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The Supercam Microphone to support LIBS investigation on Mars: review of the first laser-spark recordings.

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Abstract:

The Mars 2020 Perseverance rover, which landed in February 2021, is carrying the SuperCam remote sensing suite [1,2]. It is a multifunctional spectroscopy instrument to analyze Martian rocks and soils with Laser-Induced Breakdown Spectroscopy (LIBS), time resolved Raman and luminescence, Visible and Infrared Reflectance Spectroscopy, and color context imaging. It also includes a microphone (see Fig. 1) that records acoustic pressure fluctuations in the 100 Hz to 10 kHz frequency bandwidth. In particular, it supports LIBS investigation by listening to laser-induced sparks caused by the supersonic expansion of the plasma plume [3, 4]. The microphone also contributes to atmospheric science by recording the ambient noise [wind, turbulence, 5, 6] and it already listened to unique sounds from the Ingenuity Mars Helicopter flights. This abstract focuses on the first analysis of the LIBS acoustic signal recorded on Martian targets near the Octavia E. Butler landing site of Perseverance.

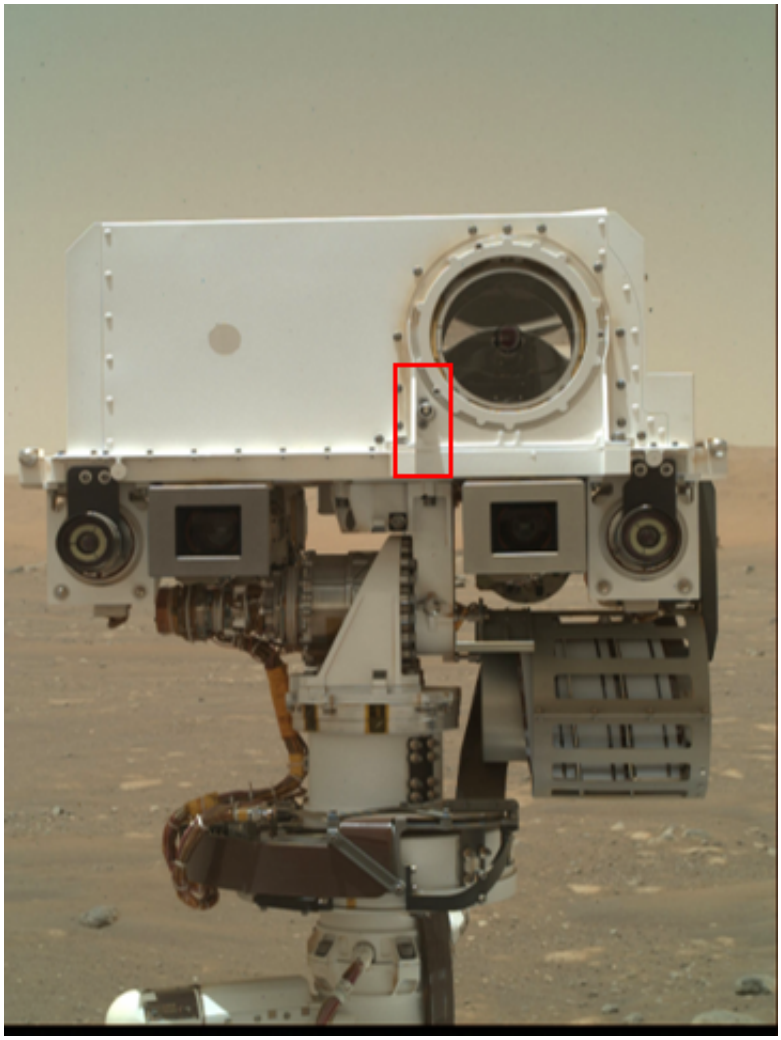

Figure 1 - WATSON image of the upper part of the Perseverance Remote Sensing Mast. The microphone is seen in the red rectangle. Credits: NASA/JPL-Caltech/MSSS/ASU

Listening to laser-induced sparks on Mars:

The LIBS experiment of Supercam uses a pulsed laser in the infrared (1064nm) to ablate rock or soil targets at the Mars surface at distance up to 7 meters. A standard LIBS burst consists of 30 laser shots repeated at the same location on a target. It creates an ablation pit up to hundreds of µm deep, depending on the target hardness (see LIBS pits in Fig. 2) [4, 7]. Longer bursts of 150 shots, called depth profiles, can also be performed to look for any chemical stratification with depth.

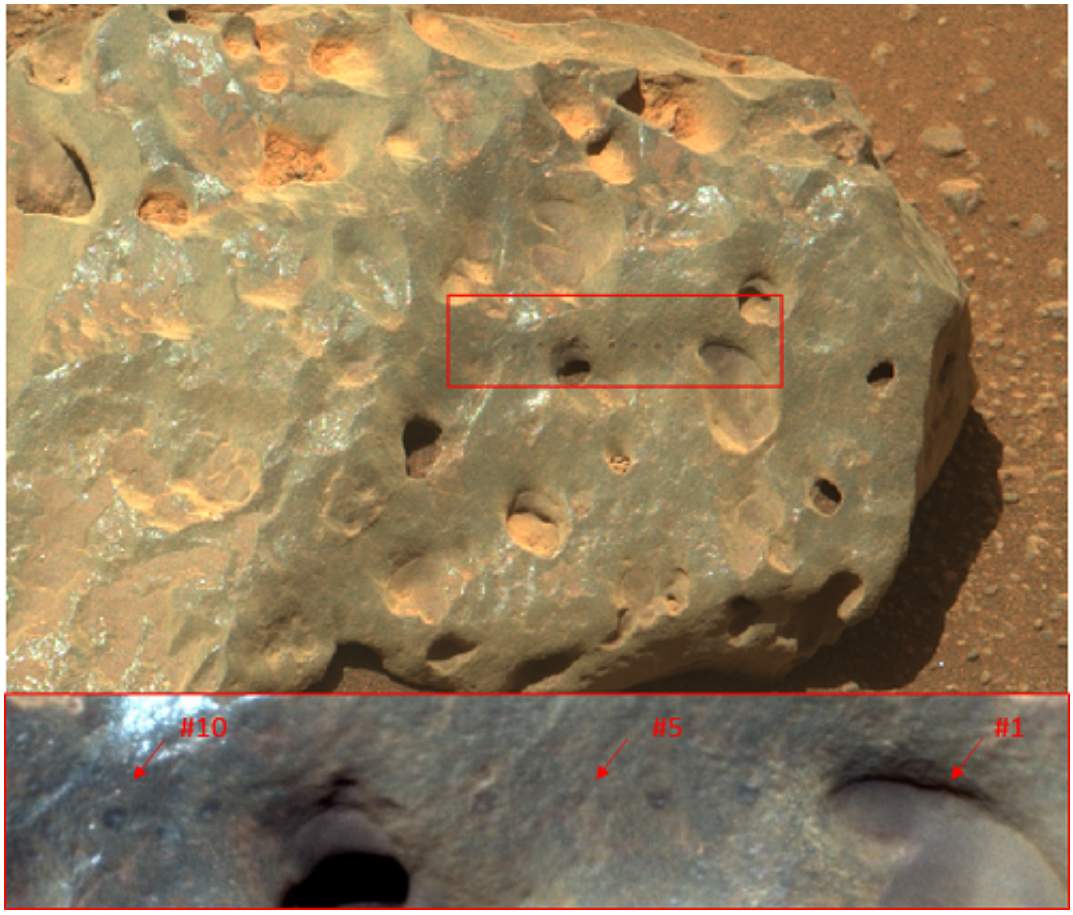

Figure 2 - Hedgehog target (sol 37) sampled by LIBS (10 points of 30 shots each). (a) Mastcam-Z documentation image. (b) RMI context mosaic highlighting the LIBS pits.Credits: NASA/JPL-Caltech/ASU/MSSS and NASA/JPL-Caltech/LANL/CNES/IRAP

It has been shown in lab studies [3, 4] that recording of the LIBS acoustic signal helps to determine the target physical properties (hardness) and also the laser pit volume by looking at the decrease of the signal amplitude with the number of laser shots performed at the same location. In addition, laser sparks may also be used to study rock coatings. In particular, it will help to determine the depth of the transition between a coating and its underlying host rock [8].

Moreover, as the start of the microphone recording is triggered on the laser pulse, the propagation time of the sound wave from the ground up to the microphone height is precisely measured. Therefore, it gives the sound speed along the sound propagation path. This parameter is used to estimate the 'acoustic temperature', an average of the air temperature over the two first meters from the ground [9].

First results on Martian targets:

Up to sol 78 of the mission, the Supercam microphone has recorded the LIBS acoustic signal from 12 targets, including 3 soil targets and 2 depth profiles.

The LIBS acoustic signal recorded on the float rock Hedgehog (sol 37) is represented in Fig. 3. The time series (Fig. 3a) shows a shot-to-shot decrease of the acoustic amplitude over the 30 shots fired in this target. The comparison with the hardness calibration curve presented in [4] suggests a soft target with a Vickers hardness lower than 10 and an ablated volume of about 200 µm. The frequency spectrum (Fig. 3b) is showing an acoustic bandwidth between 2 kHz and 10 kHz (see Fig.

3a), consistent with pre-flight calibrations [10]. Some gaps in the spectrum (5700 Hz, 10900 Hz, 14800 Hz) are indicative of destructive interferences induced by the reflection of the sound wave over the structure of the mast. Some wind-induced signal are also noticed in the time series (see red circles in Fig. 3a). They can be easily filtered, as their frequency content is lower than 500 Hz [6]. However, the influence of the turbulent atmosphere on the LIBS acoustic signal, needs to be assessed, as it was not tested in the laboratory.

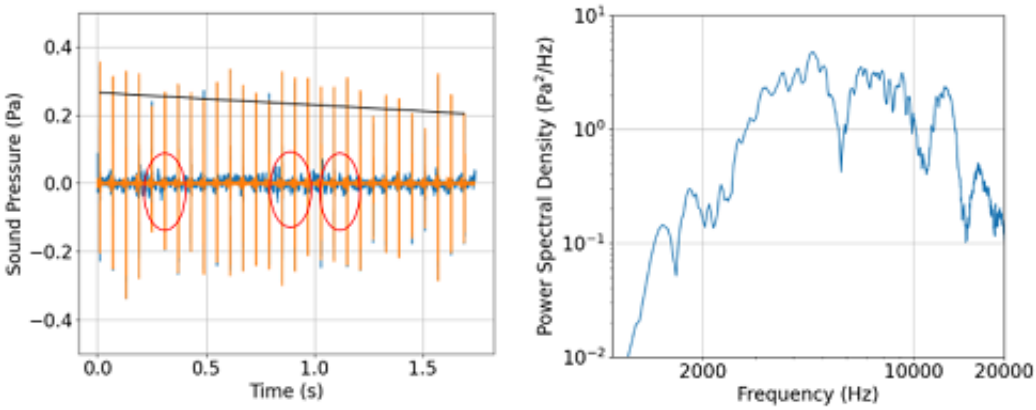

Figure 3 - Time series (a) and power spectral density (b) of the LIBS acoustic signal recorded on point #5 of the Hedgehog target (sol 37)

As for the soil targets, the LIBS acoustic data show a clear decrease with increasing shot number due to shielding within the self-induced hole and also helps to determine whether the laser hit a coarse grain (louder sound) or fine-grained soil.

Perspectives:

The Supercam microphone has the unique capability to record the acoustic signal induced by the laser-induced plasma. The microphone will help to document the target hardness along the rover traverse and complement the chemical information provided by LIBS by adding an estimation of the ablated depth. This presentation will review results from all the microphone targets observed at the time of the conference.

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