OSIRIS-REx

Asteroid Sample Return Mission

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OSIRIS-REx Techniques Applied to Earth-Crossing Object Deflection

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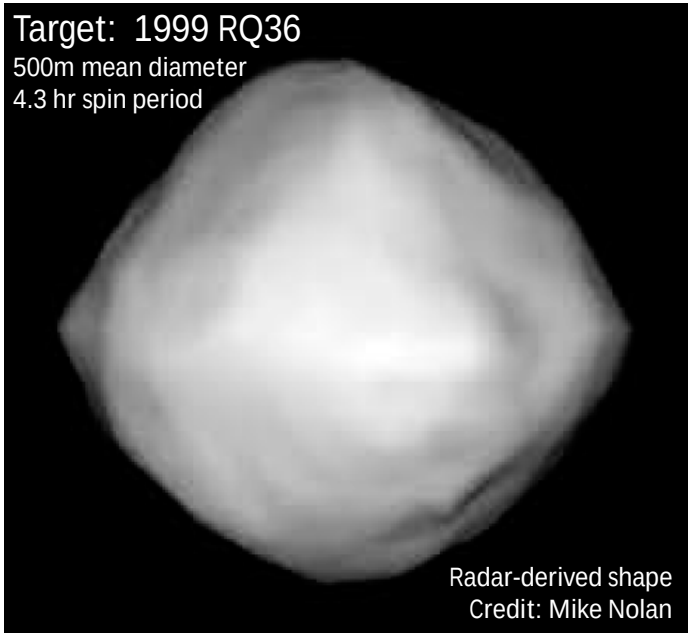
Introduction

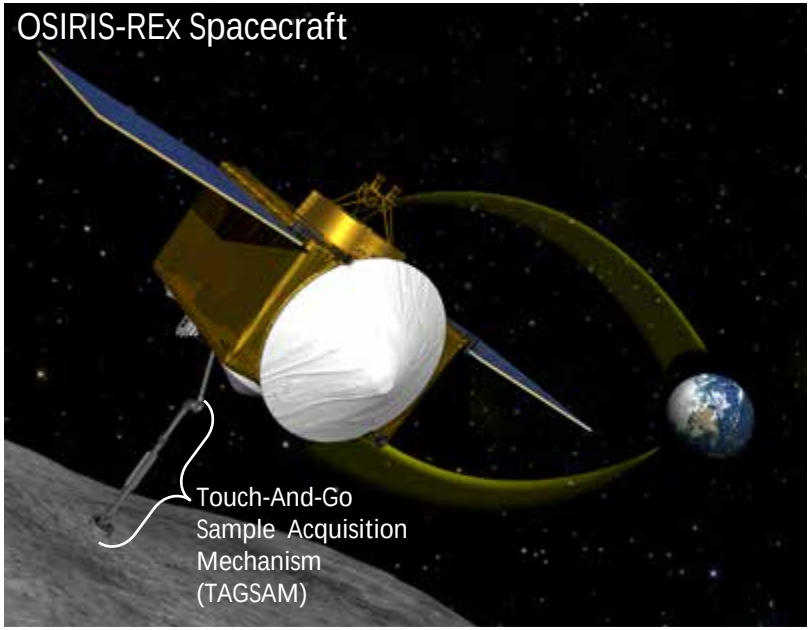
- OSIRIS-REx = **O**rigins, **S**pectral **I**nterpretation, **R**esource **I**dentification, **S**ecurity **R**egolith **E**xplorer
- Third mission in NASA's New Frontier Program, following New Horizons and JUNO
- Topics
  - OSIRIS-REx mission
  - Hazard Assessment
  - PHA Deflection Concepts
  - OSIRIS-REx Applications to PHA Missions
  - Summary

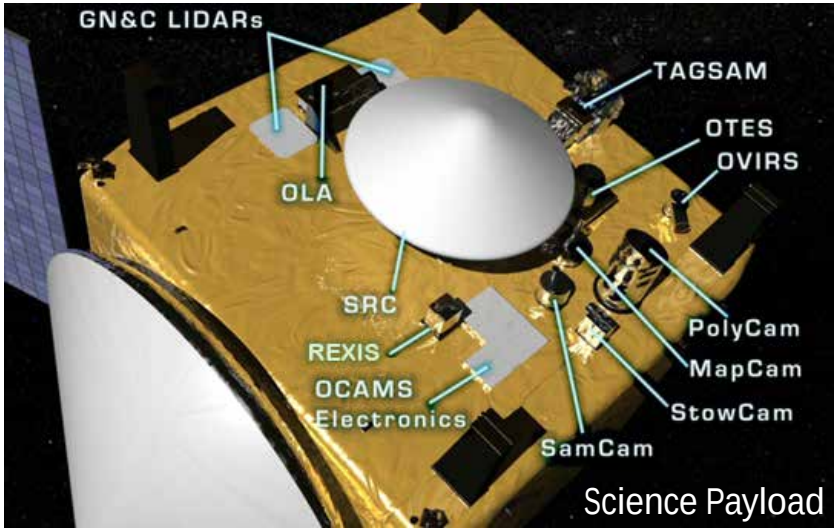
OSIRIS-REx Mission

Key Objectives

- Return and analyze a sample
- Map the global properties, chemistry, and mineralogy
- Document the sample site to sub-cm resolution
- Measure the Yarkovsky effect
- Characterize the integrated global properties for direct comparison with ground-based telescopic data

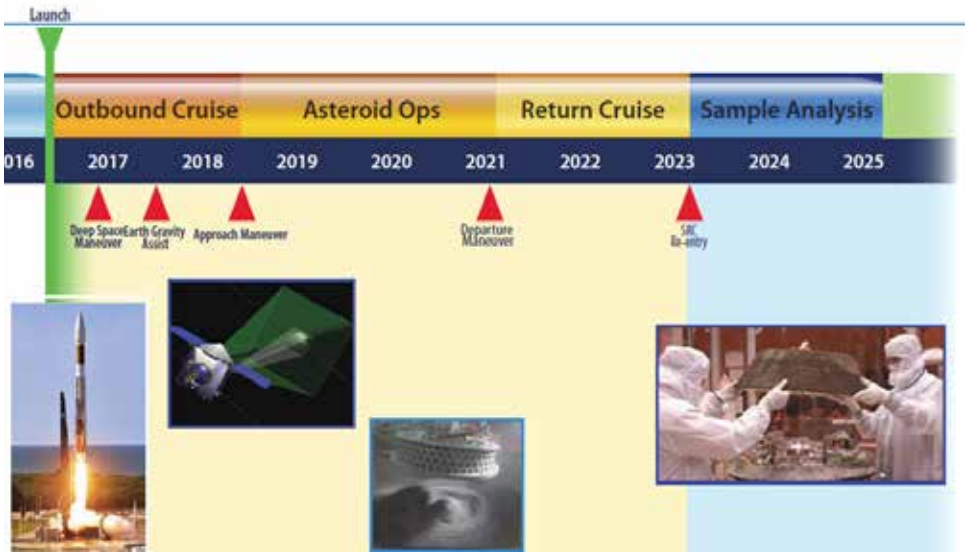


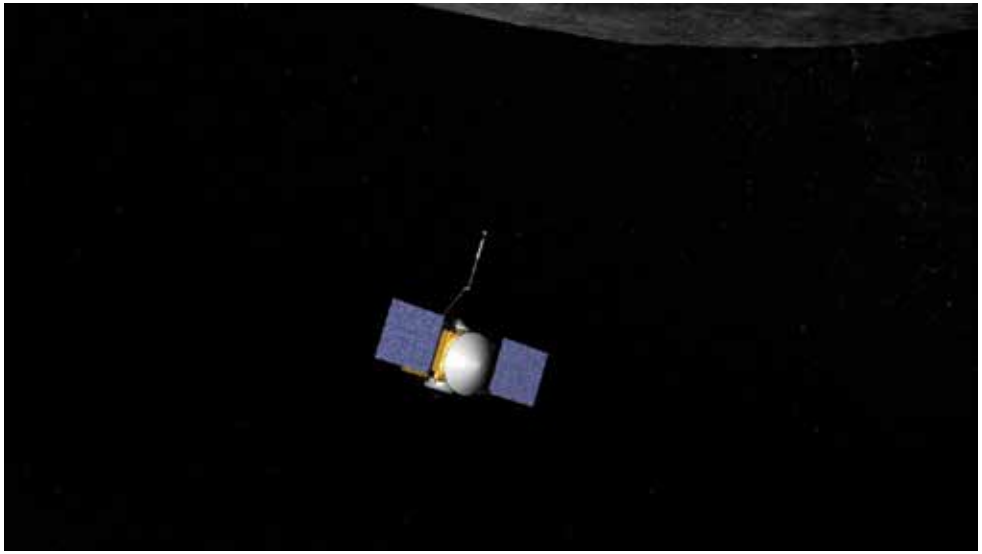




OSIRIS-REx Mission Phases

- Approach Phase
  - Initial asteroid characterization
  - Natural satellite survey
- Survey Phase
  - Mass, size, shape, and rotation state
  - Global composition maps and gravity model
- Reconnaissance Phase
  - Low-altitude flyovers of potential sample sites
- Sample Collection Phase
  - Sustained proximity operations in low-gravity environments
    - Multiple rehearsals and sampling from staging orbit
  - Closed-loop GN&C maneuvers
  - Surface contact with regolith collection

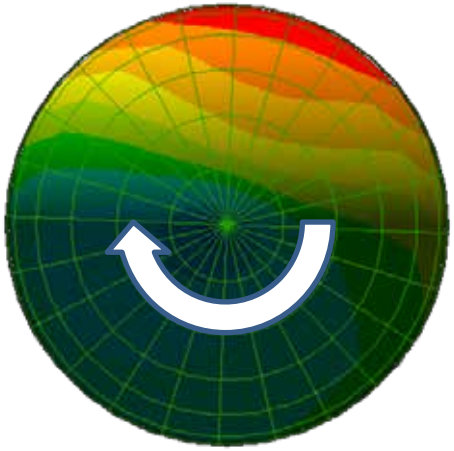




http://osiris-rex.lpl.arizona.edu/

Hazard Assessment

- OSIRIS-REx science will improve confidence in long-term impact predictions
  - Refine measurement of the Yarkovsky effect on the orbit of 1999 RQ36
  - Detailed thermophysical model of 1999 RQ36 developed from remote sensing data used to predict Yarkovsky effect
  - Model prediction correlated to measurement

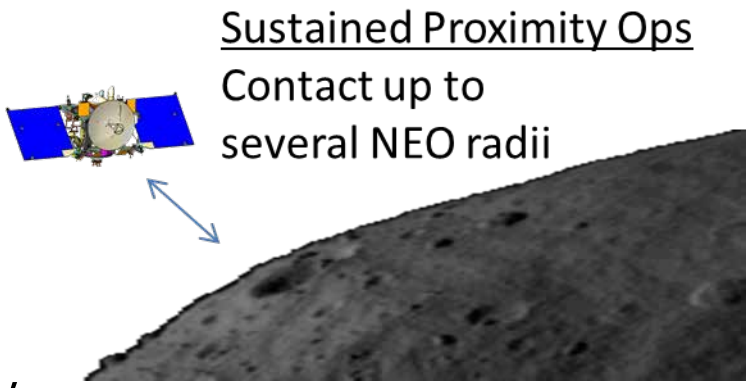


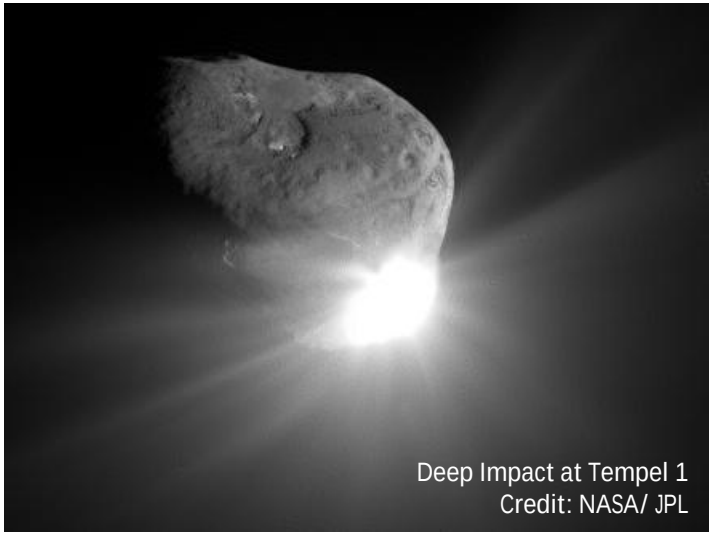
RQ36 Thermal Model

- OSIRIS-REx science will improve confidence in determination of asteroid properties relevant to mitigation from Earth-based observations
  - Properties include mass, size/shape, spin state, and surface composition
  - Provides “ground truth” for 1999 RQ36 properties estimated from Earth-based (ground and space) observations

PHA Deflection Concepts

- Minimize mass intercepting the Earth
- Low-energy deflection
  - Thermo-optical properties modification
  - Push-pull: ion-beam, gravity tractor
- High-energy deflection / disruption
  - Standoff nuclear* explosion, kinetic-energy impactor
  - Surface / subsurface nuclear* explosion
  - Mass driver
- High-energy options in general require an "observer" spacecraft to
  - Observe the deflection/disruption event
  - Track the deflected object – or dispersed objects – to confirm success





*Note: Because of restrictions found in Article IV of the *Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies*, it is presumed the use of a nuclear device would require prior international coordination

Knowledge Needs to Enable Deflection Missions

Table 1. Knowledge Needs for PHA Mitigation Missions

	Hazard Assessment	Low-Energy Deflection	High-Energy Deflection
Object Location (Ephemeris)	X	X	X
Small Force Effects: (Solar Pressure, Yarkovsky)	X	X	X
Hazards (Natural Satellites around Object, Volatiles)		X	X
Size, Mass, Shape, and Rotation State	X	X	X
Mass Distribution		X	X
Gravity Model for Stable Orbits		X	X
Object Interior Composition			X

- Hazard assessment requires knowledge of object trajectory, orbit deviations due to small forces, and NEO properties
- Asteroid deflection requires knowledge of the operational tools and techniques from sustained operation in proximity to an asteroid
- OSIRIS-REx science and mission architecture provides this knowledge

OSIRIS-REx Techniques

Table 2. OSIRIS-REx Techniques Applicable to PHA Mitigation Missions

OSIRIS- Techniques	Low-Energy Deflection	High-Energy Deflection			
	Ion-beam, gravity tractor	*Standoff Explosion*	*Kinetic-energy impactor*	*Subsurface Explosion*	*Surface Explosion, Mass driver*
Acquire Object	X	X	X[b]	X	X
Detect Natural Satellites	X	X	X[a]	X	X
Establish Size/Shape/ Rotation State	X	X	X[a]	X	X
Establish Gravity Model	X	X	X[a]	X	X
Maintain Long-Term Stable Orbit	-	X	X[a]	X	X
Position Relative to the Surface	X[b]	X[b]	X[a,b]	X[b]	X[b]
Contact the Surface	-	-	X[b]	X[b]	X[b]
Determine Asteroid / Fragment Ephemeris	X	X	X	X	X

Note: a) required to operate an observer spacecraft, b) closed-loop control, and c) operate for a time period of weeks to years

- Sustained proximity operations in near asteroid environment
- Platform applies to both asteroid deflection and observer roles

Summary

- OSIRIS-REx science, platform and operational techniques apply to the asteroid deflection problem
  - Improves hazard assessment by measuring the Yarkovsky effect and providing “ground truth” for Earth-based observations
  - Asteroid deflection role
    - Characterizes bulk and surface properties before approaching the surface
    - Performs sustained proximity operations from a few meters to several radii from the surface
    - Demonstrates closed loop GN&C maneuvers to touch the surface (needed to place deflection device on or in proximity to the asteroid surface)
  - Observer role
    - Characterizes bulk and surface properties before and after deflection event
    - Observes the deflection event
    - Verifies success of deflection event by tracking main body and fragments
- OSIRIS-REx is a pathfinder for future asteroid deflection missions