AN EUROPEAN XRD/XRF INSTRUMENT FOR THE EXOMARS MISSION. L. Marinangeli[1], I. Hutchison[2], A. Baliva[1], A. Stevoli[3], R. Ambrosi[4], F. Critani[1], R. Delhez[5], L. Scandelli[3], A. Holland[2], N. Nelms[6], and the MARS-XRD Team, [1]International Research School of Planetary Sciences, Univ. d'Annunzio, viale Pindaro 42, 65127 Pescara, Italy, luciam@irsps.unich.it, [2]School of Engineering and Design, Brunel University, United Kingdom, [3]Alcatel Alenia Space, Milano, Italy, [4] Space Research Institute, University of Leicester, United Kingdom, [5]Delft Technology University of Delft, The Netherland, [6] ESA-ESTEC, Noordwijik, The Netherland.

Introduction: The new results of the Mars Exploration Rovers and the Mars Express mission outline the importance of a correct assessment of the variety of geological contexts to understand the evolution and potential for a habitable environment. The analysis of the surface with respect to its mineralogical composition is of fundamental importance to characterize the past and present Martian environmental conditions where life could have potentially arisen.

The best candidate for mineralogical analysis is the x-ray diffractometer (XRD). The XRD is the routine instrument used in every Earth Science laboratory to decipher the mineralogical composition of rocks on the basis of the geometrical interaction of the incident x-rays and the crystal lattice of each mineral. We consider this kind of investigation of paramount importance because in conjunction with chemical composition derived from XRF, it allows to constrain the petrography and mineralogy of the Martian rocks and soil.

An x-ray diffractometer has never flown in a planetary mission yet. For the first time, a US XRD instrument, CHEMIN [1-3], has been selected to fly in the NASA Mars Science Laboratory in 2011. In the recent years, there has been a strong interest in Europe [4-8] to develop an x-ray diffractometer (XRD) for mineralogical analyses of planetary surfaces and a European XRD design, MARS-XRD, has also been pre-selected for the Pasteur Payload of the ESA ExoMars mission, planned for 2013 [9,10].

The main objective of Mars-XRD is the in situ determination of the mineral paragenesis of rock samples from x-ray diffraction (XRD) to characterize the origin, alteration processes and understand the exobiological potential of the study samples. The goal is to analyse the minerals from clays to oxides or hydroxides, including silicates, carbonates, evaporates, apatites. The identification of water ice and $C0_2$ ice would be possible only on pristine samples.

The concept design of MARS-XRD (Figure 1) is based on a reflection geometry which consists of a x-ray source that irradiates the surface of the specimen and a detection system placed on the circumference at the other side of the specimen. In addition, the associated X-ray fluorescence will be also measured in order to determine the elemental composition of the sample, based on the ability of the detector to perform the energies discrimination of the received x-ray photons.

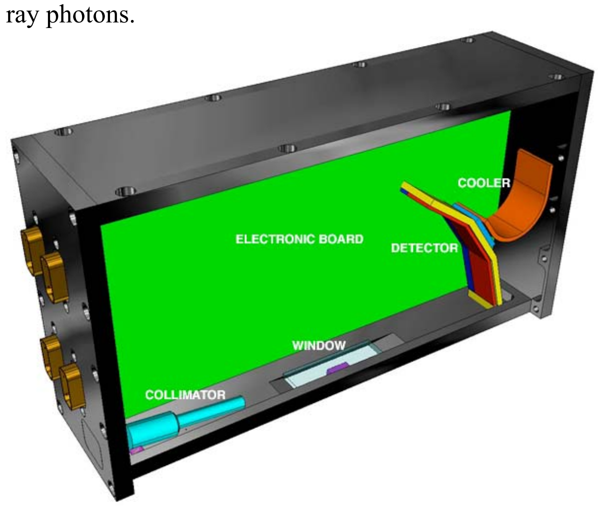

Figure 1. MARS-XRD flight version.

Laboratory XRD are commonly equipped with a tube to generate x-rays because they can easily reach a high efficiency in generating photon flux; MARS-XRD will use a radioactive source. The use of an x-ray isotopic source (^{55}Fe) for XRD purpose has been tested in the late 60s [29,30,31]. Further development has not been pursued due to the lower efficiency of a radioisotope in producing x-rays compared to tubes. For planetary exploration purposes indeed, the limitation of power resources is a rather critical issue and thus, the use of a self-emitting x-ray source would mean to save power.

A preliminary estimation of the MARS-XRD budgets for the flight model bears to ~1.3 kg and dimensions of about 22x12x6 cm. The total power consumption is estimated to be about 6W.

The prototype: ESA granted an industrial contract in 2005/2006 to build up a prototype (Figure 2) based on the MARS-XRD concept proposed for the Pasteur payload. The aim of the prototype development and testing has been the assessment of the critical issues of the concept respect to the scientific performance and, thus, to demonstrate the feasibility of the flight instrument. The structure of the consortium that built the prototype is as follows:A) IRSPS, Pescara, Italy (Prime Contractor and scientific support); B) Alcatel Alenia Space

Italia, Laben Directorate, Italy (BB engineering, source-collimation subsytem and main electronics); C) Universities of Brunel and Leicester, United Kingdom (Detection subsystem and Proximity Electronics); D) Technology University of Delft, Netherland (scientific support).

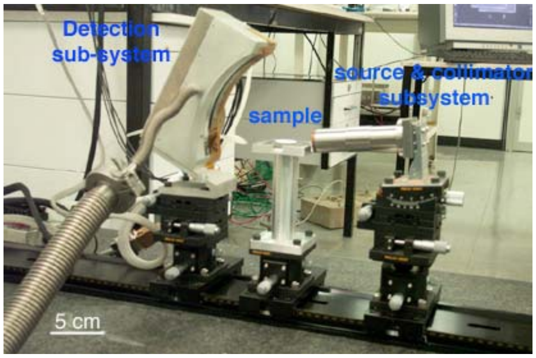

Figure 2. MARS-XRD breadboard.

The concept baseline for the breadboard consists of the following subsystems (Figure 2): i) source+collimation holding a Fe55 disk as x-ray source; ii) detection chamber containing 4 CCDs 42-10 (e2v product) arranged along a curved ceramic structure of 12cm radius and the proximity electronics; iii) a sample holder.

The Ground Support Equipment also includes: i) the main electronics board; ii) a PC with software tool for commanding, data visualisation and storage; ii) a laptop for the scientific processing of the acquired data using a software for the reconstruction of the diffraction pattern.

The diffracted photons intercepted and detected by the detector generate analog signals that are first handled by the proximity electronics and then acquired by the read-out electronics. The read-out and control electronics performs digital conversion of the signal, data pre-processing and data storage. Moreover, it controls and provides management of the detector tasks.

The overall envelope of the BB (without GSE) is about 40x40x15 cm at maximum extension.

The fluorescence spectrum is acquired simultaneously with the diffraction pattern and both are displayed on the monitor of the GSE in real time during the analysis. The spectrum is acquired once for each CCD at the same time.

The capabilities to provide information on the elemental composition derived from the fluorescence spectrum have also been tested with the breadboard. The spectra acquired during the tests campaign with the MARS-XRD breadboard showed that Si and Al, though very common in silicate minerals, couldn't be clearly identified, likely due to an air absorption effect which, however, will not be present in Martian conditions.

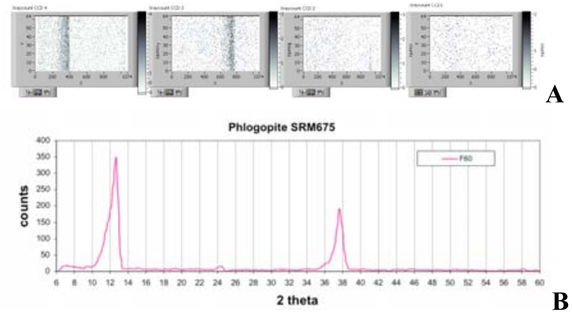

Figure 3. The diffraction pattern of Phlogopite (Phillosilicates Family, NIST standard SRM675 acquired with the prototype). A. Windows of the GSE software showing each CCD image during acquisition of the diffraction pattern. B: Derived diffractogram at ^{55}Fe wavelength (2.1 Angstrom).

Figure 4 shows the fluorescence spectrum of the basalt sample (NIST standard SRM688) where the presence of Calcium and Titanium is clearly identified. Further studies on the detector devices are on-going to enhance the fluorescence capabilities.

Figure 4. Example of the XRF spectrum acquired for a basaltic rock.

Future development: Further activities are planned during 2007 to increase the technology and scientific performances of the prototype based on funding at national level in Italy and United Kingdom. These activities will be mainly focused on the optimization of the detection and collimation subsystems in order to improve the diffraction and spectral resolution.

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