# STOP Modeling for the James Webb Space Telescope Project Techniques, Results, and Sensitivities

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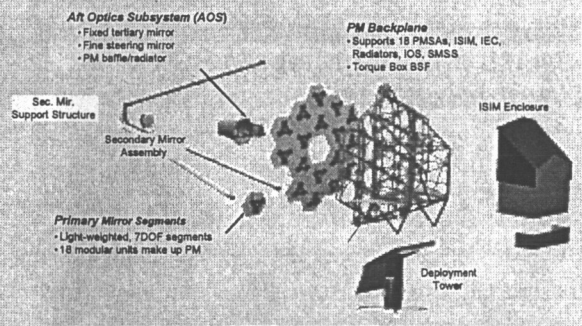
THE JAMES WEB SPACE TELESCOPE (JWST) IS A LARGE, INFRARED-OPTIMIZED, SPACE TELESCOPE SCHEDULED FOR LAUNCH TO L2 IN 2011.

- IT MUST MEET RIGOROUS THERMAL STABILITY REQUIREMENTS, ALMOST ALL OF WHICH WILL BE VERIFIED THROUGH ANALYSIS. TERRESTRIAL TESTING WILL BE PERFORMED BUT EVEN THAT WILL REQUIRE SIGNIFICANT ANALYTICAL INTERPRETATION OF RESULTS.
- PRELIMINARY ANALYSIS INDICATES THAT TRADITIONAL SECOND-ORDER EFFECTS COULD CAUSE THE TELESCOPE TO EXCEED ESTABLISHED PERFORMANCE REQUIREMENTS. THIS LEADS TO VERY LARGE DETAILED MODELS. PRIMARILY SINCE COMPOSITE TUBES ARE BEING MODELED USING SOLID ELEMENTS.
- TO MINIMIZE DIFFERENCES BETWEEN THE CURRENT BASELINE AND THE MODELTHE PROJECT IS USING A NUMBER OF RAPID ANALYSIS CYCLES THE LARGE SIZE OF THE TELESCOPE MODELS AND THE SHORT CYCLE TIME CREATES A DEMANDING MULTI-DISCIPLINARY ANALYSIS ENVIRONMENT.

## JWST Overview

***Science Requirements***
- Measure the luminosities, morphologies, and environments of galaxies within the spectral band 0.6 – 10 μm
- Measure the spectra of 2500 galaxies over the redshift range $1 < z < 5$
- 5-year lifetime.

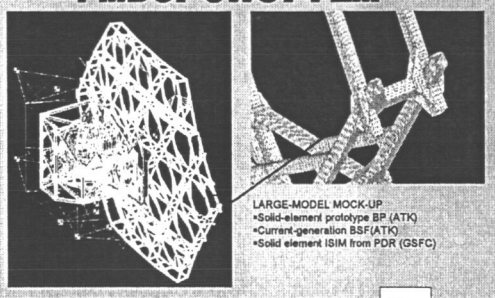



JWST Telescope Architecture

## Requirements & Design Cycles

- Design/Analysis cycles are approximately 6 months from model receipt to completion
- Typical Structural-Thermal-Optical (STOP) analyses are "worst-case hot-to-cold stability" static analyses
  - Must perform two cooldown analyses and take the difference of displacements
- Compare results to budgeted wavefront error allotments that are on orders of tens of nanometers

## 4 MDOF JWST FEM

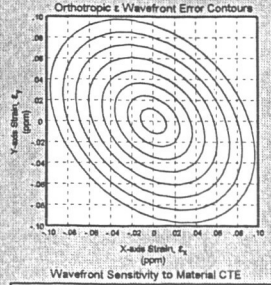


LARGE-MODEL MOCK-UP
- Solid-element prototype BP (ATK)
- Current-generation BSF(ATK)
- Solid element ISIM from PDR (GSFC)

PROJECTED SDR MODEL SIZE : 30 MDOF

MATLAB & FEMAP

***SENSITIVITY ANALYSES***
- Off-nominal CTE (α) Values Have Been Studied
  - Specific parts of interest are given unique property sets
  - NASATRAN sensitivity analyses with worst-case slew temperature loadings calculate $\delta u/\delta\alpha$
  - WFE from displacements from $\delta\alpha$ values in Matlab via LOM
- NASTRAN Limitations Preclude Use of α(T) in Sensitivity Analyses
  - NASTRAN can not use α(T) values in above process
  - Significant gradients exist within the backplane so local α are appropriate
  - Have confirmed that manual manipulation of α values can be used to find $\delta u/\delta\alpha$
  - WFE from displacements from ramdomly-selected $\delta\alpha$ values in Matlab via LOM
- Sample Sensitivity Analyses
  - Ortho-normal thermal strain sensitivity
    - Material axes assumed parallel/perpendicular to optical X/Y
    - Study range of $\varepsilon_x$ and $\varepsilon_y$ from -0.1 ppm to +0.1 ppm
  - Lot variation of axial α in Backplane tubes




Wavefront Sensitivity to Material CTE

TO BE ADDED PRIOR TO FEMCI FROM WORK IN PROGRESS

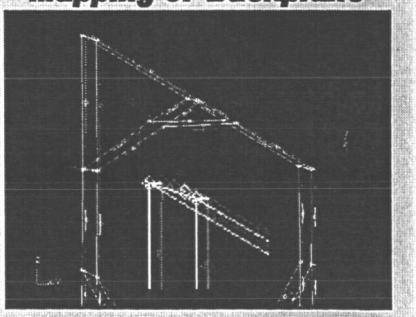
## Linear Optical Model

MATLAB

NASTRAN & MATLAB

SDR1 Worst-case Hot-to-cold Slew Wavefront Error

## Semi-automated Mapping of Backplane



## Finite-difference Sensitivity Analyses

- Overview
  - Gradients used heavily in STOP modeling
    - Uncertainty modeling, identifying critical parameters and levying requirements
  - Analytical gradients would improve process
    - less susceptible to numerical conditioning
    - if faster, enable larger parameter space
- Methodology
  - Use discipline modeling tools to compute gradients to design parameters p
    - chain rule applied to discipline models
    - validate using finite differences