the WINNOWER

REDDIT

NASA Mission AMA: We are scientists and engineers preparing for the OSIRIS-REx spacecraft's Earth flyby tomorrow. Ask us anything!

OSIRIS--REX R/SCIENCE

Thanks for the great questions, Reddit! We're done answering for the day and are off to finish preparations for tomorrow's Earth Gravity Assist maneuver.

Tomorrow, NASA's asteroid-hunting spacecraft, OSIRIS-REx, will fly by Earth and use the planet's gravitational pull to slingshot itself onto a new trajectory. This maneuver, called an Earth Gravity Assist (EGA), will put the spacecraft on course to rendezvous with a primitive, near-Earth asteroid named Bennu. The spacecraft will reach Bennu next year, map the asteroid, and collect a sample of surface material (called regolith) that will be returned to Earth for study in 2023. This mission will bring the largest sample of space material to Earth since the Apollo missions' lunar samples.

We're a group of scientists and engineers based at the University of Arizona—home to the mission's Principal Investigator's office and the Science Processing Operations Center—ready to answer your questions about OSIRIS-REx, EGA, and the mission to collect some of the oldest material in the solar system.

We'll be online from 1 to 3 pm PST (4 to 6 pm EST). Ask us anything!

Proof: https://www.asteroidmission.org/reddit-ask-us-anything-earth-gravity-assist/

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Are there any firewalls in place if you happen to find dormant microbacterial life on an asteroid?

j938920

We consider this to be a very low probability event. We don't expect any microorganisms on Bennu. It is too small and the radiation doses would kill anything living on the asteroid in a very short time. We had to prove this as part of our Planetary Protection rating – which is Unrestricted Earth Return – meaning that we do not have to take any special precautions to avoid contaminating the Earth with extraterrestrial life. Instead, we hope to find organic molecules that may have led to the origin of life on Earth. We will focus on measuring the organic molecular inventory of the samples but don't have any plans for biological assays. We will keep the sample under nitrogen purge to avoid contaminating it with terrestrial microbes.

-Dante

What an exciting time to be alive! I actually have three questions.

1) What are some of the main differences and similarities between the OSIRIS-REx and the past ESA Rosetta mission? Besides sample return.

2) Can you explain how your sample collection device works, and why this design was chosen.

3) If you were to build a cube sat (1U to 3U) today that launches in 2-3 years what type of science mission would you place on it?

Thank you for taking time to reach out.

tkoclubs

Re (1): Sample return is actually one of the most important differences between the two missions! Most of the OSIRIS-REx asteroid observations are planned either to give us the best odds of safely retrieving our sample, or else to give the best possible scientific context to the sample so that we can learn the most from it when we analyze it on Earth. By contrast, Rosetta had to do all its science in situ.

The other important difference is in the type of target: Rosetta's target was a comet ("67P/Churyumov–Gerasimenko"), which had spent most of its lifetime much further out in the Solar System (beyond Jupiter) where ices are more abundant than rocks. So the types of materials were different. This also meant that the dominant surface processes were really different: 67P's ices started to sublimate and form those spectacular plumes as it came closer to the Sun.

On the other hand, we think Bennu has been orbiting close to the Sun for over a million years, which is most likely enough time for any ices it originally had to have been "baked" out already, so we don't expect such a large amount of plume activity there (although we will look for plumes anyway). Finally, Comet 67P is much, much larger than Bennu - ~5 km across instead of ~500m across.

-Lucy

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Thank you for taking time to reach out.

tkoclubs

As a partial answer to (3), many scientists have proposed cubesat science missions to NASA, although most of these seem to be >6U instead of 1-3U:

https://www.nasa.gov/feature/nasa-selects-cubesat-smallsat-mission-concept-studies

-Lucy

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Thank you for taking time to reach out.

tkoclubs

Re (2): The sampler head operation has been explained in another answer: https://www.reddit.com/r/science/comments/71ikcs/nasa_mission_ama_we_are_scientists_and_engineers/dnbon6c/

But just to add to that: The design was chosen because it works well in microgravity and has been very reliable in testing.

-Lucy

If it takes 1 year to reach Bannu and if the OSIRIS-REx will be back on 2023, does it means it collects samples for 4 years?

gavinozzo

It will actually take about 2 years to reach Bennu. OSIRIS-REx launched about a year ago and will start approaching Bennu next summer. Before collecting a sample, we must first use the science instruments to learn as much about Bennu as possible. The data from the instruments will be put together into various maps that will then be used to select a sample site on the asteroid. We are not planning to collect a sample until July 2020.

-Anjani

Thanks for coming to talk with us today! So much of software development in regular business is a 'trial and error' sort of a thing--which is obviously a just terrible idea for a spacecraft. :) . Can you tell us about your software engineering practices? Do you patch code after launch? Have you ever fixed a serious software error after launch?

asbruckman

The OSIRIS-REx software engineering practices are treated with extreme rigor. During development, software requirements and comprehensive test plans are written for the software required for mission success; The team develops, tests and validates Spacecraft Flight Software, Science Payload Instrument Flight Software and Ground Data Processing Software. All of the software is subjected to extensive verification and validation testing in a flight like environment.

Post launch, we perform many activities during cruise that continue to verify the software is performing as expected. We (like most missions) have identified some flight software updates necessary to enhance mission operations and/or reduce risk. Software patches go through extensive ground testing as well as regression testing in the Spacecraft Test Lab prior to uploading to the OSIRIS-Rex spacecraft.

-Heather

What would be the most exciting or unexpected thing to find on Bennu?

SelectAll_Delete

Anticipating the most exciting or the most challenging part of the mission is something we are all trying to guess! Every mission has surprises and we are looking forward to that. But we won't be able to really guess ahead what it will be.

We hope that the surface of the asteroid is composed of a variety of interesting materials and topographic features. We know from remote sensing generally what its shape and composition is but not in detail. These could make choosing the sample site and taking the sample challenging but also exciting. We expect that will be the most interesting, but there may well be other challenges we won't anticipate that will come up, and we are trying to be ready for anything!

-Ellen

What do you anticipate to be the most challenging part of the planned mission for OSIRIS-REx?

Shock1217

One of the biggest challenges might be if we discover that there are any small rocks orbiting the asteroid. Since we need to touch the asteroid in order to collect our sample, this could significantly change our planning!

-Josh

What do you anticipate to be the most challenging part of the planned mission for OSIRIS-REx?

Shock1217

I agree with everything Heather hit on in her answer. There are a lot of navigational challenges with performing spacecraft maneuvers around such a small celestial object, especially when we first start proximity operations and need to gather data about the mass and spin state of Bennu.

-Sara

What do you anticipate to be the most challenging part of the planned mission for OSIRIS-REx?

Shock1217

There are many challenging aspects of the planned mission OSIRIS-REx: Accurate spacecraft navigation in the microgravity environment, precision delivery of the spacecraft to the asteroid surface, tight coupling and interdependence between the science team and spacecraft operations, and data product production on a tactical timeline to enable sample-site selection.

In addition to these challenges, the human factor is a significant challenge to the OSIRIS-Rex mission. The length of the planned mission, from development to sample return, is over 12 years. Sustaining corporate team knowledge over that length of time is a difficult thing to achieve. This requires maintaining a multi-generational team. The leadership team must proactively foster continuous transfer of knowledge and experience.

-Heather

What do you anticipate to be the most challenging part of the planned mission for OSIRIS-REx?

Shock1217

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-Ellen

OSIRIS-REx is an interesting name. Is it some sort of acronym? I'd love to hear the origin or inspiration behind naming it.

Archer2408

OSIRIS-REx stands for "Origins, Spectral Interpretation, Resource Identification, and Security -- Regolith Explorer."

Here's a bit more on what all of that means: http://www.asteroidmission.org/objectives/osiris-rex-acronym/

-Josh

I've read that asteroids can be composed of precious metals like gold, silver and platinum. What are the chances that Bennu will be made of precious metals?

LilooWoo

Bennu was chosen partly because it is a very dark, primitive type of asteroid, thought to be especially low in metal content. Meteorites do have more metals than typical Earth surface rocks, but it is not the most valuable thing they contain to teach us about the early Solar System. The most precious commodity in space is water, both for fuel if separated into hydrogen and oxygen, and for life support if humans are going to someday live and work in space. We do not yet know if Bennu has water in the surface minerals, but that is one of the important things to look for. Not in liquid form, of course, but as hydrated minerals like clays and containing bound water. Organic compounds are also of great interest, because of understanding their origin in the early Solar System and in interstellar space.

-Ellen

Hey guys! Thank you for taking the time to answer some of our questions.

My question to all of you is, as a college student pursuing a degree in computational mathematics what advice do you have regarding getting a job in your field! What types of things should I be doing to improve my chances that a company like nasa would consider hiring me?

Thank you in advance!

noobhedz

Experience, experience, experience! Your college degree alone will not get you very far, employers (Not just NASA) want to see that you actually have a usable skillset, not just an education! Internships and published research papers are a great way of showing what you can do.

Also many of the people working on a NASA mission (including most of our team) do not work directly for NASA but for one of the various companies and universities that partner with NASA. For example, most of our operations team are employed by the University of Arizona, and our spacecraft was built by Lockheed Martin.

For non-US nationals, while working at NASA may be incredibly difficult due to citizenship requirements, there are lots of universities and companies in other countries that contribute to NASA missions with science payloads. On OSIRIS-REx, the OSIRIS-REx Laser Altimeter (OLA) instrument comes from the Canadian Space Agency and MDA.

-Josh

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Thank you in advance!

noobhedz

As for young people wanting to get into this line of work – study hard and do well in school. Graduate high school and go to college. Find people with similar interests. Start with the basics – math and physics, then work your way up from there. Planetary science is multidisciplinary and requires knowledge of math, physics, chemistry, geology, biology, etc. Once in college, he should try to get a job in a research lab. Talk to scientists and engineers that are working on projects that interest and find ways to volunteer in their labs. Undergraduate research opportunities are key to getting needed experience for a job in the aerospace industry or for getting into a good graduate school. Be persistent, arrange for tours of local labs, and make it clear that you are interested and motivated to pursue a career in this field. Once you get the job, do it well and show initiative to move up to more responsibility.

-Dante

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Thank you in advance!

noobhedz

Preparing for a career in most any field of science, including planetary science or astronomy includes a lot of math and physics. Geology, chemistry and atmospheric sciences are also a fine basis at the undergraduate level. In graduate school, most planetary programs will fill in the geology for physicists, and physics for the geologists to understand rocks in space.

Planetary science is an interdisciplinary field, so people with lots of different backgrounds have a lot to contribute. Everything from telescopic observation, computer modeling and laboratory studies are applied to questions in planetary sciences.

-Ellen

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Thank you in advance!

noobhedz

One thought on this: Volunteering. Volunteering wherever you can, whether it's an after-school program, being a docent at a local museum, or even volunteering in an industry other than where your interest lies, will always pay out in dividends even if not monetarily.

I've volunteered for with a STEM program for 4th-6th graders at NASA Ames, volunteered to design lab assignments and write user manuals, and volunteered to walk dogs and clean kennels at the local humane society. Volunteering not only is a great way to network and gain new skills, but also is an important way to give back to those in need and immerse yourself in your community. Having been on the other side of job interviews more recently, I always appreciate applicants that show the motivation to put service before self.

-Sara

Be honest, did you guys ever use Kerbal Space Program for anything related to this mission?

smallatom

While we have many Kerbal fans in the OSIRIS-REx mission team, it was a unanimous decision that Jebadiah Kerman should not be trusted with anything mission critical.

That said, several of our scientists and engineers have done outreach to the KSP community using the program as an educational tool to educate people about our mission.

One example: https://www.nasa.gov/feature/goddard/2016/gamers-tackle-virtual-asteroid-sampling-mission

-Josh

How much of an increase in speed are we talking about here?

Skanky

First time Redditor and Long Time Osirian here--The effective change in speed that OSIRIS-REx will experience thanks to the exchange of momentum during the Earth Flyby ~3.8 km/sec.

-Sara

How much of an increase in speed are we talking about here?

Skanky

The main goal of the Earth flyby is to get the spacecraft to gain the 6 degree inclination out of the plane of the Earth's orbit to the orbit of Bennu. It takes a lot of fuel to do this directly, so this is a more efficient way to get the spacecraft onto a trajectory that will allow it to match position and velocity with the asteroid. It also gives us a chance to take images of the Earth and Moon to calibrate the instruments which we are greatly looking forward to! Stay tuned.

-Ellen

Is anyone working on the telemetry for this mission actively looking for any signs of the flyby anomaly that has been observed in some previous Earth flybys?

praveerk

We receive telemetry from OSIRIS-REx on a daily basis. Our Flight Dynamics Team uses this extensive log of telemetry to reconstruct the spacecraft trajectory and delta-v and plot it against the expected dispersions. The current uncertainties in the time and position of closest approach at EGA are <1 km and <0.1 seconds. Any anomalies that are detected would be extensively investigated.

-Sara

Bennu was targeted because of a confluence of various factors (size, composition, Δv/$/time budgets). If you could launch another OSIRIS-REx in the next launch window without worrying about so many of these constraints, what would be the next most interesting target for this sort of investigation in our solar system and why?

johnthebutcher

There are lots of interesting asteroids that we could visit with spacecraft. We won't ever have time or money to sample more than a few so we hope that the few we do visit will also tell us a lot more about how to interpret the remote sensing data we can collect on thousands more with Earth-based telescopes.

I would like to see other spectral types visited, and a binary or multiple system like 2001SN263 or 1998 QE2.

-Ellen

Hi All! Super big fan of what you are doing, I was in the NASA Robotics Mining Competition in May of 2016 where our team of engineers had to design a regolith mining robot so I am somewhat familiar with the overall concept of what you are going to achieve.

My question is, what method of mining will you use to take samples of the regolith to bring back to earth? At the competition I saw everything from scoops, augers, conveyor belts, etc. and the conveyor belt system appeared to do best during competition.

Thank you!!

jsf84

The sample is acquired using the Touch-and-Go Sample Acquisition Mechanism, or TAGSAM. TAGSAM is a mechanical sampling device that consists of two major components: a sampler head and an articulated positioning arm. The arm extends 2.8 meters from the spacecraft.

TAGSAM acquires the bulk sample by releasing a jet of high-purity nitrogen gas that excites and "fluidizes" at least 60 g of regolith into the collection chamber. The TAGSAM head is a simple annulus with a filter screen on the outside circumference, held at the end of an articulated arm that is extended several meters from the spacecraft. The head is mounted on a wrist assembly with a compliant U-joint that allows it to articulate and make full contact even if the angle of approach is not normal to the surface.

During the collection time, which can last for up to 8 seconds for a soft surface, high-purity nitrogen gas is injected into the interior of the annulus where fine particles and small pebbles up to 2 cm in size are entrained in the gas flow. If the TAGSAM head is firmly seated on the regolith, the only path for the gas and entrained regolith is through the wire-mesh filter, where the material is captured. The baseplate of the TAGSAM head contains 24 contact-pad samplers made of stainless steel Velcro®. These pads collect small grains up to 1-mm diameter upon contact with the asteroid surface.

The TAGSAM subsystem has three separate bottles of nitrogen gas, providing the capacity to make three separate sampling attempts. However, the baseline plan is to execute one successful sampling event. If sufficient sample is collected on the first attempt, the team will not make an additional attempt to collect more or a different type of sample. A number of ground tests and "reduced-gravity" flight tests (where a reduced-gravity flight involves the research airplane flying a parabolic trajectory, providing periods of reduced acceleration), using asteroid surface simulants, have routinely demonstrated collection of over 600 g.

-Dante

What is this thing called "Regolith" ?

lezkerr

The previous two answers are correct.

FYI, planetary scientists generally use "regolith" instead of "soil" because "soil" implies a biological component whereas "regolith" is more general.

We also have a video describing regolith:https://www.youtube.com/watch?v=3194ROG7VCE&list=PL-sncRQpy4-sN0ROwD3a1oR4VivhBBm_X&index=14

-Lucy

What is this thing called "Regolith" ?

lezkerr

Regolith is the loose material on the surface of solar system bodies. On an airless body like a small asteroid, even the fine dust will sit on the surface. Micrometeorites hit the surface and knock bits off, create small craters and move material around. As the asteroid rotates, material can become unstable and slide around as well. We hope to see and study these processes in more detail in the time we will spend orbiting and imaging the surface of Bennu in lots of different ways. The solar wind also reaches the surface and can implant atoms into the regolith. That will help us measure how long the surface has been exposed to space, once we get to analyze the samples in 2023.

-Ellen

I kickstarted your board game Xtronaut and made some modifications to it that introduce mission failures and travel time. We usually have 1 or 2 failures per game. A 30-sided die is rolled at launch and the beginning of each turn for each spacecraft until the mission is over. Mission length determined by point value, and an additional turn is added for each flyby. If the roll comes up with a 1, 15, or 30, the mission fails.

What do you think of this? Do you have any other suggestions for improvement?

zwhenry

Thank you for your support of our Kickstarter campaign! We design our games to allow for exactly this kind of flexibility. Your additions add a nice element of realism to the game – I love it! We have thought about other enhancements, as well. One that I like to add is the ability to co-manifest missions. If you have a launch vehicle with a lot of excess delta-V, offer it to one of the other players in exchange for a share of the mission points. The delta-V is calculated based on the largest spacecraft on the launch vehicle.

Be sure to check out our new game – Constellations: The Game of Stargazing and the Night Sky, coming out in October.

-Dante

This might be a stupid question, but how are you going to make sure landing on the asteroid isn't going to change its trajectory at all? Wouldn't it be dangerous to sample something that has such a close orbit when there's no way to correct its orbit?

altheist

That is not a stupid question: the spacecraft will barely touch the asteroid and has very little effect on its trajectory. In fact, we are trying to devise ways to deflect such an asteroid if it was found to be on a collision course. But it takes a lot of energy and that means a lot of mass at high velocity. The OSIRIS-REx spacecraft will touch very gently and has such a small mass compared to Bennu that even if we tried, we could not affect its orbit in a measurable way.

-Ellen

How do you know that the asteroid is covered in regolith, and that it's not a completely solid rock? Will you still be able to gather a sample if there's no regolith?

Also, is there a video or something somewhere that shows the path that OSIRIS-REx is taking?

The_DongLover

There are two independent lines of evidence that allow us to constrain the particle size on the surface

of the asteroid: thermal IR measurements made by the Spitzer and Herschel Space Telescopes and radar polarization ratio measurements made using the Arecibo and Goldstone Planetary Radar Systems. Asteroid shape analysis using radar return data from Arecibo provides additional evidence of loose granular surface material as well as information on its likely distribution.

The Spitzer measurements were conducted during the period 4 – 9 May 2007. They consist of spectra covering 5.2 to 38 µm taken of opposite hemispheres (integration time ~1/2 a rotation period) and photometric measurements at 3.6, 4.5, 5.8, 8.0, 16, and 22 µm taken at 10 different longitudes. The Herschel measurements were conducted on Sept 9, 2011. They consist of photometric measurements at 70, 100, and 160 µm. Supporting measurements at shorter wave- lengths were made during the same month using the VLT ground-based facility. These data produce a thermal inertia of ~600 J m-2 K-1 s-1/2.

Thermal inertia data constrain the average regolith grain size. The thermal skin depth for 1999 RQ36 is estimated at 2-4 cm. The thermal inertia is substantially below the bedrock value (>2000), implying the presence of sub-cm grains within the regolith.

We used Arecibo and Goldstone radio observatories to make radar observations of 1999 RQ36 in September/October 1999 and September/October 2005. The data resulted in accurate line-of-sight velocities and distances, 7.5-m resolution images, and measurements of the radar albedo and circular polarization ratio. The polarization ratio is 0.18 at 13 cm and 0.20 at 3.5 cm wavelengths, lower than those for asteroids 25143 Itokawa (0.27), 433 Eros (0.28), and 2005 YU55 (0.45). This result suggests that the transition to a radar "rough" surface happens at a scale smaller than the shortest wavelength (3.5-cm), consistent with grain sizes in the sub-cm range.

The asteroid's shape and geomorphology provides additional evidence of the presence loose particulate regolith. We find a subdued slope distribution at the spatial resolution of the shape model (7.5 m/pixel). The average slope is estimated to be 15-24˚, depending on the bulk density of the asteroid. This result suggests that there is loose material capable of migrating into geopotential lows. The global shape model of the asteroid indicates a body symmetrically disposed about the rotational axis in response to centrifugal forces, suggesting the presence of mobile particulate regolith.

-Dante

At what point does the anxiety about the mission subside for you guys?

bits3rpent

From a science operations engineer perspective, the stress goes down a lot once we leave the asteroid. But many on the team will not sleep easy until the sample return capsule is safely secured in the laboratories here on Earth!

-Josh

At what point does the anxiety about the mission subside for you guys?

bits3rpent

My anxiety will be reduced substantially when the spacecraft launched. The early part of Outbound Cruise has gone exceedingly well. The operations team has performed flawlessly. As the PI of the mission, they make my job easy. I expect that my anxiety will increase as we approach Bennu and we get our first good look at the asteroid. Of course, the real nail-biting moment will occur when we commit the spacecraft to the sampling event. I don't expect my anxiety will go away until that Sample Return Capsule is safely on Earth and in the curation facility at NASA Johnson Space Center.

-Dante

At what point does the anxiety about the mission subside for you guys?

bits3rpent

Maybe in 2023 when our samples are safely in the lab :-)

-Lucy

At what point does the anxiety about the mission subside for you guys?

bits3rpent

The anxiety will continue as long as there are still mission activities to accomplish. Until the sample is safely on the ground and in the curation facility, we will not be finished worrying about getting to that point, and the laboratory analysis will have just begun. The approach and first looks at the asteroid will answer a lot of questions, and after that a lot of worries will hopefully be put to rest. But other surprises and questions will no doubt come up. Some anxiety is a good thing!

-Ellen

At what point does the anxiety about the mission subside for you guys?

bits3rpent

I think there is always a little anxiety you carry with you, in the same way that as a parent you never stop worrying about your children.

For many of us, we've been on the OSIRIS-REx mission since the proposal stage and have seen OSIRIS-REx grow from a concept to reality. But whether you are a new member of the mission or a long-time veteran, I think the general feeling is that OSIRIS-REx and its instruments are a part of your family.

-Sara

At what point does the anxiety about the mission subside for you guys?

bits3rpent

A significant amount of my anxiety will subside once we reach Bennu and begin acquiring actual data at the asteroid. The past several years the team has designed and tested the system based on assumptions about the characteristics of Bennu. Although Bennu is one of the most characterized asteroids, there are still assumptions that can not be confirmed until we arrive.

I am looking forward to reacting to the actual data and refining our mission operations and processes to achieve maximum science return and mission success!

-Heather

At what point does the anxiety about the mission subside for you guys?

bits3rpent

Proximity operations at Bennu will be a very exciting and busy time. Like everyone else who works on OSIRIS-REx, I am very invested in making this mission successful, so with that comes some level of anxiety. I anticipate that my anxiety will first increase as we begin proximity observations and then decrease as we complete the global mapping and site selection part of the mission, culminating with successful sample acquisition and return of the sample to Earth.

-Anjani

How close is it going to get to earth at its closest point? Where is that going to be, and any chance we can see it?

HauntedByMyShadow

OSIRIS-REx will be 10,711 miles (17,237 kilometers) away from Earth during its closest approach. The closest approach point is over Antarctica just south of Cape Horn (the southernmost point of South America).

OSIRIS-REx is not visible with the naked eye, but it can be seen with telescopes. In fact, the Large Binocular Telescope in Arizona first caught a glimpse of OSIRIS-REx earlier this month on September 2: https://www.asteroidmission.org/?latest-news=large-binocular-telescope-snags-first-glimpse-nasas-osiris-rex-spacecraft-since-launch

-Anjani

On the pad, what was the delta-V of the whole craft, snd what is it at now?

Hyperbrain10

We launched on September 8th, 2016 on an Atlas V 411. Our outbound trajectory had a delta V of approximately 1.4 km/s. Our Earth Gravity Assist tomorrow will impart a delta V of approximately 3.778 km/s.

To put that in perspective the delta V of our entire propulsion system on the spacecraft is 1.986 km/s! Hence why gravity assists are so important! So far our largest burn was a planned trajectory course maneuver (TCM) that used 432 m/s of that budget!

-Josh

What happens if the sample returning to Earth hits something (satellite, space junk, etc) on its return journey and gets destroyed? Is this even remotely possible?

jl91569

If the sample is destroyed, then the mission fails, and we don't achieve our science objectives. Fortunately, there is a very small probability of the sample return capsule hitting a piece of space debris during Earth Return. Just like during the launch, A Collision On Launch Assessment (COLA) is performed before any satellite is approved for launch. If a potential collision is identified, a COLA blackout period will be placed on the launch window. We performed a COLA analysis for the Earth-Gravity Assist and had a deflection maneuver loaded on the spacecraft and ready to implement if a potential collision was identified. Yesterday, we determined that there were no collision risks and we waived off this maneuver. We will have a similar procedure in place for Earth return.

-Dante

One thing I have always wondered is exactly how spacecraft like Osiris and Rosetta decide where to point the camera or various instruments.

Say you want to take a picture of a specific part of Bennu, could you explain briefly the process of how the spacecraft orients itself to aim at the correct location?

pancakespleez

This is a great question. Our main objective is to return a pristine sample from Bennu. There's a lot of

work that will go into selecting the site on Bennu to obtain the sample from. So there are several dedicated phases of our proximity operations at Bennu involving global mapping of the asteroid with our various science instruments. The process starts with the Scientists selecting a site or region of Bennu to "image."

Then, our dedicated Science Planning Team uses software that incorporates SPICE data (which defines the position of the planets, position of OSIRIS-REx, position of Bennu, and position of each Payload Instrument) to construct a set of quaternions (think of these as GPS coordinates in Space) to determine where we need to point the instrument deck in order to obtain the images/spectra. These quaternions are rigorously simulated on the ground to ensure the safety of the spacecraft and instruments before they are uplinked to the spacecraft.

-Sara

How/How well were you able measure the trajectory of Bennu to chart a trajectory for OSIRIS?

spacewave12

The trajectory of Bennu, or its orbital elements, are known extremely well, due mostly to multiple measurements using the Arecibo planetary radar system. We measured it in 1999 when it was discovered, again in 2005 and again in 2011. The multiple line-of-sight radar measurements along with the optical measurements, which give the position relative to stars in the plane of the sky, make it the best determined orbit of any object in the solar system (including the Earth and Moon).

The biggest source of error is the position of the center of mass of Bennu and the non-gravitational forces due to radiation pressure and thermal properties that the mission will give us much better measurements for. The spacecraft position relative to Bennu is an ongoing challenge for the spacecraft navigation team to continually update, and we are working hard to make sure that the instruments are pointed accurately and that the spacecraft stays where we want it to be. The navigation cameras on board and the other cameras will help in this effort throughout the mission.

-Ellen

What minerals do you expect to find on bennu, and so you think OSIRIS-REx will lead up to asteroid ISRU?

IMLL1

Bennu resembles a B-type, carbonaceous asteroid but we do not believe we have any meteorites specifically from Bennu. So we expect that Bennu will contain lots of silicates, oxides and sulfides along with volatile organic chemicals and water. But we will not know for sure until we get there! Several of our instruments (and the sample collection task itself) are geared towards characterizing the composition of Bennu.

From an ISRU perspective the most valuable resource on Bennu is likely water! Water is the single most valuable commodity in the solar system from an exploration perspective. You can use water for drinking, watering plants, radiation shielding and creating rocket fuel!

-Josh

What minerals do you expect to find on bennu, and so you think OSIRIS-REx will lead up to asteroid ISRU?

IMLL1

The easiest way to make rocket fuel in situ is to simply electrolysis (applying an electric current) to split water into hydrogen and oxygen! While explorers on Mars and other planetary bodies might use methane or some other in-situ fuel, hydrogen and oxygen are considered NASA's "fuel of choice!"

https://www.nasa.gov/topics/technology/hydrogen/hydrogen_fuel_of_choice.html

Bennu's escape velocity is approximately 10 cm/s!

-Josh

Hi OSIRIS-REx team, thanks for taking out time. Post the EGA, what spacecraft ops shall you be performing? And what's the TCM correction you anticipate if any? May the force be with you.

victorvictoroneniner

From an Ops perspective we have lots of events coming up in the near future. Some of the highlights:

· Deep Space Maneuver Two (DSM-2) to put us on track for rendezvous with the asteroid · One or more potential Trajectory Correction Maneuvers (TCM) to ensure we're on target · Two Checkout and Calibration activities at L+18 and L+24 months to ensure all of the instruments are still working as expected

After that we're getting ready for arrival at the Asteroid! But we won't just be twiddling our thumbs between now and then, we have lots of practice activities here in the Operations center to ensure all of our engineers and scientists are well trained on operating the spacecraft. We're also developing new programs for improving how we control the spacecraft to ensure we're as efficient as possible once we arrive.

MTFBWYA,

-Josh

What telemetry software is being used on the ground to view data? Do you use AMMOS? I'm working on ASU's CubeSat mission, and we're trying to implement a similar software, called COSMOS.

liamjacob3

We use Design America's ASIST (Advanced Spacecraft Integration and System Test). We also have in-house software with a very user-friendly interface for displaying and trending telemetry data. Although I don't have experience with AMMOS or COSMOS, I suspect the ground data functions are likely similar to what we have in place in ASIST.

-Sara

Cool! Thanks. I'm in New Zealand, so at least in the correct hemisphere... I don't have a large telescope though. I should really do something about that. I'm a big fan of catching a glimpse of the ISS when it's overhead, and was hoping for a similar experience, but am mostly just content to know there's still cool space stuff going on.

Thanks for your efforts!

HauntedByMyShadow

The spacecraft will be about 10-11th magnitude, so it won't be too easy to see (you will definitely need a telescope). It is worth a try as you are well placed in New Zealand, if the sky is clear.

Good luck! There is more information on our website: https://www.asteroidmission.org/faq-spot-spacecraft/

-Ellen

How different do you expect Bennu to be from Psyche? Which asteroid might provide us deeper

insights about the formation of the solar system?

liamjacob3

Both missions will tell us new things and give new insights into origins and evolution of the solar system.

Psyche is a large main-belt asteroid, whereas Bennu is a small near-Earth asteroid. They have very different histories and compositions, and so the missions have very different goals. Bennu is a small piece of a once larger body that is of a primitive type, little changed from when the solar system first formed. It is similar to the building blocks that went into forming the Earth. We will return a sample of its material to Earth for detailed analysis in laboratories and learn about the thermal history and origin of the asteroid material. Psyche may be a remnant core of a previously melted body that may or may not have formed where it is currently. That mission is a rendevouz but will not return to Earth with a sample. The mission plans and science goals are listed for each on their websites in more detail.

-Ellen

(okay, I'm just going to ask a silly question, but I'm guessing that there are a lot of people that secretly want to know this, so I just had to take this golden opportunity. ;3) So when naming and/or building the spacecraft, did anyone decide to sneak a T-Rex sticker or picture onto the craft? And if so, was it a normal T-Rex, or a T-Rex with the satellite as a head?

Cipherous321

This question actually gave our team a laugh, as while it may seem silly to you, some dinosaur related content did make its way onboard the spacecraft in an official capacity. Prior to launch we encouraged the general public to submit creative works of art to fly aboard the spacecraft in a digital form.

You can find more information on this project here: http://www.asteroidmission.org/wetheexplorers/

-Josh

Once the sample return is complete, how will we mitigate any biohazards or contaminants that the samples may contain?

IMLL1

We consider this to be a very low probability event. We don't expect any microorganisms on Bennu. It is too small and the radiation doses would kill anything living on the asteroid in a very short time. We had to prove this as part of our Planetary Protection rating – which is Unrestricted Earth Return – meaning that we do not have to take any special precautions to avoid contaminating the Earth with extraterrestrial life.

Instead, we hope to find organic molecules that may have led to the origin of life on Earth. We will focus on measuring the organic molecular inventory of the samples but don't have any plans for biological assays. We will keep the sample under nitrogen purge to avoid contaminating it with terrestrial microbes.

-Dante

Can OSIRIS-REx detect being pinged by micrometeors?

cbellh47

OSIRIS-REx can only detect a micrometeor impact via direct imaging using the StowCam, if it occurs on a visible surface. During the design phase, we had to demonstrate that there was >99.9% probability of no critical impact. OSIRIS-REx critical electronics and hardware (e.g., propulsion) is well-

shielded from such an impact. Furthermore, the Sample Return Capsule heatshield has been shown to be resilient to micrometeor impacts.

-Dante

Is the shape of Bennu well known/measured?

sagareshwar

The shape of Bennu was determine through a detailed analysis of the radar images we obtained from Arecibo Observatory in 1999 and again in 2005. We included lots of lightcurves, which are measurements of the asteroid's brightness as it rotates. Together we used these data to determine a shape model (Nolan et al. 2013). The resolution on the surface is 15m, so smaller features than that will only be revealed by the spacecraft images as we approach and study the surface. We will find out how close to correct we were about a year from now. We are confident about the overall shape and size but there will be surprises I'm sure!

-Ellen

What can be learned by doing all this? I imagine it's all very expensive. Do we really need to know what the gravel on an asteroid is made of?

Really curious as to the practical benefits of this and similar missions.

TotallyDepraved

We are learning a lot from studying solar system bodies, both about the origin of the Earth and about potential resources in space. Bennu is possibly a type of asteroid that we do not already have in our meteorite collection, but is likely similar to primitive carbonaceous chondrites (google that for more details). The most precious commodity in space is water, both for fuel if separated into hydrogen and oxygen, and for life support if humans are going to someday live and work in space.

We do not yet know if Bennu has water in the surface minerals, but that is one of the important things to look for. Not in liquid form, of course, but as hydrated minerals like clays and containing bound water. Organic compounds are also of great interest, because of understanding their origin in the early Solar System and in interstellar space.

-Ellen

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TotallyDepraved

Asteroids are the direct remnants of the original building blocks of our solar system. They contain the earliest records of the sun and planets, which can help us better understand the formation of the solar system 4.5 billion years ago. Scientists suspect Bennu may hold clues to the origin of the solar system and the source of the water and organic molecules that may have made their way to Earth. An uncontaminated asteroid sample from a known source would enable precise analyses that cannot be duplicated by spacecraft-based instruments or by studying meteorites, revolutionizing our understanding of the early solar system.

In addition, OSIRIS-REx will provide a greater understanding of both the hazards and resources in near-Earth space and will serve as a precursor to future asteroid missions.

OSIRIS-REx will help reveal the secrets of the Universe for everyone, and at the same time, help us

understand and, ultimately, mitigate our risks, as residents of the solar system.

Missions such as OSIRIS-REx provide a unique opportunity for us, as humans, to be innovative and continue to explore and learn much of the unknown. Knowledge is a very powerful asset!

-Heather

What's the weirdest thing ever found in space?

crumbbelly

The weirdest or most surprising thing I have seen recently is the images of the surface of Pluto. I could never have imagined that its surface would be so varied, with fresh nitrogen ice flows, and such bizarre topography. We'll be learning about the history and evolution of Pluto based on these images for years to come. I hope that Bennu has similar surprises in store for us.

-Ellen

What was the process like for deciding on a launch provider (and rocket, if you got the choice, Atlas vs. Delta) for OSIRIS-REx, and how far in advance was that decided?

johnkphotos

The OSIRIS-REx team provided requirements that included the estimated spacecraft size, wet and dry mass, power, interfaces and planned mission profile to NASA's Launch Services Program. The requirements were evaluated against available launch vehicles with continuous and close communication with the OSIRIS-REx team. As the requirements were compared to various launch vehicle options such as the Delta and Atlas series of vehicles, a recommendation was made that met all of the mission and spacecraft requirements. In addition to the ability of a launch vehicle to meet the requirements, reliability, historical performance and availability were all taken into account.

As a result of this very thorough analysis and evaluation, NASA's Launch Services Program selected United Launch Alliance's Atlas V vehicle to launch the OSIRIS-REx mission. The selection was made August 2013, approximately 3 years prior to launch which occurred on September 8, 2016.

-Heather