OSIRIS-REx

OSIRIS-REx
Asteroid Sample Return Mission

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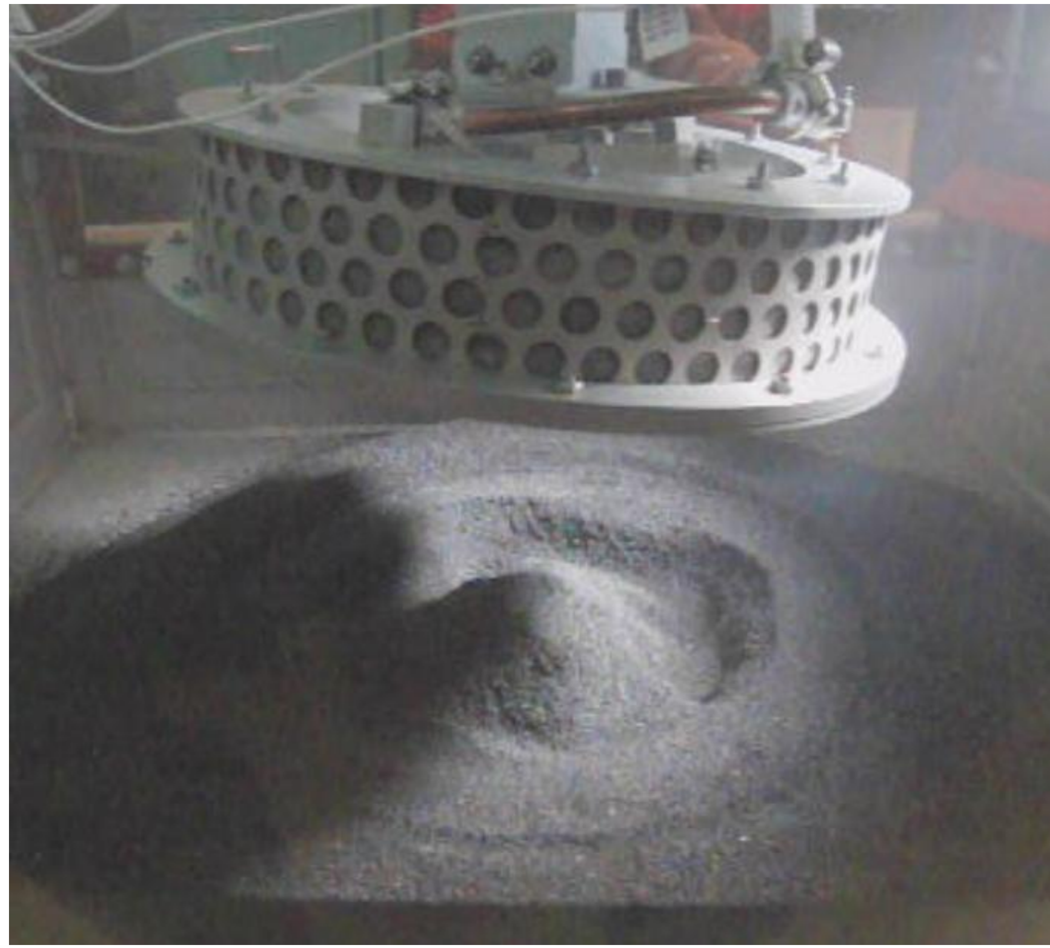
THE UNIVERSITY OF ARIZONA • NASA GODDARD SPACE FLIGHT CENTER • LOCKHEED MARTIN

What is OSIRIS-REx?

- **OSIRIS-REx** is a **Sample Return Mission** to asteroid 1999 RQ36
- The mission name is an acronym
  - **Origins**
    - provide pristine sample to reveal the origin of volatiles and organics that led to life on Earth
  - **Spectral Interpretation**
    - provide ground truth for ground-based and space based spectral observations of B-type carbonaceous asteroids
  - **Resource Identification**
    - identify carbonaceous asteroid resources that we might use in human exploration
  - **Security**
    - quantify the Yarkovsky Effect on a potentially hazardous asteroid, thus providing a tool to aid in securing the Earth from future asteroid impacts
  - **Regolith Explorer**
    - Explore the regolith at the sampling site *in situ* at scales down to sub-millimeter

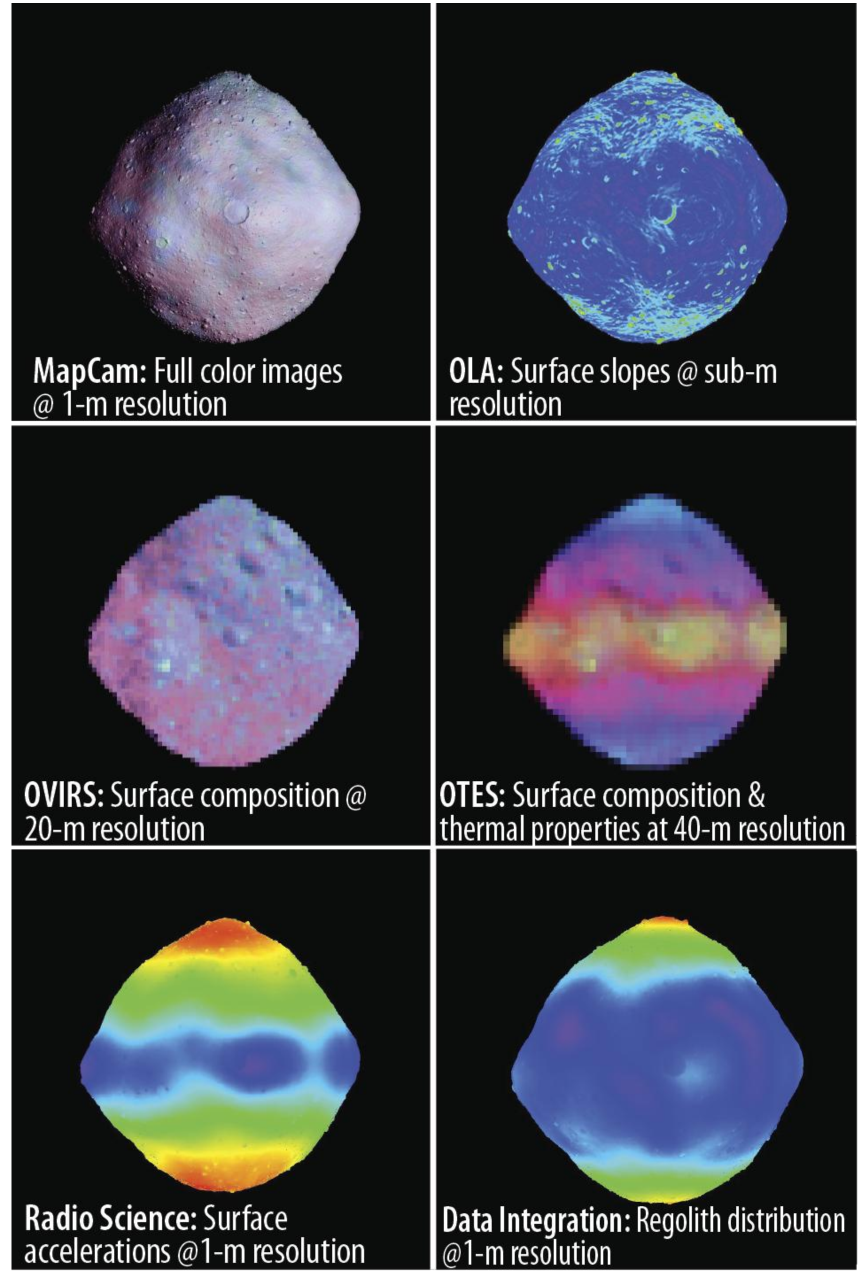
Objective 1

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



Objective 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



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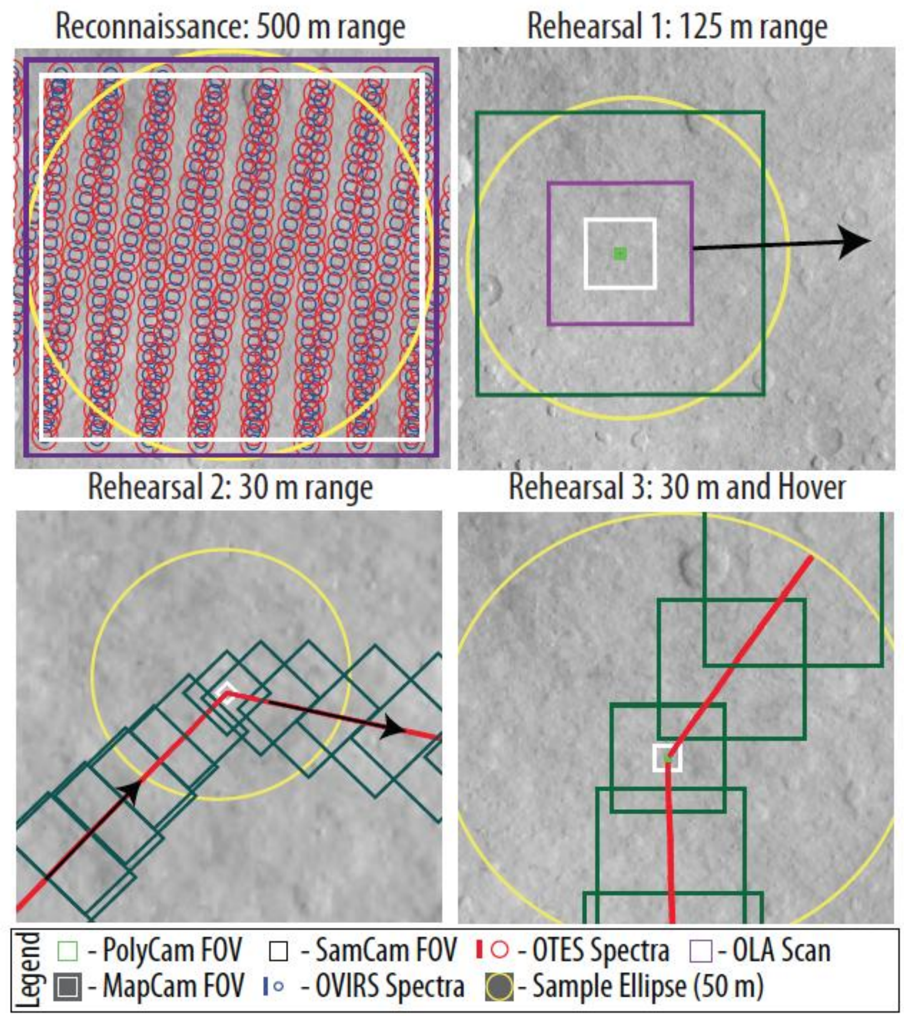
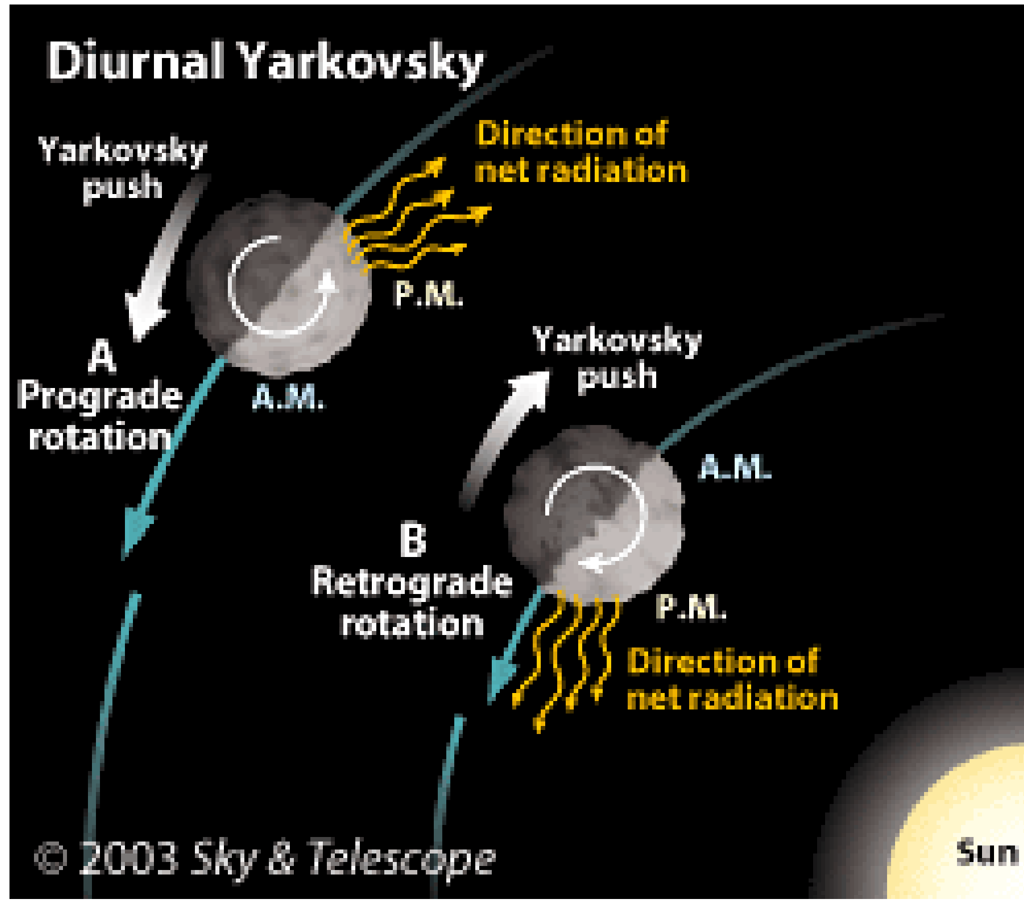
Objective 3

Document the texture, morphology, geochemistry, and spectral properties of the regolith at the sampling site in situ at *scales down to the sub-millimeter*



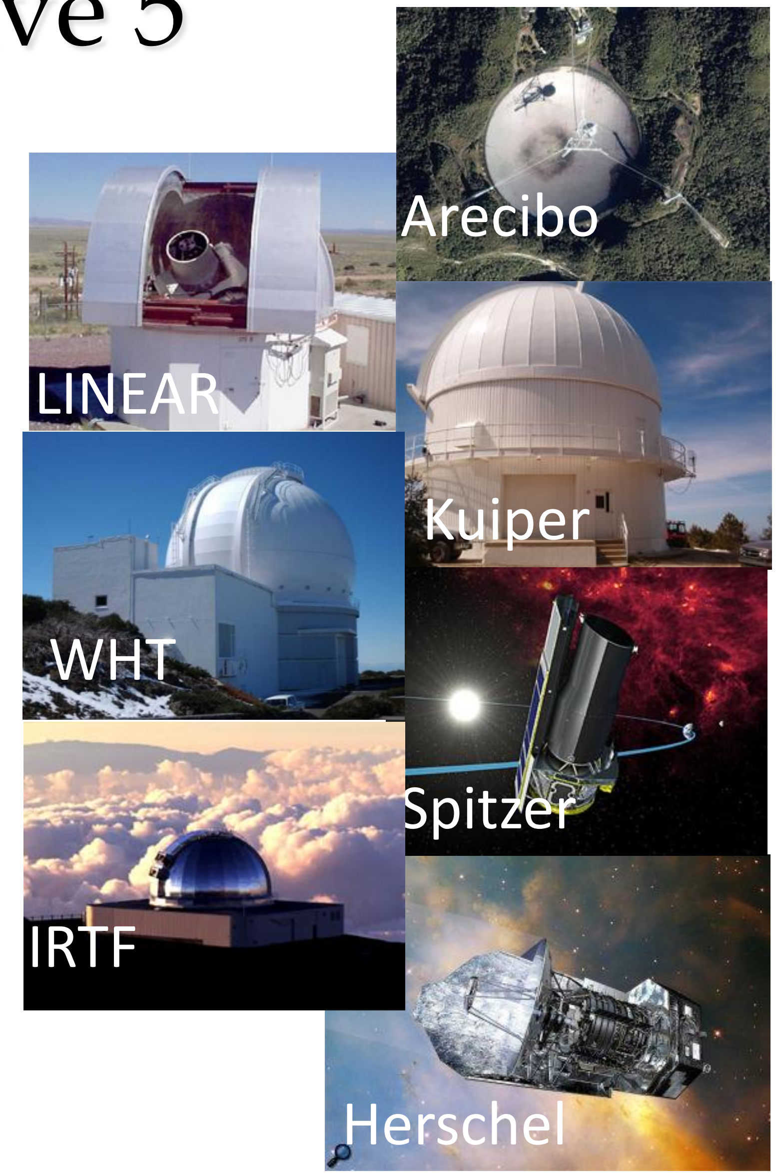
Objective 4

Measure the Yarkovsky effect on a potentially hazardous asteroid and constrain the asteroid properties that contribute to this effect

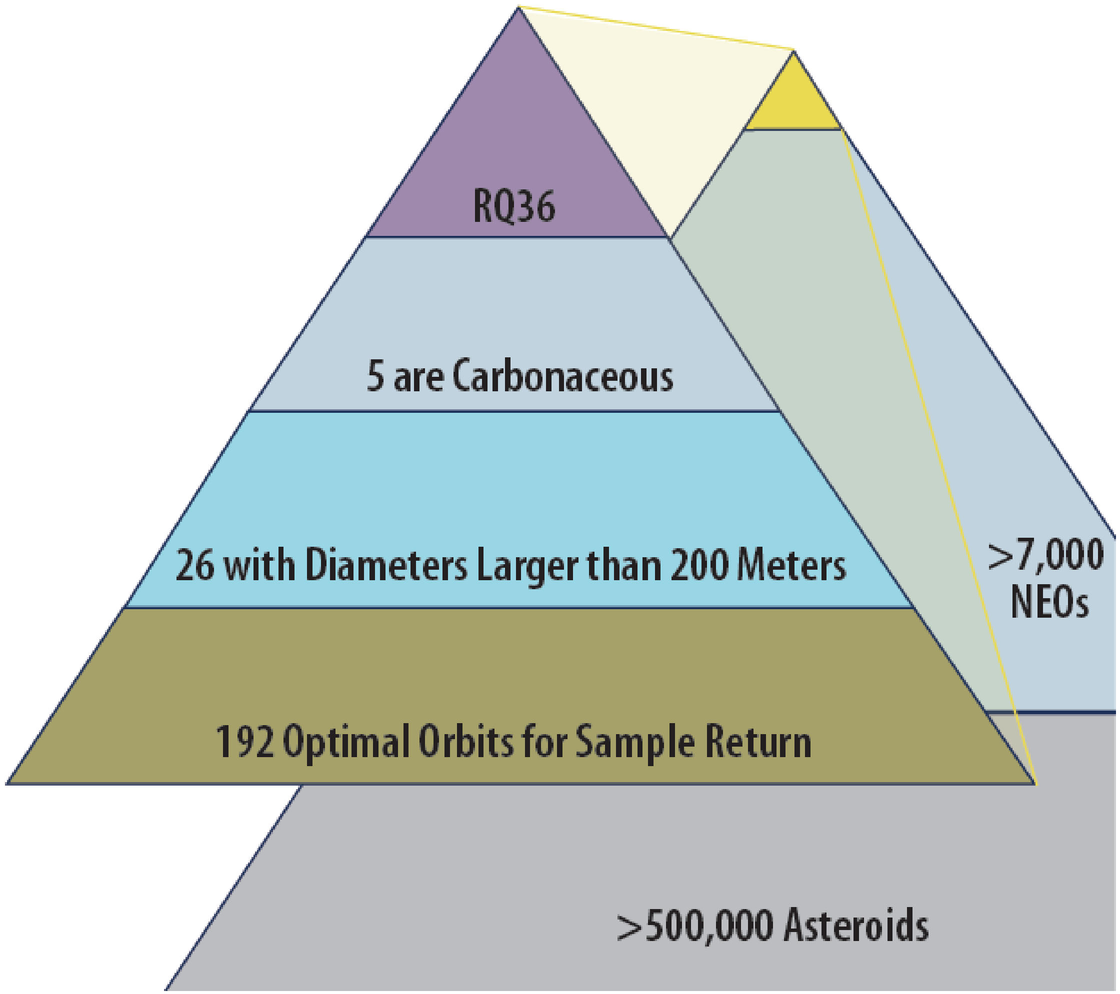


Objective 5

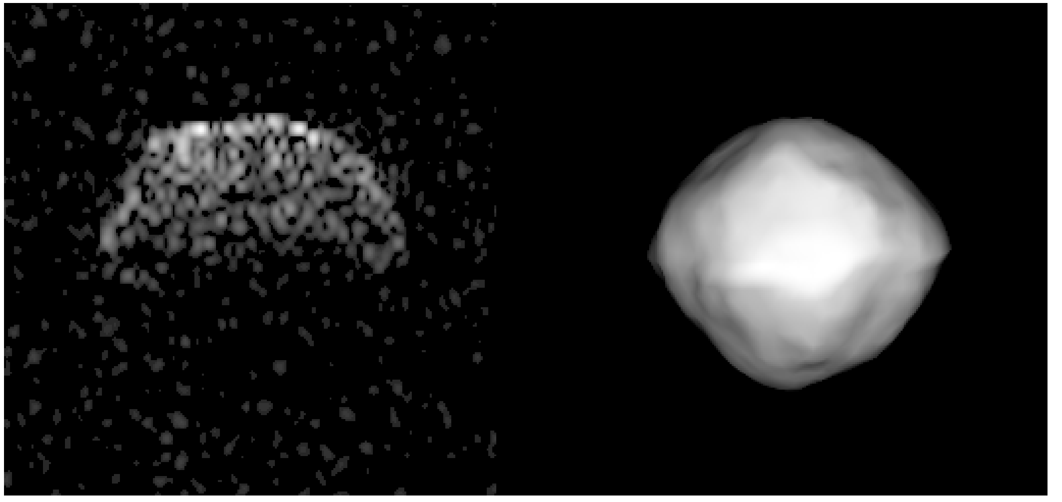
Characterize the integrated global properties of a primitive carbonaceous asteroid to allow for direct comparison with ground-based telescopic data of the entire asteroid population



1999 RQ36 Rises to the Top of the Asteroid Charts



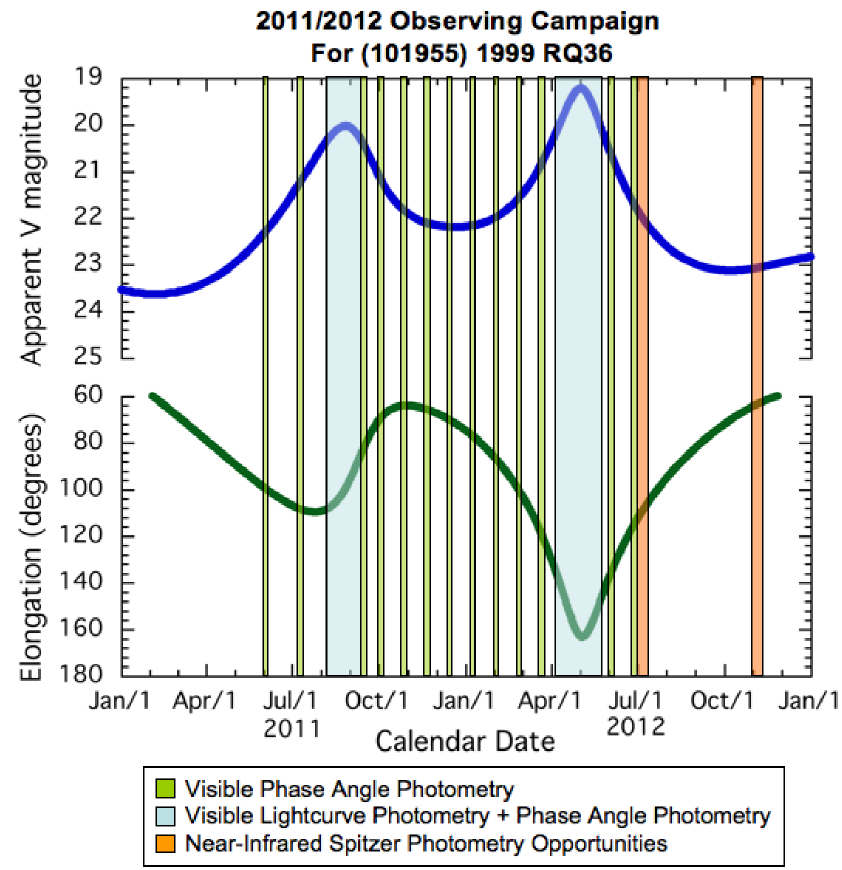
ASTEROID 1999 RQ36
IS AN EXCELLENT SAMPLE RETURN TARGET



- It provides for the most exciting science, with a spectral signature suggesting a **carbon- and volatile-rich surface**
- It is primitive B-class carbonaceous asteroid, a class of object **never before visited by a spacecraft**
- Its **size, shape, and rotation state are known** from extensive characterization by the Arecibo Planetary Radar System
- There is **abundant regolith** on the surface available for sampling
- Study of this **Potentially Hazardous Asteroid** is strategically important to NASA and Congress

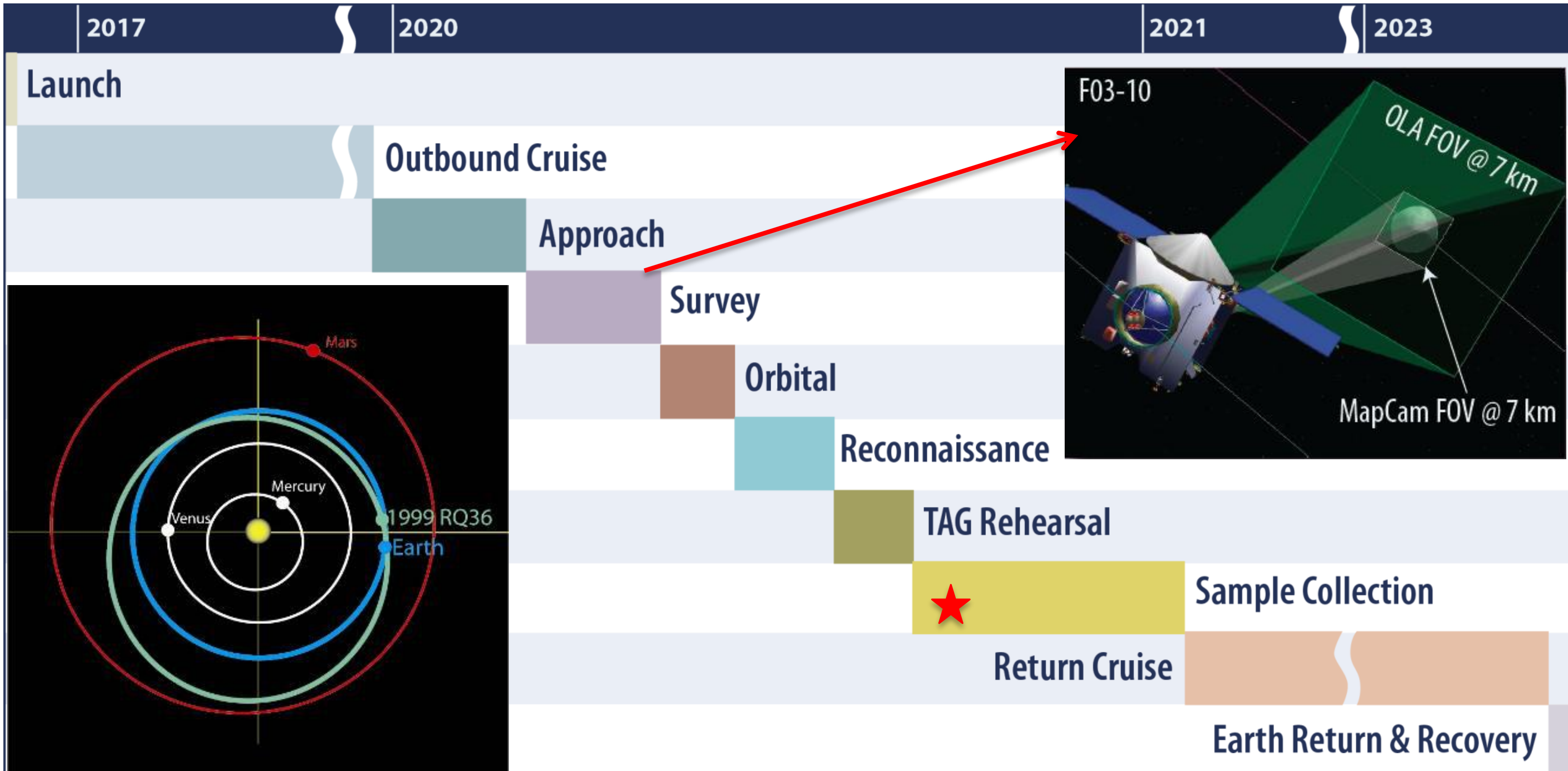
Science assumptions and constraints are documented and updated through our Design Reference Asteroid document

- Model of asteroid characteristics
- Currently contains 86 parameters
- Final observations and peer-review in October, 2012
- Most recent additions:
  - Revised and expanded surface temperature model
  - Escape velocity
  - Surface Tilt model
  - Expansion of analog documentation, including new 2005 YU55 results
  - Regolith properties
  - Re-reduction of ECAS colors, collection of new BVRI color data
  - Collection of new rotation period data



OSIRIS-REx is a Seven-Year Mission from Launch to Earth Return

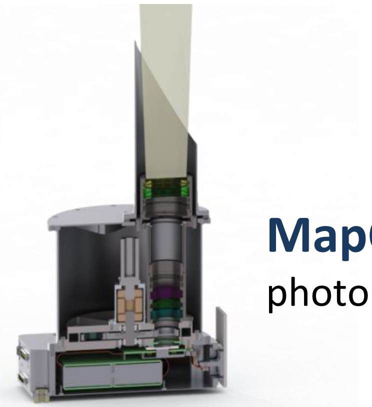
The Design Reference Mission (DRM) . . . "serves as the backbone for focusing the design effort" -- from NF-3 Step 1 evaluation



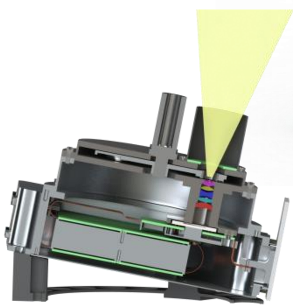
Science Requirements are Fulfilled by the Instrument Capabilities

OCAMS

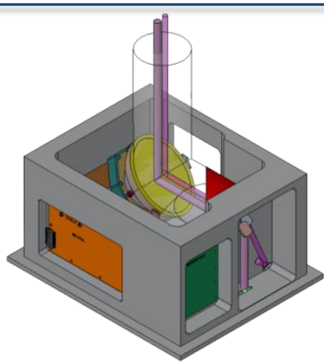
PolyCam acquires 1999 RQ36 from 500K km range, refines its ephemeris, and performs high-resolution imaging of the surface



MapCam provides narrow angle OpNav, performs filter photometry, maps the surface, and images the sample site

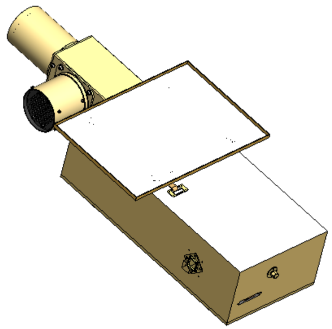


SamCam provides wide-angle OpNav, images the sample site, and documents sample acquisition



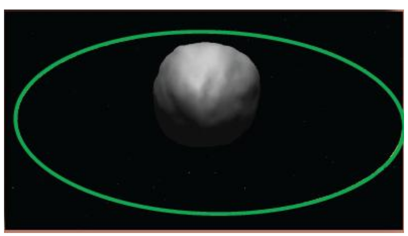
OLA provides ranging data out to 7 km and maps the shape and topography

Science Requirements Are Fulfilled by the Instrument Capabilities

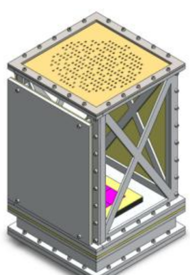


OVIRS maps the reflectance albedo and spectral properties from 0.4 – 4.3 µm

OTES maps the thermal flux and spectral properties from 4 – 50 µm



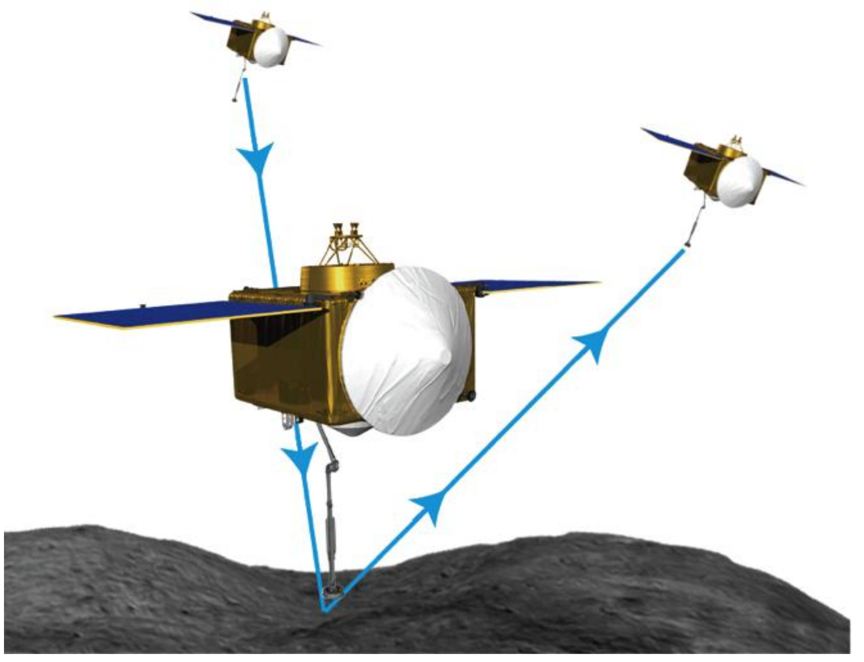
Radio Science reveals the mass, gravity field, internal structure, and surface acceleration distribution



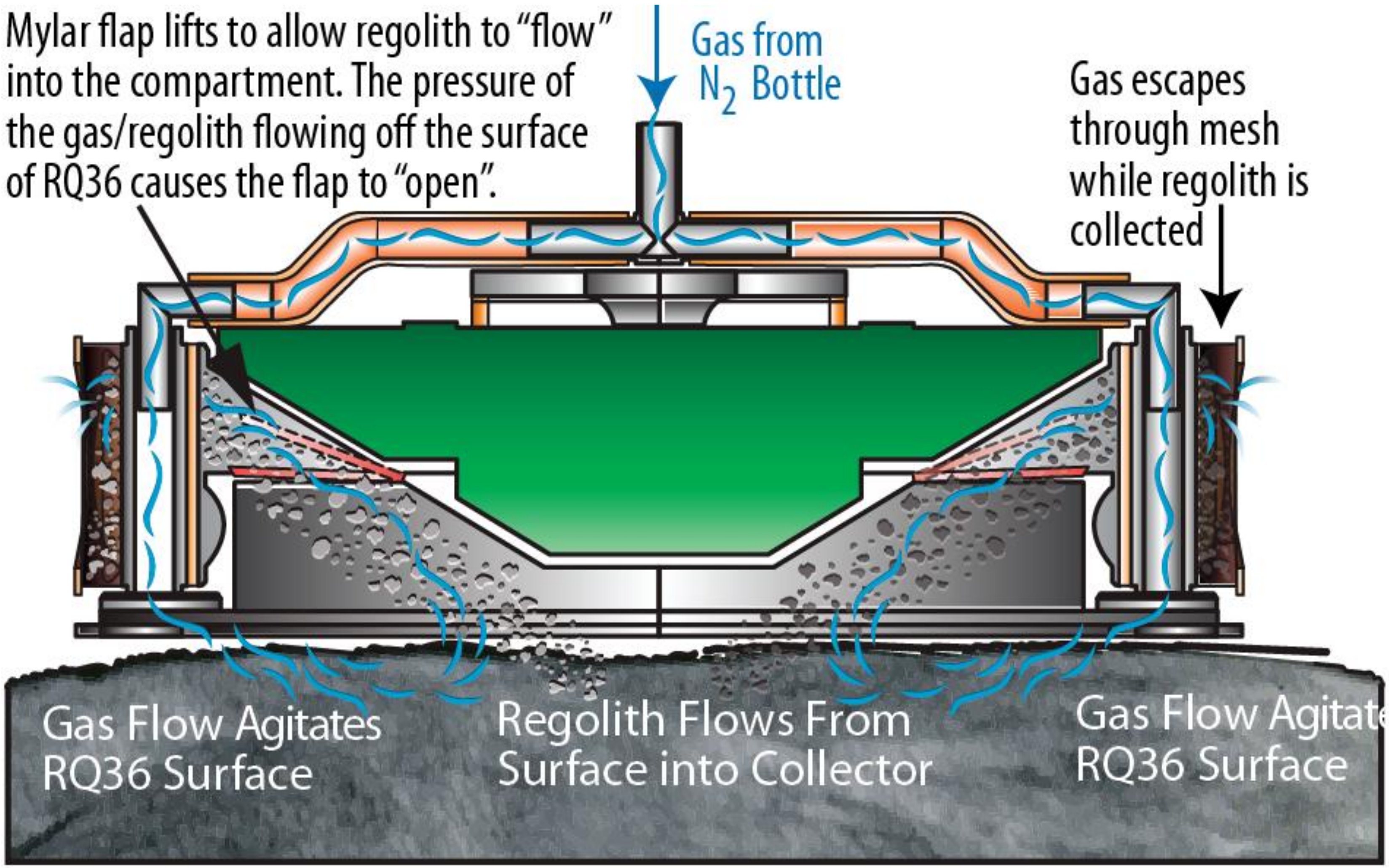
REXIS is a Student Collaboration Experiment that trains the next generation of scientists and engineers and maps the elemental abundances of the asteroid surface

Our Sample is Collected During a Five-Second Touch-and-Go Maneuver

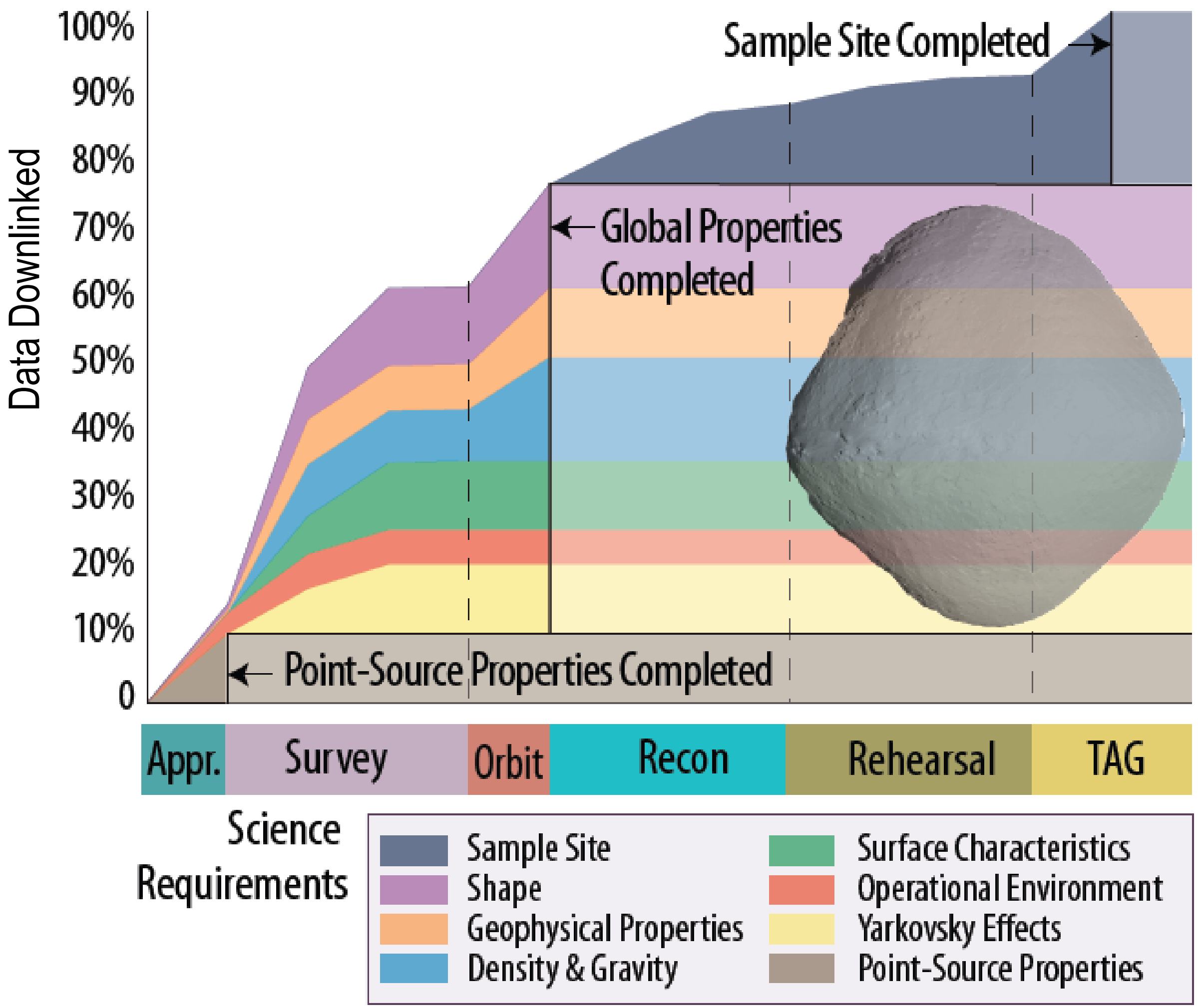
- Approach surface within vertical and horizontal speed constraints
- Surface contact is made with sampler head
- Compression of spring in the Touch-and-Go Sample Acquisition Mechanism (TAGSAM) arm
- Rebound from surface using stored energy in spring
- Fire thrusters to accelerate away from RQ36



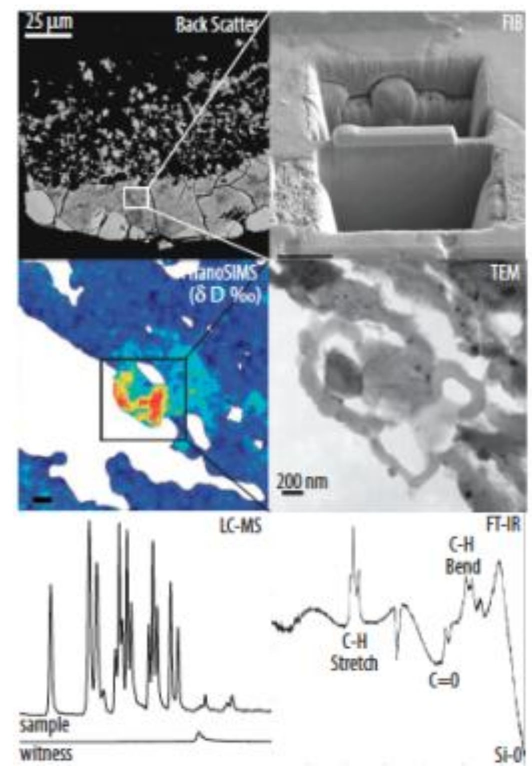
The OSIRIS-REx Sampling Strategy is Designed to Collect Abundant Pristine Regolith



WE STUDY 1999 RQ36 AT MULTIPLE SCALES



Sample Analysis



2023 and beyond →

Our Sampling Strategy is Designed to Collect Loose Regolith on the Asteroid Surface

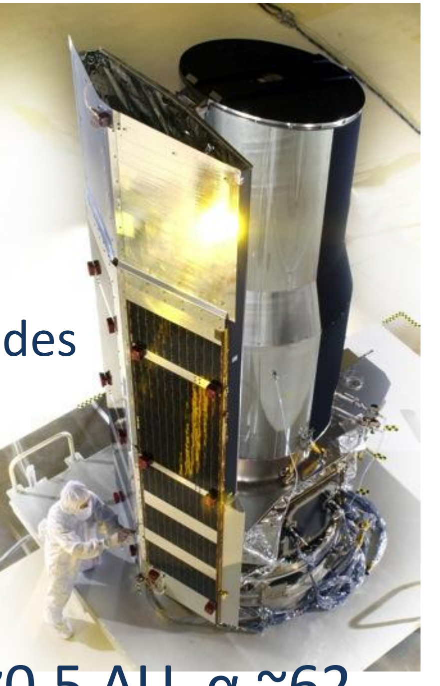
- Once contact is made, TAGSAM injects high-pressure N_2 gas into the regolith and fluidizes at least 150 g of sample into the bulk sample collector
- Simultaneously, the surface pads contact at least 26 cm^2 of the surface of RQ36 to acquire a surface sample.
- The bulk sample collector is capable of collecting particles up to 2-cm in the longest dimension
- The surface contact pads are designed to collect particles between 10 microns and 1 millimeter
- Both sampling strategies rely on the presence of loose regolith on the surface of 1999 RQ_{36}

There are Multiple Lines of Evidence for the Presence of Regolith on the Asteroid Surface

- 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
  - 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.

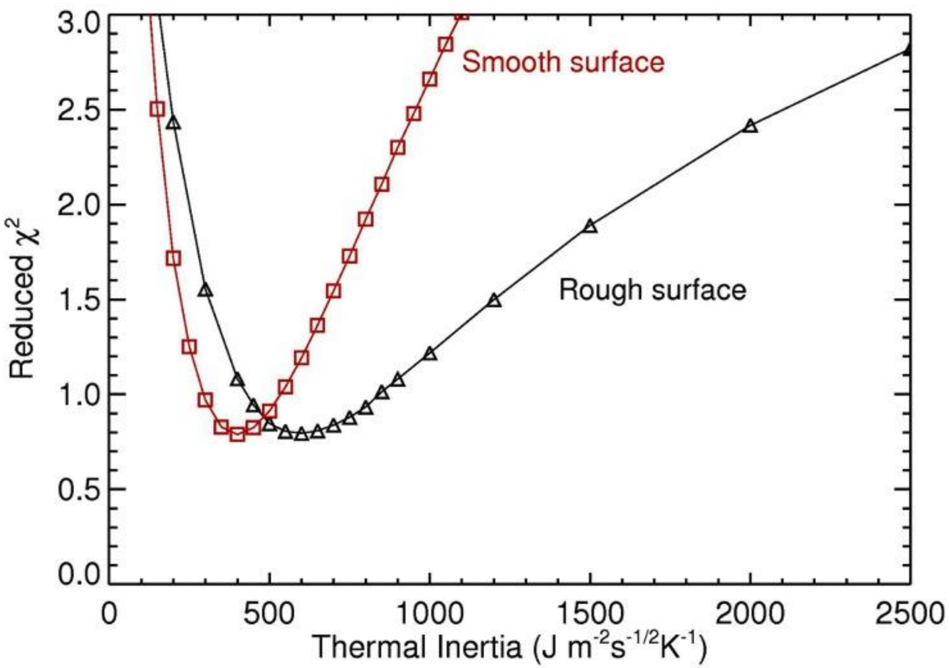
SPITZER OBSERVATIONAL CONDITIONS

- 85 cm telescope in heliocentric (Earth-trailing) orbit
- Used two instruments
  - IRS (InfraRed Spectrograph)
    - 5.2 to 38 µm spectra – 2 longitudes
    - 16 & 22 µm photometry – 10 longitudes
  - IRAC (InfraRed Array Camera)
    - 3.6, 4.5, 5.8, 8.0 µm photometry – 10 longitudes
- Match rotational phases of IRS & IRAC
  - SED from 3.6 to 22 µm for 10 longitudes
  - Search for surface heterogeneity
- All observations performed at r ~1.1 AU, Δ ~0.5 AU, α ~62 degrees



THERMOPHYSICAL MODELING PLACES CONSTRAINTS ON THE AVERAGE THERMAL INERTIA

- Using the well-known rotation period, spin pole, and shape allows us to constrain the thermal inertia (□)



- Inputs:
  - ΔLat (spin-pole) ~180°
  - D_{eff} ~ 525m
- Yield:
  - □ = 400 to 700, most likely ~600 (SI units)

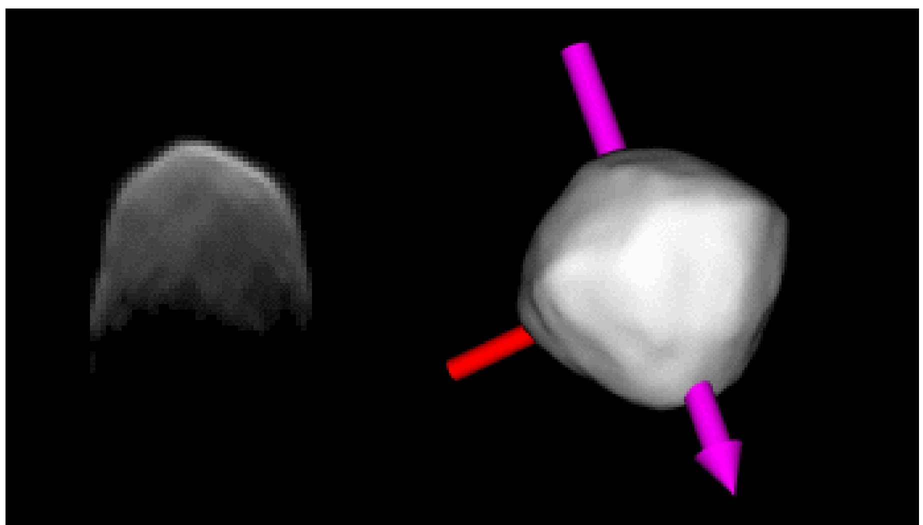
THERMAL INERTIA (?) CONSTRAINS THE GRAIN SIZE

$$\Gamma = \sqrt{k c_p \rho} \quad \& \quad l_s = \sqrt{\frac{k}{\rho c_p \omega}} \longrightarrow l_s = \frac{\Gamma}{c_p \rho \sqrt{\omega}}$$

- Γ for 1999 RQ36 is larger than that of the Moon (~50) and large asteroids
  - Implies that the average grain size on 1999 RQ36 is greater than that of the lunar regolith (~60 microns)
- The derived value of Γ is less than that of bedrock (~2500)
- This results implies that average grain size is < skin depth (l_s)
- From these data we infer that the average grain size on 1999 RQ36 is in the sub-centimeter size range
- These data provide confidence in the presence of regolith for sampling

Radar Observations of 1999 RQ_{36} Provide Independent Constraints on the Regolith Properties

- 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.



Polarization Ratio (SC/OC) Comparison with Other NEAs

Object	SC/OC	Wavelength
▪ 2005 YU55	0.36+-0.05	3.5 cm
	0.40+-0.05	13 cm
▪ 1999 RQ36	0.18+-0.01	3.5 cm
	0.18+-0.05	13 cm
▪ Itokawa	0.24+-0.02	3.5 cm
	0.27+-0.04	13 cm
▪ Eros	0.28+-0.06	13 cm

- NEA Avg 0.34+-0.25 N = 214 range = 1.5
- Dark NEA Avg 0.29+-0.12 N = 17 range = 0.40

Results from Benner et al. 2008; dark NEA average excludes 2005 YU55

Radar Polarization Ratios Constrain the Average Grain Size on the Asteroid Surface

- The polarization ratio is 0.18 at 13 cm and 3.5 cm wavelengths
- These values are 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.

Thus, the radar observations support our interpretation of the average grain size on the asteroid surface

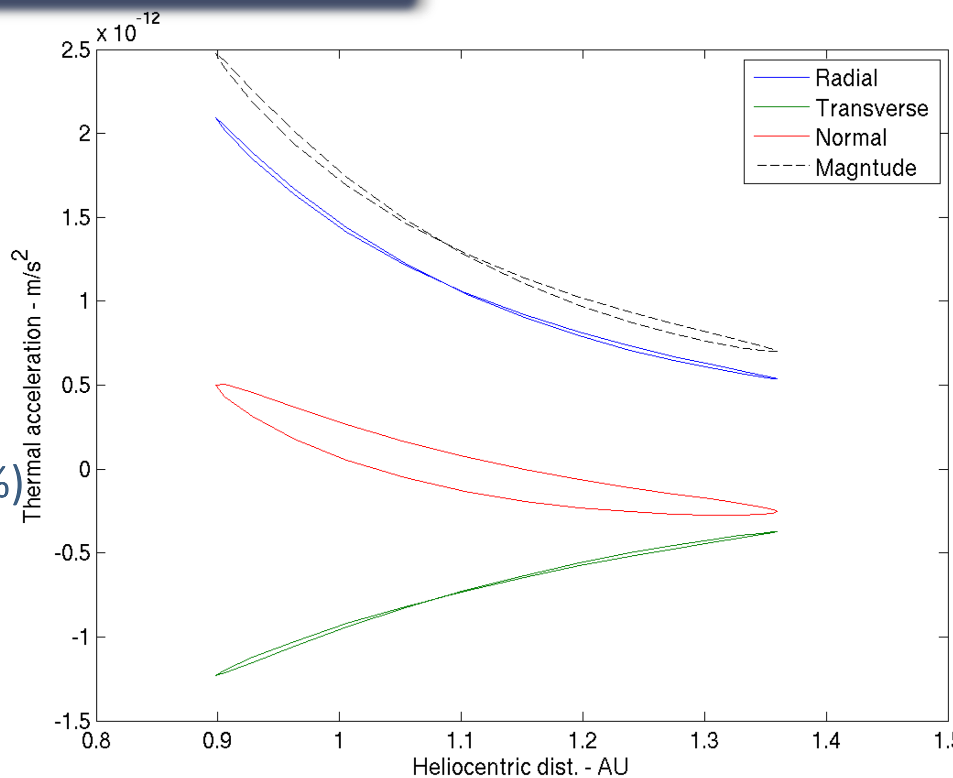
Arecibo Success! Nolan Rocks!

- For much of summer the 2011 radar opportunity was on the edge of being lost
  - Refurbished power conditioning unit was delivered Sept. 21. RQ36 ranging less than a week later!
- Three daily range points Sept. 27-29, 2011 with 2 μsec (300 m) uncertainty
  - Plus re-measurements of 2005 ranging: 4 daily points at 1 μsec became 8 twice-daily points at 0.5 μsec (75m)
  - Plus previously unreported 1999 Arecibo ranging: 6 range points over three days at 1-μsec (150 m)
- Augmented by 396 optical obs. Sept. 1999 – Oct. 2011

UPDATED YARKOVSKY DRIFT

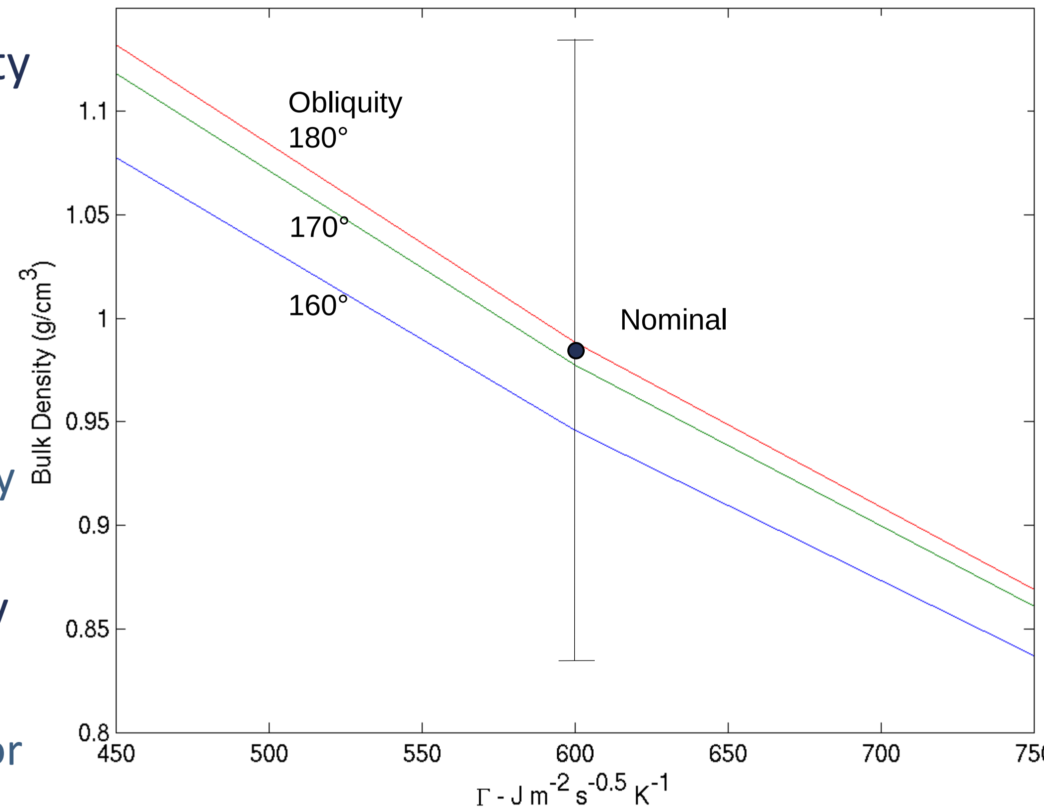
How **BIG** is the Yarkovsky Effect?
Peak acceleration 2.5e-12 m/s^2 × 6.2e10 kg = 0.16 N
On Earth that is the weight of 16 g or ~½ oz.

- New orbit determination is among the most precise in the entire asteroid catalog
  - Semimajor axis uncertainty 6 meters
  - Perihelion uncertainty 4 km
- New semimajor axis drift rate
  - da/dt = -18.7 ± 0.1 ×10^{-4} AU/My (0.5%)
  - Radar-only: -18.8 ± 0.3 ×10^{-4} AU/My (1.7%)
- Two orders of magnitude increase in precision. Even better than expected…
- Does this tell us anything?

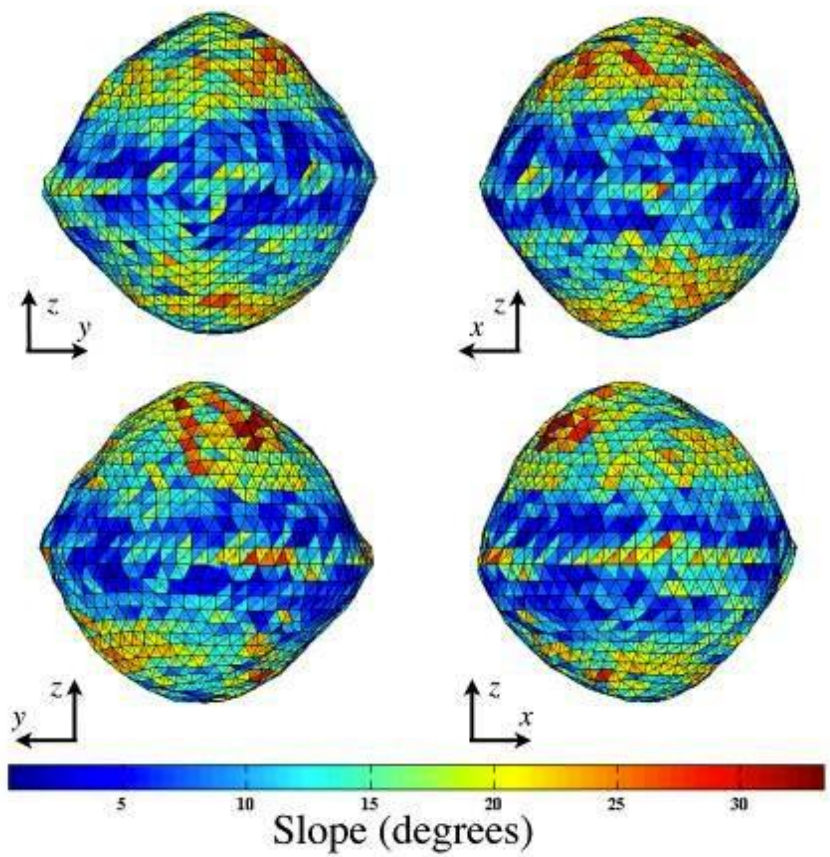


ADD THERMAL MODELING

- Yarkovsky drift depends on asteroid radius, spin state, thermal inertia, and bulk density
- We already know drift and
  - Effective radius 495 m (Nolan)
  - Spin period 4.288 h (Hergenrother)
  - Obliquity $\varepsilon > 165°$ (Nolan)
  - Γ=600±150 J m^{-2} $s^{-0.5}$ K^{-1} (Emery et al. 2010)
- Can estimate 1999 RQ_{36} density
  - ρ = 0.98±0.15 g/cm^3
  - Uncertainty in Γ dominates (for fixed Γ & ε, σ=0.002 g/cm^3)
  - This means that GM = 4.1E-9 km^3/s^2 & M=6.2E10 kg (± 15%)



Surface slope distributions suggest a regolith-covered body with a relaxed surface



- 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 that is accumulating near the equator

We are Confident in the Presence of Regolith on the Surface of 1999 RQ36

- Spitzer data provide firm constraints on the average regolith grain size.
  - The thermal inertia of RQ36 is substantially below the bedrock value, implying that the regolith grains are significantly smaller than the scale of the skin depth and therefore average less than a centimeter
- The polarization ratio for RQ36 is 0.18 at 13 cm and 3.5 cm wavelengths
  - These data suggest that the transition to a "rough" surface happens at a scale smaller than the shortest (3.5-cm) wavelength
- Analysis of the asteroid shape provides a third line of evidence in support of fine-grained regolith on the surface

Get Ready for Samples of 1999 RQ36!

- We are ready to return an abundance (>150 g) of pristine samples from asteroid 1999 RQ36
- Our Touch-and-Go Sample Acquisition Mechanism (TAGSAM) is capable of ingesting up to 2 kg of material with grain sizes from dust up to 2 cm.

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Join in the mission

- *Observe with Target Asteroids!*
- *Name 1999 RQ36*
- *Attend local displays & talks*
- *Work on the project*