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).

Top row: 1. Apollo 17 Scientist-Astronaut Harrison H. Schmitt walking on lunar surface to retrieve selected rock sample; 2. The 2015/2016 Antarctic Search for Meteorites (ANSMET) team en route to their next meteorite sample location.

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.

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

Referenes

[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 (2019), *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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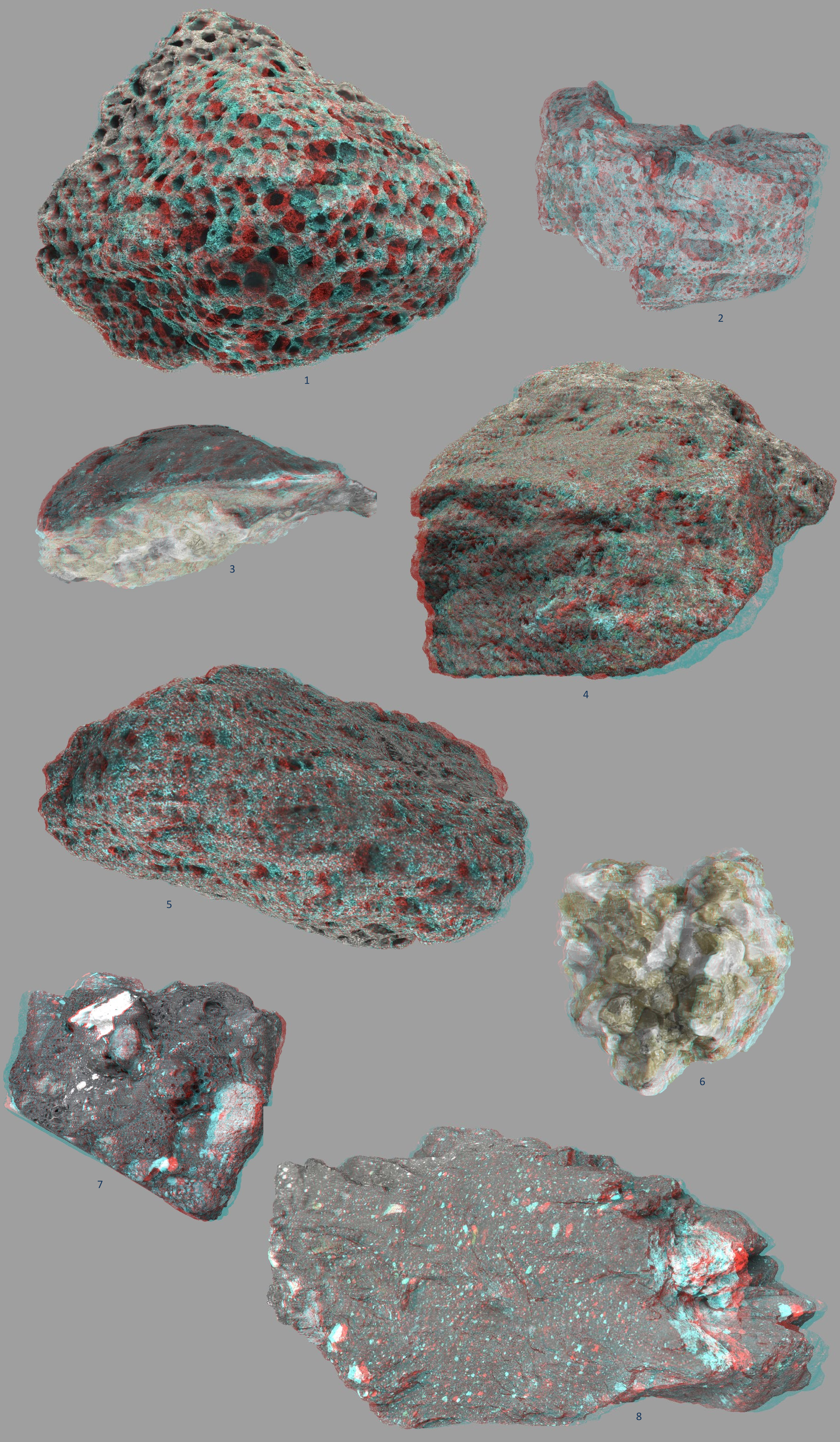
SFM 3D models (3D glasses required!):



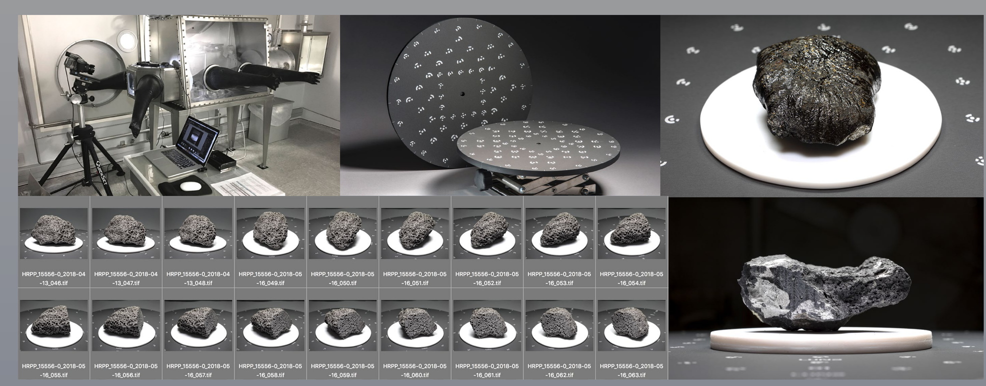
1. Apollo Lunar Sample 15016,0
2. Apollo Lunar Sample 67016,2
3. Apollo Lunar Sample 78236,0
4. Apollo Lunar Sample 15058,0
5. Apollo Lunar Sample 70017,8
6. Apollo Lunar Sample 76535,0
7. Apollo Lunar Sample 60019,4
8. Apollo Lunar Sample 79115,0

models are not shown here at the original sample size

Methods

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.

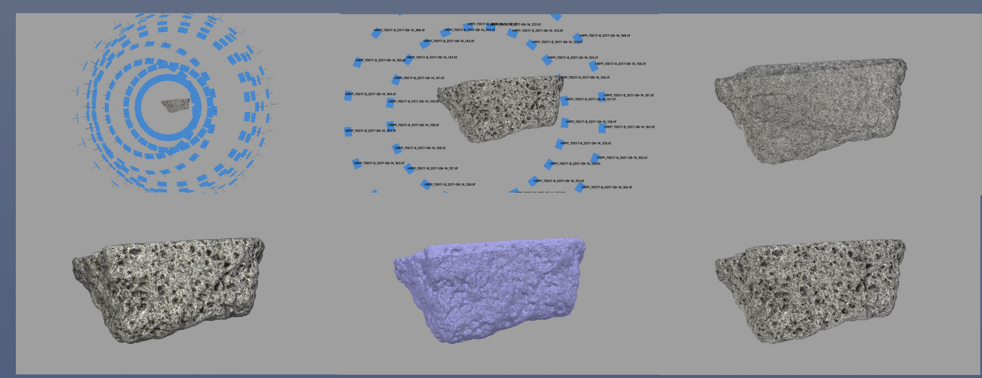
Our HRPP method is a manual imaging process that provides exceptional detail and reliable fidelity of the sample being photographed, and allows for calibration of the equipment to eliminate distortion. Our 60-megapixel Hasselblad H4D camera system with a 40.2 x 53.7mm CCD Sensor provides exceptional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



Left to right, top to bottom: 1. Equipment setup in Lunar Lab; 2. Custom calibrated rotation platforms version 2; 3. Antarctic Meteorite GRO17176,0 on rotation platform version 3; 4. Series of images of Apollo Lunar Sample 15556,0 on rotation platform version 3; 5. Apollo Lunar Sample 15455,37 in Lunar cabinet setup on rotation platform version 3.

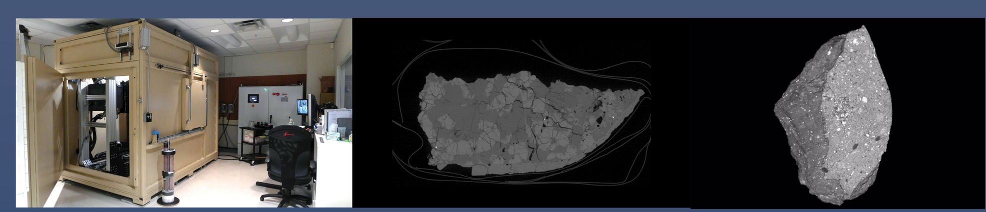
NASA's astromaterials are stored to protocol in a multi-clean room facility and kept in nitrogen cabinets [10] during the photographic process. The camera remains outside the cabinet and images are taken through the optical glass of the Scientific Observation Port. Each sample is imaged at 15-degree 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].



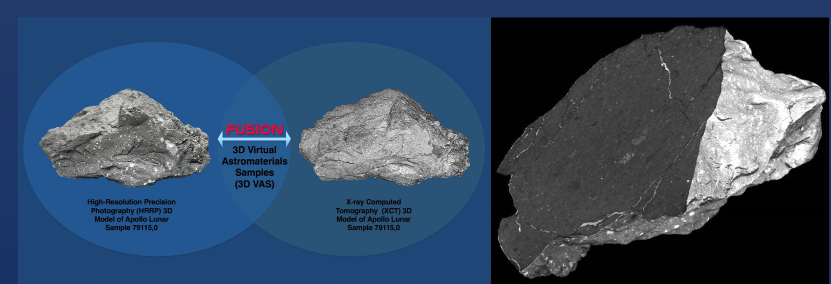
Top row: 1. View of aligned cameras for the 3D reconstruction of Apollo Lunar Sample 70017,8; 2. Aligned cameras showing originating photo files; 3. Point Cloud. Bottom row: 4. Dense Cloud; 5. Wireframe; 6. Final textured model.

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



From left to right: 1. View of X-ray scanner at the UTCT Facility; 2. Single XCT slice of Apollo Lunar Sample 78236,0; 3. Cutaway animation of XCT scans from Antarctic Meteorite QUE97001-18.

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]



Left: Both the XCT and HRPP 3D models of Apollo Lunar Sample 79115,0 prepared for fusion. Right: Visualization of Apollo Lunar Sample 79115,0 showing the first fused XCT and SFM-derived data sets, viewed in VGSTUDIO MAX.