Sample Analysis Plan for NASA's OSIRIS-REx Mission

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OSIRIS-REx [1,2] is the third mission in NASA's New Frontiers program and its first asteroid sample return mission. In October 2020, the OSIRIS-REx spacecraft successfully performed its Touch-and-Go (TAG) maneuver to collect a sample of regolith [3] from the surface of its target, asteroid (101955) Bennu, and is now on its return cruise to Earth. On 24 September 2023, the Sample Return Capsule (SRC) is scheduled to be released from the spacecraft and gently land in the desert of the western U.S. state of Utah. After it is recovered, the SRC will be placed into an inert environment, safely packed, and flown to Houston, Texas, where it will go directly to the new OSIRIS-REx curation facility located within NASA's Johnson Space Center. Once within the facility, the SRC will be opened, and the sample will be quickly (within hours to days) processed for distribution to the OSIRIS-REx Sample Analysis Team (SAT) for immediate investigation. In addition, the Japan Aerospace Exploration Agency will receive 0.5% of the unprocessed bulk material and the Canadian Space Administration will receive 4%. A catalog of the entire sample will be produced within six months and will enable requests of the remaining material by the scientific community.

The OSIRIS-REx Sample Analysis Plan (SAP) establishes a hypothesis-driven framework for integrated, coordinated analyses of the returned sample with the goal of satisfying the mission requirement to "return and analyze a sample of pristine carbonaceous asteroid regolith in an amount sufficient to study the nature, history, and distribution of its constituent minerals and organic material." Through analysis of the returned sample, the SAT will test a total of 12 primary hypotheses, each encompassing several secondary hypotheses. The primary hypotheses are:

1. Remote sensing of Bennu's surface has accurately characterized its mineral, chemical, and physical properties.
2. Bennu contains prebiotic organic compounds.
3. Bennu contains presolar material derived from diverse sources.
4. Bennu's parent asteroid formed beyond the snow line by accretion of material in the protoplanetary disk.
5. Geological activity occurred in the interior of Bennu's parent asteroid early in solar system history.
6. Bennu's parent body experienced > 3 billion years of solar system history before being destroyed in a catastrophic disruption.
7. Bennu is a rubble pile that formed by re-accumulation of material from the catastrophic disruption of a precursor asteroid.
8. The Yarkovsky effect pushed Bennu far enough inward to reach a dynamical resonance, which flung it out of the main belt and onto a terrestrial planet-crossing orbit.
9. Bennu has experienced surface processing throughout its history.
10. The physical, chemical, and spectral properties of Bennu's surface materials have been modified by exposure to the space environment.
11. The Hokioi Crater in which the Nightingale sample site is located was recently formed and contains relatively unweathered material [4].
12. OSIRIS-REx asteroid proximity operations, the TAG event, and Earth return modified the collected samples, Touch-and-Go Sample Acquisition Mechanism (TAGSAM), and the SRC.

Each hypothesis is mapped to one or more SAT working groups and analytical technique(s) needed to produce the data to test it.

The SAP applies a three-tiered approach to allocating sample mass for analyses. (i) The "baseline" analysis plan assumes that 15 g of sample will be available to the SAT. This mass is based on the assumption of returning 60 g, the mission-required minimum, and the fact that 75% of the sample (in this scenario, 45 g) will be archived for future community analysis. (ii) The "overguide" analysis plan assumes that 62.5 g of sample will be available to the SAT. This mass is based on the best-available spacecraft-based estimate of the total mass of sample stowed, about 250 g [5]. (iii) The "threshold" analysis plan assumes that

3.75 g of sample will be available to the SAT. This mass addresses a contingency scenario in which an anomaly during Earth return results in a significant mass loss, such that only 15 g is recovered. The threshold plan's other purpose is to guide analysis of any rare lithologies that might be returned as part of the bulk sample.

To test the effectiveness of our SAP and ensure that the SAT is prepared for the analysis of the returned sample, the mission will conduct a Sample Analysis Readiness Test (SART) from June 2022 to June 2023. The SART will focus on aspect of the SAP for which verification or demonstration of proficiency is needed such as follow-on analyses, testing of new or updated equipment, and implementation of new software discussed below. During the SART, the mission will implement a new data storage, processing, sharing, and visualization system designed to enable coordinated analysis, called the Sample Analysis Micro-Information System (SAMIS). SAT members will test their proficiency with the two user-facing modules of SAMIS: the Sample Analysis Tracking Application (SATA), which provides real-time tracking of the location and condition of sub-samples as they are shipped between laboratories and the curation facility, and the Sample Analysis Desktop Application (SADA), which provides a central point of upload, download, spatial co-registration, and visualization of analytical data. Finally, because all data from the mission's sample analysis phase will be archived, the SAT will use the SART to practice data archiving. Periodic reviews of the SART will occur during its implementation, and lessons learned will be applied to the SAP, applications, and archiving approach. A final report on the outcomes of the SART will be produced in the summer of 2023 (before the sample is returned to Earth).

References

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