A NEW X-RAY FLUORESCENCE SPECTROMETER FOR PLANETARY EXPLORATION. W. T. Elam[1], Warren C. Kelliher[2] andIngrid A. Carlberg[2], [1]Applied Physics Laboratory, Univ. of Washington, Seattle, WA 98195, [2]NASA Langley Research Center, Hampton, VA 23681.

Introduction: We have designed, built, and characterized a borehole X-ray Fluorescence Spectrometer (XRFS) as part of the Mars Subsurface Access Program [1]. It can be used to determine the composition of planetary regolith at various depths by insertion into a pre-drilled borehole. Analytical performance of the new instrument gives ppm detection limits over most of the periodic table.

Figure 1. Measurement head unit of the new borehole instrument.

Figure 2. Complete instrument ready for field tests.

Description:. The instrument consists of a measurement head with 27.1 mm diameter which goes down the borehole. This head contains the excitation source and the detector together with beam collimation and other mechanical arrangements. A silver target X-ray tube is used to excite the regolith and is typically operated at 35 kV and 2 µA. No filters or other optics are used in the incident beam. The detector is a Si PIN diode and has an internal collimator to restrict the beam to the center of the diode for improved energy resolution. Data collection time is usually 1000 sec, but a 100 sec. spectrum yields most of the same information. The components can be reconfigured for a wide variety of planetary mission requirements, including deployment on a robot arm, qualitative real-time regolith evaluation from rover look-down operation, part of a penetrator instrument complement, or as an astronaut hand held unit.

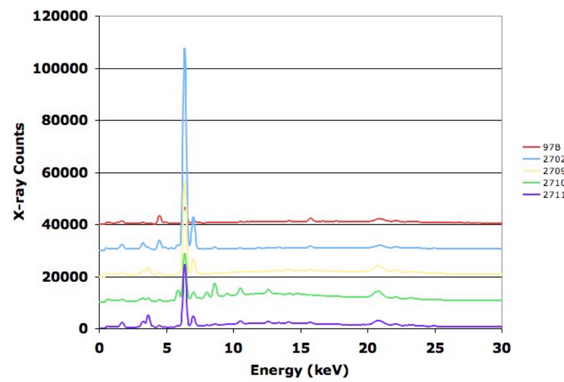

Figure 3. Spectra of the SRMs used to characterize the performance of the new instrument.

Performance: Analytical performance was determined by checking the lower limits of detection for several elements over a wide range of the periodic table and measuring the energy required per spectrum. The performance was tested in a simulated Mars atmosphere using terrestrial soil Standard Reference Materials and compared to a laboratory setup with similar components. Minimum detection limits are below 10 ppm for the heavy elements, comparable to laboratory XRFS instruments. Elements down to Mg can be quantified with higher detection limits (up to 1.4% for Mg). Power consumption as well as time to acquire a spectrum were measured and yield an energy per measurement of about 12 kJ (for 1000 sec., less if shorter measurement times are used). This is comparable to or less than current planetary X-ray instruments. In addition, sensitivity to water saturation, ice formation, and variation with distance to the borehole wall were investigated. The analytical results were not sensitive to the presence of water, but the scattered radiation can be used to obtain water content. The analytical results are also insensitve to borehole diameter for variations greater than 10%.

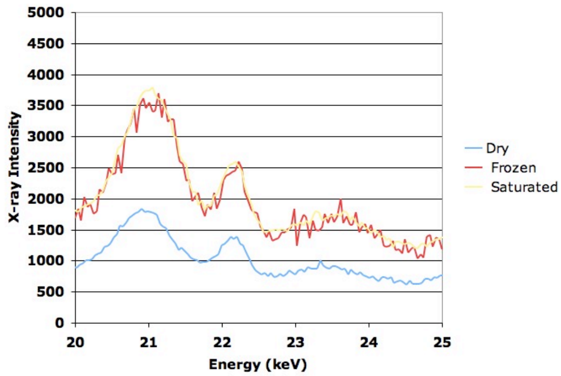

Figure 4. Spectrum region showing increase in scatter peaks due to the presence of water in the sample.

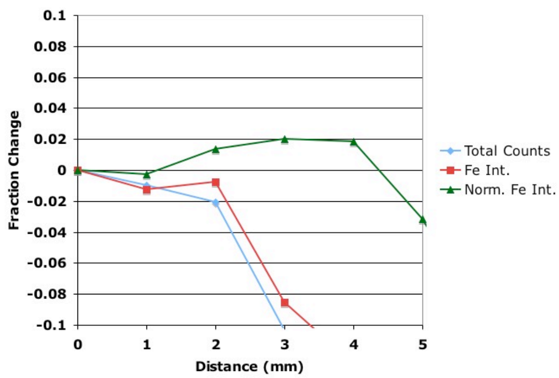

Figure 5. Variation in count rates with distance from the measurement window in the head. This corresponds to variations in borehole diameter. Using the peak counts (for Fe in this case) normalized to total counts provides good analytical results with variations up to 5 mm.

Conclusions: A borehole X-ray fluorescence spectrometer (XRFS) has been successfully constructed and tested. Miniaturization has been performed to a diameter of 27.1 mm and components can be configured in a variety of XRFS instrument designs. Modifications can be easily incorporated, such as upgrading thedetector to an SDD, the use of a different target X-ray tube, or use of radioactive sources for excitation. Performance is very good, with detection limits of about 10 ppm for many elements and detection of light elements down to magnesium at 1.4%. Power consumption is 12 watts during data collection and the total energy per spectrum is comparable to or less than previous planetary inorganic analysis instruments. Adequate data can be collected in 100 sec, facilitating investigation of strata with vertical resolution of about 1 cm in a reasonable time.

References:

[1]http://marstech.jpl.nasa.gov/content/detail.cfm?Sect=MTP&Cat=base&subCat=SSA&subSubCat=&TaskID=2256

[2]http://www.nrl.navy.mil/techtransfer/fs.php?fs_id=S06