A rendezvous with asteroid Bennu

The OSIRIS-REx mission has reached its target, asteroid Bennu, and is engaging in reconnaissance and early science observations in preparation for sample collection. Principal investigator team Heather Enos and Dante Lauretta provide an overview.

NASA's OSIRIS-REx spacecraft launched on 8 September 2016, embarking on a seven-year journey to asteroid (101955) Bennu and back. OSIRIS-REx will be the first NASA mission to travel to an asteroid, retrieve a sample, and deliver it to Earth[1]. Returning pristine carbonaceous regolith from Bennu will help us understand the role that primitive asteroids may have played in the origin of life on Earth and how they served as fundamental 'building blocks' of planet formation.

In August 2018, the OSIRIS-REx team began conducting observations of the asteroid's surface and immediate environment (Fig. 1). We will spend more than a year carefully characterizing Bennu to select an optimal sample site, making scientific observations throughout. The science investigations are codified in five mission objectives: globally map the physical, chemical and geological properties of Bennu; document the sample site in detail; return and analyse a sample; study the effect that sunlight has on the asteroid's orbit (that is, the Yarkovsky effect); and provide empirical data to improve asteroid astronomy.

The principal components of the spacecraft[1] include all the supporting subsystems for operation and control, the Touch-and-Go Sample Acquisition Mechanism (TAGSAM)[2], navigation cameras (TAGCAMS)[3], the sample return capsule, and the science payload.

One of the key technologies developed specifically for OSIRIS-REx — which can also be used for future missions to small bodies — is TAGSAM[2]. The TAGSAM articulated positioning arm extends 2.8 m from the spacecraft. The sampler head is an annulus with a filter screen on the outside circumference, held at the end of the arm. TAGSAM will acquire a sample by releasing a jet of high-purity nitrogen gas that agitates the regolith, creating a reverse vacuum-cleaner effect. TAGSAM will acquire at least 60 g of material in its collection chamber.

The science payload consists of five science instruments. The camera suite (OCAMS)[4] has three imagers: PolyCam, MapCam and SamCam. The three cameras provide the ability to image the asteroid over a wide range of distances, from 500,000 km down to 2 m from the surface of Bennu. OCAMS supports navigation of the spacecraft and reveals the asteroid's surface to sub-centimetre resolution. A visible and near-infrared spectrometer (OVIRS)[5] provides spectral maps to identify minerals and organic material. A thermal emission spectrometer (OTES)[6] also determines mineral compositions and captures surface temperatures. A scanning lidar system (OLA)[7] produces high-resolution topographical maps. A student-designed X-ray imaging spectrometer (REXIS)[8] determines the presence and abundance of elements on the surface of Bennu. In addition, the spacecraft has telecommunications equipment that enables radio science[9].

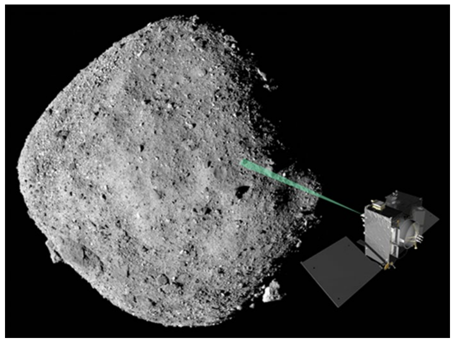

Fig. 1 | Artist's rendering of the OSIRIS-REx spacecraft observing the surface of asteroid Bennu. The photograph of Bennu was taken by OCAMS on 2 December 2018. Credit: NASA/Goddard/University of Arizona (photograph); Heather Roper/University of Arizona/NASA Goddard Space Flight Center (graphic)

Because of the interdependent nature of science and operations on this mission, our approach to planning and implementing science activities differs from that of other planetary science missions. Traditionally, science instrument teams have independent objectives and do not directly support tactical operations. The OSIRIS-REx team has one common goal: select a sample site. The integrated approach starts with planning that reaches across the science, navigation, systems engineering and spacecraft teams. As the details for science observation activities are developed, multiple and often conflicting constraints must be taken into consideration. Priority for resources is given to the activities that provide the most critical data to support sample-site selection.

An asteroid sample return mission poses significant operational challenges, including accurate spacecraft navigation in the microgravity environment, data production on a tactical timeline to enable sample-site selection, and precision delivery of the spacecraft to the asteroid surface. Ultimately, the spacecraft will slowly descend to the surface and make contact for less than five seconds, in a manoeuvre very similar to docking, to gather the sample.

While operating in close proximity to the asteroid, the spacecraft experiences non-gravitational forces from solar radiation pressure, re-emitted infrared radiation from the spacecraft and the asteroid, spacecraft outgassing, and other sources. These forces are comparable to that from the asteroid's gravity. The flight dynamics team[10] therefore developed new navigation techniques demonstrating the ability to predict the small forces with exquisite precision and perform simultaneous star-field and asteroid landmark tracking.

Mission operations thus far, including orbital insertion, have been a phenomenal success, exceeding all pre-encounter expectations for optical navigation, manoeuvre performance, and trajectory accuracy. The initial orbital phase was so stable that no maintenance manoeuvres were required. In its encounter with Bennu, OSIRIS-REx earned two Guinness World Records: the smallest object ever orbited and the lowest orbit ever captured. We are looking eagerly ahead to the achievements that will follow. ❐

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