Development of a Full-Scale Finite Element Model of the Fokker F28 Fellowship Aircraft and Crash Simulation Predictions



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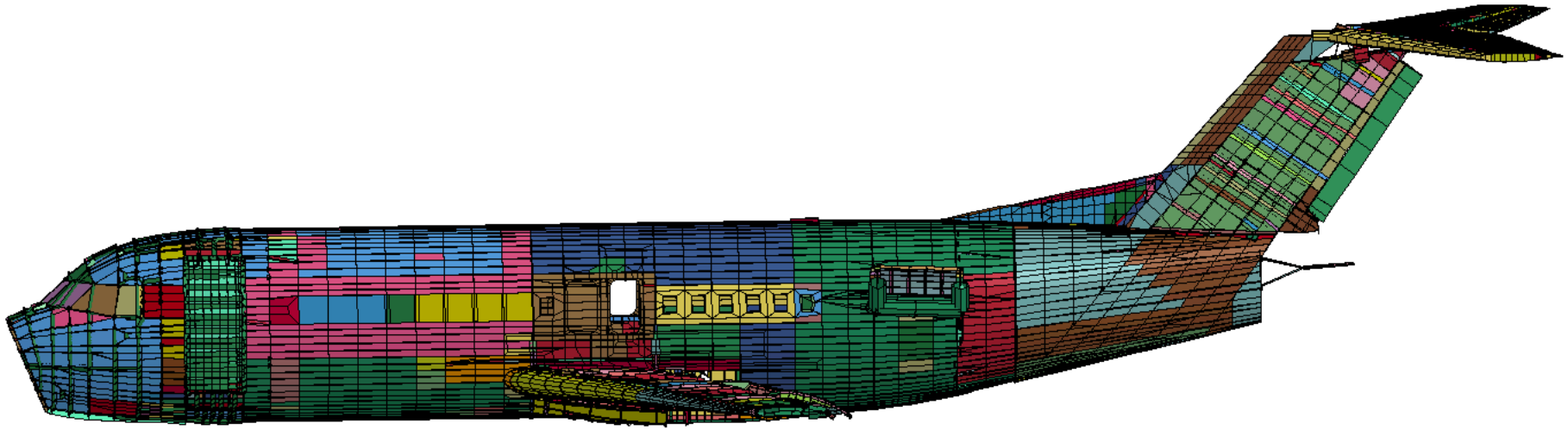
9th TRIENNIAL INTERNATIONAL AIRCRAFT FIRE AND CABIN SAFETY RESEARCH CONFERENCE
Atlantic City, NJ
October 28-31, 2019

Outline

- Description of the F28 Model Development
- Test-Analysis Comparisons
  - Inertial Property Comparisons
  - Kinematic Comparisons
  - Time History Comparisons
  - Airframe Damage Comparisons
- Conclusions
- Future Work

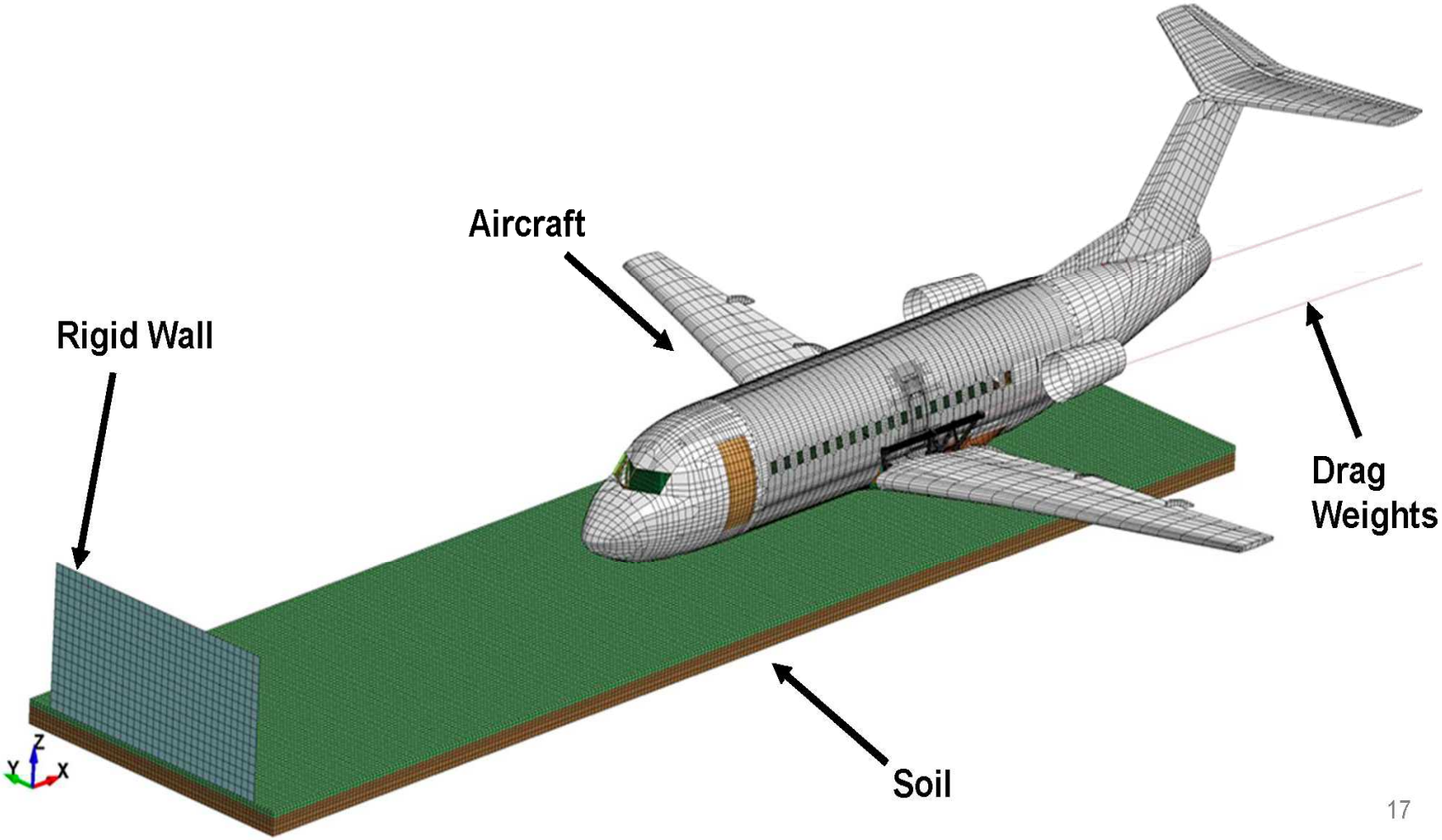
Description of the F28 Model Development

- When the F28 hardware was purchased in 2000, NASA also obtained a NASTRAN loads model of the aircraft from Fokker
- The NASTRAN model was converted into LS-DYNA format, material properties were updated, and missing structure was added



NASTRAN loads model

Description of the F28 Model Development



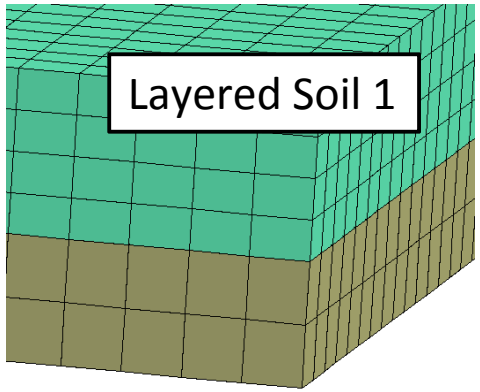
Description of the F28 Model Development

Measured Initial Velocities

Forward Velocity = 65.3-ft/s, 783.6-in/s
Vertical Velocity = 31.8-ft/s, 381.6-in/s
Lateral Velocity = 0.0=ft/s, 0.0-in/s

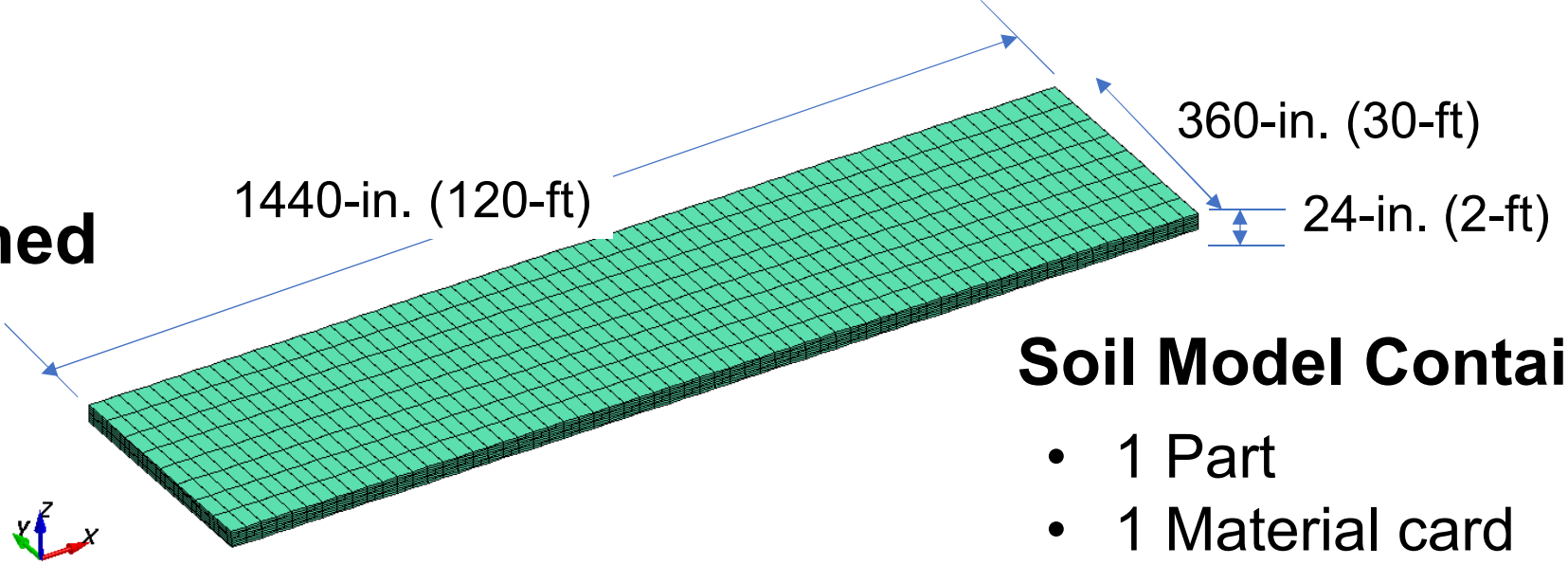
Measured Initial Attitudes

Pitch = 0.38° nose down
Roll = 4.3° Starboard side down
Yaw = 2.58° nose left



- The Layered Soil 1 model was executed to an end time of 1.75-seconds and required approx. 26 hours to execute to normal completion on 8 processors of a Linux-based workstation (blueridge). Version ls1010d (double precision) of LS-DYNA was used.
- Nodal output was requested for frame and seat base accelerometers (in local coordinates)

Gantry Unwashed Sand Model

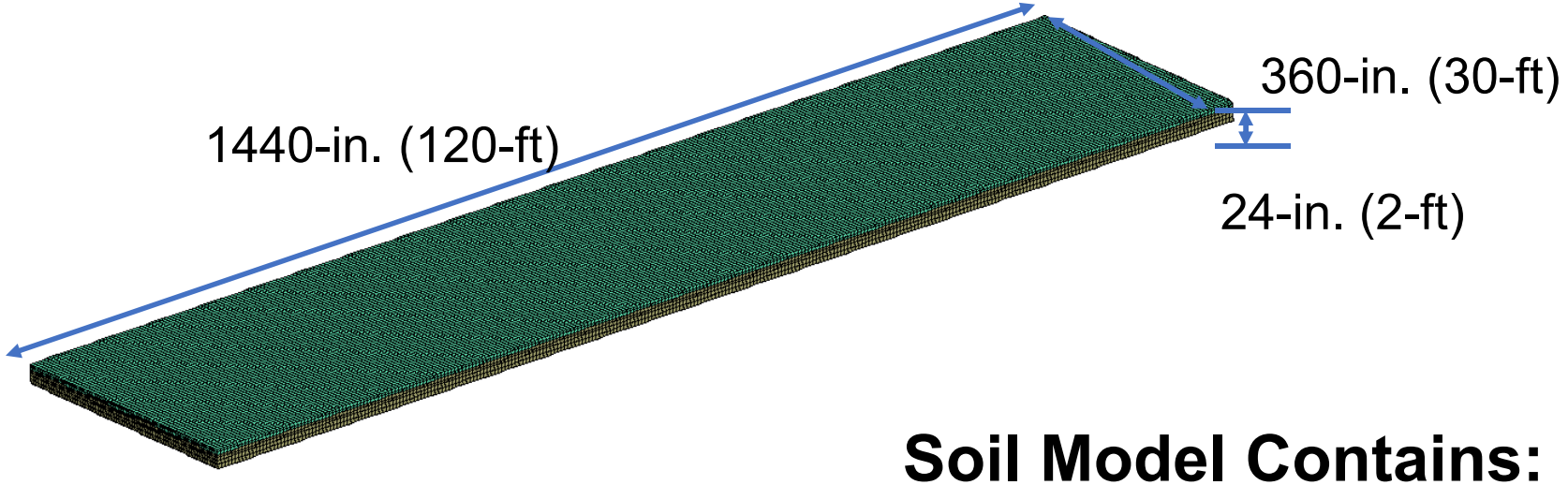


Soil Model Contains:

- 1 Part
- 1 Material card
- 170,082 Nodes
- 125,280 Solid elements
- 1 Boundary SPC to fix bottom nodes and nodes on two sides

```
*MAT_SOIL_AND_FOAM_TITLE
Gantry Unwashed Sand (GUS)
$#     mid        ro         g        bulk       a0        a1        a2        pc
     99510 1.96E-4  3340.0   19370.0    6.326     3.707    0.5432    -1.0
$#     vcr        ref       lcid
       0.0        0.0          0
$#    eps1       eps2       eps3       eps4       eps5       eps6       eps7       eps8
       0.0  -0.00252  -0.00479  -0.00703  -0.00917   -0.0103  -0.01143  -0.01254
$#    eps9      eps10
 -0.01362  -0.01599
$#      p1         p2         p3         p4         p5         p6         p7         p8
       0.0       10.0       20.0       30.0       40.0       45.0       50.0       55.0
$#      p9        p10
     60.0      71.15
```

Layered Soil Model




```
*MAT_SOIL_AND_FOAM_TITLE
Carson Sink Wet
$    MID        RO         G         K        A0        A1        A2        PC
       504  0.000135       500     12600     1.968     1.858     0.439        -1
$    VCR       REF
       0.0       0.0
$   EPS1      EPS2      EPS3      EPS4      EPS5      EPS6      EPS7      EPS8
          0    -0.007   -0.0102    -0.013    -0.019    -0.063    -0.125    -0.185
$    EPS9     EPS10
       -0.22     -0.259
$      P1        P2        P3        P4        P5        P6        P7        P8
          0       4.5      5.36         6         7        12      19.6        32
$      P9       P10
         47        67
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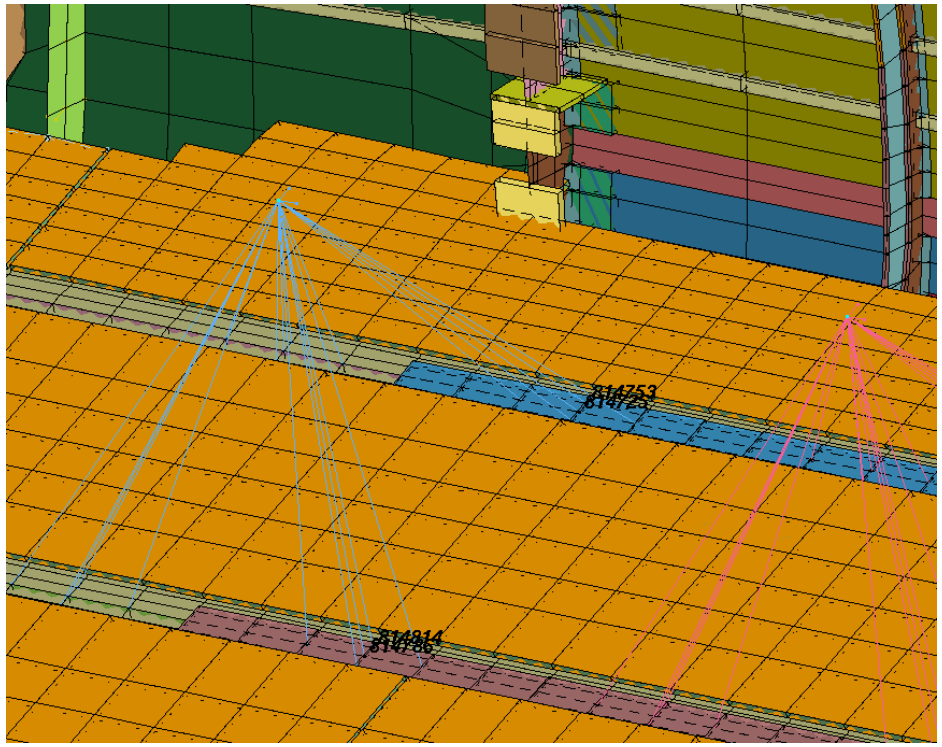
Soil Model Contains:

- 2 Parts
- 2 Material cards
- 170,082 Nodes
- 125,280 Solid elements
- 1 Boundary SPC to fix bottom nodes and nodes on two sides

Description of the F28 Model Development

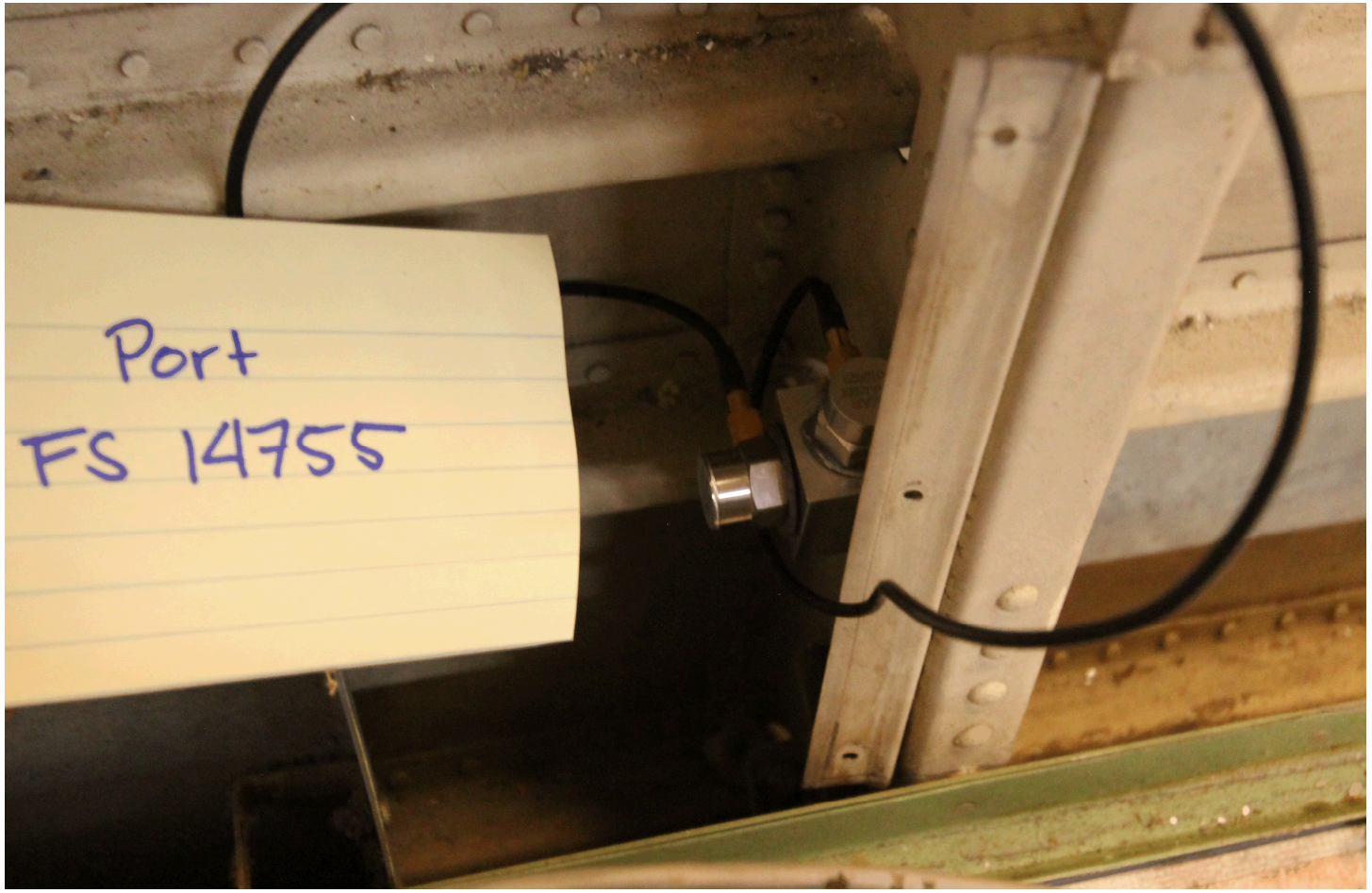


Seat Accelerometer

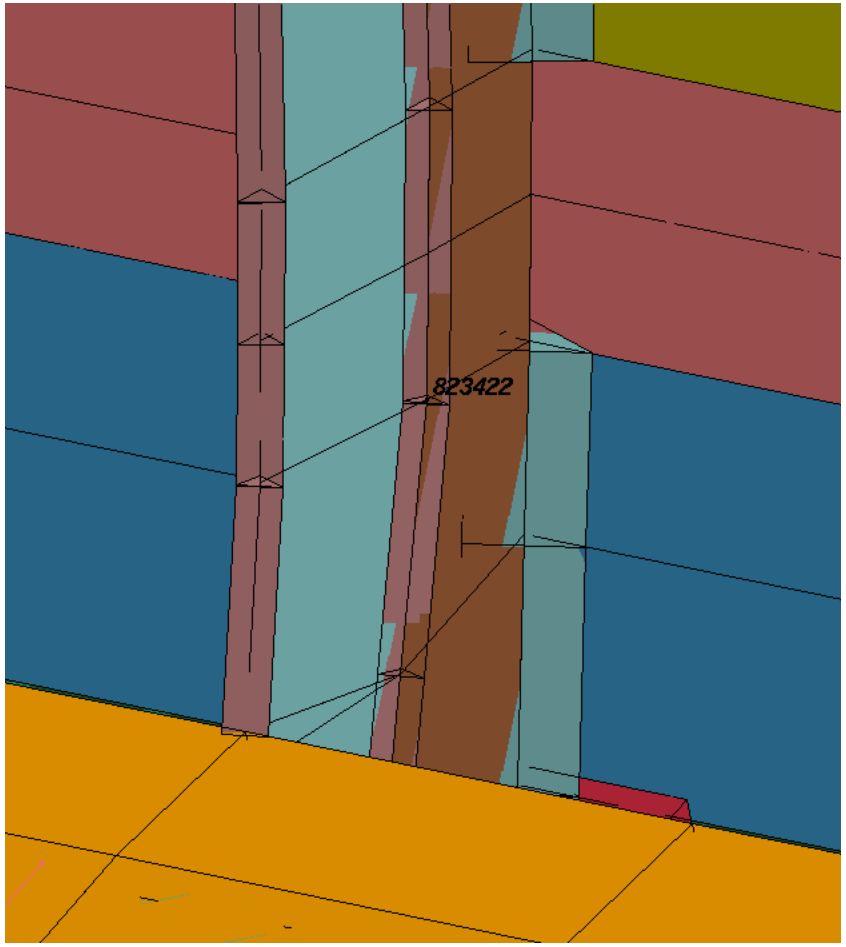


Four nodes where the seat mass attaches to the rear seat rail

Description of the F28 Model Development



Frame Accelerometer



Nodes on the frame, located 3-4-inches above the floor

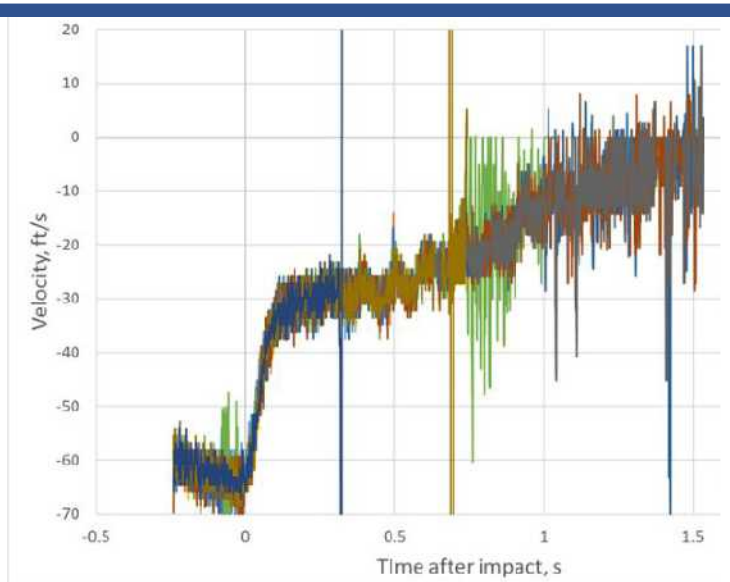
Test-Analysis Comparisons: Inertial Properties

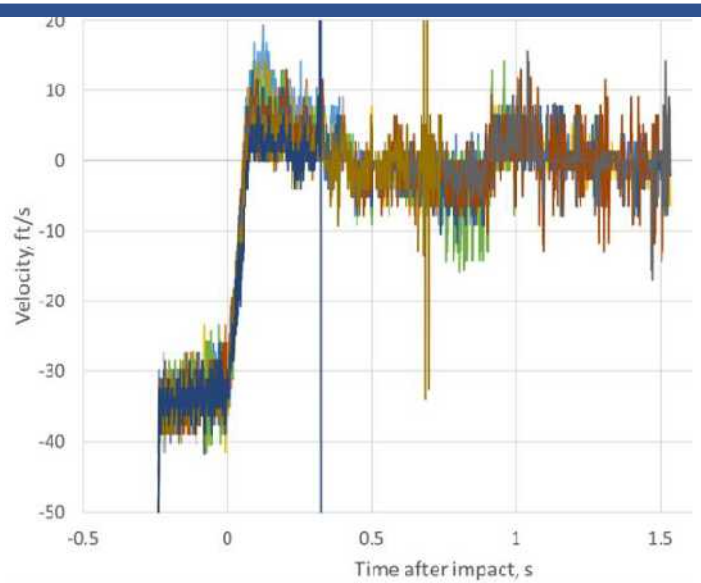
Parameter	Model	Test	Difference (percent)
Weight, lb.	32,951.4	33,306	354.6 (1.06%)
CGx, in.	449.5	455.0	5.5 (1.2%)
CGy, in.	0.89	0.0	0.89
CGz, in.	-85.3	-80.0	5.3 (6.6%)

Test-Analysis Comparisons: Kinematics

TEST

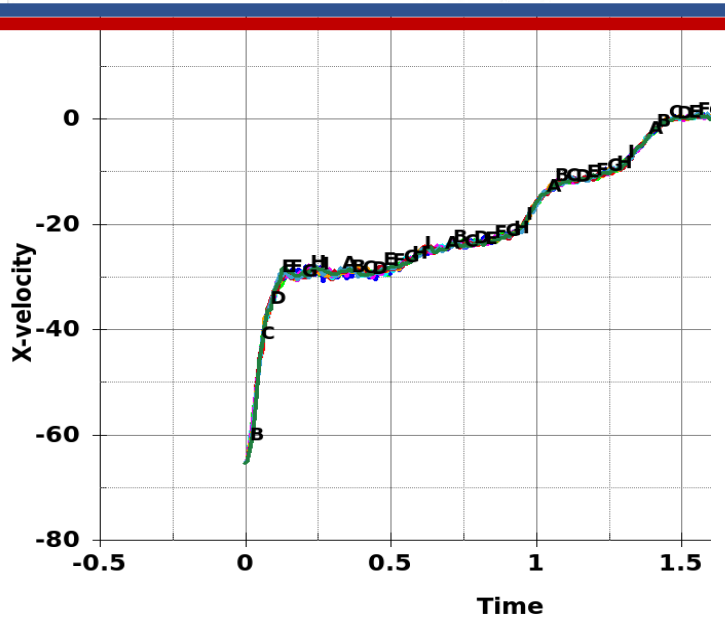
Photogrammetric responses of 10+ targets, forward and vertical velocity

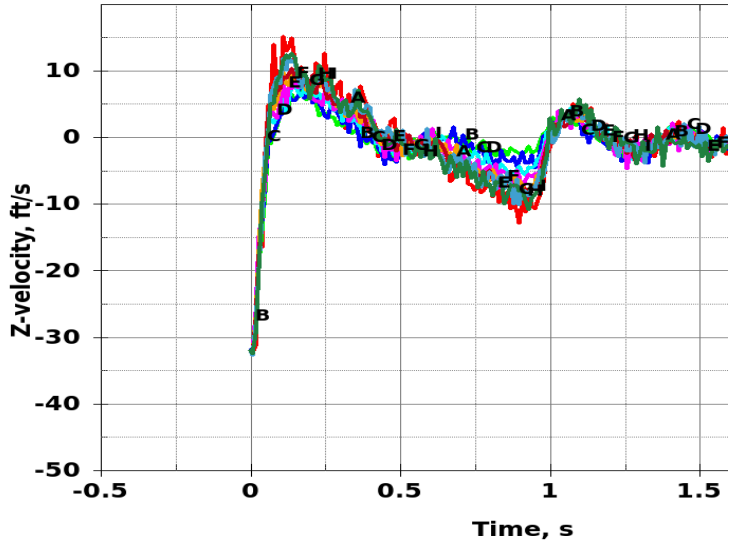




Analysis

Forward and vertical velocity responses of 10+ nodes on the surface of the model



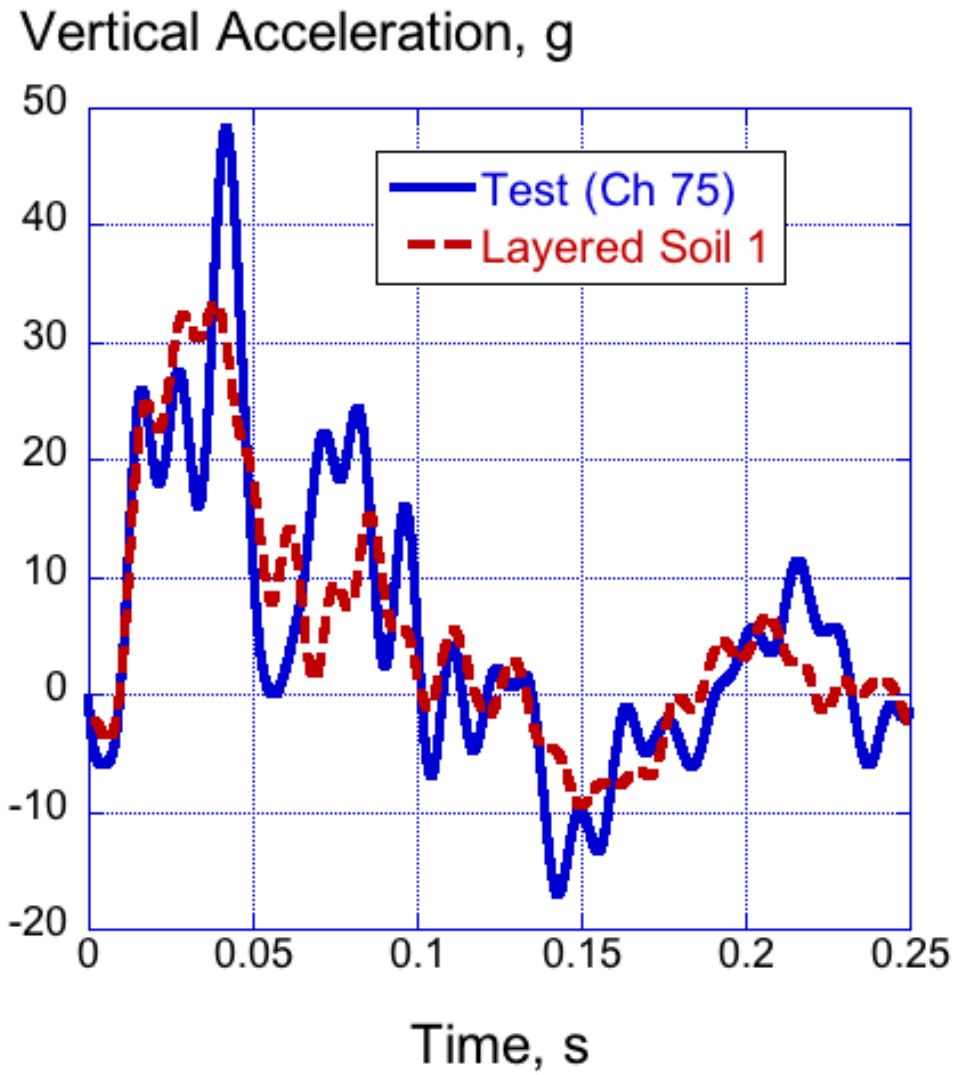


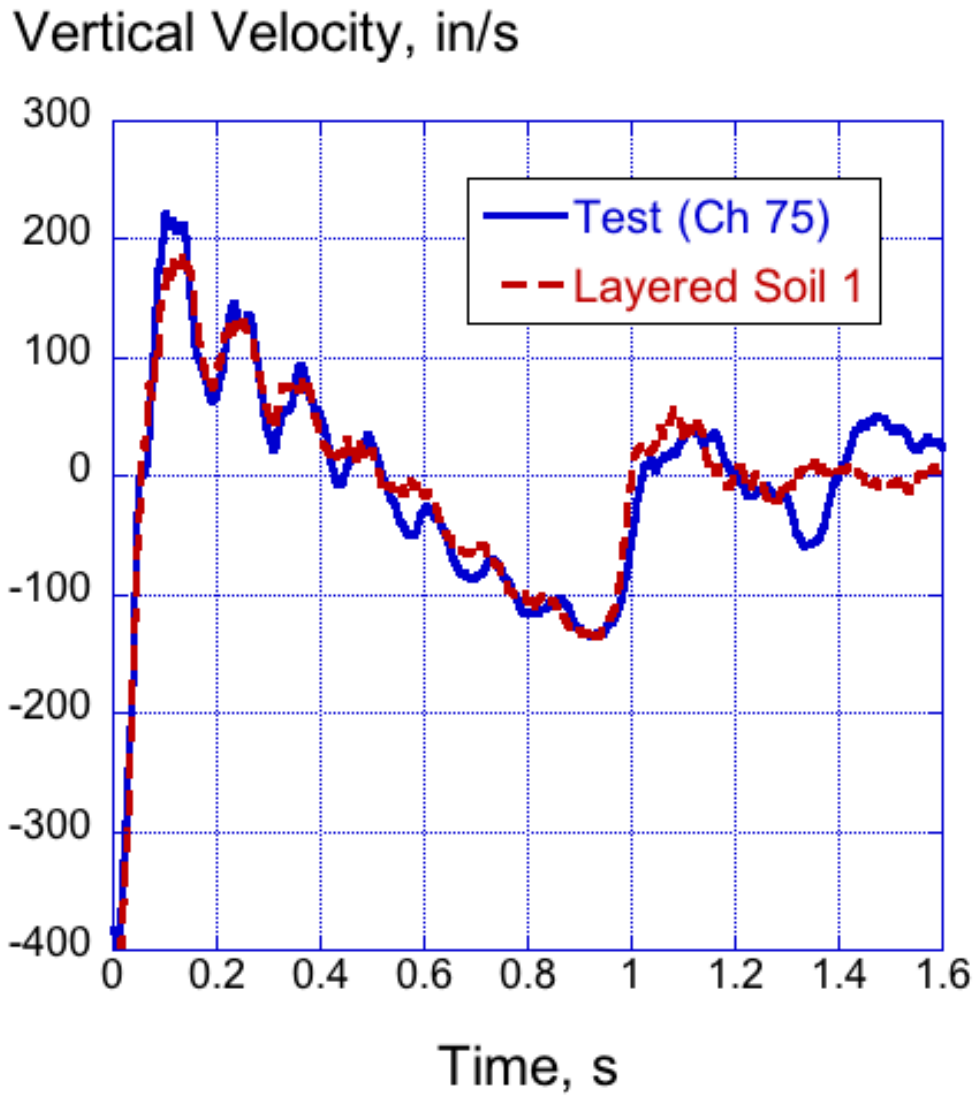
Test-Analysis Comparisons: Kinematics



Parameter	Distance to the Rigid Wall
Post-test measurement	21.5-ft.
Model prediction	21.2-ft.
Percentage difference	1.4%

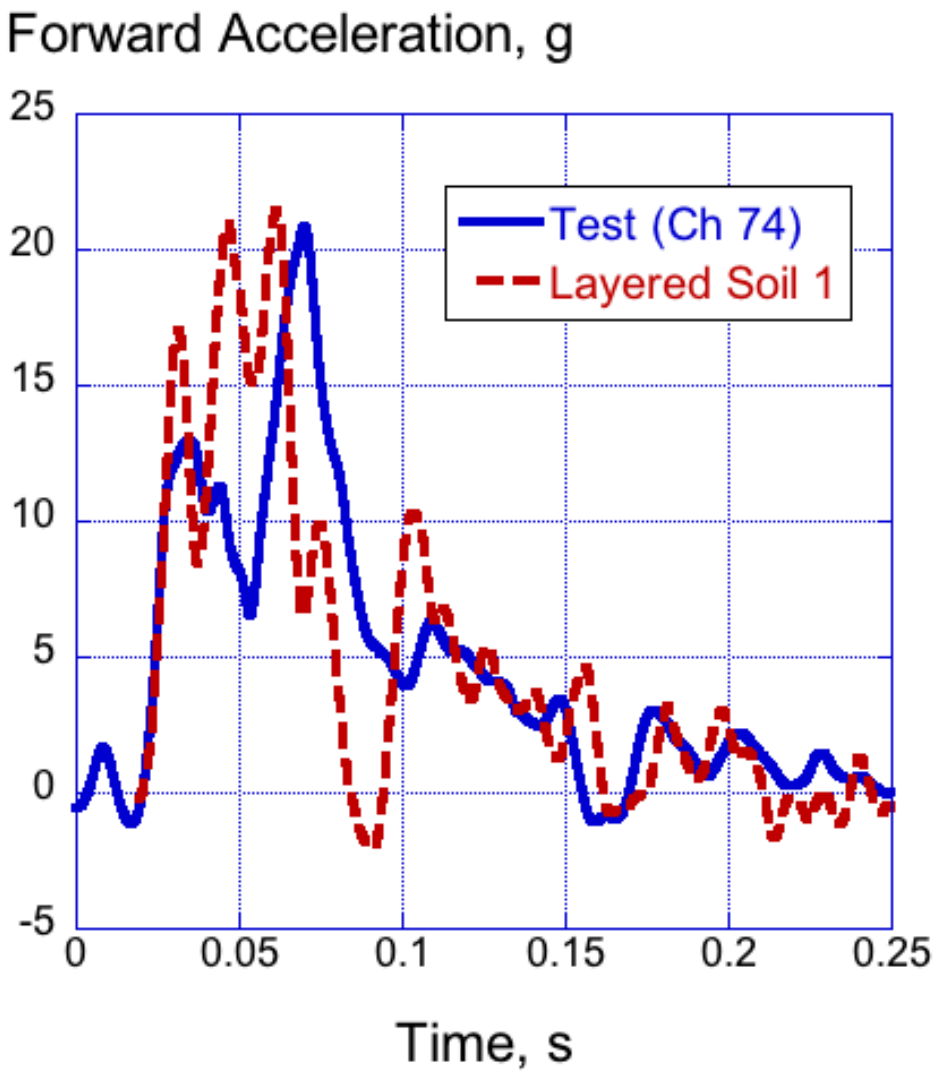
Test-Analysis Comparison: Pilot Seat Vertical Responses

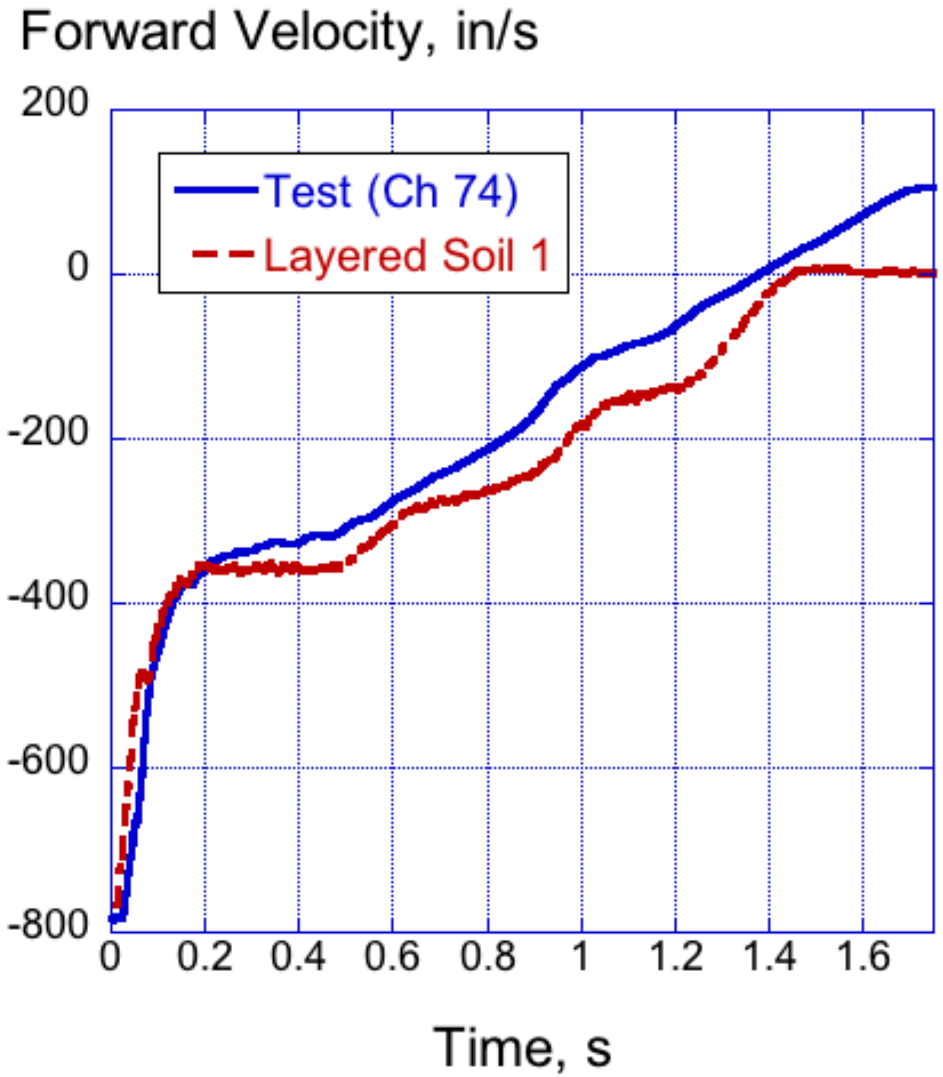




*Both test and analytical responses were filtered using a Butterworth 60 Hz low pass filter

Test-Analysis Comparison: Pilot Seat Forward Responses

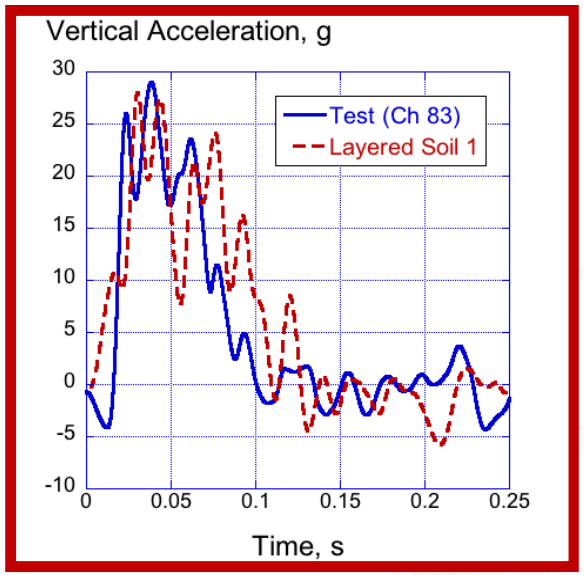


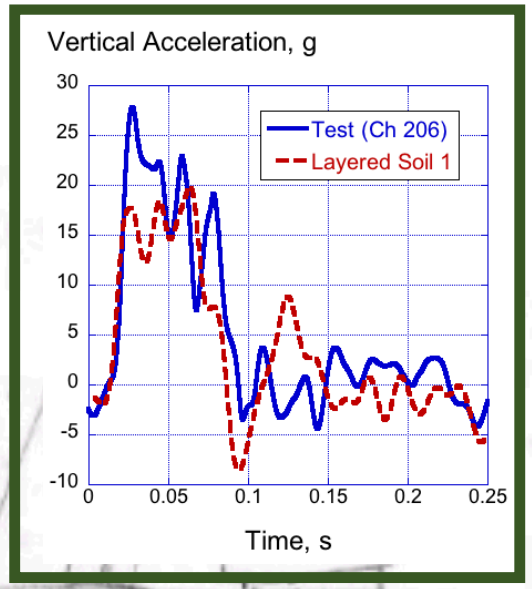


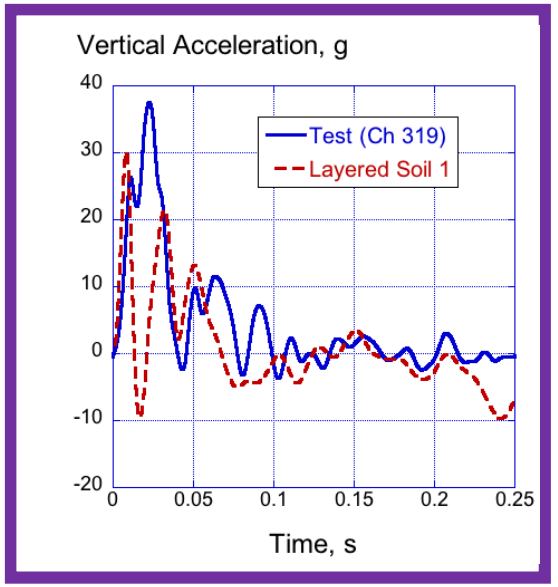
TAC: Cabin Seat Base Vertical Acceleration Responses

Star-board

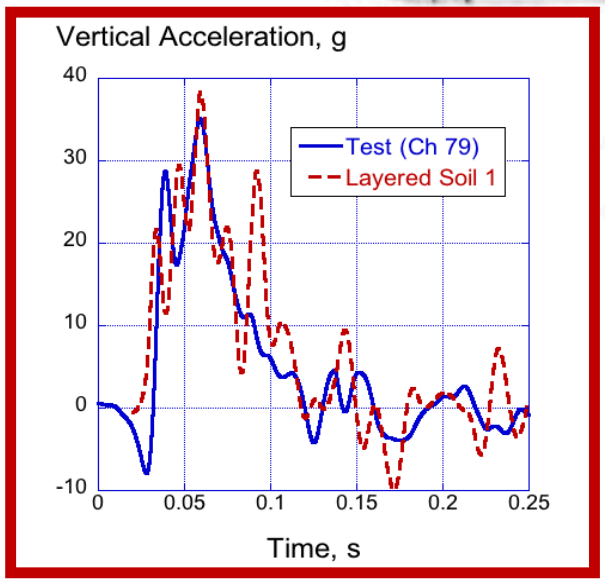
Port

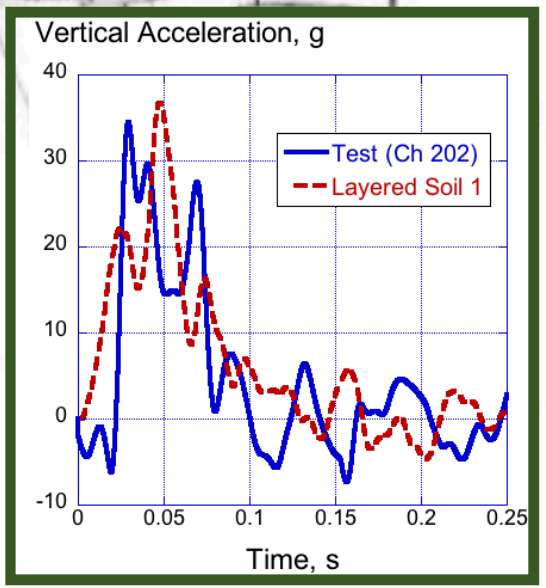


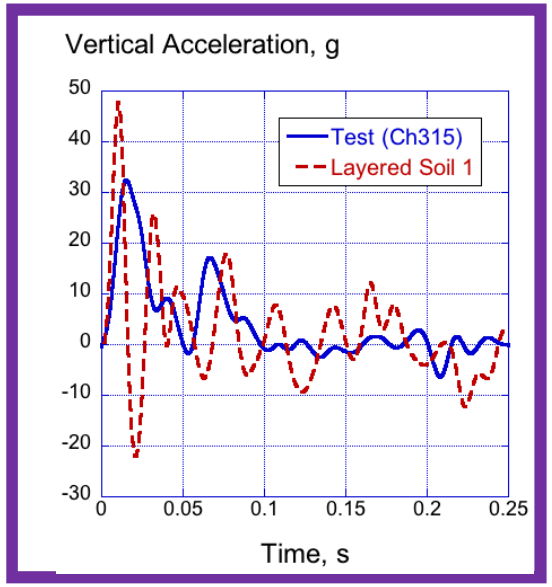




Row 2 **Row 5** **Row 10**







TAC: Cabin Seat Base Forward Acceleration Responses

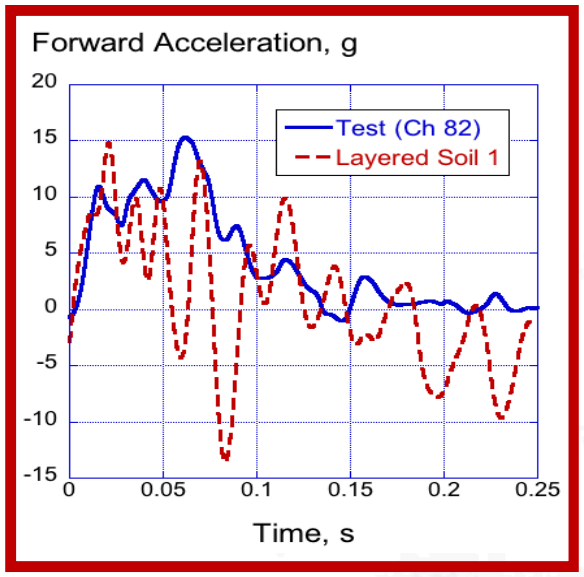
Star-board

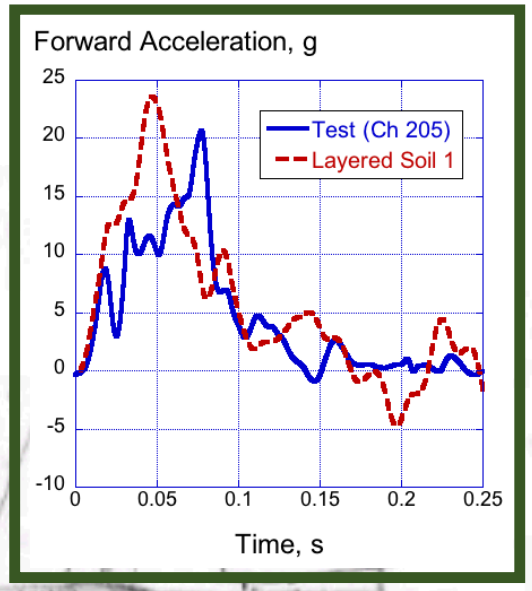
Port

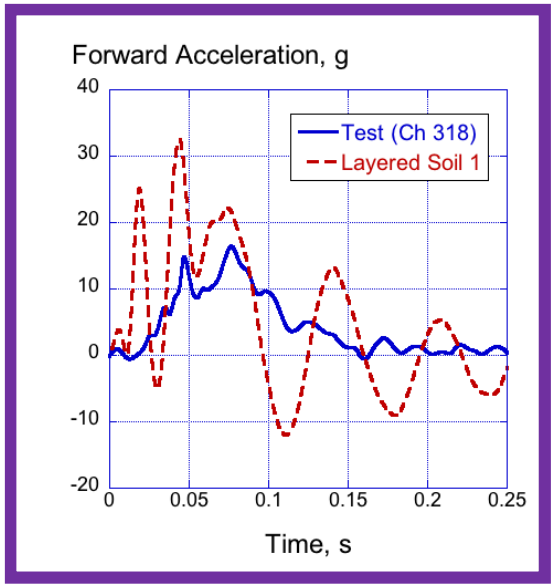
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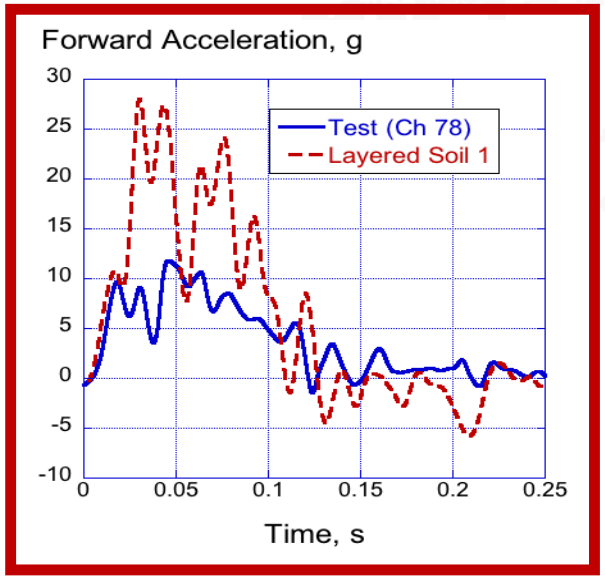
Row 5

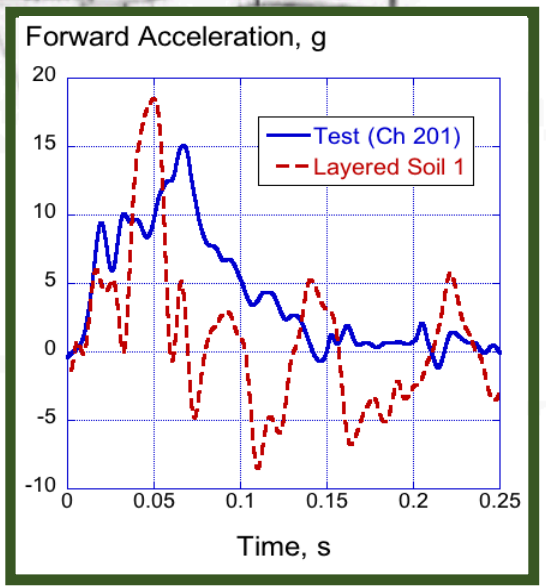
Row 10

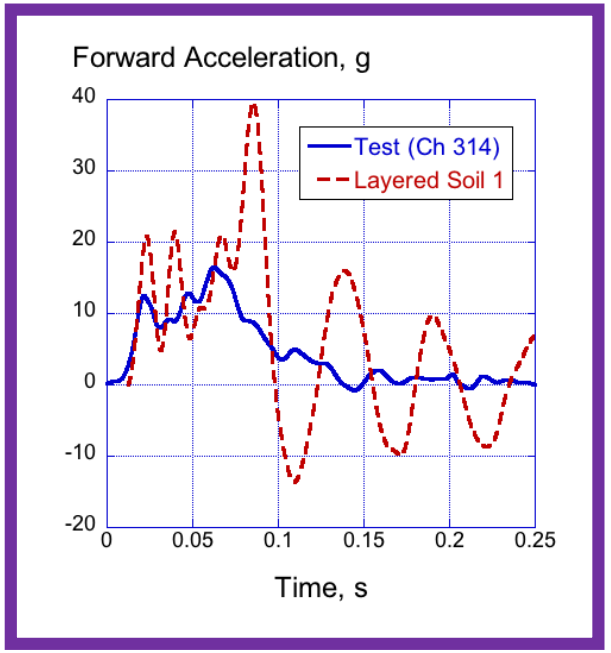




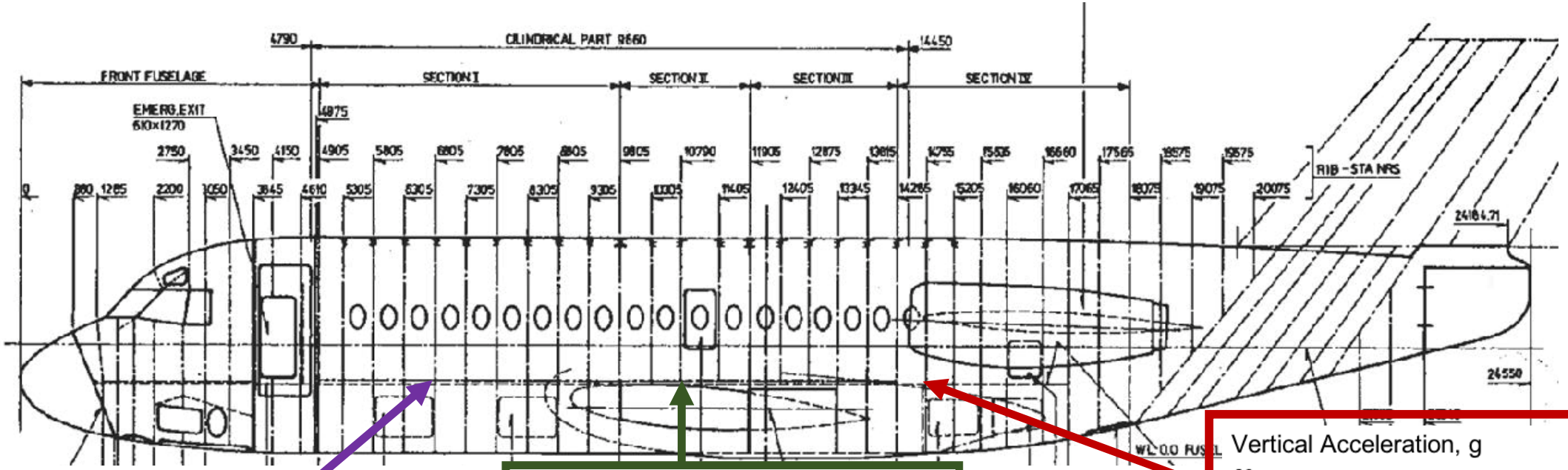


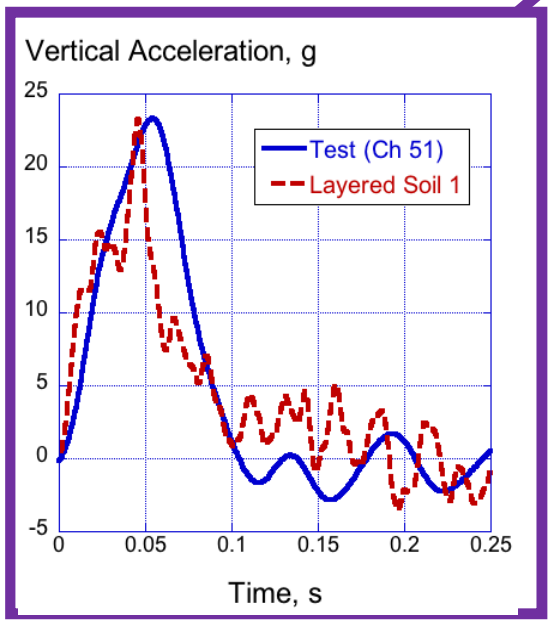


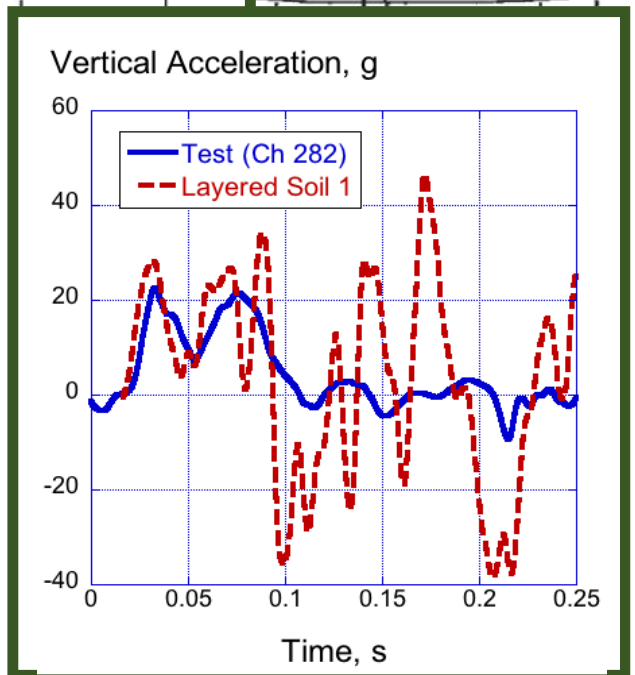


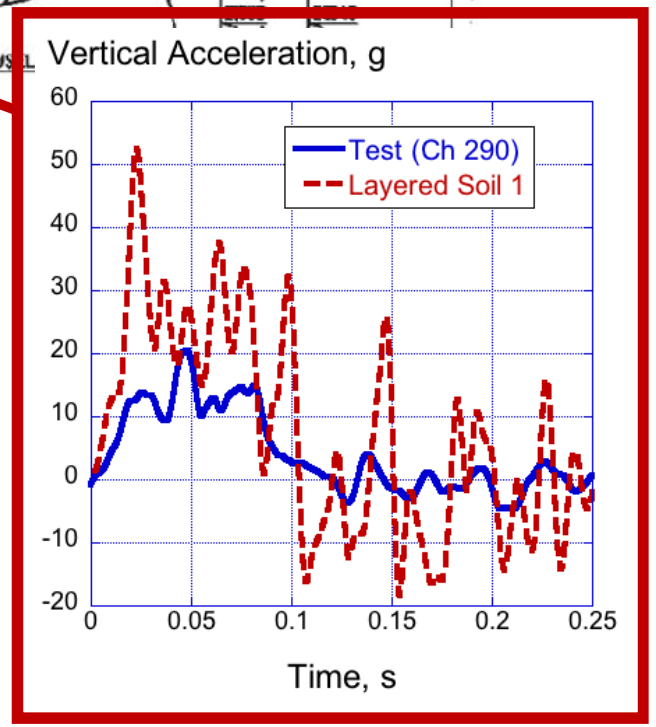


TAC: Cabin Frame Vertical Acceleration Responses (Port Side)

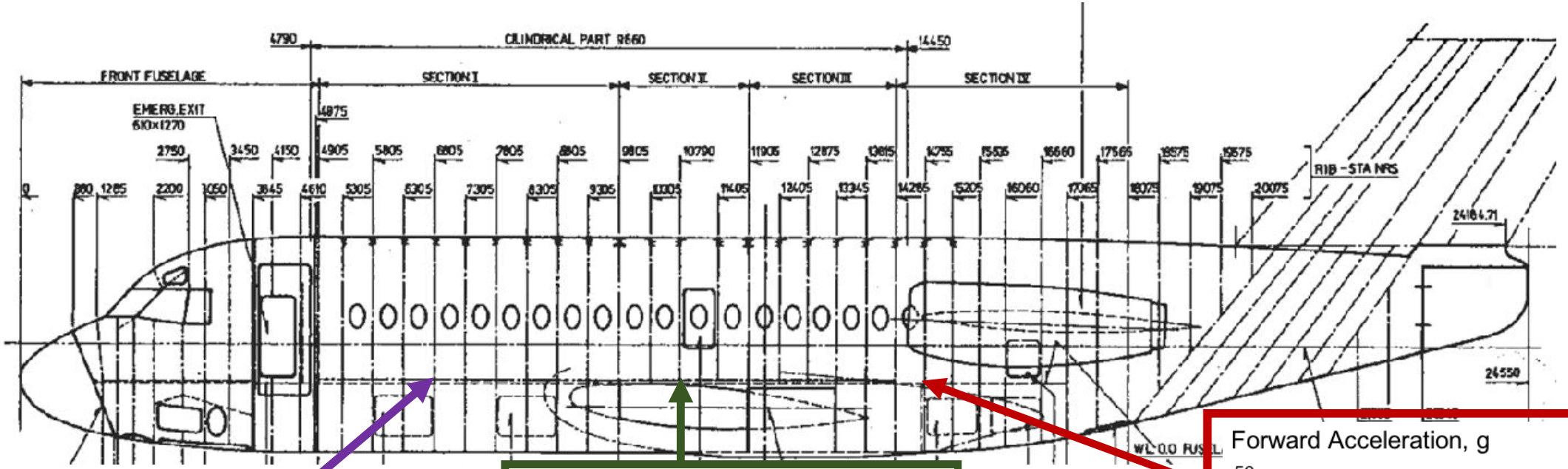


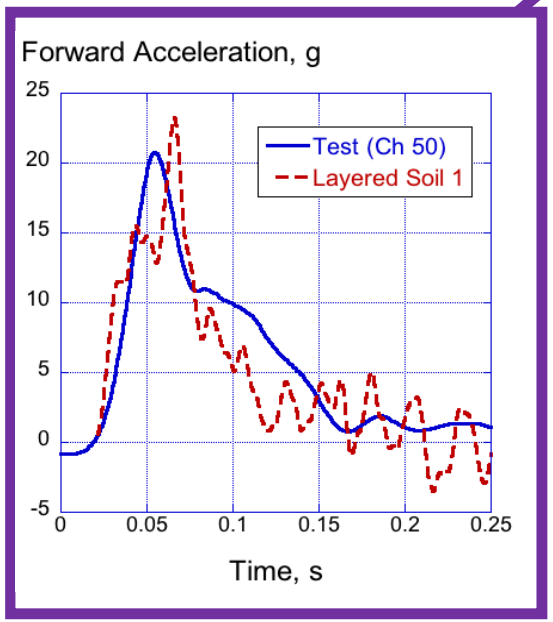


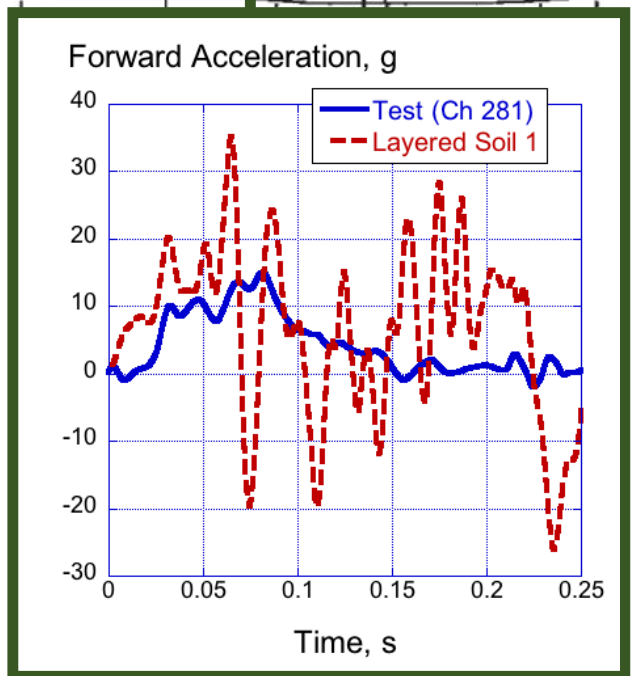


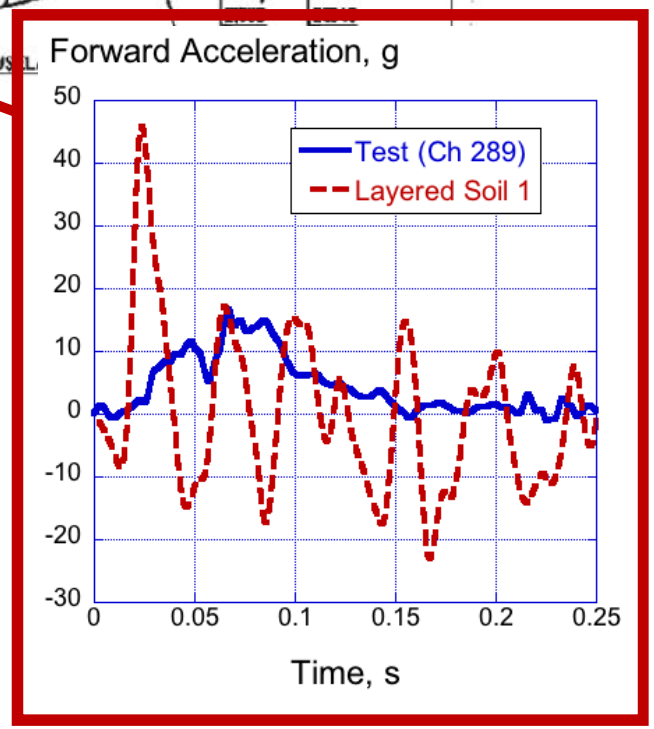


TAC: Cabin Frame Forward Acceleration Responses (Port Side)

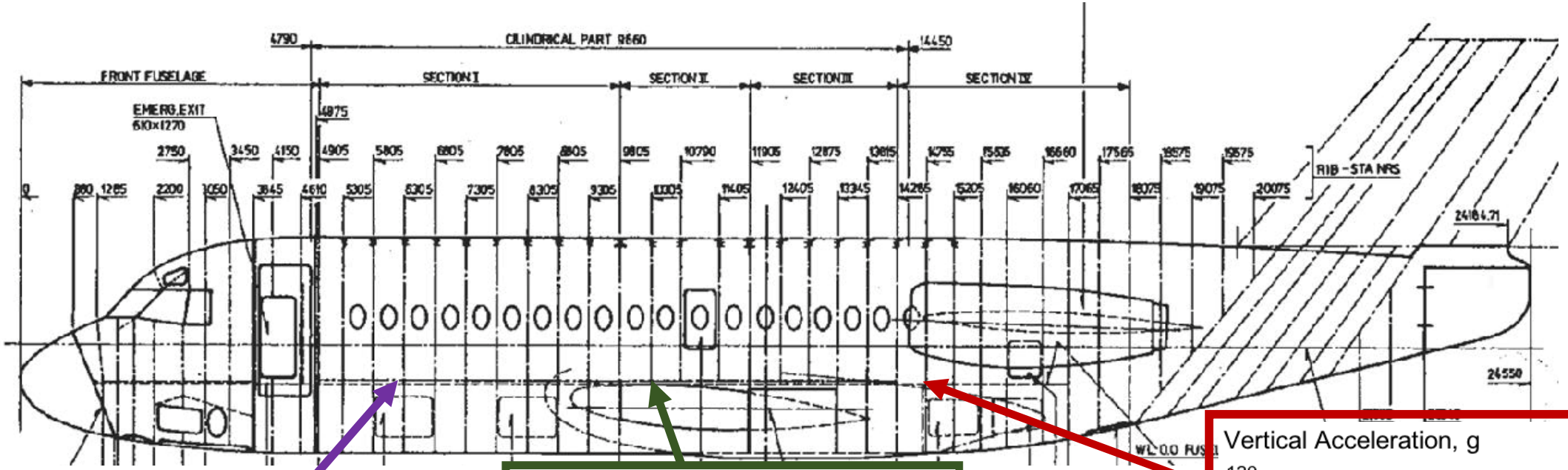


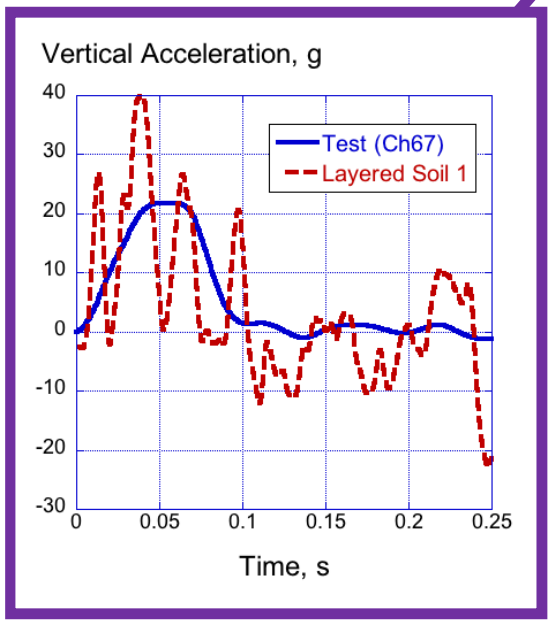


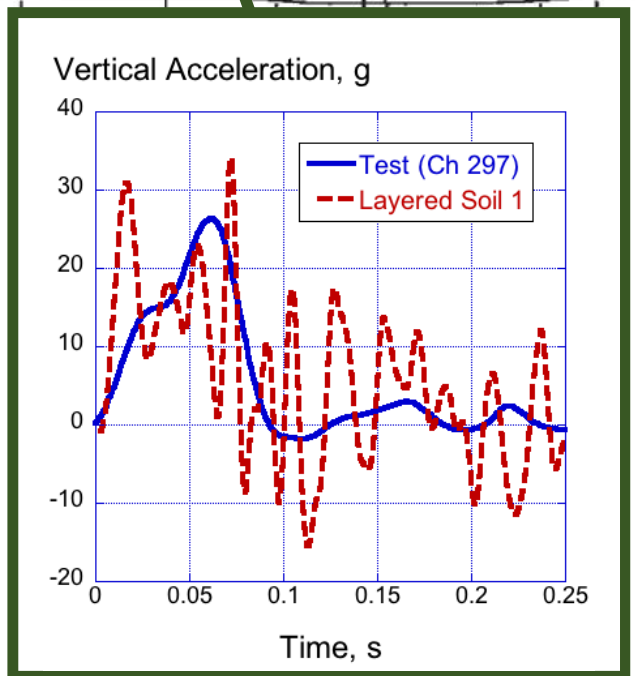


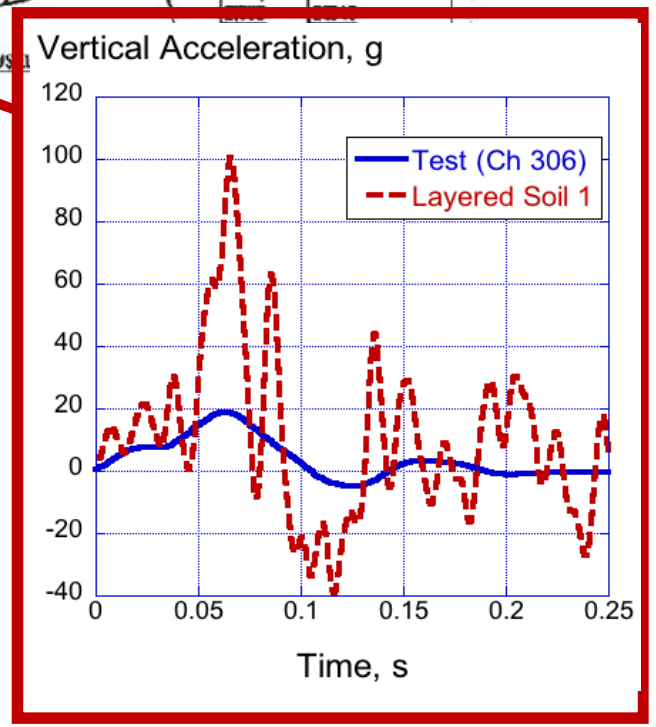


TAC: Cabin Frame Vertical Acceleration Responses (Starboard Side)

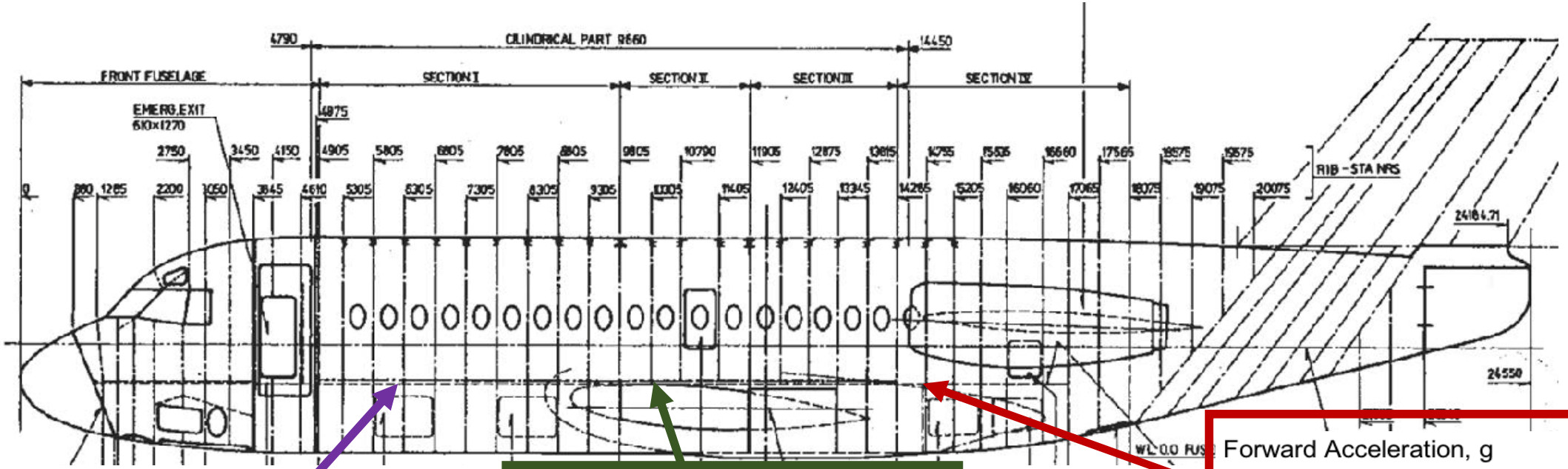


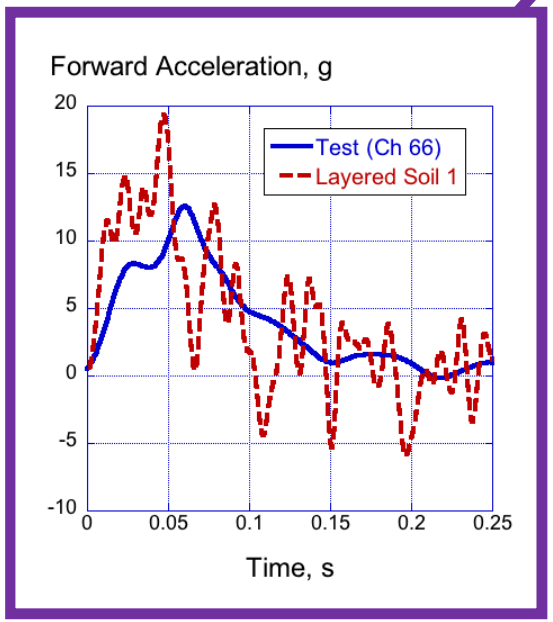


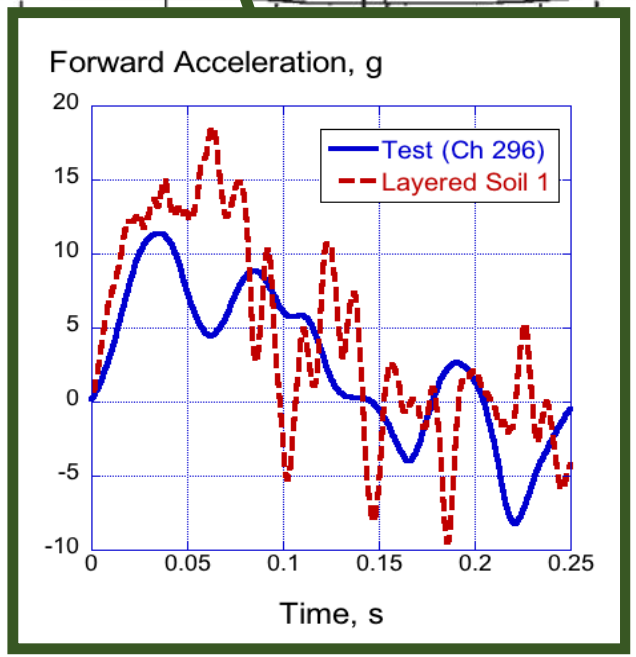


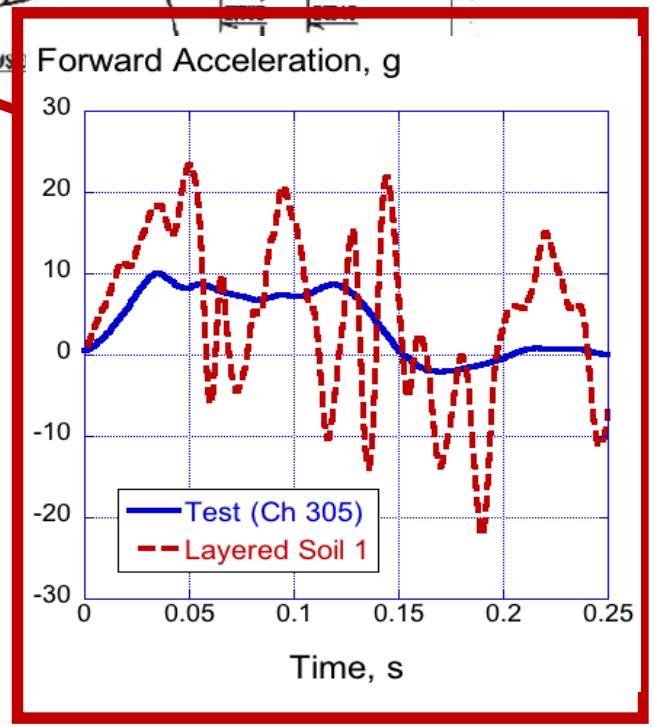


TAC: Cabin Frame Forward Acceleration Responses (Starboard Side)

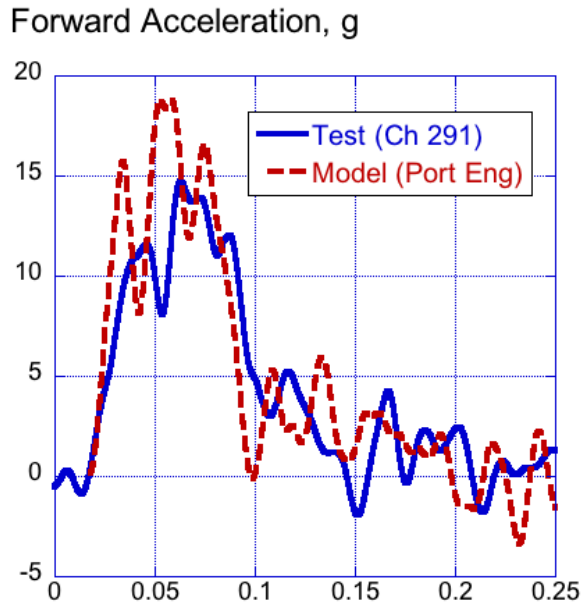


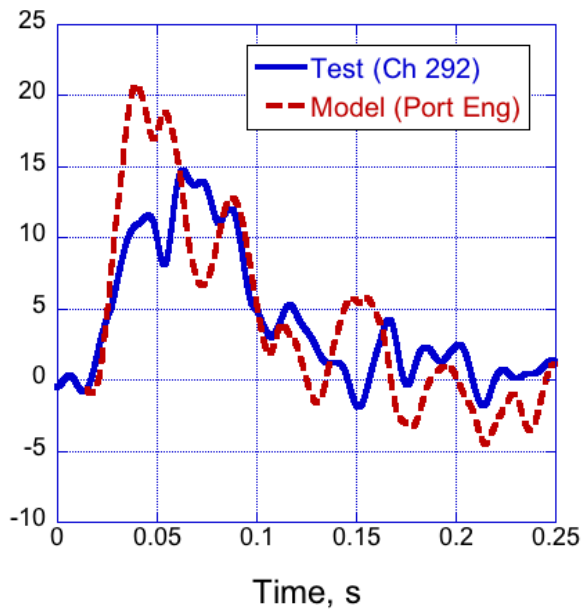


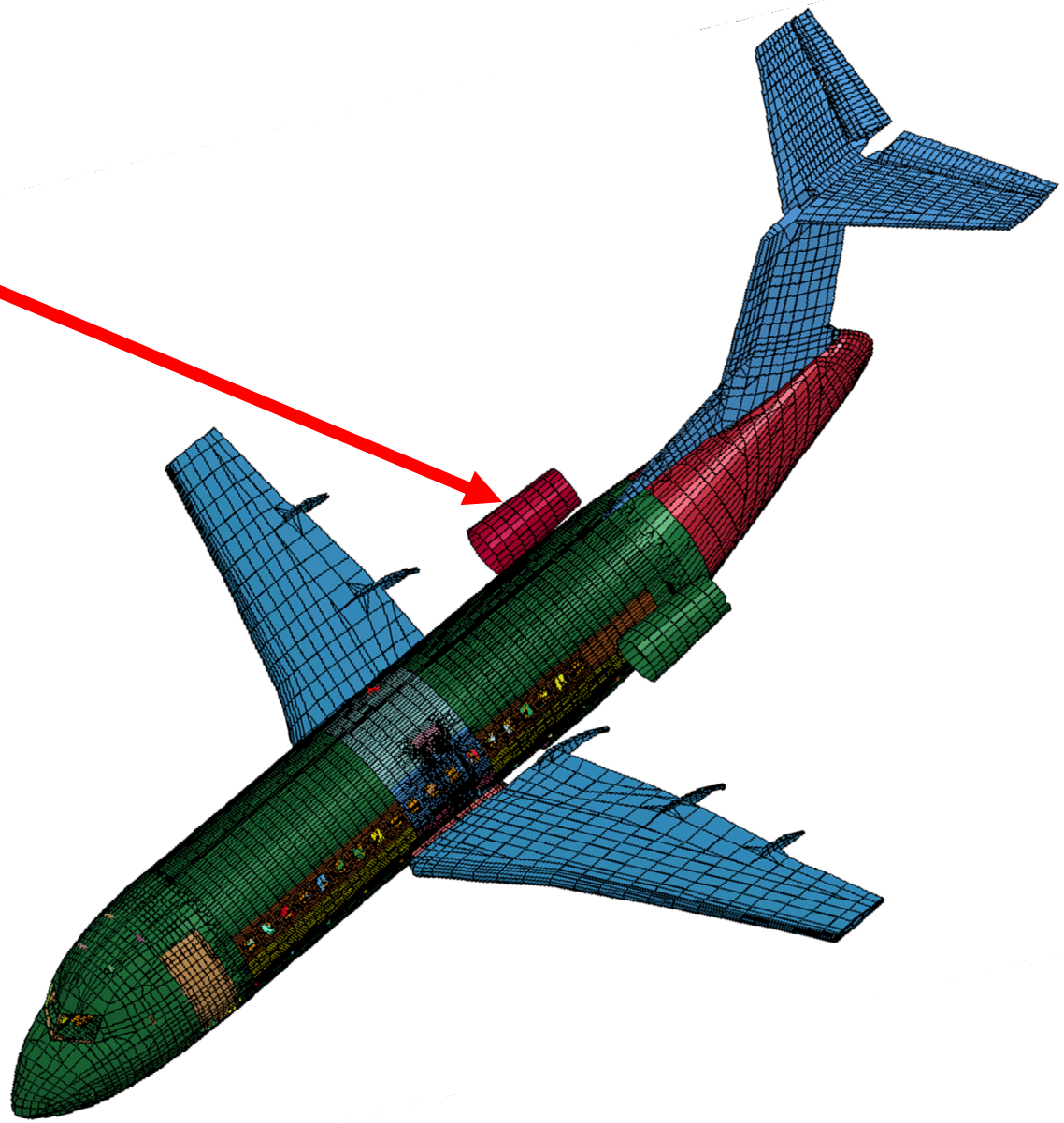




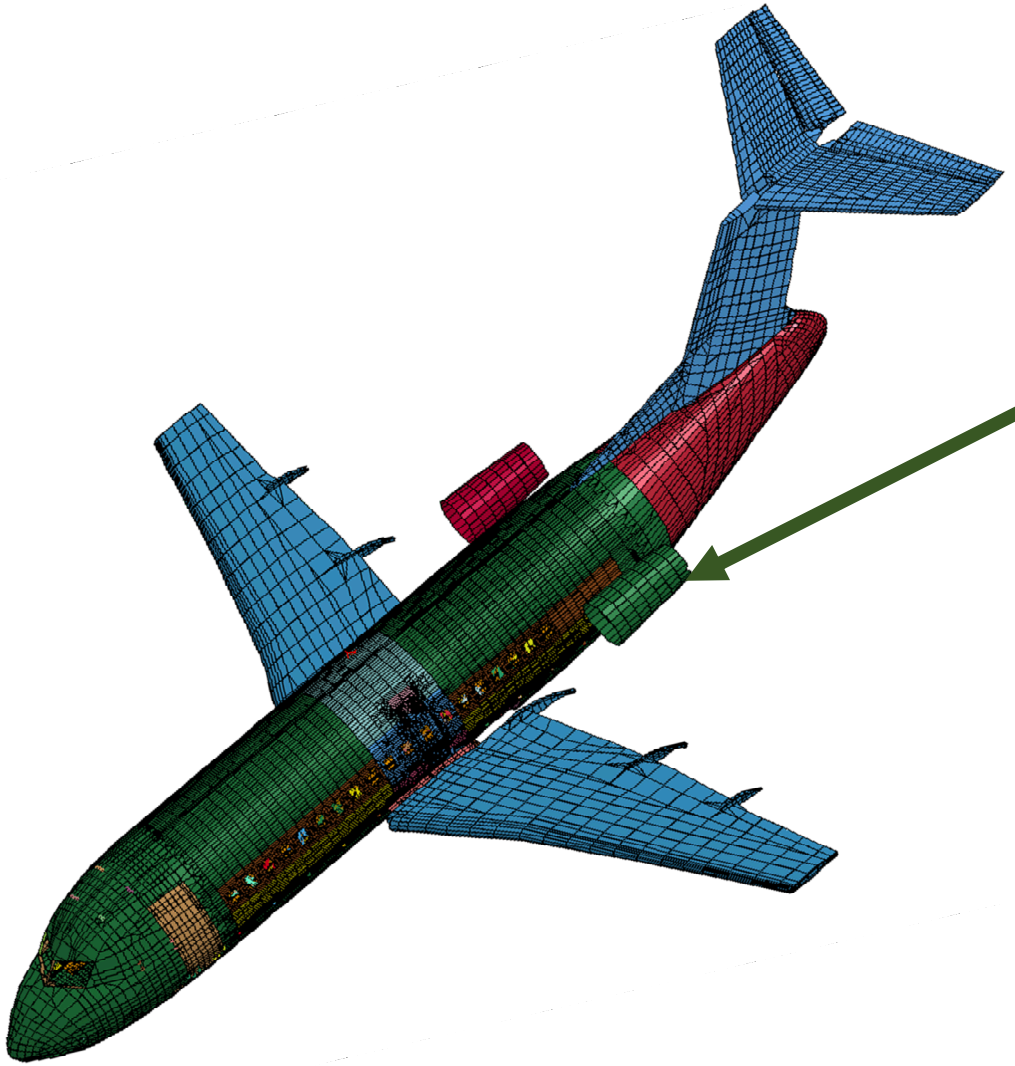
TAC: Nose, Port & Starboard Engines and Tail

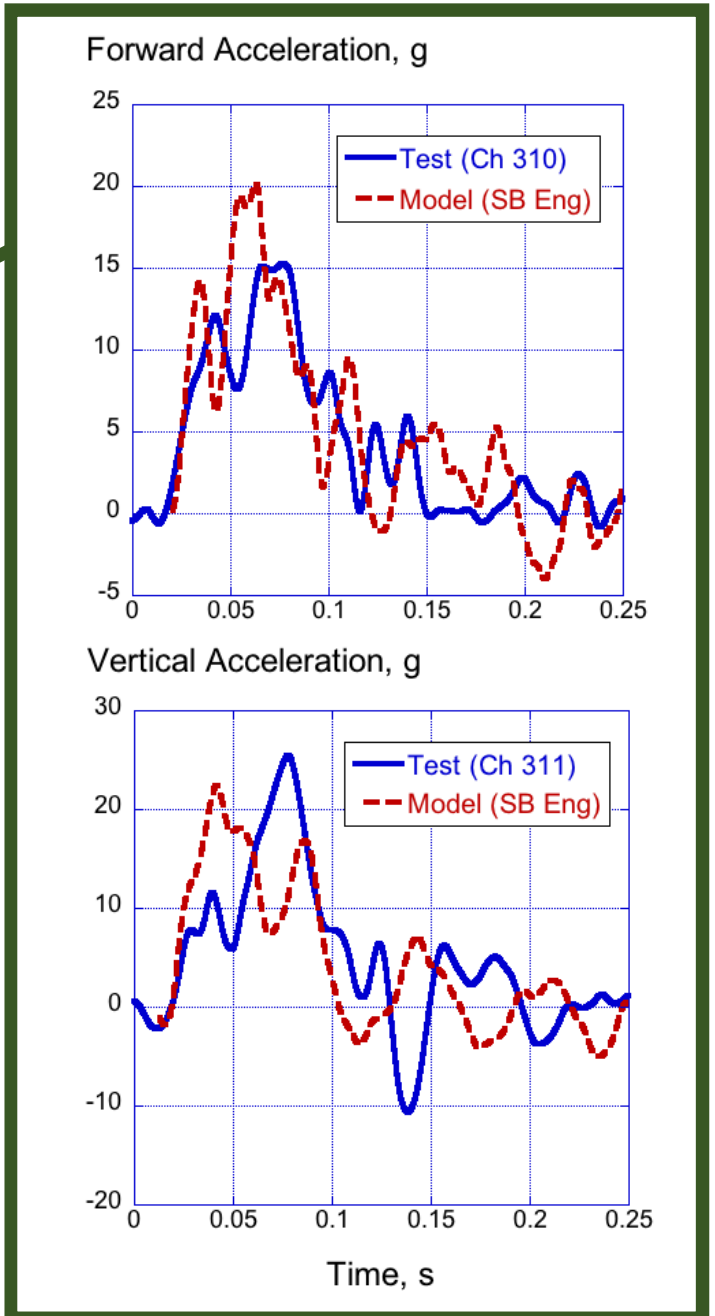






TAC: Nose, Port & Starboard Engines and Tail

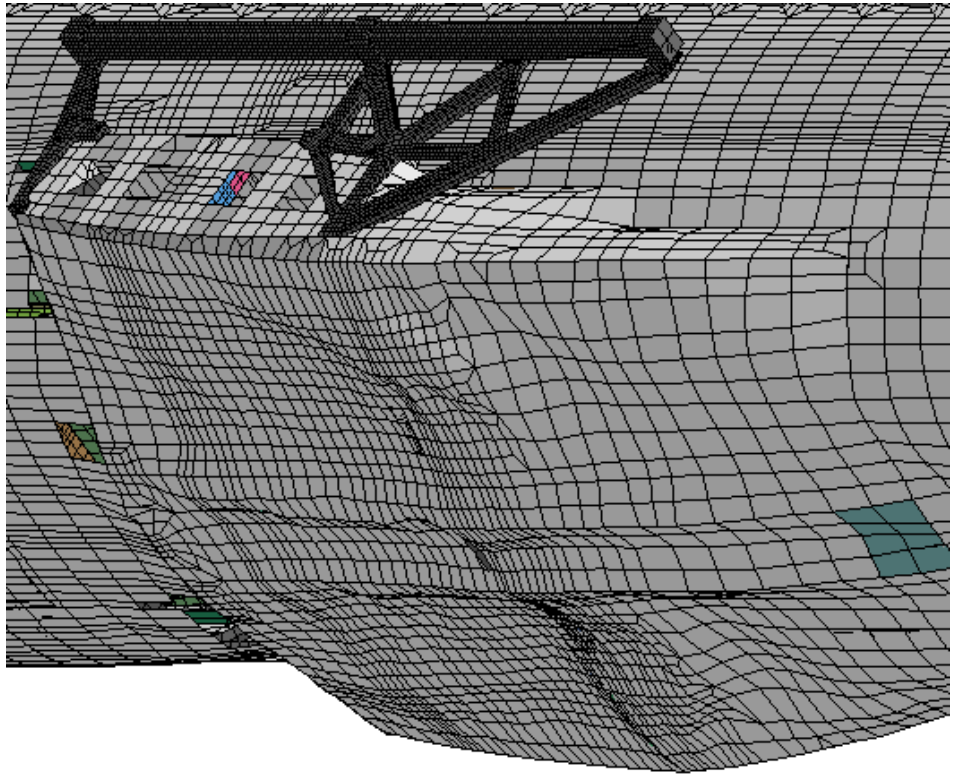




Test-Analysis Comparisons: Airframe Damage



Photo showing airframe damage, crushing and flattening of the bottom surface, and skin wrinkling



Model depiction showing crushing of the bottom of the wing-box

Conclusions

- A finite element model of the F28 aircraft was developed and executed using LS-DYNA
- Inertial and kinematic comparisons with test data showed excellent agreement
- Time history responses were inconsistent, some channels showed good agreement with test, some showed poor agreement
- Currently, using the ISO 16250 standard to evaluate the test-analysis comparisons quantitatively

Future Work

- Once we are satisfied that the model is “validated,” water impact and ditching simulations will be performed