DiSCO (Dual In-Situ Spectroscopy and Coring). A. Yanchilina,[1] K. Simon,[1] E. Eshelman[1], C. Sudlik[1], O. Pochettino,[1] M. Willis,[1] P. Sobron.[1] [1]Impossible Sensing (ayanchilina@impossiblesensing.com).

Mapping Mineral Resources: High resolution, *in-situ* elemental, chemical, and mineralogical mapping/imaging are critical to study both lunar and planetary surface processes. This is because processes that include physical and chemical weathering, water activity, diagenesis, metamorphism, and biogenic activity leave traces of their actions as features on the scale of 10 to 100 µm. It is essential to acquire compositional information on length scales that are less than or equal to the dimensions of grains or phases being analyzed from these processes. Here we feature Dual *in-situ* Spectroscopy and coring (DiSCO), pioneered at Impossible Sensing, an instrument that has the capabilities necessary to make spectroscopic measurements on scales necessary for exploration & characterization of lunar & planetary surfaces.

DiSCO Innovation: DiSCO is an innovative arm-mounted instrument for acquiring and analyzing planetary subsurface materials (Figure 1). The instrument extracts 5 × 1 cm cores, and immediately performs *in-situ*, time-resolved, coregistered imaging and spectroscopic mapping at high resolution – 10 µm and 50 µm, respectively. The significant attribute of our technology is the ability to auto-focus on a specific layer or location on the rock (and sub rock surface) without any moving parts – something that none of the previous, current, or even future surface missions have capability to do but is essential for extraterrestrial planetary exploration missions.

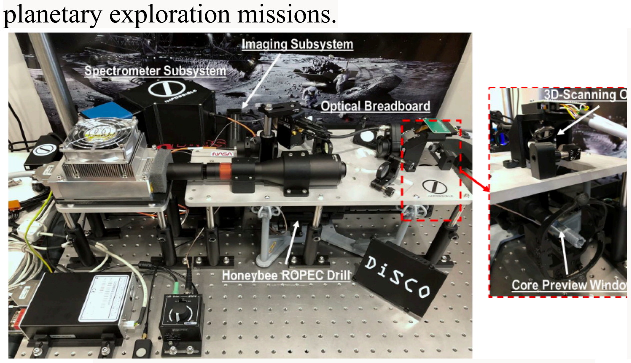

Figure 1: DiSCO Mk 1 represents function of a notional. flight model. DiSCO architecture is highly modular, so exact packaging design and spacecraft accommodation can be tailored to specific missions. This breadboard uses a mix of commercial and flight-grade components. Notional breadboard SWaP: 11,500. cm3, 4.6 kg, 15.2 W (probe), 4500 cm3, 1.6 kg, 20 W (spectrometer/imager). Data volume: 0.1 MB/spectrum, 0.9 MB/image.

The Mars Exploration Rovers clearly illustrated the need for such technology by exposing rock surface and identifying round nodules. Unfortunately, the arm mounted instruments were unable to analyze the nodules themselves, but rather could only take an 'average' mineral and element profile of the area of interest. DiSCO is the first instrument that boasts integrated drilling/ coring /caching, imaging, and laser spectroscopic mapping systems. DiSCO integrates a combined fiber-based optical imaging, laser Raman spectroscopy (LRS), laser-induced breakdown spectroscopy (LIBS), and laser-induced native fluorescence (LINF) system into an SBIR-funded, demonstrated drilling and coring platform.

DiSCO delivers three game-changing advantages in lander/rover based planetary exploration: a) unprecedented analytical capabilities – in-situ, coregistered high-resolution imaging and LRS+LIBS+LINF core mapping, b) minimization of the resources and complexity required to perform subsurface science analyses – no need for core processing and delivery systems or robotic arm movement between the rock and an instrument onboard of the rover, and c) possibility for novel mission architectures – coring + analysis + caching capabilities are offered within a single, highly modular arm-mounted instrument.

DiSCO Coring & Subsequent Analyses Capabilities: Figure 2 demonstrates DiSCO's core extraction & processing capabilities for producing Raman spectra. It notionally integrates Honeybee's ROPEC drill system (Zacny et al., 2012). The characterization included in Figure 2 demonstrates illumination of the site of interest, showing tailings produced when coring, and the core extracted following the drilling. A major highlight of Honeybee's systems is that they facilitate *in-situ* characterizations of captured rock core within a drill bit without requiring additional mechanisms to remove the core from the bit.

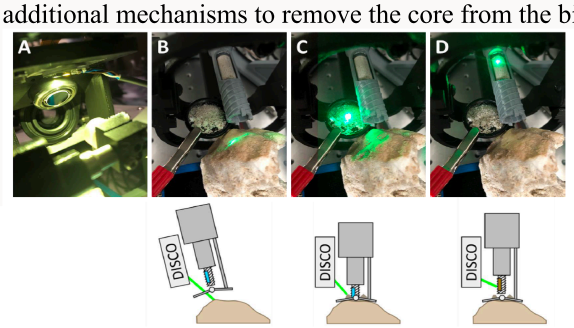

Figure 2: Demonstration of DiSCO operating sequence for imaging sites of interest. Visual inspection using LED illumination finds site of interest first (A). Green spot marks laser as focused and analyzing (B) site prior to making contact with the drill, (C) tailings produced when drilling, and (D) the core extracted from the site.

DiSCO Performance: Figure 3 indicates DiSCO Raman mapping capabilities for a section of a coarse grained biotite granodiorite, provided for analysis by the Magmachem Research Institute. Example of product outputs are 5,000 point spectra over a ~1.5 x 3 cm high resolution map region of a mineral rock. The minerals mapped include silicates, products of hydration, carbonates, and organics.

TRL advancement plan: DiSCO responds directly to S1.07 In-Situ Instruments/Technologies for Lunar and Planetary Science: "*development of advanced instrument technologies and components suitable for deployment on in-situ planetary and lunar missions*." Phase II (in progress) is scheduled to advance DiSCO to TRL 5/6 due Spring 2023.

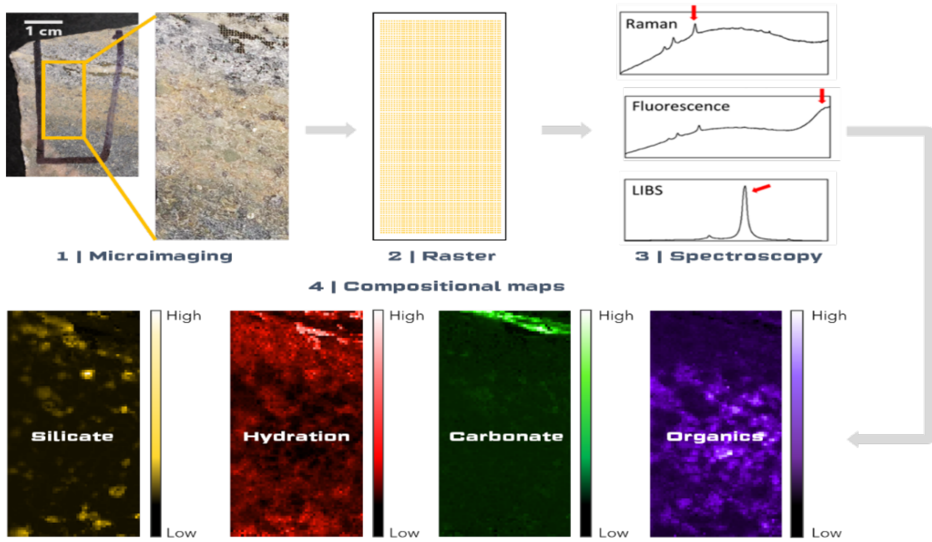

Figure 3: DiSCO automated mapping capability, showing a 5,000 point map across a spatial region covering ~1.5 cm by 3 cm of a section of coarse grained biotite granodiorite cut by quartz-sericite-pyrite grains, sample rock provided by the Magmachem Research Institute. DiSCO Raman spectroscopy capabilities are able to detect and make high resolution maps of silicates, hydration, carbonates, and organics (images on the bottom panel, left to right).

Advancement and upgrades: DiSCO is on track to reach TRL 5/6 in Spring 2023 as funded under NASA SBIR Phase II. Upgrades in Phase II include an expanded spectral window for LIBS measurements (expected 250-900 nm) and miniaturization of key subsystems (micro-imager, demultiplexer, spectrometer, optical probe) to accommodate integration into Honeybee's ROPEC drill (Figure 4).

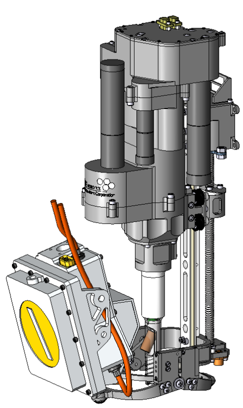

Figure 4: Artist rendering of high-TRL DiSCO integrated into ROPEC drill (Honeybee Robotics).

Significance: DiSCO supports the characterization of both surface and subsurface materials, significantly improving instrument measurement capabilities for planetary science missions such as Discovery, New Frontiers, Mars Exploration, and other planetary programs, including: a) landed exploration missions to Venus, Moon, Mars, Europa, Titan, comets, and asteroids; b) sample return missions to Moon, Mars, comets and asteroids, and ISRU

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References:

Zacny, K., G., Paulsen, P. Chu, A. Avanesyan, J. Craftt, T. Szwarc, Mars Drill for the Mars Sample Return Mission with a Brushing and Abrading Bit, Regolith and Powder Bit, Core PreView Bit and a Coring Biit, IEEE Aerospace conference, 4-10 March 2012, Big Sky, Montana.