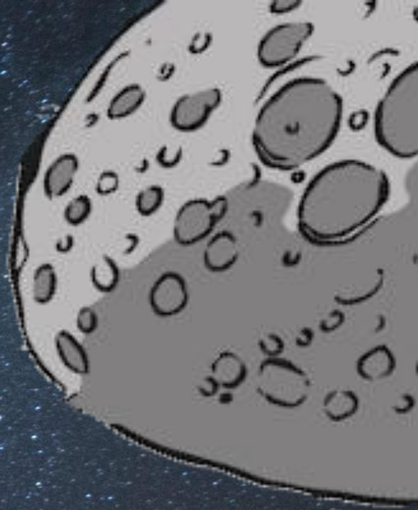
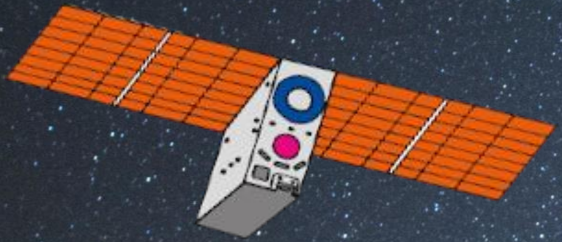




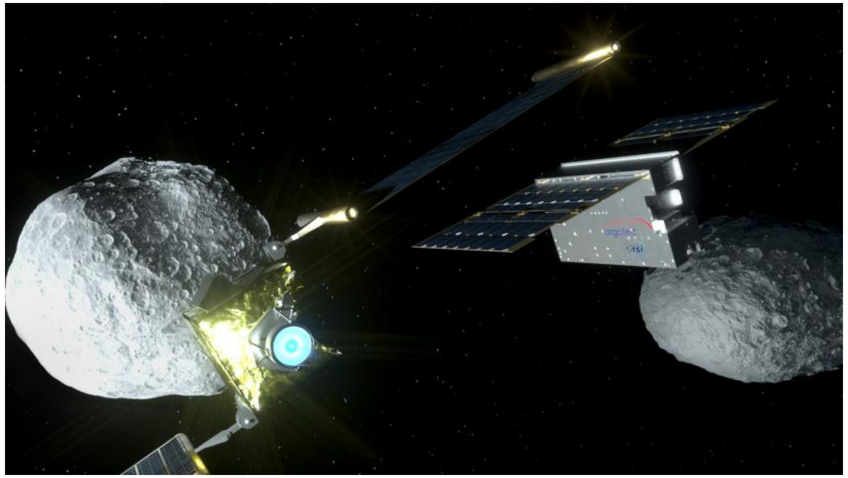
LICIACube

the Light Italian Cubesat for Imaging of Asteroids

Elisabetta Dotto (INAF-OAR)

INAF – Audizioni RSN3, 9 Maggio 2022

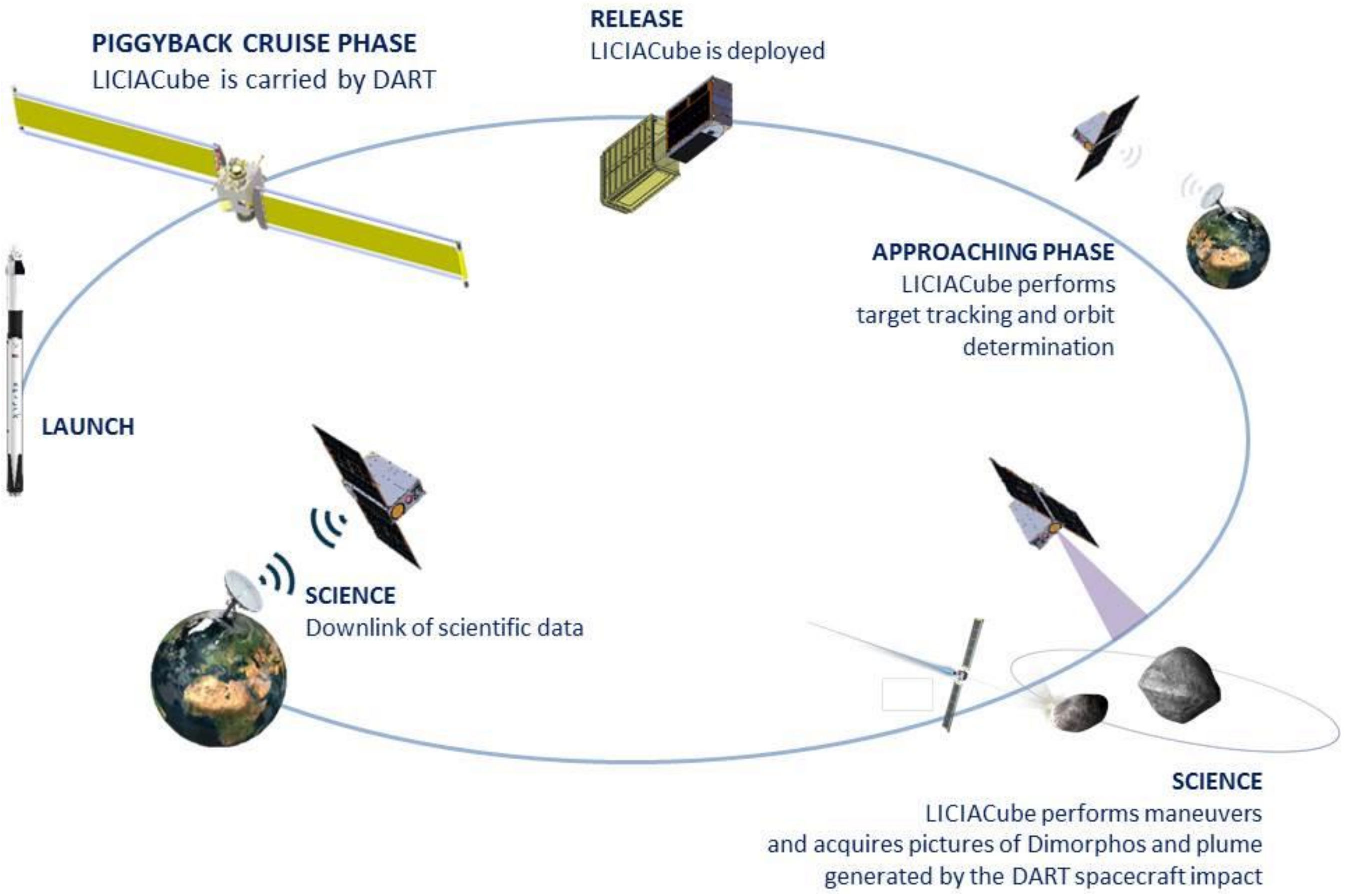
LICIACube



LICIACube is a 6U Italian CubeSat, financed by ASI, which is part of the NASA mission DART.

DART will be the first test of kinetic impactor for planetary defense.

LICIACube will witness the DART impact and collect scientific images of its effects.

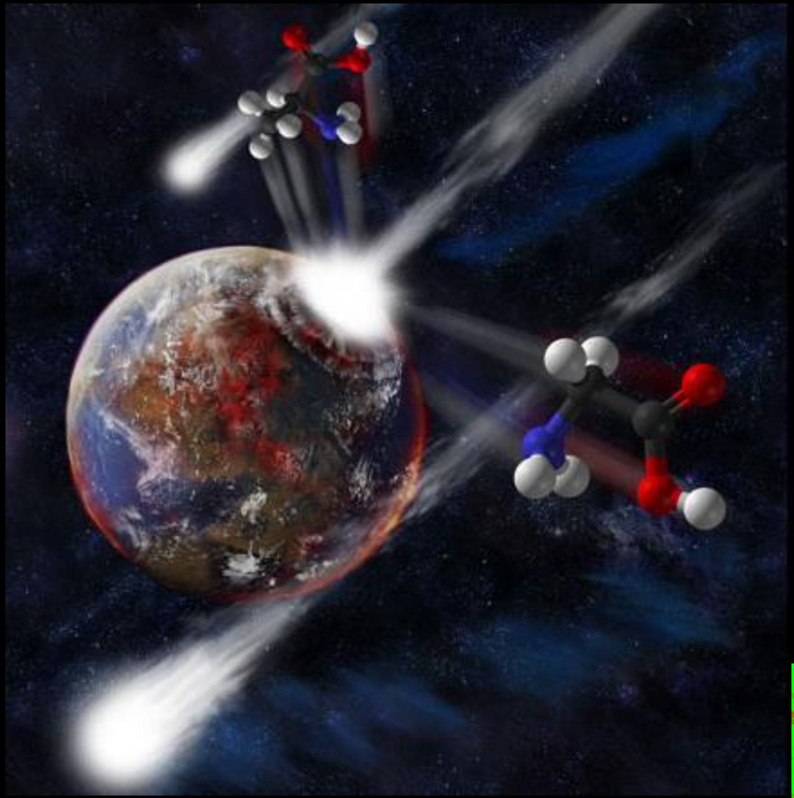


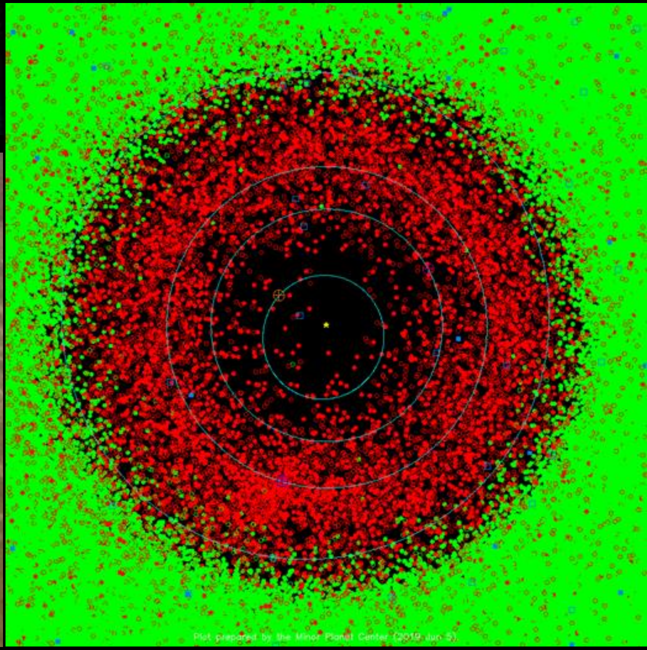
Why do we study Near Earth Objects?

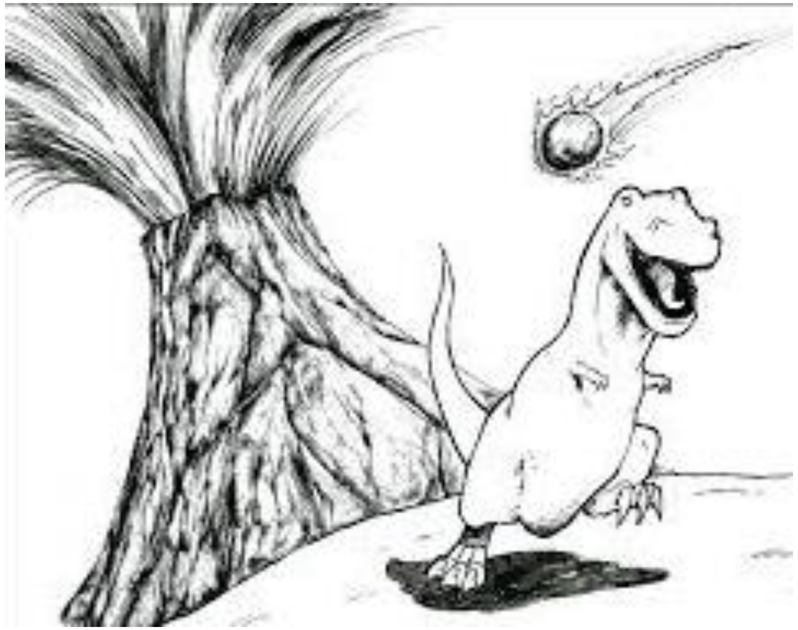
Near Earth Objects (NEO) are the "building blocks" of the Solar System closest to us.

They are important:

- to study the origin of the prebiotic material that arrived on Earth immediately after its formation;
- as mineral mines and water reserves;
  - as a potential threat to our planet.







Chicxulub-sized

Dinosaur Killer

Diameter: 10–15 kilometers

Last known: 65 million years ago

Frequency: every few 100 million years

Tunguska-sized

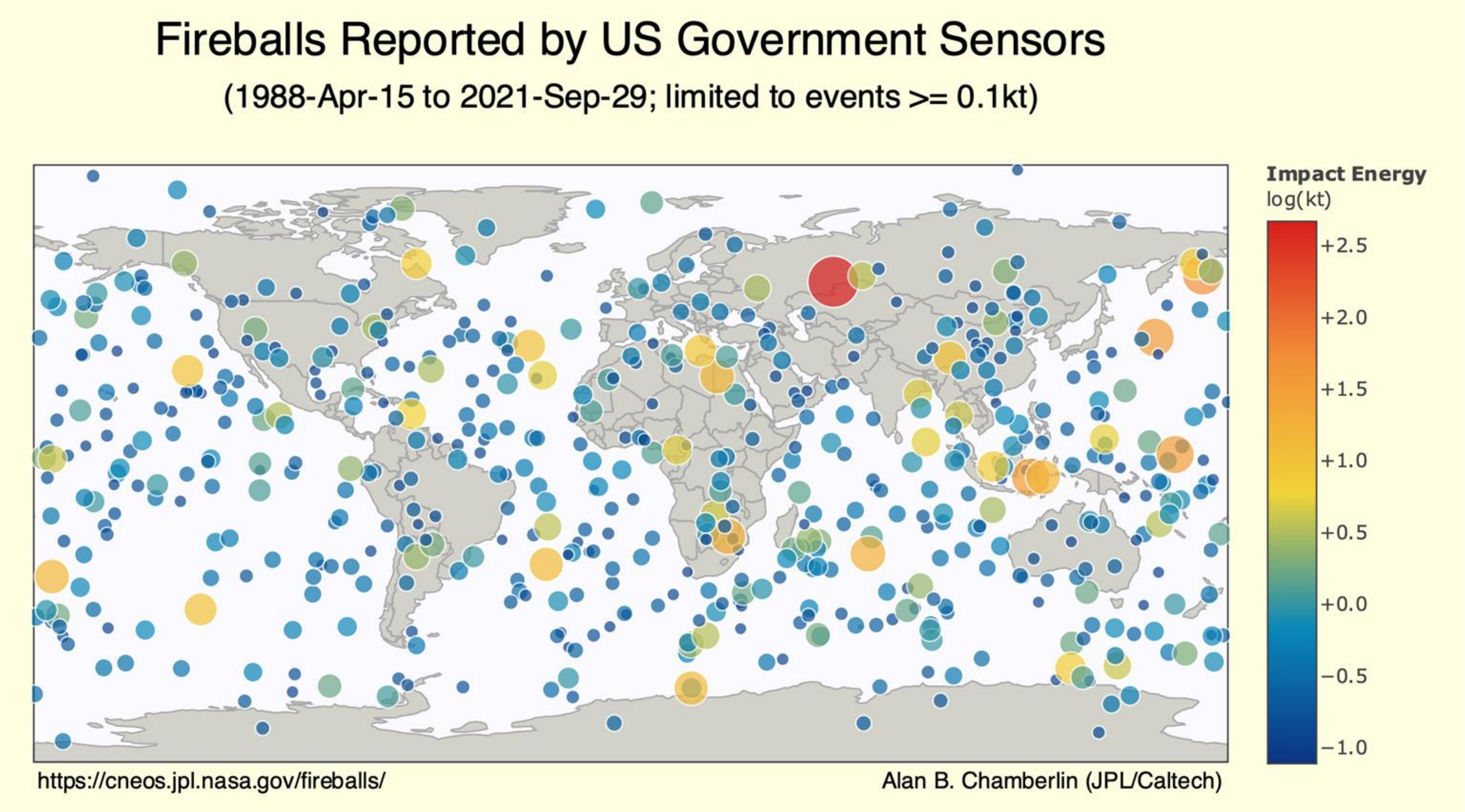
Diameter: 60–190 meters

Equivalent to: ~5 megatons of TNT

Last known: 1908

Frequency: every few centuries to millennia

Small Asteroids Hitting Earth, 1988 – Now



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Dinosaur Killer

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Frequency: every few 100 million years

Tunguska-sized

Diameter: 60–190 meters

Equivalent to: ~5 megatons of TNT

Last known: 1908

Frequency: every few centuries to millennia

Chelyabinsk-sized

Diameter: ~20 meters

Equivalent to: ~500 kilotons of TNT

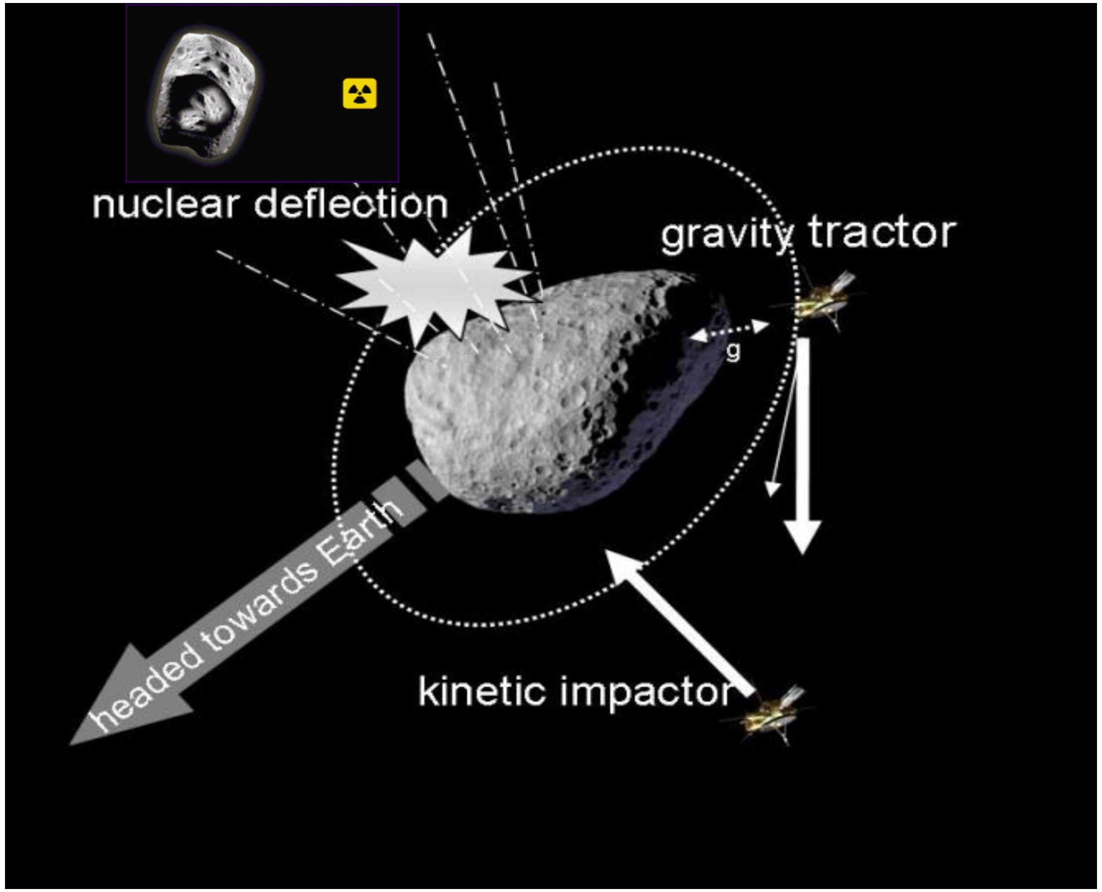
Last known: 2013

Frequency: every few decades to centuries

H2020: NEOShield-2
www.neoshield.net

Three deflection mitigation techniques:

- ✓ Nuclear deflection
- ✓ Gravitational Tractor
- ✓ Kinetic impact



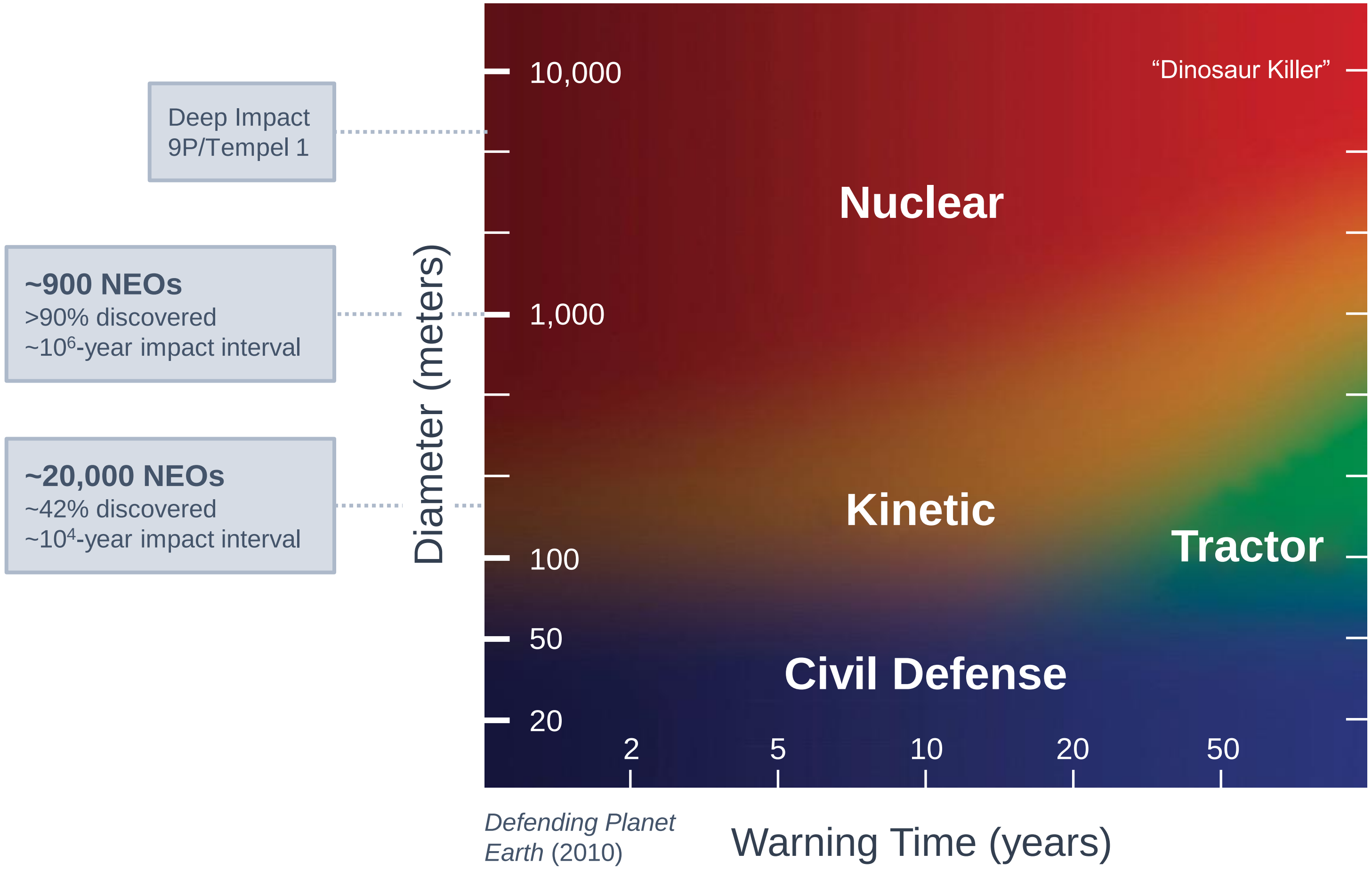
Warning time is a critical parameter.

Top Priority for a Mitigation Mission

Mitigation Techniques for Potentially Hazardous Asteroids

“The first priority for a space mission in the mitigation area is an experimental test of a kinetic impactor.”

— from *Defending Planet Earth: Near-Earth-Object Surveys and Hazard Mitigation Strategies*
published in 2010 by the
National Academy of Sciences



Defending Planet Earth (2010)

Top Priority for a Mitigation Mission

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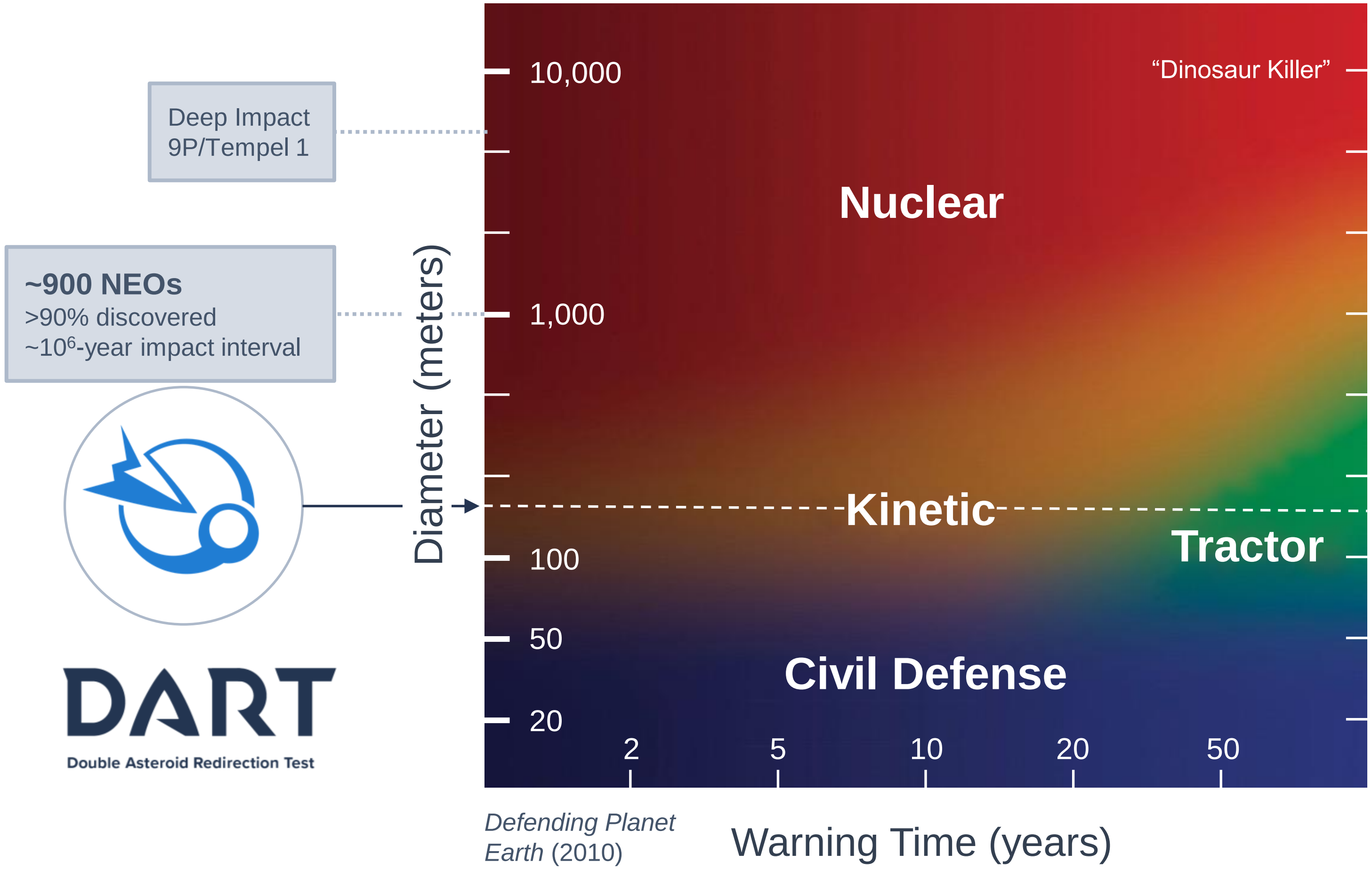


Defending Planet Earth (2010)

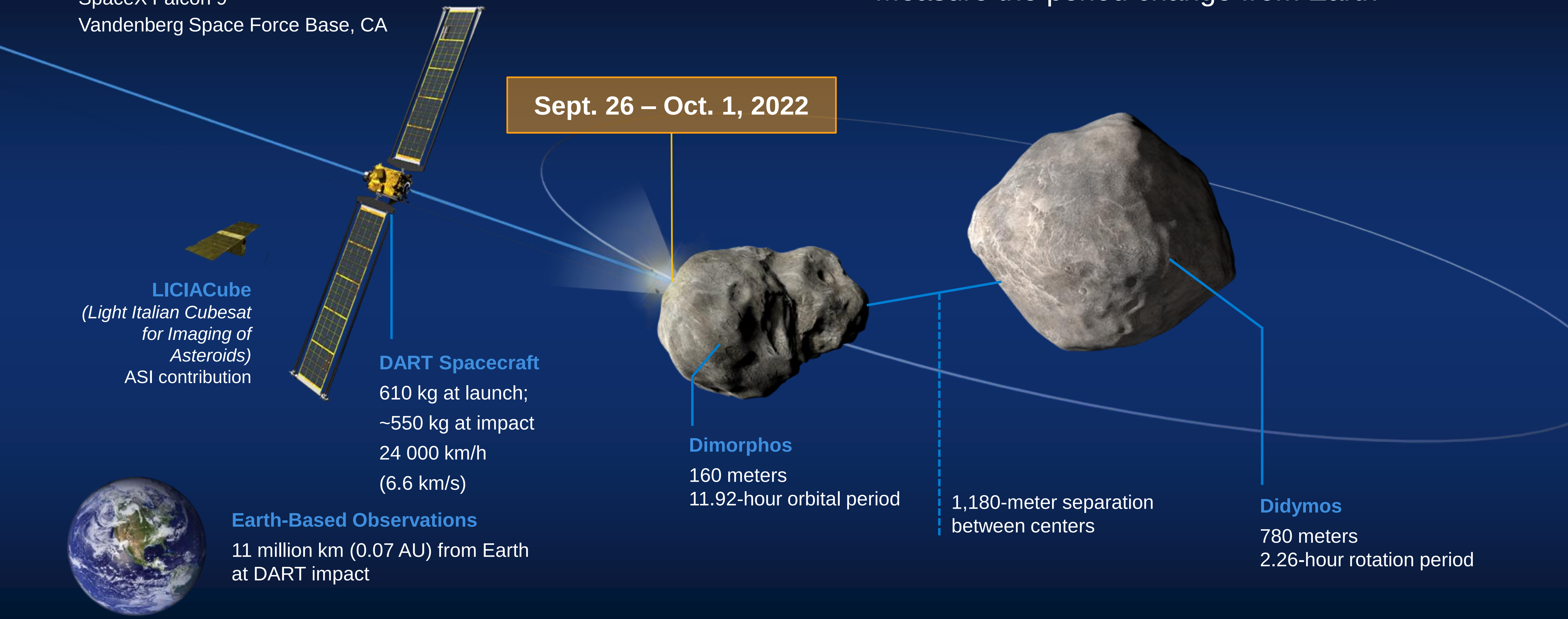
Launch

Nov. 24, 2021

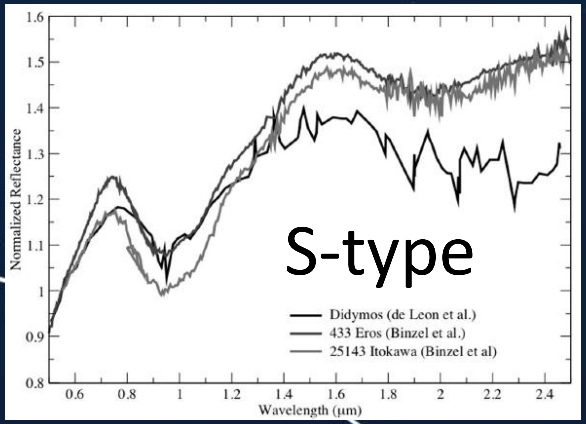
SpaceX Falcon 9

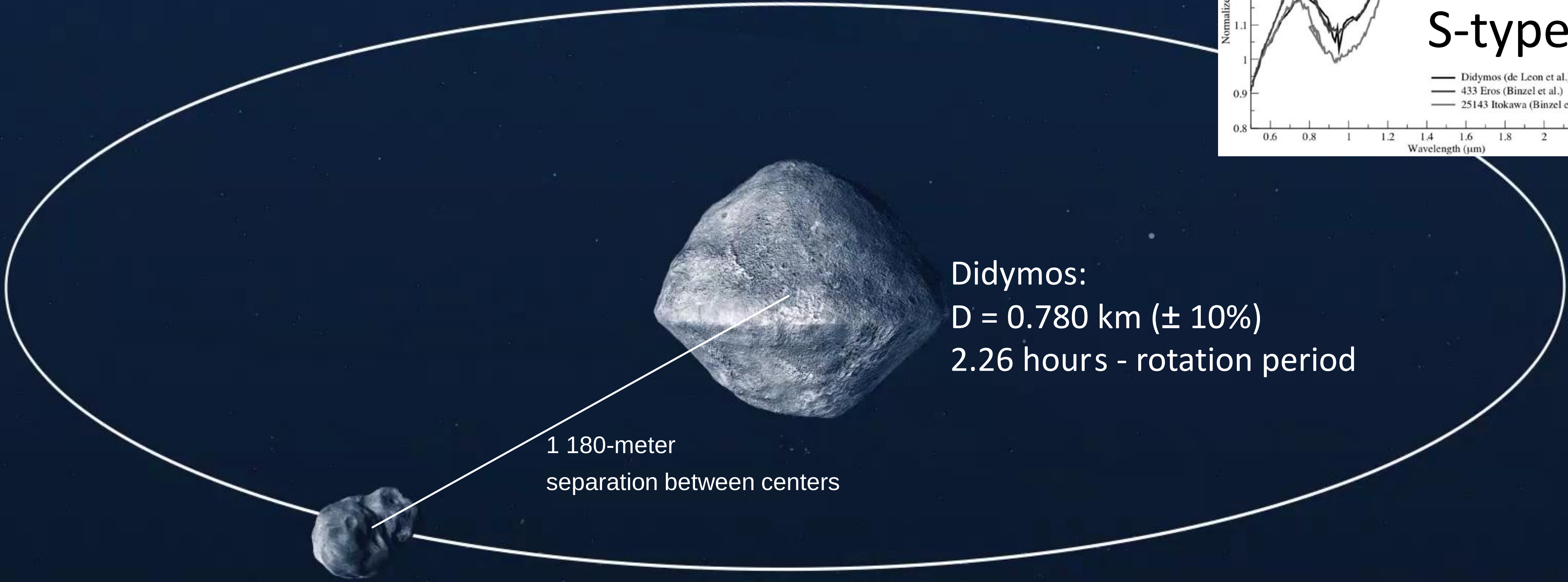
Vandenberg Space Force Base, CA

- Target the binary asteroid Didymos system
- Impact Dimorphos and change its orbital period
- Measure the period change from Earth



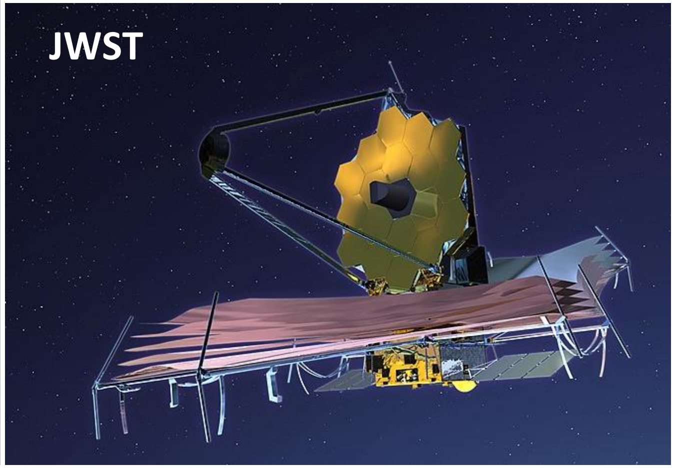
The target: Didymos & Dimorphos



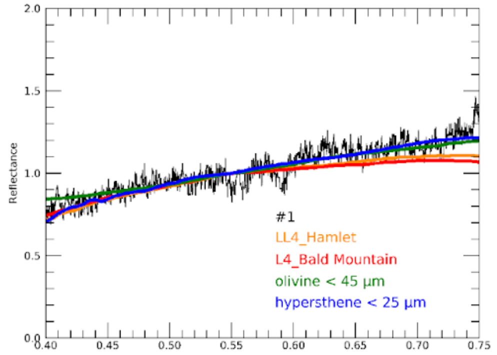


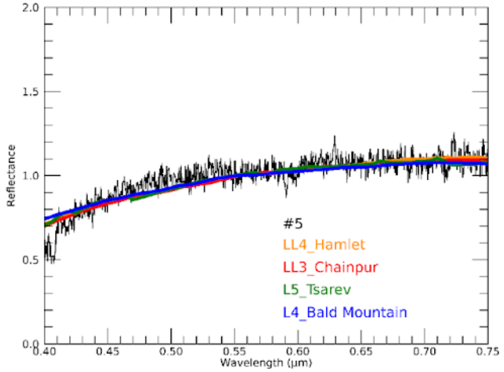
Earth-based observations

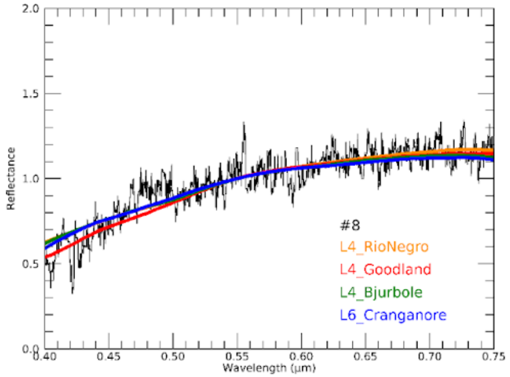
Ground-based and orbiting telescopes



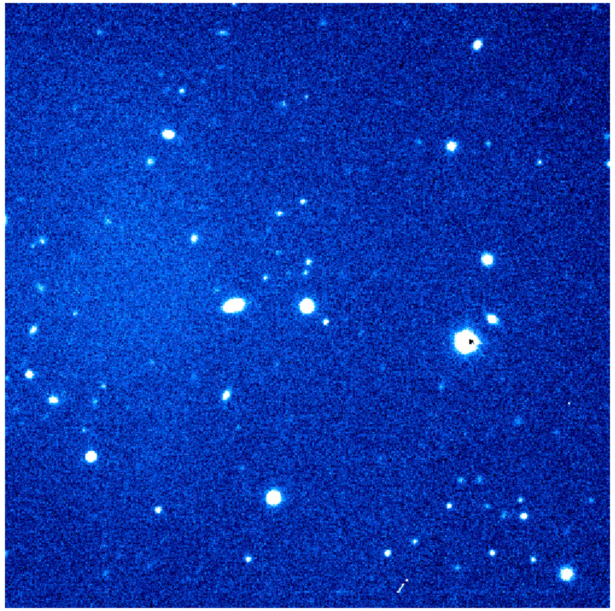
Current Knowledge about Didymos







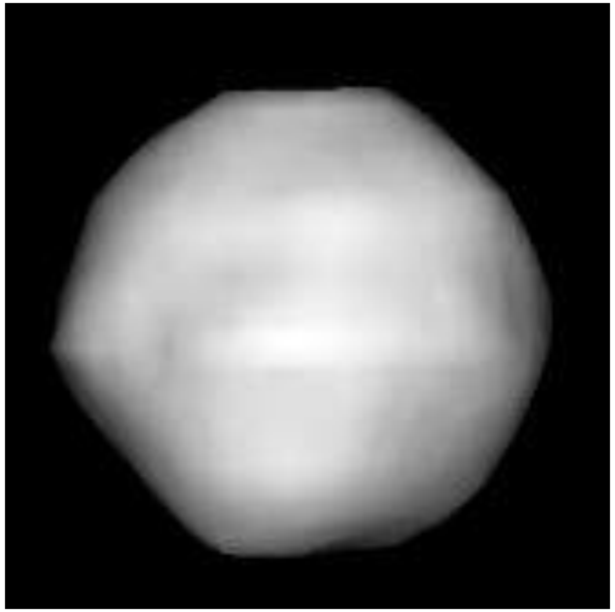
Observation



Images centered on Didymos, moving through star fields

Taken from the Telescopio Nazionale Galileo (TNG), January 2021

Radar Shape Model

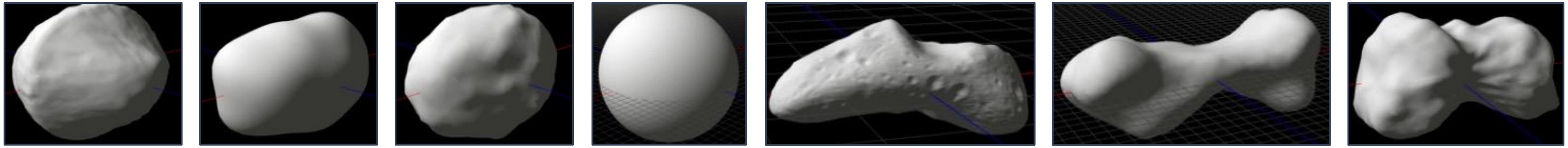


Preliminary shape model of the Didymos primary asteroid from combined radar (acquired in 2003) and light curve data (diameter, ~780 meters)

Current Knowledge about Dimorphos

Dimorphos

?

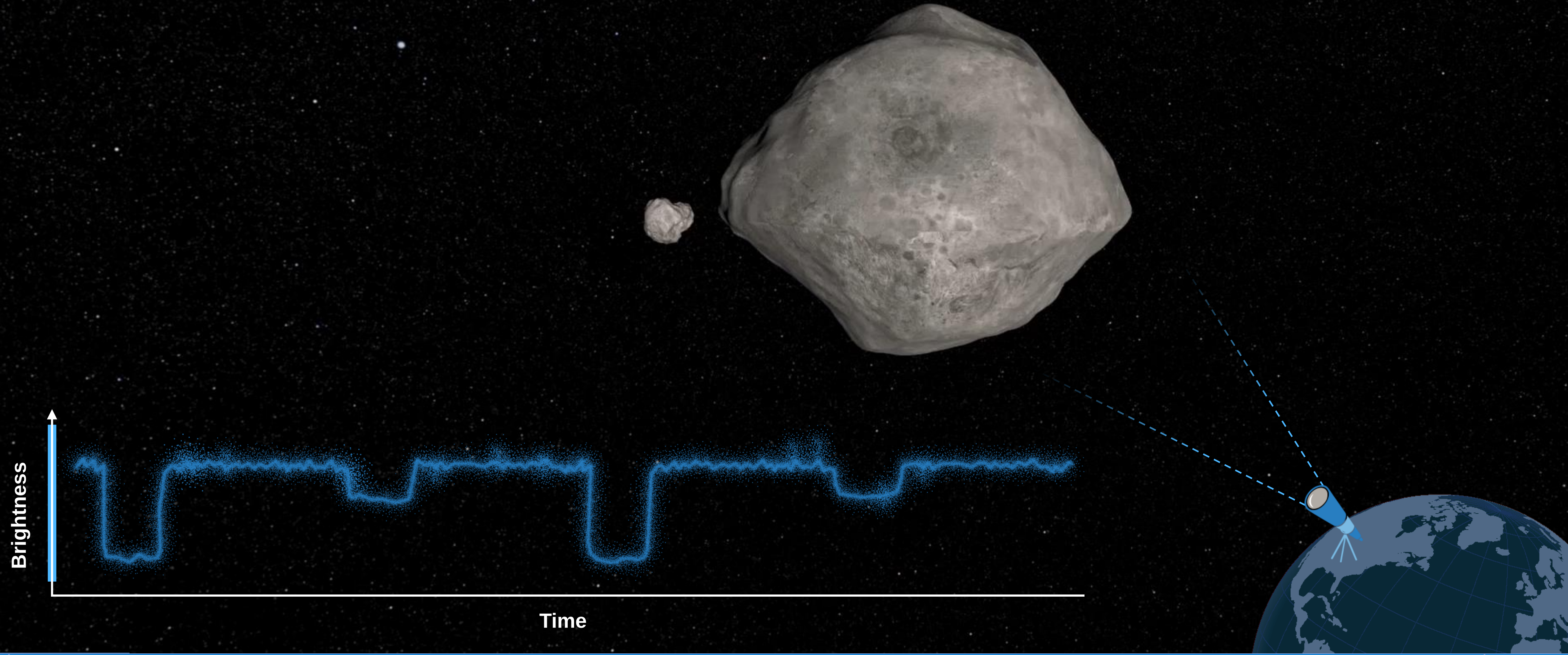


ID1: 1999 KW4a **ID2:** 1999 KW4b **ID6:** Rashalom **ID7:** sphere **ID4:** Eros **ID5:** Kleopatra **ID3:** Mithra

Examples of asteroid shapes being considered during DART simulation and testing

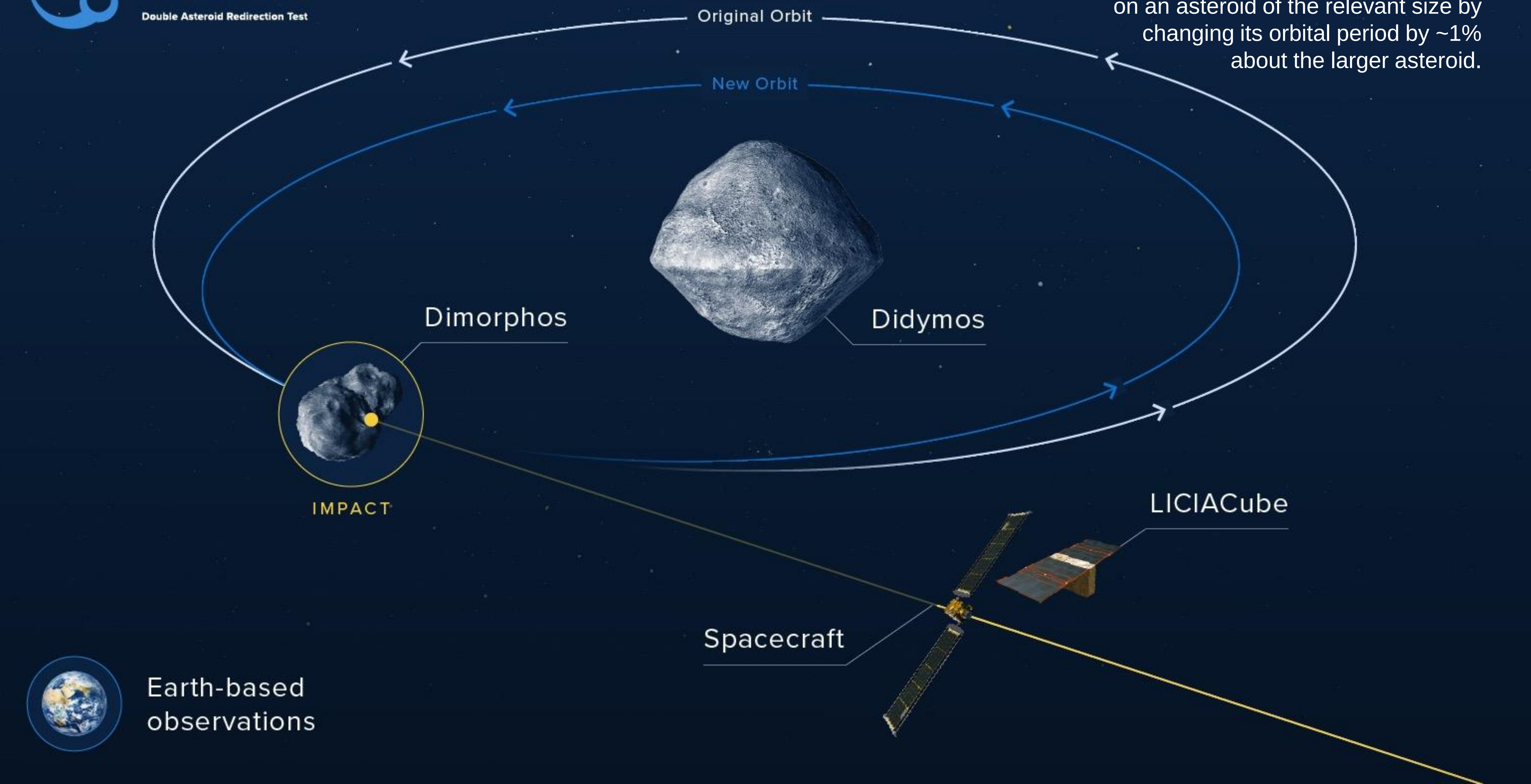
Measuring the Binary Asteroid System from Earth

Dimorphos Orbiting about Didymos



The Ideal Target

It allows a deflection demonstration on an asteroid of the relevant size by changing its orbital period by ~1% about the larger asteroid.



LICIACube

- CubeSat (6U: 20 cm x 10 cm x 34.05 cm) provided by Agenzia Spaziale Italiana (ASI)
- Based on Argomoon CubeSat that will be flying on the first flight of NASA's Space Launch System (SLS)
- Two cameras: LEIA and LUKE (2 m/pixel best resolution from flyby images)
- Closest flyby of Dimorphos ~3 minutes after DART's kinetic impact
- Data downlinked for weeks after the encounter

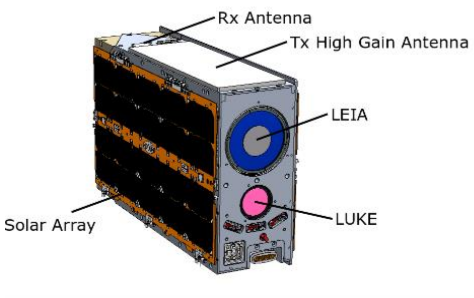
E. Dotto and the LICIACube team

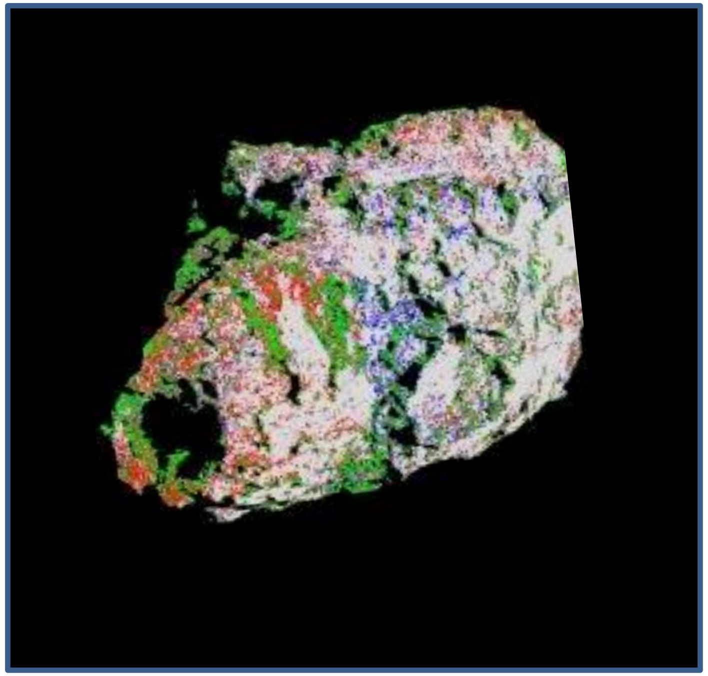
LICIACube: Analysis of LEIA and LUKE data

LEIA: High resolution images: best spatial scale of 1.38 m/px

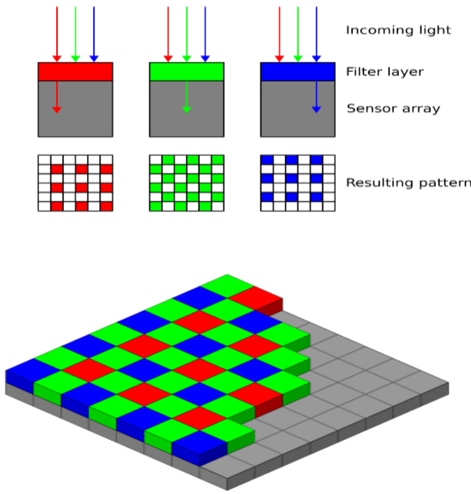
LUKE: Multi-color data: to constrain the surface composition and heterogeneity of the target

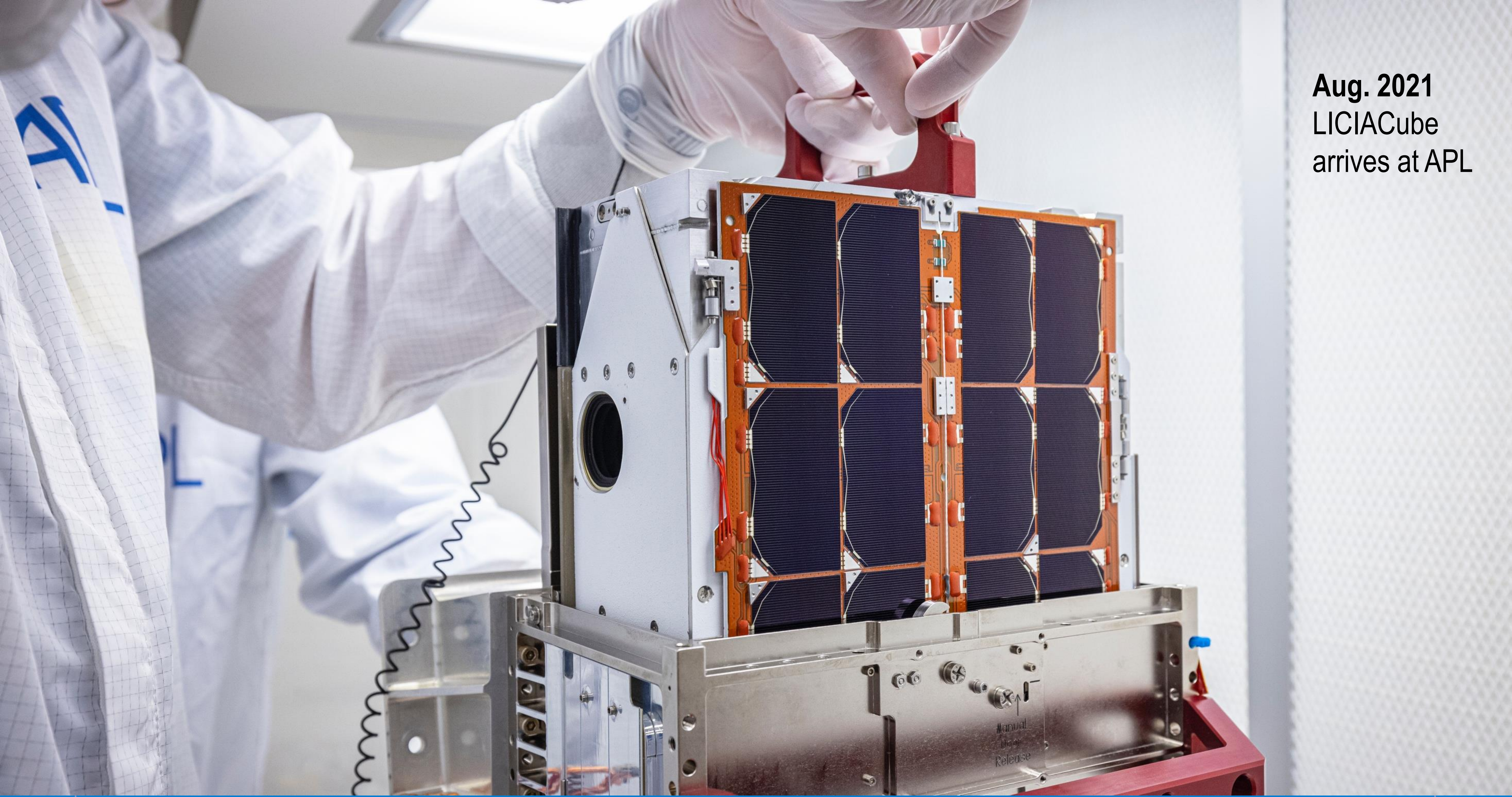
LEIA





LUKE





Aug. 2021
LICIACube
arrives at APL

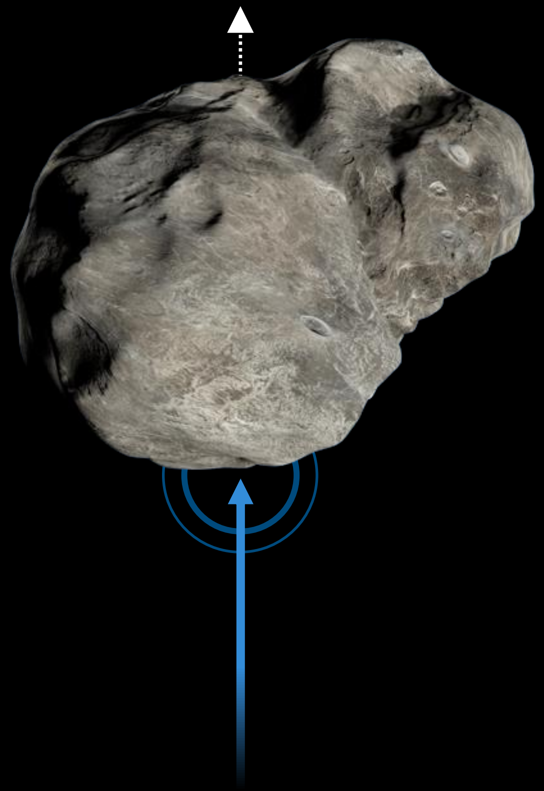
Sept. 2021
LICIACube
Integration

Sept 2021
Lift to the container

DART and LICIACube

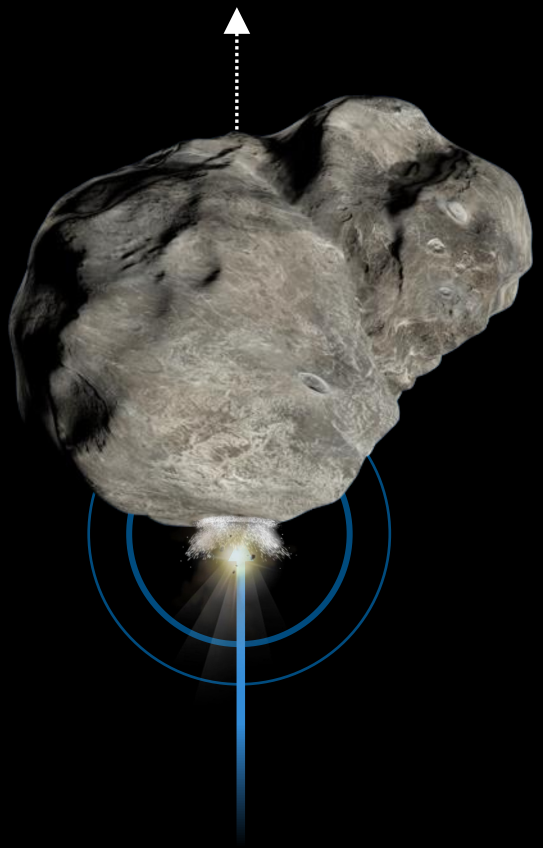
DART and LICIACube

Determining "Beta" – the Momentum Transfer



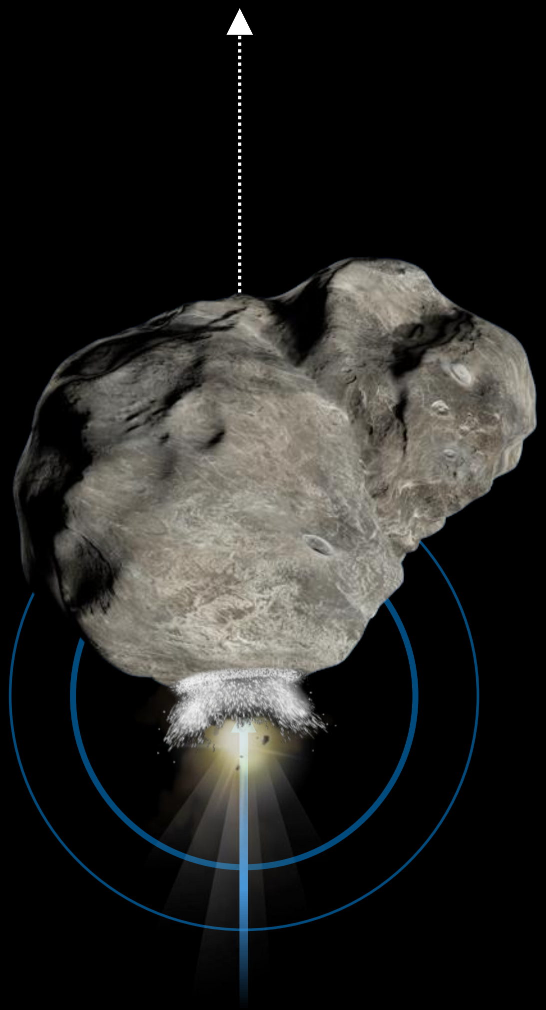
Beta = 1

No ejecta and small momentum increase



Beta = 2

Moderate ejecta and momentum increase

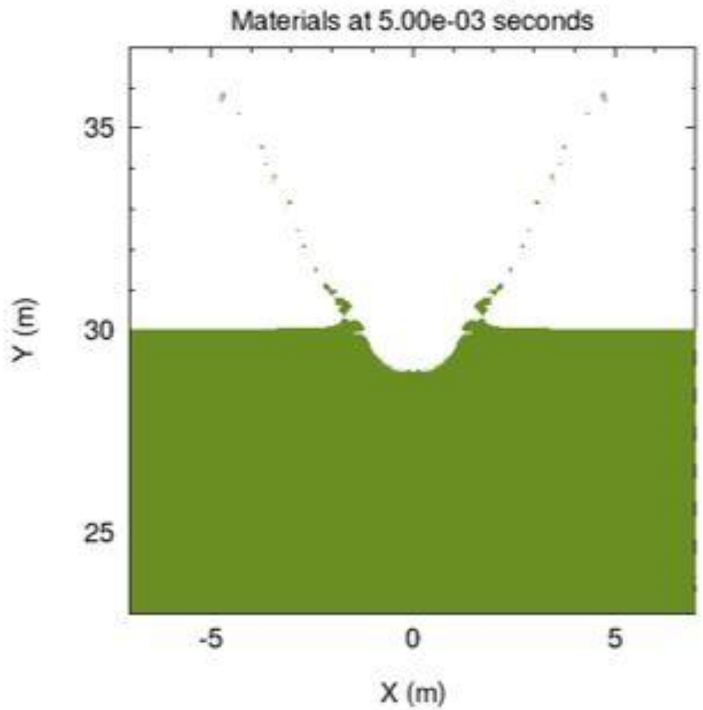


Beta = 4

Heavy ejecta and large momentum increase

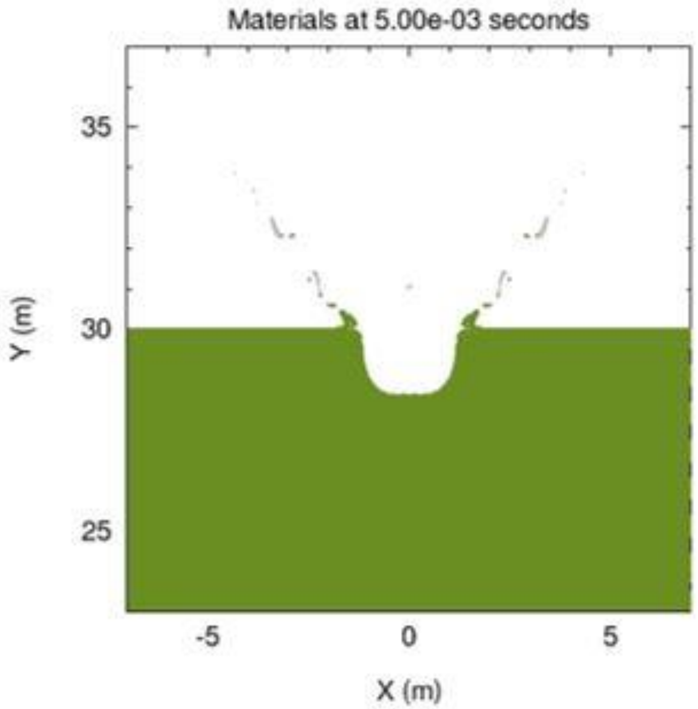
Modeling DART’s Impact

No porosity



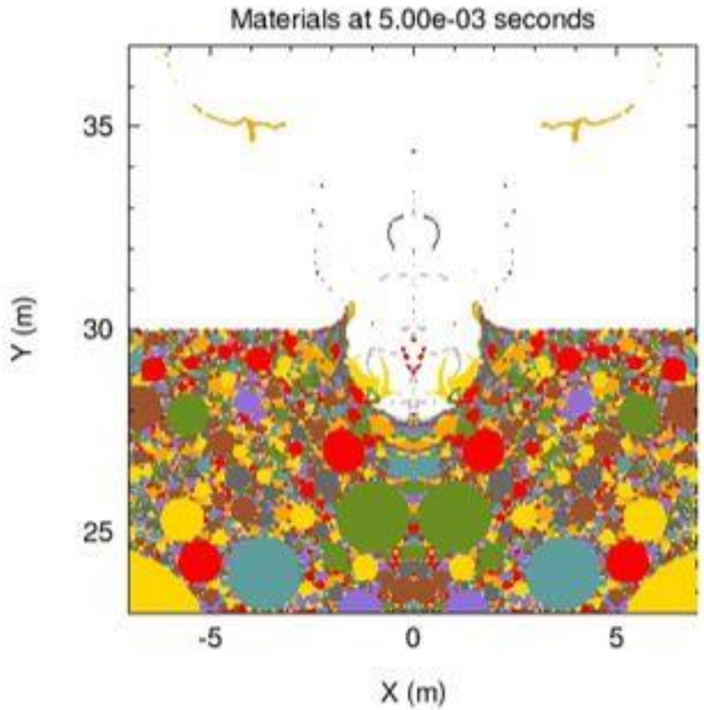
β value = 1.32
Velocity change = 1.75 cm/s

Microporosity



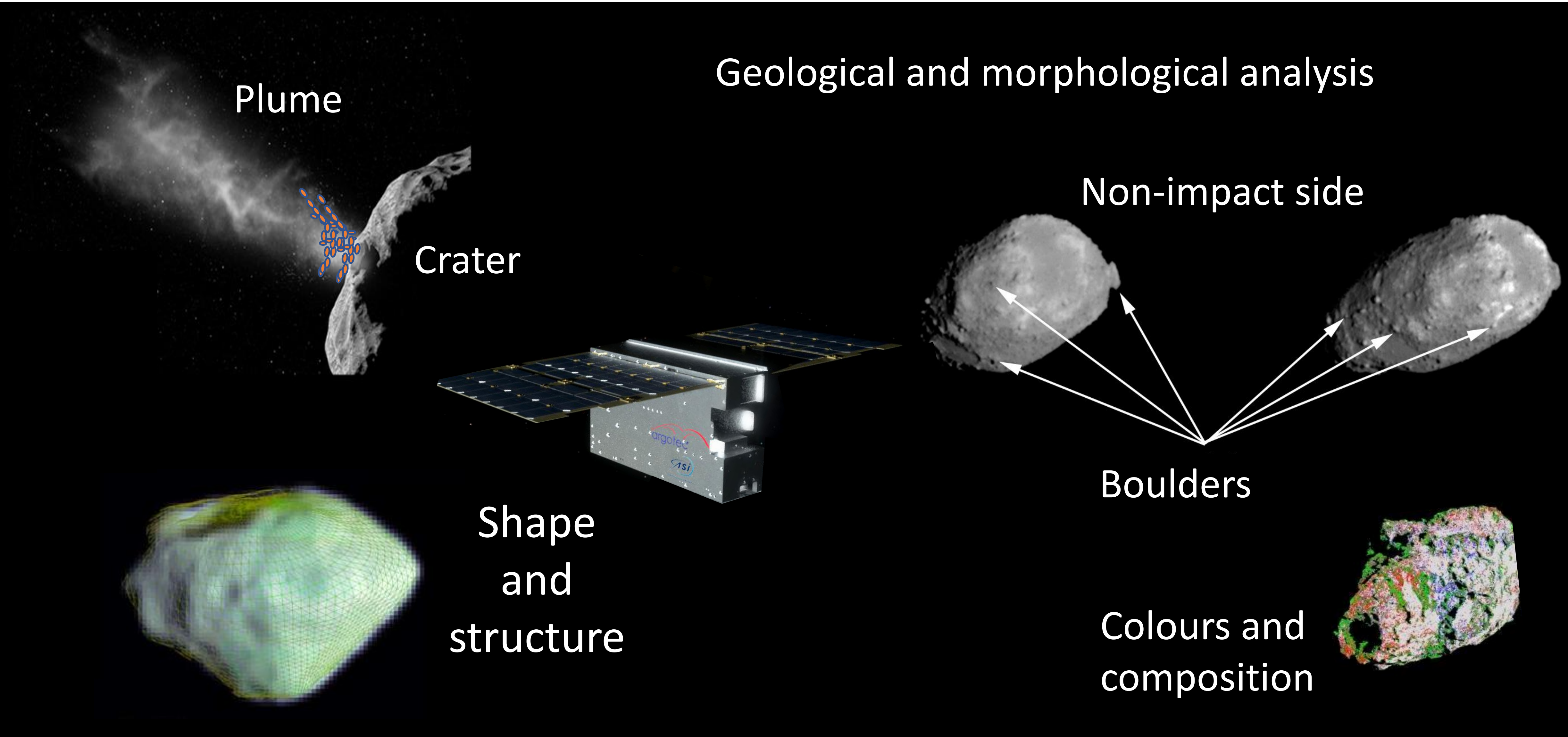
β value = 1.14
Velocity change = 1.87 cm/s

Rubble Pile



β value = 1.55
Velocity change = 2.53 cm/s

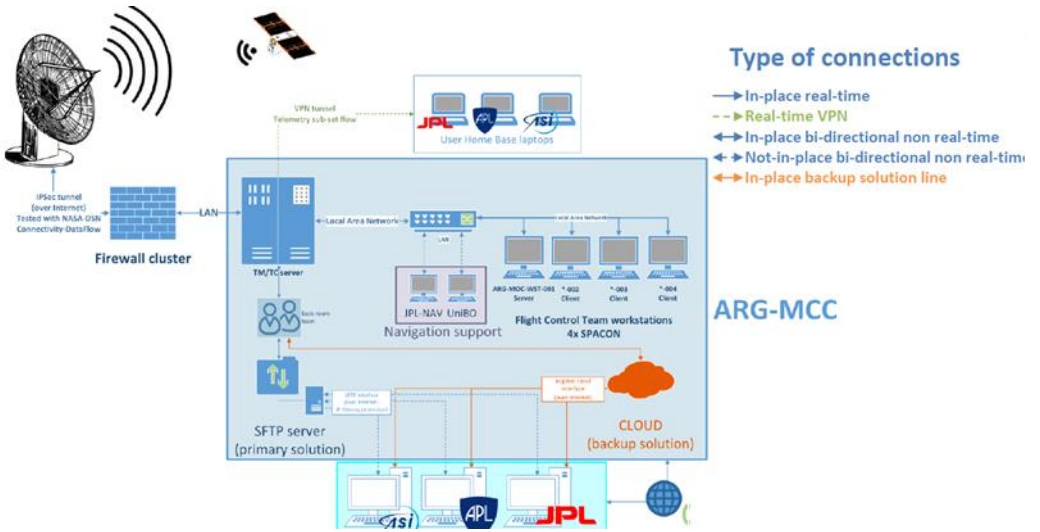
Scientific Objectives



Ground Segment

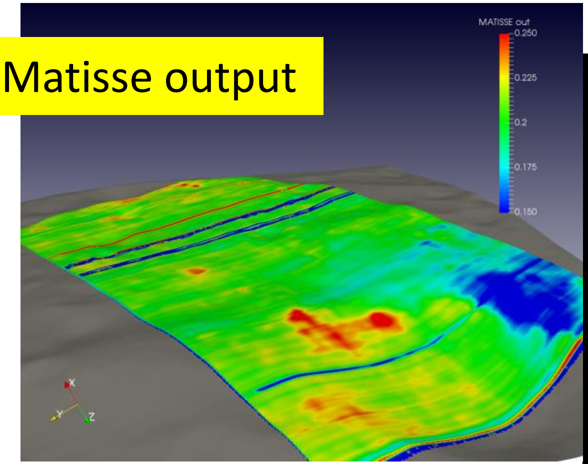
The mission Ground Segment architecture includes DSN antennas and the two main elements located in Italy:

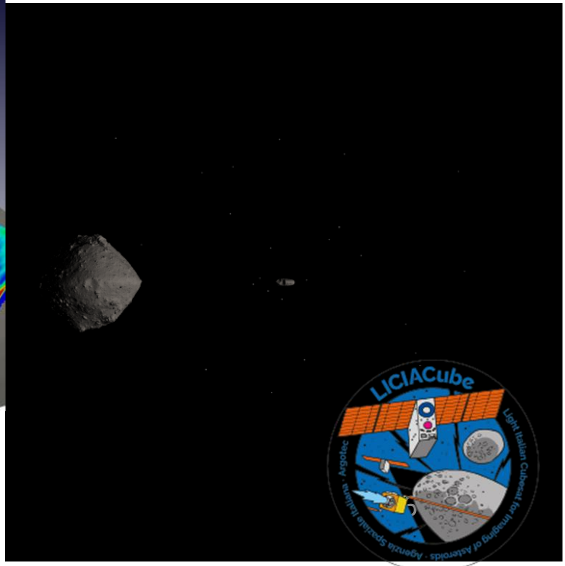
- Mission Control Center (MCC): @ Argotec (Turin)
- Science Control Center (SOC): @ ASI SSDC (Rome)
  https://www.ssdc.asi.it/liciacube/



Data will be accessible (first of all to the team and in a second time to public) by means of the SSDC MATISSE webtool https://tools.ssdc.asi.it/Matisse, with advanced 2D and 3D visualization capabilities.

Matisse output





The LICIACube team:

ASI:	S. Pirrotta *(Program Manager)*, M. Amoroso *(Interface Manager)*, G. Impresario (*PA Manager*)
ASI SSDC:	A. Zinzi *(SOC Lead)*
INAF:	E. Dotto *(Science Team Lead)* V. Della Corte *(Instrument Team Lead)* E. Mazzotta Epifani *(WP Observations Lead)*, S. Ieva, D. Perna, M. Dall'Ora J.R. Brucato *(WP Laboratory experiments Lead*), A. Meneghin, G. Poggiali S.L. Ivanovski *(WP Ejecta Lead)* A. Lucchetti *(WP Impact Simulation Lead)*, G. Cremonese, E. Simioni M. Pajola, P. Deshapriya, P. Hasselmann
IFAC-CNR:	A. Rossi *(WP Dynamics Lead)*
Univ. Parthenope:	P. Palumbo, I. Bertini
Politec. Milano:	M. Lavagna *(WP Mission Analysis Lead)*, A. Capannolo, G. Zanotti
Univ. Bologna:	M. Zannoni *(WP Orbit determination Lead)*, I. Gai, P. Tortora, D. Modenini
Argotec:	F. Miglioretti *(Argotec Program Manager)*, S. Simonetti *(System Engineer)*, B. Cotugno, V. Di Tana

@LICIACube: E. Nichelli (INAF), E. Mazzotta Epifani (INAF), A. Zinzi (ASI), F. Cruci (ASI), E. Dotto (INAF)

LICIACube – evoluzione programmatica attività

2021 – lancio
2022 – fase di crociera della missione.
Preparazione all’analisi, interpretazione e modellizzazione dei dati acquisiti
26/09/2022 – impatto
2023-2024 – analisi e interpretazione dei dati acquisiti.

LICIACube – FTE

- Stima dell'inviluppo complessivo di FTE INAF dall'inizio a fine attività: 6.3 FTE
- Stima delle FTE INAF a Tempo Indeterminato dall'inizio a fine attività: 2.3 FTE
- Stima dell'inviluppo complessivo di FTE (includendo tutti i partners dall'inizio a fine attività): 15.3 FTE

LICIACube – finanziamento

- Stima inviluppo complessivo intera attività: 1100 keuro
- Stima inviluppo complessivo per la parte di attività INAF dall'inizio a fine attività: circa 650 keuro

LICIACube - pubblicazioni:

- Oggetto di più di 30 presentazioni a convegno
- Pubblicazioni su riviste con referee:
  - LICIACube – 8 articoli (PSS, Acta Astronautica e Focus Issue PSJ)
  - DART – 10 articoli

LICIACube – Public outreach:

- Divulgazione
- Media INAF

@LICIACube

LICIACube - conclusioni:

LICIACube è un progetto finanziato da ASI, che **nasce dalla ricerca di base:**
il team INAF, coordinatore, ha una lunga esperienza e fama internazionale **nello studio e nella modellizzazione delle proprietà fisiche** dei piccoli corpi dei NEO a partire da **osservazioni da Terra** e **missioni spaziali (OSIRIS-REx, Hayabusa2).**

I **piccoli corpi** del Sistema Solare, e i **NEO** in particolare, sono un **tema strategico** a livello internazionale, sia per le attività legate alla Planetary Defence che per le connessioni con l'astrobiologia.

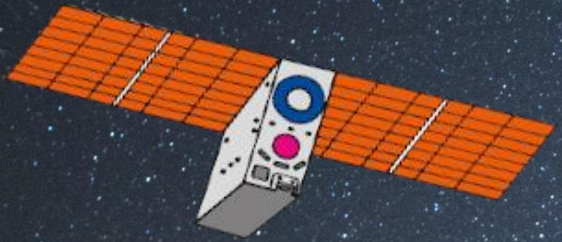
Necessità di continuità nel finanziamento dell'attività di base.

Politica di arruolamento – necessità di un piano di assunzione di:

- **personale scientifico**, per garantire la continuità.

LICIA

Light Italian Cubesat for Imaging of Asteroids



LICIACube

the Light Italian Cubesat for Imaging of Asteroids

Elisabetta Dotto (INAF-OAR)

INAF – Audizioni RSN3, 9 Maggio 2022

DART

Double Asteroid Redirection Test