NASA's Earth Science (ES) Division is committed to studying how our global environment is changing. Using the unique perspective available from spaceborne and airborne platforms, NASA is observing, documenting, and assessing large-scale environmental processes with emphasis on atmospheric composition, climate, carbon cycle and ecosystems, the Earth's surface and interior, the water and energy cycles, and weather. A major objective of ES instrument development programs is to implement science measurement capabilities with small 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. Consequently, the objective of this SBIR topic is to develop and demonstrate instrument component and subsystem technologies that reduce the risk, cost, size, and development time of Earth observing instruments and to enable new Earth observations measurements. The following subtopics are concomitant with this objective and are organized by measurement technique. For more on science and technology needs, visit http://estips.nasa.gov.

Subtopics

S6.01 Passive Optics and Stepping Motors for Spaceborne and Airborne Platforms

Lead Center: LaRC
Participating Center(s): GSFC

Passive optical remote sensing generally requires that deployed devices have large apertures and large throughput. NASA is interested primarily in instrument technologies suitable for aircraft or space flight platforms, and these inherently also prefer low mass, low power, fast measurement times, and a high degree of robustness to survive vibrations in flight or at launch. Wavelengths of interest range from ultraviolet through the far infrared. Development of techniques, components and instrument concepts that can be developed for use in actual deployed devices and systems within the next few years is highly encouraged.

Technologies and components that are not clearly suitable for use in high throughput remote sensing instruments are not applicable to this subtopic. The technology areas of primary interest are described below:
- Technology leading to significant improvements in capability, availability, or cost of large format (> 2.5 cm diameter), very narrow band (~1 full-width at half-maximum), polarization insensitive, high throughput infrared (6 - 15 µm) optical filters. These filters must be able to operate in vacuum at cryogenic temperatures.

- High performance four-band two-dimensional (2D) arrays (128x128 elements or more) in the 0.4 - 2.5 µm wavelength range with high quantum efficiencies (60%-80% or higher) in all spectral bands, low noise, and ambient temperature operation.

- Detector arrays with unusual 3-dimensional geometries. Of particular interest is the development of a photon counting system with multiple cylindrical detecting elements (detecting surface on the outside edge) formed into a stack connected through one end to the cable leading to the readout electronics. The stack should be 2 to 5 cm in length with at least 12, and up to 48, individual elements. The diameter of the stack/elements should be minimized and on the order of 0.5 cm or less. Each detector element should have a clear field of view for most of the 360 degrees perpendicular to the stack. Exact details for the sensitivity are negotiable at this early stage, but applications are for fluorescence type measurements.

- High performance 2-color array detectors (128x128 or higher) covering the 3 - 15 micron spectral range with high efficiencies, low noise and operating at relatively high temperatures (>150K desired, 80K minimum).

- Improved cryogenic stepping motors with high running torques at 80K. The motors must operate in vacuum and at temperatures at or below 80K. It is desired that these motors have minimal size and power requirements, and especially important that they use minimal current. Typical torque values desired are in the range of 10 - 20 oz-inches. Proposed motors should have at least 200 steps per revolution of the axis.

S6.02 Lidar System Components for Spaceborne and Airborne Platforms

**Lead Center:** LaRC

**Participating Center(s):** GSFC

High spatial resolution, high accuracy measurements of atmospheric parameters from ground-based, airborne, and spaceborne platforms require advances in the state-of-the-art lidar technology with emphasis on compactness, reliability, efficiency, low weight, lifetime, and high performance. Innovative technologies that can expand current measurement capabilities to airborne, Unmanned Aerial Vehicle (UAV), or spaceborne platforms are particularly desirable. Development of components that can be used in actual deployed systems within the next few years is highly encouraged. Technologies and components that are not clearly suitable for effective lidar remote sensing or field deployment are not applicable to this subtopic. This subtopic considers components that enable Earth-sun system measurements such as:

- Cloud and aerosols with emphasis on aerosol optical properties;
- Wind profiles using direct-detection (noncoherent) lidar, or coherent-detection (heterodyne) lidar, or both;
- Land topography (vegetation, ice, land use); and
- Molecular species (carbon dioxide, ozone, and water vapor).
Innovative component technologies that directly address the measurement needs above will be considered. Dual-use technologies addressing Planetary Exploration are highly desirable. This subtopic is soliciting only the specific component technologies described below.

1. Pulsed, single frequency, diode laser or fiber laser based seeded MOPA systems are desired due to inherent robustness, efficiency, thermal and alignment stability. If the cost per unit is reasonable, and the size is small, then many of these can be installed on a spacecraft for either parallel operation or as backup units to lengthen the life of the mission. Systems with the following specifications are solicited:

   - Stable single frequency operation at 1047nm, 1064 nm, or 1570 nm;
   - Small, integrated assemblies that can generate CW powers in the 100's of mW to several Watts range and higher peak power pulsed operation yielding at least 10 to 500 nJ pulse energies;
   - Fiber laser and amplifier designs with high SBS suppression;
   - Gaussian pulsewidths between 100 ps and 50 ns;
   - MOPA design configuration is desired where the pulse production cavity is short and more readily impedance matched for the fast rise times, gain switching, etc.;
   - A semiconductor amplifier, or possibly a small cm-scale rare Earth doped fiber amplifier, can be coupled to the oscillator chip's output, itself contained in a hermetic butterfly or similar package;
   - Repetition rates as low as 100 Hz and as high as 10 kHz are needed, with pulsed lifetimes in the trillion shot regime ($10^{12}$);
   - Single mode, polarization maintaining (PM) fiber output is needed;
   - Short term drift less than 1 MHz;
   - Second and third harmonic generation techniques that can be packaged with the CW and pulsed diode or fiber laser sources to produce additional wavelengths in the visible or ultraviolet.

2. High speed fiber multiplexers for single and multimode fiber. A 1-to-10, or greater, multiplexer that is capable of switching on the order of 10 to 100 kHz with low insertion losses is required. Unit must be small, lightweight, and use little power. Single mode fiber version must be capable of handling high power (>100 microJoules at 10 kHz at 1064 nm). Multimode version will be used in low power applications and must be compatible with 0.22 NA fiber with 100 to 600 micron core size. Switching speeds faster than 10 microseconds are required.

3. Efficient and compact single frequency solid state or fiber lasers operating at 1.5 and 2.0 micron wavelength regimes suitable for coherent lidar applications. These lasers must meet the following general requirements: pulse energy 2 mJ to 100 mJ, repetition rate 10 Hz to 200 Hz, and pulse duration of approximately 200 nsec.
4. Single element, low noise, high quantum efficiency, HgCdTe avalanche photodiode detector (APD) capable of photon counting at rates >10 MHz for use in the 1570 nm range. Should be suitable for operation with a thermal electric cooler.

5. Lightweight compact lidar telescopes operating at one or more of the primary laser wavelengths in 1.0 to 2.0 micron wavelength region. The general requirements are: optical quality better than 1/6 wave at 632 nm, mass density less than 12 kg/m², and aperture diameter from 10 cm to 30 cm. Proof of scalability to 50 to 75 cm diameter for deployment in space is required.

6. Interferometric lidar aft-optics receiver subsystems/components to separately derive aerosol and molecular backscatter via High Spectral Resolution Lidar (HSRL) technique. The subsystem/component is to be implemented into a HSRL system with the goal of independently derive aerosol backscatter and extinction. Subsystems/components are needed at 355 and 532 nm wavelengths. Architectures could be based on Fabry Perot, Mach Zehnder, or other interferometric implementations. Resolving power of the order of 1 GHz and high frequency stability of pass/stop bands are required. Concepts must address issues associated with etendeau of large-aperture (1 - 1.5 m) lidar receivers with field of view of the order of 200 micro-radians.

7. CCD detectors with high quantum efficiency at 355 and 532 nm for spaceborne lidar instruments measuring cloud and aerosol backscatter and extinction. CCD detectors are needed to replace single element PMT detectors for imaging fringes from interferometric elements of a HSRL instrument. Clocking schemes to move charge on the CCD to achieve on-chip profile averaging and reduce dark current and readout noise should be considered.

S6.03 Earth In Situ Sensors

Lead Center: GSFC

Proposals are sought for the development of in situ measurement systems. These systems are sought for use on radiosondes, dropsondes, tethered balloons, kites, mini-Unmanned Airborne Vehicles (UAVs), Unmanned Undersea Vehicles (UUVs), or Unmanned Surface Vehicles (USVs). Data acquisition methods should be included. Technology innovation areas of interest include:

- Measurements of atmospheric properties including temperature, humidity, solar radiation, clouds, liquid water, ice, precipitation, carbon dioxide, methane, and sulfur dioxide;

- Measurements of three-dimensional atmospheric winds near the Earth's surface, and within the troposphere and lower stratosphere, with high spatial resolution and accuracy. Of particular interest are systems intended for measurements of atmospheric fluxes as well as those for convection;
Measurements of oceanic properties including inherent and apparent optical properties, ocean temperature and salinity, and sea surface height.

S6.04 Passive Microwave

Lead Center: GSFC

Proposals are sought for the development of innovative passive microwave technology in support of Earth System Science measurements of the Earth's atmosphere and surface. These microwave radiometry technology innovations are intended for use in the frequency band from about 1 GHz to 1 THz. The key science goal is to increase our understanding of the interacting physical, chemical, and biological processes that form the complex Earth system. Atmospheric measurements of interest include climate and meteorological parameters-including temperature, water vapor, clouds, precipitation, and aerosols; air pollution; and chemical constituents such as ozone, NOx, and carbon monoxide. Earth surface measurements of interest include water, land, and ice surface temperatures, land surface moisture, snow coverage and water content, sea surface salinity and winds, and multi-spectral imaging.

Technology innovations are sought that will provide the needed concepts, components, subsystems, or complete systems that will improve these needed Earth System Science measurements. Technology innovations should address enhanced measurement capabilities such as improved spatial or temporal resolution, improved spectral resolution, or improved calibration accuracies. Technology innovations should provide reduced size, weight, power, improved reliability, and lower cost. The innovations should expand the capabilities of airborne systems (manned and unmanned) as well as next generation spaceborne systems. Highly innovative approaches that open new pathways are also an important element of competitive proposals under this solicitation.

Specific technology innovation areas include:

**Electronics Technologies**

- Imaging radiometers, receivers, or receiver arrays on a chip;
- Microwave and millimeter-wave frequency sources as an alternative to Gunn diode oscillators. Compact (3) self-contained oscillators with output frequency between 40 GHz and 120 GHz, low phase noise 100 mW, and low power consumption (;
- Wideband and ultra-wideband sensors with >15dB cross-pole isolation across the bandwidth;
- Low noise (3), heterodyne mixers requiring low local oscillator drive power (;
- Undersampling, multibit, analog-to-digital converters with Multigigahertz RF input bandwidth, low power consumption, and associated digital signal processing logic circuit;
- Low power, lightweight microwave with DC power consumption of less than 2 W;
- Electronic design approaches and subsystems that can be incorporated into microwave radiometers to
detect and suppress RFI within or near the reception band of the radiometer, thus insuring higher data quality;

- Innovative new designs for highly stable noise-diode or other electronic devices as additional reference sources for onboard calibration. Of particular interest are variable correlated noise sources for calibrating correlation-type receivers used in interferometric and polarimetric radiometers;

- Monolithic microwave integrated circuit (MMIC), low-noise amplifiers (LNA). Of particular interest are LNAs covering the frequency range of 165 to 193 GHz with low 1/f noise, and having a noise figure of 6.0 dB or better; and

- GPS receiver systems for application as bi-static altimeters and scatterometers.

Antenna Technologies

- Sensor elements with low mutual coupling allowing close spacing within large arrays;

- Large format, millimeter wave, focal plane array modules for large-aperture passive imaging applications; and

- Large aperture, deployable antenna concepts. Such large apertures can be real or synthetic. Of particular interest are highly compact launch configurations.

Calibration Technologies

- New technology calibration reference sources for microwave radiometers that provide greatly improved reference measurement accuracy. Of particular interest are high emissivity (near-black-body) surfaces for use as onboard calibration targets for microwave radiometers-which will significantly reduce the weight of aluminum core target designs, while reliably improving the uniformity and knowledge of the calibration target temperature; and

- New approaches, concepts, and techniques for microwave radiometer system calibration over or within the 1-300 GHz frequency band-which provide end-to-end calibration to better than 0.1K, including corrections for temperature changes and other potential sources of instrumental measurement drift and error.

S6.05 Active Microwave

Lead Center: JPL

Participating Center(s): GSFC

Active microwave sensors have proven to be ideal instruments for many Earth science applications. For global coverage and the long-term study of Earth's eco-systems, space-based radar is of particular interest to Earth scientists. Radar instruments for Earth science measurements include Synthetic Aperture Radar (SAR), scatterometer, sounder, altimeter and atmospheric radar. The life-cycle cost of such radar missions has always been driven by the resources - power, mass, size, and data rate - required by the radar instrument, often making radar not cost competitive with other remote sensing instruments. Order-of-magnitude advancement in key sensor
components will make the radar instrument more power efficient, much lighter weight and smaller in stow volume, leading to substantial savings in overall mission life-cycle cost by requiring smaller and less expensive spacecraft buses and launch vehicles. On-board processing techniques will reduce data rates sufficiently to enable global coverage. Technologies that may lead to advances in instrument design, architectures, hardware, and algorithms are the focused areas of this subtopic. In order to increase the radar remote sensing user community, this subtopic will also consider radar data applications and post processing techniques. Specific areas in which advances are needed include:

- L-band SAR for surface deformation, topography, soil moisture measurements:
  - Lightweight, electronically steerable, dual-polarized, L-band phased-array antennas;
  - Lightweight deployable antenna structures and deployment mechanisms suitable for very large aperture systems (e.g., 2x100m antennas);
  - Rad-hard, high-efficiency, low-cost, lightweight L-band T/R modules;
  - L-band MMIC single-chip T/R modules;
  - High-power L-band transmitters (2KW to 10KW);
  - Integrated (e.g., ASIC) arbitrary waveform generators;
  - High performance, low power, rad-hard, real-time SAR processors and SAR data processing algorithms and data reduction techniques;
  - Thin-film membrane compatible electronics. This includes: Reliable integration of electronics with the membrane, high performance (>1.2GHz) transistor fabrication on flex material including identifying new materials, process development and techniques that have potential to produce large area passive and active flexible antenna arrays.

- Ku-band and Ka-band interferometers for snow cover measurement over land (Ku-band) and wetland and river monitoring (Ka-band):
  - Large, stable, lightweight, deployable structures (10-50 meter interferometric baseline);
  - Phase-stable Ku-band and Ka-band electronically steered phased arrays and multi-beam antennas;
  - Lightweight deployable reflectors (Ku-band and Ka-band);
  - Phase stable Ku-band and Ka-band receive electronics and T/R modules;
  - High-power Ka-band transmitters (2KW to 10KW);
  - High performance, low power, rad-hard, real-time radar processors and SAR data processing algorithms and data reduction techniques.

- X-band to W-band doppler radars for precipitation and cloud measurements:
  - High efficiency RF power amplifier (Ku-, Ka-, and W-band);
- Compact, low loss phase shifters (Ka- and W-band);
- High power and low insertion loss transmit-receive switches (Ka-, W-band);
- Wide dynamic range low noise amplifiers (Ka- and W-band);
- Low sidelobe (-90 dB) pulse compression technology (W-band);
- Compact frequency synthesizer (Ku- and Ka-band);
- High power, low sidelobe, compact antennas for high altitudes (X-Ka-band).

- Low Frequency (HF, VHF and UHF) airborne sounders:
  - Technology for creating large Ground Penetrating Radar (GPR) baselines with wireless phase lock loops;
  - High Power (800W), linear amplifiers;
  - Innovations in system design or hardware improvements to minimize the effect of the transmit signal leakage into receiver.