Scope Description
Relatively inexpensive small spacecraft offer several advantages over larger, more expensive spacecraft: small spacecraft can perform inspection and repair of larger spacecraft; several can be deployed for more frequent revisit rates over Earth’s surface or planetary objects; and multiple craft can achieve affordable mission reliability through redundancy. To date, the utility of small spacecraft in missions involving remote sensing (in any spectral band) has been constrained by their low budget and compact size: optical sensitivity is limited in proportion to the diameter of a telescope's aperture and magnification is limited by the effective focal length. The cost to produce one-of-a-kind optical assemblies is disproportionate and the production times too long to incorporate into the tight budgets and schedules typical of small spacecraft missions.

The objective of this subtopic is to receive proposals that articulate a demonstrable ability to manufacture, test and control ultra-low-cost optical systems that can meet the reference mission performance requirements (including infrastructure issues) within a time frame and budget compatible with a small spacecraft development cycle. For the purposes of this subtopic, small spacecraft are defined as CubeSats of 12U volume. Proposals are sought that will specify telescope figures of merit for a potential small spacecraft mission (e.g. Earth resource management, maritime traffic monitoring, observations for agricultural industry, lunar exploration precursors, manned spacecraft inspection, NEO asteroid detection, or other reference mission to be specified by proposer) and will include discussion of current state-of-the-art for telescope optical parameters (sensitivity, resolution and magnification within a spectral band), production cost and schedule significantly improved by the proposed telescope design. Detector electronics are not specifically sought for this subtopic.

References
None

Expected TRL or TRL range at completion of the project: 3 to 6

Desired Deliverables of Phase II

Prototype

Desired Deliverables Description
Prototype telescope appropriate for inclusion in a 12U CubeSat with up to 8U available for optics. A CubeSat class
precision optical system would include an aperture of up to approximately 0.2m diameter. For Phase I, deliverables should include a design reference mission relevant to the telescope design, with key performance parameters identified. Identification of key relevant subcomponents of a telescope system require a prototype demonstration for fabrication, test or control technology required for a successful Phase II delivery of a prototype. Ideally Phase I includes a reviewed preliminary design and manufacturing plan which demonstrates production feasibility, appropriate material behavior, process controls, optical performance, and mounting/deploying issues especially with considerations to small spacecraft should be resolved and demonstrated. While final manufacturing and assembly 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 proposed performance measures, survival of the launch environment and performance in the space environment (Earth orbiting or deep space).

In Phase II the project could complete environmental qualification testing of the telescope including measuring optical figure before and after vibration testing, acoustic testing, and thermal cycling. It would also demonstrate that the telescope maintains optical figure in a reference thermal environment including thermal gradients.

A successful mission oriented Phase II would yield a credible plan to deliver (in phase III) flight hardware within the allocated budget for a fully assembled and tested telescope assembly which can be integrated into the potential mission; and, demonstrate an understanding of how the engineering specifications of their system meets the performance requirements and operational constraints of the mission (including mechanical and thermal stability analysis). Cost and schedule goals and optical performance goals are listed under State of the Art and Critical Gaps.

State of the Art and Critical Gaps

Technical Challenges: To accomplish NASA CubeSat-class missions, a low-cost telescope with ultra-stable, normal incidence mirrors with low mass-to-collecting area ratios, should be delivered on short schedules. After performance, the most important metric for an advanced optical system is affordability. Long telescope fabrication times add significant program cost. Current normal incidence space telescopes in the 0.2-0.5m aperture class have lead times of 12-18 months and cost $1 million to $5 million. This research effort seeks a schedule compression and cost reduction for precision optical components by 10 times, to 4-6 months and $100K-$500K for a 0.2 m aperture class telescope.

Specific metrics are defined for each wavelength application region:

For UV/Optical:

- Wavefront Figure < 5 nm RMS.
- Wavefront Stability < 1 nm / 10 min
- First Mode Frequency >500 Hz.
- Actuator Resolution < 1 nm RMS.

For EUV:

- Slope < 0.1 micro-radian.

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

Relevance / Science Traceability

A new class of low-cost, optically stable, wide spectral range telescopes designed specifically for small spacecraft have application in a variety of exploration, commercial and science missions. Existing missions can be accomplished in novel and more affordable ways with small spacecraft, and new missions will be enabled by high-performance telescopes in small spacecraft. A few examples include: Earth resource management, maritime traffic monitoring, observations for agricultural industry from Low Earth Orbit; lunar exploration precursors and manned spacecraft inspection in cislunar space; and near Earth object detection or exoplanet transit detection in deep space.