Advanced Mirror Technology Development

H. Philip Stahl
NASA Marshall Space Flight Center, Huntsville Alabama 35821
h.philip.stahl@nasa.gov

Abstract: The Advanced Mirror Technology Development (AMTD) project matures critical technologies required to enable ultra-stable 4-m-or-larger monolithic or segmented ultraviolet, optical, and infrared (UVOIR) space telescope primary-mirror assemblies for general astrophysics and ultra-high-contrast observations of exoplanets.
OCIS codes: (220.4880) Optomechanics; (220.4610) Optical Fabrication; (350.1260) Astronomical Optics

1. Introduction

The Advanced Mirror Technology Development (AMTD) project is a multiyear effort initiated in 2012, to mature critical technologies required to enable 4-m-or-larger ultraviolet, optical, and infrared (UVOIR) space telescope primary-mirror assemblies for general astrophysics and ultra-high-contrast observations of exoplanets. UVOIR measurements provide robust, often unique, diagnostics for investigating astronomical environments and objects. UVOIR observations are responsible for much of our current astrophysics knowledge and will produce as-yet-unimagined, paradigm-shifting discoveries. A new, larger UVOIR telescope is needed to help answer fundamental scientific questions such as: Does life exist on nearby Earth-like exoplanets? How do galaxies assemble their stellar populations? How do galaxies and the intergalactic medium interact? How did planets and smaller bodies in our own solar system form and evolve?

AMTD uses science-driven systems engineering to derive engineering specifications directly traceable to science requirements, and mature technologies necessary to achieve those specifications – with an emphasis on solutions that are affordable, practical, and reduce risk. Because future launch capabilities or external technology advances are unpredictable, AMTD is pursuing multiple design paths to provide the science community with options to enable either large-aperture monolithic or segmented mirrors with clear engineering metrics. AMTD's demonstrated deep-core manufacturing method enables 4-m class mirrors with 20-30% lower cost and risk. The design tools we have developed increase speed, resulting in reduced cost of trade studies. In addition, the integrated modeling tools we have developed enable better definition of system and component engineering specifications.

2. Accomplishments

AMTD-1 matured six key technologies required to make an integrated primary mirror assembly (PMA) for a large aperture UVOIR space telescope: *(1) Large-Aperture, Low-Areal Density, High-Stiffness Mirror Substrates; (2) Support System; (3) Mid/High-Spatial Frequency Figure Error; (4) Segment Edges; (5) Segment-to-Segment Gap Phasing; and (6) Integrated Model Validation*

AMTD-1's key accomplishment was the successful demonstration the new 5-layer 'stack & fuse' process for fabricating deep-core mirror substrates. Using this new process, a 43 cm diameter 'cut-out' of a 4 m diameter, 40-cm thick, < 45 kg/m2 mirror substrate was fabricated (Figure 1). This demonstrated that the technology can make mirrors with sufficient thickness for a mechanically ultra-stable 4 m to 8 m class mirror.

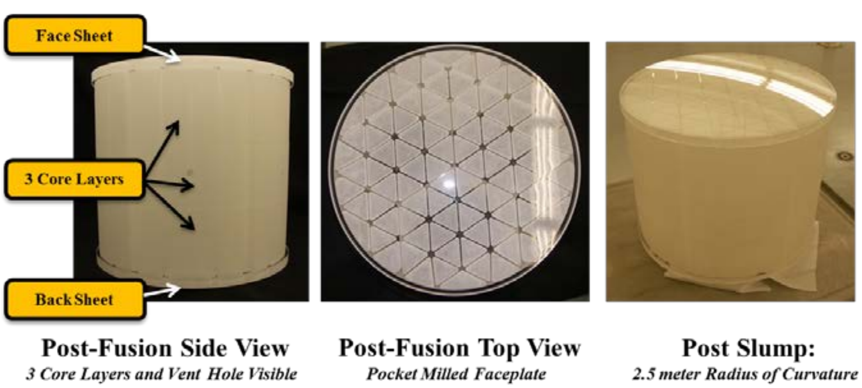

Fig. 1. *Deep core mirror attributes and at different processing stages.*

AMTD-2 continued maturing three technologies needed to enable large monolithic (4- to 8-m) and segmented (8- to 16-m) UVOIR space telescopes: 1) *Large-Aperture, Low-Areal Density,* 2) *High-Stiffness Substrates; Support System:* to ensure launch survival and on-orbit stress-free deployment; and, 3) *Integrated Model Validation:* since on-orbit performance depends on mechanical and thermal stability and compliance cannot be 100% tested (because large telescopes are not stiff enough to test), validated models are required.

AMTD-2 successfully low-temperature-fused/low-temperature-slumped a 1.5-meter diameter ULE© mirror that is a 1/3rd scale model of a 4-meter mirror (Figure 2).

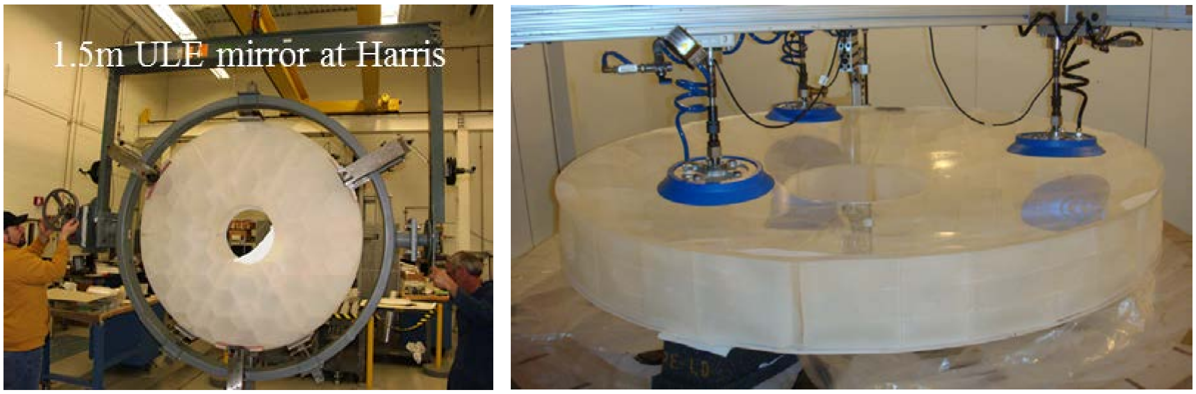

Figure 2: 1.5 meter diameter (1/3rd scale of 4-meter) LTF/LTS ULE© mirror

Additionally, AMTD-2 characterized the cryogenic figure change of a 1.2-meter Extreme-Lightweight Zerodur® mirror (Figure 3) from ambient to 230K. To correlate test results with a performance model, the mirror was instrumented with multiple thermal sensors and its front surface temperature monitored with a thermal camera. The 1.5m ULE© mirror will characterize in spring 2017.

Figure 3: Static Thermal Test Configuration 1.5 meter diameter (1/3rd scale of 4-meter) LTF/LTS ULE© mirror

Finally, the Zerodur® test results and performance model were correlated (Figure 4).

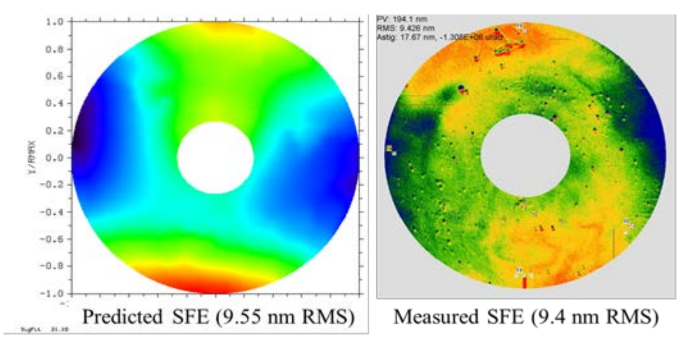

Figure 4: Predicted Thermal Deformation assuming 5 ppb CTE homogeinity and Measured Deformation.

3. AMTD Publications

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