

Beyond the Black Box: The Forensics of Airplane Crashes

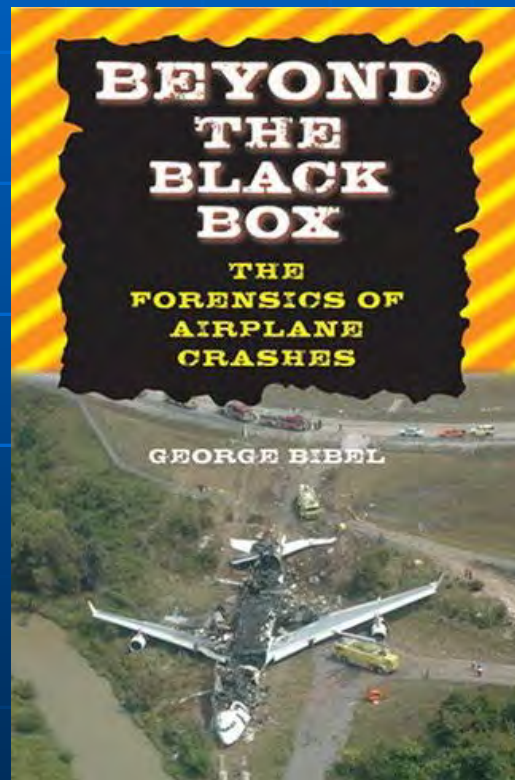
Professor George Bibel

George Bibel, Ph. D., P. E.

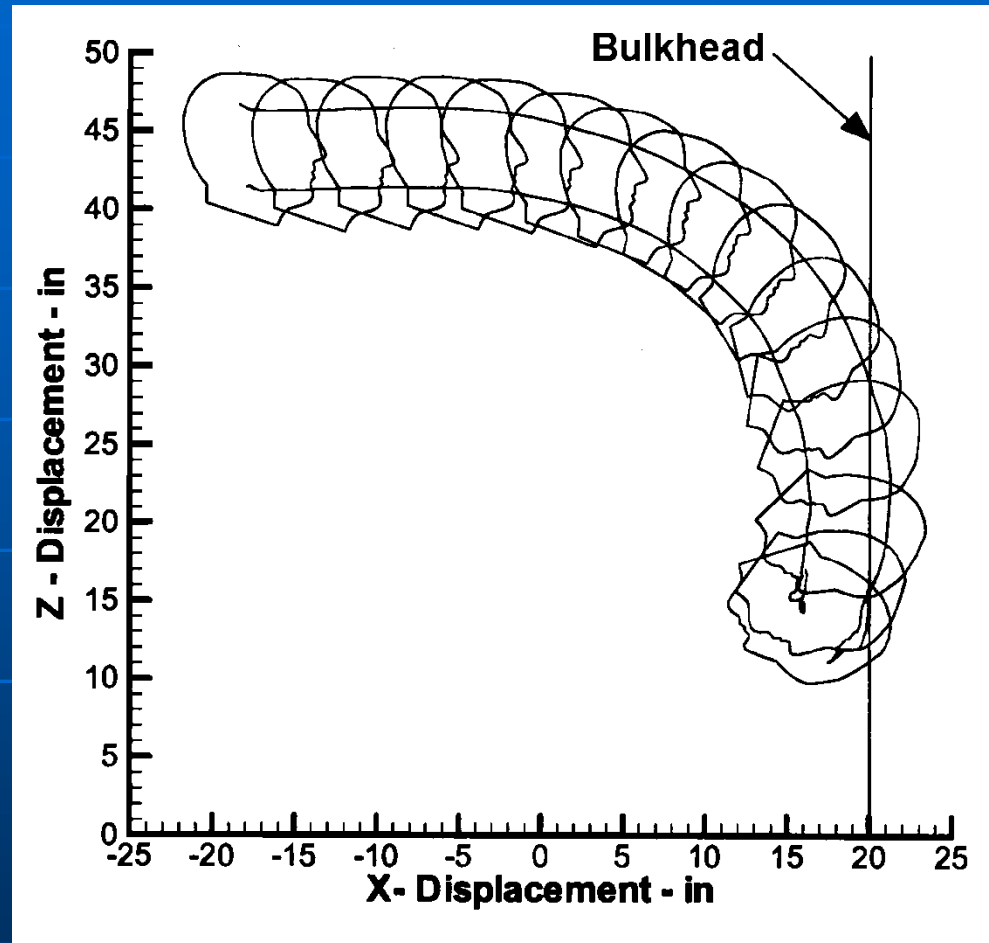
- Professor of Mechanical Engineering,
University of North Dakota
- Former NASA researcher
and Summer Faculty Fellow
- Graduate; Airline Pilots
Association Advanced
Accident Investigation
Course
- **Boeing Consultant**



THE JOHNS HOPKINS UNIVERSITY PRESS



...and explains the science of safety



Computer simulation is used to make planes more crashworthy

Very common



(Just another pretty picture)



Surprisingly...

... Airplane Crashes are in fact highly survivable!!

- **446 DC-10's made**

- **27 Destroyed in crashes**

- **Only 4 had total loss of life**

(Terrorist bomb, flew into a mountain and 2 mechanical failures)

In the remaining 23 DC-10's destroyed in crashes...

...Even though the plane's destroyed, sometimes even broken into 2 or 3 sections.

85% of the time 90% of the passengers survived !

What does this mean?

Listen to the flight crew !
Follow instructions !

Can Always Impact Severe Enough...

... to kill everyone.

Not the usual scenario.

**Usually a bad landing or takeoff
where speeds are lower.**

Miracle Crash

L-1011: Crashed in Everglades 1972

Debris field: 300' X 1600'

4 major section

No recognizable circular cross section

.....Judged non-survivable

Nothing to learn from a
fragmented plane

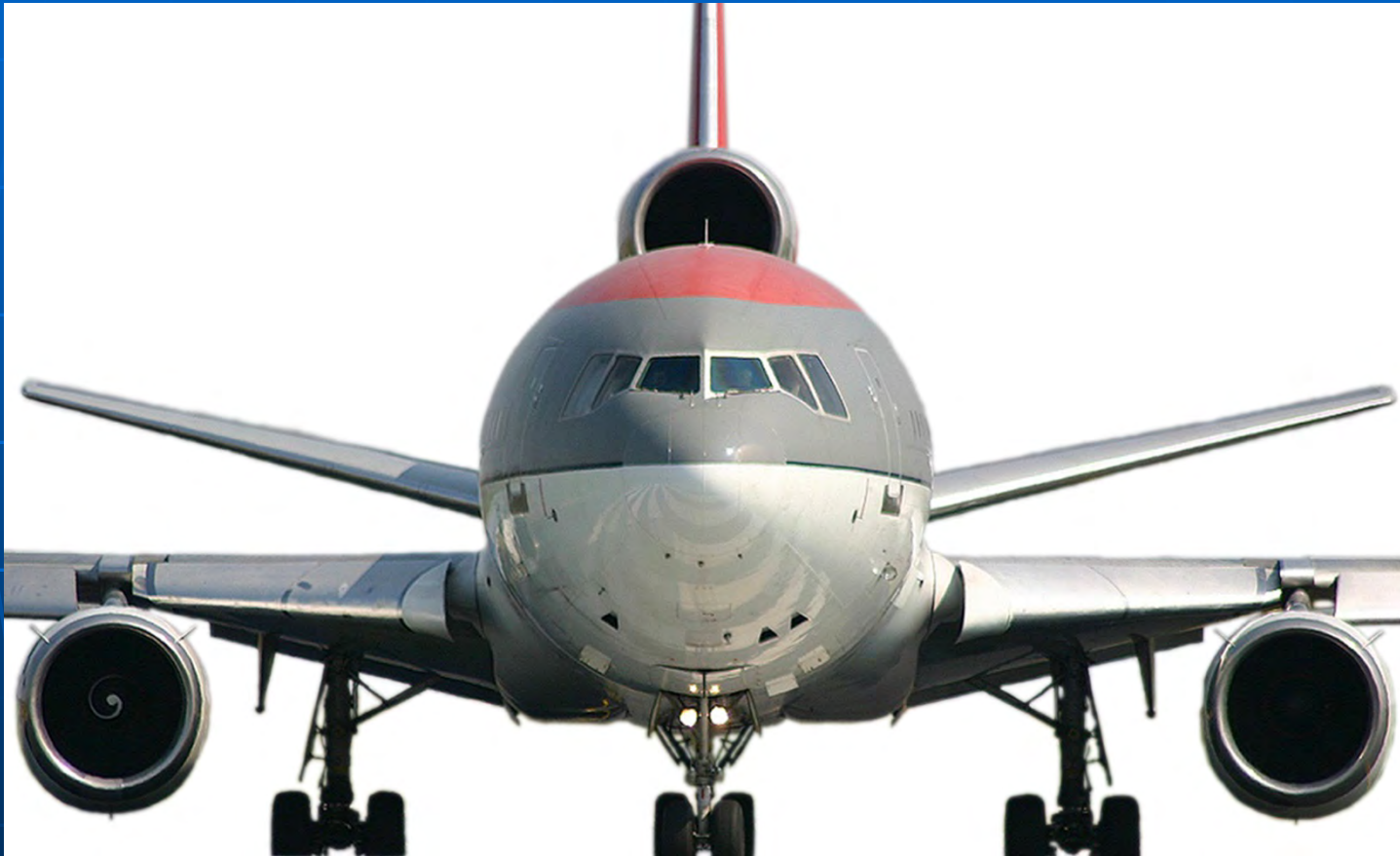


Only Problem

77 of 176 survived!!

Most Severe Mostly Survivable Accident?

1989 DC-10 Sioux City, Iowa





Plane breaks into three pieces and lands upside down—before the fireball. Of the 296 people roughly 2/3rd survive **including a baby placed on the floor as instructed**

Ground Scar on Runway Illustrates Impact



737 Crash Lands in Caribbean

August 16, 2010



131 passengers and crew, 2 fatal injuries

Flight 8250

Post Crash Fire

Everyone safely evacuates in under 2 minutes despite half the exits blocked by fire



Air France Flight 358
8-2-05

Certification requires 90 sec
evacuation with half the exits blocked



CNN videos

Airbus A380 Evacuation Test

**873 people in 80 seconds using
8 of 16 exits**



(One broken leg)

Saudi Arabia Airlines

L-1011: 301 Fatalities in 1980

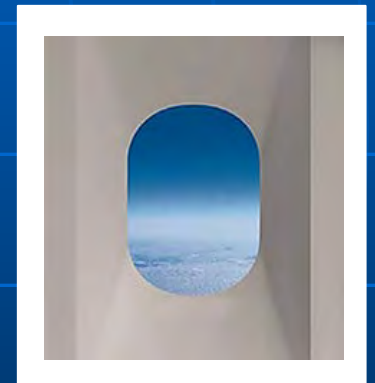


Explosive Decompression

DeHavilland Comet
Invents the Problem:
1950's

Recovered Wreckage

(Note rivets at window's edge)



De-Havilland Comet Water Tank Test



(Balloon tests)

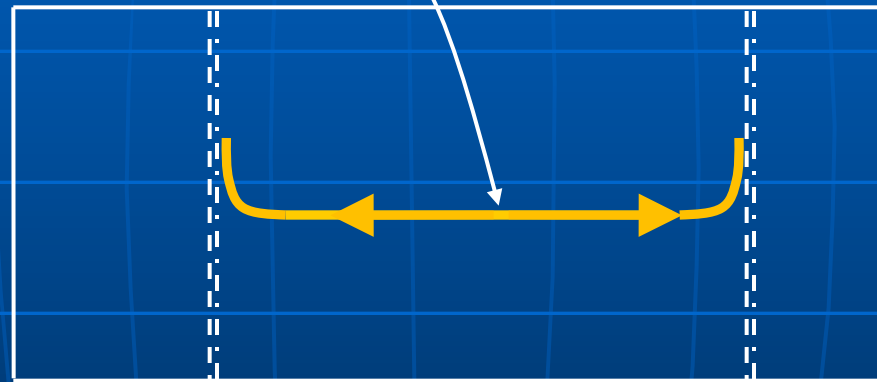
De Havilland Comet Test



Boeing Adds Tear Straps to 707

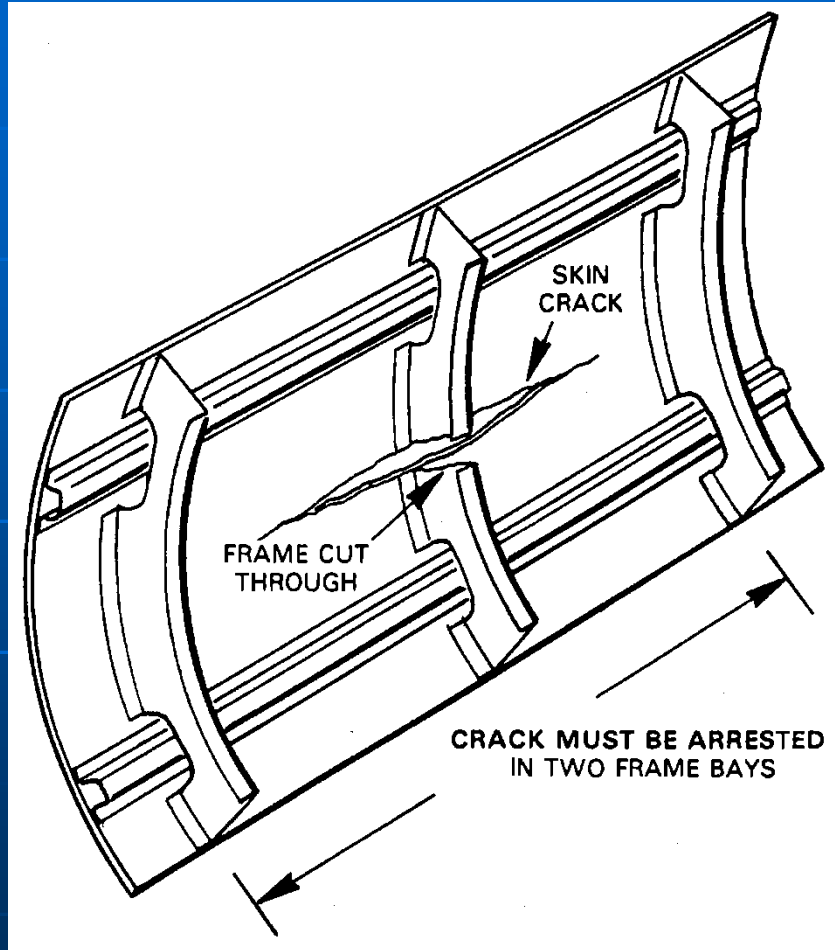
Fatigue crack forms a flap and acts like a safety valve

Crack Initiation



Tear Straps

Standard Design: Safe with 40" Fatigue Crack



(39" crack found in DC-9)

2009: Southwest Airlines fined 7.5 million

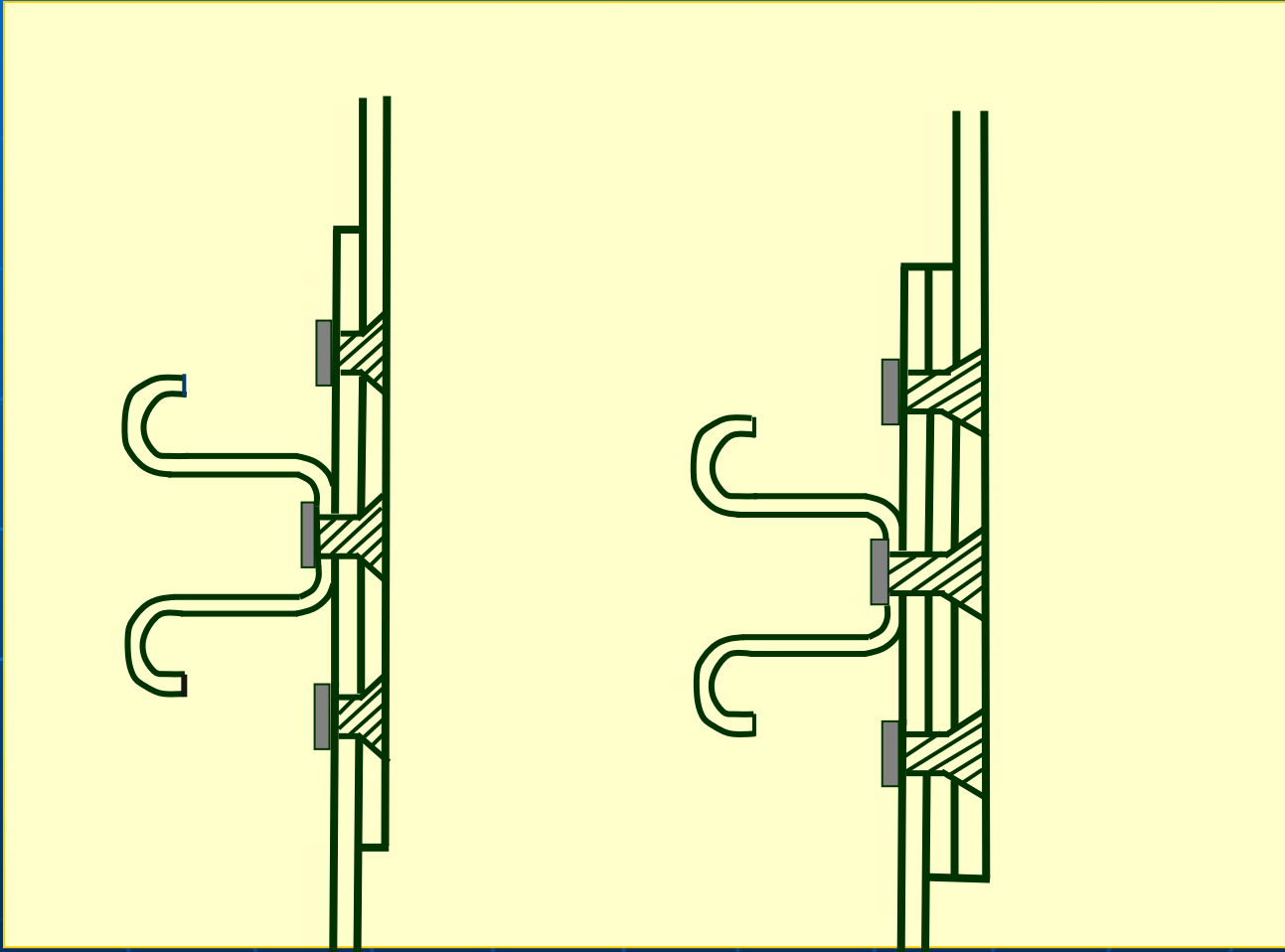
Explosive decompression...



**Aloha
Airlines
Flight 243**

4-28-88

One flight attendant lost, all passengers have seatbelts on and survive with injuries. (Popped ear drums, concussion, broken arm, etc.)



Planes 1 through 291

Why Flap Didn't Form

Glued Joint Disbonded and...

After 20,000 pressure cycles



After 40,000 pressure cycles

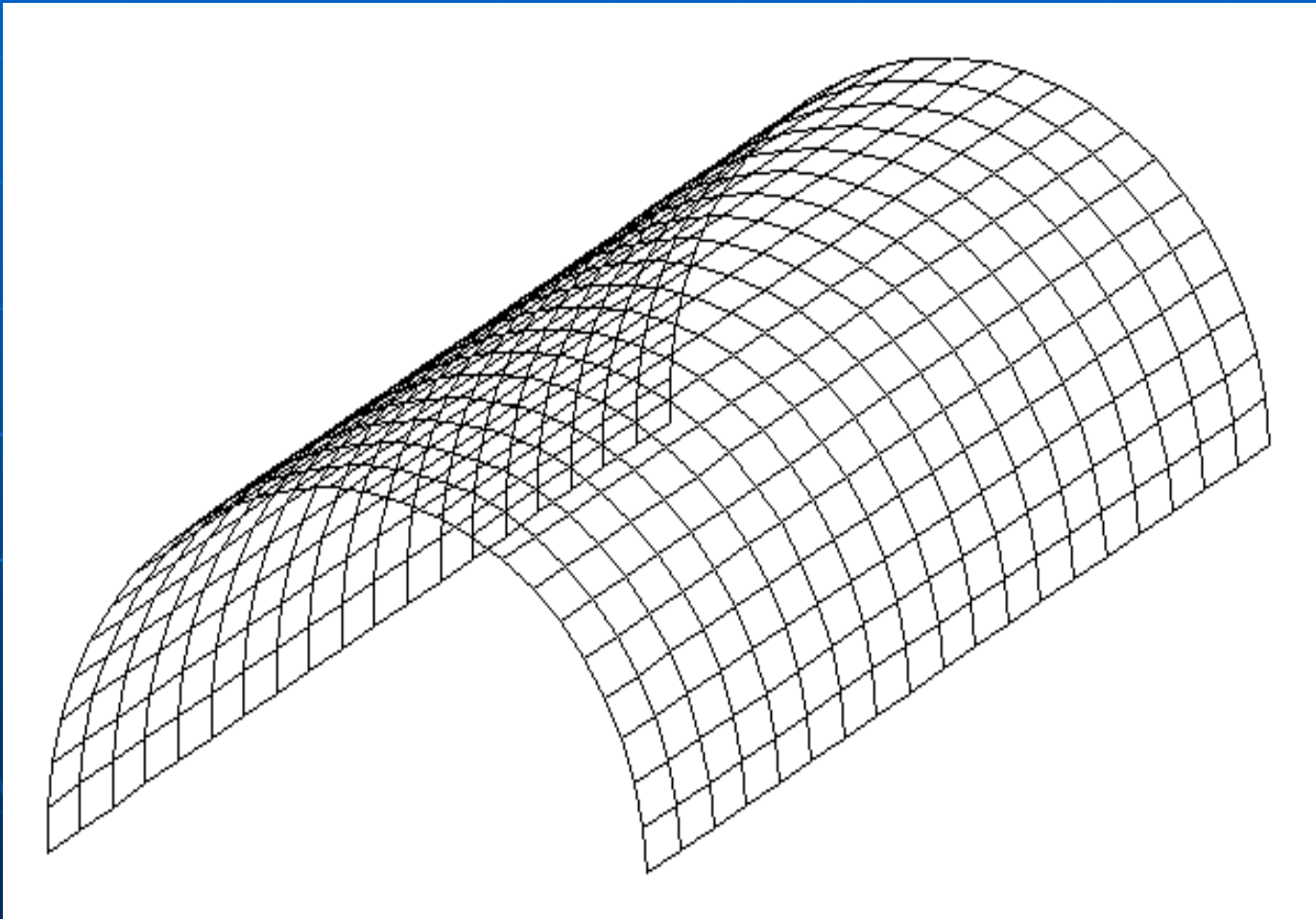


After 60,000 pressure cycles



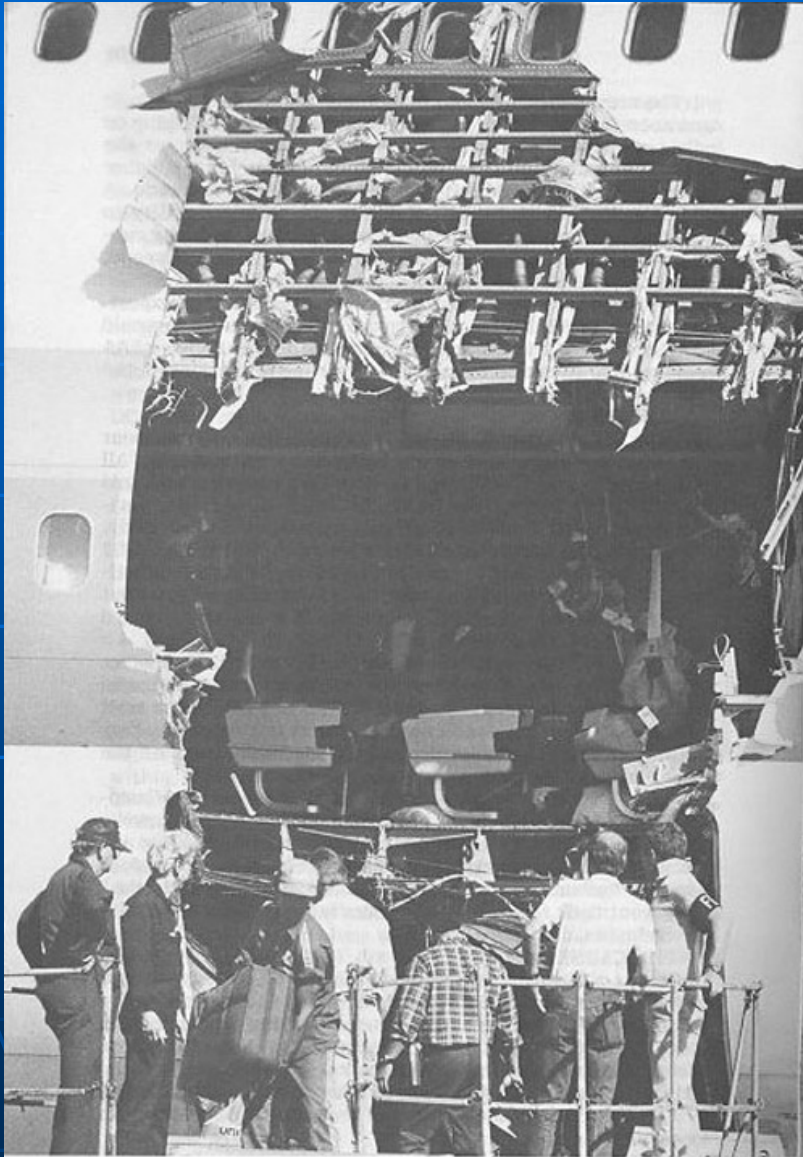
(Had to rethink fatigue design: National research effort)

Fuselage has extensive reinforcing ribs, not for pressure containment



Ribbing Inside a Boeing 737





United Flight 811

2/24/1989

Improperly
latched cargo
door

9 passengers
sweep out at
22,000 feet

Probably cause:
Bad wiring

Most Recent Example: Boeing 747

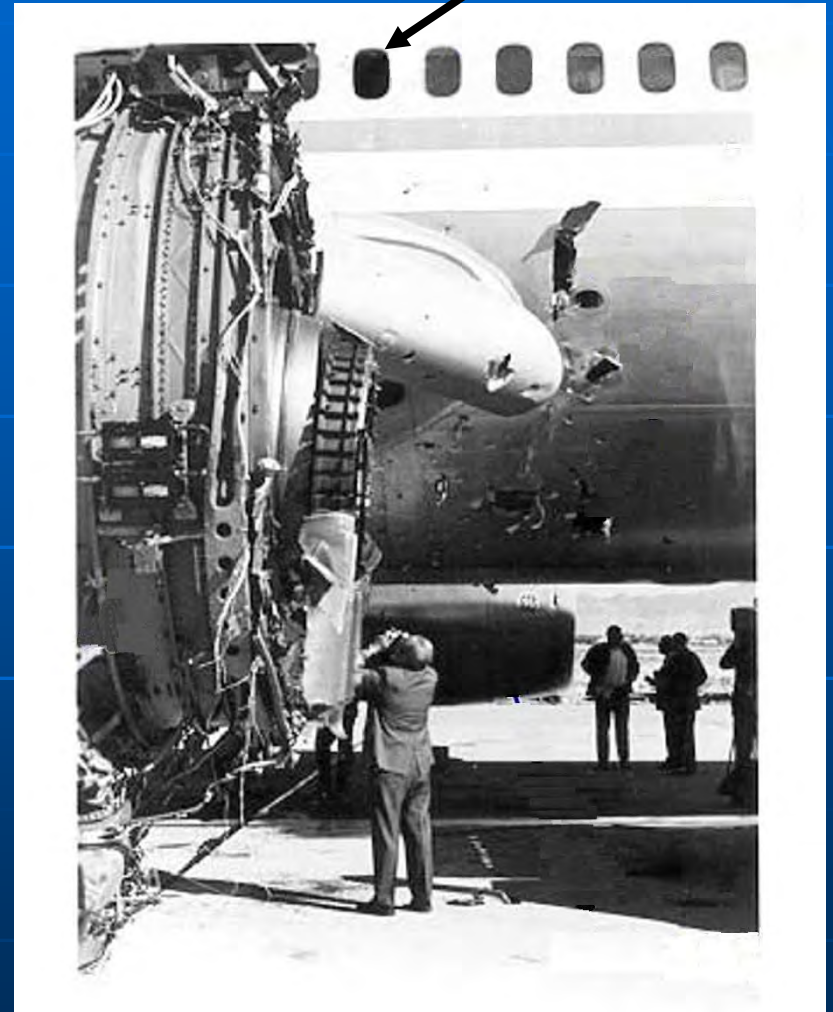
China Airlines May 25, 2002



Tail strike 22 years earlier—and unapproved 120" by 22" patch buried a scratch

Other Decompression Accidents

Passenger sucked out of this window



National Airlines Flight 27
11-3-73

Pilot partially sucked out of left windscreen

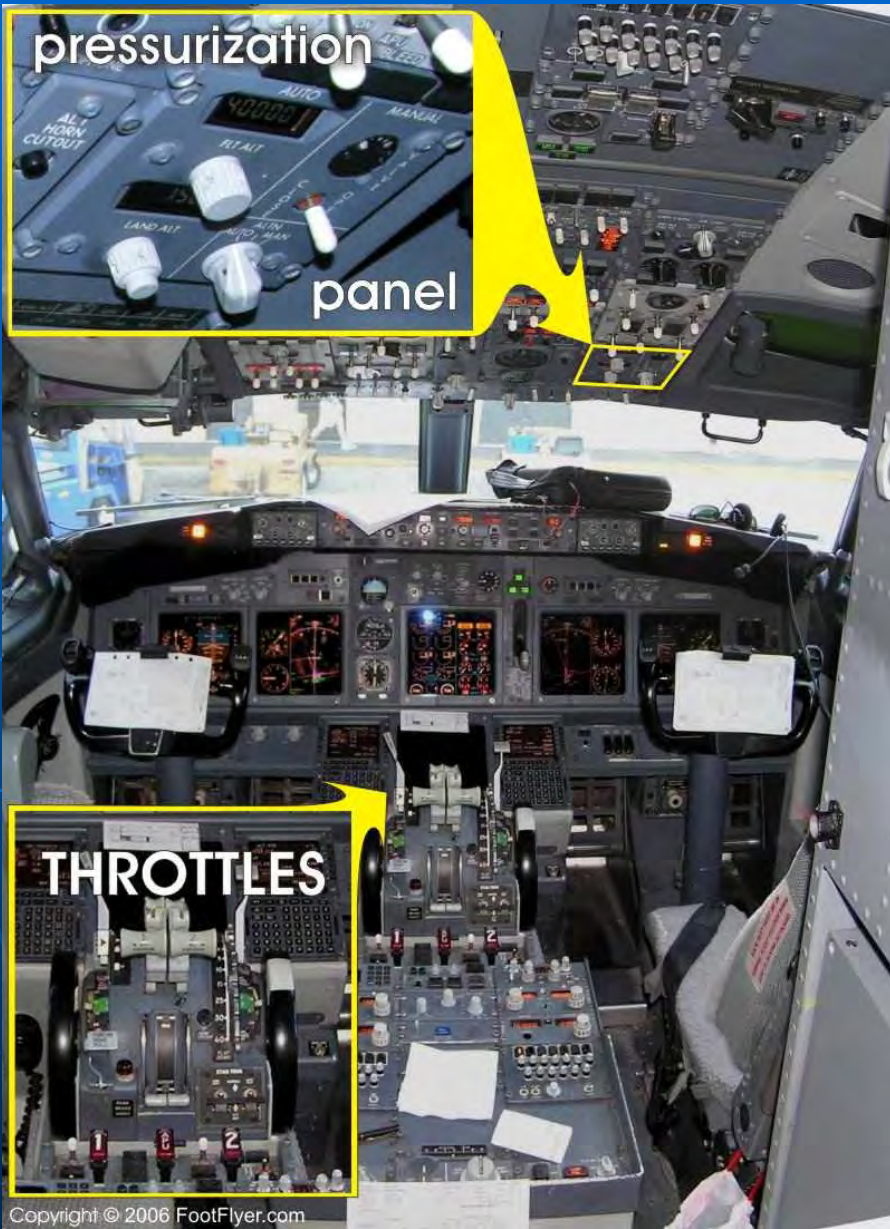


British Airways Flight 5390
6-10-90

Exact Opposite of Decompression: **Hypoxia**

Helios Flight HCY522
Boeing 737 August 14, 2005
Cyprus to Athens





Crash Testing



NASA aircraft crash test #21
NASA Langley Research Center

6/10/1981

Image # EL-2001-00463



NASA aircraft crash test #21
NASA Langley Research Center

6/10/1981

Image # EL-2001-00464



NASA aircraft crash test #21
NASA Langley Research Center

6/10/1981

Image # EL-2001-00465



NASA aircraft crash test #21
NASA Langley Research Center

6/10/1981

Image # EL-2001-00466

Very Few Full Scale Crash Tests

Drop Tests More Common

**Vertical
vs.
Horizontal Crashing**

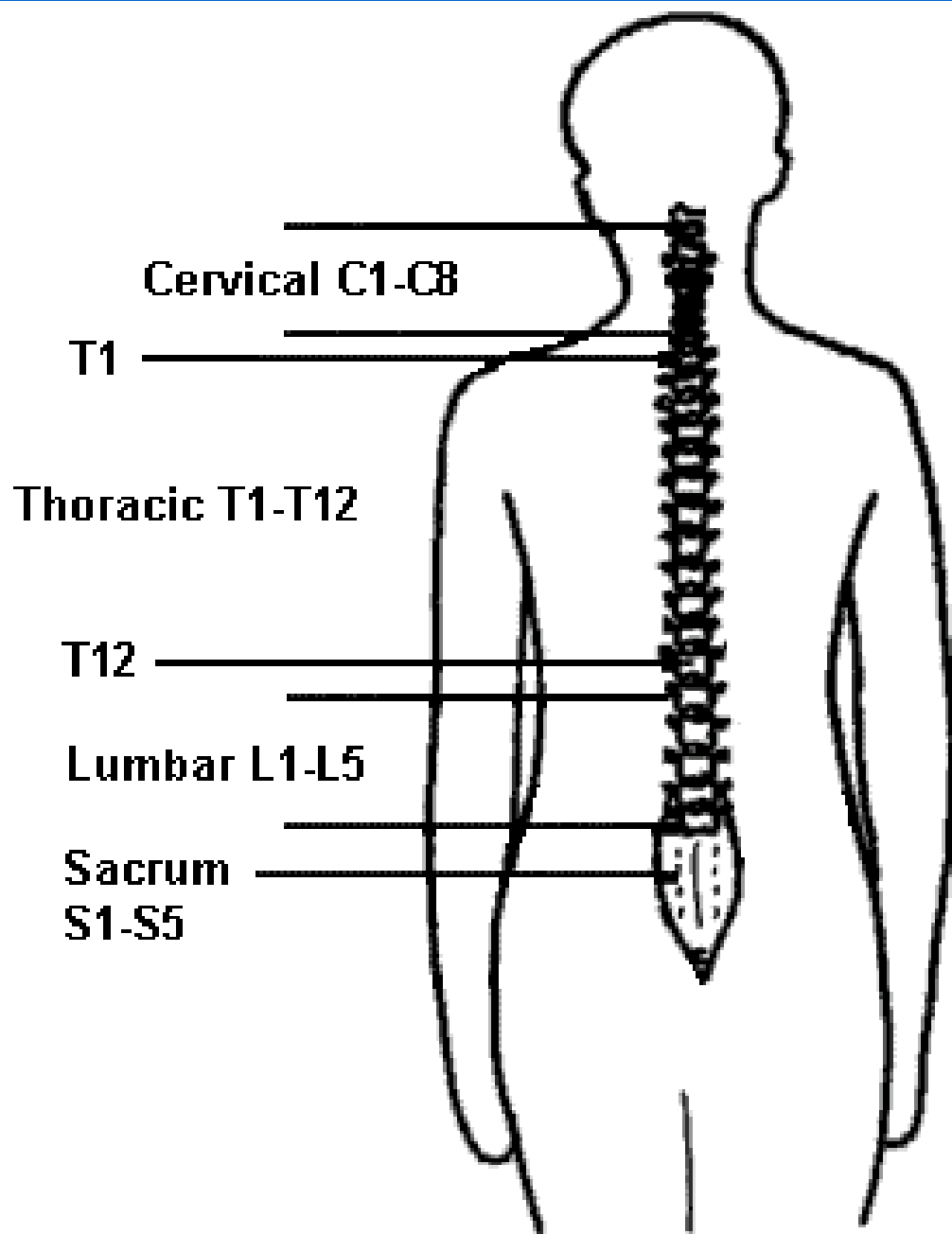
Ejecting ↑ and Crashing ↓
Compress the Spine



Pilot shrunk by 2 inches

7% of Air Force ejections resulted in spine fractures





**Germans test
spine for
ejection during
WWII**

25 g's, 1500 lbs

Crash Test Dummy



Load cell in spine



**Dropped 6.2
feet;**

**Impact at
20 fps**

40-60 g's in
dummy's spine.

No crush to
absorb
energy





Full Scale Crash Test: 1984



The most studied, instrumented, and photographed crash in history



FAA/NASA
Test Crash
12-1-84

Impact survivable, FAA estimates 19 of 52 simulated passengers would have survived the fireball

17 fps ↓



FAA estimates 19 of 53 simulated passengers would have survived the fireball

Landing Gear Design

- Pilots report hard landing: **4 fps**
- Design Limit: **10 fps**
18.7 inch drop
- Expected Plane Damage: **>12 fps**
- Fatalities Expected: **> 25 fps**
NOTE: Post crash fire can cause fatalities at lower sink rates.
- Miracle Crash: fragmented plane **37 fps**

100% Fatalities > 42 fps

777 Crashes in London, Jan 2008



Wake Turbulence

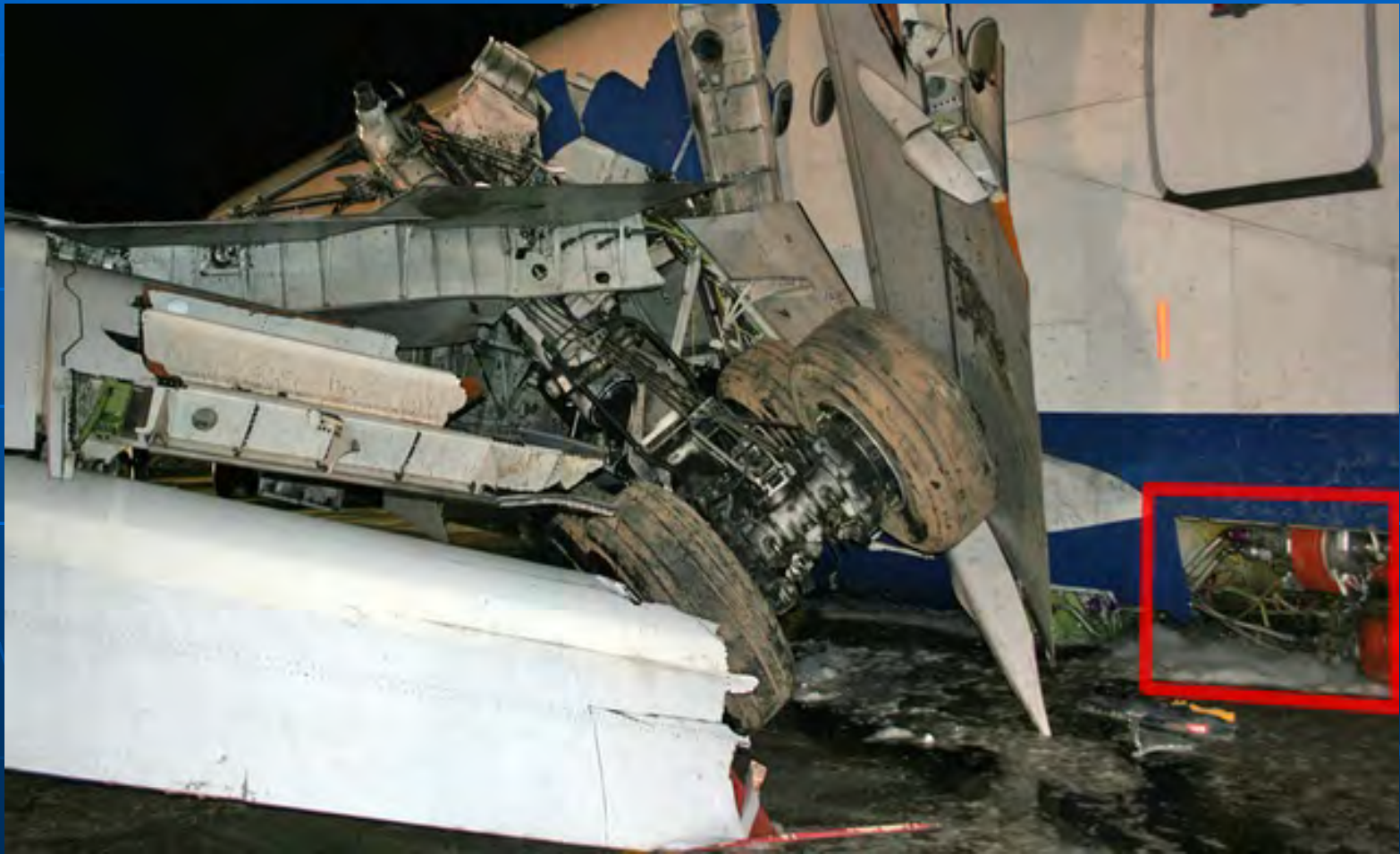


25 fps ↓ Impact





Torn Up Landing Gear

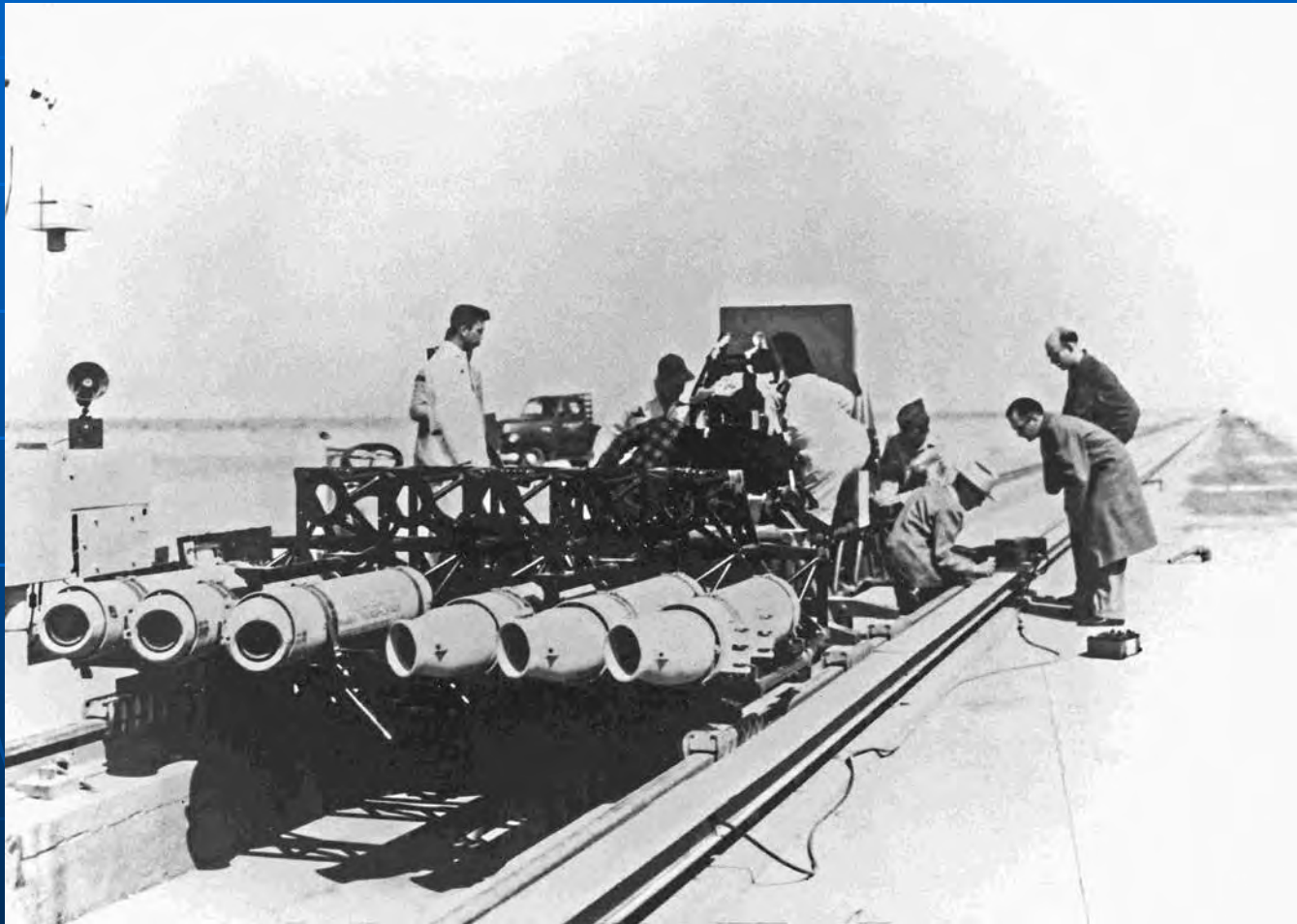


Do Composites Crush? **No**

- FAA requires Boeing to demonstrate similar safety of metal fuselage
- **Redesign passes 30 fps drop test**

Historical G Testing

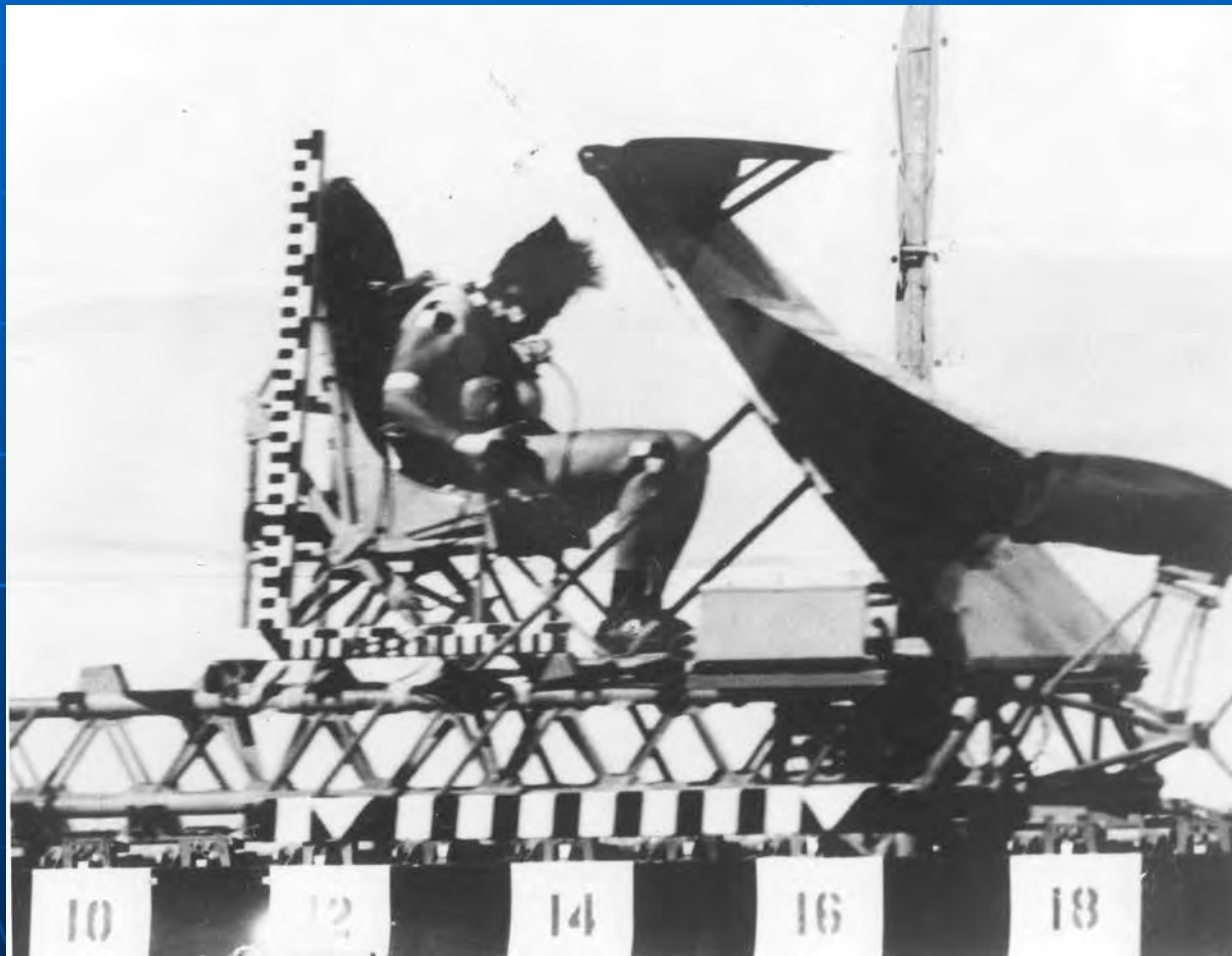
Colonel Stapp 1947: Testing for Mach II ejections



Broken ribs, concussions, broken wrist

46 G's horizontal

Test animals till they came apart



Damnably Forces of Physics



ABRUPT END!

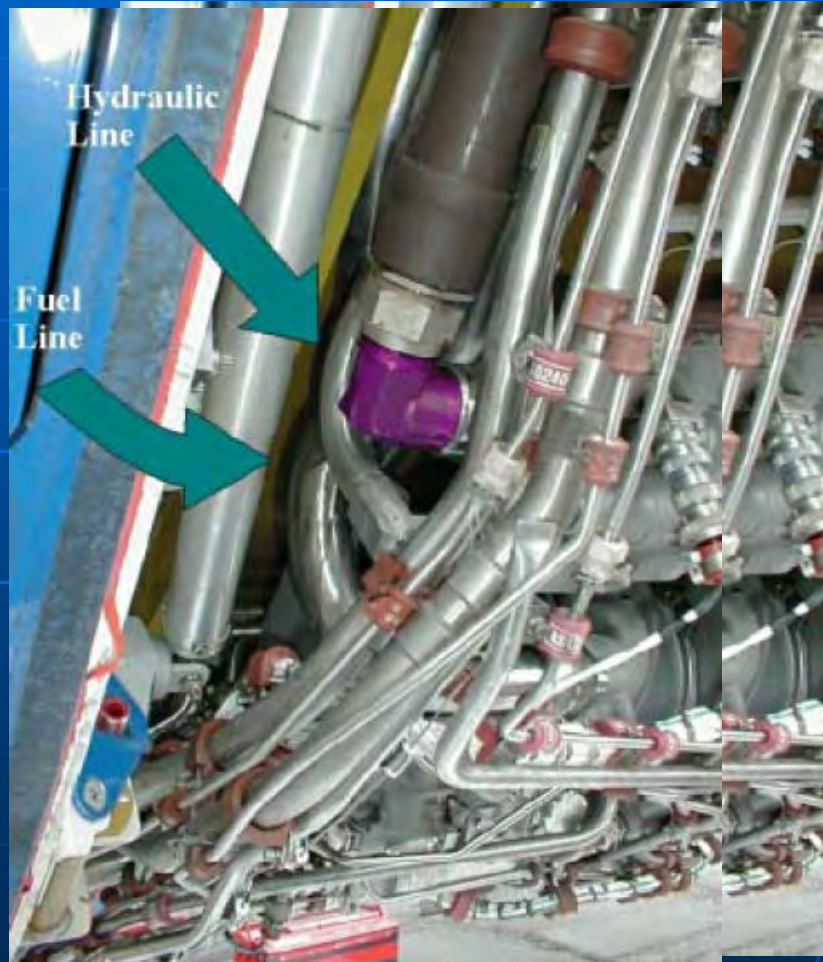
(Time for one more story?)

Airbus A330

Air Transat Flight 236

August 24, 2001

Runs out of Fuel over the Atlantic
Glides 75 miles to safe landing in
Azores



Hydraulic
Line

Fuel
Line

