NASA SBIR 2010 Phase I Solicitation

S1.01 Lidar and Laser System Components

Lead Center: LaRC

Participating Center(s): GSFC, JPL

Accurate measurements of atmospheric parameters with high spatial resolution from ground, airborne, and space-based platforms require advances in the state-of-the-art lidar technology with emphasis on compactness, efficiency, reliability, lifetime, and high performance. Innovative lidar component technologies that directly address the measurements of the atmosphere and surface topography of the Earth, Mars, the Moon, and other planetary bodies will be considered under this subtopic. Frequency-stabilized lasers for a number of lidar applications such as CO$_2$ concentration measurements as well as for highly accurate measurements of the distance between spacecraft for gravitational wave astronomy and gravitational field planetary science are among technologies of interest. Innovative technologies that can expand current measurement capabilities to spaceborne or Unmanned Aerial Vehicle (UAV) platforms are particularly desirable. Development of components that can be used in planned missions or current technology programs is highly encouraged. Examples of planned missions and technology programs are: Deformation, Ecosystem Structure and Dynamics of Ice (DESDynI), Laser Interferometer Space Antenna (LISA), Doppler Wind Lidar, Lidar for Surface Topography (LIST), or Active Sensing of CO$_2$ Emissions over Nights, Days, and Seasons (ASCENDS).

Research should be conducted to demonstrate technical feasibility during Phase I and show a path toward a Phase II prototype demonstration. For the PY10 SBIR Program, we are soliciting only the specific component technologies described below.

- Highly efficient solid state laser transmitter operating in the 1.0 μm - 1.7 μm range with wall-plug efficiency of greater than 25%. The proposed laser must show path in maturing to space applications. The laser transmitter must be capable of single frequency with narrow spectral width capable of generating transform-limited pulses, and M2 beam quality 70% are of interest. Although amplifiers such as planar waveguide or grazing incidence have been shown to generate optical efficiencies >50%, much higher efficiency is needed for space applications. Proposed solutions should incorporate electronics packages suitable for use in aircraft demonstration (i.e., small, well packaged, low power).

- Efficient and compact single mode solid state or fiber lasers operating at 1.5 and 2.0 micron wavelength regimes suitable for direct detection DIAL and coherent lidar applications. These lasers must meet the following general requirements: pulse energy 0.5 mJ to 50 mJ, repetition rate 10 Hz to 1 kHz, and pulse duration of either 10 nsec or 200 nsec regimes.
• Single frequency semiconductor or fiber laser generating CW power greater than 50 mW in 1.5 or 2.0 micron wavelength regions with less than 10 kHz linewidth tunable over several nanometers. Frequency modulation with about 5 GHz bandwidth over 1 msec period is highly desirable.

• Novel compact solid-state UV laser for Ozone DIAL measurements operating within the 300 nm - 320 nm wavelength range generating laser pulses of up to 1 KHz rate and average output power greater than 1 Watt. Operation at two distinct wavelengths separated by 10 nm to 15 nm is required for the Ozone measurements. Scalability of the laser design to power levels greater than 10 W for space deployment is important.

• Novel scanning telescope capable of scanning over 360 degrees in azimuth with nadir angle fixed in the range of 30 to 45 degrees. Clear apertures scalable to 1 m, good optical performance (although diffraction limited performance is not necessary), and high optical efficiency are desired, as is ability to operate at multiple wavelengths from 1064 nm to 355 nm. Optical materials (e.g. substrates and coatings) and components should be space qualifiable. Phase II should result in a prototype unit capable of demonstration in a high-altitude aircraft environment, with aperture on the order 8 inches. Due to issues with spacecraft momentum compensation and previous investments, concepts for large articulating telescopes will not be considered responsive to this request, nor will holographic substrates.

• High quantum efficiency, low-noise detectors operating at 355, 532, and 1064 nm suitable for space applications. Detectors must have an active area diameter greater than 0.5 mm and be capable of temporal resolutions less than 0.67 microsecond. Detectors must be linear over 4 orders of magnitude in dynamic range and suitable for analog detection schemes. Associated electronics including amplifiers and filters with matching impedance are desired.

• Flash Lidar Receiver for planetary landing application with at least 128X128 pixels capable of generating 3-dimensional images and detection of hazardous terrain features, such as rocks, craters and steep slopes from at least 1 km distance. The receiver must include real-time image processing capability with 30 Hz frame rate. Embedded image enhancement and classification algorithms are highly desirable. Proposals for low noise Avalanche Photodiode (APD) arrays with 256x256 pixels format suitable for use in Flash Lidar receiver will be also considered. The detector array must operate in the 1.06 to 1.57 micron region and be able to detect laser pulses with 6 nsec in duration. The array needs to achieve greater than 90% fill factor with a pitch size of 50 to 100 microns with provisions for hybridization with an Integrated Readout Circuit (ROIC).

Proposals should show an understanding of one or more relevant science needs, and present a feasible plan to fully develop a technology and infuse it into a NASA program.

S1.02 Active Microwave Technologies

NASA employs active sensors (radars) 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 and for planetary landing. We are seeking proposals for the development of innovative technologies to support future radar missions and applications. The areas of interest for this call are listed below:
• **High -density low- loss millimeter-wave packaging and interconnects** for Advanced Cloud and Precipitation Radars and Mars Landing Radars. These packing and interconnect technologies are critical to achieving the density and RF signal performance required for scanning millimeter-wave array radars.

  ○ Frequency: 35 - 160 GHz
  ○ Interconnect loss:
  ○ Line loss:

• **High -speed, low- power analog -to -digital converters (ADCs) and digital -to -analog Converters (DACs)** for Advanced SAR, Advanced Interferometer for Surface monitoring, ice topography, and hydrology. Digital beam forming (DBF) systems require an array of ADCs. The power consumption of current ADC chips prohibits implementation of large DBF arrays. Furthermore, large arrays require true time delays, which can be implemented using low- power high speed ADCs and DACs. Ideal ADCs are modeled with perfectly linear input-output transfer functions. In addition to seeking novel devices, we are seeking innovative methods to correct for both differential and integral nonlinearities (DNL and INL) in ADCs to increase ADC ENOB. Proposed methods should be adaptable to a wide range of sampling rates, input frequencies, and device types; furthermore, they should be amenable to realtime operation on an FPGA.

  ○ Bandwidth: 1.5 GHz
  ○ Sampling rate: 500 MS/s
  ○ ENOB: 12 bits
  ○ Power consumption: 100 mW

• **Compact True-Time Delay Beamformers** for Advanced Cloud and Precipitation Radars, Mars Landing Radars, and Advanced SAR. Large, wideband scanned arrays require true-time-delay beamforming to avoid beam squint over operating frequency range.

  ○ Center Frequencies: 35, 94, 160 GHz
  ○ Inputs: 128
  ○ Loss:
  ○ Mass:

• **Dual frequency Millimeter-wave transmit/receive MMICs** for Advanced SAR, Advanced Interferometer for surface monitoring, ice topography, hydrology, Advanced Cloud and Precipitation Radars, and Mars Landing Radars. Monolithic integration of TR function is required to meet space constraints for high-density arrays and to reduce assembly costs.

  ○ Frequencies: 35/94 GHz
  ○ Transmit Power: 5W@35GHz, 1W@94 GHz
  ○ TX PAE: >25%
  ○ TX Gain >20 dB
- TX/RX Switch Isolation: 40 dB
- RX NF:
  - RX Gain: > 20 dB
- Phase Shifter: 360 deg, 6-bits

- **Ultra - high efficiency P-band and L - band power amplifiers** for Advanced SAR / Interferometers, Geosynchronous SAR for earthquake monitoring, and Mars subsurface sounding. Using lower efficiency amplifiers in large arrays leads to much higher power system requirements and thermal management challenges.
  - Frequency: 400-500 MHz, 1.2-1.3 GHz
  - Efficiency: >85%

- **High Efficiency Ka-band and W-band Vacuum Device Amplifiers** for Advanced Cloud and Precipitation Radars, Advanced SAR, Telecommunications. Using lower efficiency amplifiers leads to much higher power system requirements and thermal management challenges.
  - Center Frequencies: 35, 94 GHz
  - Power output: 1-5 kW (for pulsed operation); 25 W (for CW operation)
  - Efficiency: >50%

- **Frequency selective surface at Ka and W-band** for Clouds and Precipitation, ACE Decadal Survey Mission. A Ka/W frequency selective surface will enable the development of compact dual frequency radar using a shared single aperture antenna, significantly reducing the dual radar beam pointing error, and radar development cost.
  - High reflection at Ka-band (35GHz) and high pass (low loss) at W-band (94 GHz).
  - Power handling requirement: 2 kW (peak), 100 W (average)

- **FPGA based Radar Pulse Compression Technology and techniques** for Clouds and Precipitation, and ACE Decadal Survey Mission. Cloud and precipitation radars require very high system sensitivity that can be achieved using pulse compression. However, conventional pulse compression techniques cannot be used in downward-looking spaceborne and airborne radar applications due to poor range sidelobe performance.
  - Achieves low range side lobe levels

- **Radar Receiver Protector** for Clouds and Precipitation and ACE Decadal Survey Mission. Spaceborne and airborne cloud/precipitation radars require medium to high peak power transmitters in order to achieve the desired system sensitivity. High speed, low loss receiver protector is necessary to prevent RF damage of
the receiver components.

- W-band (94 GHz), Ka-band (35GHz), low loss

- **Technologies and techniques for noise assisted data analysis of I-Q ensemble detection** for Clouds and Precipitation, ACE Decadal Survey. Radar receiver technologies that mix in-phase and quadrature components of radar returns with calibrated-correlated noise references and noise assisted data analysis algorithms are sought to reduce the effects of platform motion on Doppler measurement and retrieval of hydrometeor drop size distribution. Pulse pair and spectral processing drive the need for a large aperture to reduce the effect of platform motion on Doppler estimates.

- **Multi-frequency compact, light weight electronically tunable antennas and radar systems** for Ice sheet sounding, subsurface exploration of planetary and near-Earth objects. Low, multi-frequency active radars are often used for ice sounding and subsurface exploration of planets, moons and near-Earth objects/bodies. The large size and narrow bandwidth of HF/VHF antennas and radars make them unsuitable for many applications. Compact, light weight electronically tunable antennas and radar systems will enable a range of missions.

  - Compact, light weight, electronically tunable antennas, and radars units to make up basic building blocks of transmission-reflection tomography radars.

  - Tunable Frequency Ranges:
    - 3-30 MHz, 25-100 MHz
    - VSWR:
    - Length:
    - Gain: >0 dBi
    - Power handling: >200W

**S1.03 Passive Microwave Technologies**

NASA employs passive microwave and millimeter-wave instruments for a wide range of remote sensing applications from measurements of the Earth’s surface and atmosphere (http://www.nap.edu/catalog.php?record_id=11820) to cosmic background emission. Proposals are sought for the development of innovative technology to support future science and exploration missions employing 450 MHz to 5 THz sensors. Technology innovations should either enhance measurement capabilities (e.g., improve spatial, temporal, or spectral resolution, or improve calibration accuracy) or ease implementation in spaceborne missions (e.g., reduce size, weight, or power, improve reliability, or lower cost). While other concepts will be entertained, specific technology innovations of interest are listed below for missions including decadal survey missions (http://www.nap.edu/catalog/11820.html) such as PATH, SCLP, and GACM and the Beyond Einstein Inflation Probe (Inflation Probe - cosmic microwave background, http://science.gsfc.nasa.gov/660/research/)
MEMS switches with low insertion loss (18 dB), capable of switching with speeds of >100 Hz at cryogenic temperatures (below 5 K) for 10^8 or more cycles. Technology applies to Beyond Einstein Probe.

MEMs variable delay line up to 40 GHz with 180 degree of phase variation at room temperature. The delay line’s phase increment should be linear or with at least 16 discrete steps. Applies to: Venture class airborne instruments.

MMIC Low Noise Amplifiers (LNA). Room temperature LNAs for 165 to 193 GHz with low 1/f noise, and a noise figure of 6.0 dB or better; and cryogenic LNAs for 180 to 270 GHz with noise temperatures of less than 150K. Earth Science Decadal Survey missions that apply: PATH and GACM.

Enabling technology for ultra-stable microwave noise references (three or more) embedded in switched network with reference stability (after temperature correction) to within 0.01K/year. Applies to: PATH, SCLP, GACM, SWOT.

Low power >200 Mb/s 1-bit A/D converters and cross-correlators for microwave interferometers. Earth Science Decadal Survey missions which apply: PATH, SCLP, SWOT.

Automated assembly of 180 GHz direct conversion I-Q receiver modules. Technology applies to both the Beyond Einstein Initiative probe and the Decadal Survey PATH concept.

High emissivity (>40 dB return loss) surfaces/structures for use as onboard calibration targets that will reduce the weight of aluminum core targets, while reliably improving the uniformity and knowledge of the calibration target temperature. Earth Science Decadal Survey missions which apply: PATH, SCLP.

Multi-Frequency and/or multi-Beam Focal Plane Arrays (FPA) as a primary feed for reflector antennas. Enables technology for ultra-stable microwave noise references (three or more) embedded in switched network with reference stability (after temperature correction) to within 0.01K/year. Applies to: PATH, SCLP, GACM, SWOT.

Low DC power spectrometer (channelizer) covering 4 GHz with 125 KHz resolution for planetary radnometer missions and covering 500 MHz with 125 KHz resolution for Earth observing missions. Also RFI mitigation approaches employing channelizers for broad band radnometers. Earth Science Decadal Survey mission which applies: GACM.

Broad band 180 - 270 GHz radomes for aircraftborne submillimeter remote sensing instruments.

MMIC Low Noise Amplifiers (LNA). Room temperature LNAs for 165 to 193 GHz with low 1/f noise, and a noise figure of 6.0 dB or better; and cryogenic LNAs for 180 to 270 GHz with noise temperatures of less than 150K. Earth Science Decadal Survey missions which apply: PATH and GACM.

- 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.
- Large format (megapixel) broadband detector arrays in the 30 to 300 micron wavelength range are needed for SAFIR. These should offer background limited operation with cooled (5 K) telescope optics, and have minimal power dissipation at low temperatures. Low power frequency multiplexers are also of interest for readout of submm bolometer arrays for SAFIR and Inflation Probe.

High performance sensors and detectors that can operate with low noise under the severe radiation environment (high energy electrons, ≈1 megarad total dose) anticipated during the Europa Jupiter System Mission (EJSM) are of interest (see the Jupiter Europa Orbiter Mission Study 2008: Final Report, http://opfm.jpl.nasa.gov/library/). Notional instruments include visible and infrared cameras and spectrometers, a thermal imager and laser altimeter. Devices can be radiation hardened by design and/or process:

- Hardened visible imaging arrays with low dark currents even in harsh radiation environments, line or framing arrays suitable for use in pushbroom and framing cameras. Detectors include CCDs (n or p-channel), CMOS imagers, PIN photodiode hybrids, etc.
- Hardened infrared imaging arrays with a spectral range of 400 to 5000 nm with high quantum efficiency and low dark current, as well as compatible radiation hardened CMOS readouts. These devices could include substrate removed HgCdTe hybrid focal plane arrays responsive from 400 to 2500 nm and IR only focal plane arrays responsive from 2500 nm to 5000 nm.
- High speed radiation hardened avalanche photodiodes that respond to a 1.06 micron laser beam suitable for use in time of flight laser rangefinders. Devices should have high and stable gain with lower dark current in harsh radiation environments.
- Radiation hardened detectors suitable for use in uncooled thermal imagers that respond to spectral bands ranging from 8 to 100 microns. Detectors could include thermopile or microbolometer small line arrays.

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://planetquest.jpl.nasa.gov/TPF/tpf_index.cfm) and Stellar Imager (http://hires.gsfc.nasa.gov/si):

- 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

- 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).