NASA SBIR 2015 Phase I Solicitation

S2.03 Advanced Optical Systems and Fabrication/Testing/Control Technologies for EUV/Optical and IR Telescope

Lead Center: MSFC

Participating Center(s): GSFC, JPL

This subtopic solicits solutions in the following areas:Â

- Components and Systems for potential EUV, UV/O & IR missions.
- Technology to fabricate, test and control potential UUV, UV/O & IR telescopes.Â

Proposals should show an understanding of one or more relevant science needs, and present a feasible plan to fully develop a technology and infuse it into a NASA program.Â

This subtopicâ€™s emphasis is to mature technologies needed to affordably manufacture, test or operate complete mirror systems or telescope assemblies. Section 3 contains a detailed discussion on specific technologies which need developing for each area.Â

An ideal Phase I deliverable would be a precision optical system of at least 0.25 meters, or a relevant sub-component of a system, or a prototype demonstration of a fabrication, test or control technology. An ideal Phase II project would further advance the technology to produce a space-qualifiable optical system greater than 0.5 meters or relevant sub-component (with a TRL in the 4 to 5 range); or a working fabrication, test or control system. Phase I and Phase II mirror system or component deliverables would be accompanied by all necessary documentation, including the optical performance assessment and all data on processing and properties of its substrate materials. The Phase II would also include a mechanical and thermal stability analysis.Â

Successful proposals will demonstrate an ability to manufacture, test and control ultra-low-cost optical systems that can meet flight requirements (including processing and infrastructure issues). Material behavior, process control, active and/or passive optical performance, and mounting/deploying issues should be resolved and demonstrated.Â

IntroductionÂ

2010 National Academy Astro2010 Decadal Report specifically identified large light-weight mirrors as a key technology needed to enable potential Extreme Ultraviolet (EUV), Ultraviolet/Optical (UV/O) and Infrared (IR) to Far-IR missions.Â

2012 National Academy report â€œNASA Space Technology Roadmaps and Prioritiesâ€ states that one of the top technical challenges in which NASA should invest over the next five years is developing a new generation of larger effective aperture, lower-cost astronomical telescopes that enable discovery of habitable planets, facilitate advances in solar physics, and enable the study of faint structures around bright objects.

Finally, NASA is developing a heavy lift space launch system (SLS) with an 8 to 10 meter fairing and 40 to 50 mt capacity to SE-L2. SLS will enable extremely large space telescopes, such as a 12 to 30 meter class segmented primary mirrors for UV/optical or infrared wavelengths.Â

Technical Challenges

To accomplish NASAâ€™s high-priority science requires low-cost, ultra-stable, large-aperture, normal incidence mirrors with low mass-to-collecting area ratios. Specifically needed for potential UVO missions are normal incidence 4-meter (or larger) diameter 5 nm rms surface mirrors; and, active/passive align/control of normal-incidence imaging systems to achieve < 500 nm diffraction limit (< 40 nm rms wavefront error, WFE) performance. Additionally, recent analysis indicates that an Exoplanet mission, using an internal coronagraph, requires total telescope wavefront stability of less than 10 pico-meters per 10 minutes. Specifically needed for potential IR/Far-IR missions are normal incidence 12-meter (or larger) diameter mirrors with cryo-deformations < 100 nm rms.Â

In all cases, the most important metric for an advanced optical system (after performance) is affordability or areal cost (cost per square meter of collecting aperture). Current normal incidence space mirrors cost $4 million to $6 million per square meter of optical surface area. This research effort seeks a cost reduction for precision optical components by 5 to 50 times, to less than $1M to $\$100\text{K/m}^2$.Â

Technology development is required to fabricate components and systems to achieve the following Metrics:Â

- Areal Cost < $\$500\text{k/m}^2$ (for UV/Optical.
- Areal Cost < $\$100\text{k/m}^2$ (for Infrared).
- Monolithic: 1 to 4 meters.
- Segmented: > 4 meters (total aperture).
- Wavefront Figure < 5 nm rms (for UV/Optical).
- Cryo-deformation < 100 nm rms (for Infrared).
- Slope < 0.1 micro-radian (for EUV).
- Thermally Stable < 10 pm/10 min (for Coronagraphy).
- Actuator Resolution < 1 nm rms (for UV/Optical).Â

Finally, also needed is ability to fully characterize surface errors and predict optical performance.Â

Optical Components and Systems for potential UV/Optical missions

Potential UV/Optical missions require 4 to 8 or 16 meter monolithic or segmented primary mirrors with < 10 nm rms surface figures and < 10 pm per 10 min stabilty. Mirror areal density depends upon available launch vehicle capacities to Sun-Earth L2 (i.e., 15 kg/m^2 for a 5 m fairing EELV vs. 60 kg/m^2 for a 10 m fairing SLS). Regarding areal cost, it is necessary to keep the total cost of the primary mirror at or below $100M. Thus, an 8-m class mirror (with 50 m^2 of collecting area) should have an areal cost of less than $\$2\text{M/m}^2$. And, a 16-m class mirror (with 200 m^2 of collecting area) should have an areal cost of less than $\$0.5\text{M/m}^2$.

Key technologies to enable such a mirror include new and improved:

- Mirror substrate materials and/or architectural designs.
- Processes to rapidly fabricate and test UVO quality mirrors.
- Mechanisms and sensors to align segmented mirrors to < 1 nm rms precisions.
- Thermal control to reduce wavefront stability to less than 10 pm rms per 10 min.
- Vibration isolation (> 140 db) to reduce phasing error to < 10 pm rms.Â

Also needed is ability to fully characterize surface errors and predict optical performance via integrated opto-mechanical modeling.Â

Potential solutions for substrate material/architecture include, but are not limited to: silicon carbide, nanolaminates or carbon-fiber reinforced polymer.Â

Potential solutions for new fabrication processes include, but are not limited to:Â

- 3-D printing.
- Additive manufacture.
- Direct precision machining.
- Rapid optical fabrication.
- Roller embossing at optical tolerances.
- Slumping or replication technologies to manufacture 1 to 2 meter (or larger) precision quality components.Â

Potential solutions for achieving the 10 pico-meter wavefront stability include, but are not limited to: metrology, passive and active control for optical alignment and mirror phasing; active vibration isolation; metrology, passive and active thermal control.**Â**

Optical Components and Systems for potential Infrared/Far-IR missionsÂ

Potential Infrared and Far-IR missions require 12 m to 16 m to 24 meter class segmented primary mirrors with ~ 1 Î¼m rms surface figures which operates at < 10 K.Â

There are two primary challenges for such a mirror system:Â

- Areal Cost of < $100K per m^2.
- Cryogenic Figure Distortion < 100 nm rmsÂ

Fabrication, Test and Control of Advanced Optical SystemsÂ

While the â€œOptical Components and Systems for potential UV/Optical missionsâ€ and â€œOptical Components and Systems for potential Infrared/Far-IR missionsâ€ sections detail the capabilities need to enable potential future UVO and IR missions, it is important to note that this capability is made possible by the technology to fabricate, test and control optical systems. Therefore, this sub-topic also encourages proposals to develop such technology which will make a significant advance of a measurable metric.Â