SIEMENS

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Modeling the First Light Machine with FEMAP

FEMAP SYMPOSIUM 2014
Discover New Insights

Femap Symposium 2014
May 14-16, Atlanta, GA, USA

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The First Light Machine

- The James Webb Space Telescope is an infrared telescope with a 6.5m primary mirror.
- GSFC manages the project and Northrop Grumman Aerospace Systems is the prime contractor.
- JWST will observe
  - First luminous glows after the Big Bang
  - Formation of solar systems capable of supporting life on planets like Earth
  - Evolution of our own Solar System
- There are 4 science instruments mounted in the Integrated Science Instrument Module (ISIM), which was designed and integrated by GSFC staff independent of the JWST project office.
- SGT and our partners on the MSES IIA contract have supported GSFC's management of JWST and development an delivery of ISIM in a myriad of ways. Our analysis support using FEMAP is one small part of the work we have been horned to do in concert with NASA/GSFC.

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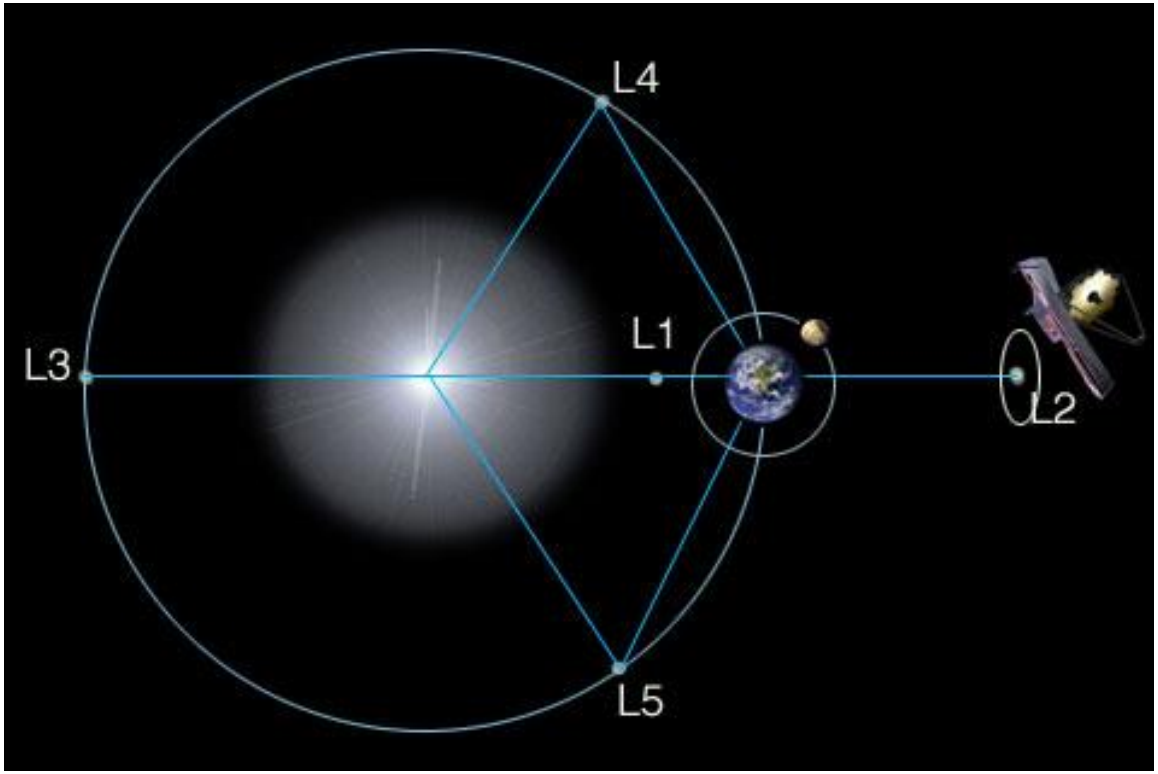
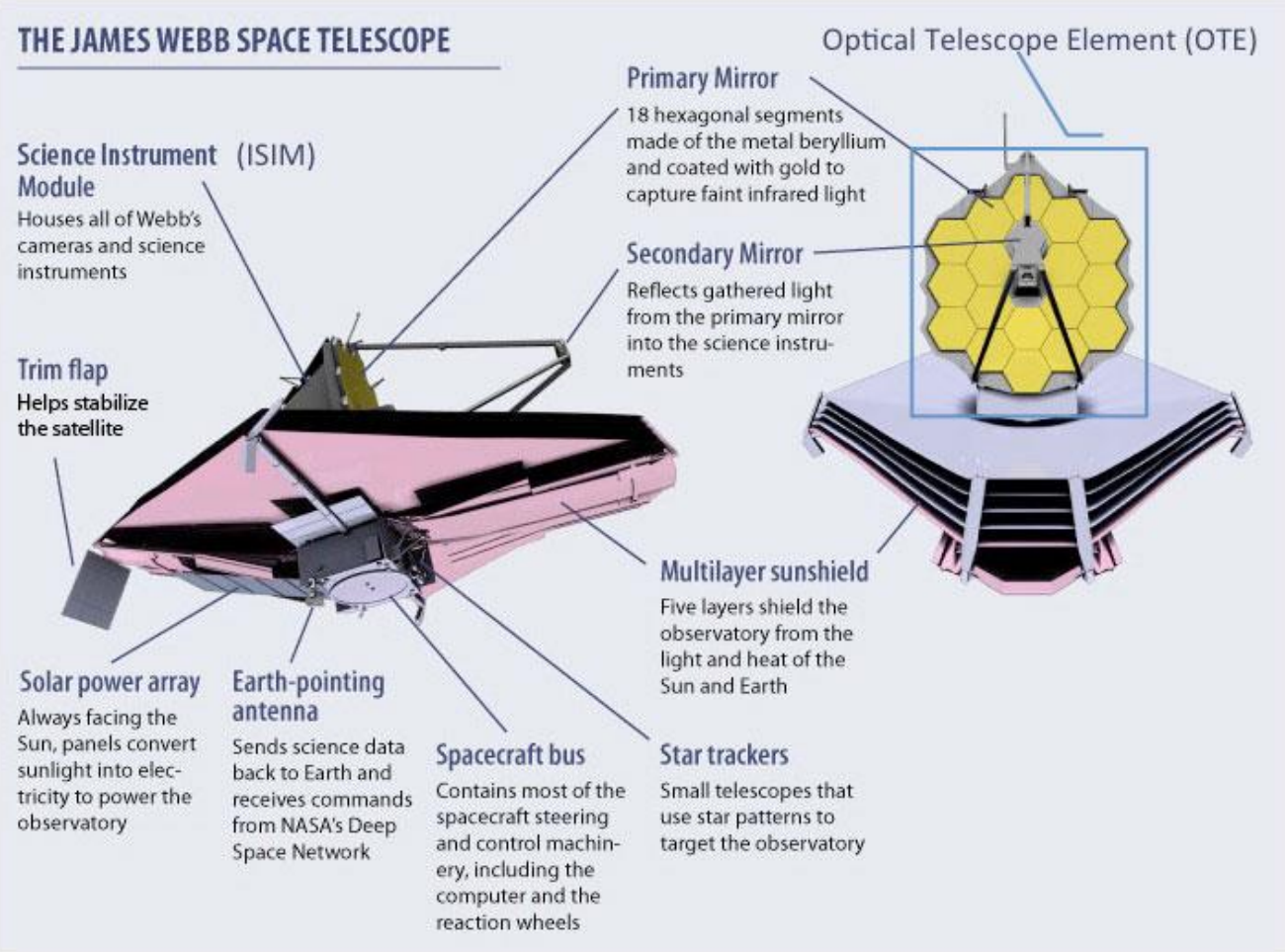
Launch and Orbit

- JWST will be launched via an Ariane V from French Guiana.
- For thermal and optical reasons JWST cannot operate in low-Earth orbit. It will orbit about the LaGrange point L2, 1.5 million km from Earth.

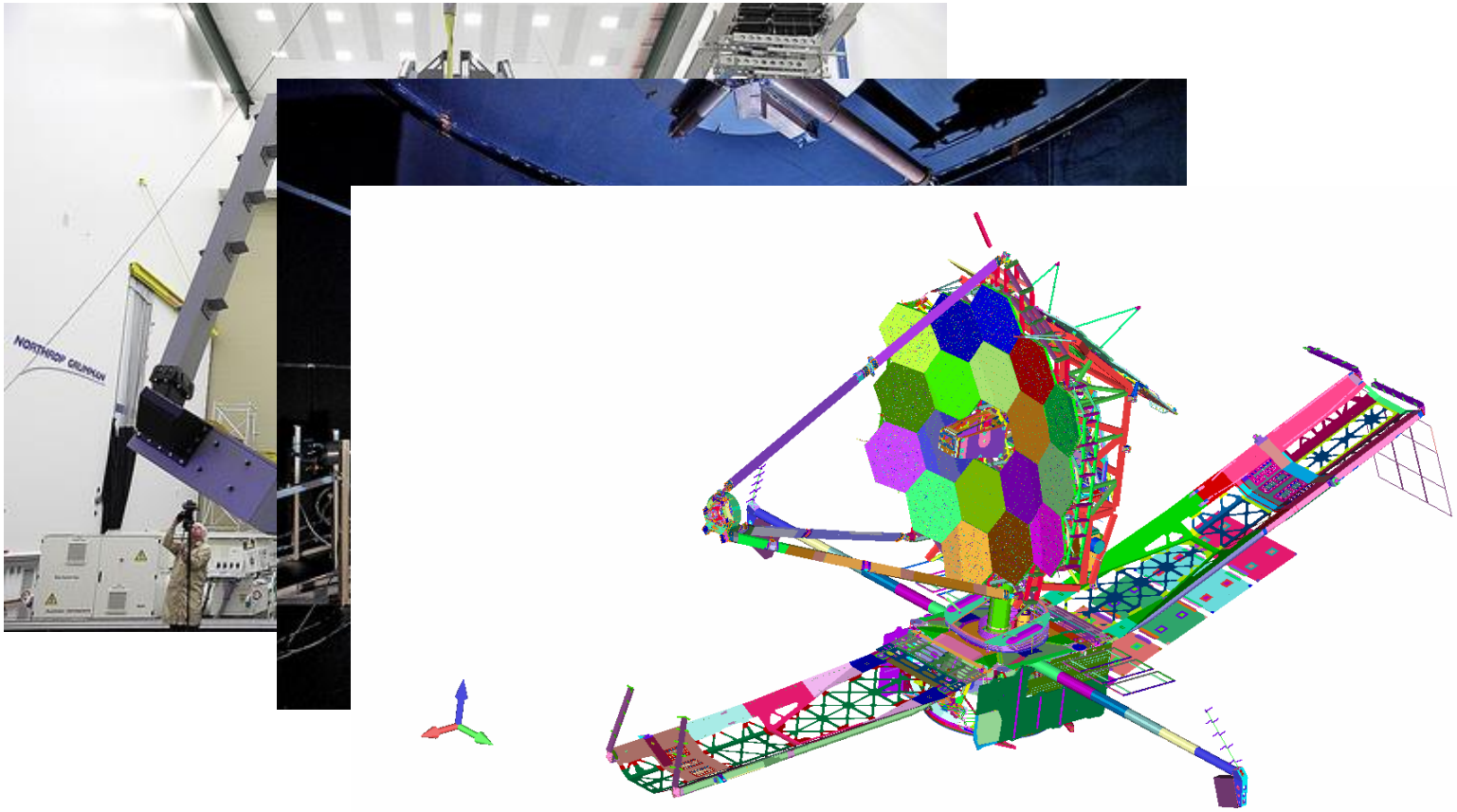


Major Elements



FEMAP's role on JWST

- Traditional Loads modeling
- Design and testing of the ISIM
- On-orbit stability of the observatory — Thermal and Jitter



Developing Models

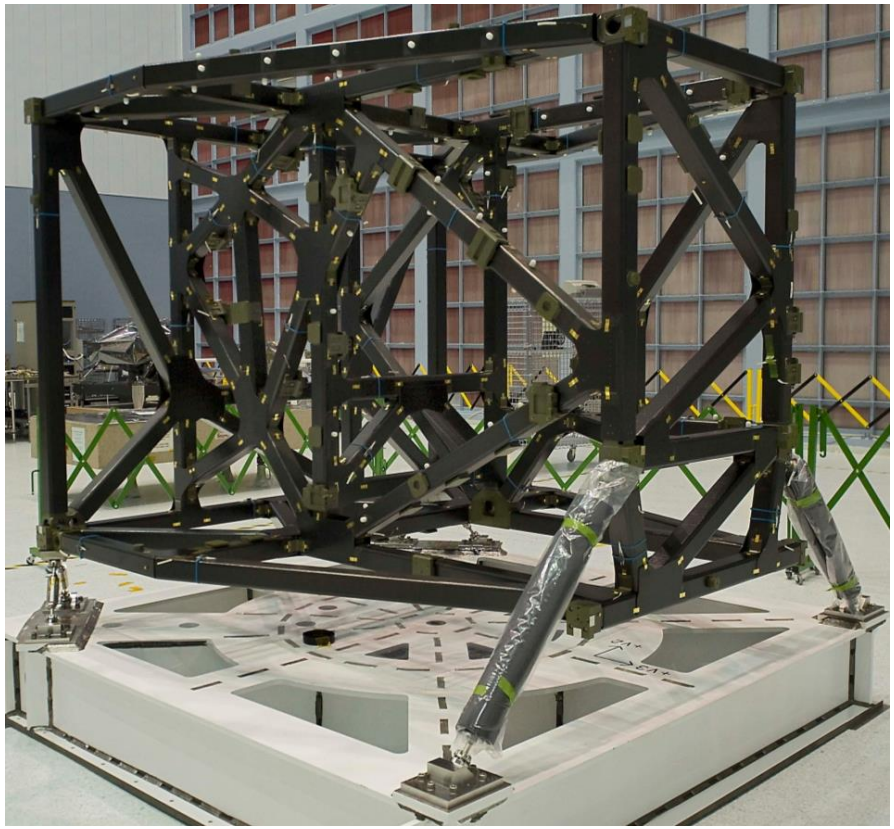
Model Validity Checks

- GSFC has a long history with NASTRAN but we don't trust models
- Checks are done on all models - a requirement written into the documents defining the analysis process for the project
  - Grounding and free rigid movement
  - Mechanism checks and rigid/flexible modal separation
  - Free thermal expansion
- These checks build confidence that models are usable for further analysis
- FEMAP is used to review these results

http://femci.gsfc.nasa.gov/validitychecks/index.html

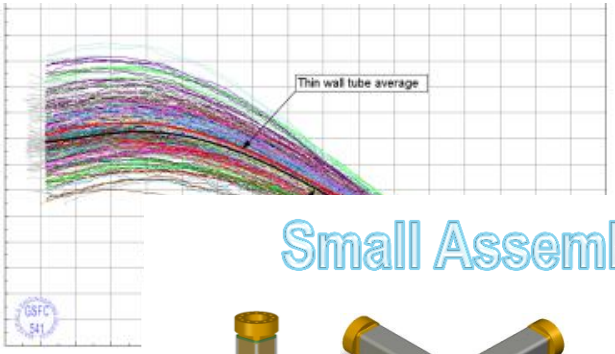
ISIM Structure

- GSFC developed the ISIM structure
  - Houses 4 science instruments in a strong, stable truss assembly
  - Operating temperature is 40K with variations of about 1K
  - Structure is 2m x 2.3m x 2.3m and weighs 860kg
- Status
  - Design, build and bench structure proof testing is complete
  - Populated with all instruments
  - Completed 2 cryogenic proof tests and 1 system operational test
  - Another operational test is scheduled for June 2014

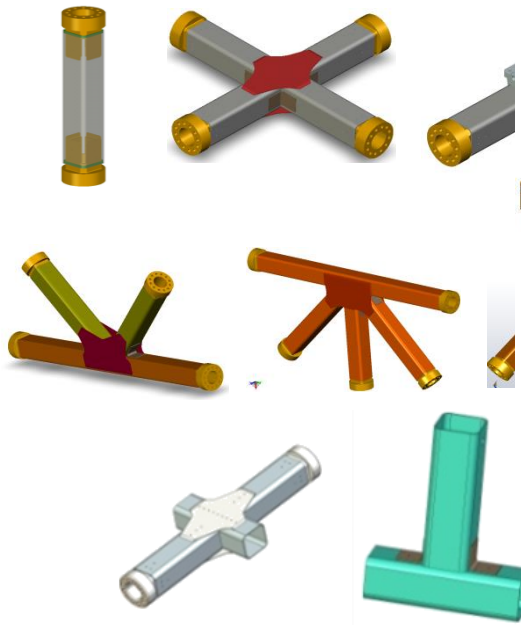


ISIM's Stepping Stones

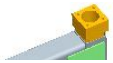
Materials



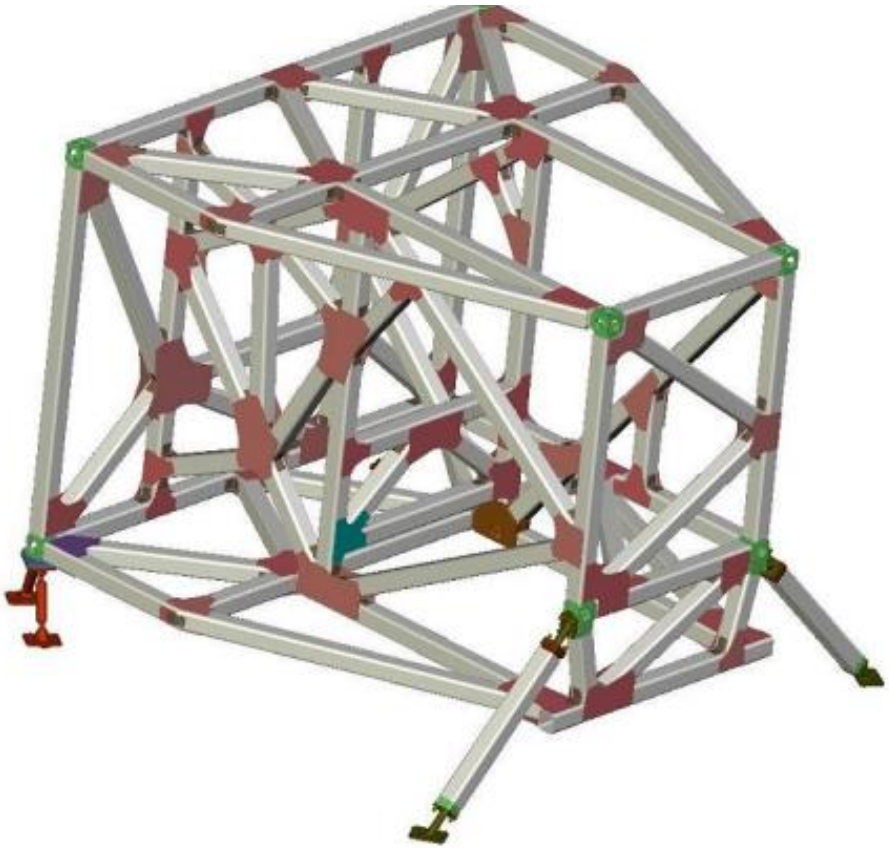
Small Assemblie



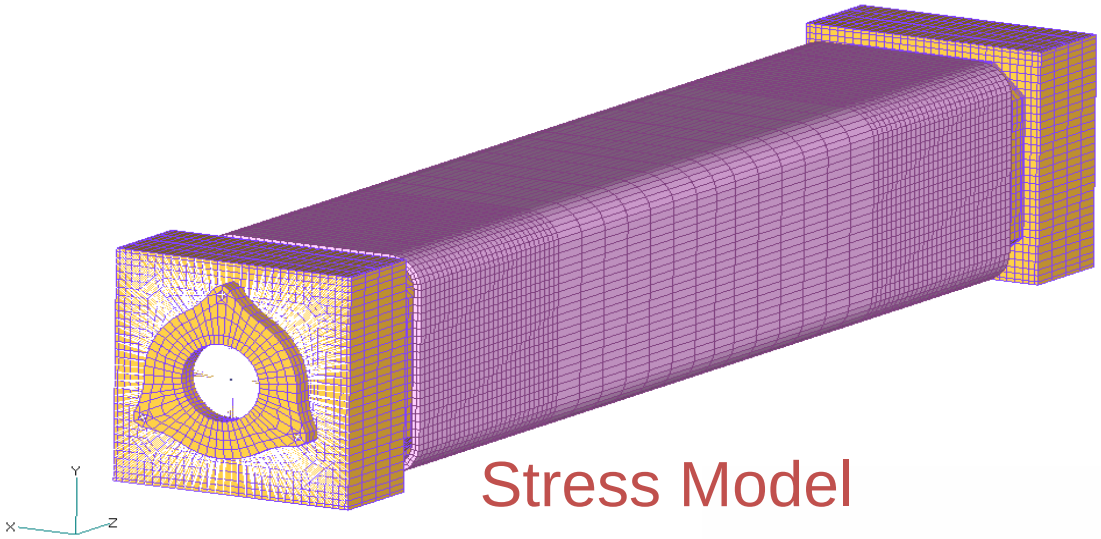
Large Assembly



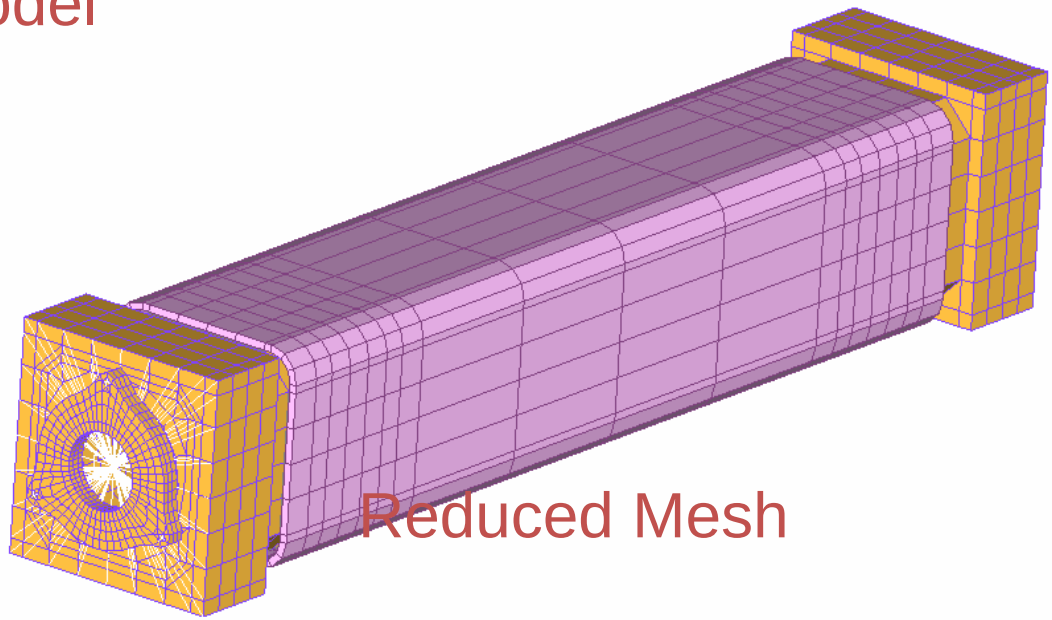
ISIM Structure



Convergence Studies Models

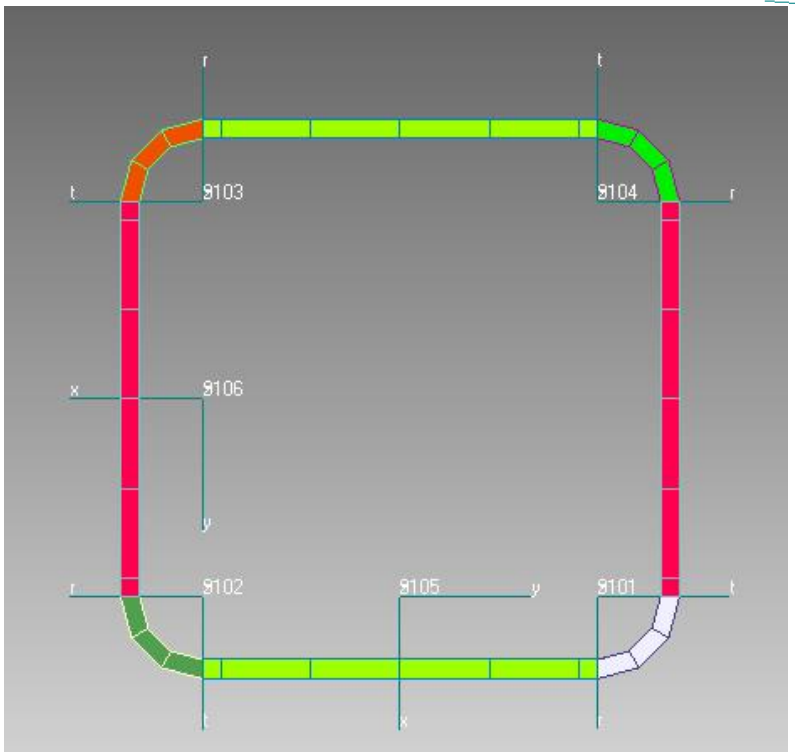


Stress Model

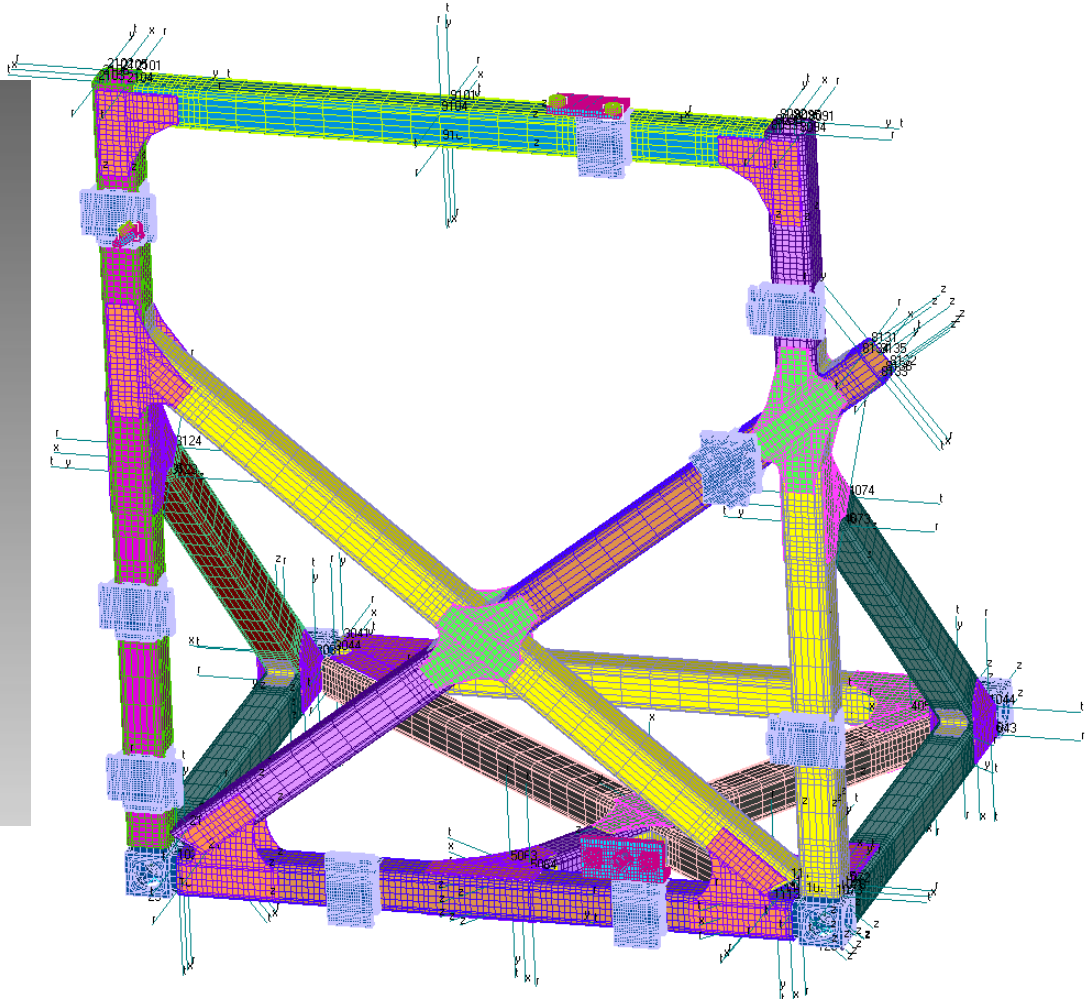


Reduced Mesh

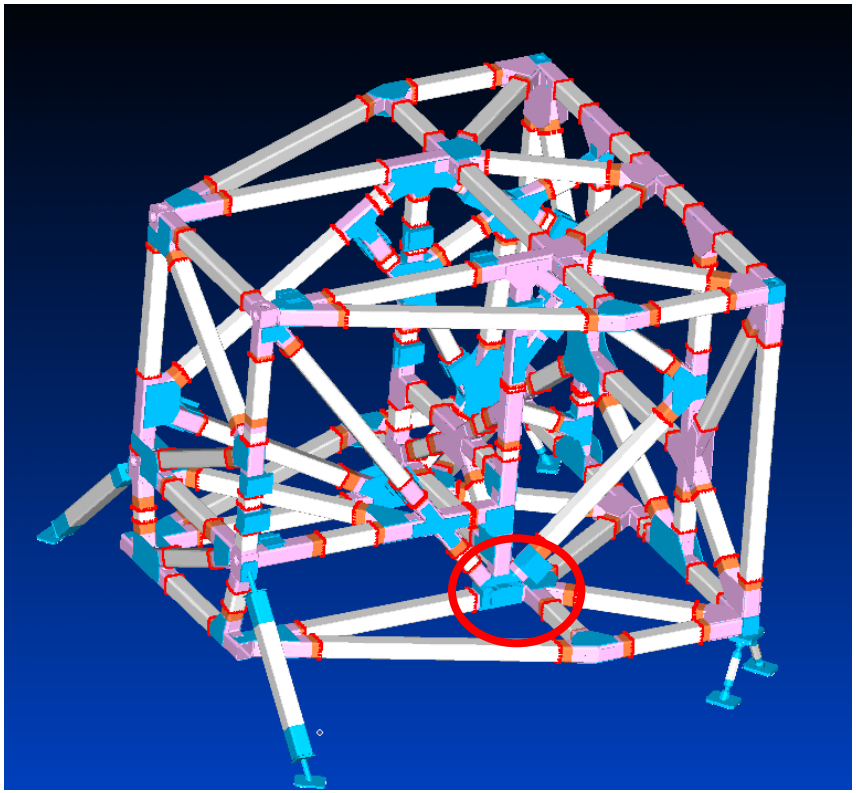
Composite Modeling with FEMAP

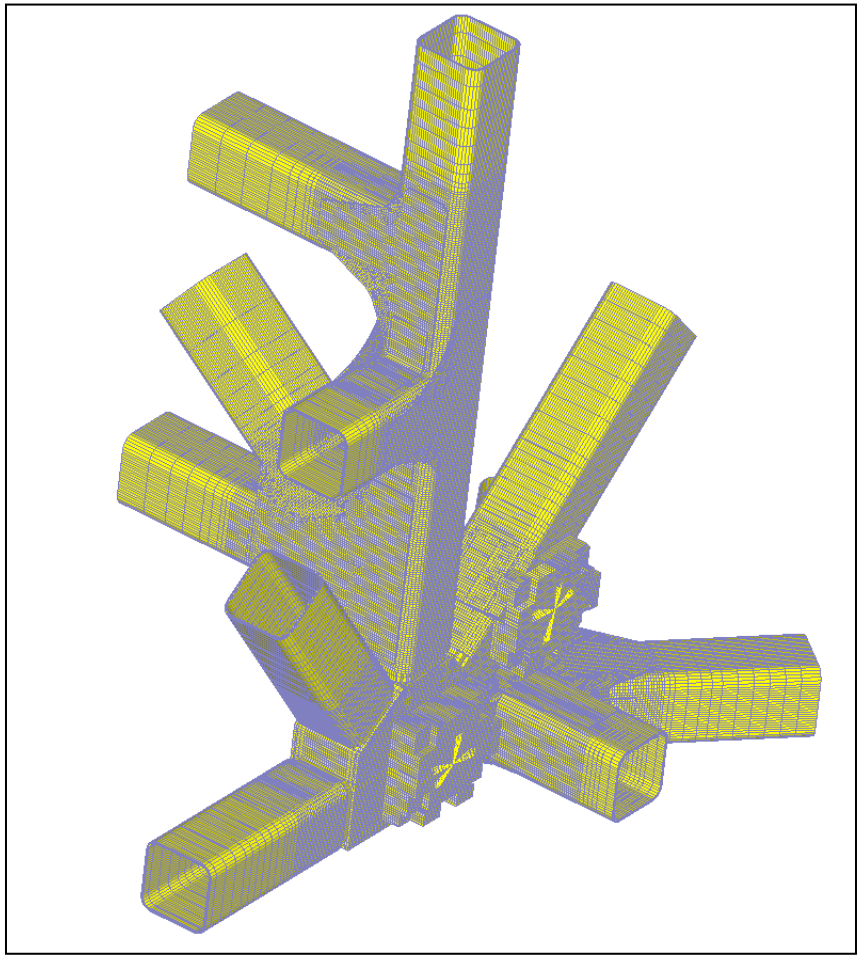


Local Coordinate Systems



Global to Local





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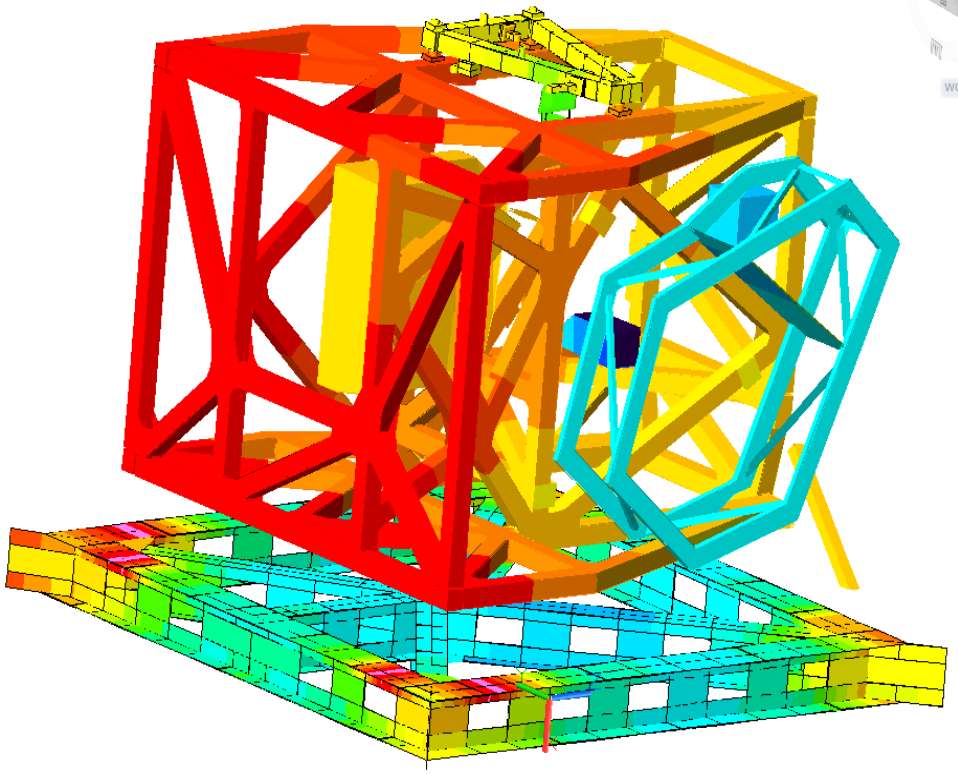
JWST Model Building

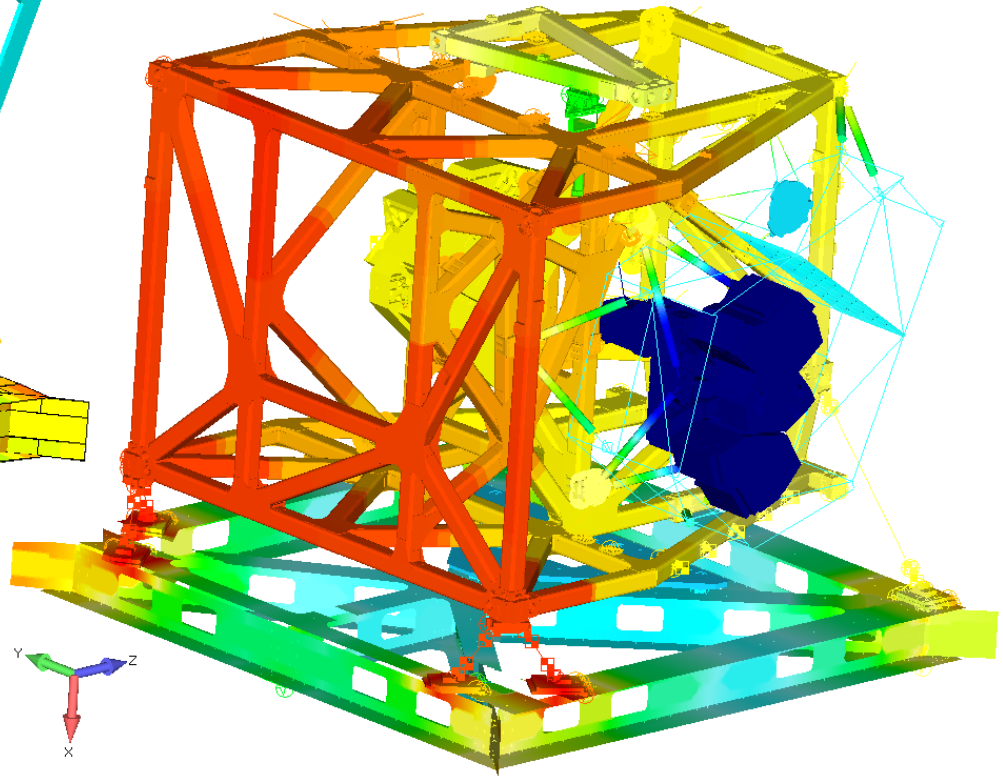
- Thermal Distortion
  - Used to predict thermally-induced wavefront error during observing periods
  - Component models form manufacturers
  - NGAS and GSFC collaborate on building and validating the observatory model
- Final models are huge
  - 5.2M Elements (mostly solids)
  - 27 MDOF
  - On-orbit models tend to exclude parts not important to wavefront error
- Deployed Dynamics
  - Used to predict mechanically-induced wavefront error during observations
  - Component models from manufacturers
  - NGAS and GSFC collaborate on building and validating the observatory model
- Analysis models make substantial use of Craig-Bampton reduction of TD models
- Substantial effort is put into avoiding grounding and other mathematical errors

Using the Models

ISIM Temperature Mapping

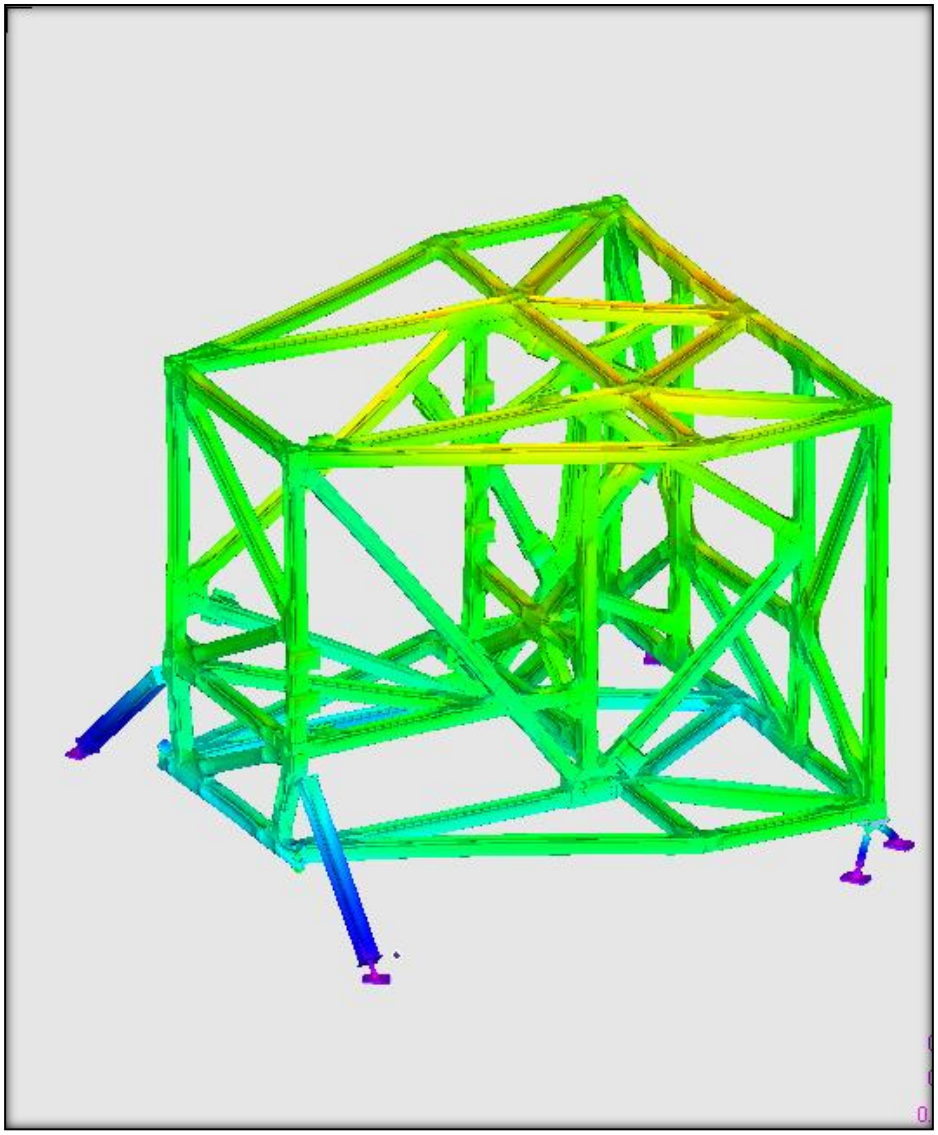


Thermal Model

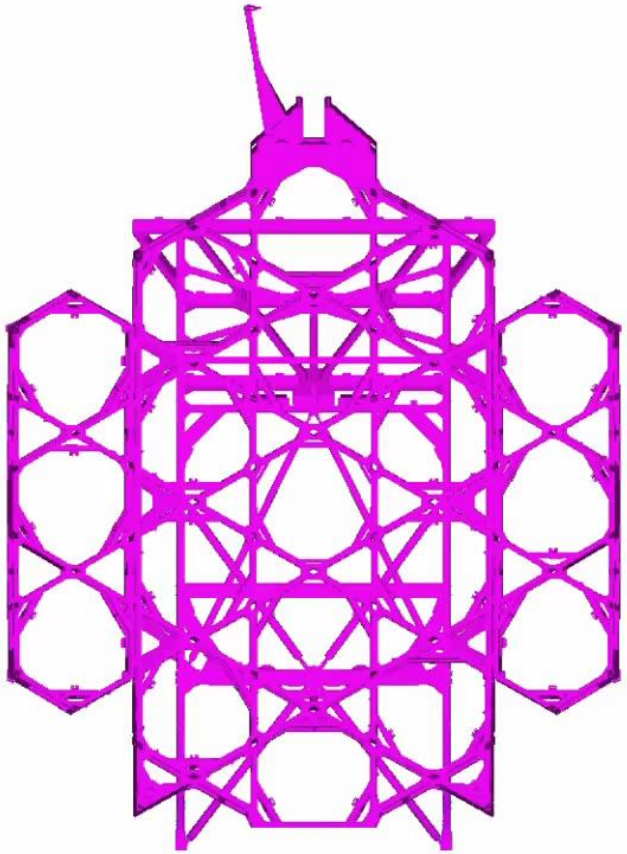


Structural Model

Operational Temperatures Distorted Shape



JWST Temperature Progression



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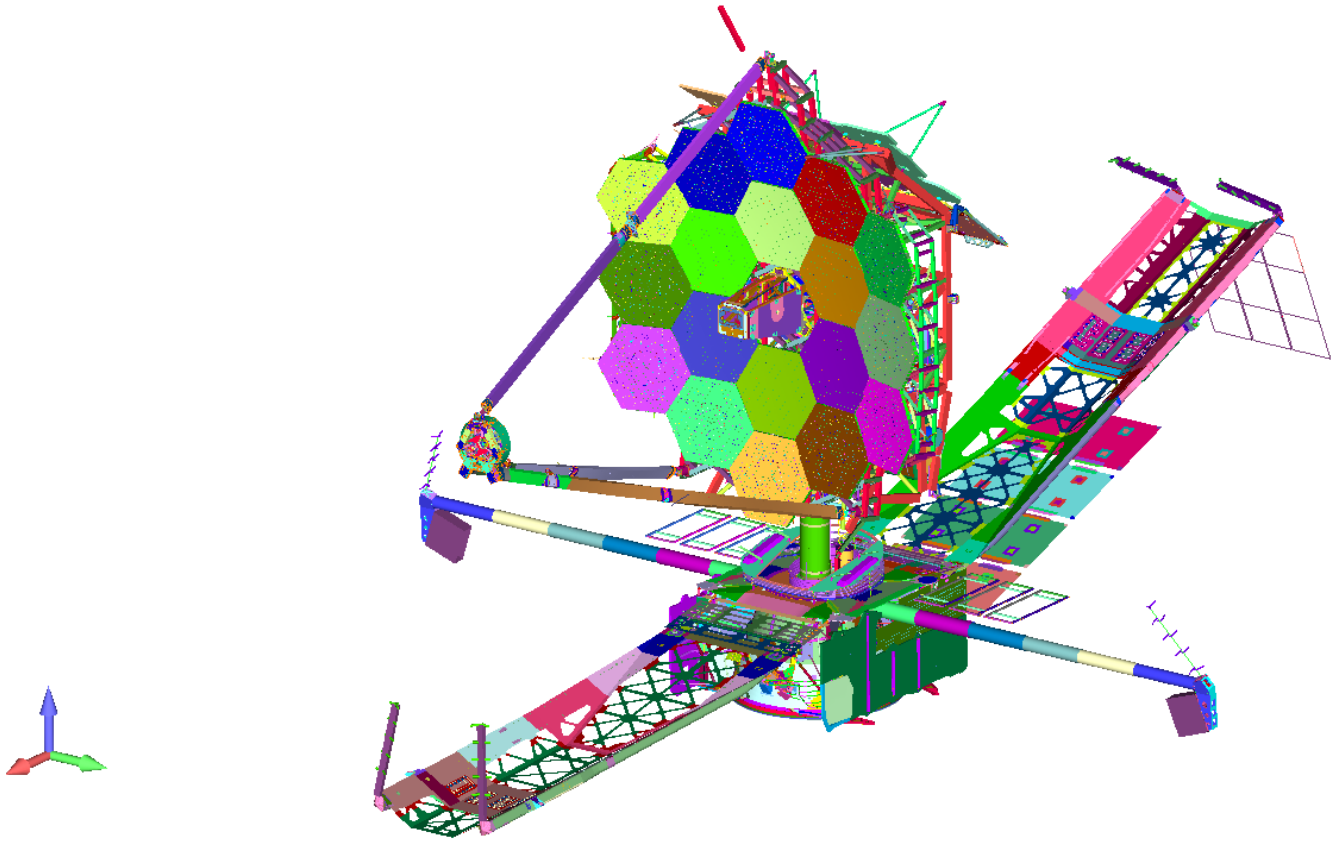
Dynamics Modeling
Key Modes



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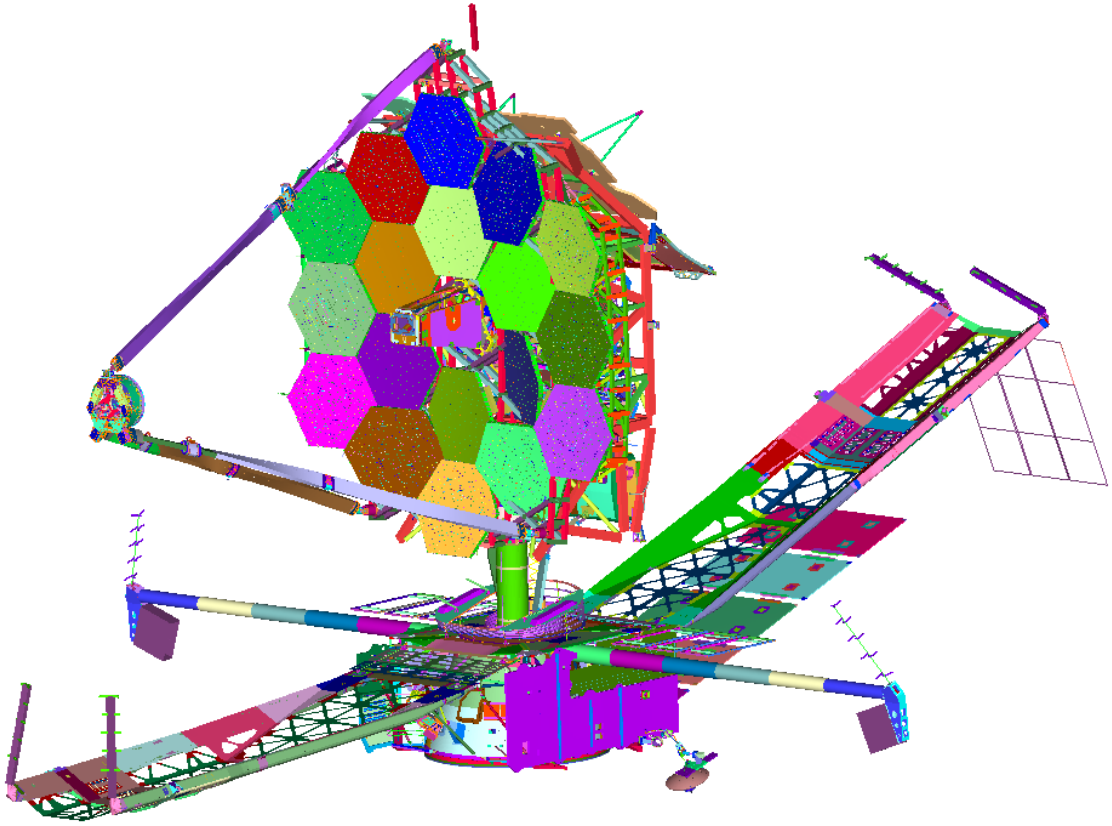
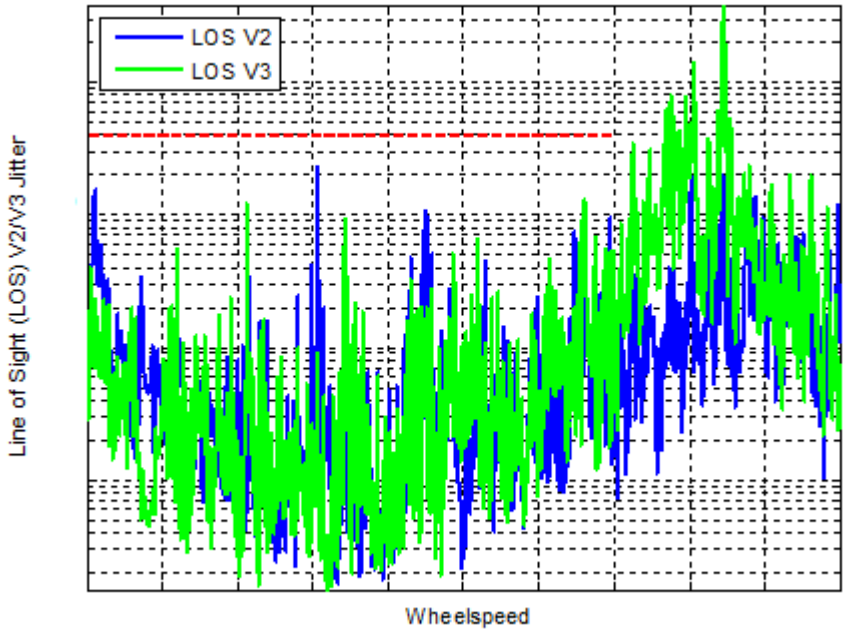
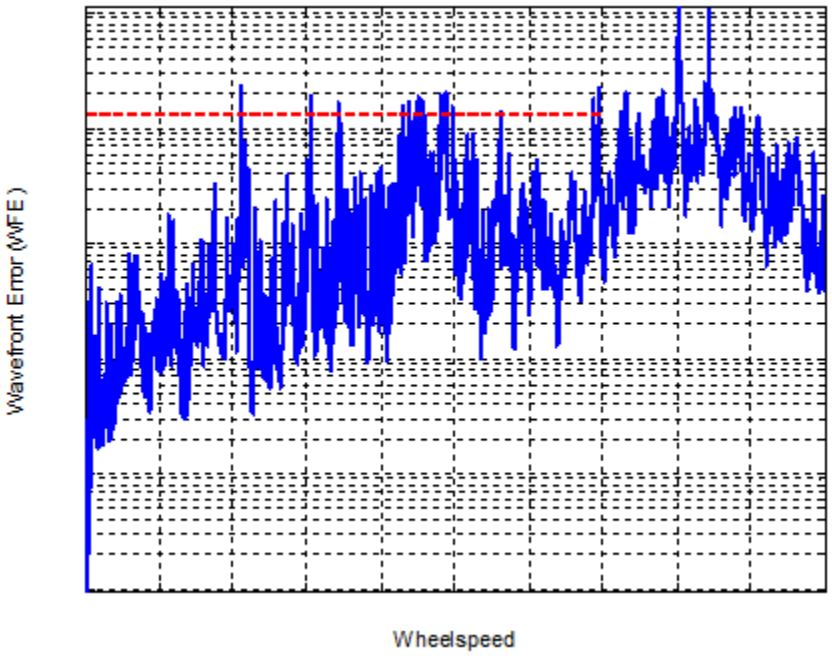


JWST Dynamics Modeling



Line of Sight Error



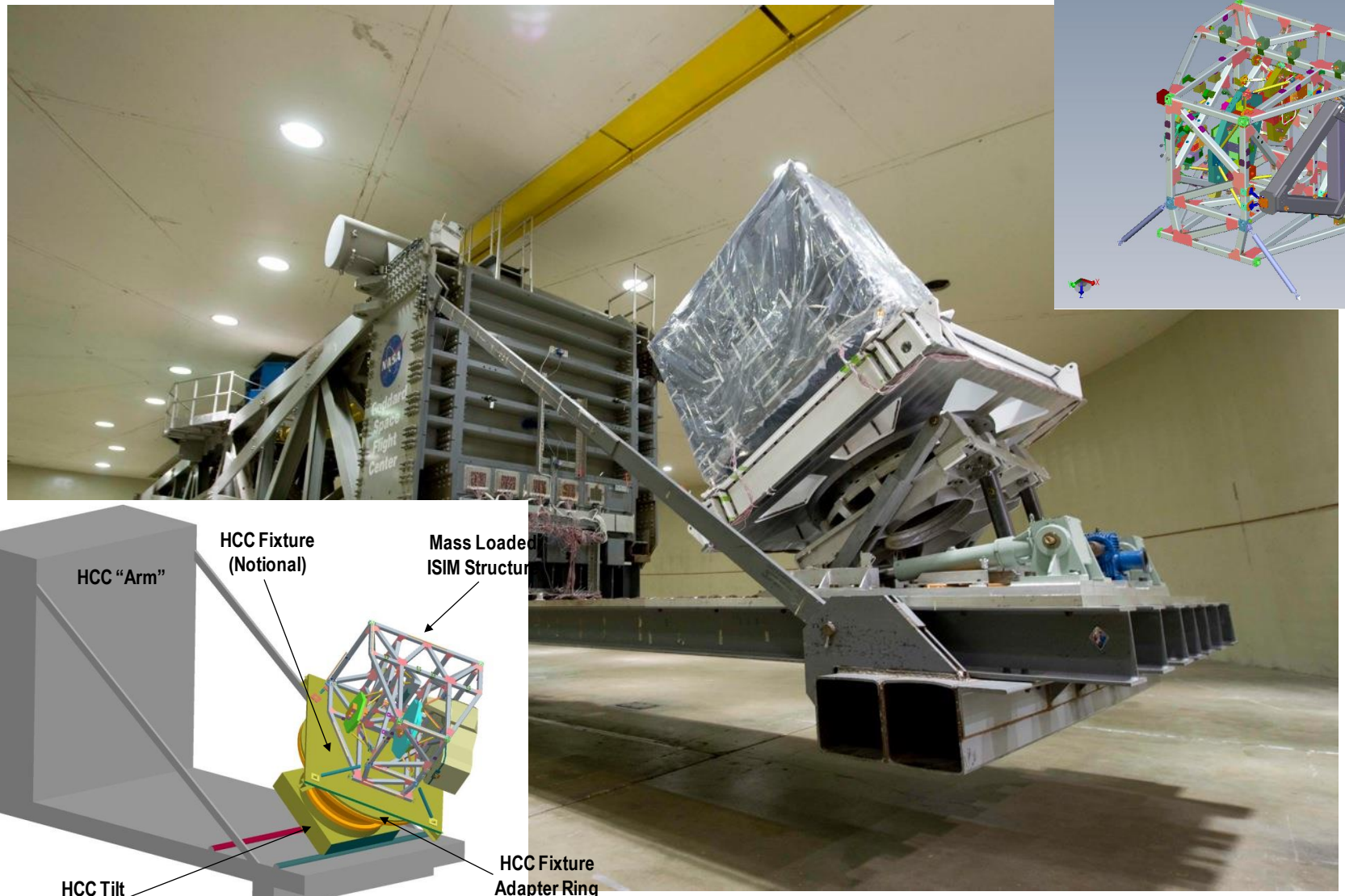
Wavefront Error

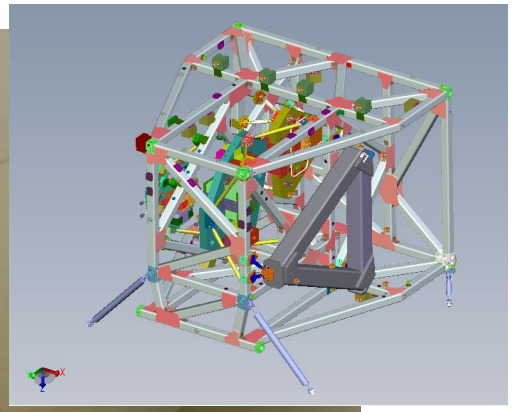
Modeling the Tests

Testing the Hardware

- An engineering effort isn't complete until it is proven that hardware meets the requirements.
- ISIM has completed multiple strength and cryogenic proof tests.
- JWST will undergo testing against structural requirements.
- Operational stability requirements can't be proven by test; we will prove by analysis.

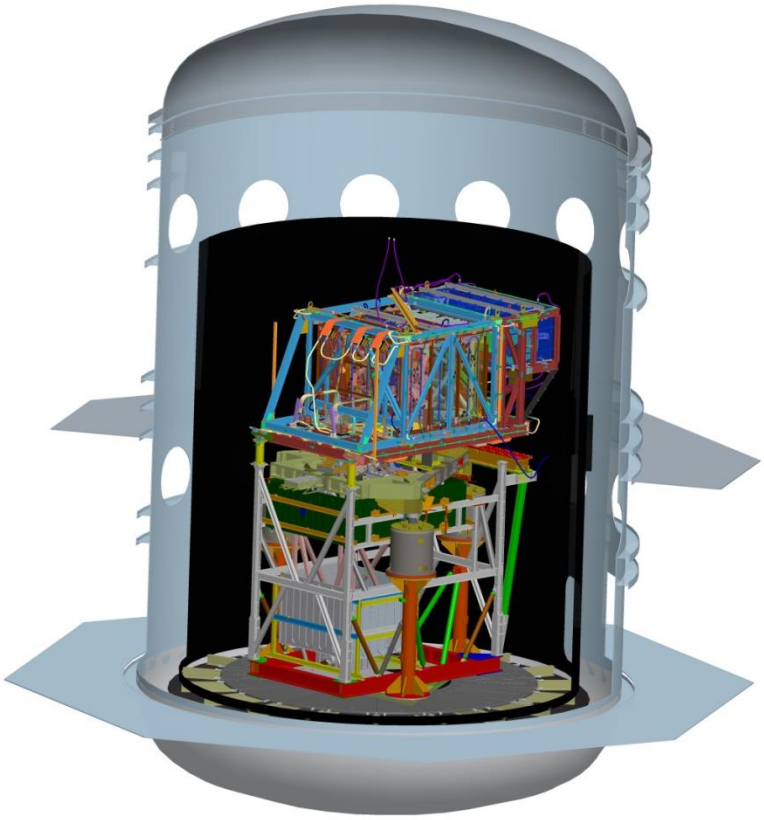
ISIM Strength Proof Testing



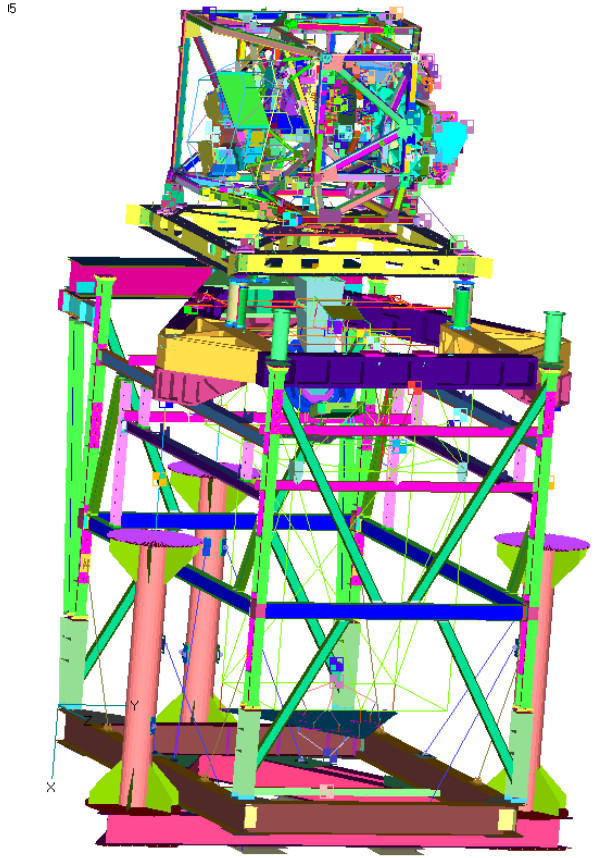


ISIM Performance Predictions

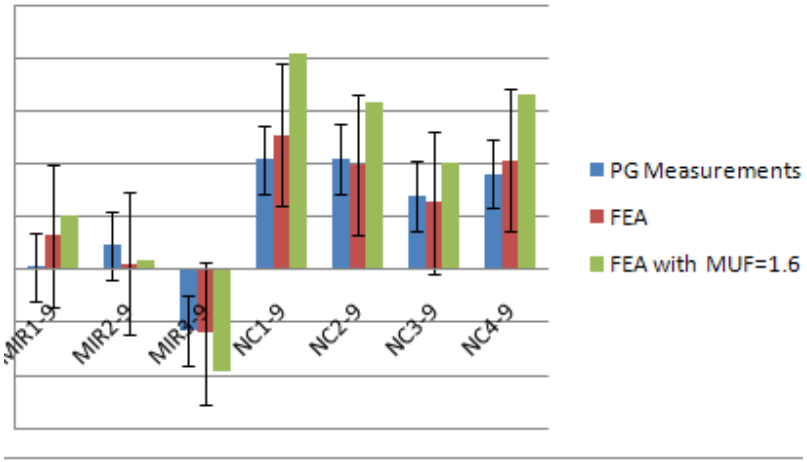
Cryogenic Test Thermal Model

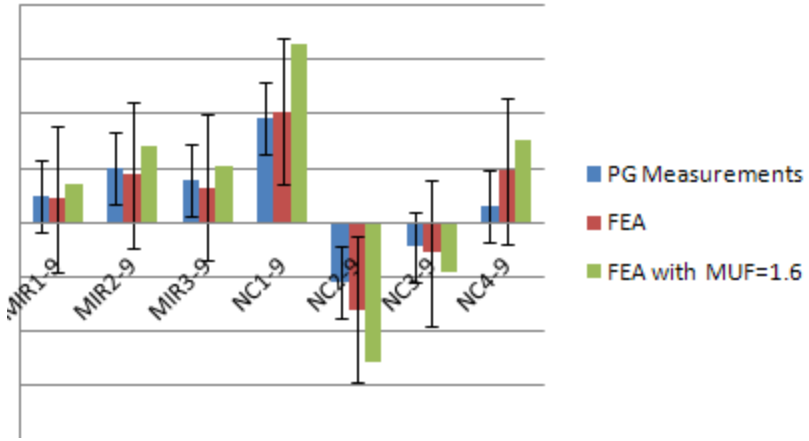


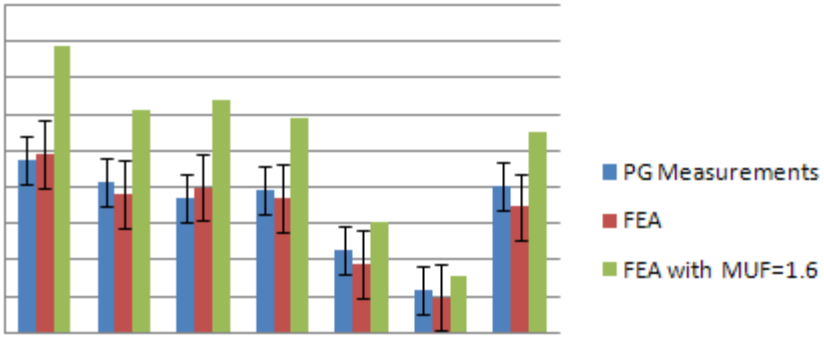
Cryogenic Test Structural Model



ISIM Test Results vs. Model







- ISIM TD testing was successful
  - These compare test translations from PG to models
  - Models with static MUF and stochastic predictions are both shown

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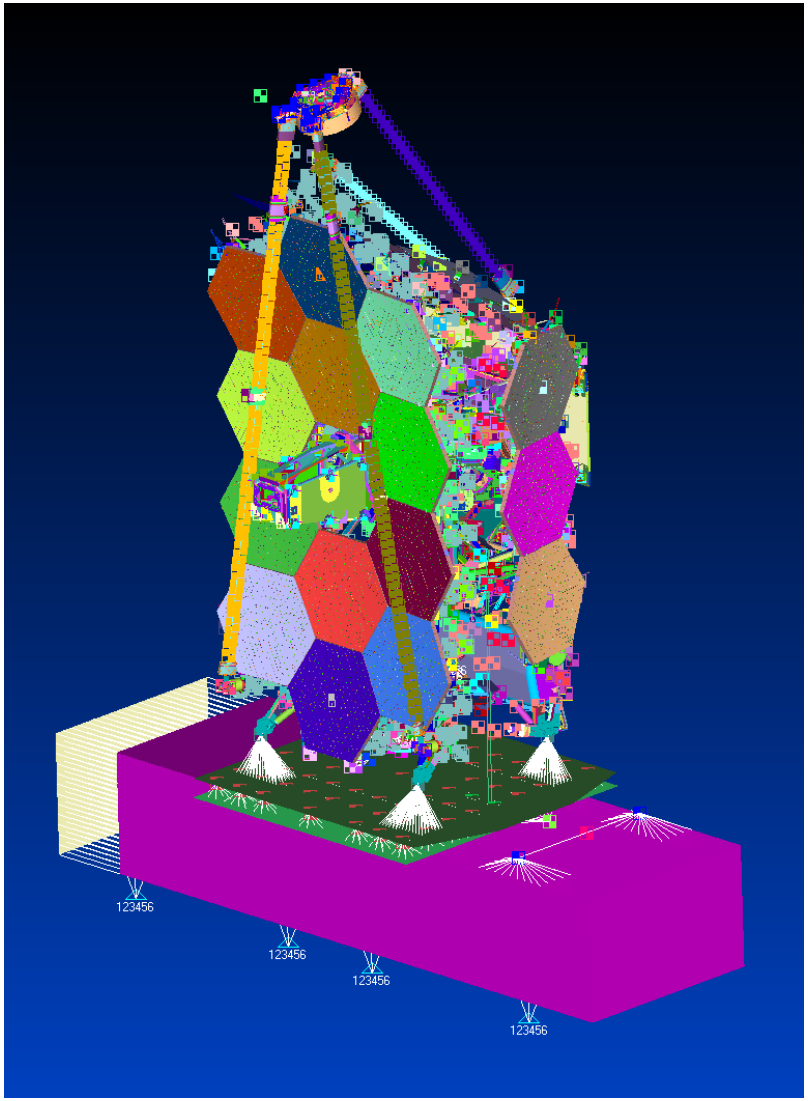
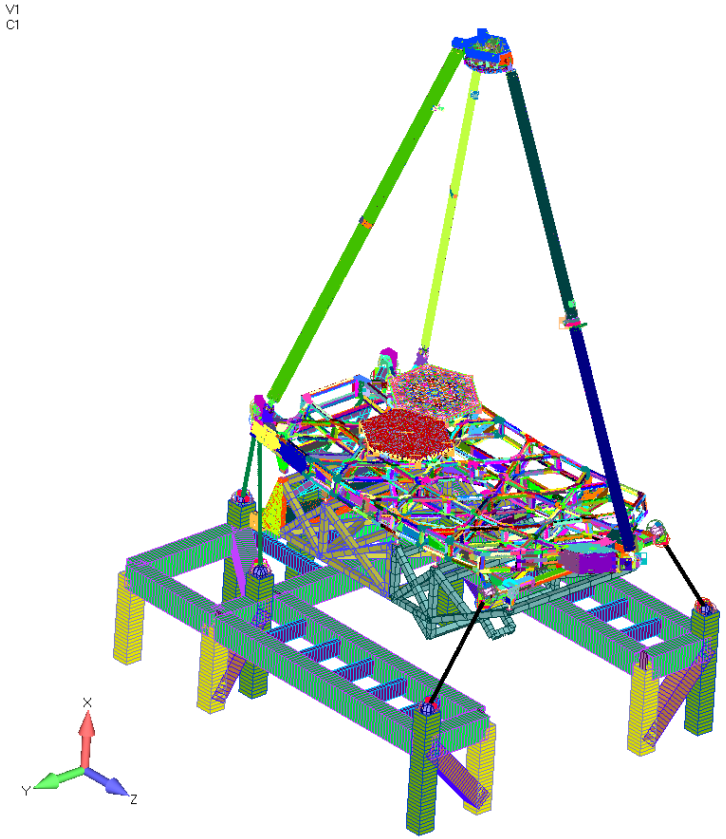
JWST Strength Testing

- GSFC and NGAS are both procuring new vibration test equipment
- Analysis performed to show the required capacity
- Will model random and sine vibe testing for strength and workmanship as part of pre-test planning
- Will correlate the model post-test



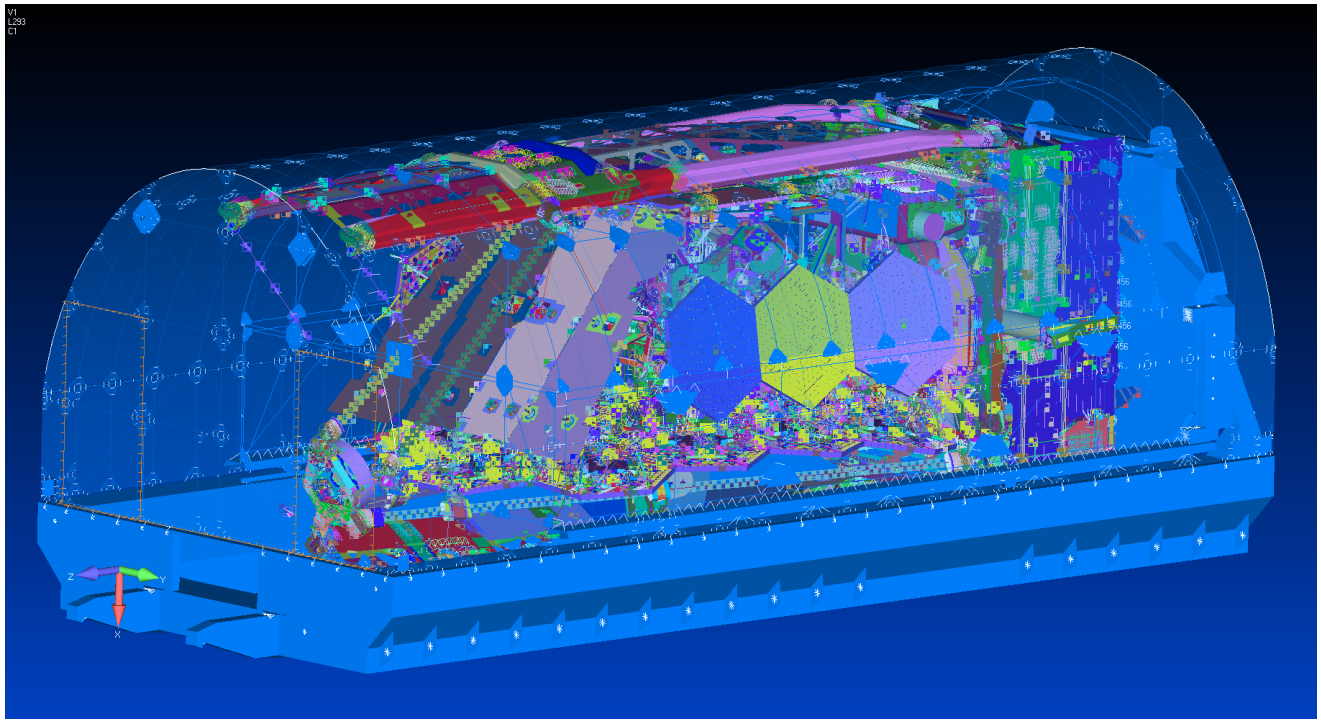
Deployed Dynamics Testing

- JWST deployed dynamics modal correlation will be done at room temperature
  - Cryo damping effects are well understood from prior tests
  - Not a requirements proof test
  - Flight model will be adjusted based on this test
- We have developed a model of this test
  - Once the model is well tuned to the test, it is then extracted and used for operational DD requirement verification by analysis

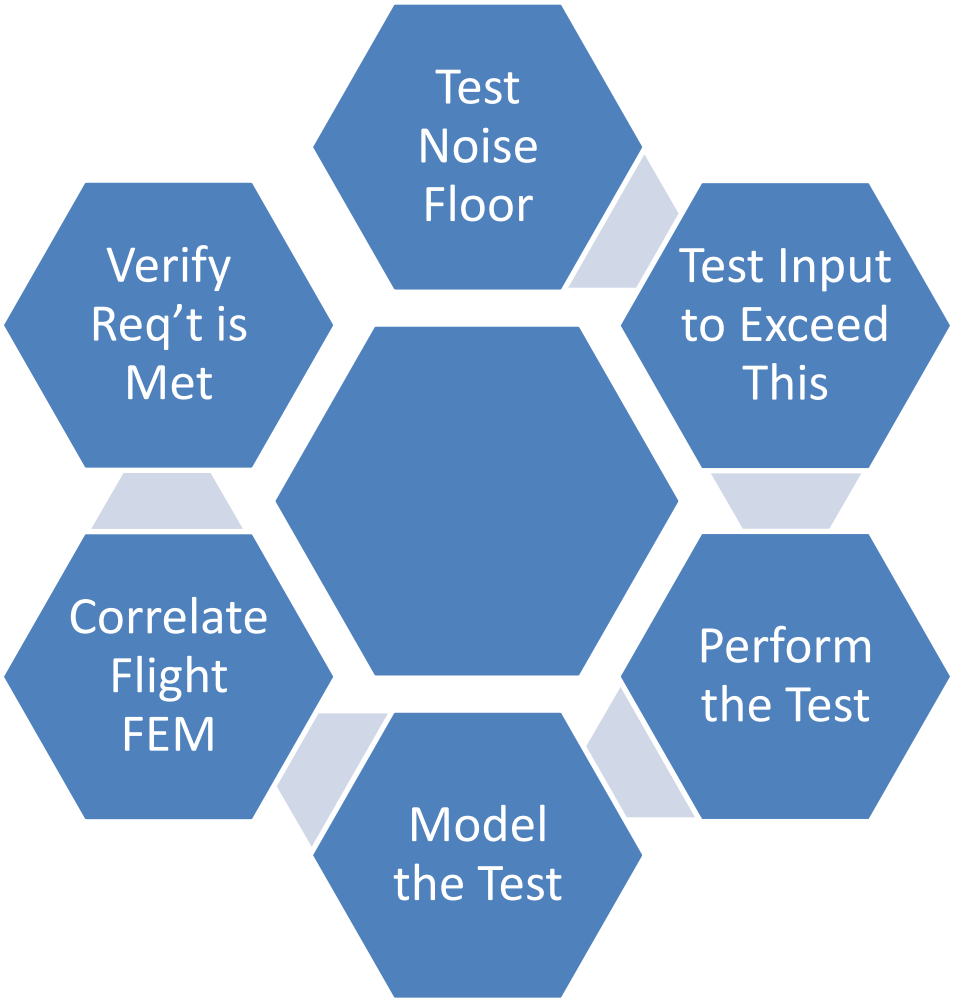


Transportation Modeling

- After partial assembly of the structure it will be transported to JSC for testing. It will also be transported after full assembly.
- Nelson Manufacturing created the trailer, which was modeled by SGT staffers to ensure the transportation loads were acceptable.
- Transit environments include trucking, C5, and ship. GSFC collected vibration data from the ship as an analysis input.



Overdrive Testing



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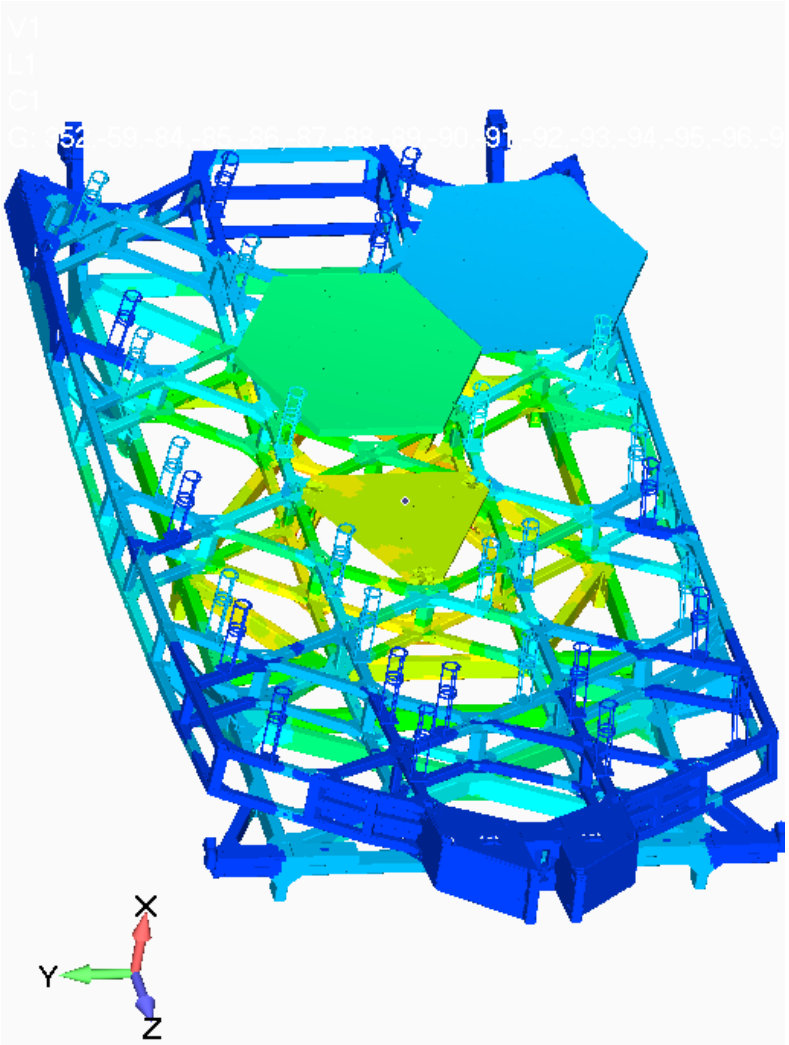
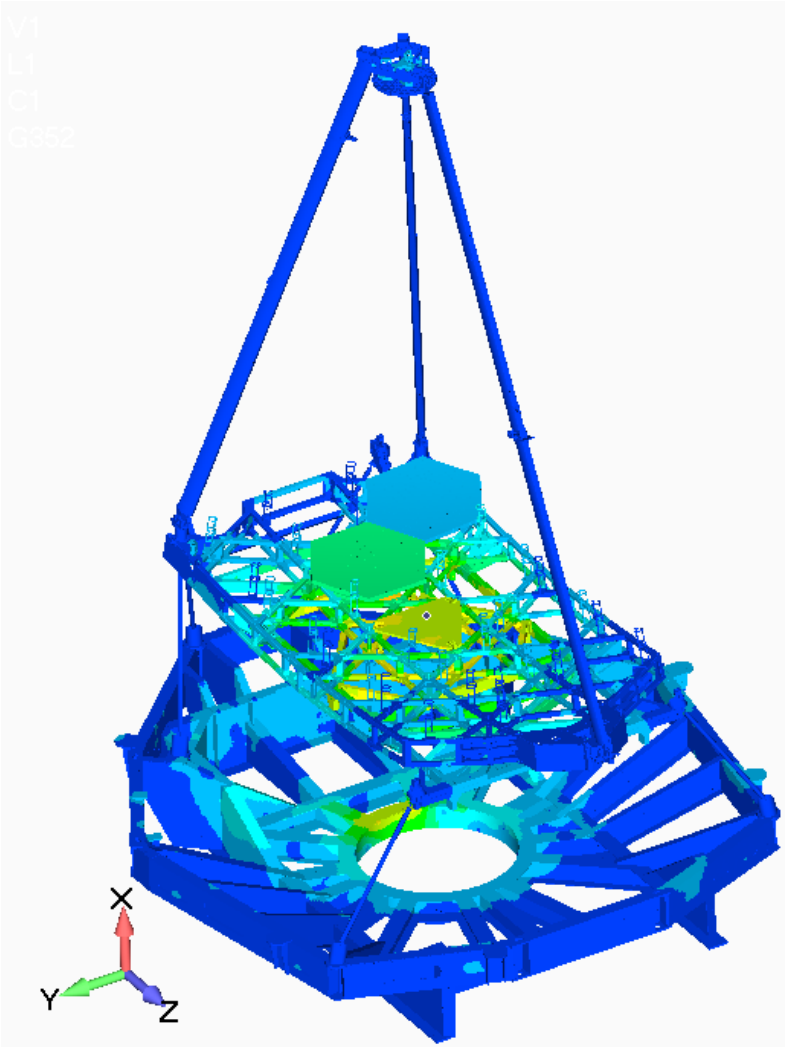
Thermal Distortion Testing



Output Set: GS TD1
Criteria: Temp Load Set 1



Output Set: GS TD1
Criteria: Temp Load Set 1

FEMAP Specific Benefits

- API's were developed as needed
  - Extracting displacement results form massive models
  - Summing strain energy by Group expedited design improvement
  - Access to the full 16-digit grid locations assured completely coincident grids on export, critical when results are in nanometers
  - Modal data exported for further processing in MATLAB
  - Automated Global-Local Modeling
- Efficient results reading through attachment of OP2 files - saved as much as an hour on every modal run
- Limited property visualization (bar/beam only) is beneficial
- Dongle-based licensing allows for use of the software without internet access

Conclusion

- JWST is making excellent strides toward completion and launch in 2018
- FEMAP is a part of the effort to make sure we successfully observe the first light of the universe
- There is still much to be analyzed between now and the delivery of the telescope
- Questions?