LUVOIR Mirror Technology Update

Face to Face Status - May 11, 2018

MATTHEW EAST

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TECHNOLOGY TO CONNECT, INFORM AND PROTECT™

Outline

- **Driving Requirements**
- **Passive UV Surface Solutions**
- **Picometer Stability Solutions**
- **Segment Design for Coronagraphy**
- **Technology Roadmap**

Driving Requirements

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Notional Static WFE Requirements

Spatial Frequency Band	Spatial Freq Definitions	Spatial Periods (assuming 9m aperture)	Estimated Requirement (Wavefront)
Low	Full parent aperture < 6 CPA	~9m-1.5m	< 10 nm rms
Mid	~6 – 60 cpa	~1.5m- 0.15m	< 10 nm rms
High	> 60 cpa	~0.15m-0.001m	< 3 nm rms
Micro-roughness	High angle scatter	~1mm-0.001mm	< 1 nm rms

PMSA Requirements (Mid, High, Micro-roughness)

Notional Stability WFE Requirements

10 - 40 pm RMS WFE

- Mirror Figure Drift
- Alignment Drift or Metrology/Control
- Jitter / Line of Sight
- Instrument Drift

PMSA driven by

- **Static UV surface**
- **Stability**
- **Mass**

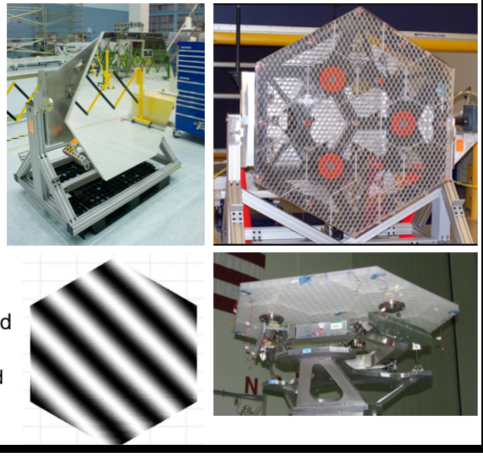
Allows Enough Instrument Mass	Allows Feasible Instrument Mass	Not Enough Instrument Mass
25-29	30-34	35+

PMSA Mass Budget (kg/m^2)

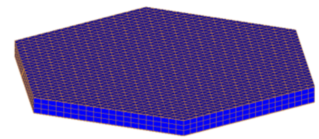
Passive UV Surface Solutions

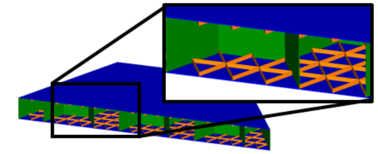
ULE Mirrors: Demonstrated Performance

- MMSD: low substrate mass: 10 kg/m²
- Measured WF error:
  - 16 nm RMS WFE pre-actuation
  - 8 nm RMS WFE post-actuation
- Survivability tested to high level
  - Random vibe and shock



2x Thick MMSD	Lightweight Concept
290 Hz free-free	460 Hz free-free
14.3 kg/m² (model)	16.5 kg/m² (model)
2.6x global stiffness	10.5x global stiffness
Low Complexity	Higher Complexity





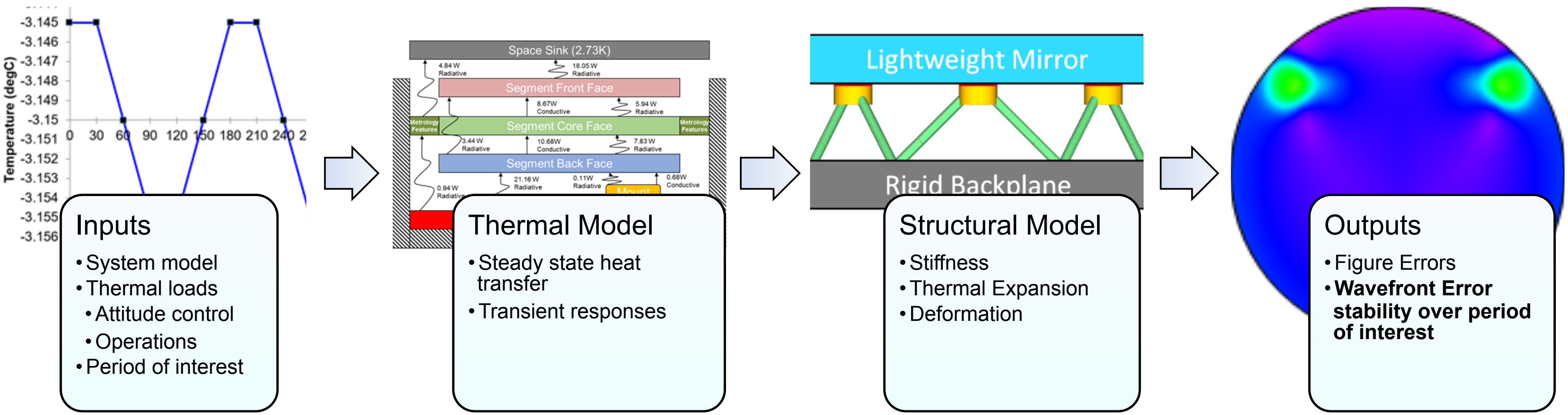
- **~25 kg/m² PMSA (figure actuated)**
  - 10 kg/m² substrate
- **~25 nm RMS WFE**
  - (Including predicted On-Orbit and Ground-to-Orbit Effects)

- **~31-34 kg/m² PMSA (no figure actuators)**
  - ~17 kg/m² substrate
- **10-15 nm RMS WFE**
  - (Including predicted On-Orbit and Ground-to-Orbit Effects)

- Consider all WFE sources **and corresponding uncertainties** (factory, ground-to-orbit, on-orbit)
  - Metrology Accuracy
    - RoC matching
    - Polishing Residuals
  - 0g surface in 1g metrology
  - Invar Growth
  - Mount Induced Strain
  - Operating Thermal Gradients
  - Hygroscopic Effects, etc…

Stiffer PMSA substrate may satisfy all WFE considerations without figure actuation

Picometer Stability Solutions



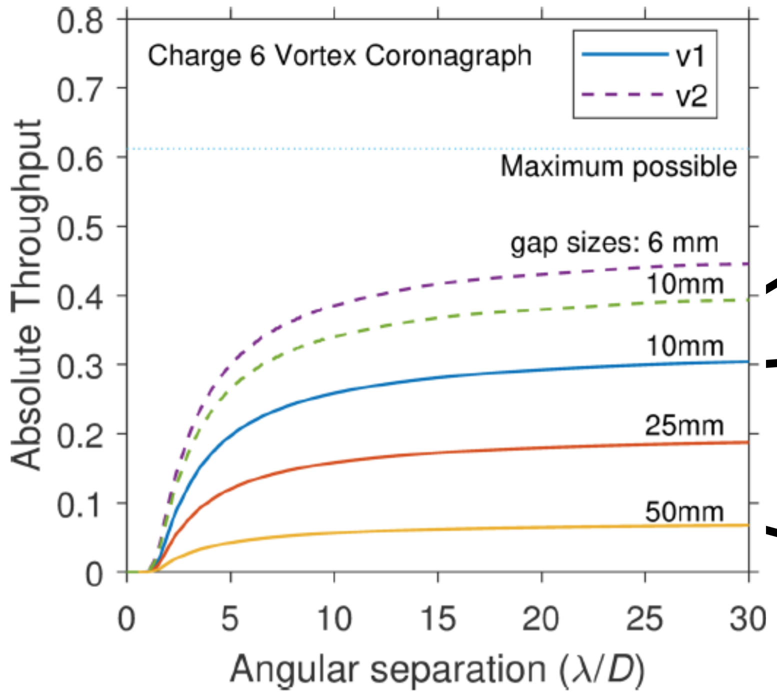
Wavefront Stability Analysis Process

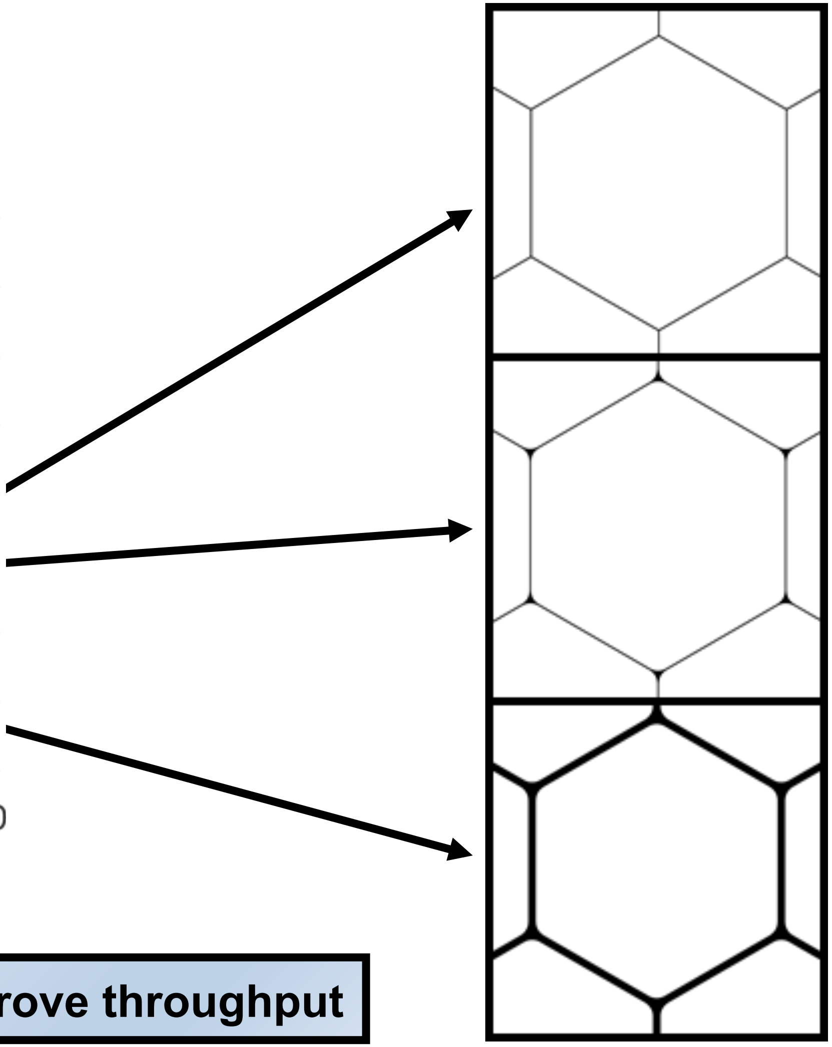
- STOP analysis predicts that mount adhesives drive PMSA 10-minute stability
  - ~5 pm rms over 10 mins predicted for Harris TRL 9 stable mounting approach
    - With rigid body correction
    - With representative cyclic load
  - Harris has TRL 6 design solution to enable better stability with no rigid body correction over 10 mins
    - TRL increasing via WFIRST
- Method could be used to uncover stability drivers across the LUVOIR OTA

Harris TRL 9 stable mounts can be tailored for 10-minutes

Segment Design for Coronagraphy

Apodized Vortex Results For
Off-Axis Segmented HabEx
Credit: Garreth Ruane, Cal Tech

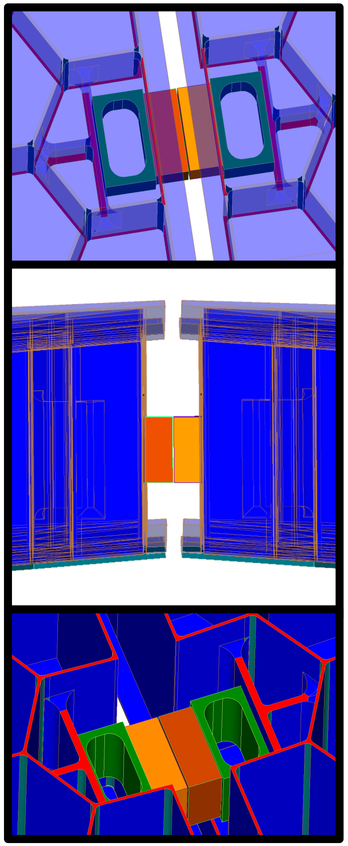




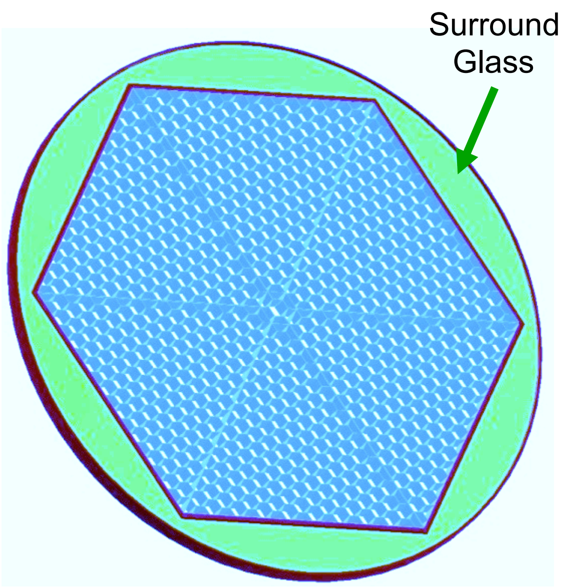
Smaller gaps and corner radii improve throughput

Segment Design for Coronagraphy

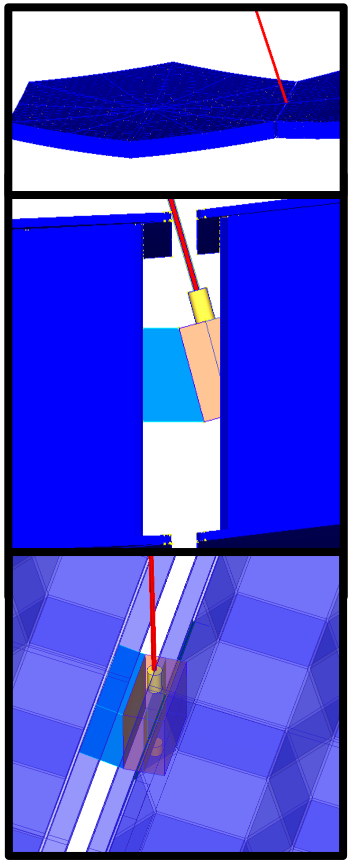
Gap Reduction
Embedded Edge Sensor



Corner Reduction
Extra surround glass cut from mirror segment after replication allows smoothing in corners



Gap Reduction
Embedded Beam Launcher



Harris concepts improve gaps and corners, while facilitating segment metrology and manufacturing

Technology Roadmap

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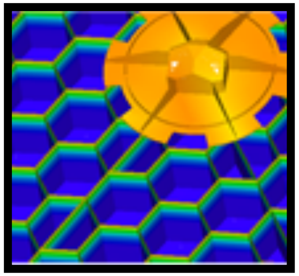
Design and Analysis

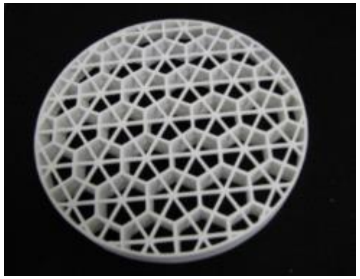
System WFE: Fabrication, Integration, Test, On Orbit



WFE Stability - Transient Loads

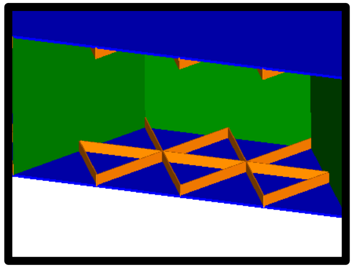
Process Development

Constructed Core Mirror

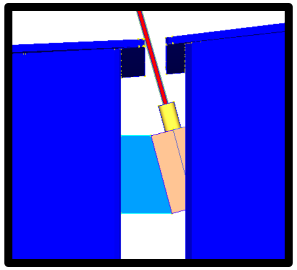


3D Printed Architecture for Lightweight Mirrors

New Concepts

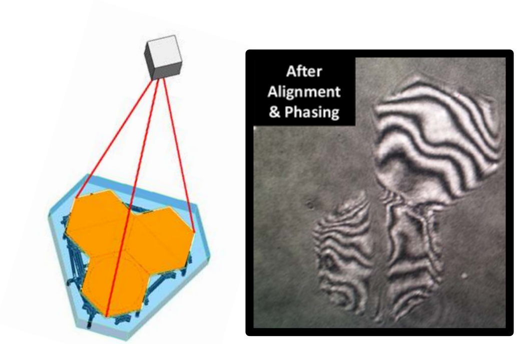


Structurally Efficient PMSA

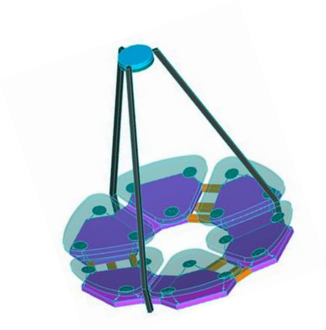


Small Gap Segment Metrology

Demo Planning



Ground-Based Demos

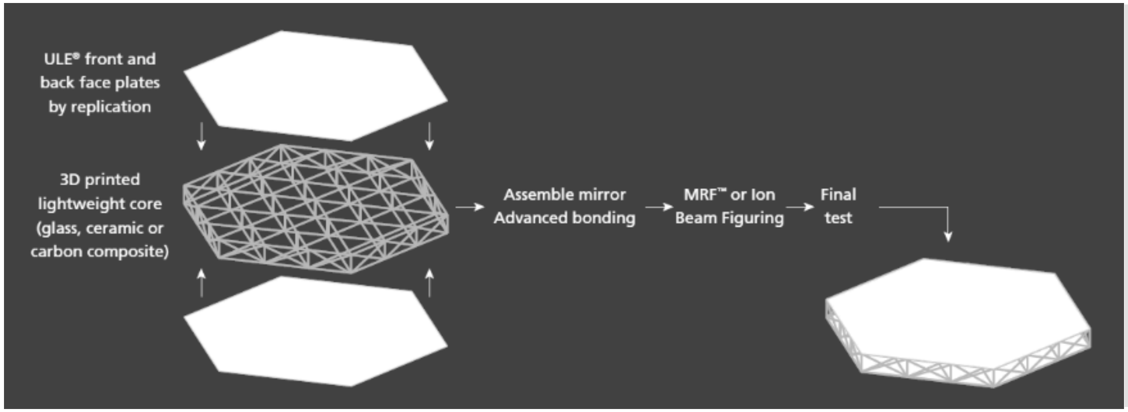


Space-Based

AMC strategy: 3D Printed Architecture

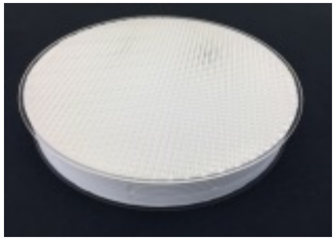
Harris employs additive manufacturing combined with demonstrated replication and advanced bonding to optimize mirror production for schedule, weight, affordability, and performance.

Process Description

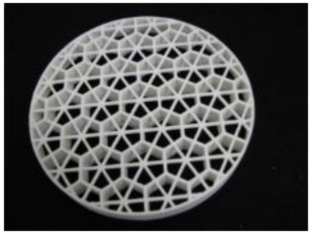


- Order of magnitude reductions in primary mirror schedule and cost.
- Maximizes mirror stiffness and stability while minimizing mirror weight.
- Low risk, short duration development path

3D Printed fused silica core



Mirror constructed with 3D Printed fused silica core



Innovative mirror designs enabled by 3D printing

In addition to significant schedule and cost advantages, 3D printing enables more mass efficient ultra-lightweight designs