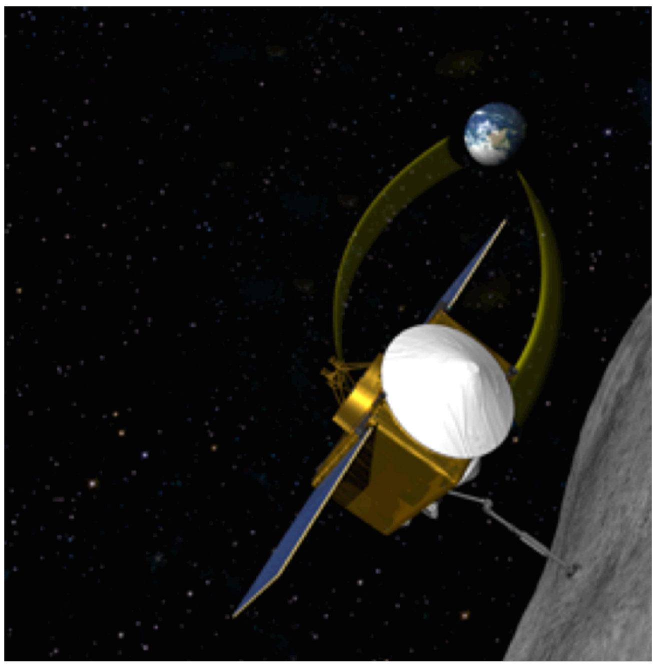
OSIRIS-REx

Origins, Spectral Interpretation, Resource Identification, and Security - Regolith Explorer
Asteroid Sample Return Mission

Presentation to the
Small Bodies Assessment Group



Science Overview

Dante S. Lauretta
Principal Investigator
With modifications by
Beth Ellen Clark
Mission Asteroid Scientist

OSIRIS-REx–
The Right Team For The Job

Principal Investigator:	**Dante Lauretta (UA)**
Deputy PI:	
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

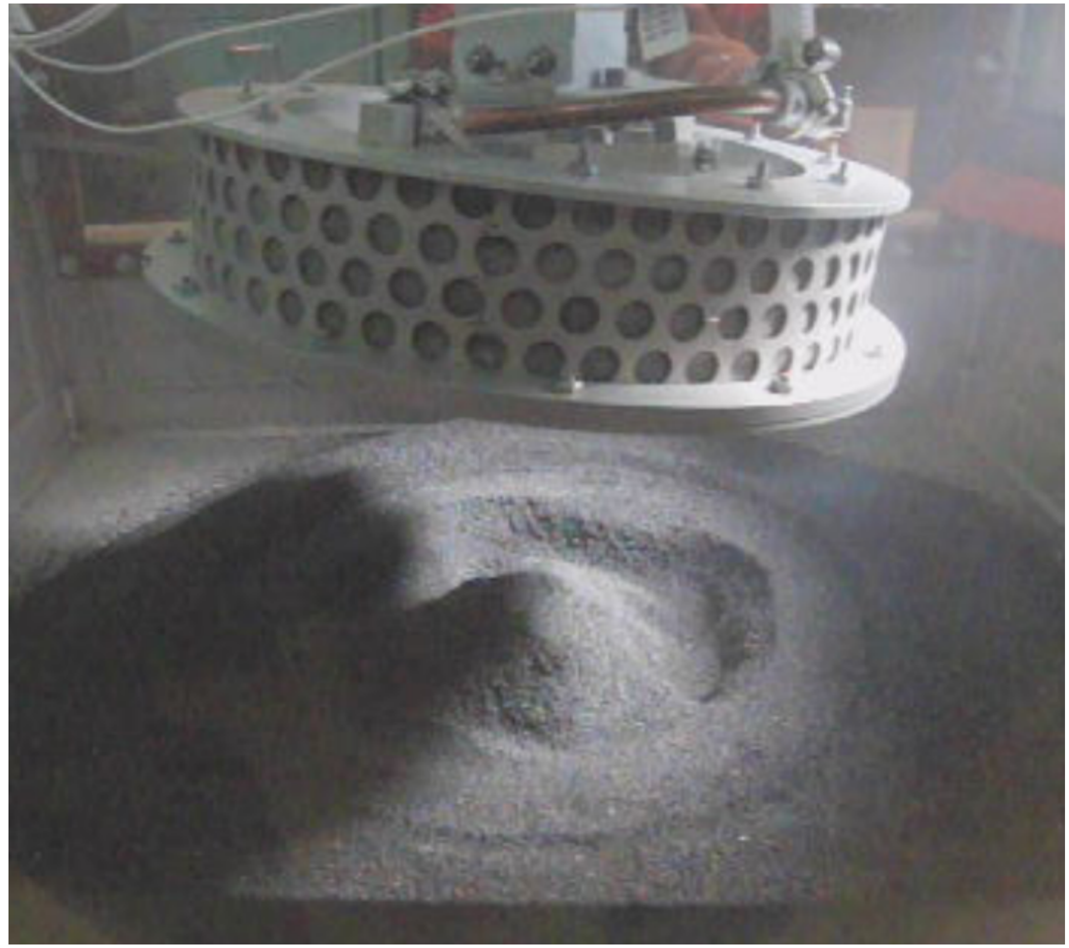
Canadian Space Agency – OSIRIS-REx Laser Altimeter (OLA)
Arizona State University – OSIRIS-REx Thermal Emission Spectrometer (OTES)
KinetX – Navigation/Flight Dynamics
Johnson Space Center – Sample Curation
Ithaca College – Asteroid Science

OSIRIS-REx Guiding Principles

- **OSIRIS-REx addresses deep questions** – Where did we come from, what is our destiny?
  - Sample return leverages the evolution of ground-based instrumentation
- **OSIRIS-REx uses a focused approach to technical implementation and cost control**
  - If it doesn't support sample return, it's not on the spacecraft
- **OSIRIS-REx has built an experienced multigenerational team**
  - We're developing the next generations of science, engineering, and management leaders
- **OSIRIS-REx has built a badgeless, integrated team**
  - Science, engineering, and management all understand each other's requirements
  - The "Buck Stops" with the P.I.
- **OSIRIS-REx provides near continuous public and scientific engagement for over a decade**
  - Near live coverage of RQ36 operations and return to Earth enthralls the general public
  - Asteroid encounter and sample return energizes the scientific community

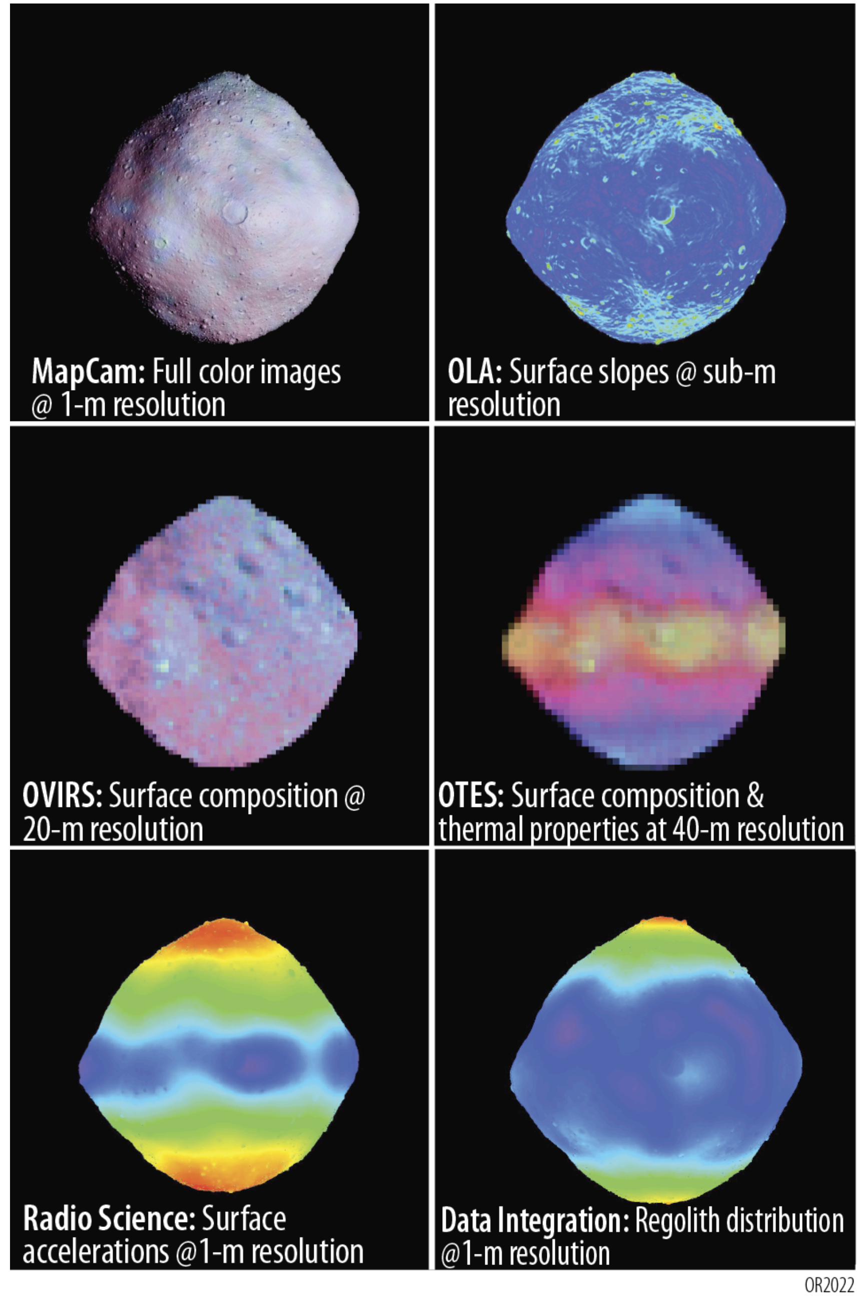
Objective 1

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



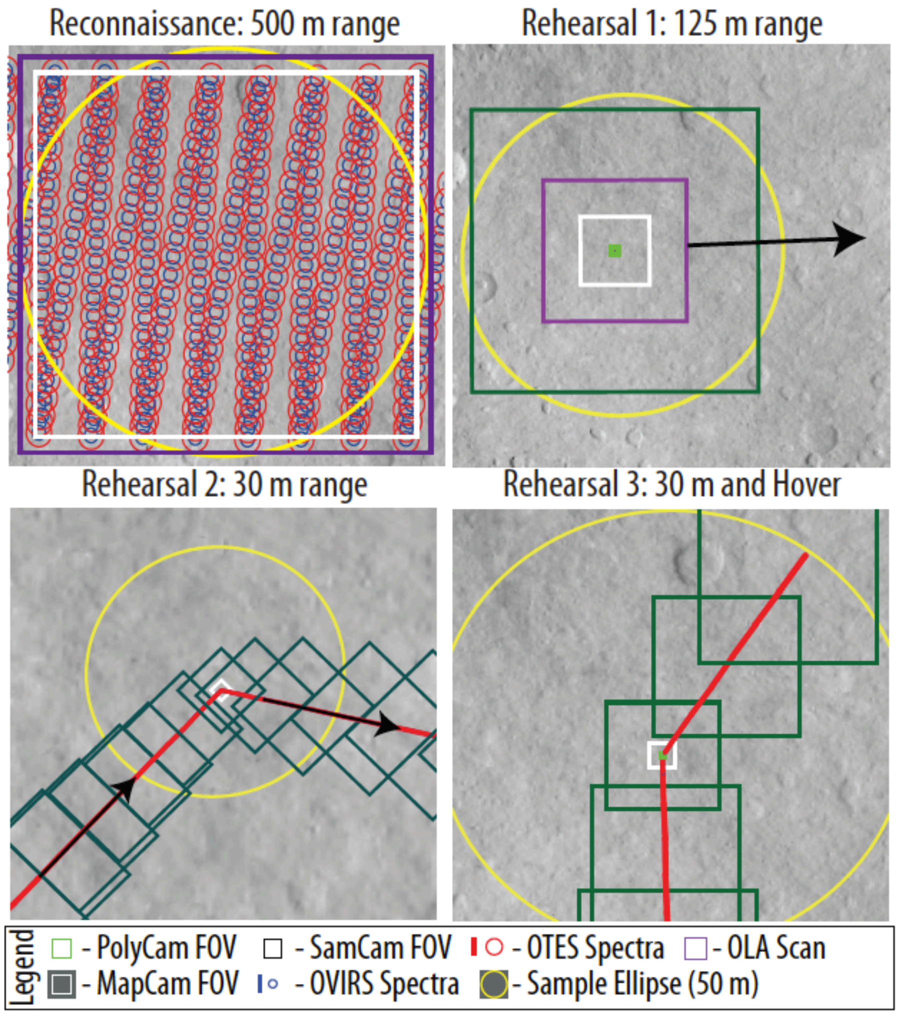
Objective 2

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



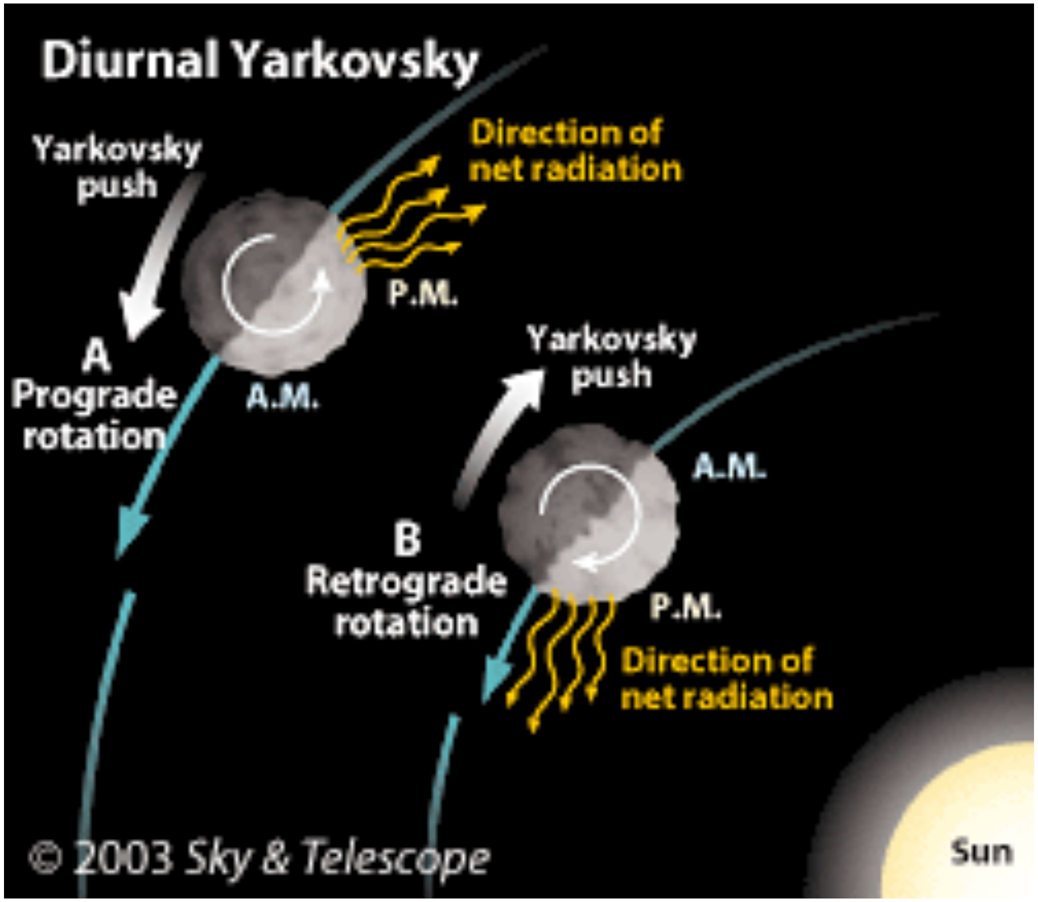
Objective 3

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

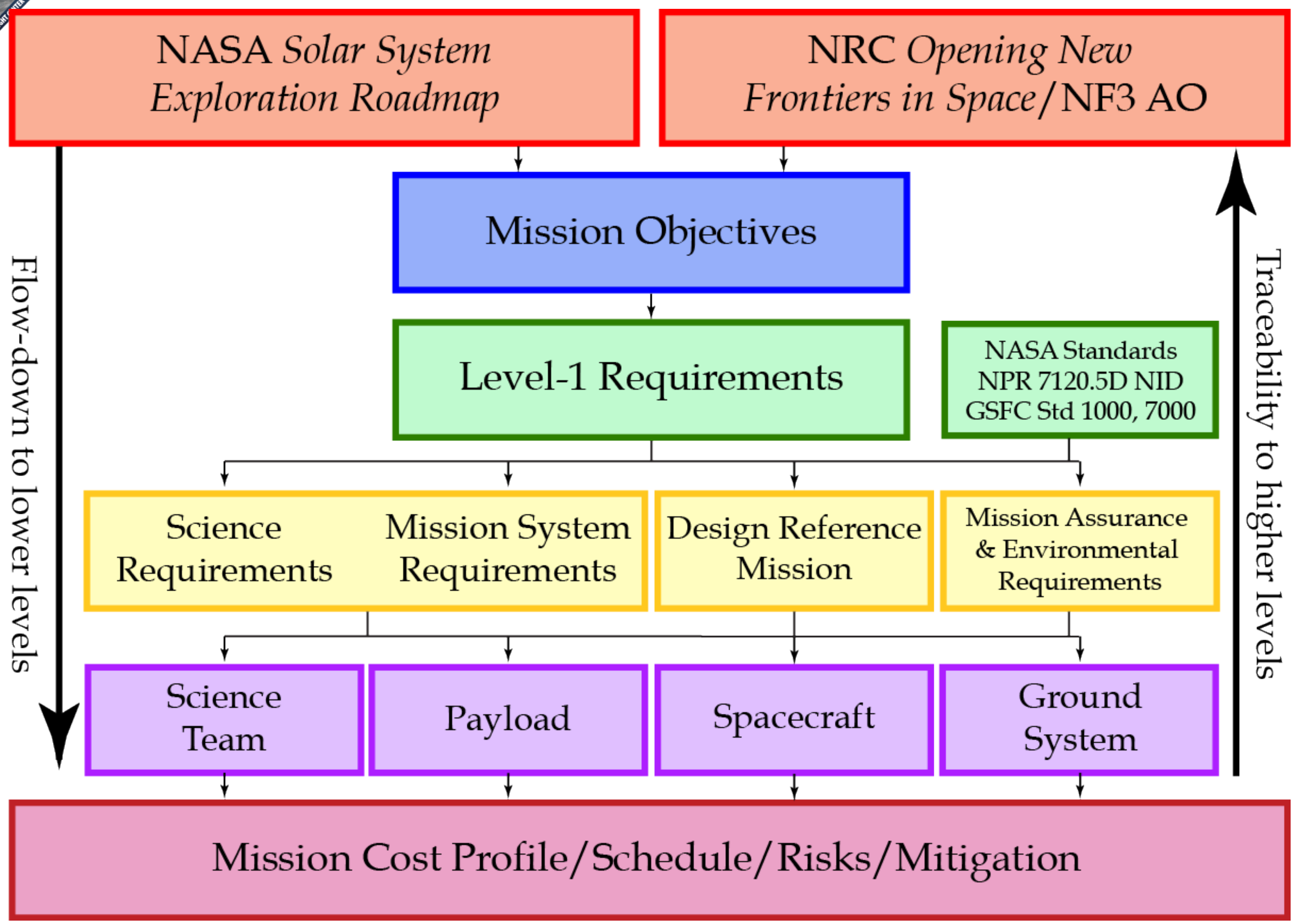
Measure the Yarkovsky effect on a potentially hazardous asteroid and constrain the asteroid properties that contribute to this effect



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

OSIRIS-REx Science Requirements Flow Down to All Levels of the Mission

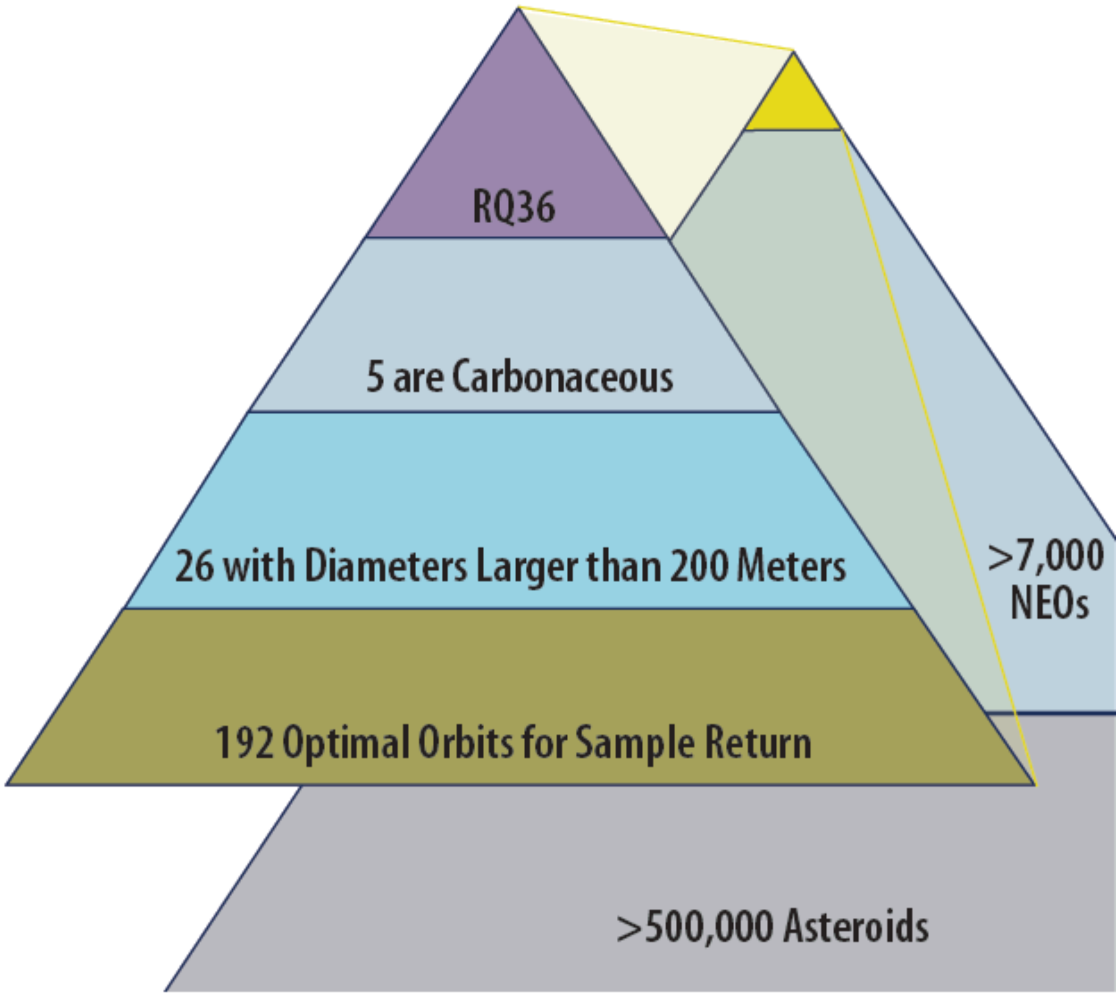


Fifteen Level-1 Requirements Define our Science Implementation Strategy

Requirement	TAGSAM	PolyCam	MapCam	SamCam	Radio Sci	OLA	OVIRS	OTES
1.1 Return 60 g of bulk sample	X							
1.2 Document sample contamination	X							
1.3 Contact 26 cm^2 of surface material	X							
1.4 Document the sampling site		X	X	X		X	X	X
1.5 Produce a sample catalog and analyze samples	Lab Requirement							
1.6 Produce a shape model		X	X			X		
1.7 Determine slopes, accelerations, and geopotential		X	X		X	X		
1.8 Determine density, structure, and gravity field		X	X		X	X		
1.9 Map the surface geology		X	X			X		
1.10 Map minerals & organics							X	X
1.11 Search for & characterize volatile outgassing		X	X				X	X
1.12 Search for & characterize satellites		X	X				X	X
1.13 Search for & characterize space weathering		X	X				X	X
1.14 Measure the Yarkovsky effect		X	X		X	X	X	X
1.15 Measure point-source properties		X	X				X	X

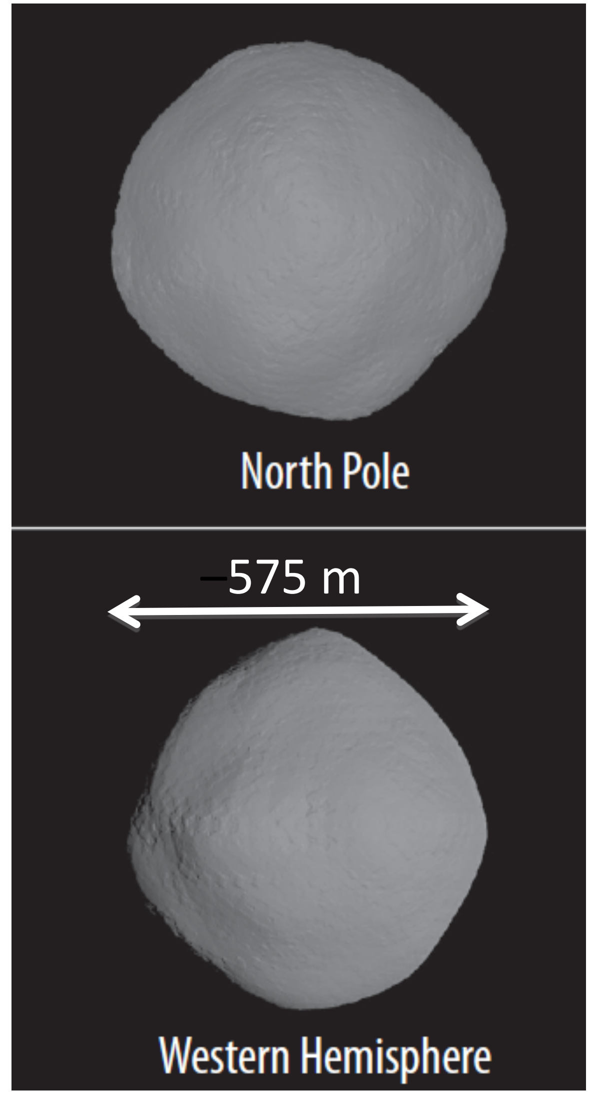
L1	Level 2 science requirement		T or B	Rationale	Mission Phase	Mission Element	Primary Co-I	Working Group	Notes
1.1	2.1.1	Return ≥15 g of bulk material for analysis in support of mission science objectives	T	Amount of returned sample required to achieve mission science objectives	8. Sample Collection 10. Earth Return	TAGSAM, SRC	Ben Clark	Regolith Development	
	2.1.2	Return and archive ≥45 g of bulk material in support of NASA objectives	T	NASA requirement not to consume more than 25% of returned sample	8. Sample Collection 10. Earth Return	TAGSAM, SRC	Righter	Regolith Development	
	2.1.3	Return and maintain the bulk sample exposed to total carbon contamination <180 ng/cm^2 on the TAGSAM surface	B	Analysis of key prebiotic compounds is central to mission science objectives. Science rationale for contamination derives from NRC guidelines for "Exploring Organic Environments in the Solar System"	All	TAGSAM, SRC, Spacecraft	Dworkin	Contamination Control	
	2.1.4	Limit total hydrazine contamination on TAGSAM to <180 ng/cm^2	B	Total allowable hydrazine contamination equal to total organic carbon contamination allowed by mission guidelines	All	Spacecraft, Mission Design	Dworkin	Contamination Control	
	2.1.5	Return and maintain the bulk sample exposed to total amino acid contamination <180 ng/cm^2 on the TAGSAM surface	B	Stardust contamination control successfully achieved mission science objectives. Stardust worst case is 180 ng/cm^2 amino acids	All	TAGSAM, SRC, Spacecraft	Glavin	Contamination Control	
	2.1.6	Return and maintain the bulk sample exposed to total inorganic contamination <TBD ng/cm^2 on the TAGSAM surface	B	Trace element and isotopic analysis are critical to achieve sample-analysis objectives	All	TAGSAM, SRC, Spacecraft	Messenger	Contamination Control	New Requirement 11/9/2011
1.2	2.2.1	Document the contamination acquired by the TAGSAM Head during flight	T	Ensure a chain of evidence linking the acquired sample with its contamination experience	All	TAGSAM, SRC	Dworkin	Contamination Control	
	2.2.2	Generate and follow the requirements in a project contamination control plan	T	Details of the project contamination control and documentation procedures are best described in a detailed plan (to be completed in Phase B)	All	All	Dworkin	Contamination Control	
1.3	2.3.1	Return 6.5 cm^2 of the surface-contact pad capable of acquiring particles from 10 µm to 1 mm in size while the TAGSAM head is in contact with the asteroid surface	T	Backup sample collection technique in case primary bulk sample acquisition is unsuccessful. 10 µm is the average size of interplanetary dust particles. 1 mm is the average size of coarse-grained components in carbonaceous chondrites.	8. Sample Collection 10. Earth Return	TAGSAM, SRC	Marshall	Regolith Development	Requirement clarified, particle size specified 11/30/2011
	2.3.2	Return and archive ≥ 19.5 cm^2 of the surface-contact pad capable of acquiring particles from 10 µm to 1 mm in size while the TAGSAM head is in contact with the asteroid surface	T	NASA requirement not to consume more than 25% of returned sample	8. Sample Collection 10. Earth Return	TAGSAM, SRC	Righter	Regolith Development	Requirement clarified, particle size specified 11/30/2011
	2.3.3	Image the TAGSAM Head contact surface with TBD resolution prior to stowing the Head in the SRC.	T	Image analysis provides estimate of amount surface sample collected. Shows if material on TAGSAM contact surface could prevent stowage of the Head.	8. Sample Collection	TAGSAM, OCAMS	Smith	Regolith Development	New Requirement 11/9/2011

1999 RQ36 Rises to the Top of the Asteroid Charts



Asteroid 1999 RQ36 is an Excellent Sample Return Target

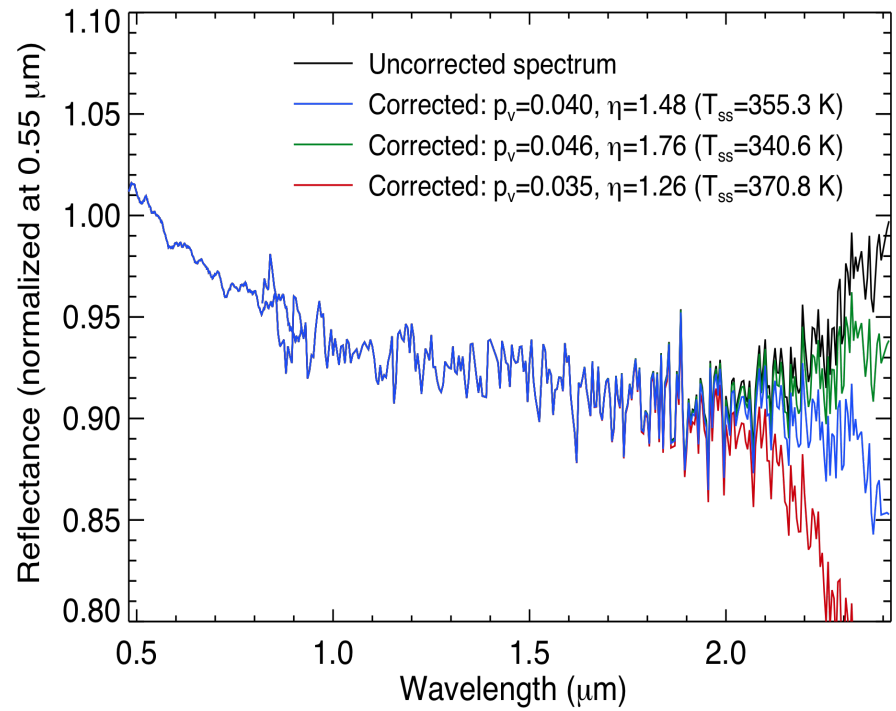
–Arecibo Radar Data



- It provides for the **most exciting science**, with a spectral signature suggesting a carbon- and volatile-rich surface
- It is a 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 **abundant regolith** on the surface available for sampling
- Study of this Potentially Hazardous Asteroid is **strategically important** to NASA and Congress

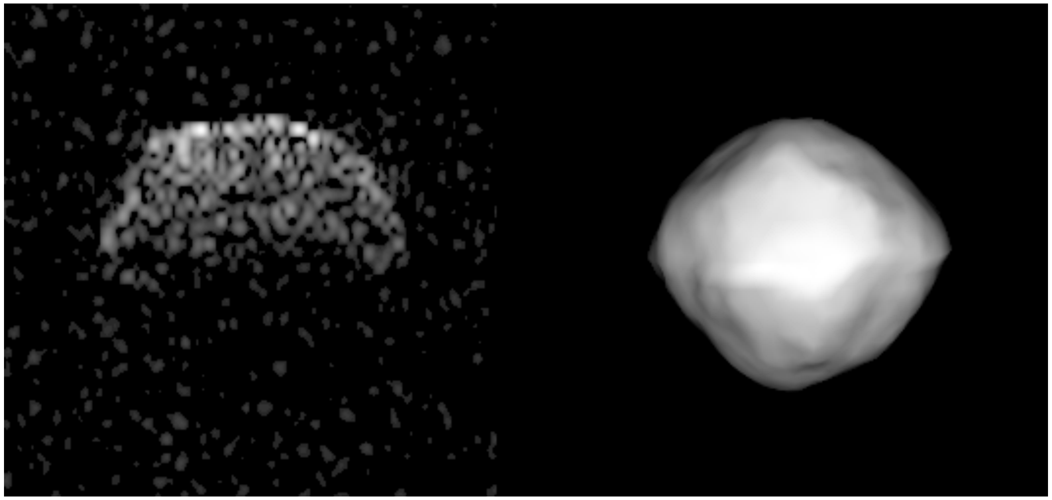
B-CLASS ASTEROIDS ARE SOME OF THE MOST VOLATILE-RICH SMALL BODIES

- 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 **CI/CM chondrites are the most likely meteorite analogs**.
- RQ36 is spectrally similar to Themis and Pallas – other B-type asteroids.
  - Asteroid 24 Themis was recently discovered to have H_2O ice and organics on its surface (Rivkin and Emery 2010; Campins et al. 2010).

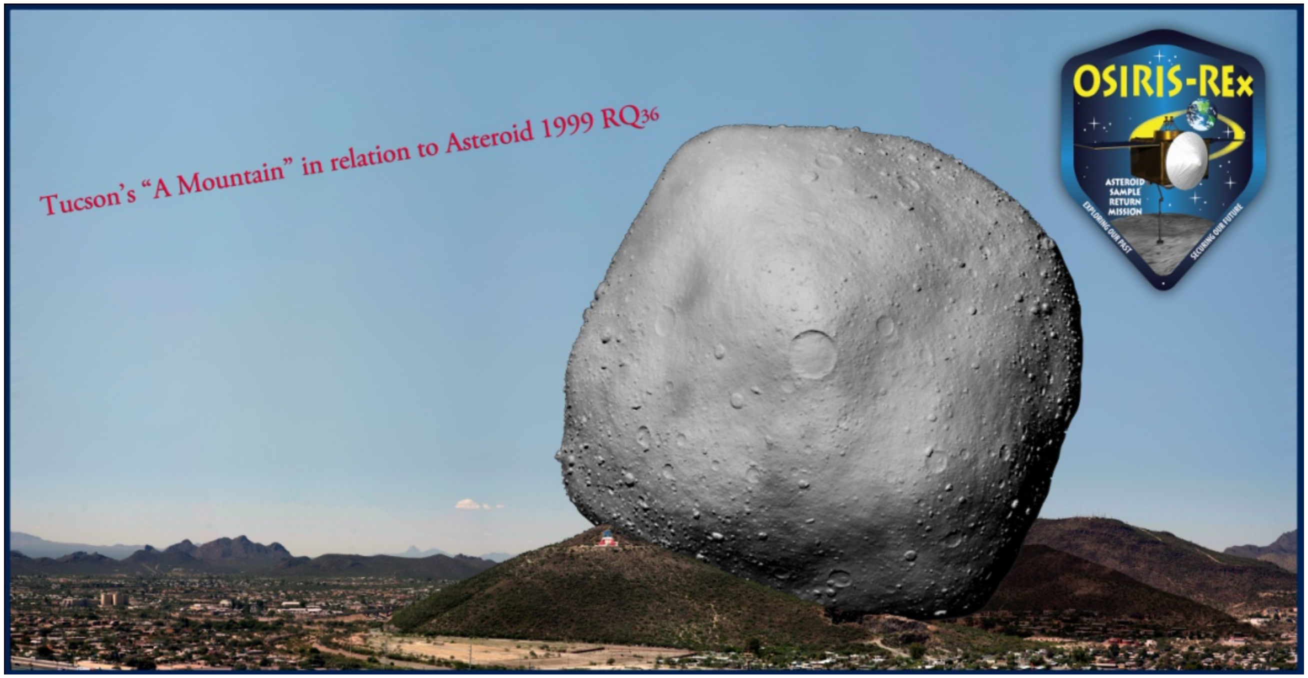


–B. E. Clark et al. 2011

Radar Observations Provide Unparalleled Knowledge of 1999 RQ36

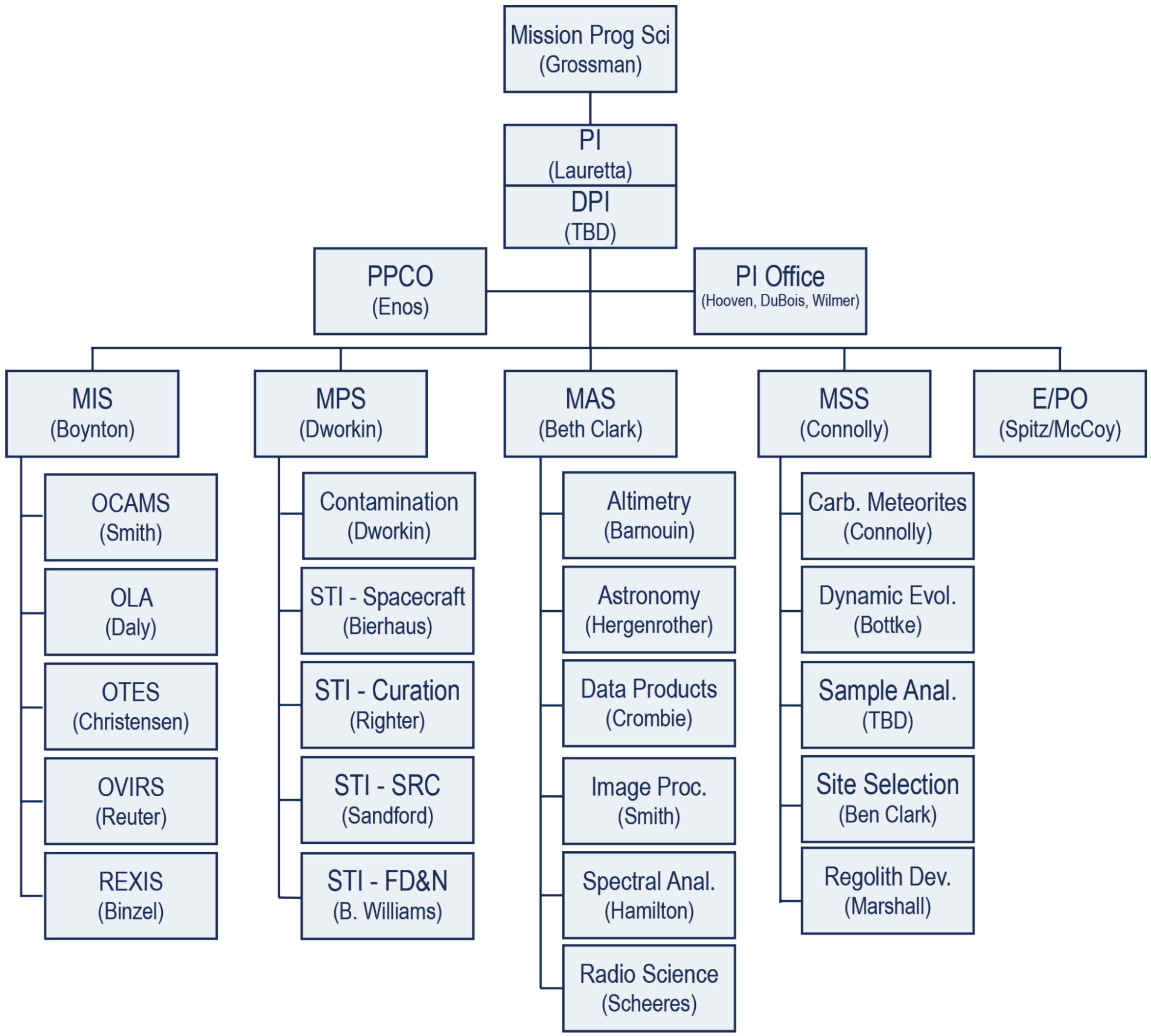


- Ephemeris position known to within 10 km
  - **Enables navigation** to the target
- Nearly spherical object—575 m diameter
  - **Simplifies** orbital and sampling **operations**
- Smooth surface—one discernable feature >7.5-m
  - Provides confidence in the **presence of regolith**
- 0° obliquity, retrograde rotation
  - **Ensures illumination and Earth communication** during sampling



- By Ross Dubois, UA

The Science Team is organized for flight and ground system development, data processing, and analysis



OSIRIS-REx Bulk Sample Contains the History of 1999 RQ36

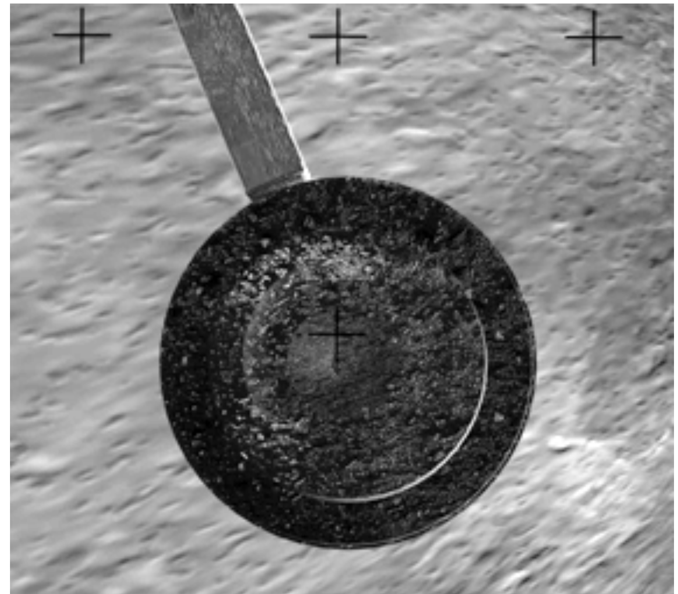
- 11.5 g of bulk sample for immediate analysis after Earth return
  - Measure the bulk abundances and isotopic compositions of the asteroid
  - Constrain the presolar, nebular, and parent-body history of 1999 RQ36
  - Test hypotheses based on dynamical and chemical evolution models of the Solar System
  - Perform first 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

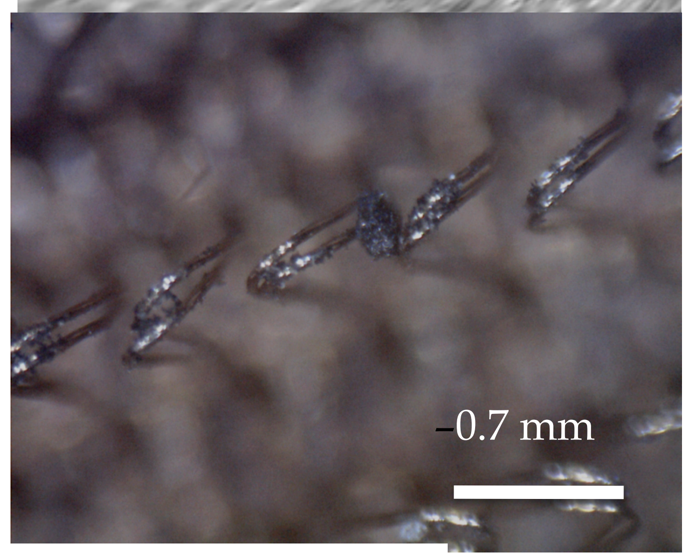
Sample in Cavity

Acquired Regolith Sample

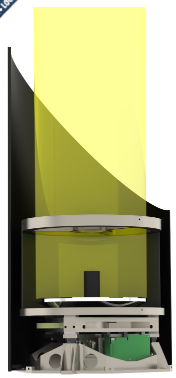
OSIRIS-REx Surface Samples Provide Critical Data for the Spectral Interpretation of Carbonaceous Bodies

- 5 cm^2 of surface sample for immediate analysis after Earth return
  - Provide a backup sample to the bulk collection
  - Characterize the optical properties of the upper surface layer
  - Constrain the mineralogy of the space-exposed surface
  - Perform first analysis of space-weathering on carbonaceous material
- 1.5 cm^2 for margin
- 73.5 cm^2 archived for future generations

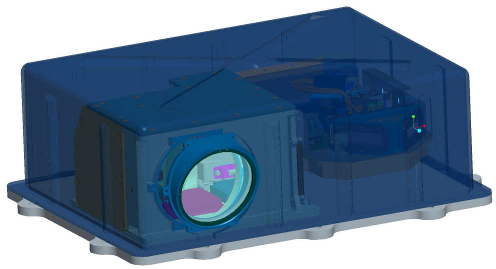




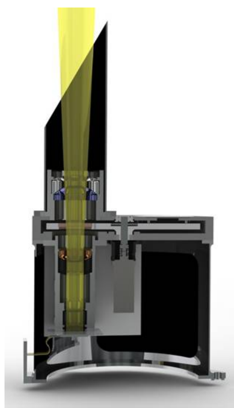
Science requirements are fulfilled by our instrument capabilities



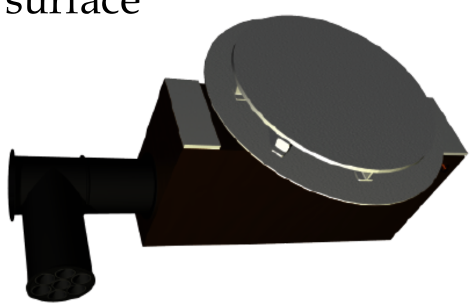
–**PolyCam** acquires 1999 RQ36 from 2M km range and refines its ephemeris



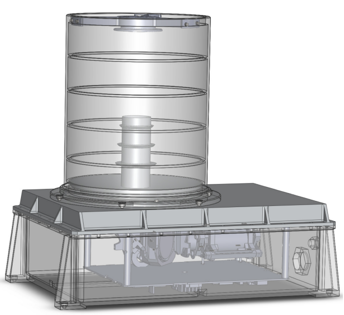
–**OLA** maps the shape and topography



–**MapCam** performs filter photometry and maps the surface

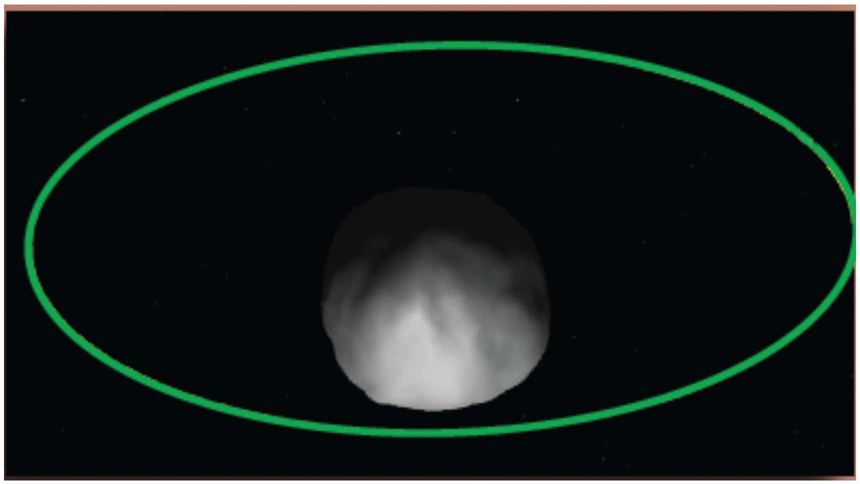


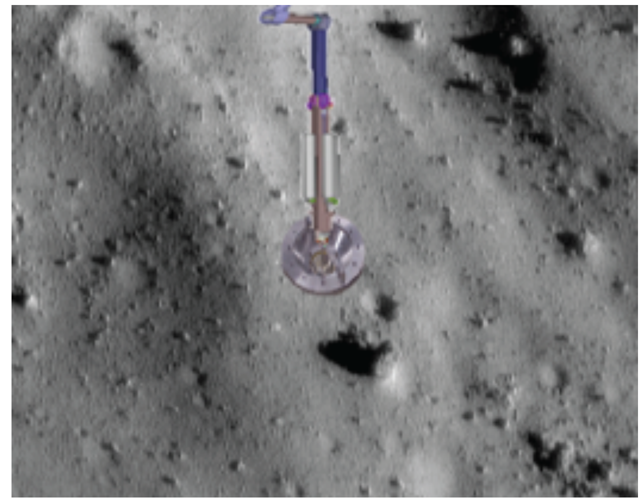
–**OVIRS** maps the spectral properties from 0.4 – 4.3 µm



–**OTES** maps the spectral properties from 5 – 50 µm

Observations performed at RQ36 achieve science beyond anything obtainable from Earth

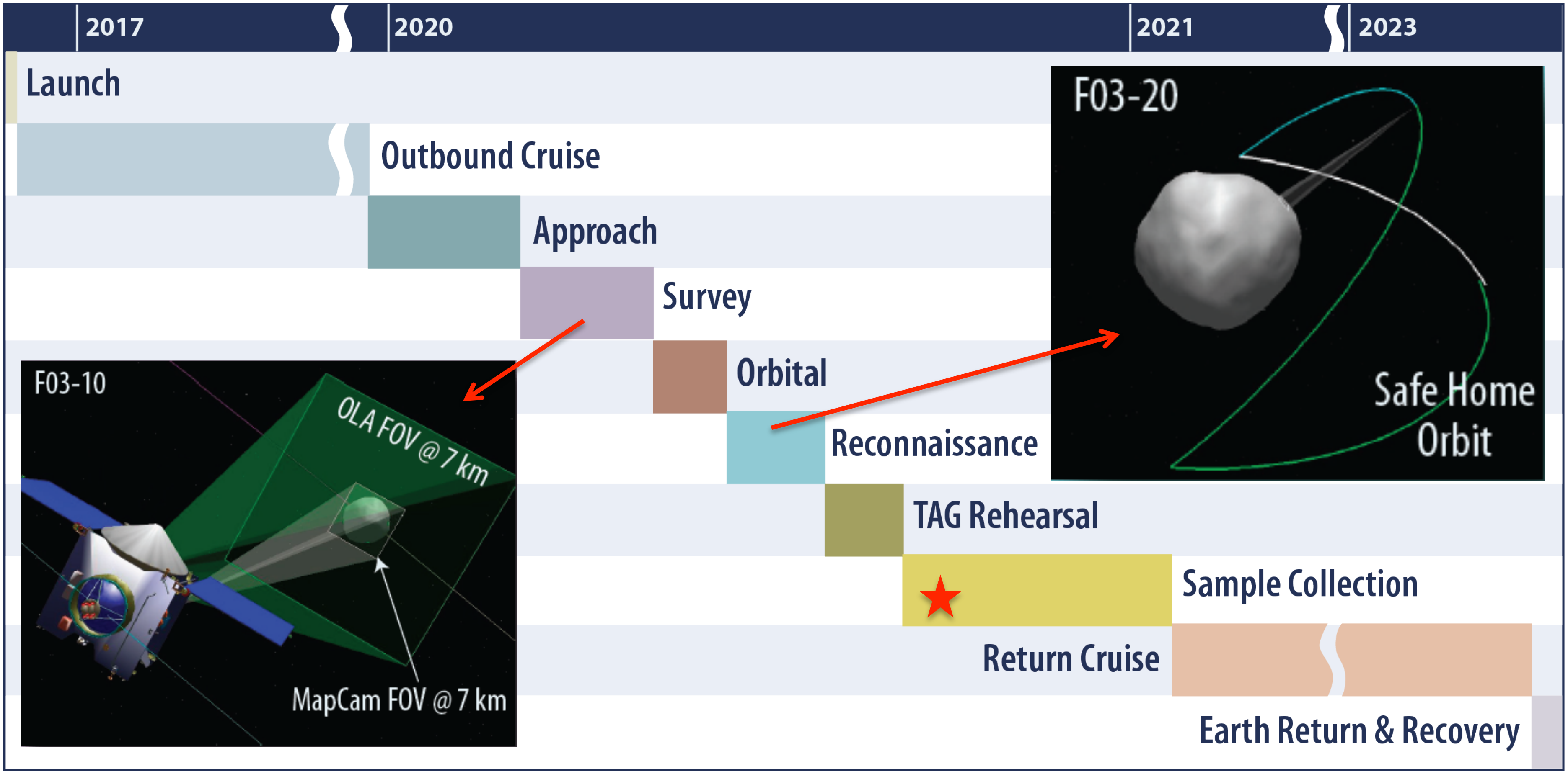




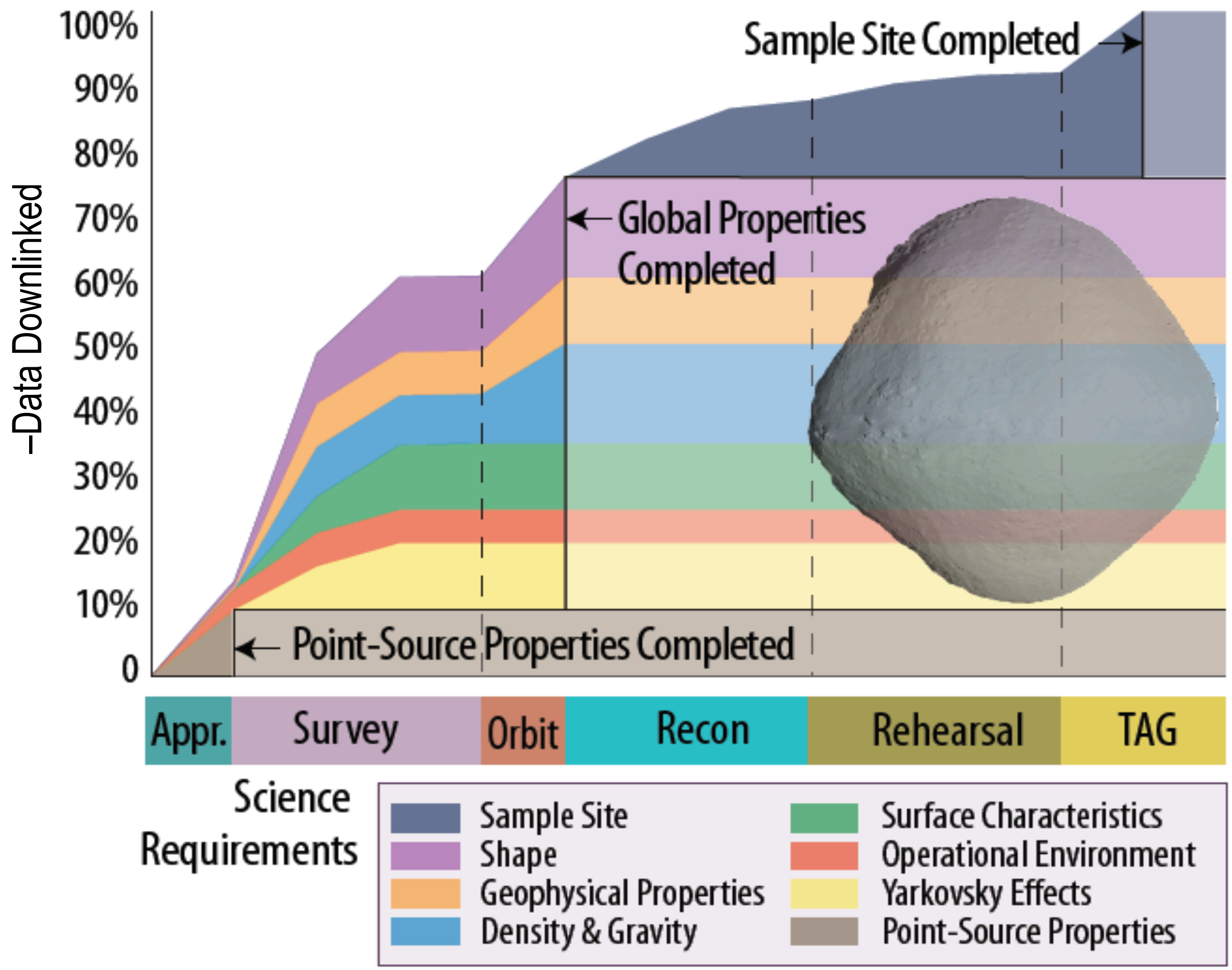
- **Radio Science** reveals the mass, gravity field, internal structure, and surface acceleration distribution
- **SamCam** and **PolyCam** study the regolith at high-resolution and SamCam documents sample acquisition at 1 Hz

Requirements are fulfilled by our mission design…

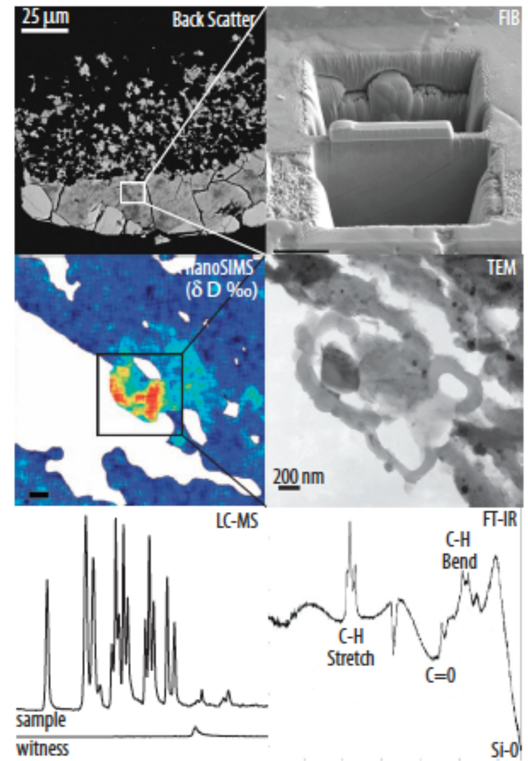
The Design Reference Mission (DRM) . . . "serves as the backbone for focusing the design effort" -- from NF-3 Step 1 evaluation



…and our data analysis



–Sample Analysis



–2023 and beyond

All samples are archived in the Astromaterials Curatorial Facility at Johnson Space Center (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.

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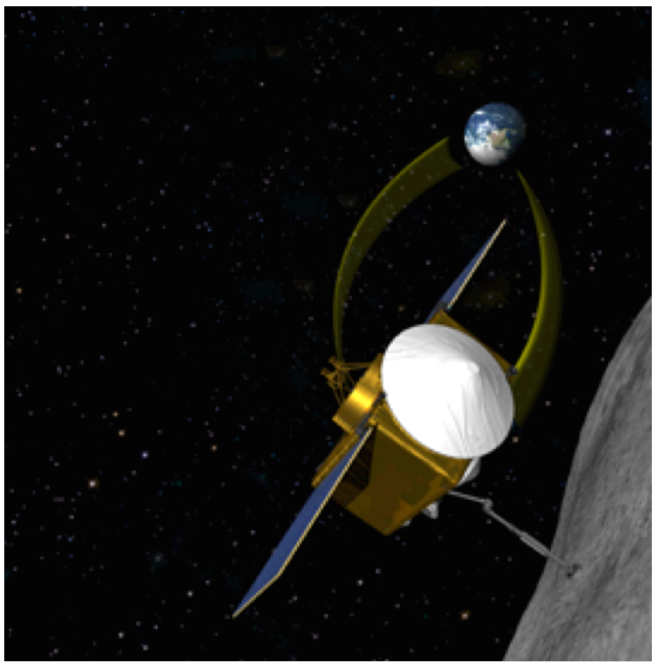

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