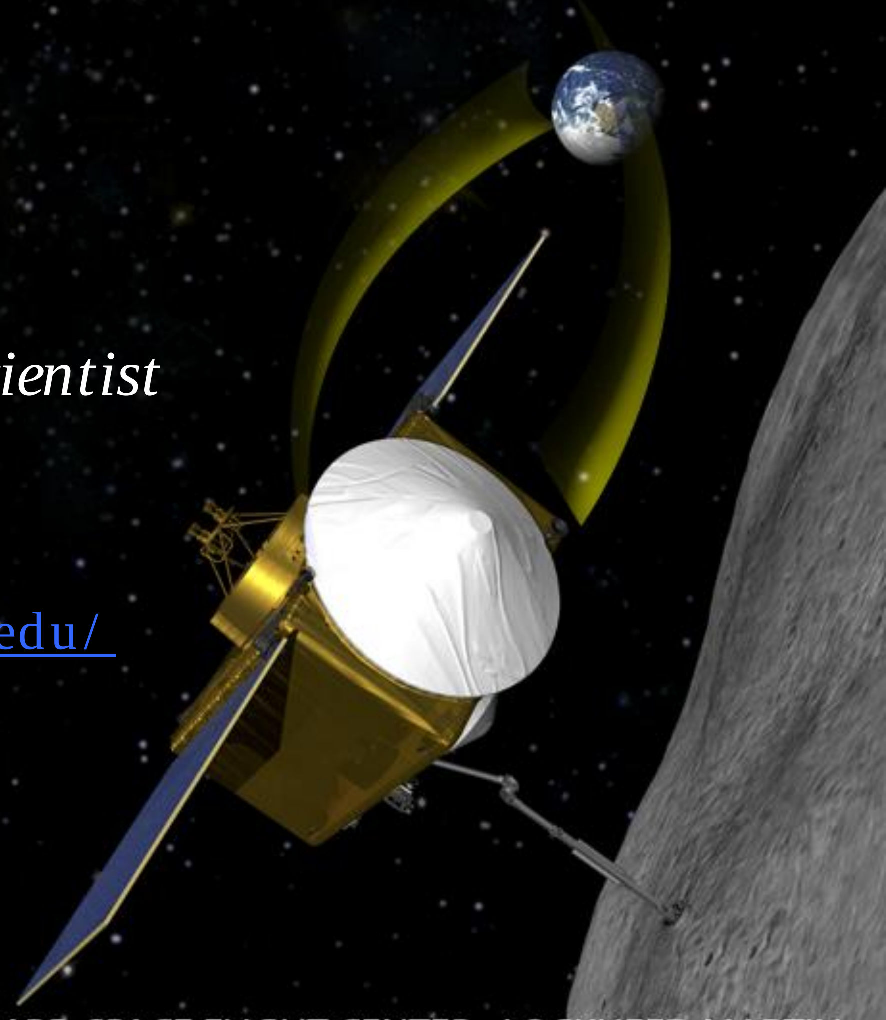
OSIRIS-REx
Asteroid Sample Return Mission

Jason Dworkin– Project Scientist
GSFC

[http:/ / osiris-rex.lpl.arizona.edu/](http://osiris-rex.lpl.arizona.edu/)



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What is OSIRIS-REx?

- OSIRIS-REx is a **PI-led** New Frontiers **sample return mission** that returns at least 60 g (and as much as 2 kg) of **pristine carbonaceous regolith** from asteroid 1999 RQ36.

- **OSIRIS-REx 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 low-albedo (e.g. carbonaceous) asteroids
  - **Resource Identification**
    - identify 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 (1 in 1,800 for RQ36 in 2182)
  - **Regolith Explorer**
    - Explore the regolith at the sampling site *in situ* at scales down to sub-centimeter

OSIRIS-REx – The Right Team for the Job

Principal Investigator:	**Dante S. Lauretta (UA)**
Deputy PI:	**Edward Beshore (UA)**
Project Manager:	**Robert Jenkens (GSFC)**
Flight System Manager:	**Joe Vellinga (LM)**

University of Arizona

- Principal Investigator & Deputy PI
- Project Planning and Control Officer
- Mission Instrument Scientist
- Science Team Management
- OSIRIS-REx CAMera Suite (OCAMS)
- Science Processing and Operations Center (SPOC)
- Data Management and Archiving
- Education & Public Outreach

Goddard Space Flight Center

- Project Management
- Project Scientist & Deputy Project Scientist
- Mission Systems Engineering
- Safety & Mission Assurance
- OSIRIS-REx Visible and near Infrared Spectrometer (OVIRS)
- Flight Dynamics Lead

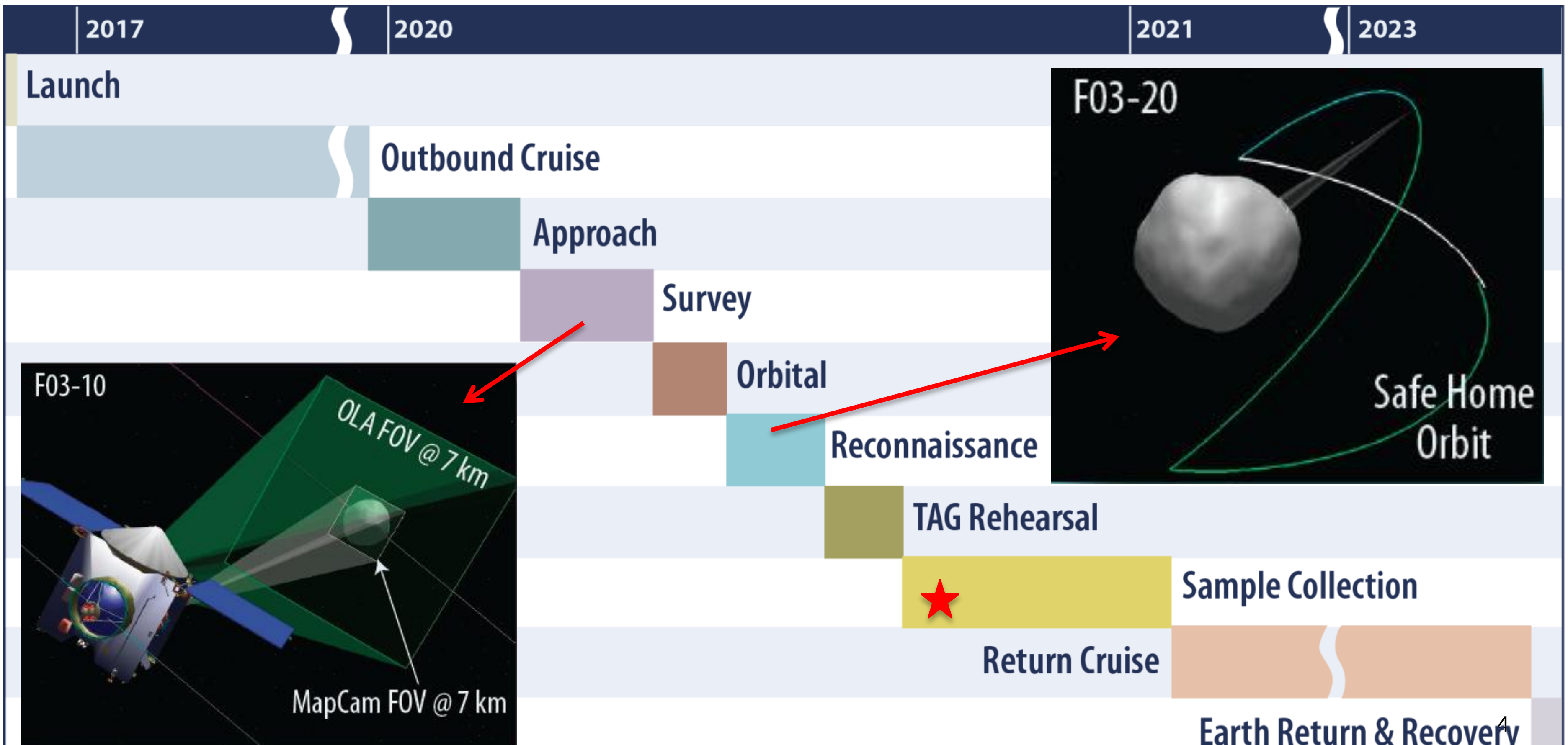
Lockheed Martin

- Flight System
- Sampling System
- Sample Return Capsule
- Mission Operations

Canadian Space Agency – OSIRIS-REx Laser Altimeter (OLA)
Arizona State University – OSIRIS-REx Thermal Emission Spectrometer (OTES)
KinetX – Navigation/ Flight Dynamics
Johnson Space Center – Sample Curation
Indigo Information Services – PDS Archiving

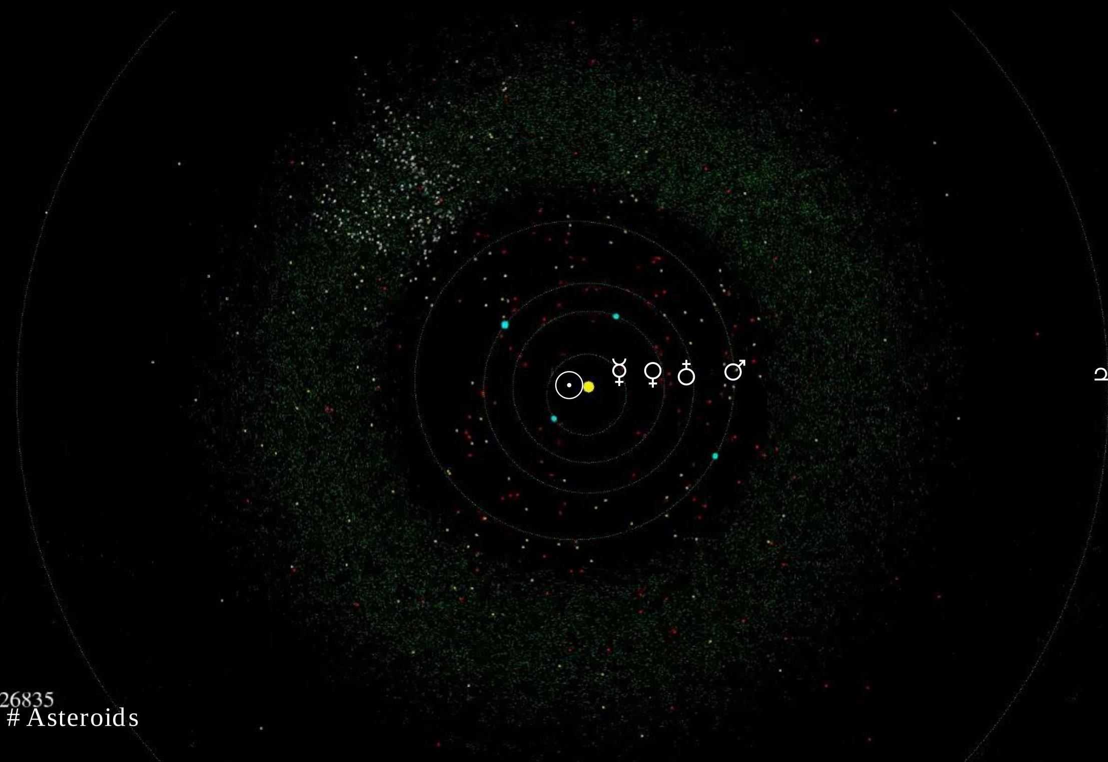
What will OSIRIS-REx do?

- Sample significant amounts of **ancient pristine** material from the early solar system.
- Explore the **asteroid-comet continuum** via samples with known geologic context.
- Catalyze the **emerging integration** of remote sensing & sample analysis communities.
- Develop operational capabilities **essential for humanity to explore near-Earth space.**



Asteroid Discoveries 1996-2010

Earth crossing
Earth approaching
Non-Earth approaching
Asteroid discovery



1996 26835
Year # Asteroids

after http://star.arm.ac.uk/ and
http://www.youtube.com/user/szyzyg/

Only Carbonaceous Asteroid Visited to Date

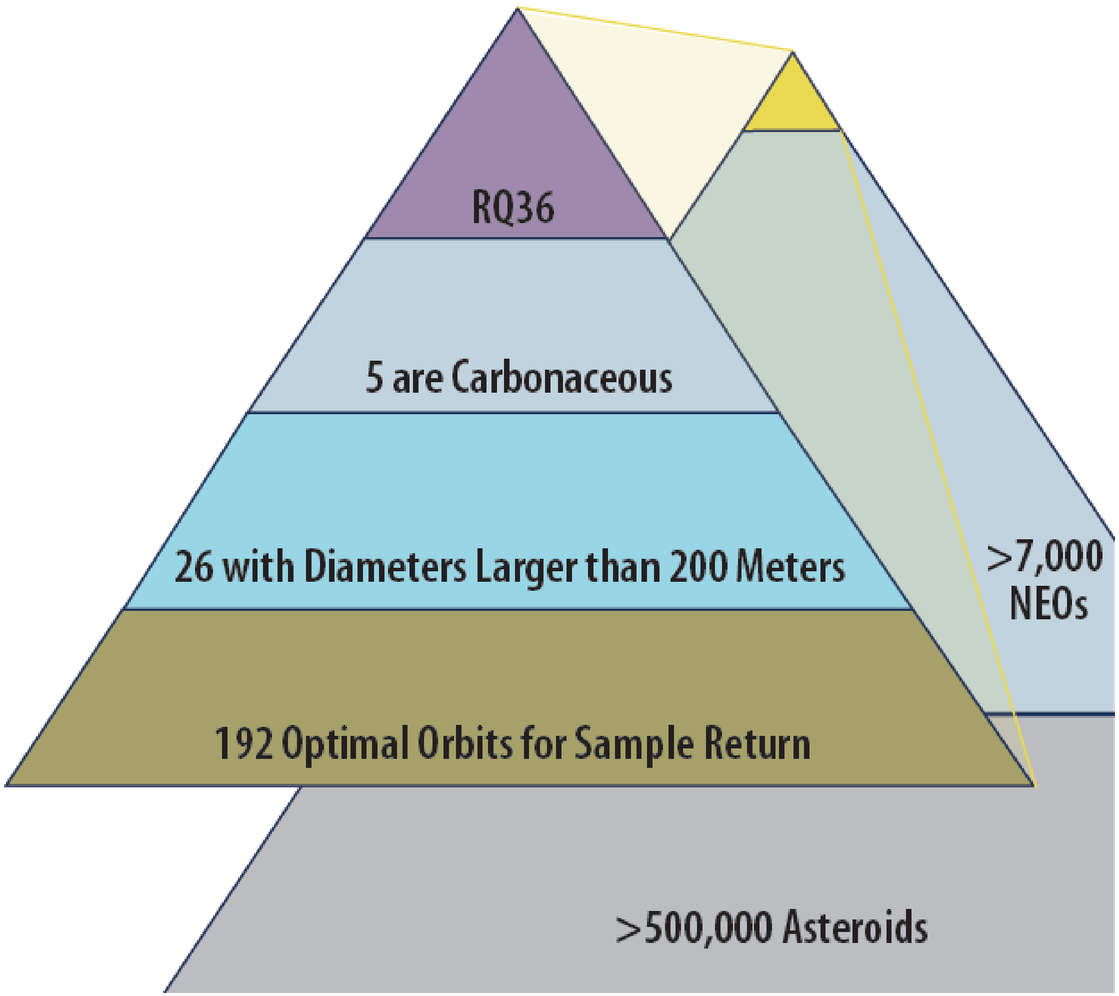
NEAR did a 2400 km flyby of asteroid (253) Mathilde on 27 June 1997

Mathilde is a 50 km C-type asteroid with an albedo of 4%.

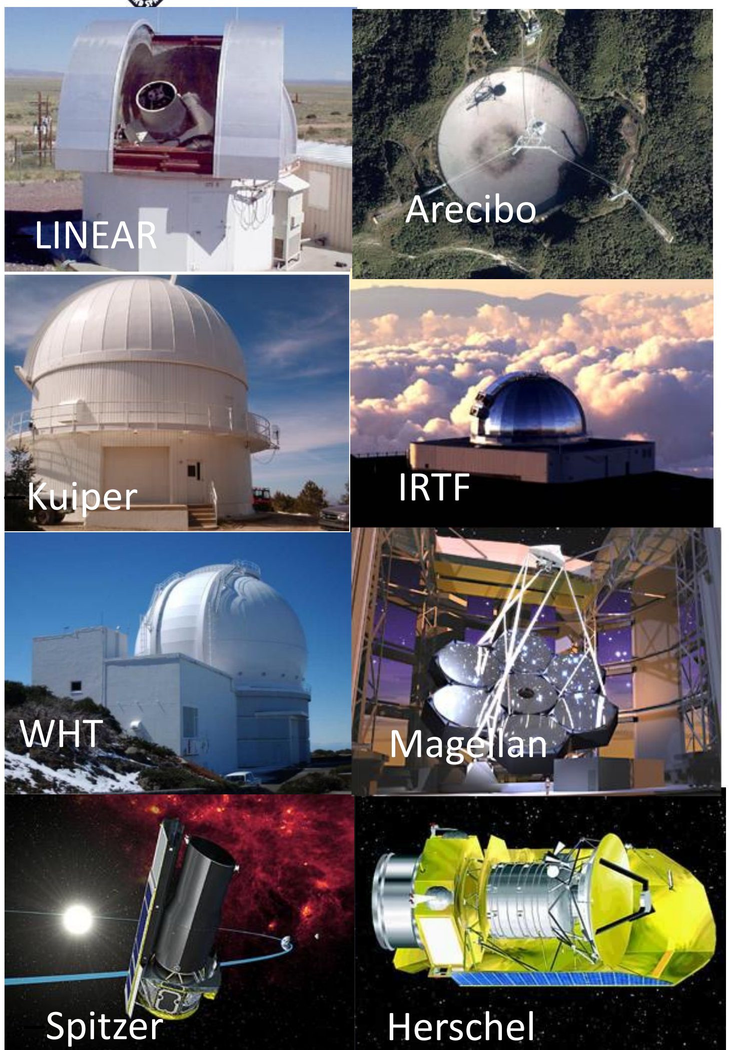
But far too high ΔV to return a sample

Why go to (101955) 1999 RQ36?

It Rises to the Top of the Asteroid Charts!



1999 RQ36 is One the Most Extensively Characterized NEOs



–Discovered on Sept. 11, 1999 by the LINEAR survey

–Observed with the Arecibo Planetary Radar system in Sept. 1999 and Sept. and Oct. 2005 (also with Goldstone)

–Observed with the Kuiper 1.5-m telescope multiple times in Sept., Oct. 2005, Sept. 2011

–Observed with the NASA Infrared Telescope Facility in Sept. 1999, Sept. 2005, and August 2011

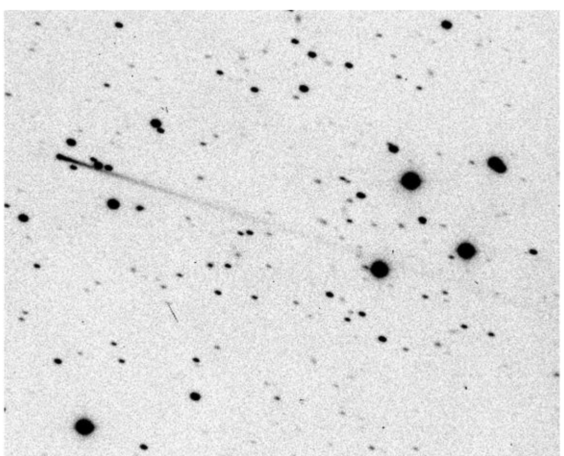
–Observed with the Spitzer Space Telescope between May 3rd-8th, 2007

–Observed with the Herschel Space Observatory, Giant Magellan Telescope, and WHT in Sept. 2011

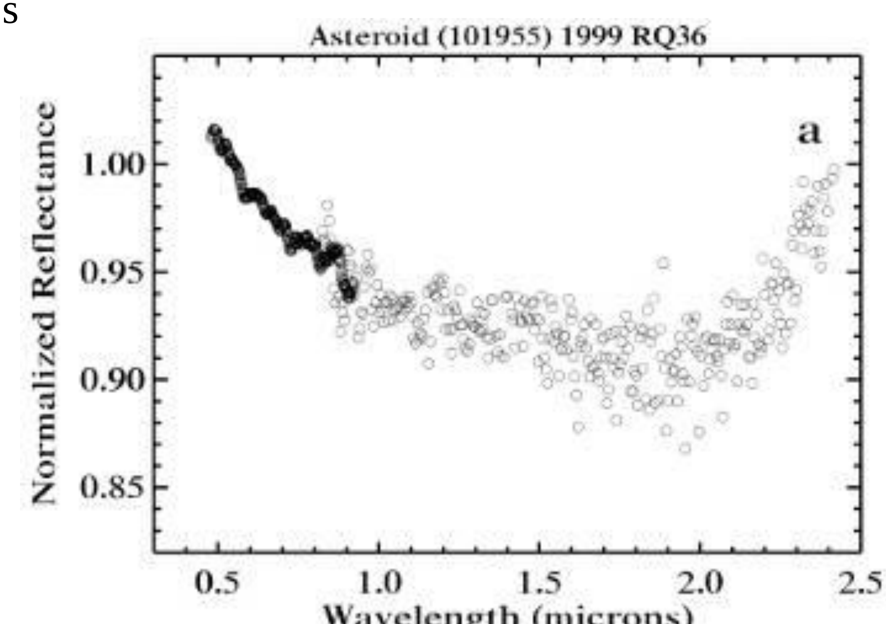
–Other observations planned for 2012

B-Class Asteroids are Some of the Most Volatile-Rich Asteroids

- 1999 RQ36 is a **B-class asteroid** characterized by a linear, featureless spectrum with a bluish slope in the visible.
- The thermal tail longward of 2 microns suggests a **very low albedo**.
- The **CM chondrites are the most likely meteorite analogs**.
- It is spectrally similar to the **Themis Group** B-type asteroids.
  - Main belt asteroid 24 Themis shows H_2O ice and organic features.
  - Main belt comets are B-type asteroids

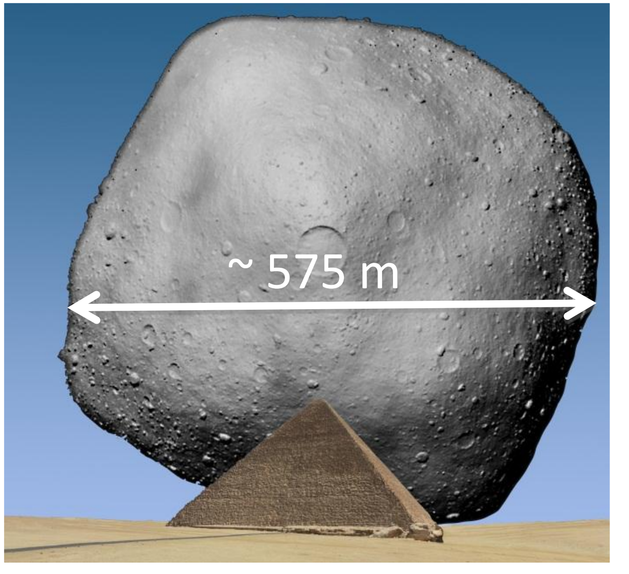


133P/ Elst–Pizarro
7968 Elst–Pizarro



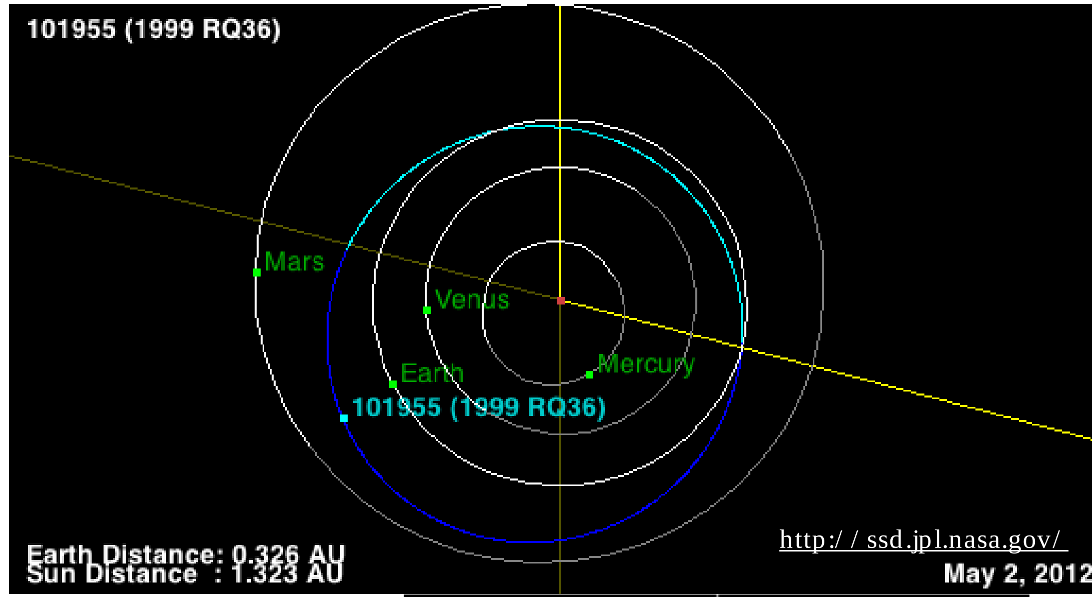
Summary: Asteroid 1999 RQ36 is an Excellent Sample Return Target

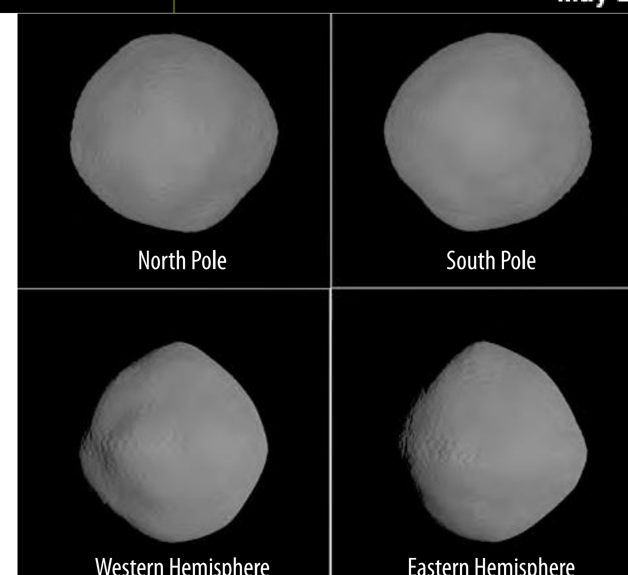
- It provides for **highly exciting science**, with a spectral signature suggesting a carbon- and volatile-rich surface.
- It is primitive B-class carbonaceous asteroid, a class of object **never before visited** by a spacecraft.
- Its **size, shape, and rotation state are known** from extensive characterization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



Can I have more details about the object?

Property	(101955) RQ36	
Epoch Date	1-January-2019 00:00 TT	
Reference Frame	Sun centered, Earth ecliptic & equinox of J2000	
Semi-Major Axis	1.126 AU	
Eccentricity	0.204	
Inclination	6.034°	
Longitude of Ascending Node	2.018°	
Argument of Perihelion	66.304°	
Perihelion	0.897 AU	
Aphelion	1.355 AU	
Orbital Period	1.195 years	
Mean Diameter	575±28m	
Volume	7.1×10^7 m^3	
Bulk Density	1.4 g/cm^3	± 0.7
Mass	9.9×10^{10} kg	($+5.4 \times 10^{10}$) (-4.5×10^{10})
Rotation Period	4.2968 hrs	± 0.0018
Direction of Rotation	Retrograde	
Obliquity	0 - 15°	
Pole Position	(0, -90)	±15°
Taxonomy	B	
Albedo	0.030	± 0.003
Phase Function	0.043 mag/°	± 0.001
Magnitude of Opposition Effect (OE)	0.10 mags	± 0.10
Absolute Magnitude w/o OE (w/ OE)	20.51 (20.41)	± 0.20





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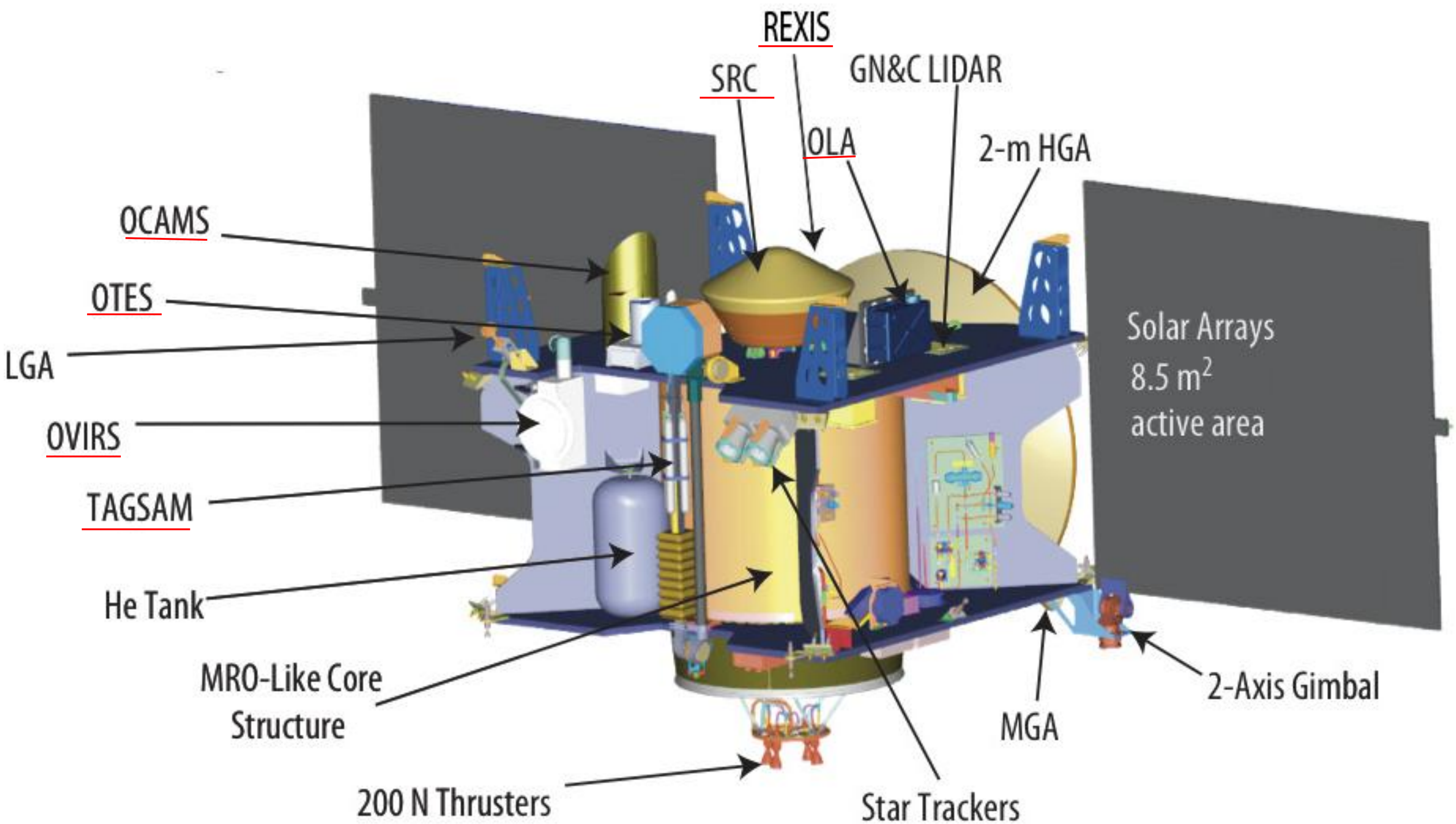
OSIRIS-REx Mission Objectives Map Directly to NASA Key Questions

NASA Key Questions	OSIRIS-REx Objectives
How did life begin and evolve on Earth and has it evolved elsewhere in the Solar System?	**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.
How did the Sun's family of **planets and minor bodies originate**?	**2.** Map the **global properties, chemistry, and mineralogy** of a carbonaceous asteroid to characterize its geologic and dynamic history and provide context for the returned samples.
How did the **Solar System evolve** to its current diverse state?	**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.
What are the **hazards and resources** in the Solar System environment that will affect the extension of human presence in space?	**4.** Measure the **Yarkovsky Effect** on a potentially hazardous asteroid and constrain the asteroid properties that contribute to this effect.
What are the characteristics of the Solar System that led to the **origin of life**?	**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.

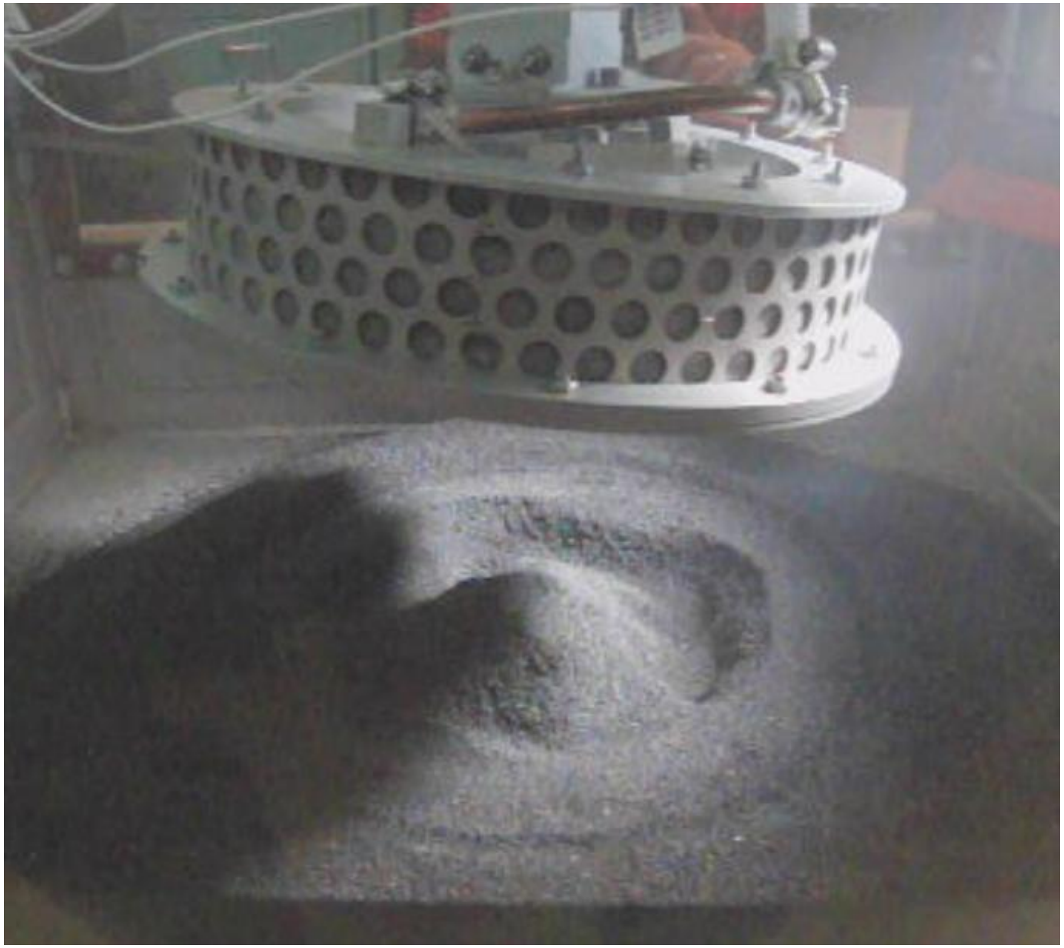
That said, if it doesn’t support sample return, it’s not on the spacecraft



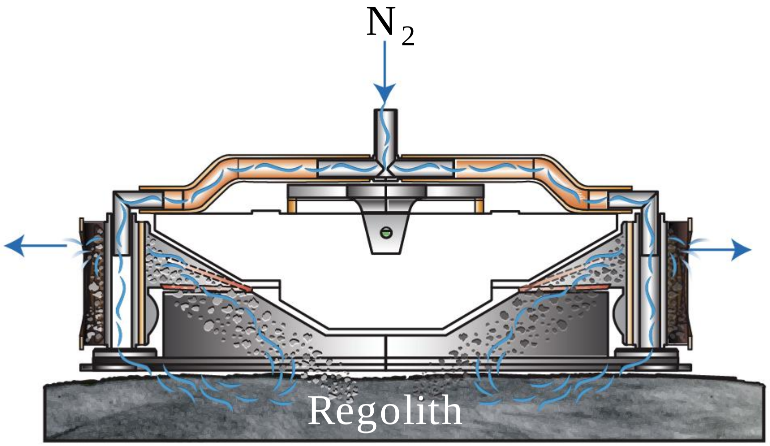
Mentioned in this presentation

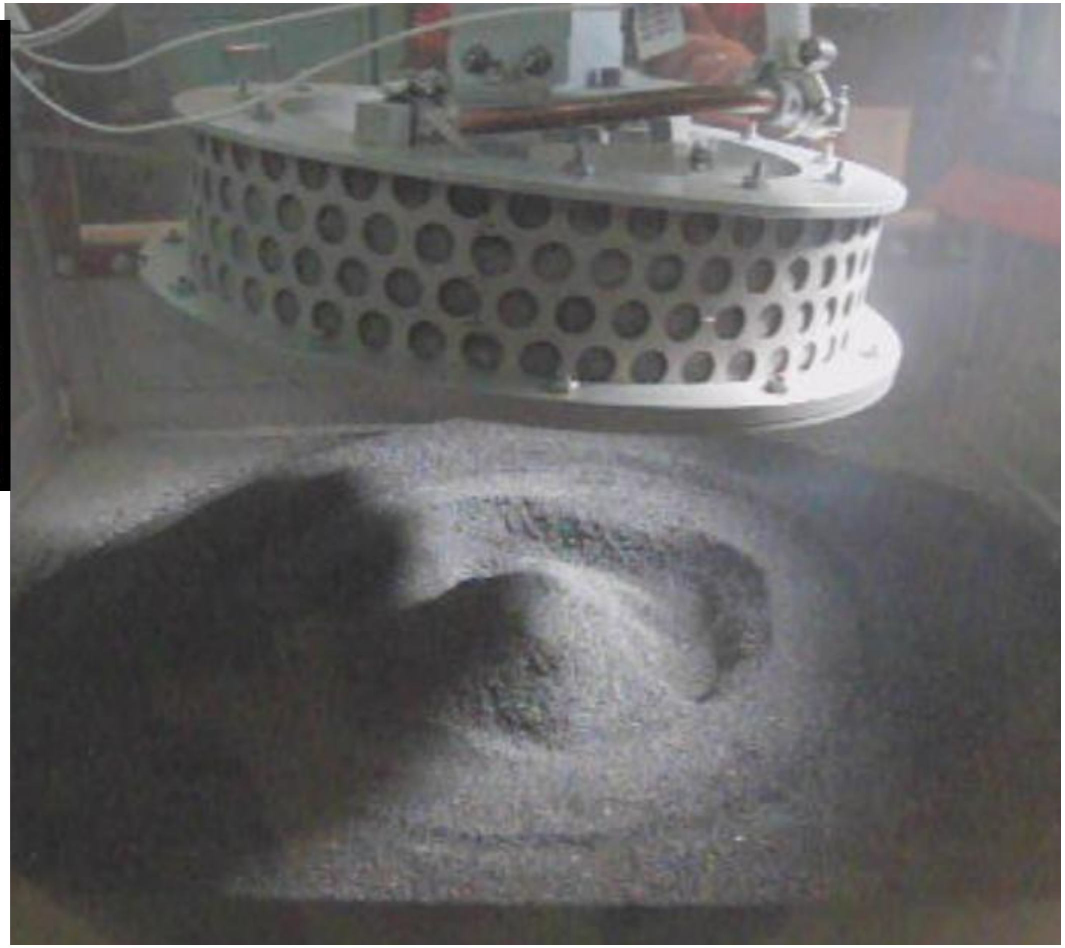
1: Return a Sample

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.

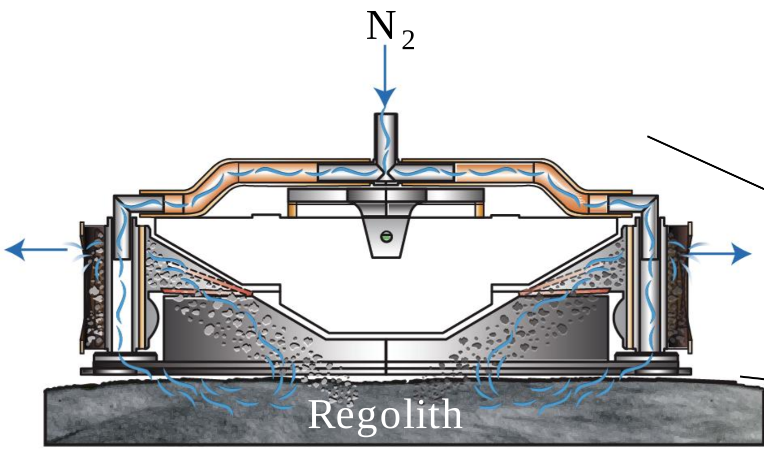


1: Return a Sample





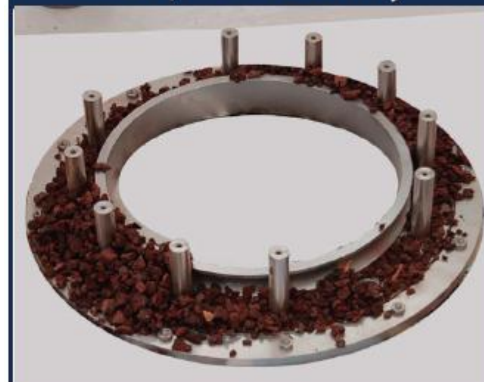
1: Return a Sample



OSIRIS-REx Bulk Sample Contains the History of 1999 RQ36

- 11.5 g of bulk sample for immediate analysis after Earth return.
  - Measure the bulk elemental and isotopic abundances of the returned material.
  - Constrain the presolar, nebular, and parent-body history of 1999 RQ36.
  - Test hypotheses based on dynamical and chemical evolution models of the Solar System.
  - Perform an analysis of space-weathered carbonaceous material.
  - Measure thermal properties important for the Yarkovsky Effect.
  - Provide ground truth for remote-sensing data.
- 3.5 g for margin
- 45 g archived for future generations

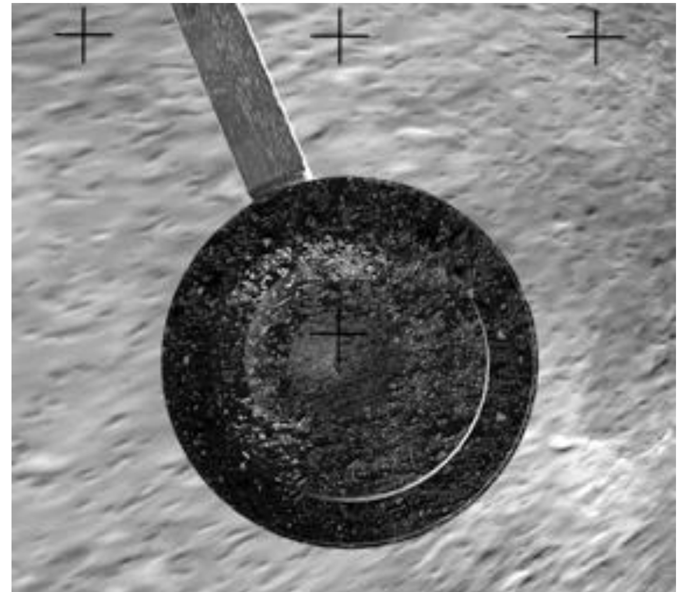
Sample in Cavity

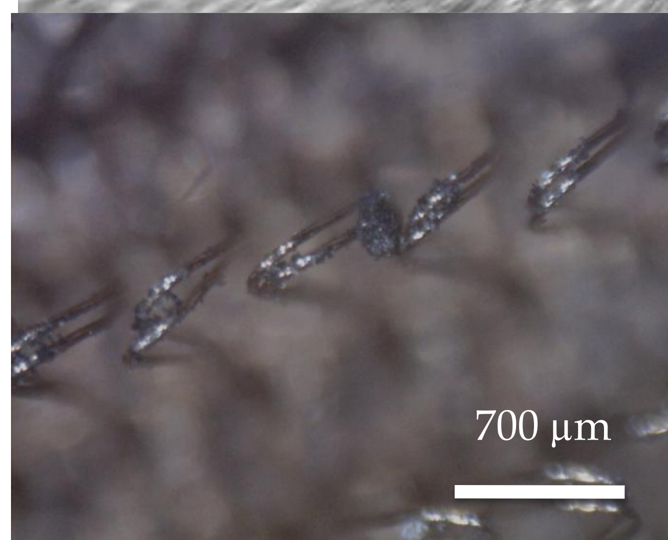


Acquired Regolith Sample

Surface Samples Provide Critical Data for the Spectral Interpretation of Carbonaceous Bodies

- Return 75 cm^2 of surface sample.
- 5 cm^2 of surface sample for immediate analysis after Earth return:
  - Provide a **contingency** sample to the bulk collection.
  - Characterize the **optical properties** of the upper surface layer.
  - Constrain the **mineralogy** of the space-exposed surface--carbonaceous.
- 1.5 cm^2 for margin
- 69.5 cm^2 archived for future generations





Samples are archived in the Astromaterials Curatorial Facility at JSC

- Within six months of sample return, the OSIRIS-REx science team produces a catalog containing sufficient information to allow the community at large to propose research with the samples.
- During the subsequent six-month period, the Science Team is allocated samples to conduct the measurements required to address the mission science objectives.
- How can the samples be best preserved for the future?

State-of-the-Art Analytical Instruments Cannot Be Flown on Spacecraft

Mineralogy & Petrology

Understanding Asteroid History

NanoSIMS

Electron Microprobes

FIB

Elements & Isotopes

Understanding Solar System History

LA-ICP-MS

GC-MS/c-IRMS

TOF-SIMS

Accelerator Mass Spectrometer

Organics

Detecting the Molecules of Life

LC-FT-MS

LC-TOF-MS

GC-MS

Spectroscopy

Linking Asteroids to Meteorites

FE-STEM

IR Microscope

ALS Synchrotron Beamline for XANES

Thermal

Understanding the Yarkovsky Effect

FT-IR

SEM

Future Scientists will Invent New Instruments

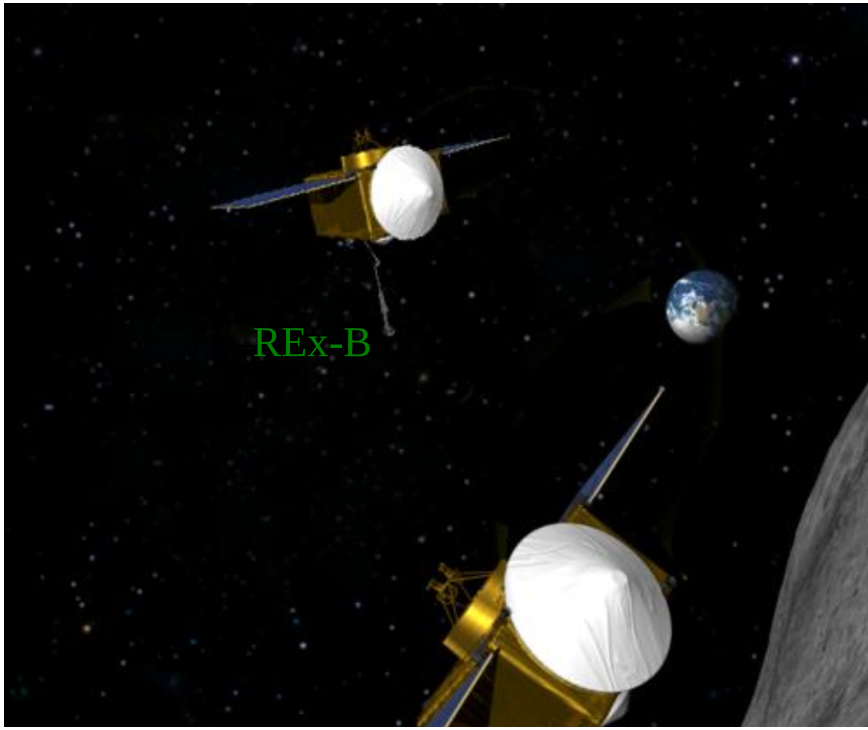
Lab Approach to “Pristine”

Fly two identical spacecraft one samples and one does everything but sample. Return both and analyze both the sample and the control in a double-blind experiment.

This is obviously impossible.

But no less impossible than other contamination control desires

- Return the sample under vacuum
- Viking-style heating of s/ c
- Monolayer levels of organic films
- Detailed assay at each step in ATLO



Instead we need contamination control requirements which are scientifically valid, verifiable, and achievable.

Contamination Control & Knowledge

We derived our implementation of contamination control from the highly successful Stardust mission.

- Implement the 10 **Lessons Learned** (Sandford et al., 2010)
- **Contamination Control**
  - 100 A/ 2 to control key elements (C, K, Ni, Sn, Nd, Pb)
  - 180 ng/ cm^2 for amino acids and N_2H_4
- Aggressive **archiving and documentation**
  - Allows future scientist to analyze as needed
- **Contamination Knowledge**
  - Discover unknown unknowns and test assumptions in contamination control

10 Stardust Lessons

	Stardust Lessons	OSIRIS-REx Implementation
1	Efforts need to be made both for contamination control and assessment	Budget and schedule to minimize contamination, and allow contamination assessment.
2	Cooperative efforts between s/ c manufacturers, the s/ c operators, the Science Team, and the NASA Curatorial Office.	Individual responsibilities in each group. Close work between groups
3	Agree on the definition of "clean"	Major effort on understanding and communicating how we define "clean" & "pristine"
4	Document what materials are used; samples of these materials should be collected and archived.	Major effort on understanding and archiving material.
5	Witness coupons need to be examined quickly so unexpected or problematic contaminants can be dealt with rapidly.	We plan on 100 ATLO coupons to be analyzed both of contamination control and knowledge to identify potential problems

Sandford et al., 2010

10 Stardust Lessons

	Stardust Lessons	OSIRIS-REx Implementation
6	Witness coupons need to be designed so that they can easily be divided and distributed to multiple analysts.	We are designing witnesses to be pre-divided or pre-scored for distribution.
7	Sample return spacecraft should carry a significant number of relevant witness coupons.	We have witnesses sampling three different intervals on TAGSAM and in the SRC with >30 cm^2
8	It is generally desirable to use more than one type of witness coupon.	We plan to have two types of witnesses (aluminum and silicon, TBR).
9	Plans must be made in advance for the distribution and storage of the returned samples, contamination control and assessment materials, and relevant SRC components	We are refining commitments form JSC, MSFC, and HQ
10	Develop the cleanest possible aerogel	There is no aerogel used

Stardust Lesson #4

• To the surprise of the science team, a mold release compound was used to un-mold aerogel after manufacture. The substance used was called Synlube 100. Fortunately, some of this material was archived. Synlube is similar to brake fluid.

• **No studies were made** on what Synlube 100 does during aerogel bake-out, etc.

• **Getting information on what is in Synlube 100 was difficult**

- The material, when it was purchased, was called Synlube 100
- The company changed ownership
- All records were lost to arson
- The product's rights were sold to other companies
- The owner of the original company when interviewed has a suspicion that Synlube 1000, now sold by SYNAIR may be an equivalent

• **As a result the Stardust Organics PET spent significant time analyzing Synlube 100 samples and Synlube 1000**

• It remains unclear to what extent Synlube affected the aerogel

Planetary Protection

Preliminary Designation

Category II Outbound

Category V Unrestricted Earth Return

The documentation requirement of Category II is accomplished by our **archiving and documentation requirements** already

Kevin Righter (JSC Curation Lead) and I am interested in learning how the sample can be **protected from biological contamination during curation**.

National Aeronautics and
Space Administration

Headquarters
Washington, DC 20546-0001

Reply to Attn of: Science Mission Directorate

20 December, 2011

Dr. Dante Lauretta
Principal Investigator, OSIRIS-REx Mission
Lunar and Planetary Laboratory
Department of Planetary Sciences,
University of Arizona, PO Box 210092
Tucson Arizona 85721-0092

Subject: OSIRIS-REx Planetary Protection Categorization

Dear Dr. Lauretta:

In response to your request for a formal Planetary Protection Categorization of the OSIRIS-REx mission, and after consultation with the Chair of the Planetary Protection Subcommittee of the Science Committee of the NASA Advisory Council, this letter confirms that a designation of Category V 'Unrestricted Earth Return' for OSIRIS-REx will be recommended to the SMD AA, in accordance with NASA Procedural Requirements 8020.12D. This recommendation is based on evaluations of previous OSIRIS mission concepts, on the understanding that the earlier information still pertains.

Prior information indicates the OSIRIS-REx mission plans to return a sample to Earth collected from the near-Earth asteroid 1999 RQ36. Previous mission descriptions indicated that the spacecraft would utilize a trajectory that does not encounter any other planetary bodies on either the outbound or return legs of the mission, and I understand that OSIRIS-REx will utilize a similarly isolated trajectory.

In response to the information provided in your letters and presentations to the Planetary Protection Subcommittee, OSIRIS-REx is assigned requirements equivalent to Category II for the outbound mission, as a mission to a body of significant interest relative to the process of chemical evolution but for which there is only a remote chance that contamination by spacecraft could jeopardize future exploration. Formal requirements of this categorization involve documentation as described in NPR 8020.12D, and the avoidance of impact on Mars by any launched hardware, as detailed therein.

Based on the deliberations and recommendation of the Planetary Protection Subcommittee, the sample return portion of the OSIRIS mission was provisionally designated Category V, Unrestricted Earth Return. Accordingly, for OSIRIS-REx, there are no additional planetary protection restrictions on this phase of the mission, other than the required end-of-mission report.

In addition, my office must be informed promptly should new information be obtained that brings into question the 'unrestricted' status of asteroid 1999 RQ36, or should the trajectory of the OSIRIS-REx mission be revised to include encounters with other planetary bodies. In such a case, additional review by the Planetary Protection Subcommittee and others may be indicated.

Best wishes for the success of your mission.

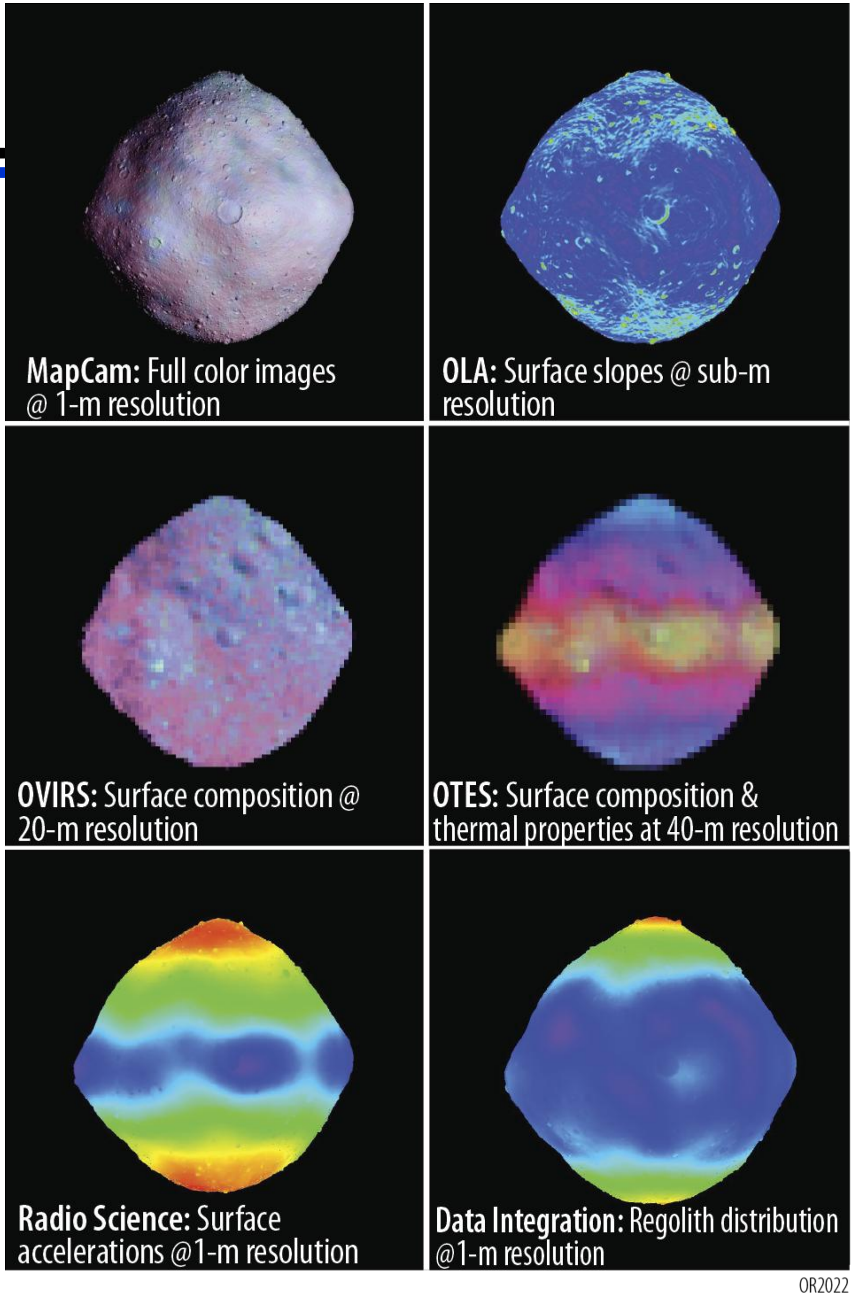
Cordially,

cc: Genex Systems/Mr. Stabekis

Catharine A. Conley, Ph.D.
Planetary Protection Officer
Phone: 202-358-3912; Fax: 202-358-3097; E-mail: cassie.conley@nasa.gov

2: Global Map

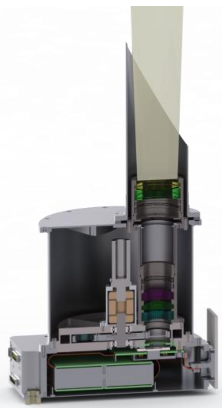
Map the global properties, chemistry, and mineralogy of a primitive asteroid to characterize its geologic and dynamic history and provide context for the returned samples.



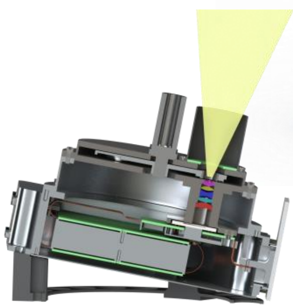
Instrument Capabilities

OCAMS

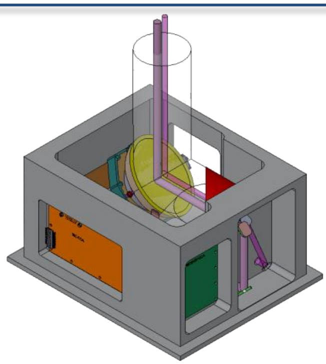
PolyCam acquires 1999 RQ36 from 500K km range, refines its ephemeris, and performs high-resolution imaging of the surface



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

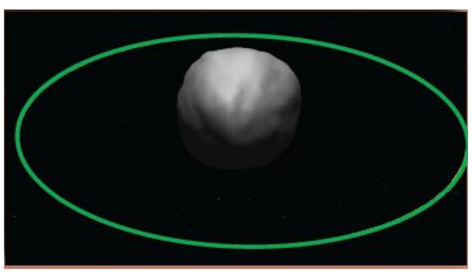


–**OLA** provides ranging data out to 7 km and maps the shape and topography

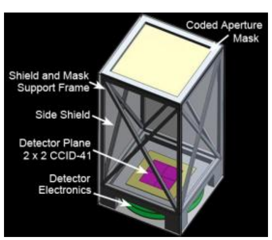
Instrument Capabilities

–**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



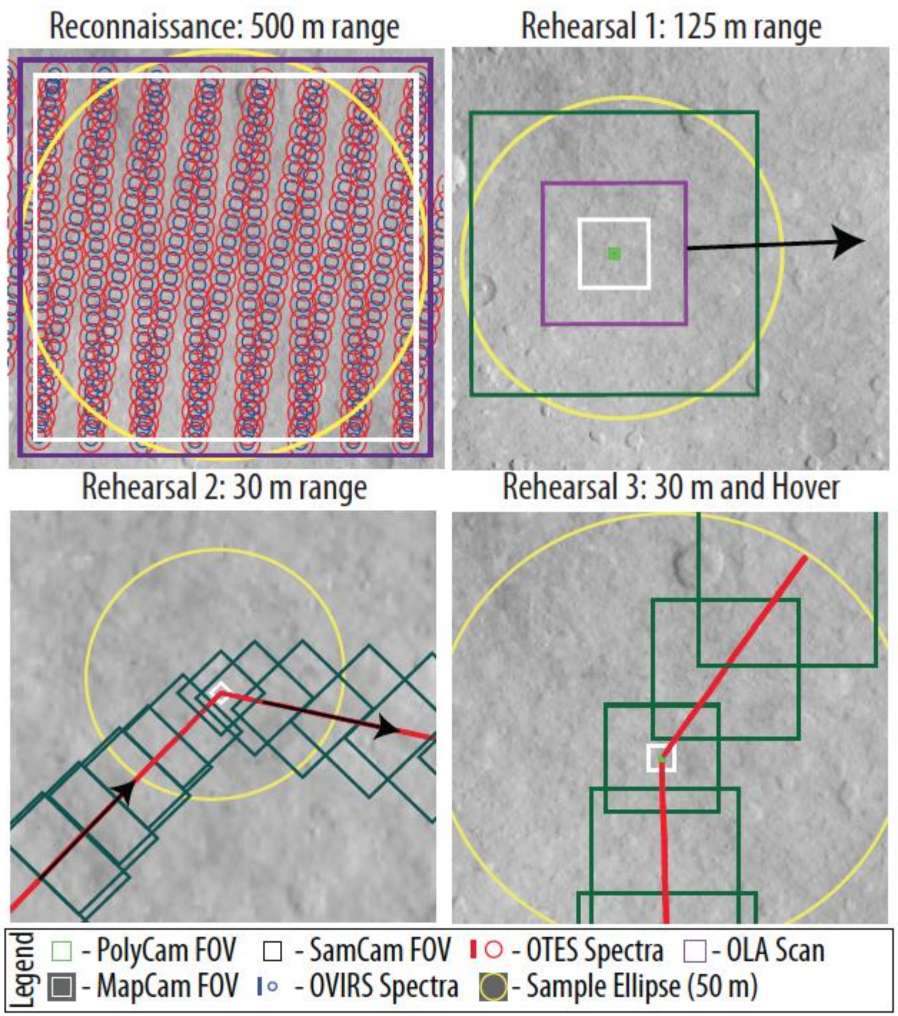
–**Radio Science** reveals the mass, gravity field, internal structure, and surface acceleration distribution



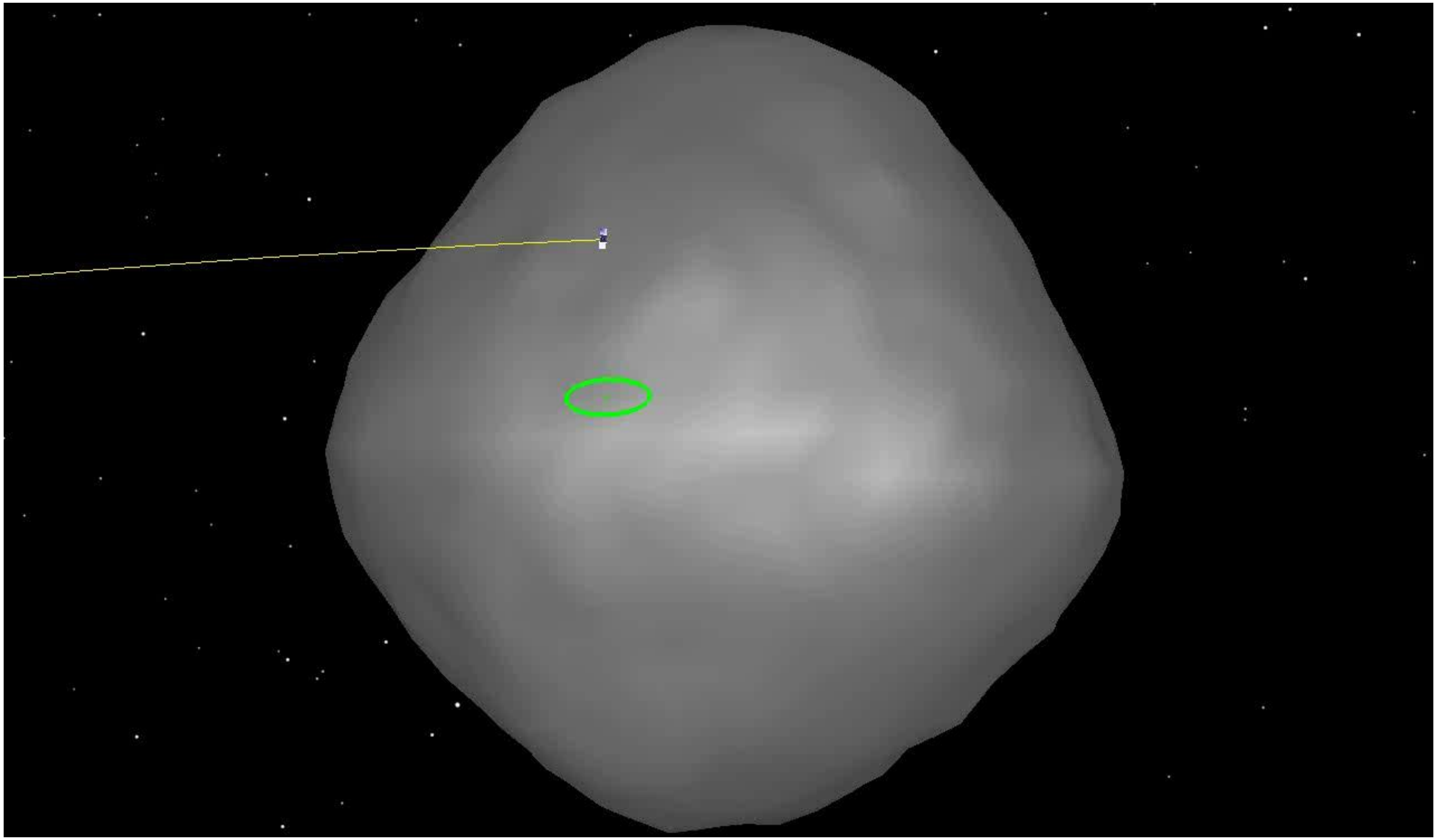
–**REXIS** is a Student Collaboration Experiment that trains the next generation of scientists and engineers and maps the elemental abundances of the asteroid surface

3: Local Map

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

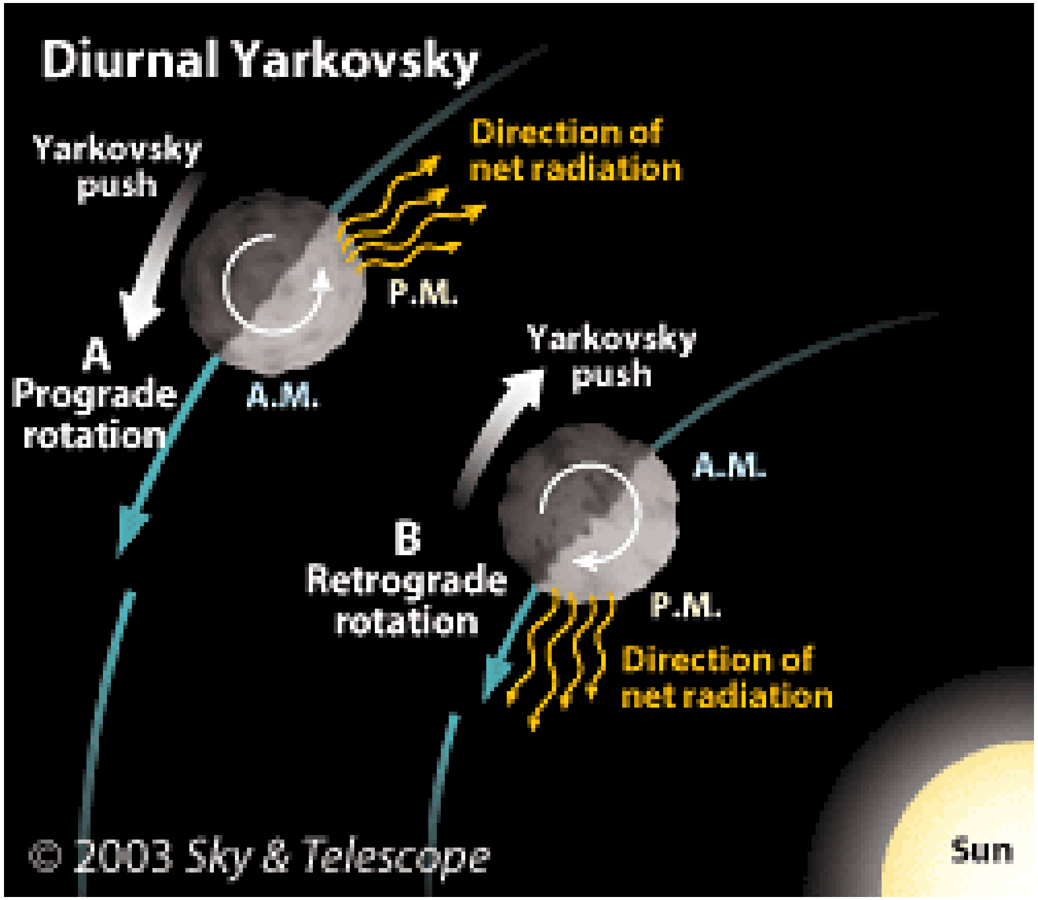


e.g. via 500 m Reconnaissance Scans



4: Measure Orbit Deviations

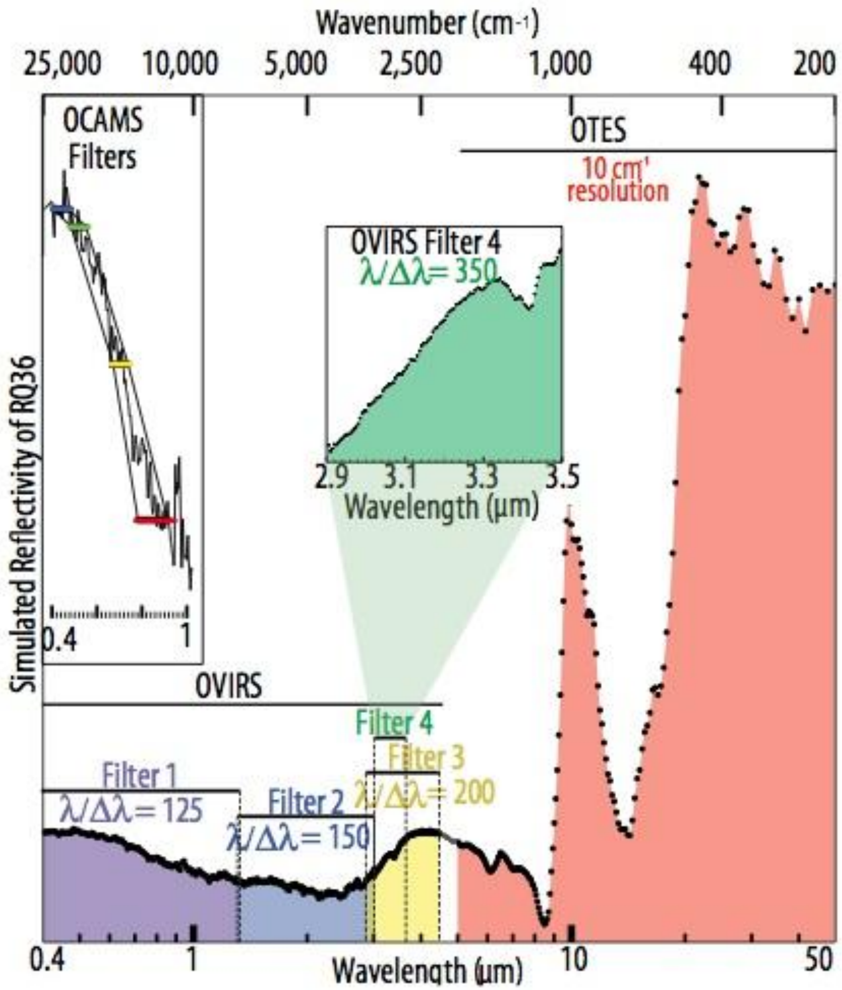
Measure the Yarkovsky Effect on a potentially hazardous asteroid and constrain the asteroid properties that contribute to this effect.



The Crookes Radiometer suggests but doesn't actually demonstrate the Yarkovsky Effect since it relies on a rarified atmosphere to turn.

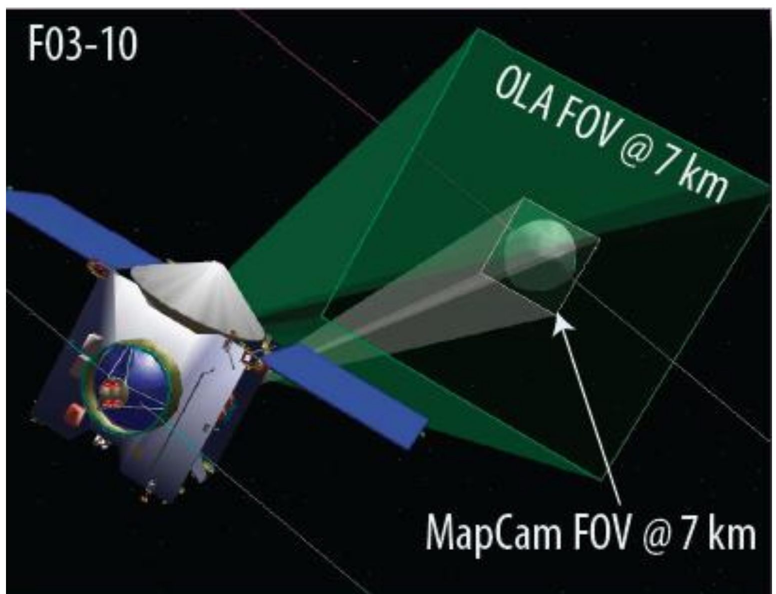
Objectives 2-5

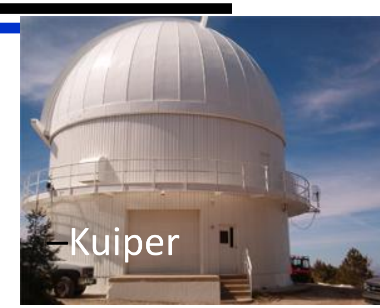
Spectral coverage from OCAMS, OVIRS, and OTES provides information to determine Yarkovsky effect as well as mapping mineralogy and organic features



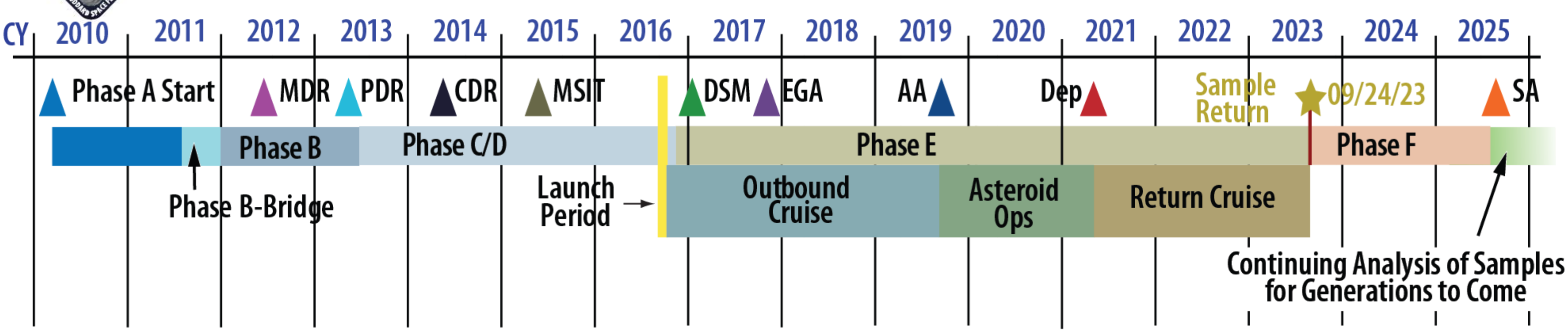
5: Compare to Observatories

Characterize the integrated global properties of a carbonaceous asteroid to allow for direct comparison with telescopic data of the entire asteroid population—know the geological context of what we are observing.



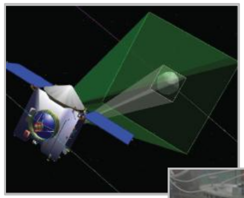


Summary Time Line



▲ Phase A Start 02/10
▲ Mission Definition Review 05/12
▲ Preliminary Design Review 03/13
▲ Critical Design Review 04/14
▲ Mission Systems Integration & Test 03/15
▲ Deep Space Maneuver 01/17
▲ Earth Gravity Assist 09/17
▲ Asteroid Acquisition 10/19
▲ Asteroid Departure 03/21
▲ Project Sample Analysis Complete 06/25

today



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Acknowledgements