OSIRIS-REx spacecraft touches an asteroid, attempts sample collection

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The NASA mission OSIRIS-REx, having orbited and studied asteroid 101955 Bennu for the last two years, undertook a precarious trip to the asteroid's surface Tuesday. In the almost infinitesimal gravity of the tiny asteroid, about 8 millionths that of Earth, it attempted to collect a sample, with the goal of returning it to Earth nearly three years from now.

The name of the spacecraft is a clumsy acronym, standing for Origins, Spectral Interpretation, Resource Identification, Security, Regolith Explorer.

The collection of physical specimens from beyond the Earth and their return for study in laboratories is a relatively recent achievement, not counting the hundreds of kilograms of lunar rocks retrieved by Apollo astronauts and three robotic Soviet missions from 1969 to 1976.

The first successful effort beyond the Earth-Moon system was made by the NASA Stardust spacecraft, which, five years after its 1999 launch, collected microscopic particles as it flew by Comet Wild 2 in 2004, returning them to Earth two years later.

The NASA Genesis mission, launched in 2001, performed another sort of "microscopic" collection, exposing pristine collection wafers to the high-speed solar wind for over two years. Despite a design error that led to a crash landing on return, the fragmented wafers still safely held embedded solar wind contents, inaccessible from Earth because of the atmosphere, that realized the spacecraft's scientific mission.

Missions to collect large samples, necessitating a "touch and go" approach instead of a high-speed sweep, have proven more problematic.

The Japanese mission Hayabusa was launched in 2003 and arrived at its target, asteroid 25143 Itokawa, in 2005. A number of instrument failures prevented the sampling sequence from triggering on two touchdown attempts, but about 1,500 microscopic grains of asteroid material still entered the sample return chamber, which returned to Earth in June 2010.

A successor mission, Hayabusa 2, launched in late 2014, successfully collected macroscopic quantities of material from asteroid 162173 Ryugu in June 2018, and will complete its return to Earth on Dec. 6. Ryugu is a carbonaceous asteroid apparently similar to Bennu, the target of OSIRIS-REx.

The most ambitious sample return mission of recent times was also an unfortunate failure. The Russian mission Fobos-Grunt, launched in November 2011, was to have entered Mars orbit, then orbited and sampled hundreds of grams of material from the Martian moon Phobos. But the launch rocket itself failed, stranding the mission in low Earth orbit, and it was destroyed on reentry shortly thereafter. No funding has been available for a successor mission.

A Chinese lunar mission, Chang'e 5, is expected to launch next month and later return at least two kilograms of samples to Earth, the first return of lunar materials since 1976. It will land in and return material from some of the youngest volcanic surface on the Moon.

While remote robotic exploration remains a keystone of our exploration of the solar system, its pace is limited by the tempo of the scientific process itself. Each robotic explorer is designed to answer questions posed by prior work, and is outfitted with scientific tools which can illuminate those questions. But invariably new questions arise, and it may be years before a mission can be mounted with new tools sent across space to repeat the cycle. A sample in hand may represent only a small window into a remote solar system object, but the questions that arise in its study can draw on the resources of a planet's worth of curious scientists and their laboratories.

Each form of exploration illuminates the results of the other and speeds the scientific cycle.

In the case of the OSIRIS-REx mission, the goal is to better understand the processing of carbon in the early history of the solar system. Asteroid 101955 Bennu is a carbonaceous asteroid, the most common variety as surveyed from Earth, in an orbit not too different from Earth's, representing material which has essentially remained "frozen out" from the early processing of material within the inner solar system.

A cruder type of "sample return" mission takes place naturally, through the entry of bits of the same leftover components of the solar system as meteors, and their collection from the Earth's surface as meteorites. But despite carbonaceous asteroids being the dominant variety, their fragility means they represent under 5 percent of actual meteorites collected, and the most fragile variety, the "CI" type, of material similar to that expected at Bennu, is only known from a handful of meteorites on Earth.

Such meteorites are altered through their entry through Earth's atmosphere, and any trace contents they might contain are immediately at risk of confusion with earthly contamination. The samples returned from Bennu will be guaranteed pristine.

Robotic observations from the OSIRIS-REx extensive survey of the asteroid have already suggested the surprising presence of carbonate minerals, which hint that components of the asteroid at one time may have been formed on a larger, now fragmented, parent body with a presence of liquid water. And observations suggest that not just carbon, but organic carbon compounds with C-H bonds are present, perhaps even amino acids, a precursor to life.

Harold Urey and his student Stanley Miller first prepared in 1952 mixtures of the best-known estimates of primordial inorganic compounds in the solar nebula and subjected them to conditions that would be found on youthful planetary bodies. The reaction chambers produced a wealth of organic compounds, including amino acids—an indication that the precursors to the chemistry of life were not so rare on the young Earth.

Others, including Carl Sagan, have extended this famous "Miller-Urey" experiment in the years since. But looking for these signature compounds in carbonaceous meteorites has been complicated by fears of contamination. This is but one of many questions which can be addressed to the Bennu samples.

The Bennu "touch and go" attempt provided high drama to a broad worldwide audience. In a sequence choreographed to the second, the spacecraft configured itself for maximum safety in encountering the asteroid, changed its trajectory for a very gentle course towards the surface, just a few inches per second, and began its descent.

The unexpectedly rocky surface of the asteroid meant that plans for the collection made prior to launch had to be completely reconfigured on arrival, with two much smaller sites, a prime and a backup, selected as suitable, if only some 50 feet in size. The smaller safe landing spot meant the hardware built into the spacecraft to navigate this sequence was inadequate to the task: new software, using real-time imagery by the onboard cameras, was written to run on the spacecraft's limited computers. This software not only had to calculate corrections on the descent, but identify conditions that posed excessive risk and would trigger aborts.

At a distance of over 200 million miles, these decisions could not be made by scientists on Earth: telemetry from the spacecraft was 14 minutes old on arrival, and new commands would take an additional 14 minutes to reach and correct the spacecraft. Thus, scientists as well as their audience were all spectators to the encounter they had choreographed.

Every update from the spacecraft indicated a successful milestone, and as the spacecraft indicated it had made contact, triggered its collection hardware, and begun a safe retreat, cheers erupted in the control room.

The collection itself (see video) took place during several seconds of contact during which nitrogen gas blew against the surface to send a spray of debris into a filter-like collector. It will take up to two weeks to determine how much material was collected during the attempt—up to two new attempts can be made. The mission design calls for at least 50 grams of sampled material, but the sample container can hold up to 2 kilograms.

At just over a billion dollars in cost, OSIRIS-REx is considered a medium-sized spacecraft mission. At just over one-thousandth of the annual military budget, it represents a pittance of the money spent on war, either in the US or the world. And as its prime contractor is Lockheed Martin, the largest defense contractor in the world, the technology development can hardly be described as separate from this drive.

OSIRIS-REx must begin its return to Earth during a maneuvering window that opens in March 2021, and the sample return capsule should reenter Earth's atmosphere in September 2023. Some very eager scientists await, some who began work on such a mission over two decades ago. Were the budgets of its constructor fully dedicated to exploration rather than destruction, it is almost incalculable what results would be delivered within our lifetime.