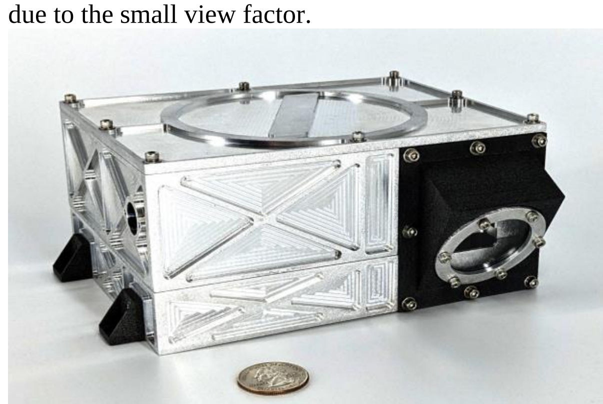
L3VIN: Lunar-Laser-Lab for Volatiles Investigation. A CLPS-compatible in situ lunar instrument., N.D.S. Webb[1], E. Eshelman[1], K. Simon[1], D. Van Hoesen[1], O. Pechettino[1], and P. Sobron[1], A. Wang[2], B. Jolliff[2], and J. Gillis-Davis[2]. [1]Impossible Sensing 3407 S. Jefferson Ave. St. Louis, MO 63118, [2]Washington University in St. Louis 1 Brookings Dr St. Louis, MO 63130.

Introduction: NASA's Commercial Lunar Payload Services (CLPS) program aims to deliver science instruments to the lunar surface [1]. Instruments and instrument payloads are desired under this program to enable science investigations that address NASA's lunar priorities, including investigations that seek to better constrain lunar elemental and mineral composition to increase knowledge of lunar geology [2]. Under CLPS, multiple mission opportunities are expected to occur over the next decade. These opportunities motivate development of new instruments with the size, weight, and power (SWaP) requirements commensurate with the accommodation requirements of CLPS-scale rovers. Further, instruments with sufficiently low SWaP that can be part of a multi-instrument payload in this context will be highly valued to increase the science return of these resource-constrained missions.

Lunar-Laser-Lab for Volatiles Investigation (L3VIN) is a laser-induced breakdown spectroscopy (LIBS) instrument under development that incorporates spatial mapping and imaging optical assemblies into a compact package that can be integrated into small rovers or landers to enable geochemical investigations on natural unprepared samples, such as regolith and rocks. L3VIN uses active laser beam steering technology developed by our team under several NASA Small Business Innovation Research (SBIR) awards, enabling return of 20 x 20 cm maps of elemental composition, including in situ resource utilization (ISRU) -relevant materials, at 1 m distance, targeting 1 mm/pixel resolution with detection limits of 1% wt/wt. Combined with a near-infrared reflectance instrument, L3VIN would enable geochemical and mineralogical information to be obtained from the same spot on the lunar regolith, providing ground-truth characterization and information regarding the distribution of lunar materials (hydrated/hydrous compounds, minerals, metals, and volatiles) in locations of high interest in the south polar region and the Gruithuisen Domes [3].

System Description: The L3VIN Sensor Unit (LSU) is required to interface with the front of the rover body such that the optical window is exposed to the lunar surface (Fig. 1). The electrical components (scan mirror, imager, linear focusing stage) have spaceflight heritage. The L3VIN Electronics Unit (LEU) connects to the LSU by electrical and fiber optic cables (Fig. 1). To interface with the rover, the LSU accepts unregulated or regulated 28 VDC power and wired RS-422 for communication. Electronics includes the C&DH, power for both L3VIN and MIR3100 (Fig. 1), and electronics for the laser, imager, and scan mirror boards. Waste heat produced during operation (<5 W) would be handled by the rover. The optical aperture exposed to the lunar surface is small (~1" diameter) and can be shielded from sunlight with a small visor. Radiative emission from the lunar surface is small into the instrument due to the small view factor.



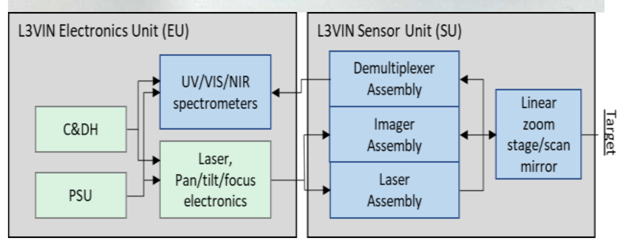


Figure 1. L3VIN prototype, containing the laser housing and optical probe assemblies, with a quarter for scale. Block diagram with laser, imaging, signal, and electrical/power paths shown. L3VIN prototype hardware containing optics for pan/tilt/focus, co-boresighted imaging, and demultiplexing of the collected LIBS emission.

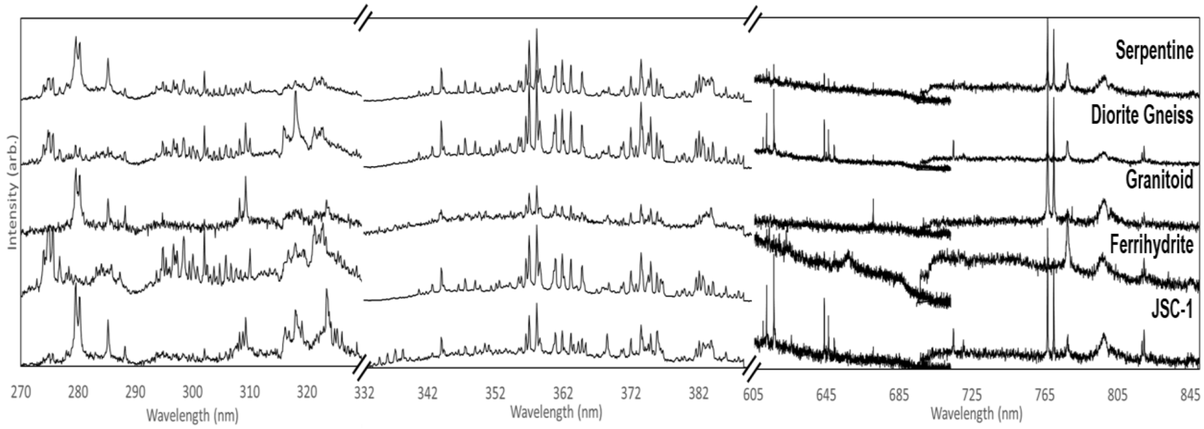


Figure 2. LIBS spectra obtained with L3VIN prototype on select relevant lunar analog samples.

Science capabilities. Focusing L3VIN's Yb:YAG 1030nm laser at 10 kHz repetition rate and 120 µJ of pulse energy, onto a target ablates a small amount of material, producing spectral emission features unique to each element. L3VIN was designed to spectrally separate collected light from 200-980 nm into UV, VIS, and NIR components via the demultiplexer and direct the light to three spectrometers to balance the need for a wide wavelength observation window and high spectral resolution. An imager co-boresighted with the laser was incorporated into the design in order to focus the instrument by obtaining a set of images through the focus. The imager also provides contextual information as to the point of acquisition, important when the target displays spatially varying mineralogy. The optical components enabling these capabilities are shown in Fig. 1. L3VIN's pan/tilt/focus system, using a two-axis scan mirror and a translatable zoom optic, allows for rastering over a 20 cm x 20 cm target to acquire bulk mineralogy on an inhomogeneous natural sample, providing elemental distribution across the surface.

Lunar Analog Study: To demonstrate the utility of L3VIN for a lunar application, six lunar analog materials were analyzed: serpentine, diorite gneiss, granite, basalt and ferrihydrite standard samples, and a well-known lunar analog JSC-1 (regolith) [4] due to their strong correlation to lunar regolith chemistry and suite of elements of interest more broadly.

Differentiation in the weight percent (wt%) of elements, i.e., titanium, can help to determine the approximate age and formation process of mare basalts [5]. Our instrument has demonstrated the ability to detect Ti as indicated by the regolith, basalt, and granite spectra (Fig. 2). Moreover, lunar regolith is typically very rich in Ca (i.e., diorite gneiss/regolith) and deficient in alkali metals such as Na, K, and Rb apart from KREEP rocks (i.e., those enriched in K, rare earth elements, and P) [6]. The sensitivity of our detector was quantified with a 4.5 wt% Si in Ca solid solution where the Si peak was detected well above the noise floor, indicating the ability to detect Si at lower concentrations.

Conclusions: L3VIN's SWaP were designed to be commensurate with presumed accommodation requirements for rovers within the scope of NASA's CLPS program. The novel benefit of L3VIN is the ability to acquire 2D raster LIBS from a standoff distance across natural surfaces (rocks and regolith).

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