NASA SBIR 2021 Phase I Solicitation

S1.01 Lidar Remote-Sensing Technologies

Lead Center: LaRC

Participating Center(s): GSFC

Scope Title:

Lidar Remote-Sensing Technologies

Scope Description:

NASA recognizes the potential of lidar technology to meet many of its science objectives by providing new capabilities or offering enhancements over current measurements of atmospheric, geophysical, and topographic parameters from ground, airborne, and space-based platforms. To meet NASA's requirements for remote sensing from space, advances are needed in state-of-the-art lidar technology with an emphasis on compactness, efficiency, reliability, lifetime, and high performance. Innovative lidar subsystem and component technologies that directly address the measurement of atmospheric constituents and surface features of the Earth, Mars, the Moon, and other planetary bodies will be considered under this subtopic. Compact, high-efficiency lidar instruments for deployment on unconventional platforms, such as unmanned aerial vehicles, SmallSats, and CubeSats are also considered and encouraged. Proposals must show relevance to the development of lidar instruments that can be used for NASA science-focused measurements or to support current technology programs. Meeting science needs leads to four primary instrument types:

- Backscatter: Measures beam reflection from aerosols and clouds to retrieve the optical and microphysical properties of suspended particulates.
- Laser spectral absorption: Measures laser absorption by trace gases from atmospheric or surface backscatter and volatiles on surfaces of airless planetary bodies at multiple laser wavelengths to retrieve concentration of gas within measurement volume.
- Ranging: Measures the return beam's time of flight to retrieve distance.
- Doppler: Measures wavelength changes in the return beam to retrieve relative velocity

Expected TRL or TRL Range at completion of the Project: 3 to 6
Primary Technology Taxonomy:
Level 1: TX 08 Sensors and Instruments
Level 2: TX 08.1 Remote Sensing Instruments/Sensors
Desired Deliverables of Phase I and Phase II:

- Prototype
- Hardware
- Software

Desired Deliverables Description:

Phase I research should demonstrate technical feasibility and show a path toward a Phase II prototype unit. A typical Phase I deliverable could be a technical report demonstrating the feasibility of the technology and a design that is to be built under a Phase II program. In some instances where a small subsystem is under investigation, a prototype deliverable under the Phase I is acceptable.

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. Higher fidelity Phase II prototypes that are fielded in harsh environments such as aircraft often require follow on programs such as Phase III SBIR to evaluate and optimize performance in relevant environment.

State of the Art and Critical Gaps:

- Compact, efficient, and rugged narrow-linewidth continuous-wave and pulsed lasers operating between ultraviolet and infrared wavelengths suitable for lidar. Specific wavelengths are of interest to match absorption lines or atmospheric transmission: 290 to 320 nm (ozone absorption), 450 to 490 nm (ocean sensing), 532 nm, 817 nm (water vapor line), 935 nm (water vapor line), 1064 nm, 1550 nm (Doppler wind), 1645 to 1650 nm (methane line), and 3000 to 4000 nm (hydrocarbon lines and ice measurement). Architectures involving new developments in high-efficiency diode laser, quantum cascade laser, and fiber laser technologies are especially encouraged. For pulsed lasers two different regimes of repetition rate and pulse energies are desired: from 1 to 10 kHz with pulse energy greater than 1 mJ and from 20 to 100 Hz with pulse energy greater than 100 mJ. For laser spectral spectral absorption applications such as Differential Absorption Lidar or Integrated Path Absorption Lidar a frequency-agile source is required to tune >100 pm on a shot-by-shot basis while maintaining high spectral purity of >1000:1. Laser sources of wavelength at or around 780 nm are <u>not</u> sought this year. Also, laser sources of wavelength at or near 2050 nm are <u>not</u> sought this year. Laser sources for lidar measurements of carbon dioxide are <u>not</u> sought this year.
- Novel approaches and components for lidar receivers such as: integrated optical/photonic circuitry, frequency-agile ultra-narrow-band solar blocking filters at 817 and/or 935 nm, and phased-array or electro-optical beam scanners for large (>10 cm) apertures. Development of telescopes should be submitted to a different subtopic within S2 “Advanced Telescope Technologies,” unless the design is specifically a lidar component, such as a telescope integrated with other optics. Infrared photodetectors involving new semiconductor materials/architectures should be submitted to a different subtopic, S1.04 “Sensor and Detector Technologies for Visible, IR, Far-IR, and Submillimeter,” unless the design is specifically a lidar component, such as a photodetector combined with electronics or optics for lidar application that match wavelength ranges listed for lasers in the above bullet. Receivers for direct-detection wind lidar are <u>not</u> sought this year.
- New 3D mapping and hazard detection lidar with compact and high-efficiency diode and fiber lasers to measure range and surface reflectance of planets or asteroids from >100 km altitude during mapping to <1 m during landing or sample collection, within size, weight, and power fit into a 4U CubeSat or smaller. New lidar technologies are sought that allow system reconfiguration in orbit, single photon sensitivities and single beam for long distance measurement, and variable dynamic range and multiple beams for near-range measurements.
- Transformative technologies and architectures are sought to vastly reduce the cost, size, and complexity of lidar instruments. Advances are needed in generation of high-efficiency and high-pulse energy (>>1 mJ) from compact (SmallSat to CubeSat size) packages, avoiding the long cavity lengths associated with current solid-state laser transmitter designs. Mass-producible laser designs, perhaps by a hybrid diode/fiber/crystal architecture, are desirable for affordable sensor solutions and reducing parts count. Heat removal from lasers is a persistent problem, requiring new technologies for thermal management of laser transmitters. New materials concepts could be of interest for the reduction of weight for optical benches and subcomponents. Novel low-SWaP (size, weight, and power) electrical systems are of interest for data acquisition from multipixel linear mode photon detector arrays in future multichannel lidar receivers, capable of fast waveform capturing, onboard signal processing, and data compression.

Relevance / Science Traceability:

The proposed subtopic addresses missions, programs, and projects identified by the Science Mission Directorate, including:

- Atmospheric Water Vapor—Profiling of tropospheric water vapor supports studies in weather and dynamics, radiation budget, clouds, and aerosols processes.
- Aerosols—Profiling of atmospheric aerosols and how aerosols relate to clouds and precipitation.
- Atmospheric Winds—Profiling of wind fields to support studies in weather and atmospheric dynamics on Earth and atmospheric structure of planets.
- Topography—Altimetry to support studies of vegetation and the cryosphere of Earth, as well as the surface of planets and solar system bodies.
- Greenhouse Gases—Column measurements of atmospheric gases, such as methane, that affect climate variability.
- Hydrocarbons—Measurements of planetary atmospheres.
- Gases Related to Air Quality—Sensing of tropospheric ozone, nitrogen dioxide, or formaldehyde to support NASA projects in atmospheric chemistry and health effects.
- Automated Landing, Hazard Avoidance, and Docking—Technologies to aid spacecraft and lander maneuvering and safe operations.

References:

- NASA missions are aligned with the National Research Council's decadal surveys, with the latest survey on earth science published in 2018 under the title "Thriving on Our Changing Planet: A Decadal Strategy for Earth Observation from Space": http://sites.nationalacademies.org/DEPS/esas2017/index.htm
- For planetary science, NASA missions are aligned with the National Research Council decadal survey titled "Planetary Science and Astrobiology Decadal Survey 2023-2032": https://www.nationalacademies.org/our-work/planetary-science-and-astrobiology-decadal-survey-2023-2032
- Description of NASA lidar instruments and applications can be found at:
  - https://science.larc.nasa.gov/lidar/
  - https://science.gsfc.nasa.gov/sci/