NASA SBIR 2008 Phase I Solicitation

S2 Advanced Telescope Systems

The NASA Science Missions Directorate seeks technology for cost-effective high-performance advanced space telescopes for astrophysics and Earth science. Astrophysics applications require large aperture light-weight highly reflecting mirrors, deployable large structures and innovative metrology, control of unwanted radiation for high-contrast optics, precision formation flying for synthetic aperture telescopes, and cryogenic optics to enable far infrared telescopes. A few of the new astrophysics telescopes and their subsystems will require operation at cryogenic temperatures as cold a 4-degrees Kelvin. This topic will consider technologies necessary to enable future telescopes and observatories collecting electromagnetic bands, ranging from UV to millimeter waves, and also include gravity waves. The subtopics will consider all technologies associated with the collection and combination of observable signals. Earth science requires modest apertures in the 2 to 4 meter size category that are cost effective. New technologies in innovative mirror materials, such as silicon, silicon carbide and nanolaminates, innovative structures, including nanotechnology, and wavefront sensing and control are needed to build telescope for Earth science that have the potential to cost between $50 to $150M.Â

Subtopics

S2.01 Precision Spacecraft Formations for Telescope Systems

Lead Center: JPL

Participating Center(s): GSFC

This subtopic seeks hardware and software technologies necessary to establish, maintain, and operate precision spacecraft formations to a level that enables cost effective large aperture and separated spacecraft optical telescopes and interferometers (e.g., http://constellation.gsfc.nasa.gov/, http://lisa.gsfc.nasa.gov/). Also sought are technologies (analysis, algorithms, and testbeds) to enable detailed analysis, synthesis, modeling, and visualization of such distributed systems.

Formation flight can synthesize large effective telescope apertures through, multiple, collaborative, smaller telescopes in a precision formation. Large effective apertures can also be achieved by tiling curved segments to form an aperture larger than can be achieved in a single launch, for deep-space high resolution imaging of faint astrophysical sources. These formations require the capability for autonomous precision alignment and synchronized maneuvers, reconfigurations, and collision avoidance. The spacecraft also require onboard capability for optimal path planning and time optimal maneuver design and execution.

Innovations are solicited for: (a) sensor systems for inertial alignment of multiple vehicles with separations of 10,000 - 100,000 km to accuracy of 1 - 50 milli-arcseconds (b) development of nanometer to sub-nanometer metrology for measuring inter-spacecraft range and/or bearing for space telescopes and interferometers (c) control approaches to maintain line-of-sight between two vehicles in inertial space near Sun-Earth L2 to milli-arcsecond levels accuracy (d) development of combined cm-to-nanometer-level precision formation flying control of numerous spacecraft and their optics to enable large baseline, sparse aperture UV/optical and X-ray telescopes and interferometers for ultra-high angular resolution imagery. Proposals addressing staged-control experiments which combine coarse formation control with fine-level wavefront sensing based control are encouraged.

Innovations are also solicited for distributed spacecraft systems in the following areas:

- Distributed, multi-timing, high fidelity simulations;
- Formation modeling techniques;
- Precision guidance and control architectures and design methodologies;
- Centralized and decentralized formation estimation;
- Distributed sensor fusion;
- RF and optical precision metrology systems;
- Formation sensors;
- Precision microthrusters/actuators;
- Autonomous reconfigurable formation techniques;
- Optimal, synchronized, maneuver design methodologies;
- Collision avoidance mechanisms;
- Formation management and station keeping.

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

S2.02 Proximity Glare Suppression for Astronomical Coronagraphy

Lead Center: JPL

Participating Center(s): ARC, GSFC

This subtopic addresses the unique problem of imaging and spectroscopic characterization of faint astrophysical objects that are located within the obscuring glare of much brighter stellar sources and innovative advanced wavefront sensing and control for cost-effective space telescopes. Examples include planetary systems beyond our own, the detailed inner structure of galaxies with very bright nuclei, binary star formation, and stellar evolution. Contrast ratios of one million to ten billion over an angular spatial scale of 0.05-1.5 arcsec are typical of these objects. Achieving a very low background requires control of both scattered and diffracted light. The failure to control either amplitude or phase fluctuations in the optical train severely reduces the effectiveness of starlight cancellation schemes.

This innovative research focuses on advances in coronagraphic instruments, starlight cancellation instruments, and potential occulting technologies that operate at visible and infrared wavelengths. The ultimate application of these instruments is to operate in space as part of a future observatory mission. Much of the scientific instrumentation used in future NASA observatories for the astrophysical sciences will require control of unwanted radiation (thermal and scattered) across a modest field of view. The performance and observing efficiency of astrophysics instruments, however, must be greatly enhanced. The instrument components are expected to offer much higher optical throughput, larger fields of view, and better detector performance. The wavelengths of primary interest extend from the visible to the thermal infrared. Measurement techniques include imaging, photometry, spectroscopy, and polarimetry. There is interest in component development, and innovative instrument design, as well as in the fabrication of subsystem devices to include, but not limited to, the following areas:

Starlight Suppression Technologies

- Advanced starlight canceling coronagraphic instrument concepts;
- Advanced aperture apodization and aperture shaping techniques;
- Pupil plane masks for interferometry;
- Advanced apodization mask or occulting spot fabrication technology controlling smooth density gradients to 10-4 with spatial resolutions ~1 Âµm, low dispersion, and low dependence of phase on optical density;
- Metrology for detailed evaluation of compact, deep density apodizing masks, Lyot stops, and other types of graded and binary mask elements. Development of a system to measure spatial optical density, phase in homogeneity, scattering, spectral dispersion, thermal variations, and to otherwise estimate the accuracy of masks and stops is needed;
- Interferometric starlight cancellation instruments and techniques to include aperture synthesis and single input beam combination strategies;
- Single mode fiber filtering from visible to 20 Âµm wavelength;
- Methods of polarization control and polarization apodization; and
- Components and methods to insure amplitude uniformity in both coronagraphs and interferometers, specifically materials, processes, and metrology to insure coating uniformity.

Wavefront Control Technologies

- Development of small stroke, high precision, deformable mirrors (DM) and associated driving electronics scalable to 10^4 or more actuators (both to further the state-of-the-art towards flight-like hardware and to explore novel concepts). Multiple DM technologies in various phases of development and processes are encouraged to ultimately improve the state-of-the-art in deformable mirror technology. Process improvements are needed to improve repeatability, yield, and performance precision of current devices;
- Development of instruments to perform broad-band sensing of wavefronts and distinguish amplitude and phase in the wavefront;
- Adaptive optics actuators, integrated mirror/actuator programmable deformable mirror;
- Reliability and qualification of actuators and structures in deformable mirrors to eliminate or mitigate single actuator failures;
- Multiplexer development for electrical connection to deformable mirrors that has ultra-low power dissipation;
- High precision wavefront error sensing and control techniques to improve and advance coronagraphic imaging performance; and
- Highly reflecting broadband coatings.

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

S2.03 Precision Deployable Optical Structures and Metrology

Lead Center: JPL

Participating Center(s): GSFC, LaRC

Planned future NASA Missions in astrophysics, such as the Single Aperture Far-IR (SAFIR) telescope, James Webb Space Telescope (JWST, http://www.jwst.nasa.gov/), Terrestrial Planet Finder (TPF, http://planetquest.jpl.nasa.gov/TPF/tpf_index.cfm) missions: Coronagraph, External Occulter and Interferometer, ATLAST, Life Finder, and Submillimeter Probe of the Evolution of Cosmic Structure (SPECS), and the UV Optical Imager (UVOIR) require 10 - 30 m class cost effective telescope observatories that are diffraction limited at wavelengths from the visible to the far IR, and operate at temperatures from 4 - 300 K. The desired areal density is 1 - 10 kg/m^2. Static and dynamic wavefront error tolerances to thermal and dynamic perturbations may be achieved through passive means (e.g., via a high stiffness system, passive thermal control, jitter isolation or damping) or through active opto-mechanical control. Large deployable multi-layer structures in support of sunshades for passive thermal control and 20m to 50m class planet finding external occulters are also relevant technologies. Potential architecture implementations must package into an existing launch volume, deploy and be self-aligning to the micron level. The target space environment is expected to be L2.

This topic solicits proposals to develop enabling, cost effective component and subsystem technology for these telescopes. Research areas of particular interest include precision deployable structures and metrology (i.e., innovative active or passive deployable primary or secondary support structures); innovative concepts for packaging fully integrated (i.e., including power distribution, sensing, and control components); distributed and localized actuation systems; deployment packaging and mechanisms; active opto-mechanical control distributed on or within the structure; actuator systems for alignment of reflector panels (order of cm stroke actuators, lightweight, nanometer stability); innovative architectures, materials, packaging and deployment of large sunshields and external occulters; mechanical, inflatable, or other deployable technologies; new thermally-stable materials (CTE < 1ppm) for deployables; innovative ground testing and verification methodologies; and new approaches for achieving packagable depth in primary mirror support structures.

Also of interest are innovative metrology systems for direct measurement of the optical elements or their supporting structure; requirements for micron level absolute and subnanometer relative metrology for multiple locations on the primary mirror; measurement of the metering truss; and innovative systems which minimize complexity, mass, power and cost. The goal for this effort is to mature technologies that can be used to fabricate 20 m class or greater, lightweight, ambient or cryogenic flight-qualified observatory systems. Proposals to fabricate demonstration components and subsystems with direct scalability to flight systems through validated models will be given preference. The target launch volume and expected disturbances, along with the estimate of system performance, should be included in the discussion. A successful proposal shows a path toward a Phase 2 delivery of demonstration hardware scalable to 3 m for characterization.

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

S2.04 Optical Devices for Starlight Detection and Wavefront Analysis

Lead Center: MSFC

Participating Center(s): GSFC, JPL

The planned Ares V vehicle will enable the launch of extremely large and/or extremely massive space telescopes. Potential systems include 12 to 30 meter class segmented primary mirrors for UV/optical or infrared wavelengths and 8 to 16 meter class segmented x-ray telescope mirrors. UV/optical telescopes require 1 to 3 meter class mirrors with < 5 nm rms surface figures. IR telescopes require 2 to 3 meter class mirrors with cryo-deformations < 100 nm rms. X-ray telescopes require 1 to 2 meter long grazing incidence segments with angular resolution < 5 arc-sec down to 0.1 arc-sec and surface micro-roughness < 0.5 nm rms. Additionally, missions such as EUSO and OWL need 2 to 9 meter diameter UV-transparent refractive, double-sided Fresnel or diffractive lenses.

In view of the very large total mirror or lens collecting aperture required, affordability or areal cost (cost per square meter of collecting aperture) rather than areal density is probably the single most important system characteristic of an advanced optical system. For example, both x-ray and normal incidence space mirrors currently cost $3M to $4M per square meter of optical surface area. This research effort seeks a cost reduction for precision optical components by 20X to 100X to less than $100K per square meter.

The primary purpose of this subtopic is to develop and demonstrate technologies to manufacture ultra-low-cost precision optical systems for very large x-ray, UV/optical or infrared telescopes. Potential solutions include but are not limited to direct precision machining, rapid optical fabrication, slumping or replication technologies to manufacture 1 to 2 meter (or larger) precision quality mirror or lens segments (either normal incidence for uv/optical/infrared or grazing incidence for x-ray).

An additional key enabling technology for UV/optical telescopes is a broadband (from 100 nm to 2500 nm) high-reflectivity mirror coating with extremely uniform amplitude and polarization properties which can be deposited on 1 to 3 meter class mirrors.

Successful proposals will demonstrate prototype manufacturing of a precision mirror or lens system or precision replicating mandrel in the 0.25 to 0.5 meter class with a specific scale up roadmap to 1 to 2+ meter class space qualifiable flight optics systems. Material behavior, process control, optical performance, and mounting/deploying issues should be resolved and demonstrated. The potential for scale-up will need to be addressed from a processing and infrastructure point of view.

The Phase 1 deliverable will be at least a 0.25 meter near UV, visible or x-ray precision mirror or lens or replicating mandrel, its optical performance assessment and all data on the processing and properties of its substrate materials. This effort will allow technology to advance to TRL 3-4.

The Phase 2 deliverable will be at least a 0.50 meter near UV, visible or x-ray space-qualifiable precision mirror or lens system with supporting documentation, optical performance assessment, all data on materials and processing, and thermal and mechanical stability analysis. Effort will advance technology to TRL 4-5.

The proposal must address the technical need of a recognized future NASA space science mission, science measurement objective or science sensor for a Discovery, Explorer, Beyond Einstein, Origins, GOESS, New Millennium, Landmark-Discovery, or Vision mission. Missions of interest include the following: Constellation-X (http://constellation.gsfc.nasa.gov/); Generation-X (http://www.cfa.harvard.edu/hea/genx.html); Single Aperture Far-Infrared (http://safir.jpl.nasa.gov/technologies.shtml); Terrestrial Planet Finder (http://planetquest.jpl.nasa.gov/TPF/tpf_index.cfm); Orbiting Wide Angle Light Collector (http://owl.gsfc.nasa.gov/); Extreme Universe Space Observatory (http://hena.lbl.gov/EUSO/).

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

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S2.05 Optics Manufacturing and Metrology for Telescope Optical Surfaces

Lead Center: GSFC

Participating Center(s): JPL, MSFC

This year's subtopic focuses primarily on manufacturing and metrology of optical surfaces, especially for very small or very large and/or thin optics. Missions of interest include JDEM concepts (http://universe.nasa.gov/program/probes/jdem.html), Constellation-X (http://constellation.gsfc.nasa.gov/), TPF (http://planetquest.jpl.nasa.gov/TPF/tpf_index.cfm) and SAFIR (http://safir.jpl.nasa.gov/technologies.shtml). Optical systems currently being researched for these missions are large area aspheres, requiring accurate figuring and polishing across six orders of magnitude in period (i.e., 1st and 2nd order errors through micro-roughness). Technologies are sought that will enhance the figure quality of optics in any range as long as the process does not introduce artifacts in other ranges (i.e., mm-period polishing should not introduce waviness errors at the 20 mm or 0.05 mm periods in the power spectral density). Also, novel metrological solutions that can measure figure errors over a large fraction of the PSD range are sought, especially techniques and instrumentation that can perform measurements while the optic is mounted to the figuring/polishing machine.

By the end of a Phase 2 program, technologies must be developed to the point where the technique or instrument can dovetail into an existing optics manufacturing facility producing optics at the R&D stage. Metrology instruments should have 10 nm or better surface height resolution and span at least 3 orders of magnitude in lateral spatial frequency.

Examples of technologies and instruments of interest include:

- Interferometric nulling optics for very shallow conical optics used in x-ray telescopes;
- Segmented systems commonly span 60 degrees in azimuth and 200 mm axial length and cone angles vary from 0.1 to 1 degree;
- Low stress metrology mounts that can hold very thin optics without introducing mounting distortion;
- Low normal force figuring/polishing systems operating in the 1 mm to 50 mm period range with minimal impact at significantly smaller and larger period ranges;
- In situ metrology systems that can measure optics and provide feedback to figuring/polishing instruments without removing the part from the spindle;
- Innovative mirror substrate materials or manufacturing methods that produce thin mirror substrates that are stiffer and/or lighter than existing materials or methods;
- Extreme aspheric and/or anamorphic optics for pupil intensity amplitude apodization (PIAA).

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 Â