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APOPHIS PATHFINDER: A MILO SPACE SCIENCE INSTITUTE SMALLSAT MISSION IN SUPPORT OF SCIENCE AND PLANETARY DEFENSE

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ASU Arizona State University

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The MILO Space Science Institute

The MILO Institute is a non-profit research collaborative led by **Arizona State University** with support from **Lockheed Martin**.

Collaboration

MILO Institute missions will be conducted by a consortium of domestic and international universities and space agencies.

Affordable Access

The Institute brings members together to fund an entire mission, each paying a fraction of the total cost, leveraging lower cost mission concepts and resource sharing.

Hands on Experience

The Institute is helping to train the next generation of scientists and engineers by offering workforce development through hands-on projects, technology demonstrations, and advancement of scientific discoveries.

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2029 close encounter: (99942) Apophis comes super-close to Earth

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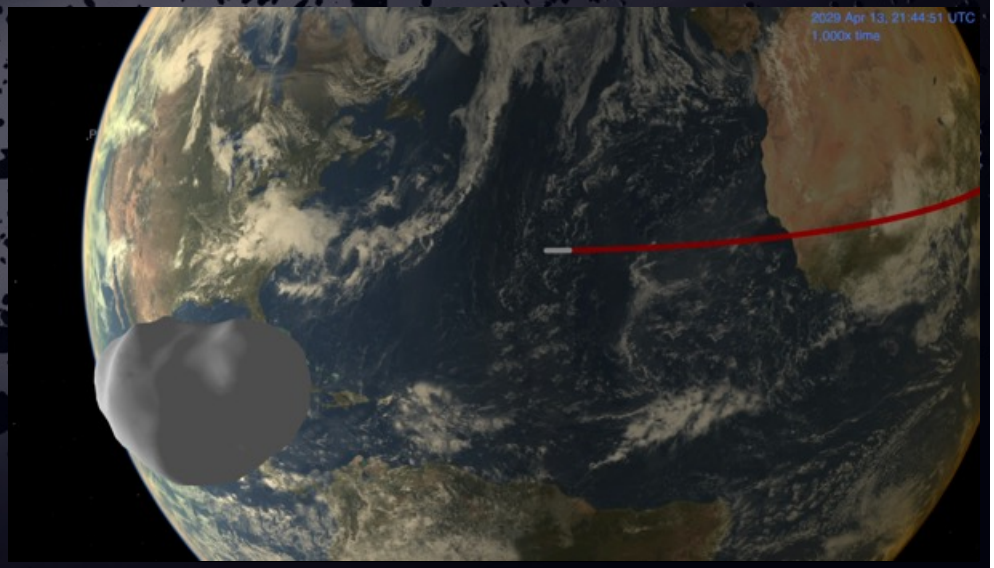
- (99942) Apophis is a ≈400 m diameter S-type Potentially Hazardous Asteroid
- April 13, 2029 Earth approach/flyby presents *a rare and unique science opportunity*
  - Closest approach is within 6 Earth radii
  - Deviation of trajectory is ≈ 30˚
  - Potential for tidal effects *on the asteroid*
- Close Earth flyby provides potential to study
  - Tidal distortion
  - Surface down-slope movement
  - Spin rate changes
  - Dust production
- Observations of any of these effects could provide *unique* and *useful* insights into the interior structure and other physical properties of Apophis
  - and thus, by analogy, of the properties of the 80% *of the PHAs* that are like Apophis



Closest approach April 12-13, 2029

Marina Brozovic/JPL

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Apophis Pathfinder

MILO is seeking member organizations interested in compelling asteroid science and planetary defense

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Mission Overview

- Perform a flyby mission with two smallsats past the potentially hazardous Near-Earth asteroid (99942) Apophis before its historic close Earth encounter in 2029

Mission Objectives

- Increase knowledge of asteroid orbit, geology, composition, and estimate mass and density
- Help inform future Planetary Defense strategies
- Influence planning and implementation of later 2029 missions, like OSIRIS-APEx

MILO Benefits

Deep space mission infrastructure provided by MILO to support member hardware contributions:

- Spacecraft bus, Integration, Launch, and/or Mission Operations

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Science Goals

- Surface geology and shape/topography
- Crater size-frequency distribution and NEO bombardment history
- Surface composition/mineralogy and relationship to meteorites
- Thermophysical/regolith properties and relationship to Yarkovsky (etc.)
- Assess geophysical parameters (the “before” measurements prior to 2029)

Planetary Defense and Future Mission Support Goals

- Assess physical properties/parameters for “threat assessment” and mitigation
  - **Mass (for future missions including OSIRIS-APEX, etc.)**
  - **Shape and Topography (for future landers, probes, etc.)**
  - **Regolith properties (for future landers, probes, etc.)**

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Simple Payload

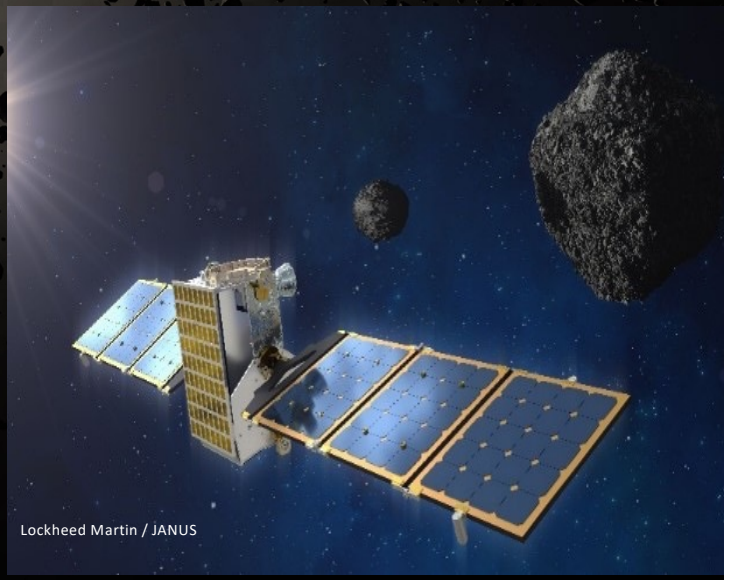
- Imaging system with RGB color and a targeted resolution of ~1 m/pix
- Near-IR point spectrometer for silicate, hydrates (?), organics (?) detection
- Thermal-IR imager, multi-band
  -Interested in talking to providers for IR instruments
- Can accommodate additional (small) member payloads...
- Innovative dual spacecraft approach to mass determination
  - Christensen, Park, & Bell (2021) *J. Spacecraft Rockets*.

Simple Spacecraft

- Heritage bus/major systems based on deep space experience
  - MARCO
  - JANUS
  - Artemis-1 CubeSats like LunaH-Map, etc.

Simple Mission Design

- Rideshare launch, short cruise, approach, flyby, & departure ops


Lockheed Martin / JANUS

Recovering Apophis Mass from Flyby*

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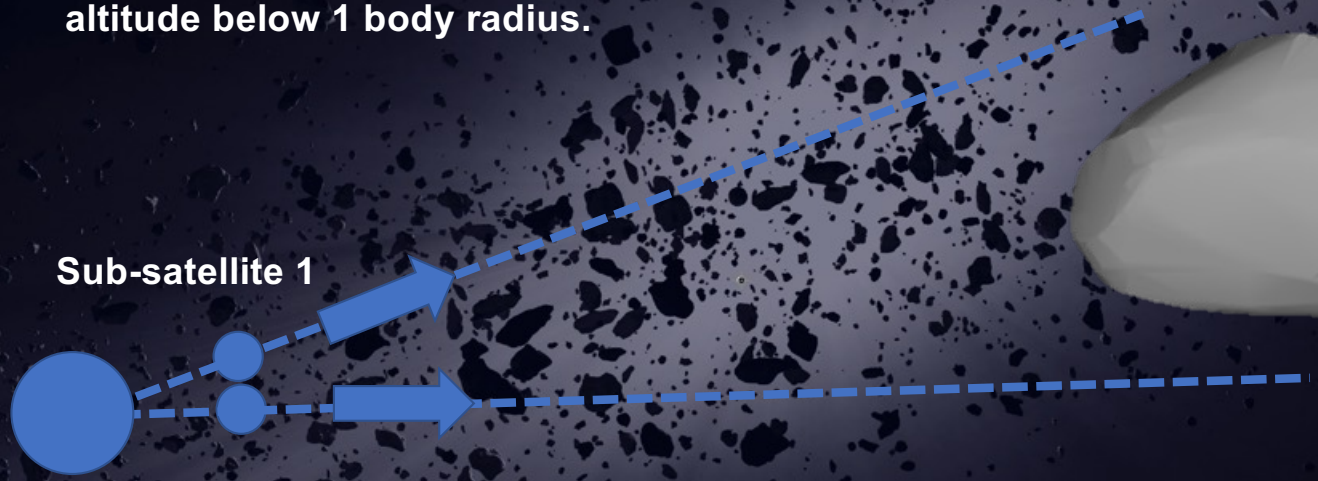
Sub-satellites are released from the main spacecraft to flyby the asteroid at altitude below 1 body radius.



*Estimating Asteroid Mass from Optically Tracked Radio Beacons, L. Christensen, R. Park, and J.F. Bell III, *J. Spacecraft and Rockets, 58,* 2021
https://arc.aiaa.org/doi/pdf/10.2514/1.A34830

Recovering Apophis Mass from Flyby

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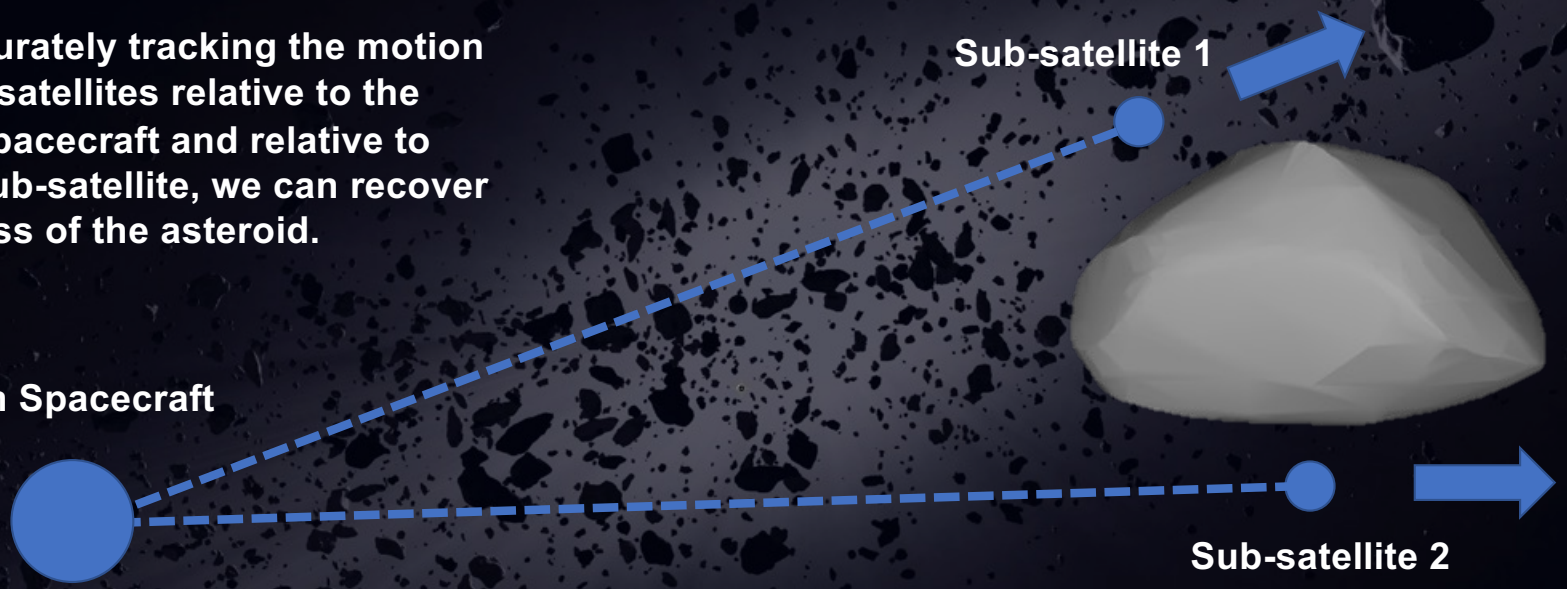
By accurately tracking the motion of sub-satellites relative to the main spacecraft and relative to each sub-satellite, we can recover the mass of the asteroid.



Possible data types are:

1. **Range:** range measurements between the main spacecraft and sub-satellites
2. **Doppler:** range-rate measurements between the main spacecraft and sub-satellites
3. **Optical:** imaging of sub-satellites by the main spacecraft

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Example: Launch 2024+
Flyby in '26, '27, '28...

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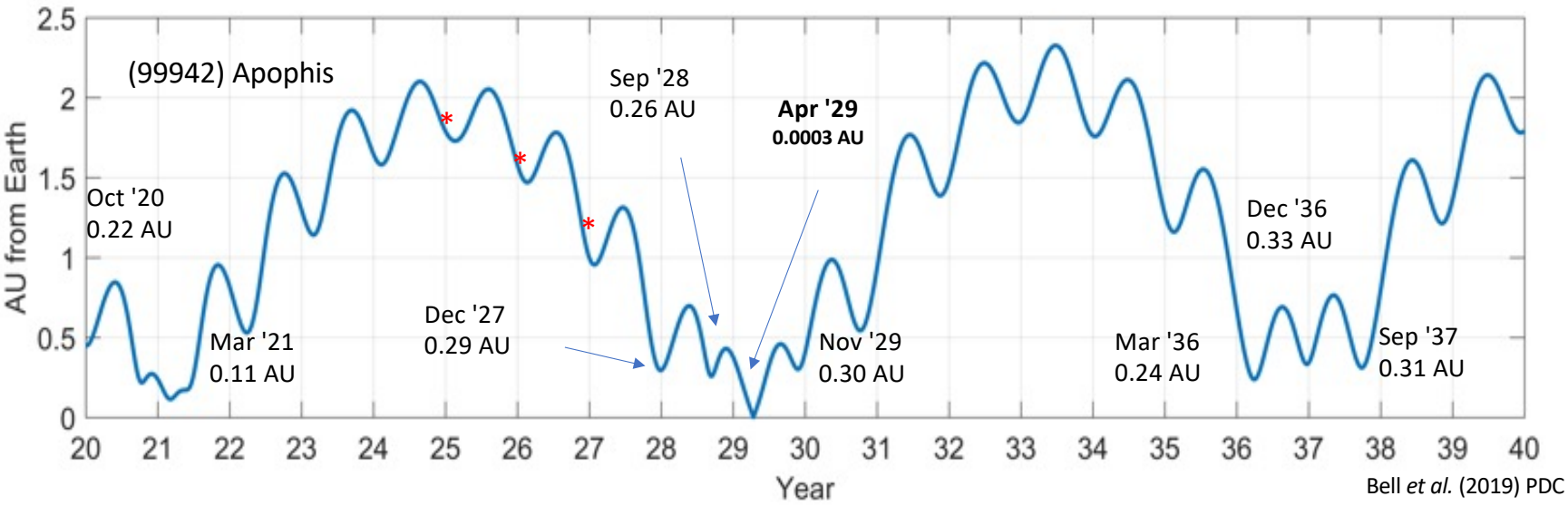

Bell *et al.* (2019) PDC

- MILO's Apophis Pathfinder mission would conduct a precursor flyby of (99942) Apophis several years or more in advance of its 2029 Earth flyby
- TARGET OPPORTUNITIES for Apophis encounters are Dec. 2027 and Sep. 2028

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Steps to MILO Membership and Workforce/Payload/Mission Involvement

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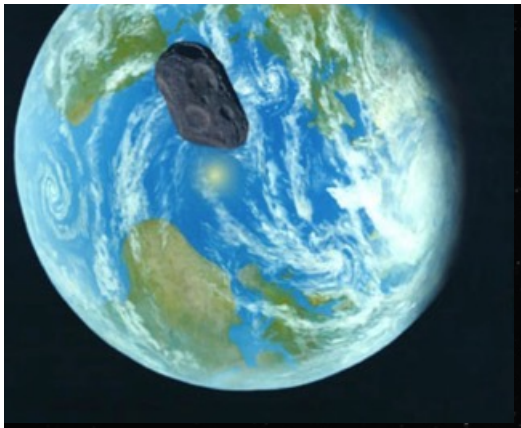
Collaborate — Share your space science plans with the Institute and collaborate on your goals

Outline — Draft a framework Memorandum to clarify collaboration plans (non-binding)

Proposal — Develop a proposal specific to your goals

Contract — Draft Statement of Work and sign the contract

Membership confirmed!



Apophis Pathfinder

A Smallsat Flyby Mission for Science,
Planetary Defense, and Feed-Forward to 2029...

Please contact us to get involved

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Thank You!

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Testing a New Model to Enable Global Access to Deep Space Science Missions

For more information and membership details please contact,
info@miloinstitute.org or visit our web site, http://miloinstitute.org