National Aeronautics and Space Administration

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OSIRIS-REx

Asteroid Sample Return Mission

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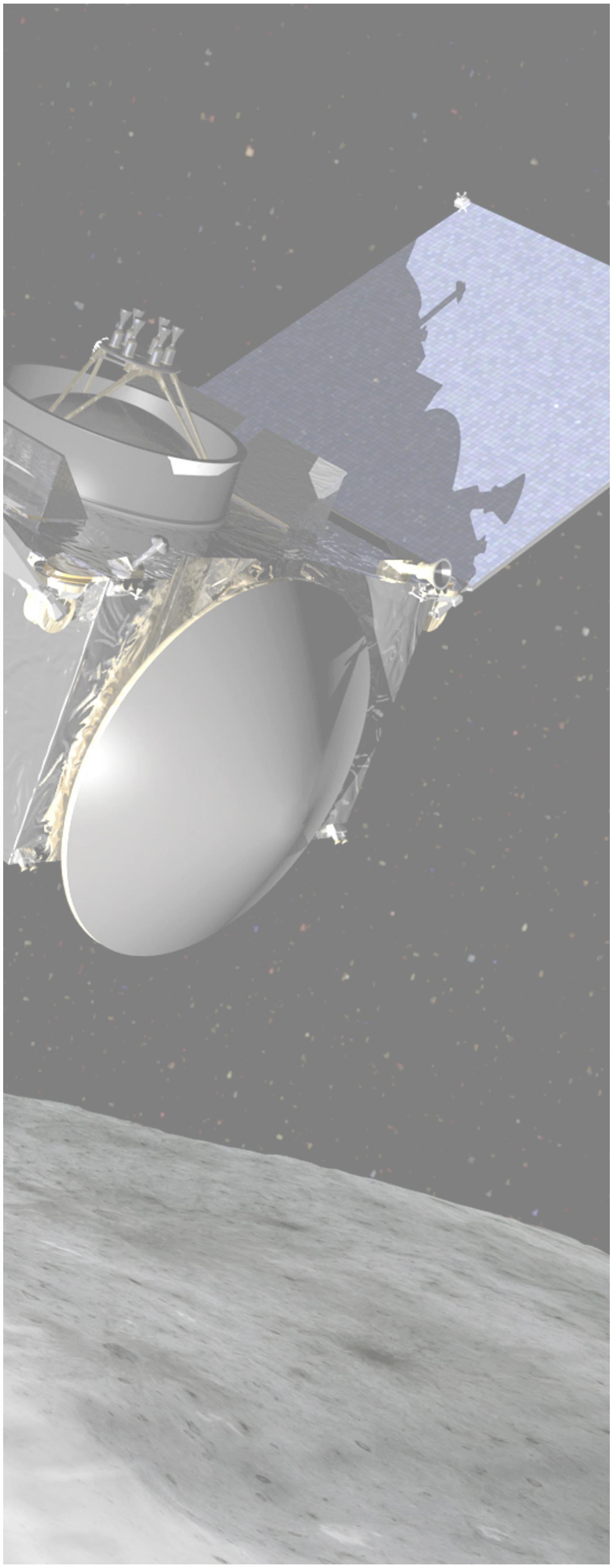

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Media Services

NASA Television

NASA Television's channels NTV-1 (formerly the Public Channel) and NTV-3 (formerly the Media Channel) are now in high definition. NTV-2 (formerly the Education Channel) is a standard digital feed. NTV-1 provides real-time coverage of NASA missions, events and special programming. NTV-2 provides real-time coverage of NASA missions, education content and special programming in standard definition. NTV-3 provides mission coverage, news conferences and relevant video and audio materials to local, national and international news-gathering organizations.

All NASA Television channels are available on Satellite AMC-18C.

NASA's Live Interactive Media Service (LIMS) is KU-Band service. KU-Band parameters are provided prior to each event. NASA Television will schedule each LIMS event on a satellite in proximity of AMC-18 whenever possible.

News networks, their reporters, and other broadcast media organizations must tune their satellite receivers to the NTV-3 to ensure reception of clean feeds for all mission coverage, news conferences, and other agency distributed news and information. NASA TV is available in continental North America, Alaska and Hawaii on AMC-18C. A Digital Video Broadcast (DVB) compliant Integrated Receiver Decoder (IRD) is needed for reception.

For digital downlink information for each NASA TV channel, access to all three channels online, and a schedule of programming for OSIRIS-REx activities, visit http://www.nasa.gov/ntv.

Media Accreditation and Access

News media representatives who would like to cover the launch in person must be accredited through the NASA News Center at Kennedy Space Center. To apply for credentials, visit https://media.ksc.nasa.gov. Journalists may contact the KSC news media accreditation office at 321-867-6598 or 321-867-2468 for more information.

News Conferences

More information to come

Online Information and Multimedia

Information about NASA's OSIRIS-REx mission, including an electronic copy of this press kit, press releases, status reports and images, is available at http://www.nasa.gov/osiris-rex and http://www.asteroidmission.org.

Frequent updates about the mission, together with public feedback, are available by following OSIRIS-REx on Twitter @ OSIRISREx and on Facebook at https://www.facebook.com/OSIRISREx.

Images, video, and animations for OSIRIS-REx can be found at https://svs.gsfc.nasa.gov/Gallery/OSIRIS-REx.html#section0-id.

General Overview

OSIRIS-REx is the third mission in NASA's New Frontiers Program. New Frontiers looks to the community to propose planetary science missions that are consistent with priorities set by the National Academy of Sciences. New Frontiers missions are led by principal investigators (PIs), and must operate as medium-sized missions under a cost cap. Following an intense competition, OSIRIS-REx was selected for flight in 2011.

NASA's first two New Frontiers missions have taken us beyond low-Earth orbit to far-reaching destinations: New Horizons flew past Pluto in 2015 and is now on its way to a more distant object beyond Pluto; Juno entered orbit around Jupiter in July 2016 and has begun science operations there. Now, with OSIRIS-REx, NASA will be traveling to an asteroid and returning a sample to Earth in 2023.

OSIRIS-REx is an acronym for "Origins, Spectral Interpretation, Resource Identification, and Security-Regolith Explorer." It is scheduled to launch on Sept. 8, 2016, with the launch window extending through Oct. 12, 2016. After traveling through space for two years, OSIRIS-REx will approach the near-Earth asteroid 101955 Bennu (provisional designation 1999 RQ36). The spacecraft will then spend two years examining the asteroid and collecting a surface sample. OSIRIS-REx will return the sample to Earth in September 2023, when it will then be transported to NASA's Johnson Space Center in Houston, Texas, for curation and sample examination.

The OSIRIS-REx mission will be the first U.S. mission to carry samples from an asteroid back to Earth and the largest sample returned from space since the Apollo era. Asteroids are remnants of the original building blocks of our solar system; they can help us better understand the formation of the solar system over 4.5 billion years ago. Scientists suspect that asteroids are a source of the water and organic molecules that may have made their way to Earth and other planetary bodies early in their histories. An uncontaminated asteroid sample from a known source would enable precise analyses, revolutionizing our understanding of the early solar system, and cannot be duplicated by spacecraft-based instruments or by studying meteorites.

Lastly, OSIRIS-REx will provide a greater understanding of both the hazards and resources in near-Earth space and will be a major advance in our continuing exploration of asteroids and other small bodies in the solar system.

Quick Facts

Spacecraft

- Length: 20.25 feet (6.2 meters) with solar arrays deployed
- Width: 8 feet (2.43 meters)
- Height: 10.33 feet (3.15 meters)
- Sampling arm (TAGSAM) Length: 11 feet (3.35 meters)
- Dry Mass (unfueled): 1,940 pounds (880 kilograms)
- Wet Mass (fueled): 4,650 pounds (2,110 kilograms)
- Sample return capsule (SRC) mass: 100 pounds (46 kilograms)
- Power: Two solar panels generate between 1,226 watts and 3,000 watts, depending on the spacecraft's distance from the sun.
- One-way light travel time between Earth and the spacecraft varies between 4.4 and 18 minutes during operation at Bennu

Launch

- Launch time and place: Sept. 8, 2016 at 7:05 p.m. EDT from Space Launch Complex 41 at Cape Canaveral Air Force Station, Florida. The launch period will last for 34 days, with a 120-minute window available each day.
- Launch vehicle: Atlas V 411 provided by United Launch Alliance. The vehicle consists of an Atlas first stage engine with a single additional strap-on solid rocket booster and a Centaur second stage engine.

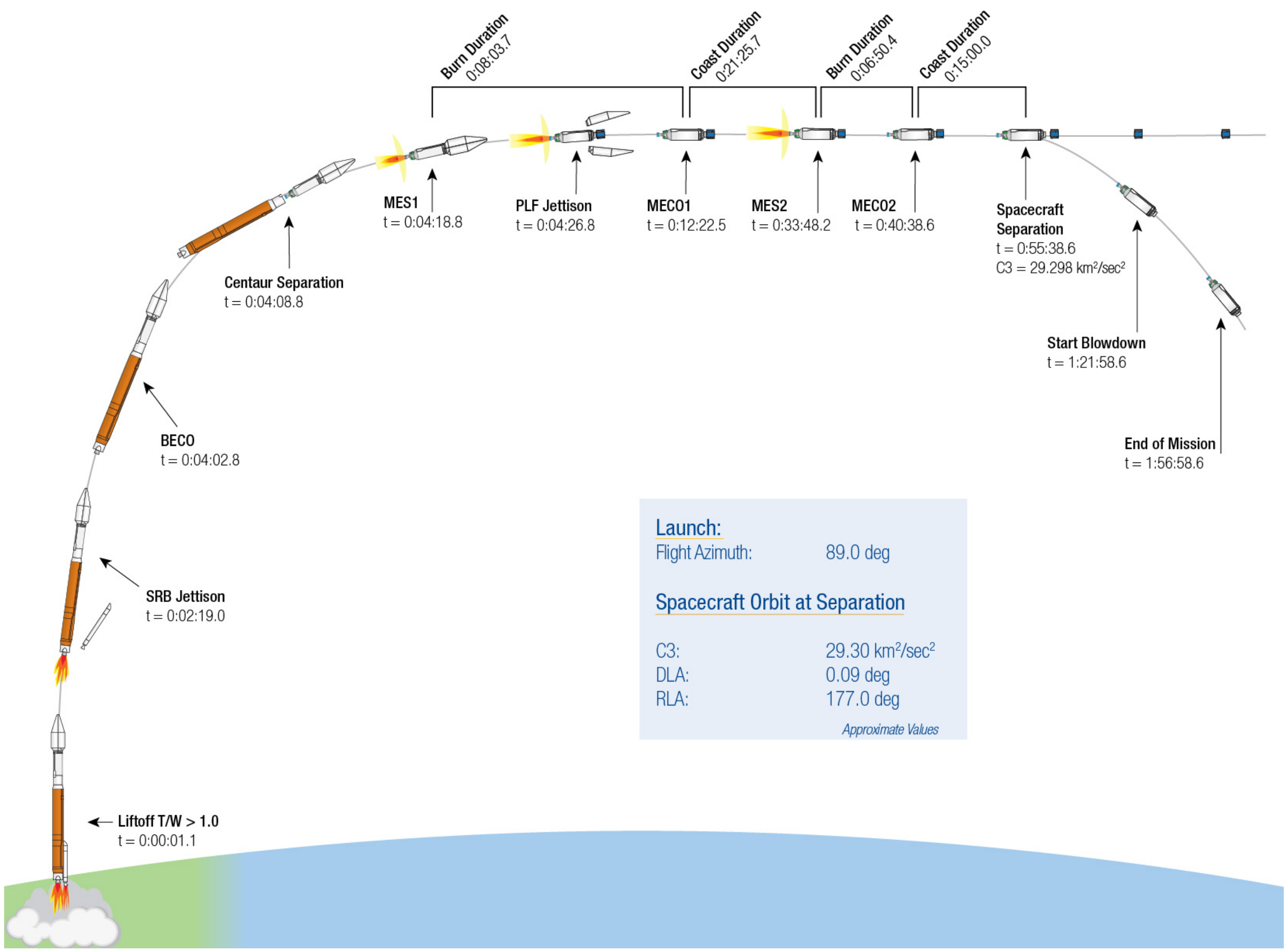
Mission

- Date of mission selection: May 25, 2011
- Date of Launch: Sept. 8, 2016
- Date of Earth flyby: Sept. 22, 2017
- Date of arrival at Bennu: August 2018
- Date of sampling Bennu: July 2020
- Date of departure: March 2021
- Date of re-entry: Sept. 24, 2023
- End of mission: Sept. 30, 2025
- Average speed of solar orbit: 63,000 miles per hour (28 kilometers per second)
- Total mission duration: 7 years of spacecraft operations (followed by 2 years of Earth-based sample analysis)

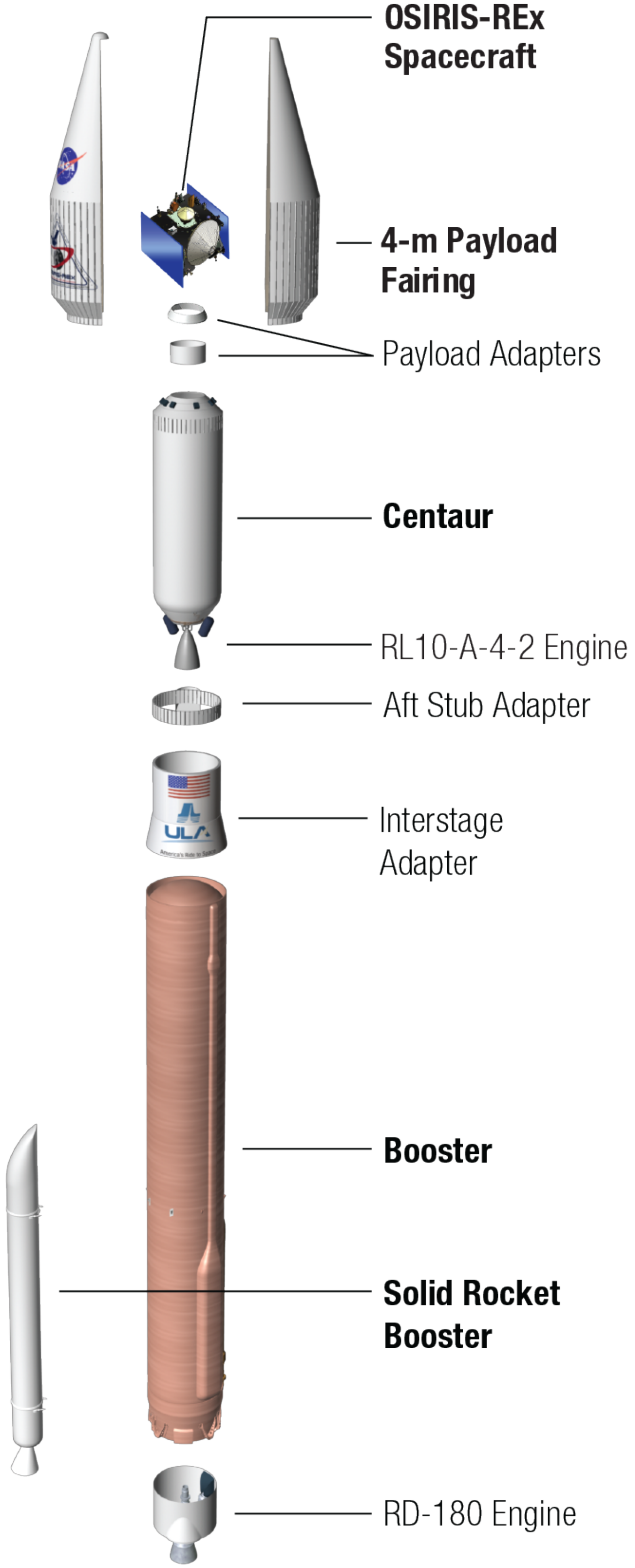
Program Cost

- Approximately $800 million (excluding launch vehicle)

Flight Profile



Launch Configuration



Meet Bennu

General

- Near-Earth Asteroid 101955 Bennu (originally designated 1999 RQ36) is the target of the OSIRIS-REx mission.
- The Lincoln Laboratory Near Earth Asteroid Research (LINEAR) project, part of NASA's NEO Observations Program survey, discovered the asteroid on Sep. 11, 1999. LINEAR is a joint collaboration of the U.S. Air Force, NASA, and the Massachusetts Institute of Technology's (MIT) Lincoln Laboratory. Follow-up radar, optical, and spectroscopic observations with NASA-supported facilities have yielded more information about the asteroid's orbit, shape, size and composition.
- Bennu was named by then third-grader Michael Puzio during an international student contest. It was named after the Egyptian mythological deity linked to rebirth and is depicted as a heron.
- Bennu is the best-characterized near-Earth asteroid that has not been visited by a spacecraft, having been extensively studied in visible and infrared light and with radar.
- Bennu is a Potentially Hazardous Asteroid (PHA) that comes close to Earth about every six years.

Physical Characteristics

- Roughly spherical with an equatorial bulge and a diameter of about 1,614 feet (492 meters)
- Orbital period of about 1.2 Earth years
- Distance from the sun varies between 126.04 million miles and 83.371 million miles (1.3559 AU and 0.89689 AU). Astronomers call asteroids like this "Apollo asteroids."
- Distance from the Earth varies between 278,867 and 213,798,356 miles (0.003 AU and 2.3 AU)
- Mass estimated at 85.5 million U.S. tons (77.6 million metric tons)
- Density estimated at 0.75 oz/in3 (1.3 grams/cm3) (similar to coal)
- Rotation period 4.288 hours
- Bennu is a "B-type" asteroid, meaning it is very dark-colored (almost black).

Scientific Significance

- Asteroids are the remnants of the original building blocks of our solar system.
- Knowledge of the nature of asteroids is fundamental to understanding planet formation, the solar system, and the origin of life.
- The return to Earth of pristine samples with known geologic context will enable precise analyses that cannot be duplicated by spacecraft-based instruments or by laboratory analysis of meteorites.
- The mission will allow researchers to better evaluate hazards and resources in the inner solar system.

Why Bennu?

The ultimate goal of the OSIRIS-REx mission is to collect a sample from an asteroid and bring it back to Earth. But why did the science team choose Bennu as the target asteroid for this mission?

Accessibility for Sample Return

The closest asteroids to Earth are called near-Earth objects (NEOs) that come within 120 million miles (1.3 Astronomical Units or AU) of the sun. 1 AU is the average distance between Earth and the sun, equal to about 93 million miles (150 million kilometers). For a sample return mission like OSIRIS-REx, the most accessible asteroids for a spacecraft to reach are located between 149 million miles (1.6 AU) and 74 million miles (0.8 AU). The most accessible asteroids also have an Earth-like orbit — one that is fairly circular and has a low inclination – an orbit in nearly the same plane as that of Earth.

Bennu has such an orbit, ranging from 0.9 to 1.4 AU from the sun and an inclination only 6° different than Earth's.

Enabling Proximity Operations and Sample Collection

Asteroids with small diameters generally rotate more rapidly than those with large diameters. With a diameter less than 650 feet (200 meters), an asteroid can spin fast enough that the some of the material on its surface can be ejected. Furthermore, it is difficult to match the rotation of a rapidly rotating asteroid while conducting close proximity operations with a spacecraft. The better asteroid destination has a diameter larger than 650 feet (200 meters) so that a spacecraft can safely come into contact with it and collect a sufficient sample of surface material.

Bennu, with a diameter of 1,614 feet (492 meters), takes just over 4 hours to rotate once (this is the length of a day on Bennu), which is slow enough to allow OSIRIS-REx to execute its mission.

Carbon-rich Composition

Asteroids are categorized into different types based on their chemical composition as inferred from telescopic observations. The most primitive asteroids are carbon-rich and are believed to have not significantly changed since they formed over 4.5 billion years ago. These asteroids could contain volatiles and organic molecules such as amino acids that may have contributed to the formation of life on Earth and are important factors in determining the potential for life elsewhere in the solar system.

Telescopic measurements suggest that Bennu's surface is indeed rich in carbon. Astronomers call Bennu a "B-type" asteroid, suggesting it has a composition similar to meteorite known as "carbonaceous chondrites," which as their name suggests, are rich in carbon compounds.

Only a handful of known asteroids share these properties of accessibility, size, and composition. This makes Bennu the best choice for OSIRIS-REx's destination asteroid.

Mission Overview

OSIRIS-REx is scheduled to launch on an Atlas V rocket from the Cape Canaveral Air Force Station in Florida on Sept. 8, 2016 between 7:05 p.m. and 9:05 pm EDT (with backup launch windows for an additional 33 days, through Oct. 12). It performs an Earth-gravity assist one year after launch, then a year later, after traveling for two years, the spacecraft will begin its approach to Bennu in August of 2018. The asteroid is likely to represent a snapshot of the early days of our solar system, as well as contain a rich supply of carbon, a key element in the organic molecules necessary for life.

The planned activities at Bennu, which will take over two years to complete, are motivated by five mission science objectives:

- Origins: Return and analyze an asteroid sample
- Spectral Interpretation: Provide ground truth or direct observations for telescopic data of the entire asteroid population
- Resource Identification: Map the chemistry and mineralogy of a primitive carbon rich asteroid
- Security: Measure the effect of sunlight to change the orbit of a small asteroid, known as the Yarkovsky effect — the slight push created when the asteroid absorbs sunlight and re-emits that heat as infrared radiation
- Regolith Explorer: Document the regolith (layer of loose, outer material) at the sampling site at scales down to the sub-centimeter

After arriving at Bennu, OSIRIS-REx will begin a series of maneuvers around the asteroid, culminating in reconnaissance flyovers at about 800 feet (240 meters) from the surface. These maneuvers are part of a comprehensive surface mapping campaign using a variety of instruments to study the asteroid. OSIRIS-REx will globally map Bennu's surface using optical cameras and a laser altimeter. The spacecraft will also use optical, infrared and thermal emission spectrometers to generate mineral, organic and thermal emission spectral maps and local spectral information of candidate sample sites.

The team will use the maps and other information gathered by OSIRIS-REx to select a location on the asteroid where the spacecraft will collect samples. Once the candidate sample site is selected, OSIRIS-REx will approach, but not land on, Bennu. Instead of landing, the spacecraft will extend a robotic arm called the Touch-and-Go Sample Acquisition Mechanism (TAGSAM) to retrieve asteroid samples for analysis. TAGSAM will release a burst of nitrogen gas, collecting a sample by causing loose rocks and surface dust to be stirred up and blown into the sampler head located at the end of the robotic arm. The team intends to obtain a sample of at least 2 ounces (60 grams) and as much as 4.4 pounds (2 kilograms). The sample will be stored in a canister inside the Sample Return Capsule (SRC) as the spacecraft travels back to Earth.

Upon completion of its investigation and sample collection of Bennu, OSIRIS-REx will begin its 2.5-year return journey to Earth in March 2021. As it approaches Earth, a final course correction will set OSIRIS-REx on course to release the sample return capsule for a parachute landing at the Utah Test and Training Range (UTTR) in Tooele County, Utah, in September 2023. The SRC will be released from the spacecraft four hours before it will enter Earth's atmosphere. Only the SRC is intended to return to Earth. Once the capsule is released, the OSIRIS-REx spacecraft will perform a collision avoidance maneuver so that it does not disintegrate in Earth's atmosphere and will continue in orbit around the sun.

The SRC will hit the top of the atmosphere at more than 27,000 miles per hour (12.2 kilometers per second), using an ablative shield on the capsule to slow it down, while protecting it from the heat of entry — much like the Apollo capsules returning from the moon and almost exactly like the NASA Stardust capsule returning from Comet Wild 2. A parachute system will slow the SRC for a soft landing at UTTR. The system consists of a drogue parachute to provide stability at supersonic speeds and a main parachute. The parachutes will deploy when the capsule reaches an altitude of 1.9 miles (3 kilometers). They will slow the capsule to a landing speed of about 11 miles per hour (5 meters per second).

The SRC will land at UTTR. It will then be transported to the Astromaterials Acquisition and Curation Office at Johnson Space Center, in Houston, Texas, for storage and sample examination. This office is the one of the premiere facilities in the world for curation of extraterrestrial materials, and is the home of the Apollo collection of moon rocks and soils, samples returned by NASA's Genesis and Stardust missions, the US Antarctic meteorite collection, the US cosmic dust collection, and a subset of samples returned by Japan's Hayabusa mission.

Proximity Operations

As OSIRIS-REx approaches the asteroid, it will use an array of thrusters to match the velocity of Bennu in its orbit around the sun, ensuring a rendezvous that will allow the next phase of the mission to begin. Once at the asteroid, OSIRIS-REx will begin what is known as proximity operations, or prox-ops. The ultimate goal of prox-ops is to find sample sites that are safe and provide the science team with a high probability of collecting a scientifically rich sample.

Prox-ops include five major phases.

1. Preliminary Survey searches for asteroid plumes and natural satellites, which may present a hazard to the spacecraft.

2. Orbit A allows the team to transition from star-based navigation to landmark-based navigation using images of Bennu's surface. The team will gather data and images from the spacecraft's instruments to construct maps of Bennu to help them navigate around the asteroid.

3. Detailed Survey enlists the help of the instruments to work together to map Bennu and determine its global spectral, thermal and geologic properties. This information is important for the scientists as they look for potential sample sites. At the end of Detailed Survey, scientists and mission engineers will select up to 12 potential sample sites for additional studies. The science team will also begin measuring how Bennu's orbit is affected by surface heating and cooling throughout its day, also known as the Yarkovsky Effect.

4. Orbit B maps Bennu at higher resolutions, allowing the scientists to focus on the 12 initial sites and identify two final candidate sample sites. The laser altimeter will also collect data to produce a high-fidelity topographic map of Bennu during this phase.

5. Reconnaissance enables the spacecraft to complete a series of passes at close range over potential sample sites. These passes will allow a final assessment of the candidate sample sites for safety, the presence of material for sampling, and scientific interest. Upon completion of Reconnaissance, the final site will be selected, allowing rehearsals for TAG maneuvers to begin.

Mapping

For OSIRIS-REx, mapping is mission-critical. It is one of the primary science goals and an integral part of spacecraft operations. Most of the global mapping work will be done during Detailed Survey and Orbital Phase B. The team will continue to survey the asteroid, with the instrument payload – OCAMS, OLA, OTES, OVIRS and REXIS – and use this information to produce four top-level maps for identifying potential sites for sampling.

1. Safety. One top-level map will deal with the safety of the spacecraft. The team has to make sure OSIRIS-REx won't encounter hazards on the surface of Bennu when it executes its TAG maneuver to collect the sample for return.

2. Deliverability. The second top-level map will address the ability to deliver OSIRIS-REx to its target. This ensures that the spacecraft can be navigated to and from the sampling site.

3. Sampling ability. The third top-level map will determine where the right kind of regolith is located. The sample head can take in dust and rocks measuring less than ¾ inch (2 centimeters). At least 2.1 ounces (60 grams) of material needs to be collected, but the sample head can hold up to 4.4 pounds (2 kilograms).

4. Science Value. The fourth top-level map will evaluate the scientific value of the surface on Bennu. From remote observations, the team knows that Bennu should contain water and organic – or carbon-rich – material, but they don't know yet how this material is distributed across the surface. Although returning a sample from anywhere on Bennu would have high scientific value, the science value map will identify the most scientifically interesting sites.

All of these maps will be built on a 3-D shape model of Bennu. This is just like what is done to make computer-animated movies, where the characters and environment are colored and shaded in such a way that they look almost life-like; all of those details require a 3-D shape in order to take form. The same is true for the detailed data gathered by OSIRIS-REx's instruments. The team is already using a preliminary shape model produced from Earth-based radar observations of the asteroid. But a new shape model with much higher resolution will be made once OSIRIS-REx surveys Bennu.

Navigation

OSIRIS-REx will not have a GPS telling it to turn right or left as it navigates Bennu. And unlike around Earth or Mars, where the forces on a spacecraft are dominated by gravity, the gravitational force from Bennu acting on OSIRIS-REx is tiny, allowing other, less predictable forces to affect the spacecraft's orbit. About 50 percent of the forces acting on the spacecraft will be due to solar wind (charged particles emanating from the sun) and the pressure of sunlight itself reflecting off the spacecraft. This requires careful and frequent navigation observations to determine the precise position of the spacecraft relative to the asteroid. The navigation team will rely on both background stars and maps of the asteroid's surface to do this.

The team will use star-based navigation as OSIRIS-REx approaches the asteroid. The navigation team will take angular measurements between Bennu and the stars visible near the horizon to pinpoint the asteroid's location. During this time, scientists will study Bennu's rotation and pole axis, as well as observe whether the asteroid wobbles in its orbit around the sun. The science team also will create maps of the asteroid's surface that will be used in the second stage of navigation.

Once OSIRIS-REx arrives at Bennu, the team will switch to landmark-based navigation. Landmark navigation is based on the maps created by the science team, and uses the same technique that pilots use when approaching a familiar location from the air. Pilots look down and see familiar landmarks, and by observing many of them, they can estimate where the airplane is and what direction they are flying. The OSIRIS-REx team will use a very similar technique to locate the position and measure the velocity of the spacecraft with high precision.

Sampling

After the science team has mapped the surface of Bennu in detail, the scientists will begin identifying candidate sample sites. The optimal sample site will need to meet the criteria of all four maps: safety, deliverability, sampling ability, and science value.

If the sample site is determined to be safe, accessible, and contains abundant material to sample, the science observations will help pinpoint a region in which organic materials or evidence of water may be found in greatest abundance. To identify these regions on Bennu, the team equipped the spacecraft with two instruments — the OSIRIS-REx Visible and Infrared Spectrometer (OVIRS) and the OSIRIS-REx Thermal Emission Spectrometer (OTES). These instruments will measure the spectral signatures of Bennu's mineralogical and molecular components. The instruments will measure light reflected or emitted as heat from the asteroid and split the light into its component wavelengths, much like a prism that splits sunlight into a rainbow. The science team can also use data from the student-built Regolith X-Ray Imaging System (REXIS) to determine the elemental composition of Bennu's surface to aid in sample site selection.

In visible and infrared light, minerals have unique signatures, or colors, somewhat like fingerprints. Depending on the molecular features on Bennu's surface, the instruments will allow scientists to identify various organic materials, as well as carbonates, clays, and absorbed water.

Once a sample site has been chosen, the team will attempt to retrieve a sample. The team will conduct several rehearsals without touching the asteroid, to ensure all is ready for sample acquisition. Once the safety criteria are met and all is ready for sample acquisition, the descent to the surface will take several hours. The TAGSAM, which consists of a robotic arm with an attached sampler head, will deploy from the spacecraft. Touching the asteroid's surface, the TAGSAM will release a burst of nitrogen gas, stirring up loose rocks and dust from the surface (regolith) and directing it all into a collector filter on the sample head. There are also contact pads on the bottom of the TAGSAM head, which will collect surface dust on contact. The sampling attempt concludes with the spacecraft slowly backing away from the surface of Bennu.

OSIRIS-REx has enough nitrogen gas for three sampling attempts. After the first TAG attempt, tests will be run to assess the amount of sample that was collected. If the first attempt was successful, the team will not try to collect additional material in order to avoid risk to the spacecraft and to maintain the scientific context of the retrieved sample. If it was not successful, the spacecraft can return to the asteroid and repeat the entire sampling maneuver up to two more times.

Once a sample has been collected, the TAGSAM head is stowed in a sample return capsule; the head is severed from the arm and the SRC is closed for the journey home.

Return

With the sample safely stowed, OSIRIS-REx will wait for the proper alignment of Bennu and the Earth in their orbits, at which time OSIRIS-REx will fire its main engines and leave Bennu. With this maneuver, the spacecraft will be on a trajectory back to Earth, returning home in September 2023.

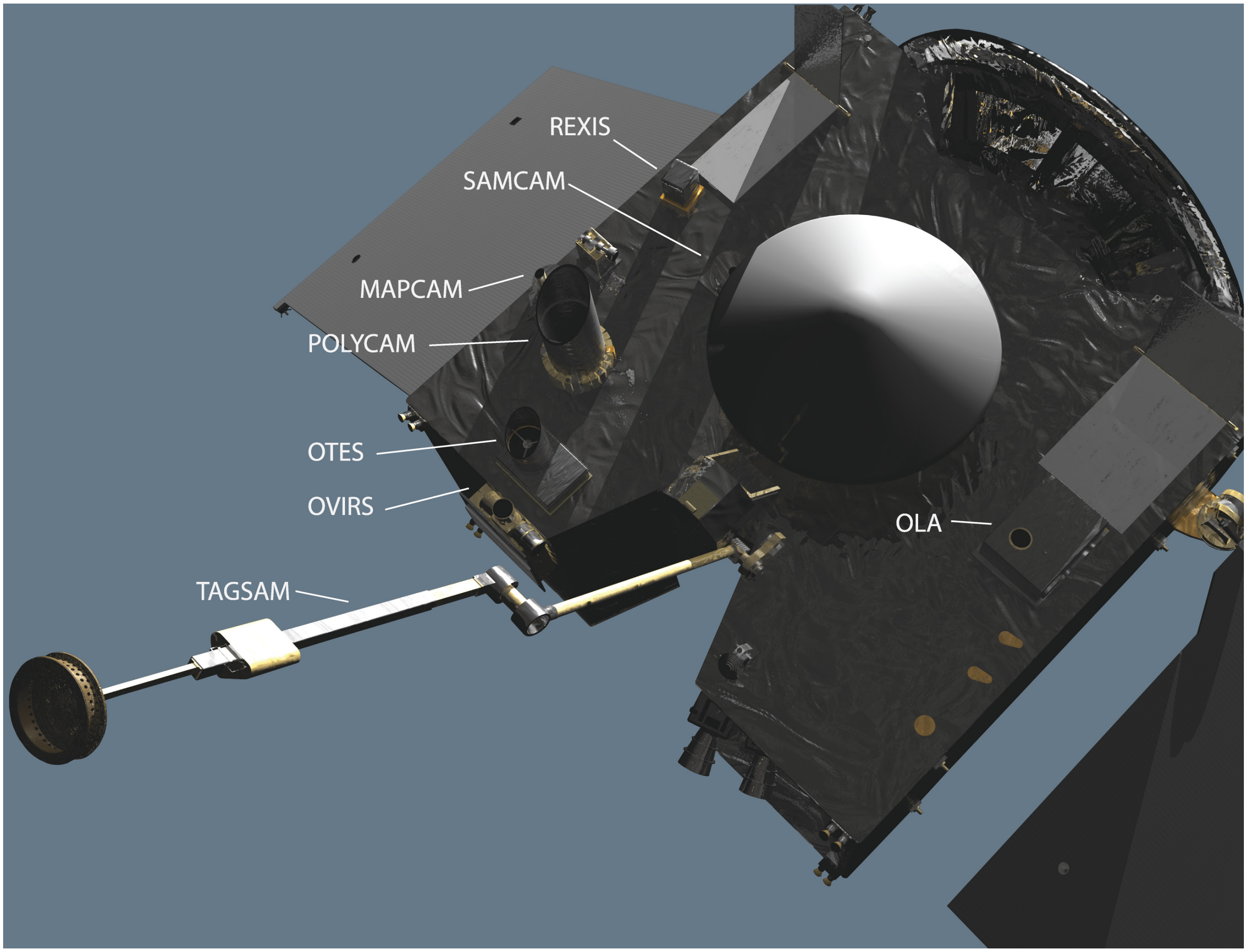
Once in the vicinity of Earth, OSIRIS-REx will release the sample return capsule containing the sample of Bennu toward Earth, and perform a deflection maneuver that places the spacecraft on a stable orbit around the sun. Depending on the amount of fuel remaining and other factors, the OSIRIS-REx spacecraft may be repurposed for other objectives. However, it will no longer be capable of collecting more samples and returning them to Earth.

The SRC will hit the Earth's atmosphere with a speed of more than 27,000 miles per hour (12.2 kilometers per second). After an initial free-fall, with the SRC protected by its heat shield, a parachute will deploy when the capsule reaches an altitude of about 1.9 miles (3 kilometers), bringing it in for a soft landing at the Utah Test and Training Range (UTTR), located about 80 miles west of Salt Lake City, Utah. The team will prepare the sample return capsule for shipment to Johnson Space Center in Houston, Texas, in a clean room at UTTR.

Scientists at the Astromaterials Acquisition and Curation Office at JSC will remove and catalog the sample, and will set aside portions of the sample for partners in the Japanese and Canadian space agencies. A portion of the sample will also be removed and stored at a secure location in New Mexico as a sort of insurance policy. The science team will conduct a preliminary analysis to determine the chemistry and mineralogy of the sample. During the analysis of the sample's chemical composition, scientists will look for organic compounds such as amino acids and sugars — the building blocks of life. At least 75 percent of the sample will be reserved for investigation and analysis by future generations of scientists.

After about six months, NASA will begin to distribute parts of the sample to research groups around the world, as was, and still is, done with the Apollo samples. These teams are selected based upon their submitted project proposals, following scientific review by NASA.

Instrument Deck



Instrument Overview

OSIRIS-REx Camera Suite (OCAMS). OCAMS will provide global image mapping and sample site imaging and characterization. It will also document the entire sampling event during the TAG maneuver. OCAMS consists of three cameras: PolyCam, MapCam and SamCam. PolyCam, an 8-inch (20-centimeter) telescope, will be the first of the cameras to acquire images of the asteroid and will provide high-resolution images at long range. It will also be refocused to image below ½ inch (1 centimeter) during the reconnaissance of potential sampling sites. MapCam will search for satellites around the asteroid and for outgassing plumes. It also will provide high-resolution images and characterize possible sample sites. SamCam will record the sample collection process. The University of Arizona built the OCAMS camera suite. The OCAMS team is led by Bashar Rizk, instrument scientist; Christian d'Aubigny, deputy instrument scientist; and Chuck Fellows, instrument manager.

OSIRIS-REx Laser Altimeter (OLA). OLA is a scanning LIDAR (Light Detection and Ranging) instrument that works similarly to RADAR, but uses infrared light instead of radio waves to measure distance. It will collect data to produce global three dimensional topographic maps of the entire asteroid and higher resolution local maps of candidate sample sites. OLA consists of two lasers, one high-energy transmitter for ranging and mapping at a distance of 0.6 to 4.7 miles (1-7.5 kilometers) and one low-energy transmitter to be used at distances of less than 0.6 miles (1.5 kilometers). It also will support navigation and gravity analysis. OLA is a contributed instrument from the Canadian Space Agency. The OLA science team is an integrated Canada-US team led by Michael Daly, OLA instrument scientist at York University, Catherine Johnson OLA deputy instrument scientist at the University of British Columbia and Olivier Barnouin, Altimetry Working Group lead at Johns Hopkins University Applied Physics Laboratory.

OSIRIS-REx Visible and Infrared Spectrometer (OVIRS). OVIRS will measure light reflected off of the asteroid in wavelengths ranging from 0.4 to 4.3 micrometers to provide mineral and organic spectral maps and local spectral information of candidate sample sites. These maps will allow the team to identify minerals and organic material. OVIRS was built by NASA's Goddard Space Flight Center. The OVIRS team is led by Dennis Reuter, instrument scientist; Amy Simon, deputy instrument scientist; and Jason Hair, instrument manager.

OSIRIS-REx Thermal Emission Spectrometer (OTES). OTES will collect thermal infrared data in wavelengths between 5 and 50 micrometers to develop mineral and thermal emission spectral maps and local spectral information of candidate sample sites. Like OVIRS, this instrument will identify minerals, such as carbonates, sulfates and oxides. It will also measure the total thermal emissions from Bennu and measure its surface temperature. Arizona State University (ASU) built the instrument. The OTES team is led by Philip Christensen, instrument scientist at ASU; Victoria Hamilton, deputy instrument scientist at the Southwest Research Institute in Boulder, Colorado, and Greg Mehall, instrument manager at ASU.

Regolith X-Ray Imaging System (REXIS). REXIS is a student collaboration experiment that will develop a map of elemental abundances on the surface of Bennu through X-ray fluorescence spectrometry. It will complement the mineral mapping capabilities from the other OSIRIS-REx instruments. Over the course of the mission, more than 100 students from Massachusetts Institute of Technology (MIT) and Harvard will have participated in the REXIS project. MIT faculty leadership is provided by Professor David Miller, Professor Richard Binzel and Professor Sara Seager. At Harvard, faculty leadership is provided by Professor Josh Grindlay. The instrument manager is Rebecca Masterson at MIT.

High Gain and Low Gain Antennas. The Radio Science team will use the high and low gain antennas, part of the Telecommunications Subsystem, to communicate with the Deep Space Network (DSN) on Earth in order to obtain accurate Doppler and range measurements of the spacecraft. The radiometric tracking data will be used to measure the mass and gravity field of Bennu, which will constrain the internal structure of the asteroid and refine the Yarkovsky measurements. The radio science team is led by Daniel Scheeres at University of Colorado, Boulder.

TAGSAM

Touch-and-Go Sample Acquisition Mechanism (TAGSAM). The TAGSAM is a simple sampler head with an articulated arm that can be extended to allow surface contact without having the spacecraft land on the asteroid. The TAGSAM will collect samples from Bennu in a two-step process:

1. During the approximately five-second contact with the surface, the sampler head will agitate the surface and loosen regolith with a jet of nitrogen gas, allowing for collection of suspended particles through a filter. The onboard nitrogen bottles can support up to three separate sampling attempts. Surface-contact pads located on the bottom of the TAGSAM head will collect fine-grained material.

2. After successful sample collection, the robotic arm of TAGSAM will place the sampler head and surface-contact pads in the SRC, where it will then be severed from the arm. The capsule will then close, protecting the asteroid material from contamination during its trip back to Earth.

NASA's Launch Services Program

The Launch Services Program, known as LSP, is based at NASA's Kennedy Space Center in Florida and boasts a roster of engineers and technicians who specialize in all aspects of rocketry and spacecraft integration. LSP selects the appropriate launch vehicle for a customer's spacecraft, in this case the United Launch Alliance Atlas V 411, for OSIRIS-REx. This selection process takes place years before launch.

Established in 1998, the Launch Services Program is a superior collection of state-of-the-art technology, business, procurement, engineering best-practices, strategic planning, studies, and techniques – all absolutely instrumental for the United States to have access to a dependable and secure Earth-to-space bridge, launching spacecraft to orbit our planet, or fly much further into the cosmic deep.

Capitalizing on a half-century of expertise and collaboration with NASA, LSP is striving to facilitate and reinvigorate America's space effort broad¬ening the unmanned rocket and satellite market by providing reliable, competitive and user-friendly services.

Working with commercial launch providers, LSP has a number of rocket models to choose from, ranging from the small, air-launched Orbital ATK Pegasus to the workhorse Delta II rocket from United Launch Alliance, or ULA, to the powerhouse Atlas V, also from ULA. The catalog is growing, too, with the addition of the SpaceX Falcon 9 and Orbital ATK Antares rockets.

Spacecraft destination requirements, coupled with the mass and volume of the spacecraft determine the launch vehicle required. The destination may be an orbit or even another planet. Additionally, spacecraft must survive ground handling and launch environments such as vibration, contamination, elec-tromagnetic, thermal, and structural loads along the way. Engineers and Analysts with LSP ensure the optimal launch vehicle is used to deliver a healthy spacecraft to the correct orbit or destination. LSP launches from Cape Canaveral Air Force Station in Florida, Vandenberg AFB in California, Kwajalein in the Marshall Islands, Kodiak Island, Alaska, and NASA's Wallops Flight Facility on Virginia's Eastern Shore.

Bennu and Planetary Defense

By current definition, Bennu is a Potentially Hazardous Asteroid (PHA). It's one of the most potentially hazardous of the known near-Earth objects, although the possibility of impact is still very low—in the late 22nd Century.

PHAs are a subclass of near-Earth asteroids that can make close approaches to the Earth. More precisely stated, a PHA is an asteroid that is predicted to come within 0.05 Astronomical Units (just under 5 million miles or ~7.5 million kilometers) of Earth's orbit and is of a size large enough to survive atmospheric entry and cause significant damage at Earth's surface. PHAs are currently defined as larger than 460 feet (140 meters) in size, though depending on composition, some may be as small as 100 to 160 feet (30 to 50 meters).

JPL's Center for NEO Studies (CNEOS) has predicted the future orbital movements of Bennu based on 29 radar observations and 478 optical observations of the asteroid conducted by trackers around the world between September 1999 and January 2011.

The next very close approach of Bennu to Earth is predicted to occur in 2135, when the asteroid is expected to pass just slightly within the moon's orbit. This particularly close approach will change Bennu's orbit by a small amount, which is uncertain at this time and which may lead to a potential impact on Earth sometime between 2175 and 2199. CNEOS has calculated that the cumulative risk of impact by Bennu during this 24-year period is 0.037% or a 1 in 2,700 chance. That means there is a 99.963% probability that Bennu will not impact the Earth during this quarter-century period.

Although there is some uncertainty in precisely predicting Bennu's orbital motion more than a century from now, future observations of this unusual asteroid – including those made by the OSIRIS-REx mission – will enable experts to update orbit predictions and revise the future impact probabilities.

NASA places a high priority on planetary defense—finding and characterizing any hazardous asteroids as much in advance as possible, to have sufficient time to protect our home planet from a potential impact. Over the past five years, the agency has increased by a factor of 10 our nation's investment in asteroid detection, characterization and mitigation activities.

To date, it is statistically calculated that 95 percent of all potentially hazardous asteroids and comets larger than 3,280 feet (1 kilometer) in size that could pose danger to Earth have been found. No significant impact threats have been detected for the next 100 years, though NASA has detected past impacts of small, meter-sized objects. However, it's worth noting that only about 51% of the near-Earth asteroids of Bennu's size and about 5% of those at 460 feet (140 meters) in size have been found.

NASA recently formalized its ongoing program for detecting and tracking near-Earth objects (NEOs) as part of the establishment of a Planetary Defense Coordination Office (PDCO). The office is within NASA's Planetary Science Division, in the agency's Science Mission Directorate in Washington.

The objectives of NASA's Planetary Defense Coordination Office (PDCO) are to ensure early detection and warning and provide accurate communications regarding potentially hazardous asteroids and comets, and to take a leading role in planning for adequate response by the U.S. government to a predicted impact threat.

The PDCO was created to serve as an interagency coordination and communications node for the federal government (FEMA, DoD, State, etc.) and the public in the event that a close-approaching or potentially impacting object is discovered. It also pursues technology and techniques that could be used to deflect or disrupt an object that threatens to impact the Earth, in collaboration with other US government agencies and other nations' space agencies.

The OSIRIS-REx mission also will be a pathfinder for future spacecraft more specifically designed to perform reconnaissance on any newly-discovered object that could pose a threat of impact to the Earth.

Management

NASA's Goddard Space Flight Center in Greenbelt, Maryland, provides overall mission management, systems engineering, navigation, and safety and mission assurance for OSIRIS-REx. Dante Lauretta is the mission's principal investigator at the University of Arizona. Lockheed Martin Space Systems in Denver built the spacecraft and provides mission operations. OSIRIS-REx is the third mission in NASA's New Frontiers Program. NASA's Marshall Space Flight Center in Huntsville, Alabama, manages New Frontiers for the agency's Science Mission Directorate in Washington.

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OSIRIS-REx
ASTEROID SAMPLE RETURN MISSION