AN OVERVIEW OF THE OSIRIS-REX ASTEROID SAMPLE RETURN MISSION.

D. S. Lauretta[1] and The OSIRIS-REx Team, [1]OSIRIS-REx Principal Investigator, Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ, 85721, USA, lauretta@lpl.arizona.edu.

Introduction: NASA selected the OSIRIS-REx Asteroid Sample Return Mission as the third New Frontiers mission in May, 2011. The mission name is an acronym that captures the scientific objectives: **O**rigins, **S**pectral **I**nterpretation, **R**esource **I**dentification, and **S**ecurity–**R**egolith **Ex**plorer. OSIRIS-REx will thoroughly characterize near-Earth asteroid (101955) 1999 RQ36. This asteroid is both the most accessible carbonaceous asteroid and the most potentially hazardous asteroid known. Knowledge of its nature is fundamental to understanding planet formation and the origin of life. Only by understanding the organic chemistry and geochemistry of an asteroid sample can this knowledge be acquired.

OSIRIS-REx brings together all of the pieces essential for a successful asteroid sample return mission– The University of Arizona's (Tucson, AZ) leadership in planetary science and experience operating the Mars Phoenix Lander; Lockheed Martin's (Denver, CO) unique experience in sample-return mission development and operations; NASA Goddard Space Flight Center's (Greenbelt, MD) expertise in project management, systems engineering, safety and mission assurance, and visible-near infrared spectroscopy; KinetX's (Tempe, AZ) experience with spacecraft navigation; and Arizona State University's (Tempe, AZ) knowledge of thermal emission spectrometers. The Canadian Space Agency is providing a laser altimeter [1], building on the strong relationship established during the Phoenix Mars mission. In addition, MIT and Harvard College Observatory are providing an imaging X-ray spectrometer as a Student Collaboration Experiment. The science team includes members from the United States, Canada, France, Germany, Great Britain, and Italy.

Science: OSIRIS-REx's detailed characterization of 1999 RQ36 and return of pristine samples will significantly enhance our understanding of the initial stages of planet formation and the sources of organics that may have ultimately led to the origin of life. Bodies from the main asteroid belt are believed to be the dominant source of primordial terrestrial organics and water. OSIRIS-REx has five mission objectives:

1. Return and analyze a sample of pristine carbonaceous asteroid regolith in an amount sufficient to study the nature, history, and distribution of its constituent minerals and organic material.
2. Map the global properties, chemistry, and mineralogy of a primitive carbonaceous asteroid to characterize its geologic and dynamic history and provide context for the returned samples.
3. Document the texture, morphology, geochemistry, and spectral properties of the regolith at the sampling site *in situ* at scales down to the sub-centimeter.
4. Measure the Yarkovsky effect on a potentially hazardous asteroid and constrain the asteroid properties that contribute to this effect.
5. Characterize the integrated global properties of a primitive carbonaceous asteroid to allow for direct comparison with ground based telescopic data of the entire asteroid population.

Target Asteroid: OSIRIS-REx will return samples from a primitive body that represents the objects that may have brought prebiotic seeds of life and volatiles to Earth. The most plausible sources of these compounds are primitive asteroids and comets. Recent observations show that many B-type asteroids in the main belt are currently releasing volatiles and appear to be transitional between asteroids and comets. Little is known about this enigmatic asteroid class. The B-type contains many significant objects, including (2) Pallas, the second largest main-belt asteroid, and the extinct comets 107P/Wilson-Harrington and (3200) Phaethon. Based on these data, the OSIRIS-REx team concluded that a B-type asteroid is the most exciting target for a New Frontiers sample-return mission.

The OSIRIS-REx team's exhaustive study of candidate asteroids that met mission planning and science objectives resulted in the selection of 1999 RQ36 as the most scientifically exciting and accessible target. 1999 RQ36 rises to the top of the list of potential sample-return targets based on both its high science value and its extensive characterization by ground- and space-based telescopes, which greatly reduce the risk for proximity operations planning. 1999 RQ36 was discovered in September 1999 by the LINEAR survey and is an Apollo NEO with a semi-major axis of 1.126 AU. Observations of 1999 RQ36 were performed by team members using ground-based telescopes [2] the Spitzer Space Telescope [3] the Arecibo Planetary Radar System [4], and other assets. These data strongly support the presence of abundant regolith, comprised of fine gravel (4-8 mm), ideal for sampling. 1999 RQ36 comes within 0.003 AU of the Earth and has the highest impact probability of any known asteroid [5].

1999 RQ36 is a B-type asteroid characterized by a linear, featureless spectrum with bluish to neutral slope. Spectral analysis suggests that the most likely meteorite analogs for 1999 RQ36 are the CI or CM meteorites [6]. Near-infrared spectroscopic data show evidence of a thermal tail longward of 2 μm, suggesting a very low albedo (0.035 ± 0.015) that is consistent with a carbonaceous surface. Thermal infrared data show that there is no observable dust or gas in the proximity of RQ36. Light-curve observations give a rotational period of 4.2968 ± 0.0018 hours [2]. The lightcurve displays no evidence of satellites in orbit about 1999 RQ36. The rotation period and axial ratio imply a minimum density of 0.7 g/cm^3 for a rubble pile. Based on other asteroids in the C spectral complex (of which the B-type is a member), the team estimates a bulk density of 1.4 ± 0.7 g/cm^3. Dynamical and spectral analysis suggest that 1999 RQ36 may be a liberated member of the Polana asteroid family [7].

Science Implementation: OSIRIS-REx delivers its science using five instruments and radio science along with the Touch-And-Go Sample Acquisition Mechanism (TAGSAM). All of the instruments and data analysis techniques have direct heritage from flown planetary missions.

TAGSAM is an elegantly simple device that satisfies all sample-acquisition requirements. TAGSAM consists of two major components, a sampler head and an articulated positioning arm. The head acquires the bulk sample by releasing a jet of high-purity N_2 gas that "fluidizes" the regolith into the collection chamber. The articulated arm, which is similar to, but longer than, the Stardust aerogel deployment arm, positions the head for collection, brings it back for visual documentation, and places it in the Stardust-heritage Sample Return Capsule (SRC).

The OSIRIS-REx Camera Suite (OCAMS) is composed of three cameras. PolyCam provides long-range 1999 RQ36 acquisition and high-resolution imaging of 1999 RQ36's surface. MapCam supports optical navigation during proximity-operations, global mapping, and sample-site reconnaissance. SamCam performs sample-site characterization and sample-acquisition documentation.

The OSIRIS-REx Laser Altimeter (OLA) provides high-resolution topographical information [1]. OLA's high-energy laser transmitter is used for ranging from 1–7.5 km that supports Radio Science and provides scaling information for images and spectral spots. OLA's low-energy transmitter is used for rapid ranging and LIDAR imaging at 500 m to 1 km, providing a global topographic map of RQ36 as well as local maps of candidate sample sites.

The OSIRIS-REx Visible and Infrared Spectrometer (OVIRS) is a linear-variable point spectrometer (4-mrad FOV) with a spectral range of 0.4 – 4.3 μm, providing full-disk 1999 RQ36 spectral data, global spectral maps (20-m resolution), and local spectral information of the sample site (0.08 – 2-m resolution). OVIRS spectra will be used to identify volatile- and organic- rich regions of RQ36's surface and guide sample-site selection.

The OSIRIS-REx Thermal Emission Spectrometer (OTES) is a Fourier-transform-interferometer, point spectrometer (8-mrad FOV) that collects hyperspectral thermal infrared data over the spectral range from 4 – 50 μm with a spectral resolution of 10 cm^{-1}. OTES provides full-disk RQ36 spectral data, global spectral maps, and local sample site spectral information.

The Regolith X-ray Imaging Spectrometer (REXIS) Student Collaboration Experiment is a joint venture of Massachusetts Institute of Technology and Harvard-Smithsonian Center for Astrophysics. REXIS significantly enhances OSIRIS-REx by obtaining a global X-ray map of elemental abundance on 1999 RQ36.

Radio Science will determine the mass of 1999 RQ36 and estimate the mass distribution to 2nd degree and order, with limits on the 4th degree and order distribution. Knowing the mass estimate and shape model, the team will compute the bulk density and apparent porosity of 1999 RQ36. These data are obtained by combining radiometric tracking data with optical observations, supplemented by OLA altimetry data. Together, this information constrains the internal structure. Most importantly, the gravity field knowledge provides information on regolith mobility and identifies areas of significant regolith pooling.

Mission Implementation: The OSIRIS-REx mission employs a methodical, phased approach to ensure success in meeting the mission's science requirements. OSIRIS-REx launches in September 2016, with a backup launch period occurring one year later. Sampling occurs in 2020. The departure burn from 1999 RQ36 occurs in March 2021. On September 24, 2023, the SRC lands at the Utah Test and Training Range (UTTR). Stardust heritage procedures are followed to transport the SRC to Johnson Space Center, where the samples are removed and delivered to the OSIRIS-REx curation facility. After a six-month preliminary examination period the mission will produce a catalog of the returned sample, allowing the worldwide community to request samples for detailed analysis.

References: [1] Dickinson et al. (2012) *LPS XLIII.* [2] Hergenrother et al. (2012) *LPS XLIII.* [3] Emery J. P. (2010) *LPS XLI*, Abstract #2282. [4] Nolan M. C. et al. (2008) *Bull. Amer. Astron. Soc.*, 39, 433. [5] Milani A. et al. (2009) *Icarus*, 203, 460. [6] Clark B. E. et al. (2011) *Icarus*, 216, 462. [7] Campins H. et al. (2010) *Astrophys. J. L.*, 721, L53.