5th Generation Fighter Aircraft Mishap Recorded Data Challenges

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In the Beginning…

- **There was no recorded data**
  - ***Photos were all B&W, if any***
  - ***Old-school tin kicking***
  - ***Witnesses***

Photo: San Diego Air and Space Museum, Album 192 Image - Catalog:AL-192 031

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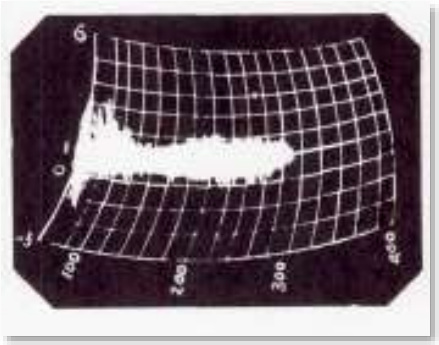
1940's

- **Meet one of the earliest recorders – the V-G Recorder**
  - ***WW II era***
  - ***Installed on transport, fighter and bomber aircraft***
  - ***Implemented for operational loads recording with structural design in mind – not crash analysis***
  - ***Not crash/fire survivable***
  - ***Recorded velocity (V) & acceleration (G)***



Photos: National Advisory Committee For Aeronautics
Technical Note 2194, by Israel Taback, Langley Aeronautical Laboratory

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Why Do They Call It A “Black Box” Anyway?

- **Merriam-Webster Dictionary:** a usually complicated electronic device whose internal mechanism is usually hidden from or mysterious to the user; broadly: anything that has mysterious or unknown internal functions or mechanisms

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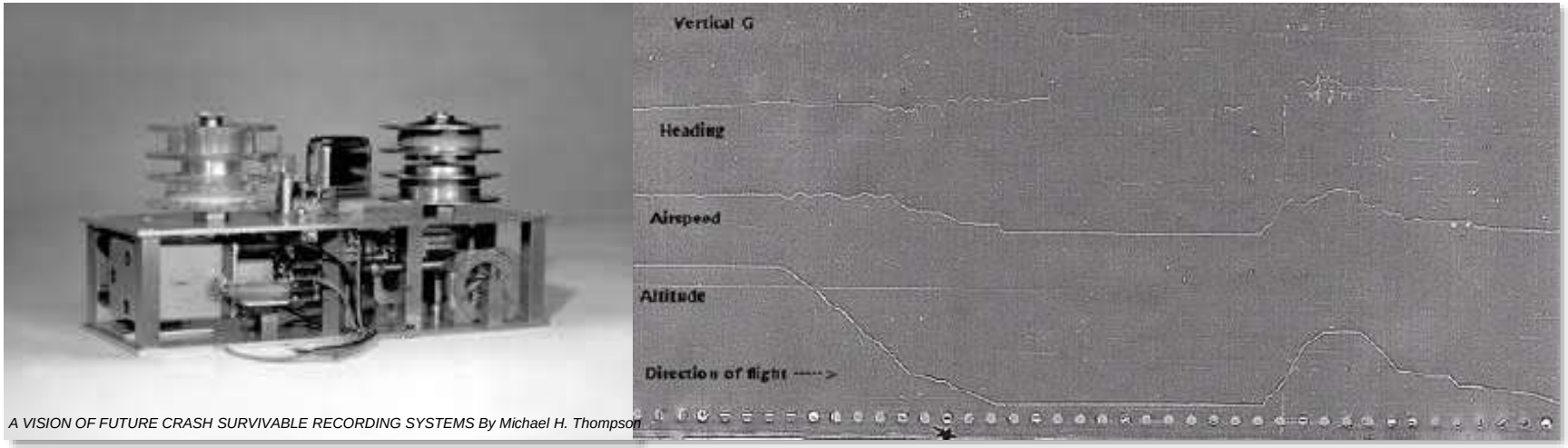
1950's

- Other than flight test, not much support to implement on aircraft yet
- Metal foil and photographic film recorders
- 5 - 6 parameters
- 1957 – Civil Aeronautics Board (predecessor into the FAA) mandated aircraft over 12,500 pounds carry an FDR
- Cockpit Voice Recorders introduced



A VISION OF FUTURE CRASH SURVIVABLE RECORDING SYSTEMS By Michael H. Thompson

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1960's & 1970's

- **Magnetic tape became popular recording medium**
- **Black boxes painted orange for visibility**
- **First hardened crash recorders were developed**
  - ***100 G's initially (10 foot drop off the ground onto a concrete surface)***
- **Up to approximately 25 discrete/analog signals recorded**
- **Recording heads, belts, bearings, and magnetic tape wear out over time resulting in reliability/playback issues**

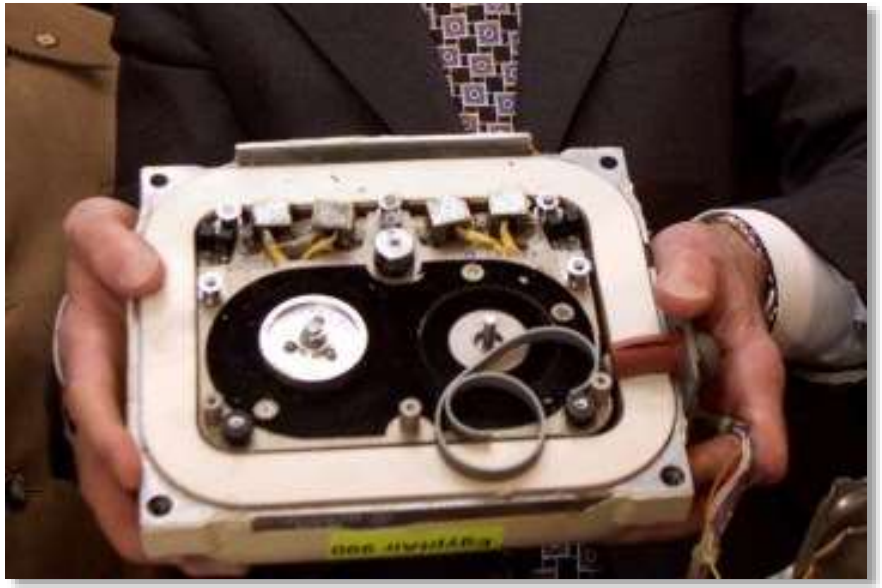

Photo: FDR from EgyptAir 990, Reuters/CORBIS

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1960's & 1970's

- **Anyone remember 8-Track?**

Photos: Paul Townsend, Relics Of A Bygone Age 8-Track, CC BY ND

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1990's & 2000's

- **Welcome to the digital age!**
- **Memory chips**
- **No more moving parts**
- **Much better chance at data retrieval than magnetic tape after mishap**

Photo: Steve Jurvetson from Menlo Park, USA - IBM's $10 Billion Machine; CC BY 2.0

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Today

- **Data, data and more data**
- **Boeing 787 records 1000+ parameters**
- **Filtering out the most important data for the mishap into a manageable format is new challenge**
- **Most civilian and some military recorders have underwater beacons**
- **Most civilian and some military aircraft record voice**
- **Recorder/data survivability is much better following a mishap**

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Current Survivability Standards

- **Major influences for CSMU survivability standards are:**
  - ***European Organisation for Civil Aviation Equipment (EUROCAE) primary influence of CSMU survivability standards***
    - EUROCAE Document 112, March 2003
  - ***International Civil Aviation Organization (ICAO)***
- **Eventually flow down to FAA and DOD specifications**

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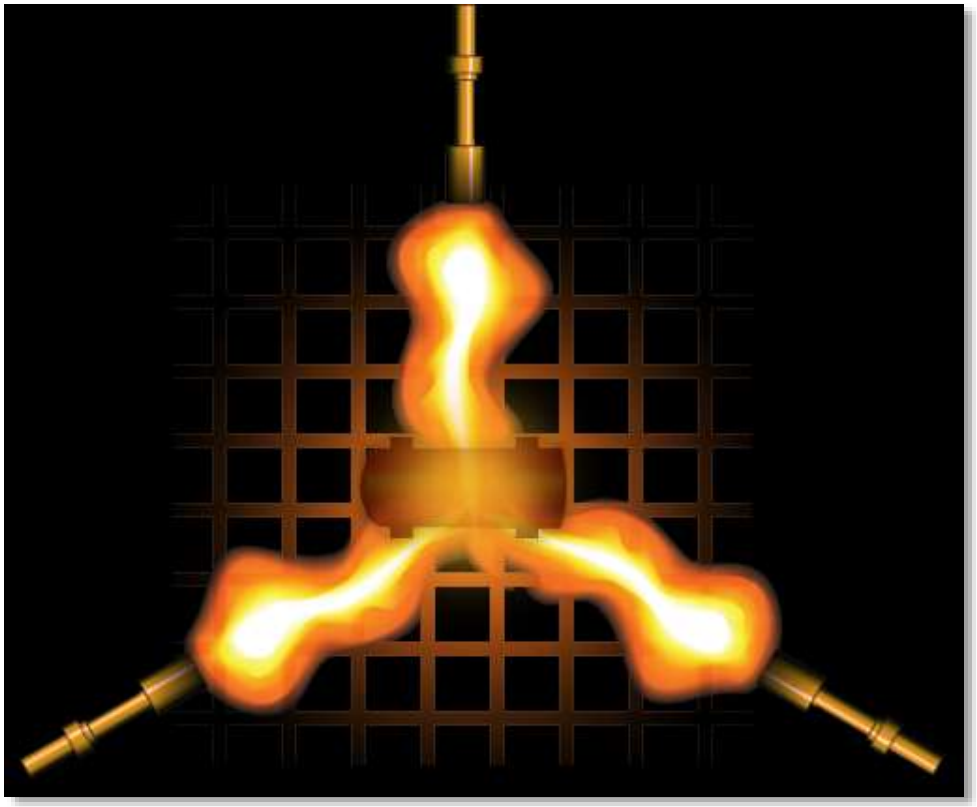
Current Survivability Standards

- **Fire Survival**
  - ***High Intensity - 1100 Deg C (2000 Deg F) for 60 minutes***
  - ***Previously 30 minutes***



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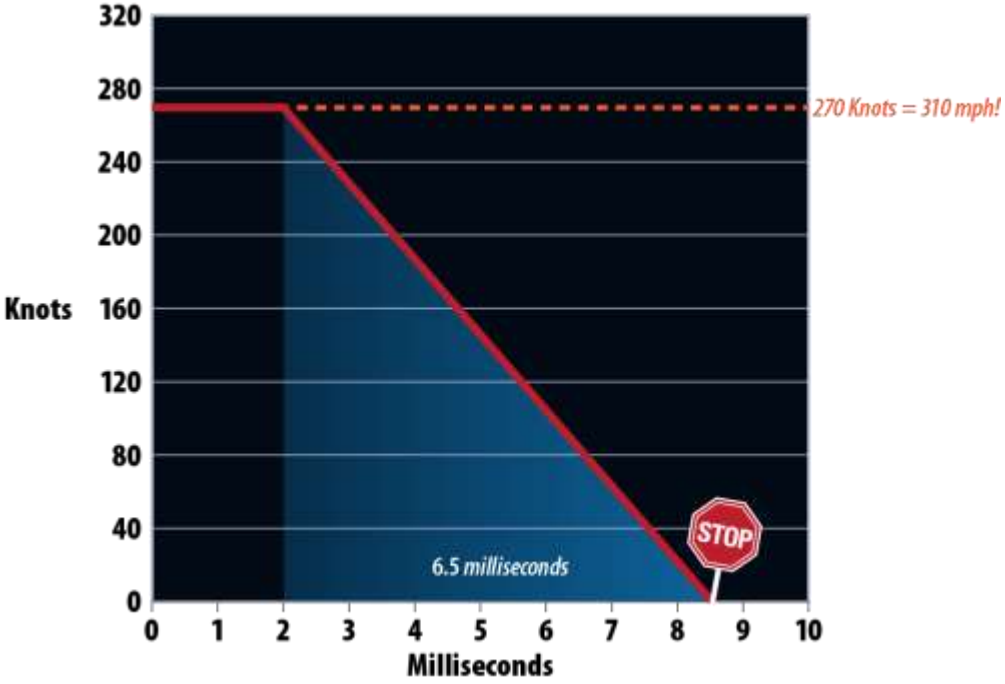
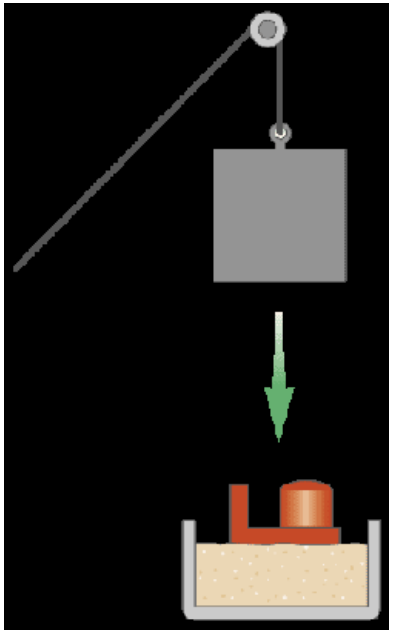
Current Survivability Standards

- **Impact Shock - 3,400 G's for 6.5 ms**
  - ***Equates to an impact velocity of 270 knots and a deceleration distance of 14.7 ft***
  - ***Previously 1700 G's***





Graphic: Scientific American, Better Black Box By Mark Alpert on September 1, 2000

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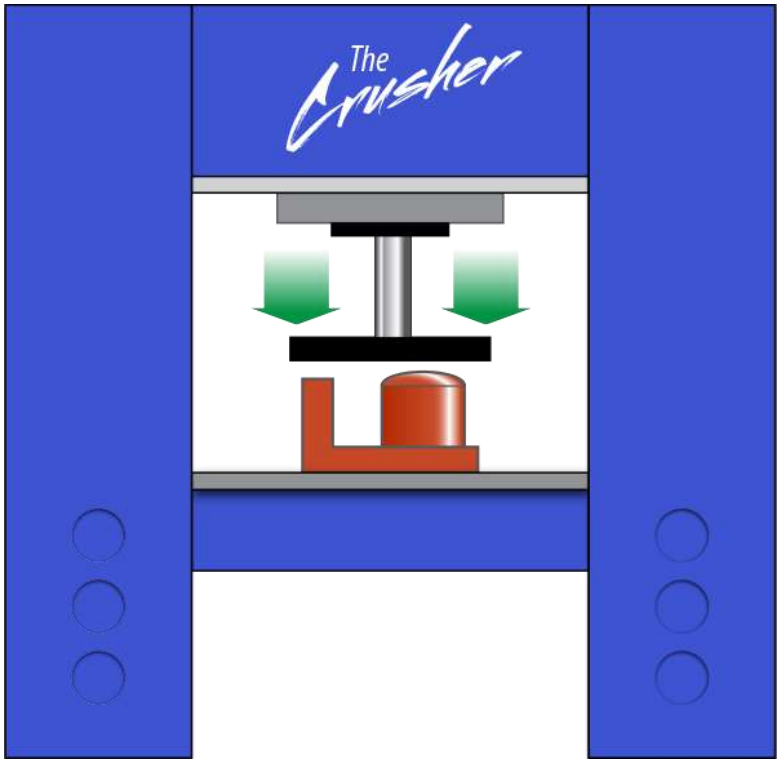
Current Survivability Standards

- **Static Crush - 5,000 lb for 5 minutes on each axis**



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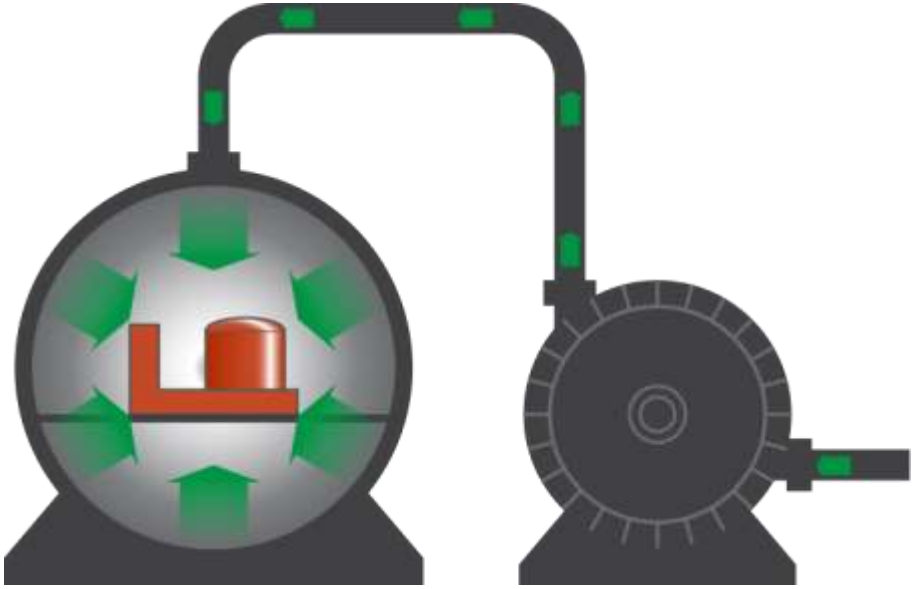
Current Survivability Standards

- **Water Immersion - Immersion in sea water for 30 days and survive pressure equal to depth of 20,000 ft.**
  - ***Previously 3 ft for 48 hours***



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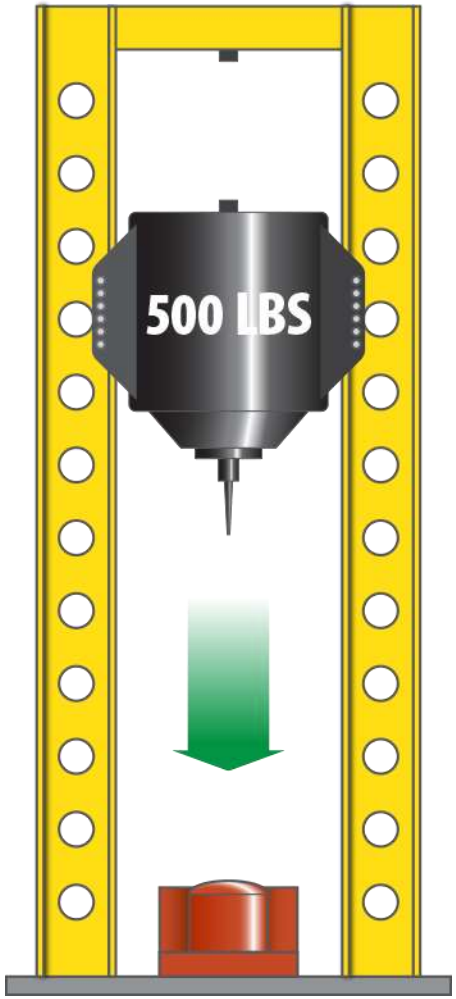
Current Survivability Standards

- **Penetration Resistance - 500 lb. dropped from 10 feet with a ¼ inch diameter contact point**



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5th Generation Fighter CSMU

- **Better chance of getting recorded mishap data**
  - ***Improved survivability specifications***
  - ***Potentially more sources of data***
    - Avionics with non volatile memory
    - Datalink
      - *Aircraft to aircraft*
      - *Aircraft to ground*
    - Flight test telemetry (if applicable)

Photo: Hi Speed – Hi Angle Crash, Lockheed Martin Aeronautics Flight Safety

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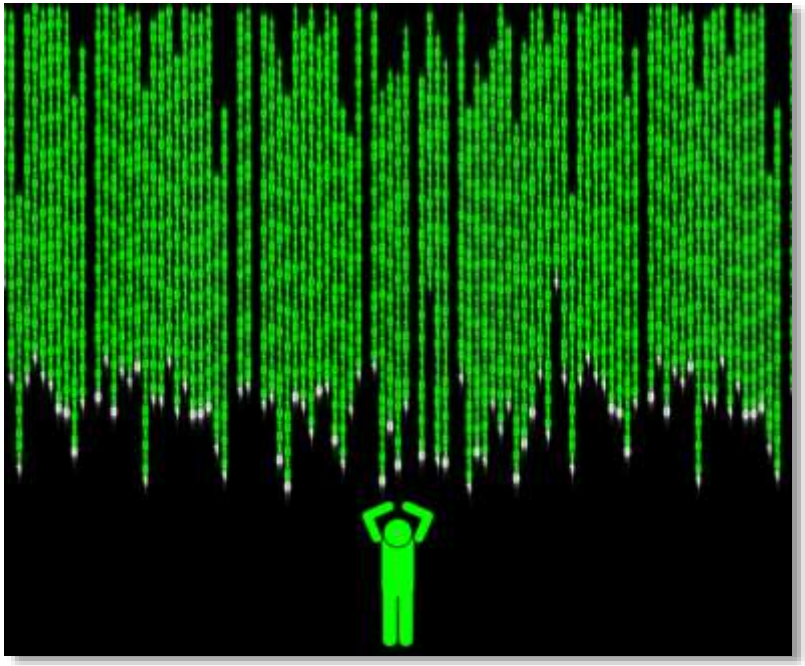
5th Generation Fighter CSMU

- **More data**
  - ***Up to thousands of recorded parameters!***
    - Most 4th generation fighters have about 100 or less
    - Expect longer wait times to get usable data
    - May no longer be able to generate initial data in the field
      - *Engineering team required to extract relevant parameters and put into SIB-friendly format*



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5th Generation Fighter CSMU

- **No crash hardened audio in USAF fighter aircraft yet!***

**Audio capability available in advanced recording systems for some 4th Generation Fighters*

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Data Retrieval

- **Recording data is only part of the process**
  - ***Getting the recorded data from the recorder is also required***

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Data Retrieval

- **Old School Data Retrieval**

Photo: The Evolution of Data Analysis, Neil A. H. CampbellFlight

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Data Retrieval

- **Data Retrieval Today**

Photo: CSMU Laboratory, Lockheed Martin Aeronautics Flight Safety

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Data Retrieval

- **Best case is a plug-and-play ready CSMU**

Photo: Undamaged CSMU, Lockheed Martin Aeronautics Flight Safety

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Data Retrieval

- **Others require a little persuasion (not plug-and-play)**

Photo: Damaged CSMU, Lockheed Martin Aeronautics Flight Safety

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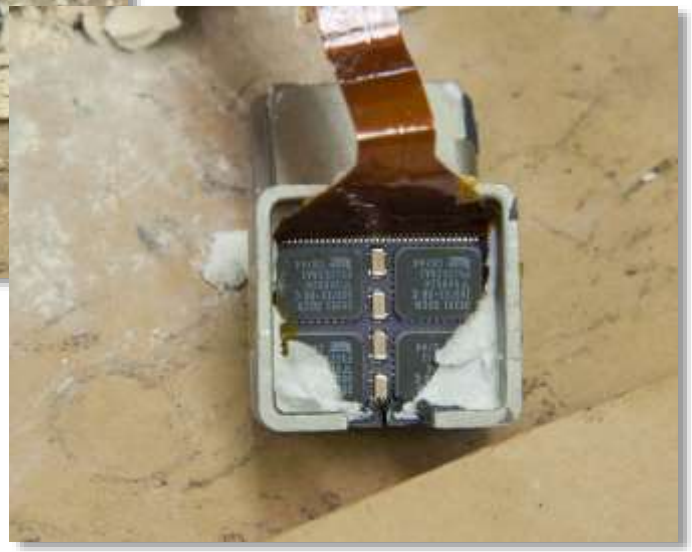
Data Retrieval

- **Others require even more persuasion**



Photos: CSMU Teardown, Lockheed Martin Aeronautics Flight Safety

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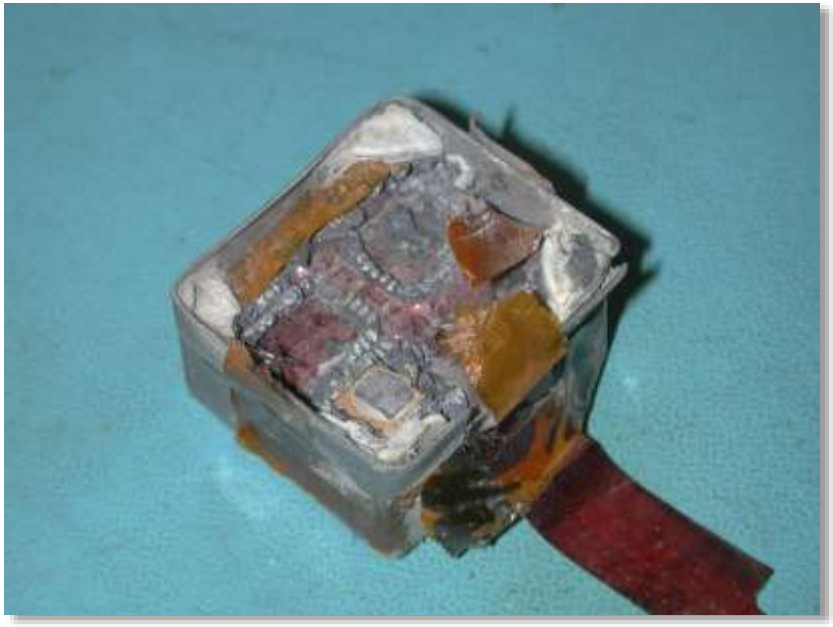
Data Retrieval

- **Occasionally it may be impossible to retrieve data**



Photos: Damaged Memory Chip, Lockheed Martin Aeronautics Flight Safety

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Making Use of the Data

- **Animations**
  - ***Helps visualize what happened***
  - ***Can combine many data sources***
    - On-board data
    - Off-board data
    - Other aircraft
    - Audio
    - Terrain
  - ***Important to understand limitations***
    - Smoothing of data

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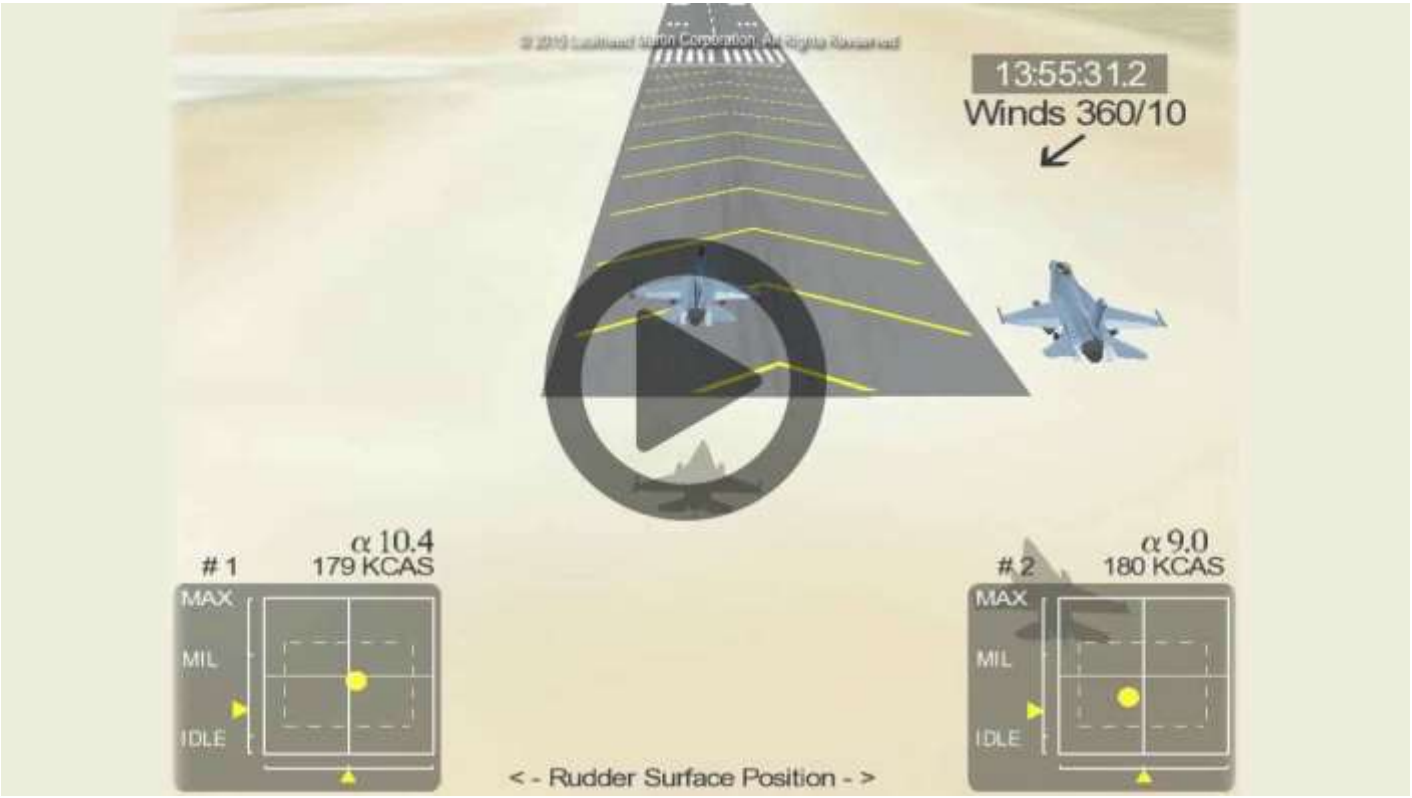
Making Use of the Data

- **Animation Example**



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What If No CSMU Data!

- CSMU is not recovered
- Wreckage/CSMU not found
- Too deep in water
- Not economically recoverable
- CSMU (or related hardware) was INOP
- Disappeared?
- Does not survive crash!

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What If No CSMU Data!

- **Back to old school methods of tin kicking and witness statements???**
  - ***Not necessarily!***
  - ***There are other ways to get useful information without CSMU data***
  - ***Let's look at a few***

Photo: JN-4B crash near Brownsville, Texas, Library of Congress's National Digital Library, Public Domain

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Other Potential Sources of Recorded Data

- **There may be other recorded data sources these days**
  - ***Datalink***
    - Military (ACMI, flight test, inter-flight DL, etc.)
    - Civilian
  - ***Witnesses***
    - Wingman
    - Cell phone cameras

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Other Potential Sources of Recorded Data

- **There may be other recorded data sources these days**
  - ***Video***
    - Security cameras
  - ***Onboard avionics***
    - Seat Data Recorder, GPS, flight planning data cartridges, etc.
  - ***PODs***
  - ***ATC***
    - Radar returns and audio

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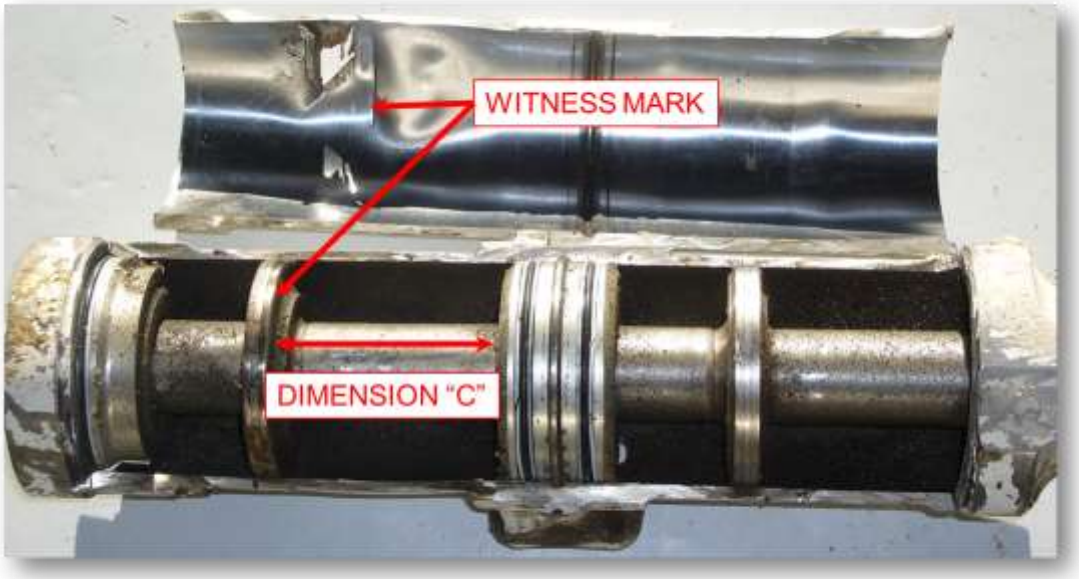
Technical Expert Hardware Analysis

- **Witness marks may provide moment of impact information**
- **Example: Elevator was streamlined position at impact suggesting no stick input**



Photos: Crash Hardware Analysis, Lockheed Martin Aeronautics Flight Safety

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Technical Expert Hardware Analysis

- **Using knowns/estimates to determine unknowns**
- **Example: Determining G from leading edge flap & speed measurements**

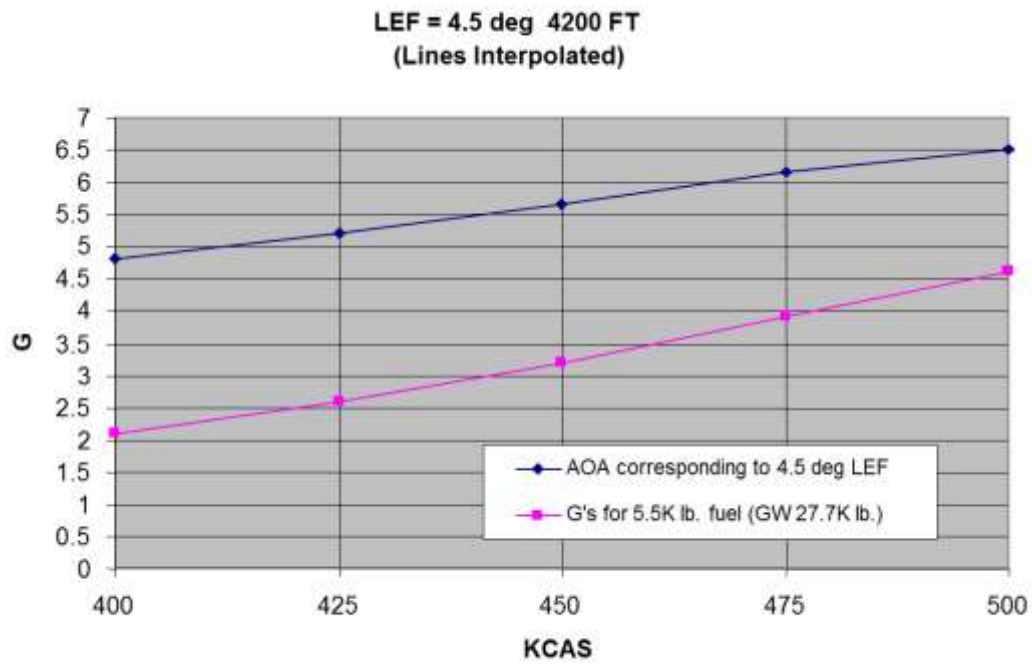

Diagram: Crash Hardware Analysis, Lockheed Martin Aeronautics Flight Safety

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Technical Expert Hardware Analysis

- **Electrical system determinations**
- **Example: Using evidence to determine which buses were powered**

BUS	EVIDENCE
Battery	MP made UHF Transmission 12 seconds prior to impact
Main AC	IFF transponder received by ground station just before impact
Main DC	HUD video operating

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Technical Expert Hardware Analysis

- **Light bulb filament analysis**
- **Example: Jet Fuel Starter light was on at impact indicating airstart was being attempted**

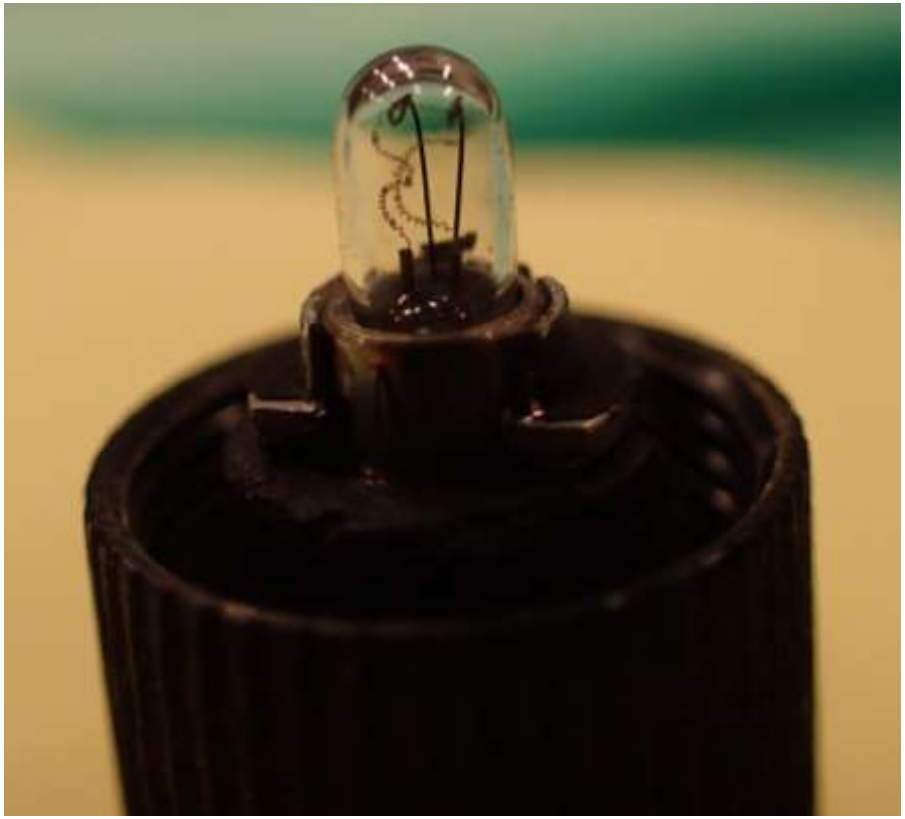

Photo: Filament Analysis, Lockheed Martin Aeronautics Flight Safety

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Technical Expert Hardware Analysis

- **Techniques learned over years of experience**
  - ***Example 1: Emergency Power Unit Gas Generator "O" Ring intact so EPU did not operate***
  - ***Example 2: Speedbrakes closed on impact***

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Photos: Crash Hardware Analysis, Lockheed Martin Aeronautics Flight Safety

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Future of Recorded Data

- **Better survivability**
- **Live streaming of data**
- **Recording devices that jettison at or prior to impact**
- **Even more recorded data**
  - ***More memory***
  - ***Better parameter resolution***
  - ***Better refresh rates***
- **Cockpit video recorders**

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Summary

- **Recorders have changed over the years but old-school investigation techniques and principles still apply**
- **Recorded data analysis is only part of the investigation; hardware analysis is also critical**
- **More data may make a better animation but does not always mean better answers for investigation**
- **Having no CSMU data is a bummer but it's not the end of the world**

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