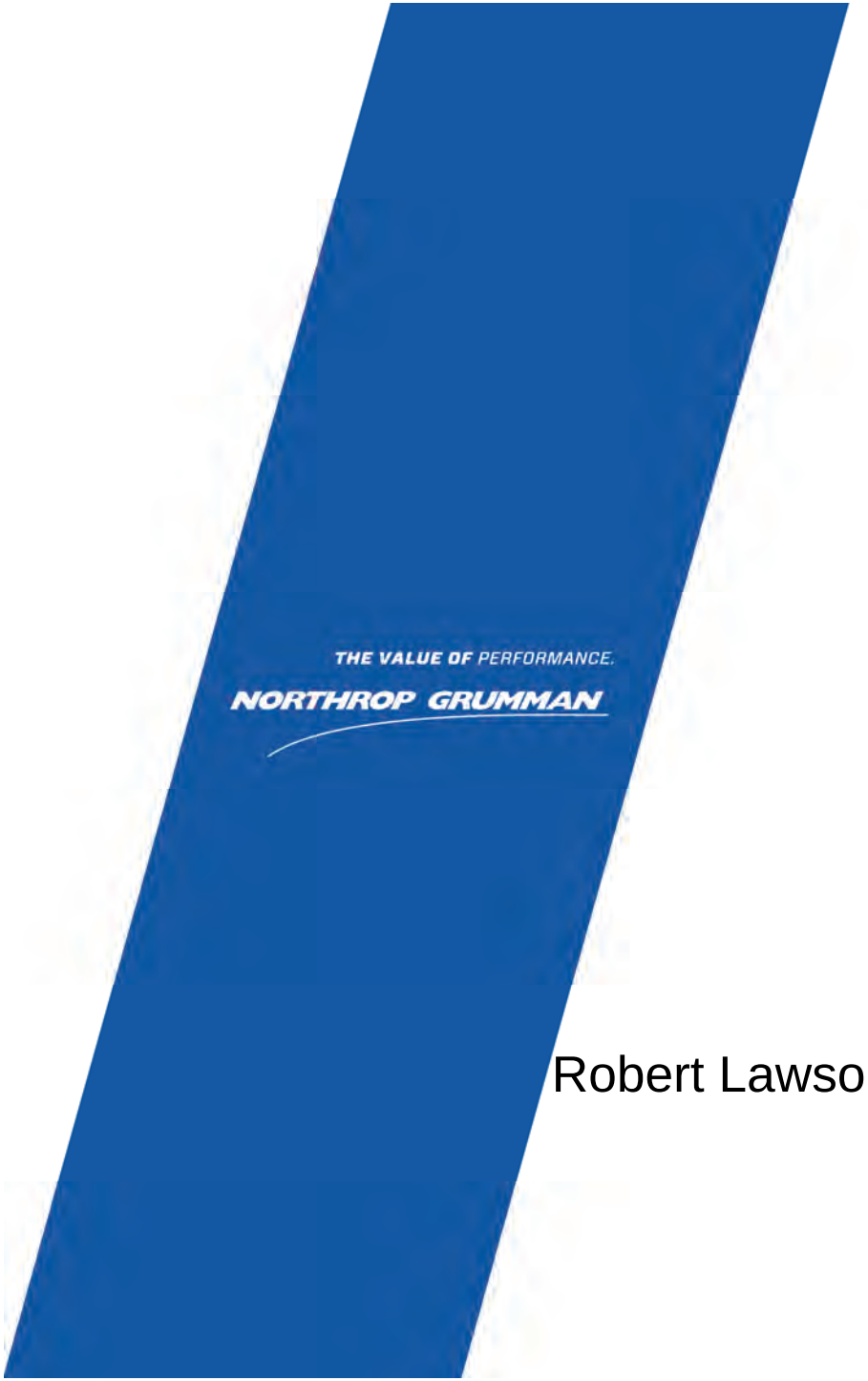

JWST SCE Modal Correlation

January 28, 2019

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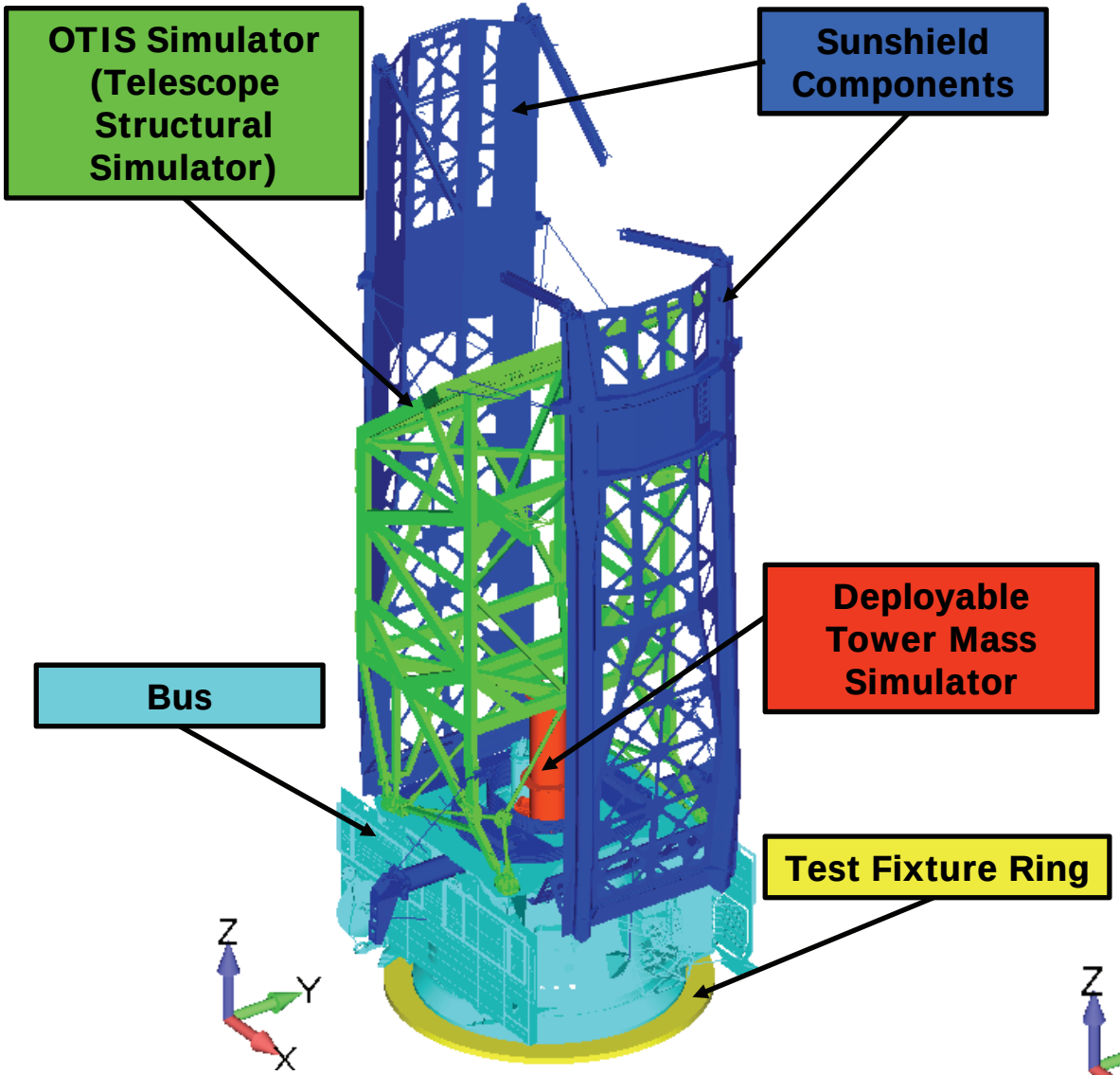
JWST Spacecraft Element: A Challenging Model to Correlate

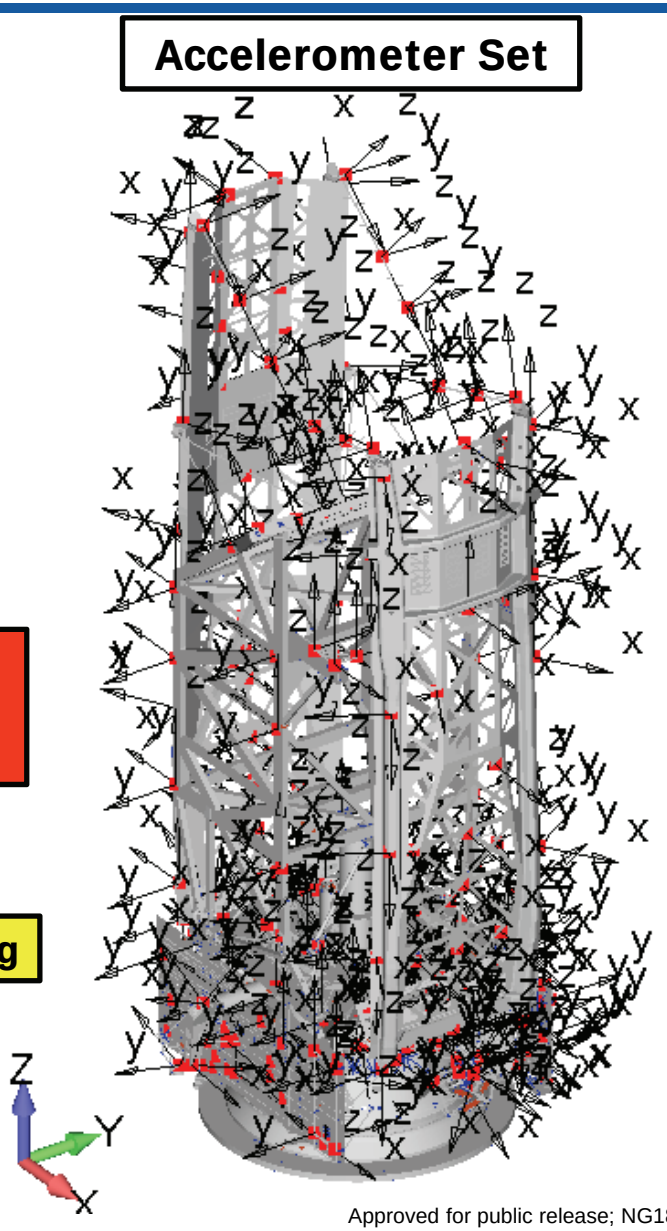
- **Spacecraft Element (SCE) FE model was the starting point for the sine vibe pre-test analysis**
  - Bus and sunshield models from this configuration along with the model of the telescope will be used for coupled loads analysis (CLA)
  - Model size is 1.4M nodes and 1.2M elements
  - Primary interest is in modes up to 30 Hz
  - Response limiting / notching is necessary to safely conduct sine vibe test – this benefits from a correlated model
- **A significant pre-test analysis effort was conducted**
  - A total of 550 accelerometers were used in order to characterize 23 expected “important” modes out of 120 modes below 30Hz
- **Many analysis iterations were conducted to improve modal frequency agreement and cross-orthogonality**
  - Sought “physically realistic” model updates
- **The resulting correlated model met desired goals for frequency and cross-orthogonality agreement between the FEM and the test data**

Pre-Test Objectives & Summary

- **Overall goals for pretest analysis were based on model-to-test correlation criteria:**
  - Use a Guyan-reduced model; compare frequencies and mode shapes with full G-set model
    - Primary modes frequency within 5% and secondary modes within 10% relative to G-set model values
    - Pseudo-orthogonality of mode shapes using Guyan reduced mass matrix:
      - > 0.9 on diagonal, < 0.1 on off-diagonal
    - Cross-orthogonality between Guyan-reduced and full G-set mode shapes:
      - > 0.9 on diagonal, < 0.2 on off-diagonal
- **Target modes selection mainly considered Modal Effective Mass (MEM), strain and kinetic energies**
  - Subassembly MEM was used to identify subassembly modes that may not be identified at the system level
- **23 target modes were selected (see slide 5)**
  - 16 based on modal effective mass
  - 7 otherwise “important” modes were also included in the pre-test effort
- **At the end of the pre-test analysis effort a total of 550 accelerometer DOFs were selected**
  - At 260 locations

FEM & Accelerometer Set





Modal Effective Mass Summary Tables

Primary Modes: 9 Secondary Modes: 7 Other: 7

Mode No.	Frequency (Hz)	Effective Mass (%)					
		X	Y	Z	RX	RY	RZ
1	7.87	37.3%	2.8%	0.1%	5.8%	80.0%	0.0%
2	8.79	1.7%	39.8%	0.0%	80.6%	3.7%	0.5%
3	9.20	3.4%	0.7%	0.0%	1.5%	5.2%	0.0%
4	9.84	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5	10.29	2.5%	0.0%	0.0%	0.0%	2.2%	0.0%
6	10.61	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
7	10.67	0.0%	1.0%	0.0%	1.2%	0.0%	0.3%
8	11.12	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
9	11.17	0.6%	0.0%	0.0%	0.0%	0.8%	0.0%
10	11.78	0.3%	0.0%	0.1%	0.0%	0.9%	0.3%
11	12.11	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
12	12.23	0.1%	1.2%	0.0%	1.9%	0.1%	10.6%
14	12.90	0.0%	3.8%	0.0%	4.0%	0.0%	8.5%
25	16.11	0.0%	0.2%	0.0%	0.2%	0.0%	29.4%
26	16.48	0.0%	0.4%	0.0%	0.2%	0.0%	4.7%
37	18.61	0.0%	0.1%	0.0%	0.1%	0.0%	0.0%
50	20.69	0.0%	0.0%	1.6%	0.0%	0.0%	0.0%
54	21.47	0.1%	0.1%	0.0%	0.0%	0.0%	0.8%
55	21.51	2.1%	0.0%	0.4%	0.0%	0.2%	0.1%
65	23.13	0.0%	0.1%	0.0%	0.0%	0.0%	0.3%
66	23.23	0.2%	0.0%	0.6%	0.0%	0.0%	0.0%
87	26.92	0.3%	2.8%	0.8%	0.2%	0.1%	0.0%
95	27.68	2.5%	0.4%	5.1%	0.0%	0.9%	0.0%
101	28.62	3.0%	0.0%	21.3%	0.0%	1.6%	0.0%
130	34.06	0.1%	0.0%	3.3%	0.0%	0.1%	0.0%
131	34.21	0.0%	0.0%	2.8%	0.0%	0.0%	0.1%
146	38.57	0.6%	2.1%	2.3%	0.1%	0.0%	2.6%
162	40.61	0.0%	2.2%	0.5%	0.0%	0.0%	0.1%
197	45.17	3.6%	0.0%	5.7%	0.0%	0.1%	0.0%
Sum up to 100Hz		82.87%	82.66%	80.74%	99.04%	99.13%	85.98%

Primary Mode > 5% Effective Mass
Secondary Mode > 2% Effective Mass
Important Mode, but < 2% Effective Mass

Effective Mass > 5%
5% > Effective Mass > 2%

Pseudo-Ortho Table
550 DOF Accels, 260 Grids

- Pseudo-orthogonality of FEM modes via Guyan reduced mass matrix (A-set) were computed
  - Verifies Guyan-reduced A-set and mass matrix

Trade 150 Reduced	Mode Number	1	2	3	4	5	6	7	8	9	10	11	12	14	25	26	37	50	54	55	65	66	87	95	101	130	131	146	162	197
Mode Number	Frequency (Hz)	7.87	8.79	9.20	9.84	10.29	10.61	10.67	11.12	11.17	11.78	12.11	12.23	12.90	16.11	16.48	18.61	20.69	21.47	21.51	23.13	23.23	26.92	27.68	28.62	34.06	34.21	38.57	40.61	45.17
1	7.87	99.20%	0.04%	0.13%	0.03%	0.08%	0.01%	0.08%	0.01%	0.23%	0.98%	0.01%	0.07%	0.00%	0.03%	0.05%	0.03%	0.00%	0.03%	0.03%	0.04%	0.00%	0.49%	1.15%	0.40%	0.24%	0.46%	0.06%	0.85%	0.21%
2	8.79	0.04%	99.22%	0.08%	0.03%	0.04%	0.00%	0.01%	0.04%	0.00%	0.08%	0.00%	0.12%	0.18%	0.42%	0.12%	0.04%	0.01%	0.25%	0.15%	0.12%	0.02%	1.46%	0.24%	0.04%	0.03%	0.06%	2.55%	0.53%	0.74%
3	9.20	0.13%	0.08%	98.21%	0.01%	0.09%	0.09%	0.13%	0.01%	1.26%	0.38%	0.00%	0.10%	0.06%	0.11%	0.11%	0.04%	0.04%	0.01%	0.09%	0.00%	0.03%	0.48%	0.26%	0.20%	0.32%	0.29%	0.18%	0.32%	0.13%
4	9.84	0.03%	0.03%	0.01%	0.00%	0.02%	0.00%	0.01%	0.00%	0.01%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%
5	10.29	0.08%	0.04%	0.09%	0.02%	96.84%	0.13%	0.37%	0.00%	0.62%	0.17%	0.01%	0.20%	0.26%	0.18%	0.28%	0.10%	0.12%	0.10%	0.30%	0.05%	0.11%	0.35%	0.27%	0.23%	0.82%	0.58%	0.81%	1.63%	0.03%
6	10.61	0.01%	0.00%	0.09%	0.00%	0.13%	98.97%	0.04%	0.00%	0.17%	0.00%	0.00%	0.02%	0.01%	0.00%	0.00%	0.00%	0.00%	0.01%	0.01%	0.00%	0.00%	0.04%	0.01%	0.01%	0.00%	0.00%	0.05%	0.08%	0.03%
7	10.67	0.08%	0.01%	0.13%	0.01%	0.37%	0.04%	97.81%	0.03%	0.13%	0.08%	0.02%	0.65%	0.41%	0.17%	0.24%	0.05%	0.08%	0.42%	0.41%	0.10%	0.19%	1.44%	0.36%	0.11%	0.62%	0.37%	0.86%	1.31%	0.61%
8	11.12	0.01%	0.04%	0.01%	0.00%	0.00%	0.00%	0.03%	0.00%	0.03%	0.00%	0.00%	0.02%	0.02%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
9	11.17	0.23%	0.00%	1.26%	0.01%	0.62%	0.17%	0.13%	0.03%	97.02%	1.18%	0.02%	0.05%	0.14%	0.09%	0.05%	0.03%	0.02%	0.12%	0.00%	0.03%	0.01%	0.49%	0.34%	0.21%	0.02%	0.05%	0.14%	0.23%	0.10%
10	11.78	0.98%	0.08%	0.38%	0.01%	0.17%	0.00%	0.08%	0.00%	1.18%	94.38%	0.02%	0.07%	0.25%	0.51%	0.18%	0.20%	0.03%	0.13%	0.04%	0.05%	0.03%	2.42%	0.77%	0.08%	0.91%	1.51%	2.48%	0.06%	0.54%
11	12.11	0.01%	0.00%	0.00%	0.00%	0.01%	0.00%	0.02%	0.00%	0.02%	0.02%	99.44%	0.03%	0.03%	0.03%	0.01%	0.01%	0.01%	0.00%	0.01%	0.00%	0.01%	0.11%	0.01%	0.03%	0.03%	0.04%	0.15%	0.05%	0.26%
12	12.23	0.07%	0.12%	0.10%	0.00%	0.20%	0.02%	0.65%	0.02%	0.05%	0.07%	0.03%	98.62%	0.79%	0.14%	0.00%	0.06%	0.06%	0.17%	0.18%	0.02%	0.11%	0.56%	0.00%	0.02%	0.44%	0.32%	0.03%	1.45%	0.80%
14	12.90	0.00%	0.18%	0.06%	0.00%	0.26%	0.01%	0.41%	0.02%	0.14%	0.25%	0.03%	0.79%	98.91%	0.34%	0.23%	0.15%	0.02%	0.07%	0.08%	0.01%	0.00%	0.50%	0.04%	0.09%	0.19%	0.28%	1.48%	0.42%	0.18%
25	16.11	0.03%	0.42%	0.11%	0.00%	0.18%	0.00%	0.17%	0.00%	0.09%	0.51%	0.03%	0.14%	0.34%	94.10%	0.83%	0.03%	0.07%	0.06%	0.11%	0.04%	0.01%	0.17%	0.63%	0.14%	0.47%	0.58%	1.21%	0.46%	0.03%
26	16.48	0.05%	0.12%	0.11%	0.00%	0.28%	0.00%	0.24%	0.00%	0.05%	0.18%	0.01%	0.00%	0.23%	0.83%	98.46%	0.10%	0.04%	0.33%	0.20%	0.04%	0.07%	0.11%	0.21%	0.10%	0.29%	0.28%	0.19%	1.29%	0.02%
37	18.61	0.03%	0.04%	0.04%	0.00%	0.10%	0.00%	0.05%	0.00%	0.03%	0.20%	0.01%	0.06%	0.15%	0.03%	0.10%	92.07%	0.03%	0.01%	0.01%	1.22%	0.07%	0.15%	0.02%	0.06%	0.18%	0.19%	0.02%	0.06%	0.08%
50	20.69	0.00%	0.01%	0.04%	0.00%	0.12%	0.00%	0.08%	0.00%	0.02%	0.03%	0.01%	0.06%	0.02%	0.07%	0.04%	0.03%	98.83%	0.12%	0.00%	0.16%	0.60%	0.08%	0.03%	0.11%	0.26%	0.24%	0.06%	0.14%	0.06%
54	21.47	0.03%	0.25%	0.01%	0.00%	0.10%	0.01%	0.42%	0.00%	0.12%	0.13%	0.00%	0.17%	0.07%	0.06%	0.33%	0.01%	0.12%	97.16%	0.97%	0.19%	0.09%	0.37%	0.02%	0.19%	0.31%	0.34%	0.23%	0.22%	0.50%
55	21.51	0.03%	0.15%	0.09%	0.00%	0.30%	0.01%	0.41%	0.00%	0.00%	0.04%	0.01%	0.18%	0.08%	0.11%	0.20%	0.01%	0.00%	0.97%	97.12%	0.02%	0.10%	0.15%	0.07%	0.24%	0.27%	0.10%	0.21%	0.39%	0.26%
65	23.13	0.04%	0.12%	0.00%	0.00%	0.05%	0.00%	0.10%	0.00%	0.03%	0.05%	0.00%	0.02%	0.01%	0.04%	0.04%	1.22%	0.16%	0.19%	0.02%	95.54%	0.27%	0.01%	0.06%	0.05%	0.28%	0.18%	0.07%	0.06%	0.11%
66	23.23	0.00%	0.02%	0.03%	0.00%	0.11%	0.00%	0.19%	0.00%	0.01%	0.03%	0.01%	0.11%	0.00%	0.01%	0.07%	0.07%	0.60%	0.09%	0.10%	0.27%	95.83%	0.05%	0.12%	0.23%	0.20%	0.21%	0.17%	0.10%	0.05%
87	26.92	0.49%	1.46%	0.48%	0.00%	0.35%	0.04%	1.44%	0.00%	0.49%	2.42%	0.11%	0.56%	0.50%	0.17%	0.11%	0.15%	0.08%	0.37%	0.15%	0.01%	0.05%	82.28%	0.11%	0.73%	1.41%	2.10%	0.58%	1.02%	2.53%
95	27.68	1.15%	0.24%	0.26%	0.00%	0.27%	0.01%	0.36%	0.00%	0.34%	0.77%	0.01%	0.00%	0.04%	0.63%	0.21%	0.02%	0.03%	0.02%	0.07%	0.06%	0.12%	0.11%	81.86%	3.89%	3.21%	3.35%	3.27%	1.97%	4.31%
101	28.62	0.40%	0.04%	0.20%	0.00%	0.23%	0.01%	0.11%	0.00%	0.21%	0.08%	0.03%	0.02%	0.09%	0.14%	0.10%	0.06%	0.11%	0.19%	0.24%	0.05%	0.23%	0.73%	3.89%	87.95%	2.44%	2.31%	2.81%	0.58%	3.08%
130	34.06	0.24%	0.03%	0.32%	0.00%	0.82%	0.00%	0.62%	0.00%	0.02%	0.91%	0.03%	0.44%	0.19%	0.47%	0.29%	0.18%	0.26%	0.31%	0.27%	0.28%	0.20%	1.41%	3.21%	2.44%	69.71%	16.43%	1.81%	0.12%	0.25%
131	34.21	0.46%	0.06%	0.29%	0.00%	0.58%	0.00%	0.37%	0.00%	0.05%	1.51%	0.04%	0.32%	0.28%	0.58%	0.28%	0.19%	0.24%	0.34%	0.10%	0.18%	0.21%	2.10%	3.35%	2.31%	16.43%	72.73%	4.69%	0.35%	4.90%
146	38.57	0.06%	2.55%	0.18%	0.01%	0.81%	0.05%	0.86%	0.00%	0.14%	2.48%	0.15%	0.03%	1.48%	1.21%	0.19%	0.02%	0.06%	0.23%	0.21%	0.07%	0.17%	0.58%	3.27%	2.81%	1.81%	4.69%	74.49%	1.92%	1.91%
162	40.61	0.85%	0.53%	0.32%	0.00%	1.63%	0.08%	1.31%	0.00%	0.23%	0.06%	0.05%	1.45%	0.42%	0.46%	1.29%	0.06%	0.14%	0.22%	0.39%	0.06%	0.10%	1.02%	1.97%	0.58%	0.12%	0.35%	1.92%	70.66%	0.59%
197	45.17	0.21%	0.74%	0.13%	0.00%	0.03%	0.03%	0.61%	0.00%	0.10%	0.54%	0.26%	0.80%	0.18%	0.03%	0.02%	0.08%	0.06%	0.50%	0.26%	0.11%	0.05%	2.53%	4.31%	3.08%	0.25%	4.90%	1.91%	0.59%	70.13%

Primary Mode > 5% Effective Mass
Secondary Mode > 2% Effective Mass
Important Mode, but < 2% Effective Mass

Note: modes 4 & 8 are local modes that are not of interest and not captured by the Aset.

Cross-Ortho – Relevant modes 550 DOF Accels, 260 Grids

- **Frequency differences & cross-orthogonality of Guyan-reduced (A-set) vs. unreduced FEM (G-set) modes**
  - For Closely-Spaced Modes:
    - Cross-orthogonality acceptable if their RSS > 0.9
    - Max frequency difference in the frequency range is shown

Trade 150 Reduced	A-set Mode #	1	2	3	4	5	6	7	8	9	10	12	18	19	26	31	36	37	38	39	40	45	46	56	58	59	60	61		
G-set Mode #	Frequency (Hz)	7.89	8.81	9.23	10.37	10.64	10.72	11.24	11.95	12.13	12.28	12.94	16.16	16.53	18.61	20.74	21.46	21.51	21.59	21.61	21.98	23.36	23.47	27.82	28.48	29.14	29.42	29.74	RSS % Correlation > 20%	Max Frequency Diff. ABS(Gset-Aset)/Gset
1	7.87	100.00%	0.10%	0.17%	0.08%	0.00%	0.06%	0.13%	0.51%	0.01%	0.04%	0.03%	0.03%	0.01%	0.00%	0.00%	0.01%	0.03%	0.02%	0.03%	0.04%	0.00%	0.00%	0.05%	0.07%	0.02%	0.06%	0.00%	100.00%	0.20%
2	8.79	0.09%	100.00%	0.37%	0.08%	0.00%	0.01%	0.03%	0.07%	0.00%	0.08%	0.12%	0.12%	0.03%	0.00%	0.01%	0.01%	0.01%	0.02%	0.02%	0.11%	0.02%	0.00%	0.16%	0.03%	0.04%	0.02%	0.00%	100.00%	0.20%
3	9.20	0.19%	0.38%	99.92%	0.45%	0.09%	0.21%	0.99%	0.26%	0.00%	0.08%	0.34%	0.01%	0.10%	0.00%	0.00%	0.04%	0.01%	0.03%	0.00%	0.00%	0.01%	0.00%	0.04%	0.01%	0.14%	0.08%	0.00%	99.92%	0.42%
4	9.84	0.02%	0.03%	0.01%	0.03%	0.00%	0.01%	0.01%	0.01%	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.02%	0.01%	0.01%	0.00%	NA*	NA*
5	10.29	0.07%	0.07%	0.34%	99.88%	1.09%	2.79%	1.02%	0.39%	0.01%	0.31%	0.53%	0.08%	0.04%	0.00%	0.00%	0.02%	0.12%	0.02%	0.10%	0.11%	0.02%	0.01%	0.03%	0.00%	0.54%	0.22%	0.01%	99.88%	0.77%
6	10.61	0.01%	0.00%	0.13%	1.09%	99.98%	1.11%	0.50%	0.04%	0.00%	0.04%	0.09%	0.00%	0.01%	0.00%	0.00%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%	0.01%	0.00%	0.01%	0.01%	0.00%	99.98%	0.26%
7	10.67	0.06%	0.01%	0.21%	2.82%	1.09%	99.93%	0.59%	0.24%	0.03%	1.21%	0.45%	0.09%	0.10%	0.00%	0.00%	0.11%	0.01%	0.06%	0.01%	0.31%	0.03%	0.02%	0.23%	0.07%	0.24%	0.07%	0.01%	99.93%	0.55%
8	11.12	0.00%	0.02%	0.00%	0.00%	0.00%	0.03%	0.03%	0.00%	0.00%	0.02%	0.02%	0.01%	0.00%	0.01%	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%	0.01%	0.00%	0.02%	0.01%	0.00%	0.00%	0.01%	NA*	NA*
9	11.17	0.14%	0.01%	1.38%	1.39%	0.59%	0.59%	99.18%	5.17%	0.06%	0.21%	1.42%	0.00%	0.21%	0.01%	0.00%	0.03%	0.06%	0.00%	0.04%	0.18%	0.01%	0.00%	0.13%	0.02%	0.03%	0.07%	0.01%	99.18%	0.56%
10	11.78	0.54%	0.07%	0.36%	0.32%	0.00%	0.18%	5.07%	99.69%	0.42%	1.04%	0.32%	0.35%	0.10%	0.08%	0.03%	0.02%	0.03%	0.01%	0.00%	0.05%	0.00%	0.00%	0.53%	0.15%	0.17%	0.06%	0.01%	99.69%	1.43%
11	12.11	0.00%	0.00%	0.00%	0.01%	0.00%	0.03%	0.05%	0.43%	99.99%	0.64%	0.09%	0.02%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	99.99%	0.14%
12	12.23	0.03%	0.08%	0.08%	0.27%	0.02%	1.21%	0.14%	0.97%	0.65%	99.89%	3.53%	0.16%	0.03%	0.05%	0.04%	0.05%	0.01%	0.05%	0.02%	0.21%	0.03%	0.01%	0.13%	0.00%	0.14%	0.04%	0.00%	99.89%	0.34%
14	12.90	0.00%	0.11%	0.03%	0.26%	0.01%	0.55%	0.09%	0.75%	0.08%	3.62%	98.77%	0.44%	0.20%	0.06%	0.03%	0.07%	0.01%	0.02%	0.03%	0.09%	0.01%	0.00%	0.13%	0.00%	0.04%	0.00%	0.00%	98.77%	0.29%
25	16.11	0.01%	0.14%	0.04%	0.09%	0.00%	0.10%	0.05%	0.36%	0.02%	0.15%	0.46%	97.54%	2.12%	0.12%	0.04%	0.16%	0.12%	0.24%	0.07%	0.07%	0.06%	0.00%	0.03%	0.21%	0.06%	0.25%	0.01%	97.54%	0.34%
26	16.48	0.01%	0.04%	0.04%	0.13%	0.00%	0.12%	0.02%	0.12%	0.01%	0.00%	0.24%	2.79%	99.67%	0.04%	0.02%	0.07%	0.09%	0.01%	0.06%	0.67%	0.05%	0.01%	0.04%	0.01%	0.14%	0.13%	0.00%	99.67%	0.34%
37	18.61	0.01%	0.01%	0.01%	0.03%	0.00%	0.02%	0.01%	0.09%	0.00%	0.02%	0.07%	0.09%	0.06%	94.99%	0.17%	0.29%	0.22%	0.01%	0.04%	0.23%	0.62%	0.16%	0.19%	0.17%	0.00%	0.00%	0.00%	94.99%	0.02%
50	20.69	0.00%	0.00%	0.01%	0.03%	0.00%	0.03%	0.01%	0.01%	0.00%	0.02%	0.01%	0.05%	0.08%	0.17%	99.50%	5.61%	1.14%	1.54%	0.61%	0.15%	0.05%	1.22%	0.08%	0.09%	0.13%	0.06%	0.00%	99.50%	0.26%
54	21.47	0.00%	0.04%	0.00%	0.02%	0.00%	0.11%	0.04%	0.04%	0.00%	0.06%	0.02%	0.05%	0.09%	0.06%	0.21%	29.01%	51.00%	68.70%	33.01%	22.44%	0.53%	0.23%	0.45%	0.07%	0.18%	0.05%	0.00%	98.77%	2.34%
55	21.51	0.00%	0.02%	0.02%	0.07%	0.00%	0.11%	0.00%	0.01%	0.00%	0.07%	0.02%	0.04%	0.10%	0.07%	0.62%	4.85%	10.64%	52.16%	82.01%	14.52%	0.09%	0.70%	0.45%	0.07%	0.43%	0.08%	0.01%	97.19%	0.44%
65	23.13	0.00%	0.02%	0.00%	0.01%	0.00%	0.02%	0.01%	0.02%	0.00%	0.01%	0.00%	0.03%	0.02%	1.10%	0.27%	0.94%	0.57%	1.17%	0.74%	0.36%	98.23%	12.33%	0.12%	0.06%	0.10%	0.13%	0.00%	98.23%	0.99%
66	23.23	0.00%	0.00%	0.00%	0.02%	0.00%	0.04%	0.00%	0.01%	0.00%	0.03%	0.00%	0.00%	0.01%	0.08%	1.20%	0.44%	0.71%	0.64%	0.17%	1.33%	12.34%	98.86%	0.27%	0.42%	0.09%	0.17%	0.01%	98.86%	1.05%
87	26.92	0.04%	0.16%	0.06%	0.05%	0.00%	0.24%	0.08%	0.51%	0.02%	0.12%	0.14%	0.07%	0.02%	0.15%	0.07%	0.00%	0.30%	0.41%	0.40%	1.34%	0.12%	0.07%	95.51%	3.44%	5.43%	1.55%	0.12%	95.51%	3.33%
95	27.68	0.09%	0.02%	0.03%	0.04%	0.00%	0.06%	0.05%	0.18%	0.00%	0.00%	0.01%	0.23%	0.09%	0.04%	0.04%	0.07%	0.09%	0.07%	0.15%	0.47%	0.13%	0.17%	2.55%	88.03%	9.35%	37.47%	2.99%	95.68%	6.30%
101	28.62	0.03%	0.00%	0.02%	0.03%	0.00%	0.01%	0.04%	0.00%	0.01%	0.01%	0.01%	0.08%	0.05%	0.02%	0.06%	0.04%	0.11%	0.05%	0.03%	0.12%	0.03%	0.21%	5.24%	37.88%	28.67%	80.05%	28.67%	97.40%	3.93%

Trade 150 Reduced	A-set Mode #	70	71	72	73	84	86	87	88	89	92	94	103	104	105	106	110		
G-set Mode #	Frequency (Hz)	34.92	35.66	36.05	36.32	40.55	41.46	41.61	41.98	42.33	43.52	44.02	46.25	46.50	47.61	47.78	49.50	RSS % Correlation > 20%	Max Frequency Diff. ABS(Gset-Aset)/Gset
130	34.06	56.90%	39.47%	0.51%	55.54%	4.43%	0.73%	0.72%	3.49%	0.81%	5.16%	1.07%	1.29%	1.68%	0.79%	3.03%	0.49%	88.77%	6.61%
131	34.21	52.58%	36.10%	21.71%	59.11%	9.40%	1.21%	0.76%	2.91%	1.18%	6.68%	0.35%	0.04%	0.12%	0.99%	2.73%	0.40%	89.63%	6.17%
146	38.57	5.30%	7.48%	3.32%	3.63%	77.04%	27.06%	21.08%	2.32%	11.77%	18.90%	16.44%	0.70%	0.35%	1.19%	6.57%	1.14%	84.33%	7.88%
162	40.61	1.35%	0.39%	1.41%	0.96%	2.07%	15.13%	14.76%	61.59%	28.26%	23.23%	33.15%	1.21%	0.34%	0.82%	2.47%	3.82%	78.93%	8.39%
197	45.17	2.59%	0.94%	0.57%	2.73%	5.97%	1.25%	0.72%	3.46%	2.62%	12.08%	0.70%	29.80%	32.52%	20.05%	63.76%	32.90%	86.58%	9.60%

Frequency Diff. < 5%
Frequency Diff. > 5%

Primary Mode > 5% Effective Mass
Secondary Mode > 2% Effective Mass
Important Mode, but < 2% Effective Mass

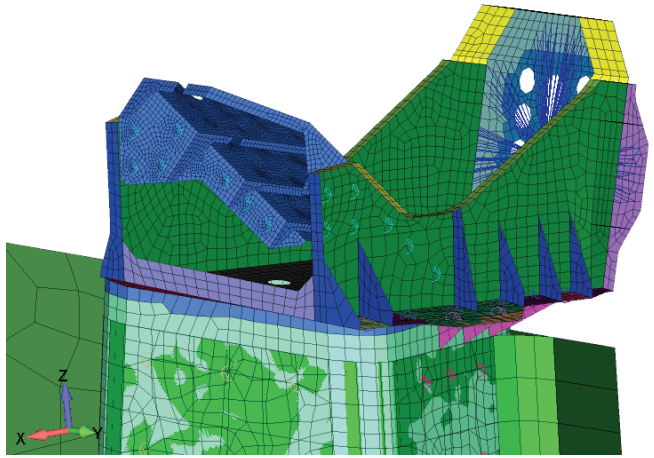
Correlation > 90%
90% > Correlation > 60%
60% > Correlation > 20%

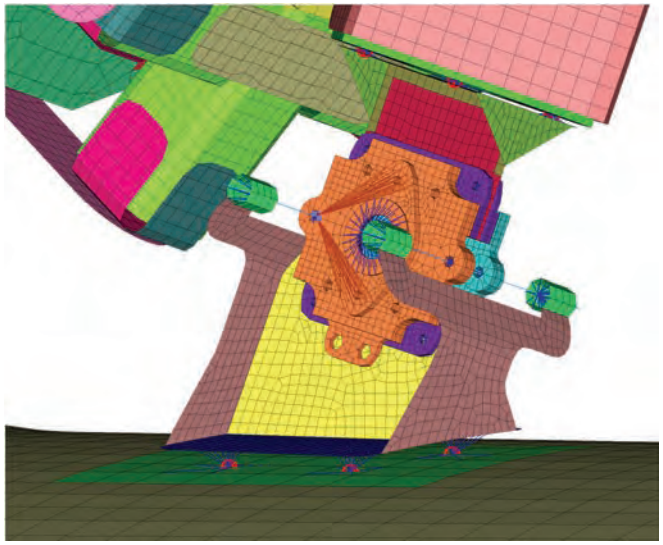
Model Updating Approach

- **Lack of correlation is caused by many factors**
  - Lack of model fidelity, errors in model, or difference between test / FEM configuration
- **Implemented model updates should have physical explanations and are "real"**
  - Preference to avoid purely numerical changes that improve correlation (ΔK & ΔM)
- **Still need to retain model functionality for load recovery**
  - i.e. can not "rigidize" I/F connections by adding fictitiously stiff elements that agree with test stiffness but can not be used to recover loads
- **Typically compared mode shapes and frequencies, and then closely examined regions with high strain energy (SE)**
  - High SE regions are typically the "knobs to turn" in modal correlation
- **Checked FEM in high SE regions for accurate representation of the actual hardware**
  - Reviewed drawings and CAD files and compared to FEM
- **Made gradual changes to iterate towards improvements**

Bolted Joint Modeling – Stress vs. Modal

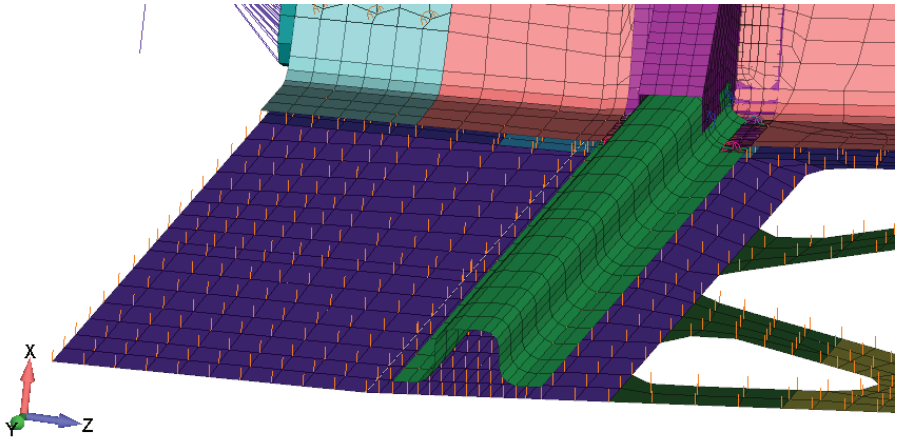
- **Stress models are often more compliant in regions of bolted joints for conservative estimates**
- **Bolted connections sometimes modeled as:**
  - Tension only for bolts / Shear only for pins
  - Rotational stiffness is frequently not included
- **Simplified modeling makes joints too compliant**
  - Ignores the surface-to-surface contact and friction behavior at these joints
- **Typical "fix" (from a modal correlation perspective) for these joints is to add RBE2 footprints, and add stiffness in all DOF at connections**
  - Typical small excitation loads from a modal test will not break friction
- **Final changes must be corroborated with previous proof load tests where available**

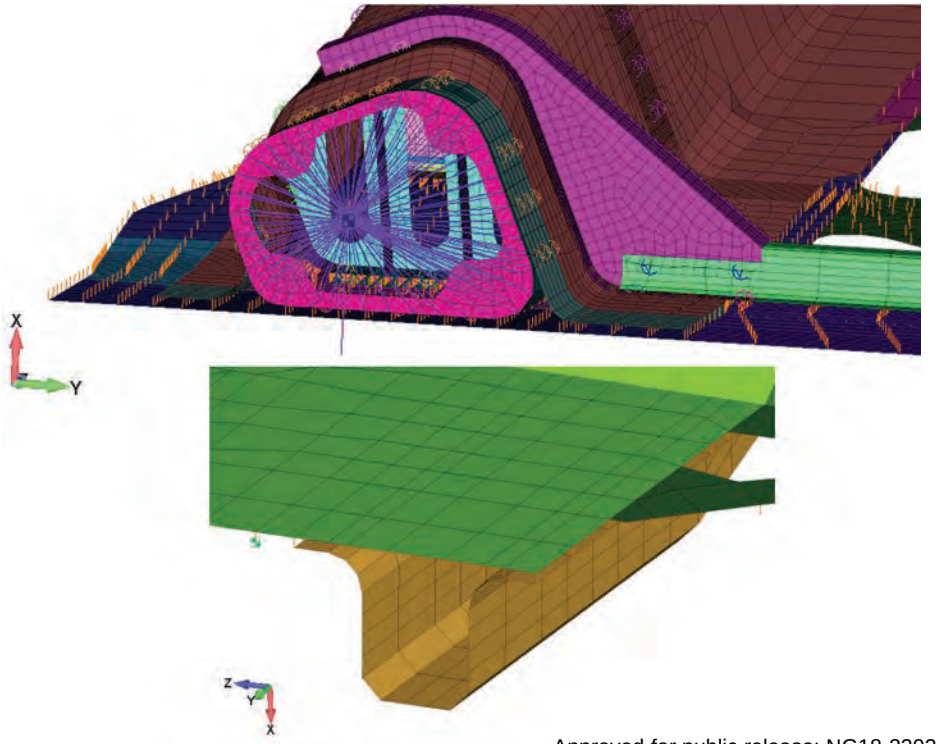




Model Update Example – Corrections of Element Offsets

- **Baseline model did not have shell element offsets on sandwich panel clamshell**
  - Grids/elements were on IML
- **Added shell element offsets to entire inner sandwich panel to put elements at neutral axis location**
  - Results in increased section height and corresponding bending stiffness



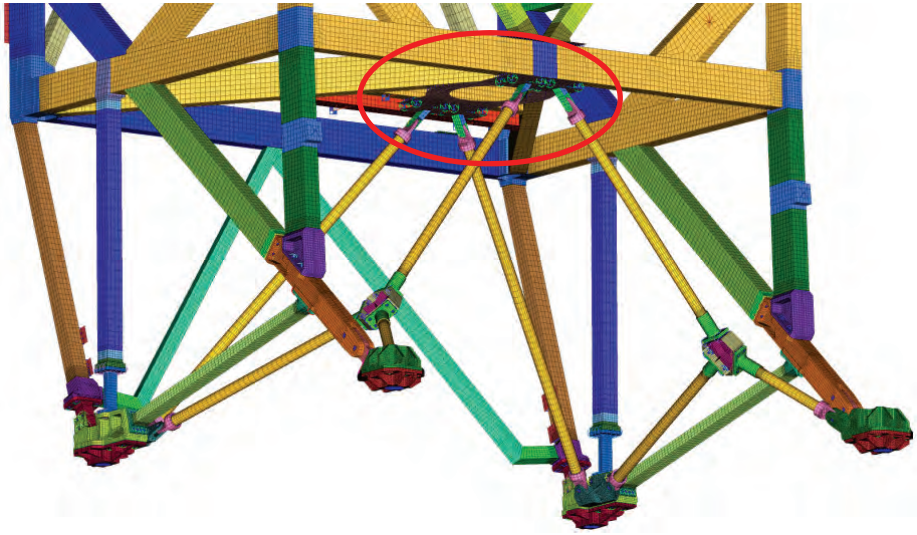


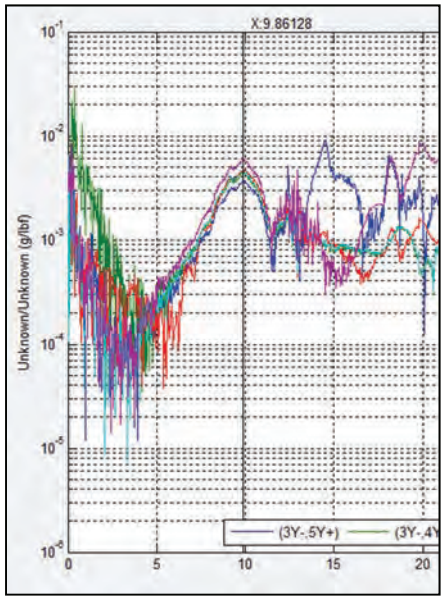
Model Speed Improvements

- **If tuning on certain portion of a model is “done”, consider reducing model to Craig-Bampton (CB) model for subsequent tuning iterations on the remainder of the full model**
  - Only works well if there are a limited number of interfaces
  - Useful when a subassembly of the model is “large”
  - Not worth the sidetrack time/effort for small subassemblies
  - Need to keep all interface and accelerometer points external
- **Example: Simulator DMIG was used for many of the SCE iterations**
  - Gray “ghost” portion at right
  - Model was previously correlated to standalone modal test and did not require significant additional changes
- **Several other analyses were done with significant portions of model reduced to “ghost” CB models**

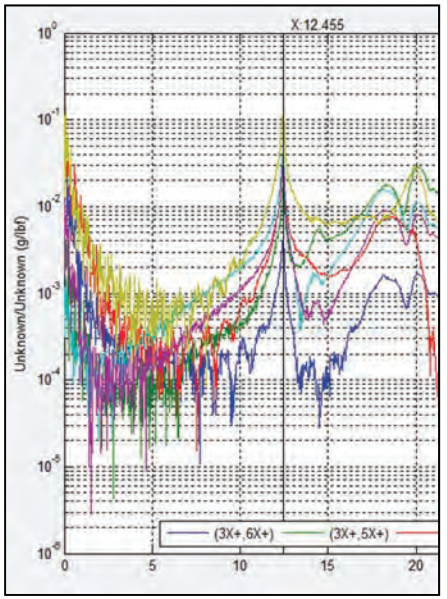
Beware of Non-Linearities

- **Modal testing of OTIS Simulator gave a much lower measured lateral bending frequency than predicted with the FEM**
- **Test FRFs had very rounded peaks indicating high damping and/or joint freeplay**
- **Small freeplay in some joints at low load levels were cause of discrepancy**





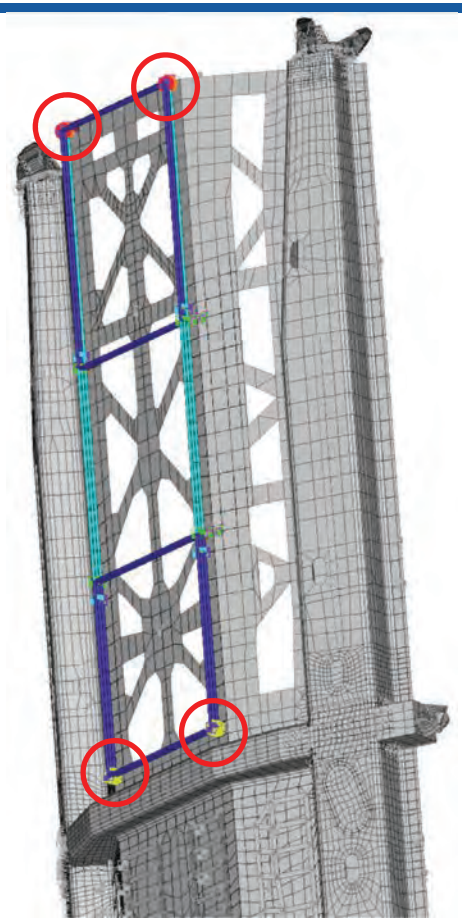
FRFs showing broad rounded peak at lateral bending mode frequency



FRFs showing very clear peak at fore/aft bending mode frequency

Non-Linearities in Deployables

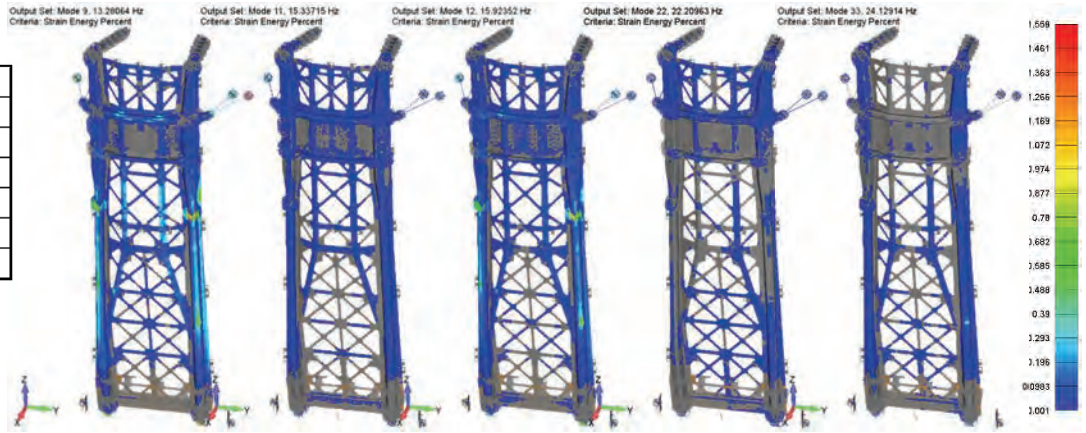
- **Deployable hardware tend to be non-linear to deploy successfully**
  - Bumpers were ignored in baseline model
  - Pre-test FEM gave deployable structure modes starting at 9 Hz, but test showed trim flap mode starting at 13 Hz
  - Correlation required adding soft spring elements to model bumpers (circled yellow & pink at right)
  - Behavior may change at higher Sine Vibe test levels due to bumper non-linearity



Strategy for Interdependent "Knobs"

- **Frequently, changing one model parameter will effect a number of modes**
- **Inevitably, one mode may need to increase, and another may need to decrease – and the high SE for both modes is in a similar region**
- **Model tuning approach:**
  - Select a 3-10 model parameters/properties to change within high SE regions
  - Create matrix of %SE within each property group for each mode of interest
    - This gives you a "menu" of tuning options, with an estimate of effects on frequencies
    - FEMAP API: Custom Tools / PostProcessing / Strain Energy Participation
  - Choose combinations of changes from "menu" that move frequencies closer to targets

Mode	Target	Target	Summed ESE% by Group								
Freq, Hz	Freq, Hz	Change	95	96	97	98	99	100	101	102	103
13.28	13.35	0.5%	6.5	9.9	5.0	4.0	30.3	2.6	4.8	1.7	5.9
15.34	15.08	-1.7%	1.2	2.1	1.2	10.2	10.9	0.5	18.2	4.8	1.4
15.92	15.67	-1.6%	4.3	7.4	3.6	7.2	27.2	3.2	6.0	1.3	8.3
22.21	22.43	1.0%	0.8	0.7	0.1	7.2	10.1	0.4	2.2	0.8	0.1
24.13	24.25	0.5%	1.5	1.7	0.2	2.5	11.7	1.0	0.2	0.0	0.8



Baseline Model
Cross-Ortho to 30Hz

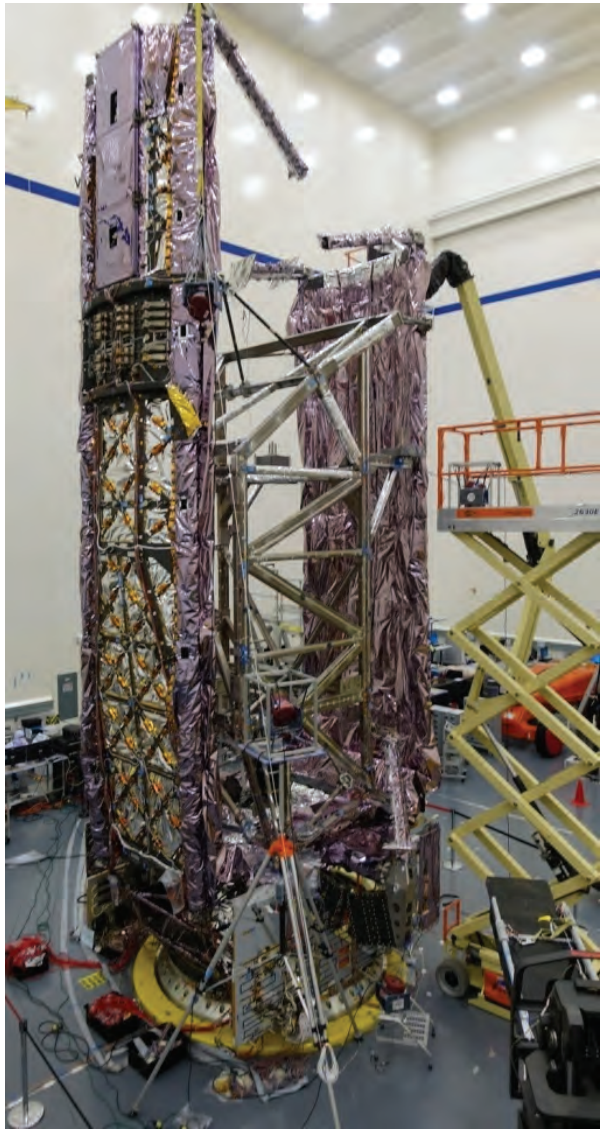
				fore/aft bend	lateral bend	AUPS fore/aft bend, some FUPS fore/aft bend IP w/ aft	AUPS Torsion, some FUPS lateral bending	AUPS Bend, SB lateral bend sym	FUPS lateral bend, AUPS torsion	FUPS fore/aft bending	Aft SS SB lateral bending asym	FUPS bending w/ Fwd SB lateral bend	FUPS torsion w/ Fwd SB's vertical bend	Aft SB vert bend sym w/ trim flap	Torsion	AUPS Bend w/ aft SB bend asym, some torsion	SSMB asym	Fwd SB lateral bend asym	SSMB vertical bend sym	-J2 SSMB fore/aft bend / torsion	Fwd SB vert bend asym	+J2 SSMB fore/aft bend / torsion	chaos	1st axial	2nd axial
				-- Test Modes --->																					
				1	2	3	4	5	6	9	10	11	12	13	14	15	16	19	20	21	22	23	24	26	30
			Freq % Error	8.53	8.99	10.65	11.25	11.70	12.11	13.35	13.75	15.08	15.67	15.93	16.45	17.59	20.71	22.43	23.23	23.99	24.25	24.25	25.22	29.87	31.16
<-- FEM Modes ---	1	7.88	-7.7%	0.96	0.23	0.07	0.01	0.03	0.02	0.02	0.01	0.00	0.01	0.01	0.05	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.02
	2	8.80	-2.1%	0.19	0.96	0.08	0.02	0.06	0.02	0.02	0.01	0.00	0.01	0.01	0.02	0.00	0.01	0.03	0.00	0.00	0.01	0.00	0.04	0.01	0.01
	3	9.23	-28.2%	0.07	0.13	0.58	0.02	0.11	0.04	0.02	0.02	0.03	0.00	0.09	0.01	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
	4	10.37	-2.6%	0.03	0.02	0.78	0.01	0.23	0.02	0.04	0.03	0.01	0.00	0.03	0.02	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.01
	6	10.72	-4.7%	0.00	0.01	0.16	0.96	0.05	0.18	0.01	0.01	0.01	0.00	0.01	0.01	0.09	0.00	0.02	0.00	0.01	0.01	0.01	0.05	0.01	0.00
	7	11.23	-4.0%	0.04	0.02	0.06	0.13	0.89	0.13	0.03	0.22	0.05	0.02	0.05	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.01
	8	11.94	-10.6%	0.04	0.00	0.04	0.01	0.23	0.14	0.95	0.08	0.12	0.03	0.09	0.01	0.04	0.00	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.02
	10	12.26	1.2%	0.02	0.01	0.02	0.16	0.20	0.84	0.10	0.37	0.00	0.01	0.06	0.06	0.14	0.01	0.10	0.00	0.00	0.02	0.00	0.03	0.00	0.02
	12	12.93	-6.0%	0.01	0.00	0.01	0.11	0.06	0.40	0.04	0.81	0.02	0.05	0.03	0.26	0.14	0.00	0.09	0.00	0.00	0.01	0.00	0.03	0.01	0.02
	13	13.75	-8.8%	0.01	0.01	0.04	0.02	0.06	0.04	0.23	0.11	0.81	0.24	0.32	0.07	0.12	0.00	0.08	0.00	0.00	0.07	0.01	0.02	0.11	0.12
	14	13.93	-11.1%	0.04	0.00	0.01	0.00	0.07	0.01	0.06	0.05	0.21	0.80	0.43	0.21	0.09	0.00	0.06	0.00	0.00	0.22	0.00	0.02	0.03	0.01
	15	13.96	-12.4%	0.03	0.02	0.04	0.00	0.06	0.04	0.13	0.06	0.51	0.45	0.70	0.03	0.24	0.00	0.09	0.00	0.00	0.12	0.00	0.02	0.07	0.07
	16	15.12	-14.1%	0.01	0.01	0.01	0.03	0.02	0.05	0.01	0.29	0.01	0.07	0.30	0.35	0.75	0.00	0.08	0.00	0.00	0.00	0.00	0.01	0.01	0.00
	18	16.14	-1.9%	0.04	0.03	0.03	0.04	0.03	0.16	0.00	0.12	0.02	0.22	0.02	0.73	0.42	0.03	0.30	0.01	0.01	0.00	0.01	0.05	0.02	0.01
	26	18.60	-10.2%	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.99	0.02	0.06	0.03	0.03	0.03	0.03	0.00	0.00
	27	18.87	-22.2%	0.00	0.02	0.00	0.02	0.01	0.09	0.00	0.06	0.04	0.14	0.01	0.18	0.05	0.05	0.46	0.01	0.01	0.68	0.02	0.07	0.03	0.02
	29	20.17	-10.1%	0.01	0.01	0.03	0.01	0.04	0.08	0.02	0.07	0.00	0.02	0.02	0.10	0.01	0.01	0.56	0.05	0.02	0.47	0.00	0.10	0.05	0.00
	31	20.66	-11.1%	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.06	0.04	0.94	0.04	0.01	0.23	0.04	0.03	0.00
	34	21.01	-6.3%	0.04	0.02	0.00	0.03	0.00	0.03	0.00	0.00	0.01	0.03	0.04	0.19	0.10	0.01	0.30	0.03	0.09	0.17	0.02	0.13	0.05	0.01
	35	21.30	-52.9%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.19	0.64	0.08	0.49	0.21	0.03	0.09
	36	21.43	-11.6%	0.01	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.03	0.03	0.18	0.58	0.10	0.67	0.05	0.04	0.02
	43	22.98	-25.2%	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.00	0.00	0.01	0.00	0.02	0.02	0.11	0.33	0.07	0.30	0.07	0.03	0.16
	44	23.08	-26.1%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.02	0.01	0.15	0.28	0.05	0.31	0.02	0.01	0.02
	49	25.56	-14.4%	0.03	0.01	0.02	0.00	0.01	0.00	0.01	0.00	0.02	0.00	0.03	0.01	0.02	0.01	0.00	0.01	0.04	0.01	0.04	0.06	0.29	0.16
	52	26.28	4.2%	0.01	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.04	0.05	0.07	0.05	0.00	0.01	0.02	0.04	0.03	0.33	0.06	0.05
	55	27.44	-21.5%	0.01	0.01	0.00	0.01	0.01	0.04	0.02	0.01	0.04	0.00	0.03	0.02	0.02	0.01	0.02	0.01	0.03	0.14	0.02	0.37	0.02	0.17
	57	28.17	11.7%	0.00	0.02	0.01	0.00	0.01	0.02	0.01	0.01	0.02	0.01	0.00	0.04	0.03	0.02	0.06	0.00	0.04	0.02	0.07	0.58	0.22	0.09
	58	28.73	-3.8%	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.01	0.04	0.01	0.00	0.01	0.01	0.00	0.06	0.00	0.01	0.01	0.01	0.11	0.71	0.11
	59	29.21	-2.197%	0.01	0.01	0.01	0.02	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.03	0.00	0.01	0.01	0.01	0.14	0.32	0.02
	60	29.53	-5.202%	0.02	0.00	0.02	0.00	0.01	0.00	0.01	0.01	0.03	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.01	0.01	0.01	0.05	0.21	0.80
	64	31.97	2.6%	0.01	0.00	0.01	0.00	0.01	0.01	0.04	0.01	0.03	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.11	0.33

Updated SCE
Cross-Ortho to 30 Hz

				fore/aft bend	lateral bend	AUPS fore/aft bend, some FUPS fore/aft bend	AUPS Torsion, some FUPS lateral bending	AUPS Bend, SB lateral bend sym	FUPS lateral bend, AUPS torsion	STSA detached bending	SS trim flap	FUPS fore/aft bending	Aft SS SB lateral bending asym	FUPS bending w/ Fwd SB lateral bend	FUPS torsion w/ Fwd SB's vertical bend	Aft SB vert bend sym w/ trim flap	Torsion	AUPS Bend w/ aft SB bend asym, some torsion	SSMB asym	SS trim flap torsion	STSA detached bending	Fwd SB lateral bend asym	SSMB vertical bend sym	-J2 SSMB fore/aft bend / torsion	Fwd SB vert bend asym	+J2 SSMB fore/aft bend / torsion	chaos	STSA	1st axial	+J2 SS MB fore/aft bending / SBA rX bending	AUPS local lattice w/ +J2 SS MB torsion	2nd axial
				-- Test Modes --->																													
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	30
			Freq % Error	8.53	8.99	10.65	11.25	11.70	12.11	12.70	12.87	13.35	13.75	15.08	15.67	15.93	16.45	17.59	20.71	20.96	22.43	22.43	23.23	23.99	24.25	24.25	25.22	28.59	29.87	30.72	30.81	31.16
-- FEM Modes --->	1	8.50	-0.3%	0.98	0.03	0.14	0.01	0.04	0.01	0.00	0.04	0.02	0.01	0.00	0.01	0.00	0.04	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.02	0.01	0.00	0.03
	2	9.11	1.4%	0.00	0.99	0.01	0.04	0.02	0.02	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.05	0.01	0.00	0.01	0.00	0.01	0.00	0.00	0.01	0.00	0.03	0.00	0.01	0.00	0.00	0.00
	3	10.67	0.3%	0.04	0.01	0.96	0.02	0.16	0.01	0.00	0.16	0.03	0.02	0.03	0.00	0.05	0.01	0.08	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.01	0.00	0.00	0.00
	4	11.21	-0.3%	0.00	0.04	0.17	0.98	0.01	0.01	0.00	0.02	0.01	0.05	0.00	0.02	0.00	0.02	0.02	0.00	0.03	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00
	5	11.76	0.5%	0.05	0.01	0.12	0.14	0.92	0.12	0.00	0.29	0.07	0.15	0.06	0.02	0.00	0.01	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
	6	12.29	1.5%	0.01	0.03	0.01	0.03	0.14	0.98	0.01	0.07	0.06	0.06	0.00	0.04	0.03	0.04	0.02	0.00	0.01	0.01	0.01	0.00	0.00	0.03	0.00	0.05	0.00	0.02	0.00	0.00	0.02
	7	12.88	0.1%	0.02	0.00	0.02	0.04	0.22	0.02	0.00	0.93	0.00	0.04	0.05	0.01	0.00	0.02	0.03	0.00	0.06	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
	8	13.00	2.4%	0.00	0.00	0.00	0.00	0.00	0.00	0.99	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00
	9	13.26	-0.6%	0.05	0.01	0.01	0.01	0.20	0.01	0.00	0.00	0.97	0.03	0.08	0.01	0.06	0.02	0.01	0.00	0.00	0.01	0.03	0.00	0.00	0.05	0.00	0.00	0.00	0.04	0.00	0.00	0.05
	10	13.69	-0.4%	0.00	0.00	0.01	0.06	0.11	0.09	0.00	0.07	0.07	0.98	0.01	0.01	0.12	0.03	0.02	0.00	0.01	0.01	0.01	0.00	0.00	0.01	0.00	0.01	0.00	0.02	0.00	0.00	0.01
	11	15.36	1.9%	0.00	0.01	0.02	0.00	0.02	0.01	0.00	0.01	0.19	0.05	0.93	0.27	0.11	0.03	0.07	0.00	0.00	0.00	0.03	0.00	0.00	0.01	0.00	0.01	0.00	0.02	0.00	0.00	0.03
	12	15.80	0.8%	0.03	0.01	0.01	0.01	0.02	0.01	0.00	0.00	0.00	0.01	0.15	0.94	0.02	0.09	0.03	0.00	0.00	0.00	0.03	0.00	0.00	0.05	0.00	0.01	0.00	0.02	0.00	0.00	0.02
	13	15.97	0.3%	0.05	0.00	0.04	0.00	0.05	0.02	0.00	0.03	0.01	0.10	0.30	0.05	0.92	0.22	0.28	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.02	0.00	0.00	0.00
	14	16.46	0.0%	0.04	0.02	0.02	0.03	0.02	0.04	0.00	0.00	0.02	0.02	0.02	0.16	0.18	0.93	0.10	0.03	0.00	0.02	0.01	0.01	0.00	0.01	0.00	0.07	0.00	0.05	0.01	0.00	0.01
	15	17.54	-0.3%	0.02	0.01	0.00	0.00	0.02	0.01	0.00	0.00	0.00	0.01	0.01	0.05	0.28	0.14	0.92	0.01	0.02	0.00	0.01	0.00	0.01	0.00	0.00	0.01	0.00	0.02	0.00	0.00	0.01
	18	20.46	-1.2%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.98	0.02	0.03	0.01	0.06	0.02	0.00	0.04	0.01	0.00	0.00	0.10	0.00	0.02
	19	20.80	-7.3%	0.02	0.01	0.01	0.00	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.02	0.01	0.00	0.02	0.02	0.01	0.07	0.01	0.01	0.03	0.01	0.01	0.00	0.01	0.00	0.00	0.04
	20	20.96	0.0%	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.95	0.03	0.01	0.00	0.01	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00
	24	22.33	-0.5%	0.01	0.01	0.02	0.01	0.01	0.03	0.00	0.00	0.02	0.01	0.01	0.02	0.00	0.03	0.01	0.00	0.02	0.19	0.86	0.02	0.01	0.04	0.01	0.00	0.00	0.05	0.00	0.00	0.01
	27	22.98	2.5%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.93	0.01	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00
	29	23.48	1.0%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.05	0.00	0.95	0.09	0.01	0.18	0.03	0.00	0.03	0.12	0.00	0.02
	33	24.11	0.5%	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.00	0.01	0.00	0.01	0.03	0.19	0.94	0.15	0.19	0.14	0.00	0.01	0.04	0.00	0.00
	34	24.20	-0.2%	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.04	0.00	0.02	0.00	0.15	0.28	0.00	0.95	0.13	0.00	0.04	0.08	0.00	0.01
	35	24.62	1.5%	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.05	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.07	0.01	0.01	0.91	0.04	0.00	0.00	0.01	0.00	0.00	0.01
	37	25.35	0.5%	0.02	0.00	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.02	0.00	0.01	0.01	0.02	0.02	0.00	0.01	0.03	0.02	0.03	0.01	0.06	0.02	0.89	0.00	0.01	0.02	0.00	0.01
	41	29.81	-0.2%	0.03	0.01	0.01	0.00	0.01	0.00	0.01	0.00	0.02	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.02	0.00	0.01	0.01	0.03	0.01	0.02	0.24	0.87	0.12	0.01	0.34
	42	30.17	5.5%	0.01	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.92	0.23	0.03	0.01	0.07
	44	31.09	-0.2%	0.03	0.01	0.03	0.00	0.01	0.00	0.00	0.00	0.02	0.00	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.07	0.01	0.01	0.03	0.17	0.07	0.04	0.81
	45	31.26	1.8%	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.01	0.00	0.09	0.01	0.00	0.03	0.03	0.00	0.02	0.94	0.01	0.13
	46	31.65	1.3%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.04	0.00	0.00	0.04	0.02	0.00	0.00	0.01	0.00	0.02	0.05	0.00	0.05
	47	31.66	1.4%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.02	0.00	0.00	0.07	0.03	0.00	0.01	0.01	0.00	0.04	0.12	0.01	0.12
	48	32.36	5.0%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.00	0.95	0.01

Summary

- In preparation for modal survey test of the SCE configuration of the JWST, pretest analysis was performed to find a set of accelerometer locations that would capture the mode shapes and frequencies of interest
  - Modal effective mass was used to determine modes of interest
  - Kinetic energies were used to help determine the accelerometer locations
  - 550 accelerometer DOF used
  - Modes up to 30Hz targeted
- After modal survey test was completed, analysis effort was made to correlate the current FEM to the test data
  - FEM was compared against CAD & drawings
  - Changes with physical explanations were considered and implemented
  - Frequency match and cross-orthogonality considerably improved vs. pretest FEM

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NORTHROP GRUMMAN