Mars Microphone testing and LIBS acoustic characterisation for the Mars 2020 rover

N. Murdoch[1], J. Lasue[2], B. Chide[1,2], A. Cadu[1], A. Sournac[1], M. Bassas-Portús[1], J. Merrison[3], J. J. Iversen[3], C. Moretto[2], C. Velasco[2], L. Parès[2], A. Hynes[2], R. D. Lorenz[4], P. Cais[5], P. Bernardi[2], S. Maurice[2], R. Wiens[6], D. Mimoun[1]. [1]Institut Supérieur de l'Aéronautique et de l'Espace (ISAE-SUPAERO), Université de Toulouse, 31055 Toulouse, France (naomi.murdoch@isae.fr), [2]IRAP, CNRS, Université Paul Sabatier, Toulouse, France, [3]Department of Physics, University of Aarhus, Denmark, [4]Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20723, USA. [5]Laboratoire d'Astrophysique de Bordeaux, LAB – UMR 5804, Bordeaux, France, [6]Los Alamos National Laboratory, Los Alamos, NM 87544, USA.

Introduction: The Mars Microphone for Mars 2020, a collaboration between ISAE-SUPAERO and the SuperCam consortium will record sounds on the surface of Mars for the very first time [1]. The primary purpose of the Mars Microphone is to support the SuperCam Laser Induced Breakdown Spectroscopy (LIBS) investigation of soils and rocks on Mars [2,3]. As the acoustic wave produced by a focused laser pulse incident on a target ("LIBS impact") is indicative of the target's physical properties [4,5], the Mars Microphone will reveal target properties that are otherwise unknown at remote distances.

In order to satisfy the SuperCam requirements, the Mars Microphone must be able to record audio signals from 100 Hz to 10 kHz on the surface of Mars, with a sensitivity sufficient to monitor a LIBS impact at distances up to 4 m. To meet these requirements, a condenser microphone has been selected and the amplification gains and dynamics of the instrument have been carefully chosen. However, testing in Mars conditions is essential given the strong acoustic attenuation at high frequencies due to the low surface pressure and the difference of acoustic impedance of the atmosphere [6]. Additionally, while studies have already been performed at ambient pressure to characterise the laser impact sounds on various rock samples [7], no detailed characterisation has ever been performed under Mars environmental conditions.

Here we will present results of the end-to-end test of the SuperCam LIBS – Microphone system in the Mars environment, and of the first detailed characterisation of the LIBS acoustic emission from various Martian soil analogs.

Test configuration: For these tests (performed in July 2017), we have used the Aarhus Wind Tunnel Simulator II [8] in Denmark. This cylindrical chamber, 2.1 m in diameter and 10 m in length, is capable of creating Mars atmospheric conditions (including wind) allowing us to test the Mars Microphone in a fully representative environment before flight. The tests were performed in 6 mbar of CO_2, achieved by evacuating the chamber and then repressurizing with CO_2. The facility is fitted with a suite of environment sensors in addition to an in-situ webcam. The test configuration (schematic and photo) is shown in Figs 1 and 2.

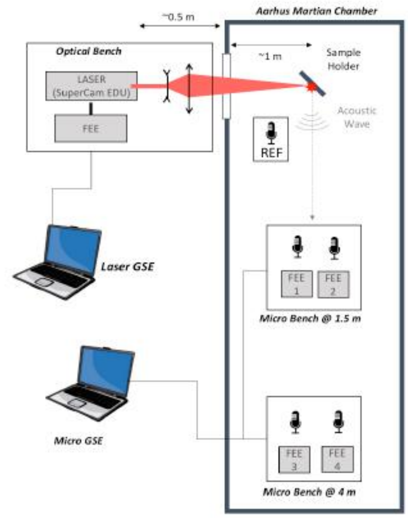

Figure 1: Schematic of the test configuration at Aarhus. FEE = Front-End Electronics; EDU = Engineering Development Unit; GSE = Ground Support Equipment.

The optical bench. The SuperCam Engineering Development Unit (EDU) laser was used for these tests. The EDU is a Nd:YAG laser with a wavelength of 1064 nm and a 4 ns pulse duration. The optical bench was located entirely outside the tunnel. Therefore, to obtain the necessary focal length of 1.5 m, a beam expander (Thorlabs BE02-1064) was used in combination with a converging lens (CVI Laser optics PLCX-25.4-772.6-C-1064/532). This resulted in an estimated irradiance and energy on target of 1.5 GW/cm^2 and ~22 mJ, respectively.

The laser targets. The mechanical interface for the laser targets consisted of a sample wheel that can hold up to 12 different targets attached to a rotating plate inside the wind tunnel. The sample wheel can be rotated from outside the chamber allowing the laser impact point to be adjusted on one target, or to change laser target. The incidence angle of the laser on the targets was ~45°.

The microphone benches. Four engineering models of the Mars Microphones were used during the tests with their respective flight-like front-end electronics (FEEs). Two microphones were placed at a distance of 1.5 m from the laser target (the anticipated distance between SuperCam and the calibration targets on the Mars 2020 rover), and two microphones were placed at 4 m from the laser target (the distance at which the

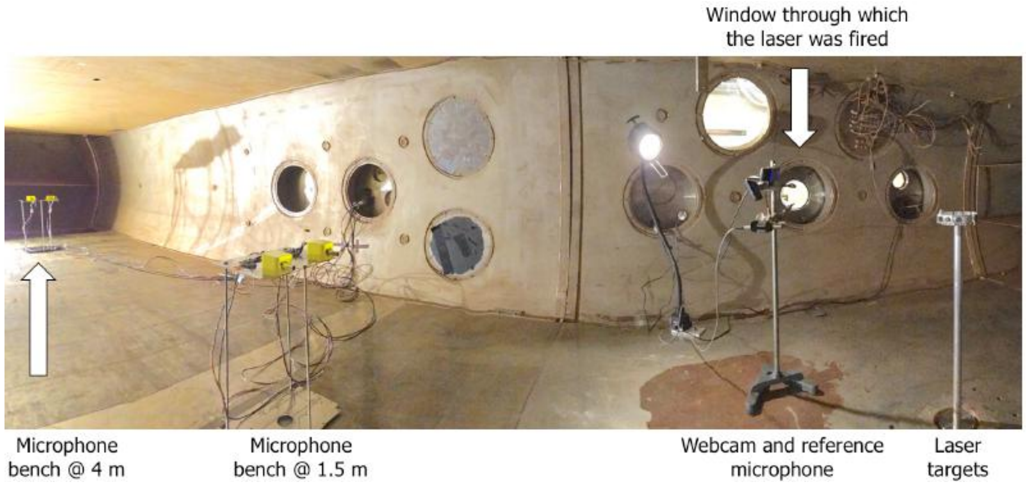

Figure 2: Panoramic photo of the test configuration inside the Aarhus wind tunnel

instrument requirement is defined). There was also a reference microphone (Brüel & Kjaer Cartridge Model 1/2 inch microphone, Type 4165) placed at 40 cm from the laser target to minimise sound reflections.

Results: The typical waveform and amplitude spectral density of the acoustic signal measured at 1.5 m from a LIBS aluminium target are shown in Fig. 3. Acoustic signals are found to have a duration of ~0.6 msec and to be clearly recordable in 6 mbar of CO_2 for the aluminium laser target at distances of both 1.5 and 4 m. Similarly to previous experiments (e.g., [9]), as the acoustic wave arrives, an initial peak can be seen in the waveform due to the compression of the gas. This is then followed by rarefaction (decompression) resulting in the negative part of the signal. The spectra show the bandwidth of the LIBS acoustic signal to be centered around 1 kHz. It can also be seen that the amplitude of both the background noise and the LIBS signals drop off above 10 kHz due to the acoustic attenuation [6].

We also tested several of the SuperCam calibration targets (sintered basalts that will be mounted on-board the Mars 2020 rover; [10]), and JSC1 (NASA's Martian soil simulant; [11]) compacted at different compression levels. For all of these targets, the ratio of the maximum signal amplitude to the RMS noise is >38 dB and >21 dB at 1.5 m and 4 m, respectively, thus satisfying the SuperCam requirements. The results of the detailed characterisation of the LIBS acoustic emission from the various targets and its variation depending on their physical properties will be presented during the conference.

References: [1] Wiens, R. et al., (2017) Spectroscopy 32(5), [2] Maurice, S. et al. (2015) 46th LPSC, #1832. [3] Maurice, S. et al. (2016) 47th LPSC, #3044. [4] Chaléard, C., et al. (1997), J. Anal. Atom. Spectrom. 12, 183–188. [5] Grad and Mazina (1993), Applied Surface Science 69, 370-375. [6] Williams, J. P. (2001). J. of Geo. Res.: Planets (1991–2012), 106(E3), 5033-5041. [7] Maurice, S. et al. (2017) 48th LPSC, #2647. [8] Holstein-Rathlou, C., et al. (2014), J. of Atmospheric and Oceanic Technology, 31(2), pp.447-4. [9] Diaci, J. & Možina, J. Appl. Phys. A (1992) 55: 352. [10] Cousin et al. (2017) 48th LPSC, #2082. [11] Allen et al. (1998) Space 98 469-476.

Acknowledgements: We gratefully acknowledge funding from the French space agency (CNES), from ISAE-SUPAERO, and from Europlanet. Europlanet 2020 RI has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 654208.

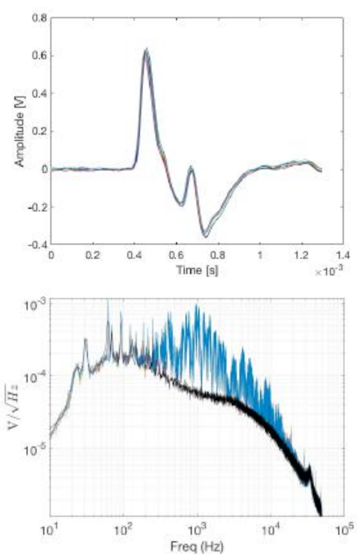

Figure 3. (Top) The waveform of a typical acoustic recording of the LIBS impact. Each line corresponds to a different laser shot. (Bottom) Typical spectra from a full 10 second acquisition containing ~50 LIBS shots. Each spectrum corresponds to a different acquisition. The background noise in CO_2 is indicated in black. All data are from tests performed in 6 mbar of CO_2 and measured at 1.5 m from the Aluminium laser target.