



## NASA SBIR 2020 Phase I Solicitation

### S1.01 Lidar Remote Sensing Technologies

Lead Center: LaRC

Participating Center(s): GSFC

Technology Area: TA8 Science Instruments, Observatories & Sensor Systems

#### 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 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 topography 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 balloons, 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 to retrieve the opacity of a gas.
- Ranging - Measures the return beam's time-of-flight to retrieve distance.
- Doppler - Measures wavelength changes in the return beam to retrieve relative velocity.
- Differential absorption - Measures attenuation of two different return beams (one centered on a spectral line of interest) to retrieve concentration of a trace gas.

#### References

NASA missions are aligned with the National Research Council's decadal surveys, with the latest survey 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>).

NASA lidar applications and technology needs for Earth Science are also summarized in the report "NASA ESTO Lidar Technologies Investment Strategy: 2016 Decadal Update." (<https://ntrs.nasa.gov/search.jsp?R=20180002566>)

Conference proceedings on NASA lidar interests in earth science, exploration, and aeronautics can be found at the

**Expected TRL or TRL range at completion of the project** 3 to 6

**Desired Deliverables of 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. 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.

**State of the Art and Critical Gaps**

- Compact and rugged single-frequency continuous-wave and pulsed lasers operating between 290-nm and 2050-nm 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 line), 935-nm (water line), 1064-nm, 1570-nm (CO<sub>2</sub> line), 1650-nm (methane line), and 2050-nm (Doppler wind). Architectures involving new developments in diode laser, quantum cascade laser, and fiber laser technology are especially encouraged. For pulsed lasers two different regimes of repetition rate and pulse energies are desired: from 1-kHz to 10-kHz with pulse energy greater than 1-mJ and from 20-Hz to 100-Hz with pulse energy greater than 100-mJ. Laser sources of wavelength at or around 780-nm are not sought this year.
- Novel approaches and components for lidar receivers such as: integrated optical/photonic circuitry, compact and lightweight Cassegrain telescopes compatible with existing differential absorption lidar (DIAL) and HSRL lidar systems, frequency agile solar blocking filters at 817-nm and/or 935-nm, and scanners for large apertures of telescope of at least 10-cm diameter and scalable to 50-cm diameter.
- New space lidar technologies that use small and high-efficiency diode or 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 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 pulse energy (>> 1-mJ) from compact (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 telescopes. Distributed transmitter/receiver apertures may offer another option for weight reduction.

**Relevance / Science Traceability**

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

Aerosols--ongoing and planned missions include ACE (Aerosols/Clouds/Ecosystems), PACE (Plankton, Aerosol, Cloud, ocean Ecosystems), and MESCAL (Monitoring the Evolving State of Clouds and Aerosols).

Greenhouse Gases--planned missions include sensing of carbon dioxide and methane. The ASCENDS (Active Sensing of CO<sub>2</sub> Emissions over Nights, Days, and Seasons) mission was recommended by the Decadal Survey.

Ice Elevation--ongoing and planned missions include ICESat (Ice, Cloud, and land Elevation Satellite), as well as aircraft-based projects such as IceBridge.

Atmospheric Winds--planned missions include 3D-Winds, as recommended by the Decadal Survey. Lidar wind

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measurements in the Mars atmosphere are also under study in the MARLI (Mars Lidar for Global Climate Measurements from Orbit) program.

Planetary Topography--altimetry similar to Earth applications is being planned for planetary bodies such as Titan and Europa.

Gases related to Air Quality--planned missions include sensing of tropospheric ozone, nitrogen dioxide, or formaldehyde to support NASA projects such as TOLNet (Tropospheric Ozone Lidar Network) and the Pandora Global Network.

Automated Landing, Hazard Avoidance, and Docking--technology development is called for under programs and missions such as ALHAT (Autonomous Landing and Hazard Avoidance Technology), SPLICE (Safe and Precise Landing Integrated Capabilities Evolution), and NPLP (NASA Provided Lunar Payloads).