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The mineralogy and chemistry analyser (MARS-XRD) for the ExoMars 2018 mission

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Abstract

The Mineralogy and Chemistry Analyser (MARS-XRD) is a miniaturised X-ray diffraction and fluorescence (XRD/XRF) spectrometer aimed to the mineralogical characterisation of Martian rocks. Simultaneously, MARS-XRD is able to acquire the diffraction pattern for mineralogical phases identification and the X-ray fluorescence spectrum for the chemical species, providing a complete rock characterization.
The X-ray diffractometer (XRD) is the routine instrument used in every Earth Science laboratory to provide the mineralogical composition of rocks. XRD produces unequivocal results because it is based on the recognition of the geometrical properties of the crystal lattice. This kind of investigation is an extremely useful tool to define the textural and petro-mineralogical characteristics of the Martian rocks or soils and provide information on the past Martian environment conditions related to life.
The analytic range we plan to cover includes all the silicate minerals, from clays or other phyllosilicates characterised by high interplanar lattice distance, to oxide and carbonates or evaporates (mainly sulphates). This rock spectrum is what we expect to be the target for exobiological exploration. These data will be integrated with those obtained by elemental analysis, in order to determine the exact elemental chemistry characterization of rock components.
As mineralogy can be unambiguously derived from XRD analysis, it is probably our most powerful tool for distinguishing targets of biologic importance.
In summary, the main scientific objectives of the proposed XRD/XRF instrument, Mars-XRD, are:
- In situ determination of the mineral paragenesis of rock samples;
- The characterization of the origin of rock samples;
- Determination of alteration processes;
- Understanding the exobiological potential of the samples.
The hardware is developed by the Thales Alenia Space Italia with an important contribution of the Univ. of Leicester for the detection system.

Instrument description

MARS-XRD is an instrument which is able to perform simultaneously X-ray diffraction (XRD) and fluorescence (XRF) to analyse in situ the mineralogy and chemistry of crystalline materials. XRD is based on the capability of matter atom lattices to diffract incident X-ray beams, in accordance with the Bragg's law. Each crystalline compound has a unique diffraction pattern, and the position of the diffraction peaks, expressed as function of the diffraction angle, provides information about the mineralogical composition of the sample under analysis. XRF is isotropically produced from the sample when illuminated by X-rays. The characteristic spectrum of each chemical element can be measured by intensity of the fluorescence emission.
Figure 1 shows a simplified scheme of the diffraction geometry for MARS-XRD. MARS-XRD has a fixed geometry (Figure 1), without any moving parts, and it follows a reflection configuration as the sample is viewed from. Based on a given wavelength of the X-rays, the diffracted ones will have characteristic

angles from the incident angle generated by the different crystal structures of the minerals contained in the sample.

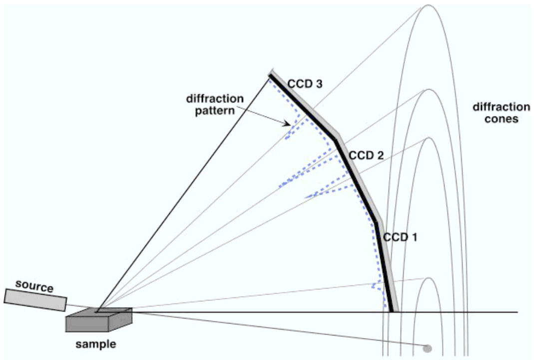

Figure 1: Reference diffraction geometry of Mars-XRD.

The X-Rays will be generated with no power consumption, just using an 55Fe radioactive source of 300mCi activity at the beginning of life. The detection system is formed by n.3 e2v CCDs mounted to a fixed radius from the sample center. Figure 2 shows the flight model design of the instrument and Table 1 the main characteristics.

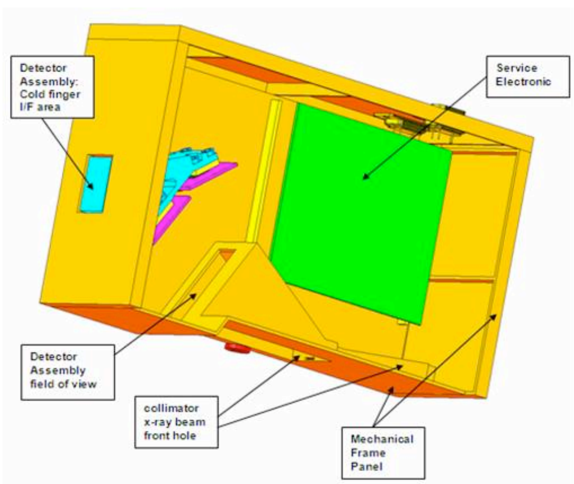

Figure 2: Drawing of the Mars-XRD flight model.

Following the selection of the XRD for the Pasteur payload in 2004, a breadboard has been developed with ESA Aurora funding to raise the technological readiness level of the instrument concept. IRSPS (Pescara, I) managed the ESA industrial contract which was concluded in 2007. The contract included the involvement of: (Alcatel) Thales Alenia Space Italia - Milan (I), Brunel University (UK), University of Leicester (UK) and Delft University of Technology (NL).

mass	~1.5 kg
power	~12 W
volume	22 x 6 x 12 cm
TRL	5.3 (assessed by ESA on May 2009)
X-ray	55Fe isotope, 300 mCi activity
Detector	3 CCDs arranged along at 8 cm radius from the sample centre
XRD range	6 ÷ ~65 deg at Mn wavelength
XRF range	Al ÷ Mn

Table 1: summary of the MARS-XRD characteristics

A structural and thermal model (STM) has been built to meet the previous mission milestones. Pictures of the STM built in Milan and the detector assembly STM built at the Univ. of Leicester are shown in Figure 3.

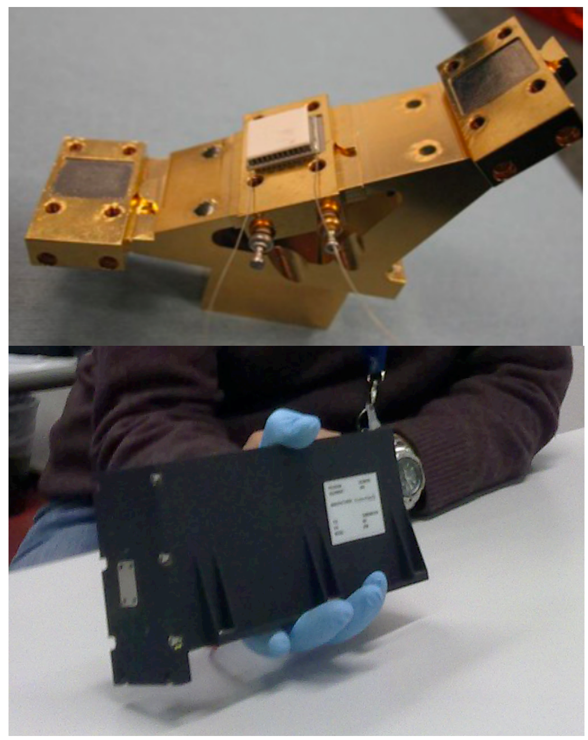
Figure 3: MARS-XRD STM: detector assembly subsystem (upper) and full instrument (lower).

Future activities will be focused on the revision of the hardware in order to meet mechanical and thermal interfaces of the new joint ESA-NASA rover and optimisation of the instrument performance.