3D VIRTUAL ASTROMATERIALS SAMPLES COLLECTION OF NASA'S APOLLO LUNAR AND ANTARCTIC METEORITE SAMPLES TO BE AN ONLINE DATABASE TO SERVE RESEARCHERS AND THE PUBLIC.

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Introduction: Since 2013, we have been developing the first 3-dimensional digital database of NASA's astromaterials collections. Once officially launched to the public, the 3D Virtual Astromaterials Samples (3DVAS) Collection will provide an information-rich visualization of research-grade 3D models of NASA's Apollo Lunar and Antarctic Meteorite samples for researchers and the public, making these remarkable samples accessible worldwide in a new way [see 1, 2, 3, 4, 5, 6, 7, 8]. As NASA's collections of astromaterials continues to grow, it is critical to recurrently update the unique preservation strategies of these scientifically and culturally significant samples. In order to meet the interests and capabilities of contemporary technologies as well as increasing accessibility demands, our interdisciplinary team has developed advanced documentation and visualization practices that enhance conservation and curation protocols for NASA's astromaterials collections. NASA's collections of astromaterials are housed within the Astromaterials Acquisition & Curation Office in the Astromaterials Research and Exploration Science Division at Johnson Space Center (JSC).

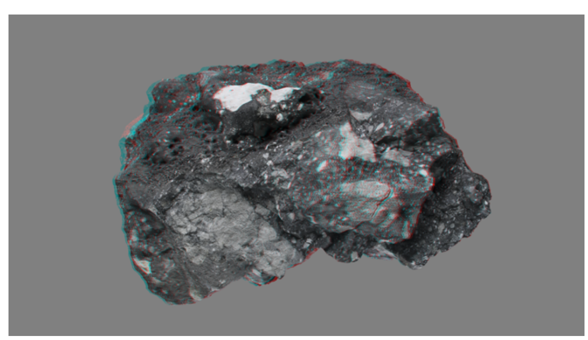
Objectives: We are an interdisciplinary team that brings together expertise in the fields of transdisciplinary art, professional photography, heritage conservation practices, geoscience, astromaterials curation, photogrammetry, imaging science, x-ray computed tomography, application engineering, and data curation. Our objective is to create virtual 3D reconstructions of 60 Apollo Lunar and Antarctic Meteorite samples that are a fusion of two state-of-the-art high-resolution data sets: the interior view of the sample by collecting Micro X-ray computed tomography data and the exterior view of the sample by collecting high-resolution precision photography data.

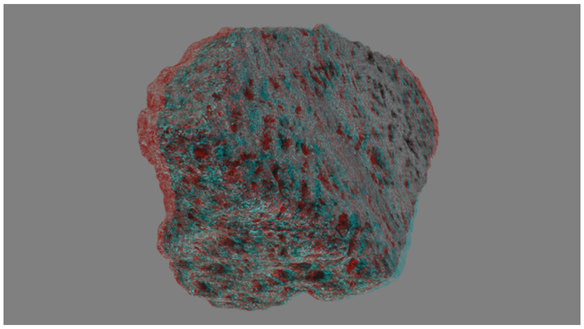
Method: Our method uses three primary existing technologies: High-Resolution Precision Photography (HRPP), Structure-From-Motion Photogrammetry (SFM) and Micro X-Ray Computed Tomography (XCT). We have designed and built custom hardware and developed novel methods to achieve research-grade interior and exterior 3D sample reconstruction that is viewable within a singular coordinate system.

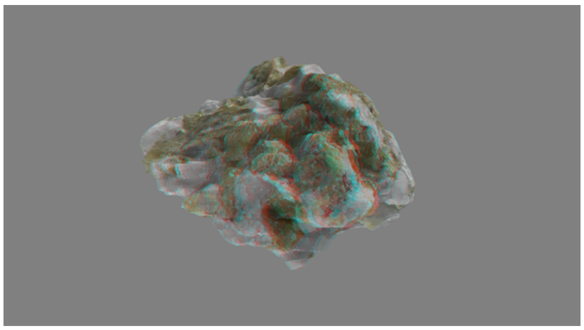
Our HRPP method is a manual imaging process that provides exceptional detail and reliable fidelity of the sample being photographed, and allows for calibration of the equipment to eliminate distortion. Our 60-megapixel Hasselblad H4D camera system with a 40.2 x 53.7mm CCD Sensor provides exceptional resolution capabilities that are meant to meet the quality demands of both today's and future users.

NASA's astromaterials are stored to protocol in a multi-clean room facility and kept in nitrogen cabinets [10] during the photographic process. The camera remains outside the cabinet and images are taken through the optical glass of the Scientific Observation Port. Each sample is imaged at 15-degree intervals at several elevations using our specialized registration and rotation stage that holds the astromaterials samples during the photography procedure (for procedural development, see 1-6).

SFM provides off-the-shelf software to produce 3D reconstructions of the HRPP images using photogrammetric principles. We work with Agisoft PhotoScan Pro, which uses image processing algorithms and techniques originating in computer vision to resolve 3D models for accurate and detailed visualization of each sample. The software provides a stepwise process that is then tailored per model based on unique spatial and specular reflectance properties [for current detailed procedure, see 8].







Figures 1-3: HRPP-derived 3D SFM models in anaglyph of the following Apollo Lunar Samples (top to bottom): 60019,0; 70017,8; 76353,0 (please use 3D anaglyph glasses to view in 3D!)

XCT provides a complete volume data set of the sample, where brightness of textural features is related to its density and composition [11].

Initial efforts in registering the coordinate system and combining the HRPP SFM models with the XCT data in order to achieve the fused 3DVAS have been reported in previous abstracts [5, 7]. Current methodologies work with the VGSTUDIO MAX software, in which XCT data is processed into an isosurface model that serves as an empty shell representation of the sample. The SFM-derived model, also an empty shell representation of the sample, is registered to the XCT isosurface model via a best fit algorithm. Within VGSTUDIO MAX, application of the best fit registration algorithm to SFM-derived and XCT isosurface models yield exceptional registration results. Once both data sets are aligned in the XCT coordinate system, visualization of the external texture and internal composition as shown in Figure 5 is achieved by controlling visibility of XCT volumetric and SFM data. [9]

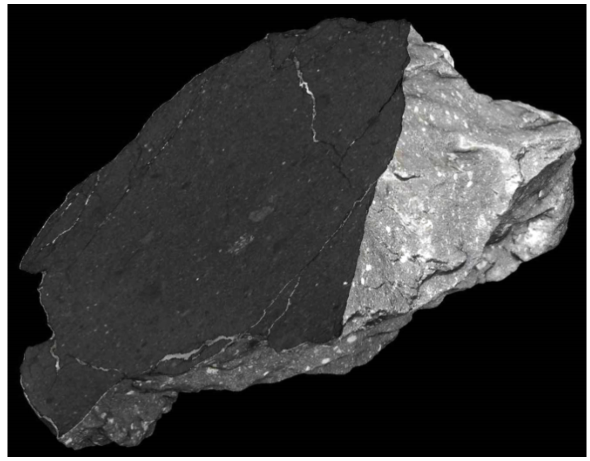


Figure 4: Visualization of Apollo Lunar Sample 79115,0 showing the fused XCT and SFM-derived data sets in VGSTUDIO MAX.

Results: The 3DVAS Collection will virtually put these samples in the hands of researchers and educators worldwide, increasing accessibility and visibility of these significant collections. With new sample return missions on the horizon, it is of primary importance to develop advanced curation standards for documentation and visualization methodologies. 3DVAS will offer scientists an unprecedented research tool for preliminary investigation and targeted sub-sample requests. Additionally, the 3D models are a visually engaging and interactive tool for bringing astromaterials science to the public. All 3DVAS models and original data will be served on NASA's Astromaterials Acquisition and Curation website.

References: [1] Blumenfeld E. H. et al. (2014) *Metsoc 77*, Abstract #5391. [2] Blumenfeld E. H. et al. (2015) 46th *LPSC*, Abstract #2740. [3] Blumenfeld E. H. et al. (2016) *AGU Fall Meeting*, Abstract #190585. [4] Blumenfeld E.H. et al (2017), *48th LPSC*, Abstract #2874. [5] Blumenfeld E.H. et al (2017), *ToScA North American Symposium* [6] Blumenfeld E.H. et al (2018) *AGU Fall Meeting*, Abstract #422858. [7] Beaulieu K.R. et al (2017), *48th LPSC*, Abstract #2649. [8] Thomas A.B. et al (2018) *AGU Fall Meeting*, Abstract #436923 [9] Beaulieu K.R. et al (2017), *50th LPSC*, Abstract #2877. [10] Allen C. et al. (2011) *Chemie der Erde, 71*, 1-20. [11] Ketcham R. A. et al. (2001) *Computers and Geosciences, 27,* 381-400.

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