A Comparative Analysis of Airframe Results Between Sub-Scale and Full-Scale Tests of Fokker F28 Aircraft Hardware

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Purpose

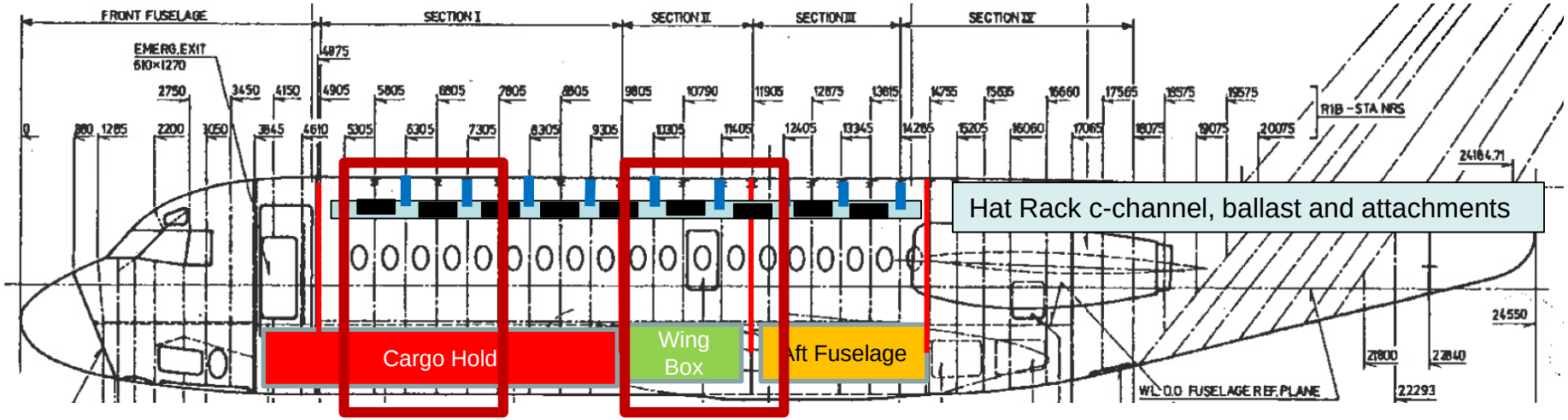
- Evaluate missing factors resulting between a pure vertical component test and a test which includes a forward velocity
  - Evaluate Anthropomorphic Test Devices (ATD's aka crash test dummies) under various injury metrics
  - Evaluate ATD motion for flail envelopes
  - Evaluate airframe deformation and loading
- Generate data for Federal Aviation Administration (FAA) ARAC Transport Aircraft Crashworthiness and Ditching Working Group (TACDWG)
- Generate data for computer modelling purposes

F-28 Ferry Flight

F-28 Taxi @ LaRC

F-28 Transport to LandIR

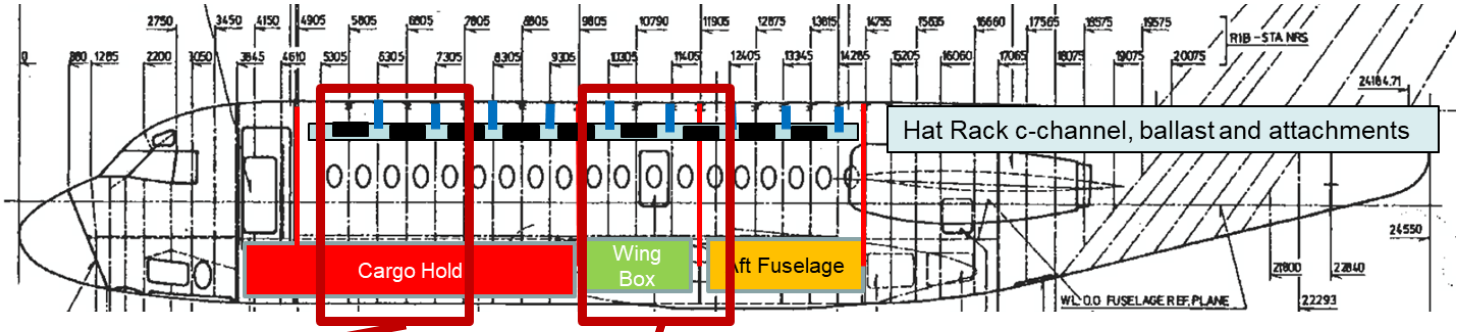
Airframe configuration



Forward Section
Test Article

Wingbox Section
Test Article

Test articles



Vertical Impact test onto flat soil

Canted vertical impact test onto sloped soil

Swing test onto flat soil

Test parameters

- Common test parameters
  - Impact surface – Gantry Unwashed Sand (dirt) built into a 2-foot bed at impact site – NOT CONTROLLED
  - Vertical Velocity ~30 ft/s

- Common test article features
  - Seats
  - ATDs
  - Luggage
  - Emergency Exit doors
  - Overhead hat rack ballast

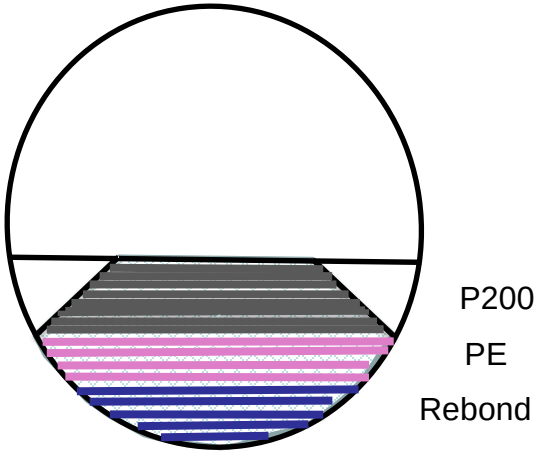
- Common test data collected
  - Accelerations on floor, seat base, hat rack and other notable features
  - ATD accelerations
  - ATD motion tracking
  - Photogrammetry on fuselage

- Barrel Sections – Retired F-28 MK-4000 Tail number unknown
  - Forward Section Test weight – 4465 lb.
  - Wingbox Section Test weight – 5182 lb.

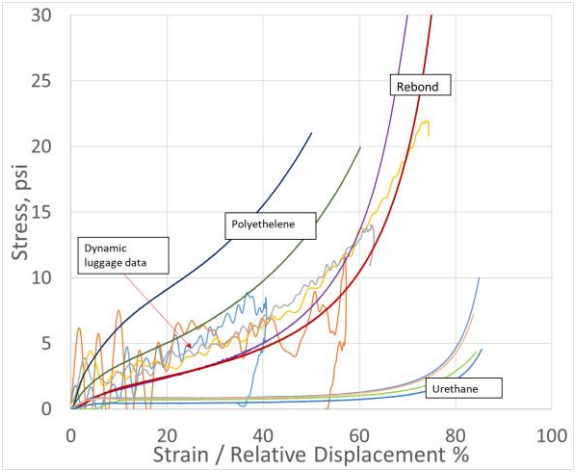
- Full Scale - Retired F-28 MK-1000 aircraft formerly Canada Regional Tail# C-GCRN
  - Full Scale measured test weight ~33,306 lb.

Luggage design and installation – Forward cargo hold

Forward section with luggage



Full-scale luggage layout



Dynamic foam response curves

- Combination of three energy absorbing foams necessary to optimize performance and weight
- 36% 6 pcf Rebond, 35% 2.2 pcf Polyethylene, 28% 2 pcf P200
- Stiffness makes a greater difference over weight as a reaction surface
  - Luggage weight 906 lb.
- Stiffness was tuned though various stacking sequences to obtain correct “luggage simulant” properties

Seats

- Seats removed from in-service (2016) United Airlines 737 triple place seats
  - Triple cut into double for F-28 port side
  - Seat leg spacing changed to 21.75 inches
  - Pitch 32 inches

Forward barrel test

Wingbox barrel test

Full scale test

Impact conditions

Horizontal Velocity	0 ft/s	1.1 ft/s*	65.3 ft/s
Vertical Velocity	28.9 ft/s	29.5 ft/s*	31.8 ft/s
Lateral Velocity (assumed)	0 ft/s	0 ft/s*	0 ft/s
Pitch	1.3 degrees nose down	2.9 degrees nose down	0.38 degrees nose down
Roll	0.7 degrees stbd side down	0 degree	4.3 degrees stbd side down
Yaw	0 degree	0 degree	2.58 degrees nose left

*local coordinate system

Forward section belly comparisons

Forward section floor structure

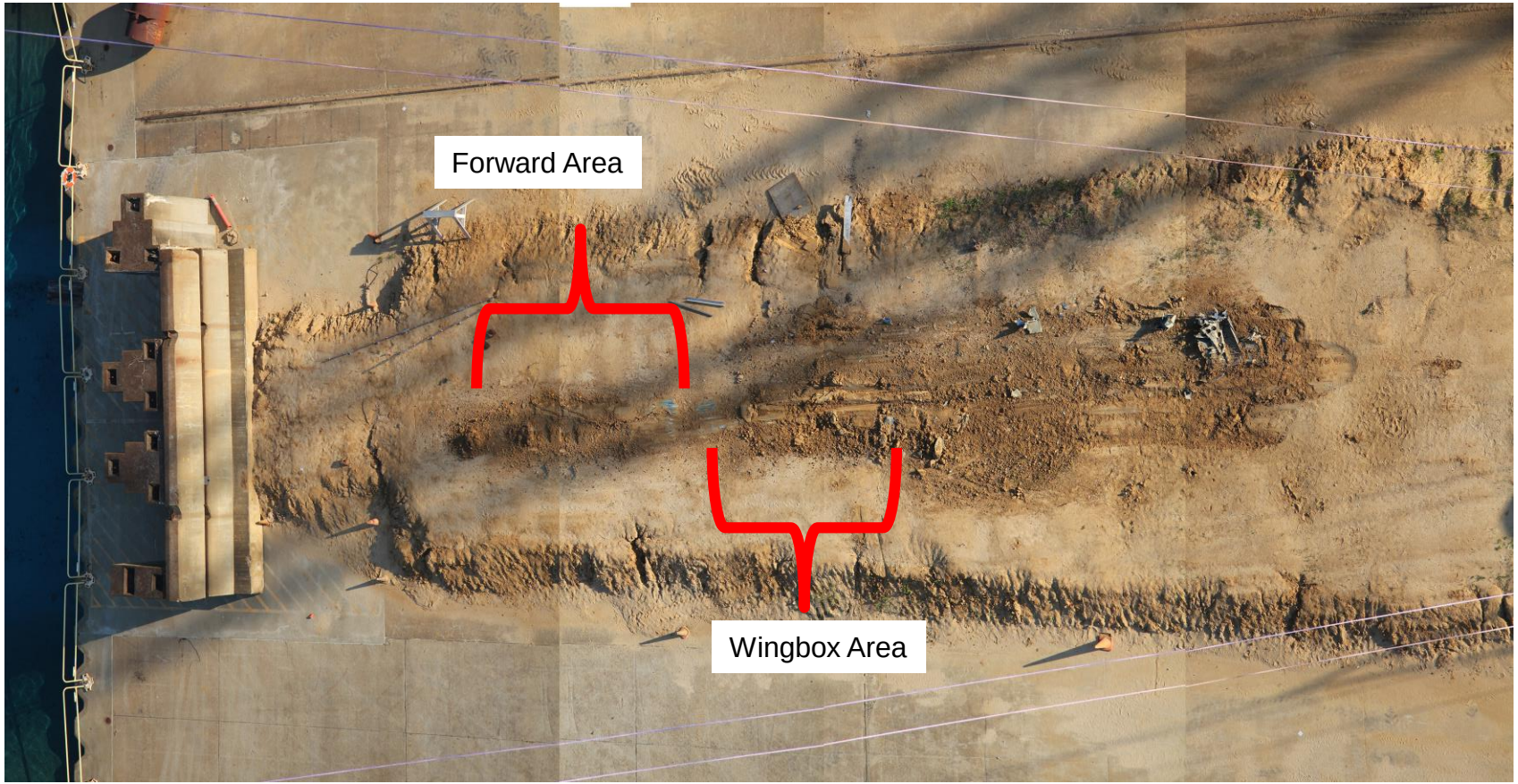
Wingbox belly deformations

Emergency exit door removal

Wingbox barrel section

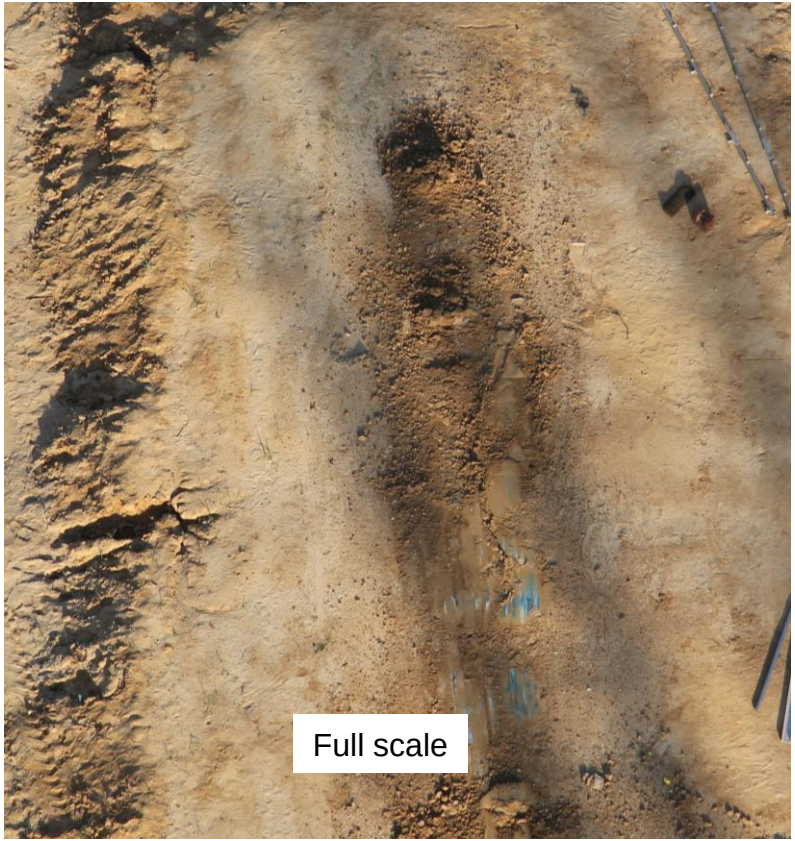
Full scale

Soil deformations



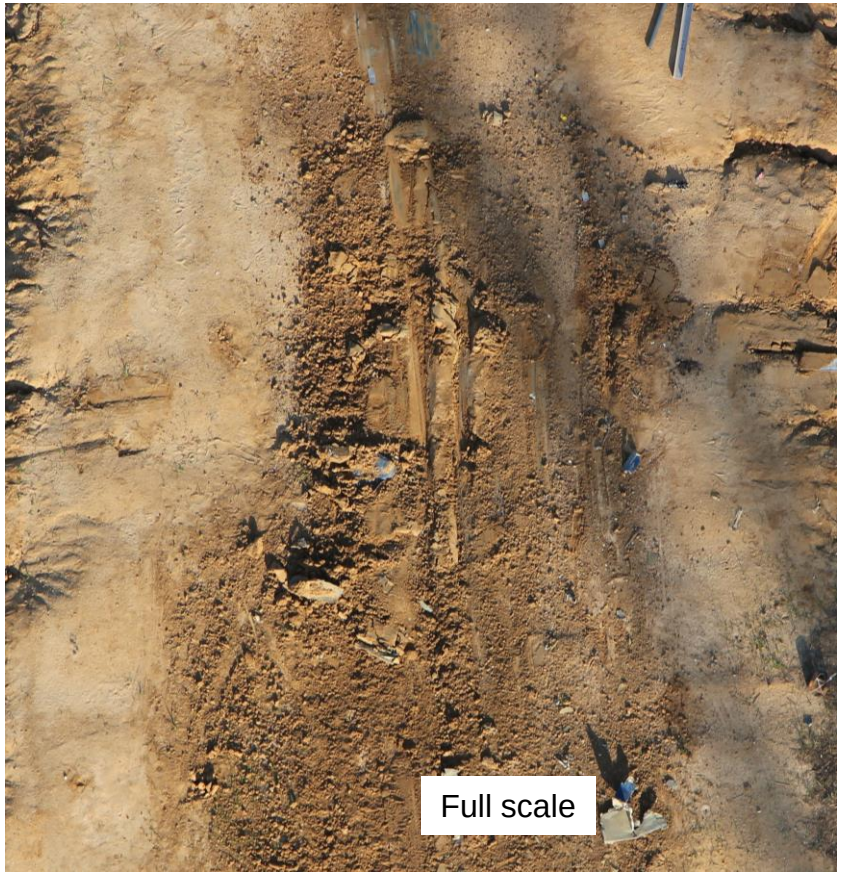
Soil deformations forward section

Forward barrel section



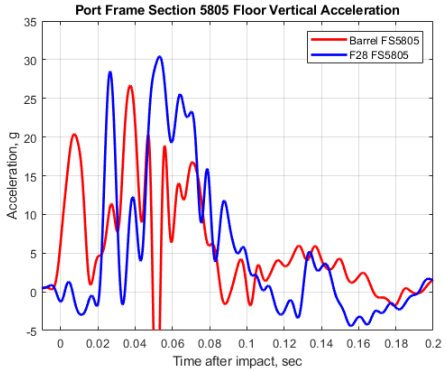
Soil deformations wingbox detail

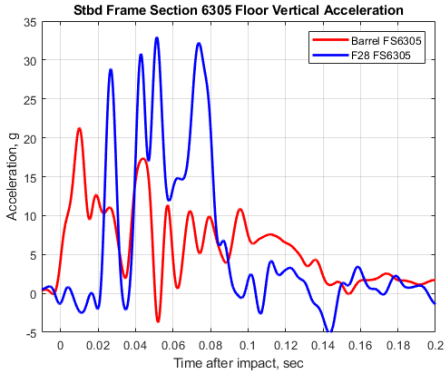
Wingbox barrel section

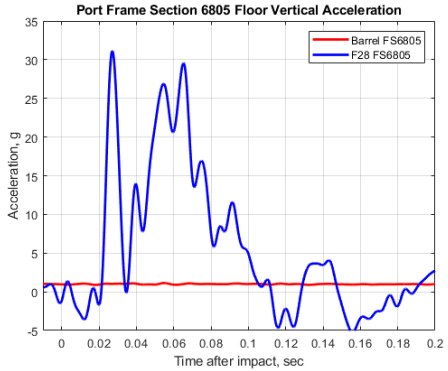


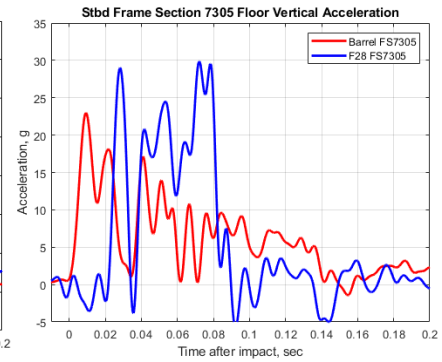
Full scale

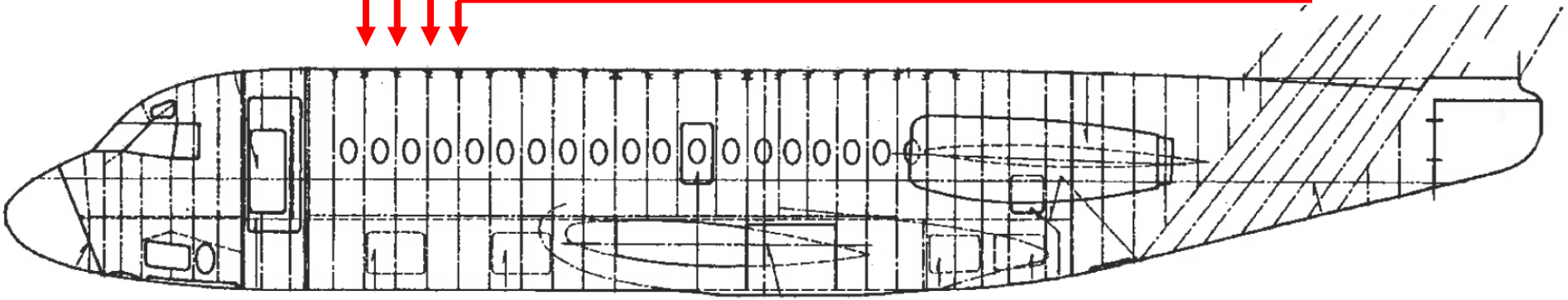
Forward barrel vertical acceleration comparisons



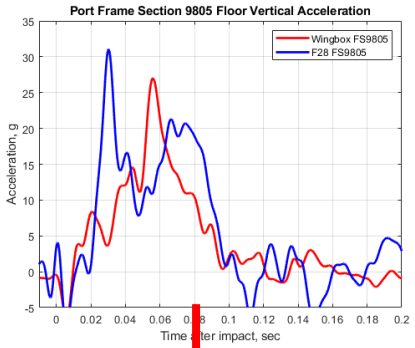


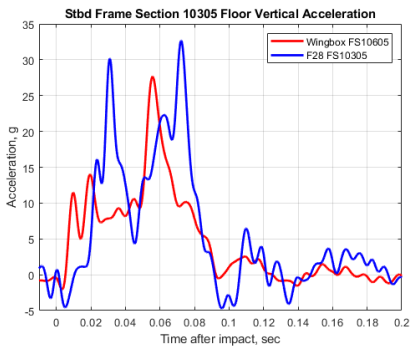


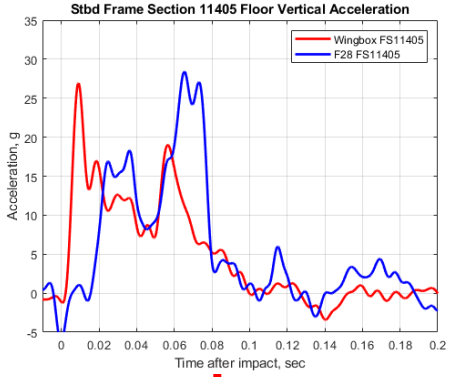


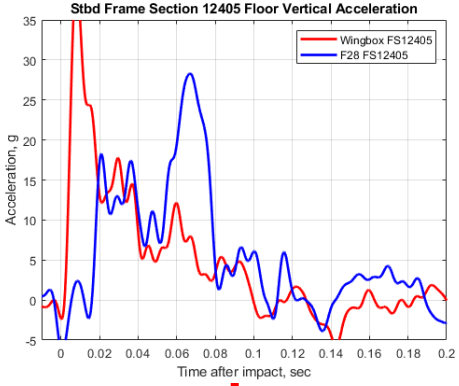


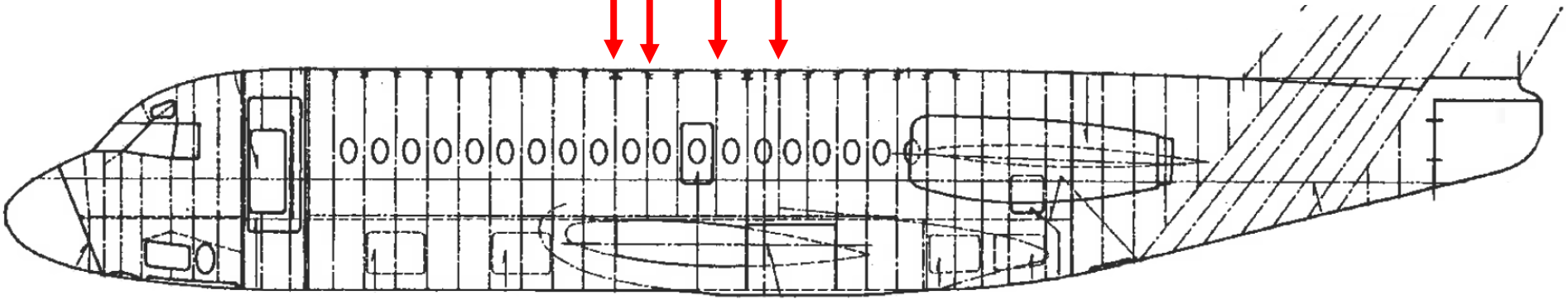
Wingbox vertical acceleration comparisons



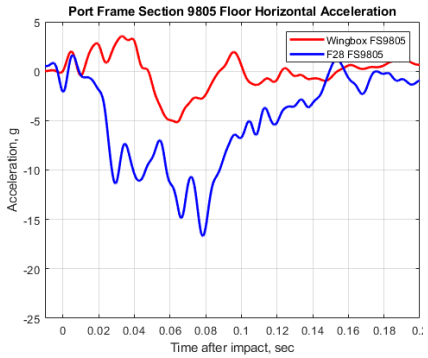


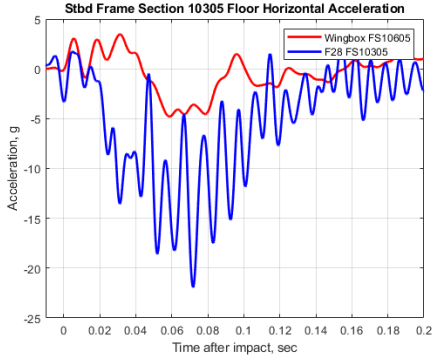


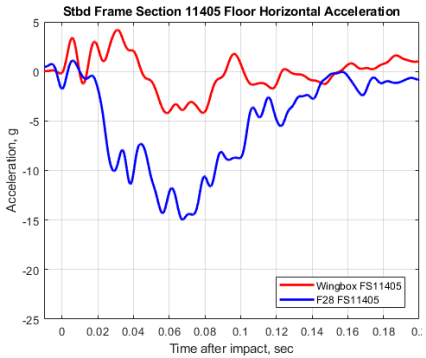


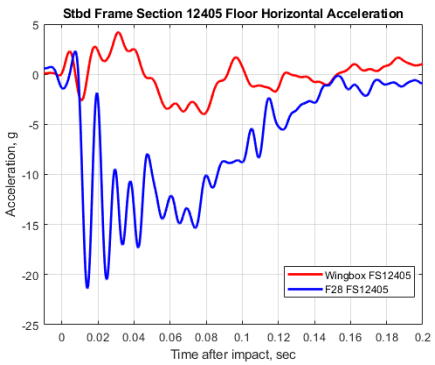


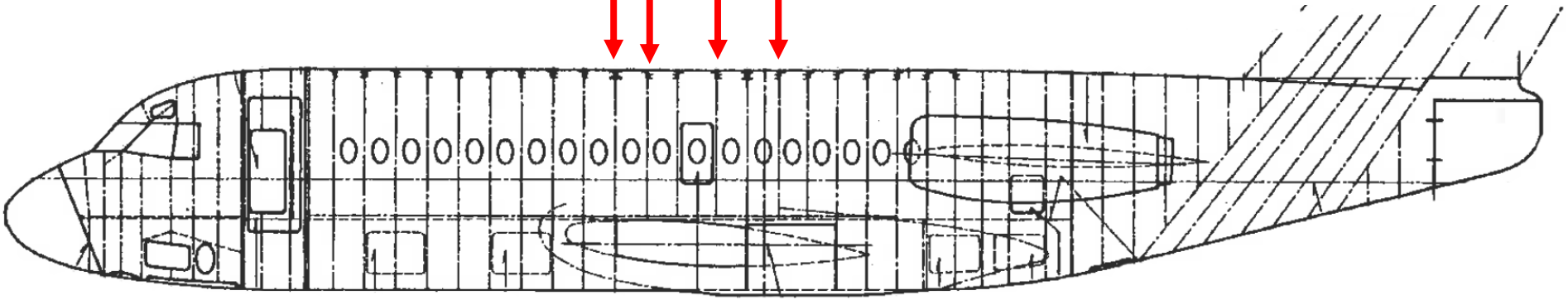
Wingbox horizontal acceleration comparisons







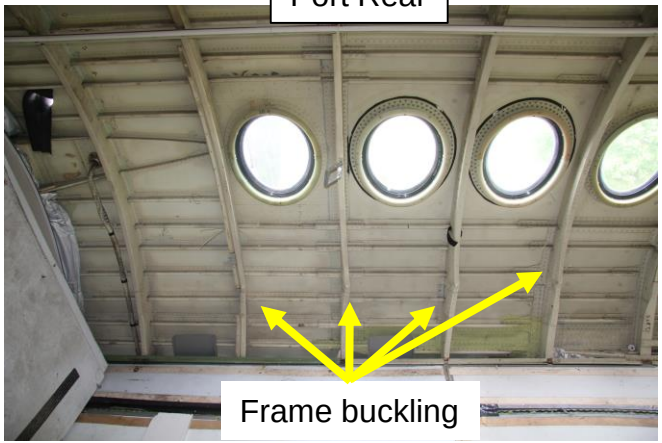


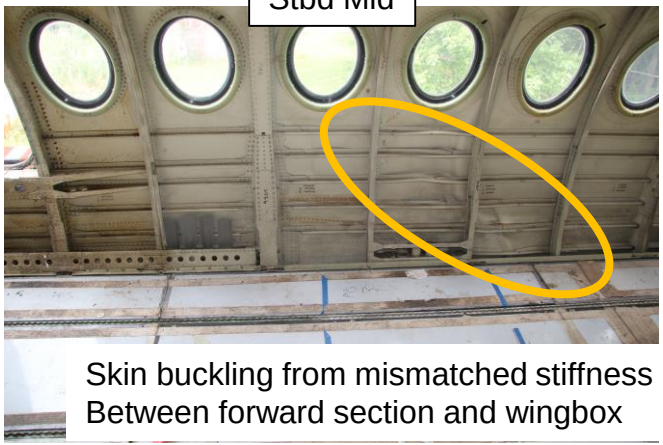


Full scale additional airframe damage

Port Rear

Stbd Mid





Skin buckling from mismatched stiffness
Between forward section and wingbox

Summary

- Forward accelerations
  - Minimal for the forward barrel test
  - Higher for the barrel due to the sloped surface, however, did not approach full scale
- Similarities
  - Belly deformation, dirt profile
- Differences
  - Fuselage structure exhibited larger deformations in fuselage structure
    - Differences in stiffness of adjacent sections not capturable in barrel testing
  - Barrel exhibited larger floor failures

- Having the entire aircraft present lead to higher acceleration loads
- Drop test onto sloped soil does not induce the types of accelerations seen in full scale
- There are large differences in ATD responses – Jacob presentation

backup

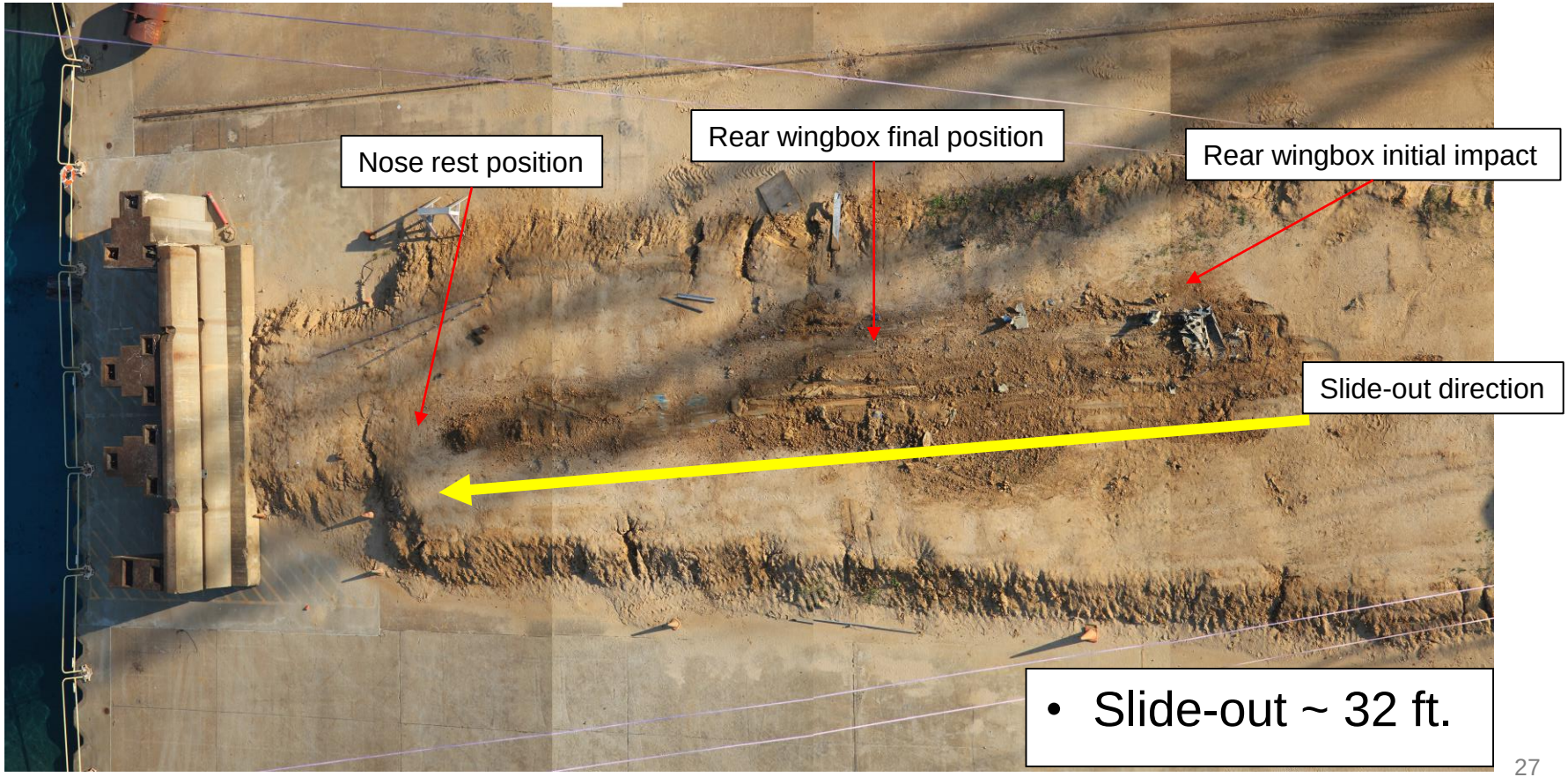
Slide-out

Weight and balance

- Initial Weight and balance 5/29/19
  - Aircraft weight of 32,370 lb.
  - CG @ ST10709; 3.29’ forward of center lift point
  - 1,900 lb. ballast added aft to move CG to center pickup location for stability
  - Ballast removed from forward aircraft
  - Vertical CG not measured due to CG location

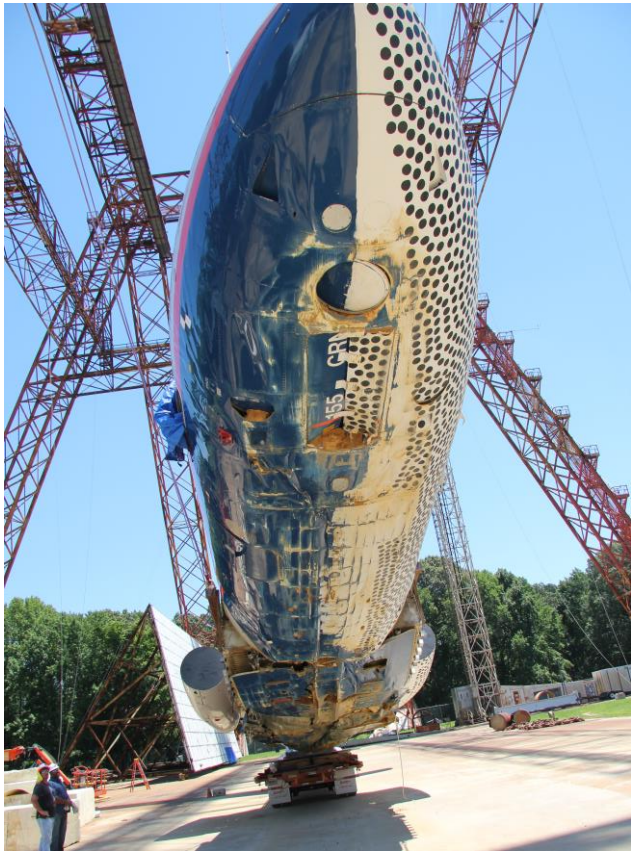
- Second weight and balance 6/03/2019
  - Aircraft final weight of 33,306 lb
  - Longitudinal CG @ pick up point, ST11555
  - Vertical CG @ WL-80
  - Lateral CG @ centerline
  - Acceptable limits according to Fokker W&B

Slide-out (cont.)

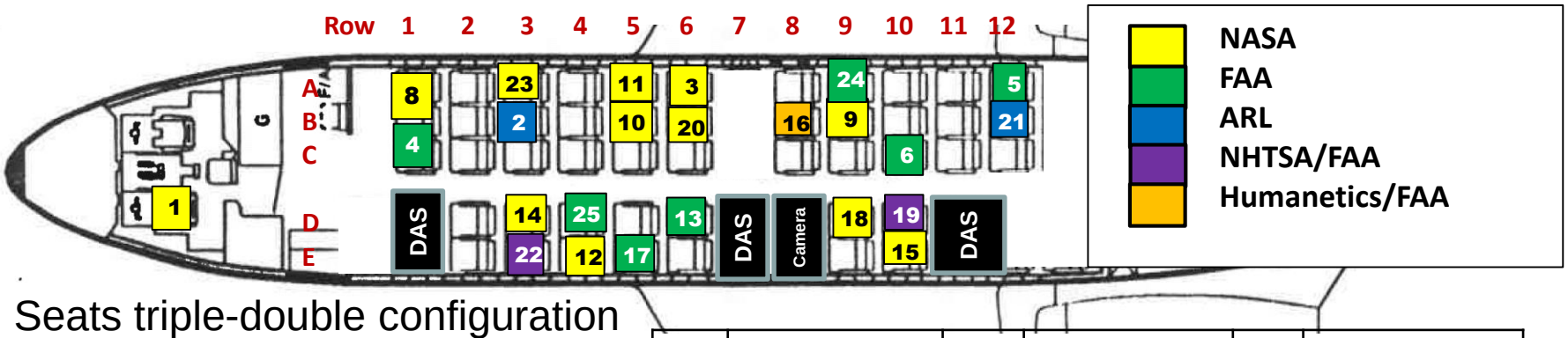


- Slide-out ~ 32 ft.

Airframe belly



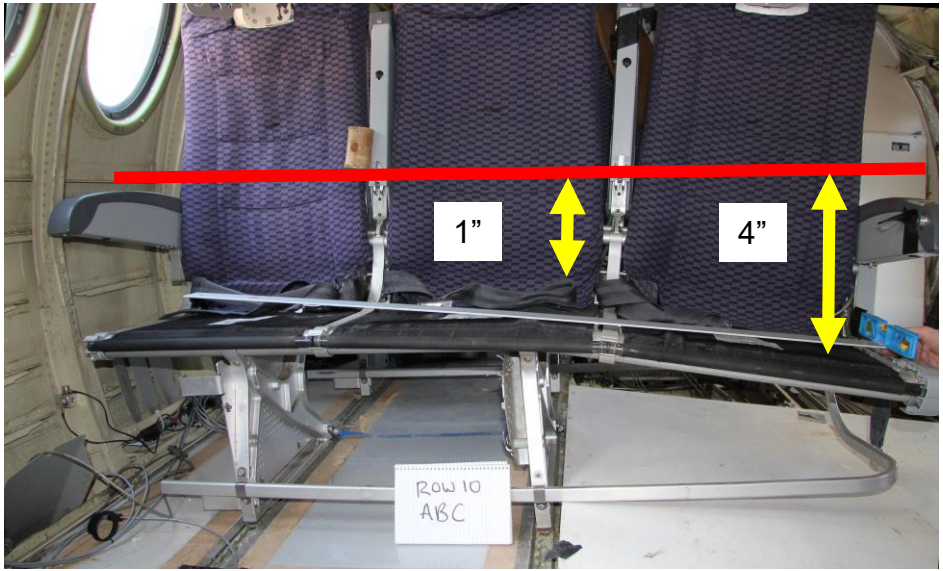
Anthropomorphic Test Device (ATD) layout



- Seats triple-double configuration
- 24 ATDs total
- 7 different ATD sizes
- 5 partners supplying ATDs
- 3 experimental ATD types
- Standard 50th percentile H2 and FAA H3 used injury
- Brace position
- Child seats

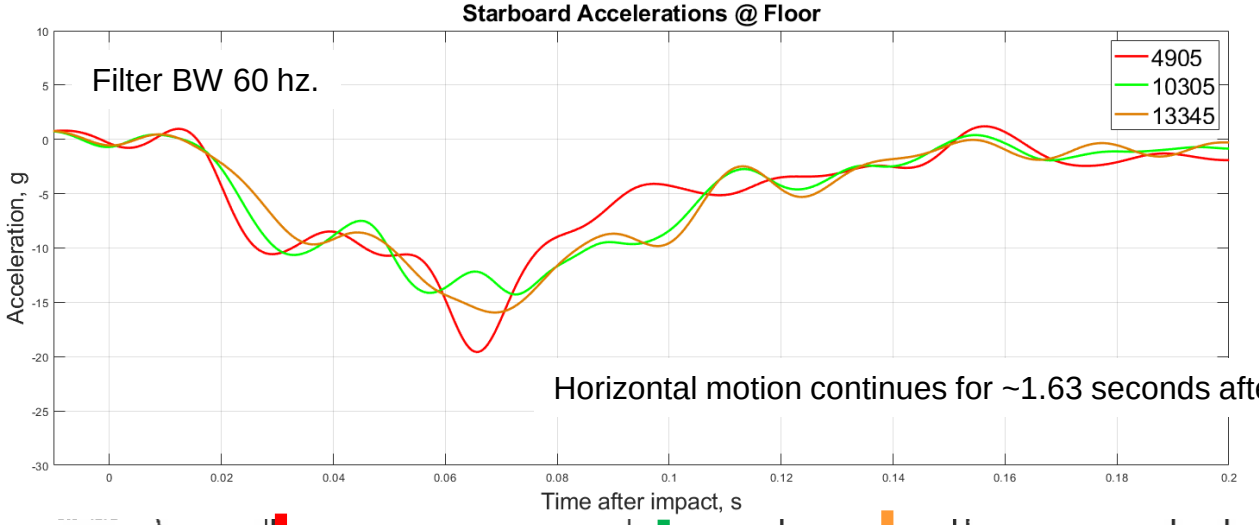
ID	Experiment	ID	Experiment	ID	Experiment
1	H2 – 50	10	H3 – 5	18	H2 -50
2	WIAMan	11	H3 – 95	19	LODA – 10 YO
3	H2 – 50	12	H3 – 6 YO	20	H2 – 50 *Brace
4	H2 – 50	13	FAA H3 – 50	21	WIAMan
5	FAA H3 – 50	14	H2 – 50	22	THOR
6	FAA H3 – 50	15	H3 – 10 YO	23	FAA H3 – 50
8	H2 – 50	16	Obese H3	24	H3 – 3 YO CARES
9	H3 – 3YO	17	Q1 Infant	25	CRABI

Seat deformation

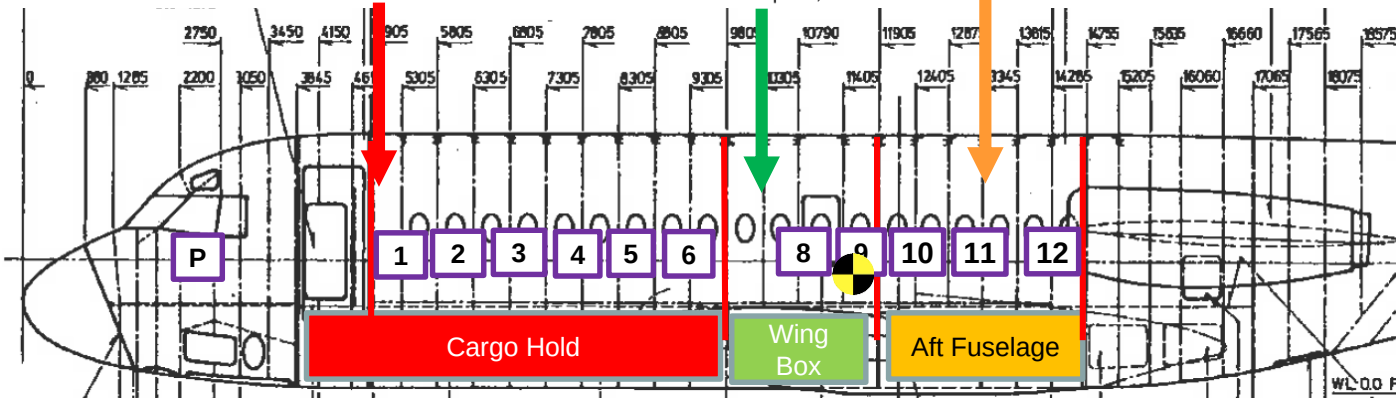


- For the triple place, only ATD seated in overhung seat was row 10 (seat C) - H3 50th
- Double seat Row 2 (seat D) seatback fail

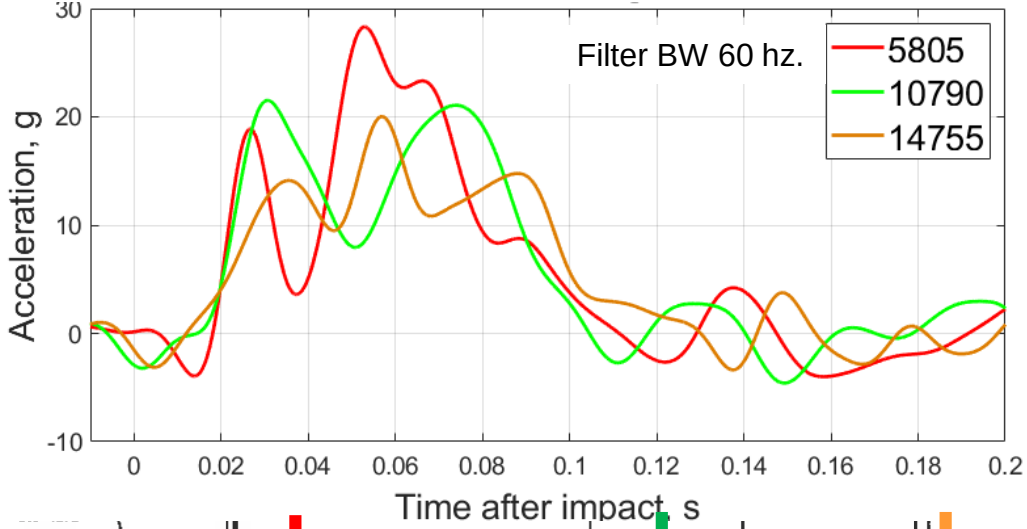
Starboard side horizontal accelerations

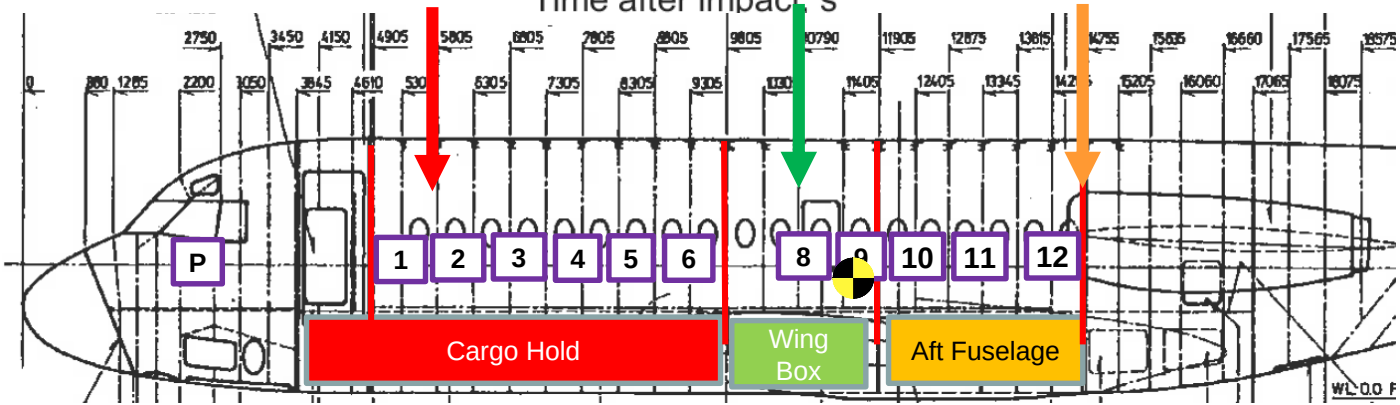


Horizontal motion continues for ~1.63 seconds after initial impact

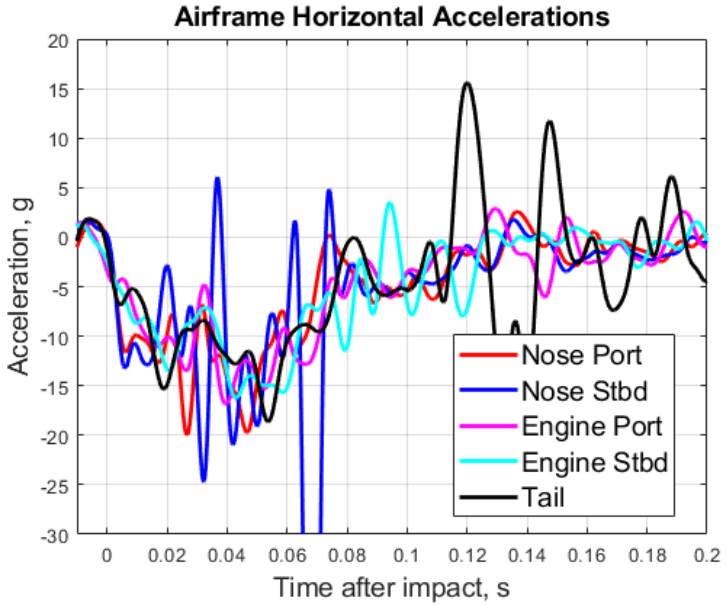


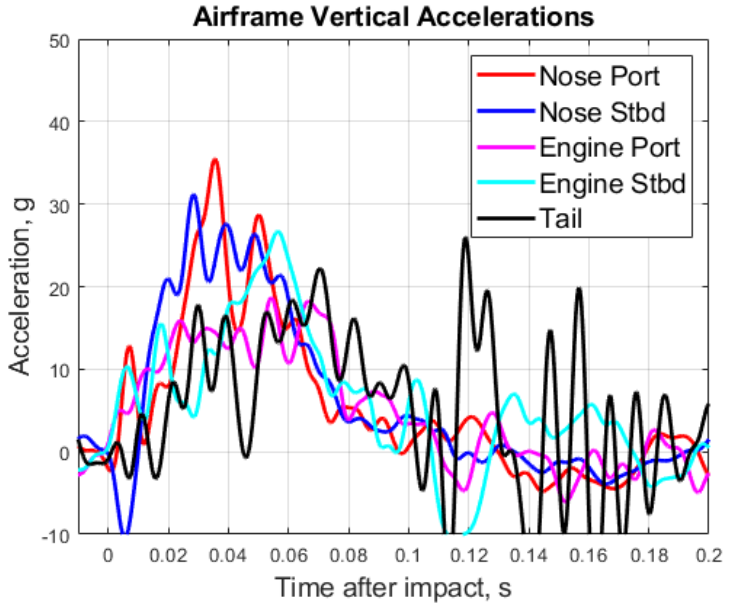
Port side vertical accelerations





Engine, tail and nose accelerations





- Horizontal
- Vertical

Post-test interior

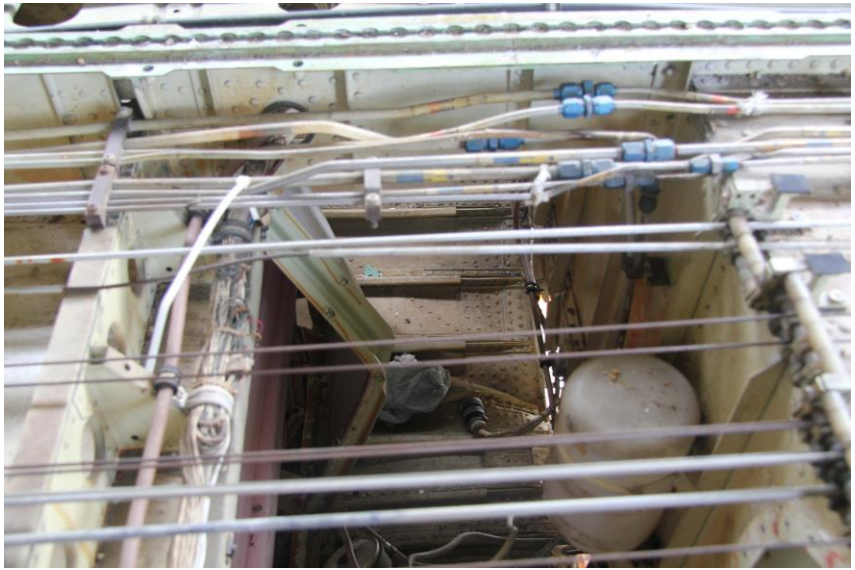
- Measurements still needed to determine total cabin deformation
  - 3-D laser scanner system at LaRC

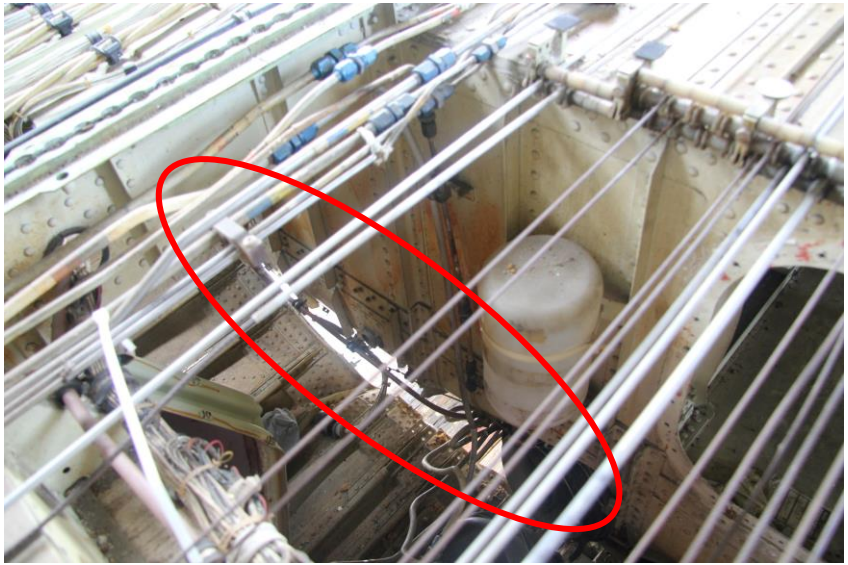
Post-test floor structure

- Seat track deformation – pushes into lower structure at seat leg positions

- Rear floor bulge / cabin intrusion

Post-test Sub-floor structure





- Forward/Wingbox junction stanchion buckling
- Wingbox detach from skin

- *NOTE: Deformation still largely unknown in the sub-floor region for the forward compartment (cargo hold)*

Hat Racks

- Hat rack
  - Attached at 3 spots every other frame section – using actual locations
  - 50 lb ballast mass every other frame section
  - Also served as onboard camera attachment locations

Summary and looking forward

- *Now:*
  - Data analysis
- *Next up:*
  - Conduct next round of post-test 3-D scans of empty interior to obtain fully documented cabin deformation quantitative numbers
  - Remove luggage foam and further document subfloor deformation
    - F-28 will collapse if foam is removed with aircraft weight on top
    - Must cut up/section then document
- *Later:*
  - Compare F-28 section drop tests to F-28 full-scale crash test