Recommendations for Injury Prevention in Transport Aviation Accidents

Presented by:
Lance C. Labun
Authors:
Anita Grierson
Simula Technologies, Inc.
Lisa Jones
NASA Langley Research Center
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 and 16-G seating
Overhead bin attachments
Fire retardation
Decreased smoke and toxicity
To Survive an Accident.. CREEP

C - Container – Maintain occupiable space
R - Restraint – Maintain tie-down chain
E - Energy – Remain within bounds of human tolerance
E - Egress
P - 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
“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

<table>
<thead>
<tr>
<th>YEAR</th>
<th>LOCATION</th>
<th>Operator and Aircraft</th>
<th>CAUSE</th>
<th>FATAL / SURVIVED</th>
</tr>
</thead>
<tbody>
<tr>
<td>1988</td>
<td>DFW, TX</td>
<td>Delta 727-232</td>
<td>Operational</td>
<td>14/76</td>
</tr>
<tr>
<td>1989</td>
<td>Sioux City, IA</td>
<td>United DC-10-</td>
<td>Engine Failure</td>
<td>111/172</td>
</tr>
<tr>
<td>1989</td>
<td>Kegworth, England</td>
<td>British Midland 737-400</td>
<td>Engine Failure, Operational</td>
<td>47/79</td>
</tr>
<tr>
<td>1991</td>
<td>Los Angeles, CA</td>
<td>Boeing 737</td>
<td>On-ground collision</td>
<td>22/69</td>
</tr>
<tr>
<td>1992</td>
<td>Flushing, NY</td>
<td>USAir Fokker 28-4000</td>
<td>Icing / Take-off</td>
<td>27/24</td>
</tr>
<tr>
<td>1985</td>
<td>DFW, TX</td>
<td>Delta L1011-385-1</td>
<td>Weather</td>
<td>135/28</td>
</tr>
<tr>
<td>1987</td>
<td>Romulus, MI</td>
<td>Northwest MD-DC-9-82</td>
<td>Operational / Take-off</td>
<td>155/1</td>
</tr>
<tr>
<td>1987</td>
<td>Denver, CO</td>
<td>Continental MD-DC-9-14</td>
<td>Icing / Take-off</td>
<td>28/54</td>
</tr>
<tr>
<td>1994</td>
<td>Charlotte, NC</td>
<td>USAir MD-DC-9-14</td>
<td>Weather</td>
<td>37/20</td>
</tr>
<tr>
<td>1989</td>
<td>Flushing, NY</td>
<td>USAir Boeing 737-400</td>
<td>Operational / Take-off</td>
<td>2/21</td>
</tr>
</tbody>
</table>
Case Study Results and Analysis

Container
Restraint
Energy Management
Egress and Environment
Post-crash Survival
Special Considerations
– Child Passengers
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)
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)
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.
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
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
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

<table>
<thead>
<tr>
<th>Accident</th>
<th>Occupiable Space</th>
<th>Restraint</th>
<th>Energy Management</th>
<th>Egress</th>
<th>Child Safety</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Floor</td>
<td>Seat</td>
<td>Seating</td>
<td>Baggage</td>
</tr>
<tr>
<td>Sioux City</td>
<td>A</td>
<td></td>
<td>B</td>
<td>B/P</td>
<td>B</td>
</tr>
<tr>
<td>1988 DFW</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kegworth</td>
<td>A</td>
<td>A</td>
<td>B/P</td>
<td>B</td>
<td>A</td>
</tr>
<tr>
<td>Los Angeles</td>
<td></td>
<td>A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1992 NY</td>
<td>A</td>
<td>B</td>
<td>A</td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>1985 DFW</td>
<td>A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Detroit</td>
<td>**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Denver</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>Charlotte</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>1989 NY</td>
<td>A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1990 NY</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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
We gratefully acknowledge the assistance of the following people and organizations:

- Dr. Dennis Shanahan and Mr. Richard Chandler
- NASA Langley Research Center, CAMI, NTSB, FAA

Thank You!
Questions?
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