Beyond the Black Box: The Forensics of Airplane Crashes

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Computer simulation is used to make planes more crashworthy...and explains the science of safety.
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.

Certification requires 90 sec evacuation with half the exits blocked.

Air France Flight 358
8-2-05
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...

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

THROTTLES
Crash Testing
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

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
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
Damnable 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