OSIRIS-REx Scientists: Taking Asteroid Sample Was Like Punching a Ball Pit [1]
Asteroid Bennu, the target of NASA's OSIRIS-REx [2] asteroid sample return mission, led by the University of Arizona, kept surprising the mission team while the spacecraft studied the asteroid from a distance. The biggest surprise, however, came when OSIRIS-REx swooped in to grab a sample of material from Bennu and encountered not a solid surface but one that gave way so easily the sampler arm sank 1 1/2 feet into it within seconds.

The OSIRIS-REx mission team has spent the time since the sample collection in 2020 processing data recorded by the spacecraft's instruments during and after the sampling event. Taking advantage of top-notch science instruments – some built at the University of Arizona – along with clever spacecraft maneuvering and detailed observations of individual rocks, the team uncovered a treasure trove of information about what Bennu and other asteroids similar to it are actually like.

Two papers in the journals Science and Science Advances detail the latest findings about Bennu's physical properties and provide a fascinating account of the events surrounding the sampling event. One paper was led by UArizona Regents Professor of Planetary Sciences Dante Lauretta [3], the mission's principal investigator, and the other was led by Kevin Walsh, a member of the OSIRIS-REx science team with Southwest Research Institute in Boulder, Colorado.

When the OSIRIS-REx spacecraft descended to the surface of Bennu on Oct. 20, 2020 – its sampling arm extended in anticipation of scooping up pristine material dating back to the formation of our solar system – mission scientists and engineers braced for an experience resembling a pogo stick bouncing off a gravel road. To everybody's surprise, that didn't happen. Instead, once the sampling head made contact with the surface, it dove right in with almost no resistance.

One of the most surprising takeaways is this: Had the spacecraft not fired its thrusters to back away immediately after grabbing dust and rock from the asteroid's surface, it would have sunk right into Bennu, and the asteroid might have swallowed it whole.

"It turns out that the particles making up Bennu's exterior are so loosely packed and lightly bound to each other that they act more like a fluid than a solid," Lauretta said.

In other words, if a person were to step onto Bennu, they would feel very little resistance, as if stepping into a pit of plastic balls that are popular play areas for kids.

The results add to the intrigue that's kept scientists on the edge of their seats throughout NASA's OSIRIS-REx sample-return mission, as Bennu has proved consistently unpredictable.

The asteroid presented its first surprise in December 2018 when NASA's spacecraft arrived to survey it. The OSIRIS-REx team found a surface littered with boulders instead of the smooth, sandy beach they expected based on observations from Earth- and space-based telescopes. Scientists also discovered that Bennu was spitting particles of rock into space.
"Our expectations about the asteroid's surface were completely wrong," Lauretta said. "There was no obvious place to collect a sample anywhere."

The latest hint that Bennu was not what it seemed came after the OSIRIS-REx spacecraft picked up a sample and beamed down stunning, close-up images of the asteroid's surface to Earth.

"What we saw was a huge wall of debris radiating out from the sample site," Lauretta said. "We were like, 'Holy cow!'"

Scientists were bewildered by the abundance of pebbles strewn about, given how gently the spacecraft tapped the surface. Even more bizarre was that the spacecraft left a large crater, 26 feet wide.

"Every time we tested the sample pickup procedure in the lab, we barely made a divot," Lauretta said. As a result of the surprises found in the images, Lauretta and his team decided to send the spacecraft back to take more photographs of Bennu's surface "to see how big of a mess we made."

The imagers of the OSIRIS-REx Camera Suite, or OCAMS, provided the researchers with high-resolution, fast-sequence snapshots of the sample site before, during and after the sample acquisition. Additionally, the spacecraft collected data with the Touch-and-Go Camera System, or TAGCAMS, which is part of its guidance, navigation and control system. Using image processing algorithms, the researchers were able to tease an amazing amount of information from the pictures taken by the spacecraft, allowing for realistic calculations of the amount of material that was kicked up by the spacecraft plunging into the surface and detailed clues about how dust, pebbles and even boulders move and behave in Bennu's microgravity environment.

Besides analyzing the volume of debris visible in before-and-after images of the sample site, dubbed "Nightingale," the mission team also looked at acceleration data collected during the spacecraft's touch-and-go sample collection maneuver. This data revealed that as OSIRIS-REx touched the asteroid it experienced the same amount of resistance – very little – that a person would feel while squeezing the plunger on a French press coffee carafe.

"By the time we fired our thrusters to leave the surface we were still plunging into the asteroid," said Ron Ballouz, a former LPL postdoctoral researcher at UArizona's Lunar and Planetary Laboratory who is now based at the Johns Hopkins Applied Physics Laboratory in Laurel, Maryland.

Ballouz and the research team ran hundreds of computer simulations to deduce Bennu's density and cohesion based on spacecraft images and acceleration information. Engineers varied the surface cohesion properties in each simulation until they found the one that most closely matched their real-life data.
Spectral analysis of light reflected from the sample site before and after the sampling revealed that the process exposed and mobilized fine dust from a few inches below the surface, reminiscent of a condition on Earth known as desert pavement, which forms when fine dust is being blown and washed away by wind and rainfall, leaving behind a relatively stable surface of similar-sized pebbles and rocks.

"Our observations confirm previous results, which have found that the most freshly exposed surfaces are among the spectrally reddest and darkest," Lauretta said. "We attribute the spectral changes to the exposure of fresh, organic-rich material, which is exactly the type of material we were hoping to get in our sample, so we can analyze it once it returns to Earth."

Now, this precise information about Bennu’s surface can help scientists better interpret remote observations of other asteroids, which could be useful in designing future asteroid missions and for developing methods to protect Earth from asteroid collisions.

It’s possible that asteroids like Bennu — barely held together by gravity or electrostatic force — could break apart in Earth’s atmosphere and thus pose a different type of hazard than solid asteroids.

The University of Arizona leads the OSIRIS-REx science team and the mission’s science observation planning and data processing. NASA’s Goddard Space Flight Center in Greenbelt, Maryland, provides overall mission management, systems engineering, and the safety and mission assurance for OSIRIS-REx. Lockheed Martin Space in Littleton, Colorado, built the spacecraft and provides flight operations. Goddard and KinetX Aerospace are responsible for navigating the OSIRIS-REx spacecraft. OSIRIS-REx is the third mission in NASA’s New Frontiers Program, managed by NASA’s Marshall Space Flight Center in Huntsville, Alabama, for the agency’s Science Mission Directorate Washington, D.C.

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