OSIRIS-APEX

NASA's Apophis Explorer

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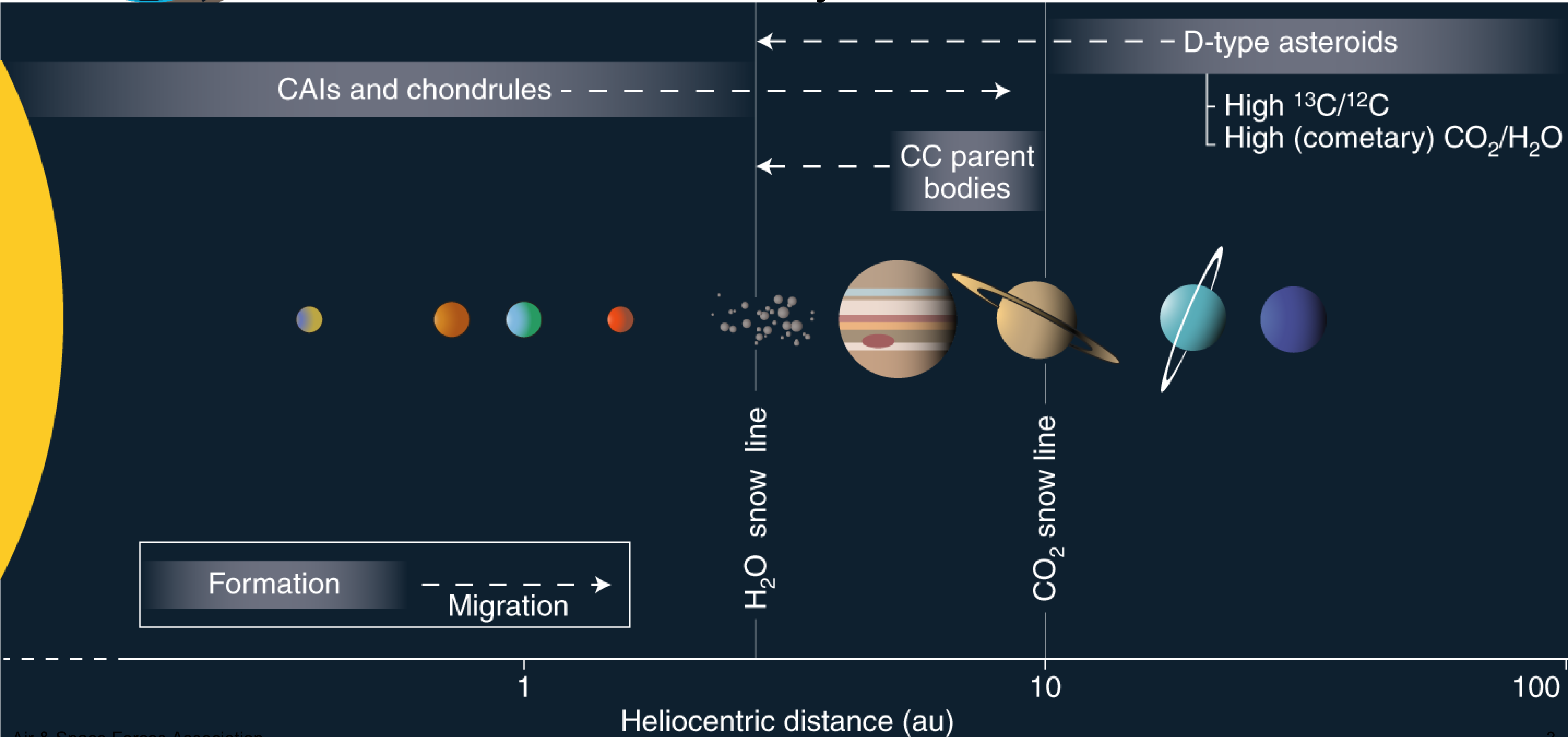
Why Study Asteroids?

- Origin of the Solar System
  - Asteroids are the main source of the meteorites from which we determine the composition of the early solar system

Debris from Solar System Formation



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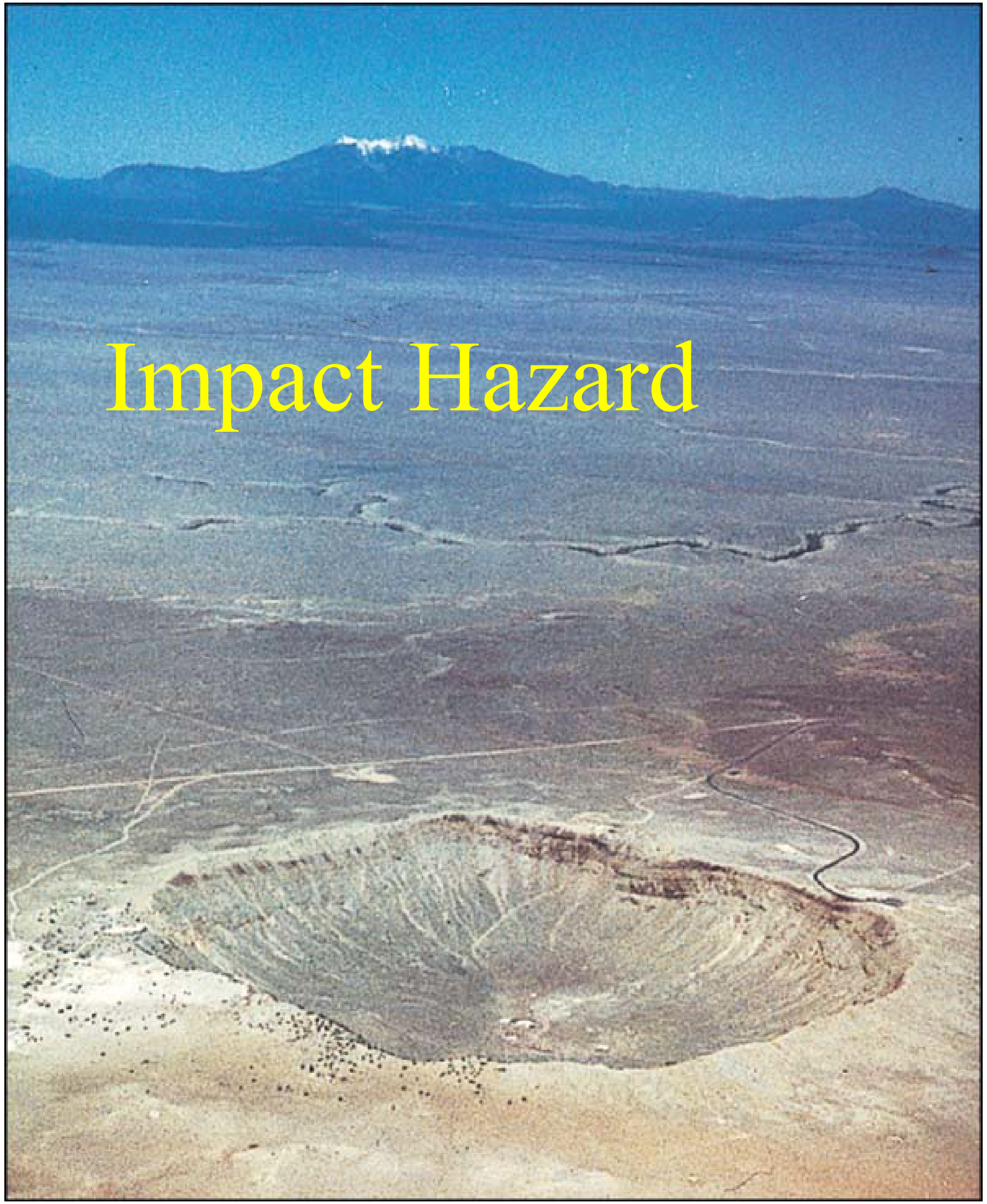
  - Asteroids present a potential hazard to Earth that can be mitigated


Impact Hazard

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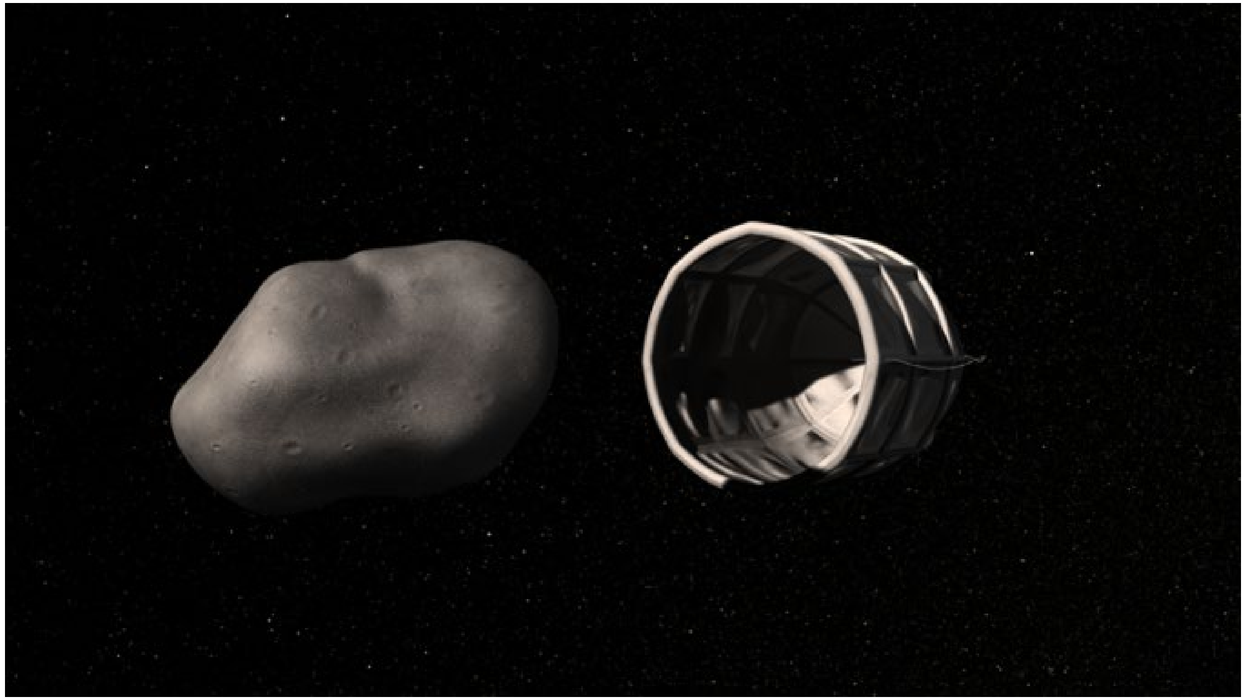
  - If humans are to live in space, they will need materials, particularly water, which are far more available from asteroids than from other sources.

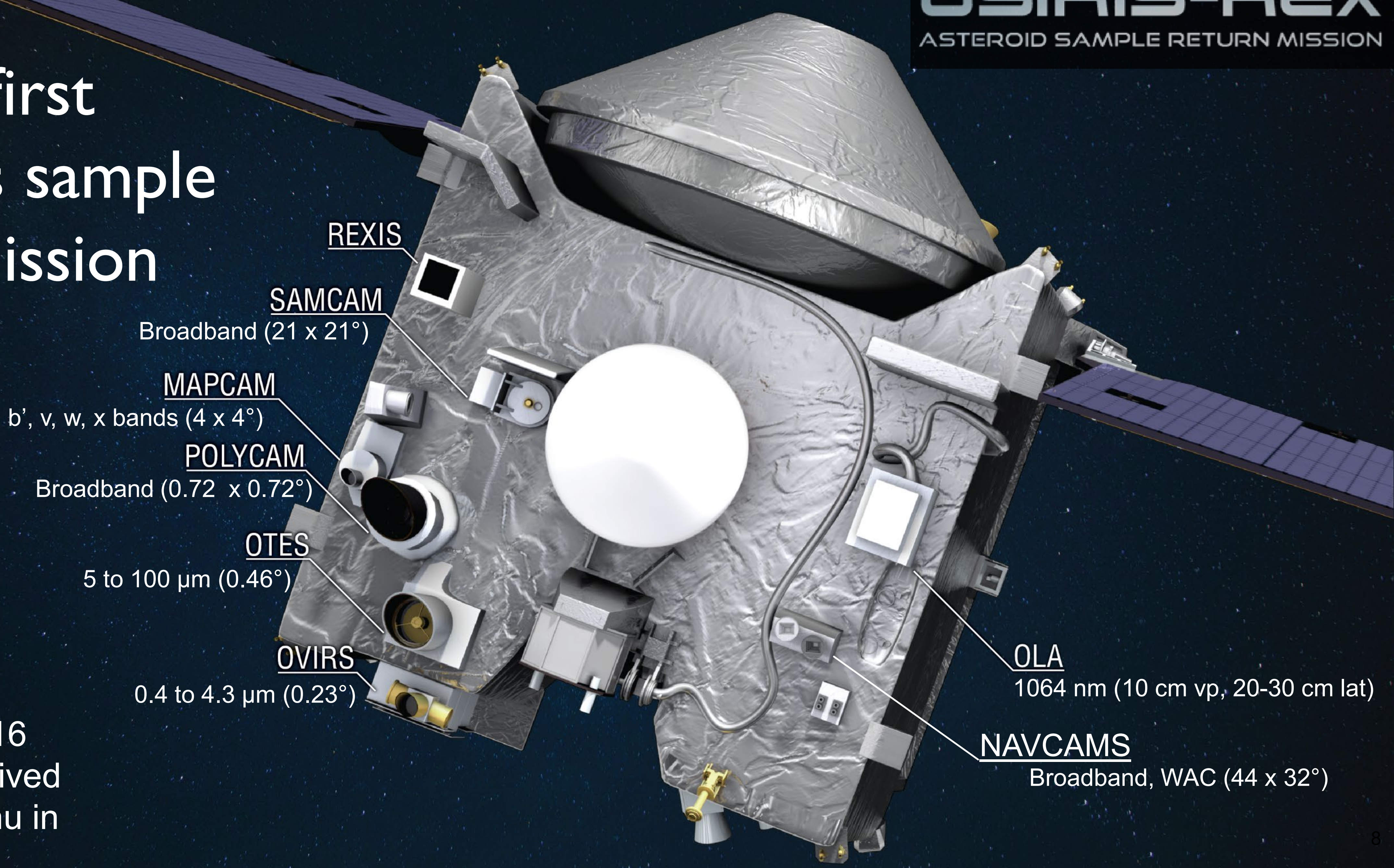
OSIRIS-APEX
APOPHIS EXPLORATION MISSION

Space Resources



OSIRIS-REx
ASTEROID SAMPLE RETURN MISSION

NASA's first asteroids sample return mission



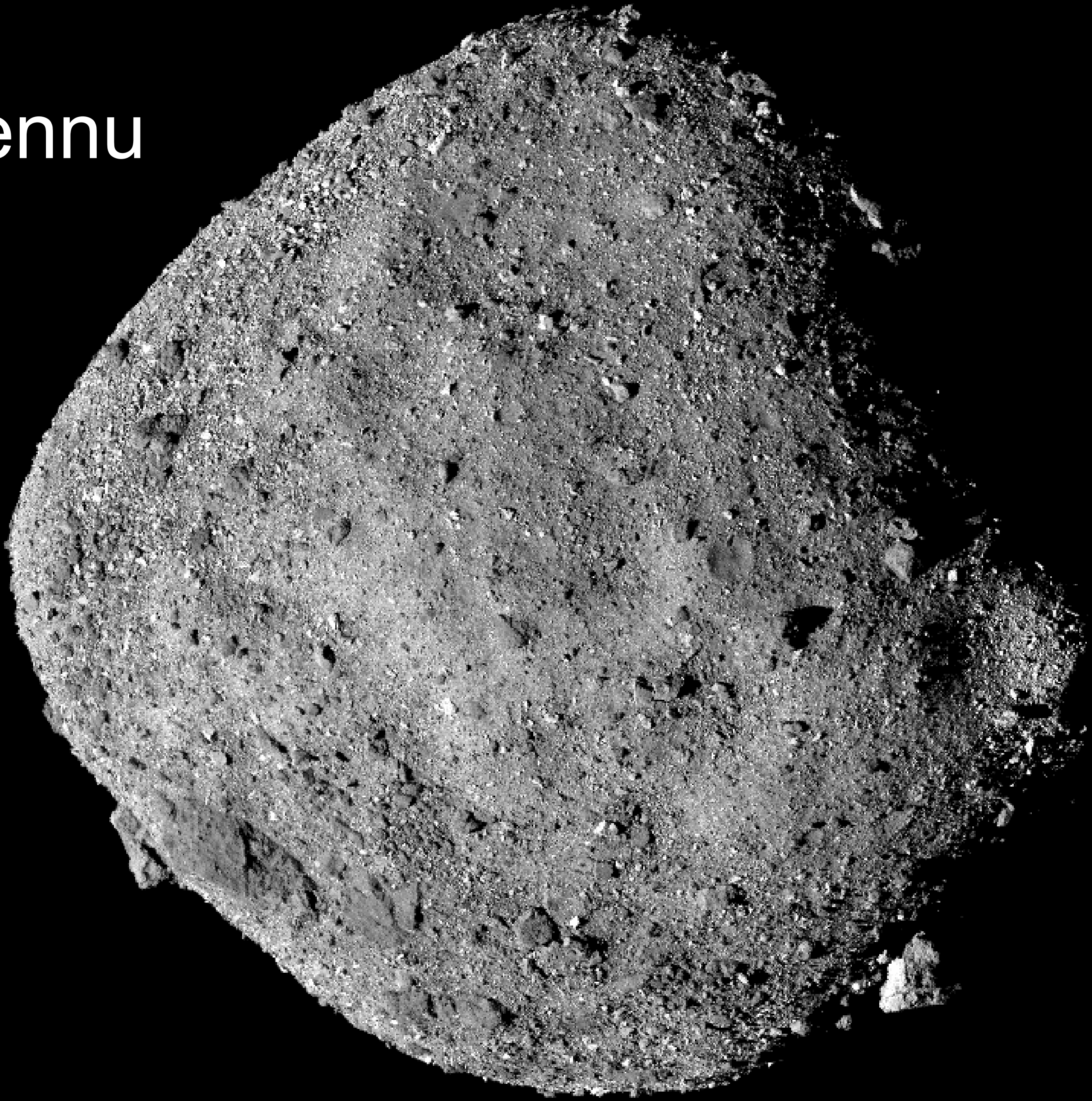
Launched in 2016 OSIRIS-REx arrived at asteroid Bennu in December 2018

OSIRIS-REx at Bennu

PolyCam Image Mosaics
December 2, 2018
33 centimeters/pixel

4.3 hr rotation period

Phase angle ~48°
Emphasizes terrain/reflief

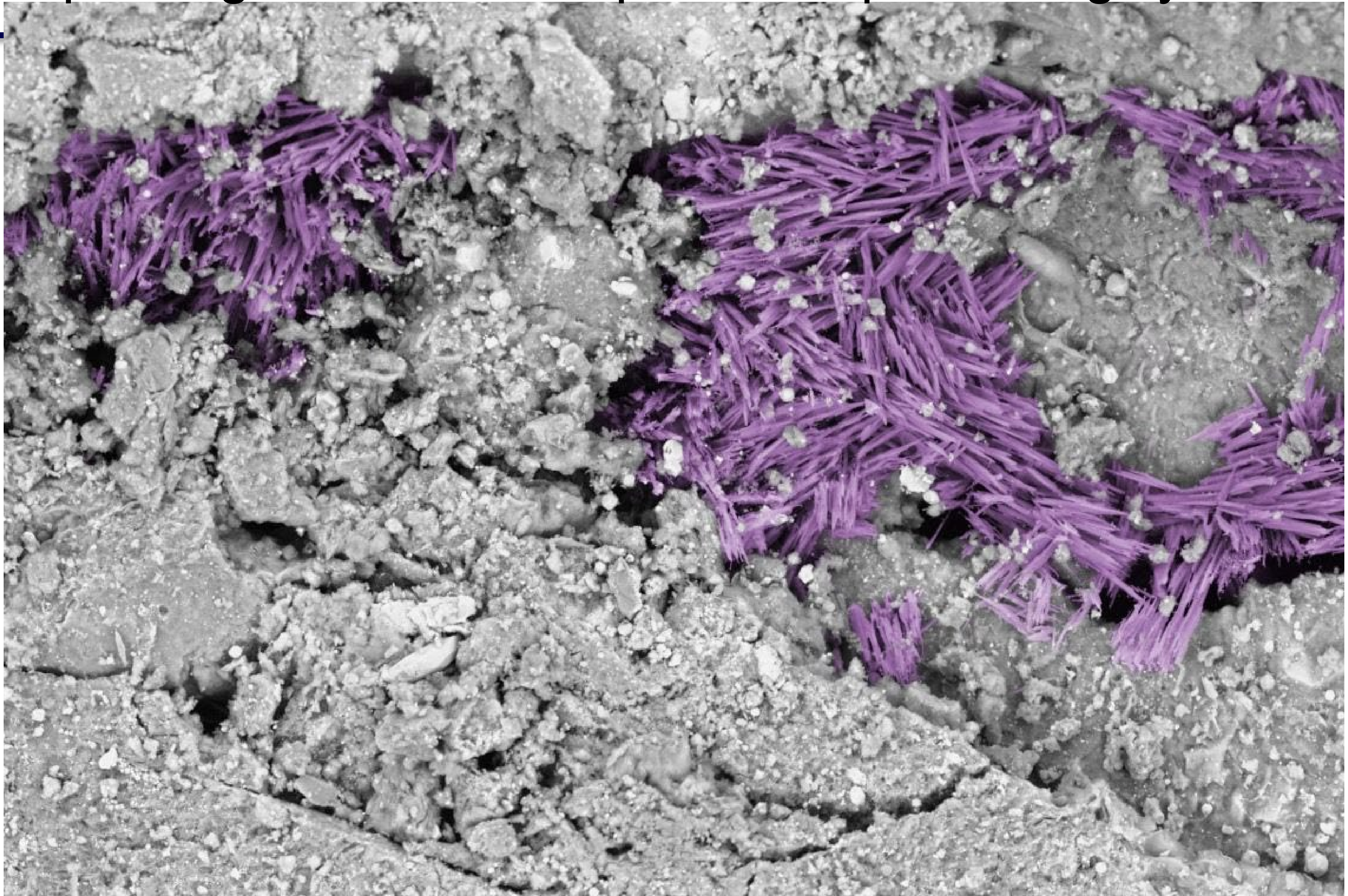


TAG – first contact with surface

- The first images after contacting the surface but before the Nitrogen gas fires shows how the sample head penetrated the surface.
- The spring in the arm was never compressed
- The total depth penetrated in ~9 sec was about 48cm.
- Surface seems extremely porous (Walsh et al., 2022).

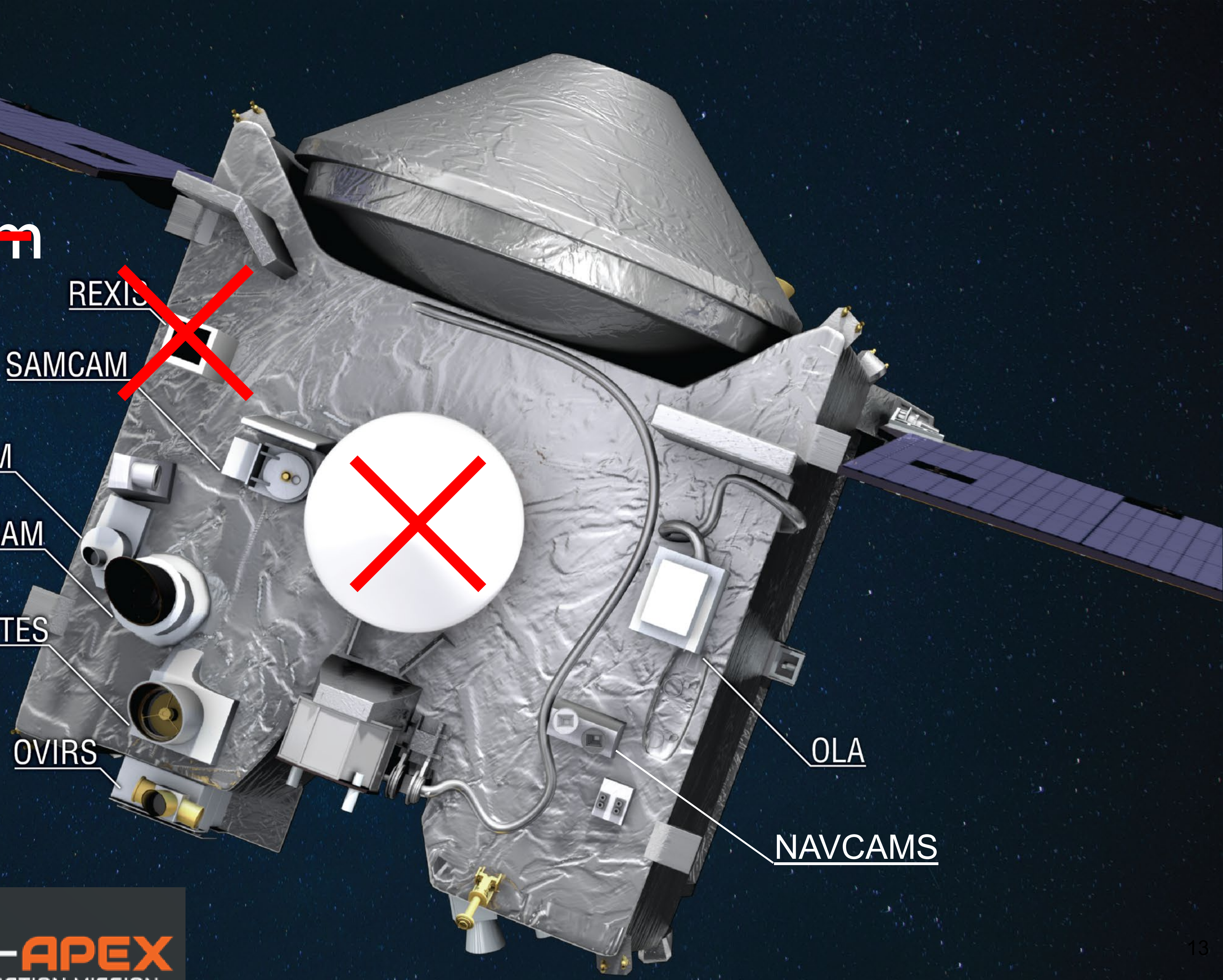
Microscope image of Bennu sample shows processing by water

Purple color to show texture. Sample is actually gray



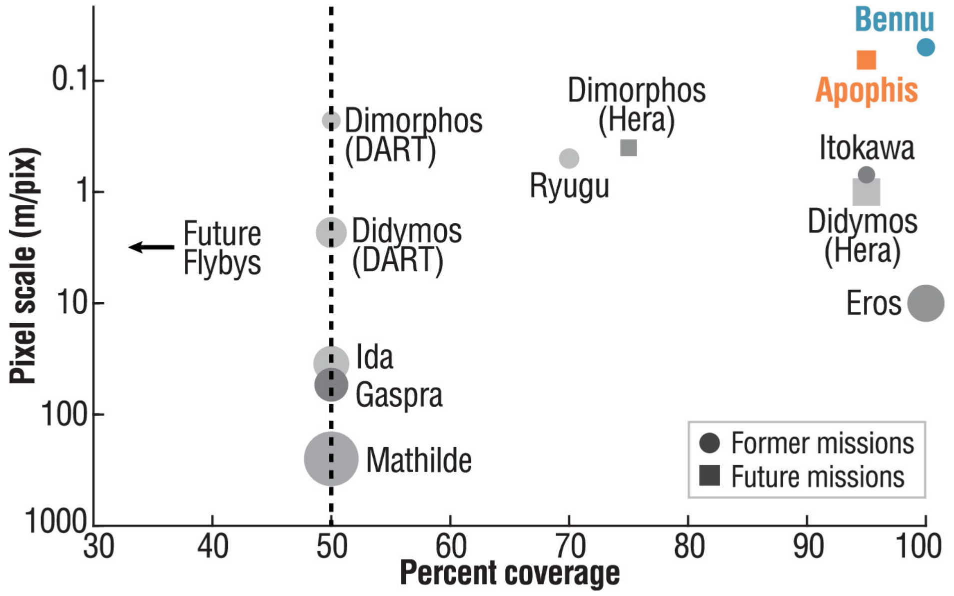
~~Sample return from~~ asteroid Apophis

Launched in 2016
OSIRIS-REx arrived at asteroid Bennu in December 2018
Sample return September 2023
Arrive at Apophis June 2029



OSIRIS-APEX
APOPHIS EXPLORATION MISSION

OSIRIS-Apophis Explorer: Repurposing the OSIRIS-REx spacecraft

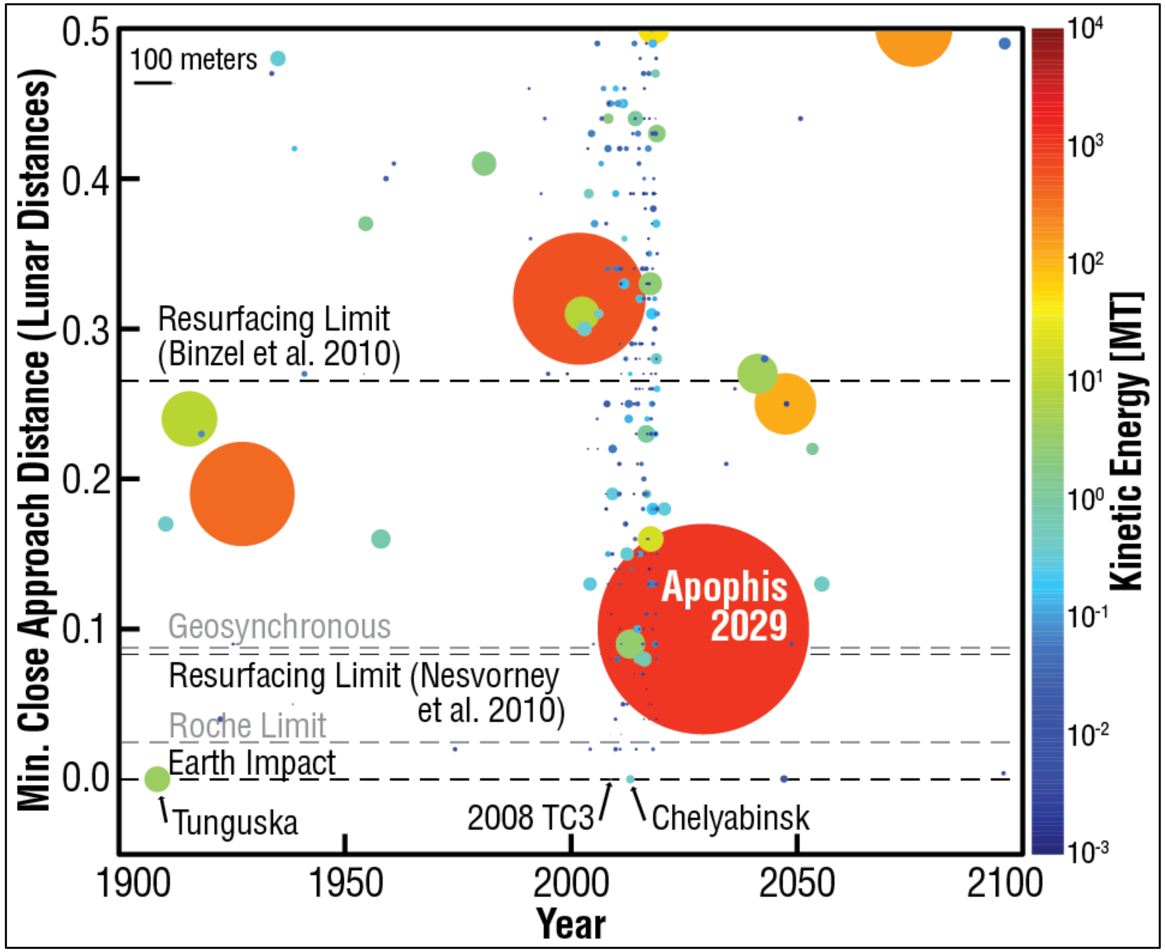


- >500 m/s remaining fuel, which can support an extended mission
- The OSIRIS-REx instruments on the spacecraft were designed for a rendezvous-style mission.
  - Not optimized for fast, distant flybys, but can achieve exceptionally high-resolution data at small surface ranges (*left*)
- An extensive target search was conducted (Sutter et al. 2022)
  - Searched for objects that could be rendezvoused with within 6 years of SRC release

Apophis is the most viable and scientifically compelling target identified by our search

Why Asteroid Apophis?

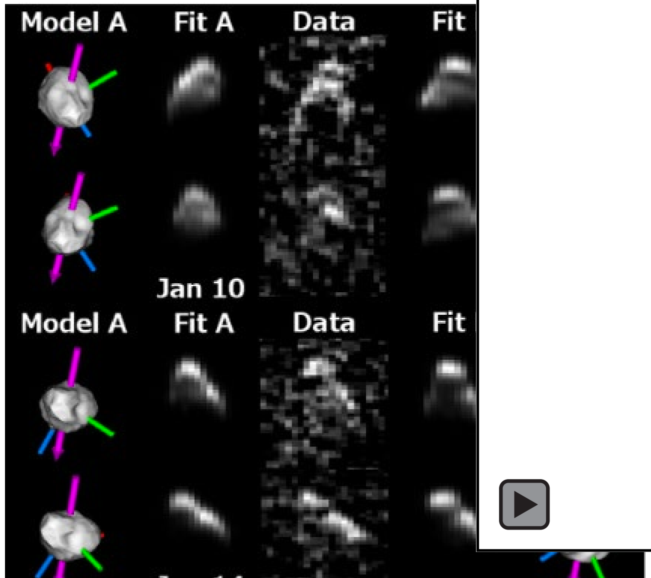
- The 2029 Apophis-Earth encounter represents a once in a 7500-year opportunity (*right*).
  - Comes within 0.1 lunar distances and is tidally perturbed by Earth, changing the orbit from an Aten to Apollo.
  - The rotation state will likely change due to the very close approach to Earth.
  - The surface may be disturbed.
- Ground-based observers cannot view Apophis shortly after the Earth encounter.
  - S/C will be the best tool for observing Apophis respond to the close Earth encounter.
- A unique opportunity to understand the volatile content and surface response of stony asteroids.
- Addresses planetary defense, human exploration, and resource extraction "Knowledge Gaps".



Above. The size and proximity of Apophis during 2029 stands out as a rare event. Adapted with permission from Binzel et al. 2020.

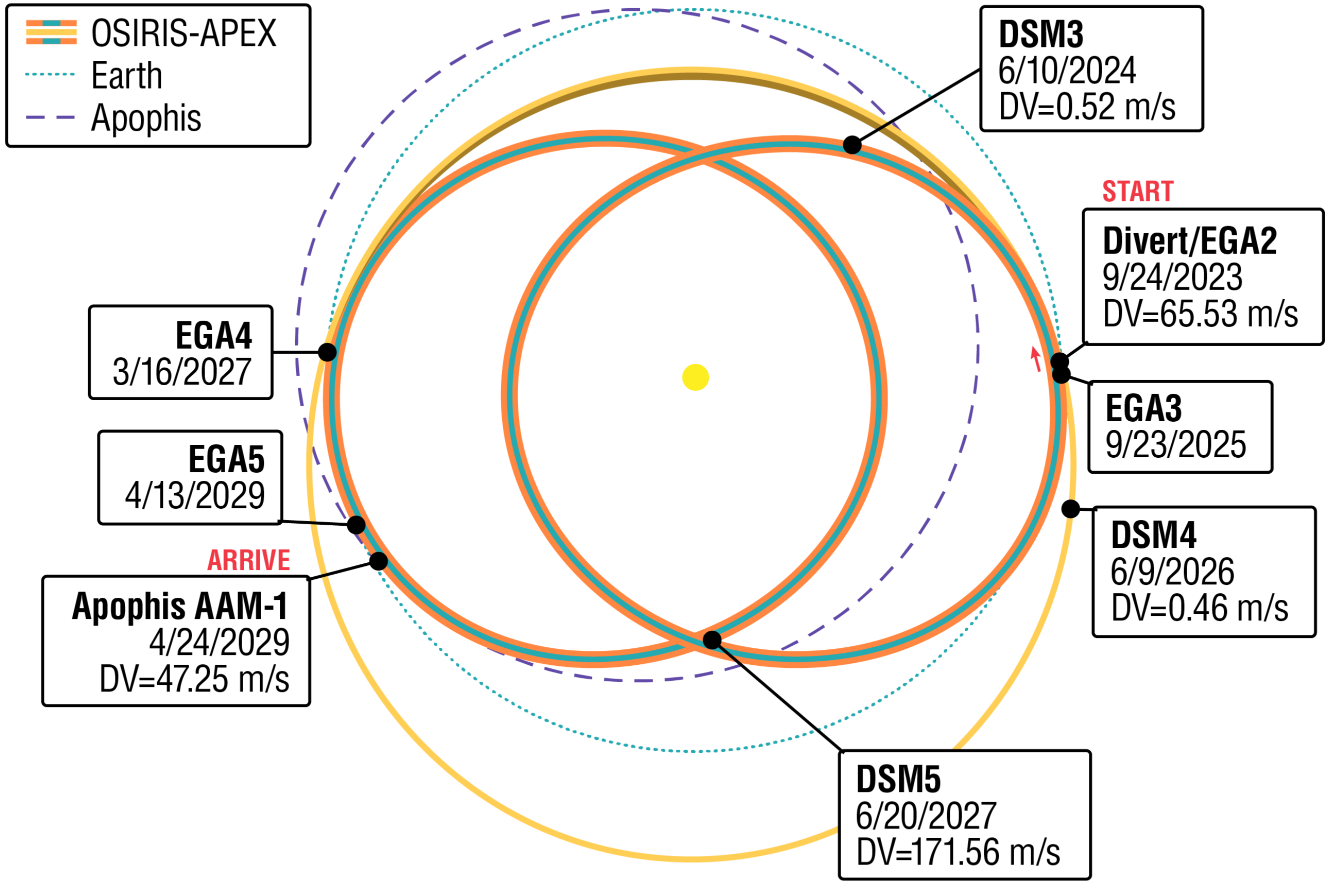
What we know about Apophis

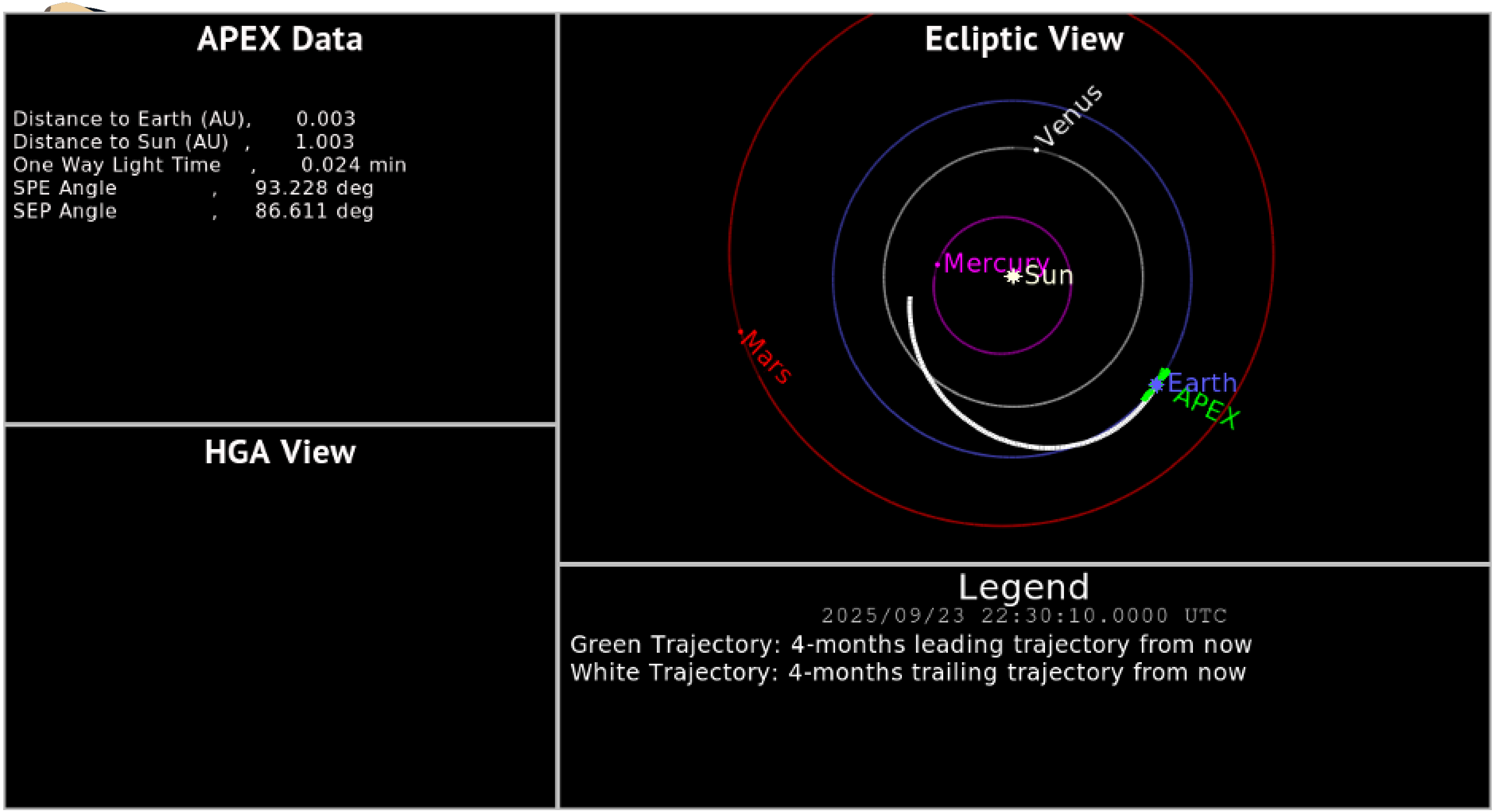
- Orbit (will change from a=0.92→1.10
- Size = 340 m (±50 m, mean diameter)
- Shape = vaguely bilobate, poorly known
- Rotation state = ~ 30h, NPA, will change at Earth encounter.
- Bulk Density = 1500-3000 kg m^{-3}
- Albedo = 30%
- Spectral Type = S (Stony)
- Mass uncertainty: large



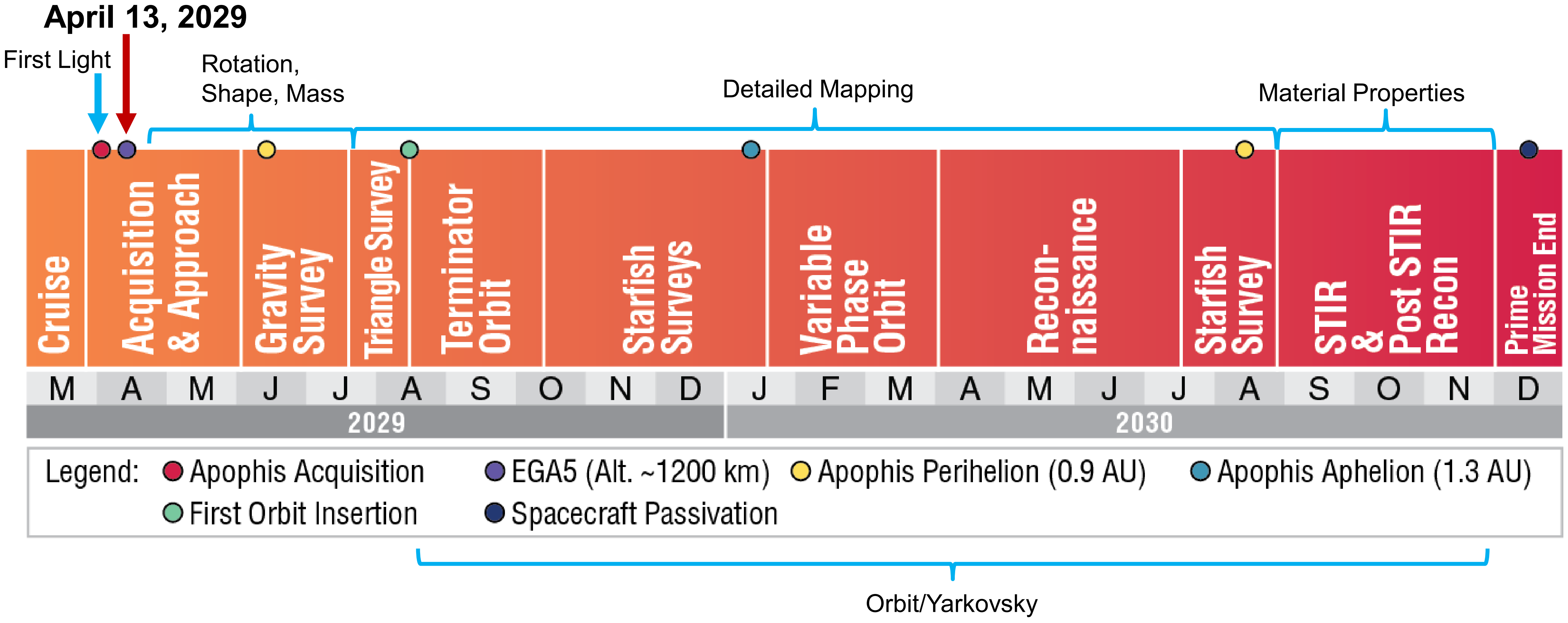
APEX trajectory

- The APEX spacecraft gets to within ~ 0.5 au of the Sun on its way to Apophis.
- Spacecraft must “hibernate” in a special mode that covers sensitive equipment with the solar panels




APEX Data
Distance to Earth (AU), 0.003
Distance to Sun (AU) , 1.003
One Way Light Time , 0.024 min
SPE Angle , 93.228 deg
SEP Angle , 86.611 deg
HGA View
Ecliptic View
Venus
Mercury
Sun
Mars
Earth
APEX
Legend
2025/09/23 22:30:10.0000 UTC
Green Trajectory: 4-months leading trajectory from now
White Trajectory: 4-months trailing trajectory from now

Proximity Operations Timeline

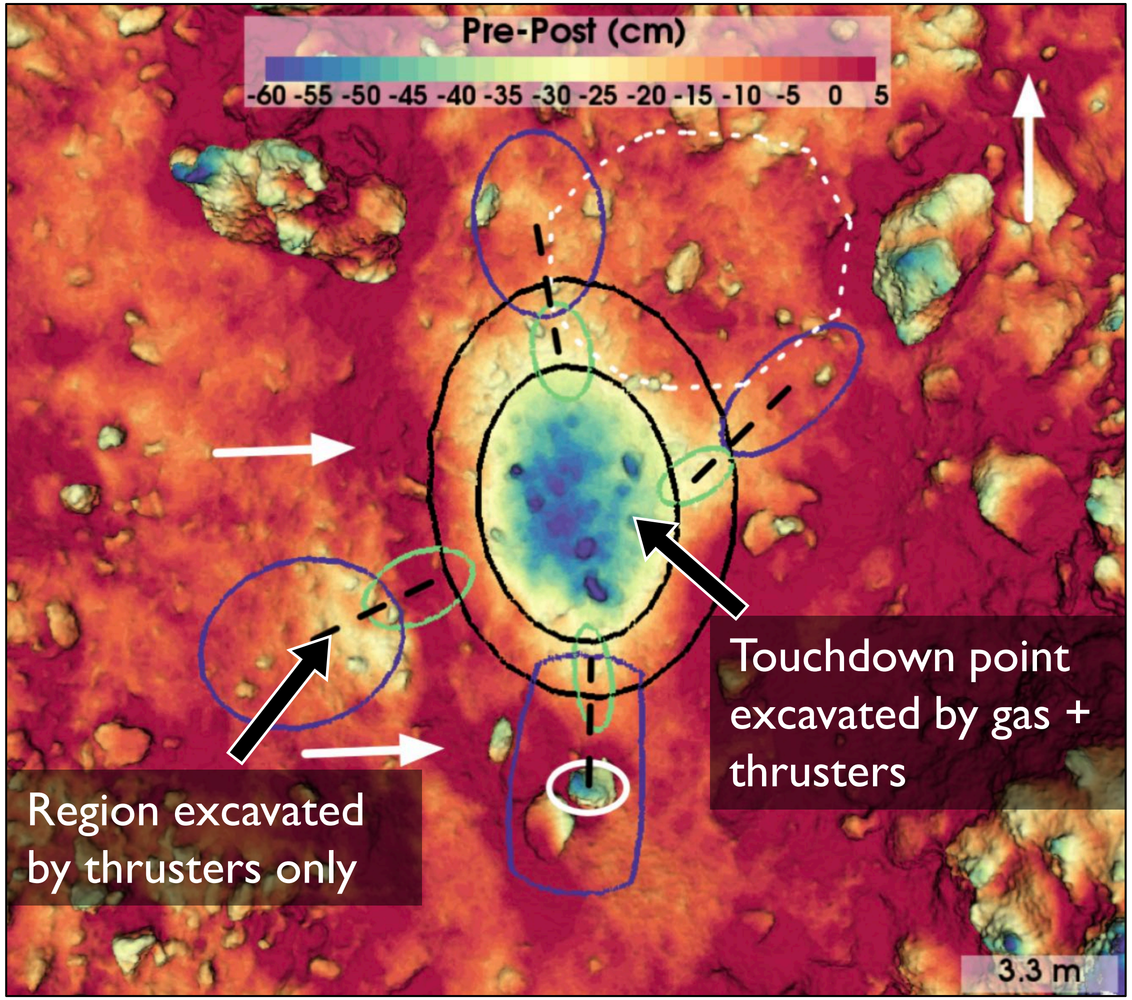


Constructed mission phases and overall mission timeline using lessons learned from OSIRIS-REx

REST – Excavating the surface

Figure C-1 The REST maneuver will provide information about the near-surface properties of Apophis.

- We will use the thrusters to excavate the surface and then study the effects with another high-resolution Reconnaissance pass.



Above: Fig. 4 from Lauretta et al. 2022. The change in topography at Nightingale due to TAG. We highlight the thruster footprint (light green ellipse for start position and dark purple for final position), and indications of debris deposits (white arrows).

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Bennu in 1999 and 2023

First Bennu Image
1999-09-23T09:30:25Z