**LIDAR IMAGING OF TOPOGRAPHY WITH MILLIMETER RANGING PRECISION FOR PROXIMITY SCIENCE AND OPERATIONS FROM ROVERS OR SPACECRAFT.** Gregory A. Neumann[1], James B. Garvin[1], J. Bryan Blair[1], Jack L. Bufton[2], D. Barry Coyle[1] [1]NASA-Goddard, Solar System Exploration Division, Greenbelt MD 20771, Gregory.A.Neumann@nasa.gov; [2]Global Science & Technology, Greenbelt, MD 20770.

**Introduction:** A new class of sensor has been developed for measuring local topography at millimeter vertical scales. A system informally known as Lidar Imaging of Microtopography for Efficient Rover Investigations and Contextual Knowledge (LIMERICK) enables three-dimensional (3-D) assessment of context geology, quantitative analysis of depositional environments in search of favorable locations for biosignature preservation, and accurate navigation and positioning of surface assets for sample acquisition, using off-the-shelf technologies fully qualified for space operation. The laser systems are eye safe and compatible with both the Mars2020 robotic program and human exploration and operations objectives. The concept is also relevant to proximity operations during close approach scenarios for sampling asteroids, as are being considered for the ARRM program, or for Terrain Relative Navigation in permanently-shadowed regions.

Currently available systems for in situ operational planning, local 3-D vision and navigation (stereo imaging) are limited by illumination and sensor geometry. Space-qualified scannerless flash lidars [1, 2] use multipixel sensors but are limited by position/range uncertainty and have cm-level resolution at best. Neither technique can provide the microtopographic knowledge required to quantify the physical expressions—shape, morphology, texture, and stratigraphy—of dynamic geological processes on Mars associated with sediment deposition. Commercial laser scanners are overcoming the precision limitations but have not previously been adapted to the accommodations and operational constraints of space. The "LIMERICK" approach offers the advantages of high-efficiency telecommunication laser technology, single-wavelength detector sensitivity, and micro-electromechanical systems (MEMS) mirror scanning to produce a digitized signal that can be summed over hundreds of laser pulses per image pixel to achieve millimeter ranging precision. Scanning a 6° field of view with 2.5 mm pixel resolution at a range of 5 m is accomplished in < 7 minutes and can be done in darkness or daylight.

**Transceiver:** Figure 1a shows our Lab Demo Unit (LDU) using an eye-safe commercial fiber laser producing pulsed signals that are collimated and reflected from a linearized two-axis MEMS mirror [3] into an output beam exiting the optical transceiver assembly (OTA, Fig. 1b). Two receiver telescopes cover a range from 2-50 m with variable gain to avoid saturation.

**Electronics:** The technology that achieves the remarkable precision is derived from extensive experience with digitized-waveform lidars [4, 5], low-power 10-bit resolution digitizers and Field-Programmable Gate Arrays (FPGAs) with signal processing capabilities. This permits summation over bursts of pulse/return waveforms to achieve high numerical precision. Data handling, control and communication are coupled into one FPGA for efficiency.

*Range correlation.* A key design factor is the digital signal processing that correlates the outgoing and incoming waveforms. The autocorrelation sequence is fit by Gaussian peaks, whose precise offset gives an unbiased range. The ratio of peaks provides a reflectance image as a geometric (zero phase) albedo, independent of illumination conditions, co-registered with range.

**Environmental Adaptations to Mars2020 Rover:** In response to the Mars2020 rover mission solicitation. the LIMERICK instrument was configured to operate within the constraints of the Mars environment. All components used have been vibration-tested, are sterilizable and routinely qualified to -35°C. The critical MEMS and laser components require modest (<3 W) operational heaters to operate in the severe cold of martian night. Ample link margin provides for anticipated visible dust opacity levels without loss of resolution, while the near-IR laser is less affected than visible wavelength instruments. All enclosures are sealed and entrance/exit optics are coated/grounded to resist dust buildup, cabled to electronics within the rover body.

| Instrument parameter | Magnitude |
|---|---|
| Range | 2–50 meter |
| Range Error | ≤ 1.0 mm @ 2–10 m |
| Wavelength | 976 nm |
| Pulse width, energy | 2 ns @ 2 nJ |
| Exit Beam Width (1/e$^2$) | 3.5 ± 0.1 mm |
| Beam Divergence | 0.75 mrad |
| Total Scanned Target Area | 100 × 100 mrad |
| Receiver Field of View | 150 mrad |
| Illuminated Pattern | 200 x 200 spots |

Table 1. LDU nominal parameters.

**References:** [1] Stettner, R. et al. (2008) *Int. J. High Speed Electronics and Systems,* 18(02), 401-406. [2] Christian, J. A. et al. (2011) *AIAA Guidance*, 1-20. [3] Milanovic, V. (2009) *OFCCE,* San Diego. [4] Blair, J. B. et al. (1997) *ISPRS J. Photogrammetry and Remote Sensing*, 54, 115-122. [5] Garvin, J. et al. (1998) *Phys. Chem. Earth, 23(9-10), 1053-1068.*

**Additional Information:** Much of this information is taken from the DELITE instrument proposal submitted in response to the Mars2020 rover mission 2013 solicitation. At that time the LDU development was supported by internal investments to evaluate performance and validate the system design. During that time, a model of a sedimentary layered rock “Last Chance” was used as a target. The figures below show the LDU and results of its testing against a 45 cm x 45 cm target at a range of approximately 4.5 m.

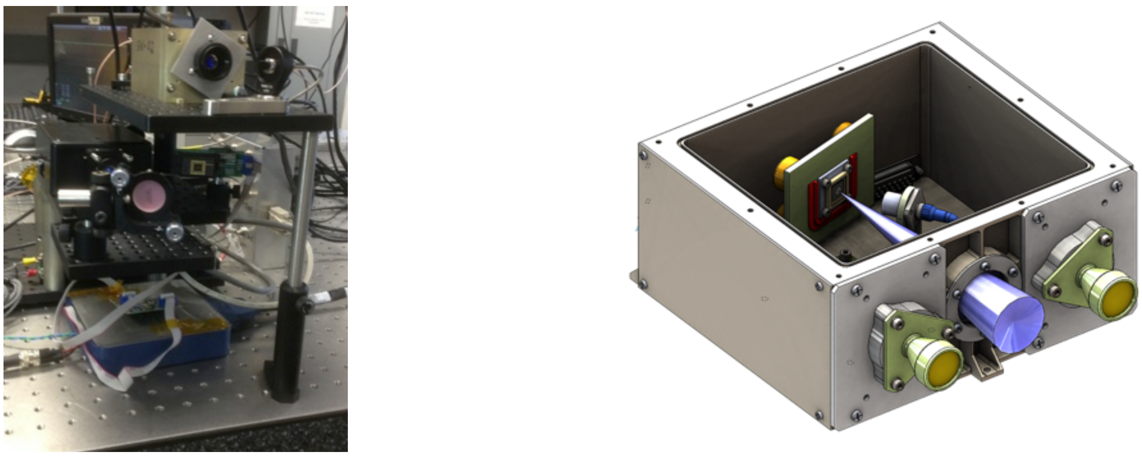

Figure 1. a) Lab Demonstration Unit. b) OTA assembly designed for rover mast.

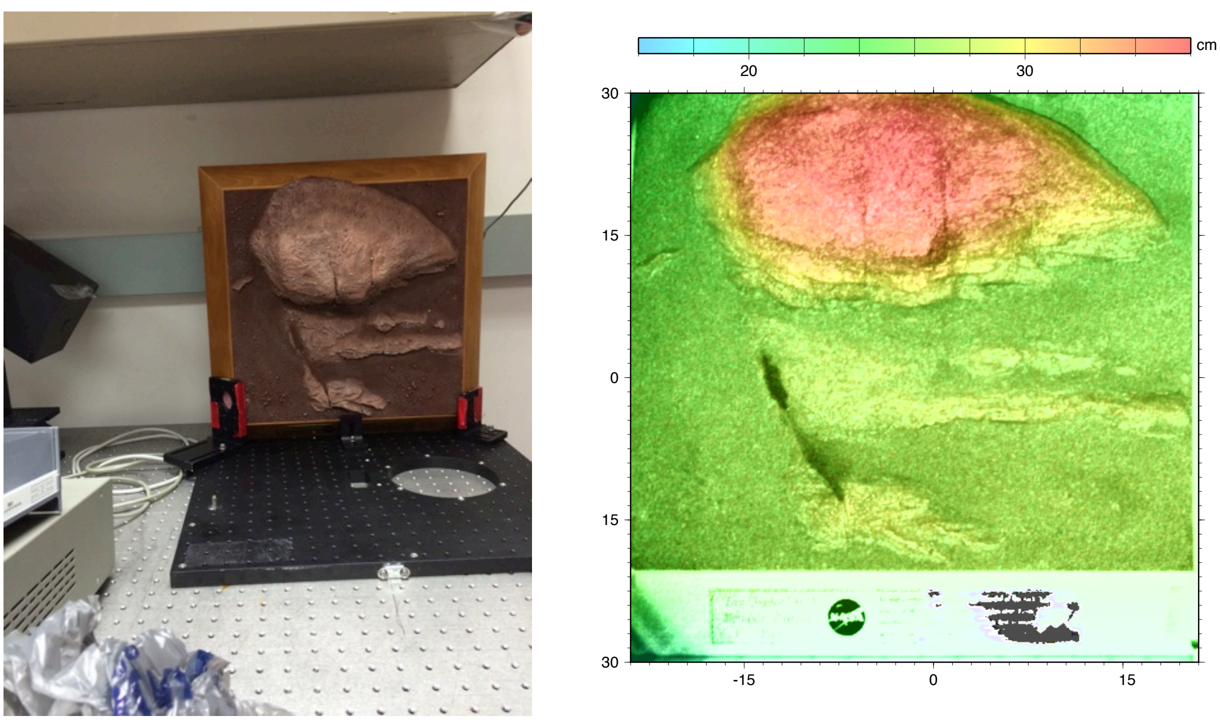


Figure 2. a) Last Chance Rock model test setup. b) Scanned topographic range image with reflectance image shading. Color scale represents vertical height and axes are in centimeters.