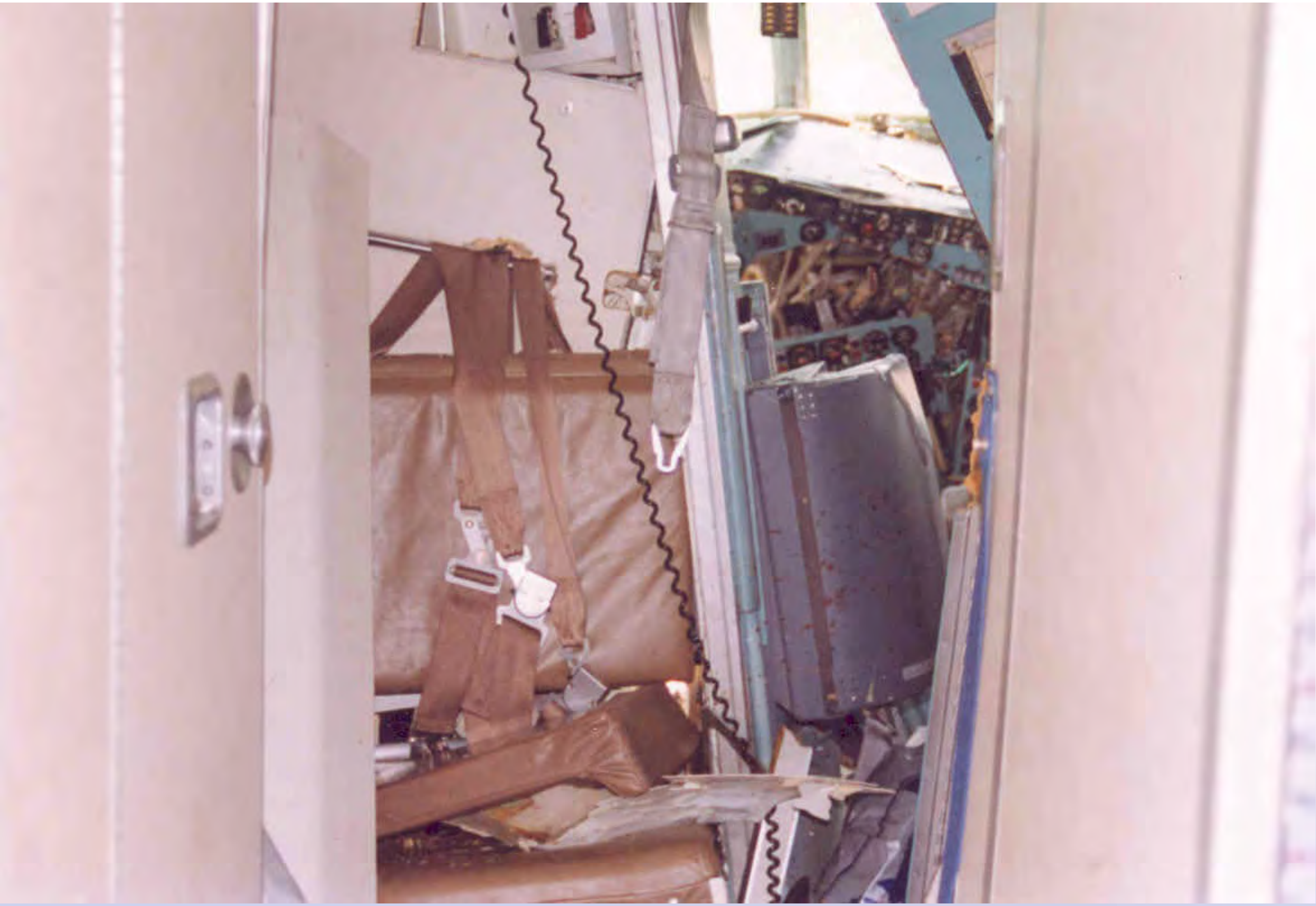

American


American


AA

National Transportation Safety Board


215AA




OPEN


AUDIO VOLUME
MUSIC
OFF
ANNOUNCE
PUSH
CALL
PILOT
ATT
RESET
LIGHTS
LOWER SIDEWALL
OFF
UPPER SIDEWALL
OFF
ENTRY
ATT
AISLE
MIRROR
PAX SEAT POWER
EMERGENCY LIGHTS


EXIT

National Transportation Safety Board


14
13

National Transportation Safety Board


15
14

Conclusions about Injuries and Fatalities

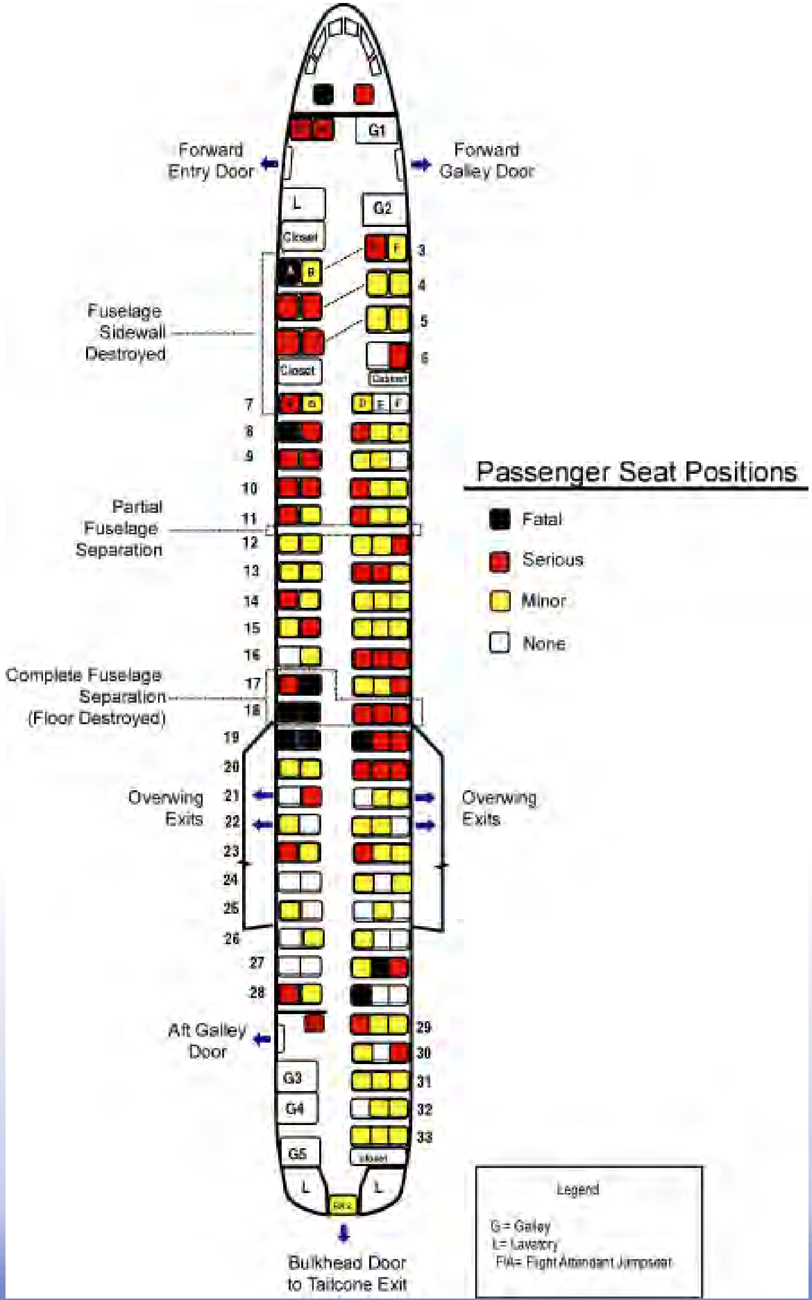
- Based on medical records, passenger questionnaires, and autopsies

-139 passengers, 2 flight crew, 4 cabin crew

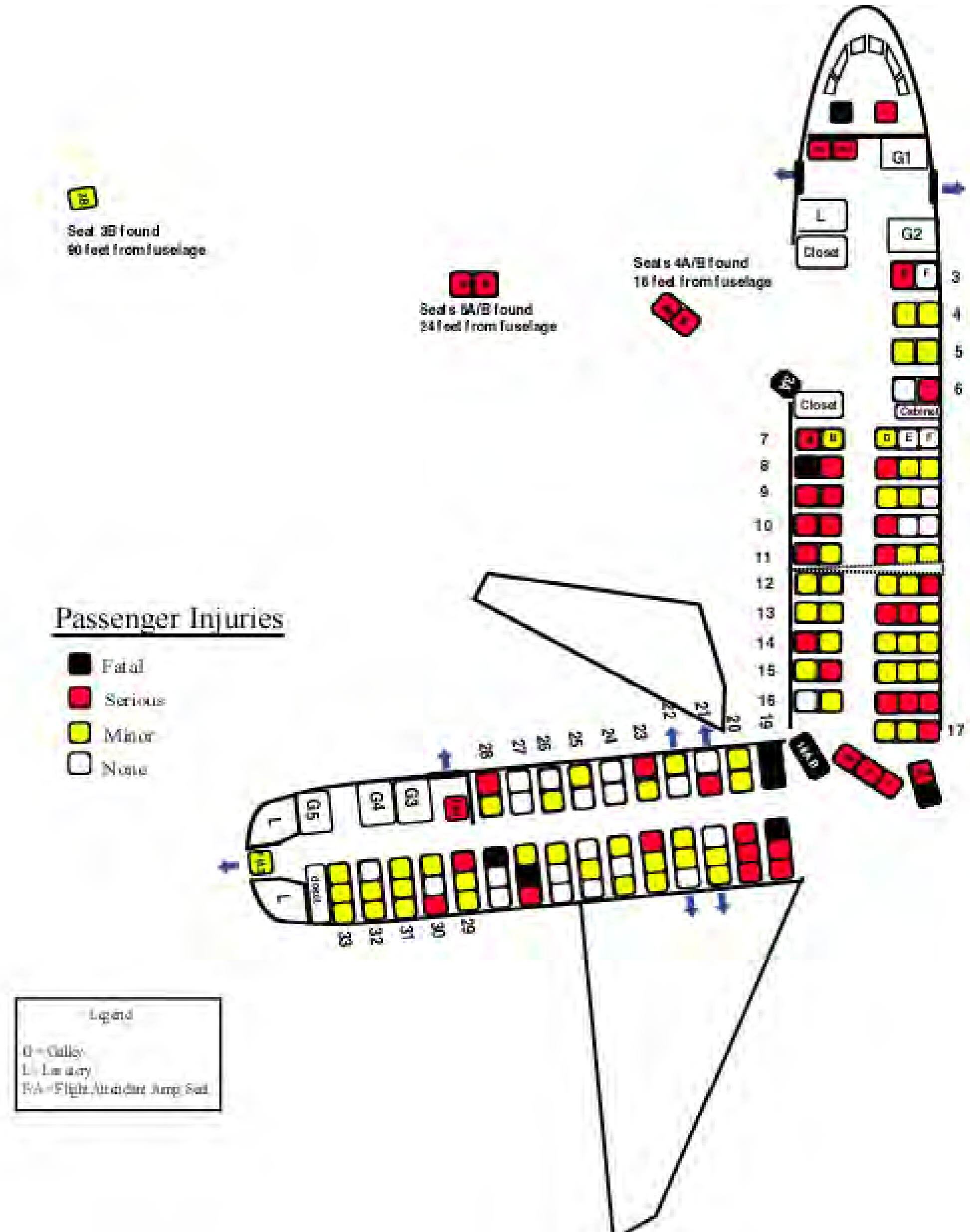
-11 fatal, 45 serious, 65 minor, 24 none

-Fatalities: 6 trauma, 5 fire/smoke

-2 fatalities during evacuation



National Transportation Safety Board



Seat 3B found
90 feet from fuselage
Seats 5A/B found
24 feet from fuselage
Seats 4A/B found
18 feet from fuselage
G1
L
G2
Closet
Closet
Cabinet
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
G3
G4
G5
Passenger Injuries
Fatal
Serious
Minor
None
Legend
G = Galley
L = Lavatory
FA = Flight Attendant Jump Seat

AAL Flight 574
San Juan, PR
July 9, 1998

San Juan, PR (July 1998)

- A300 experienced #1 engine fire shortly after takeoff
- Returned to SJU and evacuated passengers on runway
- Four left side exit not usable due to fire
- Initial report: slide at door 3R failed to deploy

Slide/Raft Problems

- Involve manufacturer immediately
- Pictures, pictures, pictures…
- Quarantine
- Usually will respond to scene
- Attempt to recreate problem
- Sometimes easy to diagnose, often not


DUE DATE


-3 YEARS
OVERHAUL DUE DATE
TO INFLATE

Video


American


LuxuryLiner


American

National Transportation Safety Board


AA
Am


Emergency opening
1. Pull cover aside
2. Lift lever to »Open« and push door firmly outward and forward to fully open position
Pull cover to open
Escape slide
EXIT
American
FOR YOUR


DO NOT SIT HERE
A300
AmericanAirlines
FOR YOUR SAFETY


EXIT
Open
FLTCHECK ONLY


EXIT

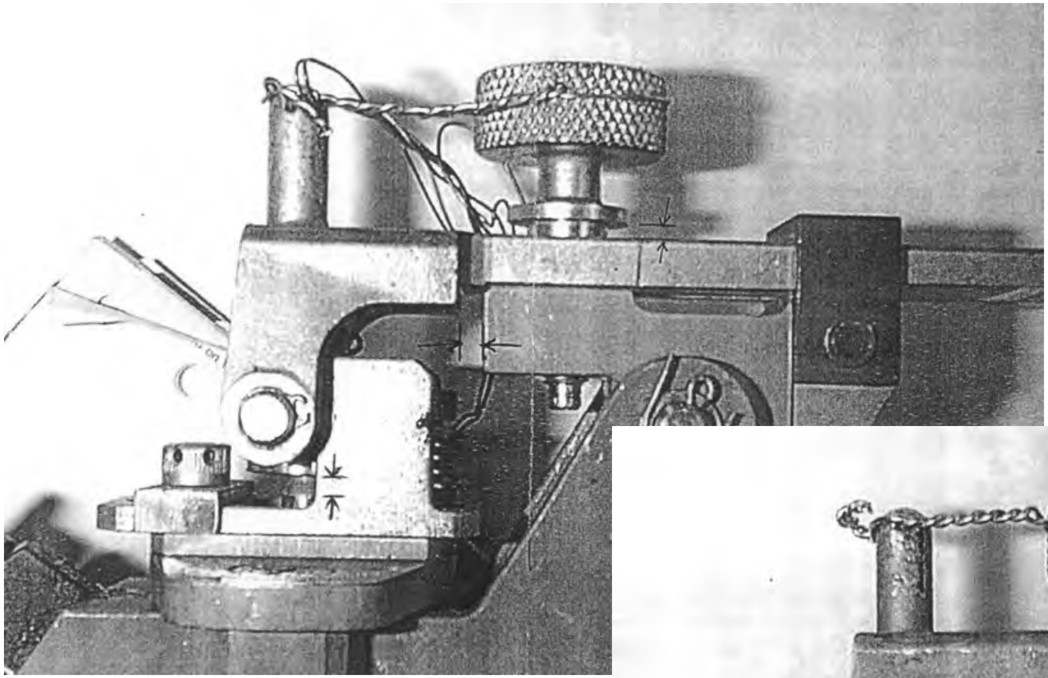
National Transportation Safety Board

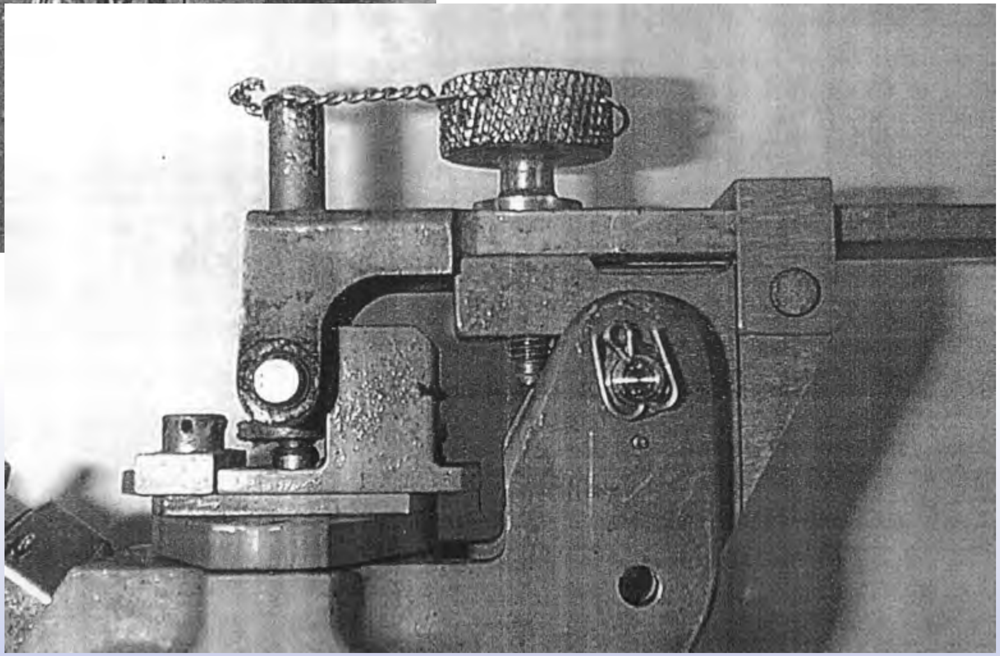
National Transportation Safety Board

Amer


A300
AmericanAirlines


DUE DATE





Manchester, UK (March 1998)

- During taxi, F/A reported strong odor of fuel in cabin
- On return to gate, ATC advised flight crew they appeared to be venting fuel
- Flight crew asked for ARFF to respond
- ARFF confirmed fuel leak and fire in #2 engine
- Captain eventually ordered evacuation

Video

Manchester, UK (March 1998)

- Findings
  - All 8 doors were opened, 6 slide/rafts functioned as designed
  - 3L off-wing slide did not inflate
  - 1R slide/raft exhibited low inflation pressure requiring the use of ground personnel to maintain usable attitude

Greensboro, NC (August 2000)

- During climbout (~10,000 ft) from GSO, flight crew noticed "sulfuric" smell
- Thick black smoke began to enter cockpit from CB panel behind captain
- Returned to GSO, evacuated 56 passengers on taxiway

Video

Guatemala City (April 1993)

- On landing, B-767-200 departed wet runway and traveled down a hill before impacting several private residences
- Approximately 224 persons on board, 9 minor injuries
- Left overwing slide compartment did not open and slide did not deploy

Video

JFK, NY (August 2002)

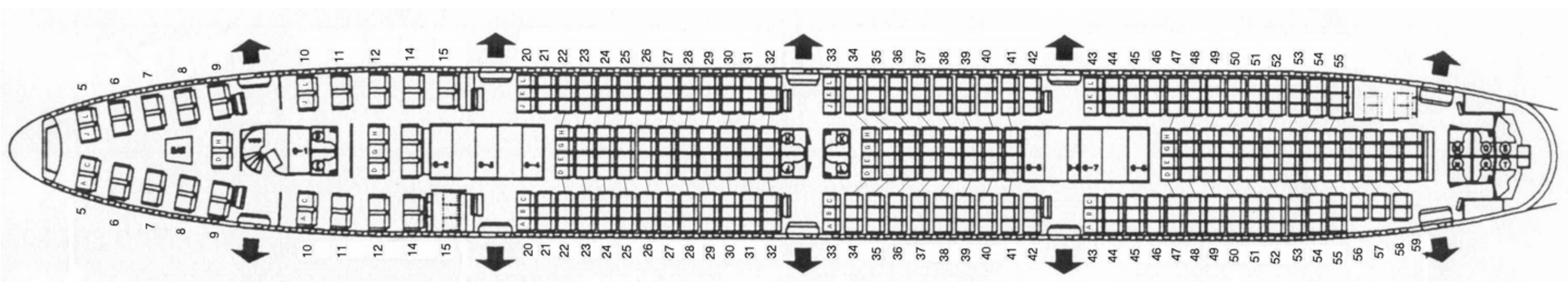
- B-747-200 experienced #2 engine fire after takeoff
- Returned to JFK and evacuated passengers on runway
- Five left side exits not usable due to fire
- 4R and 5R slide/rafts did not operate as intended


IBERIA
IBERIA

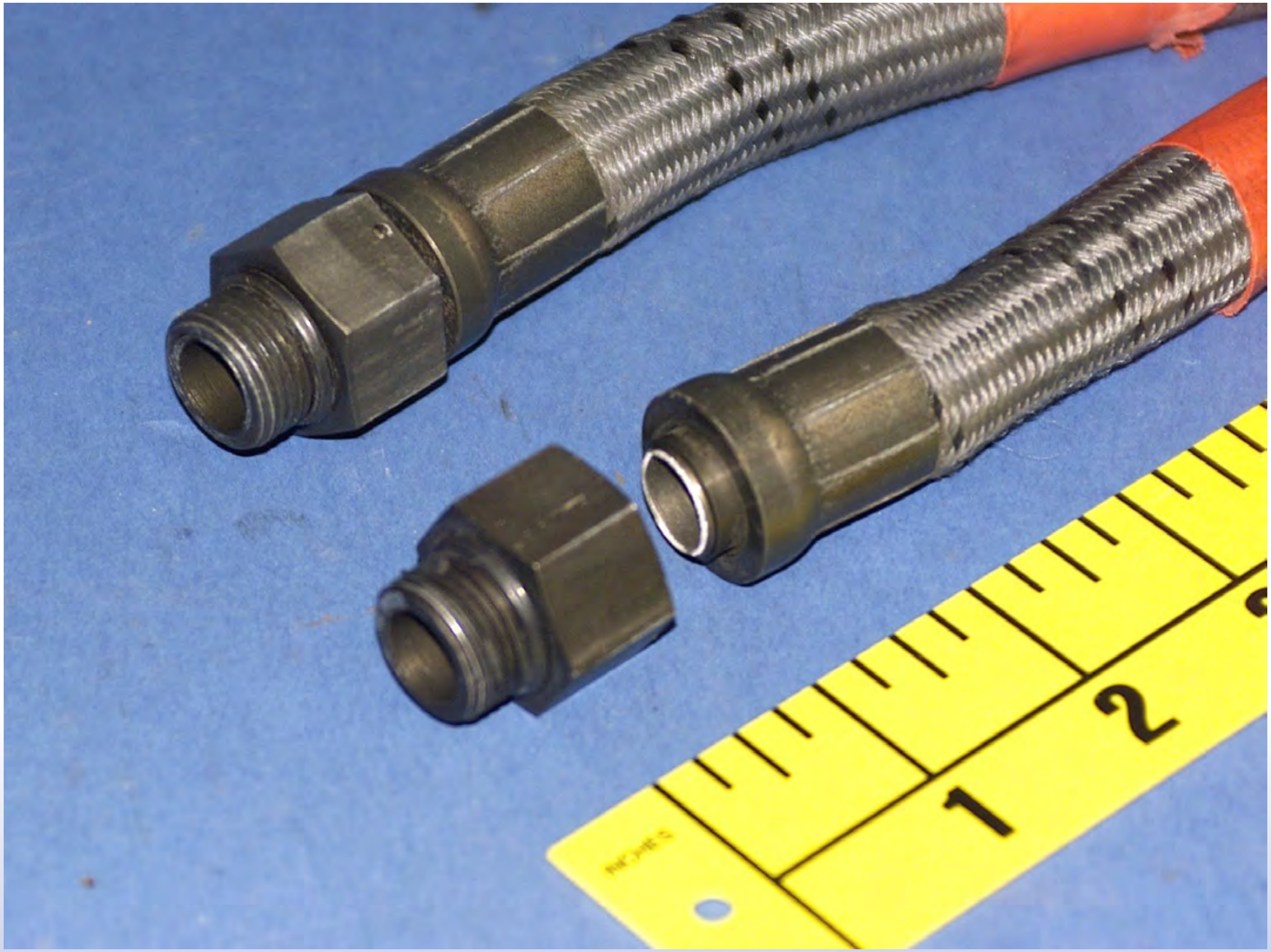

EC-DNP
POLICE EMERGENCY


1620
1580
1540

Videos




ARNING
13 12:08PM



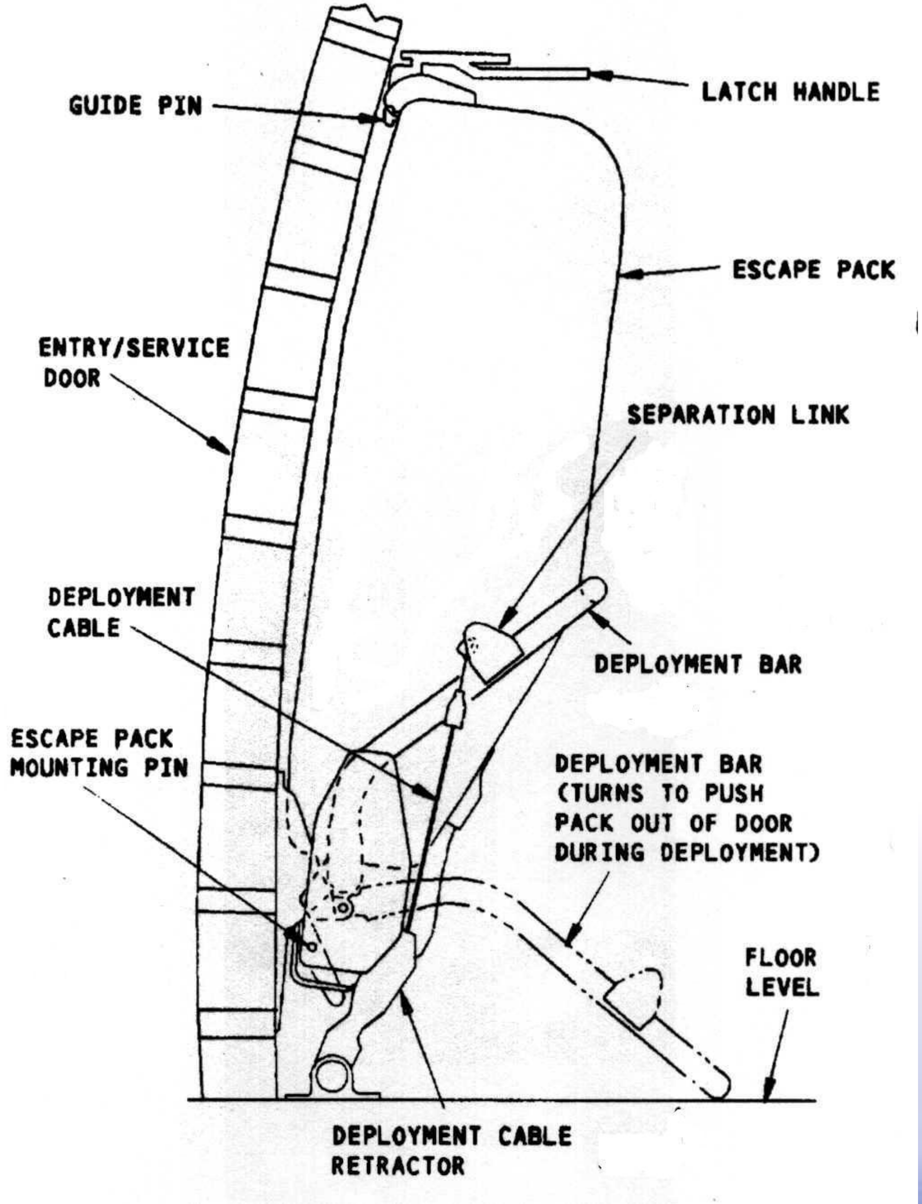
1
2

Dulles, VA (July 2001)

- B-767-300 rejected takeoff after loud bang and loss of thrust from #1 engine
- Exited onto taxiway and evacuated after ATC advised of smoke on left side of airplane
- Door 2L opened approximately 2.5 feet (slide/raft deployed and inflated normally)


N655UA


4
3

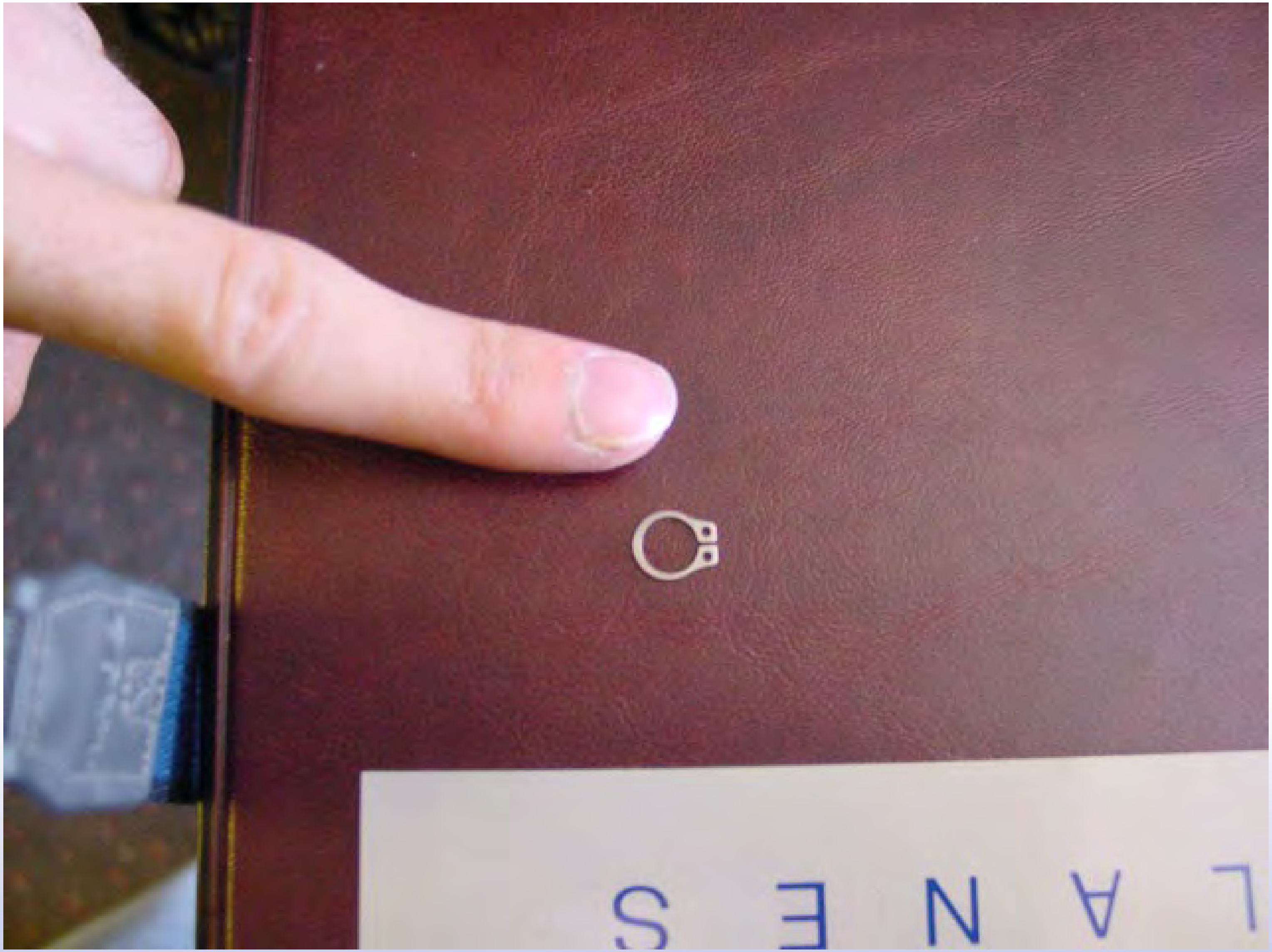


LATCH HANDLE
GUIDE PIN
ESCAPE PACK
ENTRY/SERVICE DOOR
SEPARATION LINK
DEPLOYMENT CABLE
DEPLOYMENT BAR
ESCAPE PACK MOUNTING PIN
DEPLOYMENT BAR (TURNS TO PUSH PACK OUT OF DOOR DURING DEPLOYMENT)
FLOOR LEVEL
DEPLOYMENT CABLE RETRACTOR


CORRECT ASSEMBLY


CORRECT


INCORRECT



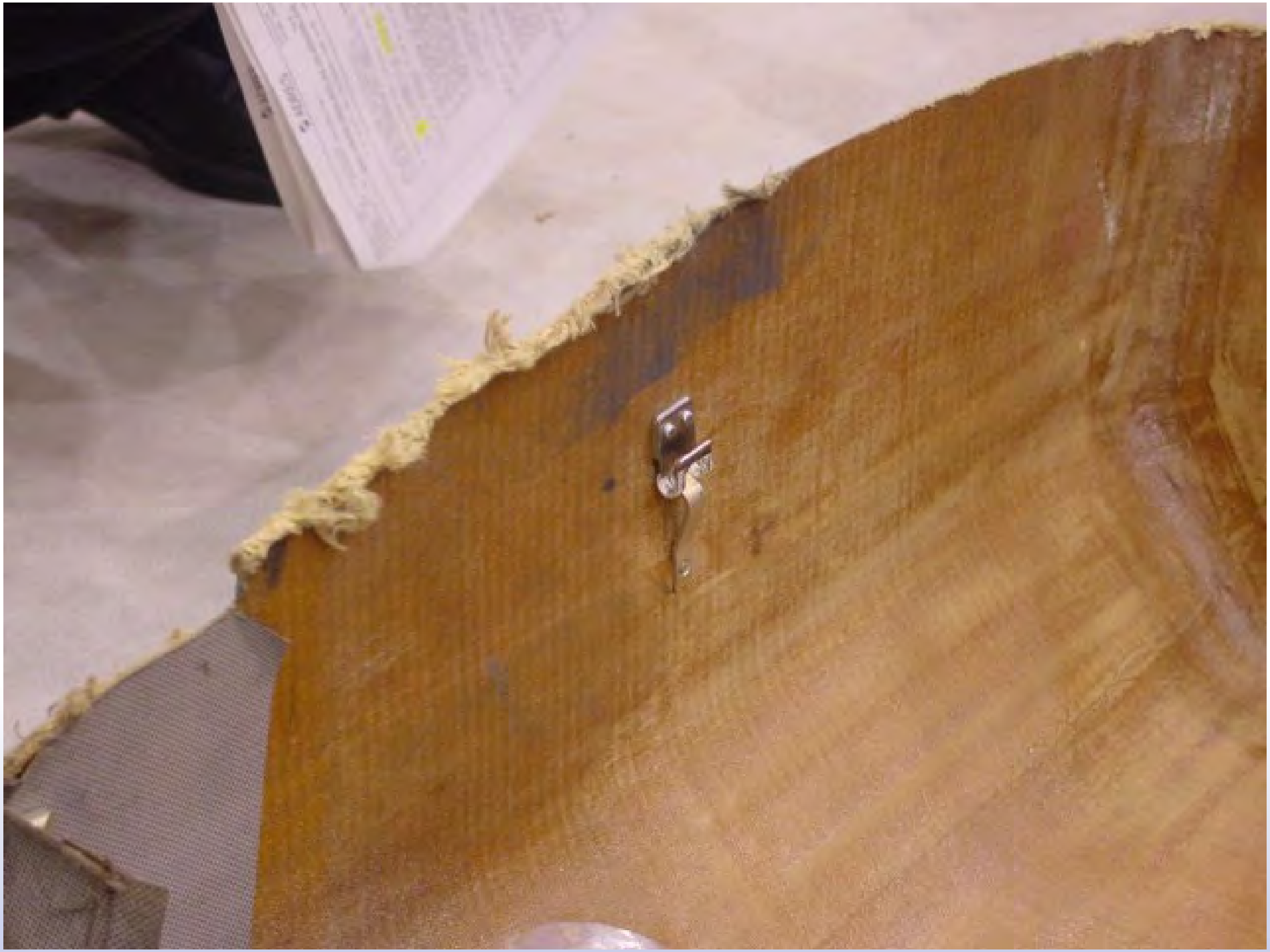
Detroit, Michigan (March 2001)

- A320 performed rejected takeoff and ran off runway
- All exits opened during evacuation
- Evacuation slide/raft at door 2L separated from airplane when door was opened
  - Pack fell to ground with girt bar and did not inflate


N357NW


QUARANTINED PARTS
DO NOT REMOVE OR DISTURB CONTENTS WITHOUT CONTACTING JOHN KELLY
AOG
PROPERTY OF NORTHWEST AIRLINES

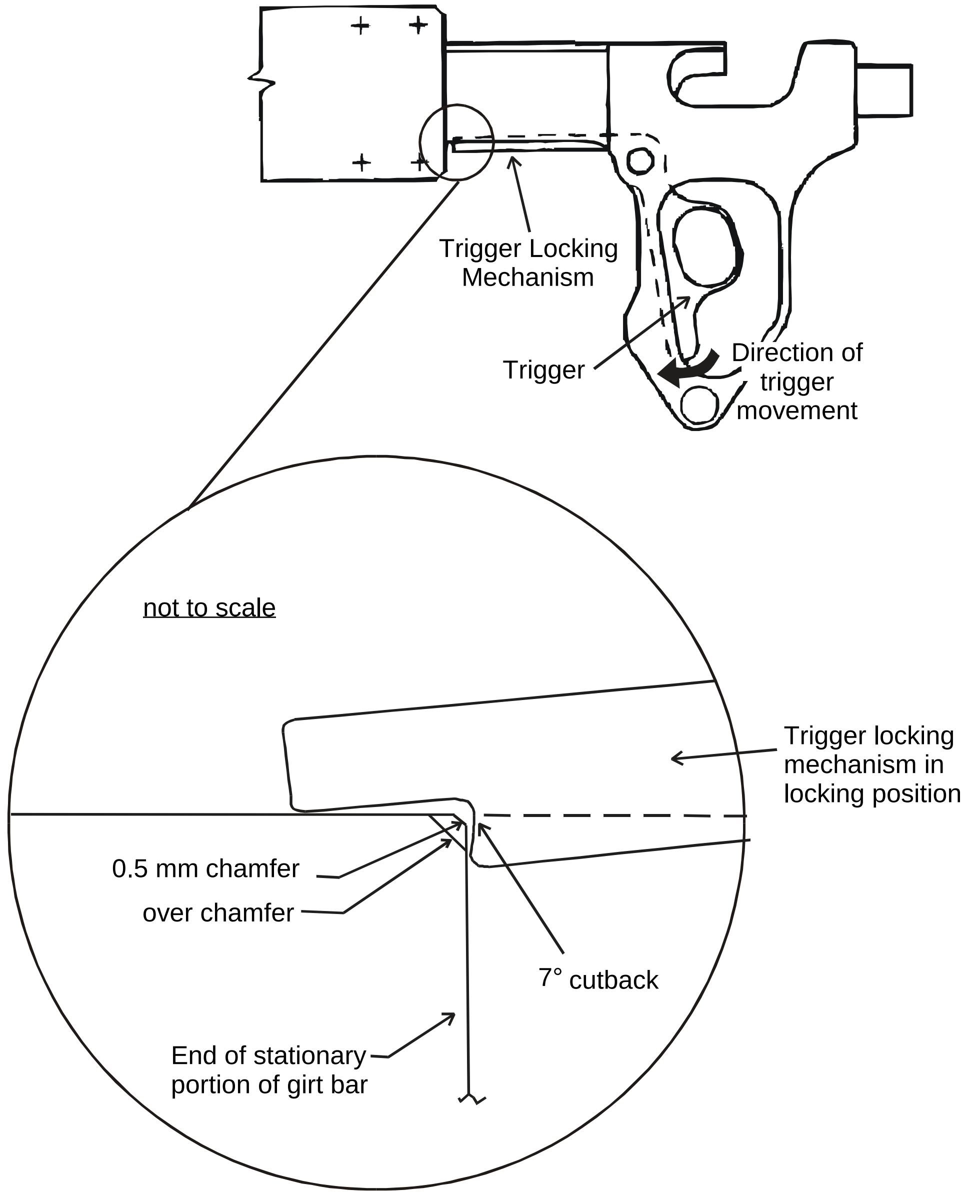

DECORATIVE COVER
SLIDE



National Transportation Safety Board

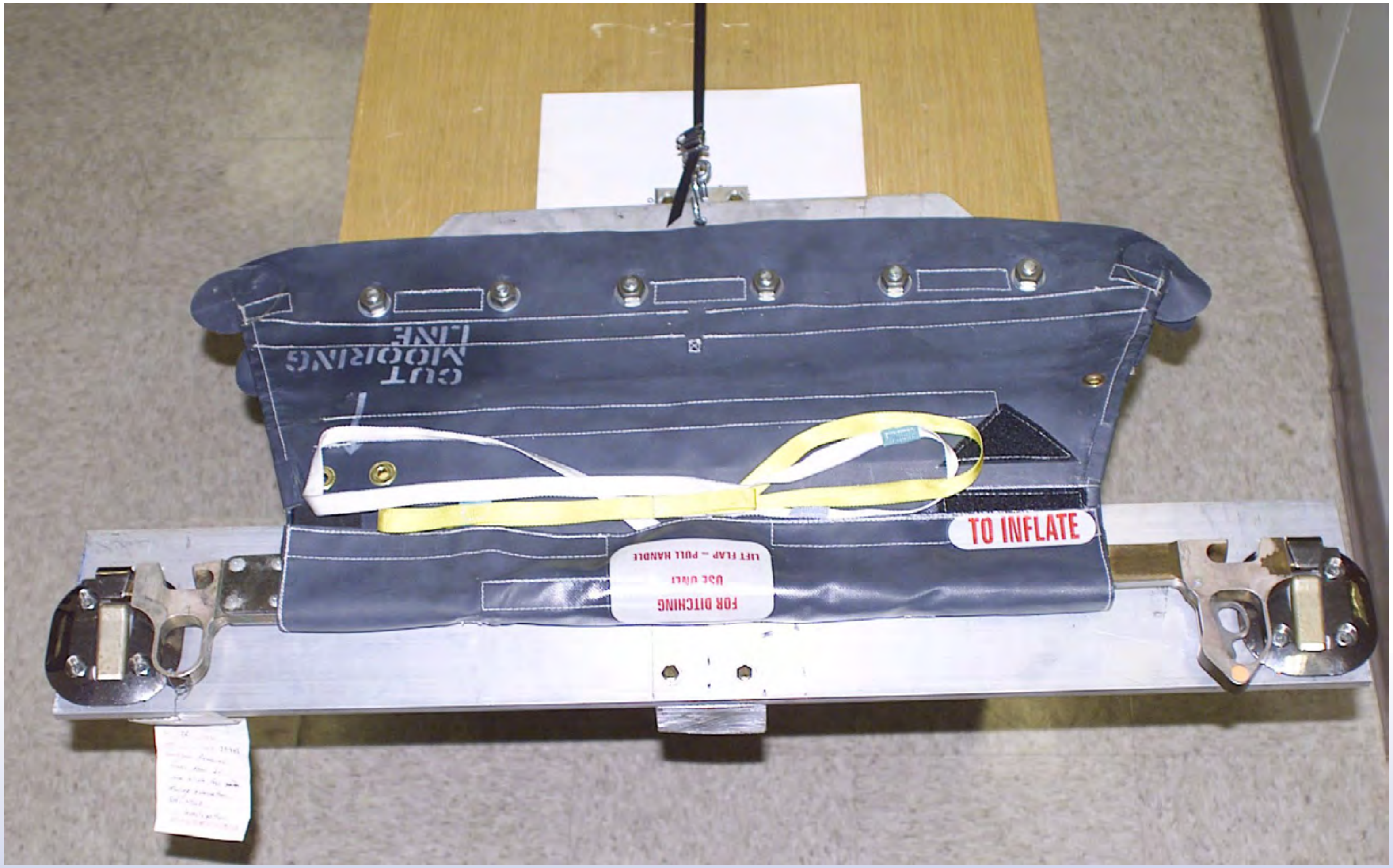

1
MADE IN USA
2
3
4
5
6
7


ARMED

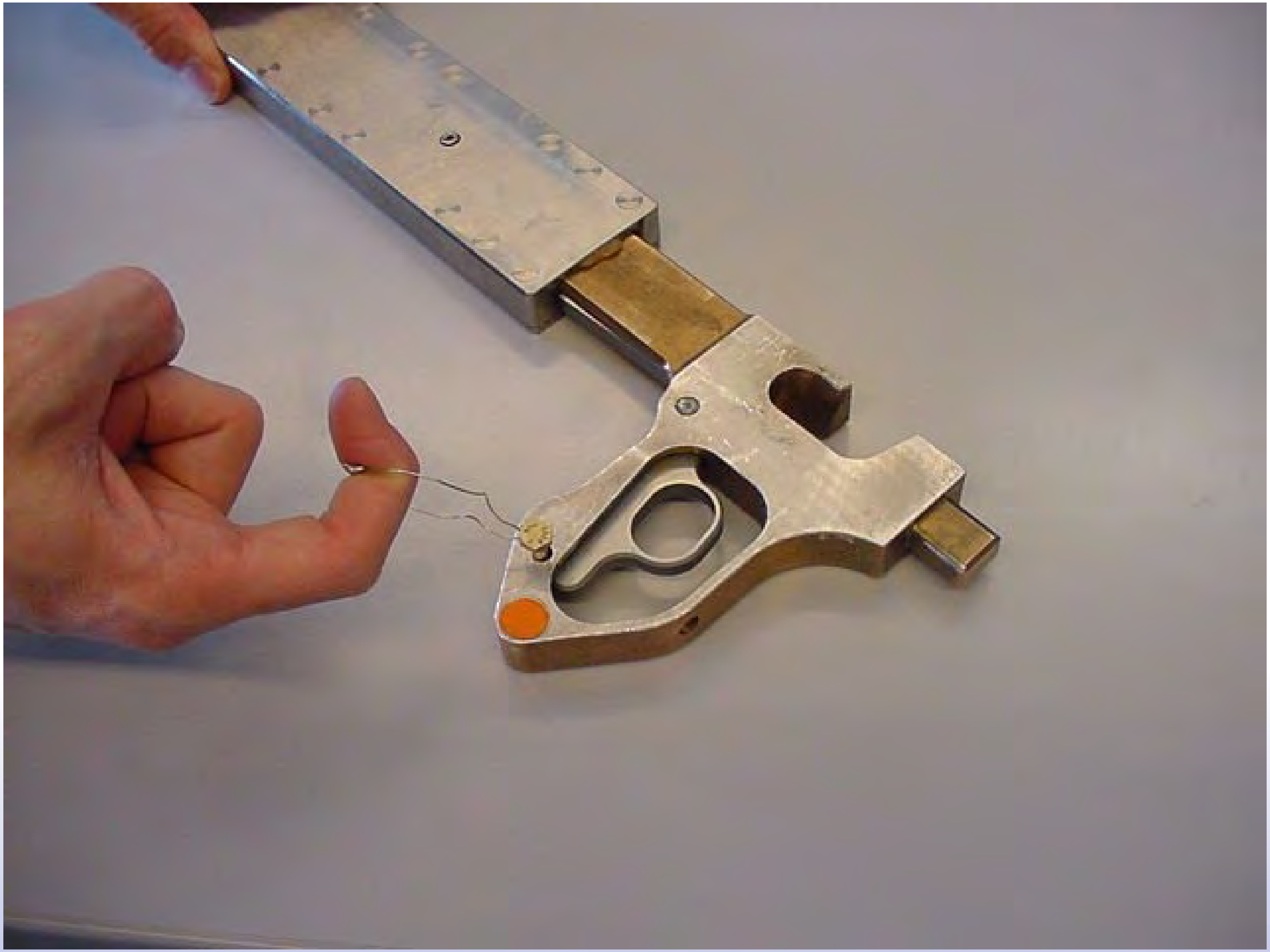


Trigger Locking Mechanism
Trigger
Direction of trigger movement
not to scale
Trigger locking mechanism in locking position
0.5 mm chamfer
over chamfer
7° cutback
End of stationary portion of girt bar

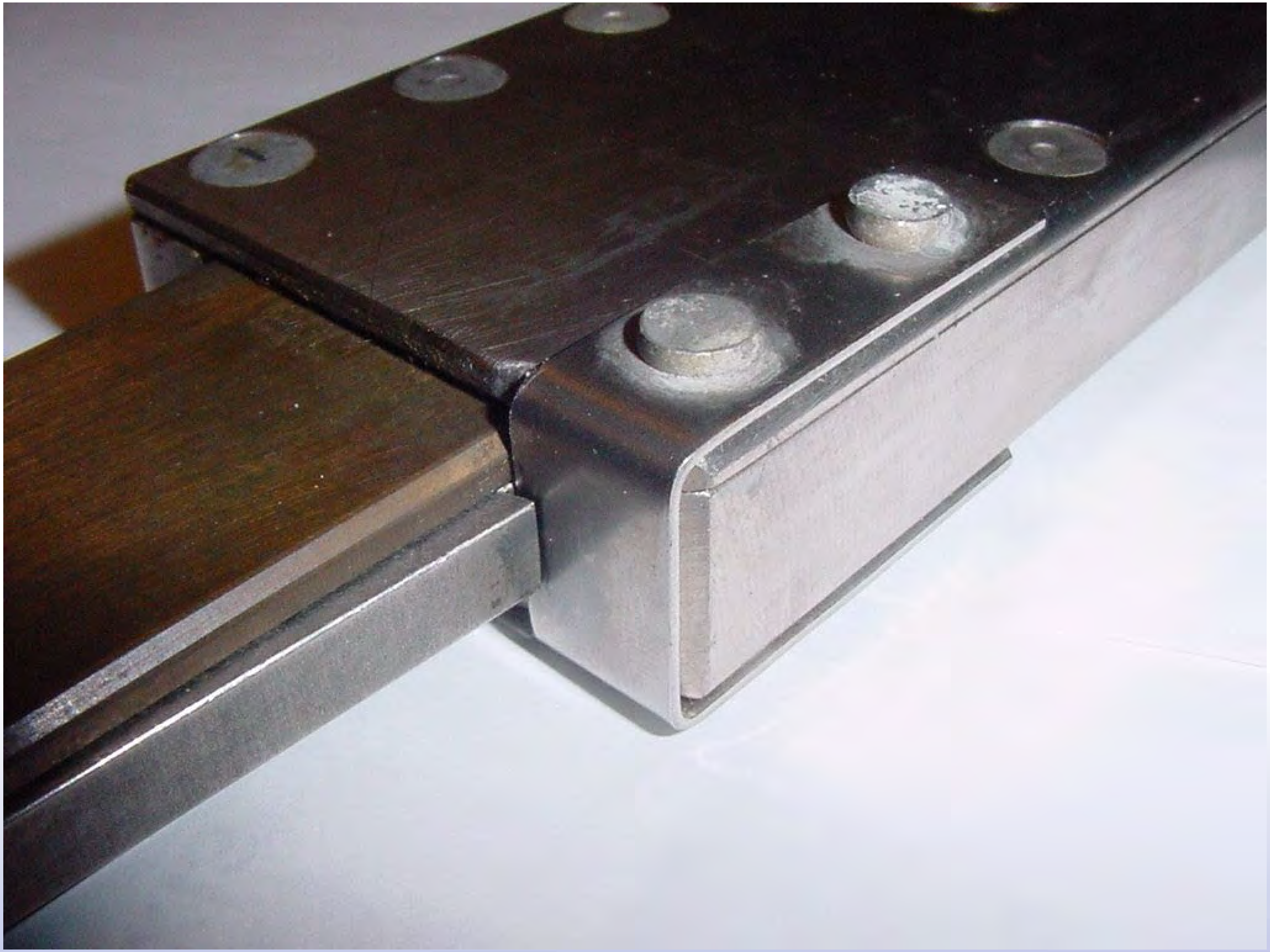

1 MADE IN USA 2 3 4 5 6 7


CUT MOORING LINE
TO INFLATE
FOR DITCHING
USE ONLY
LIFT FLAP — PULL HANDLE


CUT
MOORING



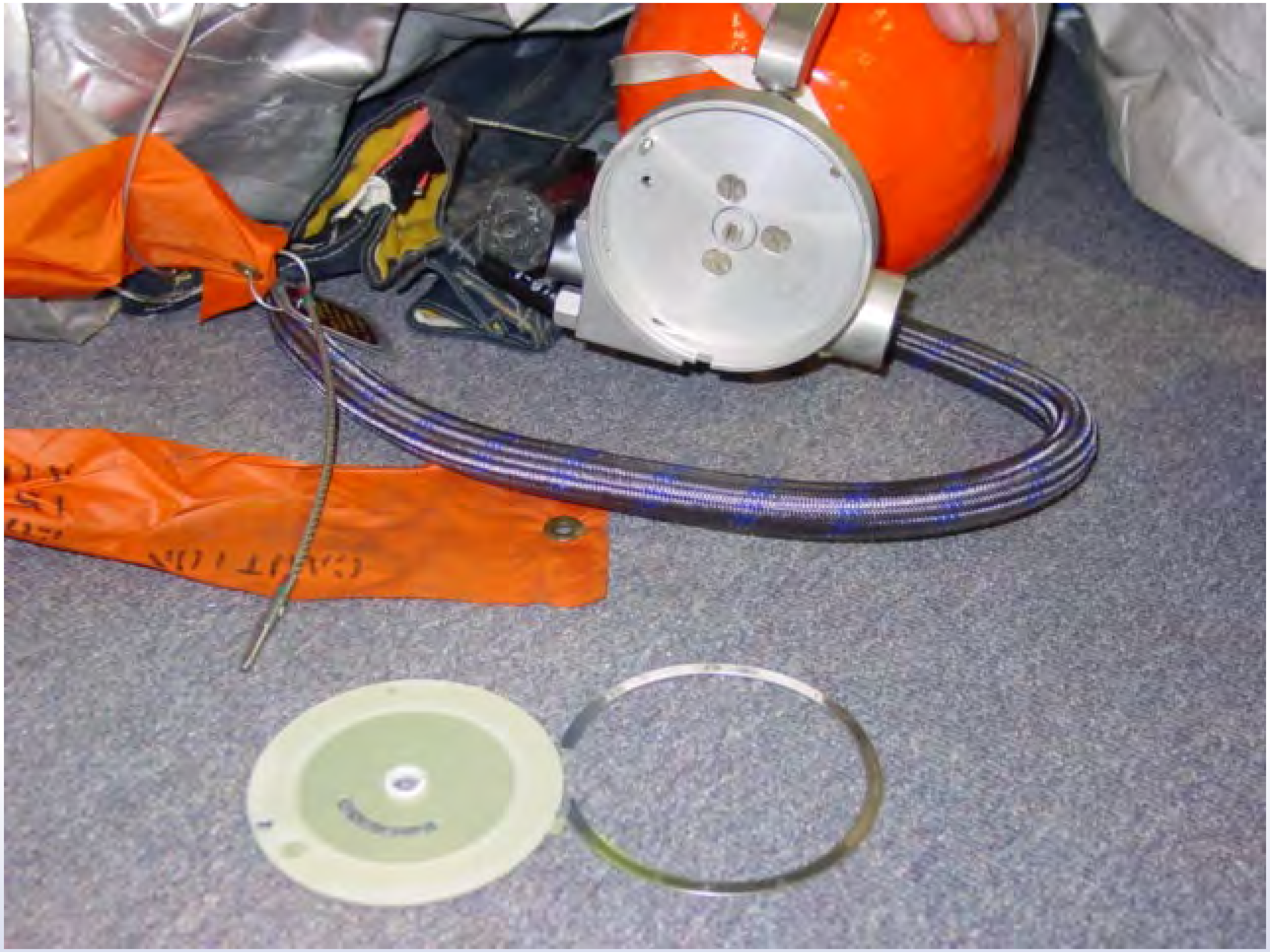

ARMED



Oakland, CA (April 2003)

- A300
- Smoke in cockpit on takeoff; returned to OAK and evacuated
- 1R slide partially deployed; no automatic inflation
- Manual inflation attempted without success


TO ARM-INSERT
CABLE, PUSH PAWL.
ALIGN PIN & MARK




TO ARM-INSERT
CABLE, PUSH PAWL
ALIGN PIN & MARK

Tampa, FL (July 2003)

- 757-200 experienced tailpipe fire on ramp after pushback
- Initial reports suggested a passenger initiated evacuation
  - F/A reportedly assaulted
- Two passengers sustained serious injuries


SACS-DVMS403
E-44
06/23/03, 07:10:08.10
song


SACS-DVMS403
E-44
06/23/03, 07:10:18.03

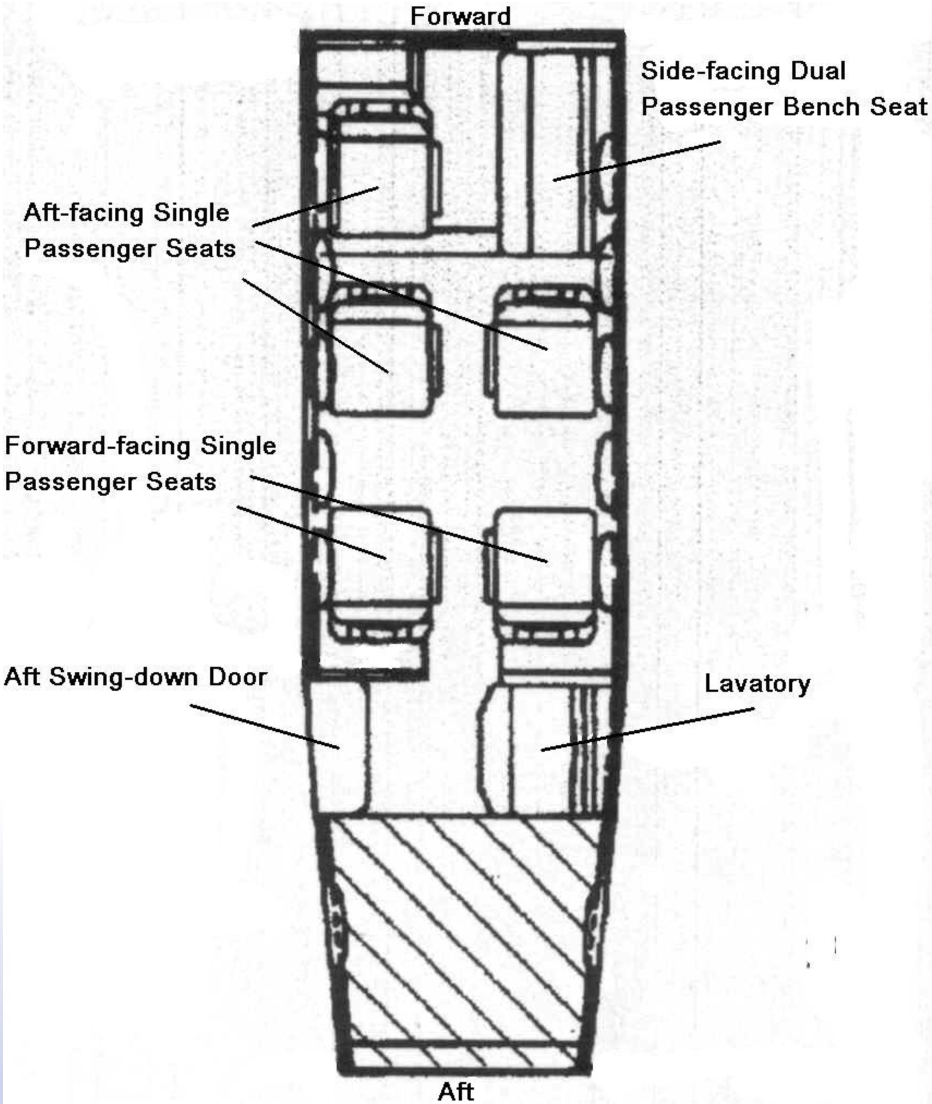

Delta

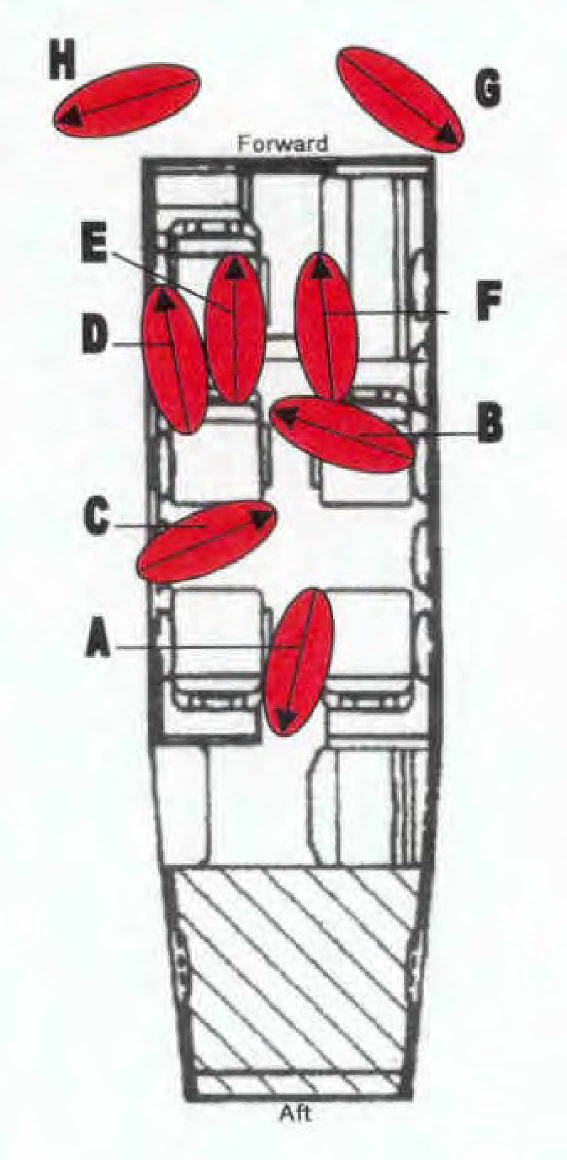

Delta

Video

Beech King Air A100
Eveleth, MN
October 25, 2002

National Transportation Safety Board


Forward
Side-facing Dual Passenger Bench Seat
Aft-facing Single Passenger Seats
Forward-facing Single Passenger Seats
Aft Swing-down Door
Lavatory
Aft

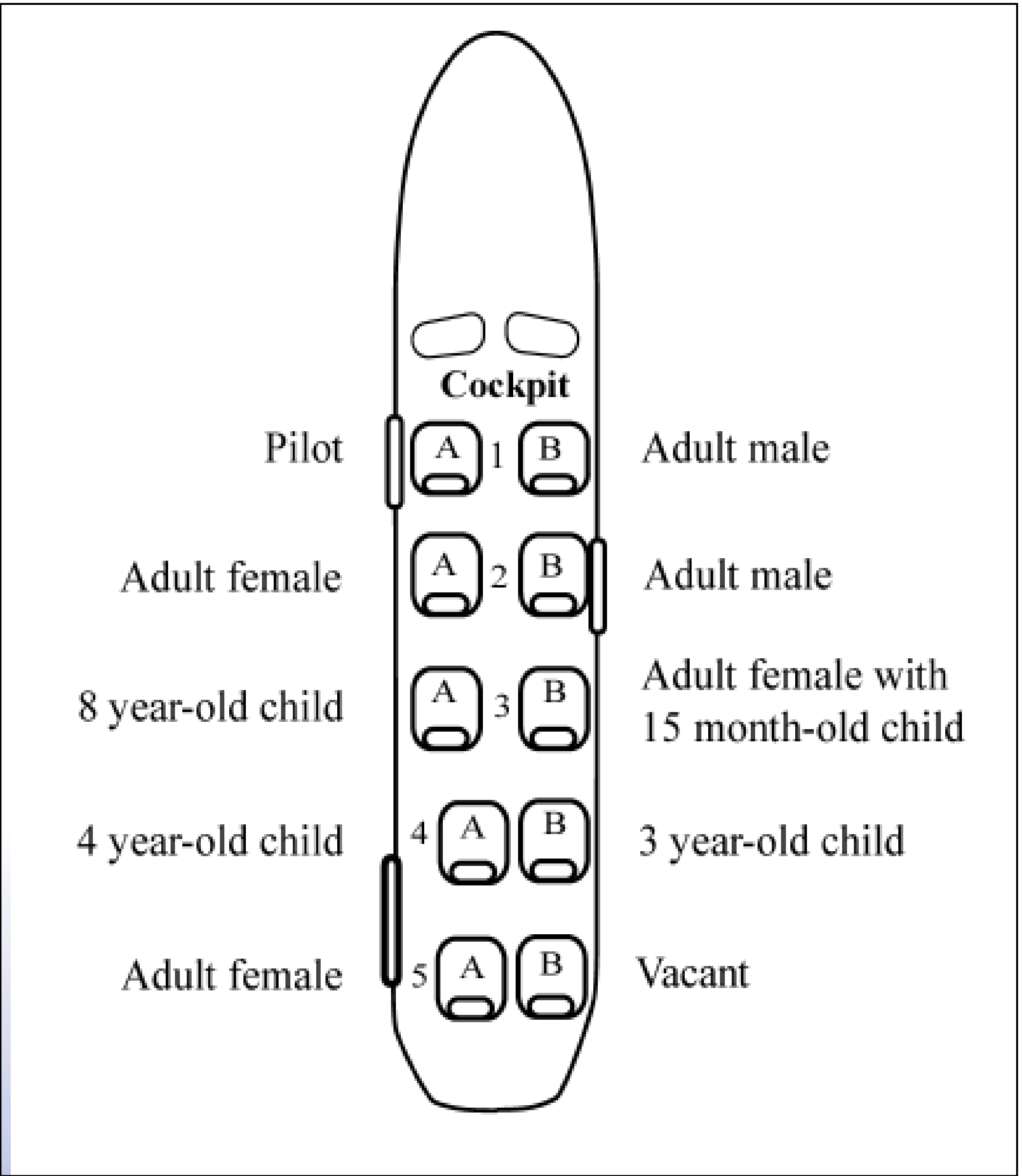

H
G
Forward
E
F
D
B
C
A
Aft

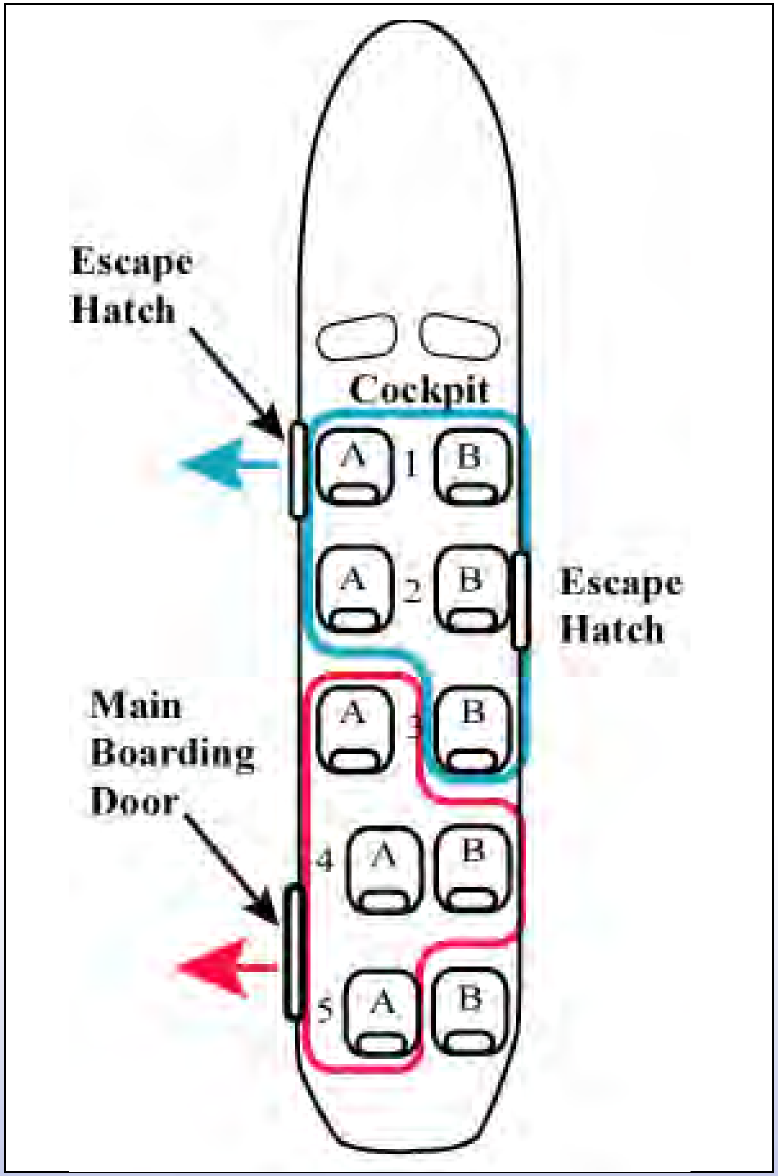
Air Sunshine flight 502

- July 13, 2003
- 6 miles west of Treasure Cay, Bahamas
- Cessna 402
- 9 passengers and 1 pilot on board
- 2 fatalities; 5 minor injuries

Air Sunshine flight 502

- Ft. Lauderdale to Treasure Cay, Bahamas
- Pilot gives passengers pre-flight briefing, including location of life vests
- Right engine quits running – airplane continues for 7 to 8 minutes, then ditches in the ocean
- Pilot does not tell passengers to retrieve life vests
- Female passenger retrieves 3 life vests – places them on her children
- One additional passenger retrieves life vest before evacuating airplane


Cockpit
Pilot
A
1
B
Adult male
Adult female
A
2
B
Adult male
8 year-old child
A
3
B
Adult female with
15 month-old child
4 year-old child
4
A
B
3 year-old child
Adult female
5
A
B
Vacant



Escape
Hatch
Cockpit
A
1
B
A
2
B
Escape
Hatch
Main
Boarding
Door
A
3
B
4
A
B
5
A
B

Air Sunshine flight 502

- Additional life vests dropped from other airplanes
- Coast Guard jet dropped 2 life rafts – not used
- Coast Guard helicopters from US rescue passengers ~ 2 hours following ditching
- Female passenger and 4-year-old seen floating face down almost immediately after evacuation
- No life vests donned properly


SHINE
N314


AIR SUNSHINE

How the Investigation Proceeds

- Circumstances of the accident.
  - What happened?
- Operational requirements
  - Extended overwater?
  - Parts 91, 135, 121
    - Required equipment
    - Required procedures
- Equipment performance
  - Technical Standard Orders (TSOs)
  - Adequacy of performance standards

Guide
to Seat Documentation Exercise

- Why document seats and restraint systems?
  - Permanent record of how certain designs and concepts actually perform in an accident.
  - Correlate seat/restraint performance with injuries.

Guide to Seat Documentation Exercise (continued)

- Tools you will need
  - Interior diagram – preferably, from the operator
  - Post-it notes and Sharpie-type pen
  - Tape measure
  - Camera
  - Notebook (descriptions and pictures)
  - Biohazard suit
  - Partner - preferably, an expert

Guide to Seat Documentation Exercise (continued)

- What to note:
  - General condition of seat
  - Data plate
  - Seat back
  - Cushions
  - Tray table
  - Arm rests
  - Attitude

Guide to Seat Documentation Exercise (continued)

- Document all:
  - Dents, cracks, bends, breaks, fire damage
    - Describe location on seat
    - Describe extent of damage.
      - Measure it
      - Estimate it
      - Draw a picture

Guide to Seat Documentation Exercise (continued)

- Structural components
  - Seat tubes
  - Spreaders
  - Legs,
  - Luggage racks
  - Floor attachments
  - Seat track
  - Floor

Guide to Seat Documentation Exercise (continued)

- Restraint systems
  - Document manufacturer and part number and if they work or not.
  - Lap belt? Shoulder harness? 4-point? 5-point?
  - Inertia reels
  - Buckle
  - Adjusters
  - Condition of belt material
  - Attachment points

Uncommanded Release of a Rotary Seatbelt Buckle

Accident Summary

- January 8, 2003, 8:47 a.m. EST
- Charlotte-Douglas Intl Airport, NC (CLT) to Greensville-Spartanburg (GSP)
- Beechcraft 1900D operated by Air Midwest
- 19 passengers and 2 flight crew - fatal injuries, and one person on ground – minor injury
- Multiple blunt force trauma

Accident Site Findings

- First Officer's body found restrained in his seat.
- Captain's body found ejected 4 feet in front of cockpit
- Another Air Midwest Pilot informed NTSB about an uncommanded seatbelt buckle release
- ALPA also reported five other similar events
- Crewmember seat positions

National Transportation Safety Board

Follow up Investigative Work

- Pacific Scientific Buckle Designs
  - Rotary buckle equipped with circular handle and four vanes
- Ground test of a Beech 1900D
  - The crew restraint was released when a person, who was same height as the captain, was seated in the captain's seat and pulled aft and rotated the yoke.


FEB 24 2003


FEB 24 2003

Additional Findings

- Initially discovered during a flight test of a Boeing 737-400 in the U.K. in early 90s
- Found during a maneuver requiring the full aft movement of control column
- Clipboard attached to the yoke inadvertently unlatched the seatbelt and shoulder harness
- Boeing & CAA requested a redesign of the buckle


FEB 24 2003

Pacific Scientific Service Bulletin

- July 23, 1992, SB 1117032-25-02 Recommended the installation of a new guarded buckle in Boeing airplanes with Pacific Scientific restraint systems.
- July 10, 1993, the CAA issued AAD 007-10-93 requiring installation of guarded buckles on all Boeing airplanes with PS restraints.

Review of a Ditching Accident

Ditching of Sight-Seeing Flight

- August 25, 2000
- Hilo, Hawaii
- Big Island Air (BIA)
- Piper PA-31-350
- Lost power to right engine
- Ditched into Hilo Bay, Hawaii
- 1 fatality, 8 minor injuries


BIG ISLAND AIR
N41073

BIA Accident Findings

- Extruded rubber seal was found between the R. engine oil filter base and engine accessory section
- Excessive oil leakage from the right engine
- R. propeller could not be feathered

Survival Factors Issues Identified

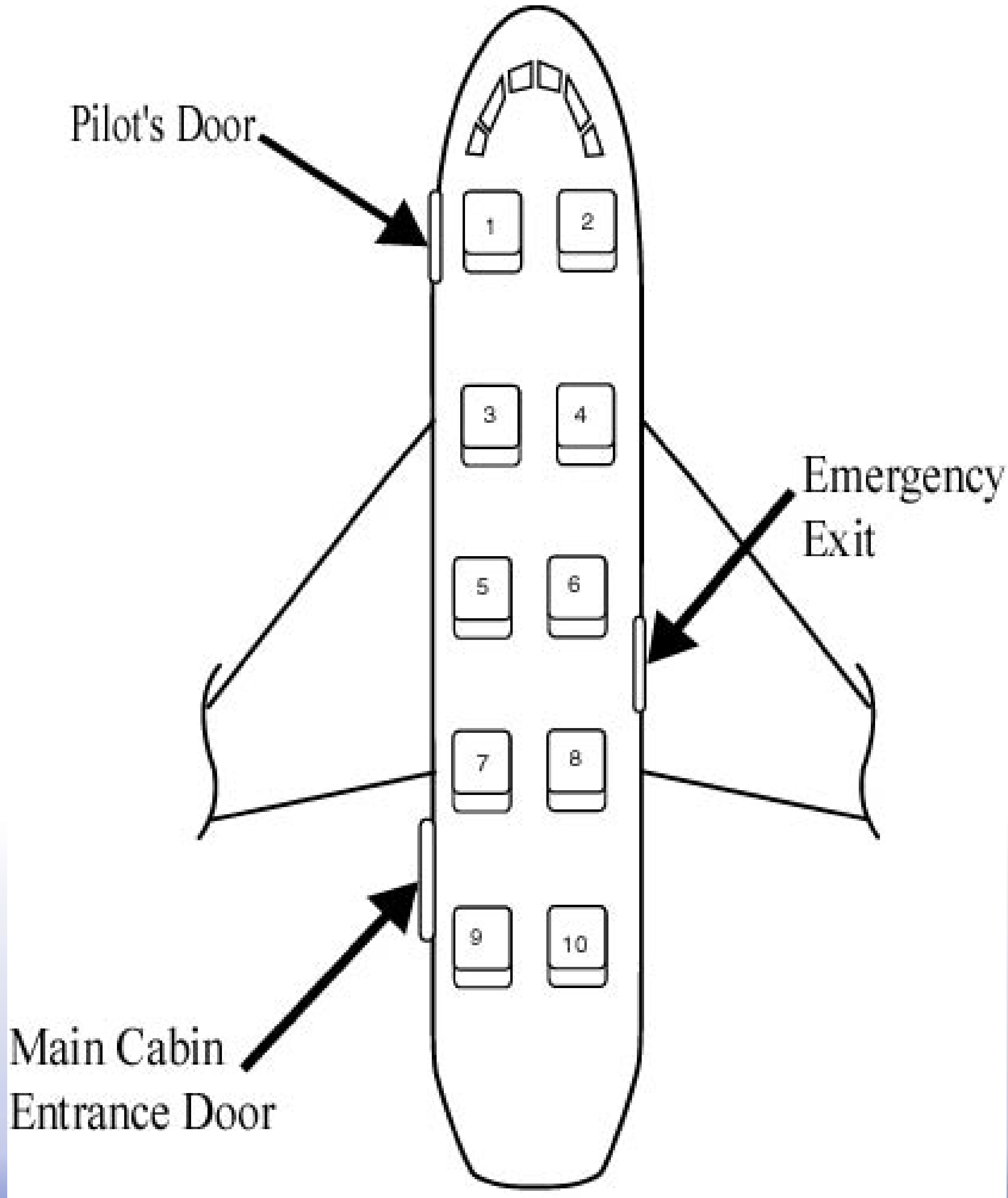
- Evacuation
- Inflation of life vest before evacuating the rapidly sinking airplane
- Donning of life vests over head phones that remained plugged into the cabin wall

Evacuation

- All occupants survived initial impact with water and were not seriously injured
- Airplane contacted ocean at low airspeed
- Hilo Fire Dept. scuba divers confirmed cabin found intact under water
- Passengers and pilot reported rapid submersion of airplane as they evacuated the airplane

Evacuation cont'd…

- The passengers reported that the fatally injured female passenger in seat 4 was last seen "frozen" in her seat with seatbelt fastened and her life vest inflated.
- Fatally injured passenger's husband indicated that she did not know how to swim
- Her cause of death was "asphyxia due to salt water drowning"



Pilot's Door
1
2
3
4
Emergency Exit
5
6
7
8
9
10
Main Cabin Entrance Door

Life Vests Inflated Before Evacuation

- Pre-flight briefing – “only inflate life vests after evacuating airplane”
- One passenger inflated her vest and had trouble escaping through the exit because of “enormous” water pressure entering the exit

Life Vests Over Headphones

- Pre-flight safety briefing did not include instructions to remove head phones before donning life vest
- A life vest found tangled in headphone chords
- BIA revised pre-flight briefing to inform passengers to first remove headphones before donning a life vest


TOP
FRONT

Questions??

Turbulence: Interior & Injury Documentation

Kelli A. Jones

Cabin Safety Consultants, Inc.

Who Am I? Kelli Jones

- UA Interior Components Engineer.
- UA Senior Investigator for cabin safety incidents and accidents and other regulatory & cabin safety issues.
- Founder & President – Cabin Safety Consultants, Inc. – work with airlines, the FAA, NASA, & NTSB - research of cabin safety issues & procedure development & certification.

United Airlines, Flight 826

- 12/28/97
- Narita, Japan to Honolulu, Hawaii (returned to Narita).
- 374 pax (including 5 infants)/19 crewmembers.
- At 31,000 feet, aircraft experienced severe turbulence resulting in one fatality & more than 190 persons injured (15 of those serious).

TOOLS

What ‘tools’ can be used during an investigation?

Tools

- FA reports.
- FA interview details.
- FA training records.
- FA manual.
- Announcement Book.
- List of injuries.
- Camera.
- Yellow post-its.
- Detailed IPC (illustrated parts catalogue)/component drawings.
- Maintenance log (look for what was replaced/ fixed).
- Interior Arrangement Drawing (cabin layout).

Interviews

- Interviewees:
  - Crewmembers
  - Passengers
  - CFR (Crash/Fire/Rescue) Personnel
  - Other Witnesses
- Questionnaires.
- Tables.

Interview Tools - Tables

F/A	Location	Immediate Reaction	Injury
1 (name)	Door 1L Aux Galley	Grabbed counter w/ LH	None/nick on hand/no pain
12 (name)	RH aisle at aft of B zone pushing cart into galley	Thrown to floor – got in empty seat by 2R before jumpseat.	Hurt knee – very minor some bruises.
7 (name)	RH aisle aft of C zone checking seatbelts	Felt initial positive Gs & squatted & grabbed baggage bar on each side of aisle.	No injuries
16 (name)	Door 4L – near a cart	Felt initial movement, dove for empty row of coach seats.	Broken pelvis vertebrae fracture.

Interviews

- Let them tell their entire story.
- Ask clarifying questions.
- Ask specific questions.
- Ask what they heard/saw.
- Ask location of lap held children.
- Ask location at time of the incident (where sitting/moved?).

Interviews (continued)

- Ask what their neighbor was wearing.
- Turbulence Specific Questions:
  - Was the a pre-departure weather briefing?
  - Seatbelt sign on? If so, for how long?
  - Was there a warning prior to turbulence?
  - What are procedures for crew communication?
- Second interviews.

Accident

- Briefing.
- Top of climb announcement.
- Language translations.
- Turbulence indications.
- Severe turbulence encounter.
- Interior arrangement drawing.

Interior Arrangement Drawing

- Blue dots – indicate FA locations.
- Pink lines – indicate cart locations.
- Yellow highlights – identify passenger injury information.
- Green dots – lap held children locations.
- Pax/cabin status at time of event.
- Injury notes and FA observations.

NTSB Past Accident Investigation Experience

- Good chance to document aircraft but no injury information.
- Good injury information, but no wreckage documentation.
- Cabin and wreckage cleaned up.

NTSB Past Experience (continued)

- Lots of pictures of unknown items or locations.

NTSB Past Experience (continued)

What's important in this picture?

What seat location has this armrest damage?

NTSB Past Experience (continued)

- Poor quality pictures.

Wreckage Documentation Steps

- Take pictures of overall wreckage first.

Wreckage Documentation Steps

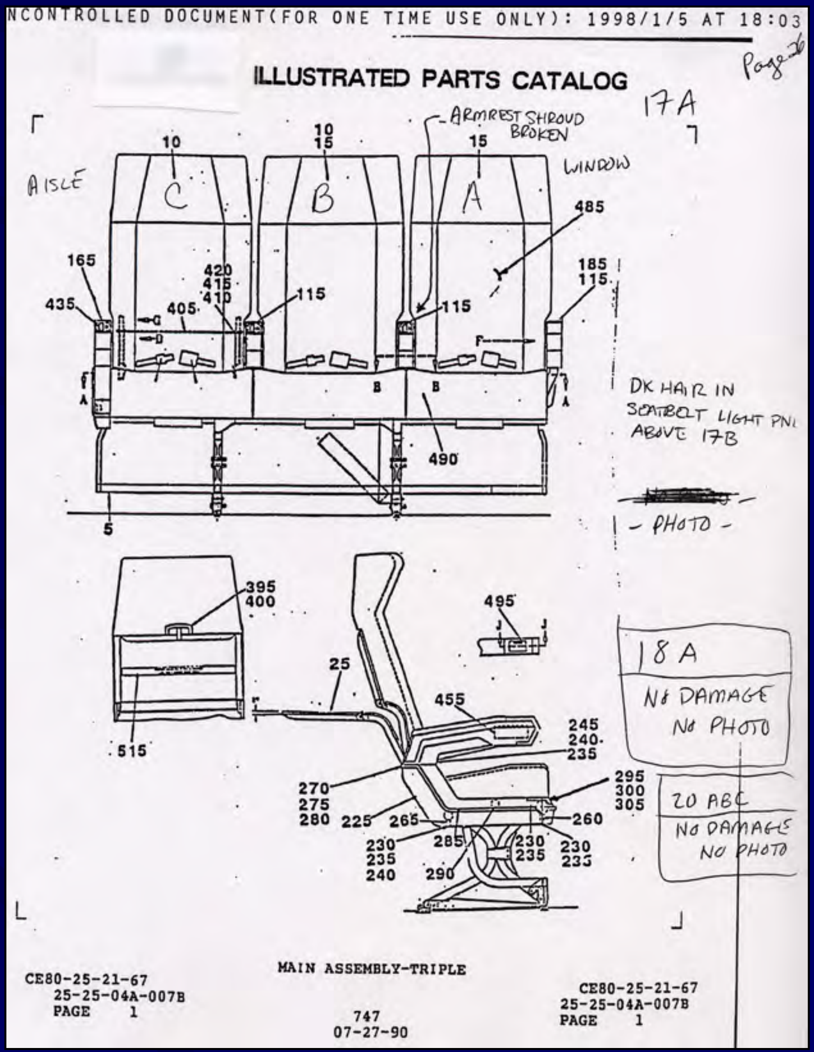
- Take detail pictures.
- How many pictures?
- Other photo sources:
  - Police
  - EMS
  - Witnesses
  - Maintenance Personnel
  - Station Personnel

Components To Document

- Seats
- Seatbelts
- PSU Panels (Passenger Service Unit Panels)
- Ceiling Panels
- Overhead Bins
- Lavs
- Sidewalls
- Galleys
- Doors
- Seatbelt Signs/ Chimes
- PA & Interphone Systems
- Carts
- Oxygen Masks
- Life Vests

Documenting Seats

- Identify manufacturer, part number, & date of manufacture.
- Identify rated loads (16g vs. 9g).
- Check integrity of track fittings.

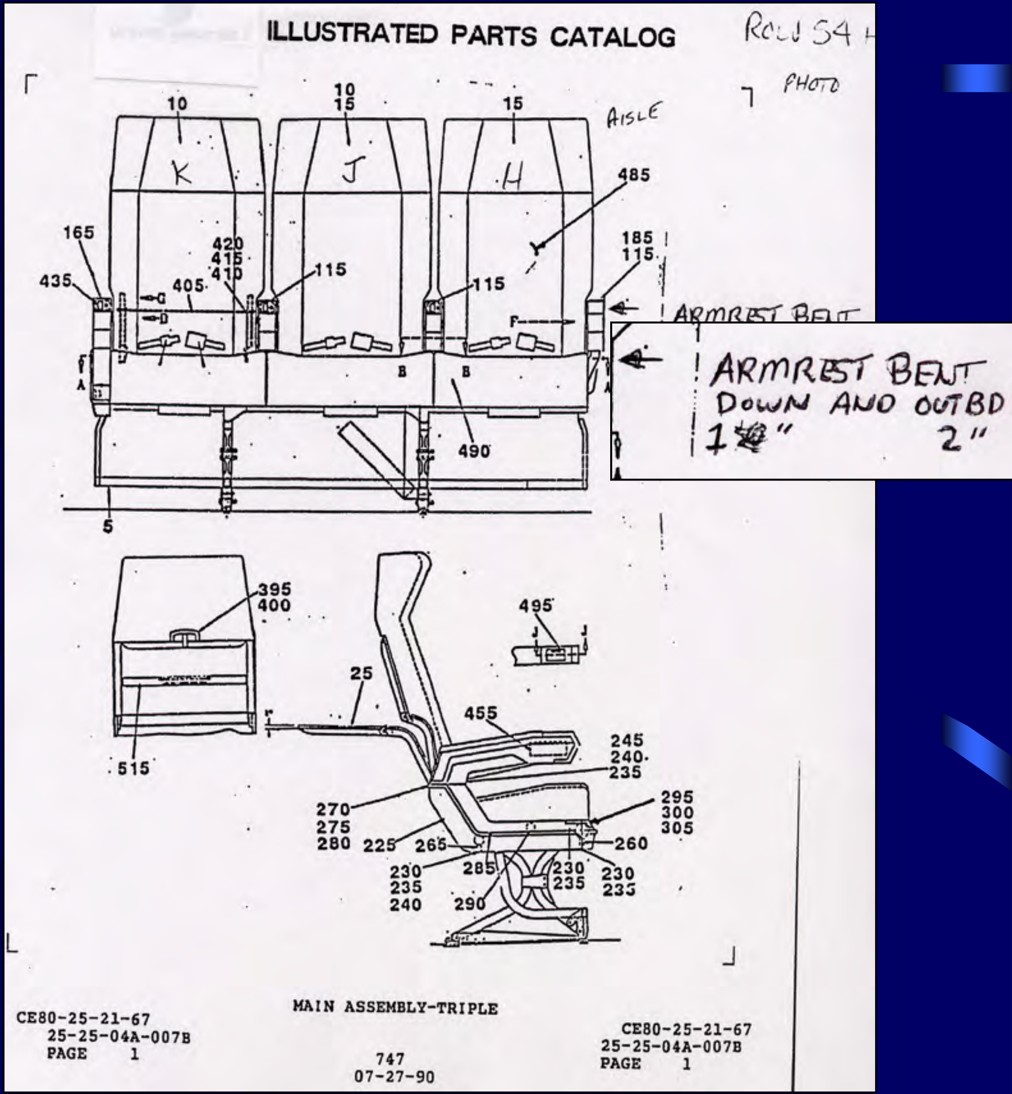


Documenting Seats (continued)

- Document condition of seats:
  - Impact Evidence

Documenting Seats (continued)

- Document condition of seats:
  - Direction and measurements of deformations



Documenting Seats (continued)

- Check tray table deformations.

Documenting Seatbelts

- Record manufacturer and date of manufacture.
- Check integrity and attachment of each seatbelt.
- Rated loads.
- Model number.

Documenting PSUs, Overhead Bins, & Ceiling Panels

- Identify any dents or damage.

PSUs

Documenting PSUs, Overhead Bins, & Ceiling Panels (continued)

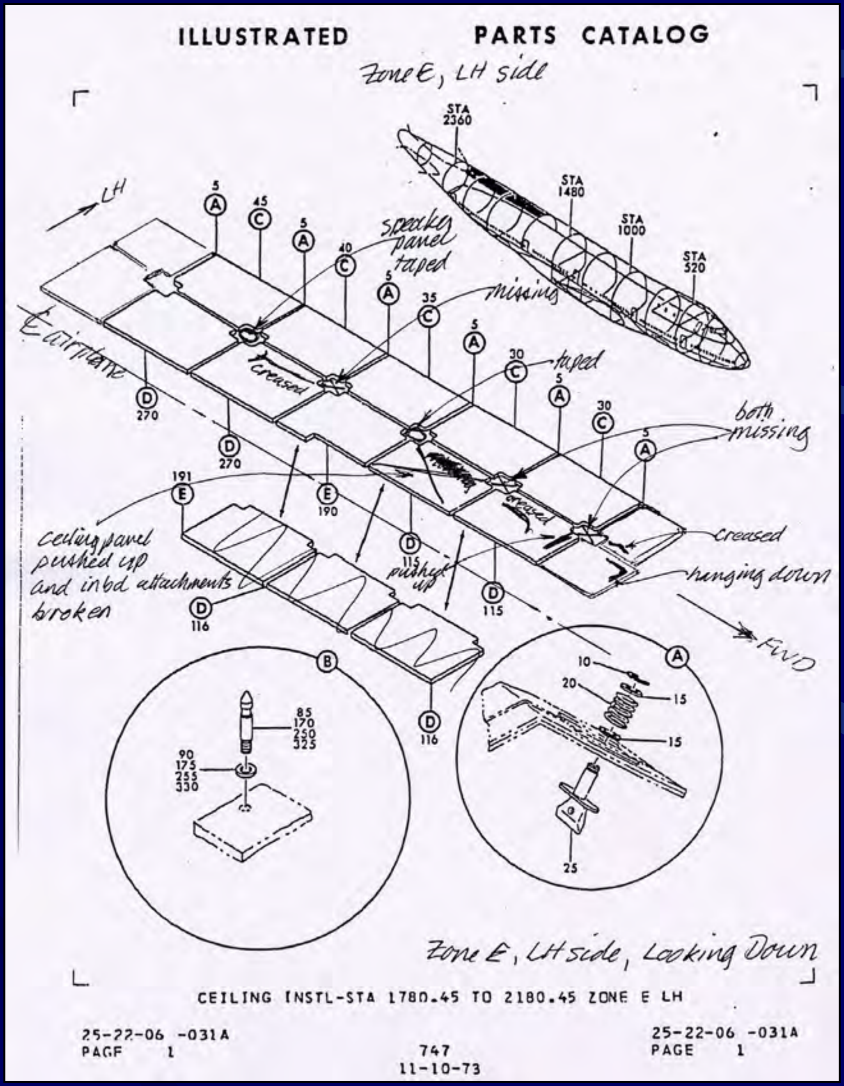
- Identify any missing pieces.

Documenting Overhead Bins

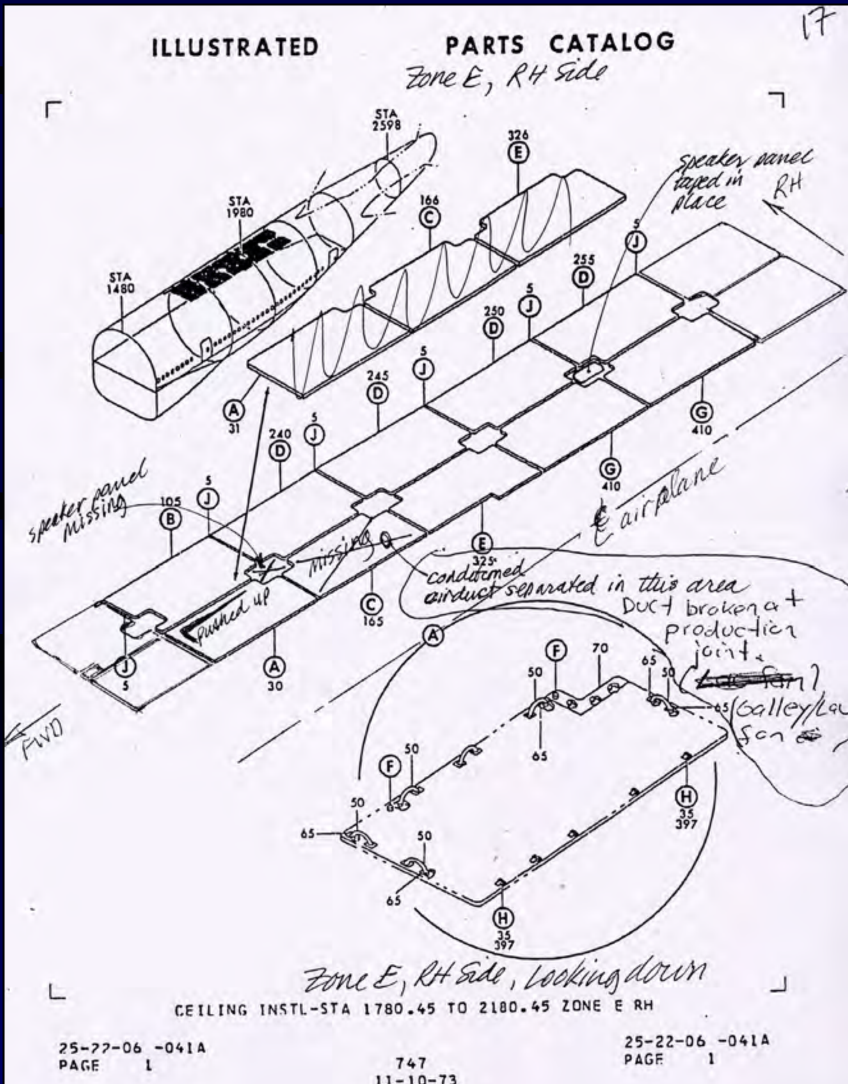
Good Labeling

Documenting Ceiling Panels

E Zone – Damaged and Missing Ceiling Panels.

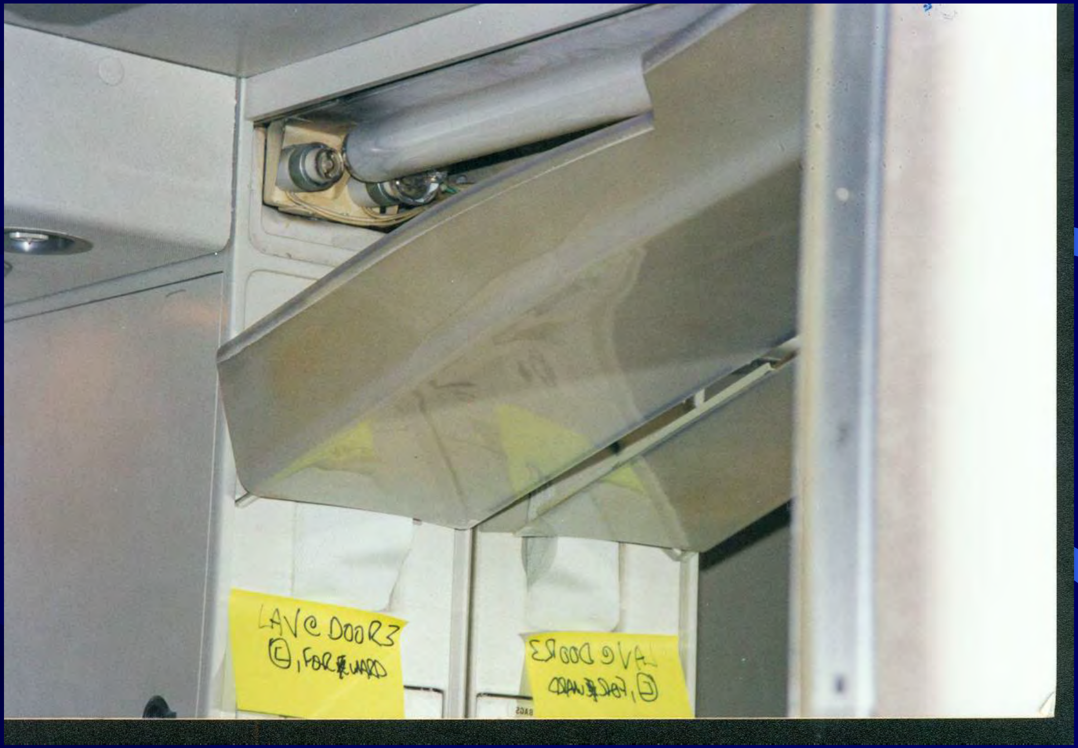


Documenting Ceiling Panels (continued)



Interviews identified that crewmembers removed panel after it had become loose during turbulence.

Documenting Lavs



Documenting Doors

Documenting Other Equipment or Discrepancies

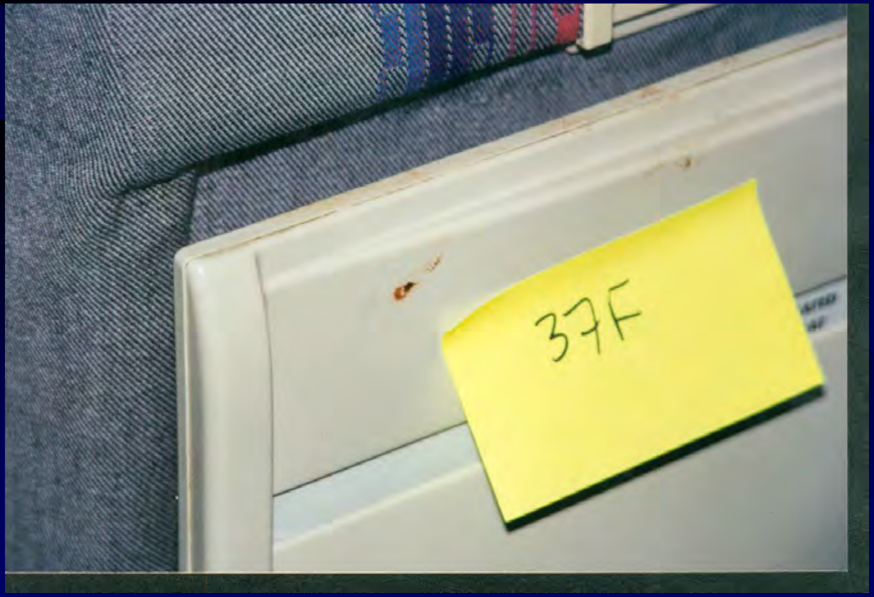
- PA & Interphone Systems at each FA handset
- Seatbelt Sign/ Chime
- Carts
- Floor Boards

Wreckage Documentation Steps (continued)

- Identify existence & condition of all emergency equipment.
- Perform equipment tests to determine failure mode.
- Review maintenance logs.
- Identify location of personal affects.
- Check security of carry-on baggage & storage areas.

Wreckage Documentation Steps (continued)

- Look for signs of blood/hair.
- Compare injury information with wreckage documentation.



Wreckage Documentation Steps (other types of accidents)

- Identify position of emergency switches such as:
  - Evac Alarm
  - ELS (emergency lighting system)
- Detail each exit configuration:
  - Armed/Disarmed
  - Slide Deployed?/Condition of Slide

2nd Sample Accident

- 5/7/98
- AirTran Airlines
- DC-9
- Atlanta to Chicago
- Encountered turbulence as aft flight attendant was standing to begin service. She sustained vertebrae compression fracture, left clavicle fracture, & scalp laceration.

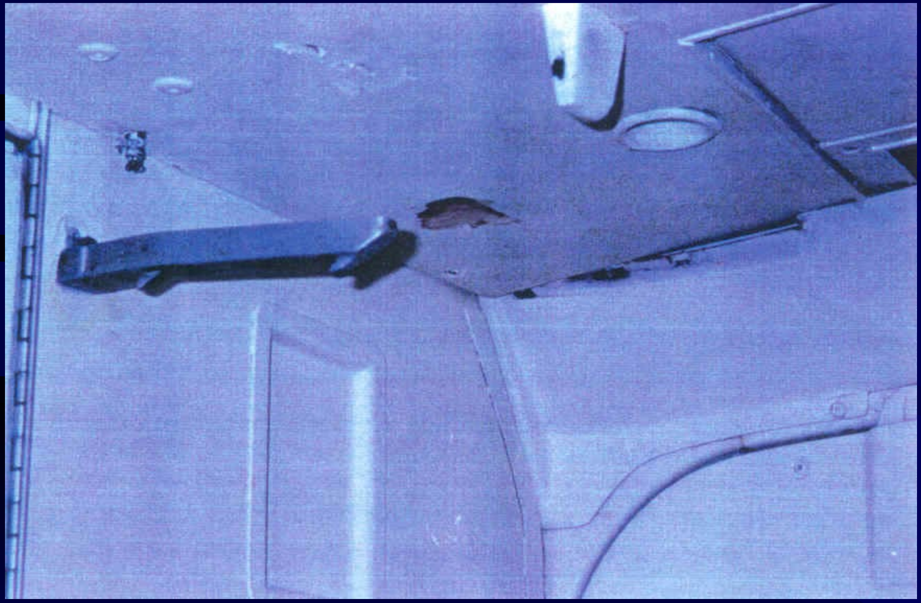
Aft FA Injury

- Aft end of cabin.
- After being notified to return to her jumpseat, aft FA injured as she folded her apron preparing to sit back down.

Aft FA Injury (continued)

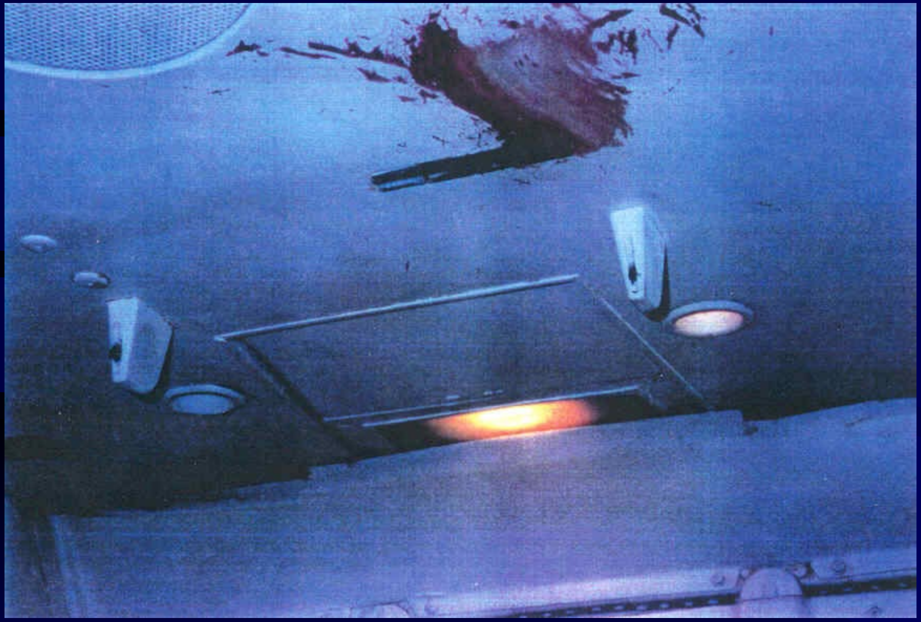
- Investigators received pictures only.
- Blood on exterior lav walls on both sides of jumpseat.

Aft FA Injury (continued)



- Initial reaction was the flight attendant must have hit the door latch, but there was no blood found on that component.

Aft FA Injury (continued)



- A closer review of the rest of the ceiling revealed a great amount of blood around the call light panel.
- That was what actually split the FAs head open.

Lessons Learned

- FAs who were not injured during turbulence recognized initial updraft and took preventative measures.
  - Dropped to the floor immediately.
  - Held onto something stationary.
  - Did not run for empty passenger seat or jumpseat.
- Know who your passengers are.
  - Be sensitive to culture.
  - Know language barriers.
- Translate important information.

Lessons Learned (continued)

- Difficult to open contents/packages in first aid kit with gloves on.
- Scissors in first aid kit did not cut well.
- More gloves needed to change them between each person injured.
- Be aware of news crews/cell phones (hold meetings onboard aircraft or in separate room).

Airline Perspective

- How airlines respond to NTSB.
- All investigators should have same goal.
- Providing NTSB with information.
- “Records of Receipt”.

Three Keys to Documentation

- Know what injuries have been identified.
- Know the airline's procedures.
- Identify the cabin damage.

THEN LOOK FOR LESSONS LEARNED AND IDENTIFY PREVENTIVE MEASURES.

AIRPORTS/ARFF CASE STUDIES

Courtney Liedler – NTSB

Survival Factors Investigator

Ground Collision Between Beech 1900 and King Air Quincy, Illinois

- November 19, 1996 at 1701 central standard time
- A Beechcraft 1900 and a Beechcraft King Air collided into one another at the intersection of two runways.
- 10 passenger and 2 crewmembers fatally injured in Beech 1900
- 2 occupants aboard the King Air were fatally injured

National Transportation Safety Board

National Transportation Safety Board

National Transportation Safety Board

Ground Collision Between Beech 1900 and King Air Quincy, Illinois

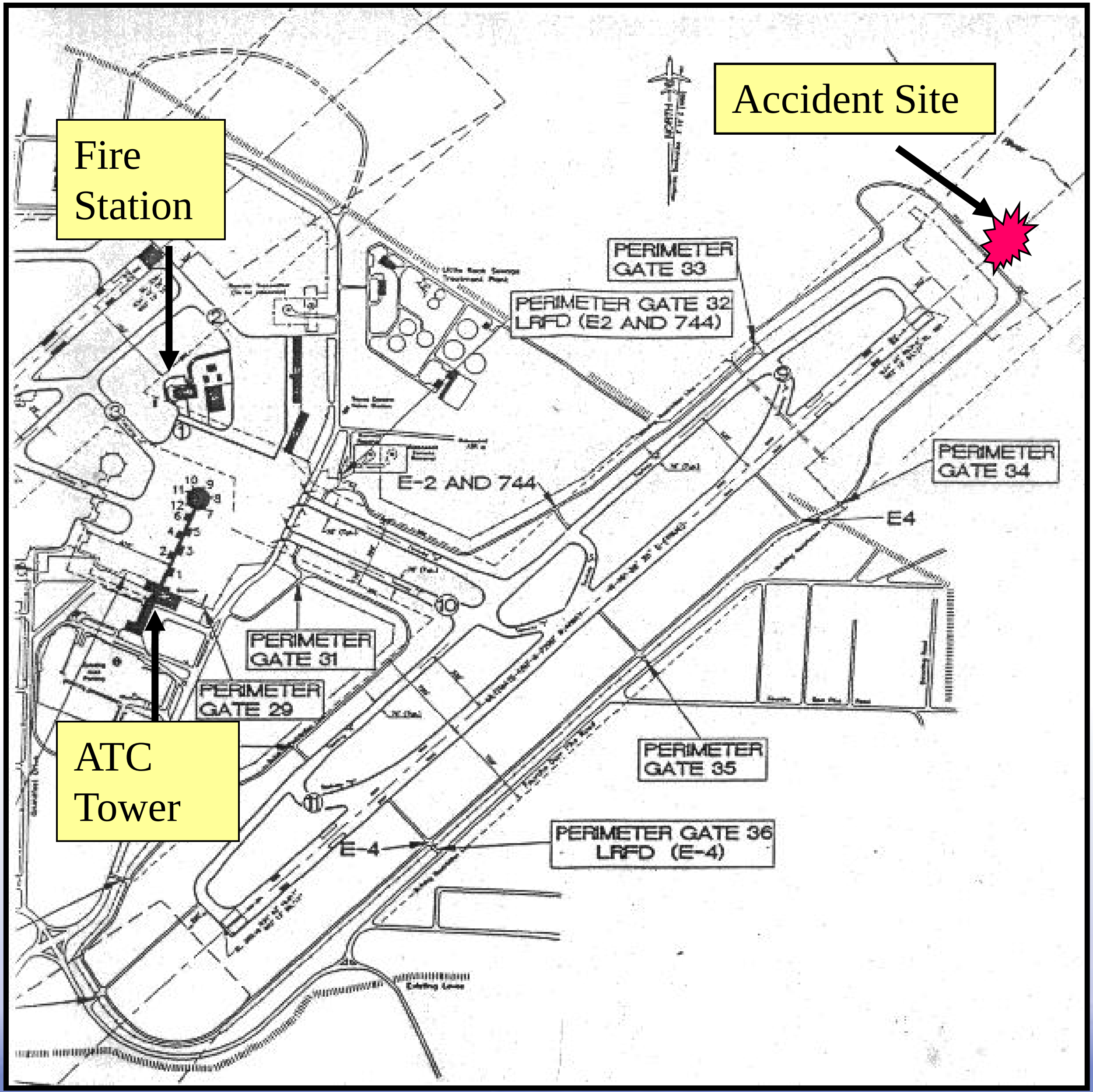
Airport Issue:

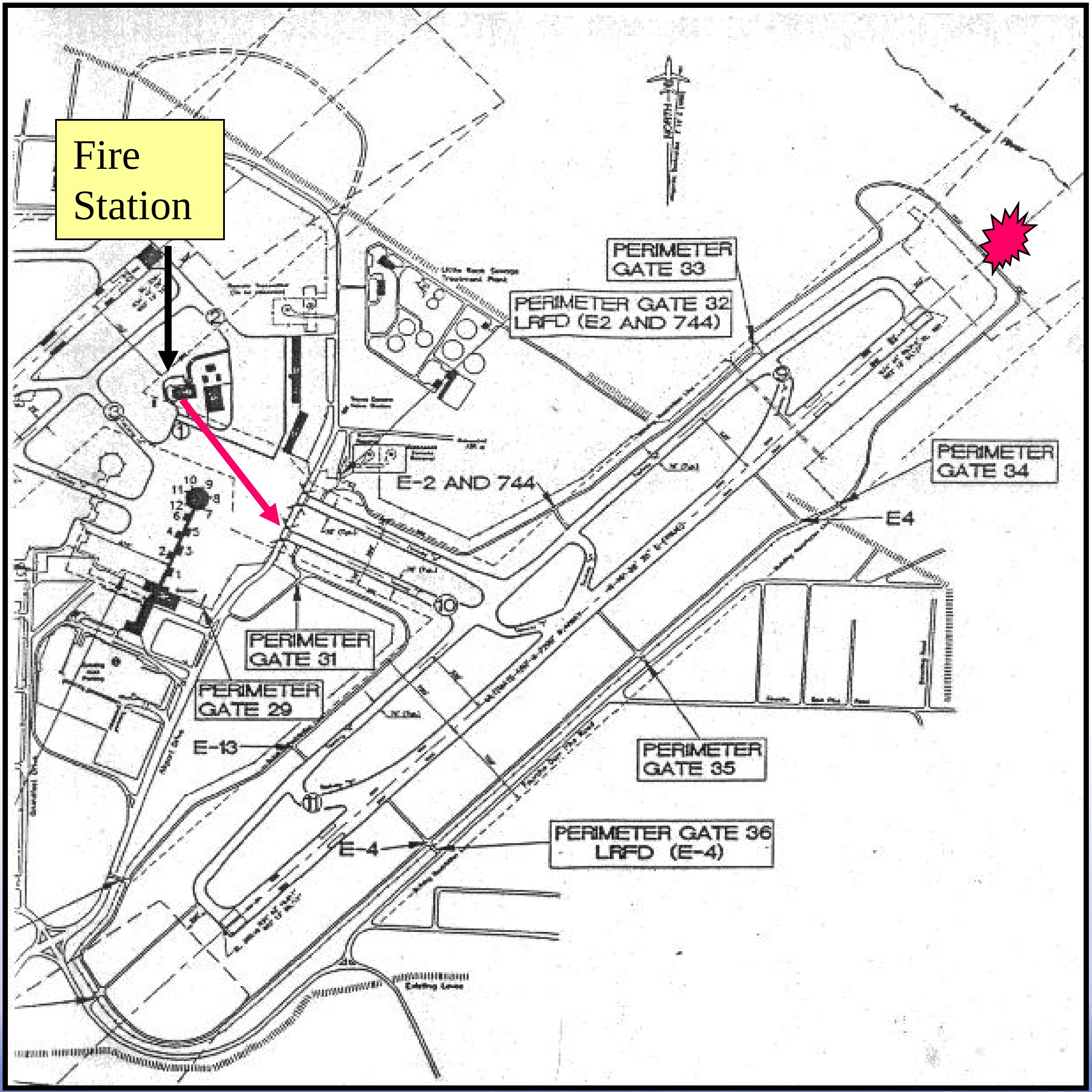
- Airport had ARFF truck, 1/3 mile from scene, however not staffed at time of accident
- Quincy Fire Department 10 miles from airport
- 12 minute response time
- If on-airport protection had been required, some occupants may have survived

Runway Overrun and Collision with ILS
Little Rock National Airport
Little Rock, Arkansas

- June 1, 1999 at 2351 Central Daylight Time.
- An MD-82 overran the end of Runway 4R and collided with the approach lighting structure.
- There were thunderstorms in the airport area at the time of the accident.
- The captain and 10 passengers sustained fatal injuries.
- 110 passengers and crew sustained various injuries, and 24 passengers were not injured


American


Accident Site
Fire Station
ATC Tower
PERIMETER GATE 33
PERIMETER GATE 32 LRFD (E2 AND 744)
E-2 AND 744
PERIMETER GATE 34
E4
PERIMETER GATE 31
PERIMETER GATE 29
PERIMETER GATE 35
PERIMETER GATE 36 LRFD (E-4)
E-4



Fire Station
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E-13
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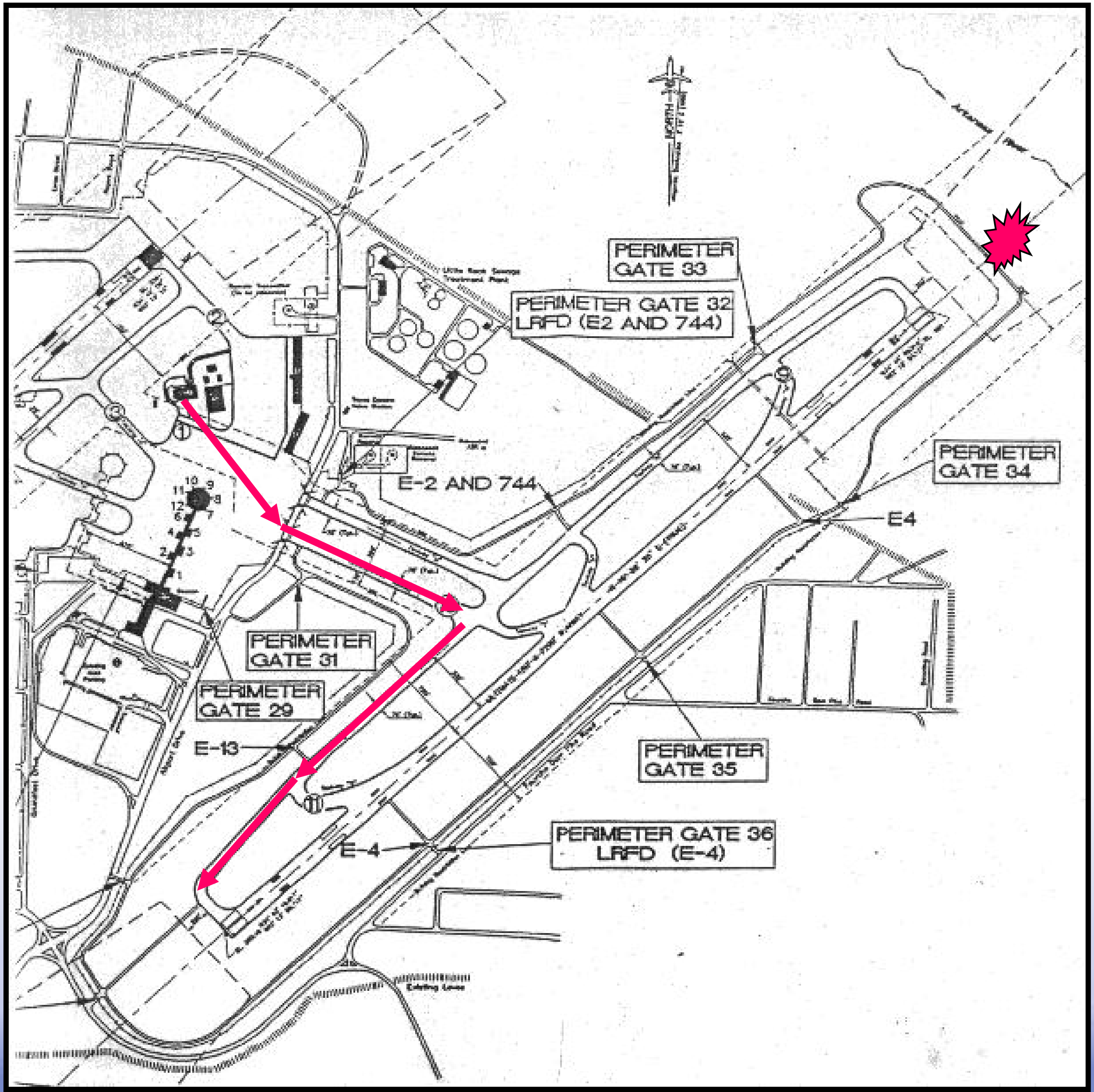
E-4
PERIMETER GATE 36 LRFD (E-4)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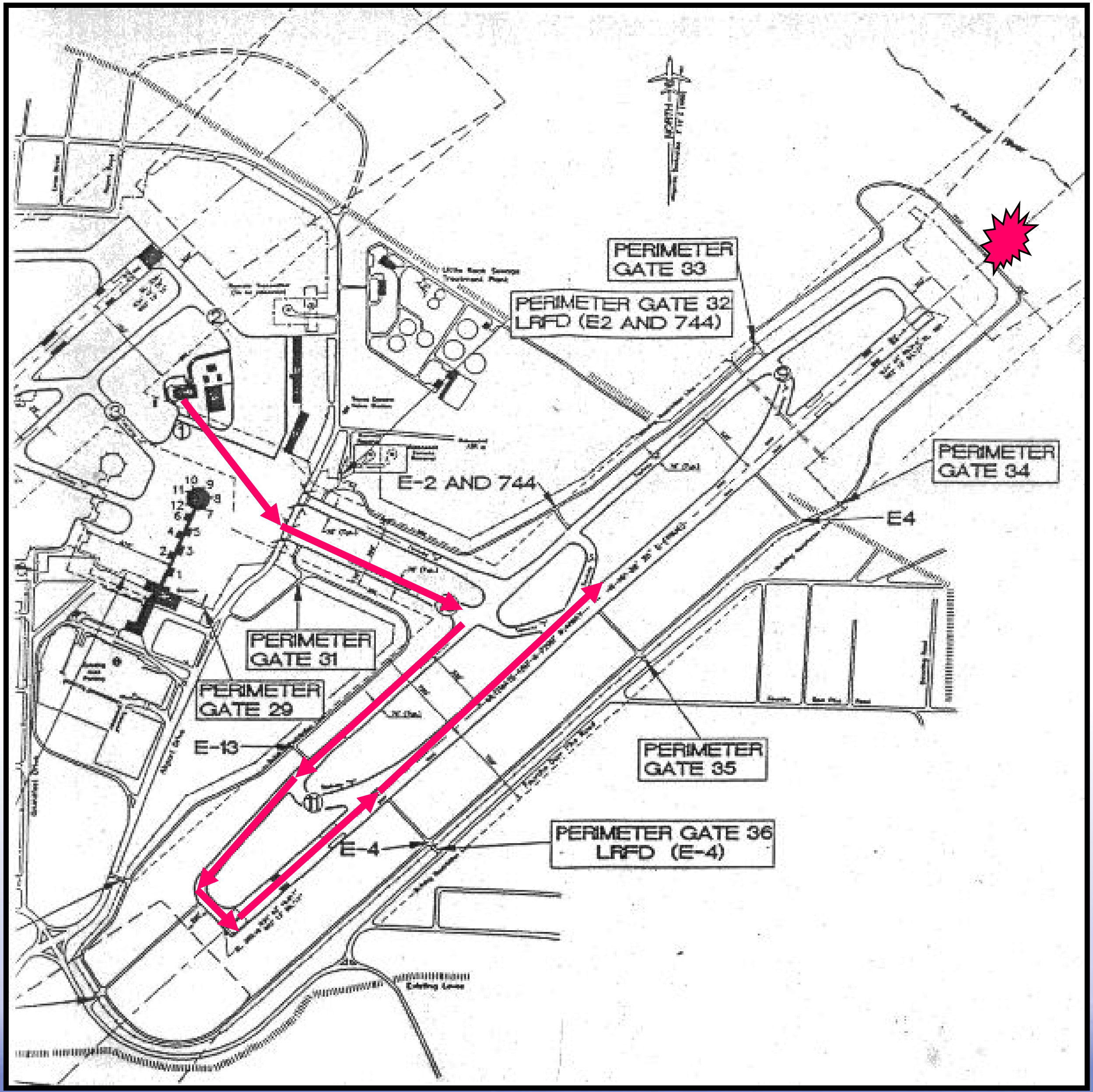
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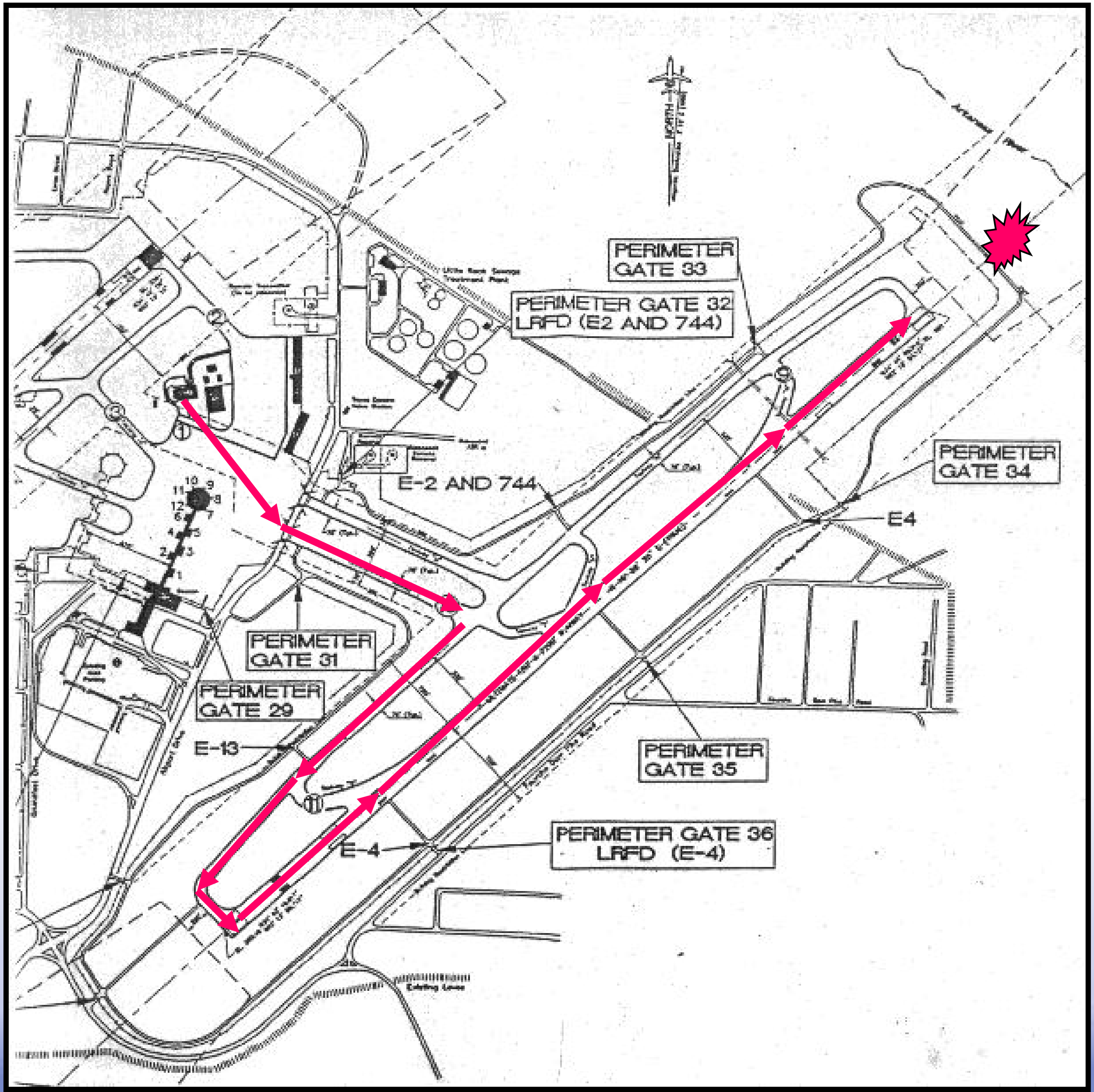
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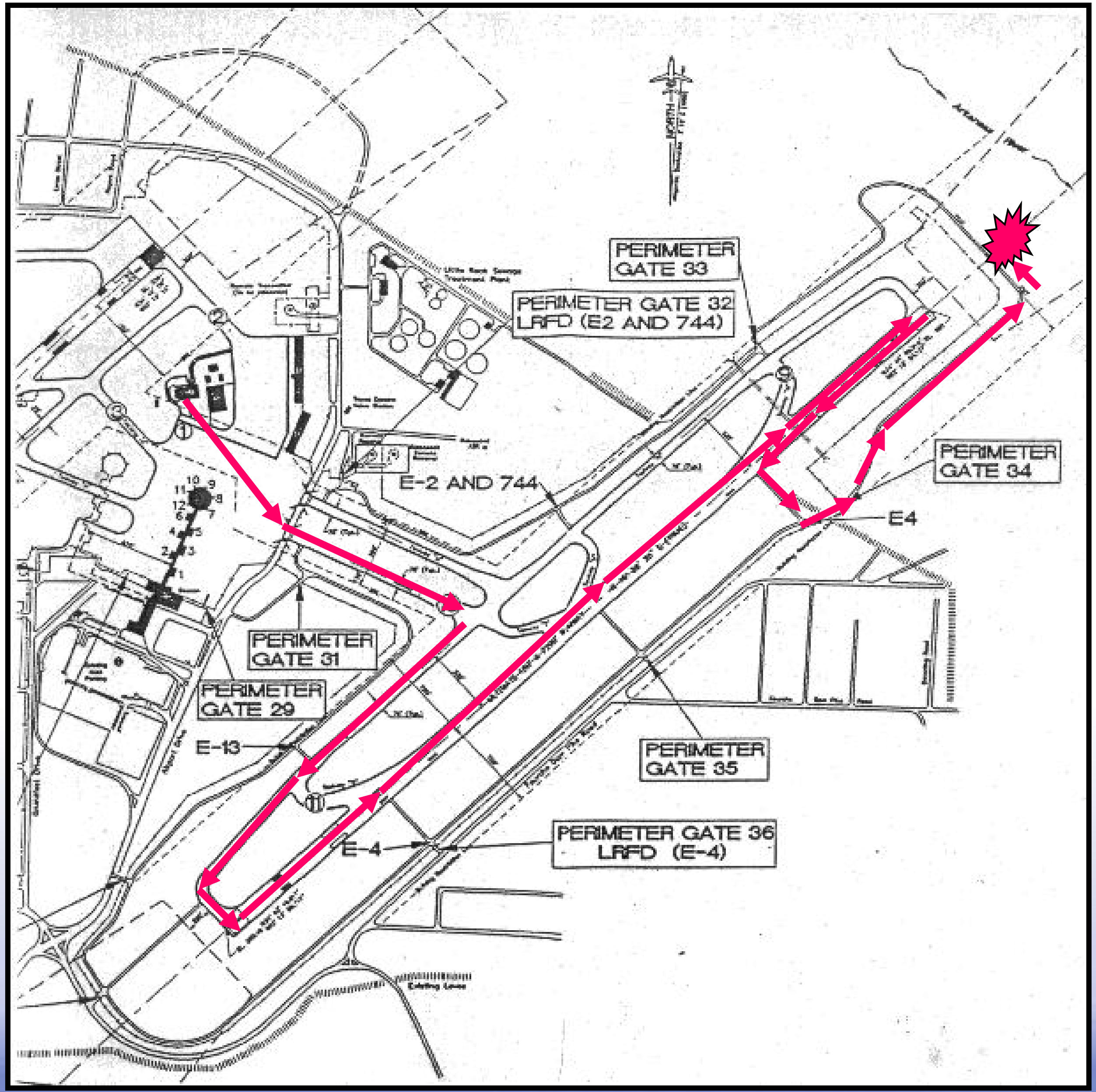
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Runway Overrun and Collision with ILS
Little Rock National Airport
Little Rock, Arkansas

Airport Issues:

- Accident location and detection equipment – controller did not know airplane had crashed, and ARFF crew did not proceed directly to crash site.
- Runway Safety Areas – 550 feet vs. 1,000 feet
- Inadequate communication with ARFF response
- Too few ARFF staff to fight fire and initiate rescue
- Approach lights not on frangible structure

Runway Overrun at Burbank Glendale Pasadena Airport Burbank, California

- March 5, 2000 at 1811 pacific time
- A B-737 over ran the runway, collided with the blast fence and the airport perimeter wall.
- Aircraft left airport property and came to rest on Hollywood Boulevard.
- Aircraft destroyed during accident.
- 137 passengers, 3 flight attendants, and two flight crew
- 41 passengers and one flight crewmember sustained minor injuries


Chevron
1.59
1.69
1.79

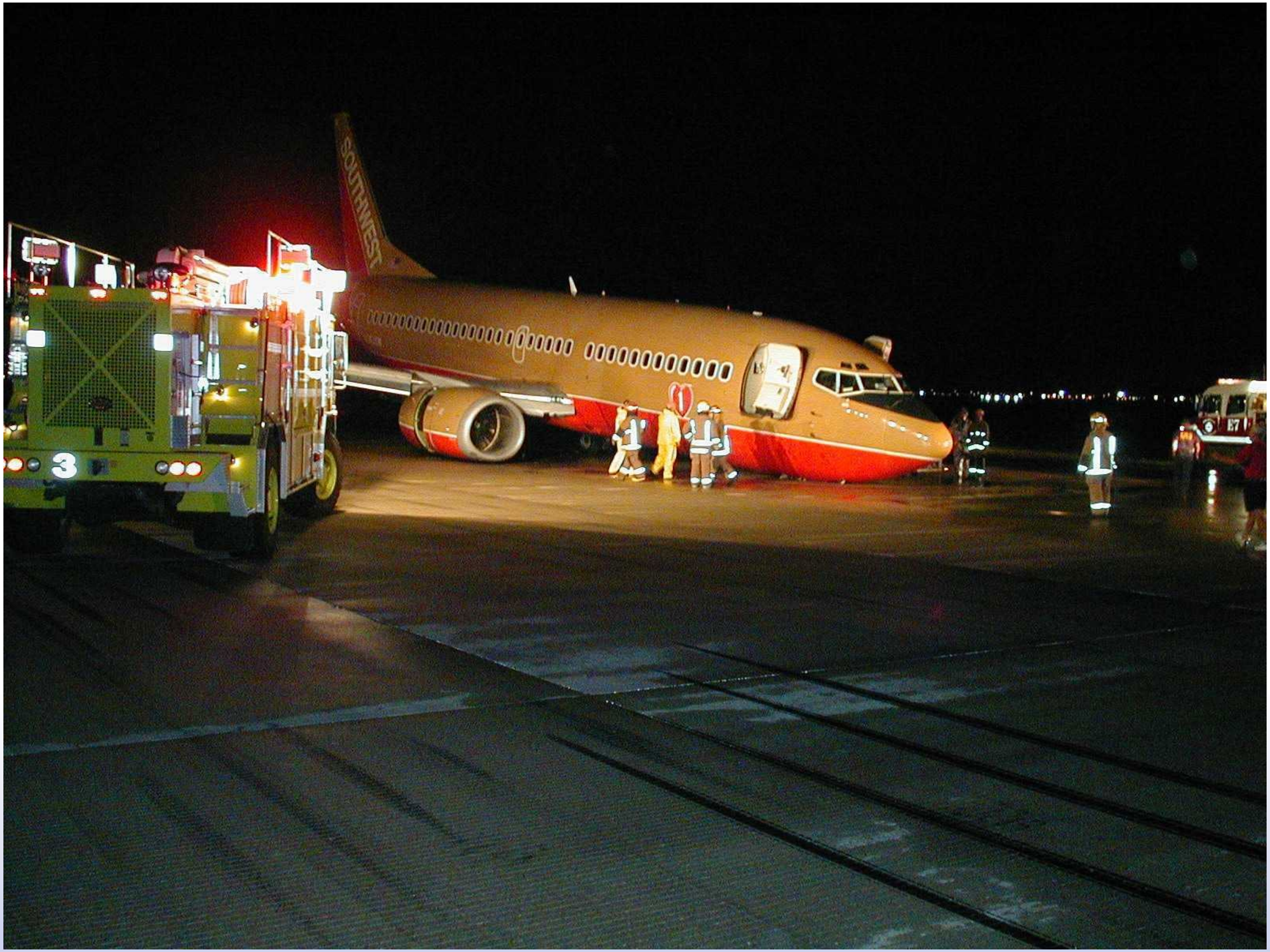
Runway Overrun at Burbank Glendale Pasadena Airport Burbank, California

Airport Issues:

- Insufficient runway safety areas
  - Lateral – 125 feet from runway centerline adjacent to terminal vs. FAA standard of 250 feet
  - Longitudinal – approx. 30 feet beyond runway end vs. FAA standard of 1,000 feet

Loss of Control During Landing at Rick Husband Amarillo International Airport Amarillo, Texas

- May 24, 2003 at 2136 Central Daylight Time
- A B-737 loss control during landing, veered off runway edge, and came to rest back on runway
- Substantial damage upon impact with the runway lights
- 63 passengers, 3 flight attendants, and two flight crew
- No injuries


SOUTHWEST


N343SW

Loss of Control During Landing at Rick Husband Amarillo International Airport Amarillo, Texas

Airport Issue:

- Forward-Looking Infrared Devices (FLIR)
  - ARFF driver did not use FLIR system due to location of screen in cab
  - FLIR systems capabilities are degraded during inclement weather conditions, such as fog, drizzle, and rain

Runway Overrun at JFK International Airport Jamaica, New York

- May 30, 2003 at 0431 eastern daylight time
- An MD-11 over ran the runway, collided with the Engineered Material Arresting System, or EMAS.
- Minor damage to aircraft during accident.
- Two pilots and one other crewmember were uninjured


703

QUESTIONS??

Survival Factors in Aviation Accidents

Introduction to Crashworthiness

Lisa E. Jones
NASA Langley Research Center

NTSB Academy
October 18 - 21, 2004

Introduction to Crashworthiness

- What is crashworthiness?
- Elements of crashworthiness
  - Container
  - Restraint
  - Energy Management
  - Environment
  - Post-crash Factors
- Crashworthiness and aircraft type
  - General Aviation
  - Rotorcraft
  - Transport/Regional Jets/Commuter
  - Cargo
- Systems approach to crashworthiness

Introduction to Crashworthiness

What is aircraft crashworthiness?

Crashworthiness of an aircraft is how well the aircraft protects the occupants in the event a “survivable” accident.

Introduction to Crashworthiness
Elements of Crashworthiness

Container

- Fuselage Structure
- Occupant Compartment
- Survivable Volume

Introduction to Crashworthiness

Elements of Crashworthiness

Container

- Fuselage Structure
- Occupant Compartment
- Survivable Volume

Elements of Crashworthiness

Restraint

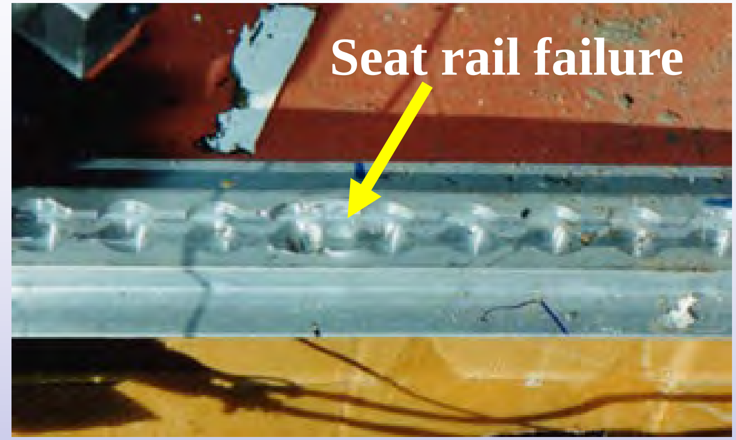
(Terry Eng/B737 video)

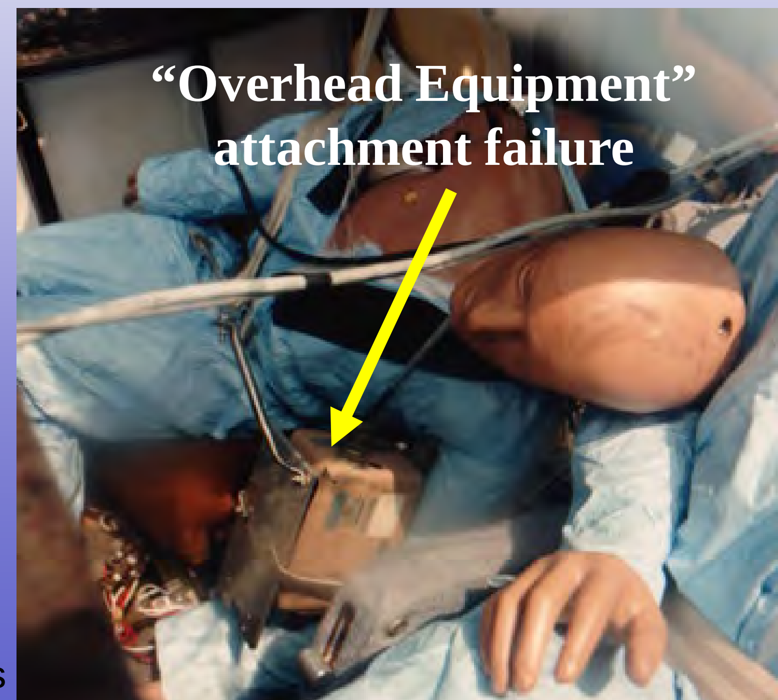
- **Restraint Systems**
  - **- Inertia loads transferred to skeletal frame instead of soft tissue**
  - **- Occupant motion controlled to prevent striking interior**
  - **- Occupant motion controlled to allow interaction with secondary restraint**
- **Seats**
  - **- Seats maintain structural integrity**
- **Attachments**
  - **- Maintain seat attachment to floor/fuselage structure**
  - ***- Prevent overhead bin failure***
  - ***- Prevent cargo from detaching***

Introduction to Crashworthiness

Elements of Crashworthiness

Seat attachment failure





Lisa E. Jones
NASA LaRC

Introduction to Crashworthiness

Elements of Crashworthiness

Shoulder harness restraint attached to aircraft structure

Attachment to aircraft structure fails allowing head strike

Introduction to Crashworthiness

Elements of Crashworthiness

Pilot with lapbelt only allowed head strike

Elements of Crashworthiness

Energy Management

Control peak decelerations and maximum forces on occupants

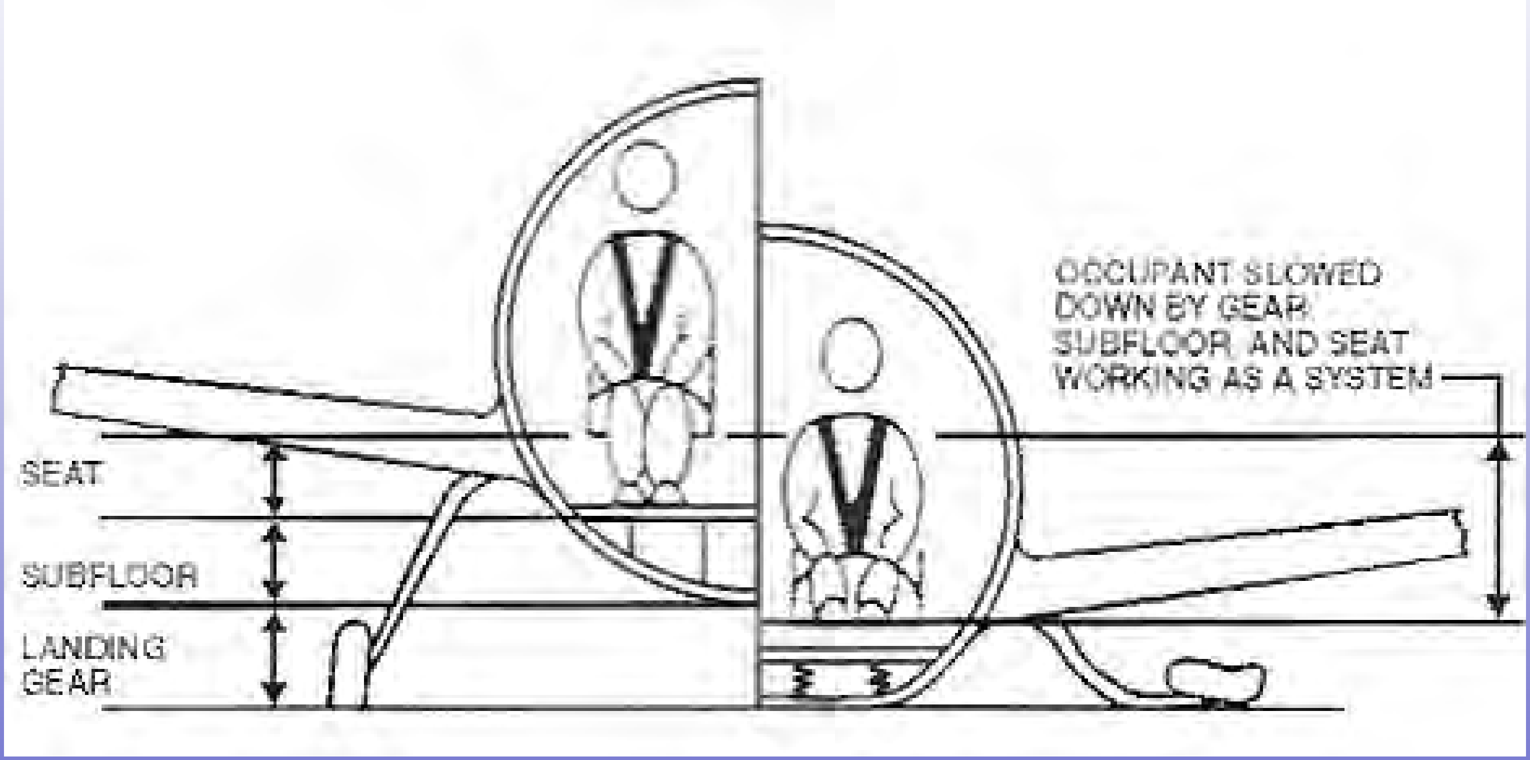
- Energy Absorption
- Fuselage structural design
- Landing gear
- Seats
- Restraints

Introduction to Crashworthiness

Elements of Crashworthiness

Energy Management

Energy Absorption



Elements of Crashworthiness

Energy Management

Energy Absorption

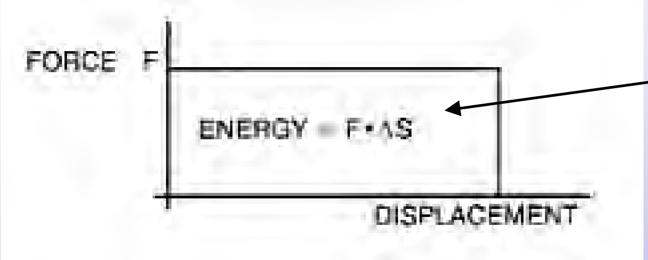
- Energy absorbed by the structure during a crash reduces the loads to the occupants.
- Energy absorbed in an aircraft accident is the energy removed by the crushing, deforming, sliding, and tearing of materials and structures. (automotive example)
- Materials and structures include fuselage, landing gear, wings, seats, restraints, impact surface, cushions.
- Data associated with vehicle accident studies and human tolerance to deceleration loads are presented in the form of time history plots of displacement, velocity, and acceleration.

Elements of Crashworthiness

Energy Management

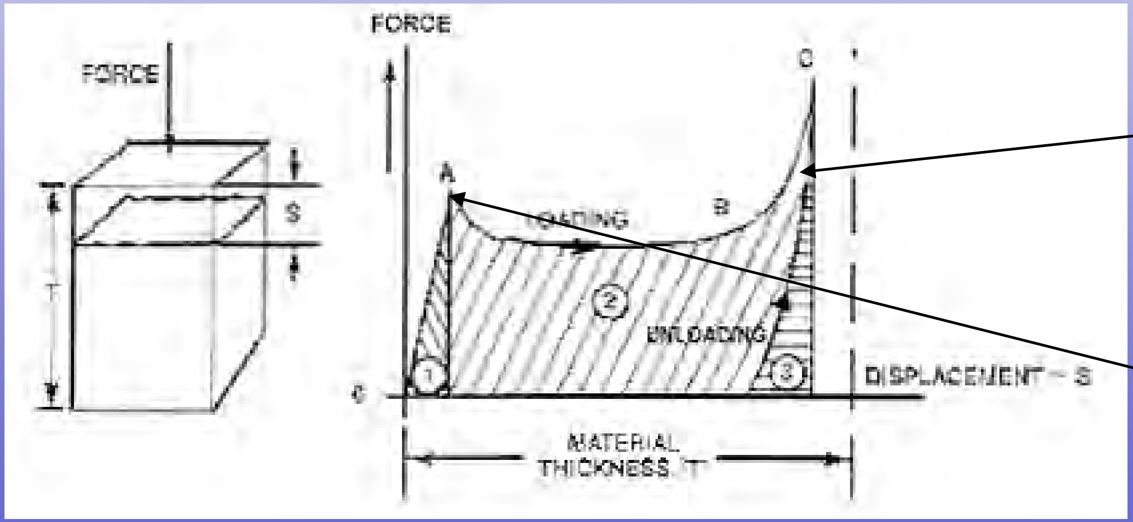
Ideal Energy Absorber

Energy Absorption



The area under the force-displacement curve represents the amount of energy absorbed.

Force-displacement Curve for Honeycomb Materials



Densification

Crush initiation load

Elements of Crashworthiness

Energy Management

Energy Absorption

Hands-on Demonstration

Samples of Energy Absorbing Structures

Introduction to Crashworthiness

Elements of Crashworthiness

Energy Management

Fuselage structural design

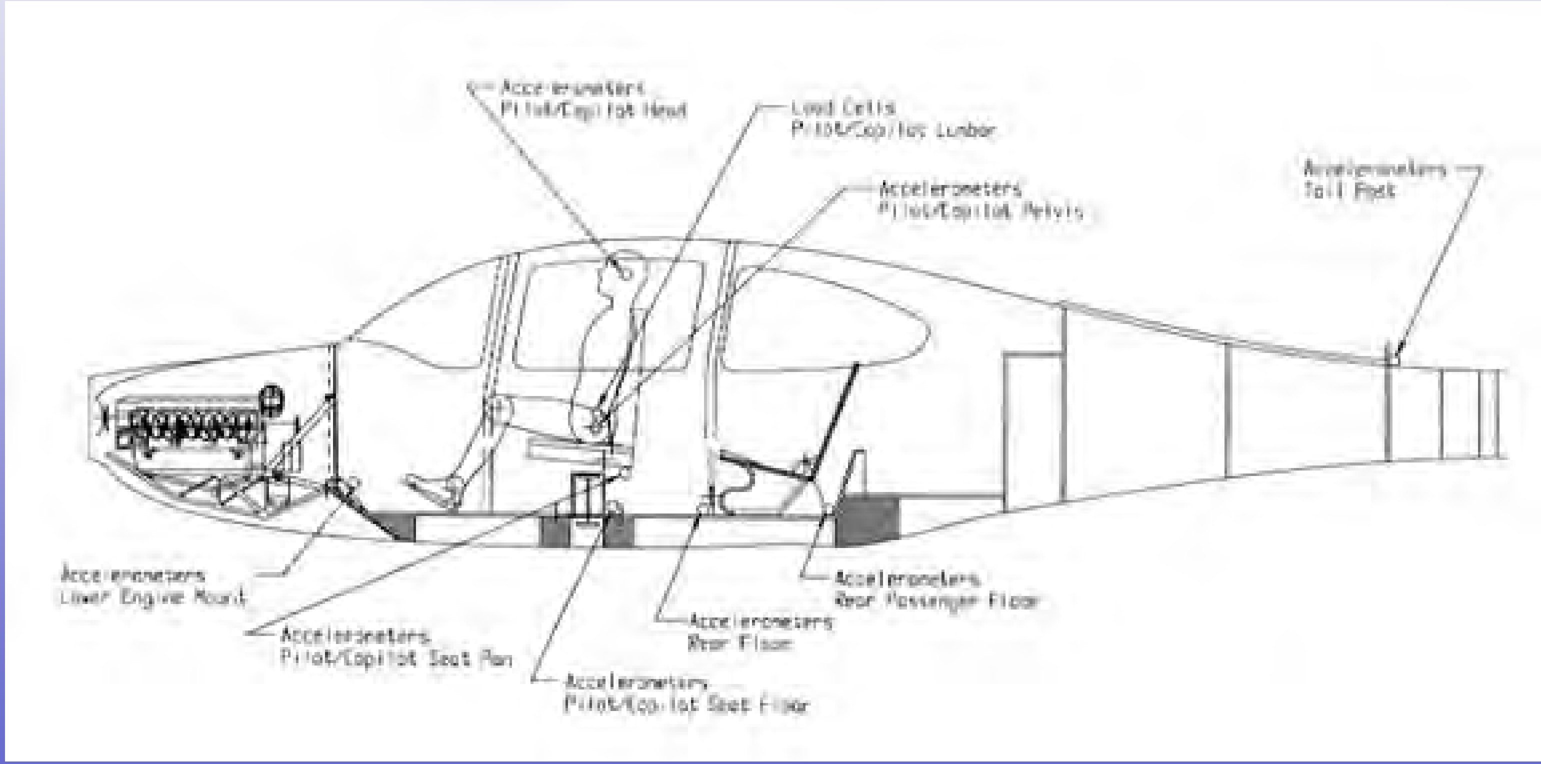
- **The structure that makes initial contact with the ground should be designed to reduce gouging and scooping of soil to limit accelerations (videos - soft soil tests)**
- **The cockpit and cabin structure should be reinforced to prevent collapse and provide adequate tiedowns for occupant and cargo. (ATR 42)**
- **Fuselage structure should provide energy absorption through controlled deformation.**
- **Fuselage structure should be reinforced to resist penetration.**
- **Wing struts, external accessories, and landing gear should be designed/modified to ensure that if these parts fail, they fail safely.**
- *Aircraft structure should be designed for mass shedding to reduce the fuselage energy absorption and strength requirements* **(controversial)**

Elements of Crashworthiness

Energy Management

Fuselage structural design

- **Fuselage structure should provide energy absorption through controlled deformation. (Video)**



Elements of Crashworthiness

Energy Management

Fuselage structural design

- **Fuselage structure should provide energy absorption through controlled deformation.**

Introduction to Crashworthiness

Elements of Crashworthiness

Energy Management

Fuselage structural design

- **Fuselage structure should be reinforced to resist penetration.**
- **Wing struts, external accessories, and landing gear should be designed/modified to ensure that if these parts fail, they fail safely.**

Fuel spillage due to gear penetrating wing tank

Elements of Crashworthiness

Energy Management

Fuselage structural design

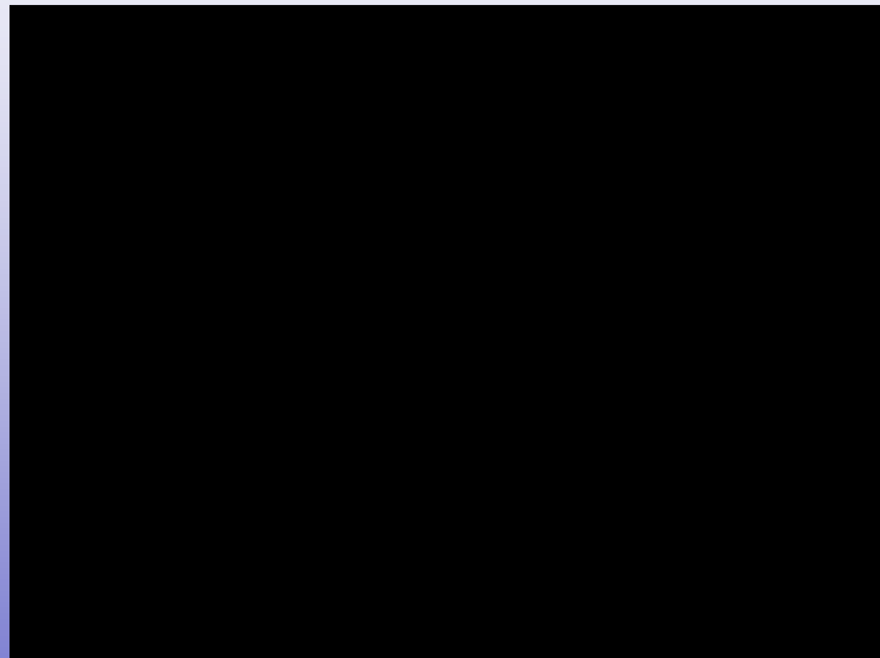
- *Aircraft structure should be designed for mass shedding to reduce the fuselage energy absorption and strength requirements*

  - *Mass shedding can be beneficial by reducing kinetic energy of the occupant compartment.*
  - *Mass must break away precisely as designed*
  - *Mass must move clear of the occupied volume of the aircraft*
  - *Designing for all scenarios is very difficult*

Elements of Crashworthiness

Energy Management

Fuselage structural design



Introduction to Crashworthiness

Elements of Crashworthiness

Energy Management

Landing Gear

- Function of the landing gear in hard landing is to avoid damage to the fuselage and mission equipment
- Function of the landing gear in a severe survivable crash is to contribute to the survival of the crew and passengers
- Performance of landing gear depends heavily on the impact terrain. Ideal surface for proper landing gear performance is firm, smooth and level.
- Performance of landing gear depends on the attitude and velocity of the aircraft. The gear is designed for the aircraft's nominal landing attitude and landing velocity.
- Benefits provided by the landing gear are reduced as the aircraft diverges from it nominal attitude.
- Energy-absorbing capability of the landing gear is important in the vertical impact. Every inch of vertical stopping distance is used to control the deceleration of the fuselage.

Elements of Crashworthiness

Energy Management

Landing Gear

(Video - rotorcraft example)

- For severe longitudinal impacts, kinetic energy levels are so great that the effective use of landing gear as an energy absorber is not practical.
- For longitudinal impacts, the landing gear should be designed to fail in a way that the risk to the occupants does not increase. Gear should not rupture fuel cell or penetrate the occupant area.
- Landing gear should be located away from flammable fluid systems.
- Provisions should be made to allow the gear to be driven upward and rearward into the supporting structure without increasing impact hazards.
- Failed landing gear should not increase gouging and/or scooping in an impact in soil.

Elements of Crashworthiness

Energy Management

Seats

- Seats are an integral part of the occupant restraint system and play a major role in occupant crash protection.
- Seats are designed to withstand crash loads.
- Seats are designed to be lightweight.
- Seats should provide comfort and proper occupant position.
- Seats must accommodate a range of occupant sizes.
- FAA regulations define seat requirements for crashworthiness.
- Seats absorb energy in crash
    - Leg structure
    - Seat pan
    - Cushion

Elements of Crashworthiness

Energy Management

Seats

Introduction to Crashworthiness

Elements of Crashworthiness

Energy Management

Seats

JAARS Energy Absorbing Seat

JAARS Energy Absorbing Seat Post-Test

Elements of Crashworthiness

Energy Management

Seats

- The seat performance depends on the occupant size and mass, the acceleration pulse and the impact attitude.
- Seats are designed for 50 percentile males.
- 95 percentile occupants are in danger of bottoming out the seat absorption capability.
- 5 percentile occupants and children will not stroke the seat.

Elements of Crashworthiness

Energy Management

Restraints

- Personal restraint systems restrain the occupant within the aircraft seat during aircraft maneuvers, turbulence crash events.
- Restraint system must limit occupant motion within the protective shell to prevent/minimize secondary impacts.
- Restraint must limit loads to those tolerable by humans.
- There are two types of restraint systems:
  - Belts or harnesses (commercial "perception of safety")
  - Inflatables (CABS, Terry Eng.)
- Restraints are categorized as active or passive
  - Active system utilizes input from a crash sensor and some type of stored energy to activate and/or alter the restraint system in a crash event (airbags, pre-tensioners).
  - Passive systems are not activated by the crash event (conventional belts, load limiter, knee bolsters)

Introduction to Crashworthiness

Elements of Crashworthiness

Energy Management

Restraints

Load Limiting Device

Crew Airbag System (CABS) and Inflatable Body and Head Restraint System (IBAHRS)

Elements of Crashworthiness

Environment

- Cabin interior design must minimize injury.
- Design must limit the size of the occupants flail envelope.
- Design must eliminate, relocate, or delethalize all potential strike hazards.

(Example - transport seat spacing/pitch)

Elements of Crashworthiness

Post-Crash Factors

- **Design must ensure safe egress for the occupants**
  - **Ease and reliability of exit operation**
  - **Availability and access to exits**
  - **Identification of exits**
  - **Availability of exits in rolled/deformed aircraft**
- **Design should prevent post crash-fire**
  - **Eliminate spillage of flammable liquids (frangible self-sealing lines and fittings, self-sealing tanks)**
  - **Control hazardous ignition sources**
  - ***Reduce flammability of fuels (AMK)***
  - ***Slow the seepage of fuels***

Elements of Crashworthiness

Post-Crash Factors

- Egress is highly dependent on human factors
  - Occupant must survive the impact (age, size)
  - Occupant must be able to initiate and perform multiple mechanical functions which may include unfastening restraints, maneuvering through the post-crash mayhem, open emergency doors
  - Occupant hostile post-crash environment changes the occupants normal motor capabilities (vision obscured by smoke, panic, pain caused by injury, shock, temperature, breathing distress from toxic gases and smoke)
  - Designer must keep it simple

Introduction to Crashworthiness

Crashworthiness and Aircraft Type

General Aviation

Multiple injuries are the leading cause of death in GA

Internal and head injury are most prevalent injury types.

- Types of Flight
  - Business operations
  - Personal travel/pleasure - most common/most dangerous
    43% of all GA flying/75% of fatal accidents (1996 data)
  - Agricultural Operations
  - Instructional
- Cause of Accident
  - Pilot error - #1 cause
  - Environmental - contributing factor more than cause
  - Aircraft problems - maintenance

Introduction to Crashworthiness

Crashworthiness and Aircraft Type

General Aviation

- **Structural issues**
  - **Survivable volume**
  - **Minimal structure below the floor - must have highly efficient energy absorbing subfloor**
  - **Soft Soil scooping -**
  - **Firewall intrusion**
- **Restraint**
  - **Flail injuries/ head strike - lap belt versus shoulder harness**
  - **Maintenance of restraints**
  - **Use of restraints**
  - **Retrofit of improved restraints into privately owned aircraft**
  - **Retrofit of secondary restraint systems existing aircraft (airbags, inertia reels, pretensioners)**

Crashworthiness and Aircraft Type

General Aviation

- Seats
  - Design of seat and location in cockpit/cabin
  - Seat FAR requirements
  - Age of seat
  - Attachment to airframe
  - Energy absorbing properties - response/performance of seat depends structural response of the airframe

Introduction to Crashworthiness

Crashworthiness and Aircraft Type

Rotorcraft

- Structure
  - Military research and investment has greatly improved crashworthiness of rotorcraft
  - Occupiable volume
  - Rotorcraft structure sees higher vertical impact velocity - no fixed wing "glide"
  - Landing gear (military versus civil)
  - Fuselage design - subfloor energy absorbing properties
  - Intrusion of rotors
- Landing gear
  - Military requirements - must be energy absorbing (42 ft/sec, 30 ft/sec)
  - Civil - 27 ft/sec

Crashworthiness and Aircraft Type

Rotorcraft

- Restraint
  - Most injuries are due to flail and head strike
  - Lap belt, shoulder harness, 5-point harness (cyclic, instrumentation panel)
- Seats
  - Energy absorbing properties for higher vertical loads
  - Attachment to structure
- Environment
  - Water impacts - landing gear does not provide energy absorption in water impact
  - Fire - military fuel bladders/fuel containment
  - Mission - transport, combat, cargo, traffic

Crashworthiness and Aircraft Type

Transport/Regional Jets

Crashworthiness and Aircraft Type

Transport/Regional Jets

"Perception of Safety" and the General Public

- **Structure**
  - **More structure to absorb energy (subfloor, luggage, etc)**
  - **In survivable crash, fuselage "breaks" in front of the wing, behind the wing and the tail section detaches (general statement).**
  - **Occupiable volume (example - ATR 42)**
  - **Floor structural integrity**
- **Landing gear (if extended)**
  - **Performance depends on surface (hard surface, soft soil)**

Introduction to Crashworthiness

Crashworthiness and Aircraft Type

Transport/Regional Jets

"Perception of Safety" and the General Public

- **Restraints**
  - **Perception of Safety - lap belt versus shoulder harness versus 5 point harness (bulkhead walls)**
  - **Human factors and egress**
  - **Occupant size and age**
- **Seats**
  - **Seat type (crew, cockpit, single, double, triple…) and pitch**
  - **Attachment to structure**
  - **Occupant size**
  - **Seat back height - survivable volume, overhead bins**

Crashworthiness and Aircraft Type

Transport/Regional Jets

"Perception of Safety" and the General Public

- **Seats (continued)**
  - **FAA seat requirements**
  - **Egress - lower extremity injuries**
- **Post Crash Environment**
  - **Human factors (previously mentioned)**
  - **Egress**
  - **Fire - suppression systems**

Introduction to Crashworthiness

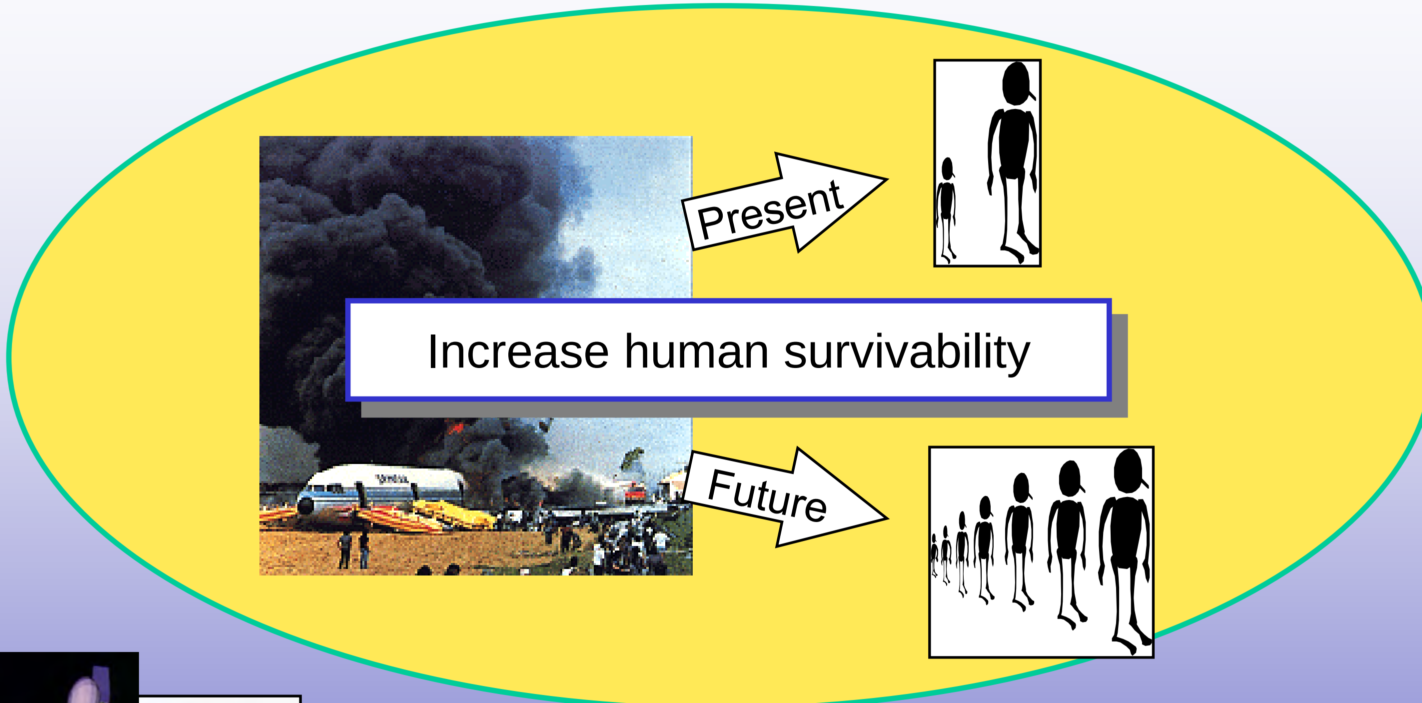
Crashworthiness and Aircraft Type

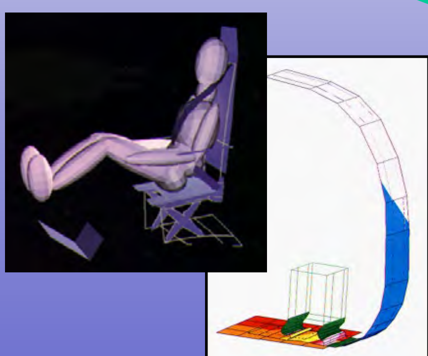
Cargo

- **Fixed wing or Rotorcraft (see previous slides)**
- **Cargo must be restrained to prevent sliding and crushing crew during a crash event - active control restraints should be used.**

Introduction to Crashworthiness

Systems Approach to Crashworthiness





Validated Analysis Methodology

Energy-Absorbing Structural Concepts

Advanced Restraints

Crash-Resistant Fuel Systems

Discussion

Class Adjourned

Survival Factors in Aviation Accidents

Crashworthiness of Metal versus Composite Airplanes

Lisa E. Jones
NASA Langley Research Center

NTSB Academy
October 18 - 21, 2004

Crashworthiness of Metal versus Composite Airplanes

Outline

- What are composites?
- Types of composites
- Advantages of Composites
- Disadvantages of Composites
- Testing
- Metal versus Composite Example #1
- Metal versus Composite Example #2
- Summary/Discussion

What are composites?
A Definition

Composite Material - Composites are considered to be combinations of materials differing in composition or form on a macro-scale. The constituents retain their identities in the composite; that is, they do not dissolve or otherwise merge completely into each other although they do act in concert. Normally, the components can be physically identified and exhibit an interface between components.

What are composites?
Types of Composites

- Dispersion-Strengthened Composites - Fine particles (diameter .01 to 1.0 micro inches) dispersed in matrix with a concentration of 1-15%. Matrix is major load bearer. Usually used for elevated temperature applications.

- Particulate Composites - Concrete, rocket propellant, aluminum paint, metallic particles in metallic matrix, cerments (ceramics suspended in metal matrix) particle size > 1.0 micro inch and concentration may range from a few to > 70%. Matrix and particles share load.

- **Fibrous Composites - Reinforcement has one long direction. The fiber may be continuous filament, chopped fibers, or whiskers. The fiber has near crystal-sized diameter. (Examples - fiber-glass, Kevlar, graphite-epoxy)**

Crashworthiness of Metal versus Composite Airplanes

Advantages of Composites

- Lightweight material with high specific strength and stiffness
- Custom tailoring of material to application or optimization of design for function (1-D and 2-D)
- Properties lead to innovative design concepts
- Manufacturing
  - Little scrappage compared to metals (spar aluminum - 700% scrap)
  - Reduce part count by co-curing (complex geometry designs)
  - Adaptable to automatic fabrication procedures.
- Improved fatigue life and reliability of composite materials

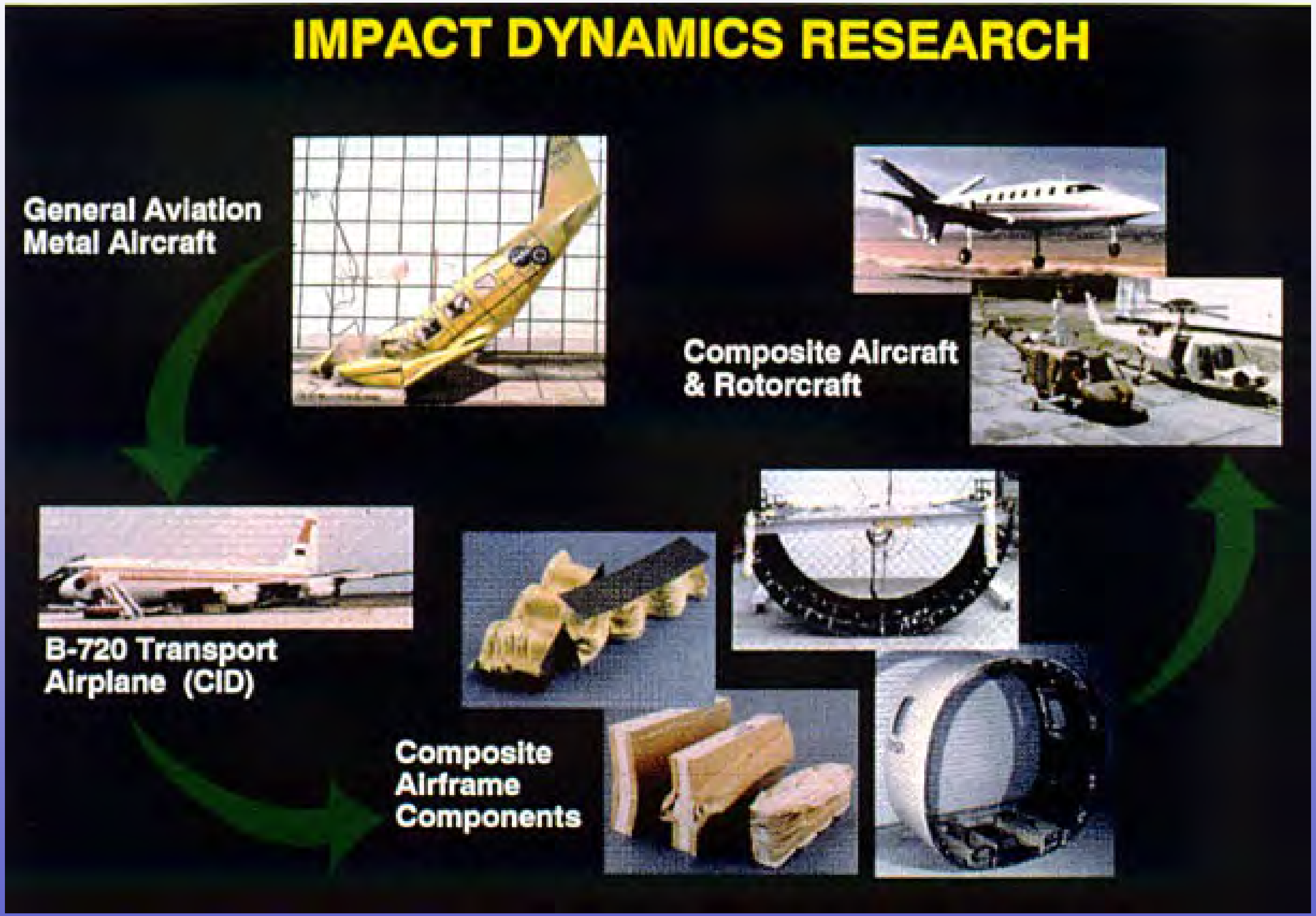
Disadvantages of Composites

(Most of the following are generalizations)

- Cost of raw materials and labor for hand lay-up may be prohibitive for certain applications.
- Delamination or weakness thru the thickness (pealing)
- Damage tolerance to impacts limited (detection of hidden damage)
  - Runway debris
  - Hail stones
  - Dropped hand tools
  - Maintenance abuse
  - Engine rotor burst
- Fiber dominated composites are brittle.

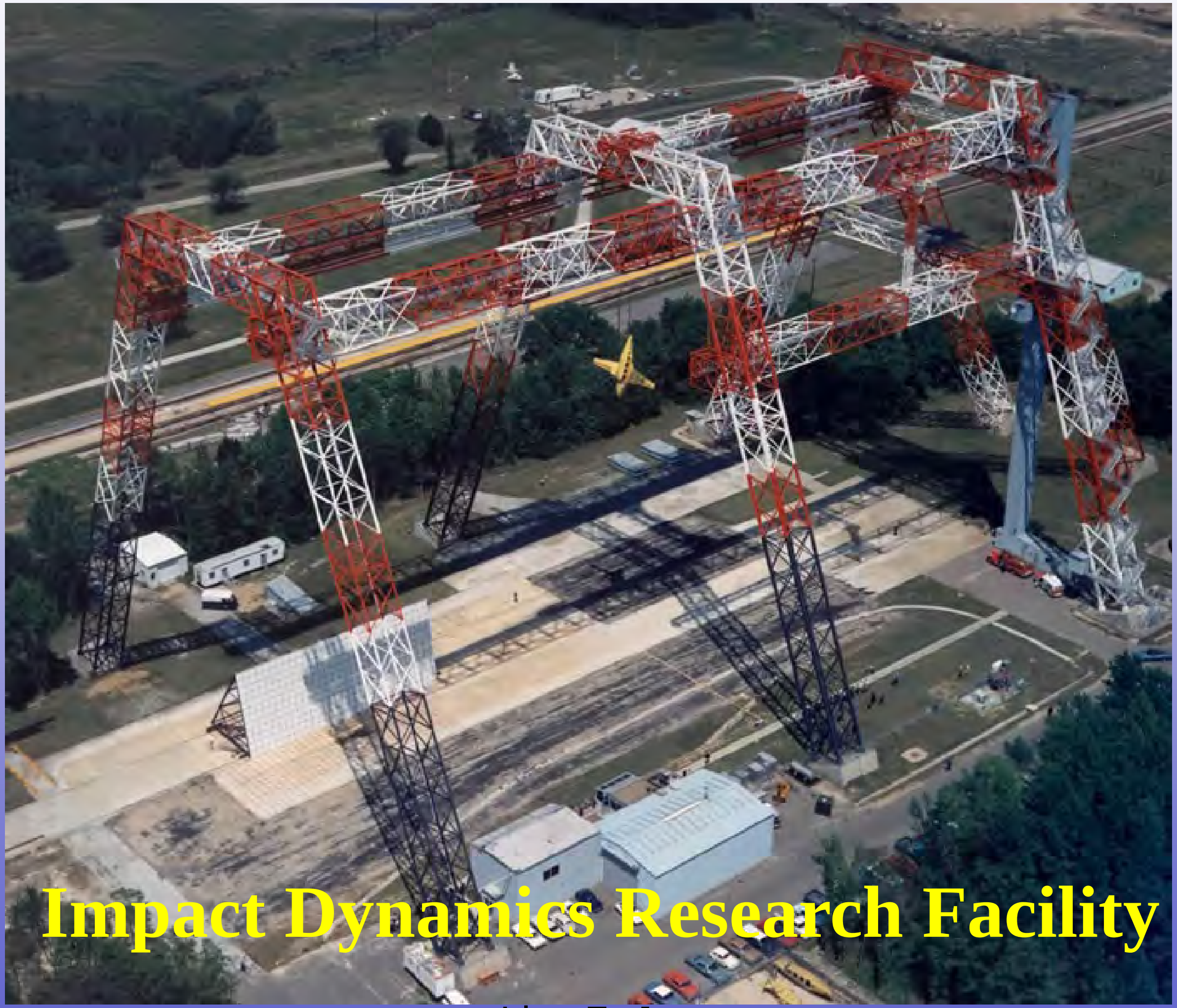
Crashworthiness of Metal versus Composite Airplanes

Testing



Crashworthiness of Metal versus Composite Airplanes

Testing



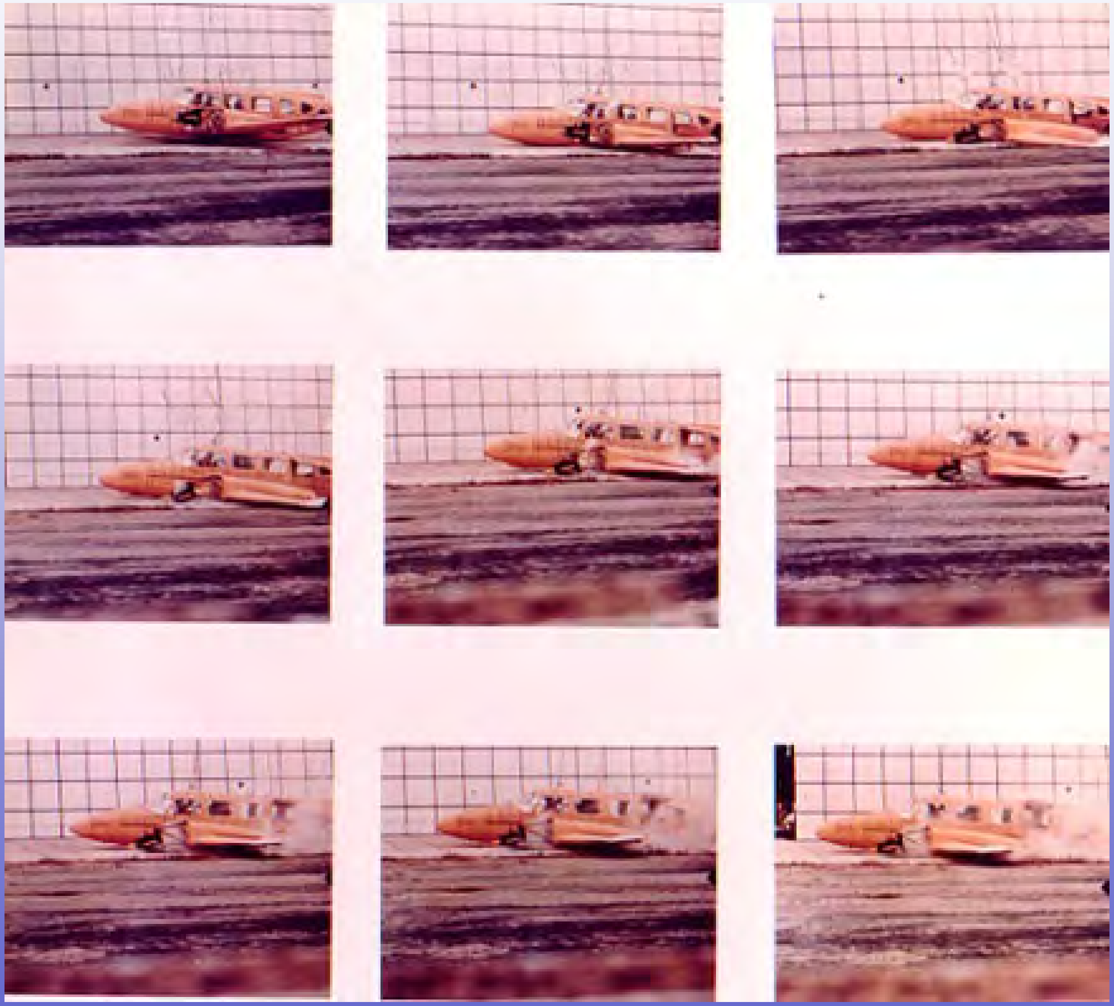
Crashworthiness of Metal versus Composite Airplanes

Metal versus Composite Example #1

Video NASA TEST 4

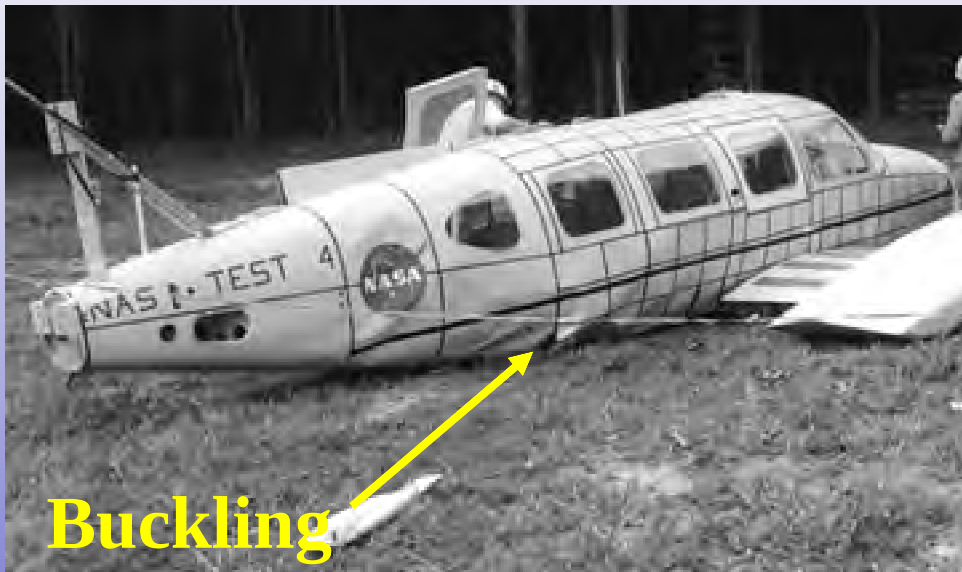
Crashworthiness of Metal versus Composite Airplanes

Metal versus Composite Example #1



Crashworthiness of Metal versus Composite Airplanes

Metal versus Composite Example #1



View Looking Aft

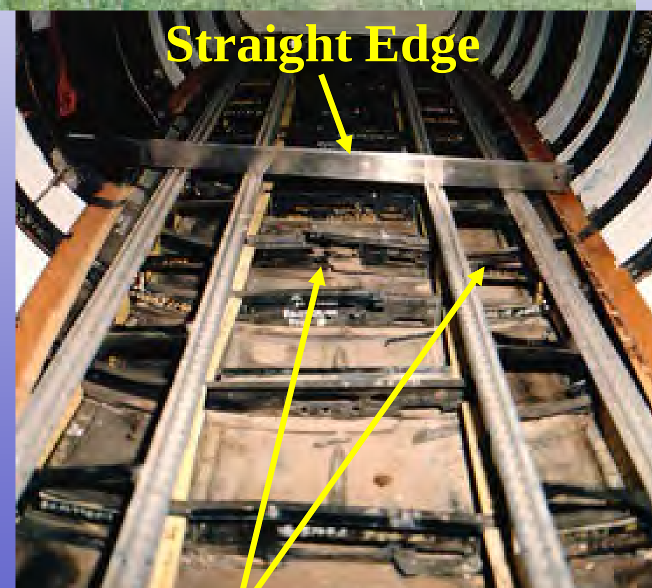
Metal versus Composite Example #1

Video Lear Fan I

Crashworthiness of Metal versus Composite Airplanes

Metal versus Composite Example #1

Post-test Interior

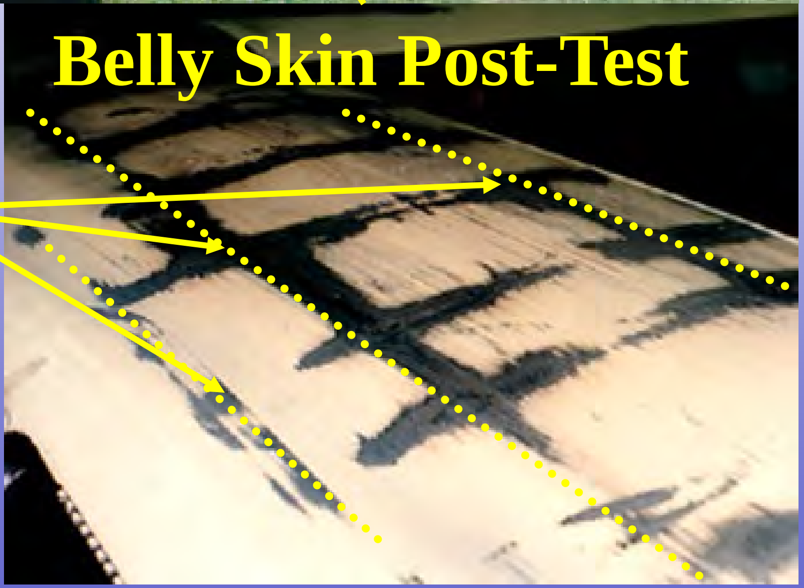


Failed Frames and Stanchions

Lisa E. Jones
NASA LaRC

Crashworthiness of Metal versus Composite Airplanes

Metal versus Composite Example #1



Floor Beams

Fuselage belly skin did not sustain permanent deformation (buckling). What does this tell us?

Crashworthiness of Metal versus Composite Airplanes

Metal versus Composite Example #1
Comparison of NASA Test 4 and Lear Fan 1

NASA TEST 4

- Impact conditions
  - 88 ft/sec along flight path (22 ft/sec vertical)
  - Pilot in 9g seat
  - Impact surface - concrete
- Pilot pelvic accelerations - 40g

Lear Fan 1

- Impact conditions
  - 88 ft/sec along flight path (30 ft/sec vertical)
  - Pilot in 9g seat
  - Impact surface - concrete
- Pilot pelvic accelerations - 80g

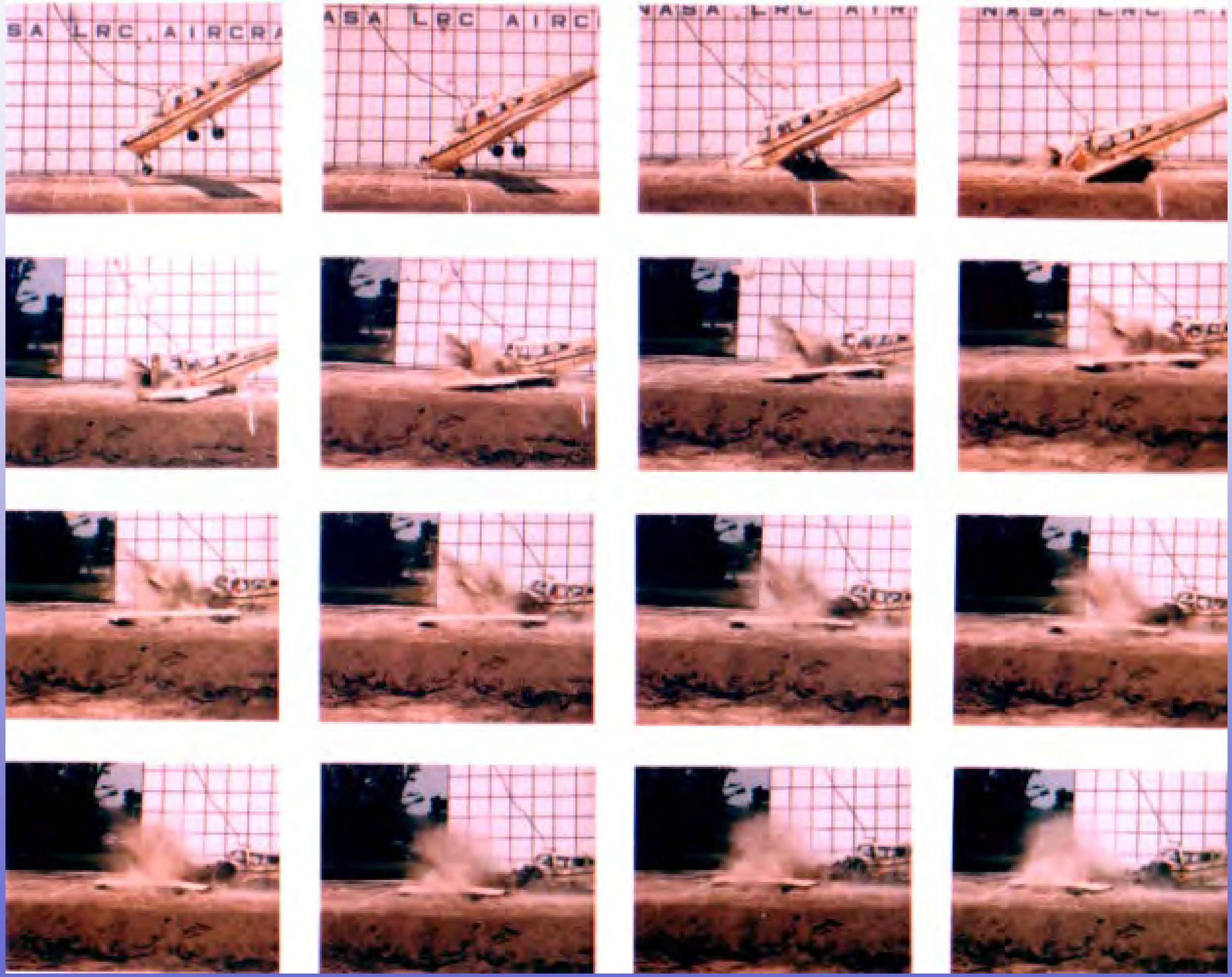
Crashworthiness of Metal versus Composite Airplanes

Metal versus Composite Example #2

Video NASA TEST 11

Crashworthiness of Metal versus Composite Airplanes

Metal versus Composite Example #2



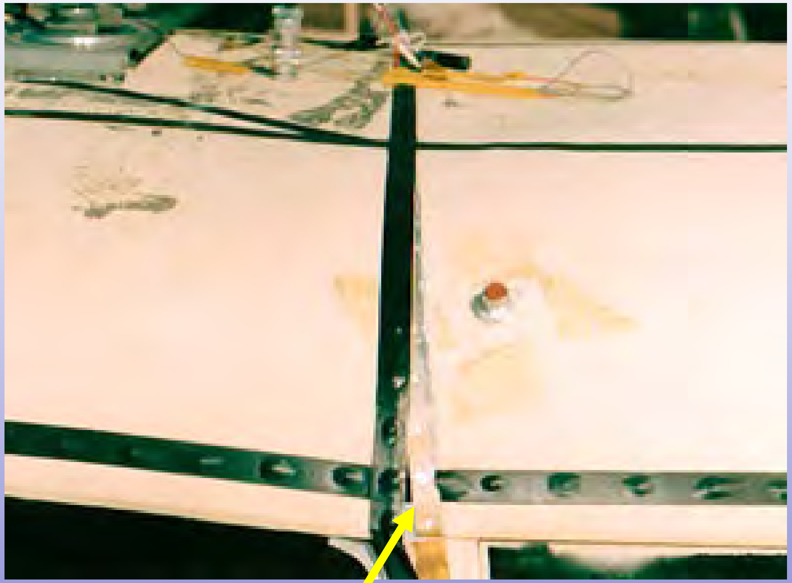
Crashworthiness of Metal versus Composite Airplanes

Metal versus Composite Example #2

Crashworthiness of Metal versus Composite Airplanes

Metal versus Composite Example #2

Rivet Line Skin Failure



Rivet Shear Failure

Metal versus Composite Example #2

Video Terry Engineering Test 3

Crashworthiness of Metal versus Composite Airplanes

Metal versus Composite Example #2

Reinforced Cowling

Failed Engine Mount

Lisa E. Jones
NASA LaRC

Crashworthiness of Metal versus Composite Airplanes

Metal versus Composite Example #2

Metal versus Composite Example #1
Comparison of NASA Test 11 and Terry Engineering 3

NASA TEST 11

- Impact conditions
  - -31° Flight-path angle
  - -30° Pitch angle
  - 78 ft/sec along flight path
  - Pilot in 9g seat
  - Impact surface - soft soil
- Pilot pelvic accelerations - 60g

Terry Engineering 3

- Impact conditions
  - -30° Flight-path angle
  - -23.5° Pitch angle
  - 82.5 ft/sec along the flight path
  - Pilot in 9g seat
  - Impact surface - soft soil
- Pilot pelvic accelerations - 23g

Summary/Discussion

NTSB Overwater Study

and DC-10 accident at Boston, MA

1985 NTSB Study “Air Carrier Overwater Emergency Equipment and Procedures”

- “Planned” ditchings of passenger transport aircraft are extrememly rare
- Inadvertent water impact accidents, though far more common than ditchings, are infrequent
- FAA requirements for equipment and training are geared toward ditchings

1985 Overwater Study (Cont)

- Most survivable inadvertent water impacts occurred closer to shore than 50 nautical miles, near an airport, on approach or departure
- 179 airports in the US with significant bodies of water within 5 miles; flights that use these airports may be at risk for inadvertent water impact, even if flight is not "extended overwater" or "any overwater."

1985 Overwater Study (Cont)

- Despite several revisions to life preserver standards, there are serious problems involving stowage accessibility, packaging, sizing, ease of donning, and performance in the water
- No realistic provision has been made for water survival equipment (including hypothermia protection) for infants and small children

1985 Overwater Study (Cont)

- The ability of flight and cabin crewmembers to assist passengers effectively during ditchings and following inadvertent water impacts may be the single most important factor in the survival outcome.

Overwater Study Recomendations

- NTSB issued 16 recommendations to the FAA addressing equipment, training and procedures


WORLD AIRWAYS
WORLD

DC-10 Runway Overrun, Boston
January 23, 1982

- DC-10-30 landed on runway 15R and went off the departure end of runway into the shallow water of Boston Harbor
- 198 passengers, crew of 12 evacuated
- 2 passengers from Row 1 presumed dead

DC-10 Runway Overrun, Boston
January 23, 1982

- The airplane came to rest just off the airport in the Boston Harbor
  - At time of evacuation, water was waist-deep at the end of the 4R slide and about knee-deep between the right wing tip and the shore
  - The nose, including the cockpit, fwd lavs, fwd F/A jumpseats, fwd exits (1L, 1R), seats in rows 1 and 2, separated from the fuselage
  - 6 exits were opened (2L, 2R, 3L, 3R, 4L, 4R)

NATIONAL TRANSPORTATION SAFETY BOARD

National Transportation Safety Board

DC-10 Runway Overrun, Boston January 23, 1982

- Usable Exits
  - The #2 engine continued to run at full reverse thrust (estimated 30 minutes) which caused R4 and L4 slides to blow against fuselage and ice and gravel blown about and into the cabin
  - Right side exits were closest to shore
- Crew Actions
  - 3 flight crew members, 2 F/As found themselves in sea water. All easily freed themselves from their restraint systems.
  - Captain swam to fuselage break and was helped into cabin by pax.

DC-10 Runway Overrun, Boston
January 23, 1982

- L1 F/A was able to don life vest even though hands were cold
- F/O and F/E swam around left wing to shore and were assisted out of water by ARFF personnel
- L1 and R1 F/As followed captain to fuselage and were helped into cabin by pax

DC-10 Runway Overrun, Boston
January 23, 1982

- Issues
  - Two passengers missing and presumed dead. Manifest problems delayed knowledge that pax from Seats 1A and 1B were missing
- Communication
  - Cockpit literally separated from cabin
  - Inoperative interphone/PA
  - Noise of No. 2 engine
  - F/As used megaphones to overcome engine noise
- Life Vest
  - Problems with donning

DC-10 Runway Overrun, Boston
January 23, 1982

- F/A procedures allowed them to initiate evacuation after airplane stopped.
- No. 2 engine running caused confusion for F/As

Survival Factors Investigation

Injury Documentation

Injury Documentation

- If we want to reduce injuries, we need to thoroughly document the injuries and try to understand how they occurred
  - Requires good injury information AND good documentation of occupant environment
- Injury Information can be perishable if not documented properly
  - Location of body in wreckage

Injury Documentation

- Subpoena Power to obtain injury information
- Work with Medical Professionals to get accurate information
  - Medical Examiner, Forensic Pathologist, physicians
- Self-reported Injuries

Injury Documentation

- Improvements in occupant survivability happen slowly and require detailed documentation
- Who uses information
  - Investigators, researchers, engineers, manufacturers, regulatory authorities

Injury Documentation

- How much detail is needed
  - What is your goal?
    - Is it a survivable accident?
      - Define survivable accident
    - Is it a possible criminal event?
    - Is it a non-survivable accident
- Looking at patterns
- Drawing conclusions
  - Based on the totality of the accident
  - May not be able to draw a conclusion

Injury Documentation

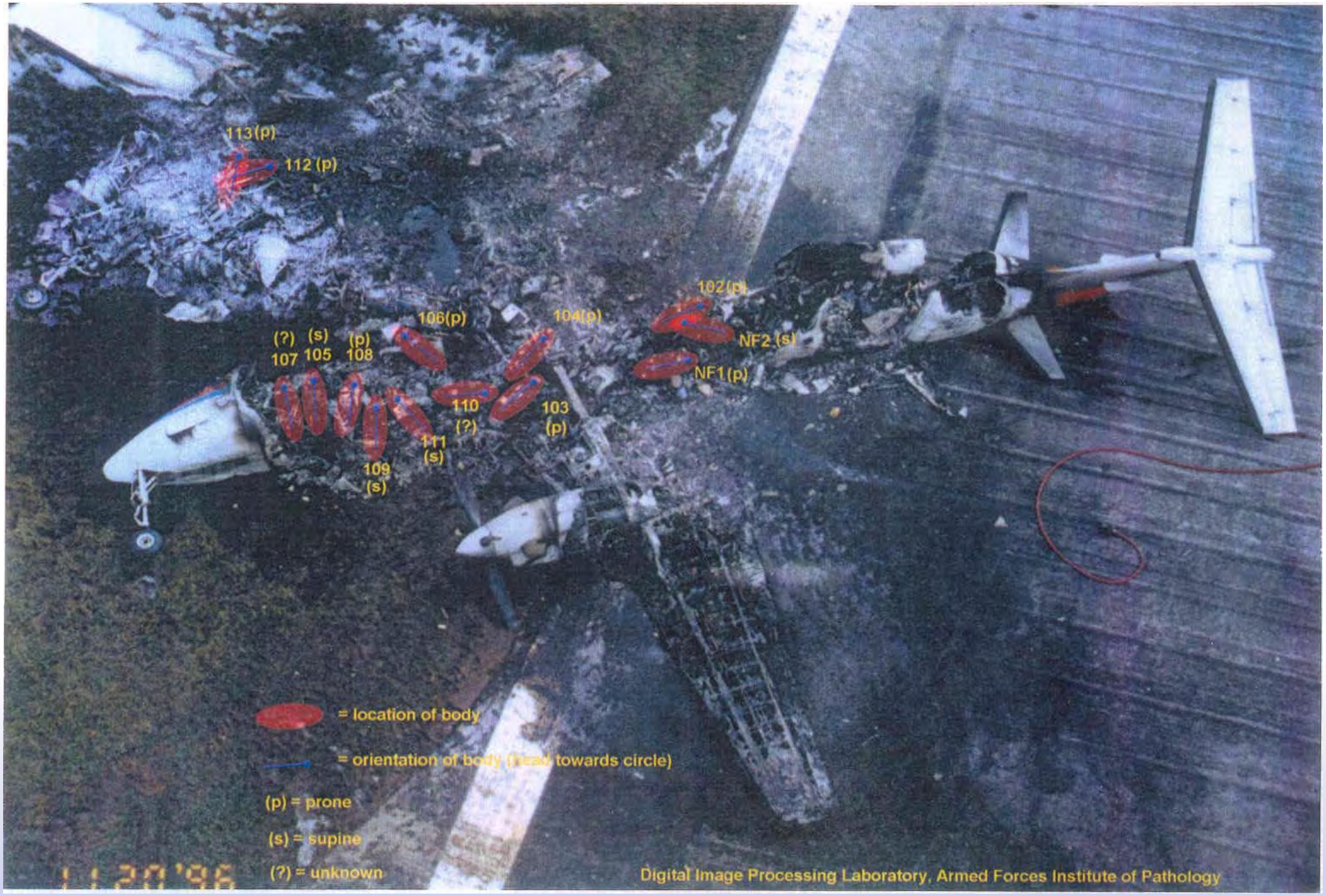
- Autopsies
  - Forensic Pathologist, Medical Examiner, Coroner
- Medical Records
  - We use only the injury description
- Self Reported Injuries
  - Obtained from interviews or passenger questionnaires

Injury Chart

- Important part of any investigation
- Should provide accurate description of injuries
- Should include age, height and weight
- Factual not analytical

Injury Myths

- Lack of good injury documentation will create myths
  - No one survives an airplane crash
  - Evacuations are dangerous because of injuries
  - Everyone lines up at forward exit
- Be careful of pre-determining that an accident is “Unsurvivable”



113(p)
112 (p)
102(p)
106(p)
104(p)
(?) (s) (p)
107 105 108
NF2 (s)
NF1(p)
110
(?)
103
(p)
111
(s)
109
(s)
= location of body
= orientation of body (head towards circle)
(p) = prone
(s) = supine
(?) = unknown
11 20 '96
Digital Image Processing Laboratory, Armed Forces Institute of Pathology

NTSB Academy
Survival Factors in Aviation Accidents

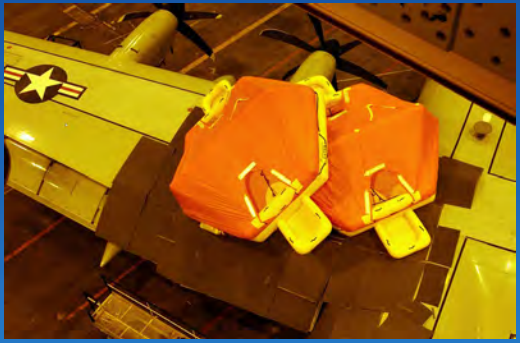
Evacuation Slides & Slide/Raft Systems
October 20th 2004

Presented by:
Mike Kret
Technical Support Manager
Air Cruisers Company

ZODIAC

AIR CRUISERS

ZODIAC



AIR CRUISERS

ZODIAC

Group profile

AeroSafety Systems

Aircraft Systems

Airline Equipment

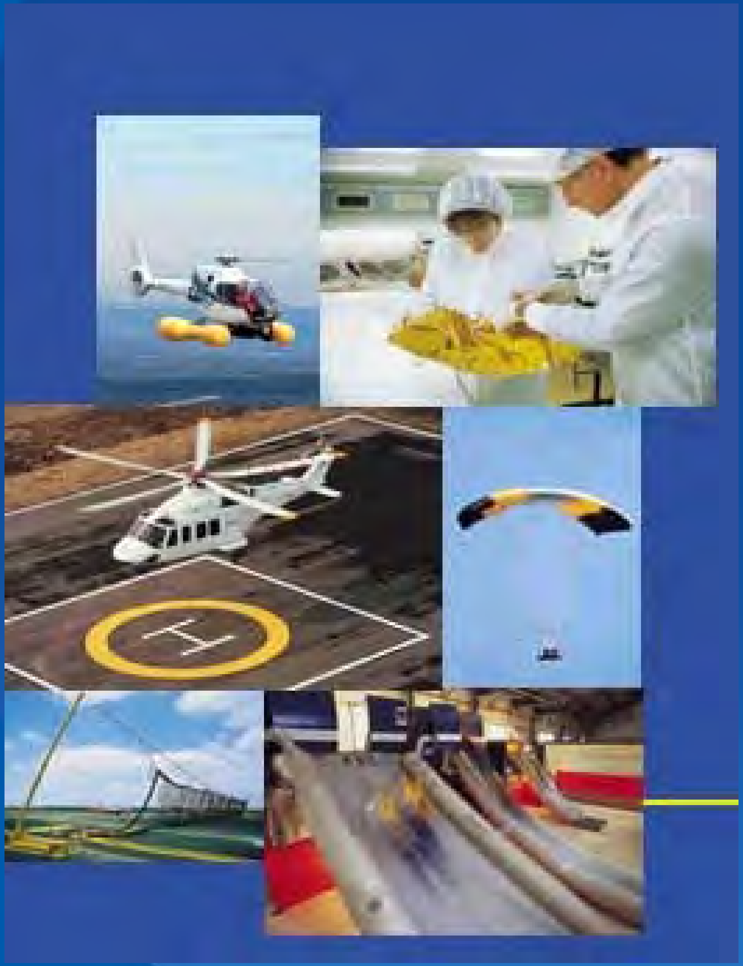
Technology

Marine

ZODIAC

AIR CRUISERS

AeroSafety Systems



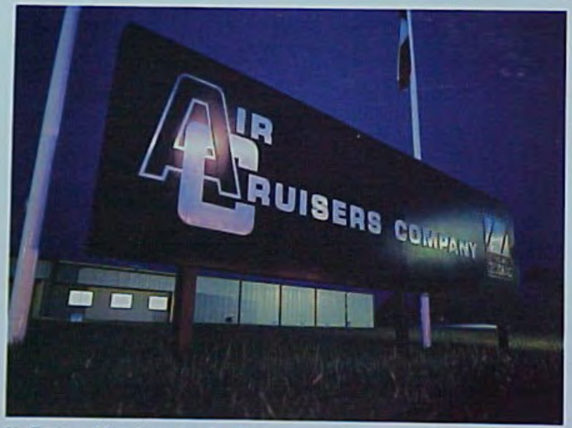
- Emergency Evacuation Systems
- Deceleration and Protection

-Air Cruisers

- Aérazur
- Plastiremo
- Parachutes de France (France)
- Pioneer Aerospace
- Amfuel (U.S.)

Air Cruisers Company

Air Cruisers Manufacturing Facility
Wall Township, New Jersey U.S.A.



Air Cruisers Manufacturing Facility
Liberty, Mississippi U.S.A.

In Business Over 65 Years
Headquartered in Belmar, New Jersey
350 Employees

Emergency Evacuation Product Listing

- **Boeing: 707, 717, 727, 737, 747-100/-200, 757, 767, 777**
- **Douglas: DC-8, DC-9, DC-10, MD-80, MD-90, MD-11, MD-95**
- **Airbus: A300, A310, A318, A319, A320, A321**
- **BAe: RJ70, RJ85, RJ100**
- **Fokker: F28, F100, F70**
- **Lockheed: L-1011**
- **Ilyushin: IL-96M, IL-96-300,**
- **Tupolev: TU-214, TU-204**
- **Beta Air: Be-200**
- **Fairchild Dornier: 728Jet, 928Jet**
- **Boeing Military: C-135, E6-A**
- **Lockheed Martin Military: C-5**

Other Air Cruisers Products

- Military Life Rafts
- Commercial Life Rafts
- General Aviation Life Rafts
- Helicopter Floats
- Life Vests
- Custom Inflatable Structures

This year Air Cruisers will manufacture and ship over 1000 life raft systems for military and commercial users worldwide.

Commitment to Excellence

Quality

1999 Air Cruisers is awarded the Quality New Jersey Governor's Award for Performance Excellence

Air Cruisers Milestones

Boeing Supplier of the Year – 1997 & 2003
Air Cruisers is Committed to Excellence

Commitment to Excellence

Quality

Slide Basics & Fault Analysis

- General Slide Description
- Primary Components
- Operation
- Fault Analysis

Slide Description

- The equipment is designed in full compliance with FAA TSO-C69 to provide a reliable and safe means of rapid egress from the aircraft to the ground in case of emergency.
- The slide system consists of three major subsystems -- an inflatable slide or slide/raft, stored gas reservoir and valve assembly, and a packboard and lacing cover assembly.

Slide Description

- A slide/raft contains pneumatically independent upper and lower chambers to meet the raft mode requirements of TSO-C69.

- A slide/raft is outfitted with additional components for survival at sea including:
  - Survival kits, canopies, heaving rings, locator lights, inflation valves, boarding aids, etc.

Slide Description

- Slides are considered FAA-TSO approved after meeting rigorous qualification requirements including but not limited to:
  - The ability to deploy into a variety of severe wind conditions.
  - The ability to resist degradation due to various fluids (hydraulic, jet fuel, aircraft cleaners, etc.).
  - The ability to resist degradation due to the environment (sand, dust, salt spray, etc.)
  - The ability to surpass flame, smoke and toxicity requirements of the applicable FARS.
  - The ability to operate under temperature extremes from -40 to 160 deg. F.
  - Many others….

Evacuation System
Primary Components

Inflation System

- A reservoir and valve assembly is installed in a sling underneath the slide near the sill end. A valve assembly, installed on the reservoir, provides regulated gas to the hoses.

- Mounted to the valve is a temperature-compensating pressure gage which indicates the gas charge level, a frangible burst disc (which limits the pressure below proof-pressure), and a filler valve which permits charging the reservoir.

- A hose assembly connects the valve to the aspirator(s). Check valves installed between the hose ends and the aspirators prevent back flow of gases once the slide is pressurized. This maintains the inflatable as a pneumatically independent assembly.

Inflation System (con't)

The aspirators are composed of:

- A cylindrical mixing tube section for mixing the stored primary gas and ambient secondary gas (air).
- A nozzle section through which the stored gas is introduced.
- A conical inlet section for the entrance of ambient air.
- A flapper valve for retaining the gas after inflation has been completed.

- The aspirator is equipped with a pressure test valve for checking tube pressure and for inflating the slide during maintenance.

Girt

- The inflatable slide is attached to the aircraft by means of a girt assembly cemented to the sill tube.
- The inboard end of the girt forms a loop through which the girt bar is retained.
- The girt bar is inserted into brackets on the aircraft floor when the door is placed in the "armed" mode.

Girt (con't)

- In ditching, separation of the inflatable slide from the aircraft is accomplished using a release handle located beneath a cover flap on the girt.
- When the handle is pulled free, the girt separates from the girt bar. This allows the slide to drift away from the aircraft until the mooring line becomes taut.
- The mooring line is stowed in a separate sheath between the girt halves.

Lighting System

- The lighting system is comprised of three major components - the lamp harness, the power unit, and a light activating lanyard.

- The lamp harness is installed in a fabric sleeve across the runway tube of the slide. The lamp harness wire is routed along the side of the inflatable and through a wire sleeve near the girt.

Lighting System (con't)

- The power unit (battery) is typically attached to the reservoir sling in a pouch constructed of nylon fabric. It has a usable life of five years from the date of manufacture.

- Lights are automatically actuated during the deployment cycle of the slide when the light activating lanyard is withdrawn from the power unit by distention of the inflatable.

- The activating pin should remain inserted in the battery whenever possible to preserve battery life.

Re-entry Strap

- A re-entry strap is provided as an aid if re-boarding the aircraft becomes necessary after an emergency evacuation. The re-entry strap is constructed of one inch wide white webbing.

- The upper end is permanently attached to the sill end of the slide. The lower end is retained with velcro fasteners.

Restraint Devices

- An intermediate restraint device is used to control the deployment sequence by restraining the unit such that it remains partially folded during the initial deployment phase.

- This prevents the slide from extending under the aircraft fuselage and assures that it is fully extended when it contacts the ground.

Pressure Relief

- Relief valves are typically installed in both the upper and lower tubes at the sill end. The relief valves limit the maximum pressure due to internal gas temperature changes to within the required operating pressure range.

Flotation Handles

- Flotation handles located on the perimeter of the lower tube serve as lifelines for survivors to grasp from the water.
- The flotation handles are constructed of one inch wide webbing and are also used to facilitate the slides use as a non-inflated apron chute.

Manual Inflation Handle

- A pull handle on the girt for manual inflation serves as a backup system should the slide fail to inflate automatically upon deployment.

- The pull handle is triangular in shape and is constructed of white webbing. The inflation valve release cable is attached to the pull handle by a threaded connector.

Manual Inflation Valves

(slide/rafts)

- Manual inflate/deflate valves are located in both the upper and lower tubes at the sill end. A manual inflation pump and adapter are stored in the survival kit. The inflate/deflate valves are spring loaded poppet types which are automatically opened or closed by the attachment or removal of the valve adapter on the pump.

- To increase the air pressure in a tube, push the pump adapter into the inflate/deflate valve and squeeze the pump until the desired pressure has been obtained.

Boarding Aids
(slide/rafts)

- Boarding handles and boarding aids are located at each end of the inflatable. They are constructed of one inch wide red webbing and enable survivors to climb aboard the slide/raft from the water.

Sea Anchor
(slide/rafts)

- The sea anchor is a cone-shaped cloth bag used to control the drift rate and orientation of the slide/raft with respect to the wind.
- The sea anchor is stowed in a fabric pouch on the side of the slide/raft near the sill end.

Locator Lights
(slide/rafts)

- Two locator lights provide aid in locating the slide/raft and its boarding stations at night. The lights are operated by water activated batteries stored in pockets on the underside of the slide/raft.

- Locator lights are located on top of the upper inflation tube, one at each end of the slide/raft, on opposite corners.

Evacuation System Operation

Slide Operation

- The girt bar is engaged in the floor fittings when the closed door is placed in emergency mode. As the door opens outboard, the pack release cable is pulled free, and the packed slide drops outboard of the door.
- The automatic inflation cable tensions and opens the inflation valve assembly, initiating inflation. The packboard and lacing cover either remain attached to the aircraft door, or are tethered below the sill end.

Slide Operation

- The released gas flows through the hoses to the aspirators and a partial vacuum is created in the mixing section of the aspirators by the high-velocity gas as it leaves the nozzles.
- As a result, ambient air enters through the flapper valves and combines with the high velocity gas in the venturi to provide for rapid inflation.
- When the inflation cycle has progressed to a predetermined internal slide pressure, the flapper valves close and the remaining stored gas is used to “top off” the slide to final operating pressure.

Slide Operation

- During inflation, restraint devices control distention of the slide by sequencing the unfolding.
- The devices separate at specific loads dependent on internal pressure and optimum performance for the particular slide configuration.
- The slide projects outward and downward while maintaining positive contact to the aircraft door sill. When the slide is fully extended, it is ready for use.

Fault Analysis

- Non-Deployment of Slide
  - Typically, inflation system related via rigging procedure error.
- Deployment and subsequent failure.
  - Typically component failure or packing error.

Non-Deployment of Slide

1. Verify that slide dropped from door.
   a. If not -
      i. Check for proper installation on door (ref. AMM).
      ii. Assure girt bar is latched to floor (door is armed).
      iii. Is lacing cover release cable attached and did it successfully pull from packboard release mechanism?

   b. If ok – Proceed to next step.

Non-Deployment of Slide

2. Verify (via records if required) that reservoir contains (ed) proper charge. Check system gage or remote indicator.
   a. If not – Recharge and check for leakage per CMM.
   b. If ok – Proceed to next step.

3. Verify that safety pin has been removed from valve.
   a. If not – Remove & repeat test.
   b. If ok – Proceed to next step.

Non-Deployment of Slide

4. Verify that valve actuation cable is installed and set in pulley.
   a. If not – Install per assembly section of CMM.
   b. If ok – Proceed to next step.

5. Verify that valve actuation cable was tensioned from pack release.
   a. If not – potential rigging issue – check cable obstructions/path.
   b. If ok – Proceed to next step.

Non-Deployment of Slide

6. Verify that valve pulley rotated.
   a. If not – Dis-assemble valve and evaluate per CMM.
   b. If ok – Proceed to next step.

7. Verify that hoses are secure and intact.
   a. If not – Evaluate hose condition per CMM check section. Perform hydrostatic test.
   b. If ok – Proceed to next step.

Non-Deployment of Slide

8. Verify aspirator condition.
   a. Verify integrity of nozzle array.
   b. Verify integrity of flapper valve.

If gas actually makes it into the inflatable then we are faced with the next type of failure mode:

Deployment & Subsequent Failure

- These type of incidents may be difficult to analyze due to “lost evidence”.
- It is vital to have the ability to review the deployment sequence on video.

Deployment & Subsequent Failure
"Inflatable Damage"

- Rigid component "stackup" may cut or puncture material.
- Incorrect positioning of major slide components.
  - Ref. S.B. 107-25-06 for 777 aspirator position.
- Strict adherence to Air Cruisers folding procedures is vital to avoid these type of incidents.

Deployment & Subsequent Failure

"Design Geometry not Obtained"

- Insufficient gas enters the inflatable.
  - Verify proper cylinder charge (via records).
  - Check valve regulation per CMM testing section.
  - Check for misc. leaks in gas flow path from cylinder to aspirator.
  - And finally, check for:

ZODIAC

AIR CRUISERS

Deployment & Subsequent Failure

"Design Geometry not Obtained"

INGESTION !!

INGESTION !!

INGESTION !!

Deployment & Subsequent Failure

"Design Geometry not Obtained"

- Aspirators can "ingest" foreign objects as well as various components of the slide.
- Strict adherence to Air Cruisers folding procedures is vital to avoid these type of incidents.
- Video evidence is typically necessary to attribute this failure mode. But not always…

Deployment & Subsequent Failure

"Design Geometry not Obtained"

Deployment & Subsequent Failure
"Design Geometry not Obtained"

- "Missing" or incorrect restraint installation.
  - Installation of undersized restraint may effect sequencing of deployment.
    - Slide can end up "underneath the aircraft".
    - Performance in wind may be severely impacted.
  - Installation of oversized restraint may prevent full extension of slide.

Deployment & Subsequent Failure

- In the event evidence has been lost and root cause is not immediately assignable, there is value in conducting an "unpack audit."
- Other units (of the same P/N) which were packed by the same team are "unpacked" to verify conformance with the applicable folding procedure.

Questions??

Survival Factors Interviews

Who Is Interviewed

- Passengers
- Flight Attendants
- ARFF
- FAA Officials
- Airport Management
- Witnesses
- Airline Training & Maintenance

Location of Interviews

- Hospitals*
- Airports
- Hotels
- Homes
- Training Centers
- Fire Stations
- Phone Interviews

Hospital Interviews

- Must obtain permission from hospital administrator and patient's physician
- Use hospital social worker if available
- Be sensitive to patient's condition
  - Let the patient set limits on length and depth of interview
- Use smallest group possible
- Check with nursing staff to determine a good time for interview

Interviewing Children

- Must have parent's permission and parent or guardian present during interview
- Obtain physician or counselor's permission if appropriate
- Avoid leading questions

Interview Techniques

- Introduce yourself, your organization, and group members
- Explain the purpose of the interview
  - Obtain information that can improve safety
  - To learn what happened during the event
  - Develop recommendations to improve equipment, procedures, and training

Interview Techniques

- Interviewee has a right to have someone with them during the interview
  - Attorney, union rep, family member, etc.
- Interviewee has the right to exclude any group member other than NTSB

Interview Techniques

- Interview not an interrogation
  - Informal but structured
- Encourage them to tell what happened – everything that they remember
- Let them talk as long as they would like
- DO NOT INTERRUPT
  - As they talk, make notes for follow-up questions

Interview Techniques

- How to handle questions about accident such as why it happened or whether someone survived or was injured
  - Explain that the investigation is not complete and the cause of the accident is yet to be determined
  - Injury information is not available during field phase of investigation

Interview Techniques

- Before interview, decide who will conduct interview. Other group members should take notes.
- If time is limited, let the person tell you what they think is important
- LISTEN – do not analyze
  - Remember that what they are telling you is true for them. You can analyze the interview later

Interview Techniques

- Be prepared for different emotions
  - Anger, irritability, confusion, sadness, crying, stoicism, etc.
- Many people are very helpful – they want to tell you what happened to them during the event

Interview Techniques

- Be prepared to conduct an interview at any time
- Equipment
  - Paper and pencil, laptop with charged battery
  - Cabin layout diagram
  - Maps
  - Photographs
  - Tape Recorder*
  - Toy airplane

Interview Techniques

- NTSB policy on tape recorders
  - Can be used only with the permission of interviewee
  - Used to write up interview summaries
    - Helps group agree on what was said

Interview Summary

- Report what they said. Use their language/terminology, not yours.
- Write the summary in a sequential manner using a "reporters narrative."
- Report "first-hand" information, not what they heard from someone else.
- Keep it factual!
  - Time estimates????
- Focus on Survival Factors issues and leave other information out of summary.

QUESTIONS????

AS320: Survival Factors in Aviation Accidents

Aircraft Seats and Restraint Systems

Physics,

Civics,

& Seats

Rick DeWeese
FAA Civil Aerospace Medical Institute
Biodynamics Laboratory

History of Aircraft Occupant Protection

- Helmets: WW I (To keep your head warm)

History of Aircraft Occupant Protection

- Seat belts: WW II (To keep you in place during maneuvers)

History of Aircraft Occupant Protection

- Padding: 1960's (1" of Ensolite to make you feel better)

AC 25-17 Section 81, Paragraph b.(3):

Surfaces within the 35-inch arc may be padded with energy absorbing material, such as one inch of either Ensolite (Type AH or HH), Klegecell or Airex 4070.

History of Aircraft Occupant Protection

- Denial: 1970's (Fly the Friendly Skies)

History of Aircraft Occupant Protection

- 1980's and 90's (Giant Leaps Forward)
  - General Aviation Safety Panel (GASP) initiated by industry as a way to help with liability issues
  - Research programs at NASA and FAA cumulated in the adoption of dynamic seat testing standards (The 16 G seat rule)

History of Aircraft Occupant Protection

- 2000 and beyond: (Where’s my Airbag?)
  - Safety sells: The public is beginning to expect to see the same safety technologies when flying that they have in their cars.
  - Safety doesn't come cheap: The expense of meeting the safety standards has prompted industry to lobby for relief

Outline of the Topics to be Presented

- Physics of Crashworthiness
  - The Energy of Impact
  - Human tolerance to impact
  - Energy Absorption
- Civics of Crashworthiness
  - Review of FAA Standards
  - The 16 G level of safety
  - Examples of Dynamic Seat Tests
- Role and Importance of Post-Crash Investigation

The Physics of Crashworthiness

How much of it can you take?

The Energy of Impact from Start to Finish

What's a G?

F = MA (Newton's 2nd Law)

Force on something is equal to it's
Mass times the
Acceleration applied to it

The Acceleration of Earth's Gravity causes a person with 170 lb of Mass to exert a Force of 170 lb on the seat they are sitting in.

The Energy of Impact from Start to Finish

- Survivable Crashes
  - Sufficient Volume
  - Low G
  - No immediate post crash fire
  - Near Airport

- Chain Reaction Event

  Ground -- Aircraft -- Floor -- Seat -- Occupant

The Energy of Impact from Start to Finish

- The primary impact transmits forces to the fuselage causing it to crush, absorbing energy. Some potential survivable scenarios are:
  - Large horizontal velocity change over a relatively long period of time. (Off the end of the runway into the trees scenario).
  - Small vertical velocity change and a moderate horizontal velocity change over a short time period (Stall on approach scenario)
  - Small vertical velocity change over a very short time period. (Auto-rotate into ground scenario)

The Energy of Impact from Start to Finish

Example of a fuselage absorbing energy

The Energy of Impact from Start to Finish

- The remaining energy is transmitted through the fuselage to the aircraft floor.
  - The resulting floor-level deceleration is transmitted to seats
  - This floor-level deceleration is the impact condition replicated in seat sled tests.

The Energy of Impact from Start to Finish

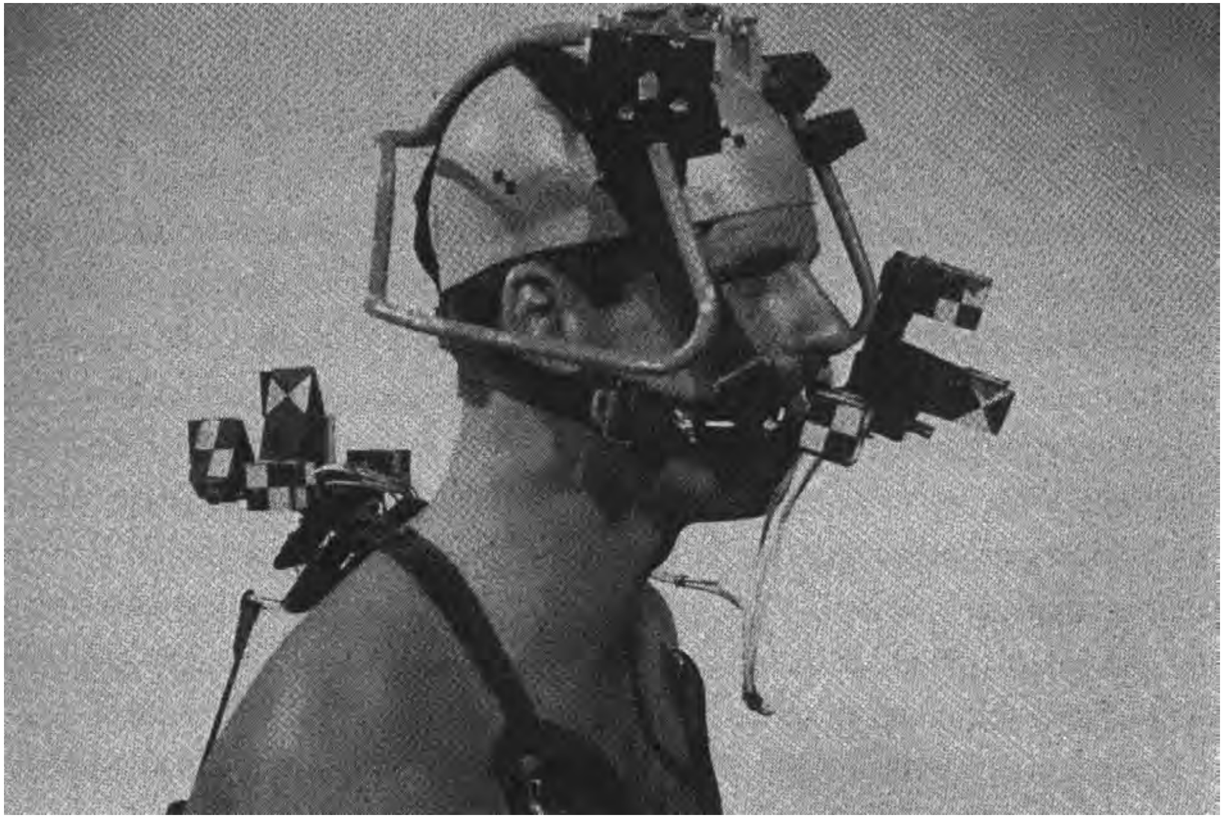
- This deceleration causes the occupant to load the seats and surrounding structure through:
  - Seat belts
  - Seat bottom cushion
  - Aft facing seat back
  - Child Restraint Device (The child loads the internal restraint system and CRD shell then in-turn the CRD loads the aircraft seat belt and bottom cushion)
  - Walls and seat backs (secondary impact by occupants head and extremities)

The Energy of Impact from Start to Finish

Example of a horizontal deceleration

Human Tolerance to Impact

Just how tough are you?



It's not all that easy to find out….

Human Tolerance to Impact

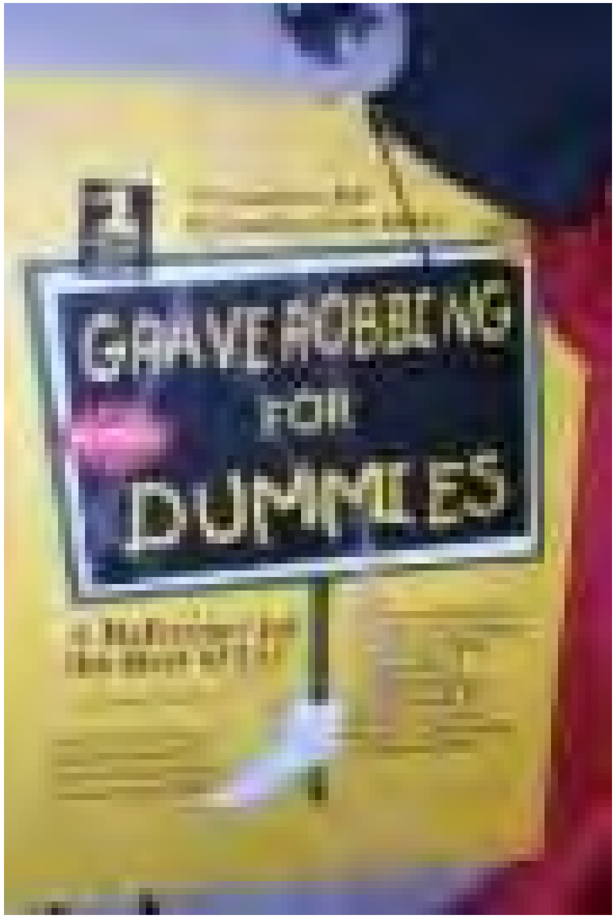
- Human volunteers are hard to get.

Human Tolerance to Impact

- Animal research unpopular with public

Human Tolerance to Impact

- Cadavers in short supply and have limitations



Human Tolerance to Impact

- Best current source are Professional Race Car Drivers (Indy and NASCAR)
  - Many teams have on board crash recorders.
  - Hospital records provide injury assessment.

Human Tolerance to Impact

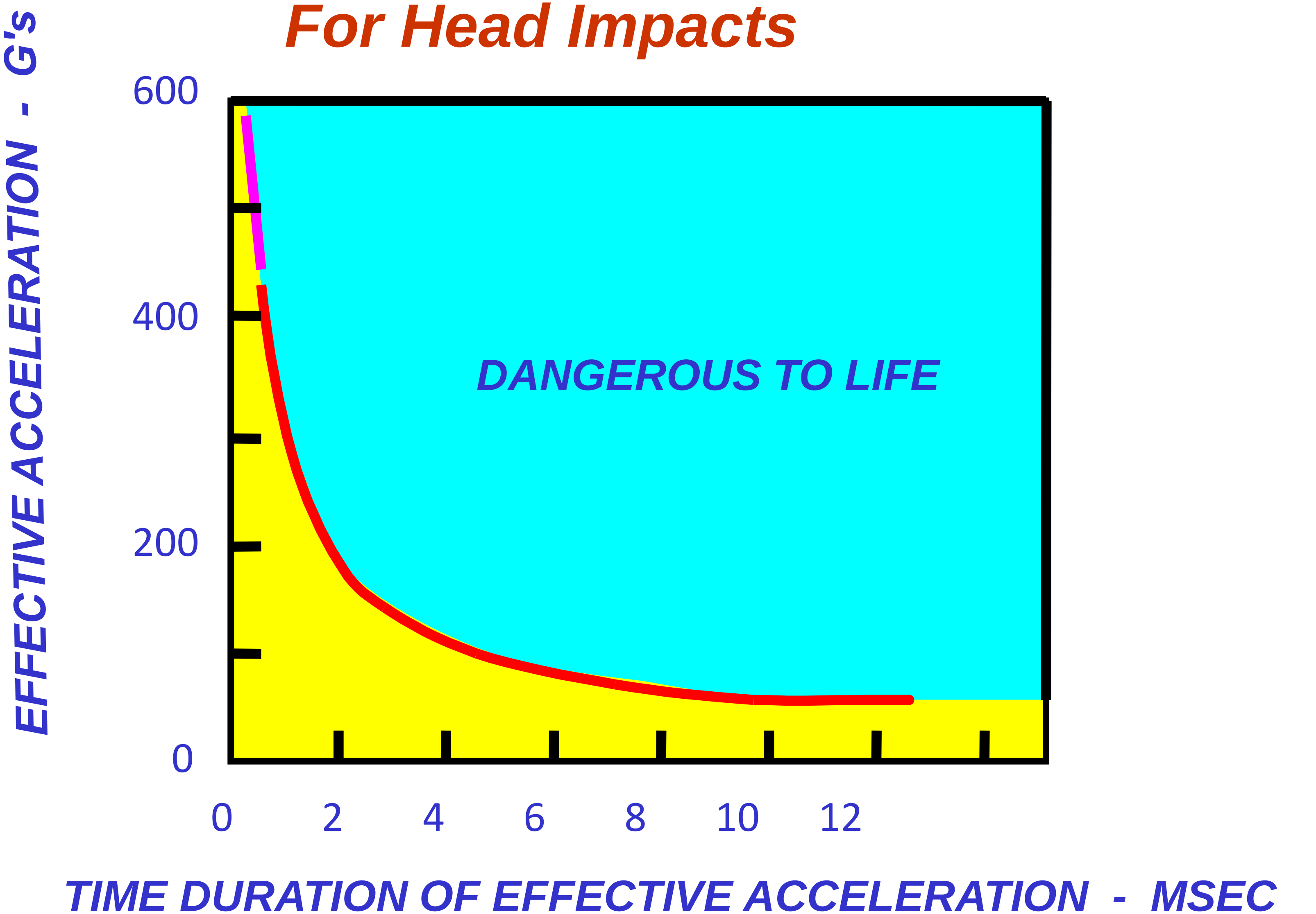
- A tolerance that can be measured by a test dummy is needed for each critical body part.

Human Tolerance to Impact

- Head injury is related to both the magnitude and duration of impact acceleration.

- The Wayne State Tolerance Curve that reflects this relationship was derived from animal, cadaver, human volunteer and accident analysis data.

Wayne State Tolerance Curve For Head Impacts



Human Tolerance to Impact

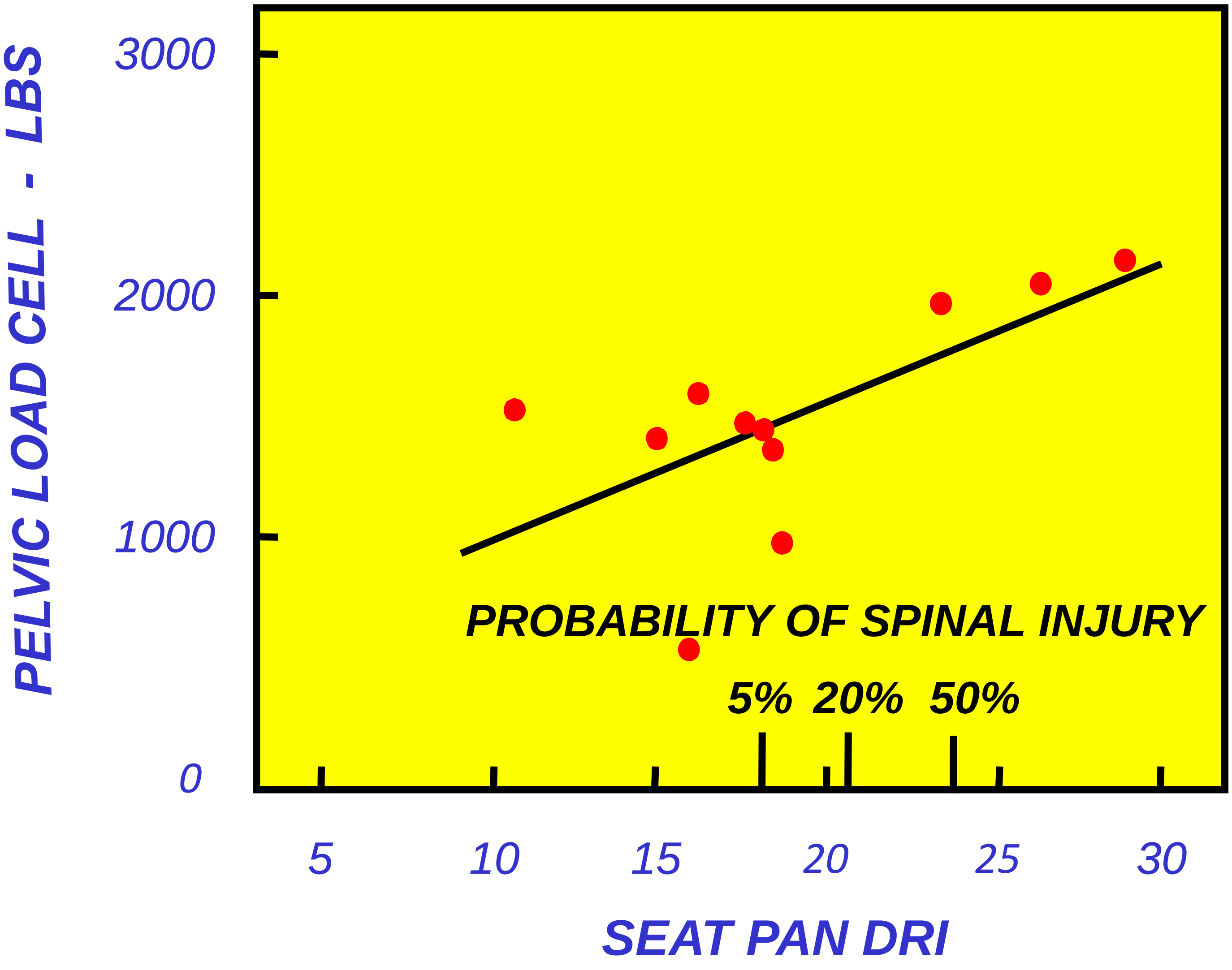
- This relationship is mathematically represented by the Head injury Criteria (HIC) calculation, which uses accelerations measured at the center of gravity of the test dummies head. For this criterion, a value of 1000 corresponds to a 16% chance of severe (AIS-3) head injury.

$$HIC = (t_2 - t_1)\left[\frac{1}{(t_2 - t_1)}\int_{t1}^{t2} a(t)\,dt\right]^{2.5}_{MAX}$$

Human Tolerance to Impact

- Lumbar Spine
  - In vertical loading the bottom-most segment of the spine (lumbar) is the most vulnerable to injury. The military had derived a relationship between seat pan acceleration and spinal injury called the Dynamic Response Index (DRI). It was based on cadaver tests and accident data from helicopters and ejection seats.
  - To be more useful for civilian applications, a relationship between DRI and the load measured at the lumbar spine of a test dummy was developed. The limit of 1500 lb chosen corresponds to a 15% chance of spinal injury.

Probability Of Spinal Injury Is Related To The Load Measured In The Part 572B Dummy 's Pelvis



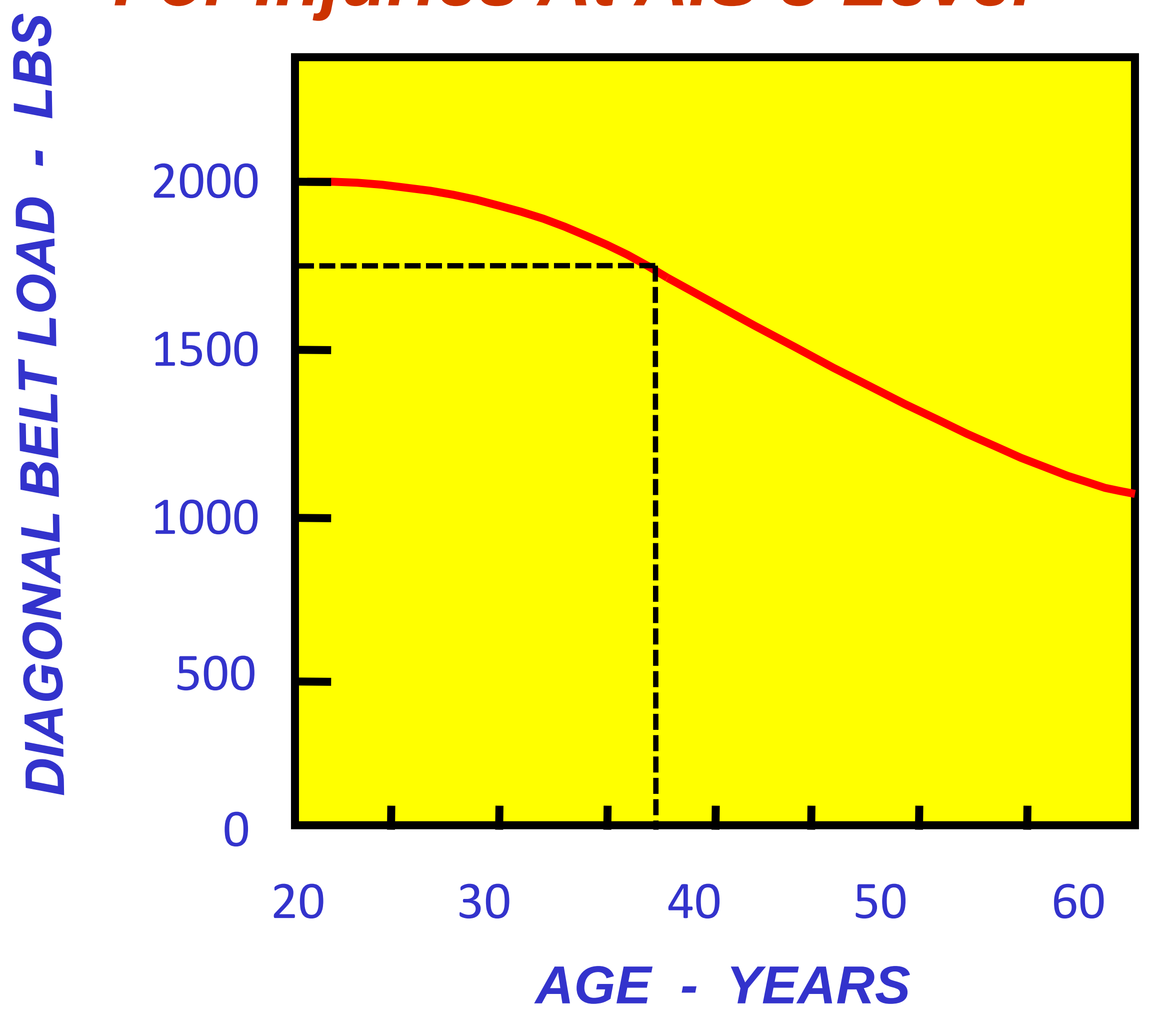
Human Tolerance to Impact

- Thoracic, Frontal Impact:
  - Primary danger is internal injuries like aortic transection and rib fractures. Since injuries that are caused by steering wheel impingement correlate to chest acceleration and deflection, these measurements are cited in the auto safety standards

Human Tolerance to Impact

- Thoracic, Frontal Impact (cont.):
  - Since aircraft do not have a steering wheel to cause direct impingement type injuries, a more appropriate means of predicting the types of injuries seen in aircraft was developed. Studies of auto crashes that utilized a force limiting shoulder belt system yielded a injury criteria based on peak shoulder belt force.
  - Because the loading area is a factor, dual strap systems have a larger peak allowable force (2000 lb) than the single diagonal type (1750 lb).

Diagonal Upper Torso Restraint Load For Injuries At AIS 3 Level



Human Tolerance to Impact

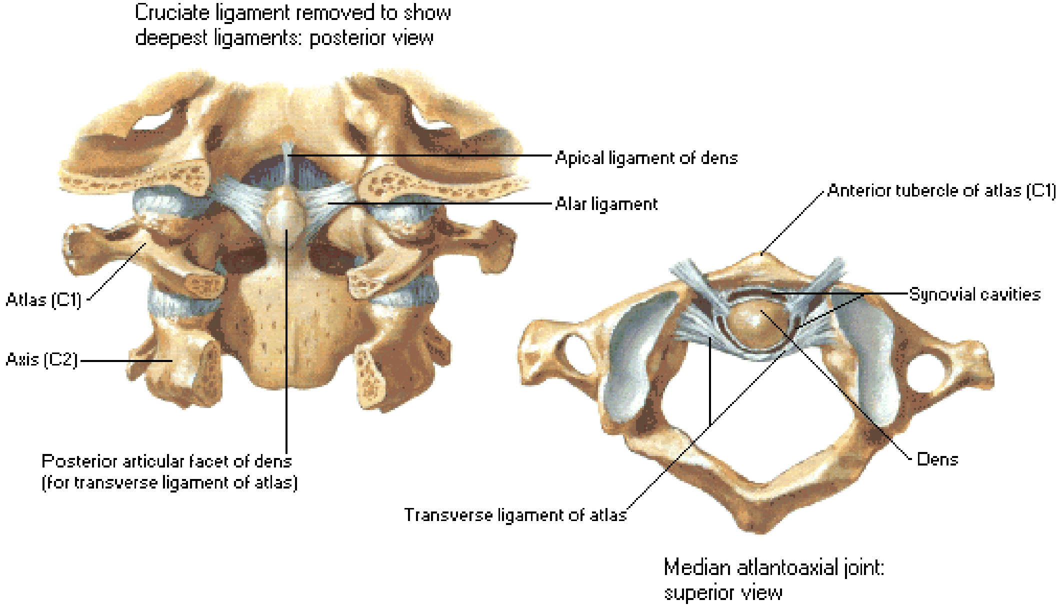
- Femur Loads:
  - Leg or pelvis fractures can impede egress (you have to get out before the fire starts). Axial load on the femur measured by the test dummy is 2250 lb. Derived primarily from cadaver tests.
- Abdomen:
  - Impingement of the seat belt on the abdomen can cause serious internal injuries. The tolerance level is so low that no limit is set.
  - The criteria is: No Contact.

Human Tolerance to Impact

- Thoracic, Lateral Impact:
  - Rib fractures and resulting internal injuries can occur at a much lower loading than in the forward direction. Several criteria have been developed to assess lateral impacts using special side impact dummies:
    - Thoracic Trauma Index (TTI) and Pelvis lateral acceleration are acceleration-based criteria that have reasonable correlation with cadaver injuries. (currently cited in the auto safety standards)
    - Deflection based V*C and rib compression predict some types of injuries better. (Currently cited in the European auto safety standards and in proposed US standards)

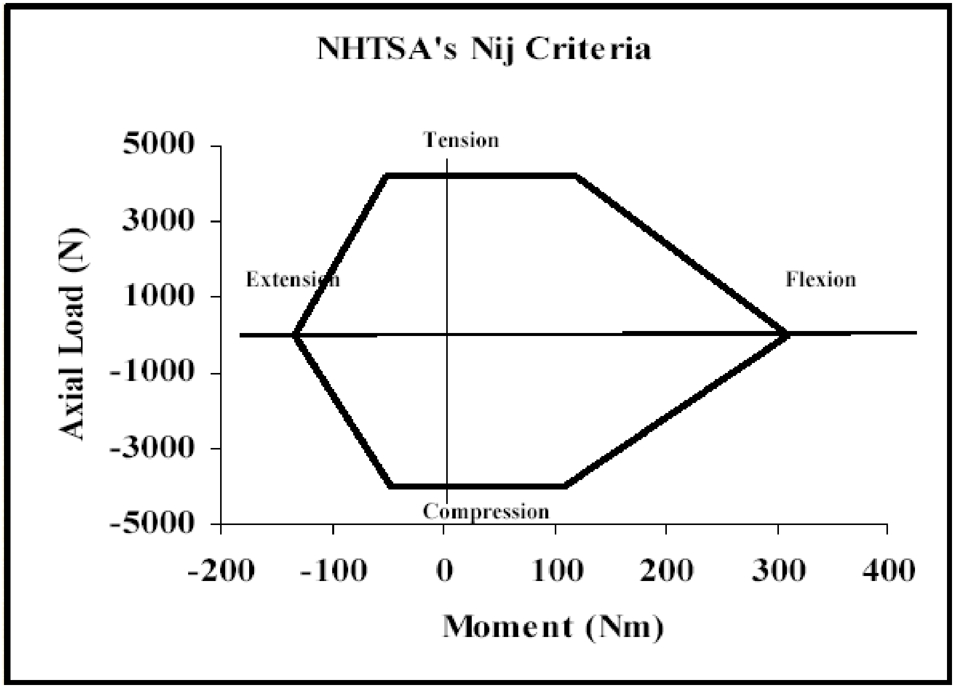
Human Tolerance to Impact

- Neck injuries:
  - The neck is a complex structure comprised of vertebrae bones with cartilage discs between held together with ligaments. Ligament damage is just as important to prevent as bone and disc fractures.



Human Tolerance to Impact

- Neck injuries:
  - The Nij criterion predicts the neck injury potential based on a combination of the forces and bending moments measured by a test dummy



Energy Absorption: Structures and People

- To limit occupant loads and accelerations, the seat and surrounding structure must absorb some of the load instead of transmitting it.
  - Seat belts: stretching and dedicated energy absorbers can lower belt loads. (This can cause head impact problems if it increases the flail envelope too much)
  - Structural deformation: seat base frame flexure, and seat back flexure can lower belt loads. (This can also increase flail envelope)

Energy Absorption: Structures and People

– Seat bottom flexure: support pan deformation and dedicated energy absorption mechanisms can lower lumbar loads.
– Seat cushion compression: usually amplifies lumbar load instead of absorbing it.
– Seat back flexure: reduces HIC for aft row occupant
– Wall crushing or flexing: reduces HIC
– Airbags: can significantly lower HIC

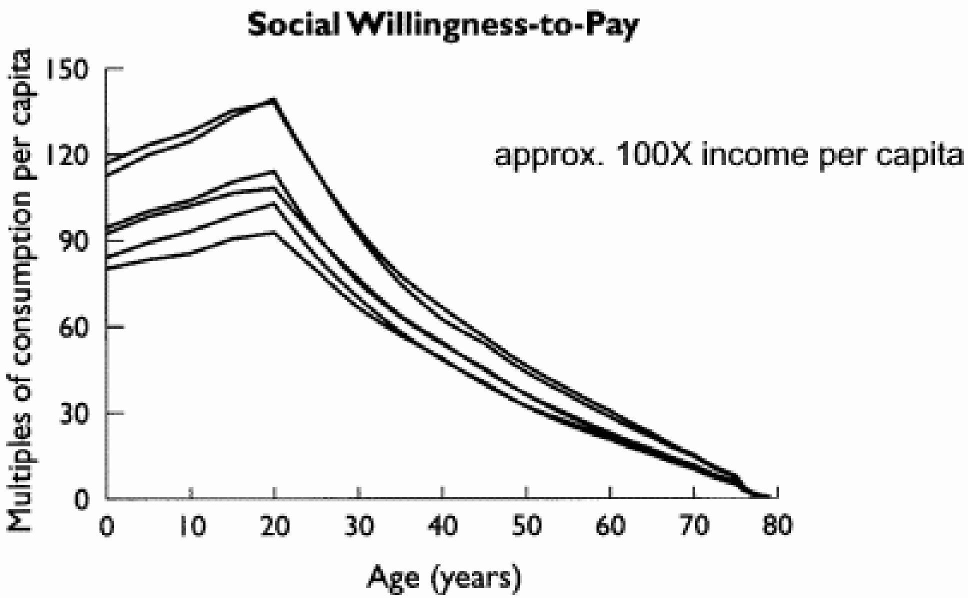
Energy Absorption: Structures and People

- Recognizing and documenting damage, particularly evidence that energy was absorbed.
  - Forward Flexure
    - Crew seat back bent forward by upper torso restraint loads.
    - Passenger seat back bent forward due to impact from occupant behind, look for dedicated energy absorbers in seat back hinge area, and/or bent side tubes.
  - Vertical stroking seats
    - Some seat pans designed to significantly deform (compare with other undamaged seats to determine amount of deformation)
    - Some seat pans designed to travel down a guide under a specific load.
  - Head impact evidence (look for dents, marks, etc)

The Civics of Crashworthiness

How much can you afford?

Figure 1.14 Willingness-to-pay to prevent a death at each age—six variants of the human capital model

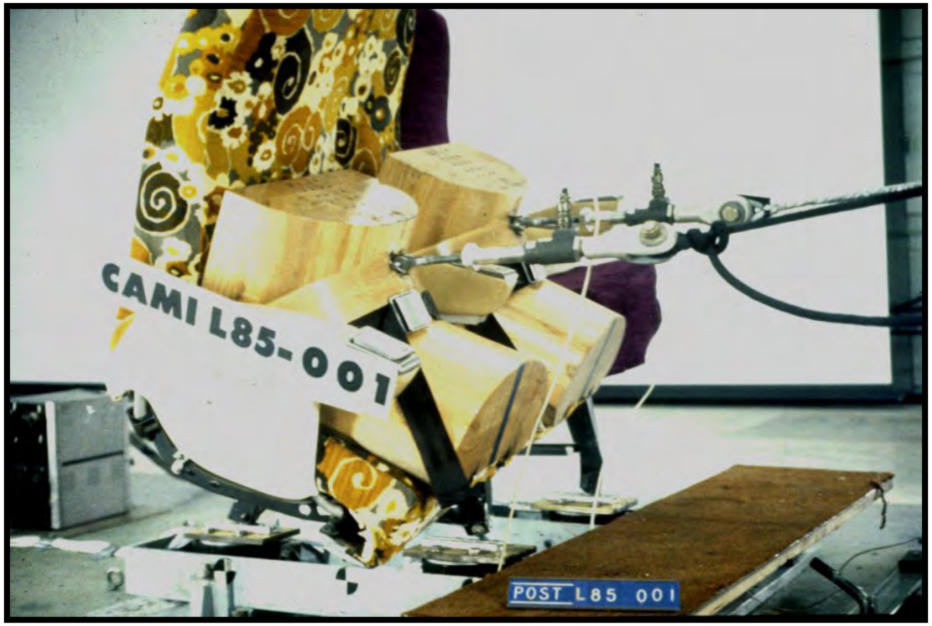


A Review of FAA Standards Related to Seats

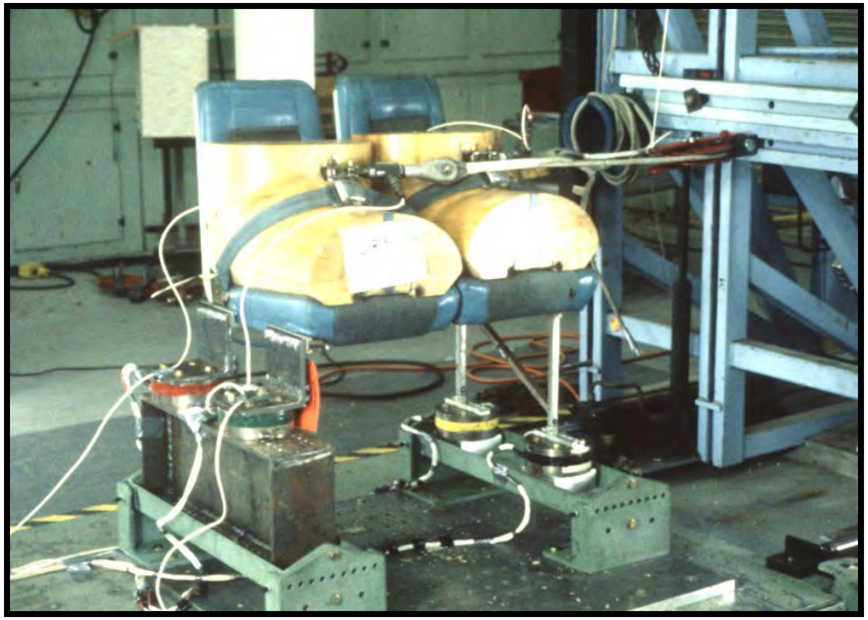
- Static test requirements essentially the same since 1958.
  - Title 14, Section 571 of Parts 23,25,27 and 29: Emergency Landing Conditions, General.
  - TSO C39b: Aircraft Seats and Berths (cites NAS 809)
  - TSO C22f: Safety Belts (cites NAS 802)
- Loads applied slowly with wooden blocks in multiple directions. Did not apply forces in the same way an actual occupant would.

A Review of FAA Standards Related to Seats

Forward Static Test

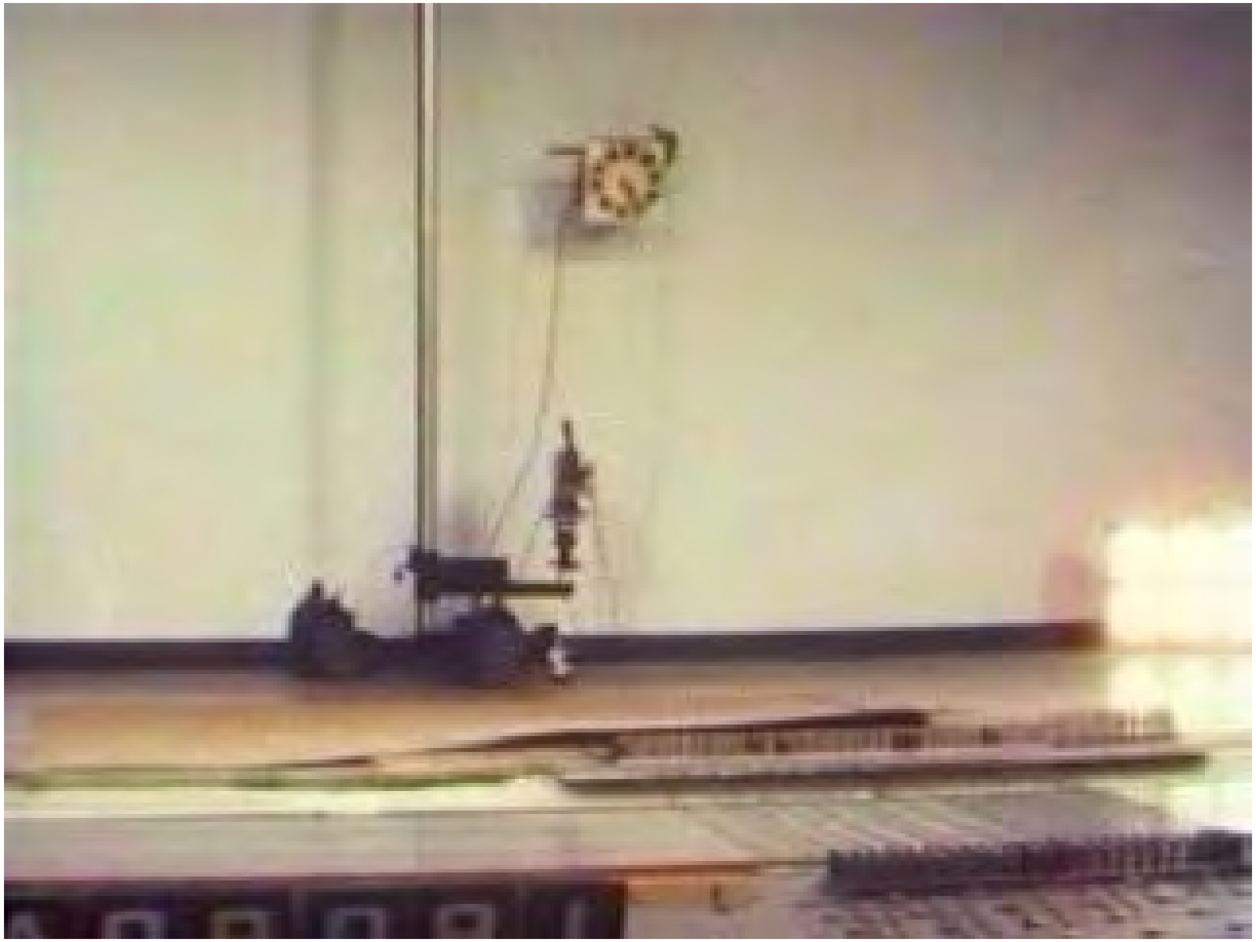


Lateral Static Test



A Review of FAA Standards Related to Seats

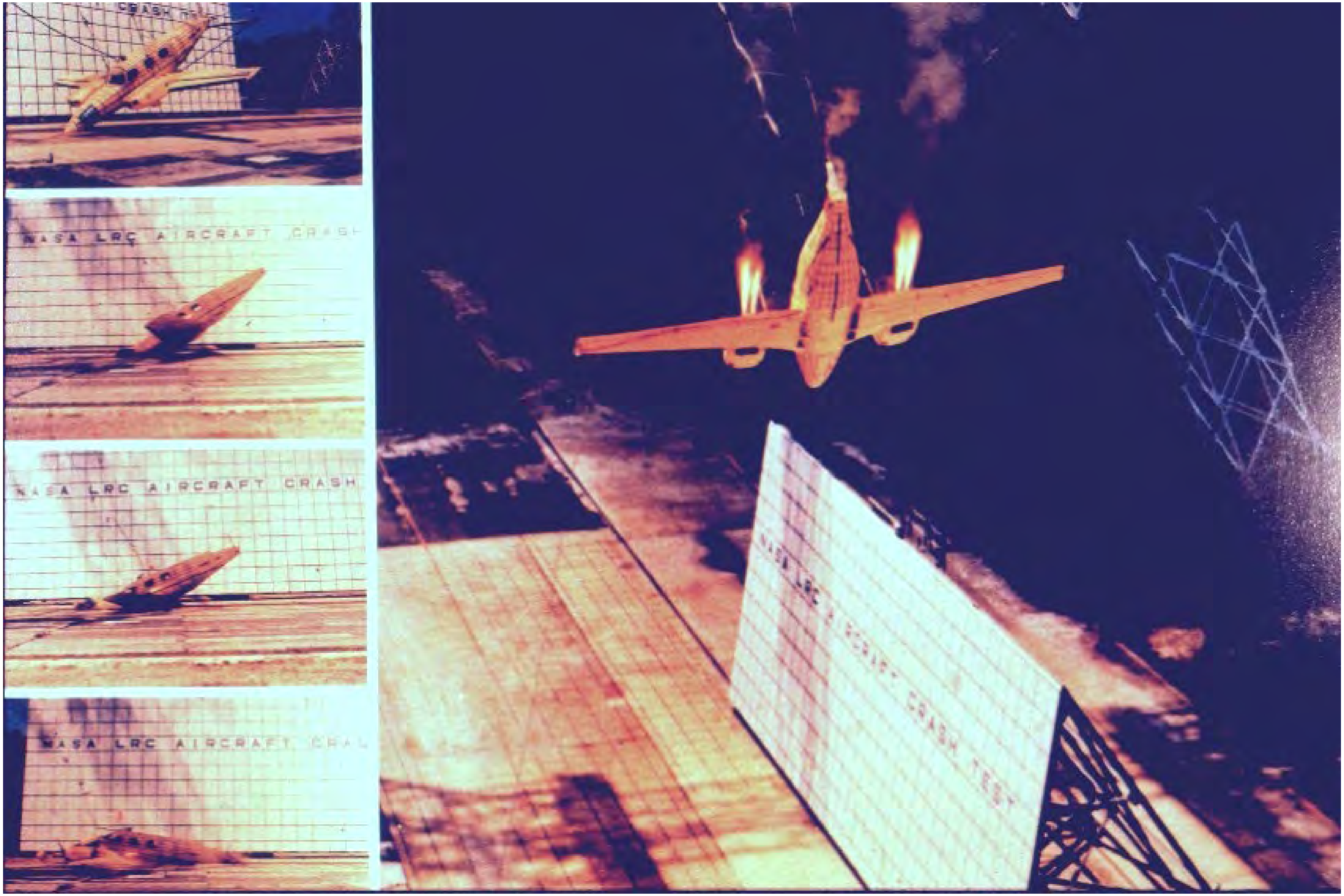
- Dynamic testing revealed serious problems with seats that met the static test standards.



A Review of FAA Standards Related to Seats

- New standards for small aircraft were developed based on full-scale fuselage impact tests (both vertical drop and combined horizontal / vertical impact tests)

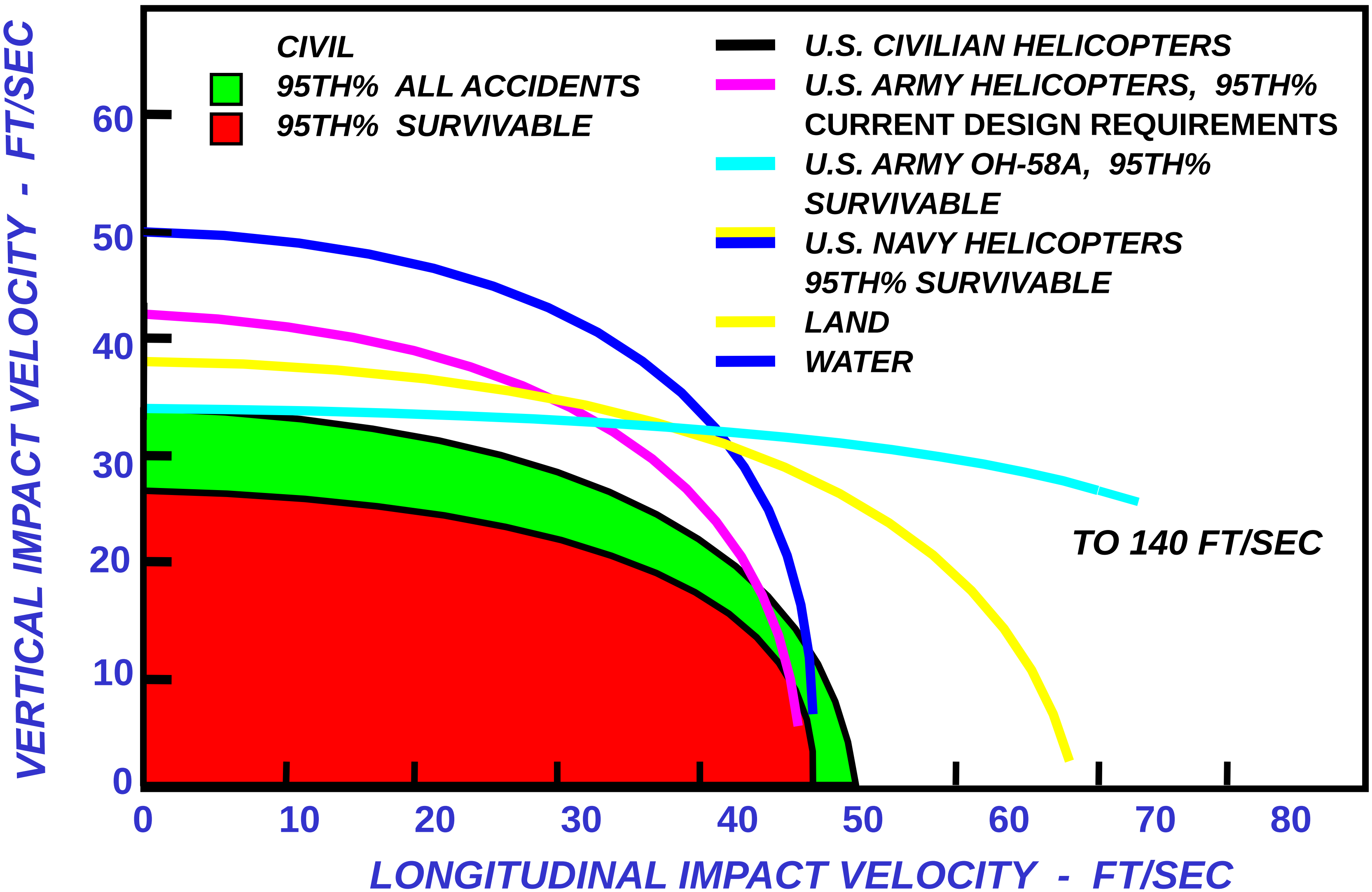
FAA/NASA General Aviation Airplane Impact Tests



A Review of FAA Standards Related to Seats

- New standards for rotorcraft were based primarily on analysis of accident data.
- Large data base available from the military

Comparison Of The Civil And Military 95th Percentile Impact Velocity Components

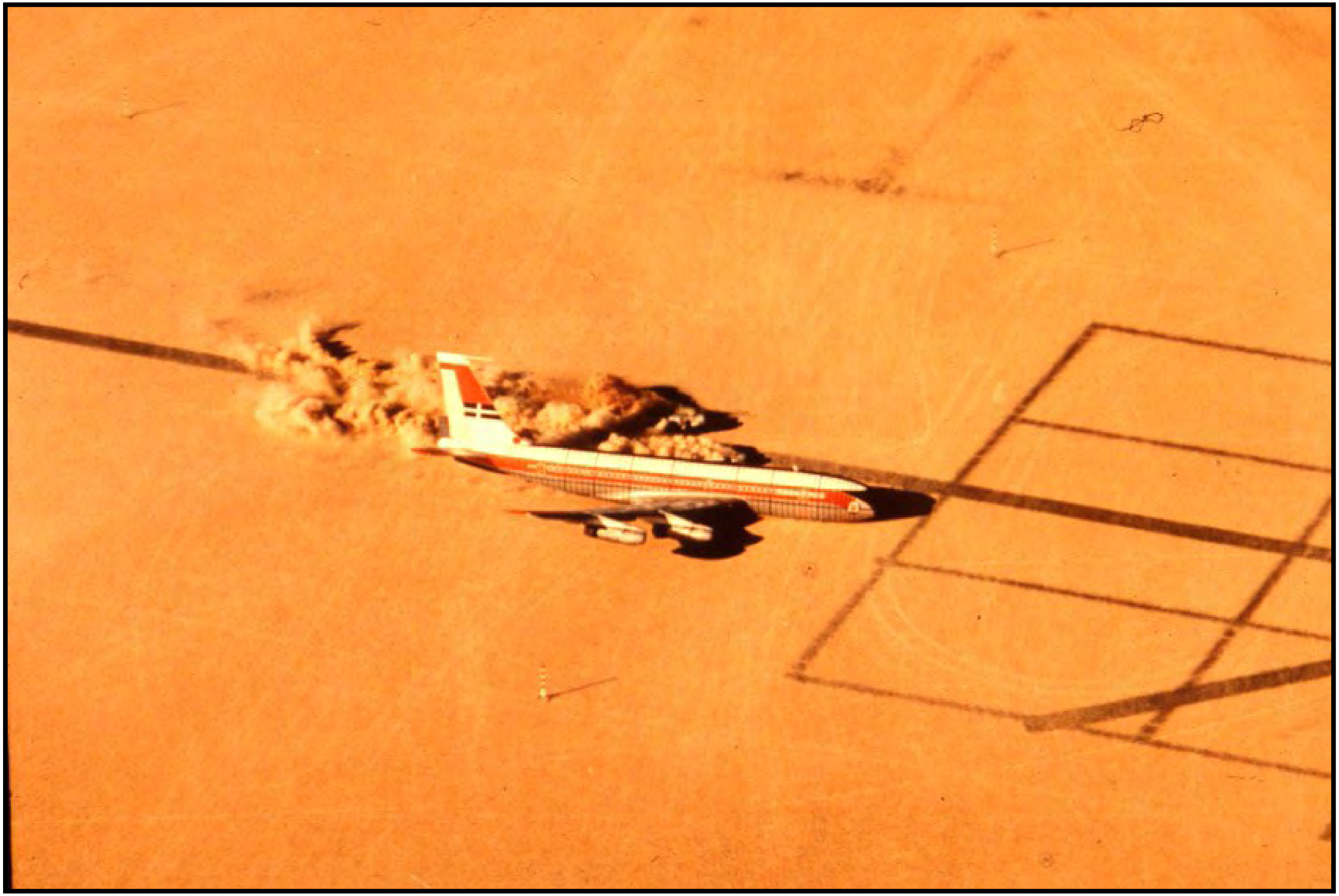


A Review of FAA Standards Related to Seats

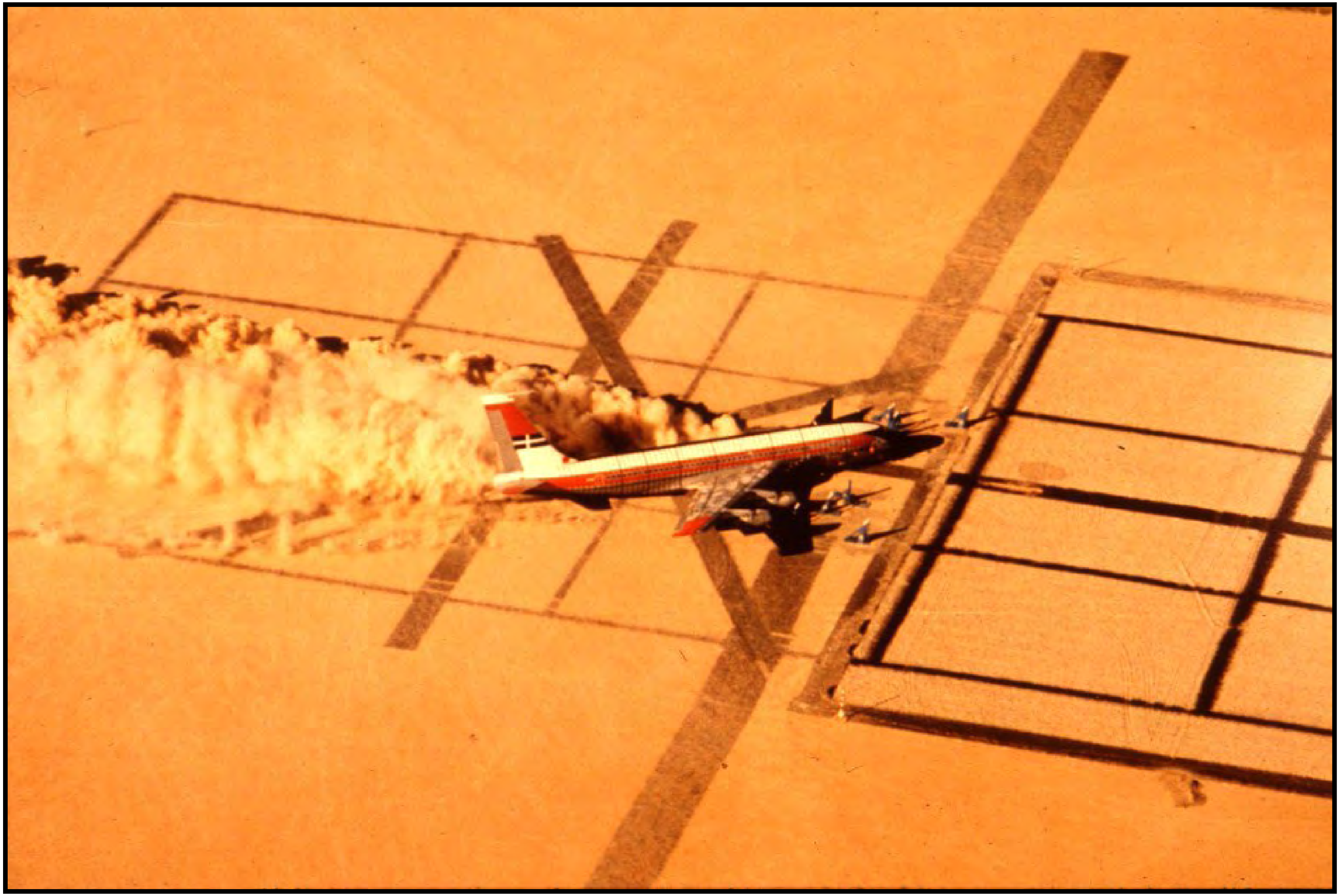
- New standards for large aircraft were developed based on:
  - Full scale tests
  - Modeling
  - Existing floor strength.

CID Air-to-Ground Impact Test

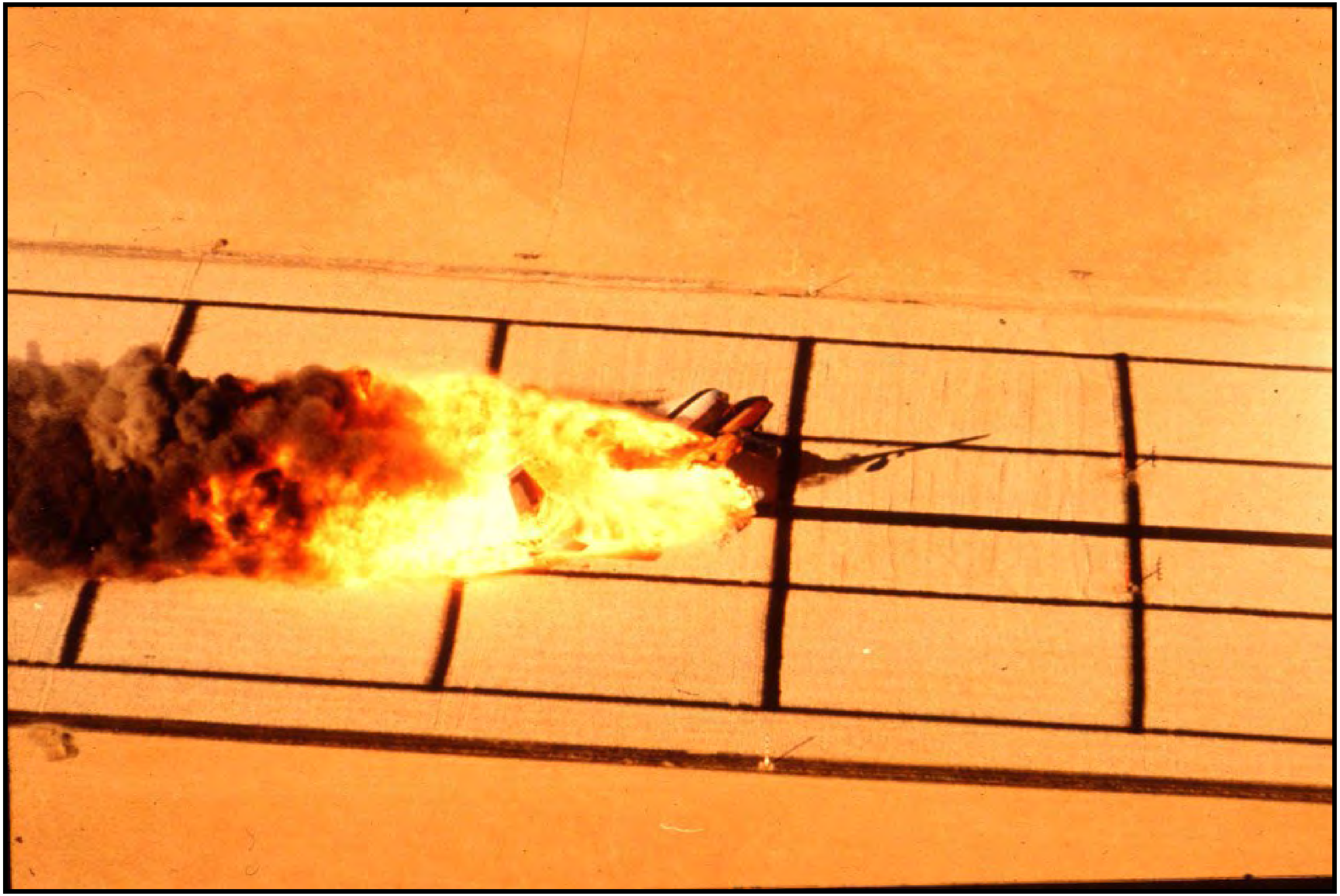
CID Air-to-Ground Impact Test



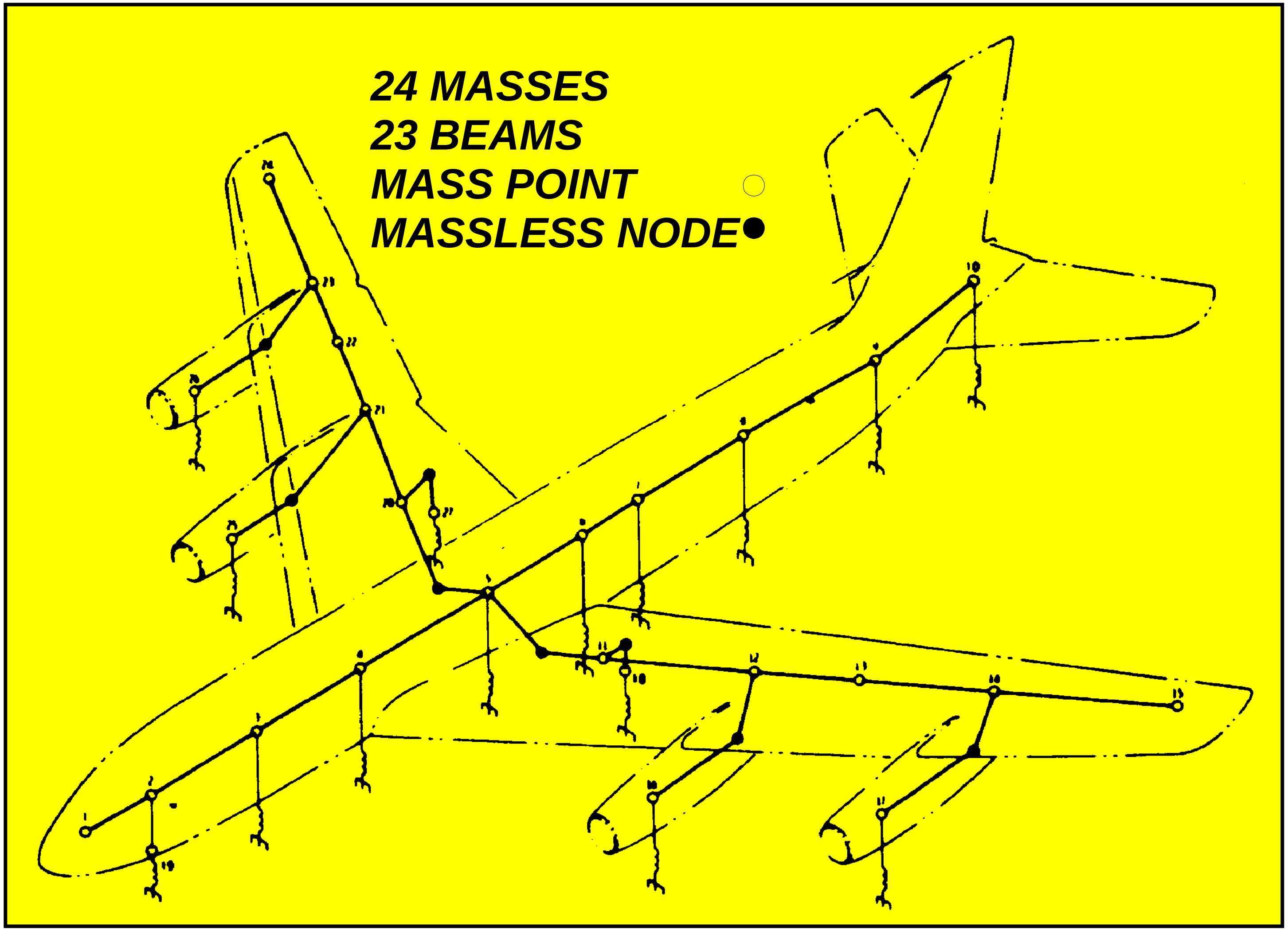
CID Air-to-Ground Impact Test



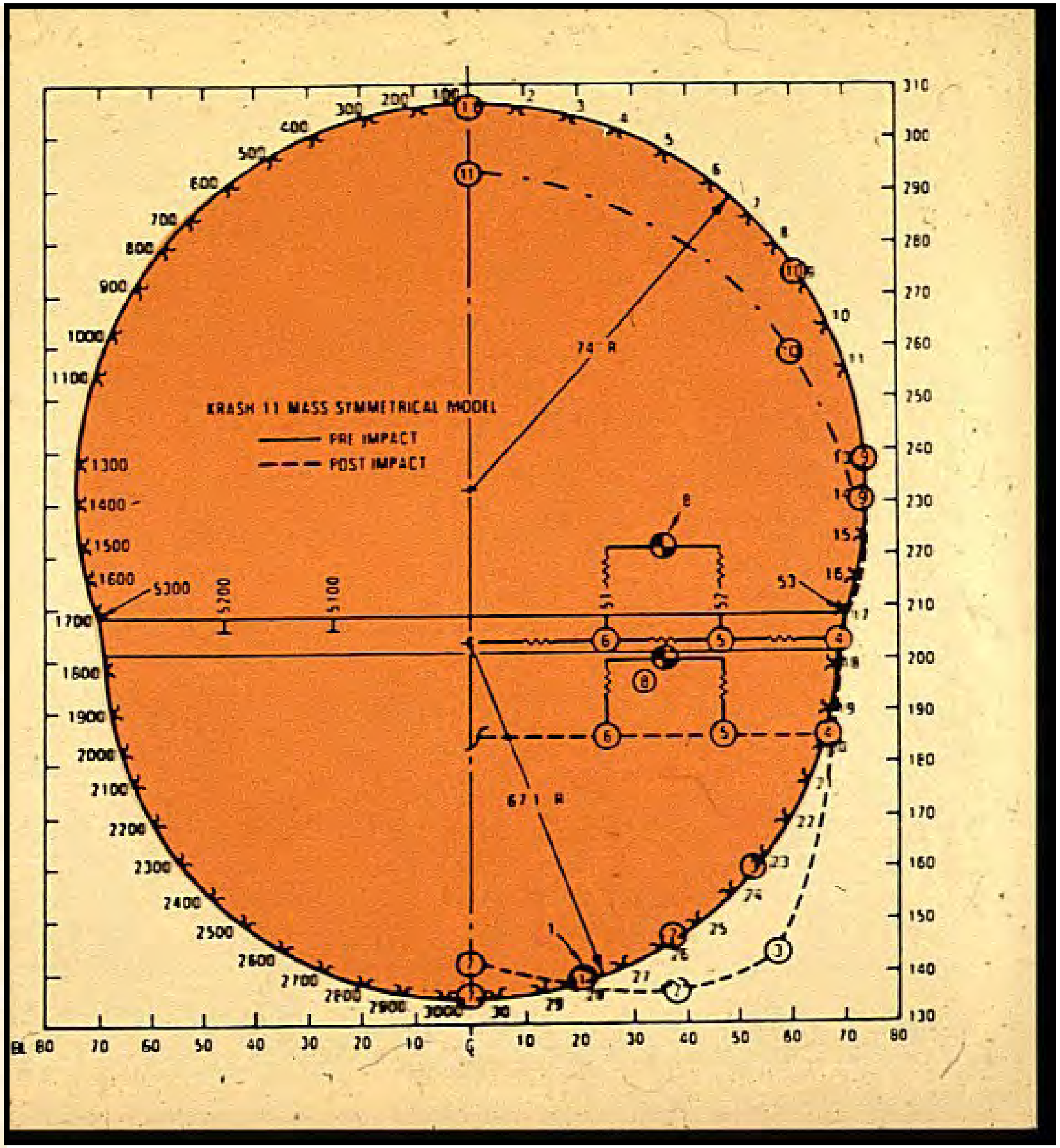
CID Air-to-Ground Impact Test



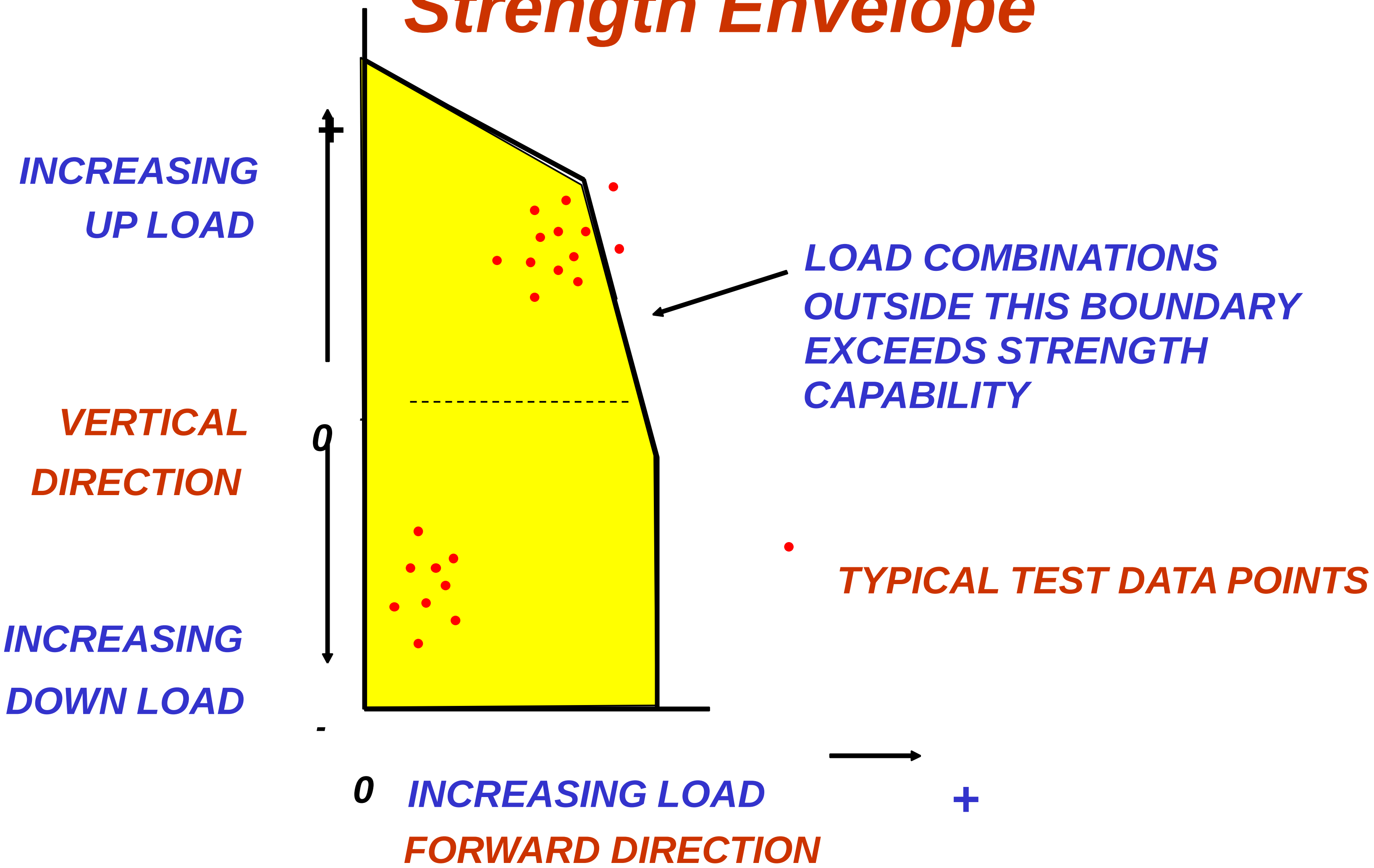
Typical Transport Aircraft Krash Model Used For Parameter Studies



Transport Airplane Fuselage Section and Analytical Model

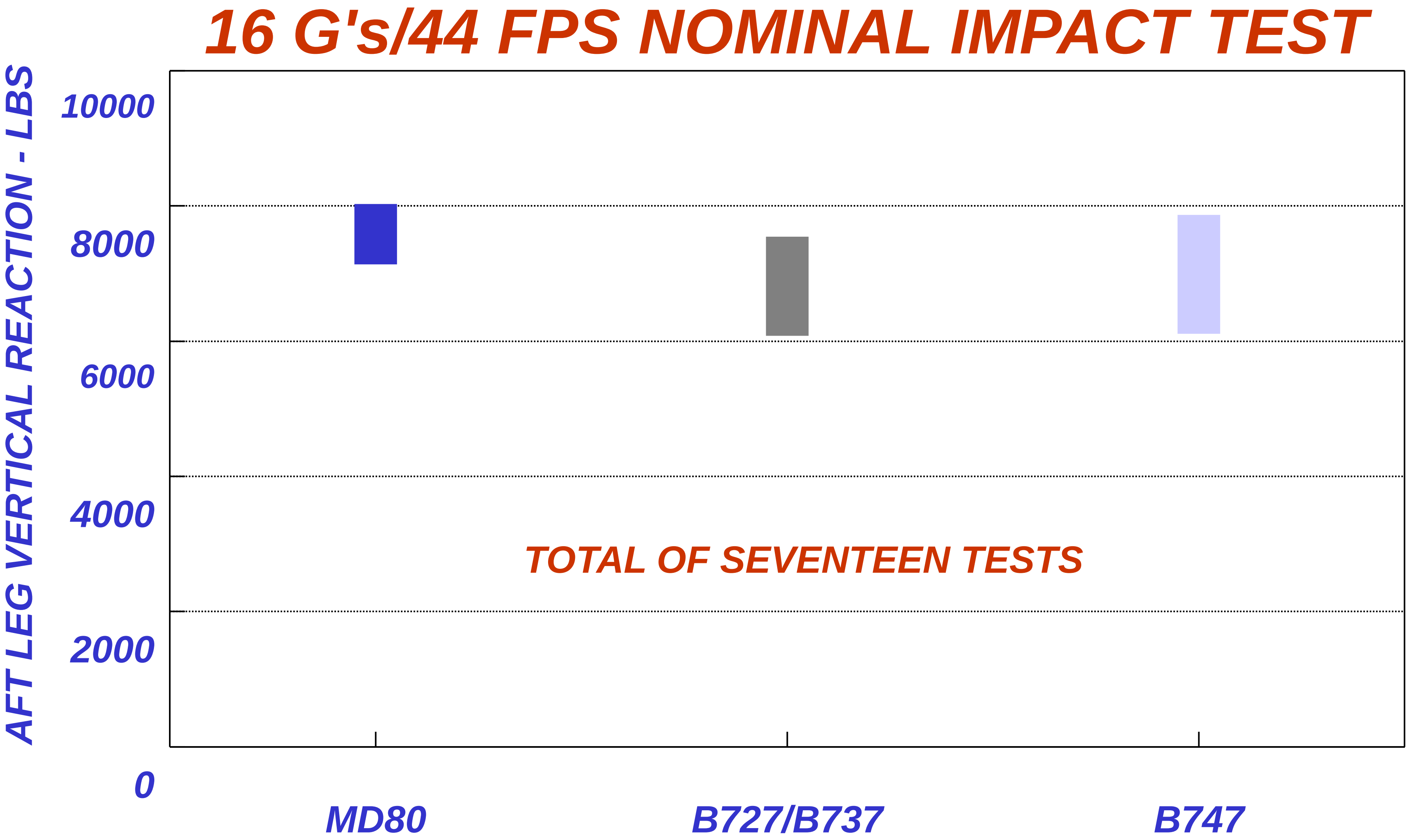


Typical Floor Track Strength Envelope



A Review of FAA Standards Related to Seats

- All of the new standards were evaluated by sled tests to ensure that meeting them would be technically feasible.


16 G's/44 FPS NOMINAL IMPACT TEST
AFT LEG VERTICAL REACTION - LBS
10000
8000
6000
4000
2000
0
TOTAL OF SEVENTEEN TESTS
MD80
B727/B737
B747

A Review of FAA Standards Related to Seats

- Dynamic test requirements were adopted in 1986 for Part 23, 1988 for Part 25, and 1989 for Parts 27 and 29. These requirements are only applicable to aircraft designed after the effective date, not to ones already in design or production.
- The new test requirements provided:
  - Realistic loading condition
  - Occupant injury evaluation

A Review of FAA Standards Related to Seats

- The new requirements can be found in:
  - Title 14, Section 572 of Parts 23,25,27, and 29: Emergency Landing Dynamic Conditions.
  - TSO C127a: Seating Systems (Cites SAE AS 8049)
  - TSO C22g: Safety Belts (Cites SAE AS 8043)
  - TSO C114: Torso Restraint Systems (Cites SAE AS 8043)

A Review of FAA Standards Related to Seats

- A notable exception is SFAR 23 Commuter Category Aircraft. Dynamic testing requirements were never adopted for this size of aircraft. Research involving full scale drop tests, accident analysis, and sled testing has been accomplished to determine the testing requirements necessary to provide an equivalent level of safety for this category of aircraft.

A Review of FAA Standards Related to Seats

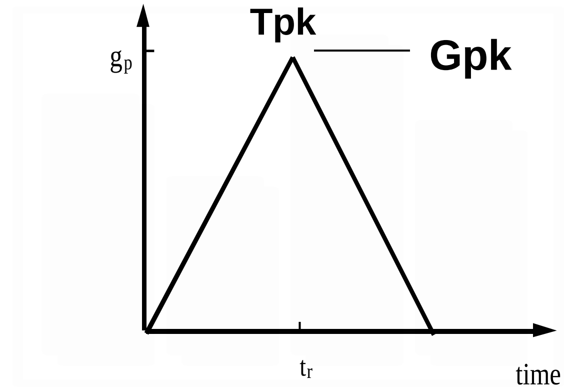
- NPRM 88-8 was proposed in 1988 for retrofit of improved seats in Part 121 and 135 Transport Category aircraft. Since the floor strength of the current fleet is compatible with the loads produced by the improved seats, there is no technical reason why the existing aircraft could not be retrofitted. This rule is still under consideration.

The "16 G" Level of Safety: What it Really Means

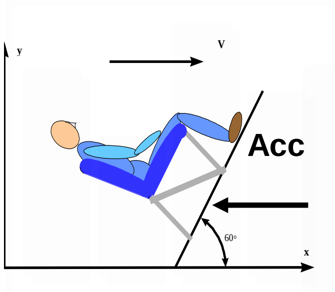
- The testing requirements for aircraft seats reflect the expected crash scenarios applicable to each aircraft type that would result in an survivable impact environment.
- The seats and restraint systems are tested dynamically using a 50% (170 lb) size test dummy.
- The pass fail criteria for the improved seat/restraint regulations include structural and occupant injury assessments.

Requirements for **NEW**

- General Aviation Aircraft
- Transport Aircraft
- Rotorcraft



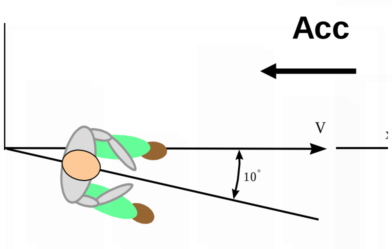
Test-1 Condition



From Right Side

Combined Vertical Horizontal Orientation	Small Airplanes (Part 23)		Transport (Part 25)	Rotorcraft (Part 27)
	Pilot	Passenger		
Gpk (gs)	19	15	14	30
Impact Velocity (f/s)	31	31	35	30
Onset Time (Tpk)	0.05	0.06	0.08	0.03

Test-2 Condition



From Above

Horizontal 10° Yaw Orientation	Small Airplanes (Part 23)		Transport (Part 25)	Rotorcraft (Part 27)
	Pilot	Passenger		
Gpk (gs)	26	21	16	18.4
Impact Velocity (f/s)	42	42	44	42
Onset Time (Tpk)	0.06	0.08	0.09	0.07

Injury/Pass-Fail Criteria

$$HIC = \left[(t_2 - t_1) \left\{ \frac{1}{(t_2 - t_1)} \int_{t1}^{t2} a(t)dt \right\}^{2.5} \right]_{max}$$

Parameter	Injury Criteria
Head Injury Criteria (HIC)	1000
Shoulder Harness loads	1750 lb. (single) 2000 lb. (dual)
Lumbar Load Fz	1500 lb.
Femur Load (axial)*	2250 lb.

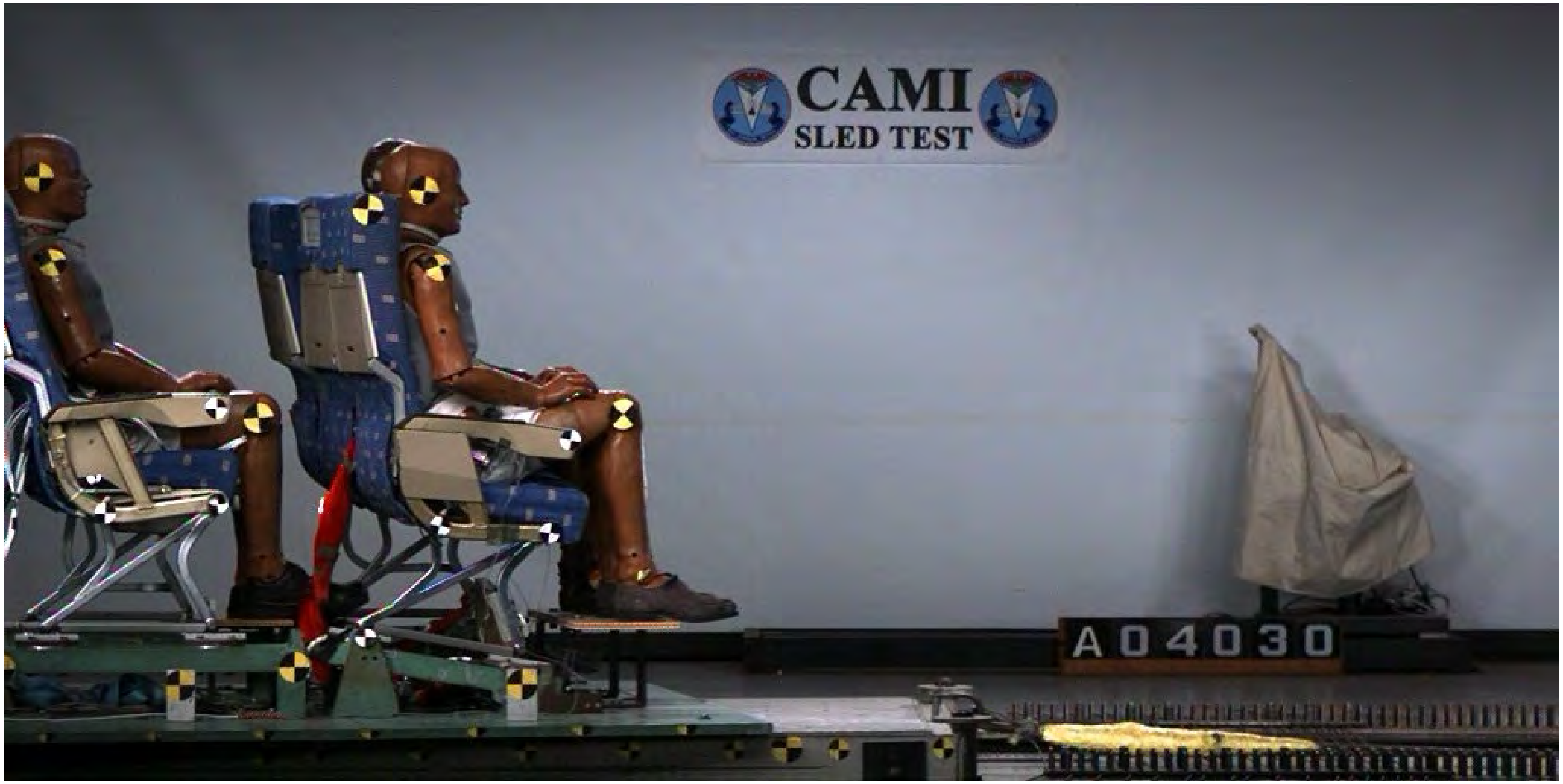
Hybrid II

Specified in Part 23.562, 25.562, 27.562, and 29.562

Measured for Part 572 Subpart B (Hybrid II)

* (part 25 only)

Examples of Dynamic Seat Tests: Video and Data

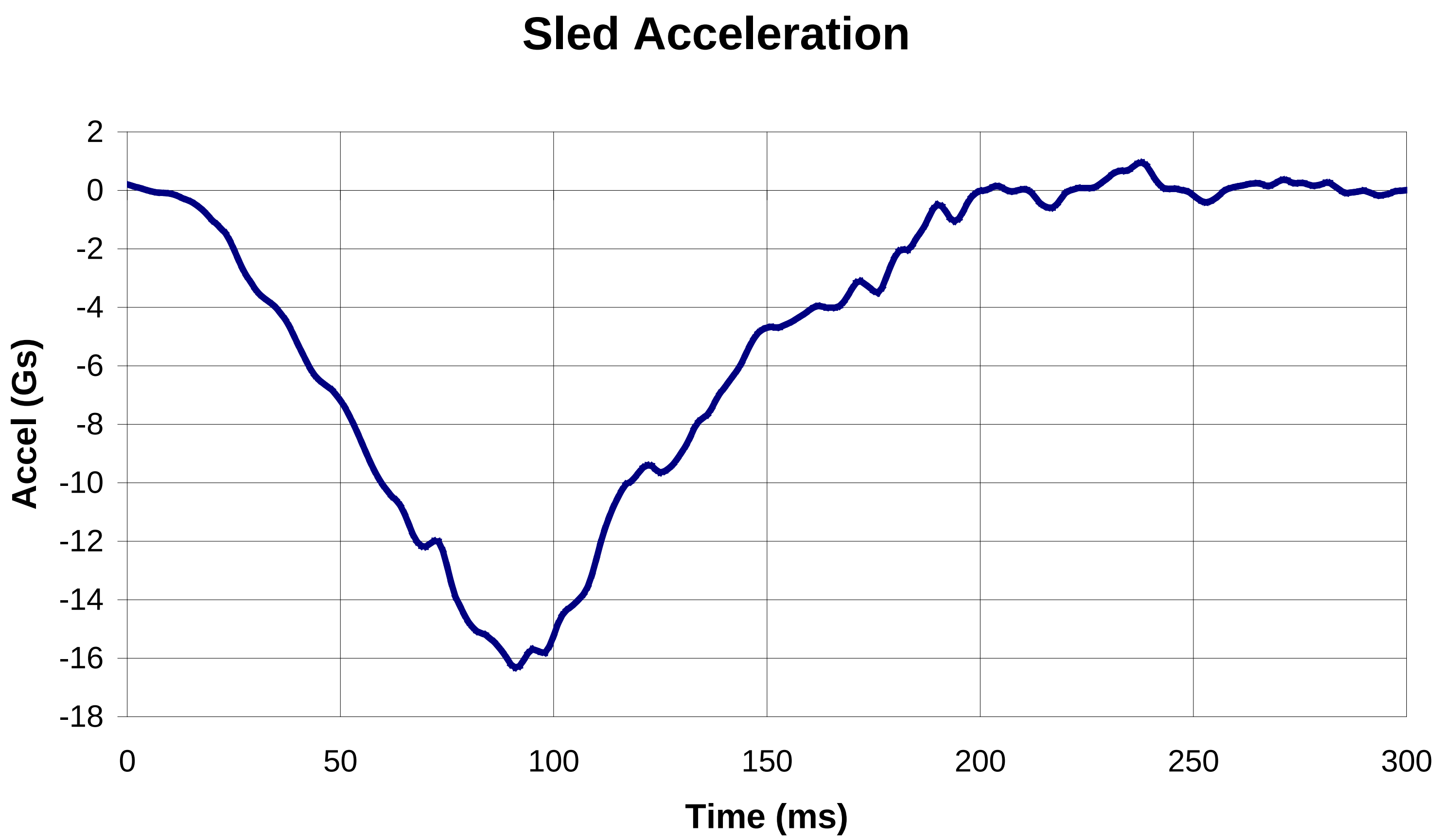


Part 25 Double Row Horizontal 16 G test

Examples of Dynamic Seat Tests: Video and Data

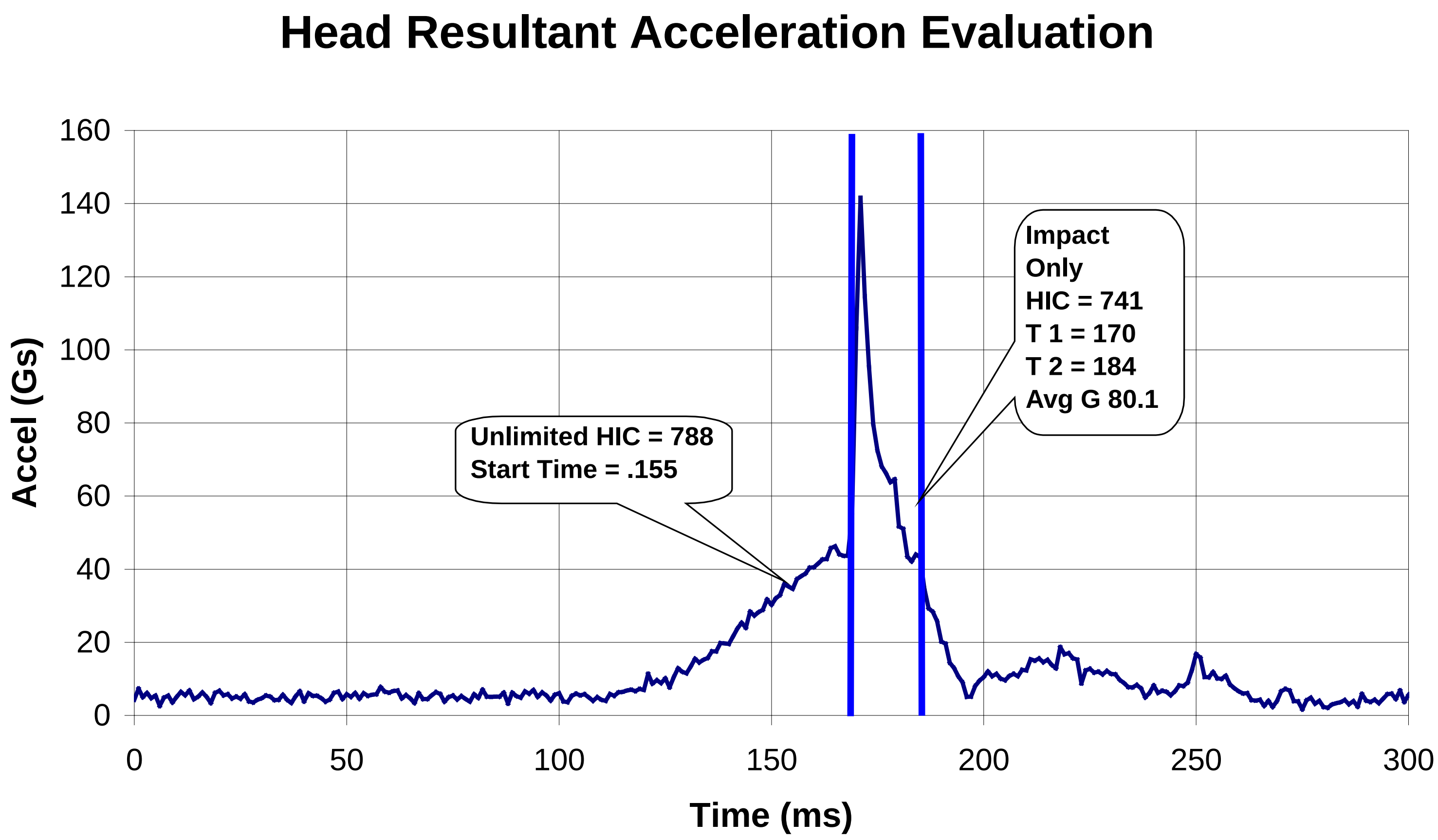
Part 25 Double Row Horizontal 16 G test

Examples of Dynamic Seat Tests: Video and Data



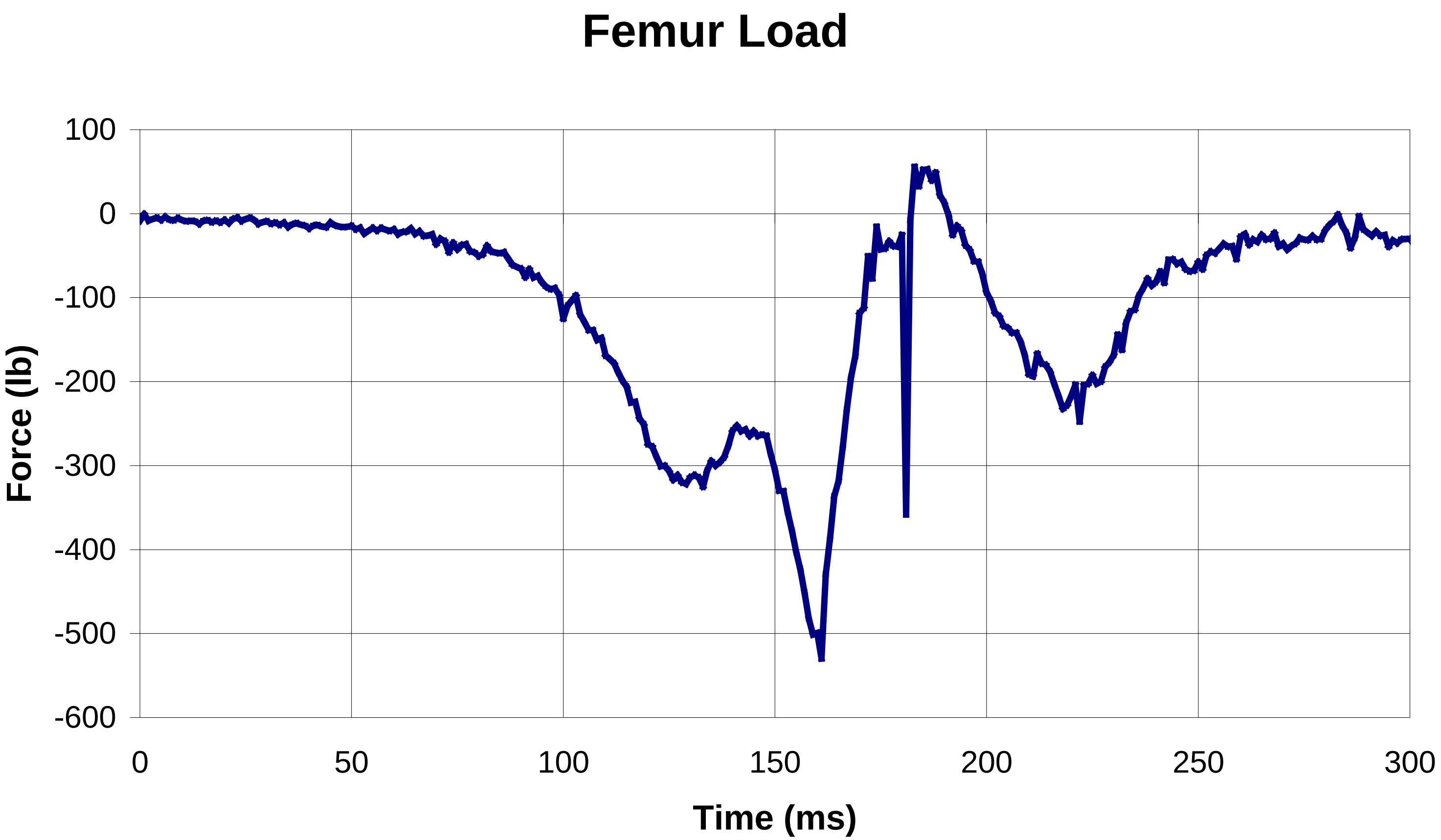
Part 25 Double Row Horizontal 16 G test

Examples of Dynamic Seat Tests: Video and Data



Part 25 Double Row Horizontal 16 G test

Examples of Dynamic Seat Tests: Video and Data

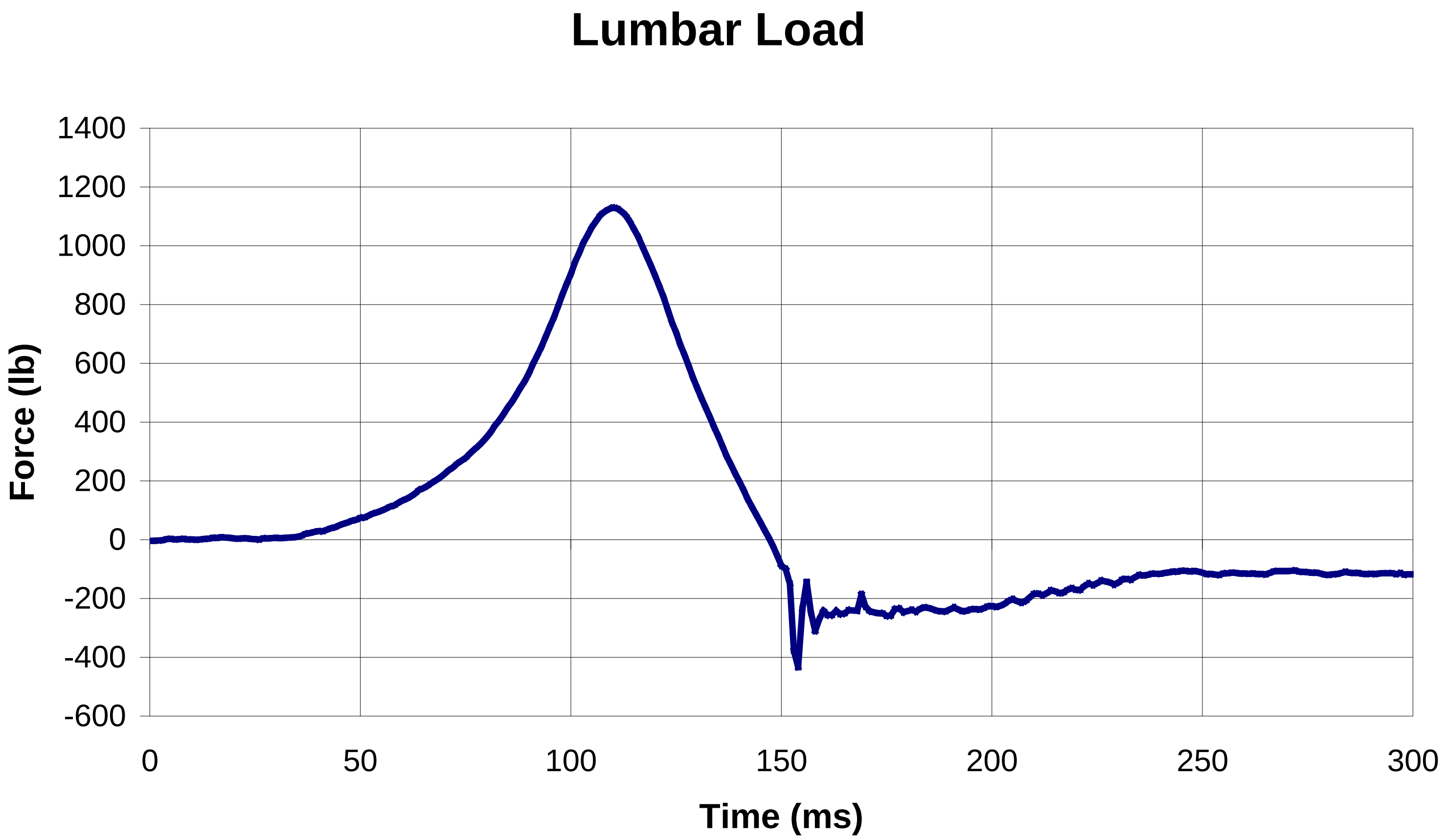


Part 25 Double Row Horizontal 16 G test

Examples of Dynamic Seat Tests: Video and Data

Part 25 Vertical 14 G Passenger Seat

Examples of Dynamic Seat Tests: Video and Data

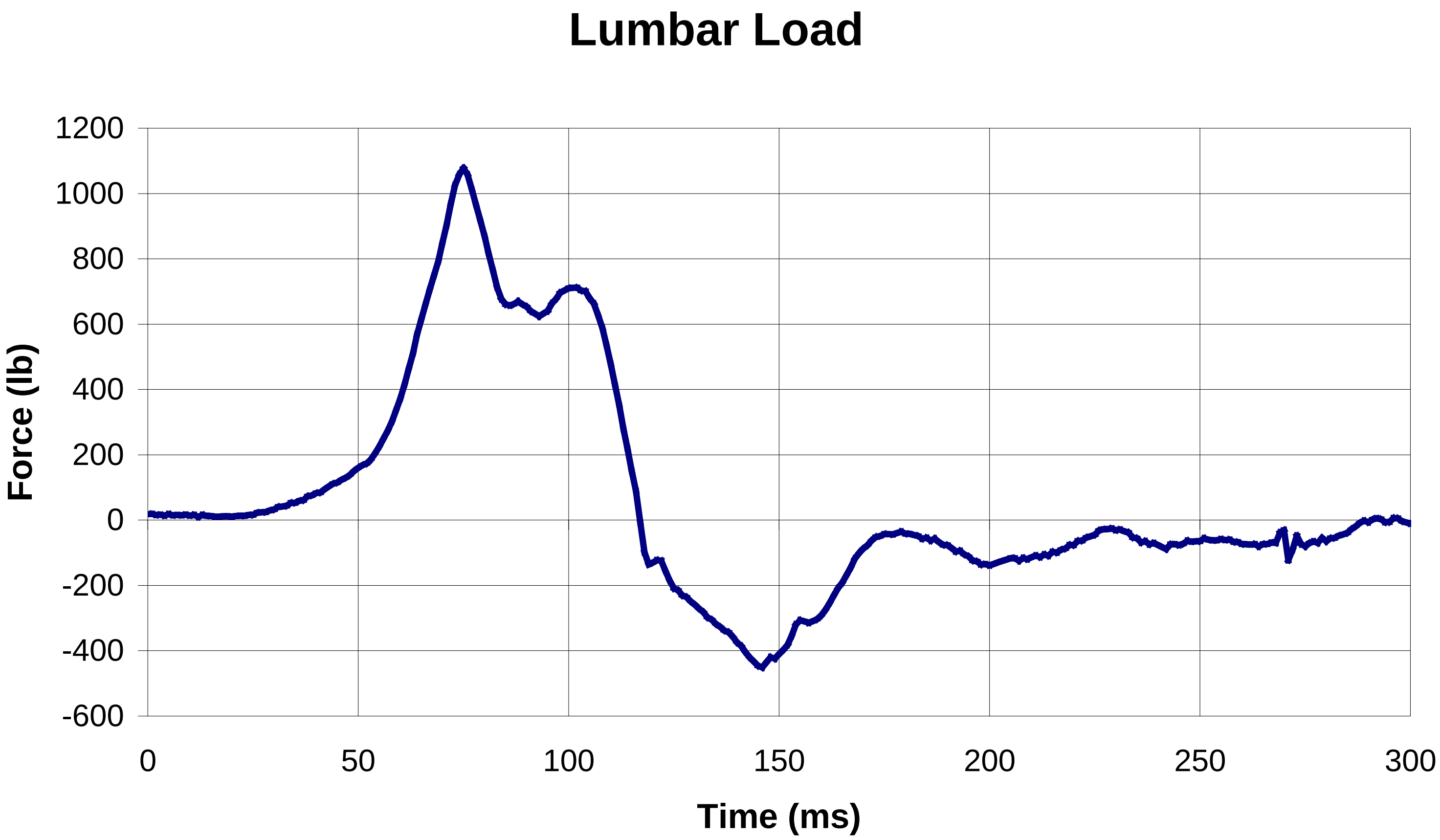


Part 25 Vertical 14 G Passenger Seat

Examples of Dynamic Seat Tests: Video and Data

Part 23 Vertical 19 G Passenger Seat

Examples of Dynamic Seat Tests: Video and Data

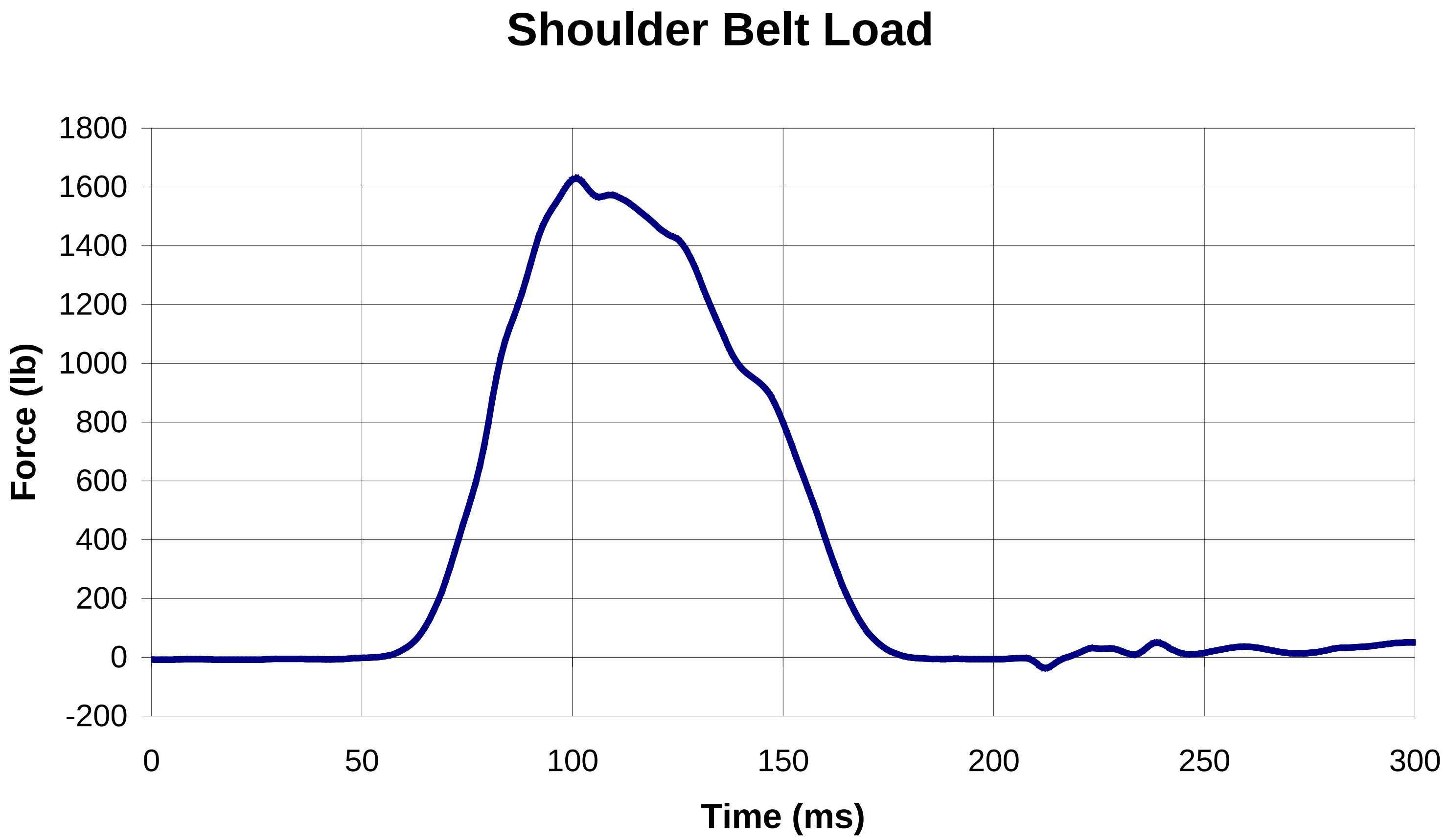


Part 23 Vertical 19 G Passenger Seat

Examples of Dynamic Seat Tests: Video and Data

Part 23 Horizontal 21 G Passenger Seat

Examples of Dynamic Seat Tests: Video and Data



Part 23 Horizontal 21 G Passenger Seat

Examples of Dynamic Seat Tests: Video and Data

Part 23 Horizontal 26 G Crew Seat

Examples of Dynamic Seat Tests: Video and Data

Part 25 Horizontal 16 G Wall Impact Demo

Examples of Dynamic Seat Tests: Video and Data

Horizontal 16 G Side Facing Sofa

Examples of Dynamic Seat Tests: Video and Data

Child Restraint Device

Examples of Dynamic Seat Tests: Video and Data

Belly Belt

Examples of Dynamic Seat Tests: Video and Data

Lap held Child

Examples of Dynamic Seat Tests: Video and Data

Lap Belt Airbag Demonstration

The Role and Importance of Post-Crash Investigation

- Examples of crash investigations involving seat issues. Both of these fit our definition of a "survivable" crash:

Avianca

British Midlands

The Role and Importance of Post-Crash Investigation

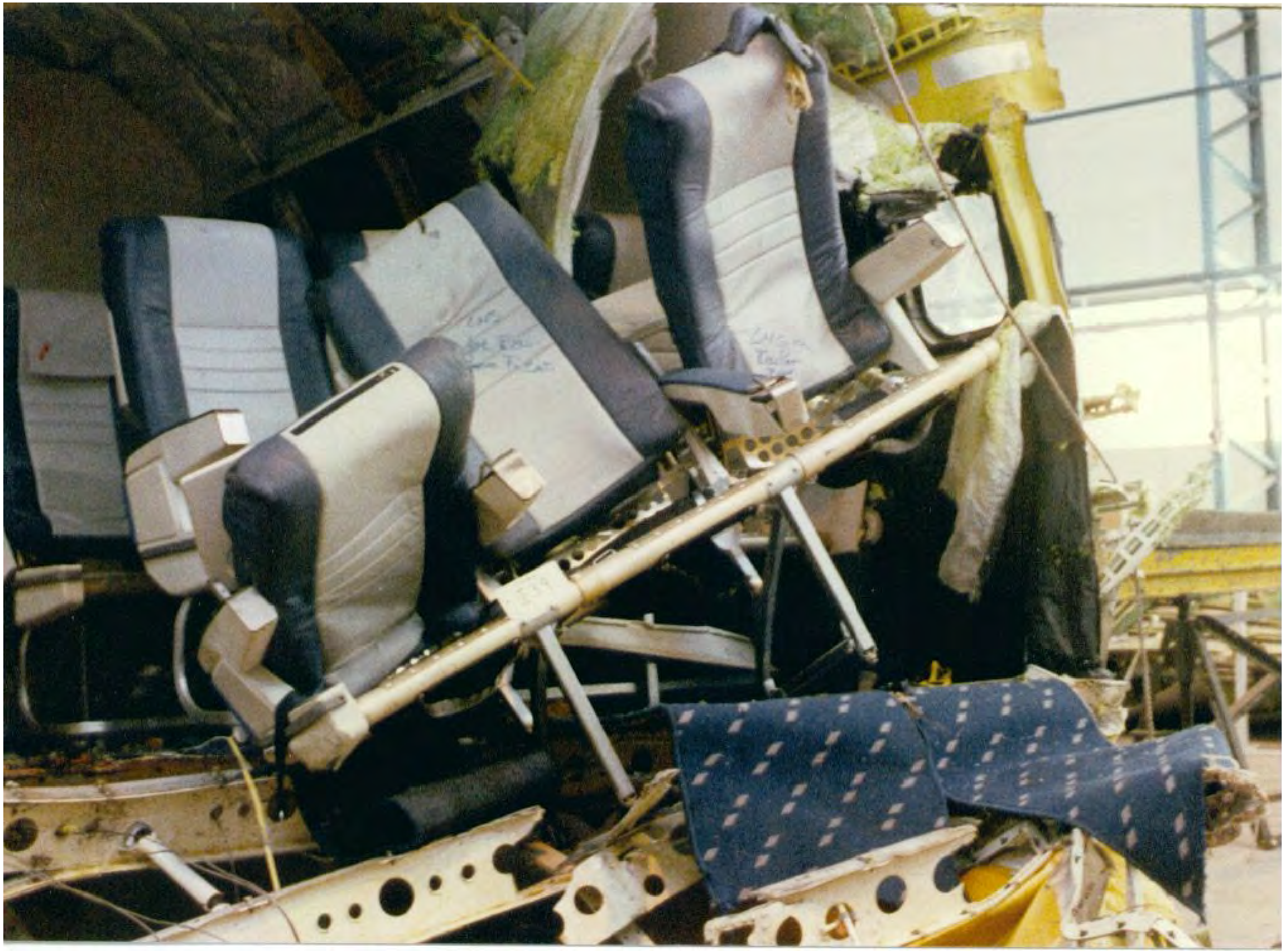
- Avianca:Jan 1990, an older Boeing 707, ran out of fuel and stuck a hill side on approach to JFK in NY.
  - Seats were of 1979 vintage that were statically qualified (9 G)
  - Almost all of the occupied seats were dislodged. The seats either separated from the floor completely or failed structurally.
  - Graphically illustrated the poor performance that had been observed in sled tests.

The Role and Importance of Post-Crash Investigation

The Role and Importance of Post-Crash Investigation

- British Midlands, Jan 1989, a nearly new Boeing 737, experienced an engine malfunction and impacted a hill side on approach to East Midlands Airport in England.
  - Passenger seats had been tested at CAMI and nominally met the 16 G requirements.
  - The seats remained attached to the floor in the areas where the floor was reasonably intact.
  - The majority of survivors were seated in the seats that had remained attached to the floor.
  - The seat performance validated the worth of the improved seats.

The Role and Importance of Post-Crash Investigation



The Role and Importance of Post-Crash Investigation

- Data from crash investigations are crucial for development of new safety standards and refinement of existing standards
  - Results can be fed back to seat and aircraft manufacturers so deficiencies can be corrected.
  - Seat structural performance can indicate the appropriateness of existing dynamic test severity levels.
  - Injury patterns can be used to evaluate the adequacy of occupant injury assessments made during dynamic tests.