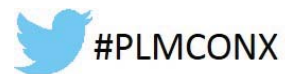


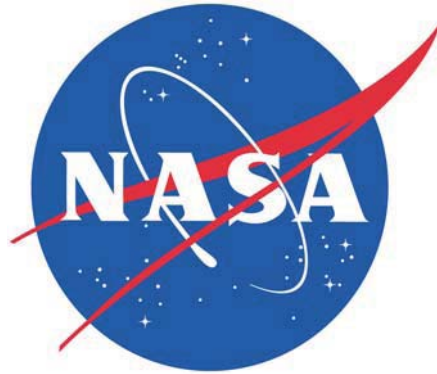
SLS Crew Access Arm Crawler- Transport Dynamic Analysis

Siemens PLM Connection 2014
Orlando, FL
June 16-19



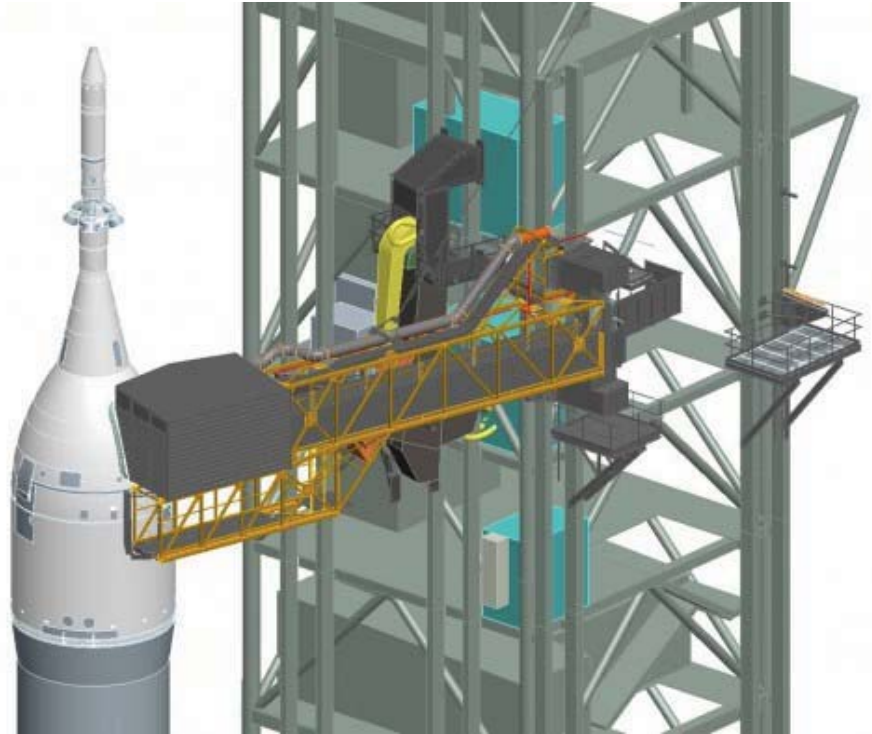
Presenters

- Tyler Sorchik & Okon Anwana
 - NASA, ESC Contract, Kennedy Space Center, FL



Background

- SLS Crew Access Arm
 - Operational interface with Orion
 - Commodity Panel and Contingency Access
 - Provides ingress and egress for astronauts
 - Arm weight: ~ 90 kip
 - Elevation: 280' from Mobile Launcher deck



Problem: Keep CAA extended or retract for crawler transport?

Keep Extended

- No additional operation
- High vibration concerns

Retract outside VAB

- Additional op to stop crawler, power up and retract arm
- More expensive
- Low vibration concerns

Why can't we leave the arm extended while transporting the vehicle to the pad?

Crawler Movement Info:

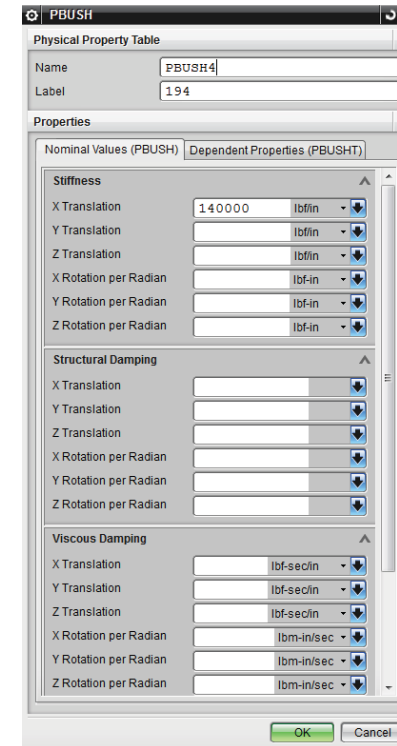
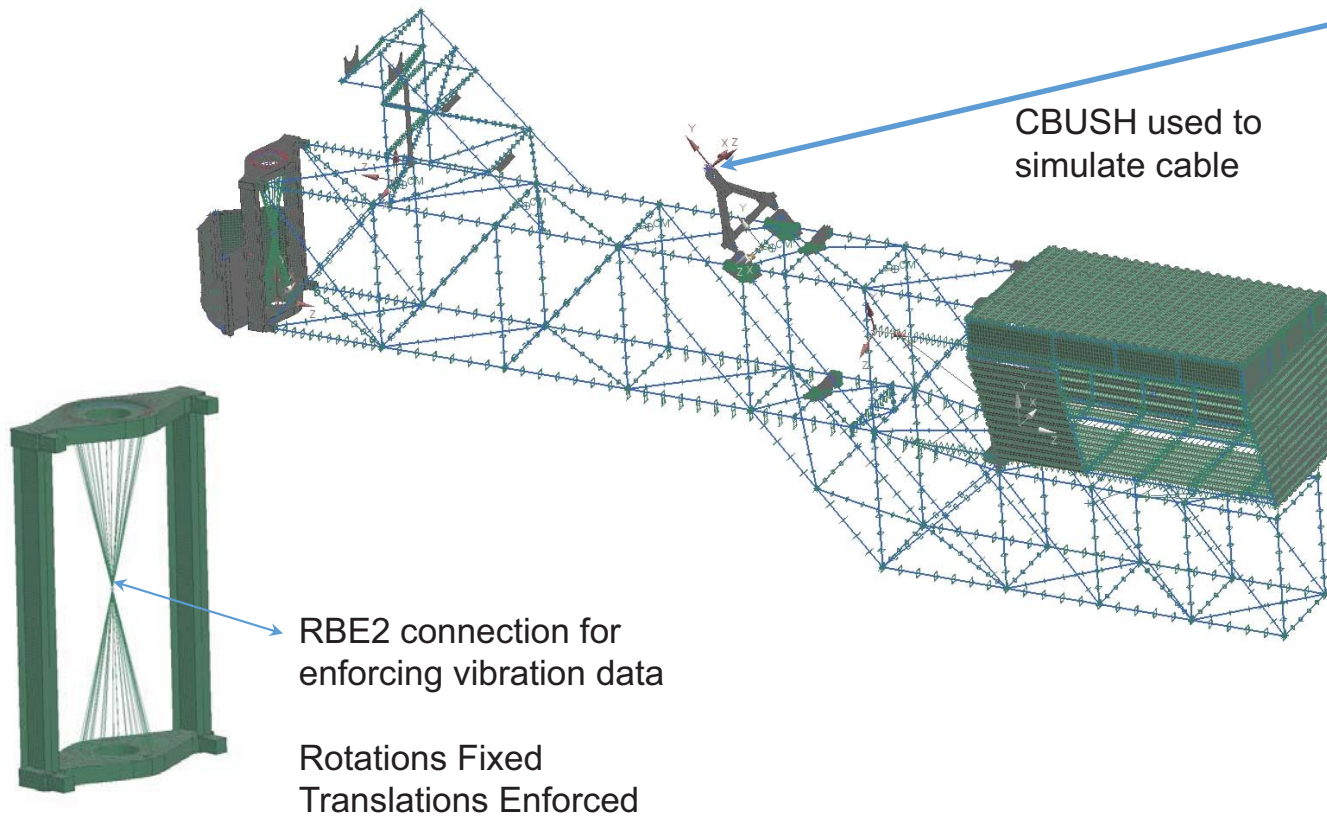
- Top Speed
 - 1.6 mph
- Time to Pad
 - ~5 hrs
- Capacity
 - 18,000,000 lbs



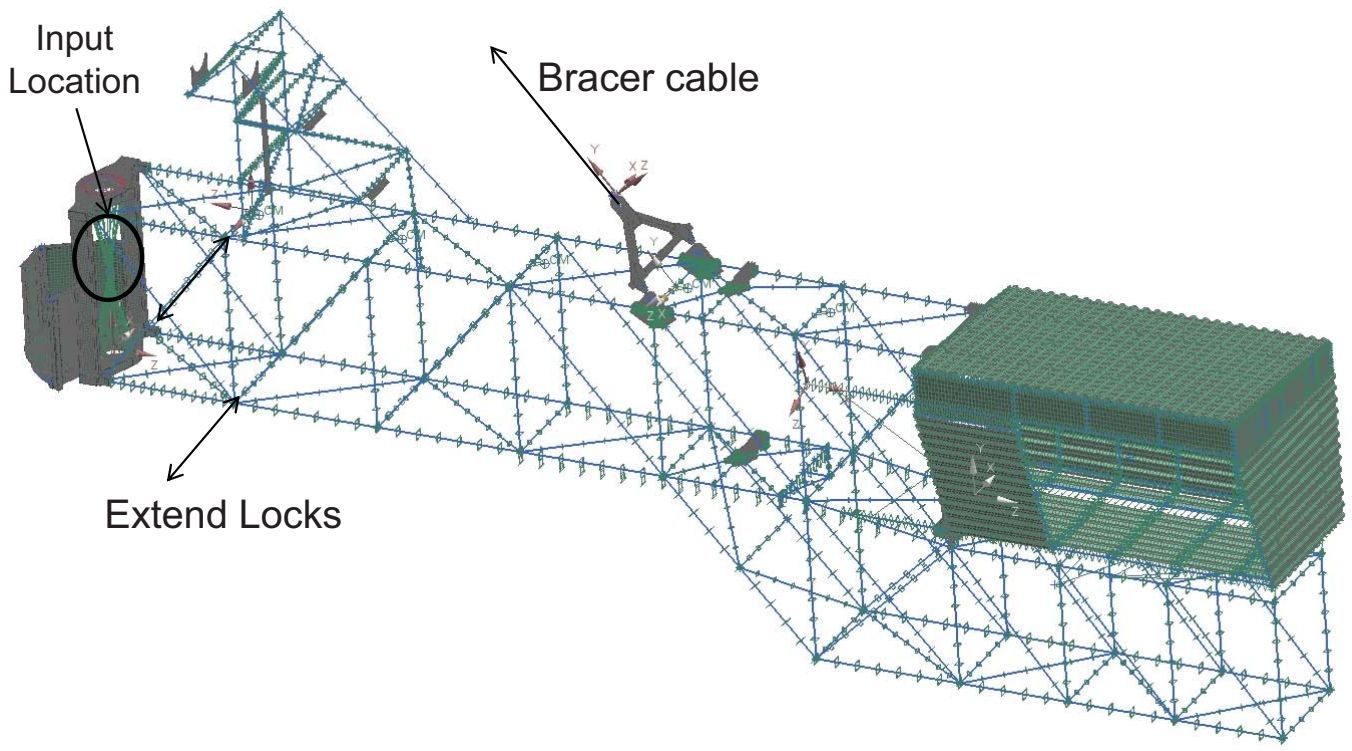
Preliminary Analysis Overview

- 80% mass participation, 100 Modes
- Assumed 4% viscous damping extended, 2% retracted
- No dynamic wind spectrum for transport wind
- Data from MSFC assumed to be mean data (one-sided PSDs)
- Bracer cable preloaded with enforced displacement (0.442" produces 46.6 kips pretension in cable)

Finite Element Model



Boundary Condition Scheme (Extended)



Arm vs. Tower Modes

- Arm first 5 modes:

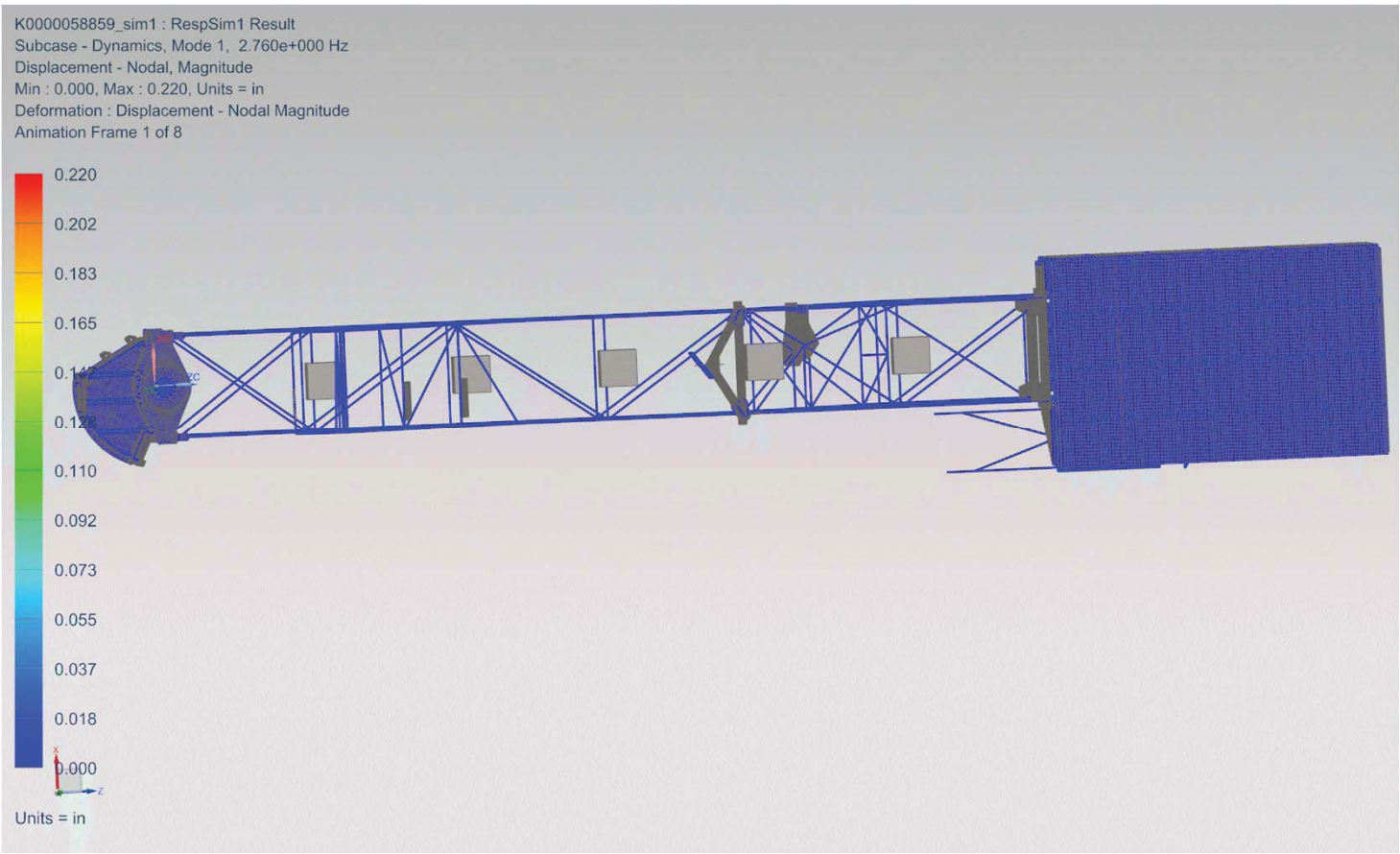
- Mode 1: 2.76 Hz
- Mode 2: 5.39 Hz
- Mode 3: 6.31 Hz
- Mode 4: 13.77 Hz
- Mode 5: 14.60 Hz

- Tower first 3 modes:

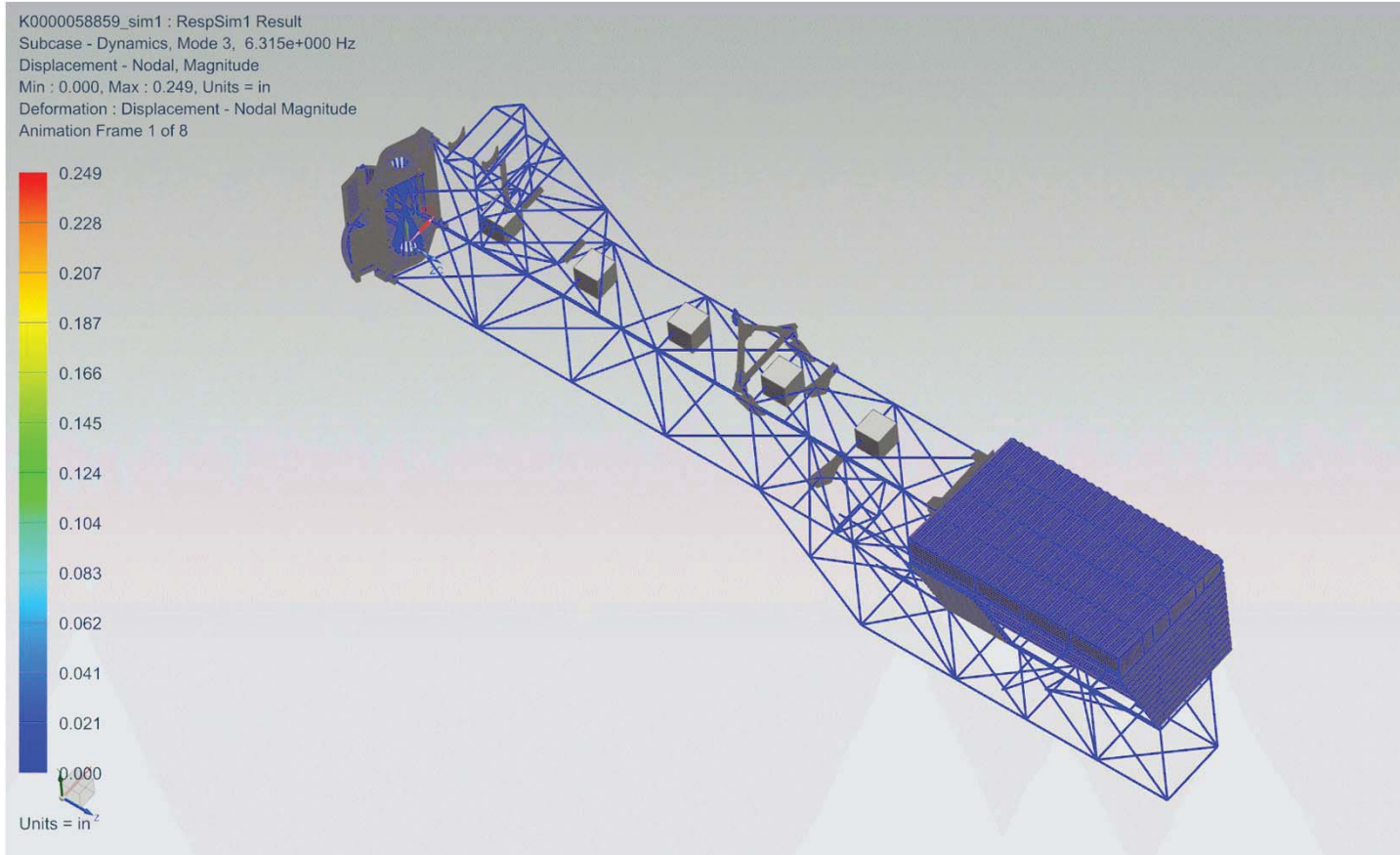
- Mode 1: ~0.38 Hz
- Mode 2: ~0.40 Hz
- Mode 3: ~2.64 Hz

Potential modal coupling

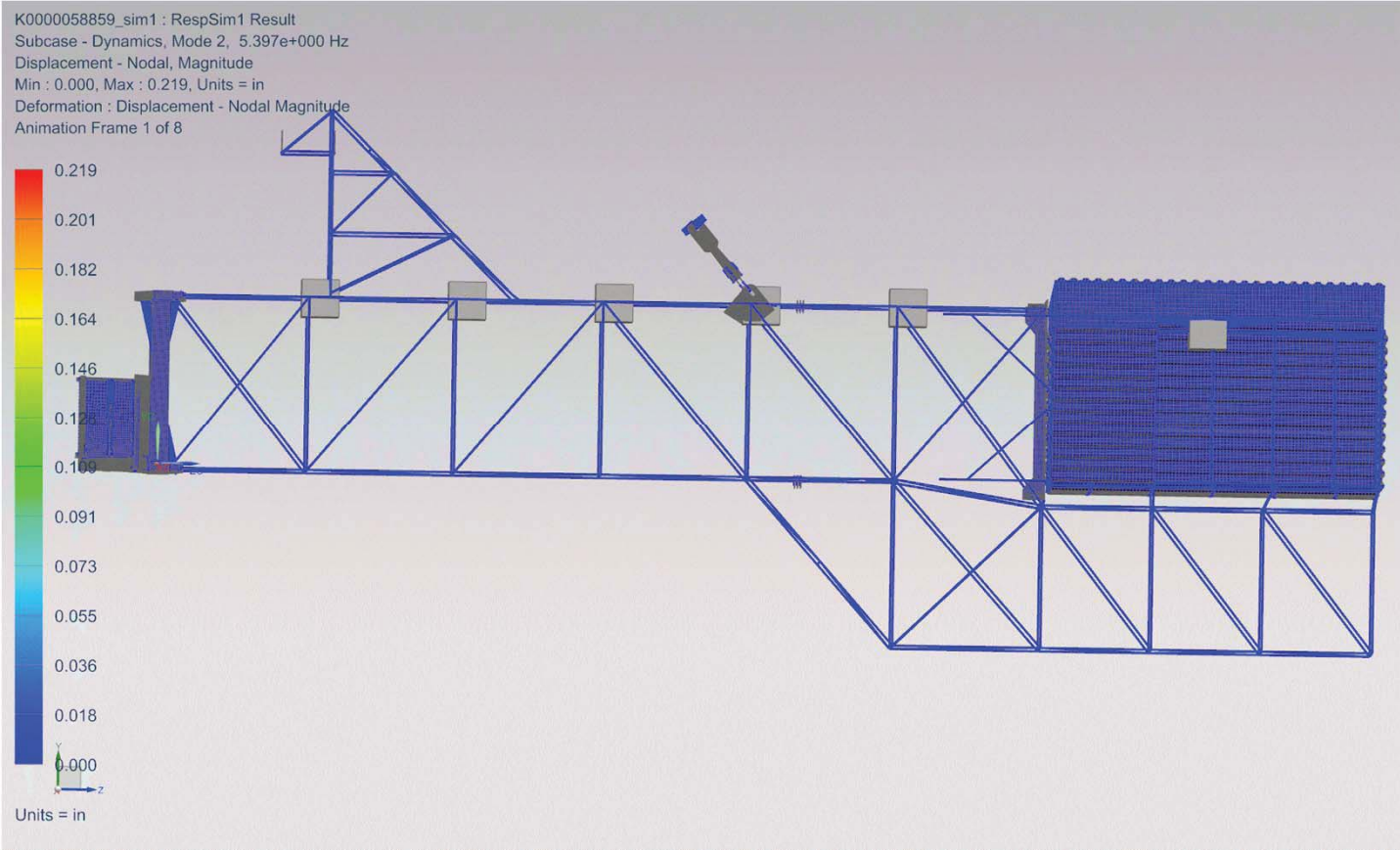
Mode 1 (2.76 Hz) Animation



Mode 2 (5.39 Hz) Animation



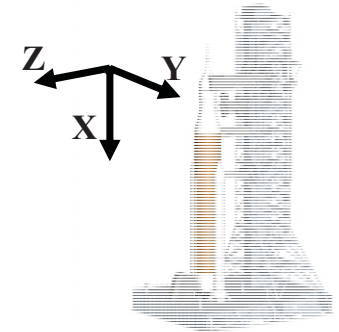
Mode 3 (6.31 Hz) Animation



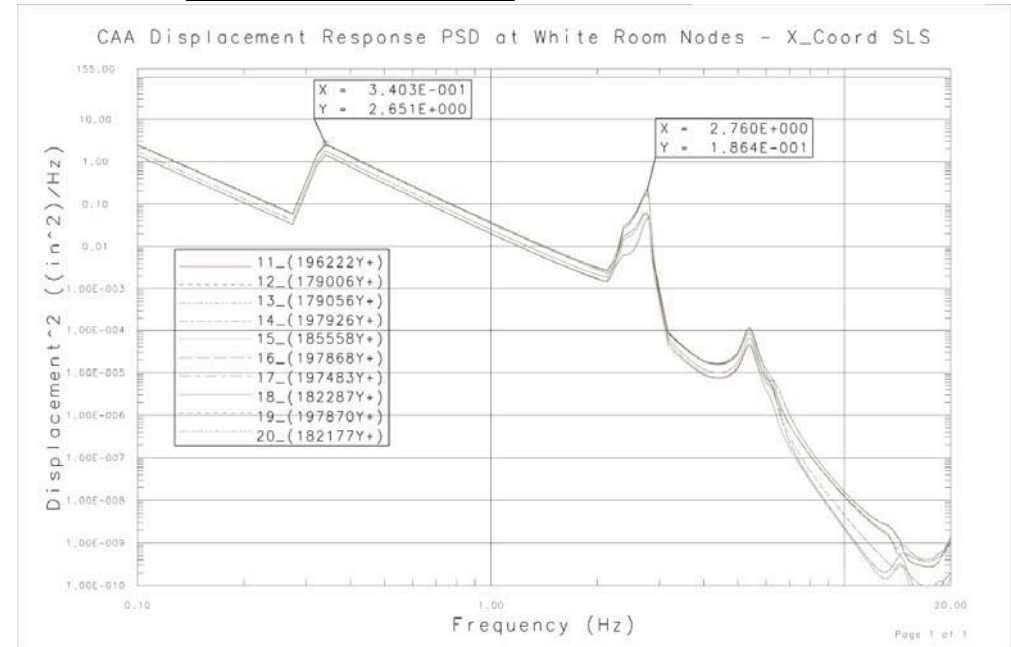
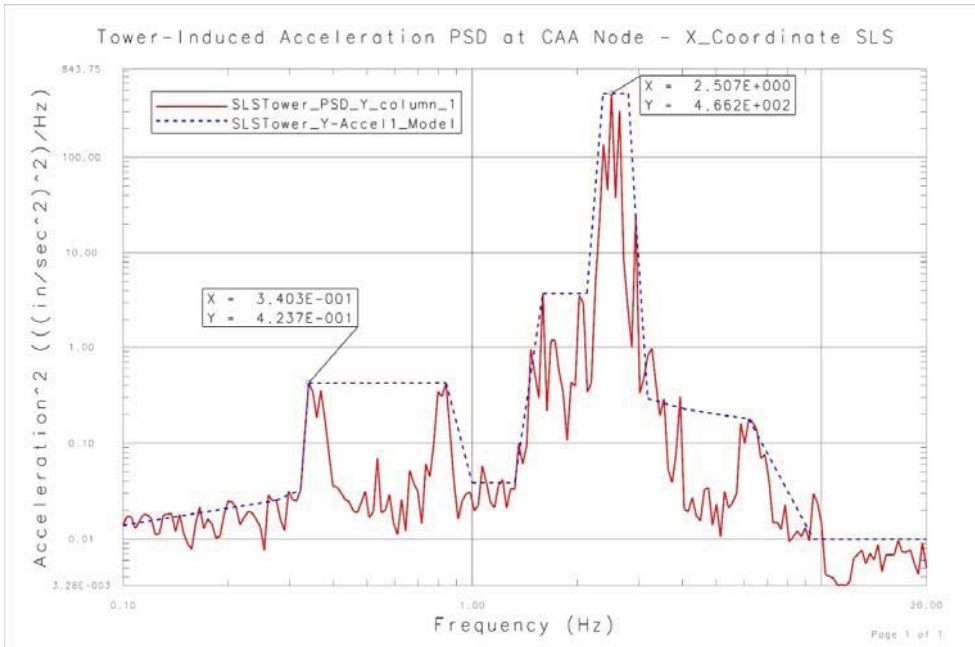
Load Input & Displacement Results Extended Condition



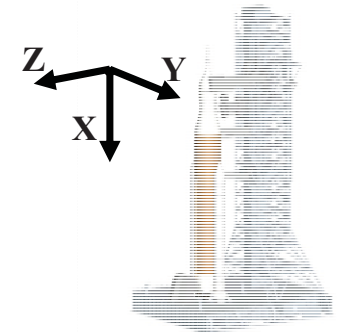
SLS X-Coordinate (Vertical)



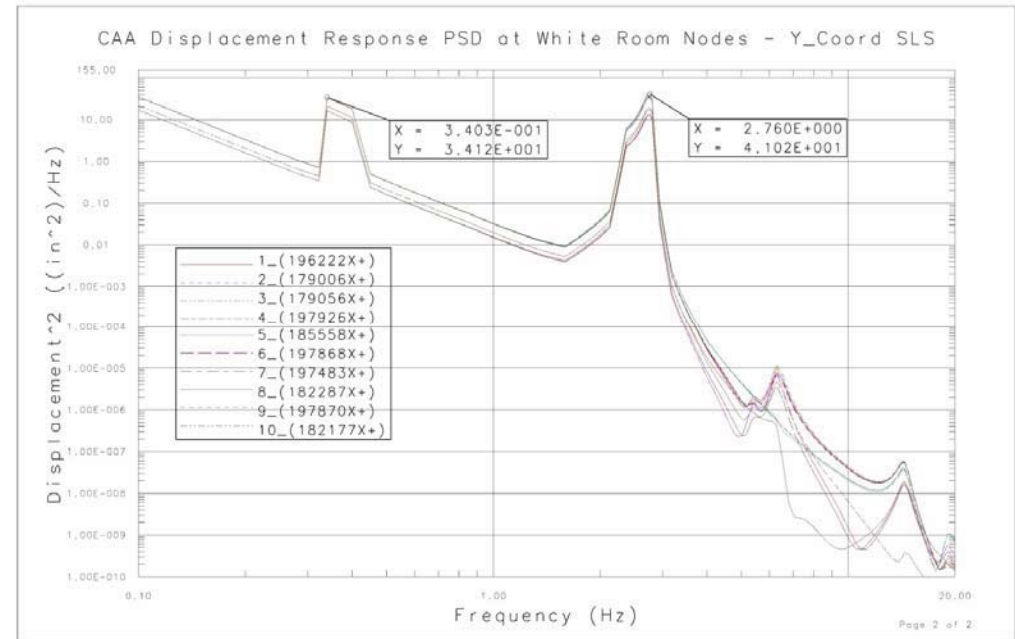
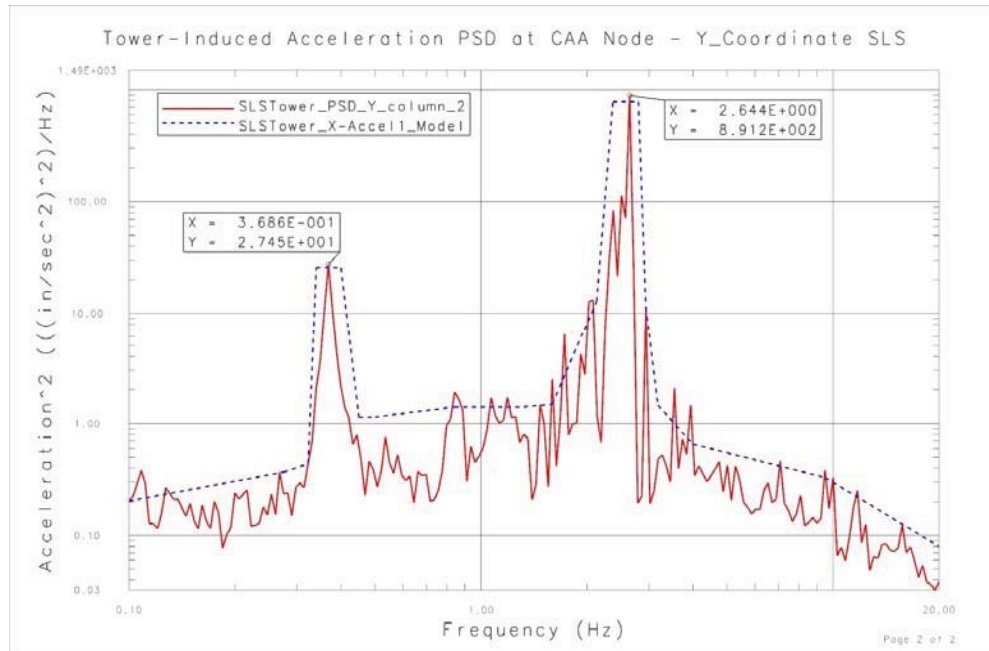
Peak Disp. = 1.62"
 3σ Peak Disp. = 4.88"
 80% Mass Participation
 100 Modes
 4% Viscous Damping



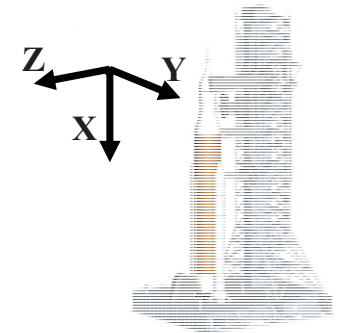
SLS Y-Coordinate (Lateral)



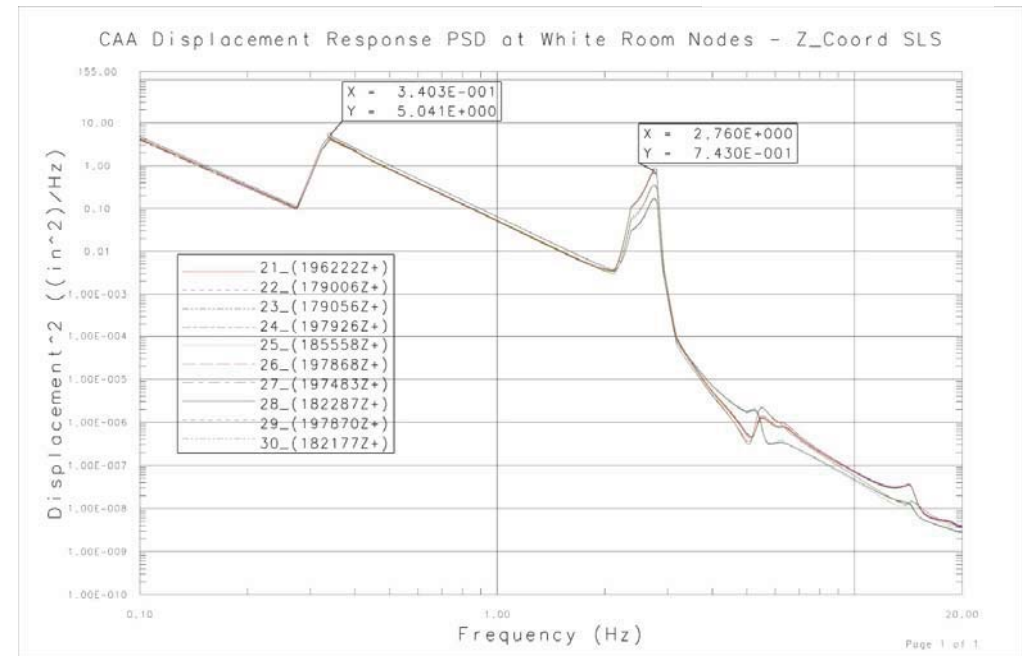
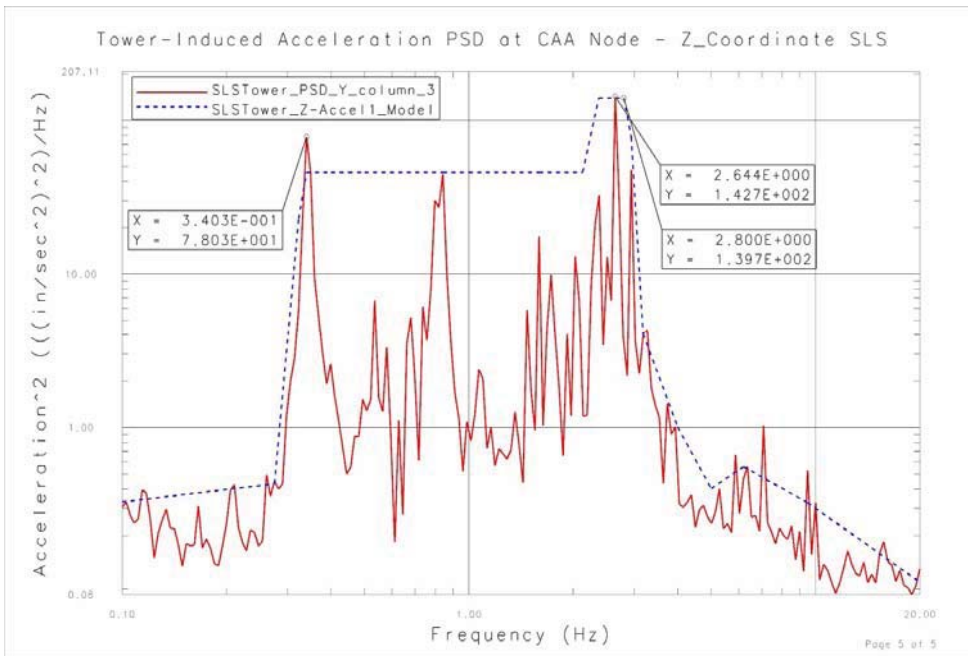
Peak Disp. = 6.4"
 3σ Peak Disp. = 19.2"
 80% Mass Participation
 100 Modes
 4% Viscous Damping



SLS Z-Coordinate (Axial)

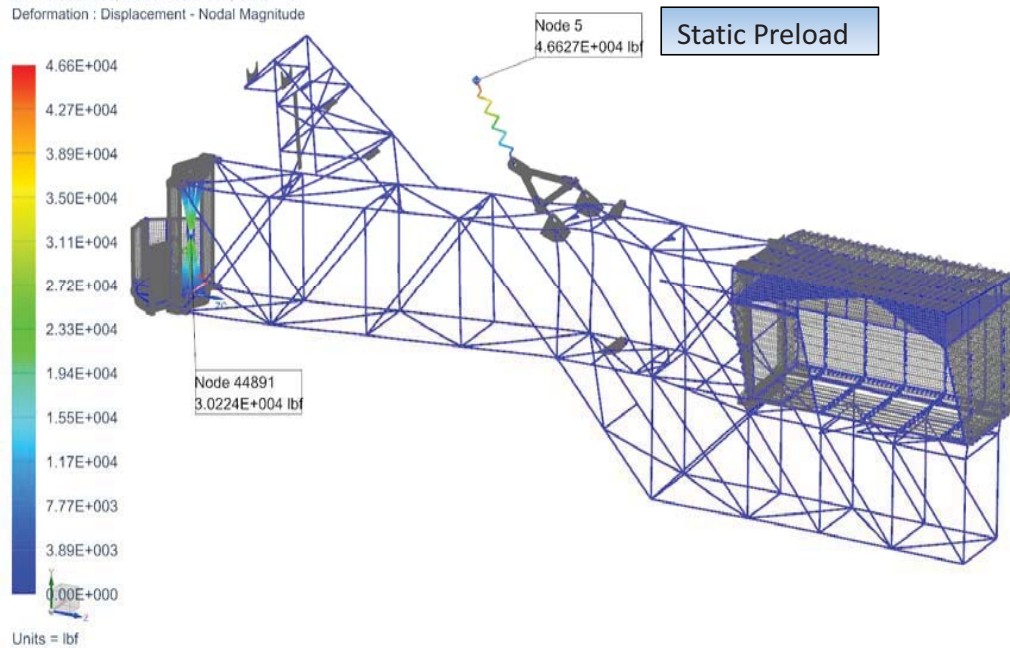


Peak Disp. = 2.24"
 3σ Peak Disp. = 4.5"
 80% Mass Participation
 100 Modes
 4% Viscous Damping

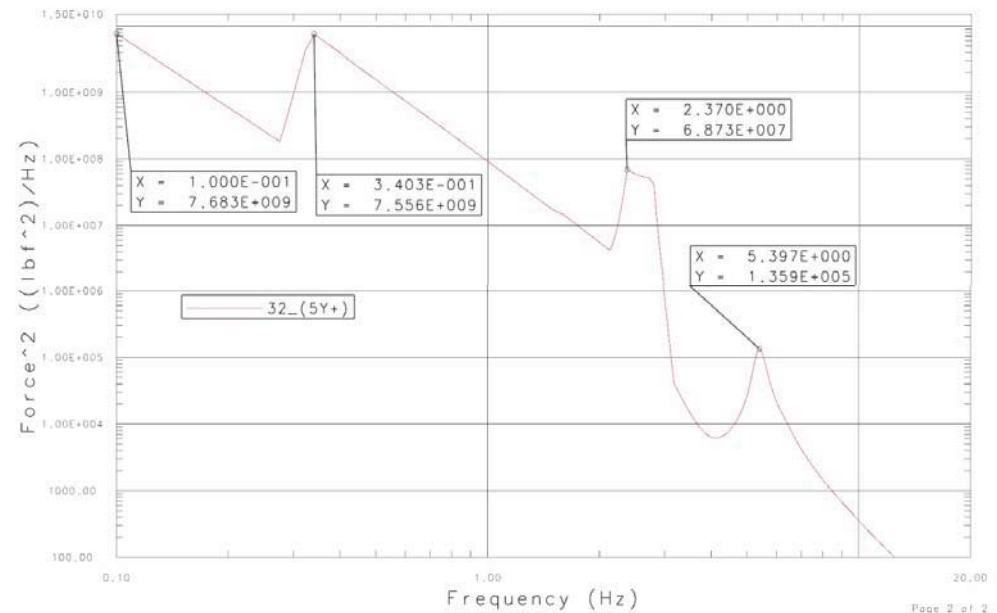


Cable Preload Evaluation

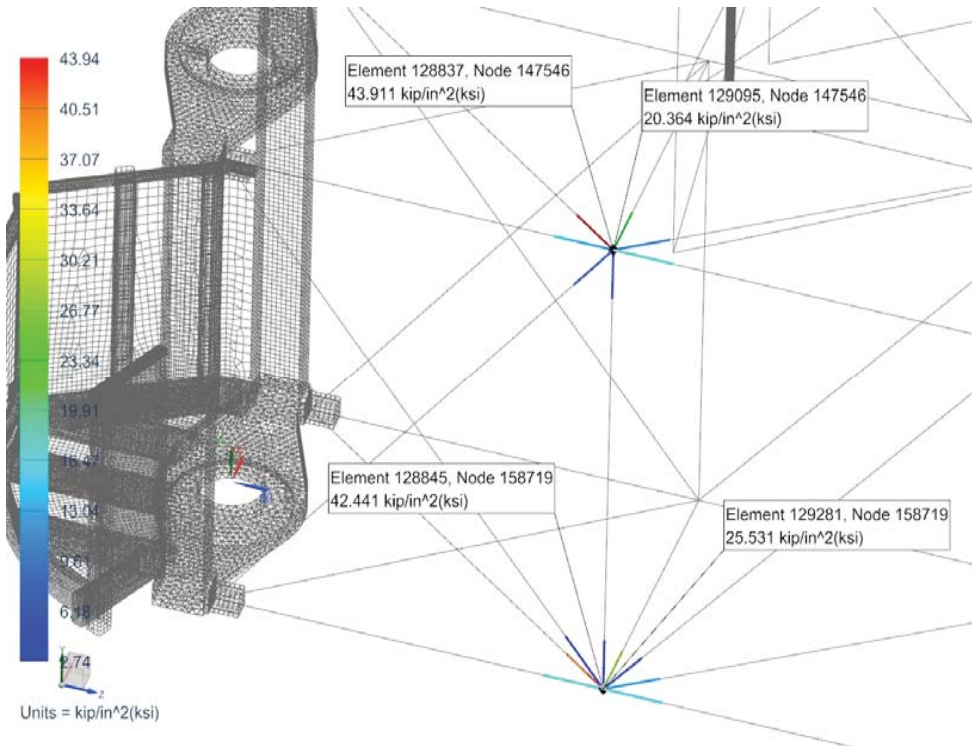
K000058859_sim1 : RespSim1 Result
 Subcase - Static Offset, Iteration 1
 Reaction Force - Nodal, Magnitude
 Min : 0.00E+000, Max : 4.66E+004, Units = lbf
 Deformation : Displacement - Nodal Magnitude



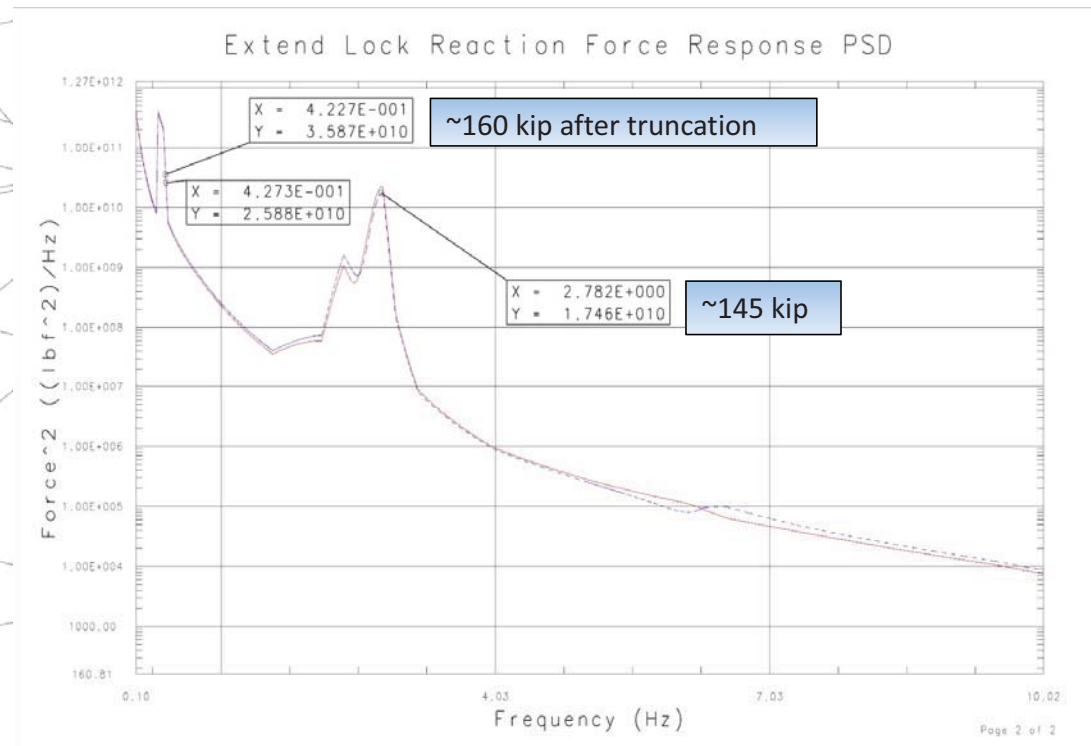
CAA Cable Reaction Force Response PSD at Hinge Node - Y_Coord Local Cable



Extend Lock Reactions



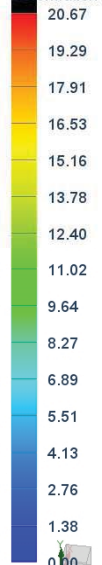
Joint RMS Stress Values



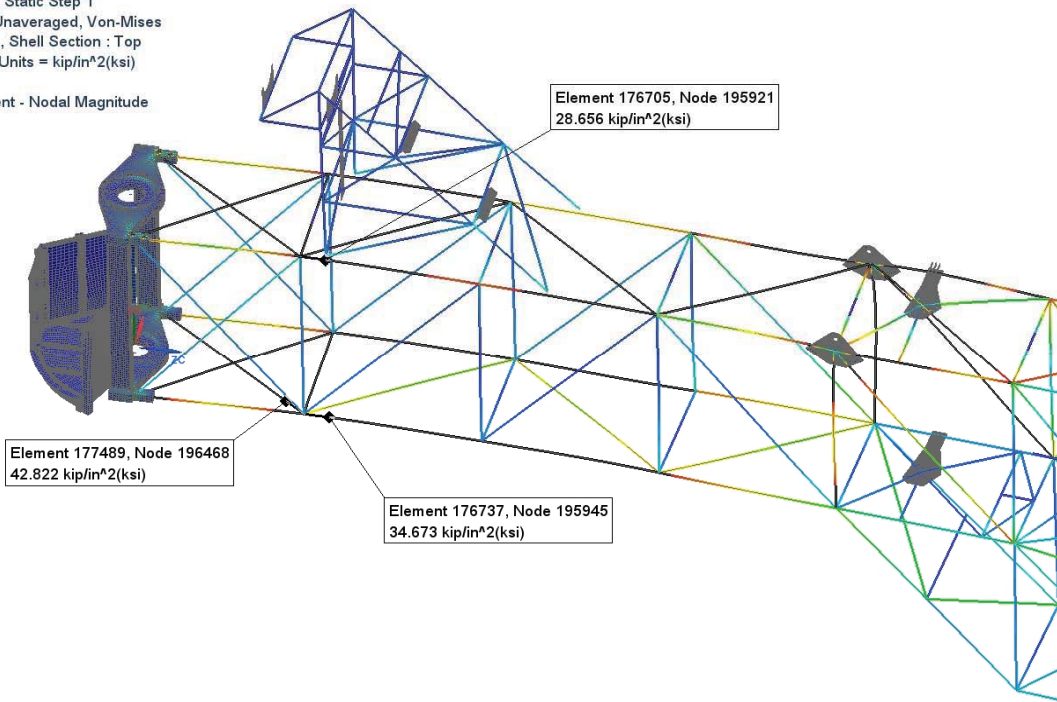
Static Stress

K0000058859_sim1 : Enforced Result
Subcase - Static Loads 1, Static Step 1
Stress - Element-Nodal, Unaveraged, Von-Mises
Beam Section : Maximum, Shell Section : Top
Min : 0.00, Max : 250.04, Units = kip/in²(ksi)
Beam Coord sys : Local

Information : Displacement - Nodal Magnitude



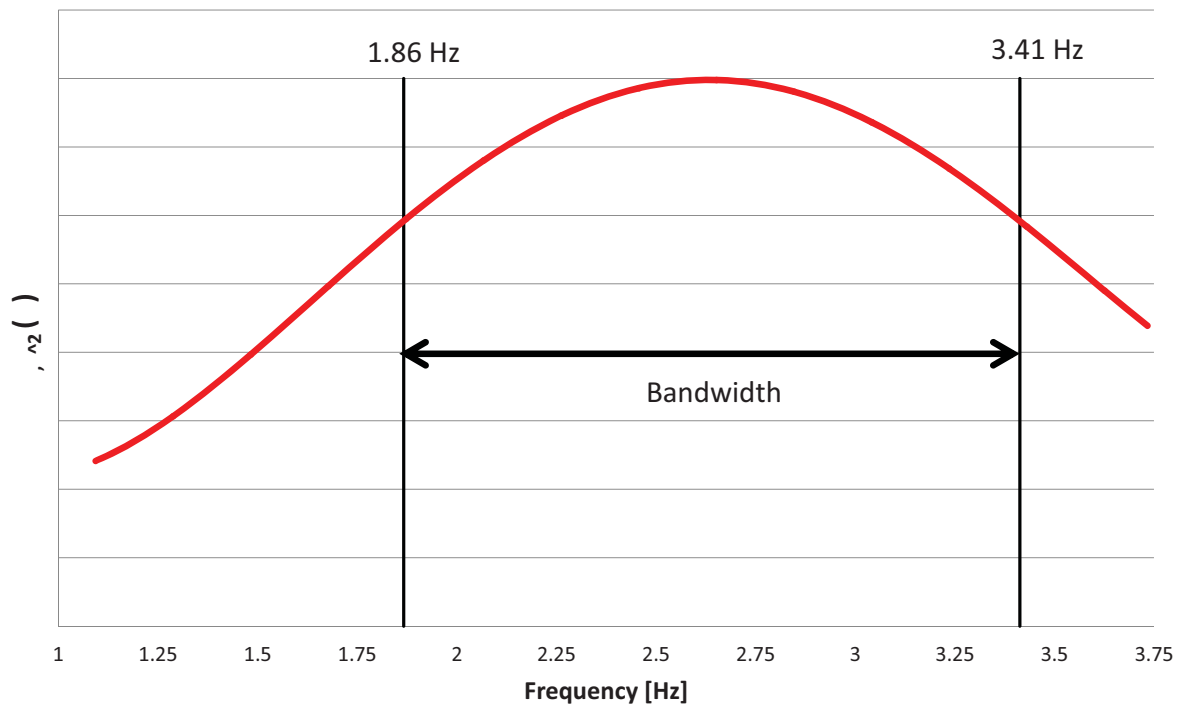
Units = kip/in²(ksi)



- Enforced 6.4” displacement at arm end
- Stress levels near material yield
- Extend lock mechanism compromised

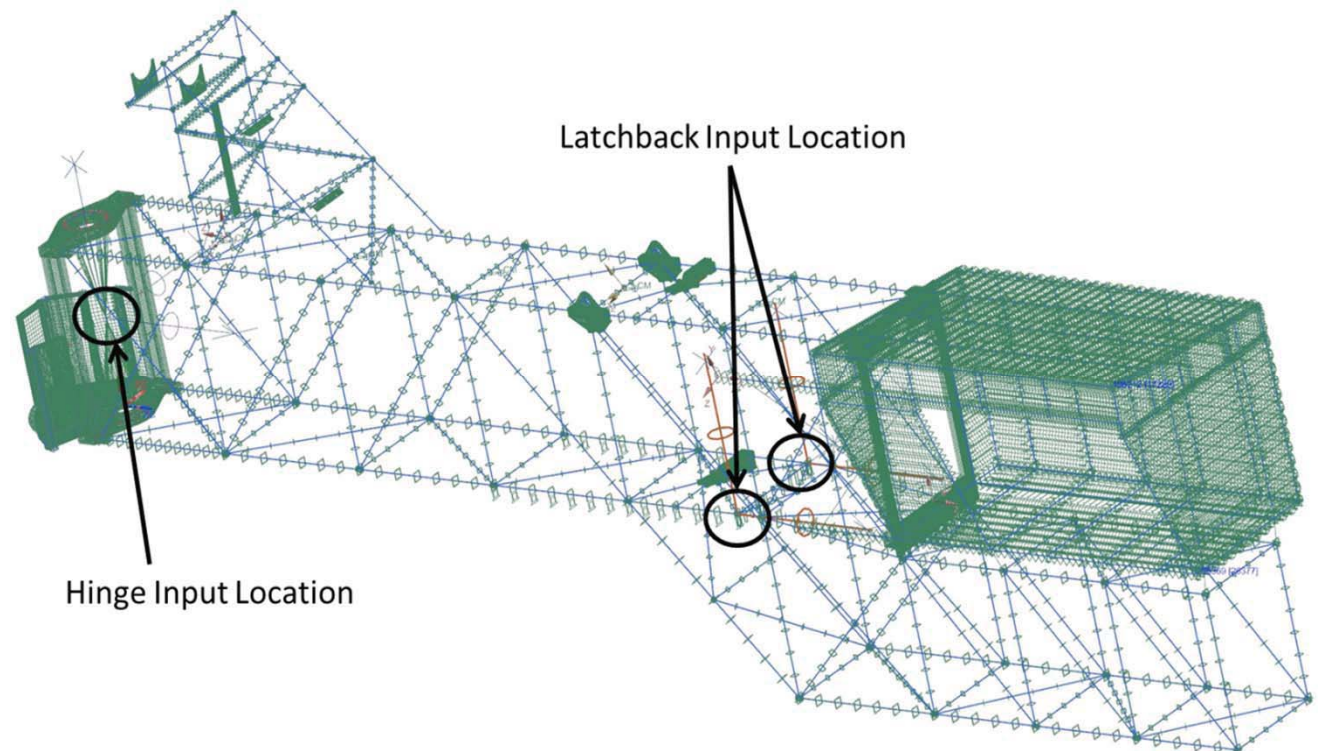
Statistical Estimate of Energy Dissipation

- Frequency outside bandwidth will dissipate majority of energy and prevent modal coupling.
- Extended truss must be 60% stiffer in lateral direction to achieve.



Boundary Condition Scheme (Retracted)

- Removed cable CBUSH
- Added latchback constraint
- Load input at both locations



Arm vs. Tower Modes

- Arm first 4 modes:
 - Mode 1: 7.41 Hz
 - Mode 2: 11.54 Hz
 - Mode 3: 12.25 Hz
 - Mode 4: 17.91 Hz
- Tower first 3 modes:
 - Mode 1: ~0.38 Hz
 - Mode 2: ~0.40 Hz
 - Mode 3: ~2.64 Hz

Load Input & Displacement Results Retracted Condition

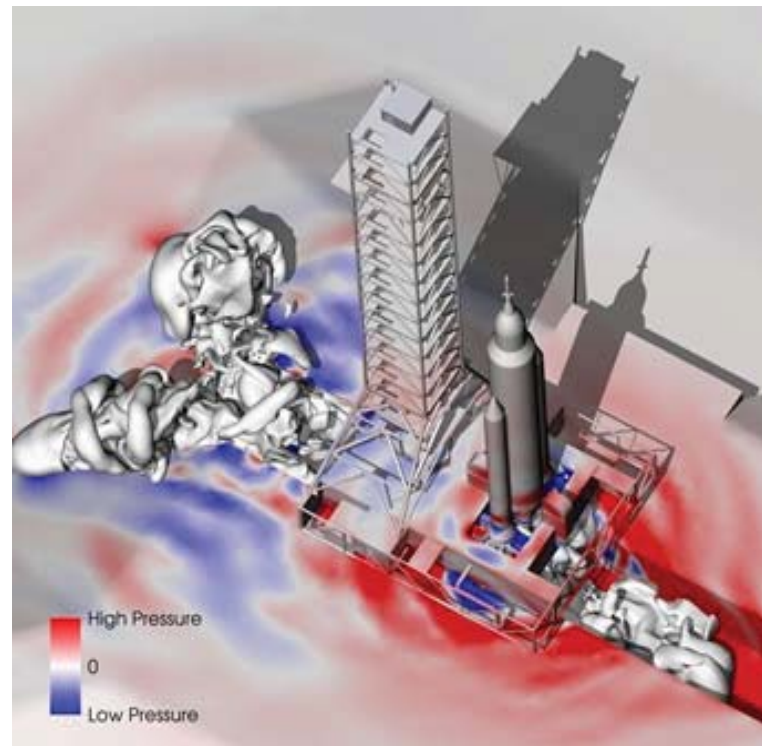
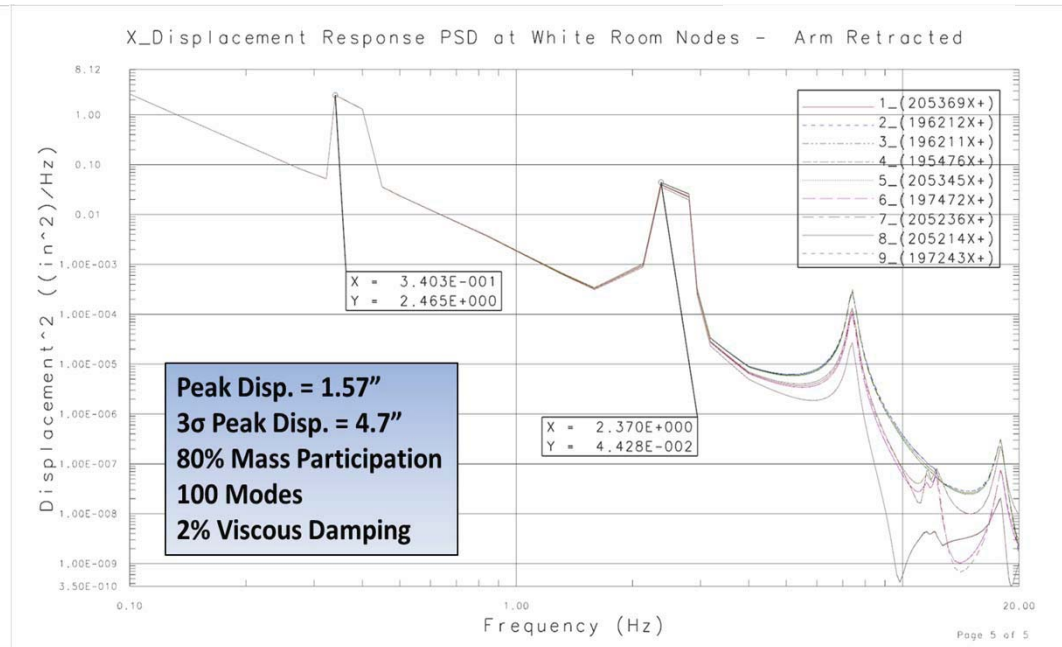
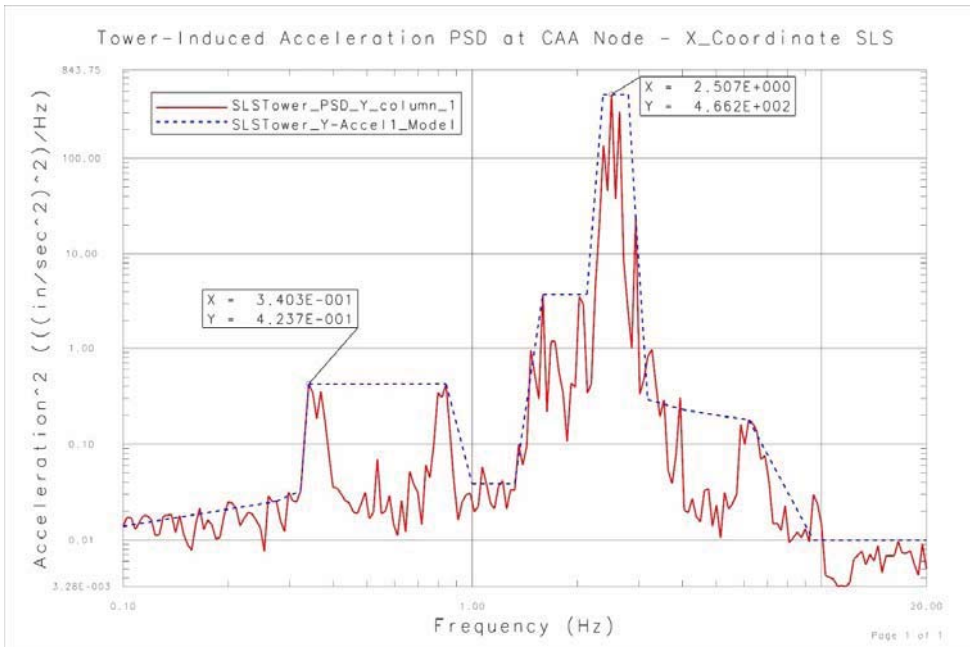
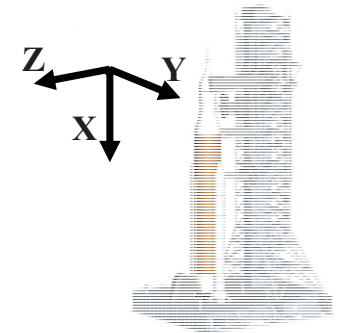
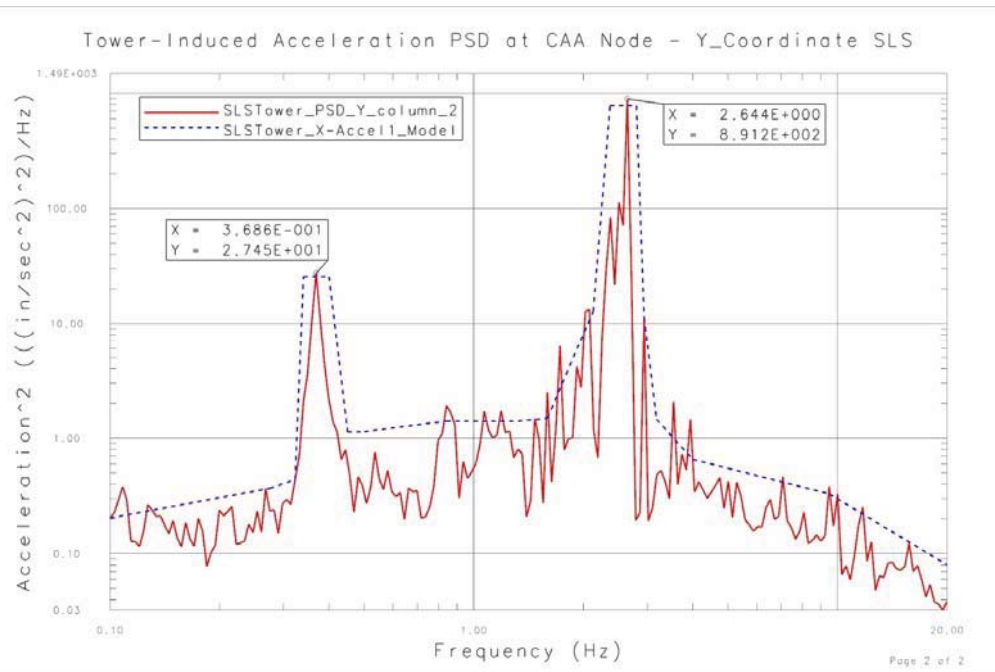
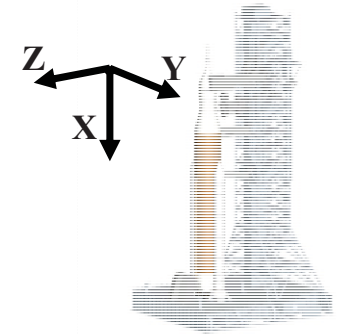


Photo courtesy NASA Ames Research Center

SLS X-Coordinate (Vertical)

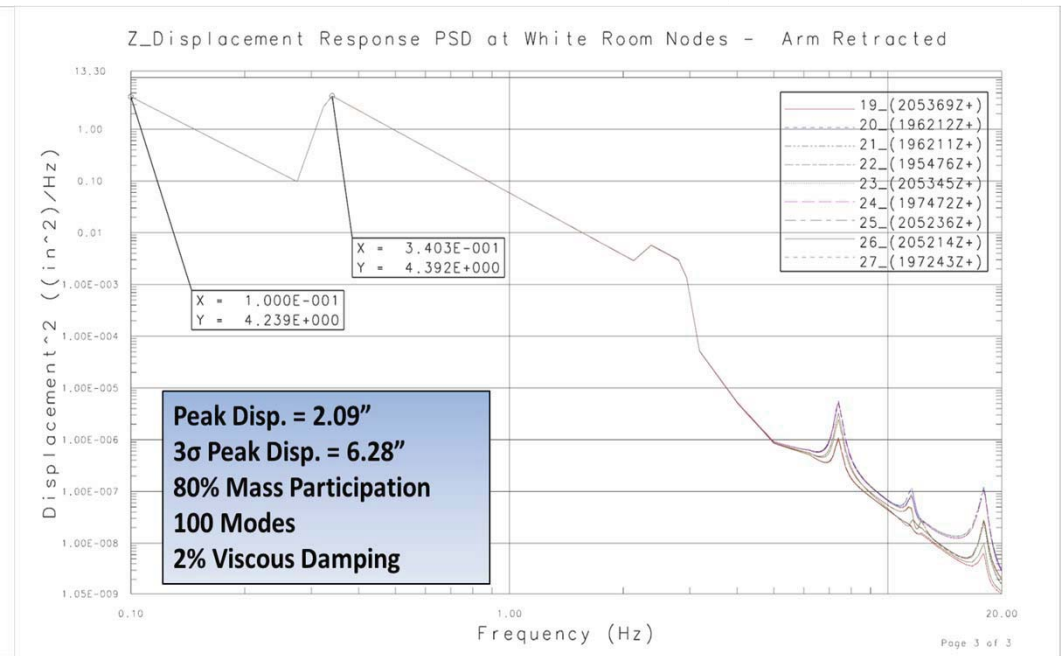
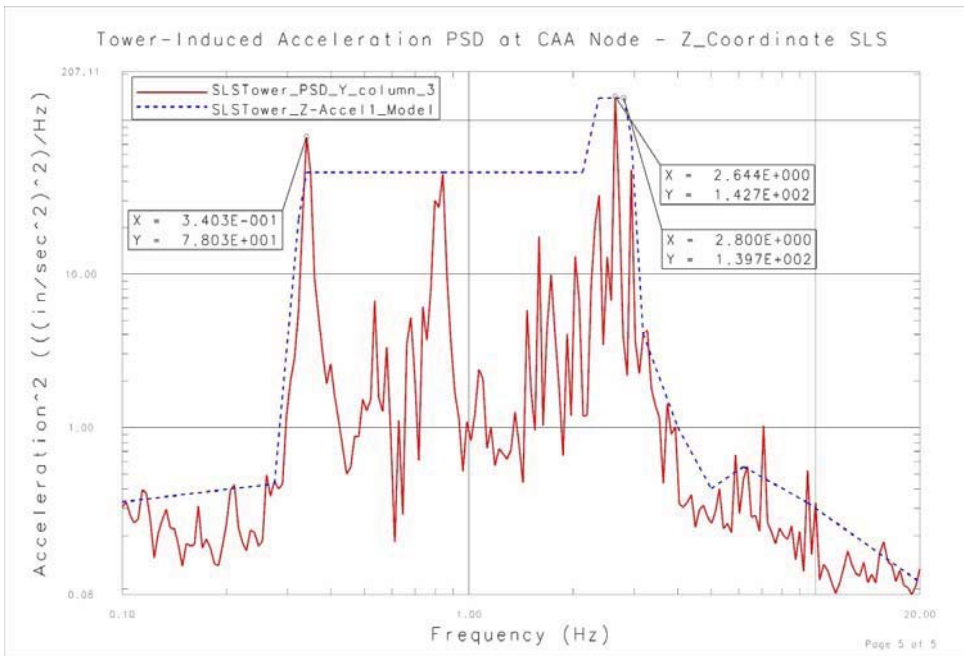
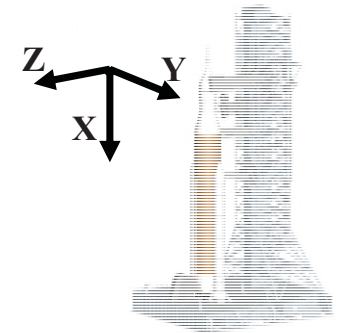


SLS Y-Coordinate (Lateral)



- Lateral displacement limited by shock absorber

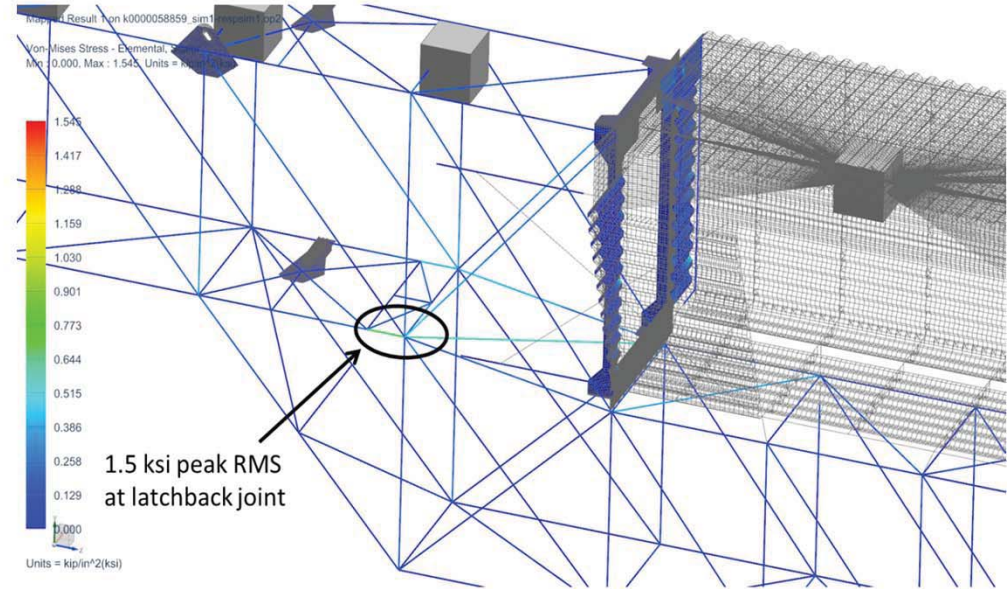
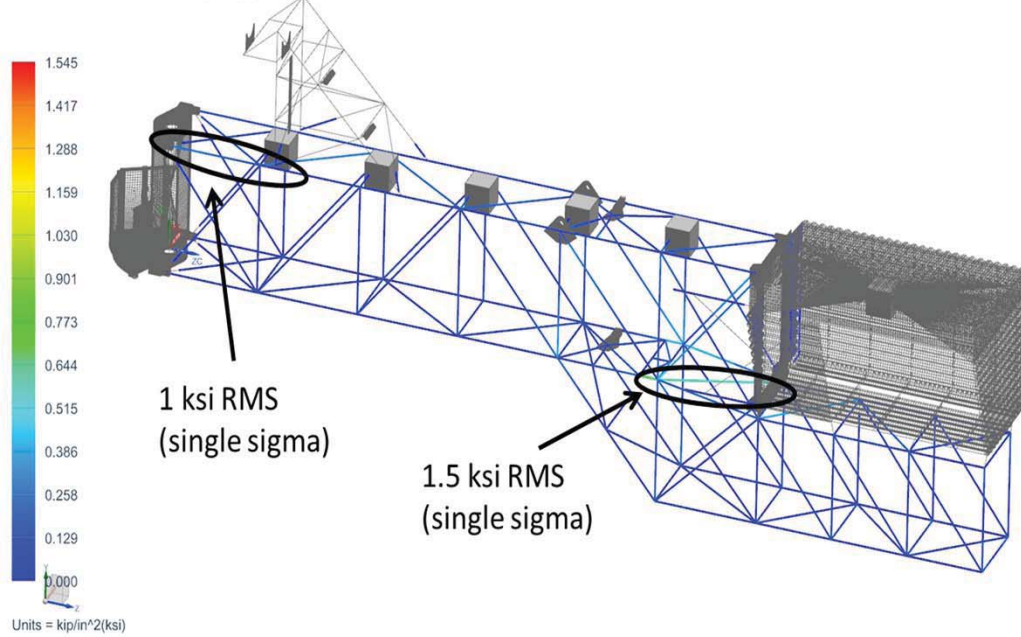
SLS Z-Coordinate (Axial)



Joint RMS Stress

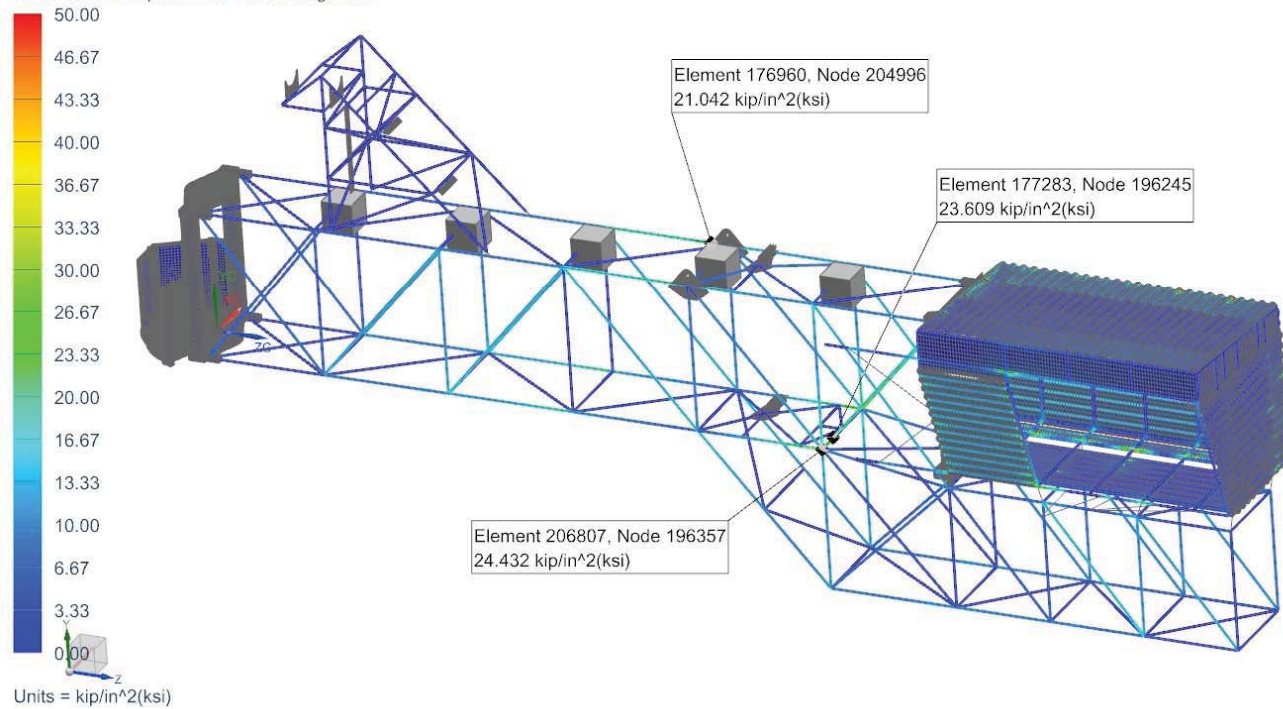
Mapped Result 1 on k0000058859_sim1-respsim1.op2

Von-Mises Stress - Elemental, Scalar
Min : 0.000, Max : 1.545, Units = kip/in²(ksi)



Static Stress

K0000058859_sim1 : Enforced_Retracted Result
Subcase - Static Loads 1, Static Step 1
Stress - Element-Nodal, Unaveraged, Von-Mises
Beam Section : Maximum, Shell Section : Maximum
Min : 0.00, Max : 209.35, Units = kip/in²(ksi)
Beam Coord sys : Local
Deformation : Displacement - Nodal Magnitude



Thank you

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Orlando, FL
June 16-19, 2014



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