



NASA SBIR Select 2012 Phase I Solicitation

E3 Science Mission Directorate Select Subtopics

Subtopics

E3.01 Laser Transmitters and Receivers for Targeted Earth Science Measurements

Lead Center: LaRC

Participating Center(s): GSFC, JPL

Earth is a complex, dynamic system we do not yet fully understand. We need to understand the Earth's atmosphere, lithosphere, hydrosphere, cryosphere, and biosphere as a single connected system. The purpose of NASA's Earth science program is to develop a scientific understanding of Earth's system and its response to natural or human-induced changes, and to improve prediction of climate, weather, and natural hazards. A major component of NASA's Earth Science Division is a coordinated series of satellite and airborne missions for long-term global observations of the land surface, biosphere, solid Earth, atmosphere, and oceans. This coordinated approach enables an improved understanding of the Earth as an integrated system. NASA is completing the development and launch of a set of Foundational missions, new Decadal Survey missions, and Climate Continuity missions. This subtopic seeks innovative laser transmitters and receivers to allow accurate measurements of atmospheric parameters with high spatial resolution from ground and airborne platforms. These developments require advances in the state-of-the-art lidar technology with emphasis on compactness, efficiency, reliability, lifetime, and high performance. This subtopic is seeking only the innovative laser transmitter subsystem or complete receiver subsystem for the three listed areas, which upon delivery would be infused into a lidar system demonstration. *(Individual lidar components are NOT solicited in this subtopic but can be submitted under the S1.01 Lidar Remote Sensing Technologies)* With the larger funded effort, NASA seeks to have delivered a full transmitter or receiver subsystem with turnkey operation meeting the requirements of one of the three targeted areas below. The selected proposal(s) will be required to work closely with the NASA customers to understand performance requirements.

- *Tunable laser system development for water vapor DIAL systems for high altitude aircraft platforms* - Need: climate, upper-troposphere, lower-stratosphere, cirrus cloud, and satellite validation studies. Application from high altitude platforms (35,000 to 65,000 ft). Water vapor in the high altitudes impacts climate, radiation, stratospheric /tropospheric exchange, and even impacts satellite validation activities. There is a critical need for high accuracy, high resolution water vapor measurement and its impact at the highest altitudes. The most critical unmet need for a high-altitude a water vapor DIAL system is a compact, rugged, and efficient tunable laser transmitter to operate on one of the strong H₂O absorptions lines near 934.55, 935.43 or 944.11 nm (H₂O line center). Tunability over the side of the line up to 100 pm is needed. Need to demonstrate the laser can operate locked at 0 pm, 25 pm, 50 pm, and 100 pm from line center position of the H₂O line at low pressure. Frequency stability of <0.1 pm and linewidths of <0.2 pm are required. High spectral purity >99.9% need to be demonstrated. Ability to switch between wavelengths within 300 micro second is needed. Pulse energies in the range 5 to 100 mJ with output power of 2-5 W (low pulse energies

will require higher average power to overcome background and detector noise issues). (Note for later spacecraft application 50 mJ - 500 mJ and output power ~ 10 W would be needed).

- *Compact, rugged laser transmitter for advanced ozone DIAL lidar systems* - NASA and other agencies have a long-term interest in lidar profile measurements of atmospheric ozone from the ground and also from aircraft. A measurement goal would be ± 5 ppb ozone throughout the troposphere. Major technology advances are needed to allow multiple ozone lidar stations to make continuous ozone profile measurements over extended time intervals. Laser transmitters are needed that simultaneously (or interleaved) produce three eye-safe ultraviolet wavelengths (preferably tunable) between approximately 280 and 316 nm with approximately 1-nm linewidth. Laser pulses would typically be less than 100-nsec in pulsewidth with ~2 Watts power in each of 3 UV wavelengths. Both high (~1kHz) and low (~20Hz) repetition rate lasers will be considered. Such a system would be required to operate reliably for extended times with a minimum of expendable supplies and be easily transportable. The total instrument volume would be approximately one square meter. The laser system is targeted for infusion in a ground system demonstration.
- *Atmospheric Lidar with Cross-Track Coverage* - A key measurement capability for NASA Earth Science applications is lidar remote sensing of atmospheric clouds and aerosols and, increasingly, cloud-aerosol interactions. The vertical resolution possible with lidar systems provides accurate identification of cloud and aerosol layer heights and structure. However, a primary limitation of existing lidar instruments is lack of horizontal (e.g., cross-track) coverage. Technologies are solicited for transmitter, transceiver, or receiver technologies that enable airborne lidar measurements of clouds and aerosols having both vertical and horizontal extent. Technologies are sought that demonstrate a capability that can be mounted on a relevant high-altitude aircraft platform (specifically, ER-2, Global Hawk, or Proteus). The ability of any proposed technology to be scalable to spaceborne application is highly desirable. The focus is on cloud and aerosols (and cloud-aerosol interaction); proposals specific to scanning/mapping surface altimetry will be considered nonresponsive. Funds available permit development of instrument subsystems. Depending on the approach chosen, the subsystem might be a novel transmitter, transceiver, or a scanner/receiver subsystem. Regardless of the subsystem developed, it is essential that the proposer demonstrate how their subsystem can be integrated into a complete instrument. That is, developing a novel scanning technology that cannot be easily or affordably coupled to a transmitter would be of little use. The successful proposal(s) will demonstrate consideration of the end-to-end instrument design, including demonstration that the system envisioned would be capable of obtaining sufficient signal over required averaging volumes (e.g., demonstrate simulation capability sufficient to convince reviewers that the resultant measurement will be useful).

Although different approaches might be proposed, and different subsystems or types of subsystems are possible, general guidance on requirements include:

- Profiling of cloud and aerosol backscatter, with emphasis on multiple wavelengths and depolarization measurement capability, if possible.
- Horizontal coverage of at least ± 5 km, with horizontal resolution < 1 km. Therefore, the system design should have at least 10 cross-track points, and more if possible.
- Along-track resolution will be driven by the specific technology proposed, but in general, along-track integration times of < 2 seconds is preferred.
- Vertical resolution can be driven by the detector(s) and data system, but nominal vertical resolution of < 100 m is desirable. System designs should be sized appropriately to obtain sufficient signal over these vertical and horizontal resolutions.
- It is desirable to utilize solid-state (e.g., photon-counting) detection if possible. Data systems can be readily obtained to interface with photon-counting detectors, thereby lowering the cost and complexity of a completed instrument.
- Size, mass, power constraints need to be considered and should be commensurate with accommodations of the NASA ER-2, Global Hawk, or Proteus aircraft. In general, the airborne platforms will limit the transceiver aperture size. Thermal, pressure, and other environmental constraints of these high-altitude airborne platforms should also be considered.

Successful proposals will demonstrate an understanding of the relevant science need, and present a feasible plan to work with a NASA sponsor to use follow-on funding opportunities to develop a complete airborne instrument. Follow-on opportunities include, but are not limited to Instrument Incubator Program (IIP), Airborne Instrument Technology Transition (AITT), Earth Venture - Instrument (EV-I), or Phase III SBIR funding. The Phase I research

activity should demonstrate technical feasibility during and show a clear path to a Phase II prototype. The Phase II deliverable should be packaged in such a manner that it can be directly infused into follow-on opportunities to develop a complete lidar instrument.

E3.02 Advanced Technology Telescope for Balloon Mission

Lead Center: MSFC

Participating Center(s): GSFC, JPL

The purpose of this sub-topic is to mature demonstrated component level technologies (TRL4) to demonstrated system level technologies (TRL6) by using them to manufacture complete telescope systems. Examples of desired technological advances relative to the current state of the art include, but are not limited to:

- Reduce the areal cost of telescope by 2X 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 such that the same aperture telescopes have half the mass of current state of art telescope. Less mass enables longer duration flights.
- 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 experiments to do high priority science. Potential missions can cover any spectral range from X-rays to far-infrared/sub-millimeter. Potential telescopes include, but are not limited to:

- High-Energy Telescope.
- Ultra-Stable 1-meter Class UVOIR Telescope.
- Low-Cost CMB Telescopes.
- Low-Cost Far-Infrared Telescopes.
- Cryogenic Far-Infrared Telescope.
- 5 to 10 meter Segmented Far-IR Telescope.
- Heliophysics UVOIR Telescope.

Deliverable for Phase I is a reviewed preliminary design demonstrating feasibility. Deliverable for Phase II is a fully integrated and tested telescope assembly, ready to be incorporated into a potential balloon mission payload. In all cases, the telescopes must be designed to survive balloon environments, including 150K to 330K temperature range and 10G shock. The mass budgets for each telescope are nominal. Successful proposals will demonstrate an understanding of how the engineering specifications of their telescope meets the performance requirements and operational envelop of a potential balloon science mission; and presents a credible plan to build the proposed telescope. Please note, for this sub-topic a telescope is defined as a complete integrated system of optical and structural components which collects and concentrates electro-magnetic photons/waves for detection by a scientific imaging and/or spectroscopic instrument. See Technical Challenges for baseline technical requirements for potential telescopes. The 2010 National Academy Astro2010 Decadal Report recommended increased use of sub-orbital balloon-borne observatories. Two specific needs include:

- 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:

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

The 2012 National Academy report "NASA Space Technology Roadmaps and Priorities" 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:

- 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 Technological developments at the telescope system level are required to enable higher capability measurements, longer duration flights and more affordable missions. The purpose of this sub-topic is to mature demonstrated component level technologies (TRL4) to demonstrated system level technologies (TRL6) by using them to manufacture complete telescope systems. Examples of desired technological advances relative to the current state of the art include, but are not limited to:

- Reduce the areal cost of telescope by 2X 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 such that the same aperture telescopes have half the mass of current state of art telescope. Less mass enables longer duration flights.
- Improve thermal/mechanical wavefront stability and/or pointing stability by 2X to 10X.

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 mission to meet a high-priority NASA science objective. Successful proposals will demonstrate an understanding of how the engineering specifications of their telescope meets the performance requirements and operational envelope of a potential balloon science mission. Phase I delivery shall be a reviewed 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 optical telescope assembly ready to be integrated into a potential balloon mission. Testing shall confirm compliance of the telescope assembly with its requirements. **High Energy Telescope** A high-energy telescope is desired which includes the collecting optic, the structure which connects the collecting optic to the detecting instrument, and any mechanisms needed to maintain alignment and pointing stability of the collecting optic relative to the detecting instrument. Collecting optic should be able to collect and concentrate high-energy photons (above 10 keV). Collecting optics can be grazing incidence reflective, refractive or diffractive with a potential focal length ranging from 4 to 10 meters. Other 'optical' elements such as coded apertures can be considered. Angular resolutions should be significantly less than 1 arcminute for grazing-incidence optics, and ideally in the arcsecond range. Active control of the optic figure may be necessary. For refractive /diffractive optics, lower resolutions are acceptable, depending on energy. Effective collecting area should be greater than 10's cm² at 10 keV to enable useful data from typical balloon observing times. Higher energy 'optics' should provide enough area for a significant signal during flight. Optical assemblies must ideally be light weight to satisfy future mission demands. Total telescope mass budget goal is 200 kg. **Ultra-Stable 1-meter Class UVOIR Telescope** Potential Exoplanet balloon studies require a complete optical telescope system with 1 meter or larger of collecting aperture to characterize exoplanets and dust disks over the range of wavelengths from 300 to 1100 nm, and ideally as long as 1600 nm. The telescope should be diffraction limited at 500 nm (< 36 nm transmitted wavefront) over a total field of view subtending at least 10 arc-seconds and over a field of regard extending from 20 to 70 ° elevation angle with respect to the gravity vector. The wavefront error power spectral density should monotonically decrease with increasing spatial frequency i.e., have no strong harmonics, from 0 to 30 cycles per aperture. Dynamic wavefront stability must be < 0.3 nm rms over timescales of 100s seconds and < 1 nm rms over timescales of 100s minutes. Sources of wavefront instability include thermal variations with boresight angle, thermal drift, coupling of residual vibration from reaction/momentum wheels, residual wind effects above 100,000 ft, and pointing induced beam shear. The telescope can achieve the stability requirement via either passive design or an actively controlled mirror (i.e., secondary mirror, fine steering mirror, deformable mirror, etc.). Possible telescope configurations include, but

are not limited to, two mirror Cassegrain and Gregorian configurations, and 3 mirror anastigmat designs. Ideally the telescope is an unobscured off-axis system that can function with several different types of coronagraphs. But on-axis systems with simple secondary support spiders are allowed for a subset of possible high-contrast instruments. The telescope should form a centimeter scale real pupil image after the primary mirror vertex. The total telescope mass budget goal is 300 kg. **Low-Cost CMB Telescopes** Potential balloon measurements of CMB linear polarization desire complete 3 to 4 meter class off-axis telescope systems which are 2X lower areal cost and 2X lower areal mass than the current 2 meter class state of the art (as represented by the BLAST telescope) with the following optical, mechanical and operational requirements. Optical requirements:

- 3 meter to 4 meter diameter primary mirror.
- Diffraction-limited performance at 500 micron wavelength at 250 K.
- Wavefront stability of 15 micrometers rms per K.
- F/1 to F/1.5 primary mirror.
- 70 arc-minute field of view at 500 micron wavelength.
- Strehl ratio > 0.95 at edge of field of view.

Mechanical and operational requirements:

- Telescope to operate at ambient temperature 250 K (200 to 300K range).
- Telescope and mount to survive 10G shock (vertical).
- Telescope and mount to survive 5G shock (tilted 45 °).
- Mass of telescope to be 200 kg or less.
- Recurring production cost < \$200 K per telescope.

Successful proposals will deliver a complete preliminary design for the telescope at the end of Phase I and two to four complete telescope systems at the end of Phase II. **Low-Cost Far-Infrared Telescopes** Potential balloon Far-Infrared missions desire complete off-axis telescope systems which are 2X lower areal cost and 2X lower areal mass than the current state of the art with the following optical, mechanical and operational requirements. Optical requirements:

- 2.5 meter to 4 meter diameter primary mirror.
- Diffraction-limited performance at 100 micron wavelength at 250 K.
- Wavefront stability of 2.5 micrometers rms per K.
- F/1 to F/1.5 primary mirror.
- 15 arc-minute field of view at 100 micron wavelength.
- Strehl ratio > 0.95 at edge of field of view.

Mechanical and operational requirements:

- Telescope to operate at ambient temperature 250 K (200 to 300K range).
- Telescope and mount to survive 10G shock (vertical).
- Telescope and mount to survive 5G shock (tilted 45 °).
- Mass of telescope to be 200 kg or less.
- Recurring production cost < \$200 K per telescope.

Successful proposals will deliver a complete preliminary design for the telescope at the end of Phase I and two to four complete telescope systems at the end of Phase II. **Cryogenic Far-Infrared Telescope** Potential Far-Infrared balloon missions achieve significant improvements in sensitivity using cryogenic optics. Anticipated missions require a complete telescope system with larger collecting apertures and lower areal mass than the current state of the art. A cryogenic telescope is desired with 3 meter on-axis collecting aperture maintained at temperatures below 20 K. Low mass and long cryogenic hold time are particularly important. Optical requirements:

- Diffraction-limited performance at 300 micron wavelength at 20 K.
- F/1 to F/1.5 primary mirror.

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- Field of view 20 arc-minutes minimum, 40 arc-min desired.
 - Strehl ratio > 0.95 at edge of field of view.

Cryogenic requirements:

- Maintain entire telescope at 20 K or colder.
- Hold time 48 hours or longer, with goal of 21 days.

Mechanical requirements:

- Telescope and cryostat to survive 10G shock (vertical).
- Telescope and cryostat to survive 5G shock (tilted 45 °).
- Mass of telescope + cryostat to be < 1000 kg (goal 500 kg).

Successful proposals will deliver a preliminary design for the complete telescope and cryostat at the end of Phase I. Successful proposals will deliver the complete telescope and cryostat at the end of Phase II. **5 to 10 meter Segmented Far-IR Telescope** Potential Far-IR balloon studies required a complete optical telescope system with a 5 to 10 meter segmented aperture; 250 to 500 micrometer diffraction limited performance; wavefront stability of less than 10 micrometers rms; and a total mass of 400 (5m) to 800 kg (10m). **Heliophysics UVOIR Telescope** Potential Heliophysics studies require a complete optical telescope and/or camera system with: 1 to 2 meter collecting aperture, 20 ° field of view, 0.001 ° angular resolution and UV to Visible (120 to 700 nm) spectral range.

E3.03 Extreme Environments Technology

Lead Center: JPL

Participating Center(s): ARC, GRC, GSFC, LaRC, MSFC

The present state of practice for building space systems for exploring our solar system planets is based on the placing space craft subsystems into environmentally protected housings that are power inefficient and bulky. The goal of the subtopic is to develop technologies that dramatically change this practice resulting in the development of highly power efficient and light weight space subsystems by developing space subsystems that would be capable of operating directly in the extreme environment of the planets of our solar systems. *High Temperature, High Pressure, and Chemically Corrosive Environments* - NASA is interested in expanding its ability to explore the deep atmosphere and surface of Venus through the use of long-lived (days or weeks) balloons and landers. Survivability in extreme high temperatures and high pressures is also required for deep atmospheric probes to giant planets. Proposals are sought for technologies that enable the in situ exploration of the surface and deep atmosphere of Venus and the deep atmospheres of Jupiter or Saturn for future NASA missions. Venus features a dense, CO₂ atmosphere completely covered by sulfuric acid clouds at about 55 km above the surface, a surface temperature of about 486 degrees Centigrade and a surface pressure of about 90 bars. Technologies of interest include high temperature and acid resistant high strength-to-weight textile materials for landing systems (balloons, parachutes, tethers, bridles, airbags), high temperature electronics components, high temperature energy storage systems, light mass refrigeration systems, high-temperature actuators and gear boxes for robotic arms and other mechanisms, high temperature drills, phase change materials for short term thermal maintenance, low conductivity and high-compressive strength insulation materials, high temperature optical window systems (that are transparent in IR, visible and UV wavelengths) and advanced materials with high specific heat capacity and strength for pressure vessel construction, and pressure vessel components compatible with materials such as steel, titanium and beryllium such as low leak rate wide temperature (-50 degrees Centigrade to 500 degrees Centigrade) seals capable of operating between 0 and 90 bars. *Low Temperature Environments* - Low temperature survivability is required for surface missions to Titan (-180 degrees Centigrade), Europa surface (-220 degrees Centigrade), Ganymede (-200 degrees Centigrade), near earth objects and comets. Also the Earth's Moon equatorial regions experience wide temperature swings from -180 degrees Centigrade to +130 degrees Centigrade during the lunar day/night cycle, and the sustained temperature at the shadowed regions of lunar poles can be as low as -230 degrees Centigrade. Mars diurnal temperature changes from about -120 degrees Centigrade to +20 degrees Centigrade. Also for the baseline concept for Europa Jupiter System Mission (EJSM), with a mission life of 10 years, the radiation environment is estimated at 2.9 Mega-rad total ionizing dose (TID) behind 100 mil thick

aluminum. Proposals are sought for technologies that enable NASA's long duration missions to low temperature and wide temperature environments. Technologies of interests include low-temperature resistant high strength-weight textiles for landing systems (parachutes, air bags), low-power and wide-operating-temperature radiation-tolerant /radiation hardened RF electronics, radiation-tolerant/radiation-hardened low-power/ultra-low-power wide-operating-temperature low-noise mixed-signal electronics for space-borne system such as guidance and navigation avionics and instruments, radiation-tolerant /radiation-hardened power electronics, radiation-tolerant/ radiation-hardened high-speed fiber optic transceivers, radiation-tolerant/ radiation-hardened electronic packaging (including, shielding, passives, connectors, wiring harness and materials used in advanced electronics assembly), low to medium power actuators, gear boxes, lubricants and energy storage sources capable of operating across an ultra-wide temperature range from -230 degrees Centigrade to 200 degrees Centigrade and Computer Aided Design (CAD) tools for modeling and predicting the electrical performance, reliability, and life cycle for low-temperature electronic/ electro-mechanical systems and components. Research should be conducted to demonstrate technical feasibility during Phase I and show a path toward a Phase II hardware/software demonstration, and when possible, deliver a demonstration unit at TRL 5 or higher upon the completion of the Phase II contract.