Manufacturing of a Multi-Surface Freeform Telescope

NASA Mirror Tech Days

November 6, 2018

Presented By:

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Prototype Optics In One Week

Outline

- Overview of Optimax
- SBIR Phase 1 two-freeform monolith
- SBIR Phase 2 three-freeform monolith
- SBIR Phase 2 light-weight monolith
- Wrap-up

Optimax Overview

Inc 5000 Top Growing Business

TOP WORK PLACES 2016 D&C Democrat & Chronicle PART OF THE USA TODAY NETWORK

OPTIMAX · 2016 · Aspheres · Cylinders · Prisms · Spheres · 1991 ·

- Founded 1991
- Ontario NY
- 65,000 ft² facility
- 300+ employees
- ISO 9001:Certified
- ITAR compliant

OPTIMAX

Optimax Systems, Inc. – Custom Precision Optics

Committed to Small Volume, High Quality, Quick Delivery

Markets:

- Semiconductor
- Aerospace and Defense
- Commercial
- Medical

- Materials
  - Glass Materials
  - Ceramics
  - Crystals
  - Fused Silica
  - Low Expansion
- Shapes
  - Spheres
  - Aspheres
  - Cylinders
  - Domes
  - Flats
  - Prisms
  - Conformal & Freeform

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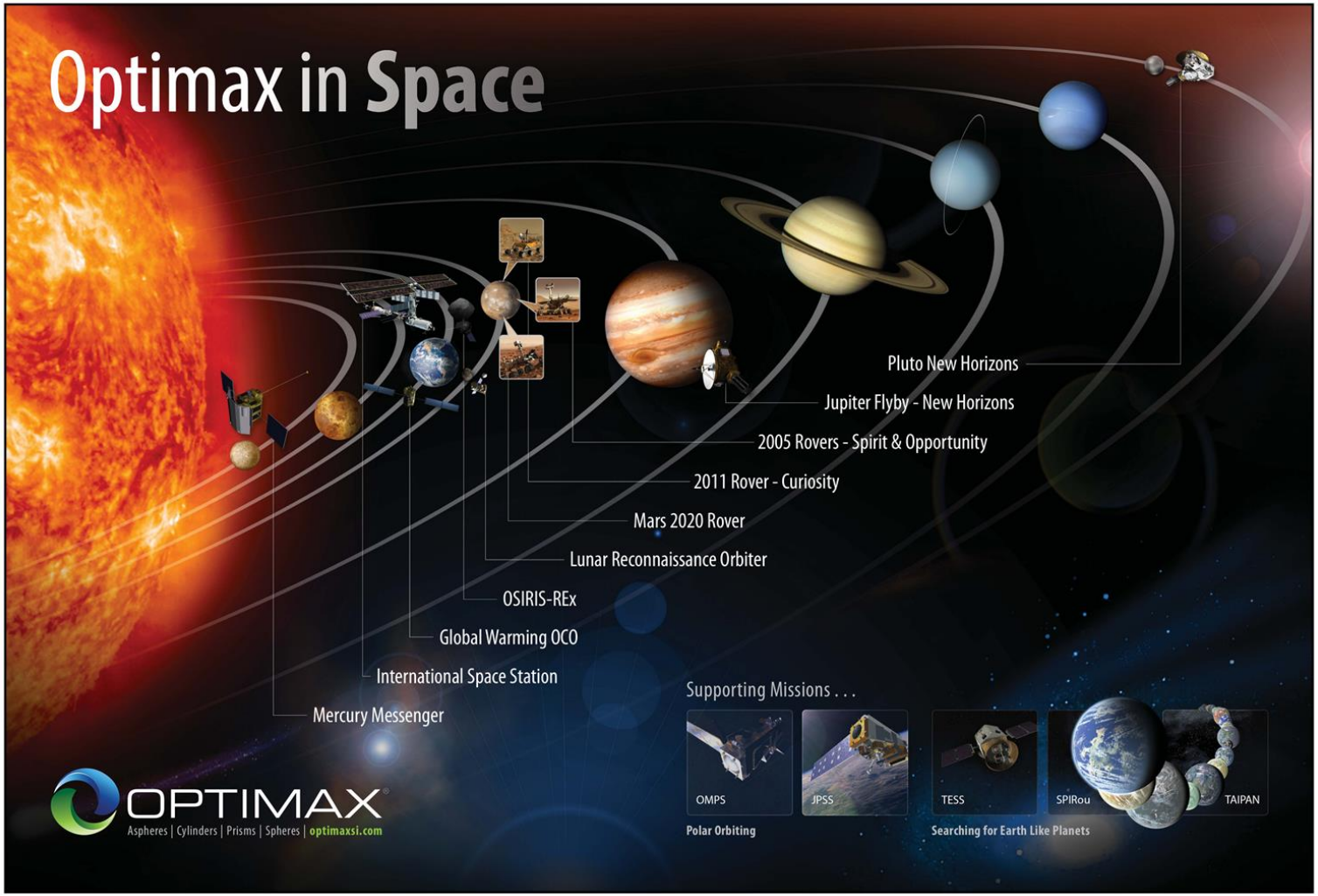
Optimax in Space

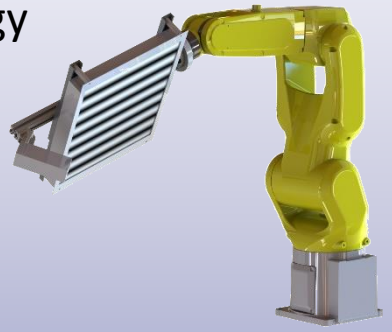


- Mars Rover Spirit & Curiosity
- Pluto New Horizons
- TESS

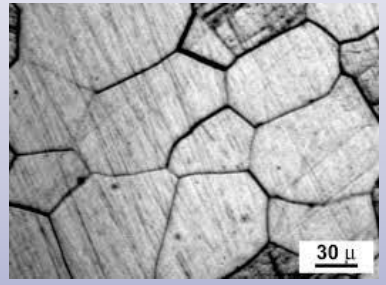
Optimax's research efforts span a number of different topic areas

Freeform optic manufacturing

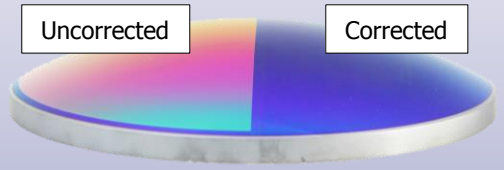
Novel metrology systems



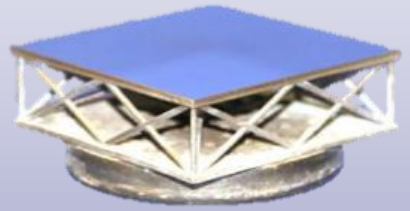
Exotic optical materials



High-performance optical coatings



Innovative optical manufacturing methods



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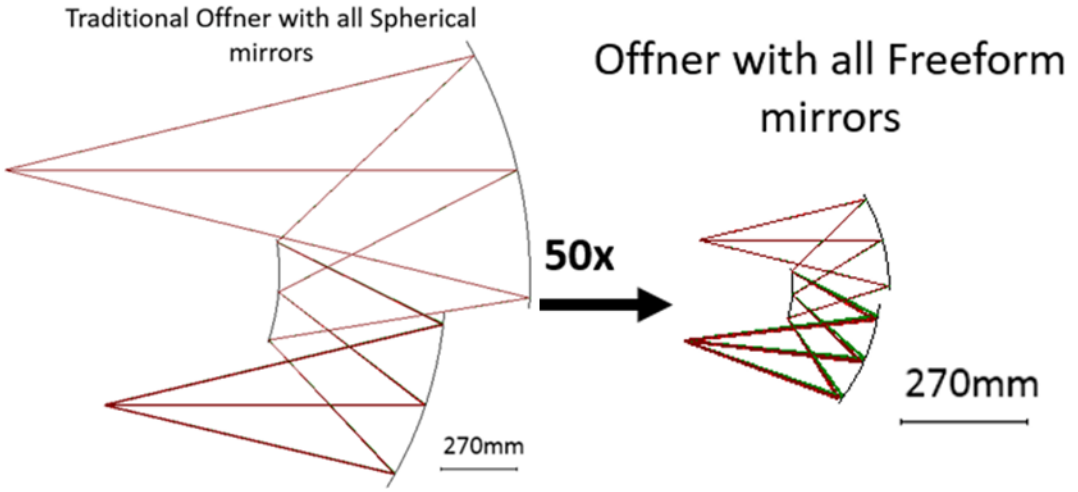
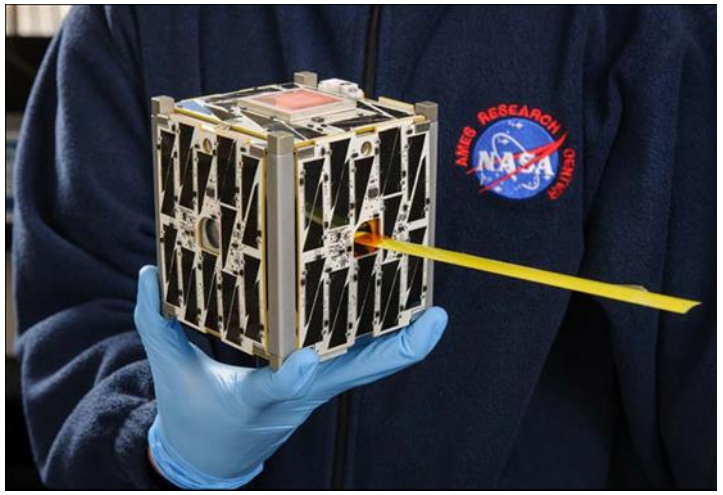
Monolithic Telescopes: Inspiration

Size Reduction → CubeSats





- Freeform design allows performance in smaller volume
- Monolithic design would allow mechanical stability
- NASA SBIR Phase 1 & 2 allowed us to explore the manufacturability of freeform monoliths

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Design evolution of monolithic telescopes

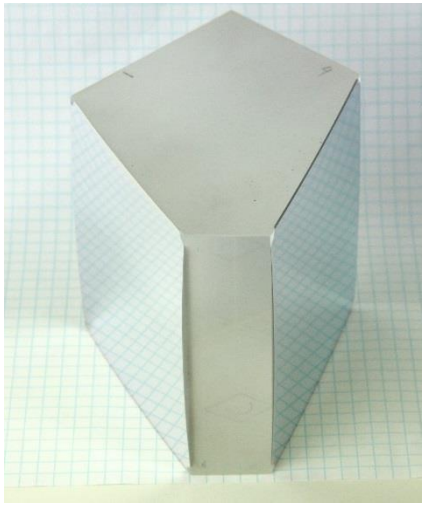
June 2015 – Dec 2015
Contract Number:
NNX15CG20P

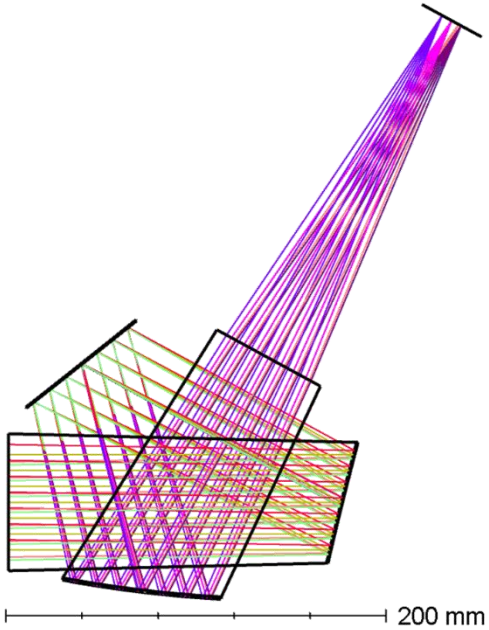
April 2016 – July 2018
Contract Number:
NNX16CG18C

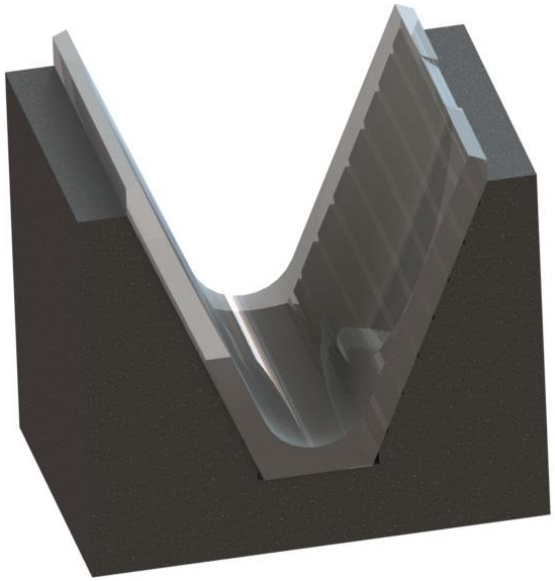
Phase 1:
Two freeform surface reflective monolith

Phase 2(a):
Diffraction-limited 3 freeform surface monolith

Phase 2(b):
Light-weighted two freeform surface reflective monolith







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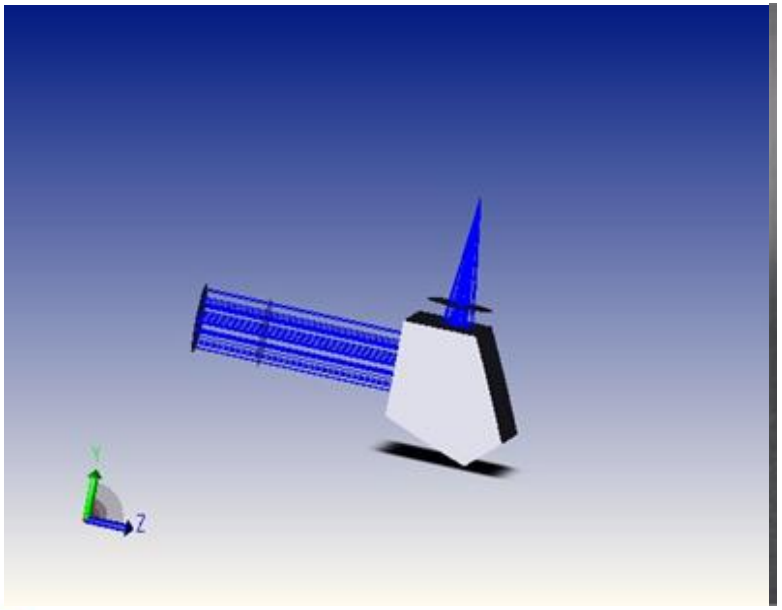
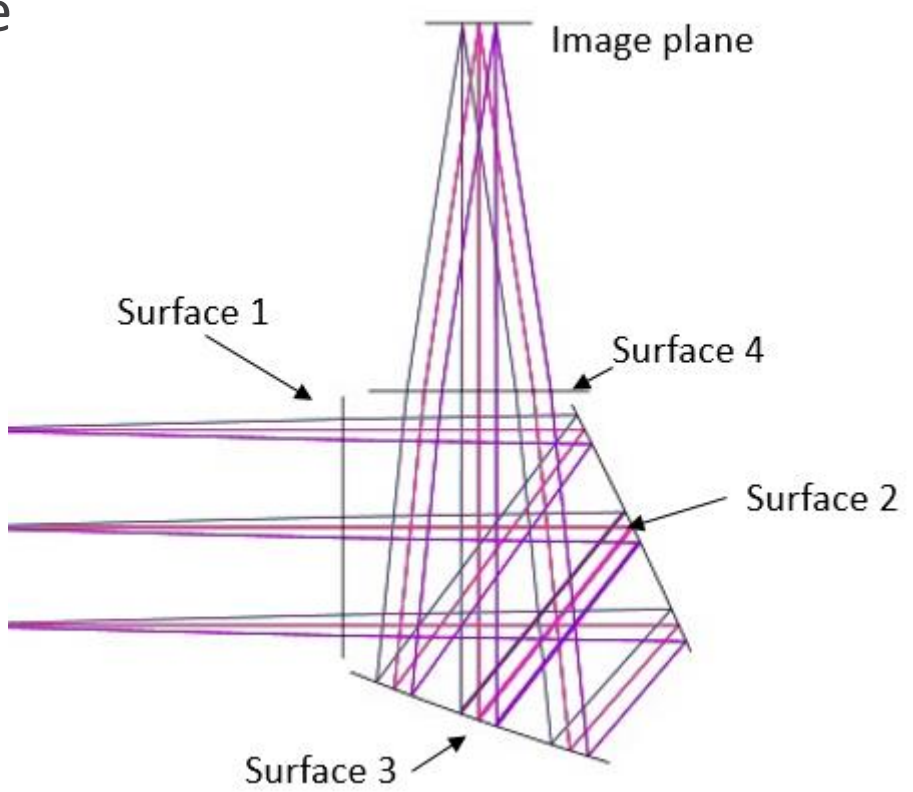
NASA Phase 1 SBIR : 2-freeform monolith

- This provides an extremely rugged optomechanical design
- Surface 2,3 freeforms with ~ 100 µm departure from sphere
- Efl : 183 mm f#/3.4. Made of high purity fused silica
- Fits in a 1U, 4 inch CubeSat volume





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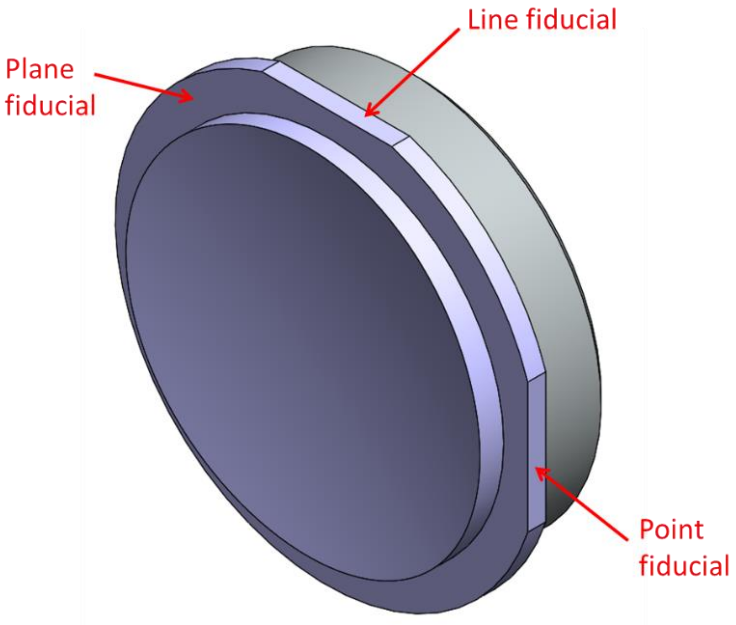
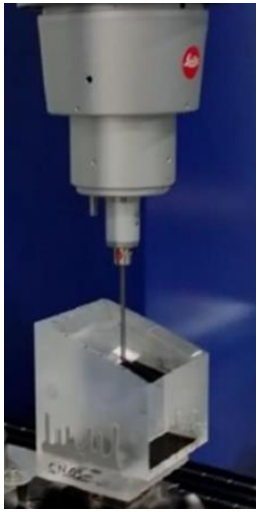
Freeform manufacturing: Optical fiducials



- There must be some reference that defines the location of the freeform surface
- Must define 6 DOF
- Fiducial surfaces could act as alignment features

Standard freeform optical manufacturing process

CNC Generate → Pre-Polish → Measurement → Deterministic Figure Correction → Smoothing



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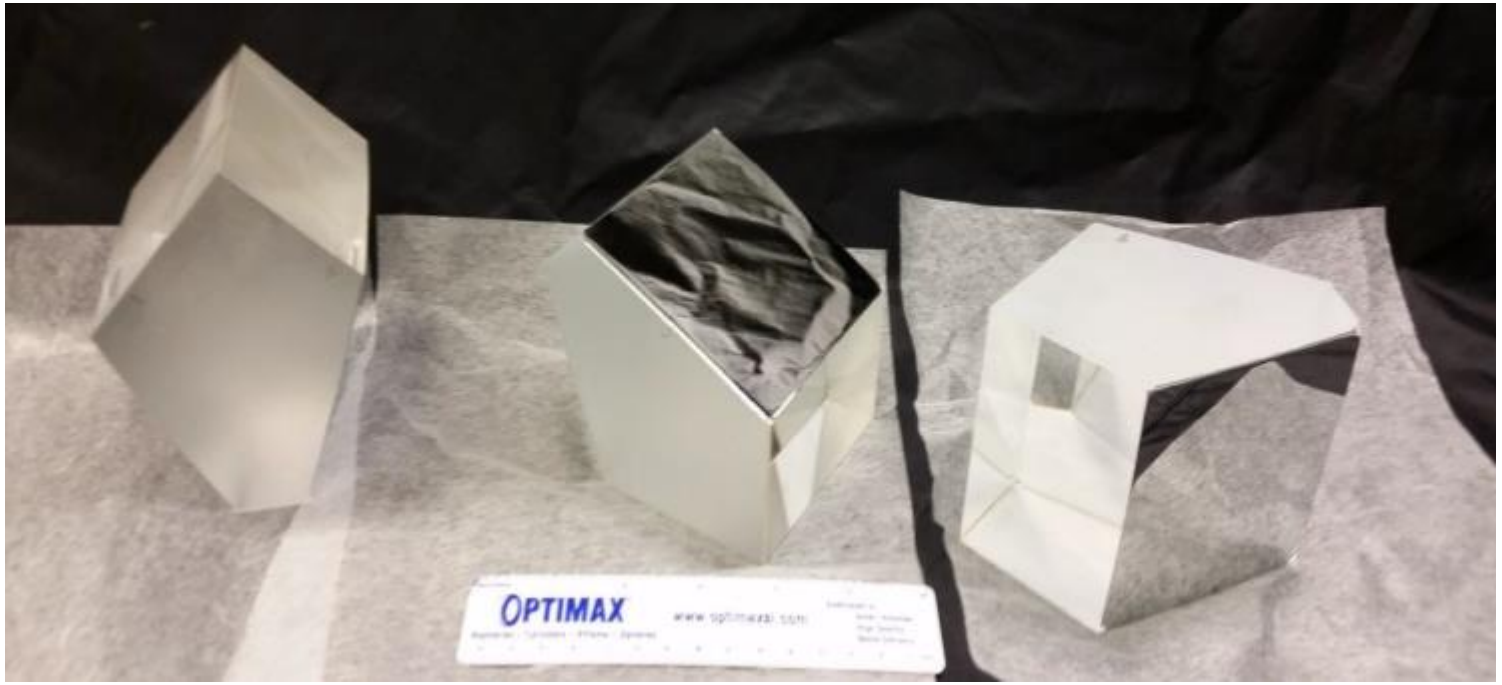
Finished Phase 1 monoliths



- Three monolith were produced
- Freeform surfaces were coated in-house with protected aluminum
- Final weight 1.3 kg

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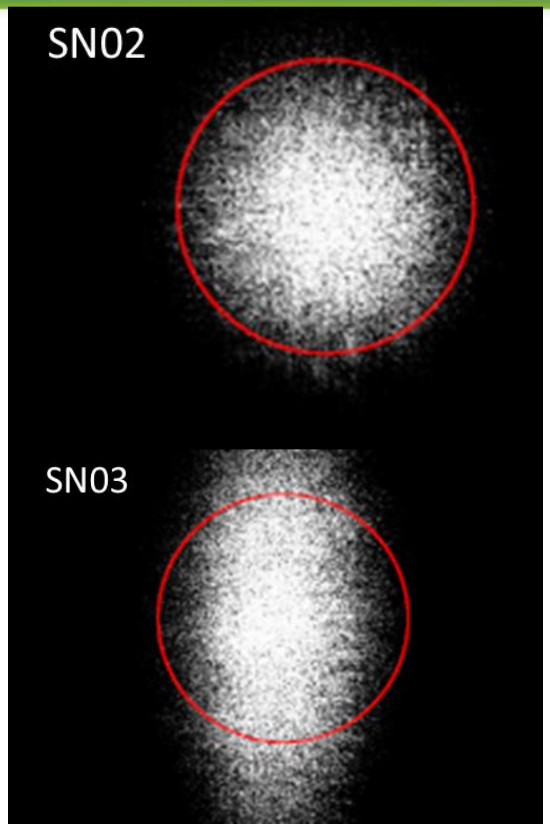
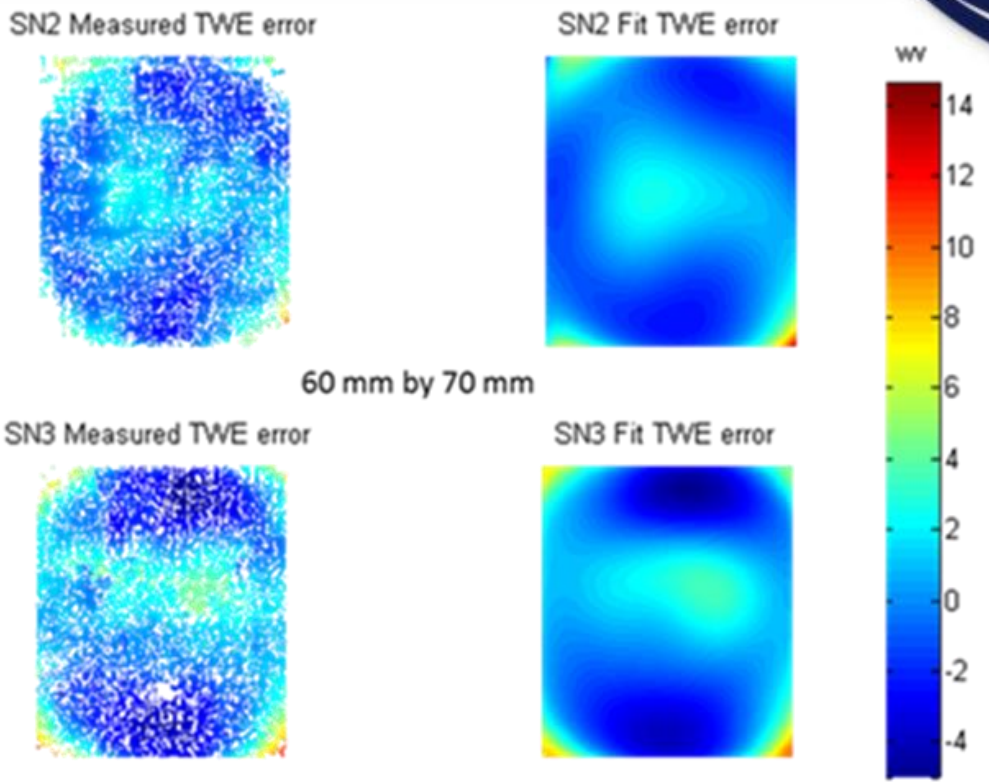
Phase 1 monolith system testing





- Spot size measurements and transmitted wavefronts were collected on SN01 and SN03 monoliths.
- SN03 had noticeable astigmatism error.
- Lots of mid-spatial frequencies errors

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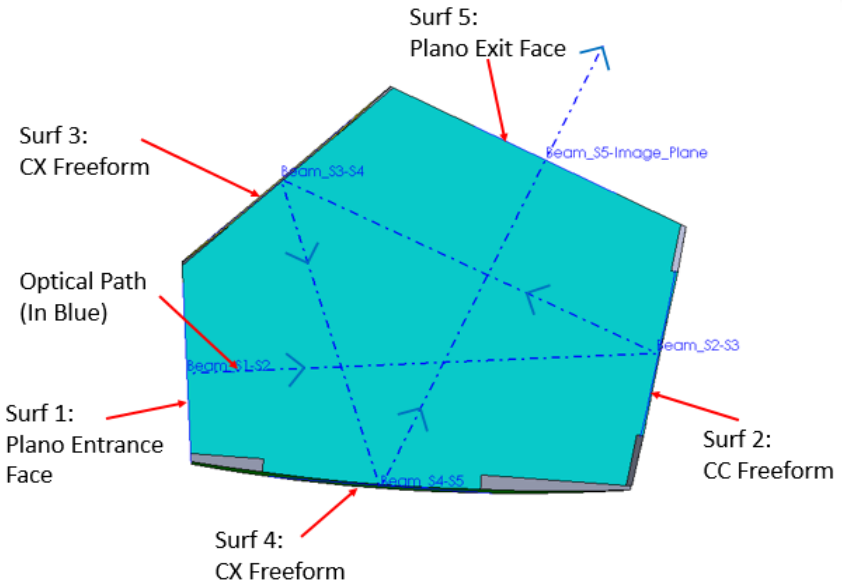
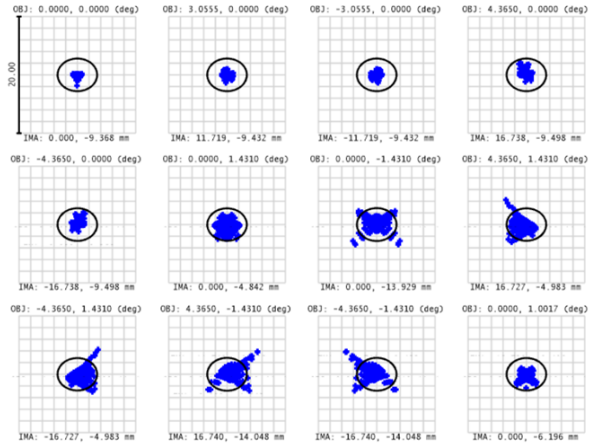
NASA SBIR Phase 2 - “High-resolution” monolith





- Wide field of view:
  - ±4.3° in Y
  - ±1.4° in X
- Simulations show diffraction-limited nominal performance
- Analysis shows high sensitivity to mid-spatial frequency errors (MSF) <10nm

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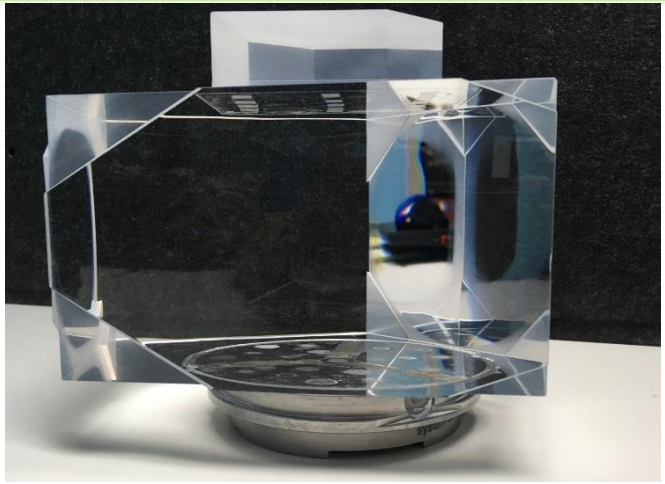
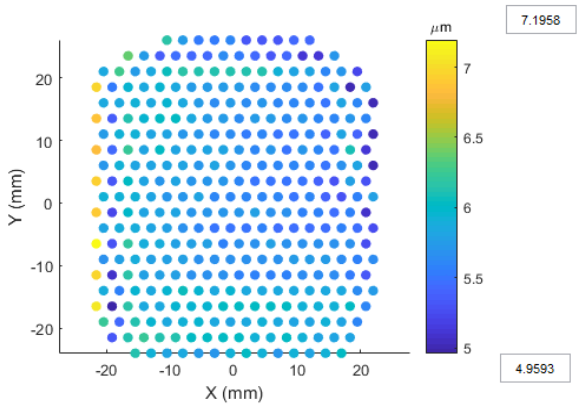
High resolution monolith final status



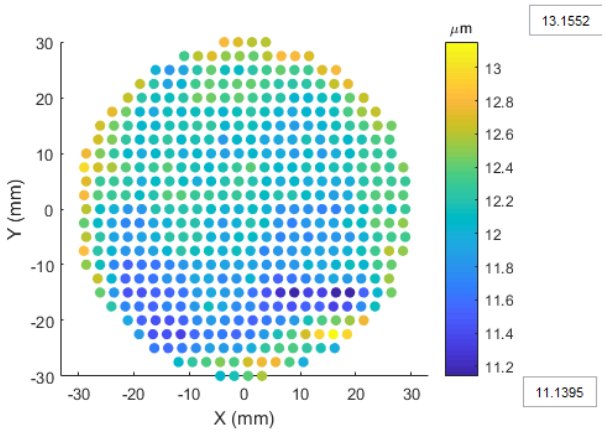
- Final weight 4.6 kg

Freeform surface 1



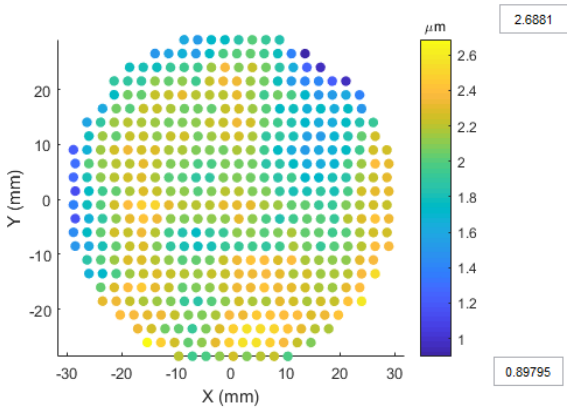
PV = 2.2 µm RMS = 0.30µm

Freeform surface 2



PV = 2.0 µm RMS = 0.33µm

Freeform surface 3



PV = 1.8 µm RMS = 0.28µm

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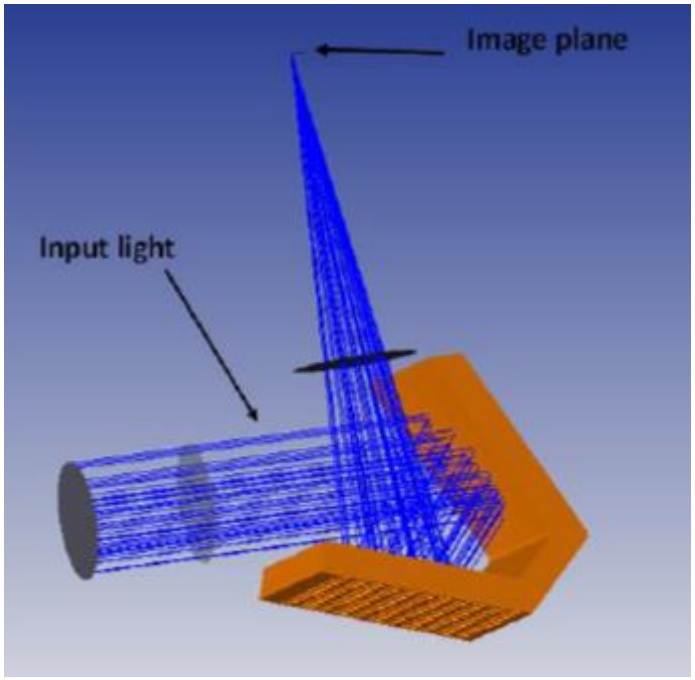
Lightweight, LW, or “open jaw” Monolith



- 183 mm effective focal length at f/3.4

- Lightweight design is based on the same freeform surface prescription as Phase 1
- The telescope light-weighted with a “clam-shell” or “open jaw” design.

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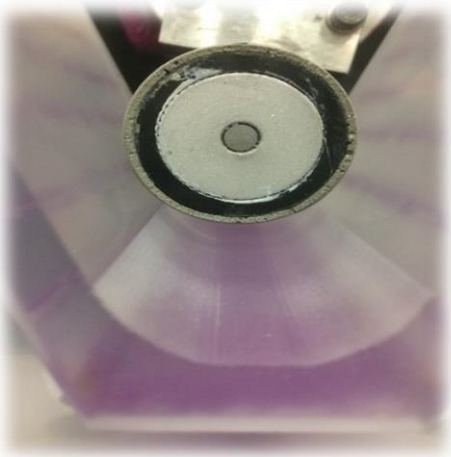
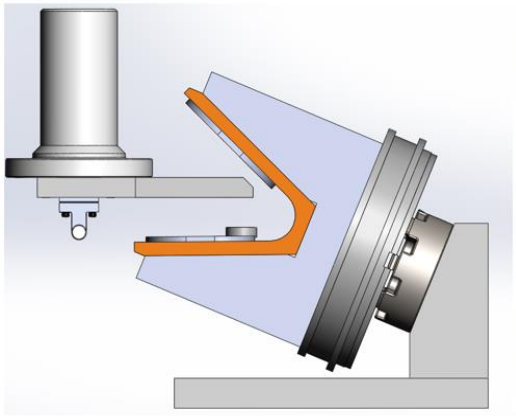
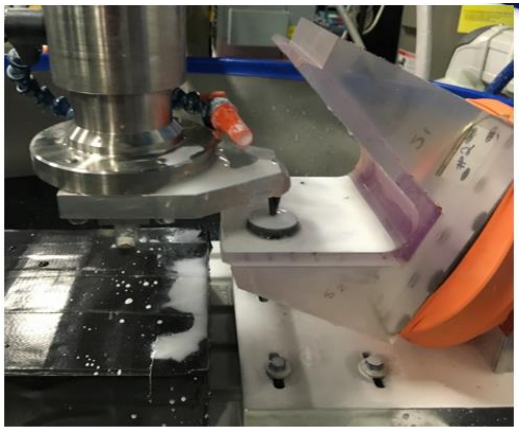
Manufacturing challenges for light-weight monolith

- The geometry of the part provides very little clearance for the polishing tool to access the part







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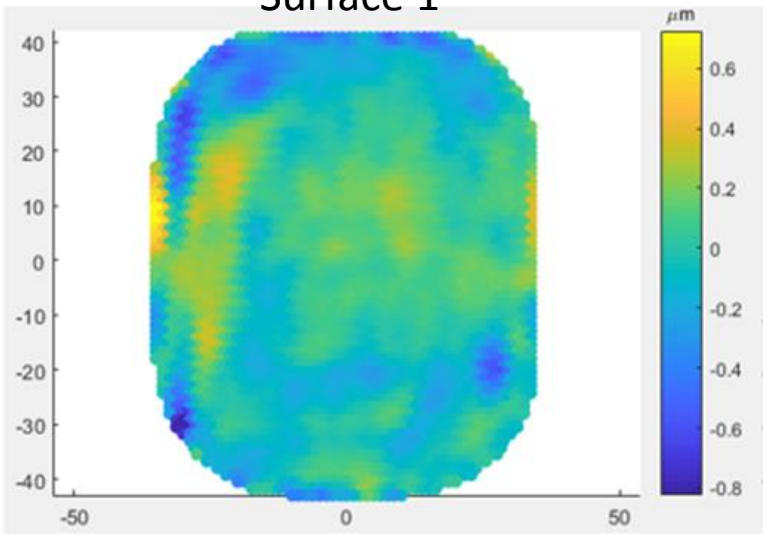
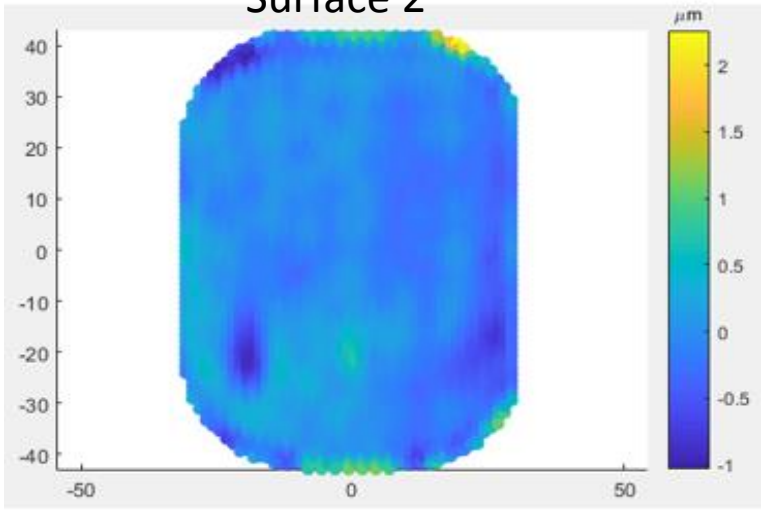
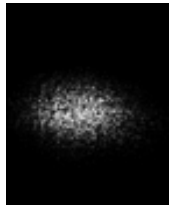
Final lightweight monolith shaped and coated

Surface 1



Surface 2





50 μm

- Coated in-house with protected aluminum
- P-V error of 1.5 to 2.5 μm, with rms of 0.2 μm
- Final weight 421 grams

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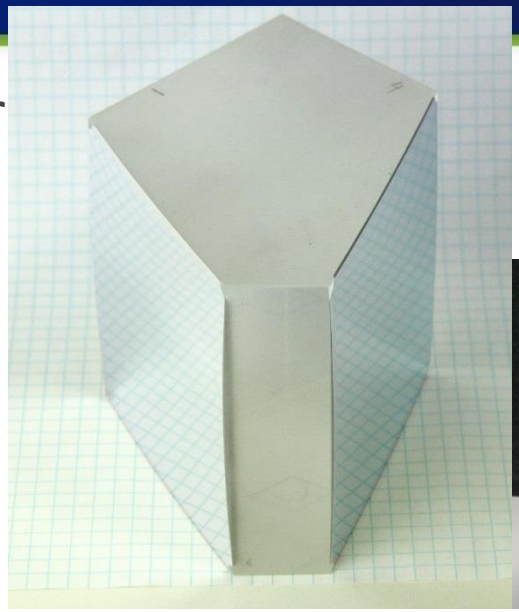
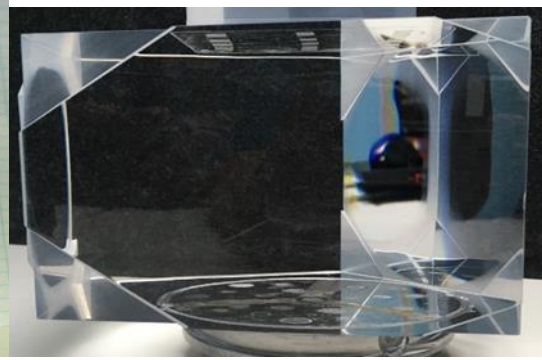
Monoliths open up new possibilities

- Freeforms will be essential for future NASA needs (LUVOIR, off-axis imaging with no central obstruction)
- Monoliths have the ability to reduce assembly needs for telescope systems
- Solid glass monoliths easier to manufacture but are heavy
- Light –weight monoliths have potential but have manufacturing challenges due to geometry





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Manufacturing of a Multi- Surface Freeform Telescope

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