SAMPLE RETURN AND PRELIMINARY EXAMINATION TIMELINE FOR THE OSIRIS-REX MISSION.

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Introduction: NASA's OSIRIS-REx spacecraft collected a sample of asteroid (101955) Bennu on October 20, 2020, using the Touch-and-Go Sample Acquisition Mechanism (TAGSAM) [1,2,3]. After sample acquisition, the TAGSAM collection head was stowed in the Sample Return Capsule (SRC; Fig. 1) for transport back to Earth. On September 24, 2023, the OSIRIS-REx spacecraft will fly by Earth and release the SRC, which will land at the Utah Test and Training Range (UTTR). The sample will be transported to the OSIRIS-REx curation facility, located within NASA's Johnson Space Center (JSC), where it will be examined, cataloged, and allocated for scientific analyses. Here we describe the timeline of operations for the return, recovery, and initial characterization of the Bennu sample.

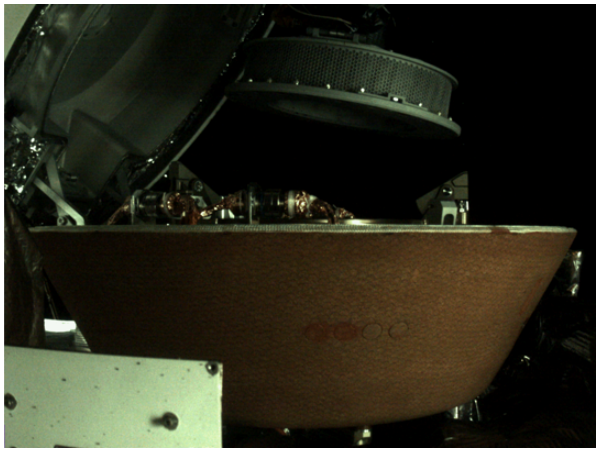

Figure 1: Image of the TAGSAM head being stowed within the SRC on the OSIRIS-REx spacecraft.

Earth Return: The OSIRIS-REx spacecraft will execute a series of trajectory correction maneuvers to refine the SRC final approach in the months leading up to sample return. The spacecraft will jettison the SRC four hours before it enters the atmosphere. Twenty minutes after this release, the spacecraft will execute a divert burn to raise its periapsis above the atmosphere — directing the spacecraft to asteroid (99942) Apophis for an extended mission [4].

Atmospheric Entry (AE) will occur at 8:41:44 MDT over the coast of California. The SRC drogue will deploy just over two minutes after AE, followed by deployment of the main parachute at ~AE+8 minutes at an altitude of ~3 km. Approximately 13 minutes after AE, the SRC will touchdown in the Utah desert.

Sample Recovery: Once the location of the SRC is determined, the OSIRIS-REx recovery team will fly via helicopter to the touchdown site. Field processing of the SRC by the recovery team will include: safety inspection; photos to document the condition of the capsule; collection of gas and soil samples; bagging and securing the SRC in a handling fixture; and attaching the SRC by long line to a helicopter for transport to a temporary cleanroom at UTTR. In this ISO 7 cleanroom, the SRC will be disassembled, the sample canister will be removed, and a high-purity nitrogen gas (GN_2) purge will be established. The sample canister will be under continuous GN_2 purge for transport to the OSIRIS-REx curation facility at JSC, with a delivery time of 36 to 96 hours after touchdown (assuming nominal conditions).

Preliminary Examination: At the curation facility, the team will implement the Preliminary Examination (PE) phase, which runs parallel with sample analysis and focuses on: disassembly of the sample canister; initial documentation of the sample; production of a sample catalog (to be completed within six months of Earth return); transfer of samples to remote storage;

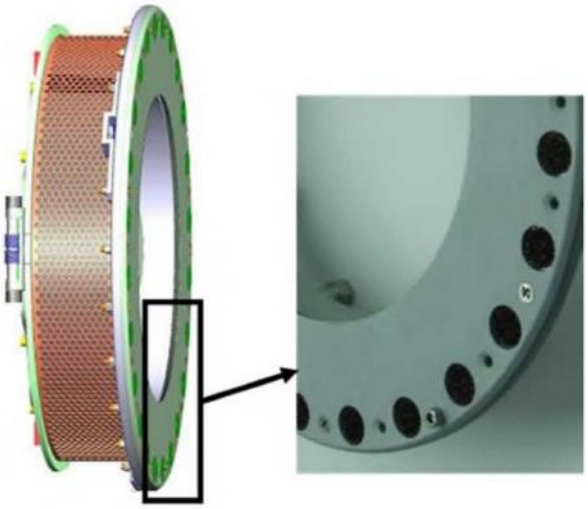

Figure 2: Image of the TAGSAM (left). Contact pads located around the TAGSAM baseplate (right). Figure from [3].

selection of samples for international partners; and the initial allocation of sample to the Sample Analysis Team (SAT). Up to 25 wt. % of the sample will ultimately be allocated to the SAT.

After arriving at JSC, the sample canister assembly will be transferred to a custom GN_2 glovebox cabinet in an ISO 5 cleanroom, where the team will remove the canister lid and photographically document the complete TAGSAM head (Fig. 2).

Within two days of arrival at JSC, sample will be collected from the exterior of the TAGSAM head for "quicklook" analyses by the SAT. Specifically, the team will use visible light microscopy, scanning electron microscopy, Fourier transform infrared spectroscopy (FTIR), and X-ray diffraction (XRD) at JSC to perform an initial mineralogical and petrologic characterization.

In parallel, the curation team will proceed with disassembly. Activities during the first week include removing the TAGSAM head from the capture ring, weighing the TAGSAM head with the bulk sample inside, and transferring the TAGSAM head to a second custom GN_2 glovebox. Contact pads on the bottom (Fig. 2) of the TAGSAM head will be photographically documented, removed, and stored in containers for further processing and analysis.

Disassembly of the TAGSAM head will continue during the second week after arrival at JSC, with the bulk sample inside the TAGSAM head being exposed and imaged (Fig. 3). The curation team will carefully pour the bulk sample into eight trays for weighing, processing, and characterization. Using results from the quicklook analysis to guide them, the SAT will focus on identification of distinct lithologies within the bulk sample using the bespoke Quantitative Reflectance Imaging System (QRIS) [5]. The sample's particle size frequency distribution (PSFD) will be measured to identify the largest particles, which the curation team will separate from the bulk sample and document for inclusion in the sample catalog. The curation team will also remove one stone for public display.

In the third week after arrival at JSC, the curation team will work to separate unprocessed samples for international partners, the White Sands Complex, and hermetically sealed samples for long term storage.

While this is ongoing, the SAT will refine the lithology characterization using QRIS images and the quicklook results. They will identify stones of interest (SOIs) from each candidate lithology. Density calculations, based on volumes from structured light scanning (SLS) and masses from weighing the SOIs, will be used to help confirm the candidate lithologies. The SAT will then identify a minimum of four individual SOIs of each lithology to ensure any SOIs selected for sample analysis do not exceed 25% of that

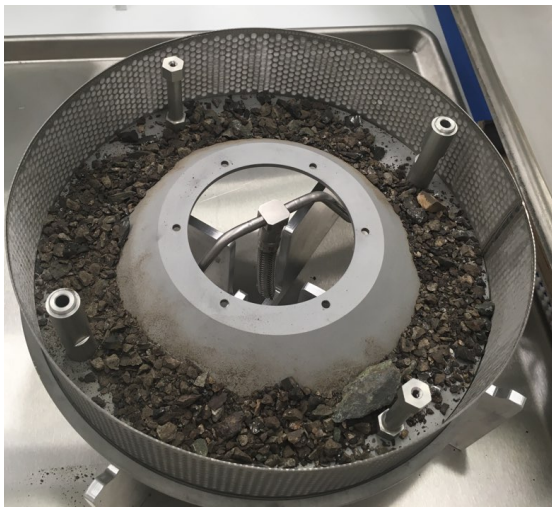

Figure 3: Image from a SAT operational exercise showing analog sample in an engineering model of the TAGSAM head.

lithology. Using this initial characterization of the bulk sample, a decision will be made on the preferred allocation to the SAT. The curation team will sweep some representative aggregate material for early distribution after some of it is further characterized at JSC using the quicklook techniques.

Starting in the third week, the SAT will select SOIs from each lithology for creation of polished sections. Splits from these stones will be sent off for initial bulk compositional analysis. The decision on which particles will be allocated to each planned subsequent science investigation are based on visual inspection, QRIS imaging, density calculations, initial analysis of bulk abundances, and quicklook results.

A month after sample return, most of the bulk sample should be containerized. The SAT will spend two years analyzing their allocation.

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References: [1] Lauretta, D.S. et al. (2021) in Sample Return Missions, Longobardo, A., ed. (Elsevier), pp. 163–194. [2] Lauretta, D.S. et al. (2022) Science 377, 285–291. [3] Bierhaus, E.B. et al. (2018) Space Science Reviews 214, 107. [4] OSIRIS-APEX Mission Plan [5] Fulford, R.E. et al. (2022) 85th Annual Meeting of The Meteoritical Society, Abstract #6532.