IN-SITU MICROCT INSTRUMENT FOR THE NORTH POLAR LAYERED DEPOSITS OF MARS.

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Introduction: Understanding the martian climate and how it has changed over its geologic history will contribute to our understanding of climate change on all terrestrial planets. The North Polar Layered Deposits (NPLD) are a multi-kilometer thick sequence of dusty-ice layers thought to contain a record of past states. Deciphering this polar record has been, and remains today, a major goal of Mars research [1].

We know that the dust-content of the NPLD is less than a few percent and that internal layers are contiguous across the entire deposit [2,3]. Sulfate and perchlorate salts have been detected within the PLD and are presumably co-deposited with silicate dust [4-6]. Internal layering has been imaged at high-resolution by MRO's High-Resolution Imaging Science Experiment (HiRISE) where it is exposed in the many troughs and scarps within the NPLD [7] and at low resolution by the Shallow Radar (SHARAD) instrument [3,8,9].

However, the resolutions of layer observations from remote sensing are too coarse and lack the detail needed to detail layer properties and infer climatic information. Fully deciphering the martian climatic record will require in situ high-resolution measurements at the surface that can resolve the properties such as such as dust content and distribution and porosity that may vary temporally and climatically.

Our current understanding of NPLD layers suggests that completely resolving annual layers over most of NPLD history will require 0.1mm vertical resolution. As most NPLD ice could be quite clean, characterizing the dustiness of polar layers requires much greater sensitivity than a few percent. We require dust detectability of 100 ppm by volume with a measurement accuracy of 100 ppm to characterize annual variations in periods of low dust activity. Porosity has important implications for layer deposition mechanism and is substantially preserved in terrestrial ice-sheets down to depths of decameters. Bramson et al. (2017) [10] recently found that substantial porosity can be preserved in mid-latitude martian ice over 10s of Myr – more than the expected age of the NPLD. Measurement of porosity vs. depth can constrain martian densification rates and climatic conditions at the time of deposition [11].

MicroCT is the most comprehensive technique to analyze the NPLD because it can provide high resolution (micron scale) information on densification, layer thickness and morphology, as well as particle size and type. A lander-mounted microCT system could provide much of the microstructural data we would seek from a PLD ice-sediment core, while avoiding the significant hurdles posed by bringing samples back to Earth.

Micro Computed Tomography.

Micro Computed Tomography (microCT) is a nondestructive technique for analyzing micron-scale internal features of a solid sample that could otherwise only be revealed by physically sectioning the material. Series of high-resolution radiographic images are collected at small angular steps, and a 3-dimensional model of the sample is computed.

Layering can be examined by particle size, shape, and relative atomic weight. MicroCT has been used extensively in the study of depositional processes in sedimentary rock [12] and ice [13,14].

Mars In Situ Tomography (MIST) System.

The Mars In Situ Tomography System is a miniaturized micro computed tomography (CT) instrument concept intended for deployment to the Mars North Polar Layered Deposits (NPLD) on a lander or rover. MISTS will provide in-situ 3D-reconstructions of ice cores, enabling the study of sediment distribution. The system consists of two subsystems, the CT instrument and a coring auger that interfaces with Honeybee Robotics' drilling system. The CT system is based on a cone-beam geometry with a simple architecture combining a microfocused X-ray tube, an X-ray image sensor and a core scanning stage.

Our objective is to design a miniaturized microCT system and associated X-ray transparent coring and breakoff tube for the TRIDENT drill and to develop/build and test prototype MIST components in a laboratory cold environment.

We have designed, developed and tested a functional breadboard tomography instrument and an ice-coring tool. The breadboard system was used to collect data from simulants and samples of manmade ice and the resulting tomographs reconstructed with software that is being developed to accommodate the unique conditions imposed by the miniaturized system and its intended use.

Figure 1 shows a lander-based MIST system. The cone-beam geometry and simple architecture is shown in Figure 2. The breadboard system is based on opto-mechanical hardware, a commercial 60 micron focused X-ray tube and a power supply, a custom sample stage based on a stepper motor, and a customized DSLR camera for X-ray detection.

Figure 3 compares a slice of the reconstructed wax core sample scanned and reconstructed with our 25 kV system (left) to a slice from nominally the same height in the sample acquired with a commercial desktop instrument. Source energy, placement of the sample relative to the axis of rotation, and volume scanned were different, hence the differences in the background (and ring artifacts). Note, however, that the same features are visible in both images, including two Al balls (white) and the voids in the wax (darker gray left, black right).

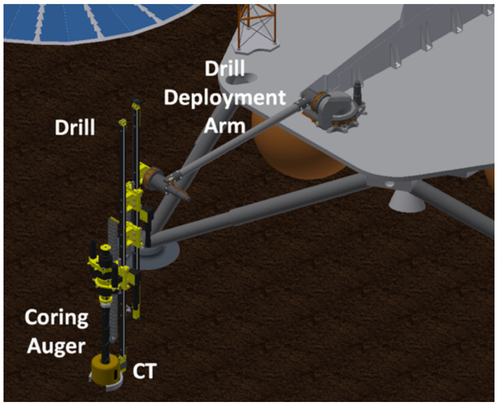

Figure 1. A CAD image of the Lander-based MISTS

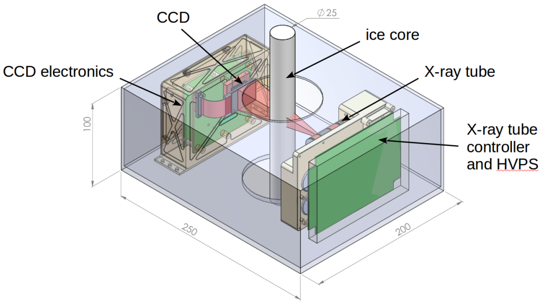

Figure 2. Rough schematic of the analytical head of MIST microCT subsystem based on flight subcomponents developed or under development at NASA ARC (derivation of MSL CheMin CCD, flight CCD electronics, micro-focused ceramic-metal tube, +25kV HVPS), dimensions in mm.

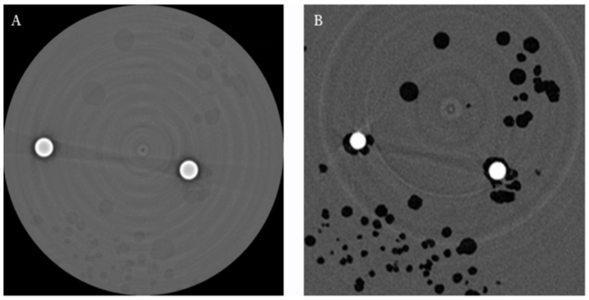

Figure 3. 3D reconstruction slice of a wax core with Al balls (0.8 mm diameter). A. MIST data at 25kV. B. same sample in commercial X-ray microCT.

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