NASA Mirror Technology Days 2014
Low Cost CMB Telescope Development

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A leader in high-performance aerospace structures.

- *Service* ▪ *Commitment* ▪ *Value*

Photo Courtesy NASA.gov

Presentation Outline

- Project Team Overview
- Vanguard Overview
- CMB Research
- Telescope Science Goals
- Project Goal & Challenges
- Key Technologies & Approach
- Telescope Performance Goals
- Design & Mass Status
- Analysis Status
- Pre-CDR Conclusions
- Plan Going Forward

Introduction and Project Team

- Phase II NASA Small Business Innovative Research Program
  - Period of performance: April 24, 2014 to April 23, 2016
  - CDR planned for Late January 2015
- Vanguard Space Technologies, Inc.
  - Eldon Kasl, Program Manager
  - Jeffrey Loomis, Principal Investigator
  - Gene Maruyama, Mechanical Design
  - Brian Catanzaro, Optical System Design (CFE)
- NASA
  - Ron Eng, Marshall Space Flight Center
  - Philip Stahl, Marshall Space Flight Center
- University of Pennsylvania
  - Mark Devlin
  - Nathan Lourie
- Vanguard would like to thank NASA for the opportunity to work on this project

Vanguard Space Technologies

- Proven expertise in the engineering, fabrication, assembly and testing of high-performance aerospace structures
- Significant flight heritage – over 12 years and >100 successful missions on orbit
  - Founded in 1994
  - ~100 employees
  - Small business classification

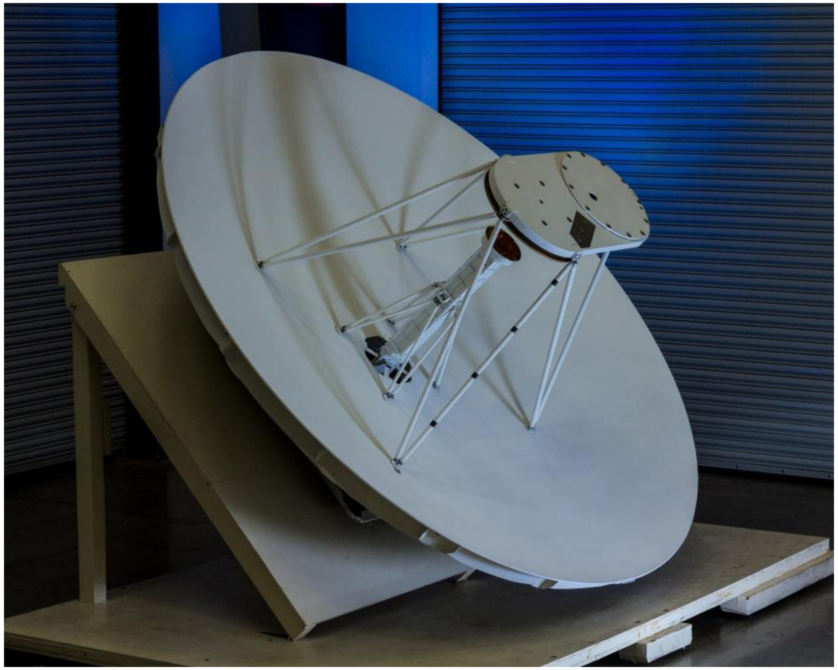
<u>Our Primary Focus</u>

We offer a portfolio of the latest advances in composite and metallic solutions, delivering <u>best-value and high performance products and services</u> to our customers

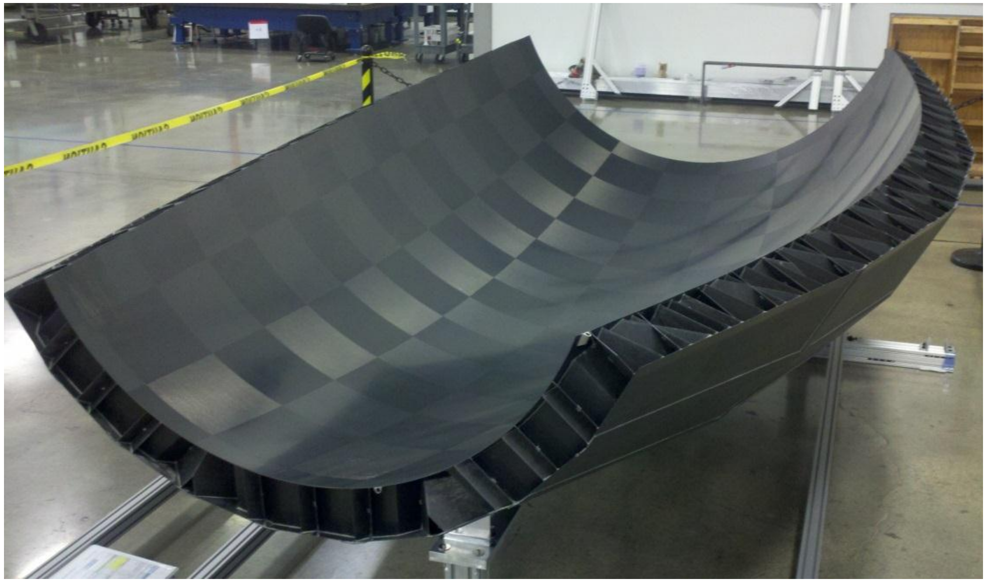
<u>Four primary business areas</u>

Vanguard Space Technologies
Up to 4 Meter Experience

3 Meter ADE



4x2 Meter Off-Axis Deployable



Cosmic Microwave Background Research

- Cosmic Microwave Background (CMB) polarization measurements on large angular scales can probe the Universe's post-birth state while measurements on small angular scales can probe the Universe's structure evolution over cosmic time
  - Achieving these goals requires state-of-the-art technology including large aperture telescopes
- Carbon fiber composite reflectors may be instrumental in advancing the science
  - Thermally stable, lower mass, and stiffer mechanical structures can lead to larger aperture sizes and larger science payloads
- Vanguard has identified the Super BLAST-pol (BLAST) mission for technology demonstration
  - BLAST: Balloon-borne Large Aperture Submillimeter Telescope
  - BLAST is not a CMB experiment, however, the technology developed for this program can be applied to future CMB telescopes

BLAST Science Goals

- BLAST
  - Mark Devlin and Nathan Lourie, University of Pennsylvania
- BLAST's primary science goals
  - High resolution measurements of the polarized submillimeter emission in star forming regions of the Milky Way can reveal the role that magnetic fields play in regulating the rate at which stars are born

Photo Courtesy blastexperiment.info

Project Goal & Challenge

- Apply advanced composite technologies to improve performance and science
  - Leverage Vanguard's low cost manufacturing approach developed under prior NASA SBIR
  - Reduced reflector cost may allow structures to become "disposable"
- Leverage composite property advantages
  - Low CTE improves stability
  - Lower material density allows aperture increase
  - High specific stiffness improves stability and increases modal performance
- Key project challenge
  - Meeting primary reflector surface accuracy requirements at 2.5m aperture up to 1.2 THz (λ = 200 µm) operating frequency

Phase II Plan

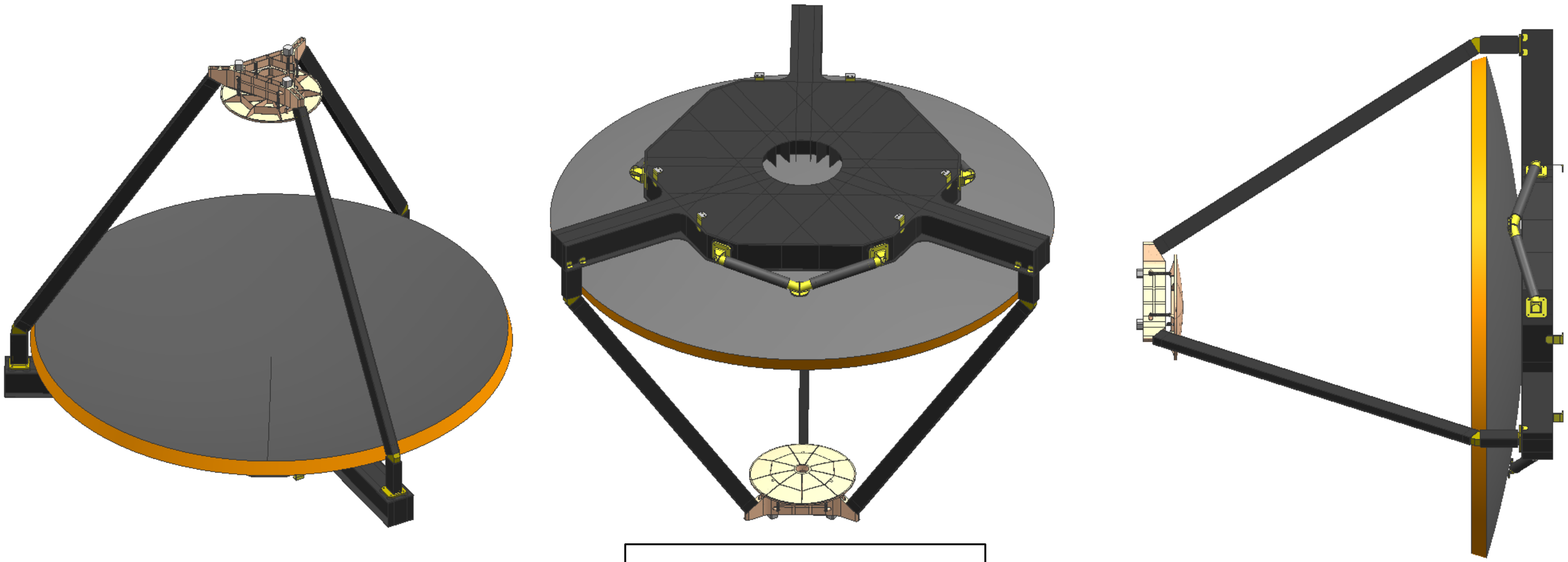
- Non-recurring engineering phase
  - Telescope engineering
  - Test coupon fabrication
  - Pathfinder skin demonstration (combine proposed M1 prepreg and tooling)
  - M1 mold and cart fabrication
  - Assembly fixtures
  - Critical Design Review
  - Component/Assembly drawings and work instructions
- Recurring phase
  - Raw material procurement
  - Composite component fabrication
  - M2 machining
  - Telescope integration
  - Alignment verification
  - M1 VDA coating

Key Technologies & Approach

- Surface accuracy
  - Composite sandwich
    - Graphite skin
    - Kevlar honeycomb core
    - Low temperature curing processes
  - Prior low cost reflector NASA SBIR work demonstrated surface accuracy of 5-10 μm on Ø10” part (qty 8)
    - Surface accuracy can be improved with additional processing steps
- Requires 2.5M mold
  - RMS ~2-5 μm accuracy

Telescope Performance Goals

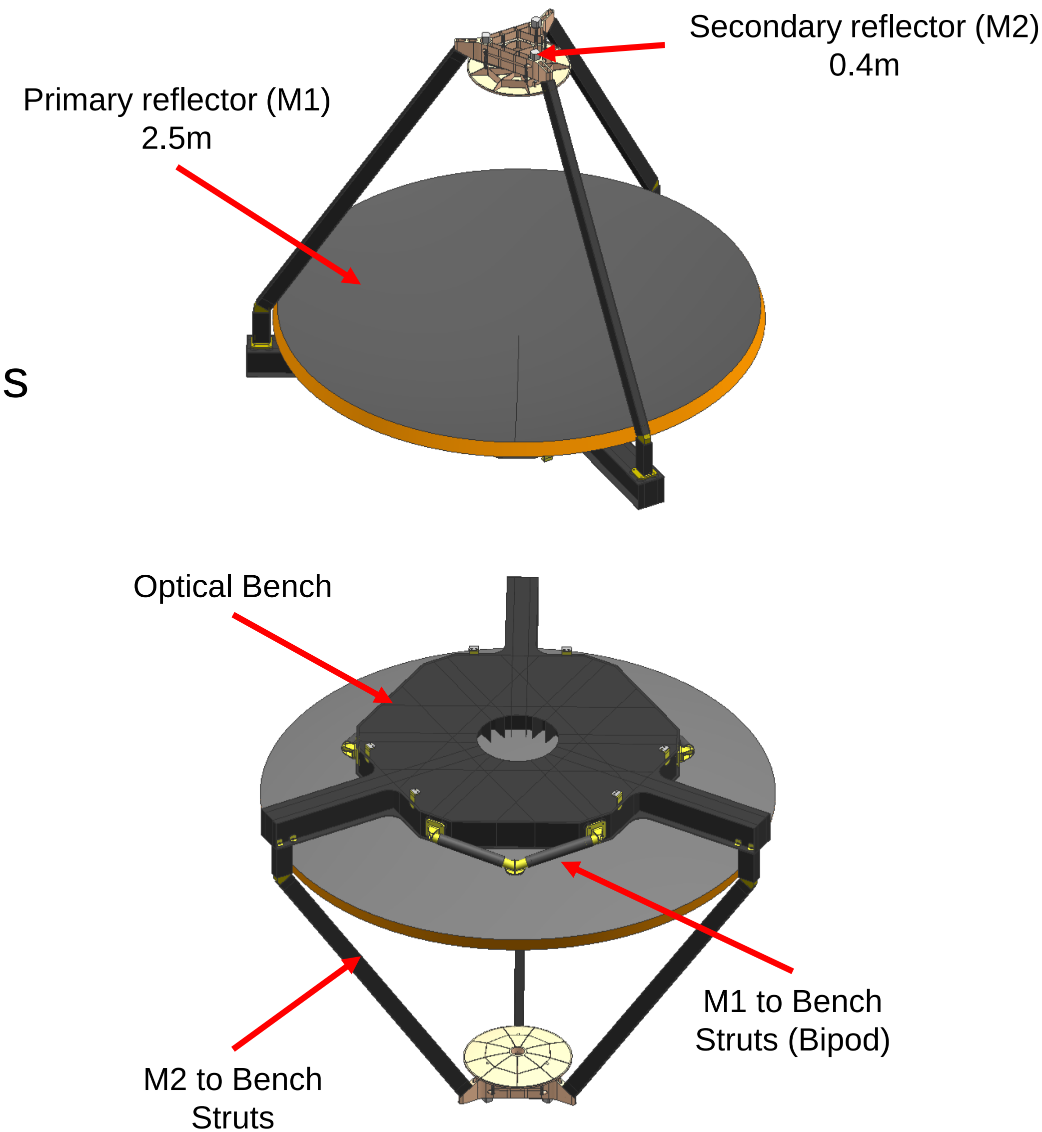
- Optical prescription based on f/4.6 and Ø2.5m primary reflector
- Operating Altitude: ~35 km
- First natural frequency: >35 Hz
- Total mass: <100 kg
- Operating temperature: 243 K
- Operational Telescope Elevation: 20° to 60°
- Total Wave Front Error (WFE): <10 µm RMS



BLAST Concept

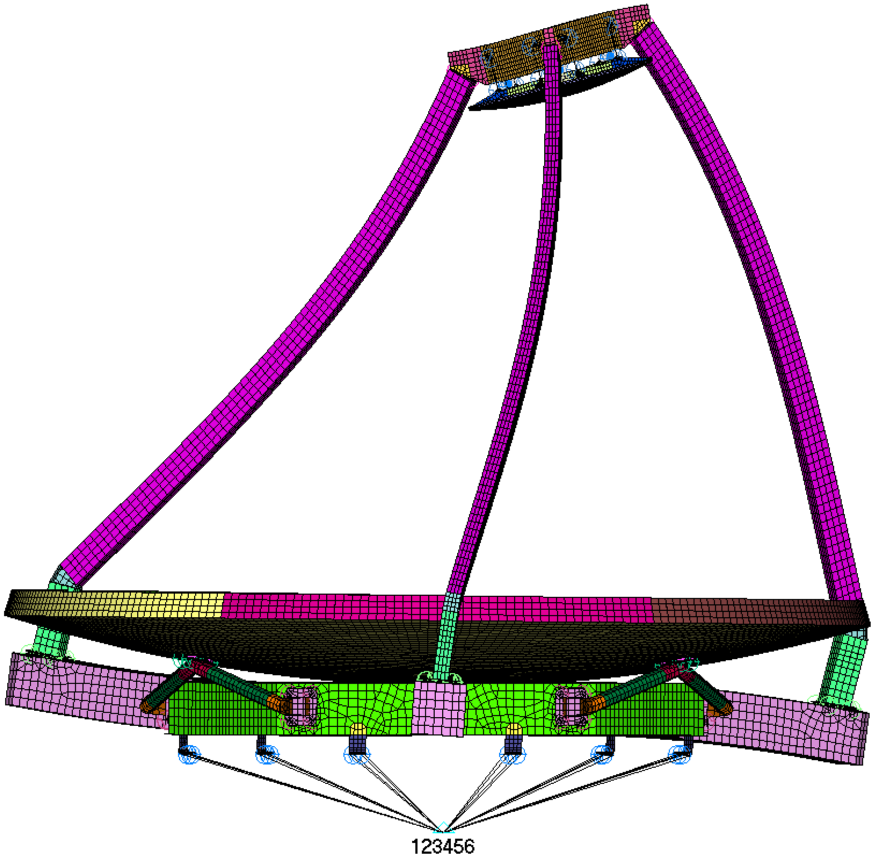
Design Highlights

- Nominal strut cross section
  - M1/Bench: Ø1.75”
  - M2/Bench: 3.0x1.5”
- M2 interfaces struts via three actuators and extension springs
- Structure Mass: 105.6 kg
  - M1: 47.2 kg (9.85 kg/m^2)
  - M2: 2.4 kg
  - Optical Bench: 27.7 kg
  - Struts/Fittings: 26.3 kg
  - Actuators: 2.0 kg
  - Close to meeting mass goal

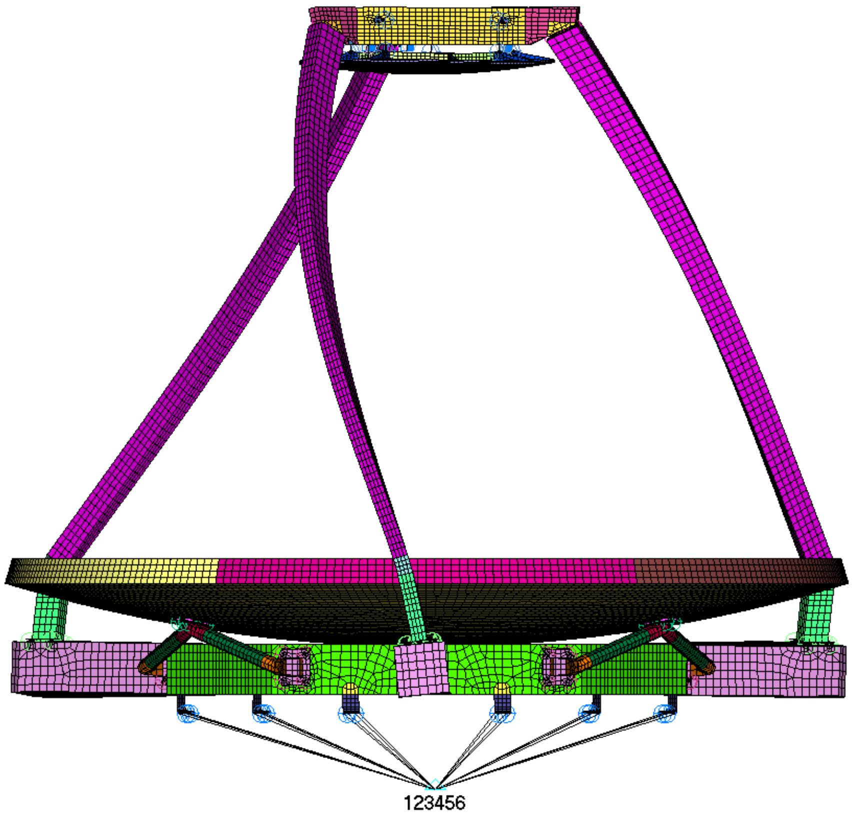


Finite Element Model – Modal Results

- First mode: 32.0 Hz



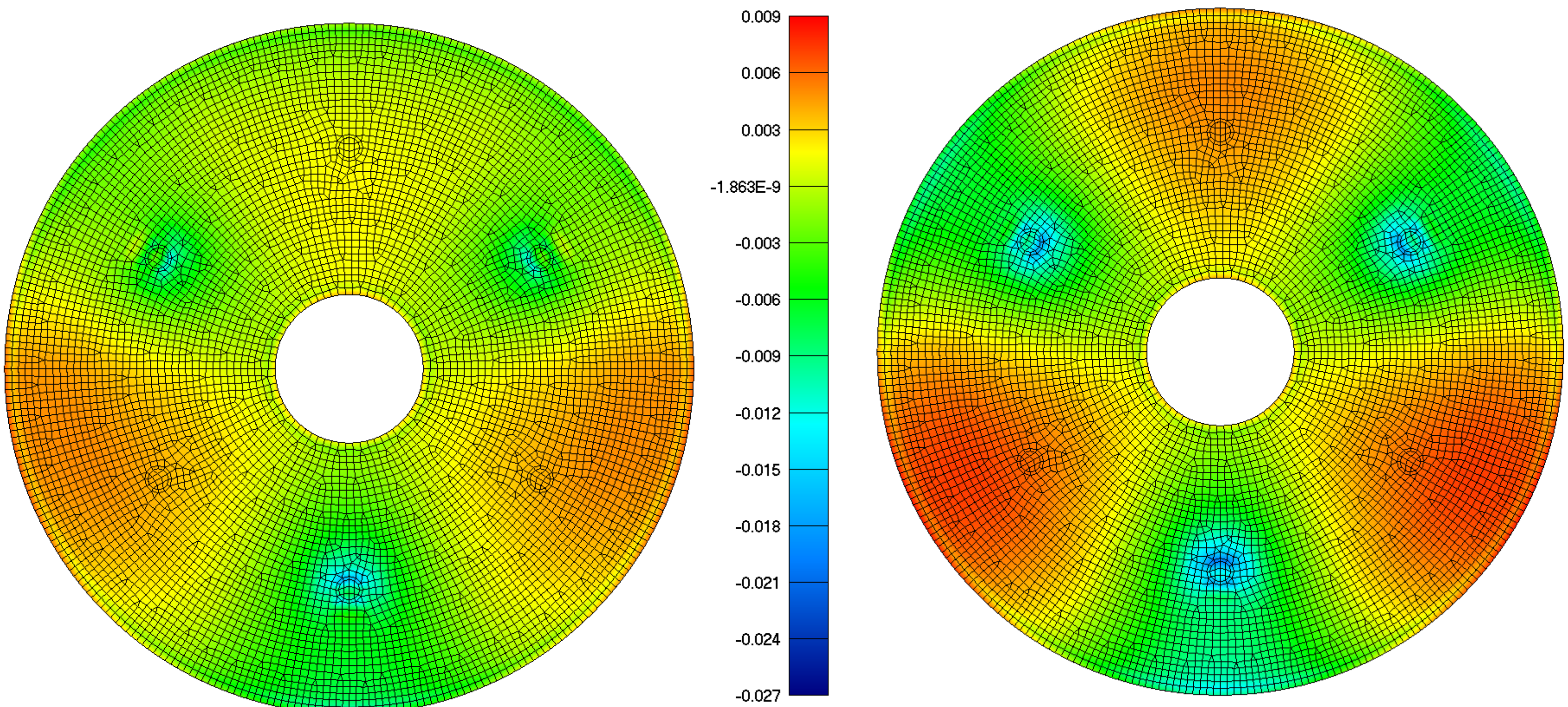
- Third mode: 33.2 Hz



First mode goal: 35 Hz

Finite Element Model – Stability Results (M1)

- Stability results are linear combination of thermal soak, hygroscopic dryout, and gravity sag
  - Load Case 1: -243 K, 50%→0% RH, 20° Elevation
  - Load Case 2: -243 K, 50%→0% RH, 60° Elevation
- Moisture dryout includes effect of “%Moisture vs time” based on laminate thickness and diffusivity
  - Epoxy based resin system is slow to absorb/desorb moisture → minimizes moisture distortion



Units are (mm)

Load Case 1: RMS 6.3 μm WFE

Load Case 2: RMS 9.7 μm WFE

Pre-CDR Conclusions

- Overall design is close to meeting project goals
  - Mass is <10% over but no light-weighting measures have been implemented
  - First mode is <10% from goal
- Stability results show M1 meets goals but does not allow for AI&T error budget
- Some additional effort required to meet all project goals

Phase II Plan Going Forward

- Confirm low temperature curing laminate yields acceptable surface finish with proposed tooling approach
- Validate engineering assumptions via small coupon test program
- Procure materials and tooling
- Fabricate a demonstration telescope
    - Includes VDA coating on M1

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