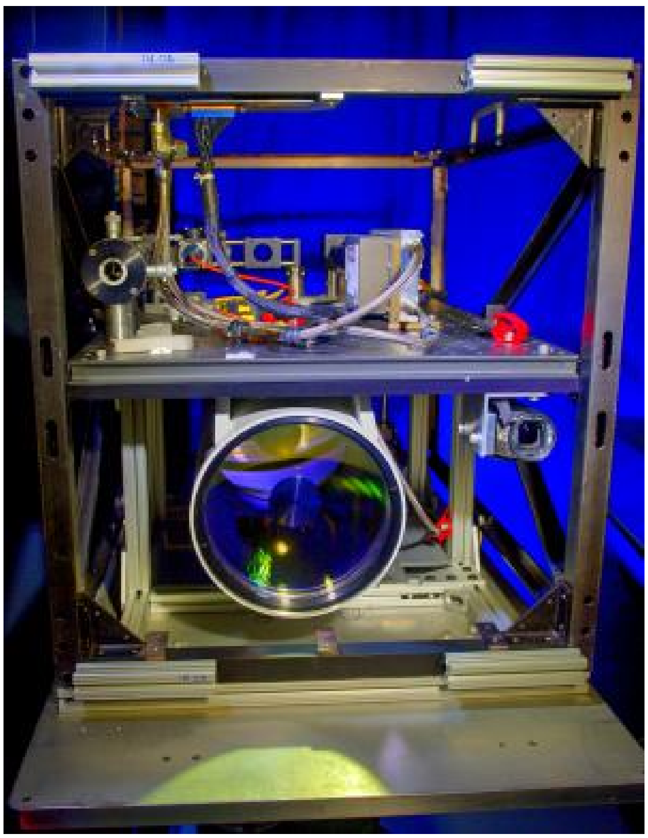
NASA technologists embrace laser instrument challenge

November 18 2013, by Kate Ramsayer



This airborne LIST simulator, which was developed with NASA funding, is a 16-beam, non-scanning, swath-mapping altimeter. It forms the basis of the proposed LEaVEs instrument. Credit: Bill Hrybck/NASA

In 2007, the National Research Council threw down a challenge: Design a space-based laser altimeter that could measure the height of Earth's surface everywhere to within a mere 10 centimeters—all at 5-meter resolution. To this day, some believe it can't be done.

Goddard scientist Dave Harding begs to differ.

He and his team have embraced the challenge and are developing a laser altimeter that could provide the data from a berth onboard the NRC-proposed Lidar Surface Topography, or LIST, mission. It would generate highly detailed maps of topography and vegetation that scientists could use to forecast and respond to natural hazards and study carbon storage in forests.

"There's no launch date for LIST. It's way out there sometime because most people say there's no way anybody can do this," Harding said. "But we want to show, yeah, you can. And we want to move it forward."

Lidar systems use lasers from airplanes to scan swaths of the ground below, timing the return of photons to create a complete and detailed 3-D elevation map of the tree canopy and ground below.

Highly detailed elevation maps, such as those the LIST mission would create, could provide an intricate view of forest structure – where limbs branch off, how much potential wildfire fuel is building up on the forest floor, and more. Scientists could use these maps to help predict fire severity, or analyze wildlife habitat, Harding said. Detailed lidar information could also help keep an eye on volcanoes, track landslides, and search for coastal hazards.

To create global elevation maps from space, however, things get complicated. Satellites travel much faster, so scanning a single laser beam would create big gaps between the zigzag pattern. Consequently, more beams are needed and that requires a lot more power—a limited resource on a spacecraft. And from about 250 miles up, the laser photons need to travel far to create a high-resolution elevation map.

Harding and his colleagues, including Goddard technologist Tony Yu—a recognized expert in lidar technologies—are tackling the LIST lidar challenge from several angles, including power-efficient lasers, more sensitive photon-counting detectors, and a new lidar architecture.

Tackling the Challenge

First is the problem of the laser itself. To get the necessary 5-meter resolution along the planned 5-kilometer swath, Harding says an instrument would need 1,000 beams. In sharp contrast, the first ICESat (Ice, Cloud, and land Elevation Satellite) laser altimeter had one. ICESat-2, scheduled for a 2016 launch, has six.

"You've got to get much more efficient to get from one beam to 1,000 beams because the spacecraft has three limits—power, mass, and volume," Harding said.

To get a more efficient, space-friendly laser, Yu has been working with the Raytheon Co. to combine several technologies, including a highly polished rare-earth-metals microchip laser and a thin, planar waveguide amplifier to increase efficiency. Yu also has scrapped more traditional high-voltage electro-optic switches to generate the laser pulses, opting instead for a passive switching technique that doesn't require any power. The new laser, Yu said, already has proven to be more than twice as efficient as more traditional models.

With these features and more, the team believes it will be able to generate a laser that is close to 50 watts—compared with the 9-watt ICESat-2 laser. The scientists' idea is to have an array of 10 of these 50-watt lasers, each split up into 100 beams, to get LIST to the 1,000 beams necessary for high-resolution coverage.

"I think we're on the path to getting there, to demonstrating one stage of the 10 we'd have to build for LIST," Yu said.

To ensure the instrument is harmless to people on the ground, the scientists calculate what the intensity of each flight mission's beam would be as it hits the ground, he said. Factoring in the distance from the spacecraft, and how the beam has a diffuse footprint when it reaches Earth's surface, the energy is small enough to be safe, he said, even to those using binoculars or other visual aids.

In designing the LIST instrument, the right number of lasers firing the right number of photons isn't enough. It also will have to detect those photons when they bounce back to the satellite. Harding and Yu's vision for LIST is to use linear-mode detector arrays. Each element of these advanced-technology arrays can count the number of individual photons that return to the satellite at the same time, providing a more complete picture that maps the shrubs, low branches, and forest canopies.

The detectors also would be sensitive to the polarization of the returning photons. Laser pulses are polarized when they leave the lidar, Harding said, but when they bounce off trees or the ground, some of the photons change polarization. When they bounce off water, however, they all reflect with the same polarization. Having a photon-counting detector that could record polarization would help researchers characterize the land cover, elevation, and identify the location of surface water.

An Eye Toward Space

With funding from NASA's Earth Science Technology Office and Goddard's Internal Research and Development program, the team has developed two airborne instruments that demonstrated the polarization measurement and the more efficient measurement approach.

The plan is to fly one of these highly sensitive multi-photon detector arrays in space on a small CubeSat satellite. In addition, the team is applying for funding to build an instrument called the Lidar Earth Venture Ecosystem Explorer, or Leaves, which would fully demonstrate the technologies that are key for LIST. The team wants to fly this instrument, which would be equipped with 25 laser beams and other advanced technologies, on the International Space Station.

"Our airborne instruments are smart, but we want to get way smarter with an instrument on the space station for LIST," Harding said.

Provided by NASA