TEST AND DELIVERY OF THE CHEMIN MINERALOGICAL INSTRUMENT FOR MARS SCIENCE LABORATORY '11. D.F. Blake[1], D. Vaniman[2], R. Anderson[3], D. Bish[4], S. Chipera[5], S. Chemtob[6], J. Crisp[3], D.J. DesMarais[1], R. Downs[7], J. Farmer[8], S. Feldman[3], M. Gailhanou[9], D. Ming[10], R. Morris[10], E. Stolper[6], P. Sarrazin[11], A. Treiman[12] and A. Yen[3]. [1]Exobiology Branch, MS 239-4, NASA Ames Research Center, Moffett Field, CA 94035-1000 (david.blake@nasa.gov); [2]EES-14, MS D462, Los Alamos National Laboratory, Los Alamos, NM 87545; [3]Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA 91109; [4]Department of Geological Sciences, Indiana University, 1001 East Tenth St., Bloomington, IN 47405; [5]Chesapeake Energy Corporation, 6100 N. Western Ave, Oklahoma City, OK 73118; [6]Dept. of Geological Sciences, Californina Inst. of Technology, Pasadena, CA 91109; [7]Department of Geosciences, Gould-Simpson Building, University of Arizona, Tucson, AZ 85721; [9]IM2NP, UMR 6242 CNRS, Universite Paul Cezanne, Aix-marseille III, Marseille, France; [10]Astromaterials Branch, NASA Johnson Space Center, Houston, TX 77058; [11]inXitu, Inc., 2551 Casey Ave., Suite A, Mountain View, CA 94043; [12]Lunar and Planetary Institute, 3600 Bay Area Blvd, Houston, TX 77058.

Introduction: The CheMin mineralogical instrument on MSL [1] will return quantitative powder X-ray diffraction data (XRD) and qualitative X-ray fluorescence data (XRF; 14<Z<92) from scooped soil samples and drilled rock powders collected on the Mars surface (Fig. 1).

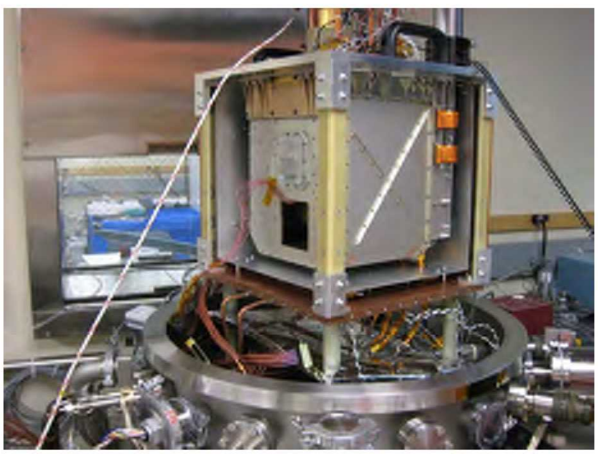

Fig. 1. *CheMin FM in Thermo-Vac Chamber. On MSL, samples are delivered through a funnel that penetrates the top deck of the rover. Dimensions are ~30X30X30 cm., mass is ~10 kg, power is ~40 w.*

Geometry of the instrument. Fig. 2 shows the geometry of the source, sample, and detector. A transmission geometry was chosen so that diffracted intensities in the low-2θ region (5-15°), important for phyllosilicate identification, could be detected.

Sample types, sample delivery and analysis. Samples of 45-65 mm^3 from material sieved to <150 μm will be delivered by MSL's sample acquisition and handling system through CheMin's funnel to one of 27 reuseable cells arrayed on a sample wheel. The funnel is shaken by piezoelectric vibrators at sonic frequencies during sample delivery to assist in sample transfer. Sample cells have 8-mm diameter chambers, 170 μm thick, with 7-μm thick mylar or Kapton™ windows. Within this volume, the sample is shaken by piezoelectric vibration at sonic frequencies, causing the powder to flow past a narrow, collimated X-ray beam in random orientations over the course of an analysis.

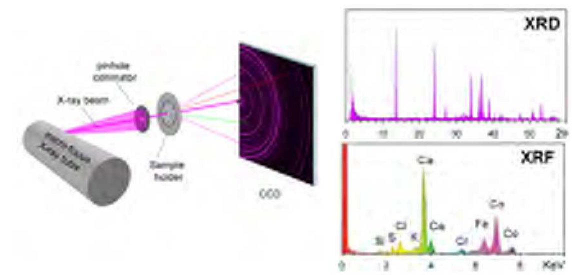

Fig. 2. *Geometry of the CheMin insrument. A 50 μm diameter collimated Co X-ray beam is directed through a powdered sample held between X-ray transparent windows.*

X-ray source. CheMin utilizes a microfocus X-ray tube having a cobalt target, so that absorption in iron-rich samples is minimized. A focusing grid in the tube yields a 50-μm diameter photon source at the anode. The beam is intersected by a pinhole final aperture to produce a ~50 μm collimated X-ray beam at the sample. The X-ray tube is nominally operated at 28 KeV accelerating voltage and 100 miliamps beam current. The tube and integrated power supply are contained in a sealed vessel of pressurized SF_6.

X-ray Detector. The CheMin X-ray detector is an E2V CCD-224 X-ray sensitive 600X600 pixel imager having 40 μm square pixels, a deep depletion zone for high quantum efficiency of 7 KeV X-rays (CoKα), and a thin polygate structure for enhanced sensitivity to lower atomic number elements. The CCD is cooled during operation to reduce dark current and its associated electronic noise. By exposing, reading, and erasing the detector often enough so that in the majority of cases only a single photon is collected in any individual x,y pixel during a single eposure, the position and energy of each photon can be determined ("single-photon counting mode"). A 2-D image of all of the 6.9 KeV X-rays detected by the array over a large number (10's-100's) of CCD exposures comprises an energy-filtered CoKα powder diffraction pattern of the sample. A conventional 1-D X-ray diffractogram is created by summing the diffracted intensities circumferentially about the central undiffracted beam and normalizing by arc length. An energy-dispersive histogram (EDH) of the energies of all photons detected by the CCD comprises an X-ray fluorescence spectrum of the sample.

Specified instrument performance. Individual analyses require several hours over one or more Mars sols. For typical well-ordered minerals, CheMin will have a Minimum Detection Limit (MDL) of <3% by mass, an accuracy of better than 15% and a precision of better than 10% of the amount present for phases present in concentrations >4X MDL (12%). The resolution of the diffration patterns is 0.30° 2θ. This performance is sufficient to allow the detection and quantification of virtually all minerals.

Instrument delivery. The CheMin Flight Model (FM) completed Thermo-Vac (T-Vac) testing in October, 2009, and has been delivered to the MSL project.

Performance of the CheMin FM during T-Vac: During T-Vac testing, the CheMin FM was operated both under vacuum and with a Mars ambient pressure of dry N_2 over a full range of Rover Avionics Mounting Platform ("RAMP") temperatures. RAMP temperatures are critical to instrument performance because the RAMP is the interface through which the CCD cryocooler dissipates its thermal load. For the proposed MSL landing sites, the RAMP is predicted to be between 0° and 20 °C during the nighttime hours when CheMin will be operating. T-Vac data indicate that the CCD can be cooled to a temperature 48 °C below that of the RAMP, so that the CCD will vary between -48 °C and -28 °C as data are collected.

Fig. 3 is an EDH pattern from an amphibole standard, showing FeKα fluoresced from the sample and CoKα from the primary X-ray beam at several RAMP temperatures. In order to collect energy-filtered CoKα patterns, it is important to discriminate diffracted from fluoresced photons. Fig. 4 shows energy-filtered CoKα diffraction patterns from the amphibole standard, obtained at RAMP temperatures of 5° and 20 °C. Despite increased background and decreased peak to background ratio (P/B), data taken at the higher RAMP temperature still meet required 2θ resolution and MDL requirements.

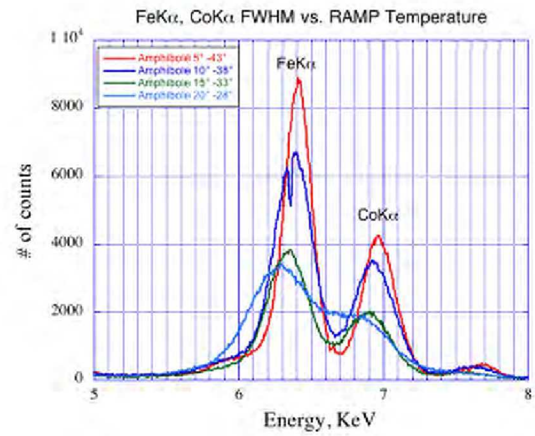

Fig. 3. *EDH of amphibole standard, showing the decrease in peak resolution as a function of rise in RAMP temperature. Decreased peak resolution results in decreased P/B in the X-ray diffraction patterns.*

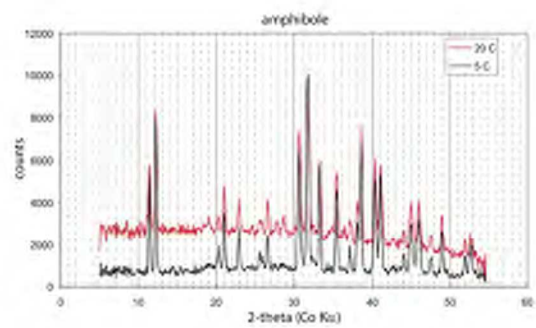

Fig. 4. *Diffraction patterns from amphibole standard collected at 5 °C and 20 °C RAMP temperatures. Diffraction data meet required 2θ resolution and P/B even at the higher RAMP temperature.*

CheMin Beginning of Life (BOL) and End of Life (EOL) performance: During the nominal MSL mission of one Mars year, the CheMin CCD will be damaged by high-energy neutrons from the nuclear power source. Strategies have been developed and tested to minimize the effect of this degradation by utilizing on-chip binning and reduced CCD exposure times. Tests performed during T-Vac show that BOL instrument performance can be maintained throughout the nominal mission using these strategies.

Conclusion: The as-delivered CheMin instrument will provide the first-ever quantitative mineralogical data from Mars rocks and soils. We anticipate that these data will revolutionize our understanding of conditions and processes on early Mars.

References: [1] http://msl-scicorner.jpl.nasa.gov/Instruments/CheMin/.