Recommendations for Injury Prevention in Transport Aviation Accidents

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Introduction

- **National Objective: to reduce the rate of fatal aviation accidents by 80% in 10 years**

#1 – Accident Avoidance

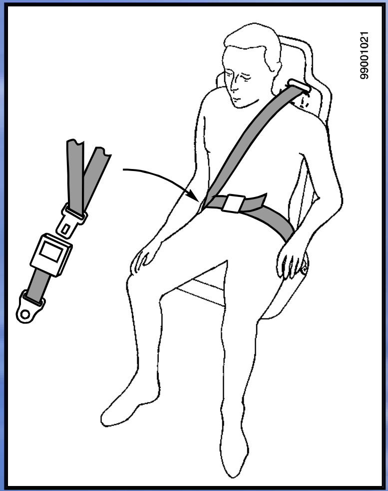
#2 – Improved Crashworthiness

Purpose of This Research

- To identify and prioritize the means to reduce injury and fatality in potentially survivable transport aviation accidents

Examples of Previous Recommendations

- 3-point restraints / shoulder harnesses
- Floor-to-seat connection and16-G seating
- Overhead bin attachments
- Fire retardation
- Decreased smoke and toxicity



To Survive an Accident… CREEP

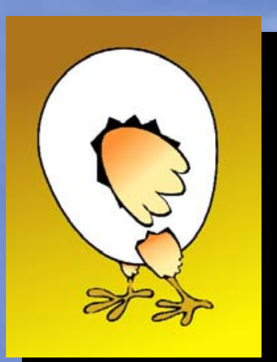
Container – Maintain occupiable space

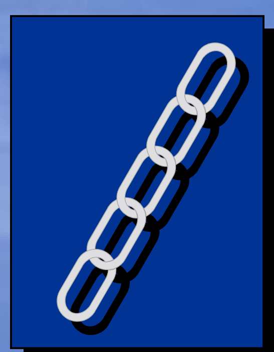
Restraint – Maintain tie-down chain

Energy – Remain within bounds of human tolerance

Egress

Post-crash Survival





Research Methods

- Case Studies
  - 11 accidents reviewed
  - Team evaluation (medical and engineering)
  - Critical technologies identified and prioritized
- Database studies and additional evaluation of commercial rotorcraft and General Aviation aircraft were performed, but are not covered in this presentation

Accident Selection Criteria

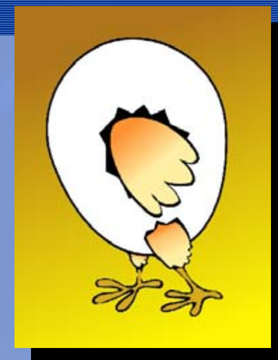
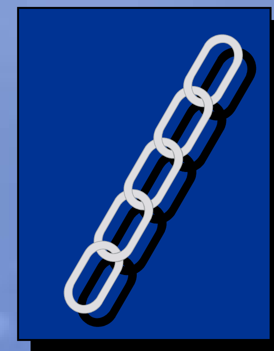
- "Partially survivable" = 1+ survivor and 1+ fatality
- Accident dates: 1985-1994
- Sufficient data for analysis, accident investigation is completed
- Diversity of accident scenarios
- U.S. operators on U.S. soil preferred

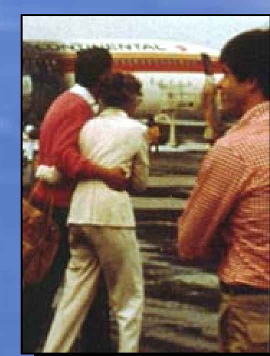
Accidents Reviewed

YEAR	LOCATION	Operator and Aircraft	CAUSE	FATAL / SURVIVED
1989	Sioux City, IA	United DC-10-	Engine Failure	111/172
1988	DFW, TX	Delta 727-232	Operational	14/76
1989	Kegworth, England	British Midland 737-400	Engine Failure, Operational	47/79
1991	Los Angeles, CA	Boeing 737	On-ground collision	22/69
1992	Flushing, NY	USAir Fokker 28-4000	Icing / Take-off	27/24
1985	DFW, TX	Delta L1011-385-1	Weather	135/28
1987	Romulus, MI	Northwest MD-DC-9-82	Operational / Take-off	155/1
1987	Denver, CO	Continental MD-DC-9-14	Icing / Take-off	28/54
1994	Charlotte, NC	USAir MD-DC-9-14	Weather	37/20
1989	Flushing, NY	USAir Boeing 737-400	Operational / Take-off	2/21
1990	Cove Neck, NY	Avianca Boeing 707-321B	Landing, Fuel Exhaustion	73/85

Case Study Results and Analysis

- **C**ontainer
- **R**estraint
- **E**nergy Management
- **E**gress and Environment
- **P**ost-crash Survival
- Special Considerations
  - Child Passengers

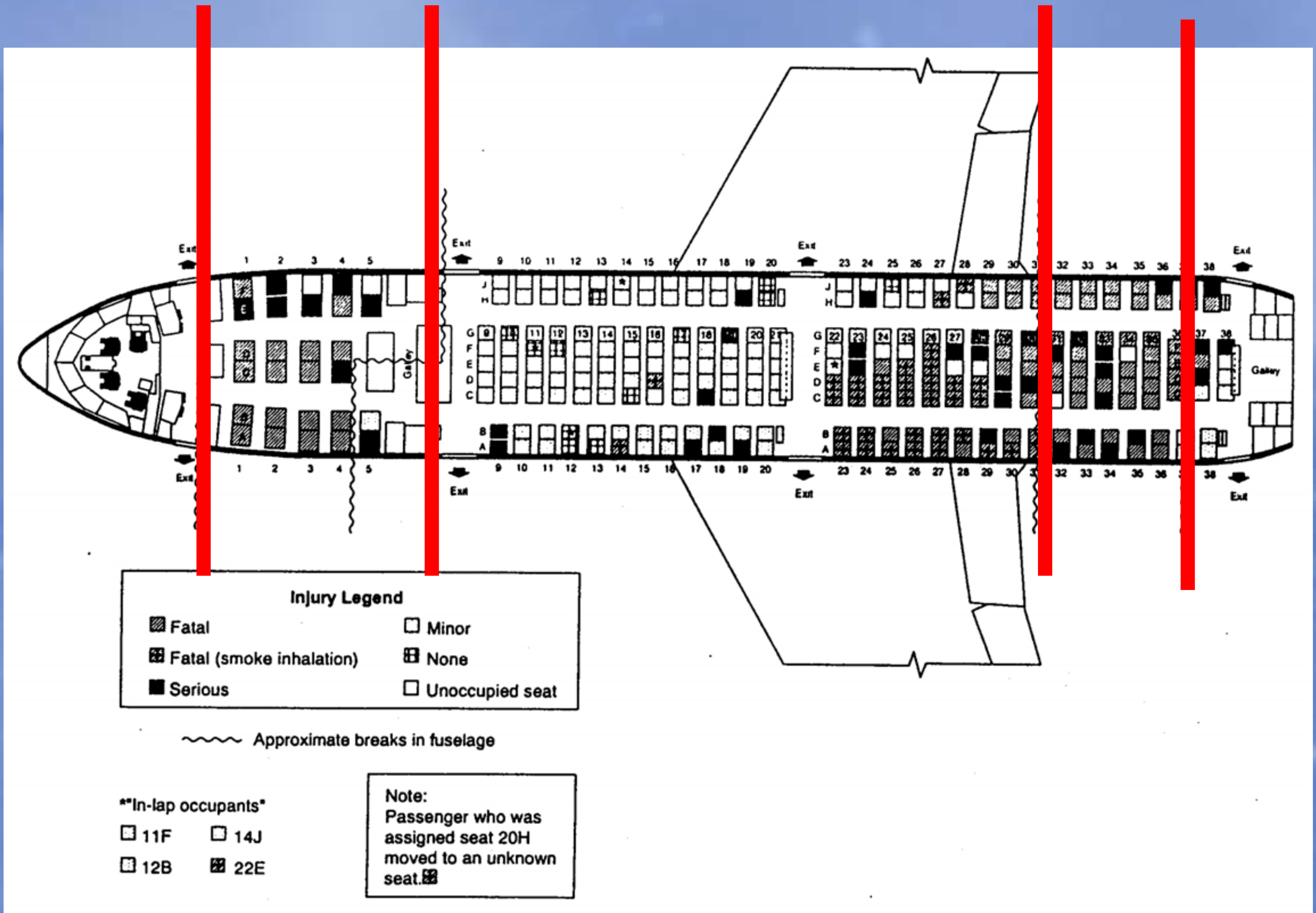



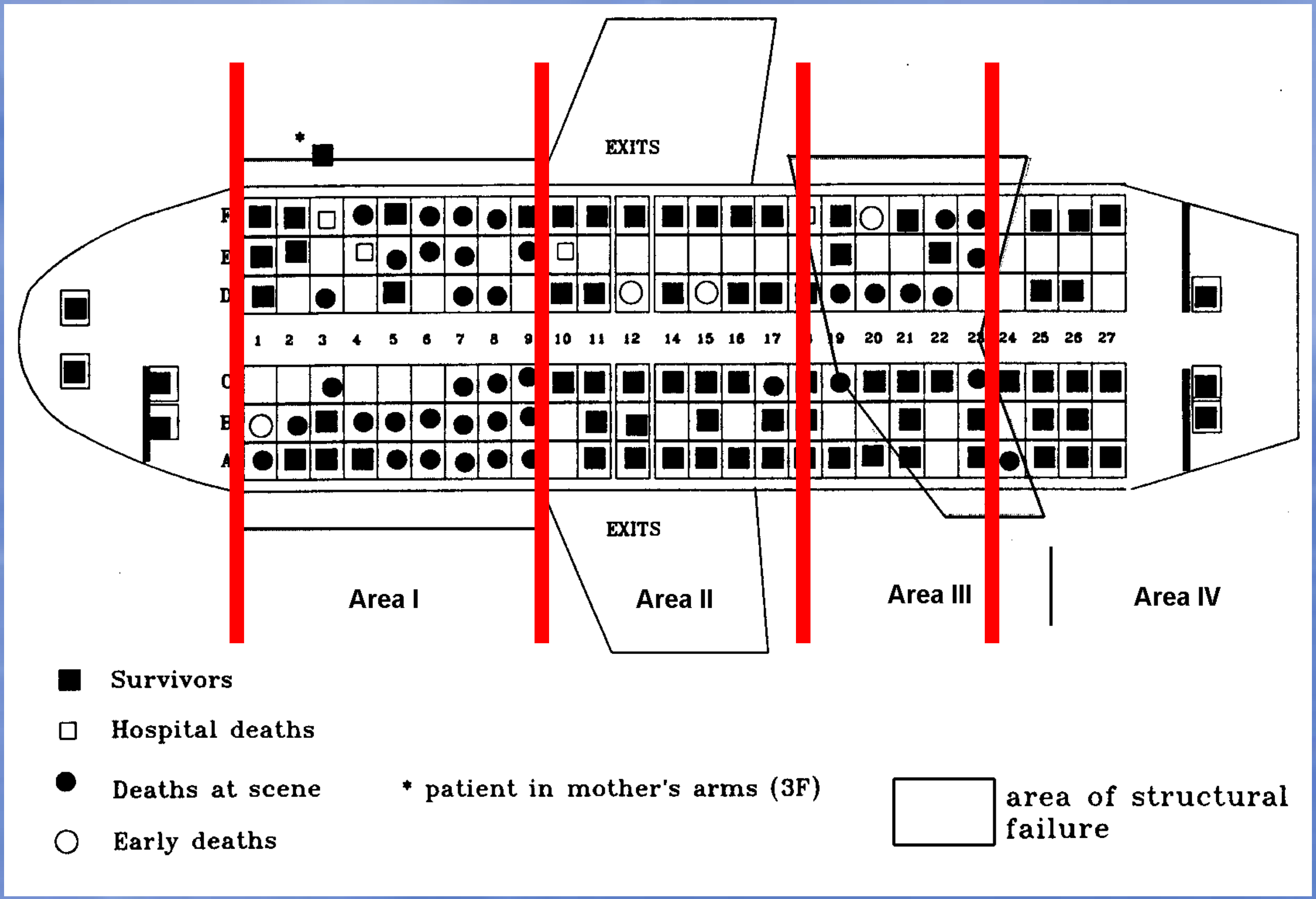
Container

- Key difference between survivable and not survivable accidents is occupiable space
- In many scenarios, we know where the aircraft is most likely to break!
  - Structural discontinuities
- Minimal ability to affect extremely localized loading and loss of occupiable space
  (e.g., Flushing, NY, 1989)

1989 Sioux City



1989 Kegworth



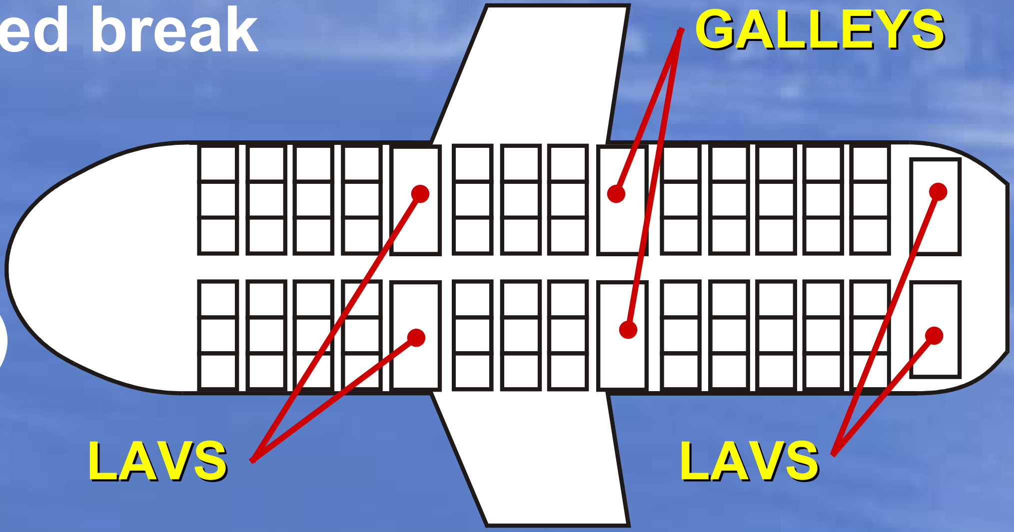
Recommendations

Long-term Recommendation

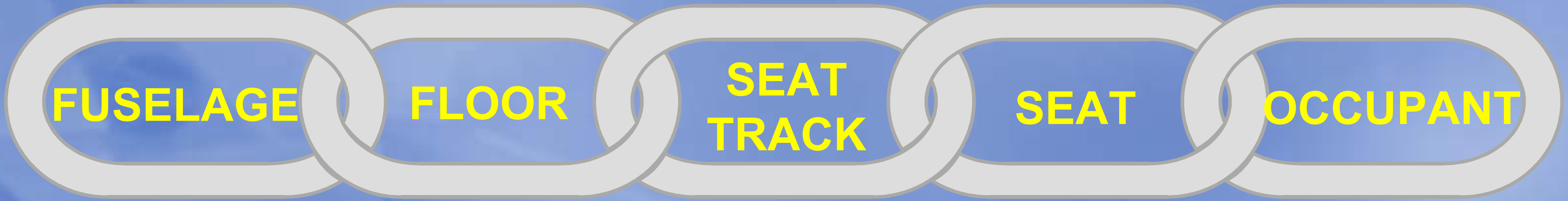
- Increased structural integrity
- Designed-in break points to take advantage of structural discontinuities

Short-term Recommendation

- Delethalize anticipated break points by locating non-passenger equipment there (e.g., lavs or galleys)



Restraint



- Failures mostly in early links of the tie-down chain
- Seats and restraints are important:
  - 9-G seats have often failed and tore out
  - 16-G seats have proven beneficial

Recommendations

- Long-term Recommendations
  - Improved floor integrity (alternative load paths and out-of-plane loading)
  - Increased seat track integrity (16-G structural)
- Short-term Recommendations
  - Limit track loading in existing systems (e.g., an EA device between 9-g seat and seat track)
  - Improved pelvic and torso restraint that can limit loads transferred top floor (e.g., haulback reels, 3-point restraints and air bags, alternative seat and restraint designs)

Energy Management

- Most serious injuries are head injury and loss of consciousness, thoracic injury, and lower extremity injury
- Various mechanisms of injury including seating and restraint loading and airborne debris

Seating

- Results:
  - Impact with seat in front produced mostly head injuries with some thoracic injury
  - Loss of consciousness can be critical
- Recommendations:
  - Delethalize seat backs
  - Seek and apply metrics for unconsciousness
  - Use 36 msec HIC so aviation R&D can be directly compared to automotive R&D

Lower Extremity Injury

- **Results:**
  - 16-G seating: Lower extremity fractures from bending around front tube or direct impact when seats become detached
  - Prevents ability to egress

- **Recommendations:**
  - Change test requirements to include femoral bending and tibial fracture

Airborne Debris

- **Results:**
  - Posterior head impact from baggage and overhead bins
  - Shorter or ‘protected’ passenger received less severe injury than their neighbors
- **Recommendations:**
  - Delethalize baggage storage – improve bins (16-G standard) or seek alternative baggage storage
  - Increase seat back height and compartmentalization

Egress and Environment

- Results:
  - Egress relied upon chance in many circumstances
    - Inability to locate usable exits, particularly when severe structural damage occurred
    - Usefulness of and flow through exits and slides particularly in non-level attitudes

  - Fire, smoke, and toxicity were factors in accidents that were otherwise survivable

Recommendations

- **Improve exit door integrity and function**
- **Increase the number and spacing of planned exits**
- **Design in break points**
- **Continued research and development in fire suppression, reduced flammability and toxicity, and alternative means to extend time to egress in fire scenarios**

Post-crash Survival

- **Survivability does not end with egress**
- **Emergency response made a life-death difference (e.g., drownings, waiting for extrication, on-site triage)**
- **Passengers cited well trained flight attendants as essential to their egress but often assistance did not continue once outside aircraft**

Special Considerations – Child Passengers

- Repeated examples of loss of control of lap-held infant (e.g., Sioux City, Charlotte, Cove Neck NY, Denver)
- Survival of lap-held children is left to chance
- Children should be afforded equivalent level of safety as other passengers
  - Require ALL passengers to be restrained
  - Require child restraint devices to perform appropriately in aviation environment

Conclusions

- Study limitations
  - Accessibility of detailed information
    - Accident reports have a limited focus on occupant survivability issues
    - Limited injury and autopsy data was available
    - Too much focus on seating system and not on whole picture of survivability
  - High variability in accident scenarios and small number of accidents limit ability to perform statistical analyses

General Recommendations

- Cabin- or seat-mounted crash data recorders to provide data usable for occupant survivability evaluation
- Increased training and resources for accident survivability investigations
- Increased survivability requirements for new aircraft
- Increased focus on short-term methods for risk reduction

Conclusions

Accident	Occupiable Space	Restraint			Energy Management		Egress		Child Safety
		Floor	Seat	Occupant	Seating	Baggage	Exits	Fire	
Sioux City	A			B	B/P	B	B	A	A
1988 DFW							A	A	
Kegworth	A	A	B/P	B	A	A		P	
Los Angeles							A	A	
1992 NY	A	B	A		B	B		B	
1985 DFW	A							A	
Detroit	**				P				
Denver	A	A	A		B	B			A
Charlotte	A	A	A		B	B	B	A	A
1989 NY	A								
1990 NY	A		A		A				B

A = Major cause of injury or fatality B = Minor cause of injury or fatality P = Preventative benefit clearly demonstrated
** = Accident was non-survivable

Container is #1 priority for long-term improvement in survivability

Future Considerations

- **Additional Complications:**
  - Larger aircraft and increased load factors
  - Aging aircraft population
  - Aging passenger population
  - Runway incursions / "land-and-hold-short"
  - Increased pressure on pilots and airlines for on-time arrivals

Acknowledgements

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Thank You!

Questions?

Crash brace position

- Results:
  - Appears to reduce severity of injury (data not clear)
  - Internal Simula study: sufficient time to instruct brace position in 20-25% of accidents
- Recommendation:
  - More research and education is needed regarding best brace positions, particularly for obese and tall passengers or when particularly small seat pitches are used