Summary of Results from Three Full Scale High Wing General Aviation Crash Tests

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Introduction: ELTSAR Program 2013-2016

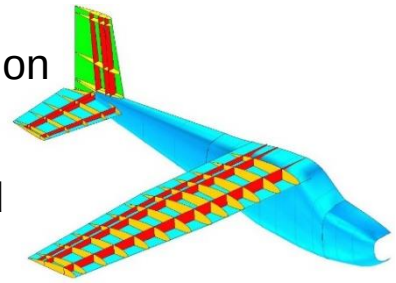
NASA Langley is supporting SAR (GSFC) with the goal of making significant improvements to ELT performance through a multi-faceted research effort

Research:

- **Historic and current failure rates**
  - Crash data from NTSB and other international sources
  - Compare current to historic trends
  - Identify previous improvements to avoid duplication of effort
  - Identify primary failure modes

Analysis:

- **Nonlinear dynamic analyses of severe but survivable airplane crash scenarios**
  - Calibrate models through test correlation
  - Investigate various ELT installations and additional impact scenarios



Test:

- **Ground-based unit testing and installed system crash testing**
  - Helicopter crash test
  - Crash safety testing
  - Vibration testing
  - Fire testing
  - **3 GA airplane crashes system level performance**

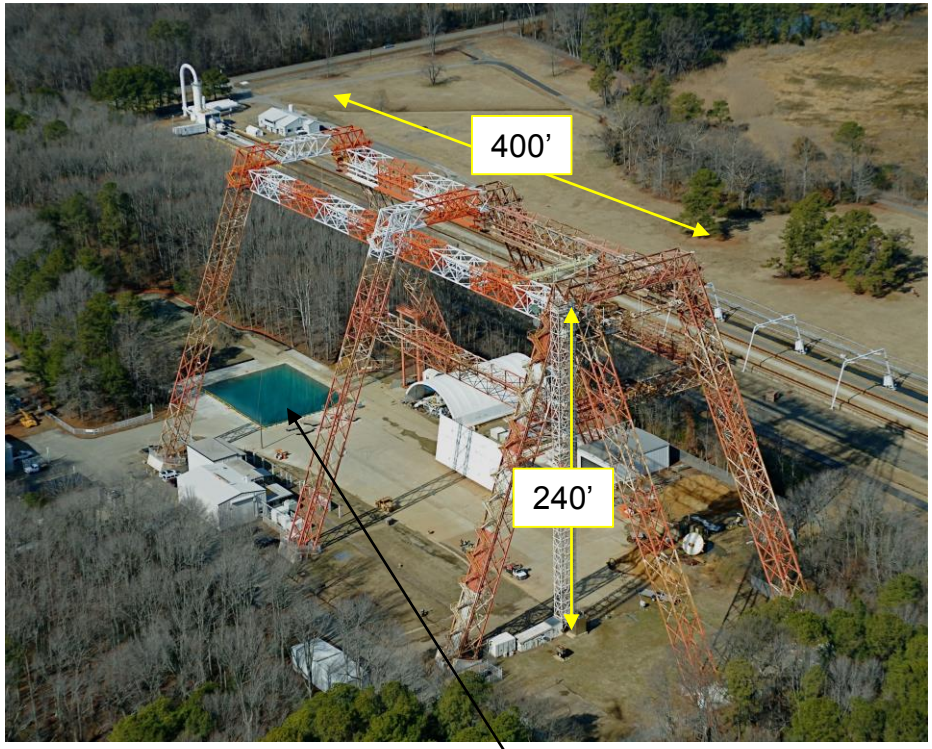
Deliverables:

- Recommendations to RTCA SC-229/EUROCAE WG-98 regarding minimum performance standards for the next generation of ELT systems

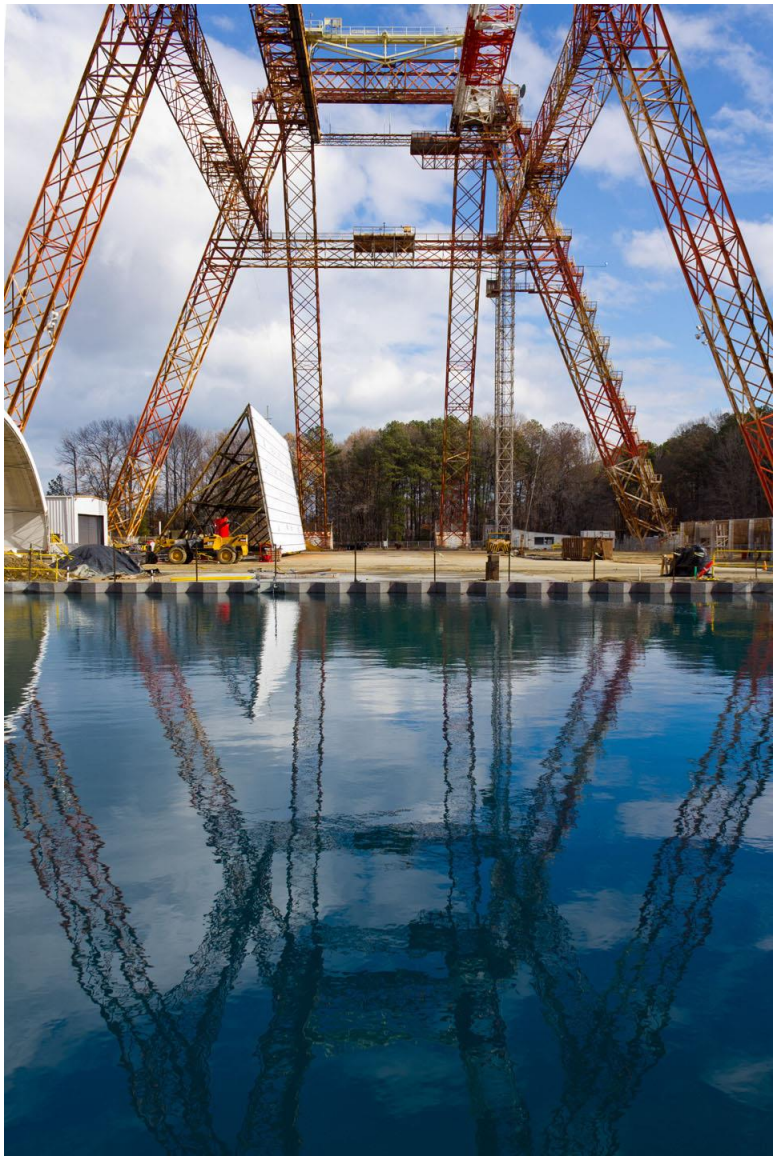
RTCA
THE GOLD STANDARD FOR AVIATION SINCE 1935

EUROCAE

Landing and Impact Research Facility (LandIR)



Hydro Impact basin (2011)
115’ long, 90’ wide, 20’ deep



Airplanes

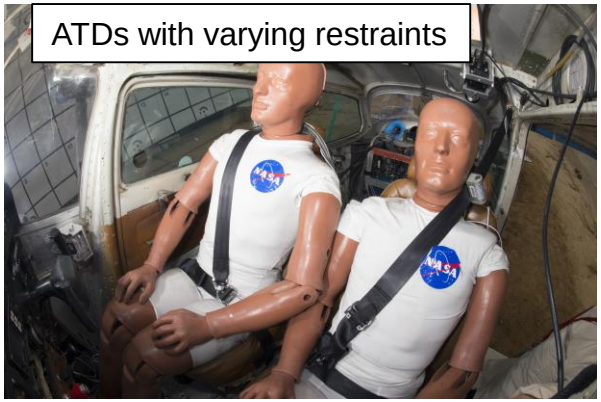
- N8834B
- 1958 C172
- TTAF 4,400 hrs
- Airworthy and current on annual inspection

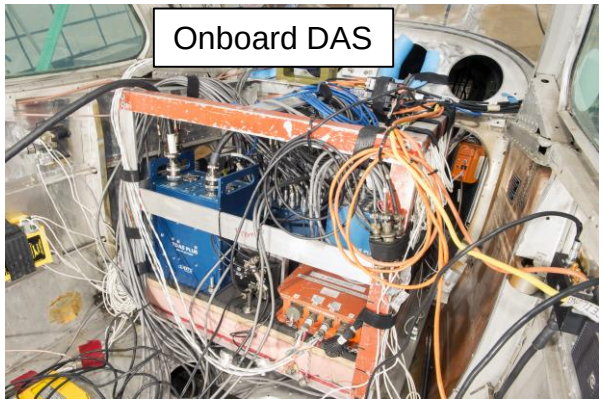
- N9400B
- 1958 C175
- Purchased out of probate
- On ramp ~ 10 years

- N9804V
- 1974 C172
- TTAF >28,000(!) hrs
- Airworthy and current on annual inspection

- Crash tests were conducted as system level ELT tests (beacon, cabling, antennas, remote switches, and associated hardware) to examine ELT system functionality and survivability
  - **Realistic, severe but survivable crash scenario**

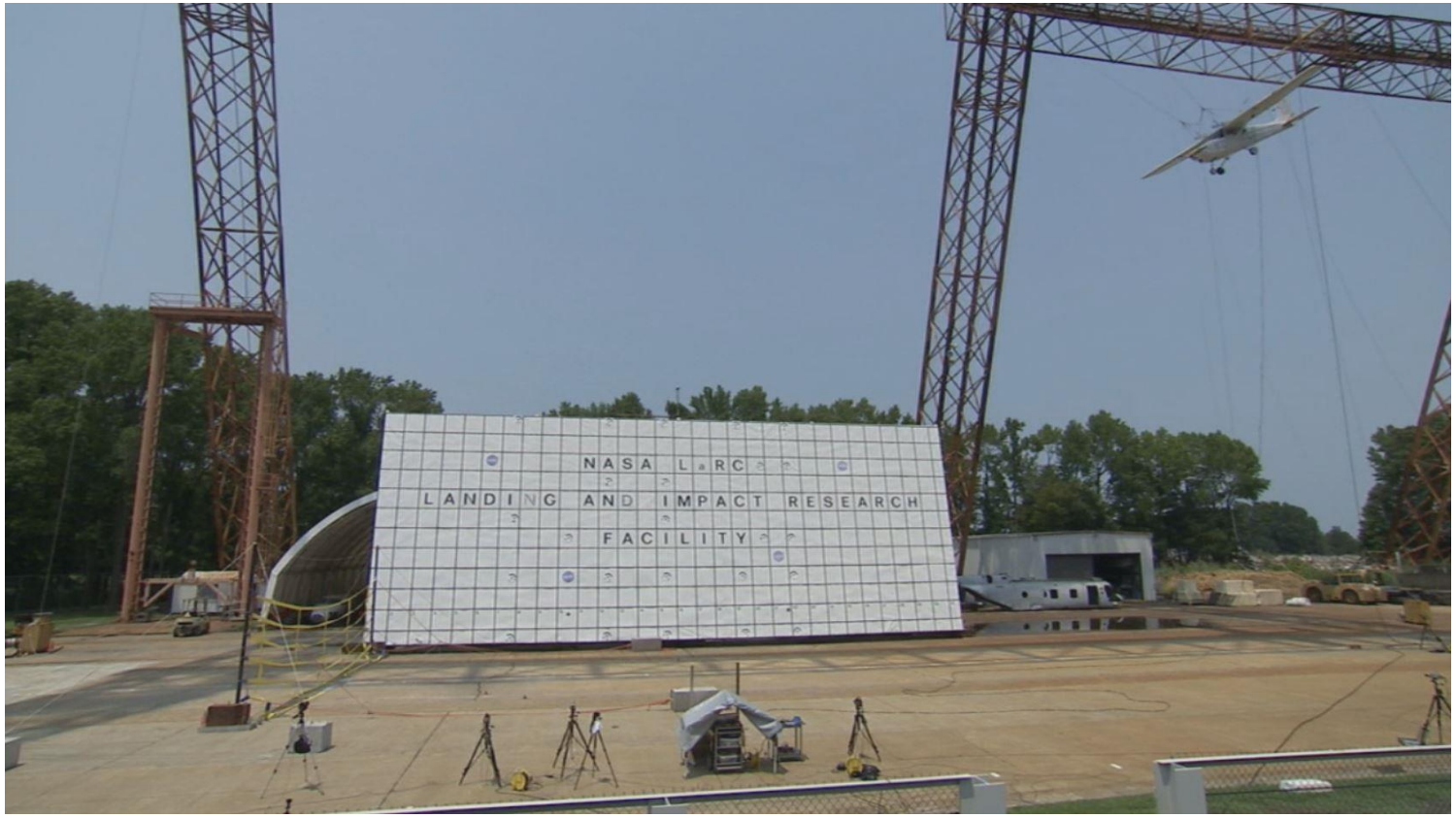
Turning Airplanes into Test Articles





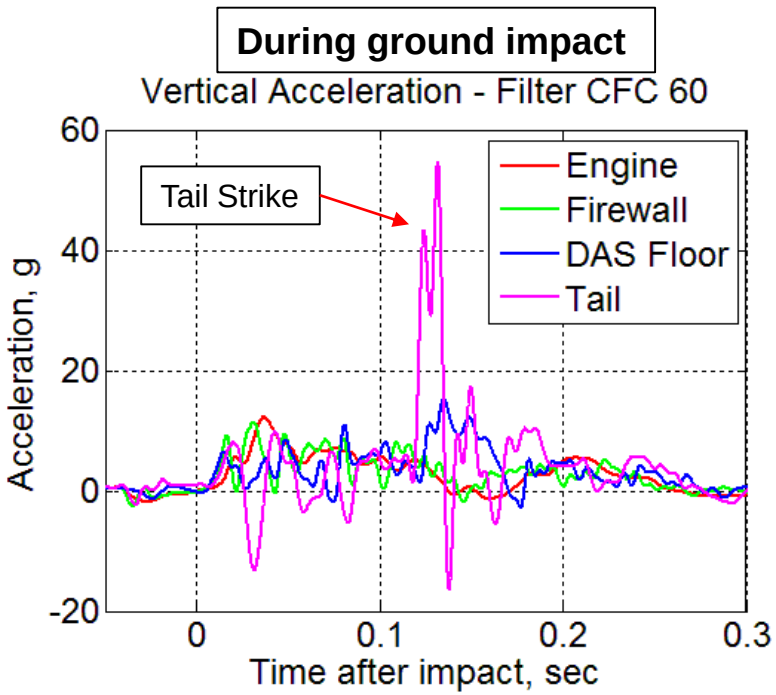
- Rigging hardware mounted above wings and on main landing gear
- 64 channel data acquisition system which includes airframe accelerations and occupant loading
- 2 Hybrid III - 50th Percentile ATD's with varying types of restraints used per test
- High speed cameras both onboard and off board
- Speckle coating used for digital image correlation
- 4-5 ELTs per airplane

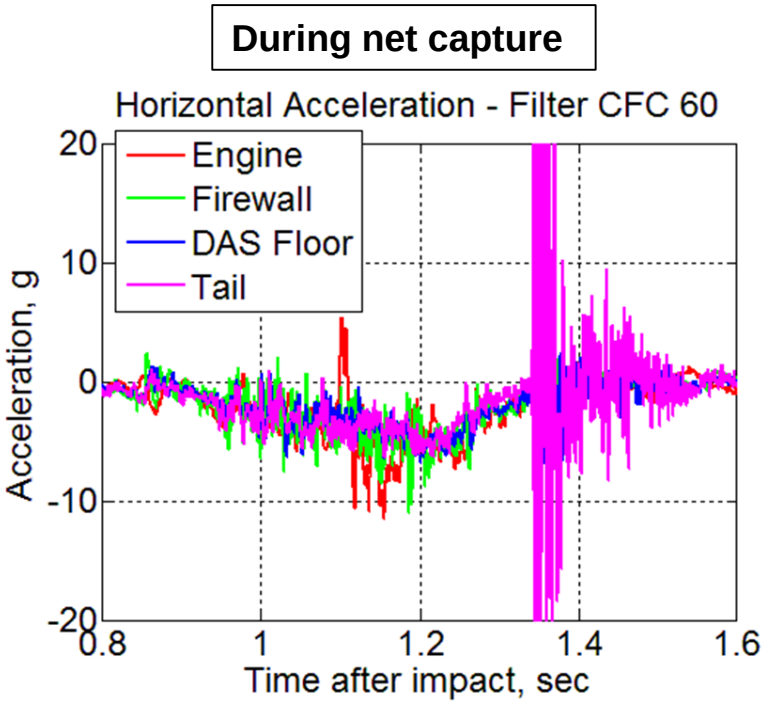
Test 1 – Hard/Emergency Landing



- Horizontal Velocity = 60.2 ft/sec
- Vertical Velocity = 23.0 ft/sec
- Pitch Angle = 1.5 deg nose up
- Main gear deflection remarkable
- Two distinct events: Ground impact and Net capture

Test 1 – Airframe Response





- During ground impact
  - Vertical accelerations resembled a plateau which ranged between 4.1 g (engine) to 5.9 g (tail)
  - Horizontal accelerations negligible
- During net capture
  - Vertical accelerations negligible
  - Horizontal accelerations were triangular in shape and peaked between 4.0 g (tail) to 5.3 g (engine)

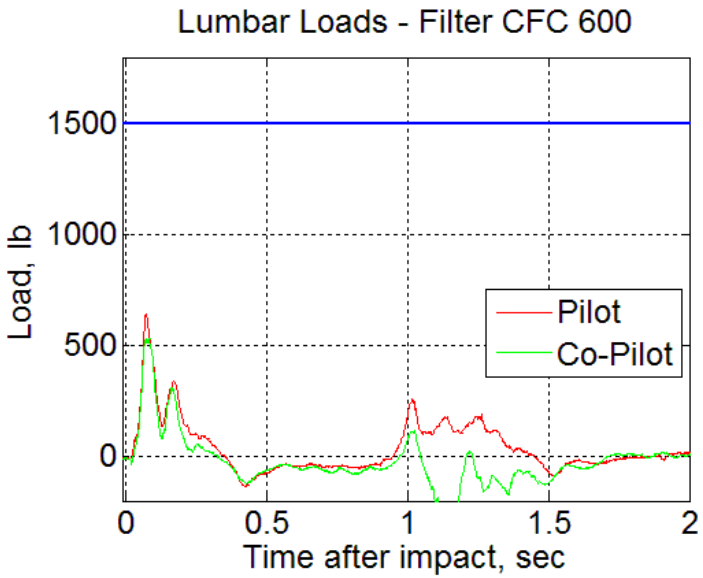
Test 1 – Occupant Response

Co-Pilot -
Fixed lap belt ONLY

Pilot -
Fixed shoulder and lap belt

- Major lumbar load occurred during ground impact
- Major head flail occurred during net capture
- Head flail was reduced by approximately 13 inches when a shoulder belt was used

Test 1 – Occupant Response (cont.)



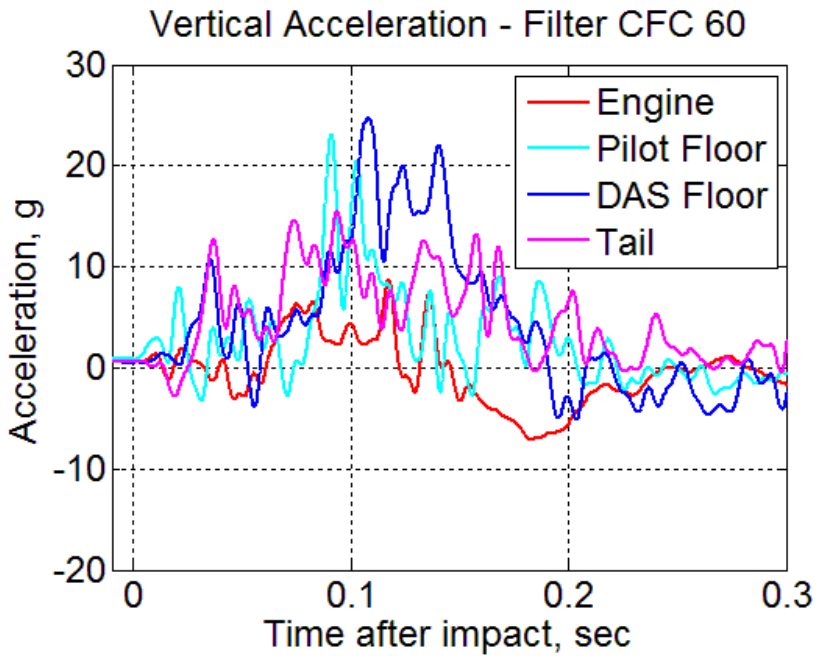
Occupant	HIC
Pilot	11
Co-Pilot	25

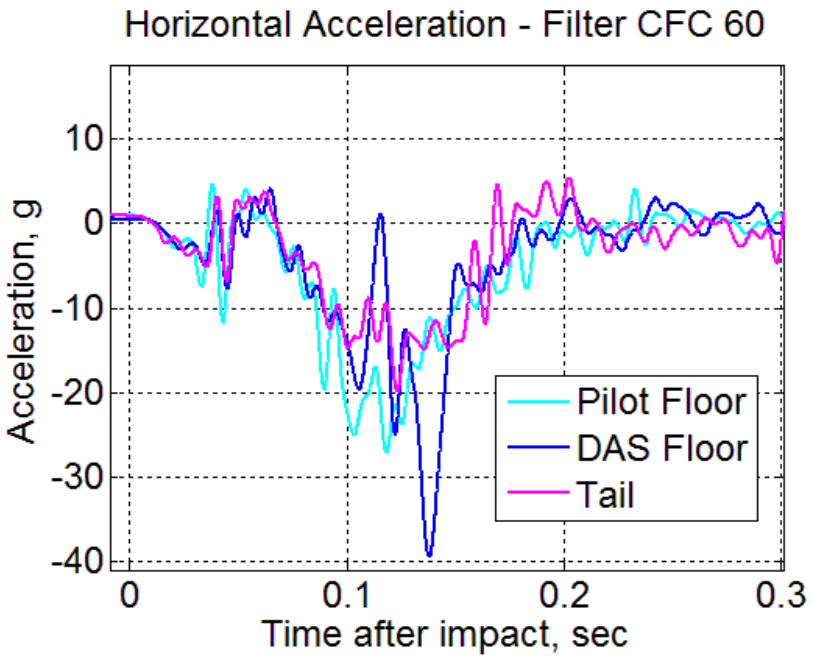
- HIC, lumbar load, and belt are below injury limits according to FAR 25.562

Test 2 – Controlled Flight into Terrain (CFIT) Nose Down

- Horizontal Velocity = 68.6 ft/sec
- Vertical Velocity = 28.7 ft/sec
- Pitch Angle = 12.2 deg nose down

Test 2 – Airframe Response





- Vertical Acceleration
  - Triangular to trapezoidal in nature
  - Peaks of 23.2 g and 24.7 g for Pilot floor and DAS floor, respectively
- Horizontal Acceleration
  - Triangular in nature with peaks of 27.1, 39.5 and 19.9 g in Pilot Floor, DAS Floor and Tail
  - Uniform in shape
  - Large spike in DAS floor could be from any number of dynamic events onboard
- Rotation of the airplane occurs well after the peak values in acceleration shown (i.e. at 1 second the aircraft is vertical)

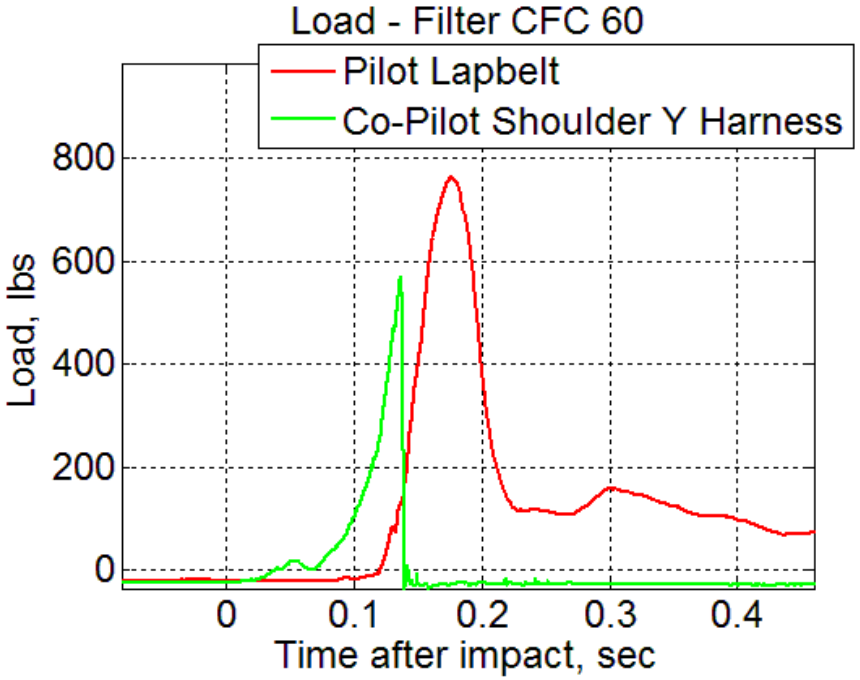
Test 2 – Occupant Response

Co-Pilot - Y-harness

Pilot - Lapbelt

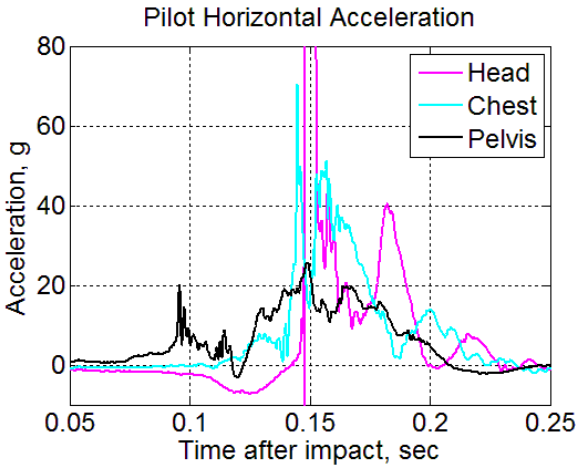
- Failure in y-harness restraint in Co-Pilot gave similar flail motion to lapbelt only restraint in Pilot

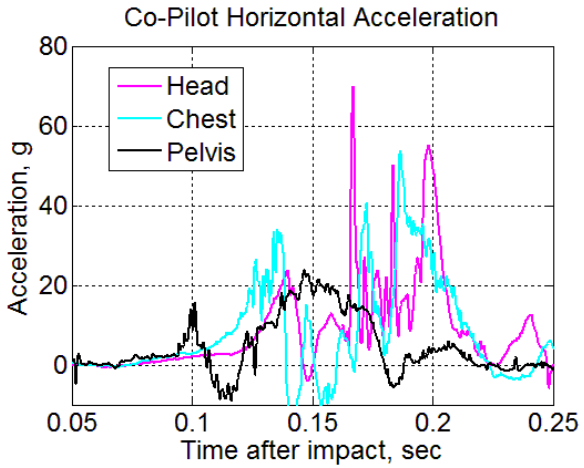
Test 2 – Restraint Fail

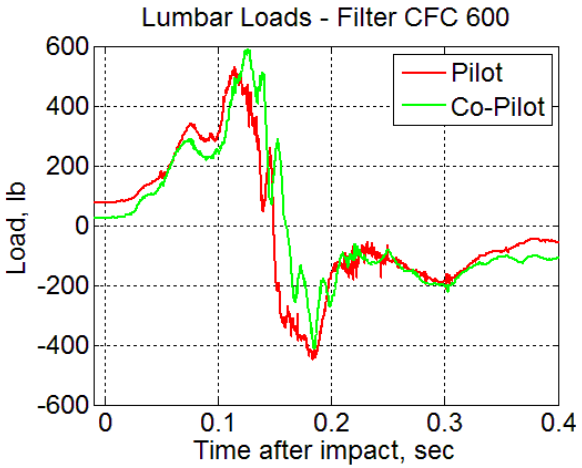


- Y-harness failed at the stitching, not webbing

Test 2 – Occupant Response (cont.)





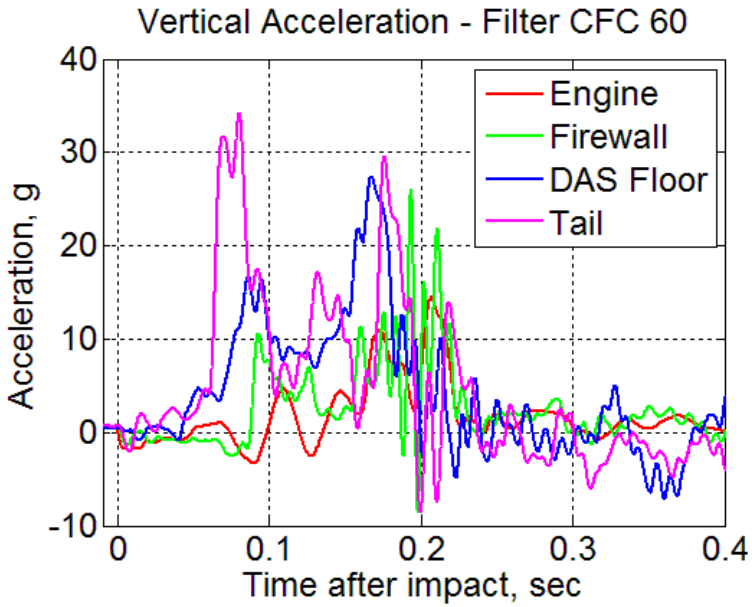


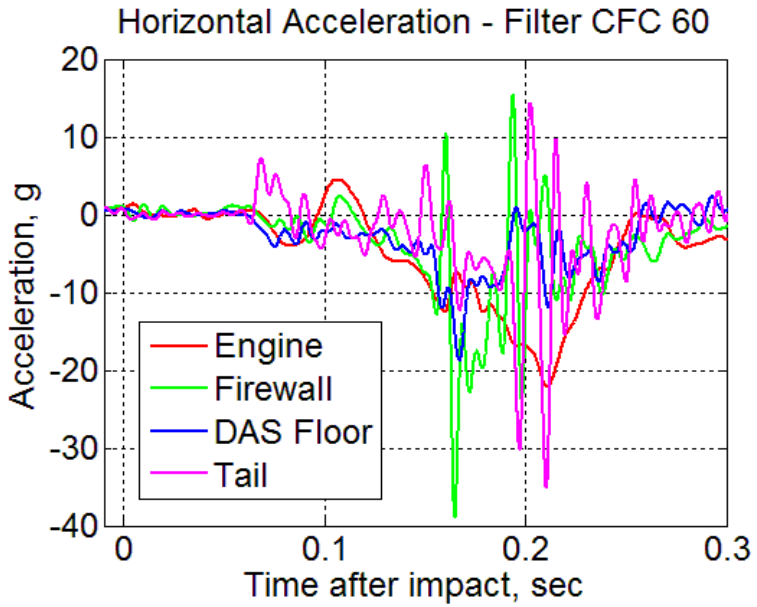
- Pilot head hitting yoke caused high accelerations, leading to high HIC value (4241)
- Even with Co-Pilot restraint failing, y-harness was able to restrain Co-Pilot enough to avoid yoke, leading to low HIC value (274)
- Lumbar loads below established limit of 1,500 lb
- Pilot injurious crash

Test 3 – CFIT Tail Strike

- Horizontal Velocity = 56.9 ft/sec
- Vertical Velocity = 23.6 ft/sec
- Pitch Angle = 8.0 deg nose up

Test 3 – Airframe Response





- Vertical Acceleration
  - Trapezoidal in nature with peaks at end, due to “slap down” effect
  - Tail strike is captured in vertical acceleration peaks at 32 g
  - Peaks of 27.5 g, 26.0 g, and 15.5 g for DAS floor, firewall and engine, respectively
- Horizontal Acceleration
  - Triangular to trapezoidal in nature
  - Firewall peaks at 38.9 g, however, signal likely noisy -> engine peaks at 22.1 g
  - DAS floor can be interpreted as being a trapezoidal pulse shape having a sustained acceleration of 50 msec and a sustained peak of 8.7 g
- Rotation of the airplane occurs well after the peak values in acceleration shown

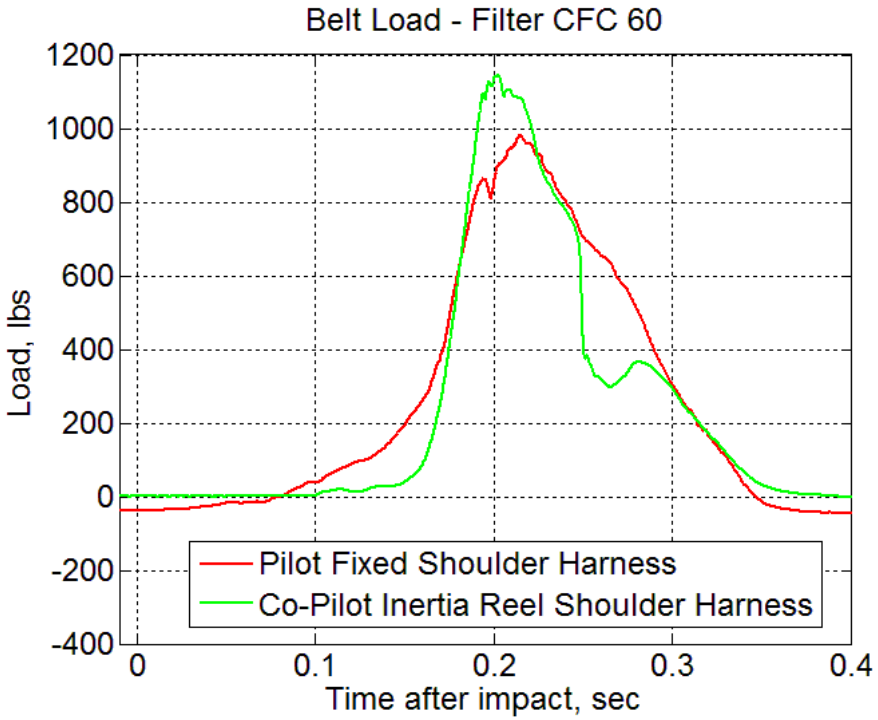
Test 3 – Occupant Response

Co-Pilot -
Shoulder+
Lap+
Inertia Reel

Pilot -
Shoulder+
Lap

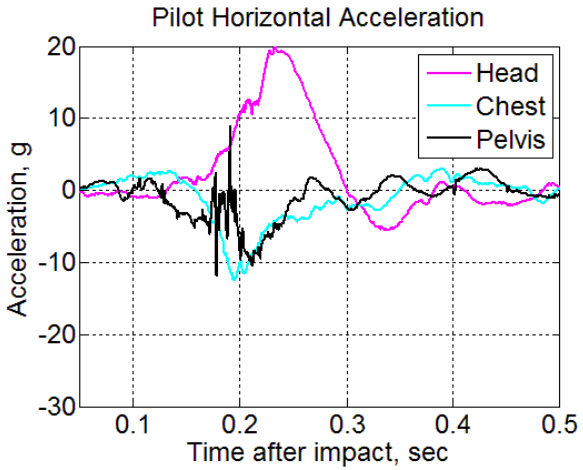
- Due to the addition of an armrest on the door, the Co-Pilot positioning was offset forward of the Pilot
- Both types of restraints limited ATD head motion

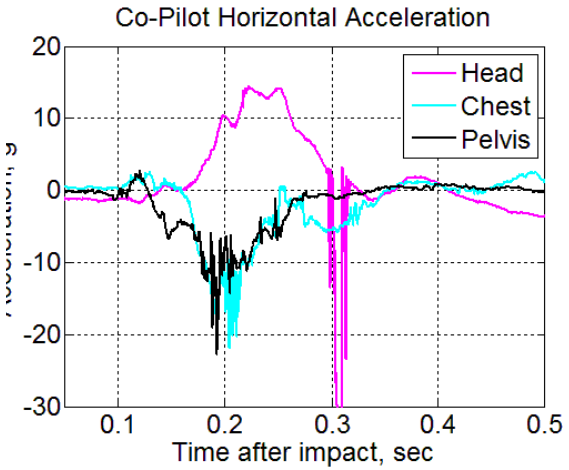
Test 3 – Restraint Loads

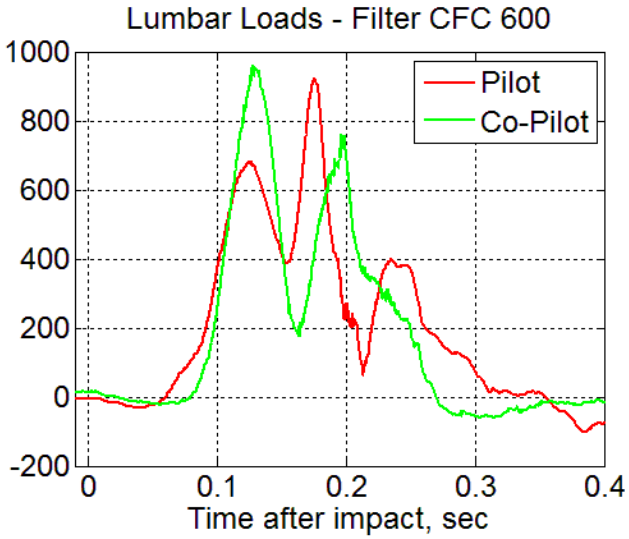


- Both measured on the shoulder harness
- Similar response exhibited by inertia real and fixed shoulder harness

Test 3 – Occupant Response (cont.)







- Similar response seen between ATDs, suggesting that the restraints restricted motion similarly for Pilot and Co-Pilot
- Lumbar load mirrored peaks likely caused by Co-Pilot ATD offset positioning
- Pilot HIC = 51
- Co-Pilot HIC = 92
- Non injurious crash based on parameters measured

More Information

- **NASA TM 2015-218987** – *"Crash Tests of Three Cessna 172 Aircraft at NASA Langley Research Center's Landing and Impact Research Facility"*
- **NASA TM 2016-219175** – *"ATD Occupant Responses from Three Full-Scale General Aviation Crash Tests"*
- **NASA TM 2016-219217** – *"Emergency Locator Transmitter System Performance During Three Full-Scale General Aviation Crash Tests"*
- **NASA TM 2016-219168** – *"Experimental Photogrammetric Techniques Used on Five Full-Scale Aircraft Crash Tests"*
- **NASA TM 2016 In Pub** – *"Simulating the Impact Response of Three Full-Scale Crash Tests of Cessna 172 Aircraft"*
- **NASA TM 2016 In Pub** – *"Emergency Locator Transmitter Survivability and Reliability Study"*

Discussion

- Three tests conducted under differing crash scenarios
  - Rigid
  - Soft soil
  - Nose up
  - Nose down
- Crash pulses were triangular to trapezoidal in nature for vertical accelerations and triangular in nature for horizontal accelerations
- Neglecting spikes, majority of accelerations were below 30 g
- All available data show that Pilot sustained injuries on test 2
  - Not all parameters measured and injury criteria checked
- One out of six restraints failed