CHROMATIC MINERAL IDENTIFICATION & SURFACE TEXTURE (CMIST) INSTRUMENT: A NEXT GENERATION CONTACT XRD/XRF TOOL. Z. Arzoumanian[1,2], J.E. Bleacher[1], K. Gendreau[1], A. McAdam[1], C. Shearer[3], C.W. Hamilton[1,2], J. Rice[1] and W.B. Garry[1]. [1]NASA Goddard Space Flight Center, Solar System Exploration Division, [2]CRESST/NASA GSFC , [3]Institute of Meteoritics, University of New Mexico.

Introduction: Contact X-ray diffraction (XRD) is an area of technology development with an advantage over traditional XRD in that no sample preparation (e.g., crushing and sieving) is required. We have built a brass-board contact XRD/X-ray fluorescence (XRF) device, CMIST (Chromatic Mineral Identification and Surface Texture), that provides chemical and unique crystalline "texture" analyses for unprepared samples, revealing surface crystal phases, morphologies, and orientations, including for volatiles (Fig. 1).

The apparatus consists of two key components: a collimated broad-spectrum X-ray source and a low noise, photon-counting X-ray CCD. The CCD detects individual X-ray photons, reporting their (x,y) positions as well as their energies (and thus wavelengths) with ~2% resolution. When X-rays strike the sample, some are diffracted in accordance with Bragg's law. Other X-rays are stopped by atoms in the sample, which then emit characteristic lines with known energies through fluorescence. The CMIST CCD captures diffracted and fluoresced X-rays, generating an "event list" of all individually detected photons. The measured photon properties are then transformed so that diffraction and fluorescence signatures are largely distinct (Figs. 2, 3): for each event, a unique d-spacing value is derived given the photon energy (and thus λ) and its position (and thus 2θ) using Bragg's law. X-ray intensity images over energy and d (Fig. 3) reflect an orthogonal space in which horizontal lines describe elemental composition (XRF) and vertical lines encode mineral identification (XRD).

Development & Application: Our goal is to develop a tool that can quickly differentiate relevant minerals to inform planetary sample collection during surface traverses, at reduced cost (in analysis time, volume, and power) and risk (through elimination of sample preparation steps) compared to existing systems. Depending on the sample's crystalline structure, a CMIST measurement can be obtained in < 10 minutes, often within several tens of seconds.

In a mature form, CMIST will consist of a low power (< 5 W), low mass (< 5 kg), compact (large coffee-cup size) X-ray diffractometer, fluorescence spectrometer, and optical imager for measuring element abundances, distinguishing mineral phases including ices, and determining the unaltered sizes and orientations of crystals over a few-mm^2 surface area, with no sample preparation (Fig. 4). The lack of moving parts and sample preparation requirements, coupled with the instrument's small size, make this an ideal tool for use during future human exploration missions.

Science: The CAPTEM-LEAG report on lunar sample acquisition and curation identifies low mass, low power, and rapid measurement (minutes) as crucial enabling capabilities for future sample return missions [1,2]. Rapid analysis is especially critical for communication with a science support team that provides additional sample selection insight during human missions. CMIST is designed to quickly inform sample selection during real-time field operations, either for return to Earth or for further analysis by a laboratory XRD located at a mission habitat.

CMIST's capability for mm-scale textural analysis of unprepared samples, with grain structure left intact, reveals petrology and morphology/size distributions. Mineral identification and elemental abundances, although important, do not by themselves tell the complete petrological story of a sample. Non-destructive optical and XRD texture analyses provide essential context from which a formation history can be inferred, including rock class (igneous, sedimentary, or metamorphic) and type (e.g., mare basalt or gabbroic anorthosite). XRD-derived microstructure information in the form of the nature of ground-mass (microcrystalline or amorphous), as well as grain arrangement, abundance, size, zoning, and orientations will provide a more thorough sense of a sample's geologic history.

Because CMIST requires no sample preparation, unbound and frozen volatiles are readily detected. This unique capability of contact XRD enables analysis of native ices and other planetary materials that would be modified during sample collection and preparation, determinations of brine chemistries, and assessment of the environmental impact that human presence may have at an outpost or landing site.

If samples are to be collected and returned to Earth for analysis, CMIST can provide a baseline geochemical, mineralogical, and volatile measurement for comparison with subsequent laboratory analyses. This would enable an assessment of possible phase changes upon exposure of samples to a habitat or terrestrial environment. Sample storage interfaces can be designed to enable measurements to be made at regular intervals during transit from the exploration target to Earth.

Safety & Health: CMIST has unique strengths related to scientific exploration. We envision additional capabilities related to safety and health of crew and hardware during lengthy missions in deep space. Long-term exposure (e.g., through breathing) to dust and other contaminants poses potential health hazards for astronauts. CMIST enables in situ analysis of air filters to assess the chemistry, mineralogy, and structure of particulates that are cleaned from a habitat's atmosphere; regular measurements would provide insights into the nature and concentrations of contaminants, as well as any changes with time. CMIST is also suited to evaluating the effects of exposure to the ambient environment—irradiation or accumulated deposition of contaminants—on internal or external surfaces critical to scientific capabilities or crew health. Optical or electrically sensitive components, even metal fatigue, can be evaluated with CMIST's unique combination of non-destructive analysis capabilities.

Conclusions: CMIST combines contact XRD/XRF and microscopic imaging of unprepared samples. Its innovative approach provides chemical composition and unique crystal texture information, including identification of volatiles. Beyond its primary application as a real-time sample triage instrument, CMIST can serve as an in situ mission assurance tool, providing assessments of equipment and environments vital for crew health and mission success.

References: [1] Shearer et al. (2007) CAPTEM Analysis Document 2007-02, http://www.lpi.usra.edu/captem/sampleReturnWorkGroup.pdf. [2]Shearer et al. (2010) Joint LEAG-CAPTEM Analysis Document, http://www.lpi.usra.edu/leag/reports/LEAG_CAPTEMCurationReview.pdf.

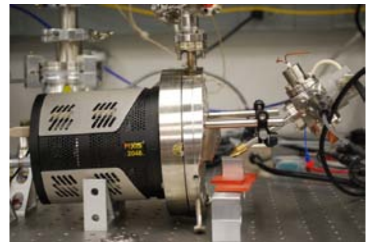

Figure 1. Laboratory model of CMIST including a commercial X-ray CCD camera and a compact X-ray source developed at GSFC.

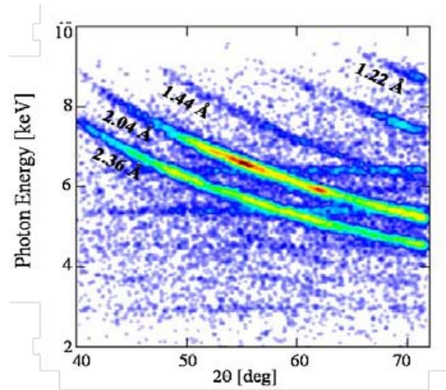

Figure 2. X-ray intensity as a function of energy and 2θ: arcs are XRD features (*d*-spacing values indicated), while XRF lines are horizontal.

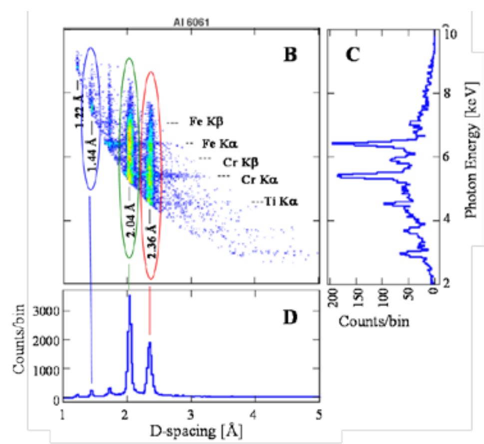

Figure 3. The Al 6061 dataset from Fig. 2 rebinned in energy vs. *d*-spacing.

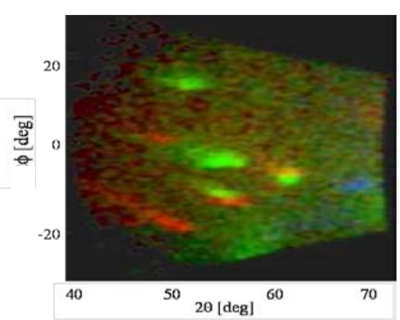

Figure 4. Specular-diffracted X-ray intensity depicting crystal lattice plane orientations for *d* = 2.36 (red), 2.04 (green), and 1.44 (blue) Å.