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OSIRIS-REx at Asteroid (101955) Bennu: The Site Selection Campaign

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Abstract

OSIRIS-REx is unique among NASA planetary missions in that remote sensing is performed primarily to support the sample-return objective. The science payload is currently being used to survey Bennu to select and document the best candidate sample sites. The team is combining coordinated observations into four thematic maps of decision-making properties: deliverability, safety, sampleability, and science value. The Site Selection Campaign concludes with selection of a primary and backup sampling site. We will have completed this process prior to the conference and will discuss the sites and the expected nature of the returned sample.

1. Introduction

The plans to produce data products were developed from pre-launch mission design requirements:

• Deliverability: The spacecraft must be delivered to within 25 m of a selected location.

• Safety: When the Touch and Go Sample Acquisition Mechanism (TAGSAM) head contacts the surface, the spacecraft must avoid any damage that would prevent a successful return to Earth.

• Sampleability: A sample site must have characteristics that permit TAGSAM to obtain 60 g or more of regolith.

• Science Value: The sample site should contain material that provides the most value toward meeting the mission objective of returning pristine carbonaceous regolith.

2. Deliverability Map

The deliverability map indicates the probability that the flight dynamics team can deliver the spacecraft to the desired location. The initial 25-m-radius requirement was based on observations of the Muses Sea region on (25143) Itokawa [1], and the astronomical data that suggested Bennu's surface was smoother than that of this asteroid, with average particle size on the order of centimeters [2]. However, we now know that the albedo, texture, particle size, and roughness of Bennu's surface are beyond the spacecraft design specifications [3]. We observe only a small number of apparently hazard-free regions, of the order of 5 to 10 meters in diameter, requiring improvement to our spacecraft guidance accuracy capability. The spacecraft is equipped with two independent, autonomous guidance systems for the final closure with the asteroid surface during sample acquisition: natural feature tracking (NFT) and LIDAR-guided TAG [4]. Based on the surface properties, we are investigating the NFT system as the prime method for accurate delivery to the surface.

3. Safety Map

Safety maps are scaled maps that quantify the probability of safety during sample acquisition. The safety maps include an assessment of the probability that physical hazards will be present during the approach to the asteroid. Also, these maps indicate whether the spacecraft operational constraints will be met at the sample site. Maps for individual safety parameters have been generated based on the initial 75-cm-resolution shape model [5]. These maps suffer from the coarse resolution. The team is developing higher-resolution global maps and site-specific digital terrain models for the final safety assessment.

4. Sampleability Map

The sampleability map quantifies the expected collected mass from the surface of Bennu, based on metrics associated with the size–frequency distribution of the regolith, and the presence of obstacles. The sampleability map is designed to provide relative assessments of different regions of interest. We planned to have individual facets on the global shape model adopt values of tilt and average grain size based on the global shape model and the thermal inertia map. However, the relationship between thermal inertia and grain size on Bennu is inconsistent with the pre-encounter prediction [6]. We are evaluating other indirect measures of particle size at potential sample sites, such as a dust cover index similar to that first developed by [7]. To date, the only direct evidence of the existence of centimeter-sized particles that would be ingestible by TAGSAM is the observed ejection of centimeter-scale particles from the surface.

5. Science Value Map

A primary goal of the OSIRIS-REx mission is to test the many hypotheses on the origin, geological history, and dynamical evolution of Bennu through coordinated analytical studies of the returned samples. Bennu is spectrally a B-type asteroid and is thought to be most similar to CM carbonaceous chondrite meteorites [8]. To date, Bennu shows little spectral variation across its surface. However, there is an unexpectedly large variation in the normal albedo, with values ranging from 3.3% to >20%. Based on these data, we have defined science value parameters based on the mean albedo (with preference given to darker material based on our knowledge of carbonaceous chondrites) and the standard deviation of the albedo (adding value for a diversity of material). We are currently evaluating the mineralogical diversity indicated in our color ratio maps. The band ratios of interest are b′/v to characterize the ultraviolet slope, the v/x to characterize the visible slope, and a combination of the v, w, and x images to characterize the presence and depth of any 0.7-micron absorption feature. These parameters indicate the relative science value for the 50 potential sample sites under investigation. Sample sites with the highest scientific value should contain hydrated and hopefully organic-rich material and as many diverse materials as possible to address the questions and hypotheses posed by the sample analysis team.

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