# NASA STTR 2007 Phase I Solicitation

## T4 Innovative Sensors, Detectors and Instruments Technology Needs for Earth Science, Space Science and Exploration

This topic solicits innovative sensors, detectors and instruments that support the research in Earth and its environment, the solar system, and the universe through observations from space. To assure that our Nation maintains leadership in this endeavor, we are committed to excellence in scientific investigation, in the development and operation of space systems, and in the advancement of essential technologies.

## Subtopics

### T4.01 Earth Science Sensors and Instruments

**Lead Center: GSFC**

As part of its mission, NASA seeks to develop a scientific understanding of the Earth system and its responses to natural and human-induced changes to enable improved prediction of climate, weather, and natural hazards for present and future generations. By using breakthrough technologies for terrestrial, airborne, and spaceborne instrumentation, we seek to observe, analyze, and model the Earth system to discover how it is changing and the consequences for life on Earth.

This STTR subtopic seeks to help provide advanced remote sensing technologies to enable future Earth Science measurements. Systems and approaches will be considered that demonstrate a capability that is scalable to space or can be mounted on a relevant platform (UAV or aircraft). New systems and approaches are sought that will

- Enable new Earth Science measurements;
- Enhance an existing measurement capability by significantly improving the performance (spatial/temporal

resolution, accuracy, range of regard); and/or

- Substantially reduce the resources (cost, mass, volume, or power) required to attain the same measurement capability.

**Lidar Remote Sensing Instruments**

Lidar remote sensing systems are required to meet the demanding measurement requirements for future Earth Science missions. A particular emphasis is placed on instruments that can be used on UAV platforms such as the NASA Ikhana or Altair platforms. Instruments are solicited that enable or support the following Earth Science measurements:

- High spatial and temporal resolution observations of the land surface and vegetation cover (biomass);
- Profiling of clouds and aerosols, with emphasis on multiple beam systems to provide horizontal coverage;
- Wind measurements (direct-detection technology only);
- Tropospheric and stratospheric ozone and $CO_2$ (profiling and total column).

**Active Remote Sensing Instruments (Radar) for Aircraft and Unmanned Aerial Vehicles (UAVs)**

Active microwave remote sensing instruments are required for future Earth Science missions with initial concept development and science measurements on aircraft and UAVs. New systems, approaches, and technologies are sought that will enable or significantly enhance the capability for: (1) tropospheric wind measurements within precipitation and clouds at X- through W-band, (2) precipitation and cloud measurements, and (3) large aperture ground penetrating radars (GPR) at P-band and lower. Systems and approaches will be considered that demonstrate a capability that can be mounted on a relevant platform (UAV or aircraft). Specific technologies include:

- High efficiency, solid state power amplifiers (>10W at Ka-band and >30W at Ku-band);
- High performance, low power, compact, real-time radar processors, FPGA-based digital receivers, data processing algorithms and data reduction techniques;
- Implementation of radar transmitters/receivers using digital signal synthesis;
- High power, low sidelobe (better than -30 dB) scanning phased array antennas (X, Ku, Ka or W-band) for high-altitude operation (65,000 feet);
- Wide-bandwidth (>=400 MHz), high efficiency FM chirp/linear pulse signal generator with amplitude modulation; and
- High power (30W at Ka-band , 5W at W-band), high speed (=250µs), high isolation (=40 dB) and low insertion ( 1.5 dB at Ka and 2 dB at W-band ) switch.

**Data Compression**

To complement data compression, data decompression processors are needed to decode compressed data streams. To target multiple missions, implementations should conform to the Consultative Committee for Space Data Systems (CCSDS, www.ccsds.org) recommendation CCDDS 122.0-B 1. This solicitation seeks development of new data decompression processors that can:

- Process instrument data at over 20 Mpixels/sec decoding rate for instruments that employ compression for either direct broadcast or during nearly real-time ground processing after telemetering the data to ground stations;
- Decode up to 16-bit of science data; and
- Decode embedded compression bit stream following the format described in CCSDS 122.0-B.1 (www.ccsds.org).

## T4.02 Space Science and Exploration Sensors and Instruments

**Lead Center: GSFC**

This subtopic focuses on key component and subsystem technologies for space science and exploration sensors and instruments. The focus is on innovative, lower TRL technologies which may have a longer term development time. The technology focus in this solicitation is for cryogenic cooling technologies, in situ sensors for miniaturized planetary instruments, optical subsystems and wavefront sensing and control, and detectors for the IR, far IR, submillimeter, and millimeter wave regions.

**Cryogenic Cooling Technologies for Space Science and Space Exploration**

Cryogenics systems are enabling technologies for cutting edge space science including infrared imaging and spectroscopy and x-ray spectroscopy. Cryogenic cooling is also needed to enable the long term storage of the cryo-propellants needed for space exploration missions. Improvements in cryogenic technologies enable space science and exploration missions at lower cost with reduced mass, reduced volume and reduced risk.

New concepts that would provide cooling with improved thermodynamic efficiency for the following applications are sought.

- Coolers for long term cryo-propellant storage with cooling power in the range of 50 to 100 Watts at 100 K and 20 Watts at 25 K to 30 K;
- Low vibration coolers for space science instruments with approximately 0.1 Watt of cooling power at 4 K;
- Highly efficient sub-Kelvin cooling technologies capable of cooling detectors to 50 milliKelvin.

**In Situ Sensors for Planetary Science**

Instruments for in situ investigations are required for NASA's planned and potential planetary science missions. Instruments are required for the characterization of the atmosphere, surface and subsurface regions of planets, satellites, and small bodies. These instruments may be deployed for in situ measurements on surface landers and rovers, and airborne platforms. These instruments must be capable of withstanding operation in space and planetary environmental extremes, which include temperature, pressure, radiation, and impact stresses. A focus is on developing components and subsystems for miniaturized instruments.

- Enabling instrument component and support technologies for a miniaturized mass spectrometry/gas chromatography instrument with improved capabilities over the SAM instrument on the Mars Science Laboratory. These include miniaturized pumps, sample inlet systems, valves, integrated bulk sample handling and processing systems, and microfluidic technologies for sample preparation.

**Optical Subsystems and Wavefront Sensing and Control**

This subtopic solicits technology for collecting and controlling star light with advanced optical telescopes and telescope arrays. This topic includes innovative optical subsystems, devices and components that directly collect and process optical signals and images for all regions of the electromagnetic spectrum from X-ray to UV to Visible to Far-IR/Sub-MM. Pre-detection technologies of interest include capabilities to preprocess or analyze an optical wave front or signal to extract time-dependent, spectral, polarization and spatial information from scenes or signals prior to detection. Specific technology areas of interest include: high reflectance UV coatings and uniform polarization coatings for all wavelengths; high angular resolution imaging enabled via large-baseline segmented-aperture telescopes and sparse aperture telescopes/interferometers. Component-level technology needed to enable the characterization and combination of wavefronts from multiple apertures. Innovative technology needed to integrate, assemble, align and control test large aperture segmented mirrors for x-ray, ambient and cryogenic applications.

Proposals in the following areas are specifically solicited:

- Optical coatings: broad-band polarization preserving and polarizing for UV to Far-IR/Sub-MM; high-reflectivity EUV; large area, high acceptance angle narrow-band optical filters; broad-band wide-acceptance angle UV anti-reflection on PMMA substrates; environmentally stable protected silver.

- Innovative mounting/support and metrology/control technologies to integrate, assemble, align and control large aperture lightweight low-cost segmented mirrors for x-ray, ambient and cryogenic normal incidence applications - also, systems with extreme alignment tolerances such as PIAA.

- Techniques to mitigate optical surface errors includes phase retrieval and wavefront sensing and control techniques and instrumentation, optical systems with high-precision controls, active and/or adaptive mirrors, shape control of deformable telescope mirrors, and image stabilization systems; techniques to sense/control segmented primary mirrors.

**Detector Technology for IR, far IR, Submillimeter, and Millimeter**

Advances in detectors, readout electronics, and other technologies enabling polarimetry and large format imaging arrays for the IR, far submillimeter and millimeter and spectroscopy with unprecedented sensitivity are sought.

Innovations are sought in detector capability for the following wavelength ranges:

- 1-30 microns: Increased sensitivity and larger array size; Large format cryogenic readout multiplexers; large format (>1000 x 1000) array hybridization techniques. Technologies for assembly of large format focal plane arrays. Photon counting detector arrays with fast readout electronics.

- 100 microns - 3 mm: Noise equivalent power (NEP) of $10e^{-20}$ W/Hze-1/2 in a 1,000 pixel spectroscopic array with low-power readout electronics, and NEP $10e^{-18}$ W/Hze-1/2 in a 10,000 pixel photometric imaging array. Capabilities for photon counting, polarimetry, and energy resolving detection.

- RF (GHz to THz) MEMS switches with low insertion loss.

- (18 dB), capable of switching with speeds of >100 Hz at cryogenic temperatures (below 10 K) for $10e^{8}$ or more cycles.

## T4.03 JPL - Large Telescopes

**Lead Center: JPL**

**Proximity Glare Suppression for Astronomical Coronagraphy**

This subtopic section 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 are 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 µm, 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 inhomogeneity, 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 µm 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.

**Precision Deployable Optical Structures and Metrology**

Planned future NASA Missions in astrophysics, (such as the Single Aperture Far-IR (SAFIR) telescope, 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 telescopes 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 may be achieved through passive means (e.g., via a high stiffness system) or through active control. 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 subtopic section 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 control distributed on or within the structure (downstream corrective and adaptive optics are not included in this topic area); actuator systems for alignment of reflector panels (order of cm stroke actuators, lightweight, submicron dynamic range, nanometer stability); mechanical, inflatable, or other deployable technologies; new thermally-stable materials (CTE

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 tens of points on the primary mirror. Also measurement of the metering truss. Innovative systems which minimize complexity, mass, power and cost are sought.

The goal for this effort is to mature technologies that can be used to fabricate 20 m class, lightweight, ambient or cryogenic flight-qualified telescope primary mirror systems. Proposals to fabricate demonstration components and subsystems with direct scalability to flight systems (concept described in the proposal) 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 on the scale of 3 m for characterization.

### T4.04 JPL - Communications

**Lead Center: JPL**

**Long Range Optical Telecommunications**

The adaptation of current standard laboratory techniques for deployment on planetary missions is a focus. Proposers are strongly encouraged to relate their proposed technology development to future planetary exploration goals. These goals include geochemical, geophysical and astrobiological objectives.

Instruments for in situ investigations are required for NASA's planned and potential solar system exploration missions. Instruments are required for the characterization of the atmosphere, surface and subsurface regions of planets, satellites, and small bodies. These instruments may be deployed for in situ measurements on surface landers and rovers, and airborne platforms. These instruments must be capable of withstanding operation in space and planetary environmental extremes, which include temperature, pressure, radiation, and impact stresses.

This subtopic seeks advances in instruments and critical components in the following areas:

- X-Ray Diffraction and X-Ray Fluorescence (XRD/XRF) instruments, with capabilities beyond those currently planned for the CHEMIN instrument on the Mars Science Laboratory (MSL - 2009), with a focus on elemental and mineralogical analysis in the Venus surface environment (90 bars $CO_2$, 450ºC);
- Scanning electron microscopy with chemical analysis capability;
- Mass spectrometry/Gas chromatography with improved capabilities over the SAM instrument on MSL or

applicability to in situ atmospheric measurements on Venus or Titan;

- Geochronology, with a focus on isotopic dating of planetary surfaces in the 100 Ma to 4.5 Ga timeframe with better than 10% accuracy;

- Gamma-Ray Spectroscopy, with a focus in short duration (
- X-Ray Photoelectron Spectroscopy (XPS) and Auger Electron Spectroscopy (AES).

Astrobiology includes the study of the origin, evolution, and distribution of life in the universe. New technologies are required to enable the search for extant or extinct life elsewhere in the solar system, to obtain an organic history of planetary bodies, to discover and explore water sources elsewhere in the solar system, and to detect microorganisms and biologically important molecular structures within complex chemical mixtures.

Astrobiology solicits new measurement concepts, advances in existing instrument concepts, and advances in critical components in the following areas:

- Instrumentation focused on assessments of the identification and characterization of biomarkers of extinct or extant life, such as prebiotic molecules, complex organic molecules, biomolecules, or biominerals. At this time we are not soliciting DNA and RNA analysis techniques.

- High sensitivity (femtomole or better) characterization of molecular structure, chirality, and isotopic composition of biogenic elements (H, C, N, O, S) embodied within individual compounds and structures.

In addition, enabling instrument component and support technologies for the above, such as miniaturized pumps, sample inlet systems, valves, integrated bulk sample handling and processing systems, and fluidic technologies for sample preparation, are also solicited. These must be presented in the context of a complete instrument system.

**Long Range Space RF Telecommunications**

This subtopic seeks innovative technologies for long-range RF telecommunications supporting the needs of space missions. Proposals are sought in the following areas:

- Ultra-small, light-weight, low-cost, low-power, modular deep-space transceivers, transponders and components, incorporating MMThe adaptation of current standard laboratory techniques for deployment on planetary missions is a focus. Proposers are strongly encouraged to relate their proposed technology development to future planetary exploration goals. These goals include geochemical, geophysical and astrobiological objectives.

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- MMIC modulators with drivers to provide large linear phase modulation (above 2.5 rad), high-data rate (10 - 200 Mbps), BPSK/QPSK modulation at X-band (8.4 GHz), and Ka-band (26 GHz, 32 GHz and 38 GHz);

- High-efficiency (> 60%) Solid-State Power Amplifiers (SSPAs), of both medium output power (10 W - 50 W) and high-output power (150 W - 1 KW), using power combining techniques and/or wide-bandgap semiconductor devices at X-band (8.4 GHz) and Ka-band (26 GHz, 32 GHz and 38 GHz);

- Epitaxial GaN films with threading dislocations less than 1e6 per cm2 for use in wide band-gap semiconductor devices at X- and Ka-Band;

- Utilization of nanomaterials and/or other novel materials and techniques for improving the power efficiency or reducing the cost of reliable vacuum electronics amplifier components (e.g., TWTAs and Klystrons);

- Long lifetime, radiation hard SSPAs, modulators and MMICs for 26 GHz Ka-band (lunar communication);

- TWTAs operating at higher millimeter wave frequencies (e.g., W-Band) and at data rates of 10 Gbps or higher;

- Ultra low-noise amplifiers (MMICs or hybrid) for RF front-ends (
- MEMS-based RF switches and photonic control devices needed for use in reconfigurable antennas, phase shifters, amplifiers, oscillators, and in-flight reconfigurable filters. Frequencies of interest include VHF, UHF, L-, S-, X-, Ka-, V-band (60 GHz) and W-band (94 GHz). Of particular interest is Ka-band from 25.5 - 27 GHz and 31.5 - 34 GHz.