Development of Onboard Calibration Targets for the Mars2020/SuperCam Remote Sensing Suite.

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Introduction: Mars2020 is the next NASA mission to send a rover to Mars. Mars2020 presents four science objectives: 1/ Study of Mars past habitability (in continuity to Curiosity's work), by identifying past environments that could have been favorable for supporting microbial life, 2/ Search for signs of past microbial life in rocks observed in such environments, 3/ Collect and Cache samples; these rock cores and soil samples will then be stored on the martian surface, and 4/ Prepare for future Human missions, by testing oxygen production from the martian atmosphere.

The SuperCam instrument suite, a US-French-Spanish collaboration, was selected to be part of the payload. This instrument is the next generation of ChemCam [1,2]: it consists of a Laser Induced Breakdown Spectroscopy (LIBS) technique in order to assess the chemical composition of the samples, but this time this capability is combined with Raman [3,4] and IR spectroscopies in order to also get their mineralogical compositions. SuperCam also includes a color Remote Micro Imager (RMI) in order to specify the textural context of the chemical and mineralogical analyses. A microphone will be used mostly to deduce physical properties of the rocks by the sound of the LIBS shock waves, but can be used to listen to other sounds. SuperCam will thus provide rapid (thanks to its remote sensing techniques), synergetic, fine-scale (<0.5 mm) mineralogy and chemistry of samples as well as color imaging after cleaning the dust in surface with the first LIBS shots.

Due to different parameters on LIBS, Raman and IR spectroscopies as well as for the imager, in situ calibrations with known targets will be of prime importance. For this purpose the rover will carry a set of 30 calibration targets for SuperCam. Here we present an overview of the science rationales for such targets, with the compositions and their fabrication processes.

Challenges for the SuperCam Calibration Targets: Targets provided for the chemical and mineralogical calibrations must be homogeneous at fine scale (<25 microns), due to the small footprint of each technique: ~ 250 microns for LIBS, 1 mm for Raman and 1.5 mm for IR. To minimize the physical matrix effects, all the targets should have similar physical properties, or at least a similar texture. Nevertheless, glasses, which are easy to make homogeneous and were part of the ChemCam calibration targets, are not optimized for Raman and IR techniques; and single crystals are generally too heterogeneous at this scale. One solution that has been investigated and chosen is the flash sintering process [5], which consists of making a pellet from a powder using a combination of high pressure, temperature and electrical current. This combination enables the creation of targets that are very durable, but resulting in much less lattice dislocations than normal pellets. All the SuperCam calibration targets are 10 mm in diameter, 5 mm in height. Each target has been made in 6 replicates: flight model and its spare, qualification model, and 3 spares that will be used for the shock/vibration tests, characterization, and laboratory experiments/cross-calibrations.

LIBS Calibration Targets: For the LIBS technique, which yields the chemical compositions of the samples, the need is to cover a wide range in composition, as well as a wide range of rock types in order to account for chemical matrix effects. Also, minor and trace elements should be present in different amounts to produce in situ calibration curves. A total of 22 LIBS calibration targets have been developed. One of them corresponds to a synthetic Shergottite glass that is already onboard Curiosity [6], and will serve for cross-calibration between SuperCam and ChemCam. One target is dedicated to the wavelength calibration of the LIBS technique and corresponds to a Ti-plate, the same as the one used for ChemCam.

Stoichiometric targets. From the ChemCam experience, targets with stoichiometric compositions are of great interest to calibrate key elemental ratios such as Al/Si, (Fe+Mg)/Si, Na+K/Si, Ca+Na/Si, Na/K which are commonly used for terrestrial and martian geochemical comparison. Natural minerals such as feldspars, pyroxenes and olivines that are widespread on Mars are thus good targets for this purpose. We have selected six compositions: three consistent with martian mineral compositon and three pyroxene endmembers. Feldspars will be represented by an orthoclase and an andesine; olivine with a Fo#70 target; and pyroxenes with diopside, ferrosilite and enstatite. All these targets come from natural minerals that have been crushed to <60 microns and then flash sintered.

Trace-elements enriched targets. Five targets dedicated to trace and minor elements have been investigated. They present a trachy-andesitic composition, doped in elements of interest: Sr, Rb, Ba, Cr, Cu, Li, Ni, Zn and Mn at trace or minor levels. Element contents have been chosen from the ChemCam experience as well as the lowest/highest values observed at Gale crater and Mars to provide a calibration curve for each trace/minor element. These targets have been synthesized from powder chemical mixtures and then melted in order to make a homogeneous glass. This glassy material was then crushed prior to the flash sintering.

Rock Powder Standards. Eight targets will provide a wide variety of rock types. All these targets correspond to well-known standards and most of them have been used for the Earth database of ChemCam [7]. Powders from the standards were sintered directly. These targets represent a wide range of rock types: basalts, Ca-carbonate, andesite, mars soil analog, iron-ore, phyllosilicates, Mn-rich nodule. They are therefore useful for calibration of chemical matrix effects.

Fluoro-chloro-hydroxy-apatite target. Apatites in mars meteorites are mainly enriched in Cl and H, while F-rich apatites have been observed at Gale crater [8,9,10]. One apatite composition has been chosen to give a reference for P, Cl, F and H abundances, which are important in order to estimate the halogen budget of the martian mantle. P and H are also relevant for organic detections. This target is synthesized from a complex process involving diffusion of Cl and F into hydroxy-apatite grains under Ar flow. This Fluoro-chloro-hydroxy-apatite powder is then sintered using the same process as the other targets.

RAMAN Calibration Target: Most of the LIBS calibration targets will also be used for Raman calibration, thereby ensuring that the instrument remains perfectly operational. In addition, a macromolecular resin target will allow making sure that macromolecular carbon can be detected on Mars and will be used to document the impact of UV irradiation under true Mars conditions. This macromolecular resin resembles the macromolecular carbon found in Martian meteorites. It consists of an aromatic skeleton on which are branched various oxygen-containing functional groups.

VISIR and RMI Calibration Targets: The VISIR and RMI investigations will also make use of the above targets. In addition, these techniques require standards to verify/validate pre-flight calibrations in martian conditions, and to monitor the stability of the calibration. Two targets are dedicated to the calibration of the IR linearity and consist of a white ceramic and a dark paint. Five targets are dedicated to the micro-imager calibrations. Three of them consist of colored ceramics (Red, Green and Cyan) to check for color balance. Those three ceramics, as well as the two IR calibration targets include the use of magnets in order to minimize the dust [11]. The other two targets dedicated to the micro-imager correspond to a USAF target to verify the resolution of the camera and a slanted-edge target to check the modulation transfer function.

Backup targets: At least five backup targets have to be investigated and provided. The objective is to be able to switch a target that may be heterogeneous at fine scale (after characterization) or that presents a composition that is less interesting depending on the selected landing site. The selection of these targets is still in progress and should be done by March 2017. For now several candidates are in the list, such as another apatite with different contents of Cl and F, in order to have 2 points of reference for these elements. Also, one salt is investigated. A second Raman-dedicated target has been proposed, focusing on its fluorescence capability this time.

Next Steps: Each target will be fully characterized (EDX, Raman, ICP-MS) before mounting, to be validated as part of the calibration set. This characterization step will be performed in Spain at Bilbao University, and should start in January. Shock and vibration tests will be performed in order to make sure targets won't break during launch and landing.

Target name	Target type	Technique
Orthoclase	K-rich feldspar	LIBS, Raman
Andesine	Plagioclase feldspar	LIBS, Raman
Diopside	Clino-pyroxene	LIBS, Raman
Ferrosilite	Fe-rich pyroxene	LIBS, Raman
Enstatite	Mg-rich pyroxene	LIBS, Raman
Olivine FO70	Olivine	LIBS, Raman
Chloro-fluoro-hydroxy-apatite	Apatite enriched in Cl, H and F	LIBS, Raman
NTE01	Trachy-basalt enriched in Cu, Zn	LIBS
NTE02	Trachy-basalt enriched in Zn, Ba, Rb	LIBS
NTE03	Trachy-basalt enriched in Rb, Mn	LIBS
NTE04	Trachy-basalt enriched in Li, Cr, Ba	LIBS
NTE05	Trachy-basalt enriched in Ni, Sr	LIBS
JB2	Basalt	LIBS
C53	Calcite	LIBS
AGV-2	Andesite	LIBS
JSC-1	Analog Mars Soil	LIBS
JMn-1	Mn-rich nodule	LIBS
STx-1	Montmorillonite	LIBS
BHVO-2	Basalt	LIBS
Chert	Si,Fe-rich natural target	LIBS
GIOP-95	Iron-ore	LIBS
Resin Delomonopox HT282	Resin	Raman

Table 1: List of calibration targets already developed.

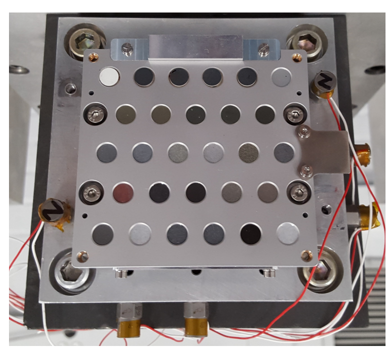

Figure 1: Picture of calibration targets mounted on the sample holder developed by the Spanish team.

References: [1]Wiens et al., 2012; [2]Maurice et al., 2012; [3]Wiens et al., this issue; [4]Ollila et al., this issue; [5]Tokita et al., 2006; [6]Fabre et al., 2011; [7]Clegg et al., 2015; [8]Forni et al., 2015; [8]Meslin et al., 2016; [10]Forni et al., this issue; [11]Lasue et al., this issue.