PROGRESS IN THE DEVELOPMENT OF MAPX, A FULL-FRAME IMAGING X-RAY SPECTROMETER FOR IN SITU ANALYSIS OF PLANETARY SURFACES. D.F. Blake1, P. Sarrazin2, T. Bristow1, R. Downs3, M. Gailhanou4, F. Marchis5, D. Ming1, R. Morris5, V. A. Solé6, K. Thompson2, P. Walter1, M. Wilson1, A. Yen7 and S. Webb6. 1NASA Ames Research Center, Moffett Field, CA - david.blake@nasa.gov, 2SETI Institute, Mountain View, CA, 3Univ. of Arizona, Tucson AZ, 4IM2NP, Université Paul Cézanne, Marseille, France, 5NASA Johnson Space Center, Houston, TX, 6ESRF, Grenoble, Fr, 7Université Pierre et Marie Curie, Paris, Fr., 8JPL, Pasadena, CA, 9SLAC, Stanford, CA.

Introduction: Many planetary surface processes leave traces of their actions as features in the size range 10s to 100s of µm. The Mapping X-ray Fluorescence Spectrometer (MapX) will provide elemental imaging at ≤100µm spatial resolution, yielding elemental chemistry at a scale where many relict physical, chemical, or biological features can be imaged and interpreted in ancient rocks on Mars or on the surfaces of other planetary bodies/planetesimals.

MapX: MapX is an arm-based instrument positioned on soil or regolith with touch sensors. The MapX concept is illustrated in Fig. 1. A source bombards the sample with X-rays or α-particles / γ-rays, resulting in sample X-ray Fluorescence (XRF). X-rays emitted in the direction of an X-ray sensitive CCD imager pass through a 1:1 focusing lens (X-ray µ-pore Optic (MPO)) that projects a spatially resolved image of the X-rays onto the CCD. The MPO lens derives from “lobster-eye” multichannel optics used for X-ray astronomy [1], here implemented in a 1:1 flat geometry. The CCD is operated in single photon counting mode so that the energies and positions of individual X-ray photons are recorded. In a single 1-3 hour analysis, several thousand frames are both stored and processed in real time. Higher level data products include single-element maps with a lateral spatial resolution of ≤ 100 µm and quantitative XRF spectra from ground- or instrument-selected Regions of Interest (ROI).

MapX is a native full-frame imager; a complete X-ray map of the sample is obtained each time a frame is collected; counting statistics improve as frames are summed. Element line scans and quantifiable XRF spectra from multiple and/or randomly shaped ROIs, etc. can be obtained after data collection by reprocessing the raw frames stored in the instrument. Earlier prototypes [2-4] demonstrated proof-of-concept using COTS components. Fig. 2 shows the MapX-II prototype along with an example dataset.

Work in progress:

Development of data processing software. The instrument collects a large number of short acquisitions that are combined into X-Y-time data cubes. Python code was developed for processing raw CCD data from the prototypes. This code includes background correction, split charge removal and optional binning features. The resulting X-Y-energy data cubes are stored in HDF5 format and quantified with PyMca [5] using fundamental parameters methods.

Characterization and correction of the MPO Point Spread Function (PSF). The MPO lens causes a signal spread on the detector that must be corrected for optimum spatial resolution. Experiments were performed at the Stanford SSRL to characterize the PSF, and ray-tracing models of the MPO were developed in parallel to assist in the development of PSF deconvolution algorithms [6] (e.g., Fig. 3). Figure 4 shows results in which a deconvolution algorithm based on an observed PSF was applied to data from an imaging standard.

X-ray and γ-ray/α-particle radioisotope source requirements. Source requirements for MapX are determined through Monte Carlo modeling and experiment. XMIMSIM [7], GEANT4 [8] and PyMca [5] are being used along with a dedicated XRF test fixture to determine detection limits and accuracy/precision for elements of interest. Preliminary results indicate that either a 3W X-ray tube source, or a 30mCi 244Cm radioisotope source (as carried on the APXS instruments)
will be sufficient to meet MapX science objectives [9].

Fig. 3. Comparison of MPO PSF data (A) collected at SSRBL2-3 and (B) obtained by ray tracing simulations at a nominal CCD-MPO distance of 25mm. Left: sample in focus (25-25); Right: sample out of focus by 10mm (25-35). A 10 mm defocus condition results in a point resolution decrease of ~100 μm. This result demonstrates that the MapX design is relatively indifferent to surface roughness ≤1-2 cm.

Fig. 4. MapX PSF Deconvolution Example (1951 USAF resolution standard, Cr on glass). A) Original image, CrKα, taken with MapX-II (MPO-CCD, MPO-Target = 50 mm). The resolution of this image is estimated to be 200μm. B) Measured PSF from the SLAC experiment (FWHM ~165μm). C) AIDA [6] deconvolution with automatized cost function parameters (resolution ~160 μm).

Development of high-TRL MapX components. MapX-III (Figs. 5-6) is being built with a CCD224 imager (MSL CheMin heritage) driven by dedicated CCD electronics using flight design standards. The new camera prototype will demonstrate the basic architecture of a flight camera for an arm mounted instrument and will serve to characterize the system capabilities at the low X-ray energies (e.g., Kα lines for Na) that are absorbed in the in-air current prototypes.

Fig. 5: Schematic of MapX-III prototype with in-vacuum flight qualifiable CCD camera and adjustable optics.

Fig. 6. TRL-4+ MapX-III prototype with X-ray tube sources. MSL CheMin heritage CCD224 CCD package, exchangeable MPO and modifiable geometry.

Fig. 7. Notional Flight configuration of MapX Arm Unit (X-ray tube version) enclosing the Camera Head Electronics (CPE).

**Flight instrument concept:** Fig. 7 shows a conceptual illustration of an arm-deployed MapX instrument (with X-ray tube sources). Replacing X-ray sources with radioisotope sources would reduce the mass by 1 kg. and the power by 10W. Not shown is a Rover Avionics Mounting Platform (RAMP) unit that houses the Control and Processing Electronics (CPE).


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