NASA SBIR 2007 Phase I Solicitation

S1  Sensors, Detectors, and Instruments

NASA’s Science Mission Directorate (SMD) encompasses research in the areas of Astrophysics, Earth Science, Heliophysics, and Planetary Science. A major objective of SMD instrument development programs is to implement science measurement capabilities with smaller or more affordable spacecraft so development programs can meet multiple mission needs and therefore make the best use of limited resources. The rapid development of small, low-cost remote sensing and in situ instruments is essential to achieving this objective. For Earth Science needs, in particular, the subtopics reflect a focus on instrument development for airborne and Unmanned Aerial Vehicle (UAV) platforms. Astrophysics has a critical need for sensitive, large format detector arrays with imaging, spectroscopy, and polarimetric capabilities which can be demonstrated on ground, airborne, balloon, or suborbital rocket instruments. Heliophysics, which focuses on measurements of the sun and its interaction with the Earth, needs a significant reduction in the size, mass, power, and cost for instruments to fly on smaller spacecraft. Planetary Science has a critical need for miniaturized instruments with in situ sensors which can be deployed on surface landers, rovers, and airborne platforms. Consequently, the objective of this SBIR topic is to develop and demonstrate instrument component and subsystem technologies that reduce the risk, cost, size, and development time of SMD observing instruments and to enable new measurements. The following subtopics are concomitant with this objective and are organized by technology.

Subtopics

S1.01 Lidar System Components

Lead Center: LaRC
Participating Center(s): GSFC

Accurate measurements of atmospheric parameters with high spatial resolution from ground, airborne, and space-based platforms require advances in the state-of-the-art lidar technology with emphasis on compactness.
efficiency, reliability, lifetime, and high performance. Innovative lidar component technologies that directly address the measurements of the atmosphere and surface topography of the Earth, Mars, the Moon, and other planetary bodies will be considered under this subtopic. Innovative technologies that can expand current measurement capabilities to spaceborne or Unmanned Aerial Vehicle (UAV) platforms are particularly desirable. Development of components that can be used in planned missions such as Laser Interferometer Space Antenna (LISA) or Earth and planetary composition is highly encouraged. Research should be conducted to demonstrate technical feasibility during Phase 1 and show a path toward a Phase 2 prototype demonstration. For the PY07 SBIR, we are soliciting only the specific component technologies described below.

- Flight qualified, radiation hardened fiber optic components for high power fiber amplifier packages at 1064 nm. Pulse energies in the hundreds of microJoules, and even milliJoule-level, are needed.

- Fiber optic components specifically for use with Yb-doped photonic crystal fibers (PCF), to permit removal of any bulk optics or air gaps in fiber amplifier systems that use a PCF amplifier stage. The following specific components are needed: standard multimode or singlemode fiber to PCF connections, pump couplers for 915 nm or 980 nm, high power isolators at 1064 nm, 1064 nm filters, fiber combiners, and fiber splitters.

- Development of polarization maintaining Er and/or Yb doped optical fibers that are optimized for suppression of stimulated Brillouin scattering (SBS). Resulting fiber must be capable of single frequency.

- Gravitational wave detection in space uses laser interferometric techniques to measure picometer distance changes over megameter baselines. The application requires a space-qualifiable high reliability frequency-stabilized CW laser source with 1 W output power and a 5 year mission lifetime. A Master Oscillator Power Amplifier (MOPA) configuration is desirable because the source must be phase-modulated.

- Efficient and compact single frequency solid state or fiber lasers operating at 1.5 and 2.0 micron wavelength regimes suitable for coherent lidar applications. These lasers must meet the following general requirements: pulse energy 0.2 mJ to 100 mJ, repetition rate 10 Hz to 1 kHz, and pulse duration of approximately 200 nsec.

- Single frequency semiconductor or fiber laser generating 10s of mW of CW power in 1.5 or 2.0 micron wavelength regions with less than 100 kHz linewidth. Frequency modulation with about 5 GHz bandwidth and wavelength tuning over several nanometers are desirable.

- Interferometer technology to separately derive aerosol and molecular backscatter via High Spectral Resolution Lidar (HSRL) technique at 532 and 355 nm. Resolving power of the order of 1 GHz over an acceptance angle up to several milliradians is required. High quantum efficiency detectors, such as electron multiplying CCDs, suitable for spaceborne HSRL instruments are also needed. Detectors should be capable of rapid sampling rates greater than 1.5 MHz at 532 and 355 nm operating wavelengths.
low frequency (less than 10 MHz) sounders to W-band radars for measuring precipitation and clouds. We are seeking proposals for the development of innovative technologies to support future radar missions. Technology innovations should either enhance measurement capabilities (e.g., improve spatial, temporal, or spectral resolution) or ease implementation in spaceborne missions (e.g., reduce size, weight, power, improve reliability, or lower cost). The areas of interest for this call are listed below.

For L- and P-band radar components for surface deformation, topography and soil moisture measurements:

- Lightweight deployable L-band antenna structures and deployment mechanisms suitable for large aperture (reflectors or phased array of 50m² and larger) systems.
- Compact (probably sub-optimal), P-band antennas (possibly folded-dipole arrays, etc.) for airborne and spaceborne systems.
- Rad-hard, high-efficiency, low-cost, lightweight L- and P-band Transmit/Receive (TR) modules (~250 W peak RF output power at ~100 us pulsewidth and 20% duty cycle) with respective energy storage unit to provide pulsed DC power to the power amplifier while minimizing ripple on the primary DC power source.
- 12-bit, 1 GSp/s, 500MHz analog bandwidth ADCs and digital filtering with an emphasis on rad-tolerance and space-qualification.
- Implementation of radar transmitters/receivers using digital signal synthesis.

For Ku- and Ka-band radars for snow cover measurement (Ku) and wetland, river, ocean surface monitoring (Ka) and precipitation radars (X to W-band):

- Lightweight deployable reflectors (Ku-band and Ka-band) and active feed electronics.
- High efficiency Ka-band (34-36GHz) TR modules with output power of 5-10W. The LNAs should have a NF less than 3dB and gain better than 30dB. Included in the TR module is a low loss phase shifter.
- Power amplifier and associated LNA for a Ka-band (34-36GHz) radar system with a peak output power of 2KW to 10KW (duty cycle of 10%) and system bandwidth of up to 1 GHz and LNA NF of less than 1.5dB. The LNA needs to have enough isolation and power handling capability to operate in this high power transmission environment.
- Wide-bandwidth (~500 MHz BW), high-efficiency, rad-tolerant linear FM (chirp) signal generators (sweep rates ~500 MHz in 10 us).
- High performance, low power, compact, rad-hard, real-time radar processors, FPGA based digital receivers, SAR data processing algorithms and data reduction techniques.
**S1.03 Passive Microwave Technologies**

*Lead Center: GSFC*

*Participating Center(s): JPL, MSFC*

NASA employs passive microwave and millimeter-wave instruments for a wide range of remote sensing applications from measurements of the Earth’s surface and atmosphere to cosmic background emission. Proposals are sought for the development of innovative technology to support future science and exploration missions employing 450 MHz to 5 THz sensors. Technology innovations should either enhance measurement capabilities (e.g., improve spatial, temporal, or spectral resolution or improve calibration accuracy) or ease implementation in spaceborne missions (e.g., reduce size, weight, or power, improve reliability, or lower cost). While other concepts will be entertained, specific technology innovations of interest are listed below for missions to measure soil moisture, temperature sounding, cloud particles, and cosmic microwave background.

- Low power >200 Mb/s 1-bit A/D converters and cross-correlators for microwave interferometers;
- Automated assembly of 180 GHz direct conversion I-Q receiver modules;
- Low power, tunable, local oscillators from 400 to 600 GHz with 4-5 mW output power;
- Low noise (3), heterodyne mixers requiring low local oscillator drive power;
- Low DC power spectrometers covering 500 MHz with 125 kHz resolution;
- Highly stable variable correlated noise sources for calibrating correlation-type receivers;
- MMIC Low Noise Amplifiers (LNA). Room temperature LNAs for 165 to 193 GHz with low 1/f noise, and a noise figure of 6.0 dB or better; and cryogenic LNAs for 180 to 270 GHz with noise temperatures of less than 150K;
- High emissivity (near-black-body, >40 dB return loss) surfaces/structures for use as onboard calibration targets that will reduce the weight of aluminum core targets, while reliably improving the uniformity and knowledge of the calibration target temperature;
- New approaches, concepts, and techniques for microwave radiometer system calibration over or within the 1-700 GHz frequency band which provide end-to-end calibration to better than 0.1K, including corrections for temperature changes, standing waves, linearity, and other potential sources of instrumental measurement drift and error;
- 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 108 or more cycles;
- Lightweight deployable L-band antenna structures and deployment mechanisms suitable for large aperture (reflectors or phased array of 50m² and larger) systems;
- Dual-polarization multi-frequency micropatch array antenna designs for combinations of frequencies in the C-, X-, or K-bands.
S1.04 Sensor and Detector Technology for Visible, IR, Far IR and Submillimeter

Lead Center: JPL

Participating Center(s): GSFC, LaRC

Advances in detectors, readout electronics, and other technologies enabling polarimetry and large format imaging arrays for the visible, near IR, IR and far IR/submm and spectroscopy with unprecedented sensitivity are sought. These advances may enable future mission concepts such as the Single Aperture Far Infrared (SAFIR) Observatory (http://safir.jpl.nasa.gov/technologies.shtml), Space Infrared Telescope for Cosmology and Astrophysics (SPICA) (http://www.ir.isas.ac.jp/SPICA/), Cosmic Microwave Background Polarization (CMBPol), and Supernova/ Acceleration Probe (SNAP) (http://snap.lbl.gov).

Research should be conducted to demonstrate technical feasibility during Phase 1 and show a path toward a Phase 2 prototype demonstration. Innovations are sought in detector capability for the following wavelength ranges:

- 0.1-1 µm: Increased sensitivity and larger array size. Improved silicon response in the UV and NIR, smart pixel arrays, solar blind response detector arrays, energy resolving calorimeter arrays.

- 1-4 µm: Increased sensitivity and larger array size. Large format cryogenic readout multiplexers, large format (>1000x1000) array hybridization techniques.

- 4-40 µm: Increased sensitivity and larger array size (megapixels). Low power cryogenic multiplexers, new sensor materials (e.g., novel dopants for extrinsic Si detectors).

- 40-200 µm: Increased sensitivity and larger array size (megapixels). Monolithic focal plane arrays (BIB technologies, new sensor materials).

- 200 µm - 1 mm: Noise equivalent power (NEP) of $10^{-20}$ W Hz$^{-1/2}$ in a 1,000 pixel spectroscopic array with low-power readout electronics, and NEP $10^{-18}$ W Hz$^{-1/2}$ in a 10,000 pixel photometric imaging array. Capabilities for photon counting, polarimetry, and energy resolving detection. Heterodyne receiver arrays operating near the quantum limit.

In addition to technologies specific to the astrophysics mission concepts above, NASA is seeking technologies and improvements to technologies leading to successful measurement of carbon monoxide, methane, nitrous oxide and other related trace species from geostationary and low-Earth orbital platforms. Of particular interest are new techniques in gas filter correlation spectroscopy, Fabry-Perot spectroscopy, or better component technologies for these. The following technologies are also of interest for the Scanning Microwave Limb Sounder Earth science instrument concept (http://mls.jpl.nasa.gov/index-cameo.php):

- Efficient, flight qualifyable, spur free, local oscillators for SIS mixers operating in low Earth orbit. Two bands: (1) tunable from 200 to 250 GHz, and (2) tunable from 610 to 650 GHz. Phase-locked to or derived from ultra-stable 5 MHz reference.

- Technologies for calibrating millimeter wave spectrometers for spaceborne missions, including:
Low power, flight qualifiable comb generators for gain, linearity, and sideband calibration of microwave spectrometers covering the bands from 180 to 270 GHz and from 600 to 660 GHz;

Flight qualifiable low noise diodes for the bands from 180 to 270 and 600 to 660 GHz;

Very low return loss (70 dB or better) calibration targets;

Techniques for quantifying and calibrating out the impact of standing waves in broadband heterodyne submillimeter spectrometers.

- Low power, stable, linear, spectrometers covering the band from 6-18 GHz with 100 MHz resolution.

S1.05 Detector Technologies for UV, X-Ray, Gamma-Ray and Cosmic-Ray Instruments

Lead Center: GSFC

Participating Center(s): MSFC

This subtopic covers detector requirements for a broad range of wavelengths from UV through to gamma ray. As would be expected requirements across the board are for greater numbers of readout pixels, lower power, faster readout rates, greater quantum efficiency, and enhanced energy resolution. Typical semiconductor devices in this energy range are based on silicon or germanium. However, proposals for other detector materials are welcomed if a compelling case is made.

Proposals are specifically solicited for improvements in microchannel plate technology for UV focal plane use; for CCD and active pixel sensor development, both for UV and x-ray use; for technologies leading to very-large-area x-ray detectors for survey instruments; and for electronic systems capable of meeting the needs of Mega-to-Giga-channel detectors. The latter can include not just device development but also, for example, novel interconnect schemes enabling efficient packaging to aid in thermal control and to reduce system noise.

The proposed efforts must be directly linked to a requirement for a NASA mission. These include Explorers, Discovery, Origins, Beyond Einstein and Vision Missions. Details of these can be found at the following URL: http://science.hq.nasa.gov/missions/index.html.

Specific technologies are listed below. Highly desirable are developments that satisfy multiple requested parameters:
Large-format focal plane detectors for use in UV and X-ray imaging and spectrometry:

- Microchannel-plate UV detectors: up to 109 readout channels; quantum efficiency up to 50%.
- UV-sensitive CCD and active pixel sensors with large formats: to 6k x 6k abutable; extended UV response below 0.2 nm.
- X-ray-sensitive CCD and active pixel sensors: up to 4k x 4k formats, 4-side abutable; power levels of 0.1 W / Megapixel; resolutions less than 120 eV; readout rates of at least 30 Hz; extended x-ray response above 6 keV.

- Very-large-area X-ray detectors for survey instruments: square-meter area capability; response from 3-30 keV; ultra-low power (10 microW/channel).

- Significant improvements in wide band gap materials, individual detectors, and detector arrays for UV and EUV applications. Specific examples include AlGaN and SiC based detector arrays and associated readout systems.

- Mega-to-Giga-Channel analogue electronic systems for very-large-area X- and gamma-ray detectors as follows: up to 108 channel capability; less than 10 microW/channel power requirement; less than 100 electron rms noise level with interconnects.

S1.06 Particles and Field Sensors and Instrument Enabling Technologies

Lead Center: GSFC

Advanced sensors for the detection of elementary particles (atoms, molecules and their ions) and electric and magnetic fields in space and associated instrument technologies are often critical for enabling transformational science from the study of the sun’s outer corona, to the solar wind, to the trapped radiation in Earth’s and other planetary magnetic fields, and to the atmospheric composition of the planets and their moons. Improvements in particles and fields sensors and associated instrument technologies enable further scientific advancement for upcoming NASA missions such as Solar Sentinels, GEC, MAGCON, ITSP and planetary exploration missions. Technology developments that result in a reduction in size, mass, power, and cost will enable these missions to proceed. Of interest are advanced magnetometers, electric field booms, ion/atom/molecule detectors, and associated support electronics and materials. Specific areas of interest include:

- Self-calibrating scalar-vector magnetometer for future Earth and space science missions. Performance goals: dynamic range: +/-100,000 nT, accuracy with self-calibration: 1 nT, sensitivity: 5 pT / sqrtHz,Max, max sensor unit size: 6 x 6 x 12 cm, max sensor mass: 0.6 kg, max electronics unit size: 8 x 13 x 5 cm, max electronics mass: 1 kg, and max power: 5 W operation, 0.5 W standby, including, but not limited to “sensors on a chip”.
- High-magnetic-field sensor that measures magnetic field magnitudes to 16 Gauss with an accuracy of 1 part 105.

- Strong, lightweight, thin, compactly-stowed electric field booms possibly using composite materials that deploy sensors to distances of 10m or more.

- Cooled (-60°C) solid state ion detector capable of operating at a floating potential of -15 kV relative to ground.

- Low noise magnetic materials for advanced magnetometer sensors with performance equal to or better than those in the 6-81.3 Mo-Permalloy family.

- Radiation hardened ASIC spectrum analyzer module that determines mass spectra using fast algorithm deconvolution to produce ion counts for specific ion species.

- Low cost, low power, high voltage power supplies 5-15 kV.

- Low power charge sensitive preamplifiers on a chip.

- High efficiency (5% or greater) conversion surfaces for low energy neutral atom conversion to ions possibly based on nanotechnology.

- Long wire boom (>= 50 m) deployment systems for the deployment of very lightweight tethers or antennae on spinning spacecraft.

- Systems to determine the orthogonality of a deployed electric field boom system in flight (for use with three-axis rigid 10-m booms) accurate to 0.1 degrees dynamic.

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**S1.07 Cryogenic Systems for Sensors and Detectors**

**Lead Center:** GSFC

**Participating Center(s):** ARC, JPL, MSFC

Cryogenic cooling systems are often enabling technologies for cutting edge science from infrared imaging and spectroscopy to x-ray calorimetry. Improvements in cryogenic technologies enable further scientific advancement at lower cost, lower risk, reduced volume, and/or reduced mass. Lifetime, reliability, and power requirements of the cryogenic systems are critical performance concerns. Of interest are cryogenic technologies for cooling detectors for scientific instruments and sensors on advanced telescopes and observatories as well as on instruments for lunar and planetary exploration. Active coolers should have long life, low vibration, low mass, low cost, and high efficiency. Specific areas of interest include:

- Essentially vibration-free cooling systems such as reverse Brayton cycle cooler technologies with cooling capability of 20 mW at 4K.

- Highly efficient magnetic and dilution cooling technologies under 1 Kelvin.
Components for advanced magnetic coolers (adiabatic demagnetization refrigerators) including:

- Small (few cm bore), lightweight, low current (under 10A, goal under 5A) superconducting magnets capable of producing at least 3 Tesla central field while operating at least 10 Kelvin. Higher temperature superconductor (HTS) magnets operating at significantly higher temperatures are of particular interest.

- Lightweight (relative to standard ferromagnetic flux guides) active and/or passive magnetic shielding for 3 to 4 Tesla magnets that reduces the stray field to tens of microTesla at a distance of several cm from the outside of the shield.

- Large (several cm) single crystals of magnetocaloric materials.

- Superconducting current leads operating between 90 Kelvin down to 10 Kelvin, capable of carrying up to 10 amperes while allowing only approximately 1 mW of heat to be conducted.

- Compact, accurate, easy to use thermometers that operate down to 10 milliKelvin.

S1.08 in situ Airborne, Surface, and Submersible Instruments for Earth Science

Lead Center: GSFC
Participating Center(s): ARC, JPL, MSFC

There are new platform systems that have the potential to benefit Earth science research activities. To capitalize on these emerging capabilities, proposals are sought for the development of in situ instruments for use on radiosondes, dropsondes, tethered balloons, kites, Unmanned Aerial Vehicles (UAVs), Unmanned Surface Vehicles (USVs), or Unmanned Underwater Vehicles (UUVs). Both miniaturization of current techniques, as well as innovative new methods that lead to compact and lightweight systems are important. Details of complete instrument systems are desired, including data acquisition, power, and platform integration. Instrument performance goals such as resolution, accuracy, and response time should be discussed. A plan for commercial production and marketing should be included as well. Technology innovation areas of interest include:

- Atmospheric measurements including temperature, humidity, solar radiation, clouds, liquid water, ice, precipitation, chemical composition (carbon dioxide, methane, reactive gases and radicals, dynamical tracer species), and aerosol properties;

- Three-dimensional wind measurements near the Earth’s surface, and within the troposphere and lower stratosphere;

- Oceanic measurements including inherent and apparent optical properties, temperature, salinity, chemical composition, nutrient distribution, and currents.

The calibration/validation of the Orbiting Carbon Observatory (OCO - 2008) is a target application. Science campaigns to be conducted within the Sub-Orbital Science Program are also a high priority – the Tropical
Composition, Cloud and Climate Coupling (TC4) is such an example: http://www.espo.nasa.gov/tc4/, as is the Arctic Research of the Composition of the Troposphere from Aircraft and Satellites (ARCTAS): http://www.espo.nasa.gov/arctas/. Systems to enable field studies aimed to research fundamental processes are also of interest.

S1.09 In Situ Sensors and Sensor Systems for Planetary Science

Lead Center: JPL

Participating Center(s): ARC, GSFC

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\textsubscript{2}, 450\textdegree C).
- 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 (}
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.