SNAP Program Technology and Capabilities Meeting

January 15, 2002

Composite Optics, Inc. • 9617 Distribution Avenue • San Diego, California 92121
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Agenda

- SNAP Program Overview
  - Mission & Program Status
  - Technical challenges & telescope requirements
- COI Overview & Instruments Heritage
- Lunch
- FIRST Program Overview
  - Telescope
  - Focus mechanism
- Tour
- Metering and precision structure technology
  - ABL, Deep Impact
  - TES
- Ultra lightweight mirror technology

COI Capabilities to support Space Based Instruments

- **Over 25 years of producing precision structures for state of the art instruments**
  - **Hubble**
  - **Chandra**

<u>Technologies of interest to SNAP</u>

- **Design, Analysis, Fabrication, Assembly, Test**
  - **Telescope metering structure**
  - **Baffles, Aperture covers**
  - **Reaction Structures**
  - **Instrument Structures, Optical benches**
  - **Thermal control technologies (cryo- radiators, Isolators)**
- **Lightweight Mirrors**
  - **Ultra-lightweight ULE**
  - **Glass/Composite hybrids**
  - **All Composite**

COI Overview & Instruments Heritage

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Herschel/FIRST Telescope

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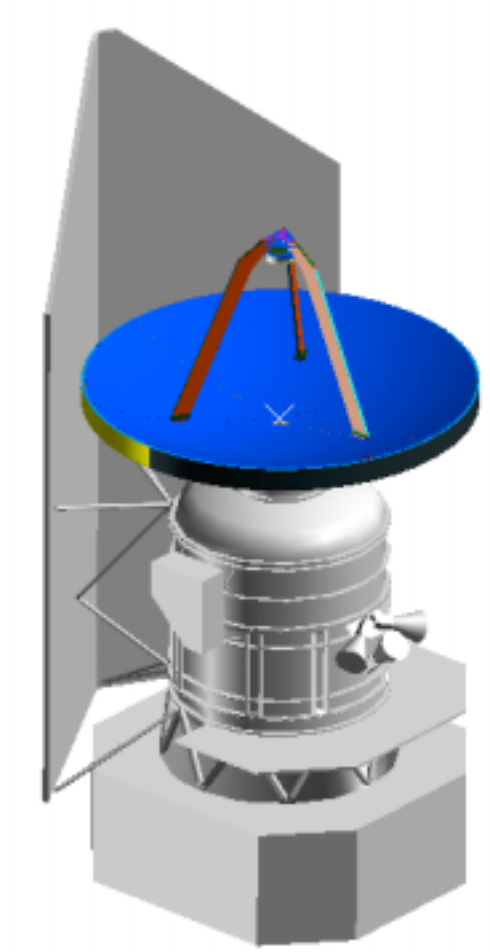
Herschel/FIRST Overview

- **Herschel Observatory - European, space based far-infrared (80-670μ) Instrument**
- **COI & JPL Teamed to provide telescope to ESA**
- **Telescope**
  - **3.5 m aperture, Ritchey Chretein**
  - **All graphite composite primary mirror (f/0.5)**
    - **118 kg (12.3 kg/m^2)**
  - **Telescope operates below 90K**
  - **Focus mechanism at secondary**
- **Technology Demonstration**
  - **2 m primary mirror test article**
    - **Optically tested to 70K**

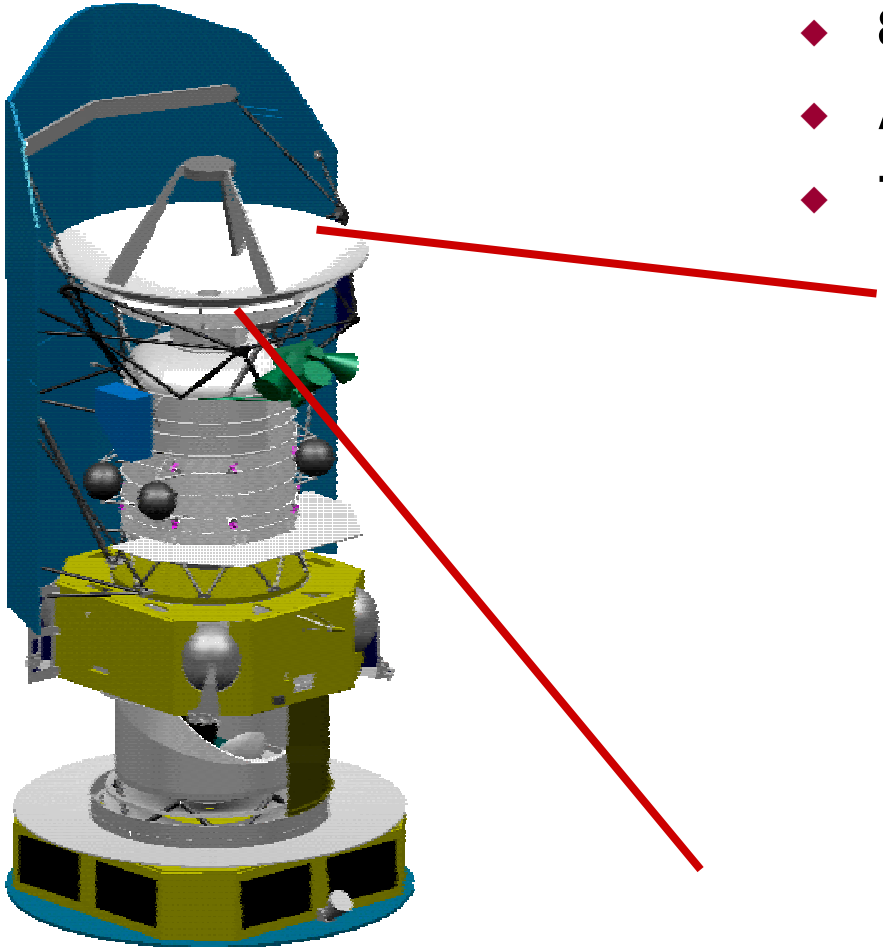


Herschel/FIRST Capabilities that apply to SNAP

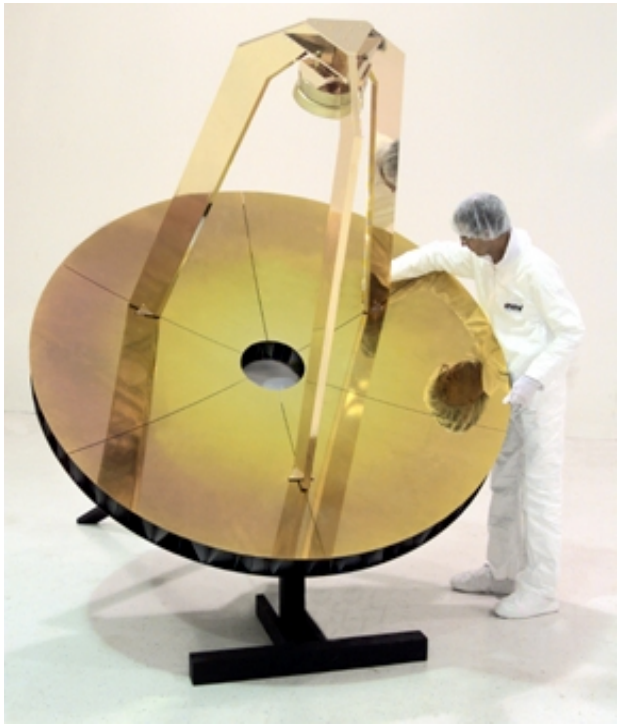
- Program used innovative organization to develop telescope
  - Team blended capabilities of three organizations – COI, JPL, LWO
- Team addressed all aspects of Telescope
- Composite Mirror (suitable for IR) pushed advances in stable structures
  - Materials characterized to 70K
  - Processes tightened to reduce variability in CTE
- Metering structure designed & analyzed for stability to 70K
- Secondary mirror focus mechanism design developed to reduce operational risk
- Telescope thermal design developed to achieve 70K with minimum gradients
- Extensive work done in developing mirror & telescope optical test techniques
  - 70 K test conditions
  - 2 m and 3.5 m test optical apertures
  - Mirror and Telescope level

FIRST
Far Infrared/Submillimeter Telescope

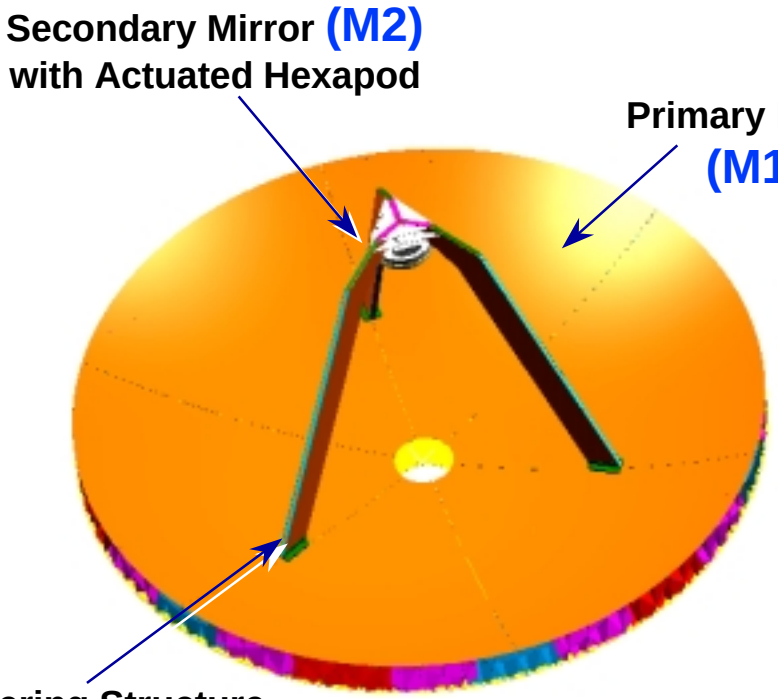
FIRST Mission Spacecraft

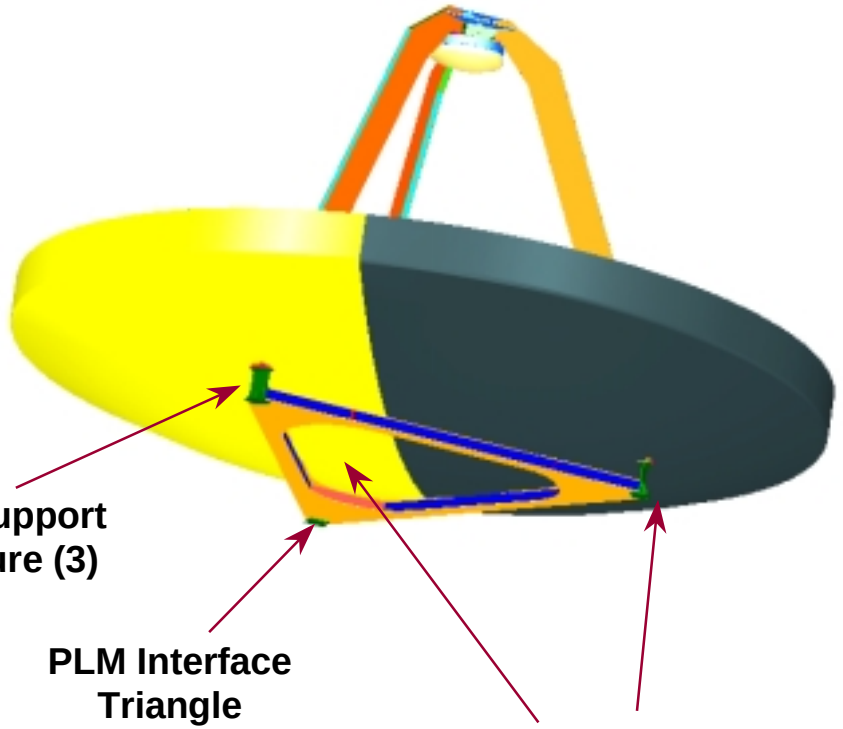


- **3.5m Aperture**
  - **2.0m Demonstration Mirror**
- **85-670 μm Waveband**
- **All CFRP; <10 Kg/M^2 (Substrate Only)**
- **70K Operation**



Telescope Configuration

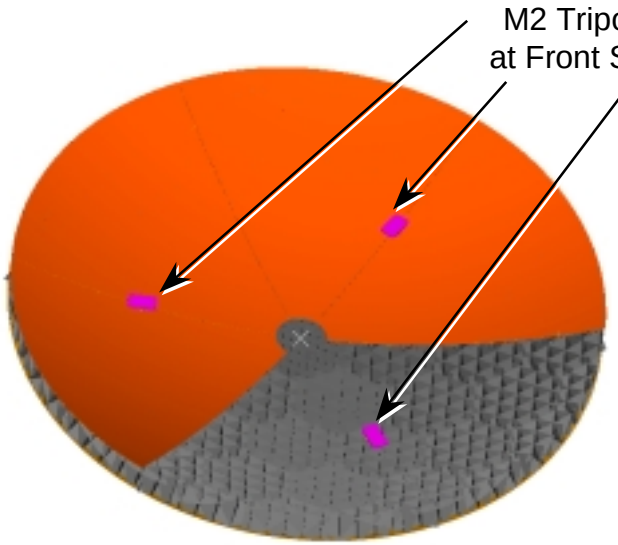


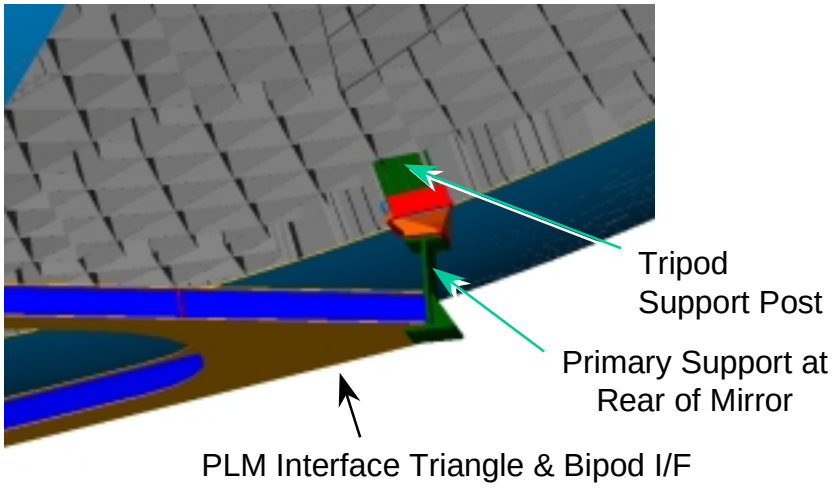


Telescope Mass Breakdown	
Primary Mirror Assembly	141 kg
PLM Interface Triangle	11 kg
Secondary Mirror Assembly	6 kg
Metering Legs	19 kg
TOTAL	177 kg
Requirement	280 kg

Primary Mirror Design

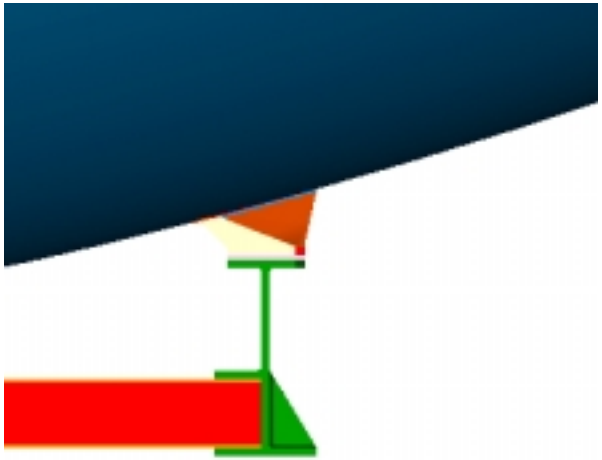
- **All-Composite, Sandwich Style Design -- Front and Back Faceskin Created from 6 Petal Segments Each -- Core Construction Results in Monolithic Mirror**
- **M55J Carbon Fiber, Cyanate Ester Resin, Epoxy Adhesive Bonds**
- **Invar Fittings Provide Interface to Tripod Attachments and PLM Interface Triangle**





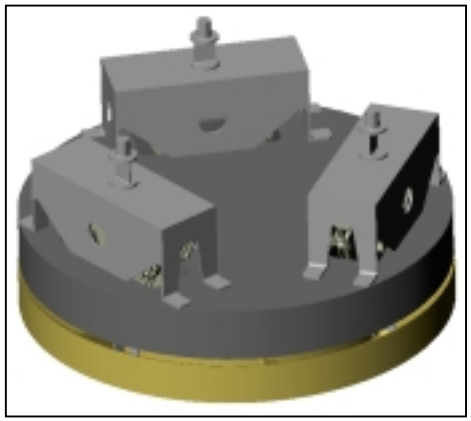
PLM Interface Triangle & M1 Interface

- **PLM Interface Triangle Functions**
  - Isolate M1 from PLM Loads (CTE, etc.)
  - Provide Handling Features for M1
  - Provide Interface/Support Provisions
    - Cabling Connectors
    - MLI
- **Primary Flexure Functions**
  - Provide Compliance for CTE Mismatch Between M1 and PLM Interface Triangle
  - Provide Stiffness for Modal Requirements
  - Provide Strength for Launch Loads
  - Provide Adjustment for M1 Axis
- **Primary Flexure Trades (Baseline)**
  - Single vs. Multi-Blade Designs
  - M1 Fitting Location: Back vs. Mid-Plane
  - Unique Part vs. Part of PLM Interface Triangle

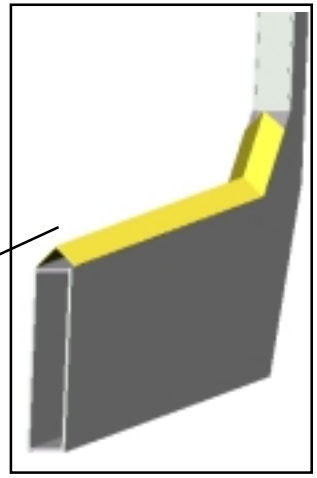


Telescope Tower Assembly Features

Tripod/M2 Structural Reinforcement
- M55J/954-3
- Bonded Construction

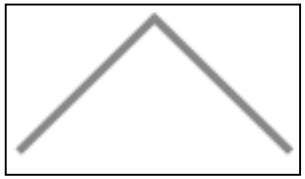


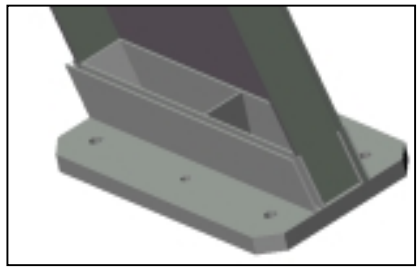
Secondary Mirror Sub-Assembly



Tripod Leg
- M55J/954-3
- Bonded Construction
- Gold Coated for Stray Light Control

Stray Light Spoilers
- M55J/954-3
- Wiring Harness Tunnel
- Gold Coated for Stray Light Control

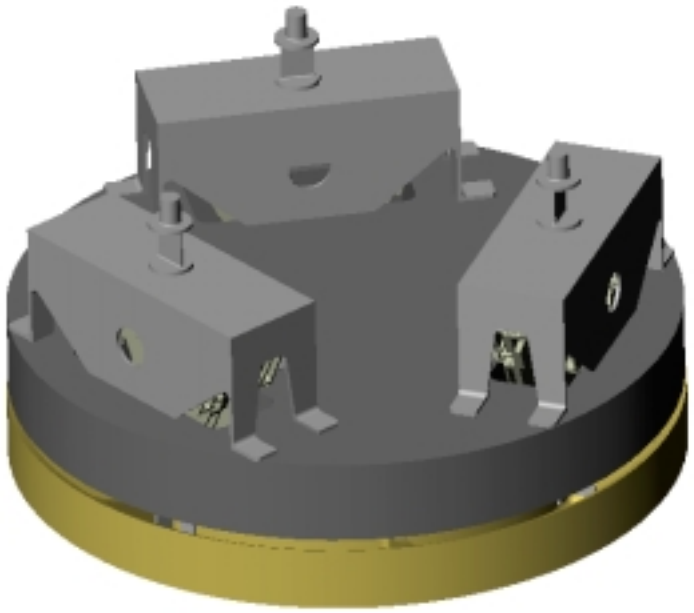


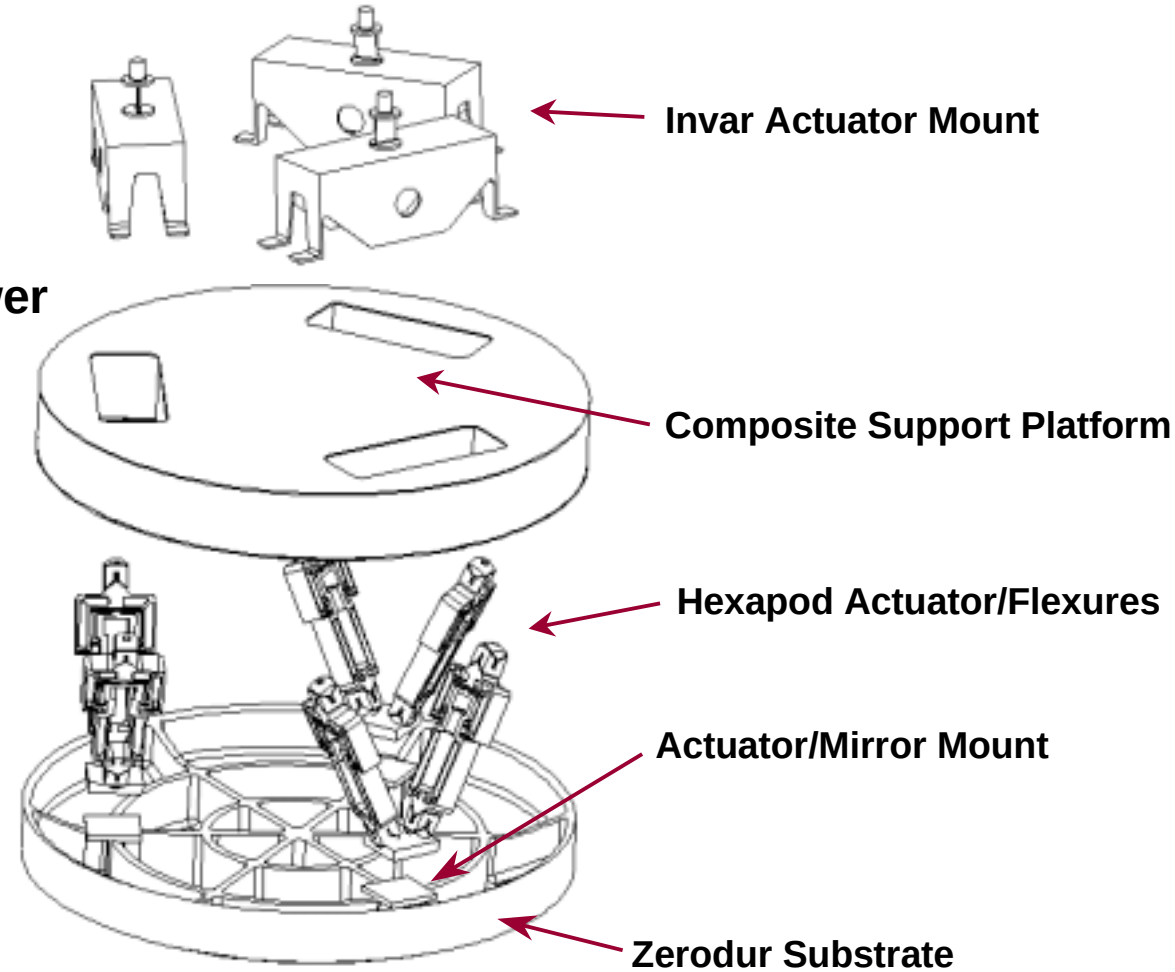


Primary Mirror Interface Fitting

Secondary Mirror Subassembly Design Features

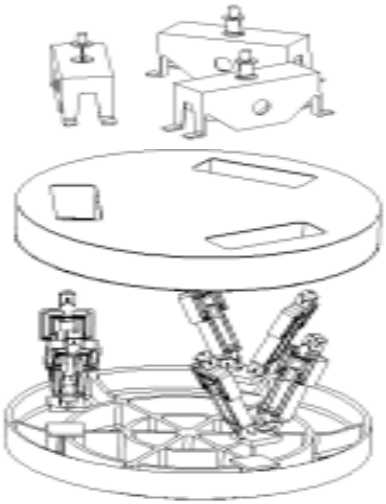
- Integral Actuation
- Stand-Alone System for Complete Bench Testing at Ambient and Cryo
- Shimmable Interface to Tower

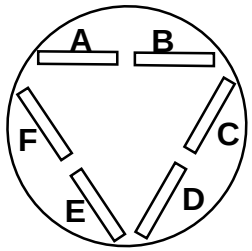




M2 Actuation System

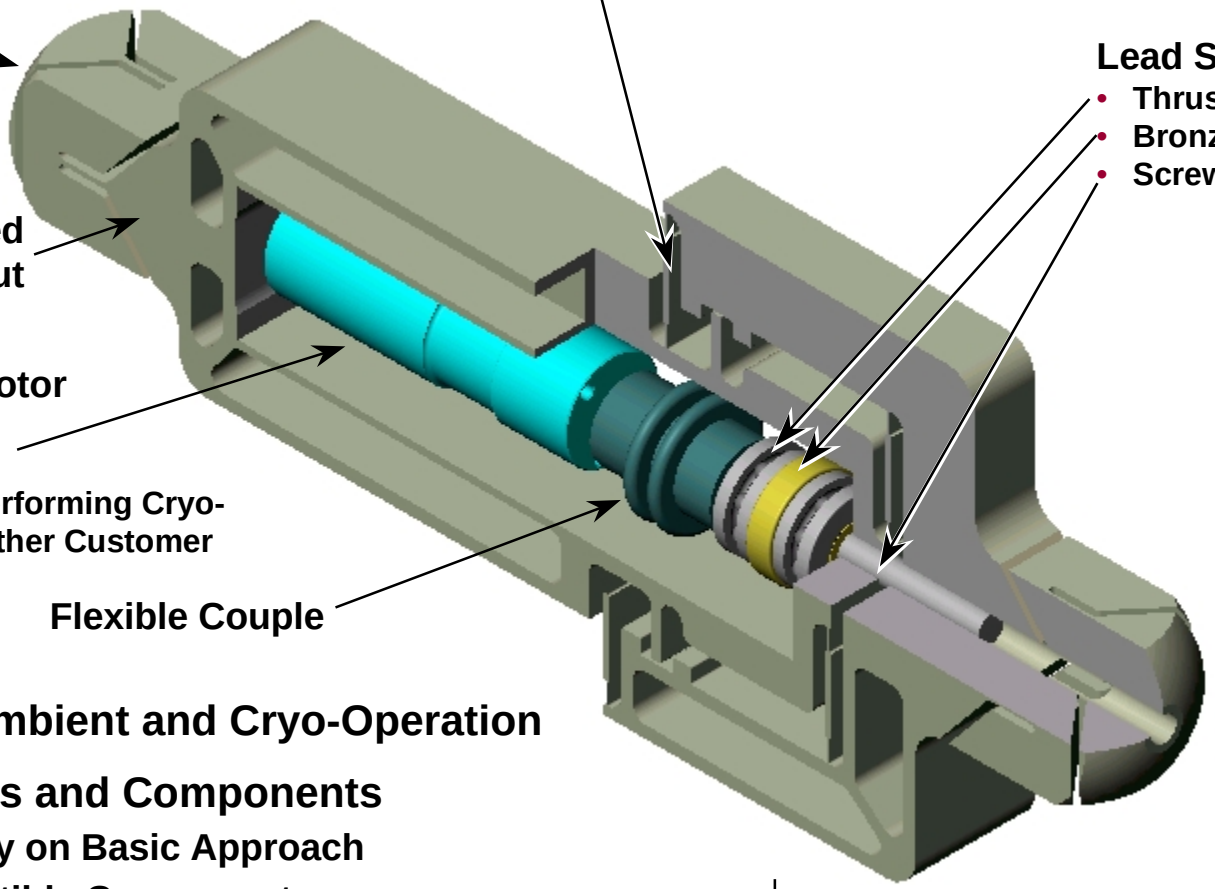
- **Baseline Approach: Hexapod System with Integral Actuators/Flexures**
  - Target Linear Displacement for Individual Actuator at +/-1mm Total Stroke
- **Primarily Used for Telescope Ground Testing**
  - Mechanical Interface (M2-to-Tower) for Gross Adjustments
  - Actuation to "Tune" M2 During Cryo-Test
- **Risk Reduction System for On-Orbit Corrections**
- **Actuation Degrees of Freedom**
  - De-Space: +/-1 mm
  - De-Center: +/-2 mm
  - Tilt: +/-15 Millirad (at Mirror Surface Centerpoint)



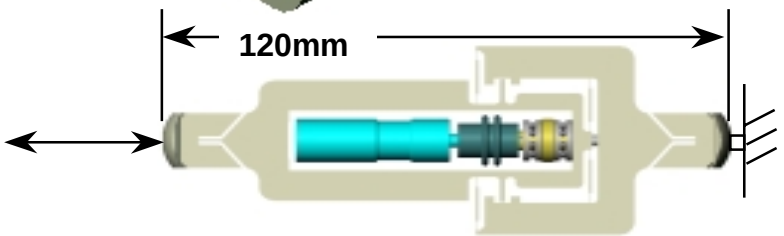


DoF	Signal for Positive Motion
1	+A +B +C +D +E +F
2	+A -B -C +D -E +F
3	-C +D +E -F
4	-A +B -C +D -E +F
5	+A +B -C -D -E -F
6	-C -D +E +F

Actuator Details

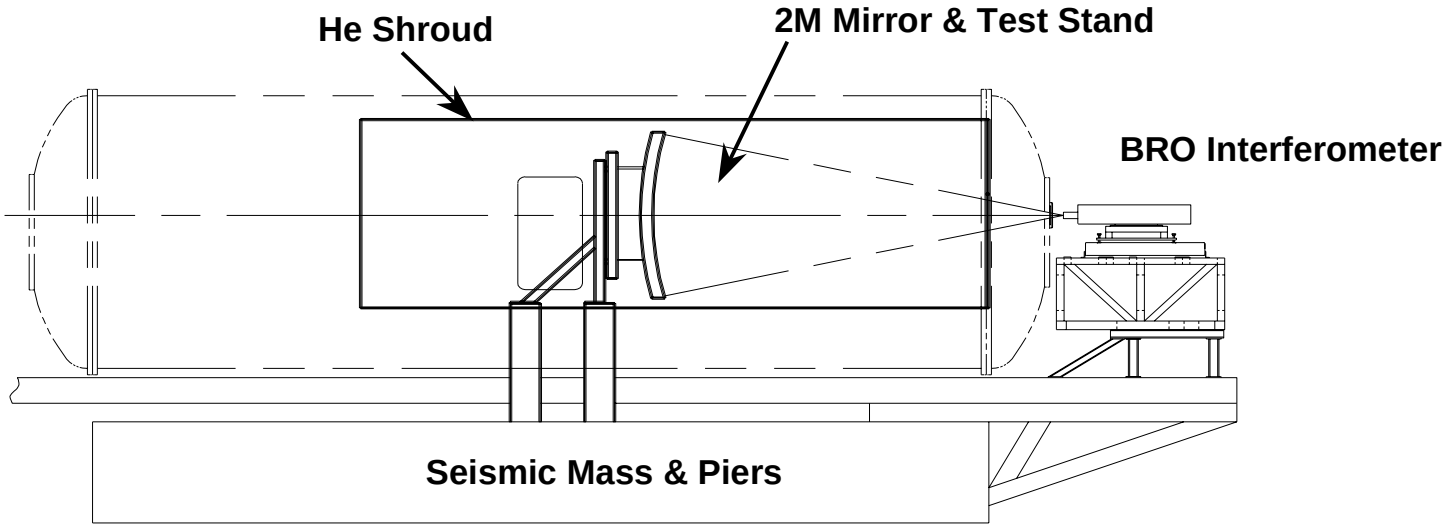


- Designed for Ambient and Cryo-Operation
- Robust Features and Components
  - Flight History on Basic Approach
  - Cryo-Compatible Components
- Sub-Micron Actuator Resolution
- 2mm Total Stroke



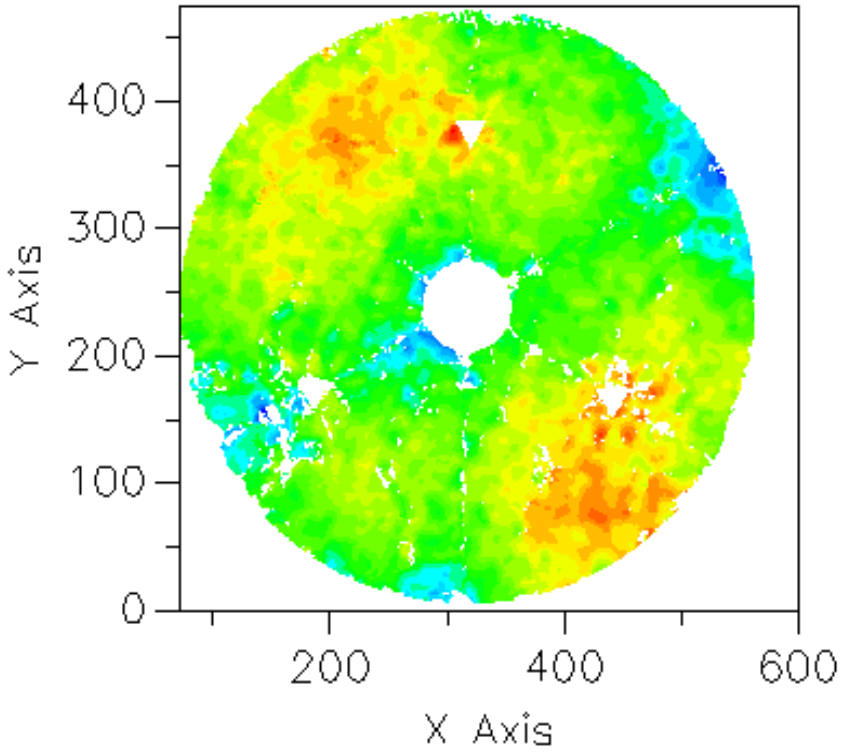
Scope of the 2m Development Mirror Tests at ADEC

- Measure the Figure of the 2m Mirror at Temperature
- Thermal Cycle to Cold Temperatures
- Induce Thermal Gradients and Understand Effects
- Explore Measurement Methodologies
  - Sub Aperture Stitching
  - IR Shack-Hartmann Instrument
- Review of Interferometric Data
  - Full Aperture
  - Sub Aperture



Test Results (Full Aperture Tests)

Delta Figure: 293K to 70K

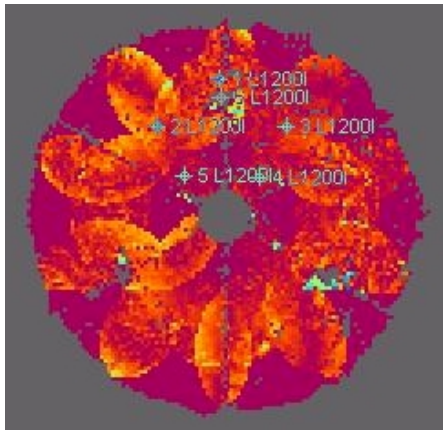


- **3.9 μm RMS**

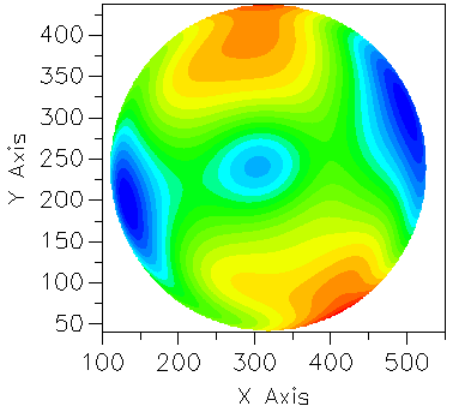
Stitching of Sub-Aperture Results to Evaluate Full Aperture Surface

- Technique Under Development by Industry for Measuring Large Optics
- COI's Test of 2M Mirror Applied Technique to Measuring Composite Surface
- Good Results Achieved, Further Optimization of Algorithms Anticipated
  - First Test of Stitching Technique on 2M mirror
  - .94 Micron Low Order RMS Difference Between Stitched and Full Aperture Results
  - Planned Efforts to CDR - Algorithm Refinement; Double Pass Test Using 2M Mirror

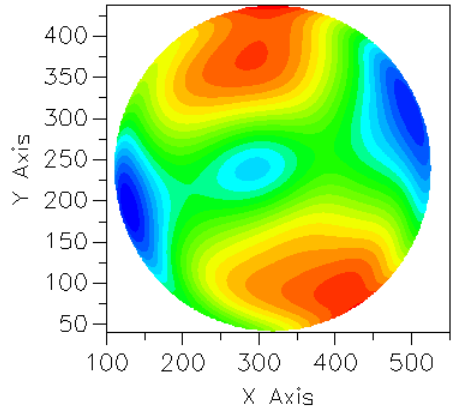
14 Sub-Apertures Stitched to Form Surface



Low Order Errors of Stitched Surface (Z_5 -Z_{36})

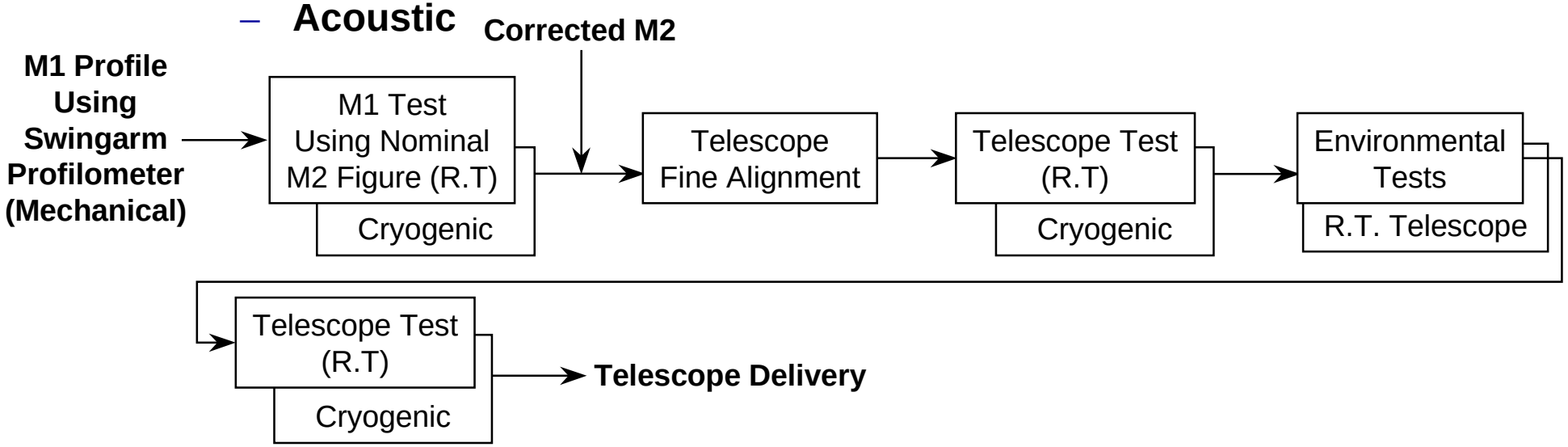


Low Order Errors of Full Aperture Surface (Z_5 -Z_{36})



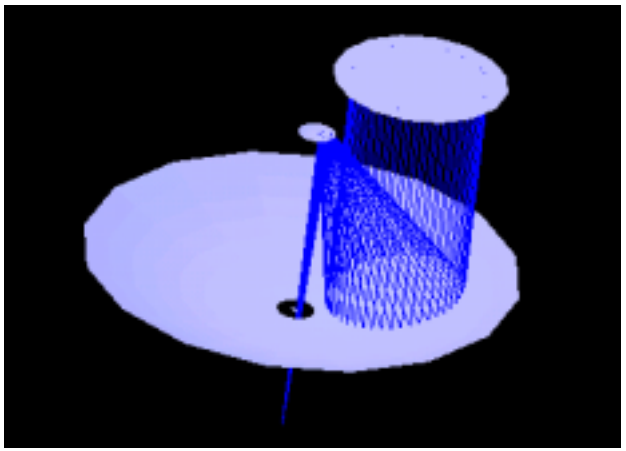
Sequence of Tests to Be Done For End Item Telescope

- **System Optical Test Configuration Is Used for Multiple Tests**
  - **M1 Characterization (Room Temp & Cryogenic)**
  - **Fine Alignment**
  - **Room Temp Telescope Test**
  - **Cryogenic Telescope Test**
- **Environmental Tests**
  - **Thermal Cycle**
  - **Sine Vibration**
  - **Acoustic**

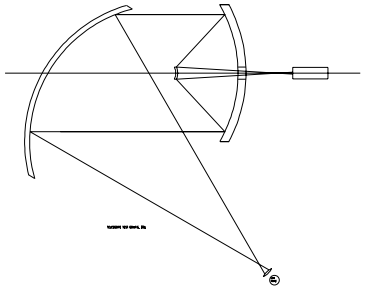


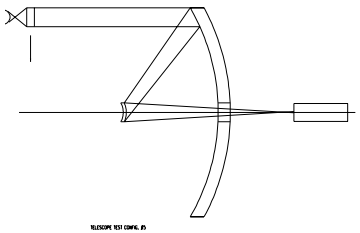
Baseline Optical Test Method

- **Baseline Test - Best Value in Cost / Schedule / Technical**
  - **Double Pass Sub Aperture Infinite Conjugate**
    - **Moveable Reference Flat**
    - **Vertical Configuration**
    - **Sub Aperture Stitching**
    - **Interferometry for Measurement**

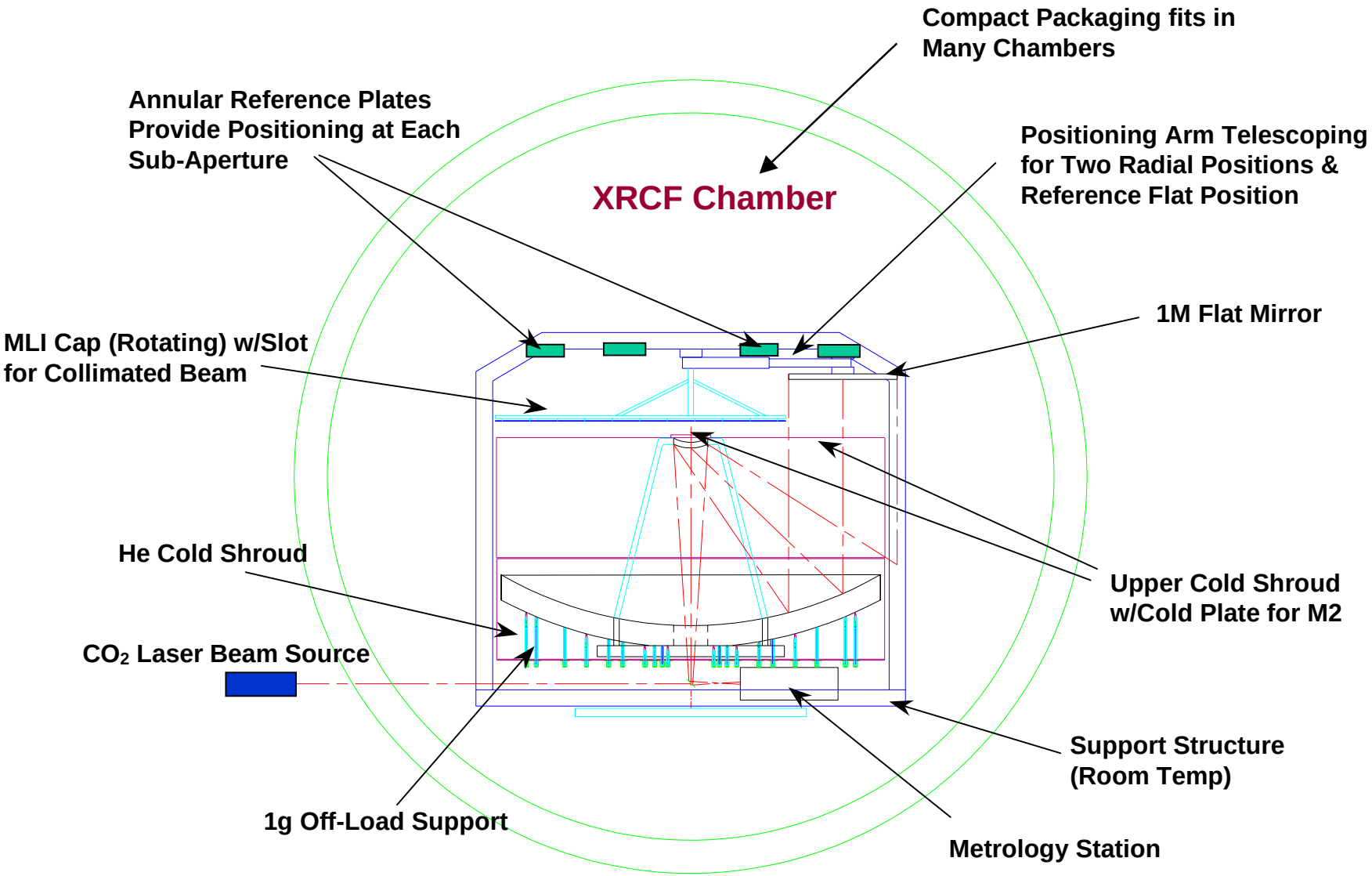


- **Backup Test Configurations**
  - **Single Pass Full Aperture Infinite Conjugate**
  - **Single Pass Sub Aperture Infinite Conjugate**





Sub-Aperture System Test



Metering Structures and Optical Benches

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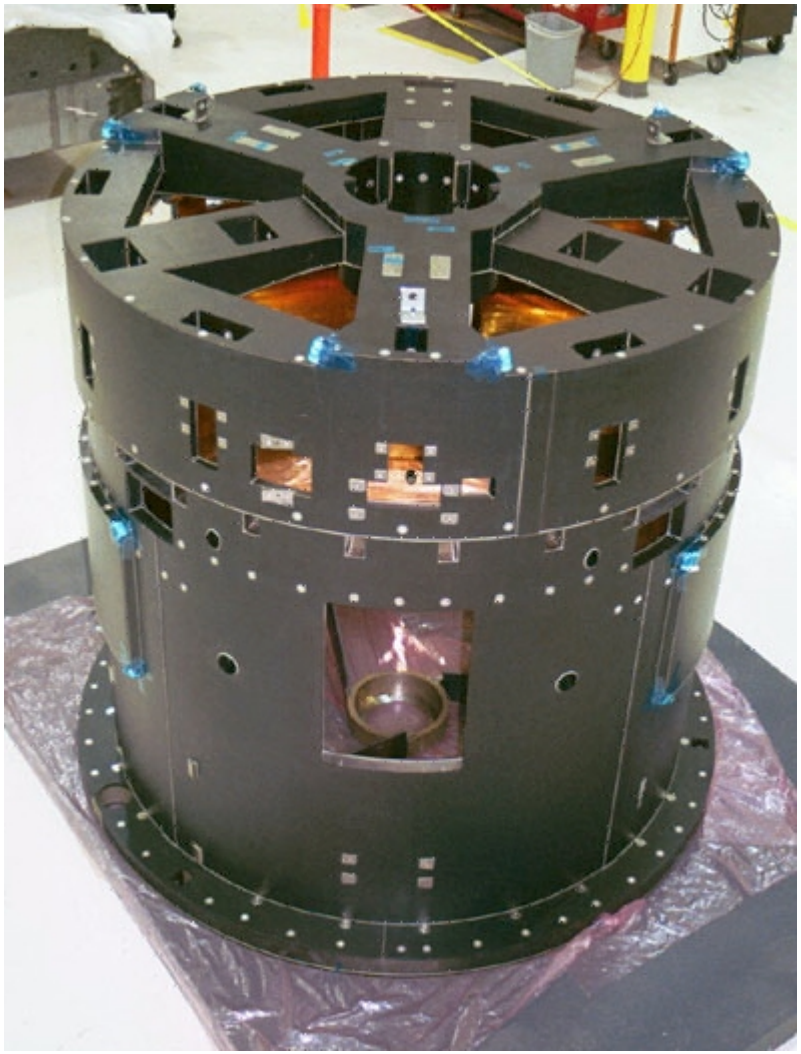
Airborne Laser Beam Expander

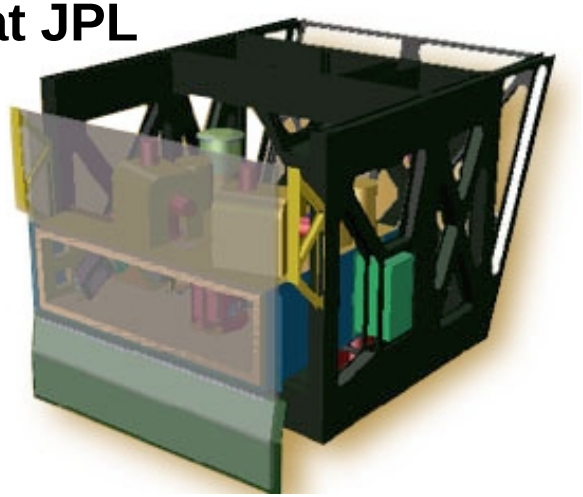
- **Provides extreme stability for a 1.5m Telesope**
- **Operates in demanding aircraft environment.**
- **COI's responsibilities**
  - **design**
  - **analysis**
  - **manufacturing & assembly**
  - **modal and structural test of the hardware.**

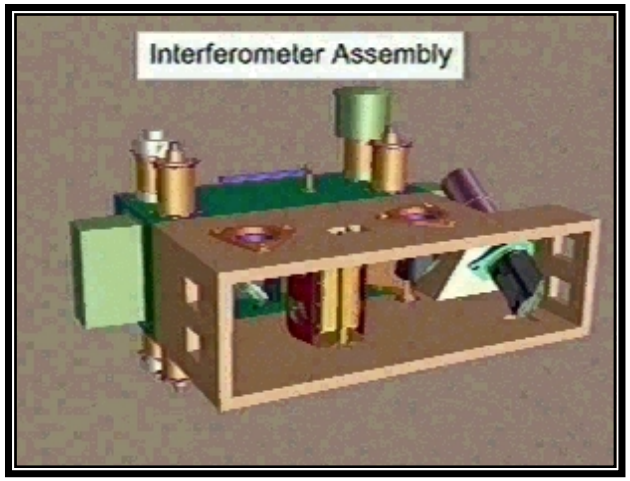


COI Designed and Built TES Instrument Structures and Thermal Control System

- **TES instrument for JPL mission on EOS**
  - Fourier Transform Spectrometer
  - COI designed and built Optical Bench to prescription
  - Dimensional stability to 170K optics temp
  - Multi-function structure used to meet thermal and structural requirements
  - Cryocooler interface and waste heat radiator system part of design

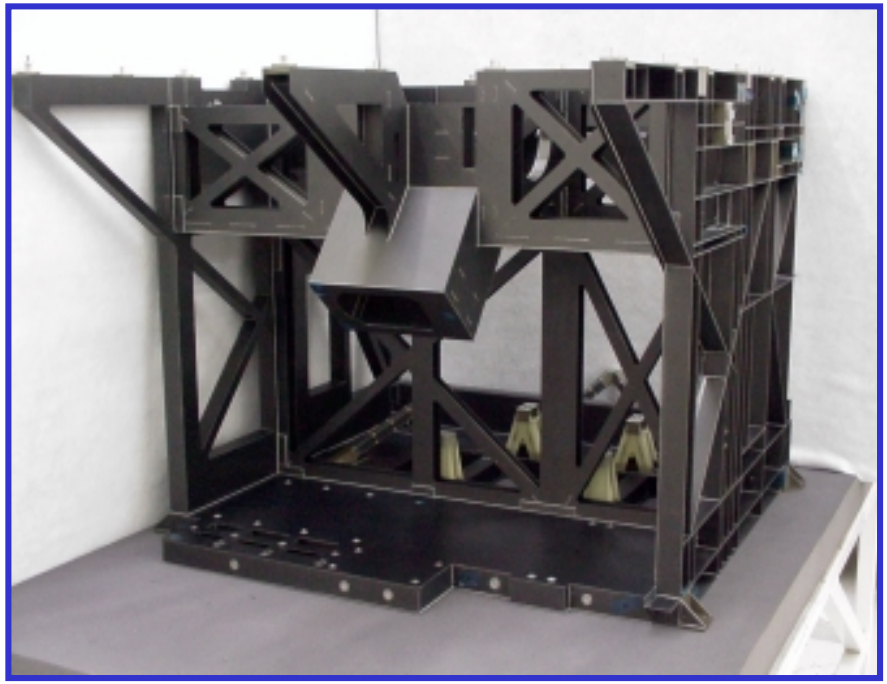
- **Instrument structure built and in integration & test at JPL**





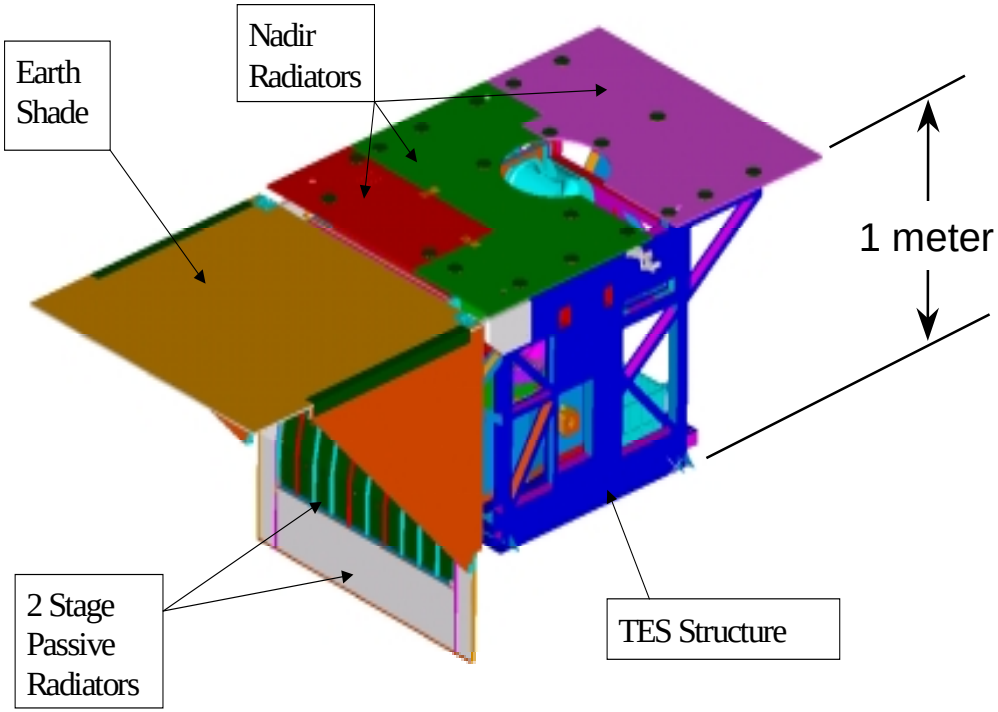
TES Instrument Structure Design Drivers

- Lightweight
- Tight Dimensional Stability Required
- Very Stiff (50 Hz Min, 100Hz M1 to M2)
- 21 JPL Supplied Interfaces
- 10 COI Sub Assembly Interfaces
- Limited Envelope

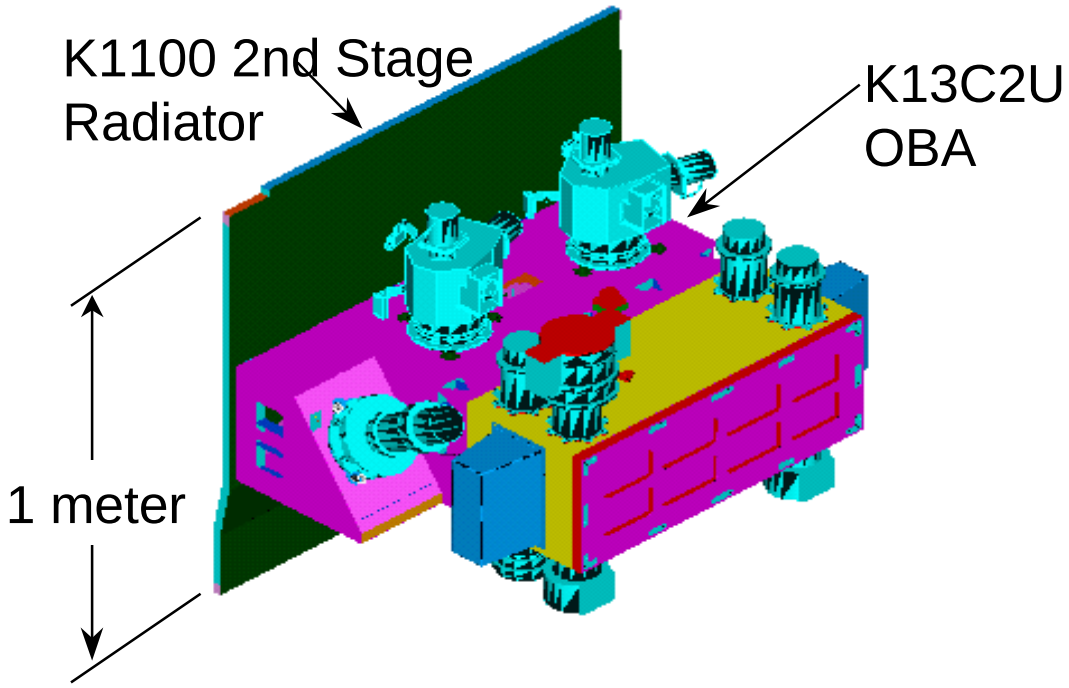


Instrument Thermal Control Design Drivers

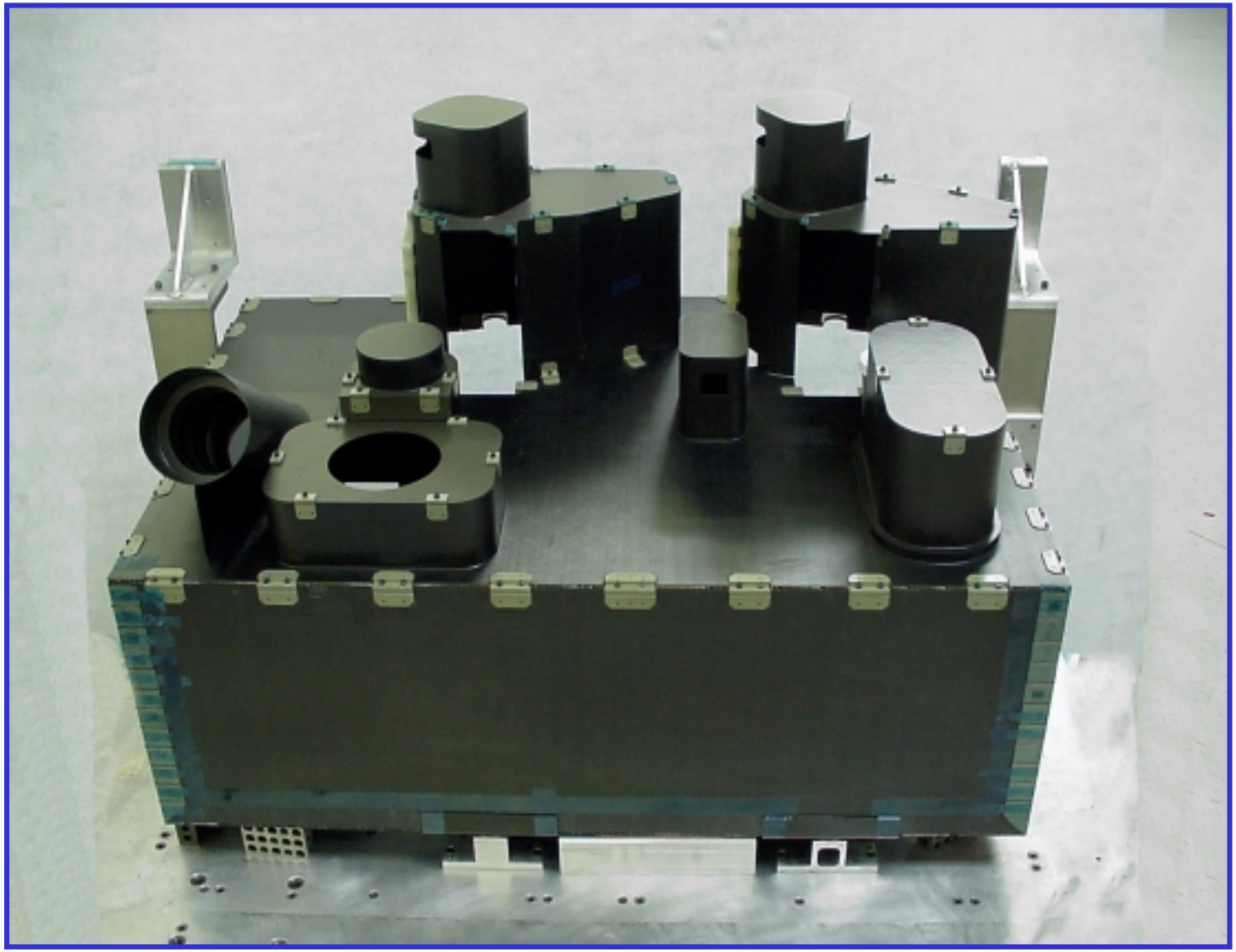
- **Excellent Dimensional Stability for Optics**
- **Four Temperature Zones**
  - Electronics and Mechanical Cooler Zone (300K)
  - Interferometer Thermal Shield Zone (230K)
  - Interferometer Zone (180K)
  - Focal Plane Zone (65K)
- **Limited Survival Mode Power Available**
  - Requires Loop Heat Pipes
- **Limited Radiator Area Available**
  - Requires Earth Shade with Internal Specular Surface
  - Highly Efficient Radiators (95%)
  - 2 Stage Passive Thermal System



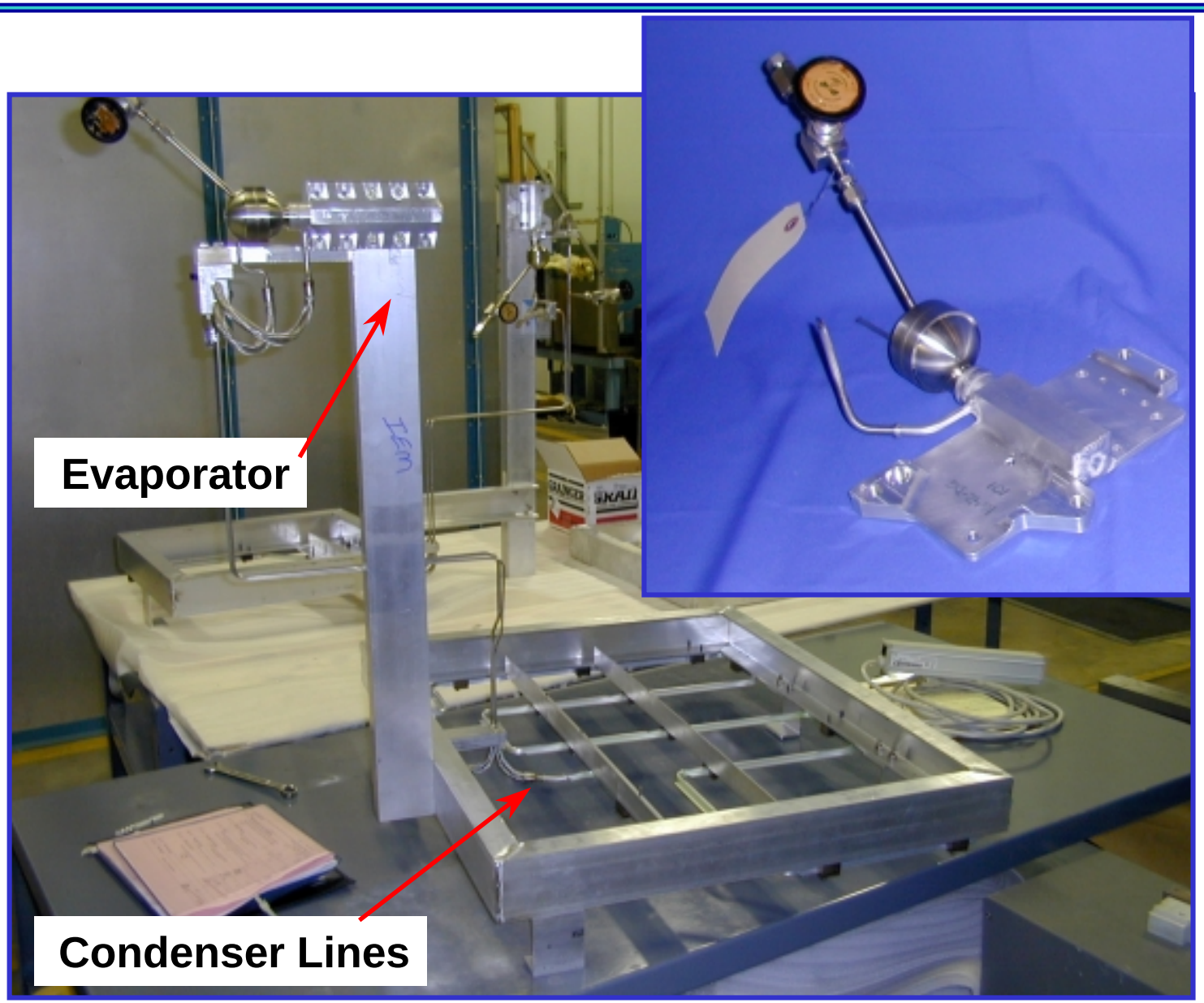
TES OBA and 2nd Stage Radiator



TES 230K Thermal Shield



TES Structure Loop Heat Pipes



TES OBA and Second Stage Radiator

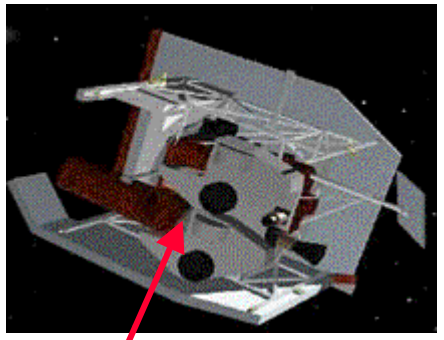
Integrated with Optics, During Thermal Vacuum Testing

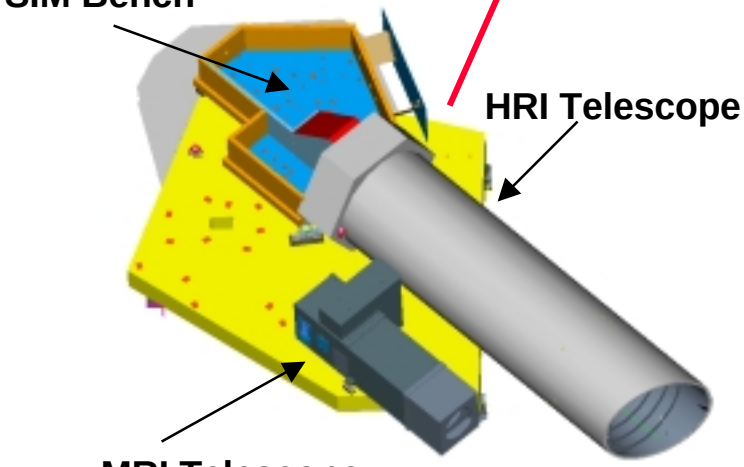
Deep Impact

- **Program Deep Impact**
  - Start Date Jan. '01
  - Projected Delivery - Dec '01 - March '02 (4 items)
- **Customer: Ball Aerospace / JPL / U of MD**
- **COI Responsibilities**
  - Concurrent system design, Detail design
  - Structural, Dimensional stability, & Thermal Analysis
  - Fabrication of 3 Telescope structures, 1 Optical bench
  - Environmental & Launch load testing
- **Performance**
  - Mass (each 4 parts) 3 - 16 kg
  - 1st Mode range 35 - 150 Hz
  - Materials K13c2u/954-3, M60J/954-3, Al, Invar
  - Ultra-high Stability Requirements
  - Operation to 110K

Comet Impactor
Includes
COI Telescope

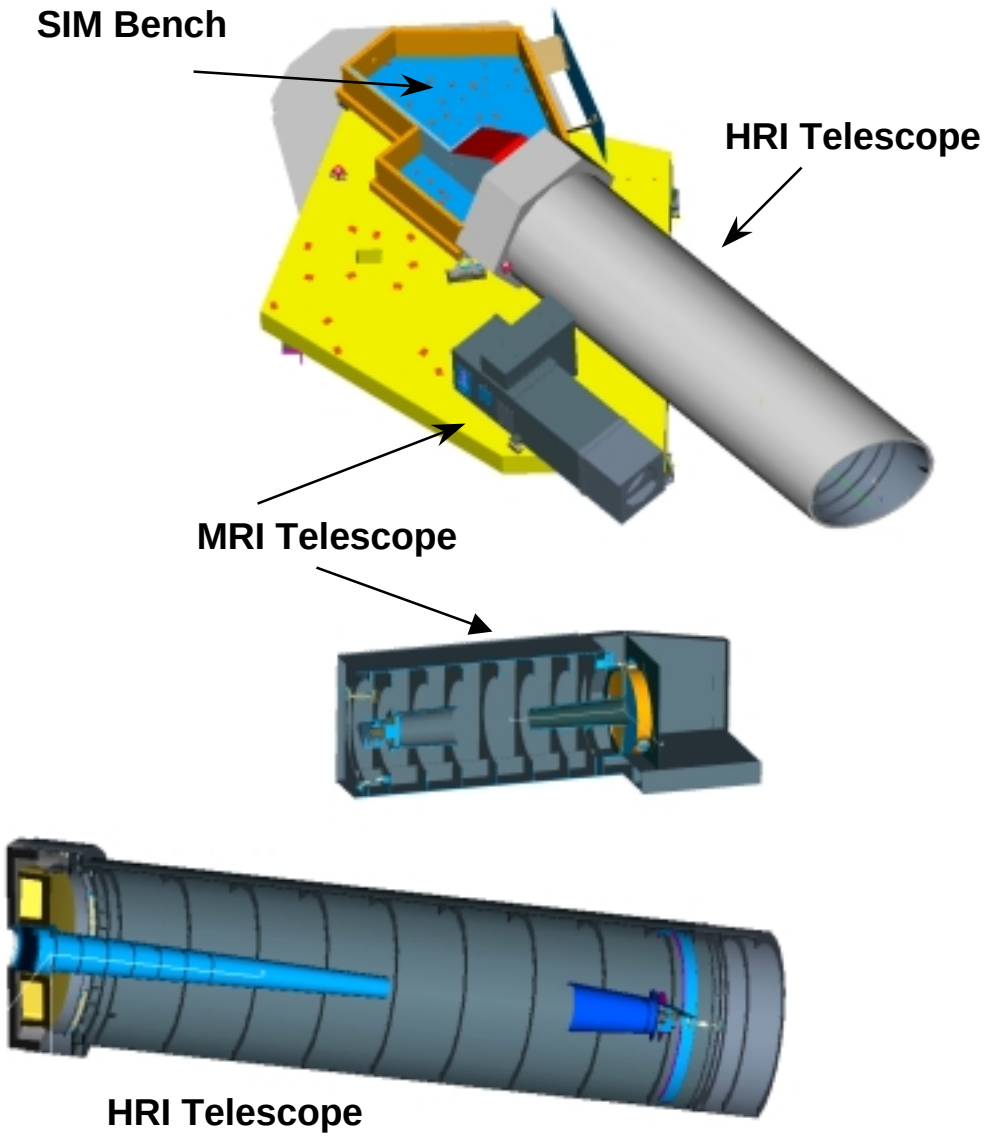
Fly-by Instruments
Include 2 COI Telescopes & Instrument Bench





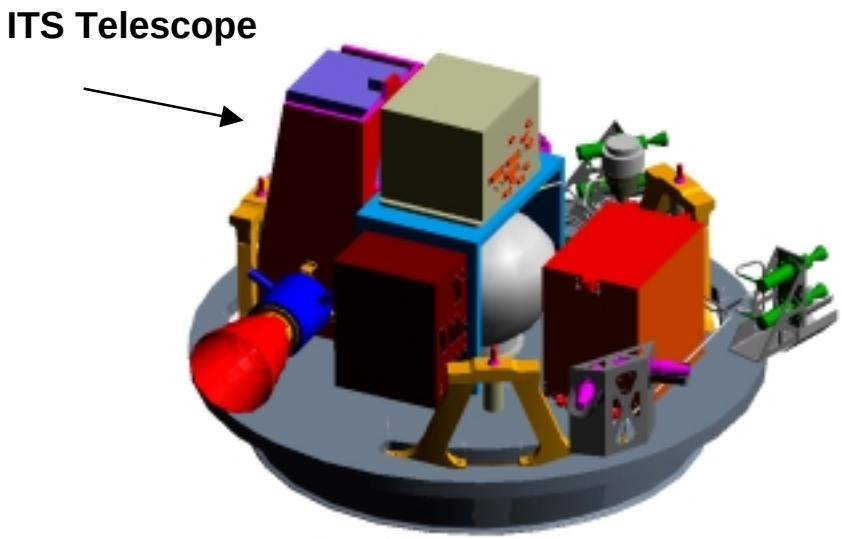
Fly-By Instruments will Record the Impact and Crater

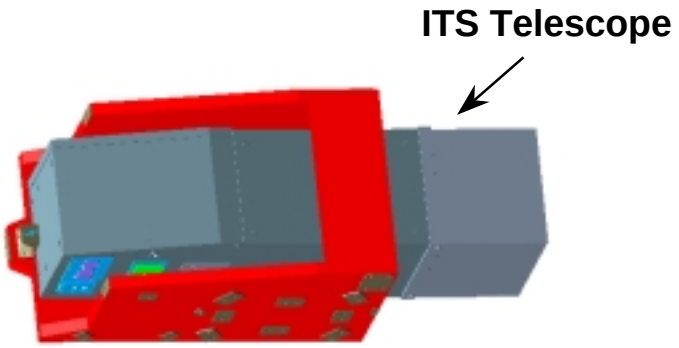
- **Two Instruments built by COI**
  - Will aim Impactor Bullet at comet
  - Take Photos of impact and football field sized crater
- **Challenges**
  - Tight stability to maintain good focus and aim
  - K13C2U being used at 110K
  - Tight tolerances for mounting mirrors and instrument parts
  - Instrument bench made of Aluminum honeycomb with tight tolerances



Impactor Instrument Guides “Bullet” and Takes Last Picture

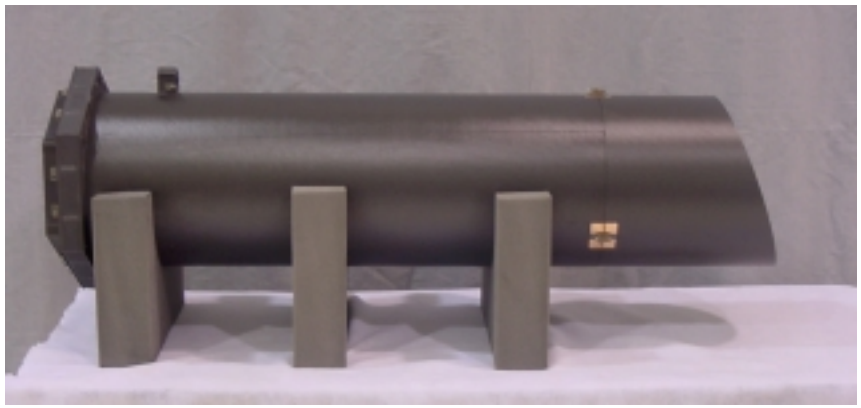
- **Instruments built by COI**
  - Will aim Impactor Bullet at comet
  - Take Photos of impact site before impact
  - Bullet with instrument will hit comet at 10 km/s
- **Challenges**
  - Tight stability to maintain good focus and aim
  - K13C2U being used at -125K
  - Tight tolerances for mounting mirrors and instrument parts





Deep Impact Capabilities Applicable to SNAP

- Telescope designed for high dimensional stability
  - Cryogenic operation
  - Visible Quality
- COI provides telescope structure, Ball integrates mirrors & instrument package
  - COI design, analysis, fabrication, & test responsibility
- Telescope structures use high thermal conductivity fiber system
  - Minimize gradients, improve stability
- COI performed end to end dimensional stability analysis
  - Includes build details (bondlines, fittings, etc.)
  - Allows Ball to achieve athermal performance with mixed materials
- COI performed detail thermal analyses
  - Includes build details
    - bondlines, fittings, etc.



Ultra-Lightweight Mirror Technologies

Composite Optics, Inc. • 9617 Distribution Avenue • San Diego, California 92121
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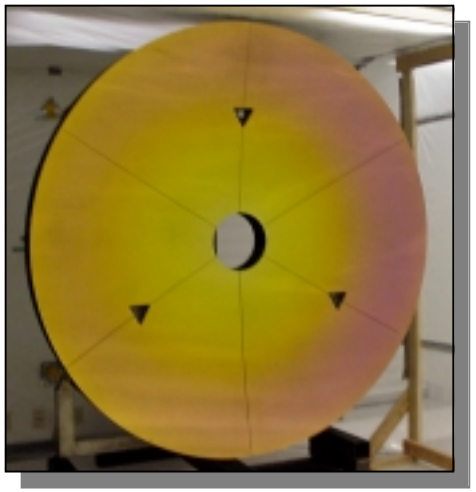
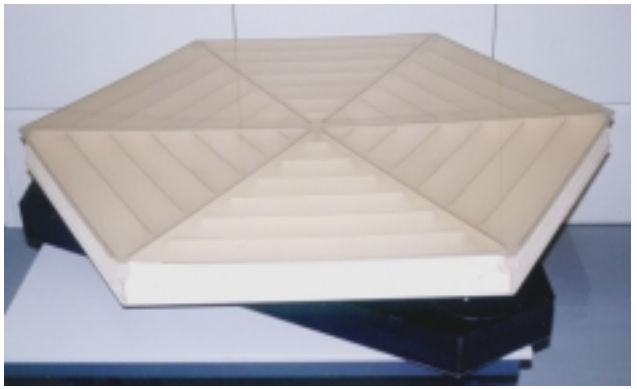
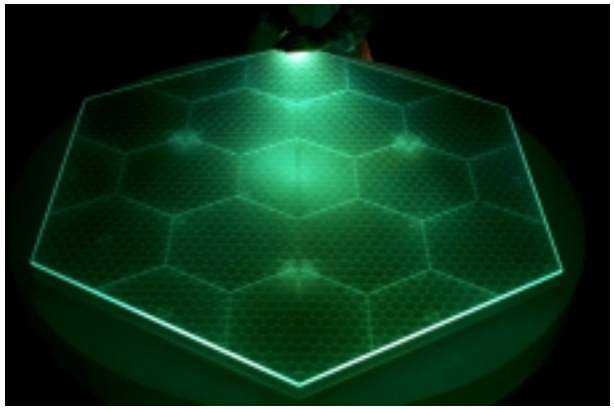
Mirror technology is being developed for wide range of applications

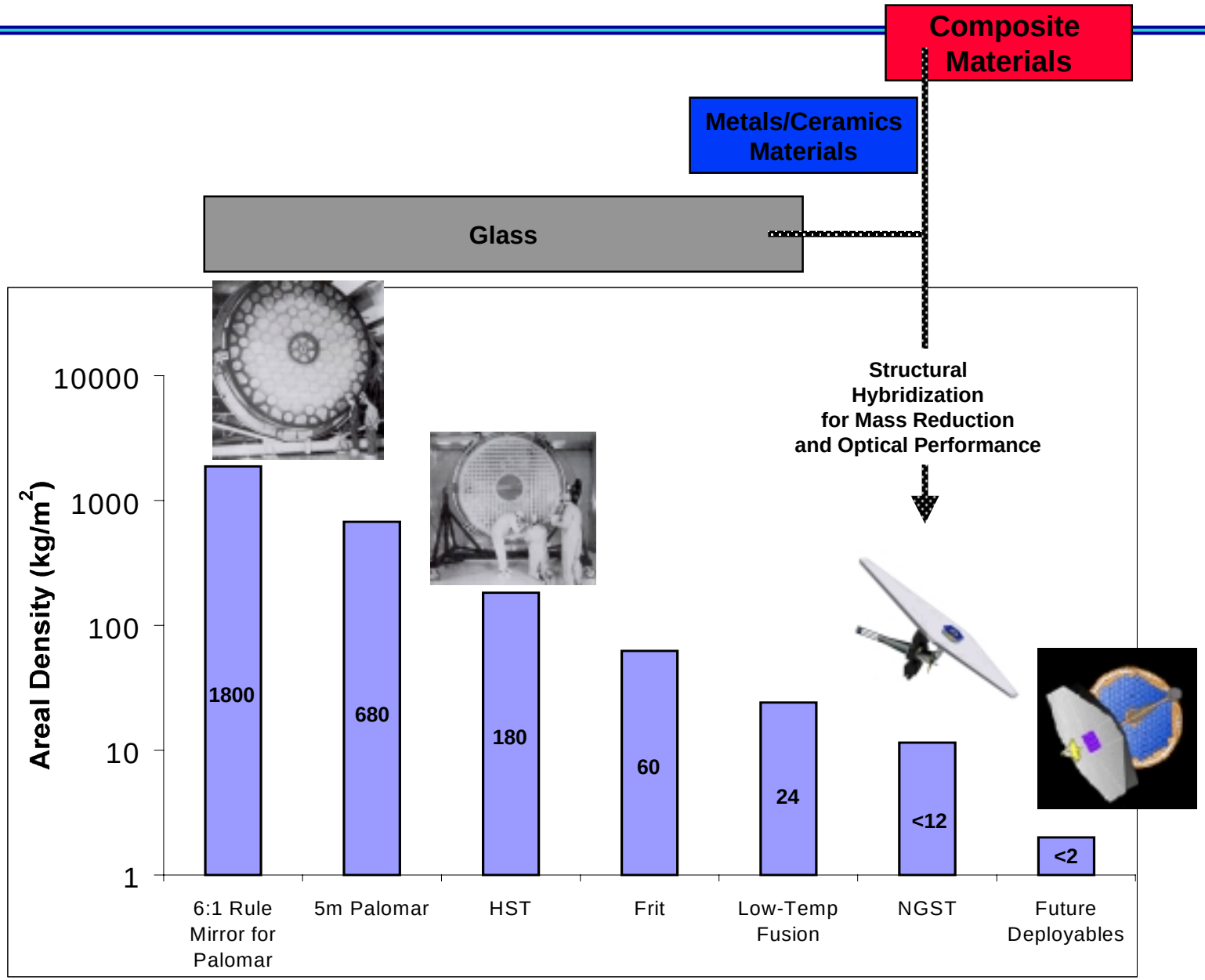
- All composite mirrors, Reflectors
  - LWIR, VLWIR, RF
- Glass – Composite hybrid mirrors
  - Visible, SWIR, MWIR
  - Primary mirrors
  - Gimbal & scan mirrors
- All Glass mirrors
  - Visible





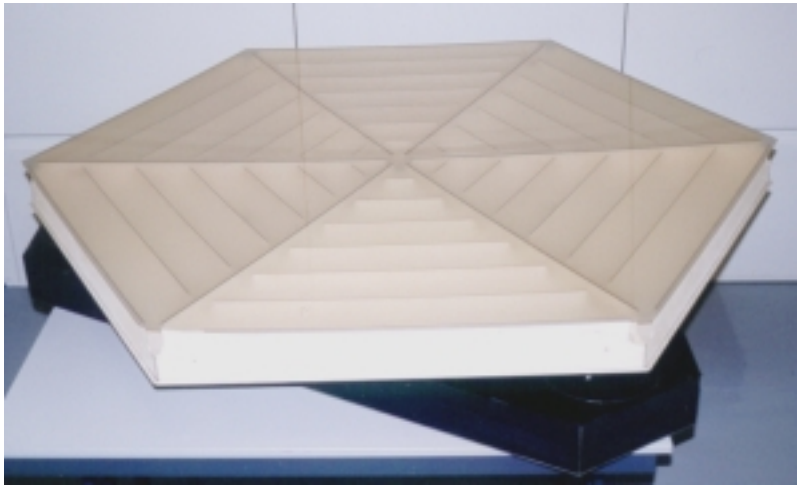


Lightweight Mirrors for Optical Systems



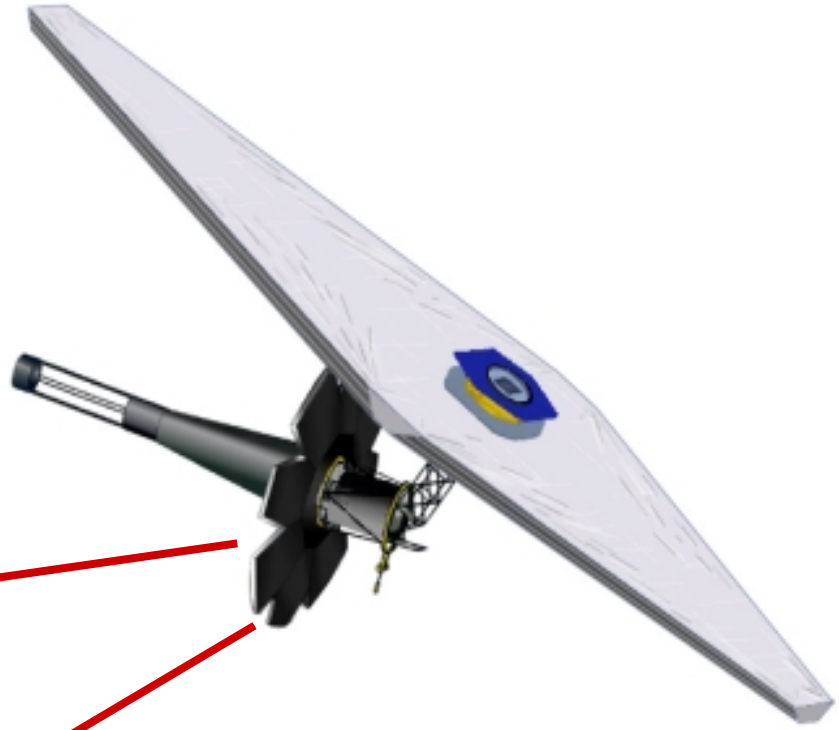
NMSD Hybrid Design Approach

- **Combine Desirable Attributes of Both Glass and Composite**
- **Structurally Efficient Bonded Sandwich Construction**
  - **Zerodur Facesheet to Meet Optical Requirements of Program**
    - **Processable Using Conventional Methods**
      - **Grinding, Polishing, Ion Figuring**
  - **Composite- Structural Support for Glass**
    - **Low Mass, High Stiffness**
    - **Match Thermal Expansion of Zerodur from Ambient to 35K**



NMSD
NGST Mirror System Demonstrator

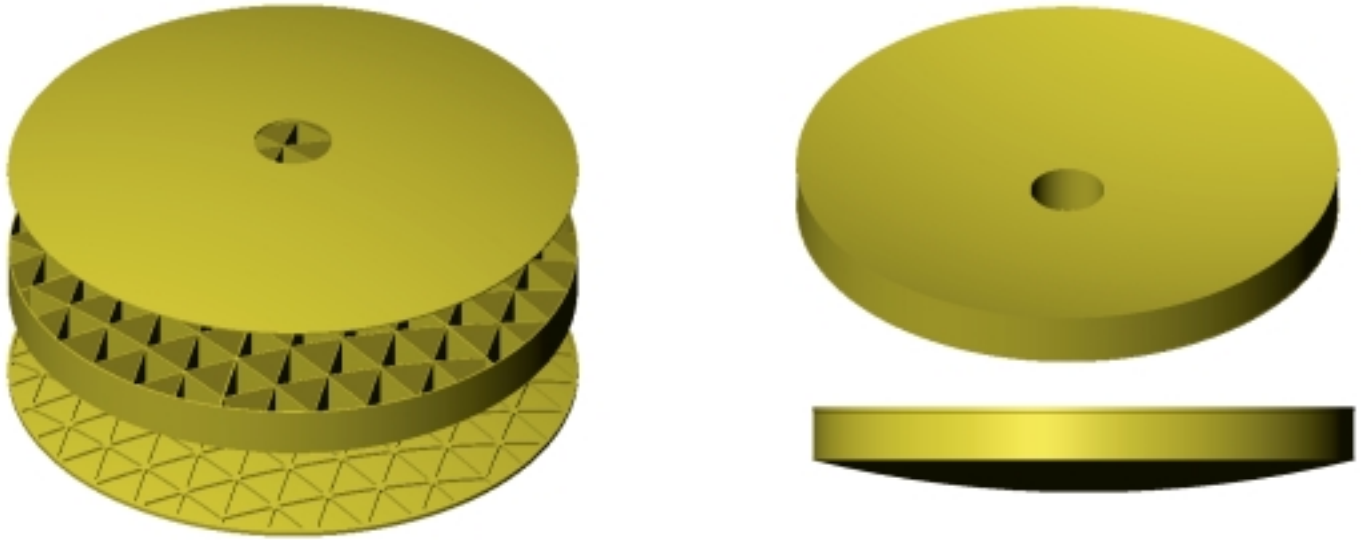
- Zerodur Face; CFRP Ribs
- CFRP Reaction Structure
- Visible Waveband
- <15 Kg/M^2 (Susbtrate and Reaction Structure)
- 35K Operation



NGST Spacecraft Concept

SNAP Notional Design

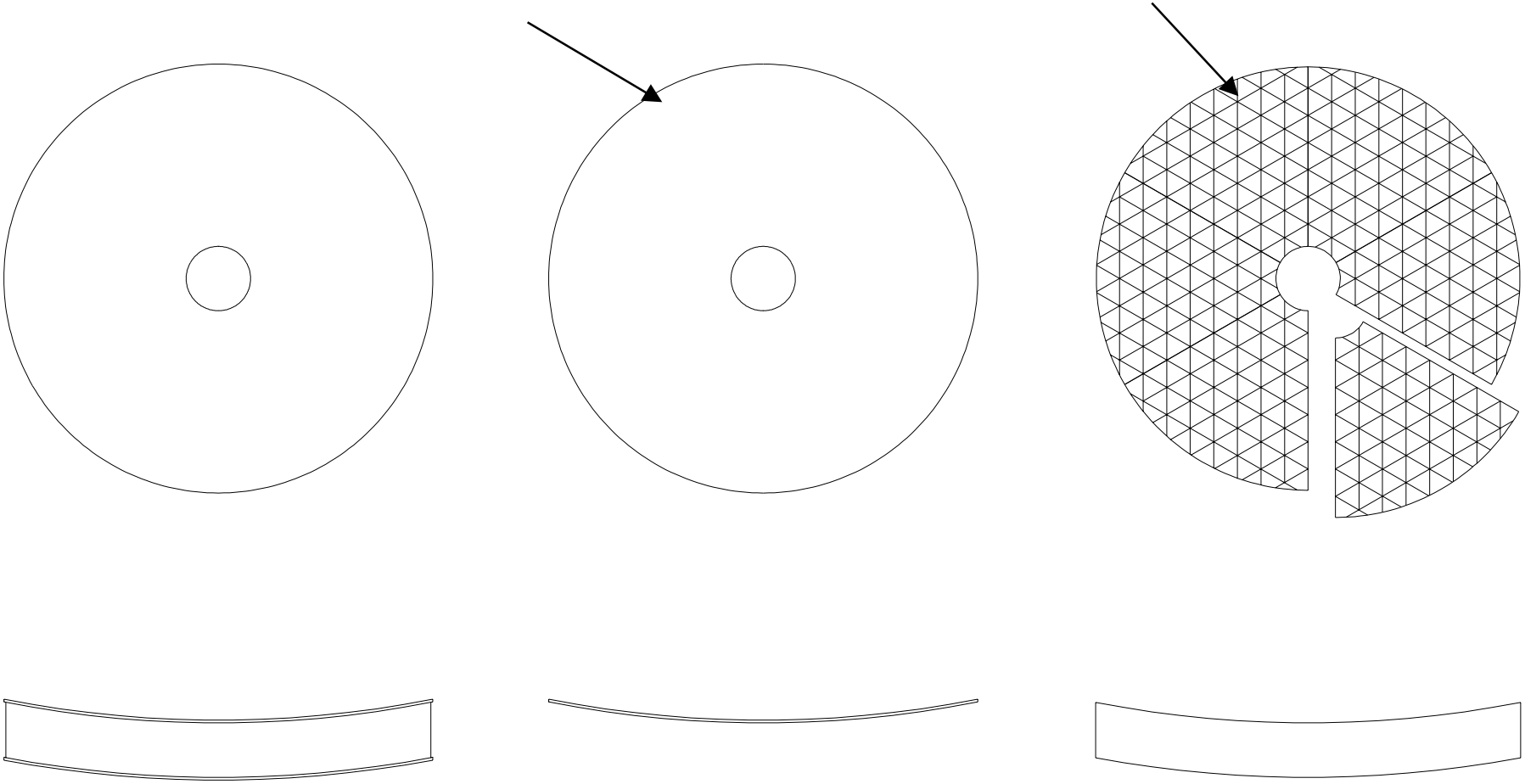
- **All Glass (ULE™), Sandwich Cross-Section**
- **Low-Cost Blank Processing**
  - **Slump Formed Faceplates**
  - **Waterjet Lightweighting of Faceplates, and Machining of Core Modules**
  - **Low Temperature Fusion of Substrate**
  - **Conventional Optical Processing**



Design Features

Faceplates (Front and Back)
- **7mm Thickness**

Isogrid Core
- **3.2mm Thick Rib**
- **Six Modules Subcomponents**

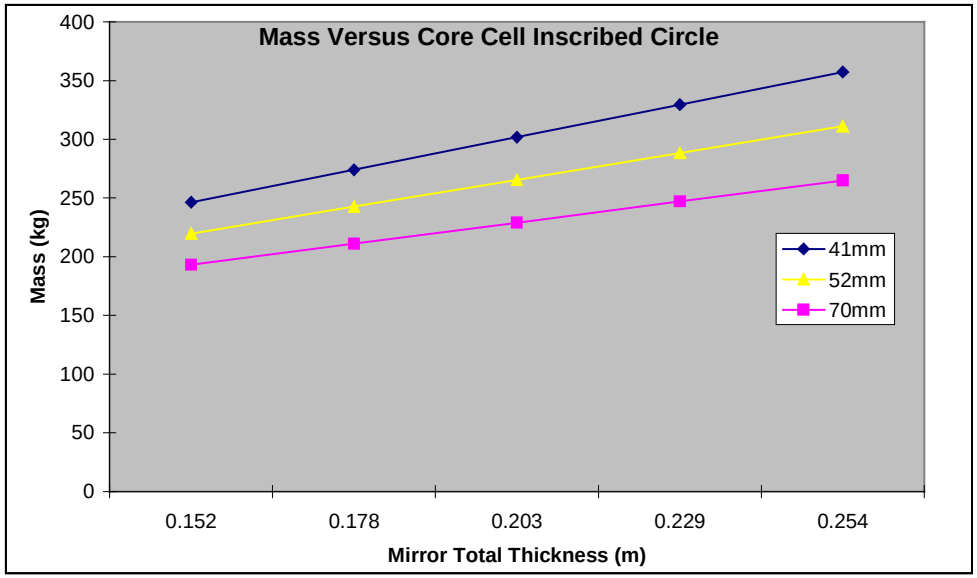


Mirror Substrate

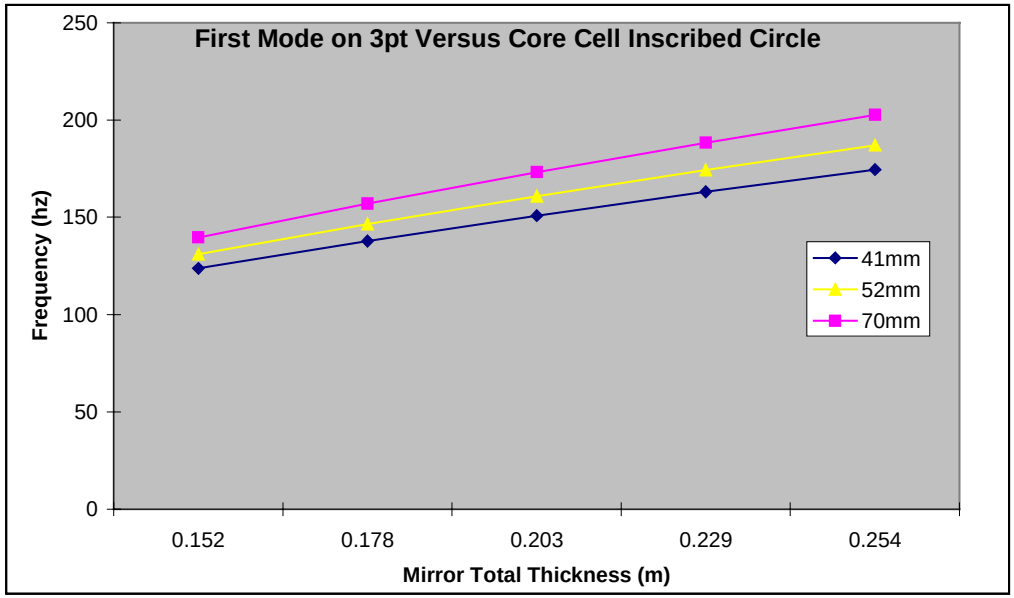
Meniscus Faceplates Front/Back

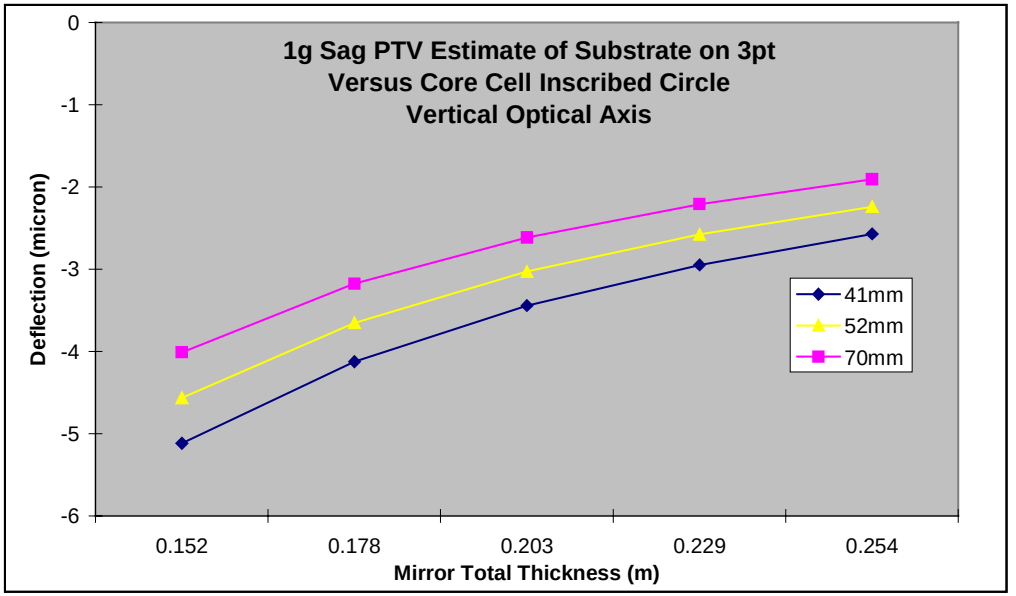
Waterjet Machined Isogrid Core

Parametric Trades



Features Held Constant:
Faceplate Thickness: 7mm
Core Rib Thickness: 3.2mm





Glass mirror development

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