A MICROPHONE SUPPORTING LIBS INVESTIGATION ON MARS.

S. Maurice[1], R. C. Wiens[2], W. Rapin[1], D. Mimoun[3], X. Jacob[4], B. Betts[5], J.F. Bell III[6], G. Delory[7], S. M. Clegg[2], A. Cousin[1], O. Forni[1], O. Gasnault[1], J. Lasue[1], P.-Y. Meslin[1]. [1]IRAP, CNRS – Université Paul Sabatier, Toulouse; [2]LANL, Los Alamos, NM; [3]ISAE, Toulouse; [4]PHASE, Université Paul Sabatier, Toulouse ; [5]The Planetary Society, Pasadena, CA ; [6]Arizona State University. [7]Spa. Sci. Lab, UC Berkeley.

Introduction. There have been several attempts for a Mars microphone: numerous unsuccessful proposals, a failure (Mars Polar Lander [1]) and even an instrument developed for Phoenix [2] but which was never turned on. However the desire by the public for such a first is still strong, and science objectives for a low-cost, low-mass instrument [3] are remarquably clear. A microphone is also going to be part of the payload of the 2018 Exomars landing platform [4].

A microphone on a Martian rover would record audio signals from both natural and artificial origins:

1/ A Mars Microphone can contribute to basic atmospheric science: wind speed statistics, convective vortices, dust devil studies at close distance or when interacting with the rover. When used in combination with other data such as visible imaging or meteorological measurements, sound spectrograms below ~5 kHz could aid in the identification and characterization of many aeolian phenomena. As an example, a wind vortex of diameter 5 m has a main frequency around 130 Hz. If a microphone was mounted on a rover mast, the recorded wind sounds would greatly benefit from the rover pointing capability and the long duration of the mission.

2/ A Mars microphone can record the unique signature of many artificial sounds: operations of the robotic arm and mast, wheels on the ground when driving, various pumps, etc. Each waveform is unique and can check the health and integrity of the material structure for engineering purposes [5]. Strong wind will also interact with the rover, resulting in acoustic signals above 20 Hz, somewhat akin to the whistling of wind around objects on Earth.

A microphone on Mars has never been considered in conjunction with a Laser Induced Breakdown Spectroscopy (LIBS) experiment. Here we describe how:

3/ A Mars microphone can support a LIBS investigation to reveal unique properties of Mars rocks and soils through their coupling with the laser beam.

Acoustic signature of a LIBS impact. When interacting with the target, the LIBS beam – typically 5 nsec in duration, at a wavelength of 1064 nm, and irradiance above 1 GW/cm^2 – generates a very sharp pressure wave which is proportional to the mass of ablated material [6]. As the plasma expands, the pressure wave accelerates supersonically for a few hundred nsec. Scientists usually refer to the "LIBS shock wave". Because the pressure wave is so sharp (µsec), the acoustic wave is broad band and contains no effective spectral information. Its energy is proportional to that of the pressure wave and therefore, all things being equal, to the mass of the ablated material (Figure 1).

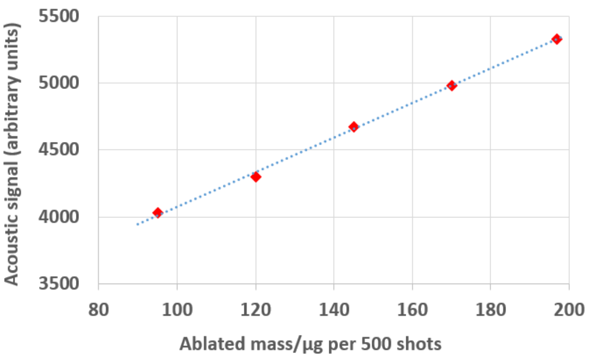

Figure 1: Acoustic signal as a function of ablated mass per 500 LIBS shots. Data from Chaléard et al., 1997 [6].

Several experiments have been conducted in Toulouse using the ChemCam qualification model [7], a Mars chamber (7 mbar, CO_2), and commercial electret microphones. The LIBS impact is very loud, ~15 Pa at 10 cm, i.e. 110 dB SPL under terrestrial conditions. For the same distance to the plasma, a 12 dB loss was observed under Martian conditions (Figure 2). It is still loud on Mars, more than expected since the larger volume of the expanding plasma in the thin atmosphere compensates for the lower atmospheric pressure.

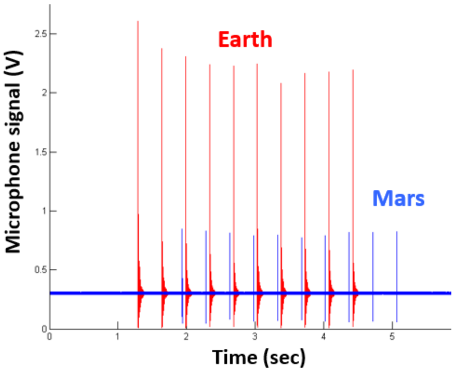

Figure 2: Measurements of 10 laser shots using ChemCam laboratory setup (see text) with the same electret microphone, under ambient conditions (red) and Mars conditions (blue).

The speed of sound on Mars is ~240 m/sec and atmospheric density 0.02 kg/m^3 (compared to Earth: 340, 1.2). We have developed a propagation code to account for the atmospheric absorption (molecular and thermal viscosity). Initial results reproduce the known absorption from Williams (2001) [8]. The waveform shape of the simulations has a good agreement with the Martian chamber data. As expected, the signal attenuation is larger on Mars than on Earth; our code yields a loss of ~30 dB within the first 7 m. For LIBS at the longest distances, co-adding of the recorded sounds will help improve the resolution of impact measurements.

Several target matrices (fine soils, grains and pebbles, rocks, glasses, etc.) are currently being tested to evaluate the intensity of their acoustic signature. As the laser focus is adjusted, the irradiance on targets varies, as does the intensity of the LIBS signal, and therefore the acoustic intensity. Incidentally, the microphone can be used to optimize the focus of the telescope, which is the way the ChemCam team and other LIBS teams have adjusted their LIBS experiment in the laboratory, by the maximizing the sound intensity.

Laser plasma formation in LIBS is a nonlinear process: minor fluctuations of the laser beam or sample properties can result in large deviations of the plasma characteristics. Thus, the calibration of a LIBS experiment is a significant challenge, since only matrix-matching calibration targets guarantee an accurate quantitative evaluation of chemical compositions. To minimize such a matrix effect, hundreds of compositions can be tested on the ground, whereas only a few calibration targets can be carried onboard. Planetary LIBS experiments could certainly increase their accuracy with independent characterization of the laser-target coupling by a microphone.

Microphone design. To fulfill the requirements described above, a microphone on Mars must be able to record audio signals from 20 Hz to 10 kHz, with a sensitivity large enough to record a LIBS impact up to 5 m on a rock. It must be mounted on a directional mast (EL/AZ pointing) and coaligned with the LIBS laser.

Our choice is a commercial Knowles electret microphone, which was also considered for Mars Polar Lander and Phoenix. Its frequency ranges from ~100 Hz to 10 kHz, with a sensitivity -53 dB ±2 dB @ 74 dB SPL. It is 5.56 x 4 x 2.26 mm, with rugged technology which can withstand extreme coldness, and costs little. The front-end electronics is a 4 x 4 cm board to acquire the signal at 20 kHz (Shannon sampling). Filters and gains (up to 128x) can be implemented. The acquisition uses 10 bits. Three and half minutes of sound can be recorded in 8 MB, which is equivalent to a standard 2k x 2k image. The whole capability, including harnesses is less than 40 g, and the power < 250 mW.

Implementation. The best opportunity for such a microphone would be the Mars 2020 rover, which will carry SuperCam, an ambitious analytical package that includes a LIBS experiment. It could protrude from the remote warm electronic box (RWEB) at the top of the rover mast (Figure 3) with very limited accommodation required by the RWEB and a “plug-and-play” incorporation with the SuperCam Mast-Unit. Several scientists of the Mars community could be associated to provide great Education and Public Outreach, great science in support of the LIBS investigation, substantial atmospheric science, and a unique vantage point to monitor rover events

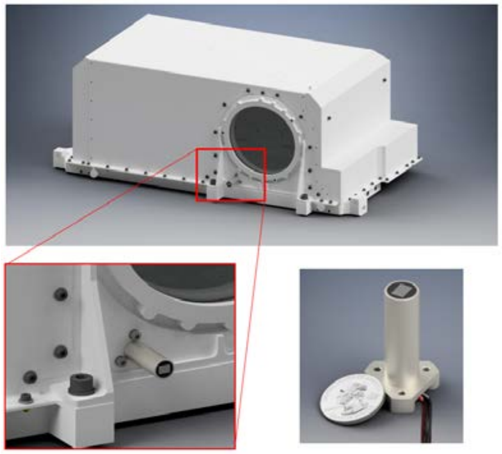

Figure 3: Possible implementation of Mars Microphone on Mars 2020. The microphone is mounted on a tiny tube that protrudes from the mast RWEB, on the bracket that holds the window for the LIBS experiment.

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