Habitable Exoplanet Imager Optical-Mechanical Design and Analysis

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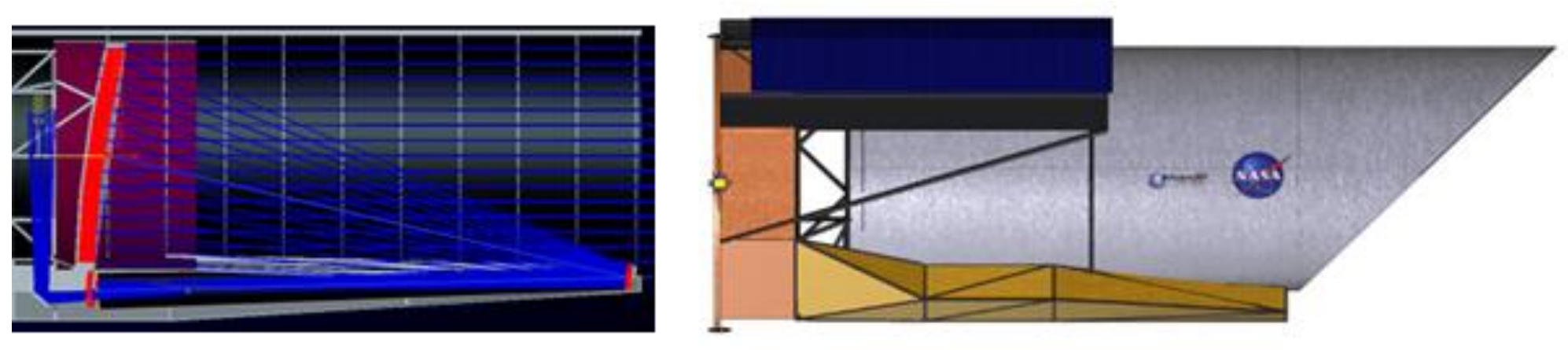
ABSTRACT

The Habitable Exoplanet Imager (HabEx) is a space telescope currently in development whose mission includes finding and spectroscopically characterizing exoplanets. Effective high-contrast imaging requires tight stability requirements of the mirrors to prevent issues such as line of sight and wavefront errors. PATRAN and NASTRAN were used to model updates in the design of the HabEx telescope and find how those updates affected stability. Most of the structural modifications increased first mode frequencies and improved line of sight errors. These studies will be used to help define the baseline HabEx telescope design.

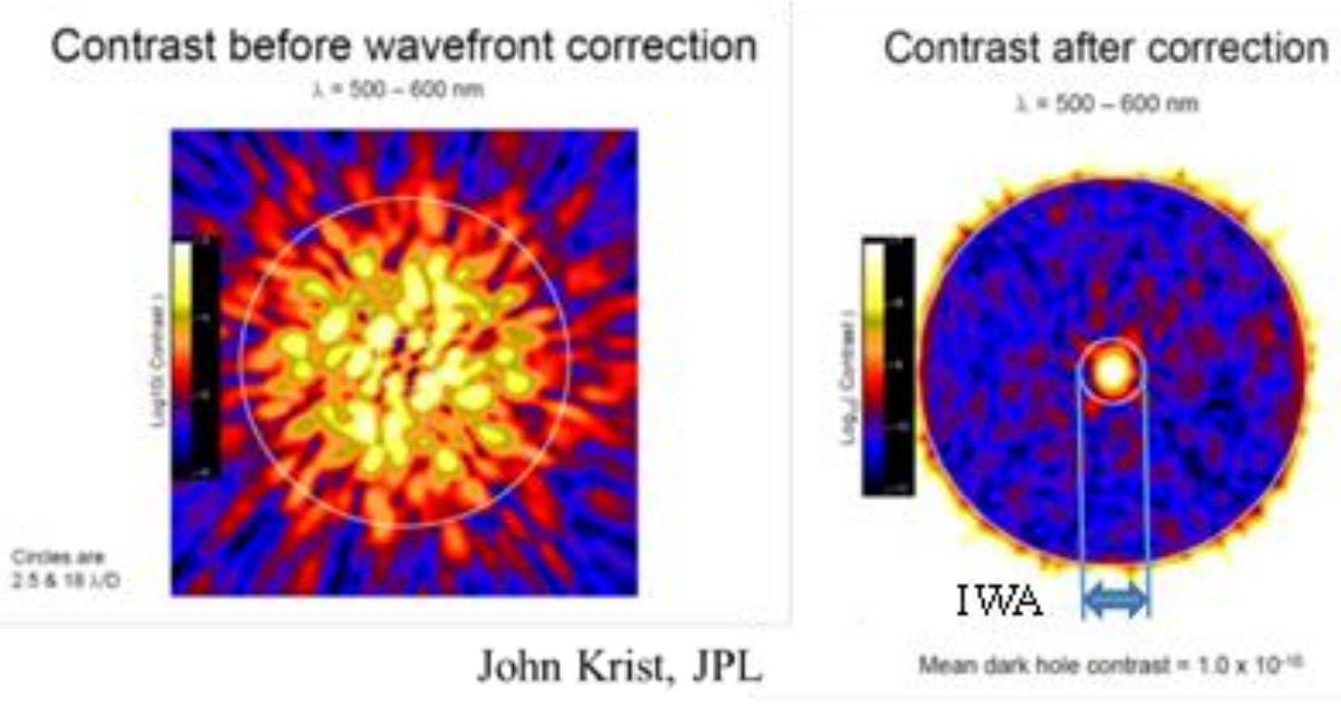


Concept for Baseline HabEx Design

BACKGROUND

Science Behind HabEx Technical Requirements

- Exoplanets are difficult to directly image due to their home star's glare which can be billions of times brighter than the planet's reflected light
- Blocking the light from the star is possible with a coronagraph
- The coronagraph has tight stability tolerances for the optical surfaces
- Technical challenges involve creating a telescope which is stiff enough to prevent deflections of the primary mirror in the realm of nanometers



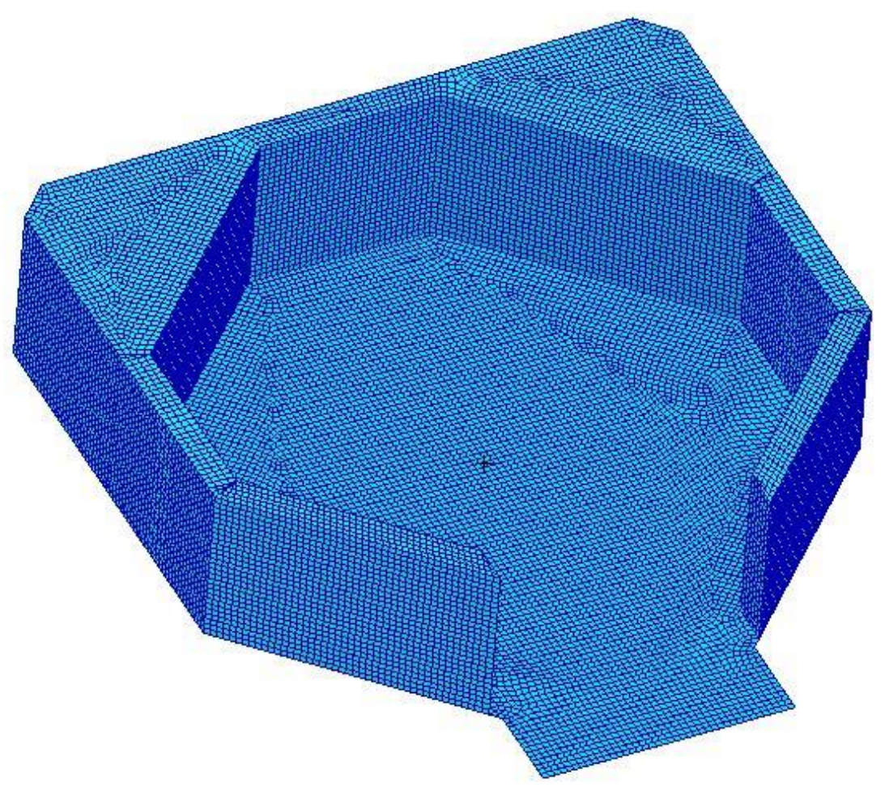
John Krist, JPL

OBJECTIVES

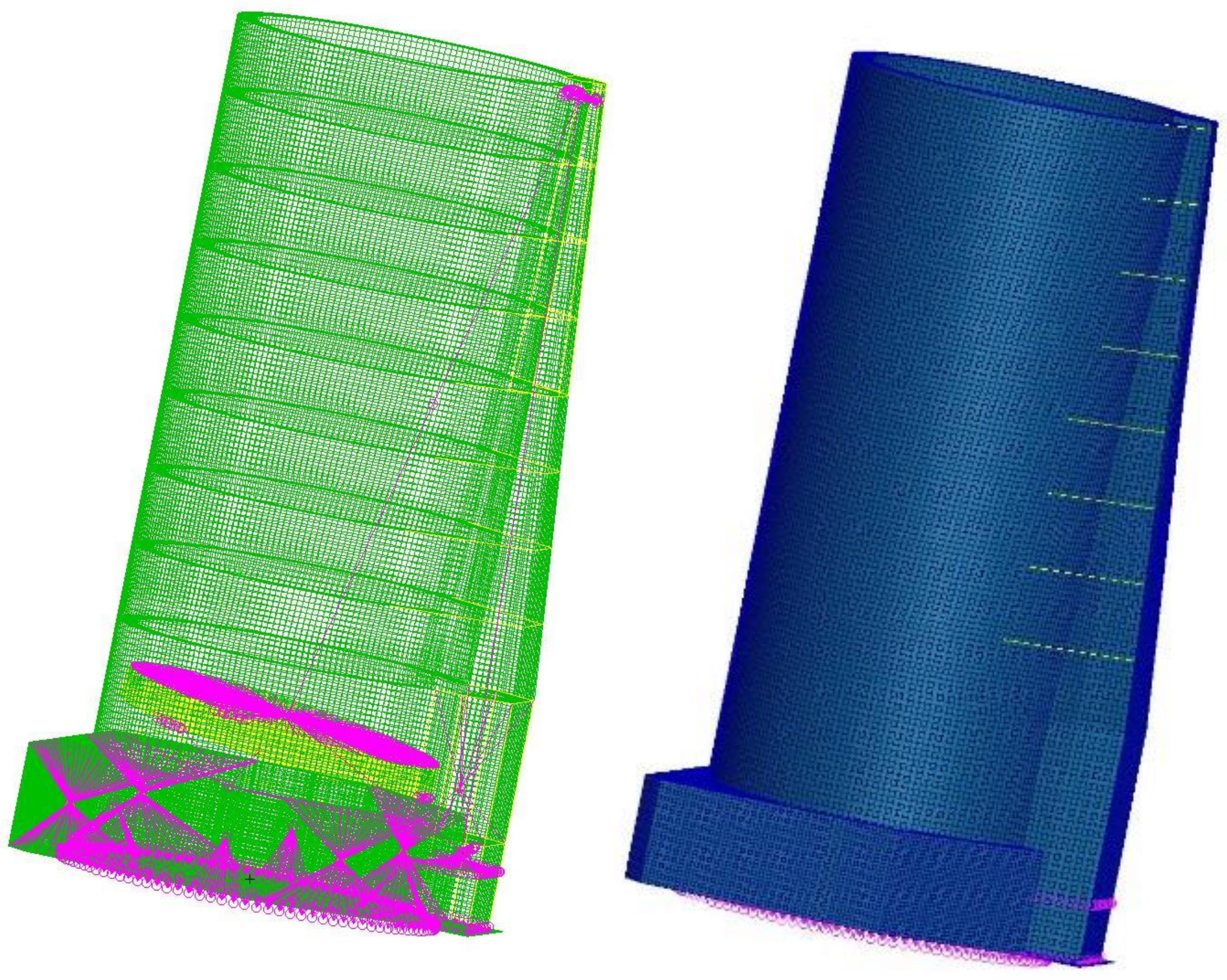
- Integrate JPL Spacecraft BUS
- Explore differences in "rigid" and flexible Spacecraft BUS
- Find jitter and line of sight differences in changing from 1% to 0.05% linear structural damping
- Find how to calculate primary mirror dynamic surface figure error
- Find how to make primary mirror assembly stiffer. Tube diameter of the support structure should be explored to see if larger stiffer tubes create higher first mode frequencies of the primary mirror assembly. Mount locations should be explored. Mount location is referred to as percentage radial distance from the edge (edge mounting is 100%)
- Find the dynamic response to reaction wheel disturbances versus micro-thruster disturbances

METHODS

- Utilized PATRAN for finite element modeling and preprocessing
- Modeled and meshed JPL Spacecraft BUS
- Integrated various design modifications into full finite element model (FEM)



JPL Spacecraft BUS Mesh



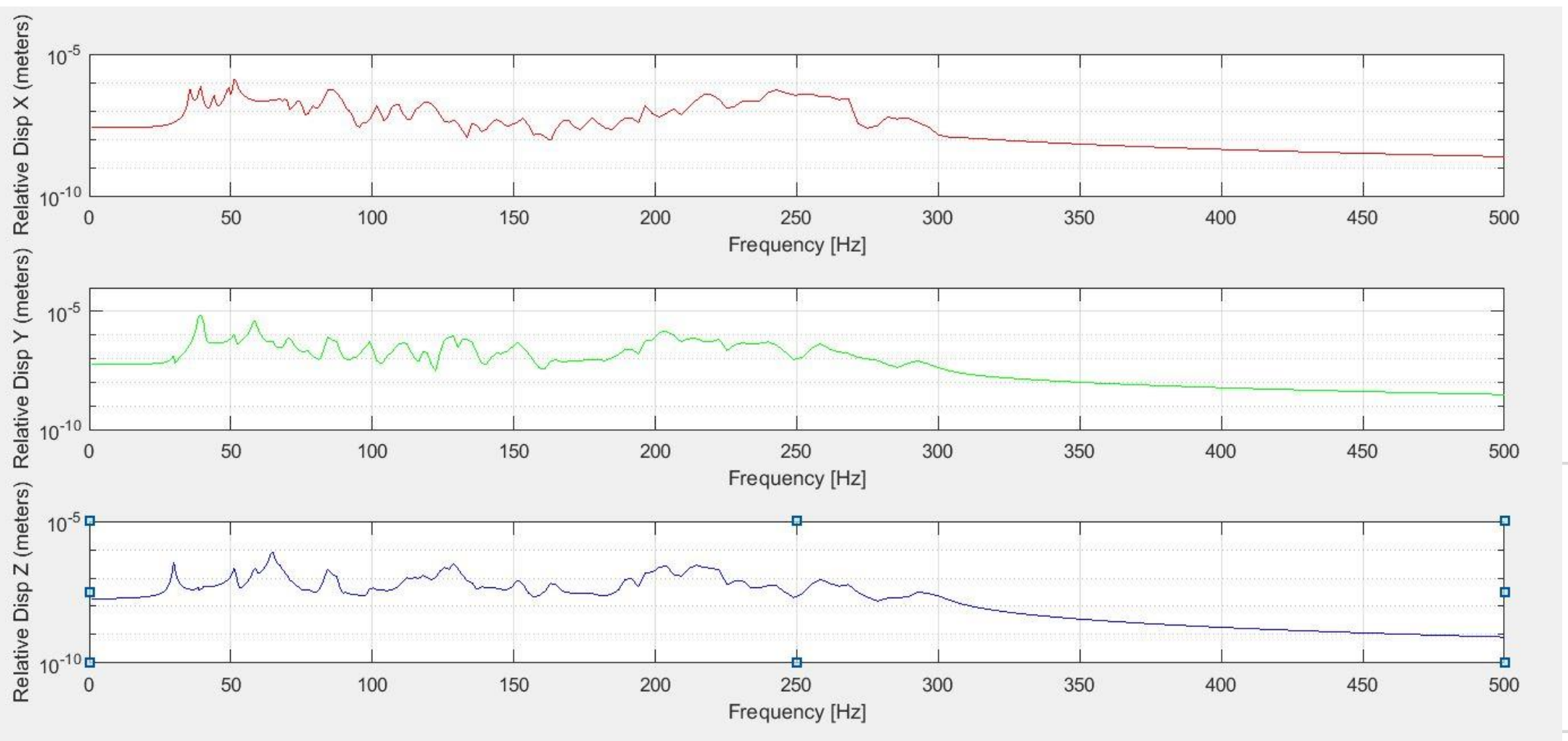
Full Finite Element Model, Wireframe (left) and Shaded (right)

- Utilized NASTRAN to perform dynamic and modal analyses
- Using a prepared MATLAB script, performed line of sight and jitter calculations
- Used a prepared Excel Workbook for applying isolation filters to data
- Finite element model of the full assembly was constantly changing throughout the analysis process

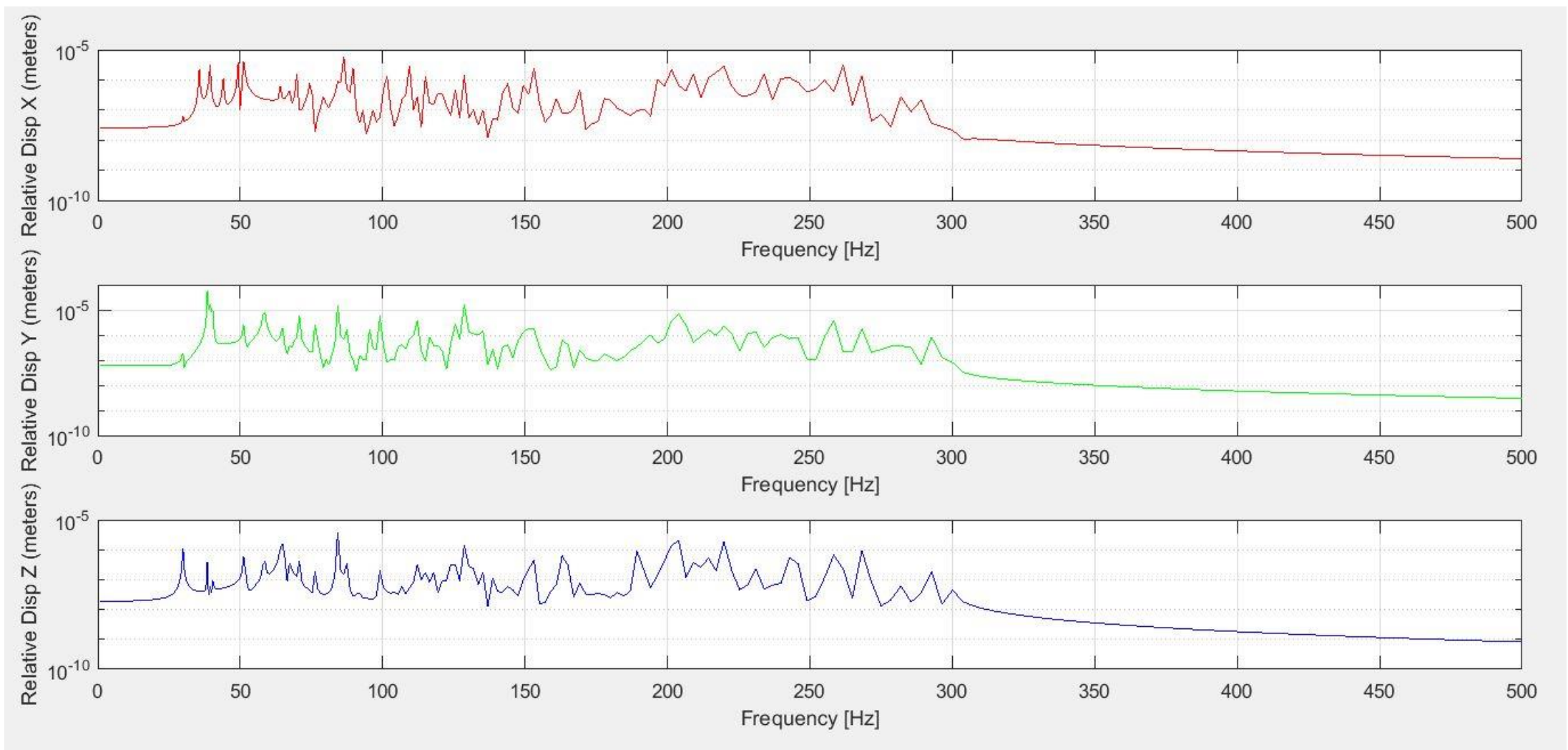
RESULTS

- Found that the "rigid" representation of the Spacecraft BUS created better LOS and jitter behaviors
- Changing from 1% damping to 0.05% damping changed displacements rotations by a factor of around 14 in the worst cases for the first few peaks
- Created a NASTRAN SOL 111 file (modal frequency response) which tracked the primary mirror nodes to find the dynamic surface figure error
- Explored mounting locations of the primary mirror and found an optimal mounting location for the current support structure design at 65% mount location.
- Created a new FEM to be used in the future for calculating microthruster disturbances

RESULTS

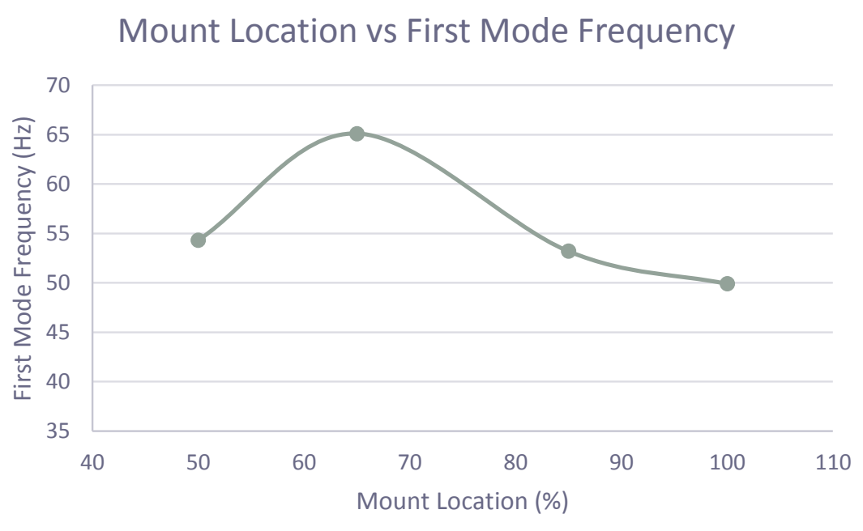


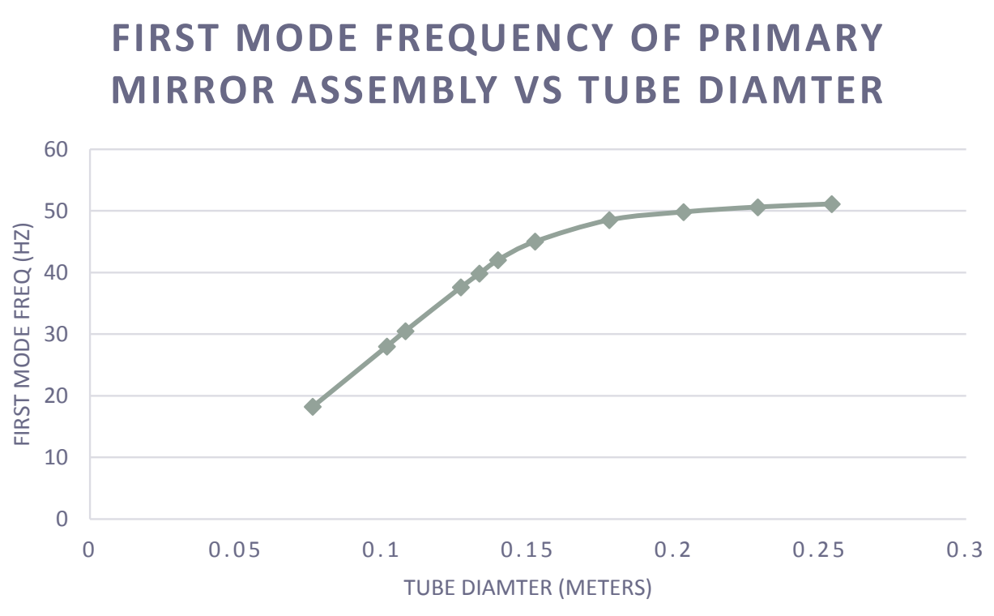
1% Structural Damping LOS Displacement Values

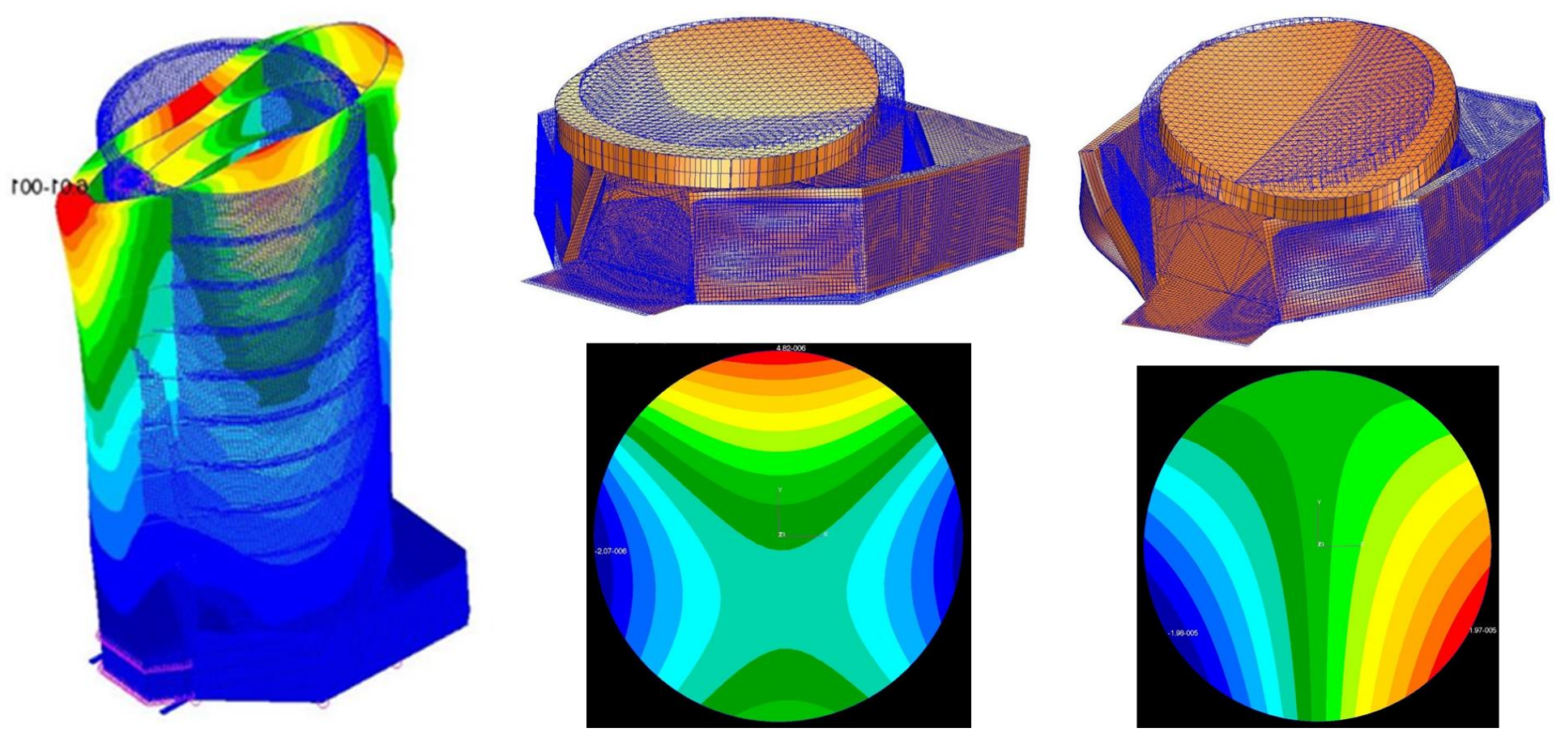


0.05% Structural Damping LOS Displacement Values

First peaks of X,Y, and Z displacements are at 32.3 Hz. The X displacement values for 1% and 0.05% damping respectively are 6.4μm and 15μm. Displacement values for Y respectively are 9.3μm and 41μm. Displacement for Z respectively are 1.7μm and 7.5 μm.







First mode of optical tower assembly at 28 Hz (left), First mode of primary mirror assembly 33Hz (middle) Second mode of primary mirror assembly at 34Hz (right)

CONCLUSIONS

- A more rigid Spacecraft BUS leads to improved optical stability by an order of magnitude for some first peaks
- Changing from 1% to 0.05% structural damping does not increase displacements and rotations by large orders of magnitude
- Tilt in the primary mirror dynamic surface figure error needs to be removed
- A new MATLAB code needs to be run for the microthruster disturbance data
- Support structure levels off at a first modal frequency of ~50Hz for tubes 20cm (8in) in diameter. The stiffness of the structure may not improve with larger tube diameters due to the members of the structure approaching their maximum stiffness

AKNOWLEDGMENTS

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