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).
- Earth Science - (http://science.nasa.gov/earth-science/decadal-surveys/).
- Heliophysics - The 2009 technology roadmap can be downloaded here (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. 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 NASA’s requirements, advances are needed in state-of-the-art lidar technology with emphasis on compactness, efficiency, reliability, lifetime, and high performance. Innovative lidar subsystem and component technologies systems 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.

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: Laser Interferometer Space Antenna (LISA), Doppler Wind Lidar (3D-WINDS), Ozone Lidar, Lidar for Surface Topography (LIST), Mars atmospheric sensing, Mars and earth re-entry atmospheric entry and descent, Active Sensing of CO₂ Emissions over Nights, Days, and Seasons (ASCENDS), and Aerosols-Clouds-Ecosystems (ACE).

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.

The proposals should target components and subsystems development 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 or an aircraft platform. For the PY12 SBIR Program, we are soliciting the component and subsystem technologies described below.

Solid state, single frequency, pulsed, laser transmitter operating in the 1.0 µm - 1.7 µm range with wall-plug efficiency of greater than 25% suitable for CO₂ measurement, interferometry, and free-space laser communication applications. The laser transmitter must be capable of generating frequency transform-limited pulses with a quality beam M² of less than 1.5. We are interested in two different regimes of repetition rate and output energy: in one case, repetition rate from 5 KHz to 20 kHz with pulse energy from 1 - 4 mJ, and in the second case, repetition rate 20 Hz to 2 kHz with pulse energy from 30 - 300 mJ. In addition, development of non-traditional optical amplifier architectures that yield optical efficiency of >70% are of interest. Attention to the compact and rugged designs for possible aircraft flight tests is highly desirable.

Single-frequency solid-state crystal, planar waveguide or fiber amplifiers/lasers operating at 1.5 and 2.0 micron wavelength regimes suitable for direct detection differential absorption lidar (DIAL) and coherent lidar applications. These lasers must meet one of the two general requirements:
Pulse energy 0.5 mJ to 2 mJ, repetition rate 2 kHz to 10 kHz, and pulse duration of 10 nsec for direct detection lidars.

- 5 mJ to 50 mJ, 20 Hz to 2 kHz, 200 nsec for coherent detection lidars.

2-micron single frequency laser system generating at least 30 mW of power with a precision frequency locking mechanism suitable for measurements of atmospheric CO$_2$. The laser must be locked to a CO$_2$ absorption line peak via a fiber gas cell with accuracy better than 200 kHz. The frequency locked laser shall be modulated to generate two preset offset frequencies from the center frequency alternatively, one at 3-4 GHz, and the other at 15-20GHz range. The frequency stability at these off-center frequencies shall be better than 500 KHz.

Pulsed, single frequency, solid state laser operating in the 450-500 nm range serving as a transmitter for an oceanography lidar. The laser must be able to produce bandwidth-limited pulses with 10 nsec or shorter duration. The proposed design must be scalable to at least 10 W of average power, preferably generating 100 mJ at 100-200 Hz, but will consider lower pulse energies with higher repetition rates. Pulse energies can be less than the above stated goals by a factor of 10 for the Phase II delivered unit.

S1.02 Microwave Technologies for Remote Sensing

Lead Center: JPL

Participating Center(s): GSFC, 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) 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:

- **Space qualifiable, High power and efficiency P-band power amplifiers:** Center Frequency: 420-450, Gain: > 40 dB, Efficiency: >80%, Duty Cycle: 10%, Mass
- **Space-qualifiable Single-Board Digital Radar Transceiver in PC-104e form factor.** Frequency bands: 400-500, 1200-1300, with arbitrary waveform generator (100 us pulselength, 30 BW), 2-channel ADC, FPGA, PCIe bus, Size: Approx 9cm x 9.6cm x 3.1cm
- **Cryogenic LNAs for 180 to 270 GHz with noise temperatures of less than 100K.** Earth Science Decadal Survey missions that apply: PATH, GACM and future Earth Venture Class low cost millimeter wave instruments.
- **Receiver technologies for the PATH mission including:** low noise (Local Oscillator technologies for 2nd generation instruments for SOFIA, next generation HIFI, and suborbital instruments (GUSSTO). This can include: GaN based frequency multipliers that can work in the 200-400 GHz range (output frequency) with input powers up to 1 W. Graphene-based (or other suitable technology) devices that can work as frequency multipliers in the frequency range of 1-3 THz.
- **Compact, light-weight array antennas with 50 - 60% bandwidth using electronic frequency hopping and tuning capabilities, dual-polarization, high cross-polarization isolation (> 25 dB) for airborne and spaceborne radar applications**
- **P-, L-, C-, X band MMIC pulsed radar transceivers with dynamic load matching, wideband (> 50) high**
power efficiency (> 30%), high T/R isolation (> 90 dB)
- Large (~5m) deployable parabolic cylindrical antennas, F=35, 94 GHz
- G-Band Microwave Components: For measurement of microphysical properties of clouds and upper atmospheric constituents (particles of less than mm sizes):
  - G-band Noise Source (ENR > 10dB).
  - W-band LO (6 dBm, Freq. Stability 5-10 (-20 C - 40 C) DC Power
  - G-band isolator (Isolation > 15 dB, Insertion Loss
  - G-band switching circulator (Isolation > 15 dB Insertion Loss
  - Integration and packaging G-band receiver for cubesat and microsat platforms.
- Multi-Frequency and/or multi-Beam Focal Plane Arrays (FPA) as a primary feed for reflector antennas. In NASA's SCLP mission, it is required to collect Earth science data at high spatial and as well as temporal resolutions simultaneously. In addition to high spatial and temporal resolutions, the proposed antenna system must offer ways to suppress RFI and control antenna illumination. NASA is looking for a small (3 x 3) focal plane array system to be used as a feed for its main reflector. Wideband array element covering 19, and 37 GHz must be used as a basic element of the proposed FPA.

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 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/).

The following technologies are of interest for the Scanning Microwave Limb Sounder (http://mls.jpl.nasa.gov/index-cameo.php) on the Global Atmospheric Composition Mission and the SOFIA (Stratospheric Observatory for Infrared Astronomy) airborne observatory:

- Radiation tolerant digital polyphase filterbank back ends for sideband separating microwave spectrometers. Requirements are >5GHz instantaneous bandwidth per sideband, 2 MHz resolution, low power ( Improved submillimeter mixers for frequencies >2 THz are needed for heterodyne receivers to fly on SOFIA. Minimum noise temperatures for cryogenic operation and instantaneous bandwidths >5 GHz are key parameters. 
- Efficient, flight qualifiable, spur free, local oscillators for SIS mixers operating in low earth orbit. Two bands:
  - Tunable from 200 to 250 GHz
  - Tunable from 610 to 650 GHz, phase-locked to or derived from an ultra-stable 5 MHz reference.
- Quantum cascade laser-based local oscillators >2THz for astrophysics applications

Thermal imaging, LANDSAT Thermal InfraRed Sensor (TIRS), Climate Absolute Radiance and Refractivity Observatory (CLARREO), BOReal Ecosystem Atmosphere Study (BOREAS), other infrared earth observing missions, Trojan Tour, Europa Jupiter System Mission (EJSM) such as a descoped Jupiter Europa Orbiter (JEO), Io Observer, or Jupiter Io Callisto Europa (JuICE) missions (see the Jupiter Europa Orbiter Mission Study 2008: Final Report, (http://opfm.jpl.nasa.gov/library/) and future planetary missions:
• Development of un-cooled or cooled Infrared detectors (hybridized or designed to be hybridized to an appropriate read-out integrated circuit) with NE?T30% and dark currents 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 strain layer super-lattices to meet these specifications.
• 2-D arrays of thermopile detectors (wavelength range 20-100 µm; Detectivity = 4x10^9; operating temp 100-200 K).

1kx1k MCT detector arrays with cutoff wavelength extended to =12 µm for use in missions to NEOs, comets and the outer planets.

New or improved technologies leading to measurement of trace atmospheric species (e.g., CO, CH4, N2O) from geostationary and low-Earth orbital platforms; see Methane Trace Gas Sounder. Of particular interest are new techniques in gas filter correlation spectroscopy, Fabry-Perot spectroscopy, or improved component technologies. Technologies are needed for active and passive wave front and amplitude control, and relevant missions include Extra solar Planetary Imaging Coronagraph (EPIC), and other coronagraphic missions such as Terrestrial Planet Finder (http://exep.jpl.nasa.gov/TPF-C/tpf-C_index.cfm) and Stellar Imager (http://hires.gsfc.nasa.gov/si):

• MEMS based segmented deformable mirrors consisting of arrays of up to 1200 hexagonal packed segments with strokes over the range of 0 to 1.0 microns, quantized with 16-bit electronics with segment level stabilities of 0.015 nm rms (1-bit) over 1 hour intervals. Segments should be flat to 2 nm rms or better and the substrate flat to 125 nm or better and high uniformity of coatings (1% rms).
• Technologies for high contrast integral field spectroscopy, in particular for microlens arrays with or without accompanying mask arrays, working in the visible and NIR (0.4 - 1.8 microns), with lenslet separations in the 0.2 -0.5 mm range, with contrast between neighboring spectra of ~10^-4. and uniform focal lengths to
• Spatial Filter Array (SFA) consisting of a monolithic array of up to 1200 coherent, polarization preserving, single mode fibers, or custom waveguides, that operate with minimal coupling losses over a large fraction of the spectral range from 0.4 - 1.0 microns. The SFA should have input and output lenslet with each pair mapped to a single fiber or waveguide and such that the lenslets maintain path length uniformity to

Blazed, holographic optical gratings on convex surfaces: The Offner spectrometer design uses a symmetric optical layout to balance aberrations, producing good imaging performance and spectral images with little or no distortion. Both of these attributes improve the measurement capability of the spectrometer by eliminating the spatial-spectral information mixing that other spectrometer forms typically produce. The key element in an Offner spectrometer is the convex spherical grating that is used to disperse the light spectrally. While such gratings can be made holographically, these gratings suffer from low efficiency due to their lack of signal-enhancing blazed groove structure. Development is needed for production of holographically-generated convex gratings that have a continuously-varying blaze angle to provide high efficiency diffraction into a chosen wavelength range and diffraction order (415 nm to 695 nm in first order and 290 nm to 390 nm in the second order). Such gratings also should have less scattered light than similar mechanically-ruled gratings, improving spectrometer performance.
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:


Specific technology areas are listed below:

- 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 (Large format UV and X-ray focal plane detector arrays: micro-channel plates, CCDs, and active pixel sensors (>50% QE, 100 Megapixels).
- Advanced Charged Couple Device (CCD) detectors, including improvements in UV quantum efficiency and read noise, to increase the limiting sensitivity in long exposures and improved radiation tolerance. Electron-bombarded CCD and CMOS detectors, including improvements in efficiency, resolution, and global and local count rate capability. In the X-ray, we seek to extend the response to lower energies in some CCDs, and to higher, perhaps up to 50 keV, in others. Possible missions are future GOES missions and International X-ray Observatory.
- Wide band gap semiconductor, radiation hard, visible and solar blind large format imagers for next generation hyperspectral Earth remote sensing experiments. Need larger formats (>1Kx1K), much higher resolution (Solar blind, compact, low-noise, radiation hard, EUV and soft X-ray detectors are required. Both single pixels (up to 1cm x 1cm) and large format 1D and 2D arrays are required to span the 0.05nm to 150nm spectral wavelength range. Future missions include GOES post R and T.
- Visible-blind SiC Avalanche Photodiodes (APDs) for EUV photon counting are required. The APDs must show a linear mode gain >1E6 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 format 1D (1 x 2k) and 2D (2k x 2k) SiC arrays (operating temp 170-300K; D* = 3x1015) including Schottky diodes, PINs and APDs for instruments on future outer planets missions.
- 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 (~106), low noise, fast time response (2. Focal plane mass must be minimized (2g/cm² goal). Individual pixel readout is required. The entire focal plane detector can be formed from smaller, individual sub-arrays.
- Large area (3 m²) 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 JEM-EUSO and OWL.
- Large area (m²) X-ray detectors with 85%). Future instrument is a Phased-Fresnel X-ray Imager.
- Improve beyond CdZnTe detectors using micro-calorimeter arrays at hard X-ray, low gamma-ray bands (above 10 keV and below 80 keV).
- Technologies to improve spatial resolution for the hard X-ray band to 10 and ultimately to 5 arc-second resolution.
- High-density, low-temperature electrical interfaces: In microcalorimeter and cryogenic IR detector assemblies, the large number of electrical connections required on the low-temperature stage (below 4 Kelvin) requires high-density, miniaturized cryogenic connectors. NASA needs suitable nano-miniature connectors that can connect to superconducting wires (Nb or Al) deposited on a high density flex cable. The metal traces will likely be layered into a stripline configuration to minimize cross-talk, leading to pads onto which the connector is attached. This type of flex cable has extremely low thermal conductivity. A modular connector, easily integrated into or removed from the superconducting flex cable, is sought.

**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 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.
- 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 ASICs including 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).
- 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.
- Miniature low-power, high-efficiency, thermionic cathodes, capable of 1-mA electron emission per 100-mW
heater power with emission surface area of 1-mm² 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 (five with three-axis rigid 10-m booms) accurate to 0.1° dynamic.
- Die-level optical interferometer, micro-sized, for measuring Fabry-Perot plate spacing with 0.1-nm accuracy.
- Diffractive optics (photon sieves) of 0.1-m aperture or larger with micron-sized outer Fresnel zones for high-resolution EUV imaging.
- Avalanche Photodiode Detectors (APDs), in single pixel and multi-pixel form, to make a breakthrough in particle detection by taking advantage of their inherent gain compared to the unity gain SSDs. 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.
- 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 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 (as well as components) further advance the mission goals of NASA through enabling performance (and ultimately science gathering) capabilities of flight detectors and sensors. Presently, there are six potential investment areas that NASA is seeking to expand state of the art capabilities in for possible use on future programs such as GEOID, SPICA, WFirst (http://wfirst.gsfc.nasa.gov/), Spirit, Specs (http://nmdb.gsfc.nasa.gov/geons) and the Europa Science missions (http://www.nasa.gov-multimedia/podcasting/jpl-europa20090218.html). The topic areas are as follows:

- **Extremely Low Vibration Cooling Systems** - Examples of such systems include pulse tube coolers and turbo brayton cycles. Desired cooling capabilities sought are on the order of 20 mW at 4K or 1W at 50K. Present state of the art capabilities display

- **Advanced Magnetic Cooler Components** - An example of an advanced magnetic cooler might be Adiabatic Demagnetization Refrigeration systems. Specific components sought include:
  - Low current superconducting magnets.
  - Active/Passive magnetic shielding (3-4 Tesla magnets).
  - Superconducting leads (10K - 90K) capable of 10 amp operation with 1 mW conduction.
  - 10 mK scale thermometry.

- **Continuous Flow Distributed Cooling Systems** - Distributed cooling provides increased lifetime of cryogen fluids for applications 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). Cooling systems that provide continuous distributed flow are a cost effective alternative to present techniques/methodologies. Cooling systems that can be used with large loads and/or deployable structures are presently being sought after.

- **Heat Switches** - Current heat switches require detailed procedures for operational repeatability. More robust (performance wise) heat switches are currently needed for ease of operation when used with space flight applications.

- **Highly Efficient Magnetic and Dilution Cooling Technologies** - The desired temperature range for proposed
systems is

- **Low Temperature/Input Power Cooling Systems** - Cooling systems providing cooling capacities approximately 0.3W at 35K with heat rejection capability to temperature sinks upwards of 150K are of interest. Presently there are no cooling systems operating at this heat rejection temperature. Input powers should be limited to no greater than 20W. Study of passive cooler in tandem with low power, low mass cryocooler satisfying the above mentioned requirements is also of interest.

**S1.07 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 & innovative scientific measurements are solicited. For example missions, see [http://science.hq.nasa.gov/missions](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/](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.

- **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-presures 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.)

Proposers are strongly encouraged to relate their proposed development to:

- NASA’s future planetary exploration goals.
- 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.
S1.08 Airborne Measurement Systems

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

A focus is on miniaturization and increased sensitivity/performance needed to support for NASA's airborne science missions. Linkage to other subtopics such as S3.05 Unmanned Aircraft and Sounding Rocket Technologies is encouraged. Complete instrument systems are desired, including features such as remote/unattended operation and data acquisition, low power consumption, and minimum size and weight.

Relevance to future space missions such as Active Sensing of CO₂ 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), 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 (multiphase).
- Surface snow thickness (5 cm resolution is desired), and potentially, snow density.
- Aerosols and cloud particles.
- Volcanic ash and gases.
- Gases: Reactive and tracers of source emissions. Examples include (but are not limited to) carbon dioxide, carbon monoxide, methane, water vapor.
- High quality three-dimensional wind instruments suitable for gas flux measurements, as well as advanced temperature and pressure systems.

S1.09 Surface & Sub-surface Measurement Systems

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

For ground-based surface vehicles, and submerged systems. Systems that are ultimately intended for flight or mobile platforms that will provide near-term benefit in a ground-based application are in scope, as this step will aid in maturation of new concepts.

Relevance to future space missions such as Active Sensing of CO₂ 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), 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., stabilized disdrometer).
• Particles: mineral, biogenic, nutrients.
• Gases – carbon dioxide, methane, etc.
• Air and water quality.
• Water and ice flow rates.
• Seismic monitoring.
• Autonomous sample collection and/or analysis systems.
• Air-dropped sensors for 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.
• Oceanic, coastal, and fresh water measurements including inherent and apparent optical properties for calibration and validation of satellite ocean color radiometric data, temperature, salinity, currents, in situ biogeochemical and chemical particle composition, sediments, and biological or ecological properties of aquatic environments including but not limited to nutrients, phytoplankton and their functional groups, harmful algal blooms, fish or aquatic plants and animals.
• 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 a Earth science role are also encouraged.