NASA SBIR 2014 Phase I Solicitation

S1 Sensors, Detectors and Instruments

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:

- Astrophysics - (http://sites.nationalacademies.org/bpa/BPA_049810).
- Planetary - (http://solarsystem.nasa.gov/2013decadal/index.cfm).
- Earth Science - (http://science.nasa.gov/earth-science/decadal-surveys/).
- Heliophysics - The 2009 technology roadmap can be downloaded at (http://science.nasa.gov/heliophysics/).

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.

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 NASA's requirements, 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 systems 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.

Proposals relevant to the development of lidar instruments that can be used in planned missions or current technology programs are highly encouraged. Examples of planned missions and technology programs are:

- Active Sensing of CO_2 Emissions over Nights, Days, and Seasons (ASCENDS).
- Aerosols-Clouds-Ecosystems (ACE).
- Doppler Wind Lidar (3D-WINDS).
- Laser Interferometer Space Antenna (LISA).
- Ozone Lidar.
- Lidar for Surface Topography (LIST).
- Mars atmospheric sensing, atmospheric entry and descent sensors for Mars and Earth, and tracking large-scale water movement (GRACE-II).

In addition, innovative technologies relevant to the NASA sub-orbital programs, such as Unmanned Aircraft Systems (UAS) and Venture-class focusing on the studies of the Earth climate, carbon cycle, weather, and atmospheric composition, are being sought. Compact, high efficiency lidar instruments for deployment on unconventional platforms, such as balloon, small sat, and cube sat, are also considered and encouraged.

The proposals should target advancement of lidar technologies for eventual space utilization. Phase I research should demonstrate the 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 2014 SBIR Program, we are soliciting the component and subsystem technologies described below.

Solid state, single frequency, pulsed, laser transmitters operating in the 1.0 µm to1.7 µm range with a wall-plug efficiency of greater than 25% suitable for CO_2 measurement, and free-space laser communication applications. The laser transmitters must be capable of generating frequency transform-limited pulses with a quality beam M^2 of less than 1.5 with an approximately 20 W of average power. We are interested in two different regimes of repetition rates: from 5 kHz to 20 kHz, and from 20 Hz to 100 Hz. In addition, development of non-traditional optical amplifier architectures that yield optical efficiency of >70% are of interest.

Compact and rugged single-frequency CW laser systems operating at 1.06 mm, 1.57 mm, 1.651 mm and 2.05 mm wavelengths suitable for precision space interferometry applications such as LISA, GRACE-II, and coherent detection lidars. The lasers must be developed with space environment considerations and demonstrate a clear path to space. Proposed lasers must be able to generate at least 20 mW of power with less than 10 kHz linewidth over a tunable range of about 50 nm. Systems must be highly wavelength stable and come with full supporting electronic systems for thermal and power control.

Long wavelength solid state laser transmitter technology (e 10 µm) is needed for atmospheric lidar and possible terrain altimeter instruments for Venus. The highly dense atmosphere, volatile clouds, and thick scattering layers make this measurement a low probability event, but should be possible with significant pulse energies at long wavelengths. In combination of large, lightweight receiver, we can maximize the possibility of achieving a round trip remote sensing link from low Venus orbit. Minimum pulse energies of e 100 mJ are needed to reach the surface in the best conditions, such as with periodic holes and gaps in the clouds. Repetition rates of e 10Hz are desired for reasonable footprint spacing should a link be achieved.

Ultra-low noise photo receiver modules, operating either at 1.6 or 2.0 micron wavelengths for measuring CO_2 concentration, comprising of the detection device, complete Dewar/cooling systems, and associated amplifiers. General requirements are: large 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 20 MHz.

Lightweight scanning telescopes capable of a conical pattern with nadir angle fixed in the range of 30 to 45 degrees. The lightweight scanning telescopes are sought for both direct and heterodyne detection wind lidars and tropospheric ozone lidars. For winds, the direct detection lidar operates in 355 nm to 1064 nm wavelength region and the heterodyne detection lidar in 1550 nm to 2050 nm. For ozone, these systems should operate between 280-300 nm. The ozone systems are designed to support NASA's TOLNet network providing data for satellite validation and the study of anthropogenic pollution. High optical efficiency and near diffraction-limited performance are among major considerations. The proposer must show a clear path to space by addressing scalability to apertures greater than 1 m, materials (e.g., substrates and coatings) selection compatible with a space environment, and thermally-stable design. Phase II should result in a prototype unit capable of demonstration in a high-altitude aircraft environment, with aperture of at least 10 inches in diameter.

S1.02 Microwave Technologies for Remote Sensing

Lead Center: GSFC

Participating Center(s): JPL, LaRC

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 (SCLP). 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:

- W-band Solid State Power Amplifier: Freq: 94 GHz +/- 500 MHz, Peak power: > 50 W, Duty cycle: > 20 % , Gain: > 40 dB, Gain flatness within band: <+/- 1 dB, Phase linearity within band:< +/- 1 degree, On/off switching speed: < 1 ?s, Noise figure: < 15 dB, Spurious: < -60 dBc, Harmonic: < -25 dBc.
- 640 GHz Polarimeter I, Q, U Channels, Polarimetric measurements to provide microphysical parameterization of ice clouds applicable to ACE.
- Broadband low noise cryogenic amplifier operating between 1 and 6 GHz.
- G-band (140-220 GHz) Components: 3-port strip line/CPW based switch (20 dB isolation, 1 dB loss, 1 kHz switching frequency), G-band (140-220 GHz) Components: Isolator with isolation > 15 dB, Insertion loss < 1.2 dB.
- High power Solid-State Ka-band Transmitter: Psat > 200W, Duty Cycle > 20%, DC to RF Efficiency > 30%, Gain > 50 dB.
- Very high-efficiency VHF Power Amplifier for CubeSats: Center frequency range: 40MHz to 100MHz, Fractional bandwidth: 20%, Psat >25W, Gain > 40 dB, Efficiency > 90%.
- Technology for low-power, rad-tolerant broad band spectrometer back ends for microwave radiometers. Includes: digitizers with 20 Gsps, 20 GHz bandwidth, 4 or more EOB and a simple interface to FPGA; ASIC implementations of polyphase spectrometer digital signal processing with ~1 watt/GHz.
- Back ends for microwave radiometers and sounders including compact low power RFI mitigation hardware for upgrading existing systems and low-power, low-mass filter back ends with >5 GHz spectral coverage, 200 MHz resolution, and less than one watt.

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

Lead Center: JPL

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 for Earth science (http://www.nap.edu/catalog/11820.html), planetary science (http://www.nap.edu/catalog/10432.html), and astronomy and astrophysics (http://www.nap.edu/books/0309070317/html/).

- Development of un-cooled or cooled infrared detectors (hybridized or designed to be hybridized to an appropriate read-out integrated circuit) with NE?T<20mK, QE>30% and dark currents <1.5x10-6 A/cm^2 in the 5-14 µm 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.

- 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.
- 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.
- 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.

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.

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

Specific mission pages:

- 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).

Specific technology areas are:

- 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.

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, ICON, GOLD, Solar Orbiter, Solar Probe Plus, ONEP, SEPAT, INCA, CISR, DGC, HMag 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 - 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.
- Strong, lightweight, thin, compactly stowed electric field booms possibly using composite materials that deploy sensors to distances of 10-m or more.
- 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 ASICs including Low-power multi-channel ADCs, DACs, and spectrum analyzer modules that determine mass spectra using fast algorithm deconvolution to produce ion counts for specific ion species.
- Low-cost, low-power, fast-stepping (?; 50-µs), high-voltage power supplies 5-15 kV. Low-cost, efficient low-power power supplies (5-10 V).
- High efficiency (5% or greater) conversion surfaces for low-energy neutral atom conversion to ions.
- Miniature low-power, high-efficiency, thermionic cathodes, and cold cathodes, capable of 1-mA electron emission per 100-mW heater power with emission surface area of 1-mm^2 and expected lifetime of 20,000 hours.
- 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/magnetic field boom system in flight (for use with three-axis rigid 10-m booms) accurate to 0.10° dynamic.
- APDs in single pixel and multi-pixel. The APDs, typically used for photons, should be optimized for particles including thin dead layer, increased energy range, gain stability and radiation hardness, but with much higher energy resolution (<0.5KeV) compared to SSDs.
- Solar Blind particle detectors less sensitive to light such as silicon carbide based.
- 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.

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

Lead Center: JPL

Participating Center(s): ARC, GRC, GSFC, JSC, KSC, LaRC, 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 and 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 Council's, Vision and Voyages for Planetary Science in the Decade 2013-2022 (http://solarsystem.nasa.gov/2013decadal/). Technologies that support NASA's New Frontiers and Discovery missions to various planetary bodies are of top priority.

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 the Europa-Jupiter System Mission (JEO) and Io Observer are sought.
- 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 and 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 and 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).

Proposers are strongly encouraged to relate their proposed development to NASA's future planetary exploration goals and existing flight instrument capability, to provide a comparison metric for assessing proposed improvements.

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.

S1.07 Airborne Measurement Systems

Lead Center: GSFC

Measurement system miniaturization and/or increased performance is needed to support for NASA's airborne science missions, particularly those utilizing the Global Hawk, SIERRA, 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:

- 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).
- Volcanic ash (0.25 to 100 micron with 10 % accuracy).
- Sulfur dioxide (4 ppb resolution).
- Carbon dioxide (1 ppm accuracy).
- Methane (5 ppm accuracy, 10 ppm precision).
- Three-dimensional wind measurement (1 mps accuracy/resolution at 10 Hz sampling).

S1.08 Surface and Sub-surface Measurement Systems

Lead Center: GSFC

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

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, Ecosystems (ACE, including Pre-ACE/PACE), etc., is important, yet early adoption for alternative uses by NASA, other agencies, or industry is recognized as a viable path towards full maturity. Additionally, sensor system innovations with significant near-term commercial potential that may be suitable for NASA's research after full development are of interest:

- 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.
- 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.

S1.09 Atomic Interferometry

Lead Center: JPL

Participating Center(s): GSFC

Recent developments of laser control and manipulation of atoms have led to a new type 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. 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.

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 (>$1x10^6$ total useful free-space atoms, <1 nK, Rb, K, Cs, Yb, Sr, and Hg are example candidates but others can be justified by the offeror).
- Ultra-high vacuum seal technologies that allow completely sealed, non-magnetic enclosures with high quality optical access (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. Clock lasers: 1 $Hz/s^{1/2}$ at 1 s, ~ 1W output power or greater; Cooling and trapping lasers: 10 kHz linewidth and ~ 1 W or greater.
- Analysis and simulation tool of cold atom system in trapped and freefall states relevant to atom interferometer and clock measurements in space.

The 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.

Recognizing the fact that the field of atom interferometry is an active research field and there are potential breakthrough approaches still being investigated in research laboratories, NASA is also interested in new ideas of atom interferometry that will lead to better and smaller inertial sensors for rotational sensors, accelerometers, and gravity measurement instruments and will benefit and enable future NASA space missions. Therefore, this subtopic call is also soliciting practical approaches to new sensor ideas that may have high risk but can have high payoffs. Some of the known examples are:

- Bose Einstein condensate based sensors.
- Sensors using large momentum transfer.
- Guided atom wave sensors.
- Non-classical atom interferometers.
- Any other cold atom-based sensor technology such as optical clocks.