SAMPLE

Solar System Missions: OSIRIS-REx

Touching an Asteroid

Aira Astralis

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Conclusion

This free sample contains the Introduction and Chapter 1. The complete book contains the full contents above.

Introduction

OSIRIS-REx was a NASA asteroid-study and sample-return mission that visited and collected samples from 101955 Bennu, a carbonaceous near-Earth asteroid. The material, returned in September 2023, is expected to enable scientists to learn more about how the Solar System formed and evolved, its initial stages of planet formation, and the source of organic compounds that led to the formation of life on Earth.

Following the completion of the primary OSIRIS-REx (Regolith Explorer) mission, the spacecraft, renamed as OSIRIS-APEX (Apophis Explorer), began a follow-up mission to asteroid 99942 Apophis. OSIRIS-REx was launched on

September 8, 2016, flew past Earth on 22 September 2017 and rendezvoused with Bennu on 3 December 2018. It spent the next two years analyzing the surface to find a suitable site from which to extract a sample. On 20 October 2020, OSIRIS-REx touched down on Bennu and successfully collected a sample.

OSIRIS-REx left Bennu on 10 May 2021 and returned its sample to Earth on 24 September 2023, subsequently starting its extended mission to study 99942 Apophis, where it will arrive in April 2029. Bennu was chosen as the target of study because it is a "time capsule" from the birth of the Solar System. Bennu has a very dark surface and is classified as a B-type asteroid, a sub-type of the carbonaceous C-type asteroids.

Such asteroids are considered primitive, having undergone little geological change from their time of formation. In particular, Bennu was selected because of the availability of pristine carbonaceous material, a key element in organic molecules necessary for life as well as representative of matter from before the formation of Earth. Organic molecules, such as amino acids, have previously been found in meteorite and comet samples, indicating that some ingredients necessary for life can be naturally synthesized in outer space.

Missions like this one are, at heart, salvage operations for the Solar System's childhood. The planets have melted, folded, and erased their own beginnings; comets and asteroids never did. Bennu belongs to the rare class of small worlds that spent four and a half billion years in cold storage — dark, carbon-bearing, and largely unchanged — which is why a spacecraft was sent to scratch its surface and why the scratches came home in a sealed capsule.

O - Origins

SI - Spectral Interpretation

RI - Resource Identification

S - Security

REx - Regolith Explorer

APEX - Apophis Explorer

Each of these words was chosen to represent an aspect of this mission.

Chapter 1: The Discovery of OSIRIS-REx

OSIRIS-REx was the first United States spacecraft to return samples from an asteroid. Previous asteroid returns include the Japanese probes Hayabusa, which visited 25143 Itokawa in 2005, and Hayabusa2, which visited 162173 Ryugu in June 2018. Overall management, engineering, and navigation for the

OSIRIS missions are provided by NASA's Goddard Space Flight Center, while the University of Arizona's Lunar and Planetary Laboratory provides principal science operations. Lockheed Martin Space Systems built the spacecraft and provides mission operations.

The science team includes members from the United States, Canada, France, Germany, the United Kingdom, and Italy. After traveling for approximately two years, the spacecraft rendezvoused with asteroid 101955 Bennu in December 2018, and began 505 days of surface mapping at a distance of approximately 5 km (3.1 mi). Results of that mapping were used by the mission team to select the site from which to take a sample of a minimum of sixty grams of material of the asteroid's surface.

Then a close approach (without landing) was carried out to allow extension of a robotic arm to gather the sample. Following the successful collection of material (121.6 grams (4.29 oz)), the sample was returned to Earth in a 46 kg (101 lb) capsule similar to that which returned the samples of Comet 81P/Wild on the space probe Stardust. The return trip to Earth was shorter than the outbound trip.

The capsule landed by parachute at the Utah Test and Training Range on 24 September 2023 and was transported to the Johnson Space Center for processing in a dedicated research facility. The launch was on 8 September 2016 at 23:05 UTC on a United Launch Alliance Atlas V 411 from Cape Canaveral, Space Launch Complex 41. The 411 rocket configuration consists of a RD-180 powered first stage with a single AJ-60A solid fuel booster, and a Centaur upper stage.

OSIRIS-REx separated from the launch vehicle 55 minutes after ignition. The launch was declared "exactly perfect" by the mission's principal investigator, with no anomalies before or during launch. OSIRIS-REx entered the cruise phase shortly after separation from the launch vehicle, following successful solar panel deployment, propulsion system initiation, and establishment of a communication link with Earth. Its hyperbolic escape speed from Earth was about 5.41 km/s (3.36 mi/s).

The launch capped years of definition and delay. The mission was proposed in

the late 2000s, competed for, and selected under NASA's New Frontiers program in 2011, beating rival concepts that included a Venus probe and a lunar sample-return flight. From selection to liftoff took another five years of design, assembly, and testing, and when the Atlas V finally rose from Cape Canaveral on the evening of 8 September 2016, the launch was, in the words of the mission's principal investigator, exactly perfect.

On 28 December 2016, the spacecraft successfully performed its first deep space maneuver to change its velocity by 431 m/s (1,550 km/h) using 354 kg (780 lb) of fuel. An additional, smaller firing of its thrusters on 18 January 2017 further refined its course for an Earth gravity assist on 22 September 2017. The cruise phase lasted until its encounter with Bennu in December 2018, after which it entered its science and sample collection phase.

During its cruise phase, OSIRIS-REx was used to search for a class of near-Earth objects known as Earth-Trojan asteroids as it passed through Sun-Earth L4 Lagrange point. Between 9 and 20 February 2017, the OSIRIS-REx team used the spacecraft's MapCam camera to search for the objects, taking about 135 survey images each day for processing by scientists at the University of Arizona.

The search was beneficial even though no new trojans were found, as it closely resembled the operation required as the spacecraft approached Bennu, searching for natural satellites and other potential hazards. On 12 February 2017, while 673×10^6 km (418×10^6 mi) from Jupiter, the PolyCam instrument aboard OSIRIS-REx successfully imaged the giant planet and three of its moons, Callisto, Io, and Ganymede. OSIRIS-REx flew by Earth on 22 September 2017.

On 3 December 2018, NASA confirmed that OSIRIS-REx had matched the speed and orbit of Bennu at a distance of about 19 km (12 mi), effectively reaching the asteroid. OSIRIS-REx performed closer passes of the Bennu surface, initially at about 6.5 km (4.0 mi) through December to further refine the shape and orbit of Bennu. Preliminary spectroscopic surveys of the asteroid's surface by the OSIRIS-REx spacecraft detected the presence of hydrated minerals in the form of clay.

While researchers suspect that Bennu was too small to host water, the hydroxyl groups may have come from water present in its parent body before

Bennu split off. OSIRIS-REx entered orbit around Bennu on 31 December 2018 at about 1.75 km (1.09 mi) to start its extensive remote mapping and sensing campaign for the selection of a sample site. This is the closest distance that any spacecraft has orbited a celestial object, closer than the Rosetta's orbit of

comet 67P/Churyumov-Gerasimenko at 7 km (4.3 mi).

At this altitude, it took the spacecraft 62 hours to orbit Bennu. At the end of its detailed survey, the spacecraft entered a closer orbit with a radius of 1 km (0.62 mi). Rehearsals were performed before sampling, during which the solar arrays were raised into a Y-shaped configuration to minimize the chance of dust accumulation during contact and provide more ground clearance in case the spacecraft tipped over (up to 45°) during contact.

The descent was very slow, minimizing thruster firings prior to contact to reduce the likelihood of asteroid surface contamination by unreacted hydrazine propellant. On 20 October 2020, contact with the surface of Bennu was detected using accelerometers, and the impact force was dissipated by a spring in the TAGSAM arm. Upon surface contact by the TAGSAM instrument, a burst of nitrogen gas was released to blow regolith particles smaller than 2 cm (0.8 in) into the sampler head at the end of the robotic arm.

The teams are sharing software, data, and techniques for analysis, and will eventually exchange portions of the samples that are returned to Earth. OSIRIS-REx II was a 2012 mission concept to replicate the original spacecraft for a double mission, with the second vehicle collecting samples from the two moons of Mars, Phobos and Deimos. It was stated that this mission would be both the quickest and least expensive way to get samples from the moons.

Why go to the trouble of bringing a piece of an asteroid home? Telescopes can measure an asteroid's brightness and color, and a probe in orbit can carry instruments to it, but a returned sample is a different kind of prize. It can be weighed, split, dissolved, heated, and examined with every technique a terrestrial laboratory can offer, and it can be curated for decades, so that instruments not yet invented can eventually ask new questions of it. OSIRIS-REx was designed around exactly that logic: fly to a primitive, carbon-rich asteroid, collect pristine surface material, seal it against Earth's atmosphere, and deliver it unopened into the hands of curators. What the mission wanted was not merely rock, but a sealed message from the raw material the planets themselves were made of.

End of free sample. The full book is available at putrabooks.github.io

ABOUT THE AUTHOR

Aira Astralis is a science writer specializing in astronomy and space exploration. Her work spans the full breadth of humanity's relationship with the cosmos -- from the earliest naked-eye observations to the engineering marvels of modern space missions.

Her books are built on a foundation of primary sources: peer-reviewed research, mission archives, and direct engagement with the scientific community. She writes for readers who want to understand not just what we know about the universe, but how we came to know it.

She believes that the most important frontier is not out there but in the gap between what scientists discover and what the public understands. Her books exist to close that gap.