SBIR/STTR
Small Business Innovation Research / Small Business Technology Transfer

NASA SBIR 2015 Phase I Solicitation

S1 Sensors, Detectors and Instruments

Lead Center: GSFC

NASA's Science Mission Directorate (SMD) (http://nasascience.nasa.gov/) encompasses research in the areas of Astrophysics, Earth Science, Heliophysics and Planetary Science. The National Academy of Science has provided NASA with recently updated Decadal surveys that are useful to identify technologies that are of interest to the above science divisions. Those documents are available at the following locations:Â

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- *AstrophysicsÂ* - (http://sites.nationalacademies.org/bpa/BPA_049810).
- *PlanetaryÂ* - (http://solarsystem.nasa.gov/2013decadal/index.cfm).
- *Earth ScienceÂ* - (http://science.nasa.gov/earth-science/decadal-surveys/).
- *Heliophysics* - The 2009 technology roadmap can be downloaded: (http://science.nasa.gov/heliophysics).Â

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 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 and the other planets in the solar system, 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 that can be deployed on surface landers, rovers, and airborne platforms.Â

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For the 2012 program year, we are restructuring the Sensors, Detectors and Instruments Topic, rotating out, combining and retiring some of the subtopics. Please read each subtopic of interest carefully. One new subtopic, S1.09 Surface and Sub-surface Measurement Systems was added this year. This new subtopic solicits proposals that are for ground-based surface vehicles, and submerged systems. Systems that will provide near-term benefit in a ground-based application but that are ultimately intended for flight or mobile platforms are in scope. A key 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. Proposals are sought for development of components, subsystems and systems that can be used in planned missions or a current technology program. Research should be conducted to demonstrate feasibility during Phase I and show a path towards a Phase II prototype demonstration. The following subtopics are concomitant with these objectives and are organized by technology.

Subtopics

S1.01 Lidar Remote Sensing Technologies

Lead Center: LaRC

Participating Center(s): GSFC, JPL

NASA recognizes the potential of lidar technology in meeting many of its science objectives by providing new capabilities or offering enhancements over current measurements of atmospheric and topographic parameters from ground, airborne, and space-based platforms. To meet NASAs requirements for remote sensing from space, advances are needed in state-of-the-art lidar technology with an emphasis on compactness, efficiency, reliability, lifetime, and high performance. Innovative lidar subsystem and component technologies that directly address the measurement of atmospheric constituents and surface topography of the Earth, Mars, the Moon, and other planetary bodies will be considered under this subtopic. Compact, high-efficiency lidar instruments for deployment on unconventional platforms, such as balloon, small sat, and CubeSat are also considered and encouraged.Â

Proposals must show relevance to the development of lidar instruments that can be used for NASA science-focused measurements or to support current technology programs. Meeting science needs leads to four primary instrument types:Â

- Backscatter measures beam reflection from aerosols to retrieve the opacity of a gas.
- Ranging measures the return beams time-of-flight to retrieve distance.
- Doppler measures wavelength changes in the return beam to retrieve relative velocity.
- Differential absorption measures attenuation of two different return beams (one centered on a spectral line of interest) to retrieve concentration of a trace gas.Â

Phase I research should demonstrate technical feasibility and show a path toward a Phase II prototype unit. Phase II prototypes should be capable of laboratory demonstration and preferably suitable for operation in the field from a ground-based station, an aircraft platform, or any science platform amply defended by the proposer. For the 2015 SBIR Program, NASA is soliciting the component and subsystem technologies described below.Â

Compact and rugged single-frequency continuous-wave and pulsed lasers operating between 0.3-mm and 2.05-mm wavelengths suitable for lidar. Specific wavelengths are of interest to match absorption lines or atmospheric transmission: 0.29-0.32-mm (ozone absorption), 0.532-mm, 1.0-mm, 1.57-mm (CO_2 line), 1.65-mm (methane line), and 2.05-mm (CO_2 line). For wavelengths associated with an absorption line, tunability on the order tens of nanometers is desired. Architectures involving new developments in diode laser, quantum cascade laser, and fiber laser technology are especially encouraged. For pulsed lasers two different regimes of repetition rate and pulse energies are desired: from 8-kHz to 10-kHz with pulse energy greater than 1-mJ and from 20-Hz to 100-Hz with pulse energy greater than 100-mJ.Â

Optical amplifiers for increasing the energy of pulsed lasers in the wavelength range of 0.3-mm to 2.05-mm. Specific wavelengths of interest are listed above in the bullet above. Also, amplifier and modulator combinations for converting continuous-wave lasers to a pulsed format are encouraged. Amplifier designs must preserve the wavelength stability and spectral purity of the input laser.Â

Ultra-low noise photoreceiver modules, operating either at 1.6-mm or 2.0-mm wavelengths, consisting of the detection device, complete Dewar/cooling systems, and associated amplifiers. General requirements are: large single-element active detection diameter (>200 micron), high quantum efficiency (>85%), noise equivalent power of the order of 10-14 W/sqrt(Hz), and bandwidth greater than 10 MHz.Â

Novel, highly efficient approaches for High Spectral Resolution Lidar (HSRL) receivers. New approaches for high-efficiency measurement of HSRL aerosol properties at 1064, 532 and/or 355 nm. New or improved approaches are sought that substantially increase detection efficiency over current state of the art. Ideally, complete receiver subsystems will be proposed that can be evaluated and/or implemented in instrument concept designs.

New space lidar technologies that use small and high-efficiency diode or fiber lasers to measure range and surface reflectance of asteroids and comets from >100 km altitude during mapping to <1 m during landing and sample return at a fraction of the power, mass, and cost of the Mercury Laser Altimeter (i.e., less than 7.4kg, 17W, and 28x28x26cm).Â The technologies can significantly extend the receiver dynamic range of the current space lidar without movable attenuators, providing sufficient link margin for the longest range but not saturating during landing. The output power of the laser transmitters should be continuously adjusted according to the spacecraft altitude. The receiver should have single photon sensitivity to achieve a near-quantum limited performance for long distance measurement. The receiver integration time can be continuously adjusted to allow trade-off between the maximum range and measurement rate. The lidar should have multiple beams so that it can measure not only the range but also surface slope and orientation.

Semiconductor lasers tunable in the 3-mm to 16-mm wavelength range with stable, narrow linewidth operation for applications in environmental gas and pollutant sensing, Earth and planetary atmospheric studies, and calibration of thermal infrared sensors.Â General requirements are for high power (>50mW), wavelength stability (<10MHz), and single-mode spectrum.

S1.02 Microwave Technologies for Remote Sensing

Lead Center: JPL

Participating Center(s): GSFC

NASA employs active (radar) and passive (radiometer) microwave sensors for a wide range of remote sensing applications (for example, see http://www.nap.edu/catalog/11820.html). These sensors include low frequency (less than 10 MHz) sounders to G-band (160 GHz) radars for measuring precipitation and clouds, for planetary landing, upper atmospheric monitoring, and global snow coverage, topography measurement and other Earth and planetary science applications. We are seeking proposals for the development of innovative technologies to support these future radar and radiometer missions and applications. The areas of interest for this call are listed below.

Ka-band Power Amplifier for CubeSats:Â

- F = 35.7 GHz +/- 200MHz.
- Volume: <1U (10mmx10mmx10mm).
- Psat>32W.
- Gain > 35 dB.
- PAE > 20%.Â

Deployable Ka-band Antennas for CubeSats:Â

- F = 35.7 GHz +/- 200MHz.
- Aperture size = 0.75m.
- Gain > 45dB.
- Sidelobe ratio > 20dB.
- Stowed volume: <2.5U (25mmx10mmx10mm).
- Polarization: Linear.Â

Components for addressing gain instability in LNA based radiometers from 100 and 600 GHz.

NASA requires low insertion loss solutions to the challenges of developing stable radiometers and spectrometers operating above 100 GHz that employ LNA based receiver front ends. This includes noise diodes with ENR>10dBm with better than d 0.01 dB/Â°C thermal stability, Dicke switches with better than 30 dB isolation, phase modulators, and low loss isolators along with fully integrated state-of-art receiver systems operating at room and cryogenic temperatures.

Technology for low-power, rad-tolerant broad band spectrometer back ends for microwave radiometers.Â

Includes digitizers with 20 Gsps, 20 GHz bandwidth, 4 or more bit and simple interface to FPGA, ASIC implementations of polyphase spectrometer digital signal processing with ~1 watt/GHz.Â

Local Oscillator technologies for THz instruments.Â

This can include GaN based frequency multipliers that can work in the 200-400 with better than 30% efficiency GHz range (output frequency) with input powers up to 1 W.Â Graphene based devices that can work as frequency multipliers in the frequency range of 1-3 THz with efficiencies in the 10% range and higher.Â

Low power RFI mitigating receiver back ends for broad band microwave radiometers.Â

Low power, low mass, low volume, and low data rate RFI mitigating receiver back end that can be incorporated into existing and future radiometer designs. The system should be able to channelize up to 1 GHz with 16 sub bands and be able to identify RFI contamination using tools such as kurtosis.**Â**

Components for addressing gain instability in LNA based radiometers from 100 and 600 GHz.Â

NASA requires low insertion loss solutions to the challenges of developing stable radiometers and spectrometers operating above 100 GHz that employ LNA-based receiver front ends. This includes noise diodes with ENR>10dBm with better than d 0.01 dB/Â°C thermal stability, Dicke switches with better than 30 dB isolation, phase modulators, and low loss isolators along with fully integrated state-of-art receiver systems operating at room and cryogenic temperatures.

Fast tuning, low-phase-noise, widely tunable, low-power, microwave synthesizers.

Used as reference source for Earth/planetary applications. The frequency tunability should be >=15% within the frequency range of 23 to 29 GHz. Power level <= 5 W, with radiation tolerance at least 100 krad, 300 krad preferable. Tuning speed <= 10 ms.Â

Development of 4 channels VHF (240-270 MHz) passive receiver for 6U Cubesat platforms.

Enables Root Zone Soil Moisture Measurements from LEO using the Follow-on military SatComm satellites as signals of opportunity transmitters.Â

Development of innovative analogue/digital hardware designs for the implementation of distributed beam forming Synthetic Aperture Radar (SAR) architectures.Â

Enables beam steering over many array elements while reducing size, weight, and power compare to state-of-the-art.

Radars operating at 17.0 GHz +/- 150 MHz, >=6W transmit power meeting a detection capability with a range of 54km for a 20 square meter target.

The radar will be part of a Laser Hazard Reduction System(LHRS). The installed LHRS provides a means of detecting aircraft before they intersect a transmitted laser beam. Upon detecting an aircraft by the radar, the LHRS provides a signal so that laser beam be blocked to transmit.Â

Interconnection technologies to enable highly integrated, low loss distribution networks that integrate power splitters, couplers, filters, and/or isolators in a compact package. Technologies are sought that integrate X, Ku, and Ka-bands transmit/receive modules with antenna arrays and/or LO distribution networks for F- and/or G-band receiver arrays.

Dual-frequency (Ka/W-band), dual polarization compact quasi-optical front-end for cloud radars.

- Freq: 35.5 GHz Â± 100MHz.
- 94 GHz Â± 100MHz.
- Loss: < 0.5 dB.
- Polarization Isolation: > 30 dB.

- Polarization: V and H.

Development of structurally integrated/embedded airborne (P3, C130 aircrafts) antennas.Â

Enables mounting in non-traditional locations (e.g., doors, wing skins, fuselage panels and wing leading edges) covering 20 MHz-500 MHz bandwidth.

Analog to Digital (A/D) and Digital to Analog (D/A) Monolithic Integrated Circuit (MMIC) for P-band and L-band radar.Â

High efficiency, low power, high throughput.

S1.03 Sensor and Detector Technology for Visible, IR, Far IR and Submillimeter

Lead Center: JPL

Participating Center(s): ARC, GSFC, KSC, LaRC

NASA is seeking new technologies or improvements to existing technologies to meet the detector needs of future missions, as described in the most recent decadal surveys:

- Earth science (http://www.nap.edu/catalog/11820.html).
- Planetary science (http://www.nap.edu/catalog/10432.html).
- Astronomy and astrophysics (http://www.nap.edu/books/0309070317/html/).Â

Development of un-cooled or cooled infrared detectors (hybridized or designed to be hybridized to an appropriate read-out integrated circuit) with NEÎ”T<20mK, QE>30% and dark currents <1.5x10-6 A/cm^2 in the 5-14 Î¼m infrared wavelength region. Array formats may be variable, 640 x 512 typical, with a goal to meet or exceed 2k X 2k pixel arrays. Evolve new technologies such as InAs/GaSb type-II strained layer super-lattices to meet these specifications.Â

New or improved technologies leading to measurement of trace atmospheric species (e.g., CO, CH_4, N_2O) or broadband energy balance in the IR and far-IR from geostationary and low-Earth orbital platforms. Of particular interest are new direct, nanowire or heterodyne detector technologies made using high temperature superconducting films (YBCO, MgB_2) or engineered semiconductor materials, especially 2-Dimensional Electron Gas (2-DEG) and Quantum Wells (QW) that operate at temperatures achieved by standard 1 or 2 stage flight qualified cryocoolers and do not require cooling to liquid helium temperatures. Candidate missions are thermal imaging, LANDSAT Thermal InfraRed Sensor (TIRS), Climate Absolute Radiance and Refractivity Observatory (CLARREO), BOReal Ecosystem Atmosphere Study (BOREAS), Methane Trace Gas Sounder or other infrared earth observing missions.Â

1k x 1k or larger format MCT detector arrays with cutoff wavelength extended to 12 microns for use in missions to NEOs, comets and the outer planets.

Compact, low power, readout electronics for KID arrays. Enables mega pixel arrays for mm to Far IR telescopes and spectrometers for astrophysics and earth observation.Â

Development of a robust wafer-level integration technology that will allow high-frequency capable interconnects and allow two dis-similar substrates (i.e., silicon and GaAs) to be aligned and mechanically 'welded' together. Specially develop ball grid and/or Through Silicon Via (TSV) technology that can support submillimeter-wave arrays. Initially the technology can be demonstrated at the '1-inch' die level but should be do-able at the 4-inch wafer level.

Development of an un-cooled (single element or array) infrared detector with an active area of 1x1 mm or greater, a sensitivity (D*) of 10^9 $cmHz^{1/2}W^{-1}$ or greater, and a response speed of 10 kHz or greater in the 5 â€“ 50 um wavelength region. This new detector will be useful for the Climate Absolute Radiance and Refractivity Observatory (CLARREO).Â

S1.04 Detector Technologies for UV, X-Ray, Gamma-Ray and Cosmic-Ray Instruments

Lead Center: GSFC

Participating Center(s): JPL, MSFC

This subtopic covers detector requirements for a broad range of wavelengths from UV through to gamma ray for applications in Astrophysics, Earth Science, Heliophysics, and Planetary Science. Requirements across the board are for greater numbers of readout pixels, lower power, faster readout rates, greater quantum efficiency, and enhanced energy resolution.Â

The proposed efforts must be directly linked to a requirement for a NASA mission. These include Explorers, Discovery, Cosmic Origins, Physics of the Cosmos, Vision Missions, and Earth Science Decadal Survey missions. Details of these can be found at the following URLs:

General Information on Future NASA Missions:Â

- (http://www.nasa.gov/missions).

Specific mission pages:Â

- IXO - (http://htxs.gsfc.nasa.gov/index.html).
- Future planetary programs - (http://nasascience.nasa.gov/planetary-science/mission_list).
- Earth Science Decadal missions - (http://www.nap.edu/catalog/11820.html).
- Helio Probes - (http://nasascience.nasa.gov/heliophysics/mission_list).Â

Specific technology areas are:Â

- Significant improvement in wide band gap semiconductor materials, such as AlGaN, ZnMgO and SiC, individual detectors, and detector arrays for operation at room temperature or higher for missions such as Geo-CAPE, NWO, ATALAST and planetary science composition measurements.
- Highly integrated, low noise (< 300 electrons rms with interconnects), low power (< 100 uW/channel) mixed signal ASIC readout electronics as well as charge amplifier ASIC readouts with tunable capacitive inputs to match detector pixel capacitance. See needs of National Research Council's Earth Science Decadal Survey (NRC, 2007): Future Missions include GEOCape, HyspIRI, GACM, future GOES and SOHO programs and planetary science composition measurements.
- Visible-blind SiC Avalanche Photodiodes (APDs) for EUV photon counting are required. The APDs must show a linear mode gain >10E6 at a breakdown reverse voltage between 80 and 100V. The APD's must demonstrate detection capability of better than 6 photons/pixel/s down to 135nm wavelength. See needs of National Research Council's Earth Science Decadal Survey (NRC, 2007): Tropospheric ozone.
- Large area (3 m^2) photon counting near-UV detectors with 3 mm pixels and able to count at 10 MHz. Array with high active area fraction (>85%), 0.5 megapixels and readout less than 1 mW/channel. Future instruments are focal planes for JEM-EUSO and OWL ultra-high energy cosmic ray instruments and ground Cherenkov telescope arrays such as CTA, and ring-imaging Cherenkov detectors for cosmic ray instruments such as BESS-ISO. As an example (JEM-EUSO and OWL), imaging from low-Earth orbit of air fluorescence, UV light generated by giant air showers by ultra-high energy (E >10E19 eV) cosmic rays require the development of high sensitivity and efficiency detection of 300-400 nm UV photons to measure signals at the few photon (single photo-electron) level. A secondary goal minimizes the sensitivity to photons with a wavelength greater than 400 nm. High electronic gain (10E4 to 10E6), low noise, fast time response (<10 ns), minimal dead time (<5% dead time at 10 ns response time), high segmentation with low dead area (<20% nominal, <5% goal), and the ability to tailor pixel size to match that dictated by the imaging optics. Optical designs under consideration dictate a pixel size ranging from approximately 2 x 2 mm^2 to 10 x 10 mm^2. Focal plane mass must be minimized (2g/cm^2 goal). Individual pixel readout is required. The entire focal plane detector can be formed from smaller, individual sub-arrays.Â

S1.05 Particles and Field Sensors and Instrument Enabling Technologies

Lead Center: GSFC

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

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 CubeSats, Explorers, IMAP, GDC, DYNAMIC, MEDICI, 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:Â

- Self-calibrating scalar-vector magnetometer for future Earth and space science missions. Performance goals: dynamic range: Â±100,000 nT, accuracy with self-calibration: 1 nT, sensitivity: 5 pT - Hz-1/2 (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 in 105.
- Low-noise magnetic materials for advanced magnetometer sensors with performance equal to or better than those in the 6-81.3 Mo-Permalloy family.
- Deployable magnetic clean booms up to 50cm.
- Strong, lightweight, thin, rigid, compactly stowed electric field booms possibly using composite materials that deploy sensors (including internal harness) to distances of 10 m or more.
- Long wire boom (â‰¥ 50 m) deployment systems for the deployment of sensors attached to very lightweight tethers or antennae on spinning spacecraft.
- Small satellite rigid electric field booms: for three-axis stabilized spacecraft. Note for Cubesat applications: Full three-component measurement (six booms) must fit inside 6U Cubesat form factor, booms must be thin, rigid, and deploy to lengths >= 2m, including sensors and harness.
- Small satellite wire booms: for spinning spacecraft. Two pairs of sensors attached to lightweight tethers or antennae. Note for Cubesat applications: Must deploy to >= 5m and fit inside a 3U or larger Cubesat form factor.
- Development of tools to study spacecraft charging for the purpose of understanding effects on charged particle measurements, particularly at reduced energies.
- Radiation-hardened >200 Krads ASICs including Low-power multi-channel ADCs, DACs >16-bits and > 100MSPS, and >20 bits and >1MSPS.
- Low-cost, low-power, fast-stepping (â‰¤ 50-Âµs), high-voltage power supplies 1V-6kV. High Voltage opto coupler components as a control element of HVPS, with >12KV isolation and >100 krad radiation tolerance.
- High efficiency (>2% or greater) conversion surfaces for energetic (1eV to 10KeV) neutral atom conversion to ions.
- High reliability cold electron emitters based on MCP or nano technology with emission surfaces 1-1000mm^2 and life time > 20,000.
- Solar Blind particle detectors less sensitive to light for particle detection in the energy Range 1KeV to 100MeV.
- Developing near real-time data-assimilative models and tools, for both solar quiet and active times, which allow for precise specification and forecasts of the space environment, beginning with solar eruptions and propagation, and including ionospheric electron density specification.Â

S1.06 In Situ Sensors and Sensor Systems for Lunar and Planetary Science

Lead Center: JPL

Participating Center(s): ARC, GRC, GSFC, JSC, KSC, MSFC

This subtopic solicits development of advanced instrument technologies and components suitable for deployment on planetary and lunar missions. These technologies must be capable of withstanding operation in space and planetary environments, including the expected pressures, radiation levels, launch and impact stresses, and range of survival and operational temperatures. Technologies that reduce mass, power, volume, and data rates for instruments and instrument components without loss of scientific capability are of particular importance. In addition, technologies that can increase instrument resolution and sensitivity or achieve new & innovative scientific measurements are solicited. For example missions, see (http://science.hq.nasa.gov/missions). For details of the specific requirements see the National Research Councilâ€™s, Vision and Voyages for Planetary Science in the Decade 2013-2022 (http://solarsystem.nasa.gov/2013decadal/). Technologies that support NASAâ€™s New Frontiers and Discovery missions to various planetary bodies are of top priority.Â

In situ technologies are being sought to achieve much higher resolution and sensitivity with significant improvements over existing technologies. Orbital sensors and technologies that can provide significant improvements over previous orbital missions are also sought. Specifically, this subtopic solicits instrument development that provides significant advances in the following areas, broken out by planetary body:

- *Mars* - Sub-systems relevant to current in situ instrument needs (e.g., lasers and other light sources from UV to microwave, X-ray and ion sources, detectors, mixers, mass analyzers, etc.) or electronics technologies (e.g., FPGA and ASIC implementations, advanced array readouts, miniature high voltage power supplies). Technologies that support high precision in situ measurements of elemental, mineralogical, and organic composition of planetary materials are sought. Conceptually simple, low risk technologies for in situ sample extraction and/or manipulation including fluid and gas storage, pumping, and chemical labeling to support analytical instrumentation. Seismometers, mass analyzers, technologies for heat flow probes, and atmospheric trace gas detectors. Improved robustness and g-force survivability for instrument components, especially for geophysical network sensors, seismometers, and advanced detectors (iCCDs, PMT arrays, etc.). Instruments geared towards rock/sample interrogation prior to sample return are desired.
- *Europa & Io* - Technologies for high radiation environments, e.g., radiation mitigation strategies, radiation tolerant detectors, and readout electronic components, which enable orbiting instruments to be both radiation-hard and undergo the planetary protection requirements of sterilization (or equivalent) for candidate instruments on proposed missions such as Europa Clipper and Io Volcano.
- *Titan* - Low mass and power sensors, mechanisms and concepts for converting terrestrial instruments such as turbidimeters and echo sounders for lake measurements, weather stations, surface (lake and solid) properties packages, etc. to cryogenic environments (95K). Mechanical and electrical components and subsystems that work in cryogenic (95K) environments; sample extraction from liquid methane/ethane, sampling from organic 'dunes' at 95K and robust sample preparation and handling mechanisms that feed into mass analyzers are sought. Balloon instruments, such as IR spectrometers, imagers, meteorological instruments, radar sounders, air sampling mechanisms for mass analyzers, and aerosol detectors are also solicited.
- *Venus* - Sensors, mechanisms, and environmental chamber technologies for operation in Venus's high temperature, high-pressure environment with its unique atmospheric composition. Approaches that can enable precision measurements of surface mineralogy and elemental composition and precision measurements of trace species, noble gases and isotopes in the atmosphere are particularly desired.
- *Small Bodies* - Technologies that can enable sampling from asteroids and from depth in a comet nucleus, improved in situ analysis of comets. Also, imagers and spectrometers that provide high performance in low light environments dust environment measurements & particle analysis, small body resource identification, and/or quantification of potential small body resources (e.g., oxygen, water and other volatiles, hydrated minerals, carbon compounds, fuels, metals, etc.). Specifically, advancements geared towards instruments that enable elemental or mineralogy analysis (such as high-sensitivity X-ray and UV-fluorescence spectrometers, UV/fluorescence flash lamp/camera systems, scanning electron microscopy with chemical analysis capability, time-of-flight mass spectrometry, gas chromatography and tunable diode laser sensors, calorimetry, laser-Raman spectroscopy, imaging spectroscopy, and LIBS) are sought. These developments should be geared towards sample interrogation, prior to possible sample return.
- Saturn, Uranus and Neptune: Technologies are sought for components, sample acquisition and instrument systems that can enhance mission science return and withstand the low-temperatures/high-pressures of the atmospheric probes during entry.
- *The Moon* - This solicitation seeks advancements in the areas of compact, light-weight, low power instruments geared towards in situ lunar surface measurements, geophysical measurements, lunar atmosphere and dust environment measurements & regolith particle analysis, lunar resource identification,

and/or quantification of potential lunar resources (e.g., oxygen, nitrogen, and other volatiles, fuels, metals, etc.). Specifically, advancements geared towards instruments that enable elemental or mineralogy analysis (such as high-sensitivity X-ray and UV-fluorescence spectrometers, UV/fluorescence flash lamp/camera systems, scanning electron microscopy with chemical analysis capability, time-of-flight mass spectrometry, gas chromatography and tunable diode laser sensors, calorimetry, laser-Raman spectroscopy, imaging spectroscopy, and LIBS) are sought. These developments should be geared towards sample interrogation, prior to possible sample return. Systems and subsystems for seismometers and heat flow sensors capable of long-term continuous operation over multiple lunar day/night cycles with improved sensitivity at lower mass and reduced power consumption are sought. Also of interest are portable surface ground penetrating radars to characterize the thickness of the lunar regolith, as well as, low mass, thermally stable hollow cubes and retro-reflector array assemblies for lunar surface laser ranging. Of secondary importance are instruments that measure the micrometeoroid and lunar secondary ejecta environment, plasma environment, surface electric field, secondary radiation at the lunar surface, and dust concentrations and its diurnal dynamics are sought. Further, lunar regolith particle analysis techniques are desired (e.g., optical interrogation or software development that would automate integration of suites of multiple back scatter electron images acquired at different operating conditions, as well as permit integration of other data such as cathodoluminescence and energy-dispersive x-ray analysis.)Â

Proposers are strongly encouraged to relate their proposed development to:Â

- NASA's future planetary exploration goals.
- Existing flight instrument capability, to provide a comparison metric for assessing proposed improvements.Â

Proposed instrument architectures should be as simple, reliable, and low risk as possible while enabling compelling science. Novel instrument concepts are encouraged particularly if they enable a new class of scientific discovery. Technology developments relevant to multiple environments and platforms are also desired.

Proposers should show an understanding of relevant space science needs, and present a feasible plan to fully develop a technology and infuse it into a NASA program.Â

S1.07 Airborne Measurement Systems

Lead Center: GSFC

Participating Center(s): ARC, GRC, JPL, KSC, LaRC, MSFC, SSC

Measurement system miniaturization and/or increased performance is needed to support for NASA's airborne science missions, particularly those utilizing the Global Hawk, SIERRA-class, Dragon Eye or other unmanned aircraft. The subject airborne instruments are intended as calibration/validation systems - the proposers should demonstrate an understanding of the measurement requirements and be able to link those to instrument performance. Linkages to other subtopics such as S3.04 Unmanned Aircraft and Sounding Rocket Technologies are encouraged. Complete instrument systems are desired, including features such as remote/unattended operation and data acquisition, low power consumption, and minimum size and weight. Desired sensors include:Â

- Miniaturized, high performance instrument suites for multidisciplinary applications.
- Spectrally resolved absorption and extinction of atmospheric aerosols (0.1 to 10 micron).
- High accuracy and precision atmospheric measurements of Nitrous Oxide, Ammonia, and Formaldehyde (>1 Hz).
- Novel measurement approaches for measurement of Carbon Dioxide (>1 ppm), Methane (5 ppb accuracy, 10 ppb precision), and Water Vapor (>0.5% precision).
- Small (<100 lbs) hyperspectral imagers: 350 to 2500 nanometers with signal to noise > 300 to 1.
- Sulfur based chemistry such as Sulfur Dioxide, Dimethyl Sulfide, Carbonyl Sulfide, Sulfate Aerosols.
- Precipitation - multiphase (0.1 mm to 20 mm with 5 % accuracy in three dimensions).
- Surface snow thickness (5 cm resolution).
- Aerosols and cloud particles (0.01 micron to 200 micron with 10% accuracy).
- Sun photometry measurements with accuracies of <1%.

- Volcanic ash (0.25 to 100 micron with 10 % accuracy).
- Three-dimensional wind measurement (1 mps accuracy/resolution at 10 Hz sampling).
- Miniature (< 7 lb) mass spectrometer with measurement range of 1 to 150 atomic mass units (amu) and resolution of 1 amu, able to detect molecular gas species of He, H_2, H_2O, N_2, O_2, Ar, CO_2, SO_2, OCS, H_2S, CH_4, NH3 with sensitivity of 1 ppm.

S1.08 Surface & Sub-surface Measurement Systems

Lead Center: ARC

Participating Center(s): GSFC, JPL, KSC, LaRC, MSFC, SSC

Surface & Sub-surface Measurement Systems are sought with relevance to future space missions such as Active Sensing of CO_2 Emissions over Nights, Days, and Seasons (ASCENDS), Orbiting Carbon Observatory - 2 (OCO-2), Global Precipitation Measurement (GPM), Geostationary Coastal and Air Pollution Events (GEO-CAPE), Hyperspectral InfraRed Imager (HyspIRI), Aerosol, Cloud, and Ecosystems (ACE, including Pre-ACE/PACE). Early adoption for alternative uses by NASA, other agencies, or industry is desirable and recognized as a viable path towards full maturity.Â

Sensor system innovations with significant near-term commercial potential that may be suitable for NASA's research after full development are of interest:Â

- Precipitation (e.g., motion stabilized disdrometer for shipboard deployments).
- Suspended particle concentrations and spectra of mineral and biogenic (phytoplankton and detritus) components.
- Gases carbon dioxide, methane, etc., only where the sensing technology solution will clearly exceed current state of the art for its targeted application.
- Miniaturized air-dropped sensors, suitable for Global Hawk deployment, for ocean surface and subsurface measurements such as conductivity, temperature, and depth.
- Miniature systems suitable for penetration of thin ice are highly desirable.
- Multi-wavelength, LIDAR-based, atmospheric ozone and aerosol profilers for continuous, simultaneous observations from multiple sites. Examples include three-band ozone measurement systems operating in the UV spectrum (e.g., 280-316 nm, possibly tunable), combined with visible or infrared systems for aerosols.
- Remote/untended operation, minimum eye-hazards, and portability are desired.
- Miniaturized and novel instrumentation for measuring inherent and apparent optical properties (specifically to support vicarious calibration and validation of ocean color satellites, i.e., reflectance, absorption, scattering), in situ biogeochemical measurements of marine and aquatic components and rates including but not limited to nutrients, phytoplankton and their functional groups, and floating and submerged aquatic plants.
- Novel geophysical and diagnostic instruments suitable for ecosystem monitoring. Fielding for NASA's Applications and Earth Science Research activities is a primary goal. Innovations with future utility for other NASA programs (for example, Planetary Research) that can be matured in an Earth science role are also encouraged.Â

S1.09 Atomic Interferometry

Lead Center: JPL

Participating Center(s): GSFC

Recent developments of laser control and manipulation of atoms have led to new types of precision inertial force and gravity sensors based on atom interferometry. Atom interferometers exploit the quantum mechanical wave nature of atomic particles and quantum gases for sensitive interferometric measurements. Ground-based laboratory experiments and instruments have already demonstrated beyond the state of the art performances of accelerometer, gyroscope, and gravity measurements. The microgravity environment in space provides opportunities for further drastic improvements in sensitivity and precision. Such inertial sensors will have great potential to provide new capabilities for NASA Earth and planetary gravity measurements, for spacecraft inertial navigation and guidance, and for gravitational wave detection and test of properties of gravity in space.Â

Currently the most mature development of atom interferometers as measurement instruments are those based on light pulsed atom interferometers with freefall cold atoms. There remain a number of technical challenges to infuse this technology in space applications. Some of the identified key challenges are (but not limited to):

- Compact high flux ultra-cold atom sources for free space atom interferometers (Example: $>1x10^6$ total useful free-space atoms, <1 nK, Rb, K, Cs, Yb, Sr, and Hg. Performance and species can be defined by offerors). Other related innovative methods and components for cold atom sources are of great interest, such as a highly compact and regulatable atomic vapor cell.
- Ultra-high vacuum technologies that allow completely sealed, non-magnetic enclosures with high quality optical access and the base pressure maintained $<1x10^{-9}$ torr. Consideration should be given to the inclusion of cold atom sources of interest.
- Beyond the state-of-the-art photonic components at wavelengths for atomic species of interest, particularly at NIR and visible: efficient acousto-optic modulators (low rf power ~ 200 mW or less, low thermal distortion, ~80% or greater diffraction efficiency); efficient electro-optic modulators (low bias drift, residual AM, and return loss, fiber-coupled preferred), miniature optical isolators (~30 dB isolation or greater, ~ -2 dB loss or less), robust high-speed high-extinction shutters (switching time < 1 ms, extinction > 60 dB are highly desired).
- Flight qualifiable lasers of narrow linewidth and higher power for clock and cooling transitions of atomic species of interest. Cooling and trapping lasers: 10 kHz linewidth and ~ 1 W or greater total optical power. Compact clock lasers: $5x10^{-15}$ Hz/$tau^{1/2}$ near 1 s (wavelengths for Yb^+, Yb, Sr clock transitions are of special interest).
- Analysis and simulation tool of a cold atom system in trapped and freefall states relevant to atom interferometer and clock measurements in space.Â

All proposed system performances can be defined by offerers with sufficient justification. Subsystem technology development proposals should clearly state the relevance, define requirements, relevant atomic species and working laser wavelengths, and indicate its path to a space-borne instrument.Â

S1.10 Cryogenic Systems for Sensors and Detectors

Lead Center: GSFC

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

Cryogenic cooling systems often serve as enabling technologies for detectors and sensors flown on scientific instruments as well as advanced telescopes and observatories. As such, technological improvements to cryogenic systems further advance the mission goals of NASA through enabling performance (and ultimately science gathering) capabilities of flight detectors and sensors. There are six potential investment areas that NASA is seeking to expand state of the art capabilities for possible use on future programs such as WFirst (http://wfirst.gsfc.nasa.gov/), the Europa Jupiter System Science missions (http://www.nasa.gov/multimedia/podcasting/jpl-europa20090218.html) and PIXIE (Primordial Inflation Explorer). The topic areas are as follows:Â

- *Miniaturized/Efficient Cryocooler Systems* - Cryocooler systems viable for application on CubeSat space platforms are sought. Present state of the art capabilities demonstrate approximately 0.4W of cooling capacity at 77K provided an input power of 5W. Contemporary system mass is on the order of 400 grams. Desired performance specifications for cryocoolers sought include a cooling capability on the order of 0.2W at temperatures spanning 30K - 80K. Desired masses and input powers will be < 400 grams and < 5W respectively.
- *Magnetic Cooling Systems* - State of the art sub-Kelvin temperature control architectures that use magnetic cooling consist of ADR (Adiabatic Demagnetization Refrigeration) systems. The Astro-H FM (Flight Model) ADR represents the state of the art in ADR system and component level technologies for space application. Future missions requiring cooling to sub-Kelvin levels will look to use new and improved ADR systems. AMRR (Active Magnetic Regenerative Refrigeration) systems are a related magnetic cooling technology that requires system and component level development in order to attain sub-Kelvin cooling levels.

Improvements at the component level may lead to better overall system performance and increased hold times at target temperatures. Both of these are highly advantageous and desirable to future science missions. Specific components sought include:

- Low current superconducting magnets (3-4 Tesla at temperatures > 15K).
- Heat Switches.
- High cooling power density magnetocaloric materials, especially single crystals with volume > 20 cm^3.
- Active/Passive magnetic shielding (for use with 3-4 Tesla magnets).
- Superconducting leads (10K - 90K) capable of 10 A operation with 1 mW conduction.
- 10 mK- 300 mK high resolution thermometry.
- *High Capacity/Efficiency Cryocooler Systems* - High Capacity/Efficiency cryocoolers are of interest for use on future science missions. State of the art high capacity cryocooler systems have demonstrated cooling capabilities spanning 0.3W - 1W with a load temperature of 20K and < 0.3 W at 10K. High Capacity cryocoolers are available at low to mid TRL levels for both Pulse Tube (e.g., 5W cooling capacity at 20K) and Turbo Brayton (e.g., cooling capacity of 20W at 20K) configurations. Desired cryocooler systems will provide cold tip operational temperatures spanning 10K to 20K with a cooling capacity of > 4W at 20K.
- *Low Temperature/Input Power Cooling Systems* - Low temperature/Input Power Cooling systems are sought for application on future Planetary missions that require performance in space environments that have limited access to power. Contemporary cooling systems are incapable of providing cooling loads as high as 0.2W at 30K while rejecting heat to an ambient environment of approximately 150K. Cooling systems providing cooling capacities of approximately 0.3W at 35K with heat rejection capability to temperature sinks at 150 K or lower are of interest.
- *Sub-Kelvin Cooling Technologies* - Contemporary ADR systems provide the highest cooling capacities and the lowest load temperatures of all sub-Kelvin techniques viable for space application. Cultivation of additional technology options are of interest. Candidate technologies for investigation may include closed cycle dilution cooling and/or alternative magnetic refrigeration techniques and cycles.
- *Continuous Flow Distributed Cooling Systems* - Distributed cooling provides increased lifetime of cryogen fluids for application on both the ground and spaceborne platforms. This has impacts on payload mass and volume for flight systems which translate into costs (either on the ground, during launch or in flight). Mission enabling components for use with distributed cooling systems are sought. Examples of such include cryo-valves and integral/non-integral cryocooler components.Â

Proposals considered viable for Phase I award will seek to validate hypotheses through proof of concept testing at relevant temperatures.Â Â