Integrated science and engineering for the OSIRIS-REx asteroid sample return mission

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Introduction: The Origins, Spectral Interpretation, Resource Identification, and Security-Regolith Explorer (OSIRIS-REx) asteroid sample return mission will survey near-Earth asteroid (101955) Bennu to understand its physical, mineralogical, and chemical properties, assess its resource potential, refine the impact hazard, and return a sample of this body to the Earth [1]. This mission is scheduled for launch in 2016 and will rendezvous with the asteroid in 2018. Sample return to the Earth follows in 2023. The OSIRIS-REx mission has the challenge of visiting asteroid Bennu, characterizing it at global and local scales, then selecting the best site on the asteroid surface to acquire a sample for return to the Earth. Minimizing the risk of exploring an unknown world requires a tight integration of science and engineering to inform flight system and mission design.

Defining the Asteroid Environment: We have performed an extensive astronomical campaign in support of OSIRIS-REx. Lightcurve and phase function observations were obtained with UA Observatories telescopes located in southeastern Arizona during the 2005–2006 and 2011–2012 apparitions [2]. We observed Bennu using the 12.6-cm radar at the Arecibo Observatory in 1999, 2005, and 2011 and the 3.5-cm radar at the Goldstone tracking station in 1999 and 2005 [3]. We conducted near-infrared measurements using the NASA Infrared Telescope Facility at the Mauna Kea Observatory in Hawaii in September 2005 [4]. Additional spectral observations were obtained in July 2011 and May 2012 with the Magellan 6.5-m telescope [5]. We used the Spitzer space telescope to observe Bennu in May 2007 [6]. The extensive knowledge gained as a result of our telescopic characterization of Bennu was critical in the selection of this object as the OSIRIS-REx mission target. In addition, we use these data, combined with models of the asteroid, to constrain over 100 different asteroid parameters covering orbital, bulk, rotational, radar, photometric, spectroscopic, thermal, regolith, and asteroid environmental properties. We have captured this information in a mission configuration-controlled document called the Design Reference Asteroid. This information is used across the project to establish the environmental requirements for the flight system and for overall mission design.

Maintaining a Pristine Sample: OSIRIS-REx is driven by the top-level science objective to return >60 g of pristine, carbonaceous regolith from asteroid Bennu. We define a “pristine sample” to mean that no foreign material introduced into the sample hampers our scientific analysis. Basically, we know that some contamination will take place — we just have to document it so that we can subtract it from our analysis of the returned sample. Engineering contamination requirements specify cleanliness in terms of particle counts and thin- films residues — scientists define it in terms of bulk elemental and organic abundances. After initial discussions with our Contamination Engineers, we agreed on known, albeit challenging, particle and thin-film contamination levels for the Touch-and-Go Sample Acquisition Mechanism (TAGSAM) and the Sample Return Capsule. These levels are achieved using established cleaning procedures while minimizing interferences for sample analysis.

Selecting a Sample Site: The Sample Site Selection decision is based on four key data products: Deliverability, Safety, Sampleability, and Science Value Maps. Deliverability quantifies the probability that the Flight Dynamics team can deliver the spacecraft to the desired location on the asteroid surface. Safety maps assess candidate sites against the capabilities of the spacecraft. Sampleability requires an assessment of the asteroid surface properties vs. TAGSAM capabilities. Scientific value maximizes the probability that the collected sample contains organics and volatiles and can be placed in a geological context definitive enough to determine sample history. Science and engineering teams work collaboratively to produce these key decision-making maps.

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References: References: [1] Lauretta and Team, 2012. 43rd LPSC, Abstract 2491. [2] Hergenrother et al., 2013. Icarus 226, 663–670. [3] Nolan et al., 2013. Icarus 226, 629–640. [4] Clark et al., 2011. Icarus 216, 462–475. [5] Binzel and DeMeo, 2013. AAS/DPS Meeting Abstracts (Vol. 45). [6] Emery et al., 2014. Icarus 234, 17–35.