NASA SBIR Subtopic: Funding History

H. Philip Stahl, Ph.D.
Sub-Topic Manager

<table>
<thead>
<tr>
<th>Year</th>
<th>Phase 1</th>
<th>Phase 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>21% (8/38)</td>
<td>71% (5/7)</td>
</tr>
<tr>
<td>2006</td>
<td>28% (8/29)</td>
<td>63% (5/8)</td>
</tr>
<tr>
<td>2007</td>
<td>36% (4/11)</td>
<td>50% (2/4)</td>
</tr>
<tr>
<td>2008</td>
<td>59% (10/17)</td>
<td>50% (4/8)</td>
</tr>
<tr>
<td>2009</td>
<td>56% (9/16)</td>
<td>50% (4/8)</td>
</tr>
<tr>
<td>2010</td>
<td>50% (11/22)</td>
<td>11% (1/9)</td>
</tr>
<tr>
<td>2011</td>
<td>28% (7/25)</td>
<td>20% (1/5)</td>
</tr>
<tr>
<td>2012</td>
<td>28% (8/29)</td>
<td>50% (4/7)</td>
</tr>
<tr>
<td>2014</td>
<td>54% (7/13)</td>
<td>46% (26/56)</td>
</tr>
</tbody>
</table>

Total 36% (72/200) 46% (26/56)

“Advanced Optical Systems” Award Statistics

<table>
<thead>
<tr>
<th>Year</th>
<th>Phase 1</th>
<th>Phase 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>22% (2/9)</td>
<td>100% (1/1)</td>
</tr>
<tr>
<td>2006</td>
<td>29% (6/21)</td>
<td>50% (3/6)</td>
</tr>
<tr>
<td>2007</td>
<td>33% (1/3)</td>
<td>100% (1/1)</td>
</tr>
<tr>
<td>2008</td>
<td>75% (3/4)</td>
<td>50% (1/2)</td>
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<tr>
<td>2009</td>
<td>66% (2/3)</td>
<td>66% (2/3)</td>
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<tr>
<td>2010</td>
<td>33% (4/12)</td>
<td>00% (0/3)</td>
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<tr>
<td>2011</td>
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<tr>
<td>2012</td>
<td>30% (3/10)</td>
<td>33% (1/3)</td>
</tr>
<tr>
<td>2014</td>
<td>66% (2/3)</td>
<td>41% (9/22)</td>
</tr>
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Total 35% (27/77) 41% (9/22)

“Optical Manufacturing & Metrology” Award Statistics

<table>
<thead>
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<th>Year</th>
<th>Phase 1</th>
<th>Phase 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>21% (6/29)</td>
<td>67% (4/6)</td>
</tr>
<tr>
<td>2006</td>
<td>25% (2/8)</td>
<td>100% (2/2)</td>
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<tr>
<td>2007</td>
<td>38% (3/8)</td>
<td>33% (1/3)</td>
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<tr>
<td>2008</td>
<td>54% (7/13)</td>
<td>50% (3/6)</td>
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<tr>
<td>2009</td>
<td>46% (6/13)</td>
<td>33% (2/6)</td>
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<td>2010</td>
<td>70% (7/10)</td>
<td>17% (1/6)</td>
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<td>2011</td>
<td>23% (3/13)</td>
<td>50% (1/2)</td>
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<td>2012</td>
<td>20% (3/15)</td>
<td>66% (2/3)</td>
</tr>
<tr>
<td>2014</td>
<td>50% (5/10)</td>
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</tr>
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Total 35% (42/119) 47% (16/34)

“Adv Tech Telescope for Balloon Mission” Statistics

<table>
<thead>
<tr>
<th>Year</th>
<th>Phase 1</th>
<th>Phase 2</th>
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</thead>
<tbody>
<tr>
<td>2012</td>
<td>50% (2/4)</td>
<td>100% (1/1)</td>
</tr>
</tbody>
</table>

Total 50% (2/4) 100% (1/1)

2014 SBIR S2.03

<table>
<thead>
<tr>
<th>Phase I</th>
<th>Phases</th>
<th>Funded</th>
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</thead>
<tbody>
<tr>
<td>Phase I</td>
<td>3 Submitted</td>
<td>2 Funded</td>
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**2014 SBIR S2.03**

**2014 SBIR S2.03**

<table>
<thead>
<tr>
<th>Phase II</th>
<th>TBD Submitted</th>
<th>TBD Funded</th>
</tr>
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**Phase II TBD Submitted TBD Funded**

*Broad-Band Reflective Coating Process for Large UVOIR Mirrors, ZeCoat*

*Advanced Mirror Material System, Peregrin Falcon*
2014 SBIR S2.04

**Phase I**

10 Submitted

- **Figuring and Polishing Precision Optical Surfaces**, OptiPro
- **Manufacture of Free-Form Optical Surfaces with Limited Mid-Spatial Frequency Error**, OptiPro
- **Optical Metrology of Aspheric and Freeform Mirrors**, OptiPro
- **Innovative Non-Contact Metrology Solutions for Large Optical Telescopes**, SURVICE Engineering
- **Monolithic Gradient Index Phase Plate Array**, Voxtel

5 Funded

**Phase II**

TBD Submitted

TBD Funded
2012 SBIR S2.03

Phase I 10 Submitted 3 Funded

- Low-Stress Silicon Cladding for Surface Finishing Large UVOIR Mirrors, ZeCoat Corp
- Broad-Band EUV Multilayer Coatings for Solar Physics, Reflective X-ray Optics, LLC
- Composite Single Crystal Silicon Scan Mirror Substrates, Onyx Optics, Inc

Phase II 3 Submitted 1 Funded

- Low-Stress Silicon Cladding for Surface Finishing Large UVOIR Mirrors, ZeCoat Corp

2012 SBIR S2.04

Phase I 15 Submitted 3 Funded

- Advanced Optical Metrology for XRAY Replication Mandrels and Mirrors, Aperture Optical Sciences Inc
- Light Weight, Scalable Manufacturing of Telescope Optics, ReliaCoat Technologies, LLC
- Low Cost Method of Manufacturing Space Optics, ORMOND, LLC

Phase II 3 Submitted 2 Funded

- Light Weight, Scalable Manufacturing of Telescope Optics, ReliaCoat Technologies, LLC
- Low Cost Method of Manufacturing Space Optics, ORMOND, LLC
2012 SBIR E3.02
Phase I 4 Submitted 2 Funded
Low Cost, Cosmic Microwave Background Telescope, Vanguard
Affordable, Ultra-stable CVC SiC UVOIR Telescope for BENI Mission, TREX

Phase II 1 Submitted 1 Funded
Low Cost, Cosmic Microwave Background Telescope, Vanguard

2011 SBIR S2.05
Phase I 13 Submitted 3 Funded
Cryogenic & Vacuum Compatible Metrology Systems; Flexure Engineering
Optical Fabrication & Metrology of Aspheric & Free Form Mirrors; OptiPro
Very Large Computer Generated Holograms for Precision Metrology of Aspheric Optical Surfaces; Arizona Optical Metrology

Phase II 2 Submitted 1 Funded
Optical Fabrication & Metrology of Aspheric & Free Form Mirrors; OptiPro

Any Questions?
NASA 2015 SBIR Subtopic:

S2.03 “Advanced Optical Systems”
S2.04 “Optical Manufacturing and Metrology”
E3.02 "Adv Tech Telescope for Balloon Mission"

H. Philip Stahl, Ph.D.
Sub-Topic Manager

Generic Instructions to Proposer

Define a customer or mission or application and demonstrate that you understand how your technology meets their science needs.

Propose a solution based on clear criteria and metrics

Articulate a feasible plan to:

• fully develop your technology,
• scale it to a full size mission, and
• infuse it into a NASA program

Deliver Demonstration Hardware not just a Paper Study, including:

• documentation (material behavior, process control, optical performance)
• mounting/deploying hardware

Instructions for Proposers

When you visit: http://sbir.nasa.gov/

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

S2.03 Advanced Optical Systems and Fabrication/Testing/Control Technologies for EUV/Optical and IR Telescope seeks solutions for 5 technical areas that are based on specific performance metrics (none of which may I discuss)

3.1 Optical Components and Systems for potential EUV/Optical missions
3.2 Optical Components and Systems for potential Infrared/IR missions
3.3 Fabrication, Test, and Control of Advanced Optical Systems

Select: Advanced Technology Telescope for Balloon and Sub-Orbital Missions seeks solutions for technical area that are based on specific performance metric (none of which may I discuss).

3.1 Ultra-Stable 1-meter Class UV/OIR Telescope
3.1.1 Exoplanet Mission Telescope
3.1.2 Planetary Mission Telescope
3.3 Infrared Interferometry Mission Telescope
3.4 Balloon Gondola with Precision Pointing System

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

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

Subtopic solicits solutions in the following areas:

• Components and Systems for potential EUV, UV/O & IR missions
• Technology to fabricate, test and control potential EUV, UV/O & IR telescopes

Subtopic’s emphasis is to mature technologies needed to affordably manufacture, test or operate complete mirror systems or telescope assemblies.

Ideal Phase 1 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. Phase 1 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.

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.
Technical Need

To accomplish NASA’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 defraction 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.

Also needed is ability to fully characterize surface errors and predict optical performance.

Metrics

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 $100K/m2.

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

- Areal Cost < $500k/m2 (for UV/Optical)
- Areal Cost < $100k/m2 (for Infrared)
- Monolithic: 1 to 4 meters
- Segmented: > 4 meters
- 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 Coronagraph)
- Dynamic Stability < 10 pm (for Coronagraph)
- Actuator Resolution < 1 nm rms (for UV/Optical)

Optical Components/Systems for potential UVO missions

Potential UVO/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 stability. Mirror areal density depends upon available launch vehicle capacities to Sun-Earth L2 (i.e. 15 kg/m2 for a 5 m fairing EELV vs. 60 kg/m2 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 m2 of collecting area) should have an areal cost of less than $2Mm2. And, a 16-m class mirror (with 200 m2 of collecting area) should have an areal cost of less than $0.5M/m2.

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 < 10 pm rms per 10 min
- Vibration isolation (> 140 db) to reduce phasing error to < 10 pm rms

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

Optical Components/Systems for potential IR/Far-IR missions

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

There are two primary challenges for such a mirror system:

- Areal Cost of < $100k per m2.
- Cryogenic Figure Distortion < 100 nm rms

Fabricate, Test & Control Advanced Optical Systems

While Sections 3.1 and 3.2 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 subtopic also encourages proposals to develop such technology which will make a significant advance of a measurable metric.

Select:

Advanced Technology Telescope for Balloon and Sub-Orbital Missions
Advanced Technology Telescope for Balloon/Sub-Orbital Missions

This sub-topics purpose is to mature component level technologies (TRL4) to system level technologies (TRL6) by using them to manufacture complete telescope systems which will fly on a high-altitude balloon or sub-orbital rocket mission.

Examples of desired advances include, but are not limited to:

- Reduce the areal cost of telescope by 2X to 4X such that the same aperture telescopes have half the mass of current state of art telescopes (less mass enables longer duration flights) for no increase in cost.
- Improve thermal/mechanical wavefront stability and/or pointing stability by 2X to 10X.
- Maturation will be demonstrated by building one or more complete telescope assemblies to be flown on potential long duration balloon or sub-orbital rocket experiments.

While proposals will be accepted for potential missions in any spectral range from x-rays to far-infrared/sub-millimeter, this year’s sub-topic is soliciting proposal specifically for:

- Ultra-stable 1-meter Class UVOIR Telescope
- Exoplanet Mission Telescope
- Planetary Mission Telescope
- Infrared Interferometry Mission Telescope
- Balloon Gondola with Precision Pointing System

Technical Challenge

Scientists continue to develop new, more sophisticated experiments for flight on high-altitude balloons and sub-orbital rockets. These require large, light weight, low cost optics, with well-behaved properties over a wide temperature range. There are currently several options, including glass, aluminum, and carbon fiber. Each of these has both advantages and disadvantages. All of the above have been used for balloon experiments, but increasing aperture sizes, and the need for multiple large optics for interferometers, is driving up the total cost of optics, such that ~10-20% of a new balloon budget can be spent on optics. Thus, new low cost methods or materials are needed.

Infrared Interferometry Mission Telescope

A balloon-borne interferometry mission requires 0.5 meter class telescopes with siderostat steering flat mirror. There are several technologies which can be used for production of mirrors for balloon projects (aluminum, carbon fiber, glass, etc.), but they are high mass and high cost.

Balloon Gondola with Precision Pointing System

A potential exoplanet mission seeks a gondola that can interface with a stratospheric balloon (such as one provided by CSBF). The gondola shall be able to operate for at least 24hrs at a float altitude of at least 35Km; and 3-5hrs during the ascent from ground to altitude. It must be able to point a 1 m class telescope (including back end optics and with a mass of 150kg) at a specific target and stabilize it along its three axes to 2 arc-seconds or better on each axis (1 sigma). The pointing accuracy shall be 1/2 deg or better during the day and 1 arc minute or better during the night (1 sigma). The required pitch range of motion is 25 to 55 deg elevation, the azimuth range of is 0 to 360 deg, and the roll range of motion is –10 to +10 deg. The gondola maximum weight shall be 700 kg or less.

Infrared Interferometry Mission Telescope

A potential exoplanet mission requires an optical telescope system with at least 1-meter aperture for UV, visible, near- and mid-IR imaging and multiplex/hyperspectral imaging.

Balloon Gondola with Precision Pointing System

A potential exoplanet mission seeks a gondola that can interface with a stratospheric balloon (such as one provided by CSBF). The gondola shall be able to operate for at least 24hrs at a float altitude of at least 35Km; and 3-5hrs during the ascent from ground to altitude. It must be able to point a 1 m class telescope (including back end optics and with a mass of 150kg) at a specific target and stabilize it along its three axes to 2 arc-seconds or better on each axis (1 sigma). The pointing accuracy shall be 1/2 deg or better during the day and 1 arc minute or better during the night (1 sigma). The required pitch range of motion is 25 to 55 deg elevation, the azimuth range of is 0 to 360 deg, and the roll range of motion is –10 to +10 deg. The gondola maximum weight shall be 700 kg or less.

Ultra-Stable 1m Class UVOIR Telescopes

1-m class balloon-borne telescopes have flown successfully, however, the cost of such telescopes can exceed $6M, and the weight of these telescope limits the scientific payload and duration of the balloon mission.

A-5X reduction in cost and mass would enable missions which today are not feasible.

3.1.1 Exoplanet Mission Telescope

A potential exoplanet mission requires a 1.0 meter class wide-field telescope with diffraction-limited performance in the visible and a field of view > 0.5 degree. The telescope will operate over a temperature range of ±10 to ±70°C at an altitude of 35 km. It must survive temperatures as low as -80°C during ascent. The telescope should weigh less than 150kg and is required to maintain diffraction-limited performance over: a) the entire temperature range; b) pitch range from 25 to 55 degrees elevation, c) azimuth range of 0 to 360 degrees, and d) roll range of -10 to +10 degrees. The telescope will be used in conjunction with an existing high-performance pointing stabilization system.

3.1.2 Planetary Mission Telescope

A potential planetary balloon mission requires an optical telescope system with at least 1-meter aperture for UV, visible, near- and mid-IR imaging and multiplex/hyperspectral imaging.

Instructions to Proposers

Successful proposals shall provide a credible plan to deliver for the allocatd budget a fully assembled and tested telescope assembly which can be integrated into a potential balloon or sub-orbital mission to meet a high-priority NASA science objective. Successful proposals will demonstrate an understanding of how the engineering specifications of their telescope meet the performance requirements and operational constraints of a potential balloon or sub-orbital rocket science mission.

Phase-1 delivery shall be a reviewed preliminary design and manufacturing plan which demonstrates feasibility. While detailed analysis will be conducted in Phase 2, the preliminary design should address how optical, mechanical (static and dynamic) and thermal designs and performance analysis will be done to show compliance with all requirements. Past experience or technology demonstrations which support the design and manufacturing plans will be given appropriate weight in the evaluation.

Please note: all offerors are highly encouraged to team with a potential user for their telescope and include that individual in their proposal as a science mission co-investigator.
Any Questions?