The SuperCam Microphone and Expected First Sounds at Jezero Crater, Mars

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Introduction: All the spectacular views of the surface of Mars returned since the first *in situ* missions are silent to a human-ear. Indeed, no microphone has ever been able to record the acoustic environment associated with these landscapes.

The Mars atmosphere is the least favorable to sound propagation among all planetary atmospheres (Venus, Earth, Mars and Titan) due to the low acoustic impedance and the drastic attenuation of carbon dioxide [1]. Although the sound sources are probably scarce, acoustic waves do propagate on Mars. It is rather because of a lack of science objectives that the first audible sounds from Mars are still pending.

The NASA Mars2020 *Perseverance* rover that is planned to land in Jezero crater on the 18th of February 2021 will begin the acoustic exploration of the surface of Mars thanks to two microphones, one activated during the landing phase [2] and the other one which is part of the SuperCam instrument suite [3, 4]. The latter is designed to record sounds in the audible range, from 100 Hz to 10 kHz during the surface mission. The microphone will open a new field of investigation on Mars by complementing the Laser-Induced Breakdown Spectroscopy (LIBS) investigation of the Mars surface by SuperCam and contributing to atmospheric science.

The SuperCam microphone: The microphone is a commercial off-the-shelf electret (based on Knowles EK-23132). It is positioned outside the Remote Warm Electronic Box (see Fig. 1) and therefore it benefits from the pointing capabilities of the mast. The microphone sensitivity at 1 kHz is 29.6 mV/ Pa. Its front-end electronics filters and amplifies the signal with four switchable gains, from a factor of x29 to x972. Data can be acquired either at 25 kHz or 100 kHz. Depending on the sound sources of interest, the microphone can be operated over three observation modes:

i. Standalone recordings that aim to monitor natural or artificial noise, independently of any other SuperCam operations. It provides 167 s long acquisitions at 25 kHz.
ii. Continuous recordings at 100 kHz to cover a full LIBS burst from the first to the last shot. It lasts 10 s for a standard burst of 30 shots.
iii. A pulsed mode that records LIBS acoustic signals over 60 ms windows thanks to an accurate synchronization between the microphone and the laser. In addition to saving data volume, it allows the determination of the propagation time of the acoustic wave from the target to the microphone.

Pre-Launch Performance: The microphone performance has been validated on engineering models in Mars conditions (6 mbar, CO_2 atmosphere and ablation capabilities similar to SuperCam) during tests in the Aarhus Wind Tunnel [5]. It showed that LIBS acoustic signals can be retrieved with a signal-to-noise higher than 10 dB for targets ablated at 4 m from the instrument even under a wind of 4.5 m/s. Characterization of the flight-model during *Perseverance*'s system thermal tests conducted under 10 mbar of N_2 highlighted a good synchronization and a signal-to-noise ratio higher than 16 dB for LIBS shots performed on the titanium and the ferrosilite calibration targets.

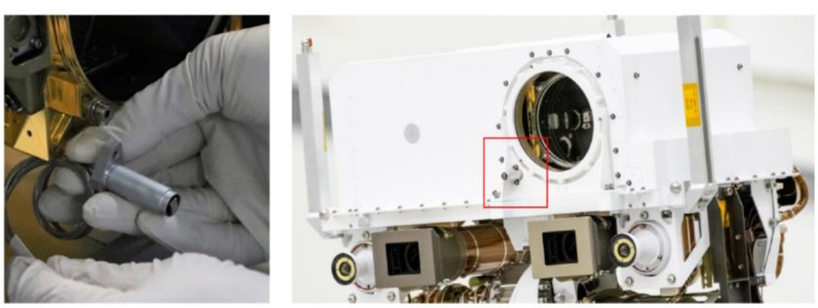

Figure 1 – The SuperCam microphone integrated on the top of the Remote Sensing Mast of *Perseverance* (Credits: NASA/JPL)

Science investigations: Science objectives of the SuperCam microphone correspond to the variety of the sound sources identified: LIBS plasma expansion and the associated shock-waves, atmospheric phenomena and rover noises and vibrations.

LIBS acoustic signal: The expansion of the laser-induced plasma in the Mars atmosphere generates a shock-wave that propagates to the microphone. Therefore it will be recorded by the microphone. It was demonstrated that listening to laser sparks on Mars [6, 7] can help determine the depth of the laser-induced pits which is new information to be used with the chemistry provided by the LIBS plasma's optical spectrum. Moreover the hardness of the target can be estimated by looking at the decrease rate of the acoustic signal energy as a function of the number of shots at the same location on a target. Finally, since the acoustic signal during a LIBS raster depends on the target hardness and ablated depth, acoustics data may also be used to characterize rock coatings. In particular, it will help to determine the depth of the transition between the coating and the underlying rock [8]. LIBS acoustic data will provide new information relative to the ablation process that is complementary to the LIBS emission spectrum and that will document rocks and soils analyzed by SuperCam on Mars.

Atmospheric phenomena: The dynamic atmospheric surface layer of Mars will be the source of phenomena that will create acoustic waves or aeroacoustic noise due to the interaction of the atmospheric flow with the structure of the rover. It was shown experimentally that the low-frequency content (resp. the high-frequency content) of the wind-induced acoustic spectrum may be used to retrieve the velocity (and the orientation) of the wind [9]. However this calibration was performed in a closed tunnel with mechanical noise and an uncontrolled level of turbulence. Hence, it has to be checked and calibrated *in situ* with the help of the MEDA weather station [10]. Models also predict the acoustic signature of convective vortices due to the variation of the tangential wind speed during a vortex encounter [11]. In addition, the atmosphere will be the propagation medium of acoustic waves. Studying the propagation parameters will allow the determination of some atmospheric properties. In particular, the propagation time of the LIBS acoustic signal from the ground to the height of the microphone can be measured to quantify the atmospheric thermal gradient [12], giving hints into the convective activity during the daytime. Finally, the reference models for the atmospheric attenuation models [13, 14], that exhibit obvious discrepancies in the audible range, will be constrained *in situ* with the evolution of the LIBS signal amplitude from targets at several distances from the rover [15].

Rover noises: The microphone can also record noises generated by the operations of Perseverance such as drill and drive activities, mast rotation (see Fig. 2) and other instruments. In particular, the microphone may be used as a diagnostic tool to listen to MOXIE (Mars Oxygen ISRU Experiment [16]) pumps during oxygen production. It may also help to understand a potential failure of a rover subsystem.

Operating a microphone on the surface of Mars is an unprecedented experience. By the time of the conference, the SuperCam microphone should have acquired the first sounds on Mars, which will be the focus of the poster, to compare these results to our pre-landing expectations.

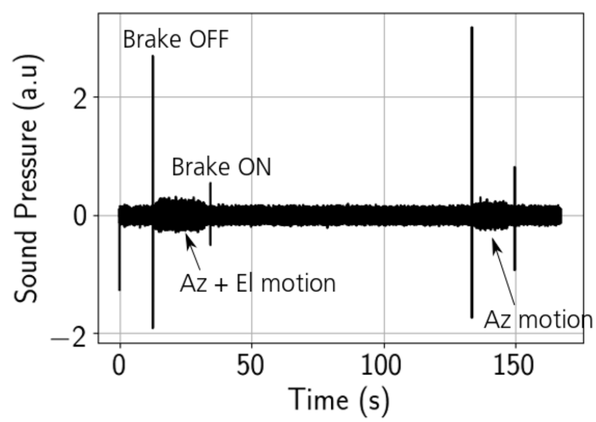

Figure 2- Rover mast motion recorded at JPL on *Optimism*, the vehicle system test bed rovet, by the SuperCam microphone Test-Unit. Az: azimuth, El: Elevation

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