NASA SBIR Select 2015 Phase I Solicitation

S20.02 Advanced Technology Telescope for Balloon and Sub-Orbital Missions

Lead Center: MSFC

Participating Center(s): GSFC, JPL

The purpose of this subtopic is to mature demonstrated component level technologies (TRL4) to demonstrated 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 technological advances relative to the current state of the art include, but are not limited to:Â

- Reduce the areal cost of telescope by 2X to 4X such that larger collecting areas can be produced for the same cost or current collecting areas can be produced for half the cost.
- Reduce the areal density of telescopes by 2X to 4X such that the same aperture telescopes have half the mass of current state of art telescope (less mass enables longer duration flights) for no increase in cost.
- Improve thermal/mechanical wavefront stability and/or pointing stability by 2X to 10X.

Technological maturation will be demonstrated by building one or more complete telescope assemblies which can be flown on potential long duration balloon or sub-orbital rocket experiments to do high priority science. While proposals will be accepted for potential missions that cover any spectral range from x-rays to far-infrared/sub-millimeter, this yearâ€™s sub-topic is soliciting proposal specifically for (see Section 3 for details):Â

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

Successful proposals shall provide a credible plan to deliver for the allocated 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 I delivery shall be a reviewed preliminary design and manufacturing plan which demonstrates feasibility. While detailed analysis will be conducted in Phase II, 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.

Phase II delivery shall be a completely assembled and tested telescope assembly ready to be integrated into a potential balloon or sub-orbital rocket mission payload. For a potential balloon mission, the telescopes must be designed to survive 150K to 330K temperature range and 10G shock. For a potential sub-orbital rocket mission, the telescope must be designed to survive nominal temperature range and nominal shock. The mass budgets for each telescope are nominal. Testing shall confirm compliance of the telescope assembly with its requirements.

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.

NASA Relevance

The 2010 National Academy Astro2010 Decadal Report recommended increased use of sub-orbital balloon-borne observatories. Two specific needs include:Â

- Far-IR telescope systems for Cosmic Microwave Background (CMB) studies.
- Optical/NIR telescope systems for Dark Matter and/or Exo-Planet studies.

Additionally, Astro2010 identifies optical components as key technologies needed to enable several different future missions, including:Â

- Light-weight x-ray imaging mirrors for future very large advanced x-ray observatories.
- Large aperture, light-weight mirrors for future UV/Optical telescopes.

Â The 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 5 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. To enable this capability requires low-cost, ultra-stable, large-aperture, normal and grazing incidence mirrors with low mass-to-collecting area ratios. To enable these new astronomical telescopes, the report identifies three specific optical systems technologies:Â

- Active align/control of grazing-incidence imaging systems to achieve < 1 arc-second angular resolution.
- Active align/control of normal-incidence imaging systems to achieve 500 nm diffraction limit (40 nm rms wavefront error, WFE) performance.
- Normal incidence 4-meter (or larger) diameter 5 nm rms WFE (300 nm system diffraction limit) mirrors.

Technical Challenges

Scientists continue to develop new, more sophisticated experiments for flight on high-altitude balloons and sub-orbital rockets. These include new large single aperture telescopes and interferometers. These experiments require large, light weight, low cost optics, with well-behaved properties over a wide temperature range. For experiments in the infrared, there are currently several material options available, including glass, aluminum, and carbon fiber. Each of these has both advantages and disadvantages. Glass mirrors have a long heritage, and are generally relatively cost effective. Unfortunately, they also tend to be fairly massive without sophisticated light-weighting, which significantly raises cost. Aluminum mirrors are suitable for long-wavelength applications, and have the major advantage that all-aluminum structures holding the optics provide good thermal behavior. The disadvantage is that it is difficult to produce the very accurate optical figure with low surface roughness, such as needed for interferometers and for experiments in the ultraviolet, optical, and near-infrared. As with glass mirrors, this problem can be solved by increasing cost. Carbon fiber mirrors can provide both the mirror quality and lightweight, but typically are still very expensive for large mirrors such as those needed for future balloon experiments. All of the above options 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 methods or materials for producing such optics at lower cost are needed.

Ultra-Stable 1-meter Class UVOIR Telescope

Multiple potential balloon missions to perform Astrophysics, Exoplanet and Planetary science investigations require a complete optical telescope system with 1 meter or larger of collecting aperture. 1-m class balloon-borne telescopes have flown successfully, however, the cost for design and contraction of such telescopes can exceed $6M, and the weight of these telescopes limits the scientific payload and duration of the balloon mission. A 4X reduction in cost and mass would enable missions which today are not feasible.

Exoplanet Mission Telescope

A potential exoplanet mission seeks a 1-m 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 150 kg and is required to maintain diffraction-limited performance over:Â

- The entire temperature range.
- Pitch range from 25 to 55 degrees elevation.
- Azimuth range of 0 to 360 degrees.
- Roll range of â€“10 to +10 degrees.

The telescope will be used in conjunction with an existing high-performance pointing stabilization system.

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 multi/hyperspectral imaging, with the following optical, mechanical and operational requirements:

Optical Requirements:Â

- â‰¥ 1-meter clear aperture.
- Diffraction-limited performance at wavelengths â‰¥ 0.5 Î¼m over entire FOV.
- System focal length: 14.052-meters.
- Wavelength range: 0.3 â€“ 1.0 Î¼m and 2.5 â€“ 5.0 Î¼m.
- Field of view: 60 arc-sec in 0.3 â€“ 1.0 Î¼m band, 180 arc-sec in 2.5 â€“ 5.0 Î¼m band.
- Straylight rejection ratio â‰¥ $1e^{-6}$.

Mechanical/Operational Requirements:Â

- Overall length: â‰¤ 2.75 meters.
- Overall diameter: â‰¤ 1.25 meters.
- Mass: â‰¤ 300 kg.
- Temperature: -80 to +50Â°C.
- Humidity: â‰¤ 95% RH (non-condensing).
- Pressure: sea level to 1 micron Hg.

Shock:Â

- 10G without damage.

Elevation angle range:Â

- 0Â° to 70Â° operating, -90Â° to + 90Â° non-operating.

Other Requirements:Â

- Must allow field disassembly with standard hand tools.
- Maximum mass of any sub-assembly < 90 kg.
- Largest sub-assembly must pass through rectangular opening 56 by 50 inches (1.42 by 1.27 meters).

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 Gondala 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 â€“10 to +10 deg. The gondola maximum weight shall be 700 kg or less.Â