The MILO Space Science Institute: Enabling New, Science-Focused Deep Space Smallsat Missions to Near Earth Objects

Jim Bell[1], Lindsay Papsidero[2],
& the MILO Space Science Institute

[1]Arizona State University (Jim.Bell@asu.edu); [2]Lockeed Martin

THE MILO INSTITUTE
http://miloinstitute.org

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

Affordable Access
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.

THE MILO INSTITUTE

http://miloinstitute.org

To enable world class scientific discovery, the MILO institute has developed a suite of mission opportunities for members

Compelling Science
The goal of all MILO missions is to enable Decadal Survey-quality science, exploration, and discovery that would otherwise not be easily accessible

"In the Neighborhood"
To ensure relatively quick scientific return (5 years or less), MILO mission targets are close to Earth, such as Venus, Mars, the Moon, and **Near Earth Asteroids**

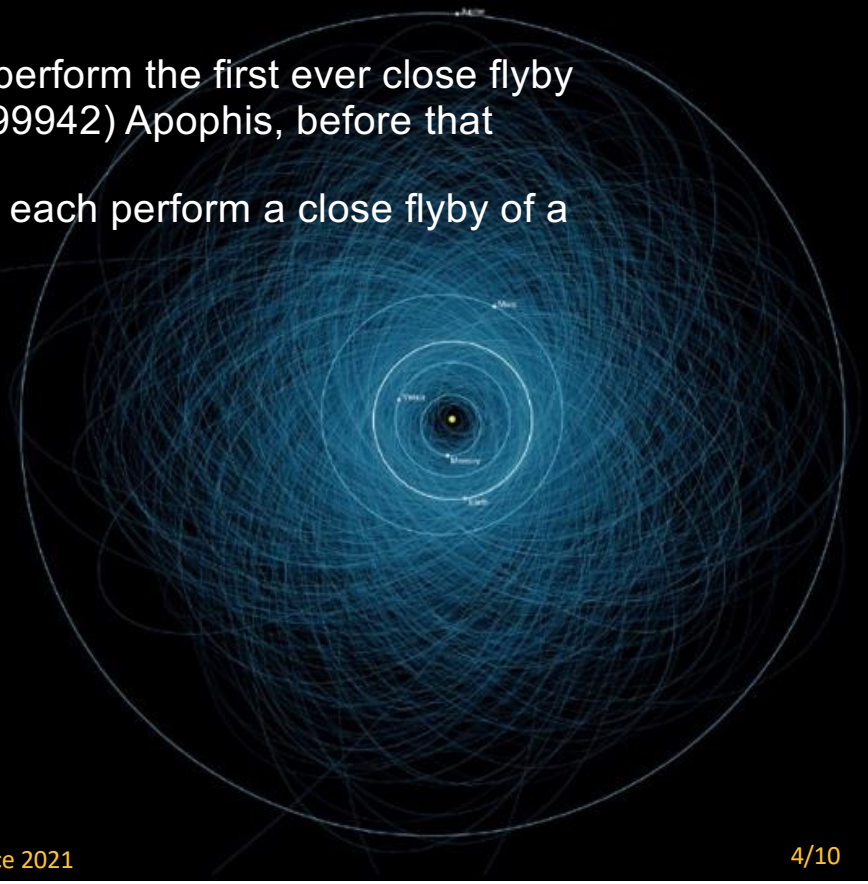
Low Cost Architectures
MILO architectures leverage high heritage commercial products, ridesharing, **smallsats, and cubesats**

THE MILO INSTITUTE
http://miloinstitute.org

NEO Smallsat Mission Concepts

Mission Opportunities

- **Apophis Pathfinder**, uses a pair of small spacecraft to perform the first ever close flyby of the 370-meter diameter Potentially Hazardous NEO (99942) Apophis, before that small body's extremely close flyby of Earth in 2029
- **NEOShare**, will launch a cluster of six smallsats that will each perform a close flyby of a different NEO close to Earth



Target Partners

- Emerging space agencies
- University space science institutes and departments
- New space companies
- Philanthropic organizations

THE MILO INSTITUTE
http://miloinstitute.org

Apophis Pathfinder

MILO is seeking members interested in compelling asteroid science and planetary defense

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 orbiters, etc.)
  - Shape and Topography (for future landers, probes, etc.)
  - Regolith properties (for future landers, probes, etc.)

THE MILO INSTITUTE
http://miloinstitute.org

Apophis Pathfinder Opportunities

(99942) Apophis

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
- Many opportunities for Apophis encounters (roughly annual), some better than others
- Initial launch window analysis provides options:
  - Earliest launch opp: 2024 with encounter ~6 months later
  - Launch opportunities in 2026 with encounter in '27-'28

THE MILO INSTITUTE
http://miloinstitute.org

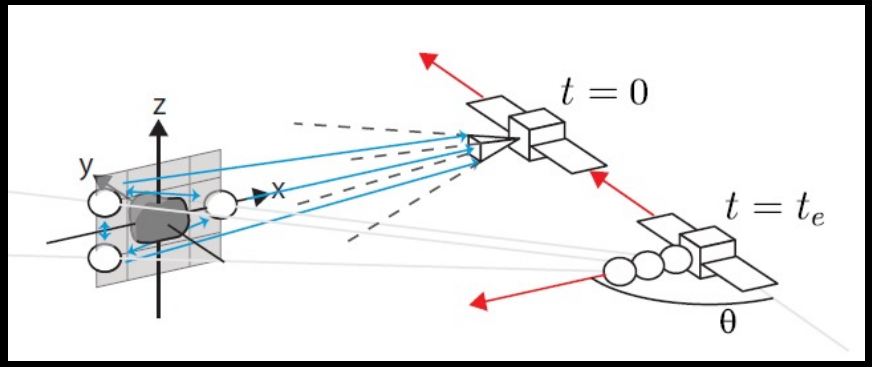
Apophis Pathfinder

Simple Payload

- Imaging system with RGB color and capable of resolution down to ~1-2 m/pix
- Near-IR point spectrometer for detection of silicates, hydrates, organics
- Thermal-IR imager, multi-band
- Can accommodate additional member payloads

Simple Spacecraft & Mission Design

- We will test and validate an innovative dual small spacecraft approach to mass determination
  - Christensen, Park, & Bell (2021) Estimating Asteroid Mass from Optically Tracked Radio Beacons, AIAA *Journal of Spacecraft and Rockets*, doi:10.2514/1.A34830
- Measure disturbances caused by asteroid's gravity
- Heritage spacecraft based on deep space experience



Christensen, Park, & Bell (2021)

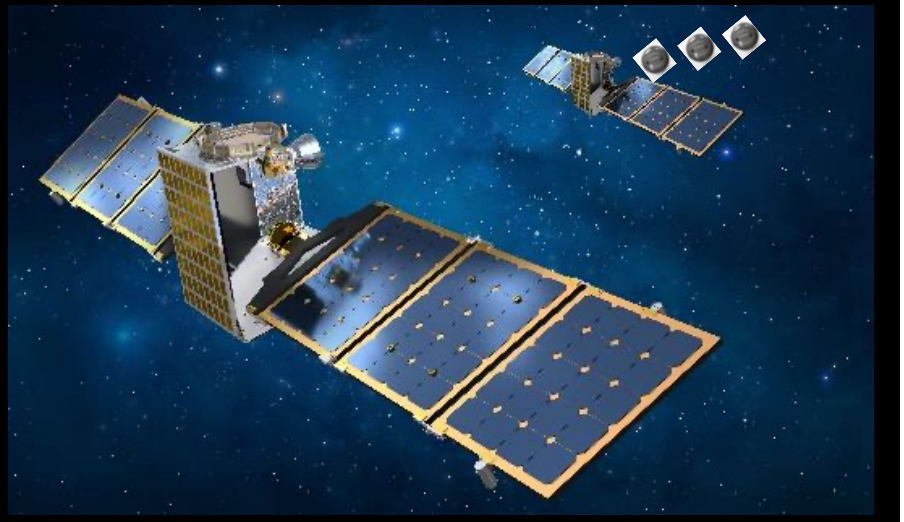


Image credit: Lockheed Martin

NEOShare

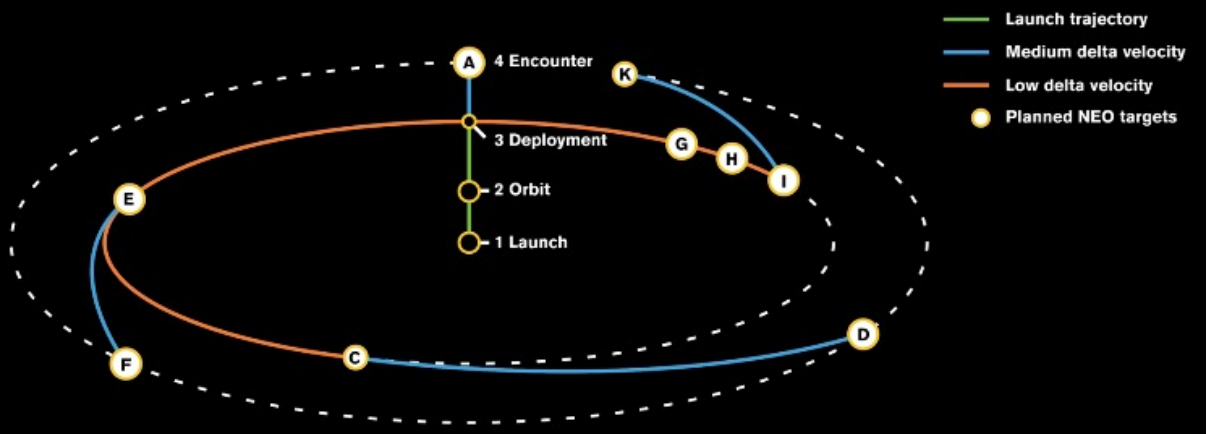
MILO is seeking members interested in detailed scientific studies of diverse NEOs

Mission Overview

- Send a cluster of propulsive small spacecraft into heliocentric orbit to perform close flyby characterization of a diverse set of Near Earth Objects (NEOs)
- Six spacecraft will individually fly by one or more different target bodies, encountering 8 or more different asteroid targets in total, in a single mission

Mission Objectives

- Perform full asteroid characterization
- Increase knowledge of asteroid orbit, geology, composition, and estimate mass and density
- Assess physical and regolith properties for science and threat assessment and mitigation
- Perform observations across a wide sample set of diverse objects (size, color, composition, binarity, orbit, etc.)



NEOShare

Member participation in the form of instrumentation and spacecraft development

Mission Requirements

- Low delta-V of 100 m/s to reach closer target objects
- High delta-V of 500+ m/s to reach farther objects, or encounter two objects
- For any given launch window, up to ~100 different NEO targets can be reached

Spacecraft Concepts

- Six small spacecraft attached to deployer ring
- Individually deploy from dispenser onto individual trajectories
- Equipped with cameras, spectrometers, and other high heritage instrumentation
- Equipped with individual communications systems for direct to Earth comms
- Platforms of 12U or larger
  - To meet difficult packaging requirements of propulsion and communications systems

THE MILO INSTITUTE

@MILOInstitute

Please contact us to get involved!

The MILO Space Science Institute

Testing a New Model to Enable Deep Space Science

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

ASU Arizona State University

LOCKHEED MARTIN

BACKUP

THE MILO INSTITUTE
http://miloinstitute.org

Participation

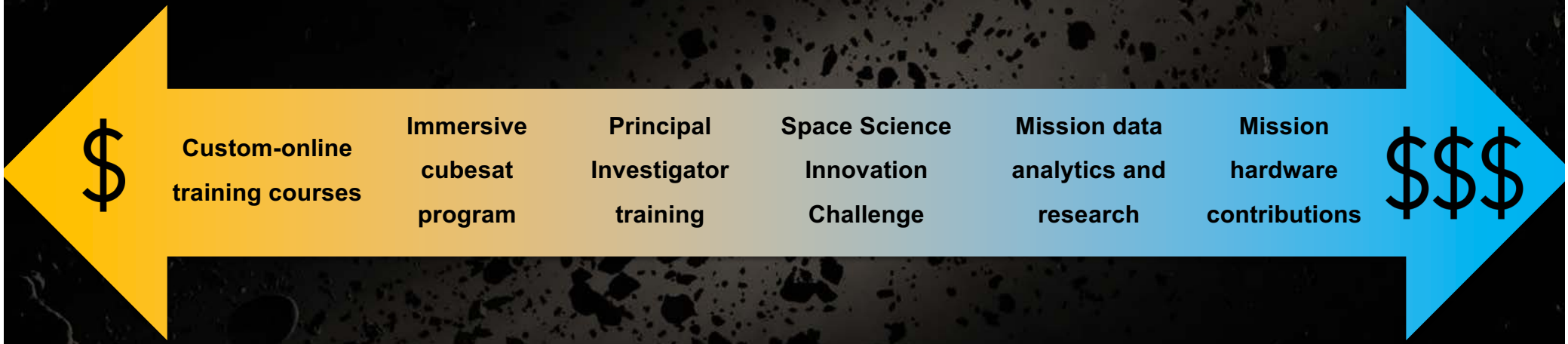
To support members at all stages of development and resources, the MILO Institute offers a range of ways to participate

Training Programs ($)
We offer various training and education programs around space science, engineering, and entrepreneurship

Workforce Development Programs ($$)
We customize programs to develop your local technology and a space ecosystem

Mission Contributions and Participation ($$$)
The Institute pulls together consortiums of interested members together to conduct deep space science missions, providing architectures, integration, launch, and operations services

Opportunity Cost



Membership pricing available to meet member budgets

Steps to Membership

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 desires

Contract — Draft Statement of Work and sign the contract

Membership confirmed!

Membership Benefits

- Affordable participation in deep space science missions
- Spacecraft or instrument development guidance
- Involvement in design reviews and mission development
- Flight opportunities for your instrument/spacecraft
- Propose/iterate on your mission ideas with the Institute
- Design, build, test, and qualify hardware