OSIRIS-REx
Mission Overview

OSIRIS-REx™
ASTEROID SAMPLE RETURN MISSION

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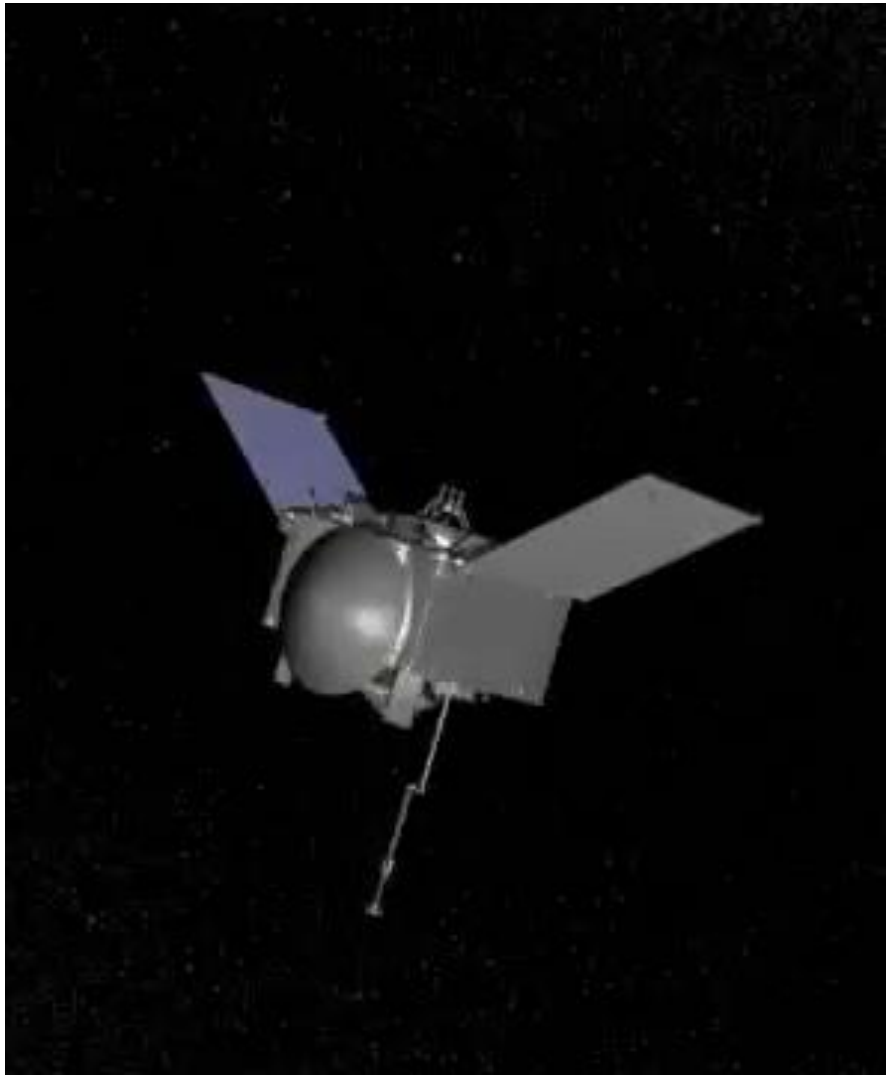
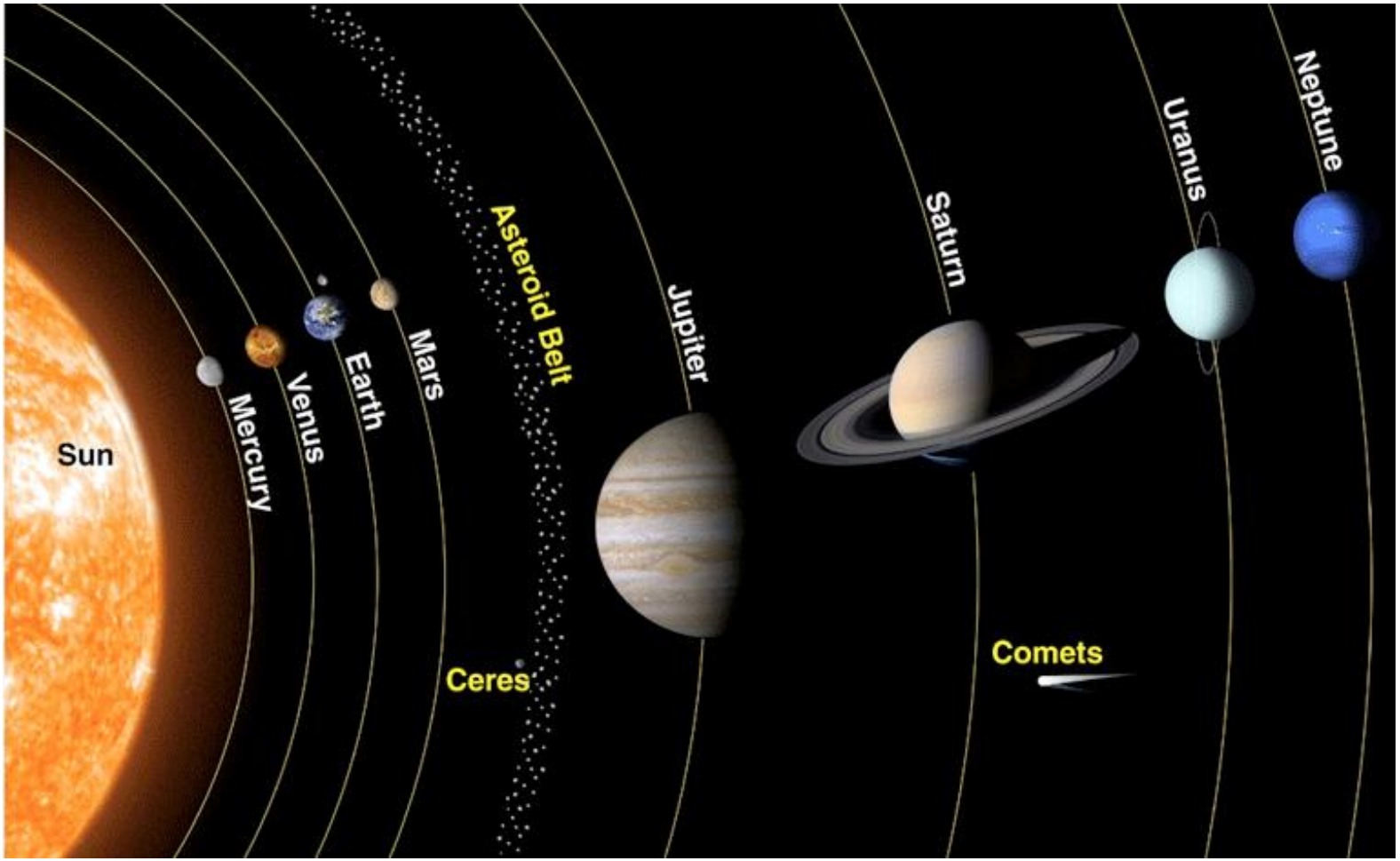
THE UNIVERSITY OF ARIZONA – NASA GODDARD SPACE FLIGHT CENTER – LOCKHEED MARTIN

OSIRIS-REx Defined

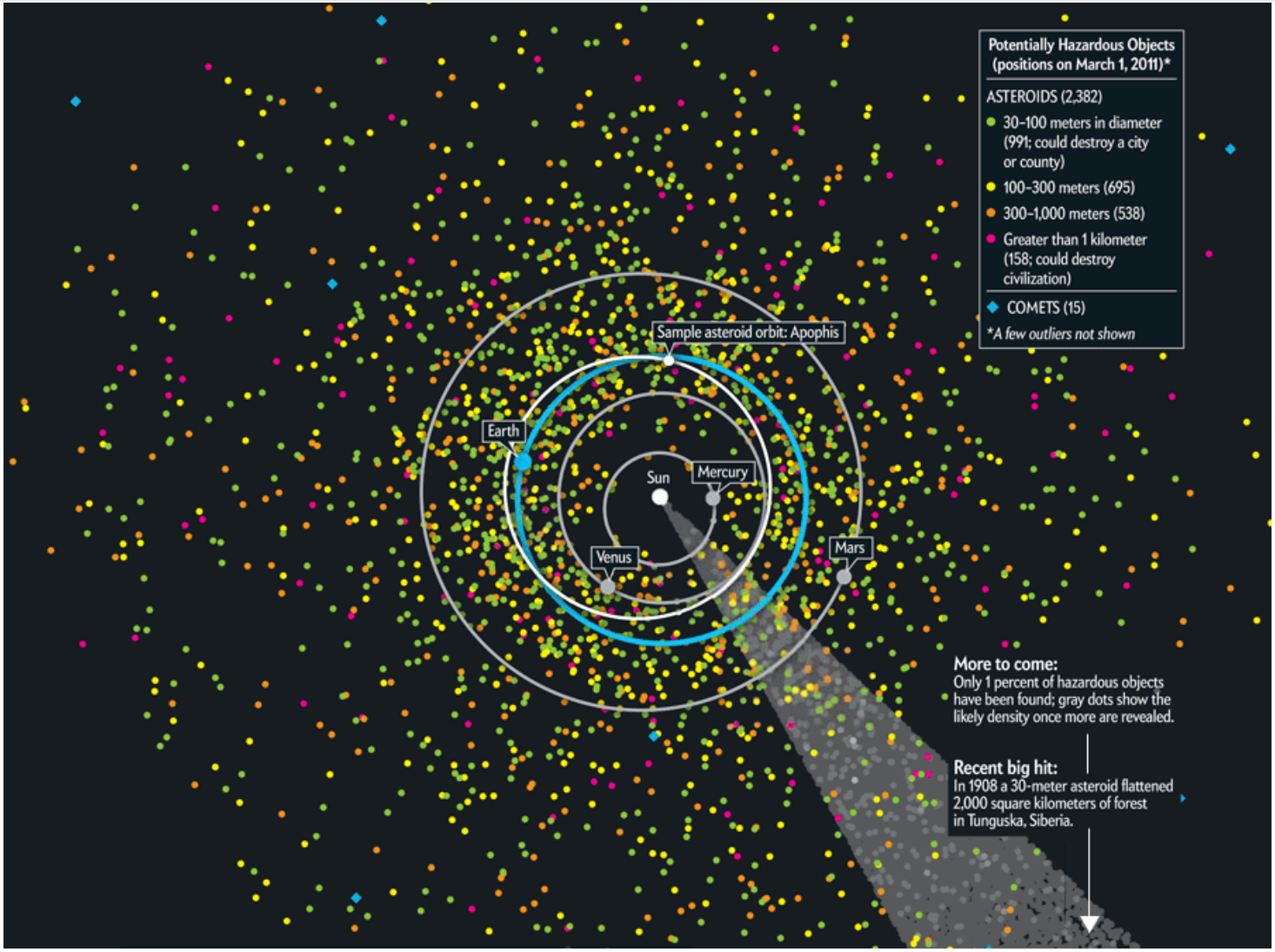


- **O**rigins
  - Return and analyze a sample of pristine carbonaceous asteroid regolith
- **S**pectral **I**nterpretation
  - Provide ground truth for telescopic data of the entire asteroid population
- **R**esource **I**dentification
  - Map the chemistry and mineralogy of a primitive carbonaceous asteroid
- **S**ecurity
  - Measure the Yarkovsky effect on a potentially hazardous asteroid
- **R**egolith **Ex**plorer
  - Document the regolith at the sampling site at scales down to the sub-cm

The Asteroid Belt

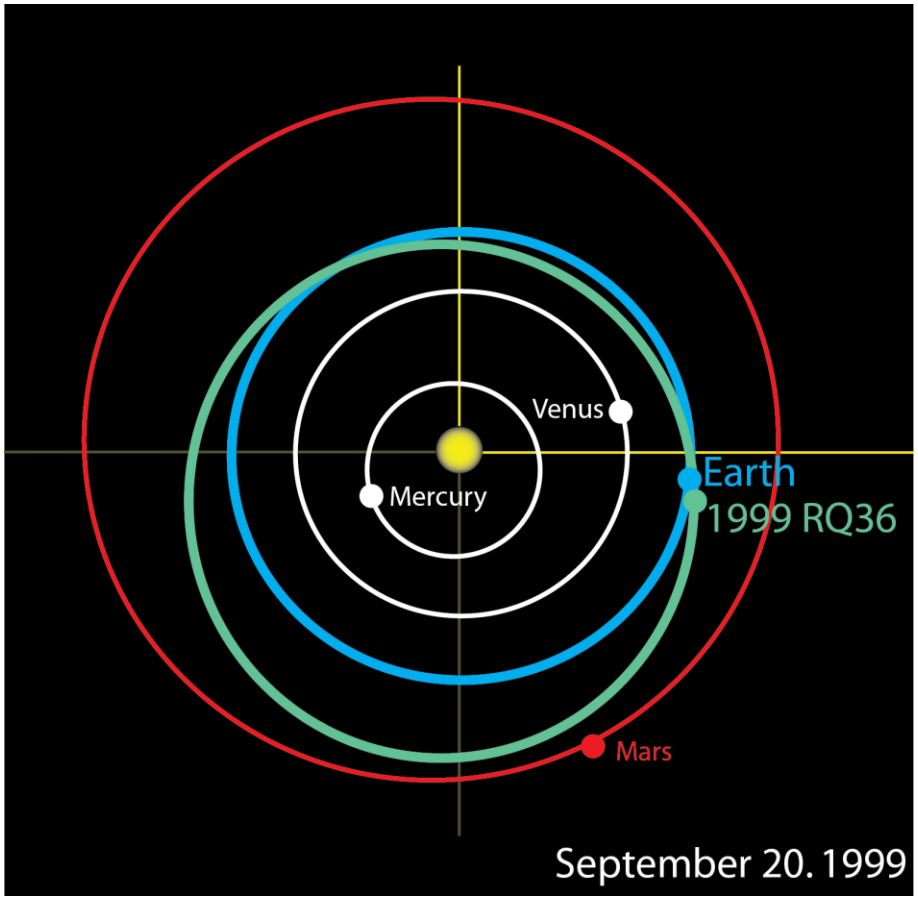


Near-Earth Asteroids

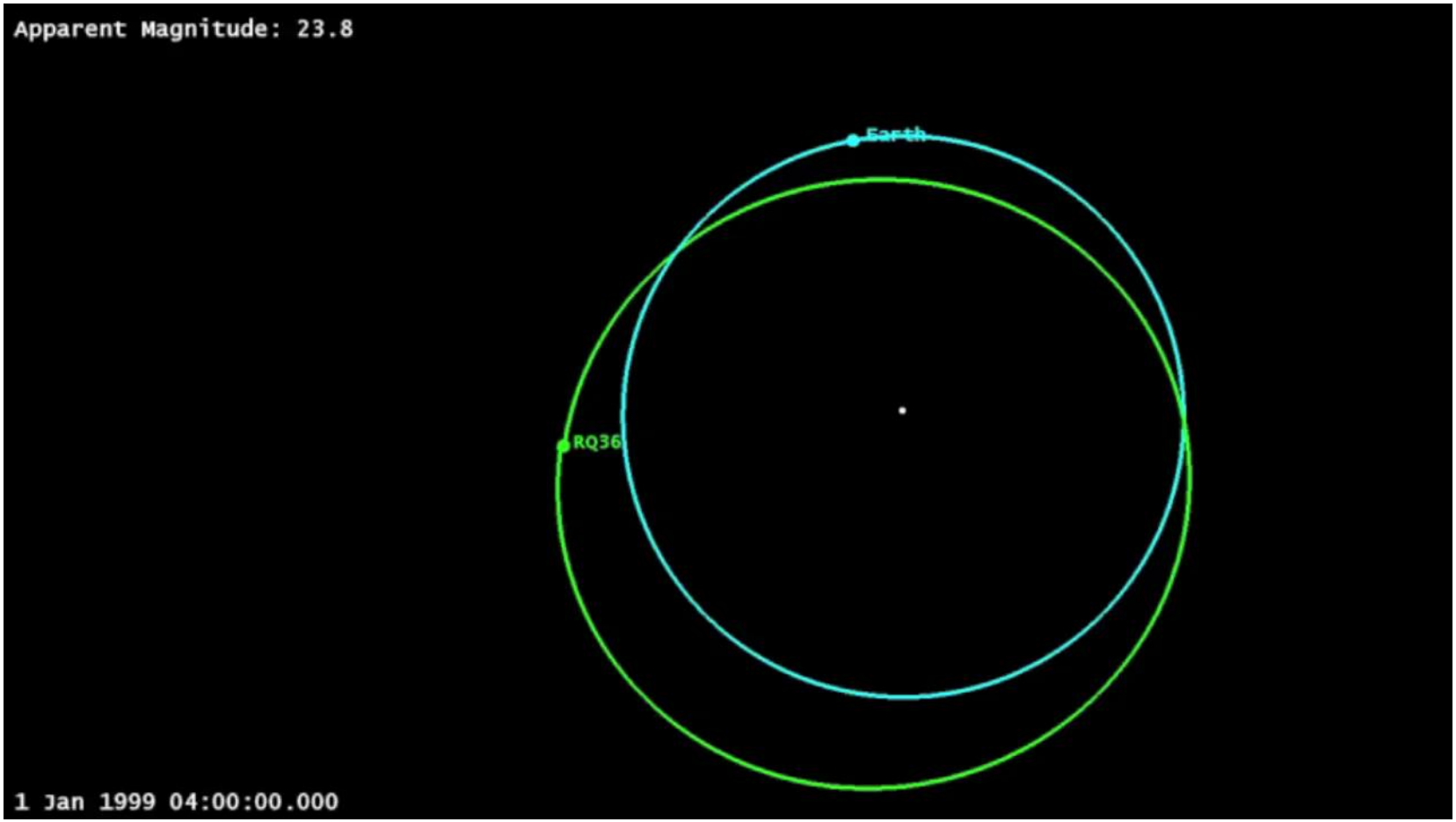


Mission Design Constraints 1: Orbit

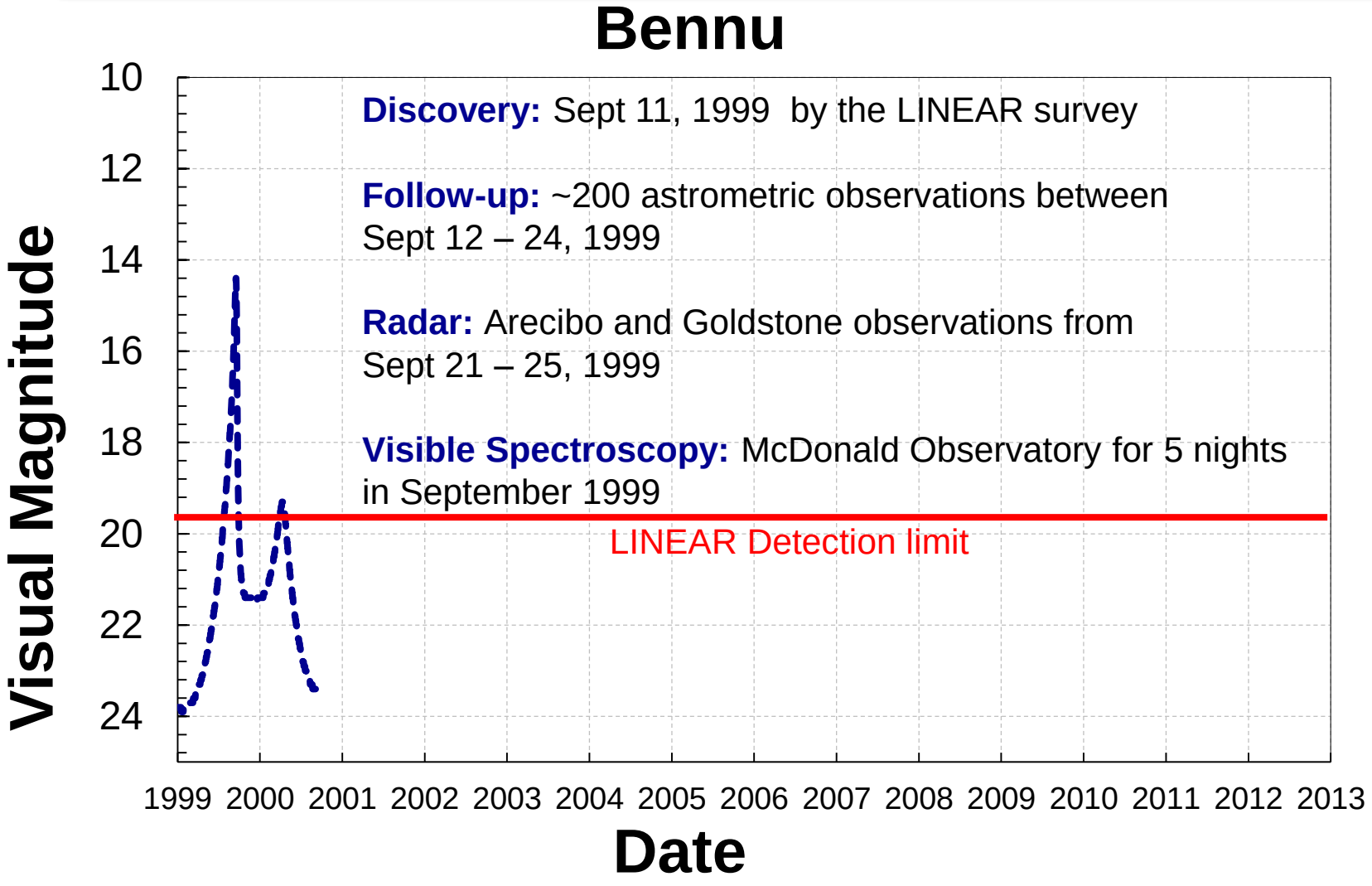
- Use of solar power: aphelion < 1.6 AU
- Thermal constraints: perihelion > 0.8 AU
  - These two requirements constrain both the semi-major axis and the orbital eccentricity of the target
- Mission propellant and sample return capsule (SRC) performance requirements: inclinations <10˚
  - Objects on low-inclination orbits require a minimum amount of delta-V for rendezvous and provide low re-entry velocities for the SRC
- Quality of orbital knowledge: sufficiently precise to allow us to design a trajectory ensuring the spacecraft could rendezvous with the target
- The orbit of Bennu (1999 RQ36) meets all of our mission-target criteria



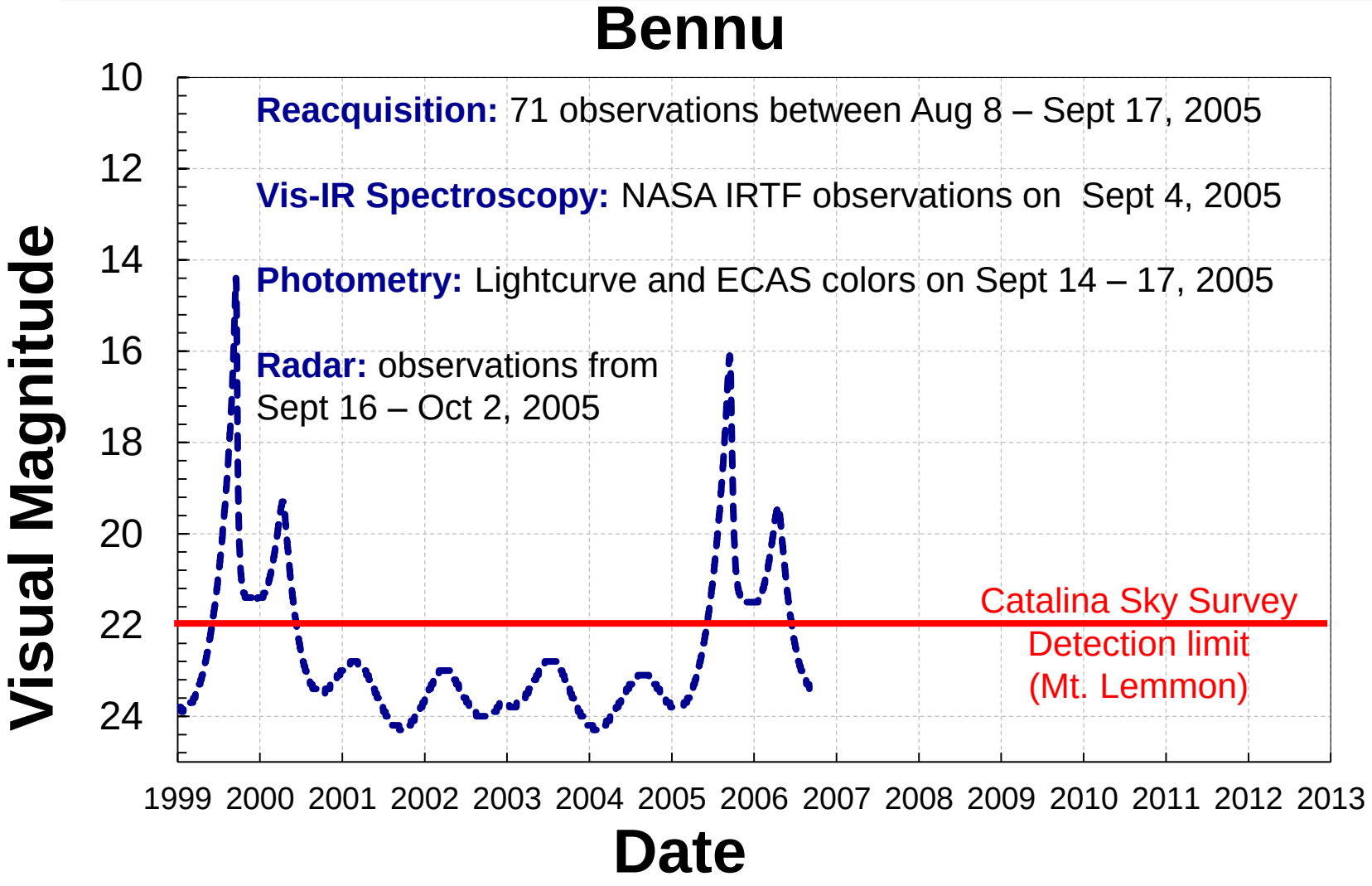
Note: Bennu inclination = 6.03˚


Apparent Magnitude: 23.8
Earth
RQ36
1 Jan 1999 04:00:00.000

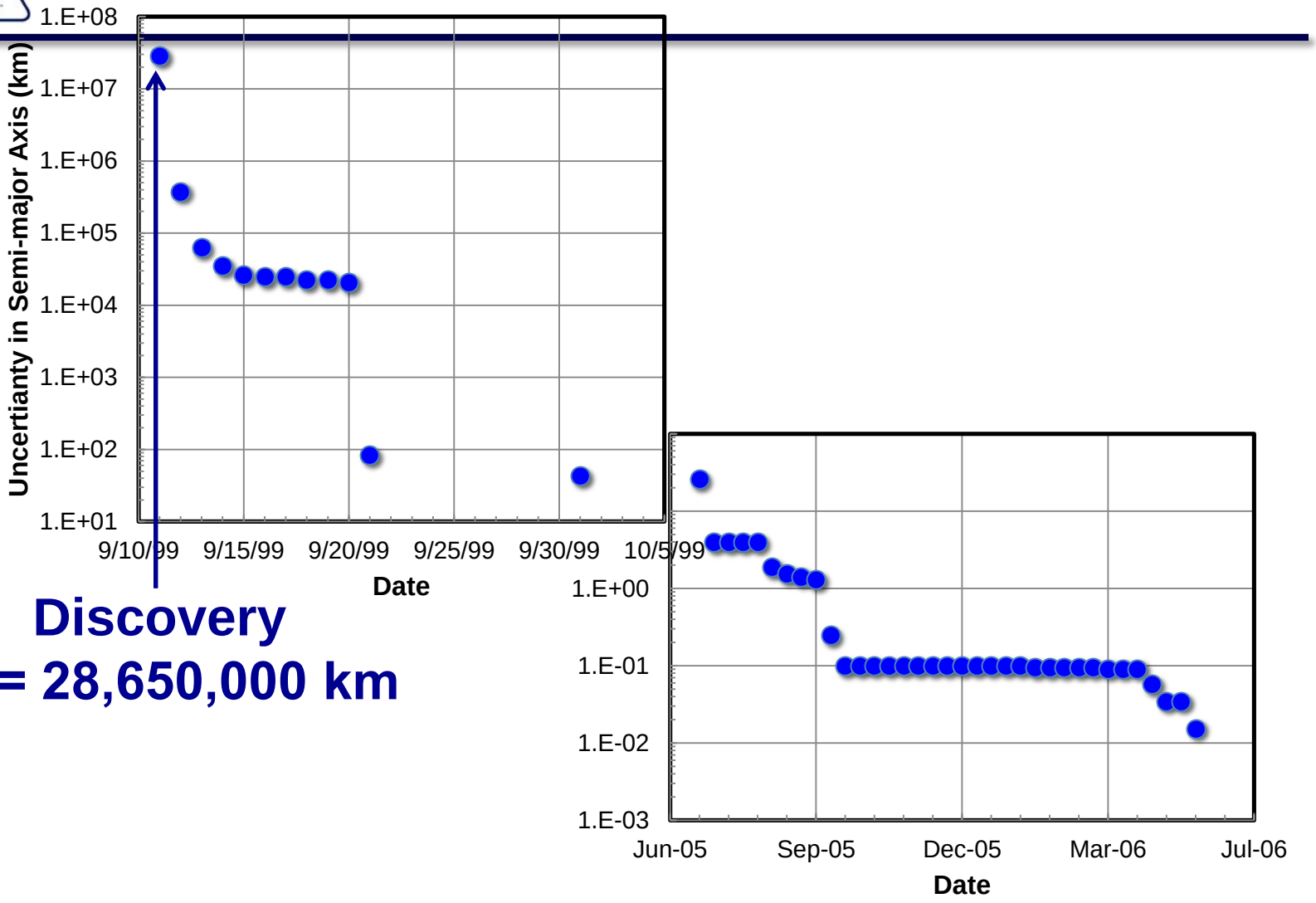
Initial Characterization: 1999



Reacquisition and Physical Characterization: 2005



A Quality Orbit Requires Extensive Observation



Discovery

Δa = 28,650,000 km

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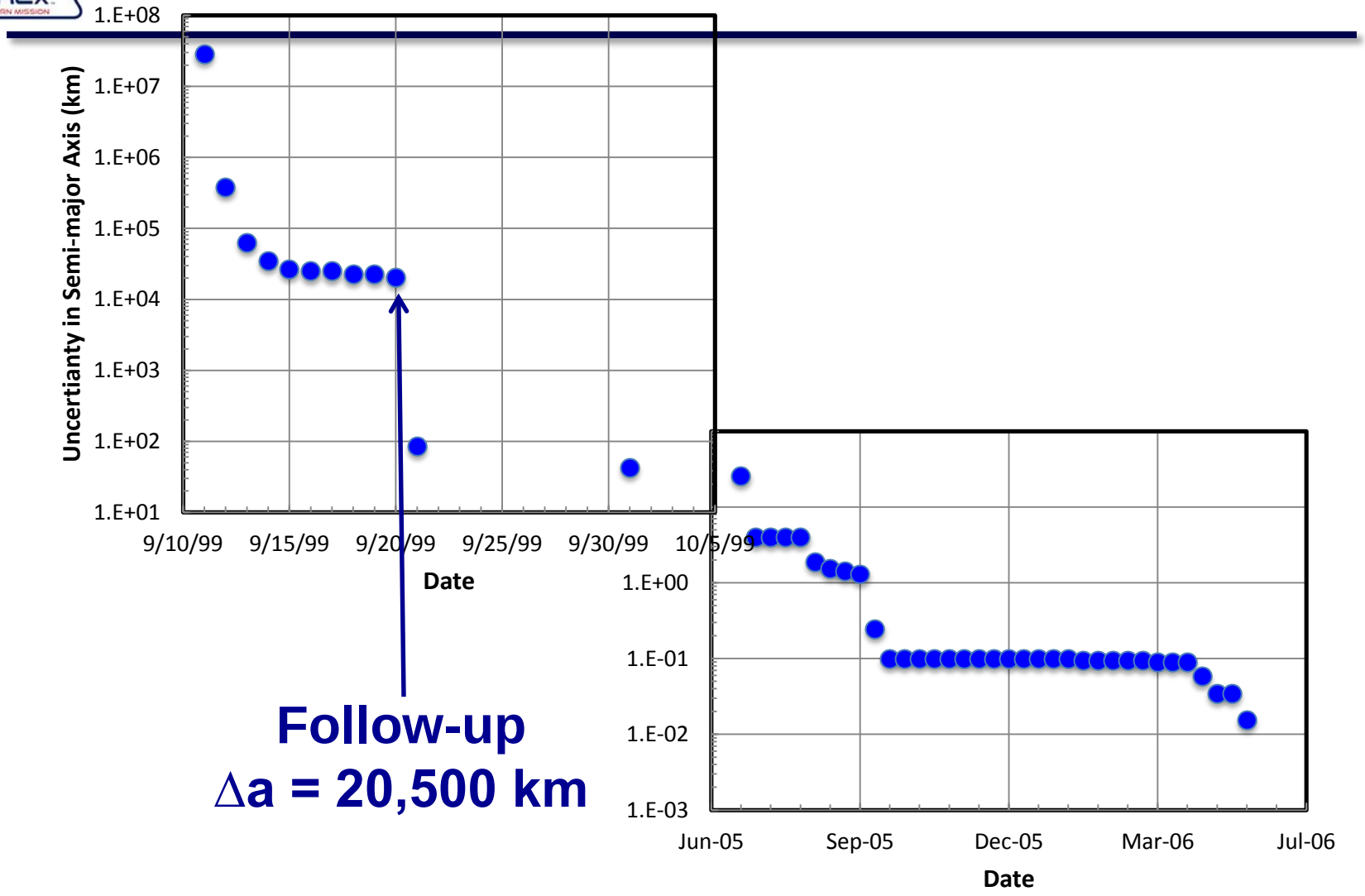

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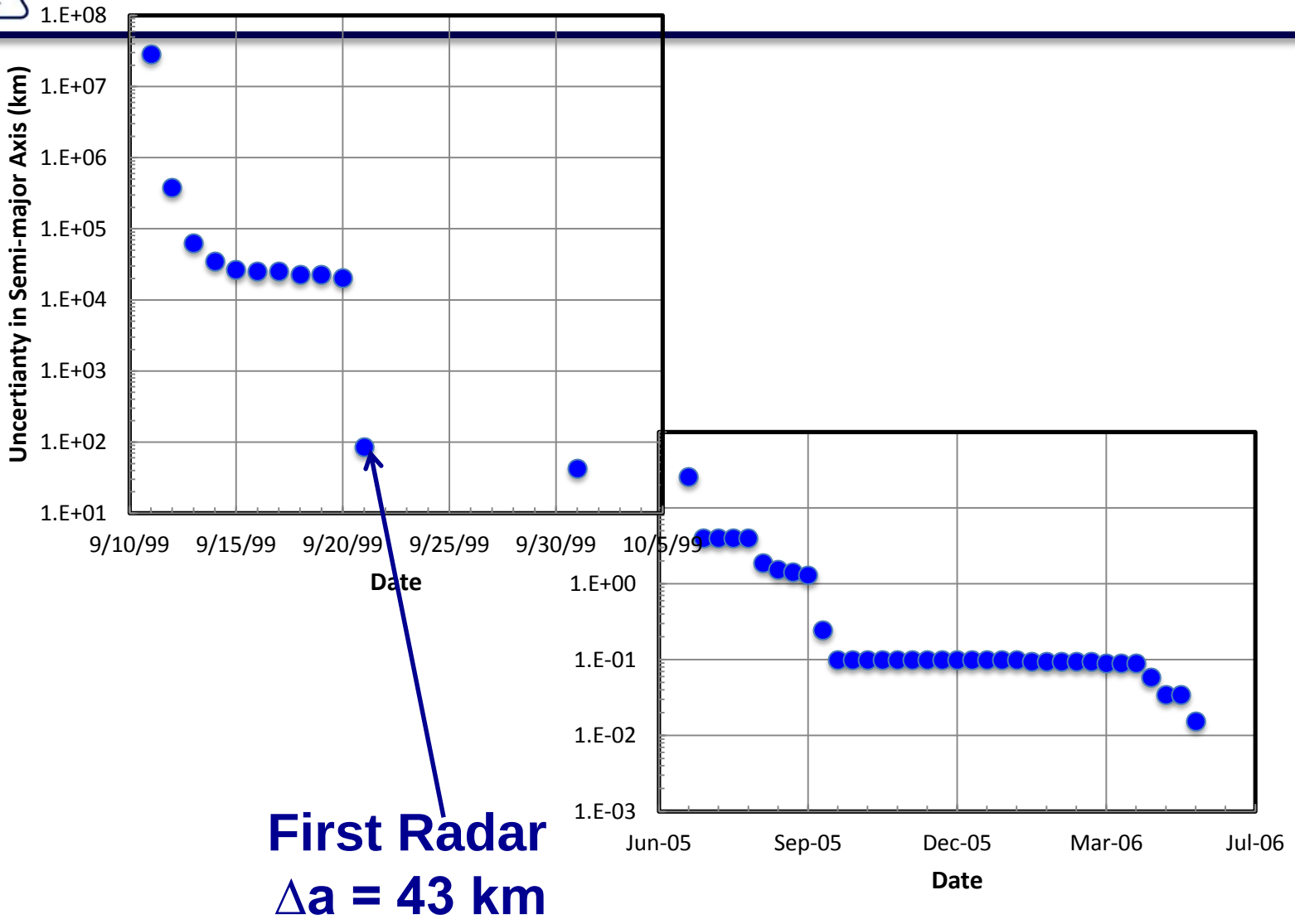

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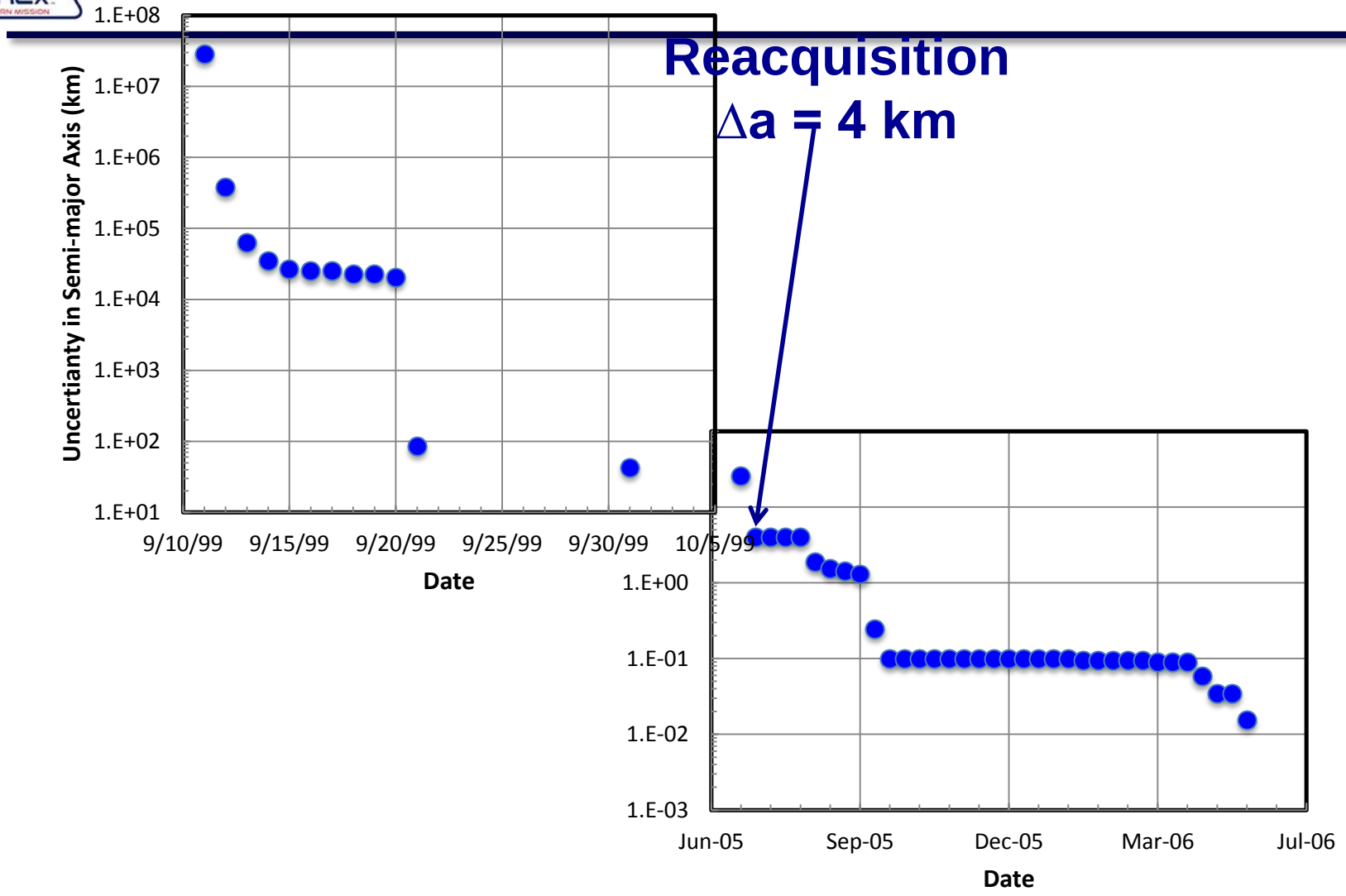

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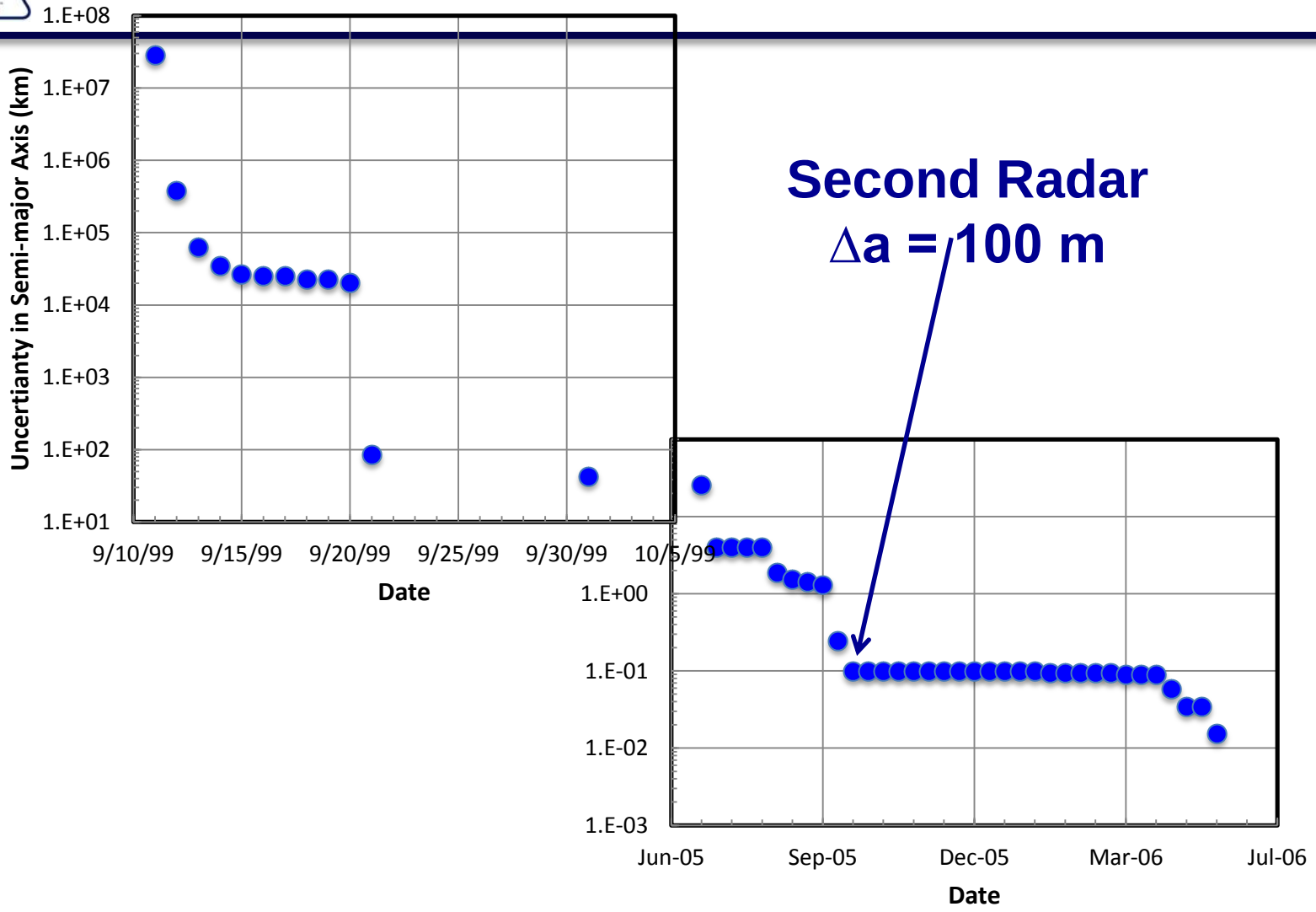

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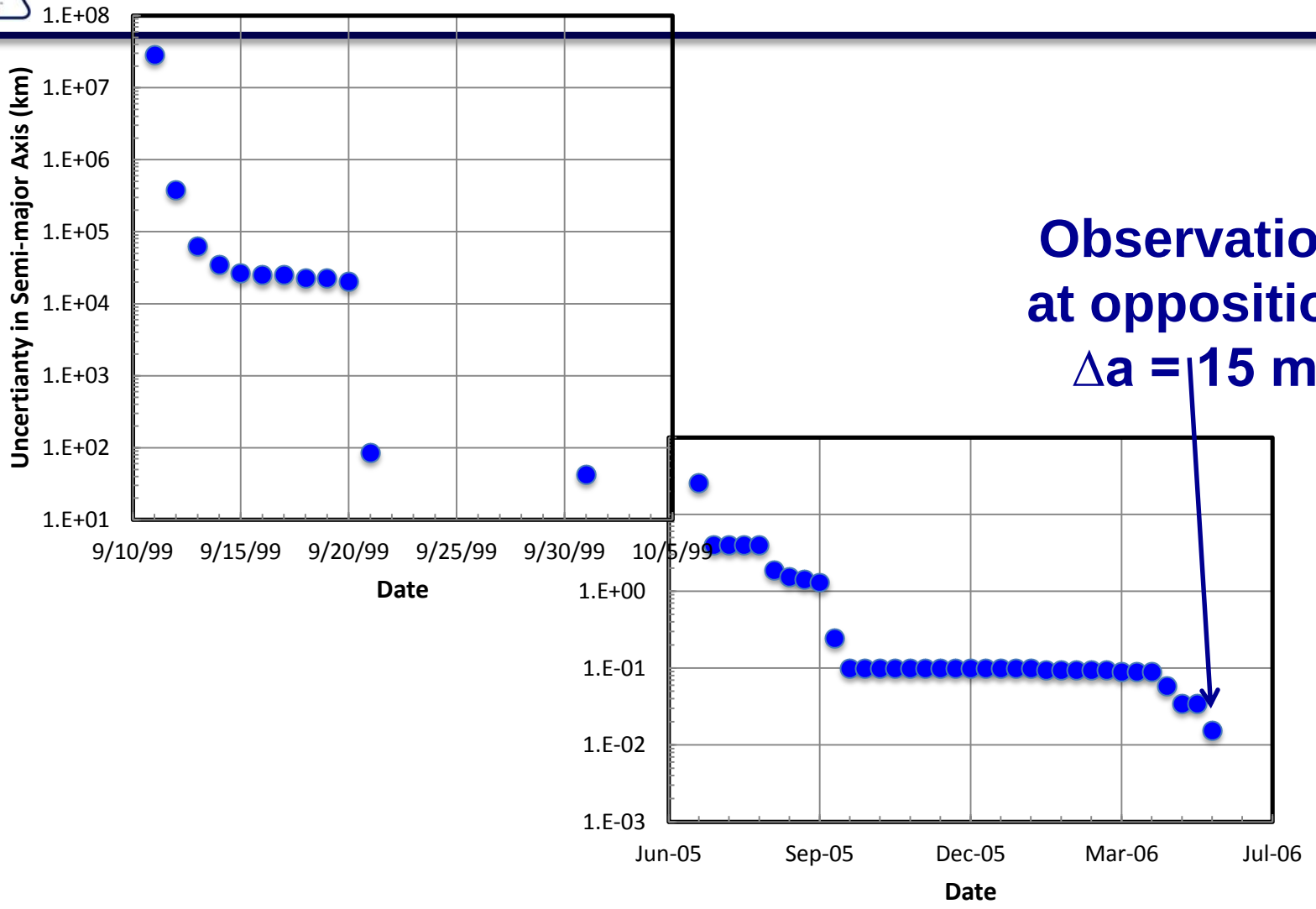


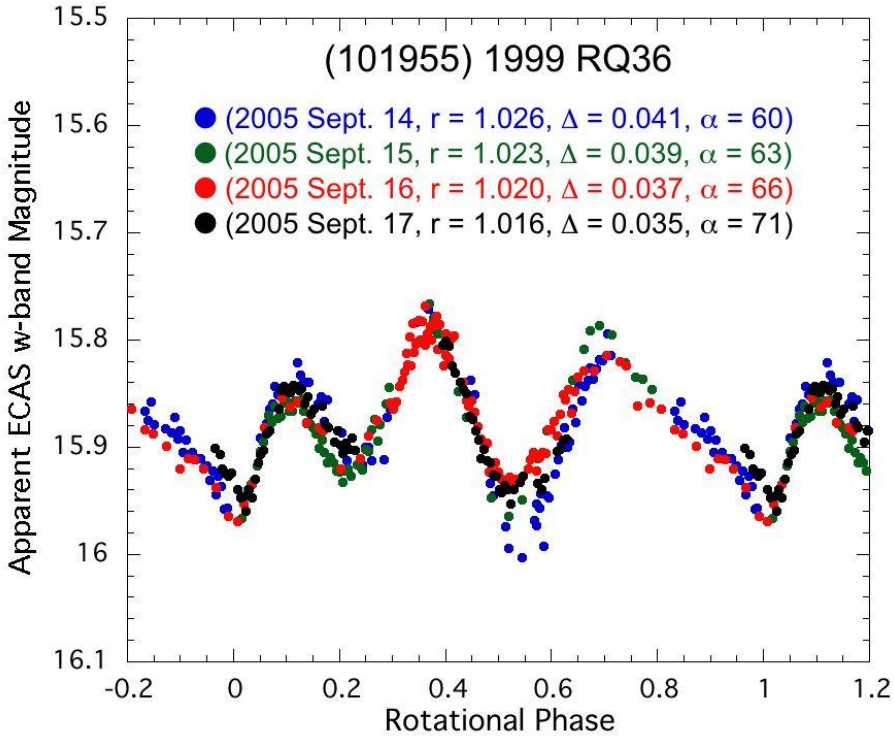
Observation at opposition
$\Delta a = 15$ m

Mission Design Constraints 2: Size and Rotation

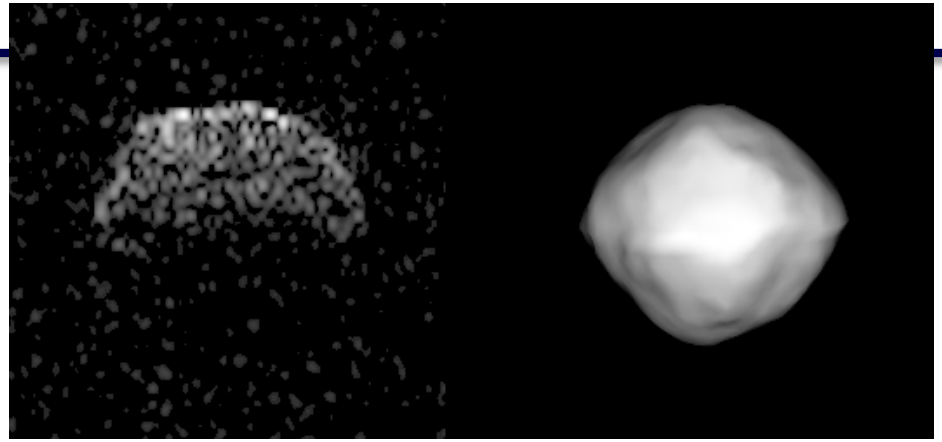
- OSIRIS-REx must be able match the rotational rate of the target, achieving a spacecraft attitude where we “hover” over the sampling site
- This constraint translates into a limit on the rotation period of the asteroid
- The majority of asteroids <200 m are rapid rotators, with rotation periods as short as one minute
- Rapid rotation greatly increase the risk during proximity operations
- Centrifugal forces have also likely ejected most regolith particles from the surface

The Rotation State is Well Constrained from Lightcurve Measurements

- Achieved a frequency of observations which resulted in a lightcurve covering a full rotation cycle each night for 4 nights of observing
- Lightcurve reveals a rotation period of 4.297 □ 0.002 hours
- The low amplitude is consistent with the rotation of a nearly spherical body



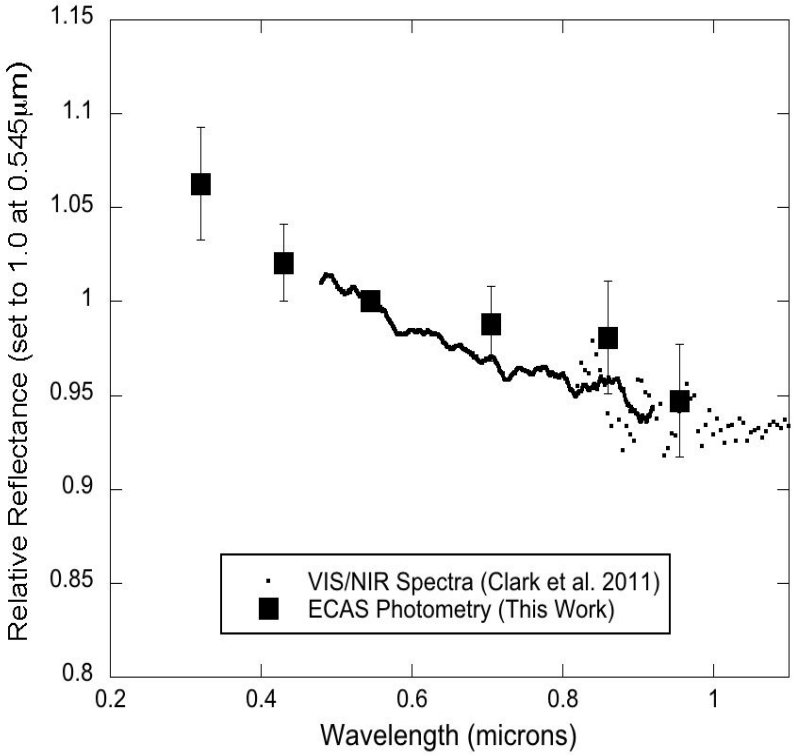
Radar is a Uniquely Powerful Source of Information about Asteroid Physical Properties



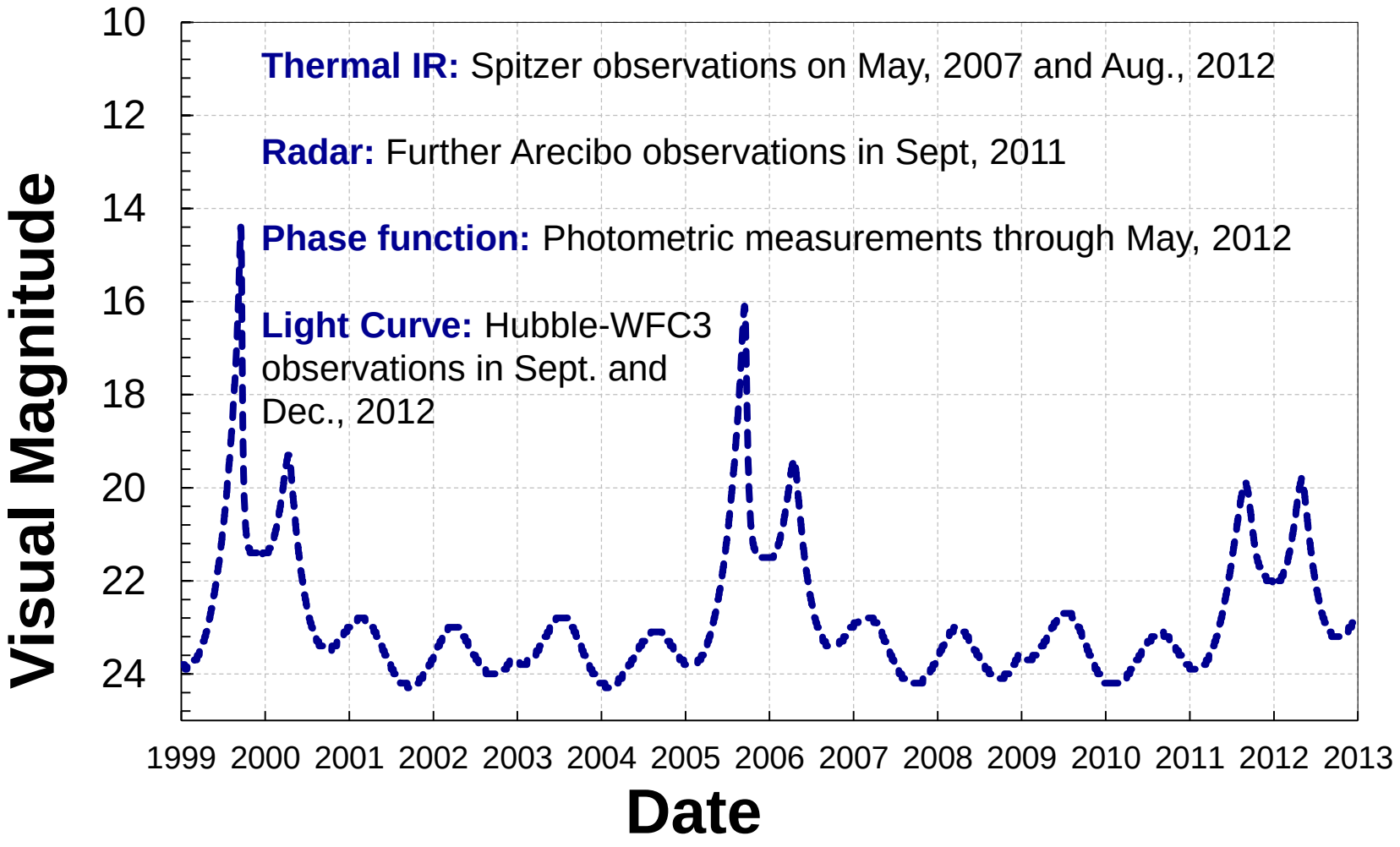
- Measurements of the distribution of range and radial velocity provided two-dimensional images with spatial resolution of 7.5 m
- Images used to construct a geologically detailed three-dimensional model and define the rotation state
  - **Size =** 492-m (±20 m, mean diameter)
  - **Shape =** spheroidal “spinning top”
  - **Rotation state =** 4.3 hr period, 180º obliquity
- Radar also probed the near-surface bulk density ($1.7\ g\ cm^{-3}$) and structural scales larger than a few centimeters

Mission Design Constraints 3: Composition

- OSIRIS-REx seeks to return samples from a Carbonaceous Asteroid
- Visible and near-infrared spectroscopy shows that Bennu is a B-type asteroid
  - Linear, featureless spectrum with bluish to neutral slope
- ECAS color-photometry measurements confirm the B-type classification
- B-type contains many significant objects,
  - (2) Pallas – the second largest main-belt asteroid
  - (24) Themis – thought to have H_2O ice and organic material on its surface
- Near-IR thermal emission starting at 2 μm suggest an albedo of 3-5%
- The hydrated CI and CM carbonaceous chondrite meteorites are the most likely analogs

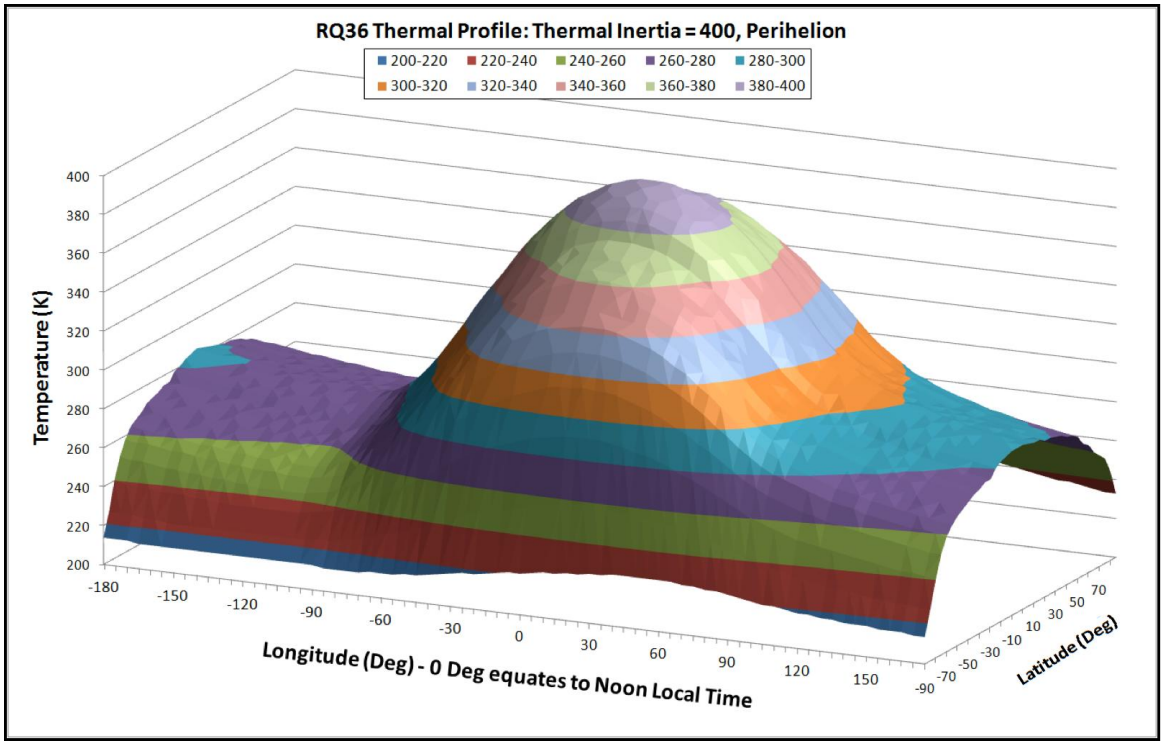


Final Campaign: 2007 - 2012



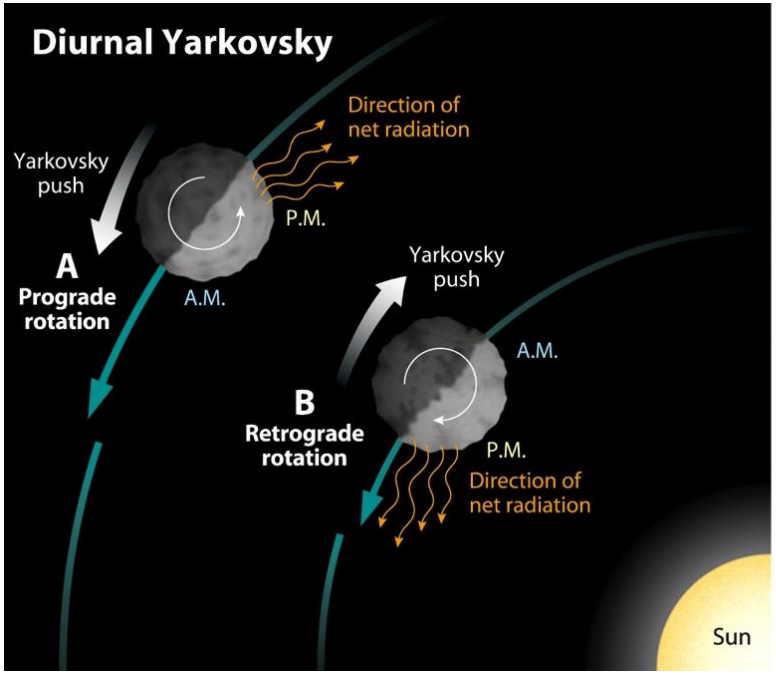
Thermal IR Observations Provide Critical Knowledge for Spacecraft Design

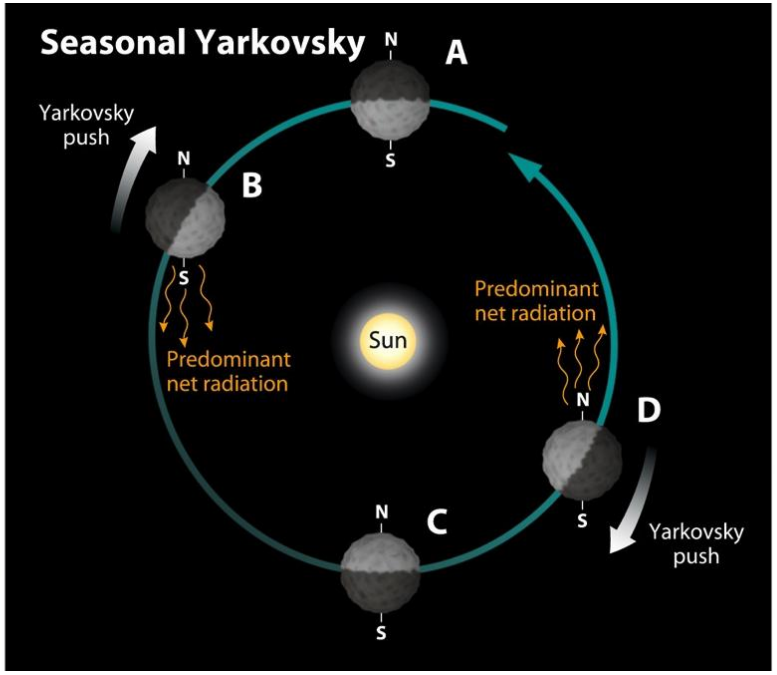
- Spitzer observations yield a very low visible geometric albedo of 4.6 ± 0.5%
- Combining the asteroid shape, rotation state, ephemeris, and albedo yields a global temperature model
- Thermal IR observations provide ground truth for this model
- Direct input into the mission Environmental Requirements Document



An OSIRIS-REx First: Measuring a Planetary Mass Using Radar and Infrared Astronomy

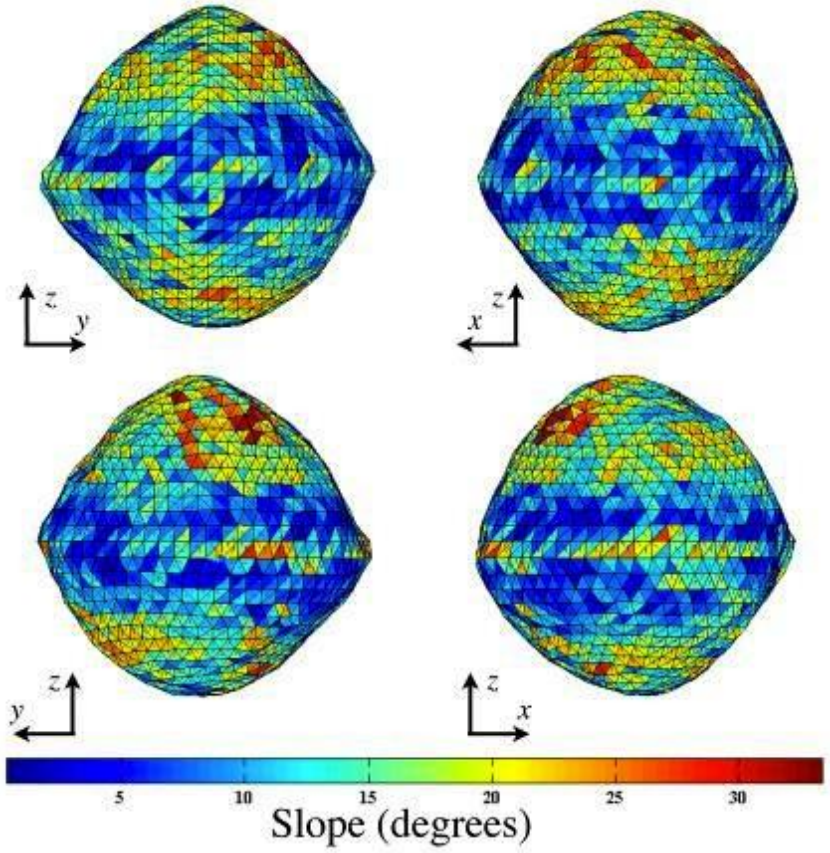
- The three precise series of radar ranging position measurements over two synodic periods allows us to measure the Yarkovsky acceleration
- The asteroid has deviated from its gravity-ruled orbit by 160 kilometers in just 12 years
- This result, when combined with the thermal inertia and the shape model, constrains the mass to 7.8 ($\pm$0.9) x 10^{10} kg





S&T ILLUSTRATION (SOURCE: RICHARD P. BINZEL)

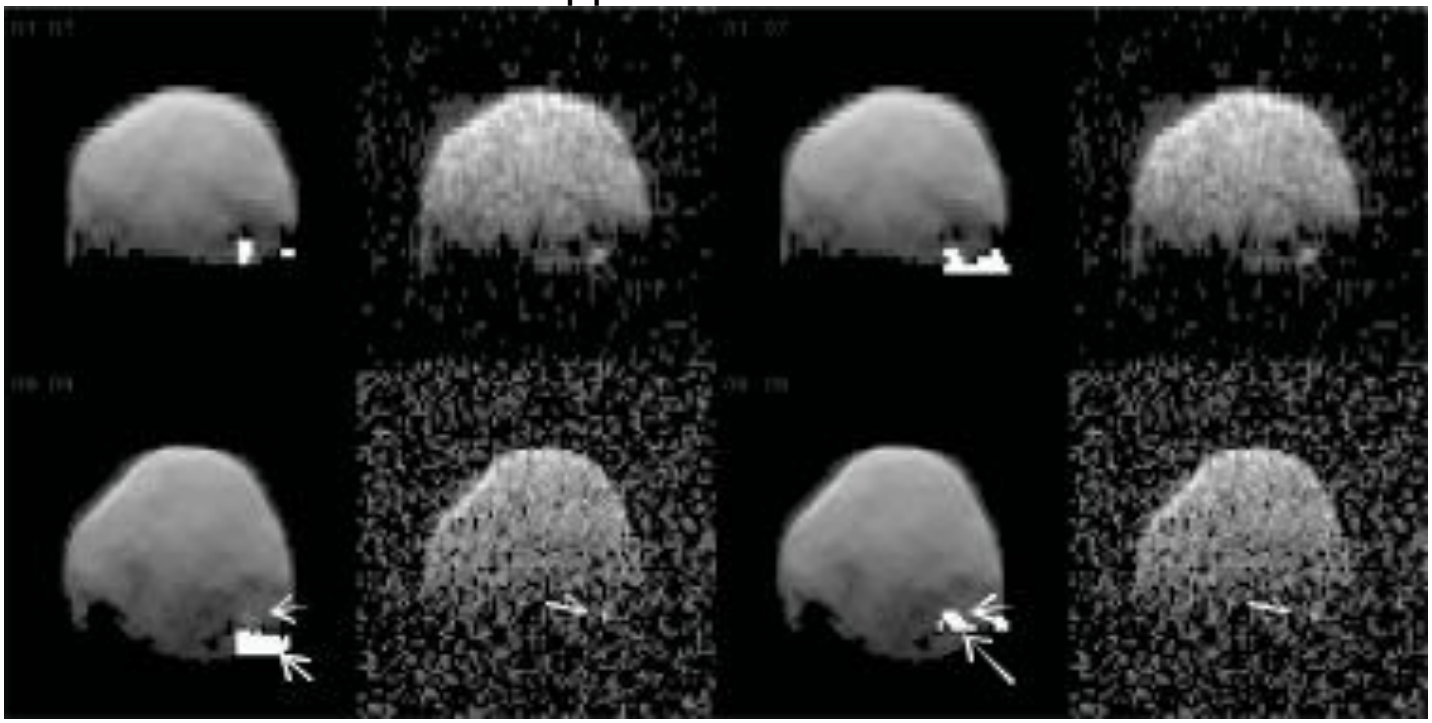
KNOWLEDGE OF ASTEROID MASS SUBSTANTIALLY ENHANCES MISSION PLANNING



- Mass and shape constrain the bulk density to 1260±70 kg/m^3
- They are combined to produce a global gravity-field model that facilitates orbital stability analysis
- Combining the gravity-field model and rotation state yields global surface-slope distributions and accelerations
- All this information is critical to evaluating our ability to safely deliver the spacecraft to the asteroid surface and maintain nominal attitude during sampling

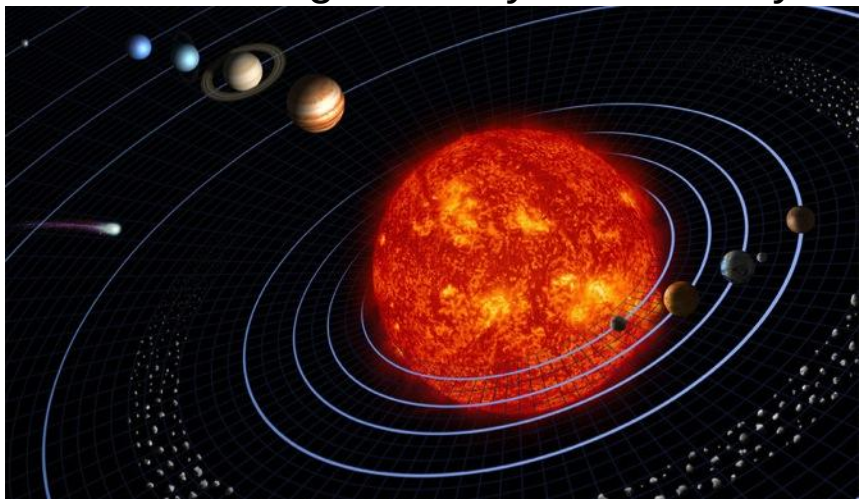
Surface Properties are Consistent with Abundant Loose Regolith Available for Sampling

- Radar polarization shows transition to a “rough” surface at a scale smaller than the shortest (3.5-cm) wavelength
- The thermal inertia (310 ± 70 J m^2 K^{-1}) is below the bedrock value – regolith grains are significantly smaller than the scale of the skin depth (~1 cm)
- The asteroid’s shape, dynamic state, and geomorphology provide additional evidence for the presence of loose particulate regolith
- There is one ~10–m boulder apparent on the surface



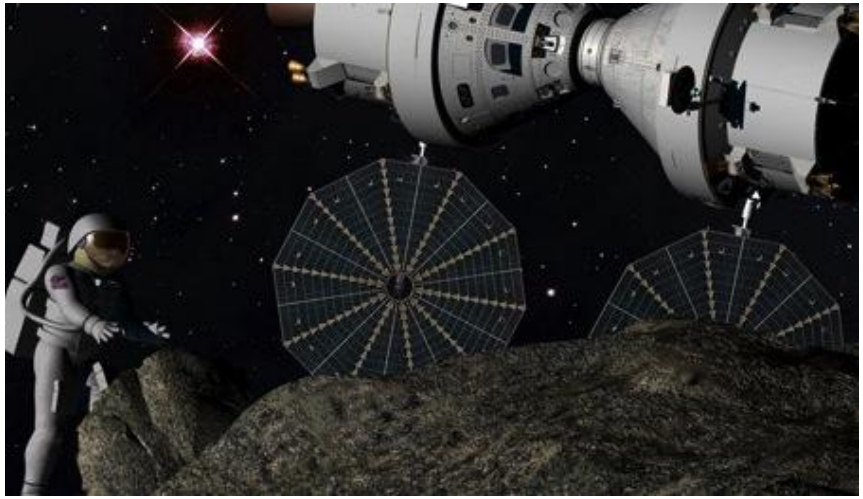
OSIRIS-REx:
Exploring our Past, Securing our Future

Revealing Solar System History



Mitigating Impact Hazards

Enabling Human Exploration

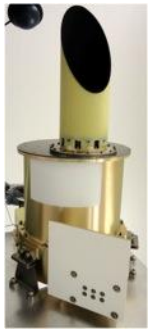


Developing a Space Economy

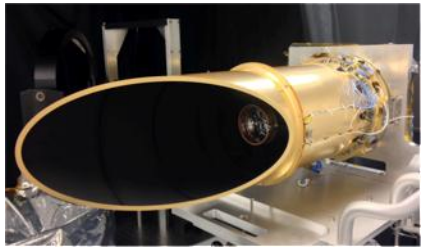
Our Payload Performs Extensive Characterization at Global and Sample-site-specific Scales

SamCam images the sample site, documents sample acquisition, and images TAGSAM to evaluate sampling success

OCAMS (UA)



MapCam performs filter photometry, maps the surface, and images the sample site



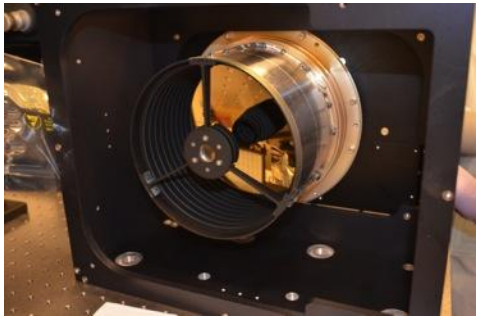
PolyCam acquires Bennu from >500K-km range, performs star-field OpNav, and performs high-resolution imaging of the surface

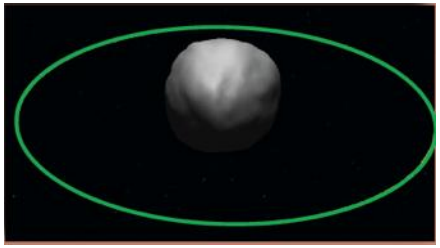
OLA (CSA) provides ranging data out to 7 km and maps the asteroid shape and surface topography

SPACECRAFT-BASED REMOTE SENSING PROVIDES GROUND TRUTH FOR OUR ASTRONOMICAL DATA

OVIRS (GSFC) maps the reflectance albedo and spectral properties from 0.4 – 4.3 µm

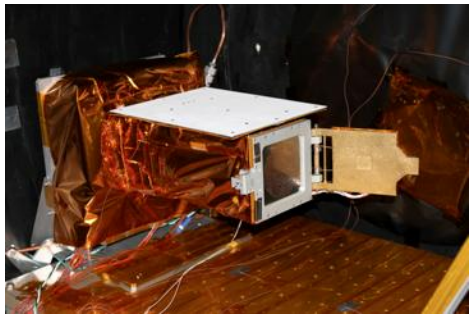
OTES (ASU) maps the thermal flux and spectral properties from 5 – 50 µm





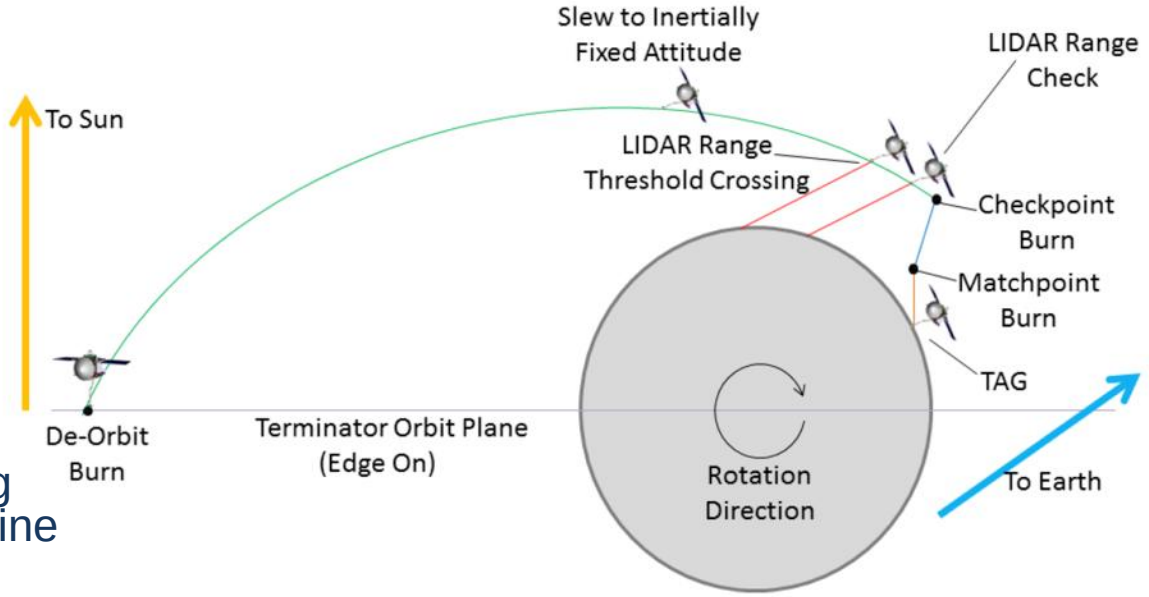
Radio Science (CU) reveals the mass, gravity field, internal structure, and surface acceleration distribution

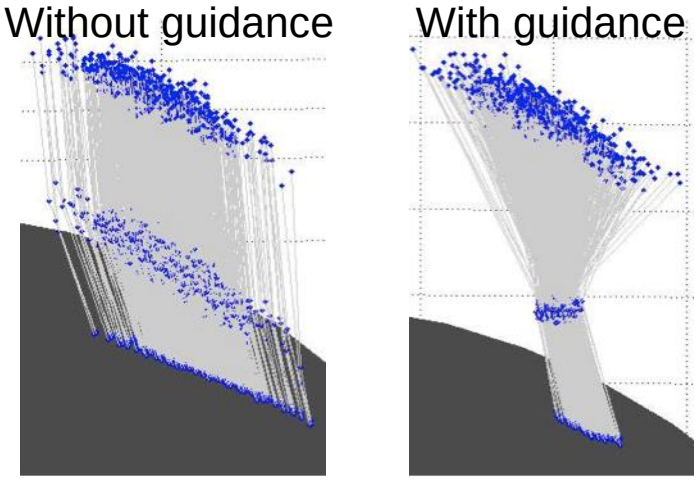
REXIS (MIT) trains the next generation of scientists and engineers and maps the elemental abundances of the asteroid surface



OSIRIS-REx is Developing Critical Technologies for Exploring Near-Earth Asteroids

- Astronomical characterization
- Measurement of global characteristics
- Detailed characterization of an asteroid surface
- Mission-critical data processing and analysis on a tactical timeline
- Accurate navigation in microgravity
- Delivery to a specific location on the asteroid surface
- Successful contact and acquisition of material from surface
- Safe return of the sample to Earth





Join the Mission on the Web!

Social Media Activities

- Website: asteroidmission.org
- PI blog: dslauretta.com
- facebook.com/OSIRISREx
- twitter.com/OSIRISREx
- YouTube/osirisrex
- instagram.com/osiris_rex