EPSC Abstracts
Vol. 13, EPSC-DPS2019-492, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

The Ma_MISS/ExoMars 2020 spectrometer: on ground instrument calibration

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Abstract

The Ma_MISS (Mars Multispectral Imager for Subsurface Studies) spectrometer, on board the ExoMars 2020 rover and integrated within the drill, will investigate the Martian subsoil in the spectral range 0.5-2.3 μm at various depths, down to 2 m. The flight instrument has been built and delivered for integration in drill and rover. Here the spectral and radiometric calibration of the spectrometer are described. The calibration campaign has been performed during 2018 spring at Leonardo Company premises.

1. The Ma_MISS instrument

Ma_MISS is the visible and near infrared (0.5-2.3 μm) spectrometer integrated in the drill of the ExoMars 2020 rover [1]. Ma_MISS will investigate the mineralogy of the subsurface down to 2 m [2]. Mission scientific objective is the search for morphological and chemical signs of past or extant life. Ma_MISS acquisitions, performed during pauses in drilling activity, will produce hyperspectral images of the drill's borehole. Ma_MISS objectives will be: (1) to determine the composition of the subsurface materials; (2) map the distribution of the subsurface H_2O and hydrated phases; (3) characterize optical and physical properties of the materials (e.g., grain size); (4) retrieve a stratigraphic column that will provide information on geologic processes.

The main instrument parts are: (i) the illumination system (5W lamp), (ii) the Optical Head, (iii) the Sapphire Window, (iv) optical fibers for signal transportation through the drill, (v) the Fiber Optics Rotary Joint and (vi) the spectrometer including grating, mirrors and detector. The whole instrument is miniaturized and embedded within the drill tip and rods ((i) to (v)), except for the detection system (part (vi)) hosted by the drill box. A more detailed description of the instrument is given in [2].

2. Spectral Calibration

Objective of the spectral calibration is to provide a characterization of the instrument scientific performances from a spectral point of view and to convert measured quantities in physical units. Instrument spectral characteristics have been determined such as: (i) detector pixel ←→ wavelength association; (ii) spectral range, delimited by λ_{cut-on} and $\lambda_{cut-off}$ of the signal; (iii) spectral resolution, computed as FWHM of the Spectral Response Function; (iv) spectral sampling, determined as $\Delta\lambda$ between two adjacent pixels; (v) determination of FOV, on the basis of illuminated rows on the detector.

In order to accomplish such objectives, spectral scans of the detector have been performed using a monochromator equipped with a Xe-lamp. Eight spectral scans were performed in order to cover most of the range 380-2210 nm, with 3 or 5-nm steps. During calibration the FM spectrometer was inside a TVC chamber in order to maintain the detector at the nominal temperature of T=-50°C. Main instrument spectral performances are listed in tab.1. In fig.1, 2 the pixel ←→ wavelength correspondence and the spectral resolution are shown respectively.

Spectral range	0.5 – 2.3 μm
Spectral resolution	<40 nm (λ<1000 nm) <20 nm (λ>1000 nm)
Spectral sampling	5 nm

Tab.1. Instrument spectral features.

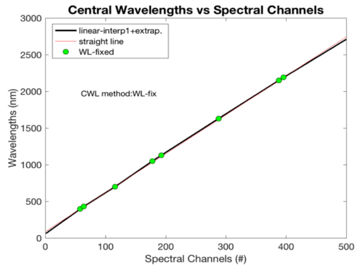

Fig.1. Fixed wavelengths (circles) from monochromator scans used to retrieve, through linear interpolation (black line), the correspondence between pixels and wavelengths.

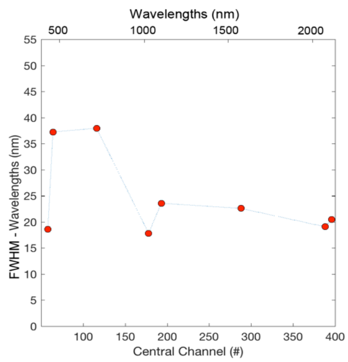

Fig.2. Instrument FWHM of the computed pixel Spectral Response Function along the spectral range.

3. Radiometric Calibration

The objective of the radiometric calibration was the characterization of the scientific performances of the Ma_MISS instrument from a radiometric point of view. The characteristics following were determined, using a LabSphere Spectralon 80% as target: (i) signal-to-noise ratio; (ii) acquisitions vs focal distance; (iii) acquisitions at two different detector temperatures, i.e. nominal and hot case; (iv) dark/ghost acquisitions and estimate of detector linearity with integration times, using a bright and dark target (Spectralon 80% and 20%); (v) determination of the Spectrometer Transfer Function (responsivity).
During radiometric calibration the FM spectrometer was inside the TVC, while the Ground Support Equipment Tip Drill Tool was used to illuminate and catch the signal from the target, on an external optical bench. Successively a series of rocks slabs were analyzed with the FM spectrometer, with the aim of validating the instrument performances. The measured reflectance was then compared with the reflectance computed by using the STF, with excellent matching.

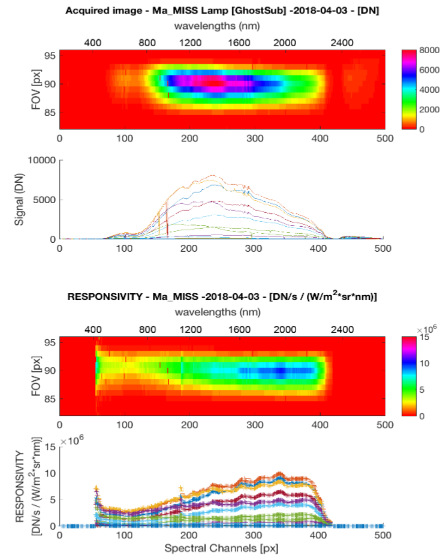

Fig. 3. Top: the signal measured with the GSE Tip Drill Tool (spectralon 80%) and FM spectrometer. Bottom: STF.

4. Summary and Conclusions

The Ma_MISS FM spectrometer has been delivered for integration in the Drill and Rover of ExoMars 2020 mission. The FM instrument has been subject in 2018 to an extensive on-ground calibration campaign, aimed to characterize its overall spectral and radiometric capabilities. In-flight calibration will permit to refine our findings.

Acknowledgements

We thank the European Space Agency (ESA) for the ExoMars Project, ROSCOSMOS and Thales Alenia Space for rover development, and Italian Space Agency (ASI) for funding and fully supporting Ma_MISS experiment (ASI/INAF grant I/060/10/0).

References

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[2]De Sanctis et al. (2017): Astrobiology, 17, 6, 7.