IN SITU MINERAL IDENTIFICATION FOR MARS: RESULTS FROM A MINIATURE X-RAY DIFFRACTOMETER DEPLOYED ON THE MARSOKHOD ROVER;

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A miniature diffractometer has been demonstrated on the Russian Marsokhod rover at NASA Ames. It was deployed at the end of the rover's manipulator arm where it conducted rock and sand analyses without sample acquisition or preparation. It was able to conform to mass, volume, power, and data-processing constraints imposed by the mobile platform. By combining engineering procedures with new analytical techniques, the device will operate in a dual mode, able to provide both rapid, cursory analyses for site reconnaissance, and detailed analyses of selected samples. Design upgrades will provide combined XRD and XRF capability. Instrument development was jointly supported by NASA's PIDDP and Exobiology Programs. Robotics and Marsokhod technologies were provided by Ames Computational Sciences Division.

Two conditions have to be satisfied for conducting diffractometry with a device simply making contact with the sample. First, the instrument must be configured for x-rays reflected from the sample without unduly compromising the required range of Bragg angles, and second, the device must be deployed against the sample surface in a way that enables correct beam-sample interaction. The ability to conduct direct surface diffractometry without sample preparation has been demonstrated in the laboratory; granular surfaces and solid, rough rock surfaces have been analyzed. Good diffraction data have been acquired even from several-millimeter size crystals because a large spot size can be used without seriously compromising diffraction-line identification. Intimate contact with a sample surface is enabled by the combination of a Debye-Scherrer illumination geometry and a scanning detector motion associated with a focussing diffractometer (Fig 1). The x-ray source is an Fe tube and the detectors are of the silicon PIN diode type. Preliminary data in Fig 2 were obtained in 20 minutes from the unprepared surface of a rough boulder of limestone; peak broadening will be greatly reduced when simple improvements are made in collimation and detector acceptance angle.

The second part of proving the instrument, field deployment, has just been successfully demonstrated in Marsokhod trials at NASA Ames. The diffractometer is mechanically and electronically integrated with the Marsokhod and is deployed at the end of the manipulator arm. Rocks are remotely visualized with the rover cameras, then approached to the point at which the electronic sensors indicate surface contact; the twin pen-light laser beams indicate when the x-ray spot is in focus for the device, and a pin-hole camera attached to the scanning arc provides close-up images of the surface under analysis. The manipulator arm is able to make optimal placement of the device with very few deployment attempts. Power for the diffractometer is supplied by the Marsokhod batteries. Data (diffraction lines) are transmitted to the remote control site where a diffraction pattern is displayed as it is being acquired. These rover trials have demonstrated that an x-ray diffractometer is indeed deployable in the field, and that the necessary robotics, imaging, power, and interface requirements can be met for such an instrument.

Current instrument upgrades include the use of high resolution detectors that register both diffraction and fluorescence information, fine tuning of collimation and scanning parameters to improve resolution, the testing of a miniature "solid state" x-ray chip source to replace the tube, engineering reconfiguration to provide a deployable weight of <0.8 kg for the JPL rover, and the development of "fingerprinting" analytical methods to enable operations in a rapid-scan mode. At present, the diffractometer can be operated in a slow, high-resolution mode (> 60 min analysis time), or in a fast, reconnaissance mode (< 20 min) which trades resolution for rapidity. A goal is to reduce analysis time to 10 min or less for this rapid mode using new analytical methods to compensate for resolution loss. These methods will apply pattern recognition to gross, whole-rock diffraction spectra; diagnostic diffraction signatures will provide broad lithological classification capability to determine variability of materials at a landing site. The recognition of diagnostic signatures will be augmented by the XRF data which are invaluable when amorphous materials are present.

X-RAY DIFFRACTOMETER DEPLOYED ON MARSOKHOD; Marshall J.R.

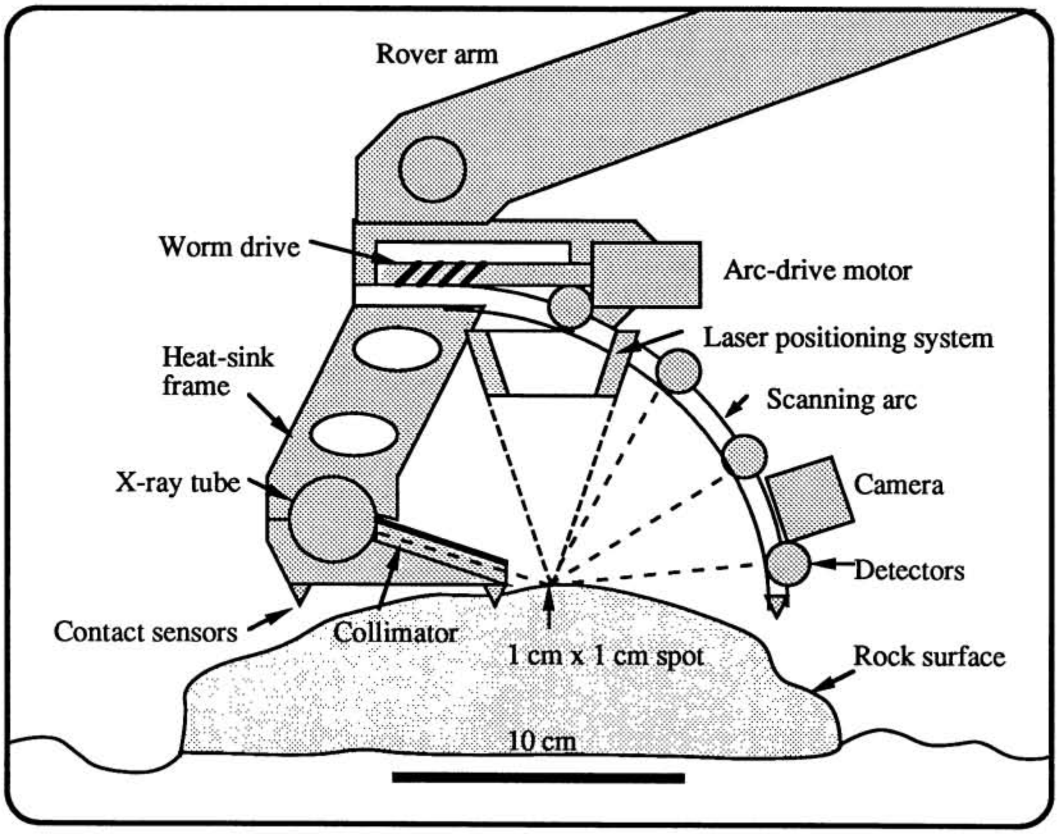

Figure 1: X-ray diffractometer-spectrometer

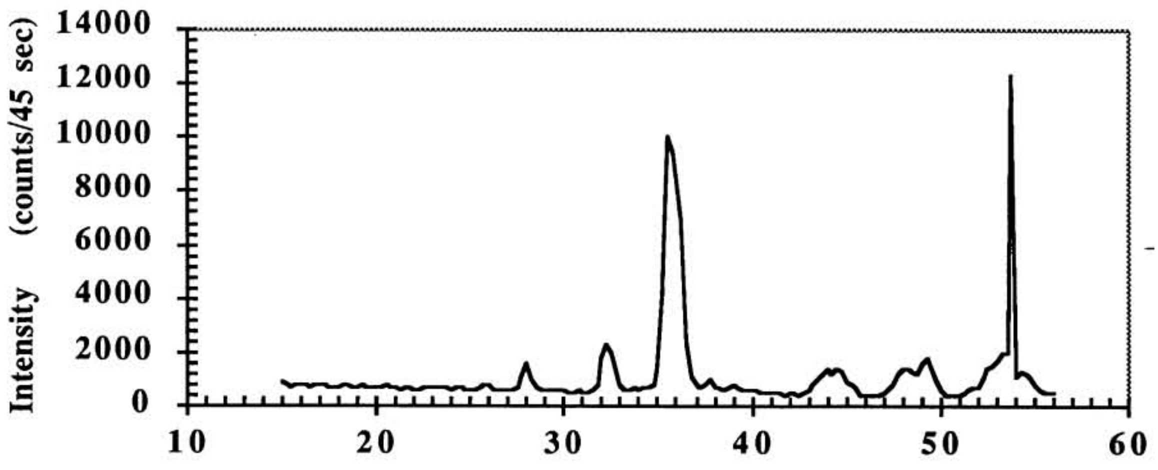

Figure 2: Limestone analysis with X-ray diffractometer.