

The Science of Survivability

FEDFLEET²⁰¹¹ A Clear Vision

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Why Survivability??

What Goes up.....

- Although flying is still one of the safest forms of transportation statistically, accidents do happen



The First Fatal Crash



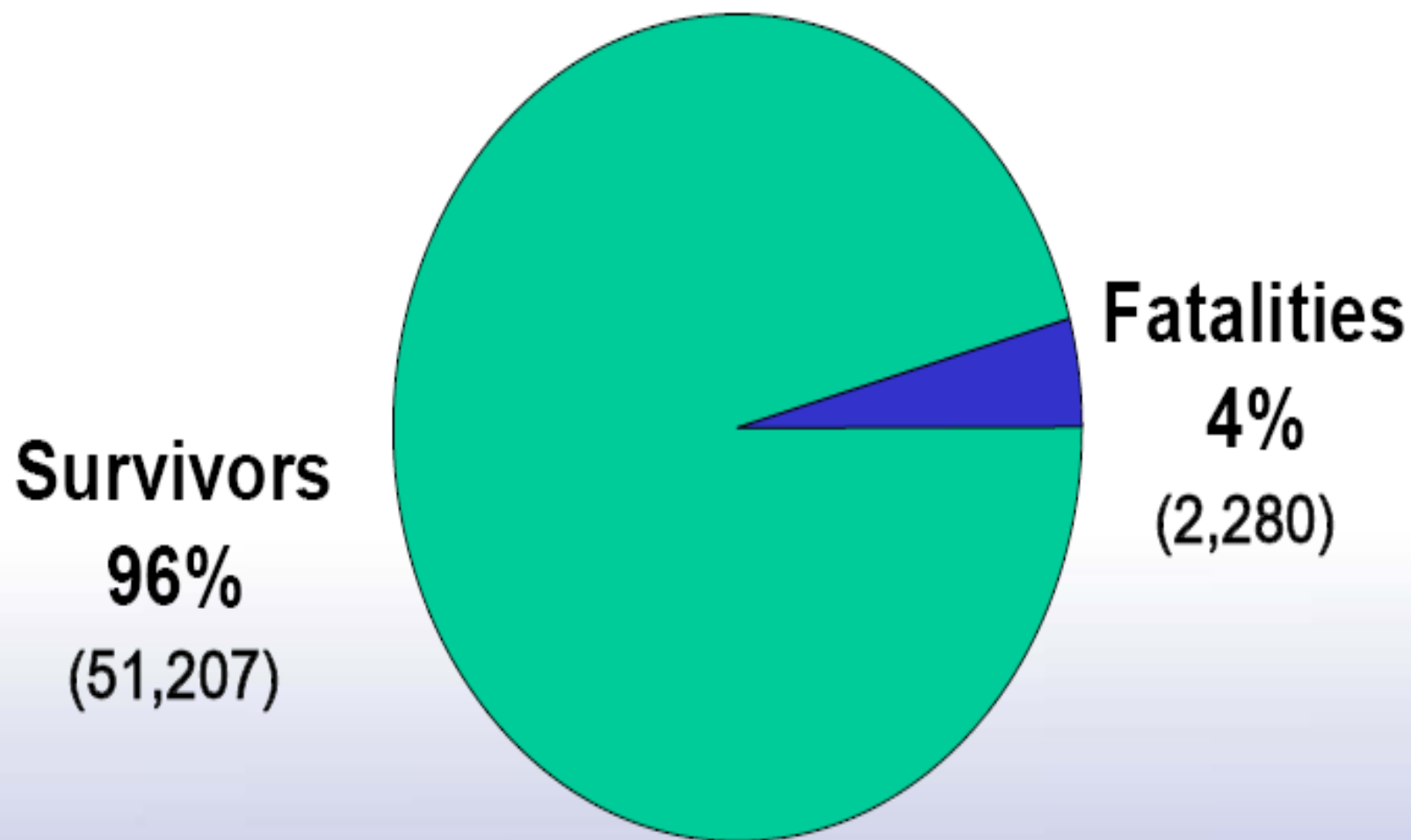




Popular Misconception

- “Everyone dies in plane crashes”

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



Areas of Focus

- Crash Survivability
- Impact and Deceleration
- Human Tolerance
- Accident Pathology
- Seats and Restraints
- Egress and Fire Survivability
- Post Crash Survival (Personal Considerations)

Crash Survivability



Crash Survivability

- Questions:
 - What actually caused the accident?
 - Did the injury have to occur?
 - Could something have been done to eliminate or reduce the severity of the injury?
- A shallow angle impact on unobstructed terrain at general aviation aircraft approach speeds should be survivable

Survivable Aircraft Impact

- A survivable aircraft impact is one during which the deceleration forces transmitted to the occupants did not exceed human tolerances and in which the structure surrounding the occupants remained substantially intact (occupiable living space)

Survivable Aircraft Accident

- A survivable aircraft accident is one during which the deceleration forces transmitted to the occupants did not exceed human tolerances and in which the structure surrounding the occupants remained substantially intact (occupiable living space)
- Plus: Favorable post crash conditions

CREEP Acronym

- **C** Container
- **R** Restraint
- **E** Energy Absorption
- **E** Environment
- **P** Post Crash Factors



bhpbilliton

MG









C = Container

- Heavy stuff in front
- Engineers can predict how & where an aircraft's structure will fail
- Landing gear not designed to end up in the cockpit
- Living space can be deceiving

R = Restraint

- Strength of all restraints should be sufficient to prevent injury during most severe but survivable crashes.



E = Energy Absorption

- The design of the aircraft structure and seats may cause the acceleration forces experienced by the crew and passengers to be either amplified or attenuated.
 - Energy absorbing structures vs. Rigid structures

E = Environment

- Delethalization
 - Cockpit
 - Cabin
 - Cargo Spaces
- Competing Interests
 - Aerodynamics
 - Human Factors
 - Economics



P = Post-Crash Conditions

- All too frequently, crew or passengers survive the dynamic portion of a crash, only to suffer additional injuries or death when they are unable to safely exit the aircraft in a timely manner.

Crash Survival Calculations

- Crash survivability is a function of both peak G experienced and the duration of the G.
- The Human Body can withstand a really big jolt for a very short time.

Peak G & Duration

- To calculate:
 - Require impact velocity
 - Vertical velocity
 - Horizontal Velocity
 - Require Deceleration distances
- Deceleration distance (either vertically or horizontally) is the sum of the depth/length of the impact crater and the aircraft structure “crush distance” the amount it deformed.

Impact and Deceleration



It isn't going fast, but **STOPPING FAST,**
that causes problems!!!

Accident Investigations

- Serve a two-fold purpose to:
 - Determine all direct and indirect causes of the accident so that steps may be taken to prevent similar accidents from happening.
 - Determine to what extent persons were unnecessarily injured or killed in potentially survivable crashes so that occupant protection criteria can be improved.

Aviation Accidents

- Survival requirements:
 - Occupants have to survive impact
 - Occupants have to evacuate aircraft
 - Occupants have to survive post-accident environmental conditions

Impact Survival

- Relatively intact cockpit/cabin structures
- Decelerative forces within [human tolerances](#)
- Adequate seat/restraint system
- Non-lethal environment
- Pilot technique

Timely Egress

- Adequate escape provisions
- Post-crash fire protection
- Fire fighting & rescue services
- Ease of release of restraint system
- Jamming of exit doors & fuselage distortion
- Ease of opening exit doors

Post-Accident Survival Factors

- Role of ELT in locating wreckage
- Survival gear & survival skills
- Search & Rescue
- Degree & type of injuries
- Promptness & quality of medical attention

The most important variable in the survival of aircraft accidents is unquestionably impact survival!

Levels of Impact Severity

- Non-Survivable Impact
- Survivable Impact
- Partly Survivable Impact

Non-Survivable Impact





Survivable Impact





Partly Survivable Impact



Reactions to Impact

- Hit & Skid
- Hit & Bounce
- Hit & Stick
- Cartwheel

Hit and Skid



Hit and Bounce



Hit and Stick



Cartwheel



Human Tolerance



The human body can withstand a very large jolt, for a short amount of time...

G – Forces (Gravitational Forces)

- The human body likes to operate in a 1G environment
- As the G-force level increases, the human body reacts
 - Discomfort to **Death**

Voluntary G Force Tolerance

Direction of Applied Force	Term Used	Direction of Body's Reaction	Voluntary Tolerance*
<u>Vertical (Parallel to Spine):</u> Positive (Headward) Negative (Tailward)	$+ G_z$ $- G_z$	Eyeballs - down Eyeballs - up	15-G 20-G 15-G
<u>Transverse (Perpendicular to the Spine):</u> Lateral right Lateral left Back to chest Chest to back	$+ G_y$ $- G_y$ $+ G_x$ $- G_x$	Eyeballs - left Eyeballs - right Eyeballs - in Eyeballs - out	20-G 20-G 50-G 45-G 50-G 45-G
* The values shown for human tolerance are approximate for short duration (0.10 second, 100 milliseconds) impacts and represent no irreversible injury for young or early middle-aged volunteer test subjects wearing special restraint systems adjusted uncomfortably tight.			

Table 3. Directions of applied forces on the body and the equal and opposite reactions of the body (from USARTL-TR-79-22).²

Prolonged G

- Changes in G level
 - Turbulence
 - Aircraft maneuvers
 - Aerobatics
- Velocity (magnitude & direction)
- Most are from change of direction vs. change in speed

Abrupt G

- Short duration (0.10 seconds or less)
- Variables include:
 - Magnitude & duration of deceleration
 - Rate at which these decelerations reach their peak (rate of onset)
 - Body orientation and the manner in which the decelerative force is applied to the body

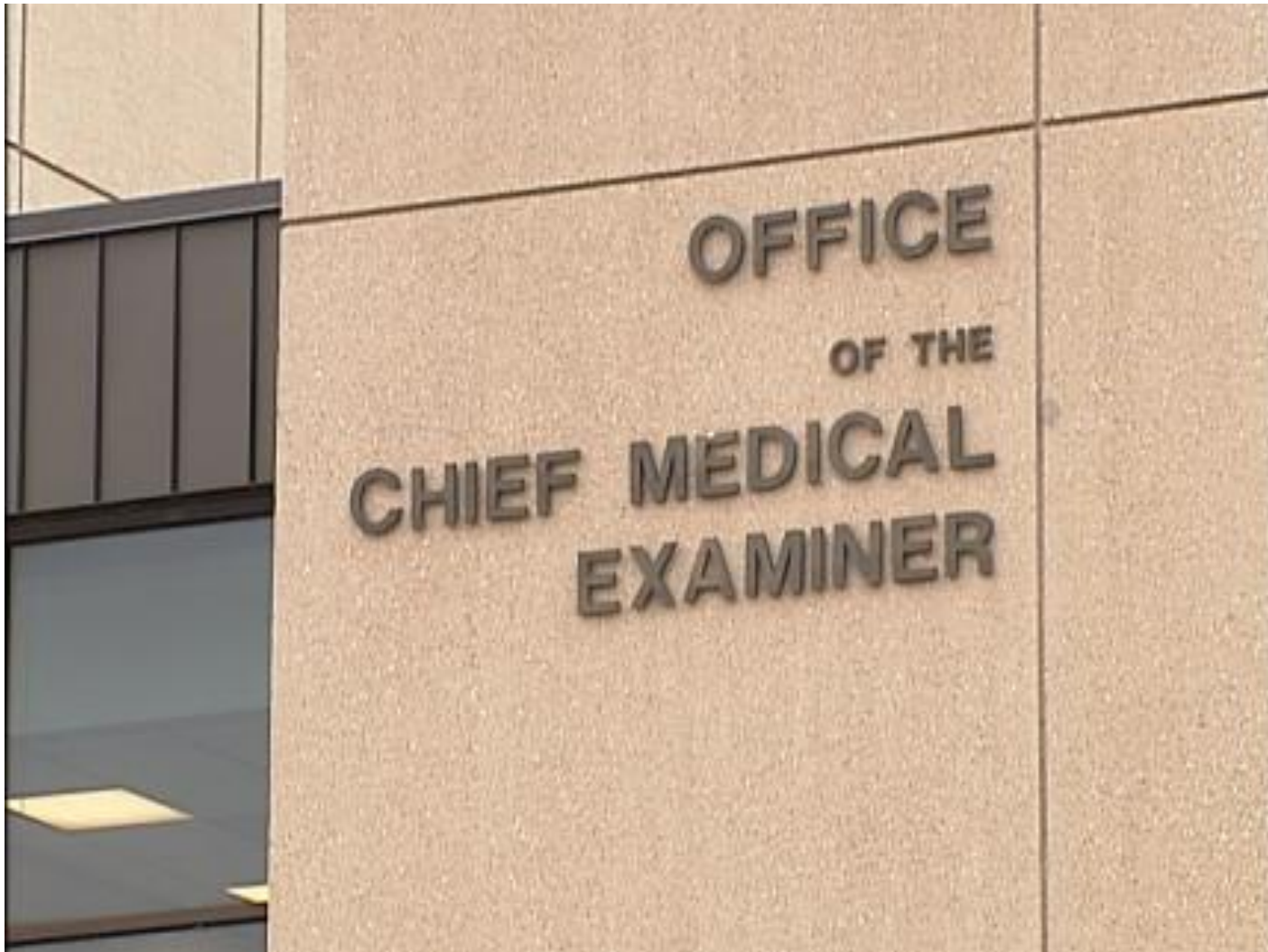
Crash Injuries

- Broad categories:
 - Contact Injuries: injuries which result from the body's striking, or being struck by, another object
 - Decelerative Injuries: injuries which occur as a direct result of the shock loads on the body

Contact Injuries

- Jackknifing & Flailing
 - Unrestrained parts of body striking the internal structure of the aircraft
 - Major sources of injury with lap belt only restraint
- Submarining:
 - Can occur when lap belt does not have proper angle
 - Involves liver, spleen, and bladder

Accident Pathology



Autopsy

- What was the physical condition of the individuals?
- Who was flying the aircraft?
- What impact forces were present?
- Was there a toxic environment present prior to impact?
- What was the cause of death?
- Was there an in-flight explosion?

Seats and Restraints



Momentum

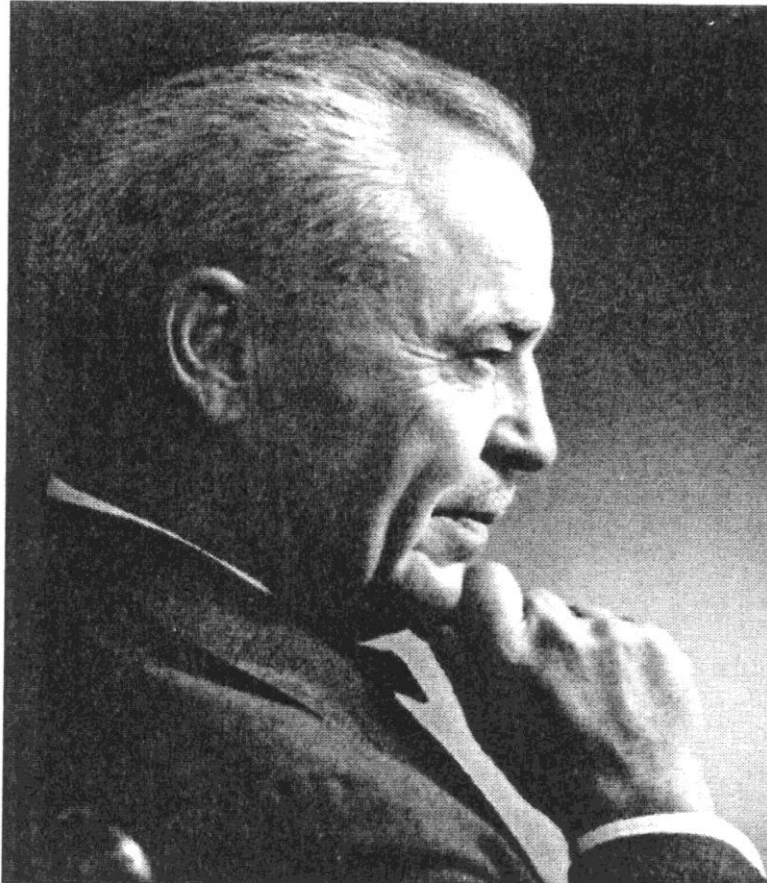


Restraint Systems

- Early Seat Belts
 - Keep passengers from falling out of planes

Hugh DeHaven

DeHaven's "Packaging Principles"



Packaging Principle #1

- The package should not open up and spill its contents and should not collapse under expected conditions of force and thereby expose objects inside it to damage.

Packaging Principle #2

- The packaging structures which shield the inner container must not be made of frail or brittle materials; they should resist force by yielding and absorbing energy applied to the outer container so as to cushion and distribute impact forces and thereby protect objects inside the inner container.

Packaging Principle #3

- **Articles contained in the package should be held and immobilized inside the outer structure by what packaging engineers call interior packaging. This interior packaging is an extremely important part of the overall design, for it prevents movement and resultant damage from impact against the inside of the package itself.**

Packaging Principle #4

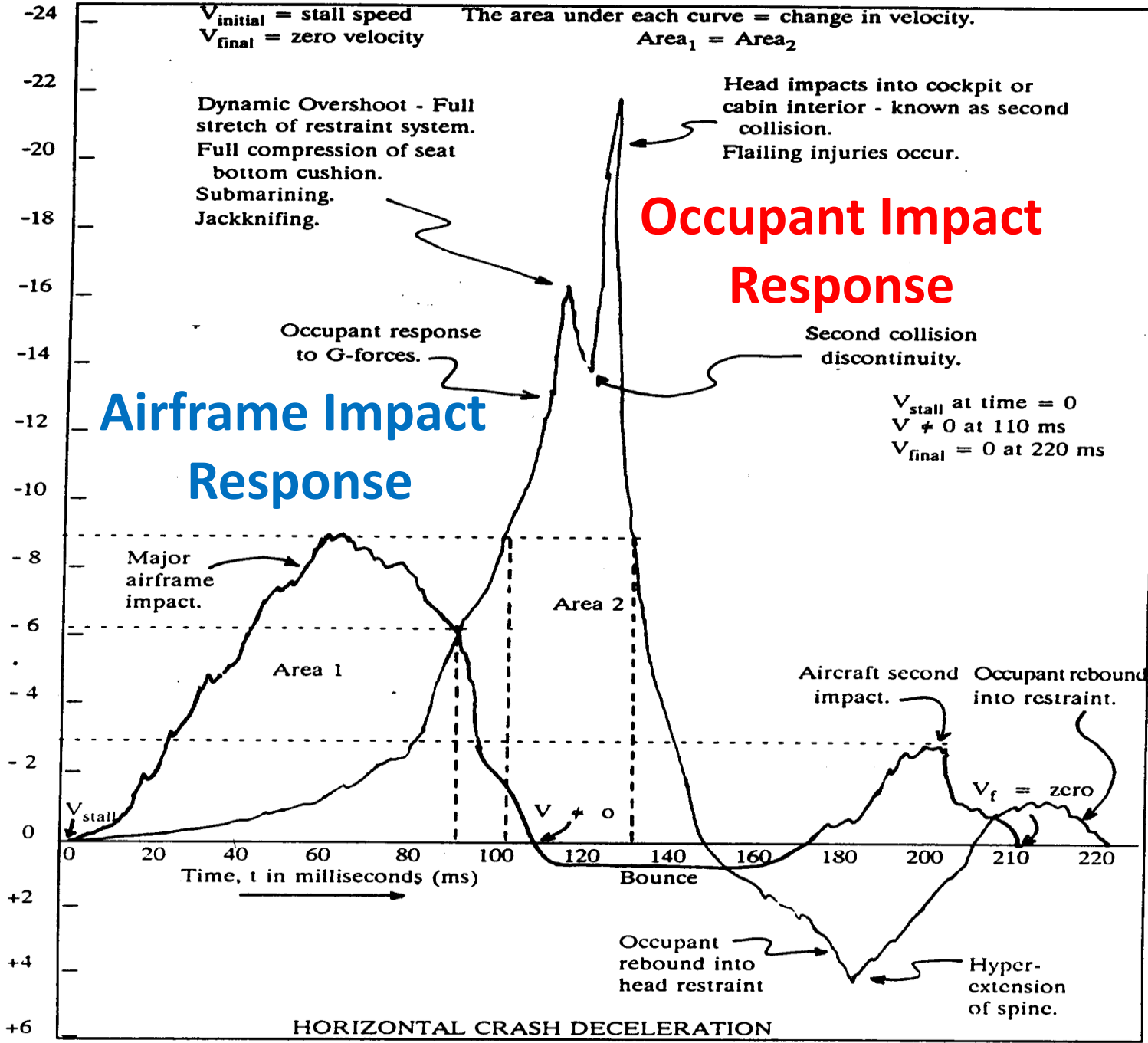
- The means for holding an object inside a shipping container must transmit the forces applied to the container to the strongest parts of the contained objects.

Cockpit & Cabin Environment

- More hostile than car:
 - Impact speeds greater
 - Vertical as well as Horizontal
 - Doubling speed increases severity of effect four-fold
- Most conditions
 - Impossible to restrain upper body's motion by bracing

Dynamic Overshoot

- Major cause of personal injury
 - 10 # string/10 pound weight
 - Occupants can reach loads well above aircraft
- Preventive measures:
 - Tightly adjusted seat belt & shoulder harness
 - Don't sit on a deep spongy cushion
 - Load limiting concepts built in



The Three Impacts

- #1: Aircraft hits the surface
- #2: You hit interior of aircraft or restraint system
- **#3: Your organs move around inside your body**

Egress and Fire Survivability



Post-Crash Conditions or Timely Egress & Fire Survivability

- All too often, crew or passengers survive the dynamic portion of a crash, only to suffer additional injuries or death when unable to exit aircraft
- Two most prominent reasons:
 - Post crash fire
 - Inability to quickly exit plane

Egress

- Fire Deaths: When an accident involves a post-crash fire, timely evacuation of the aircraft can be a matter of life and death for the occupants who survived the impact.

British Airtours Accident

- 22 August 1985 British Airtours
- Boeing 737 crew rejected takeoff
- Top burner can #1 engine came apart
- Penetrated cast iron casing, resulting in a wing fuel fire
- 54 of 137 occupants died as a result of incapacitation from smoke inhalation



British
airtours

British airtours

G-BGJL







source: Aircraft Accident Report No. 8/88
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cabin view (looking forward)



remains of combustor can no.9

both photos © Aircraft Accident Investigation Branch- AAIB

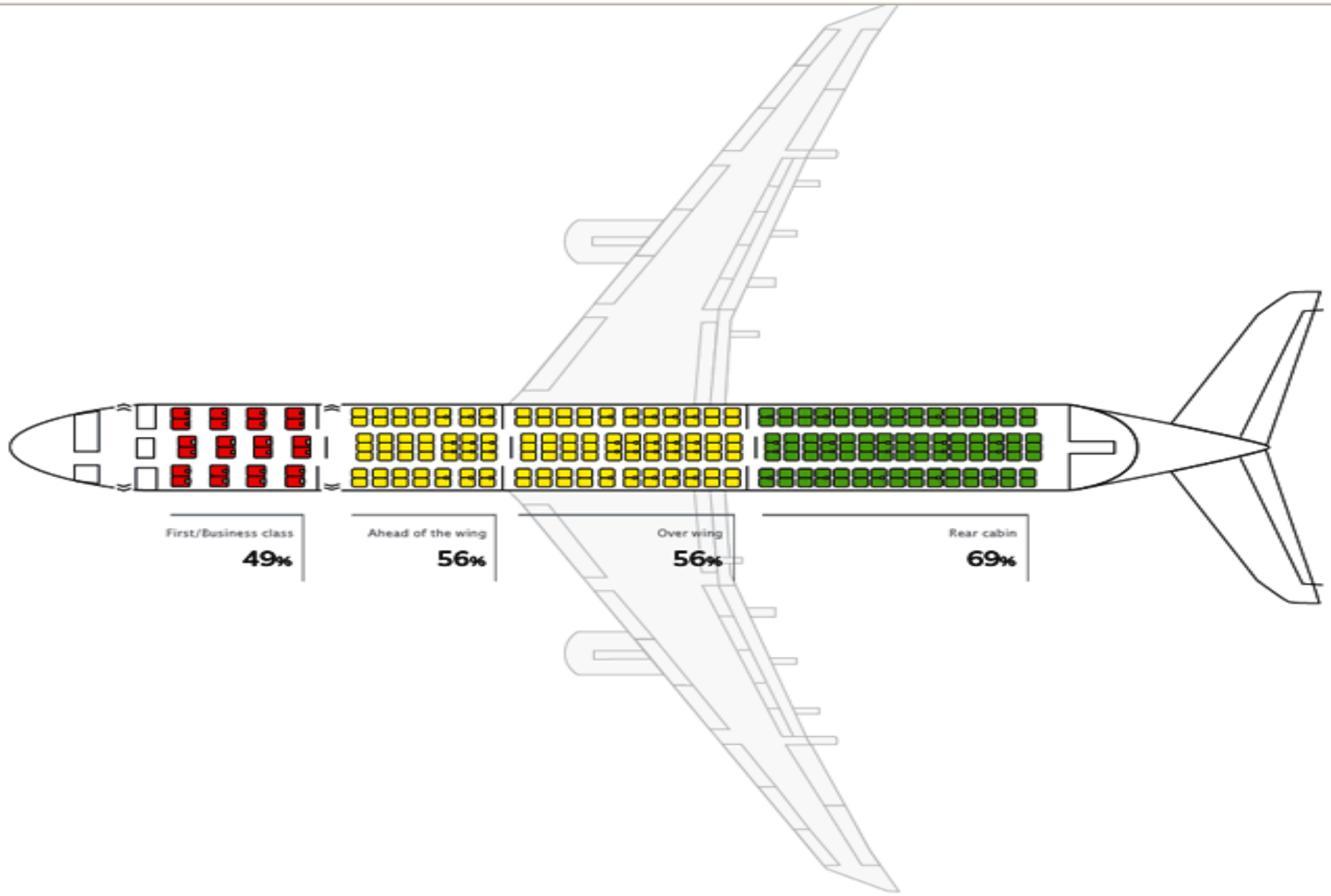
Think about this

- A 100 passenger plane
- Each passenger carries a 10 pound bag on board (probably low)
- 1,000 pounds of who-knows what
- Probably more weight than material in seats
- How do designers plan for this??

Post Crash Survival (Personal Considerations)



Safest Aircraft Seat??



Survival

- In aviation accidents survival is predicated on three factors:
 - Impact Survival
 - Timely Egress or Safe Evacuation
 - Post-Accident Survival

General Aviation Accidents

- Accidents often:
 - Occur in remote areas
 - Without having filed a flight plan
 - Without an eye witness
 - Without having made a radio transmission
 - Without a radar track
 - Without an ELT

Survival

- Survival books generally break the survival process into three phases:
- Pre-Emergency Phase (Training)
- Emergency Phase (Flying)
- Post-Emergency Phase (Survival)

Pre-Emergency Phase (Training)

- Physical Fitness
- First aid
- Statistical Data
- Survival Kit

Physical Fitness

- I can say: “You are better off in all survival situations if you are fit”
 - High altitude survival
 - Survival after being injured
- May be two exceptions:
 - Over weight/poor circulation better in cold water
 - If you smoke greater possibility you will have matches

First Aid

- No time to learn on the job! When the time comes need to know:
 - How to stop bleeding, or restart breathing
 - Immobilize fractures
 - Recognize shock
 - Weak pulse
 - Shallow breathing
 - Rapid & irregular breathing
 - Eyes dilated
 - Diarrhea
 - Insects/Parasites

Statistical Data

- Survival rate greater if you have flown in the last 60 to 90 days!
- If you file a flight plan your chances of arrival are better!
- IFR plan better than VFR!
- Importance of working ELT!

Survival Kit

- General as well as personal requirements, tailored to specific areas and needs such as:
 - First Aid Kit
 - Signaling
 - Drinking Water
 - Shelter Construction
 - Food
 - Navigation

Survival Kit

- Must have items:
 - Gauze dressings/Tape/Aspirin/Alcohol/etc
 - Mirror/Flares/Smoke signals/Plastic containers
 - Knife/Wire saw/Beef jerky/Hard candy
- Should know what is in your kit, Should keep up to date, and inspect regularly
- Should not over compensate and carry too much

Emergency Phase (Flying)

- Stay current! If not current become current!
- Apply basic knowledge
 - Slow aircraft, do not stall, land into the wind!
 - Select best terrain!
 - Know importance of seat belts, 5/4 point harness, have them tight!
 - Know the importance of a clean cockpit, a secured cabin (Delethalization)

Post-Emergency Phase

- Survival depends largely upon preparedness and resourcefulness. Are you mentally strong-in control and optimistic?
- The desire to live and a healthy frame of mind to fulfill that desire may be the critical factors determining whether you live or die.
- Second only to fortitude-and a close second at that-is your degree of physical readiness.

Survival Priorities

- Render first aid
- Prepare signaling devices
- Procure water
- Find or build a shelter
- Procure food
- Prepare to travel, if necessary
- Be aware of dangers associated with environment

First Aid Priorities

- Air: Need to solve this problem right now three minutes max
- Bleeding: Need to stop immediately
- Burns: Water requirements
- Shock: Can die from shock if not treated

Water Procurement

- Water is one of the basic necessities of life. Humans can live for several days without food but only a short time without water.
- Most people experience a tremendous thirst in a survival situation.
- Know what not to drink;
 - Salt water
 - Urine

Food Procurement

- You can go without food for many days. In fact it would take several months to starve to death, but you could die in minutes from injuries or within days from dehydration or overexposure.
- Don't need three squares but also don't show up for flight having missed meals

Closing Thoughts

- Meal(s) before flights
- Pay attention during safety briefing
- Vigilance when flying First Class/Business
- Clothing considerations
- Aware of emergency exit location

- **BE PREPARED!!!**

Thank You For Your Attention!

Questions / Comments?

