CHEMINX: A NEXT GENERATION XRD/XRF INSTRUMENT FOR QUANTITATIVE MINERALOGY AND GEOCHEMISTRY ON MARS. P. Sarrazin[1], D.F. Blake[2], E. B. Rampe[3], T. F. Bristow[2], M. Gailhanou[4], B. Lafuente[1,5], V.M. Tu[6], R.T. Downs[7] S.M. Morrison[8], R.M. Hazen[8] and K. Zacny[9]. [1]NASA ARC (david.blake@nasa.gov); [2]NASA JSC; [3]eXaminArt, LLC Mountain View, CA; [4]CNRS – Universite Paul Cezanne; [5]SETI Institute; [6]Jacobs at NASA JSC; [7]Univ. of Arizona; [8]Carnegie Inst., Wash. DC; [9]Honeybee Robotics.

Introduction: X-ray diffraction (XRD) and X-ray fluorescence (XRF) analyses provide the most diagnostic and comprehensive mineralogical and geochemical characterization of rocks and soils by any spacecraft-capable technique, improved upon only by sample return and analyses in terrestrial laboratories [1]. In a mineralogically complex sample such as a basalt or in aqueously altered basaltic sediments, XRD can definitively identify and quantify all primary and secondary minerals, establish their individual elemental compositions and quantify the X-ray amorphous component. When coupled with XRF, the composition of the amorphous component can be determined as well. XRD paired with quantitative XRF analyses of drilled rock and loose soil samples will yield:

- Identification of all minerals >1 wt. %.
- Quantification of all minerals >3 wt. %, including their structure states and cation occupancies.
- Bulk geochemistry of all major and minor elements.
- Abundance of all major elements present in each mineral (H and above).
- Valence state of all elements, including speciation of multivalent species, such as Fe.
- Abundance and composition of X-ray amorphous components, if present.

Other instruments have been deployed on Mars orbiters and landers to characterize mineralogy, including infrared, Raman, and XRF spectrometers. However, only XRD coupled with XRF can provide the quantitative mineralogy and detailed crystal chemistry necessary to characterize depositional environments and habitability. If a putative biosignature is detected, does it / did it exist in a habitable environment? Under what conditions of P, T, and chemical potential was the host mineralogy formed? Post-emplacement mineralogical alteration ("taphonomy") resulting from variations in temperature, pressure or fluid chemistry has the capacity to preserve signs of biogenicity and its processes, or to erase such evidence completely.

The MSL-CheMin Instrument: The first X-ray diffractometer flown in space is the CheMin instrument on the Mars Science Laboratory *Curiosity* rover [2]. In only its second analysis on Mars, CheMin was used to identify and characterize a habitable environment in an ancient lakebed, the first such identification in the solar system and the criterion for MSL mission success [3-5].

In CheMin, a collimated 70 µm diameter Co X-ray beam is directed through a thin powdered sample, and the position and energy of diffracted primary beam Co X-rays are detected by an energy-discriminating Charge Coupled Device (CCD) detector. CheMin's two-dimensional XRD patterns are transformed into 1-D diffractograms on the ground and analyzed using commercially available data reduction software.

Samples are delivered to one of 27 reusable sample cells on CheMin's sample wheel. Cells are 8 mm in diameter and 175 µm thick with X-ray transparent windows. Piezoelectric actuators on each cell pair induce convective grain motion during analysis such that sample powder in the cell flows through the X-ray beam in random orientations during the course of an analysis. Samples are typically analyzed for 10 or more hours, although fully quantitative analyses can be obtained in less than two hours.

CheMinX: A Next-Generation XRD/XRF Instrument [6]: Improvements in X-ray technology coupled with lessons learned during a decade of CheMin operations on Mars by our team have guided the design of CheMinX, a next generation XRD/XRF instrument intended for future Mars rovers and landers:

- CheMinX will employ Hybrid Pixel Detectors (HPDs) in place of the single CCD used in MSL-CheMin. HPDs are radiation hard and do not require cooling. An array of 4 HPDs increases the resolution of the instrument from 0.3° to 0.18° 2θ, sufficient to identify and quantify 3-pyroxene systems.
- CheMinX will employ "single use" cells, eliminating the potential for clogging and contamination experienced with MSL-CheMin.
- CheMinX will employ a Silicon Drift Detector (SDD) in reflection geometry to directly measure the overall composition of the sample (necessary for determining the composition of the X-ray amorphous component). In MSL-CheMin, data from a companion instrument (APXS) was used.

CheMinX Design: CheMinX (Fig. 1) is half the mass, one third the volume, and requires less energy and time per analysis than MSL-CheMin. The XRD measurement of CheMinX is identical to that of MSL-CheMin but uses different components and a different layout to optimize its geometry and improve 2θ resolution. CheMinX uses a SDD in reflection geometry to provide an XRF measurement of the sample. CheMinX sample cells are redesigned for a more compact sample handling subsystem. A fixed tuning fork is combined with multiple single-use cells

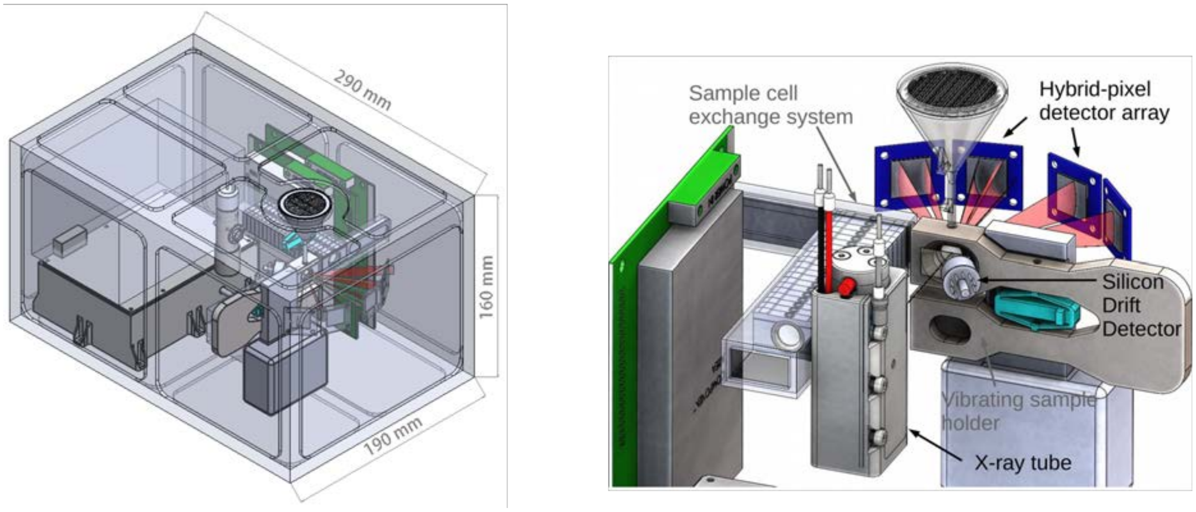

Fig 1: Preliminary design of the CheMinX flight instrument. (left) Instrument with dimensions (in mm), projected mass is 5 kg. (right) Sample handling subsystem for the vibrated sample method based on single-use cells in a cartridge dispenser system.

in a cartridge/dispenser arrangement.

Sample Collection and Delivery: Simplified Sample Acquisition and Delivery Systems (SA/DS) are critical for the deployment of XRD instruments on smaller landers and rovers. Such systems are being developed by our group including a micro-sampling drill based on a miniaturized design of the Honeybee Robotics powdering drill [7]. CheMinX will be integrated and demonstrated with powdering drills and arm prototypes developed and tested at Honeybee Robotics in a flight-like configuration.

Development of Hybrid Pixel Detectors for XRD: HPD detectors (Fig. 2) will replace the CCDs used in our earlier instruments. These detectors do not require cooling, are radiation hard, and can be tiled to dramatically improve 2θ resolution. We anticipate that the new detectors will allow for 3-5 times more X-ray flux, resulting in decreased analysis times and substantially reduced power requirements.

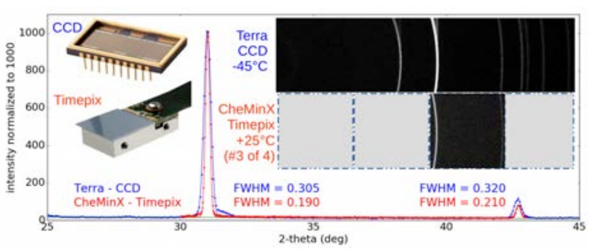

Fig 2: Comparison of XRD data of quartz using a CCD based Terra [8] vs. a HPD detector placed twice as far from the sample. HPDs not require cooling, while the CCD must be hermetically sealed in a chamber and cooled to -45C. This preliminary measurement verifies the much improved resolution of CheMinX.

Discussion: CheMinX [9,10] is suitable for deployment on MER-class rovers with the inclusion of a miniature drilling system. The instrument is identified as a payload element of Mars Life Explorer (MLE), one of the missions chosen by the Planetary Decadal Survey for development in the coming decade [11]. Fig. 3 shows the preliminary design of the MLE lander, intended to search for signatures of life and understand the habitability of near-surface ice.

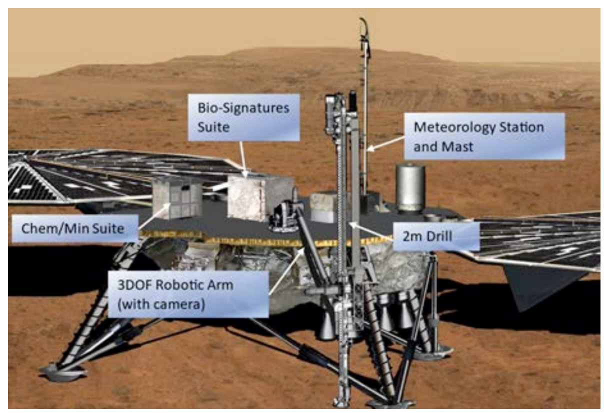

Fig 3: Artist's concept of the Mars Life Explorer lander, showing the payload elements, including the Chem/Min (CheMinX) XRD/XRF instrument.

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