LICIACube: the Italian small satellite for the close-up observation of the NASA DART impact on the asteroid Dimorhpos

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thanks to Simone Pirrotta

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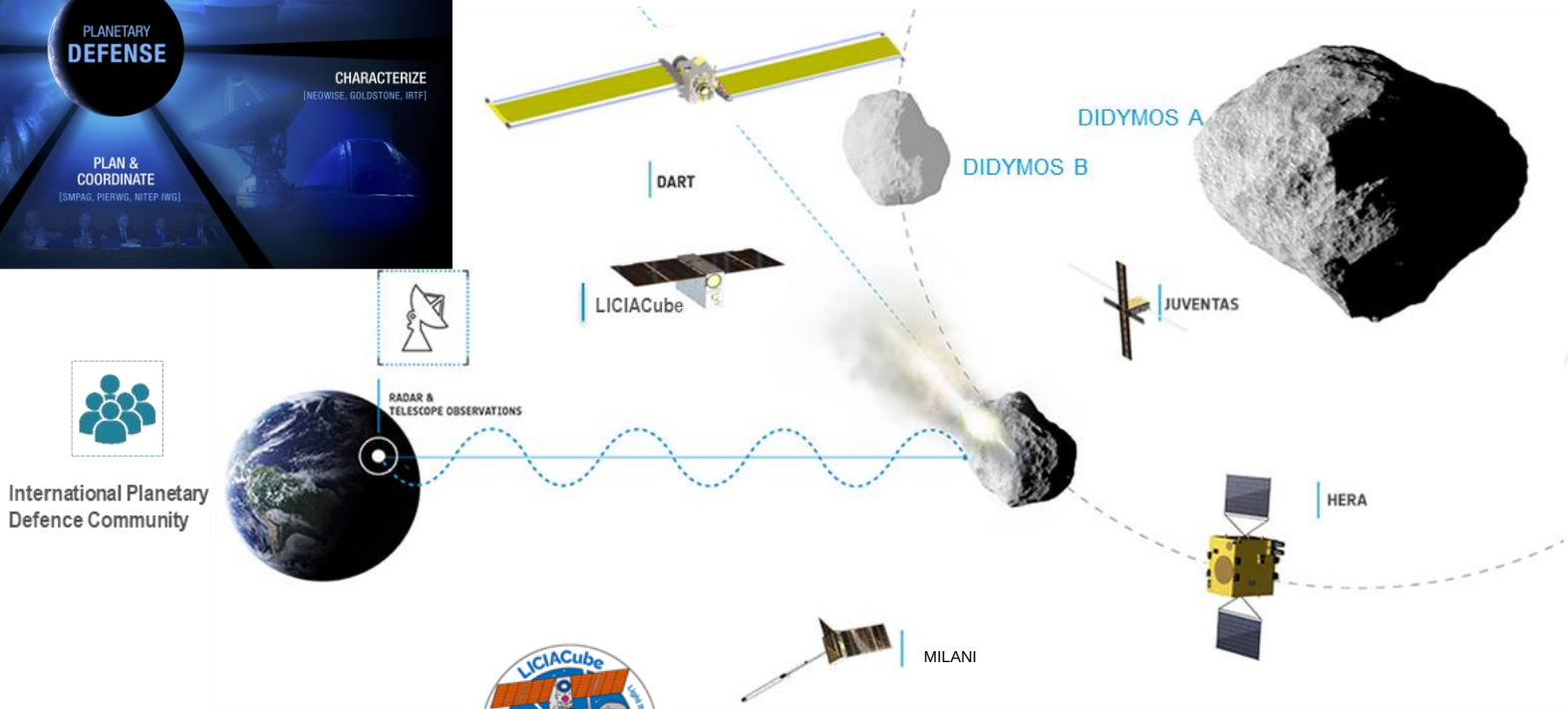
LICIACube in DART, for AIDA



AIDA

DART

First demonstration of asteroid deflection by kinetic impact on Didymos B, to change its orbit

with

LICIACube

First prompt imaging of the impacted surface, ejecta plume evolution and of the non-impacted hemisphere of Didymos B

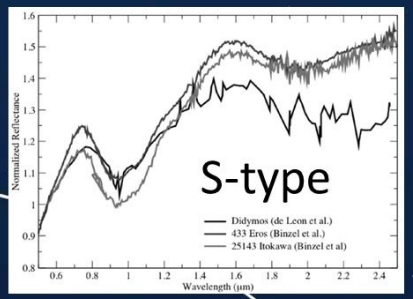
+

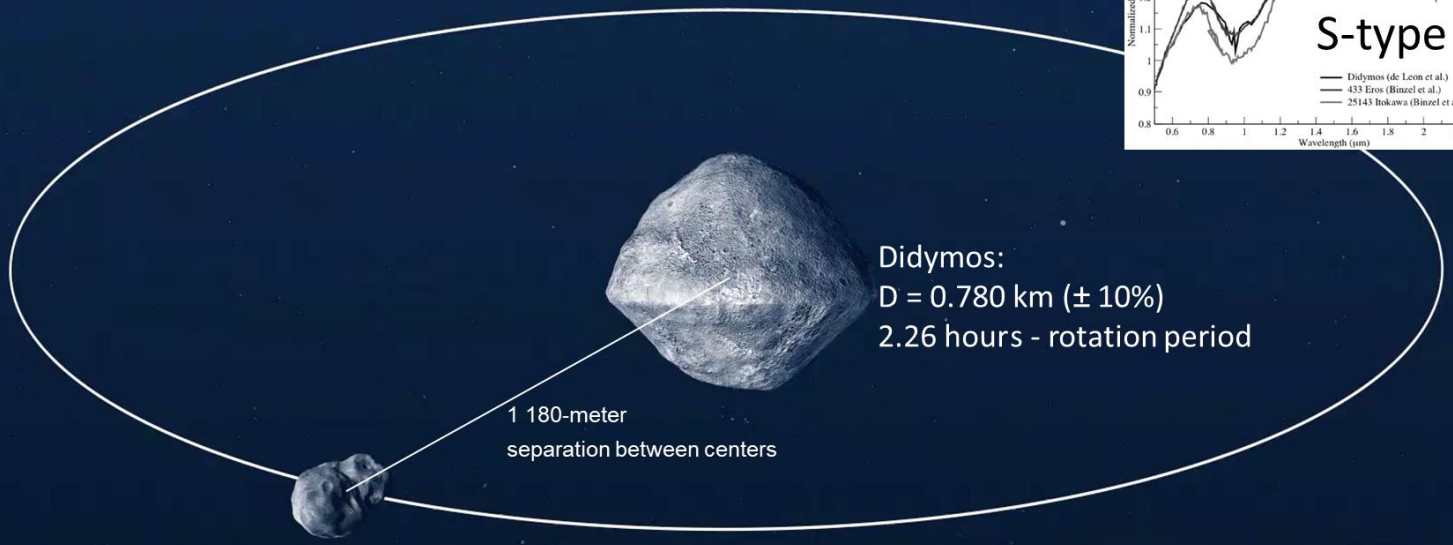
Hera

Mass of Didymos B
Detailed dynamical characterization, investigation of final crater, overall characterization of the asteroids

LCC data processing

The target: Didymos & Dimorphos



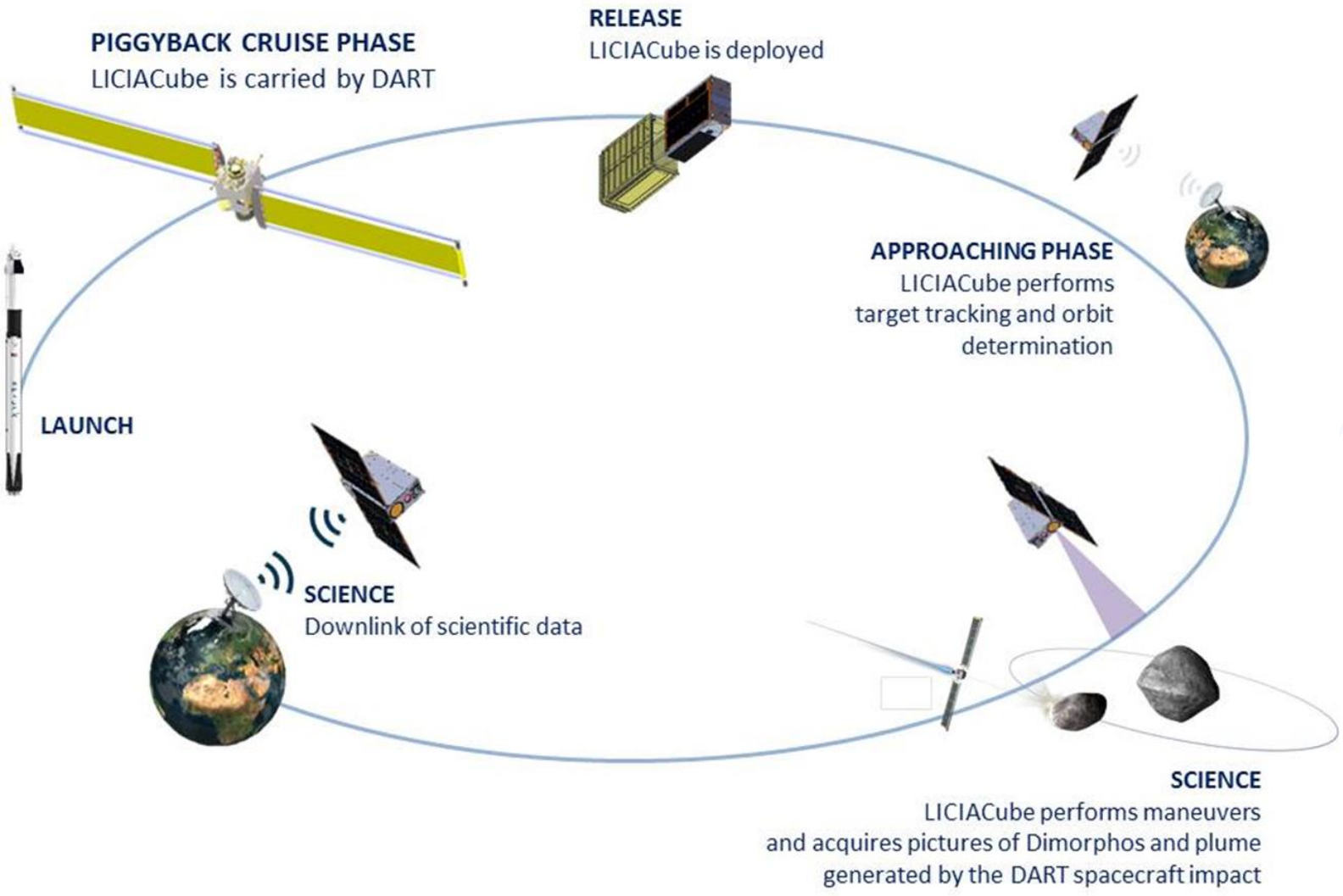


Didymos:
D = 0.780 km (± 10%)
2.26 hours - rotation period

Dimorphos:
0.163 ± 0.018 km
11.92 hours - orbital period

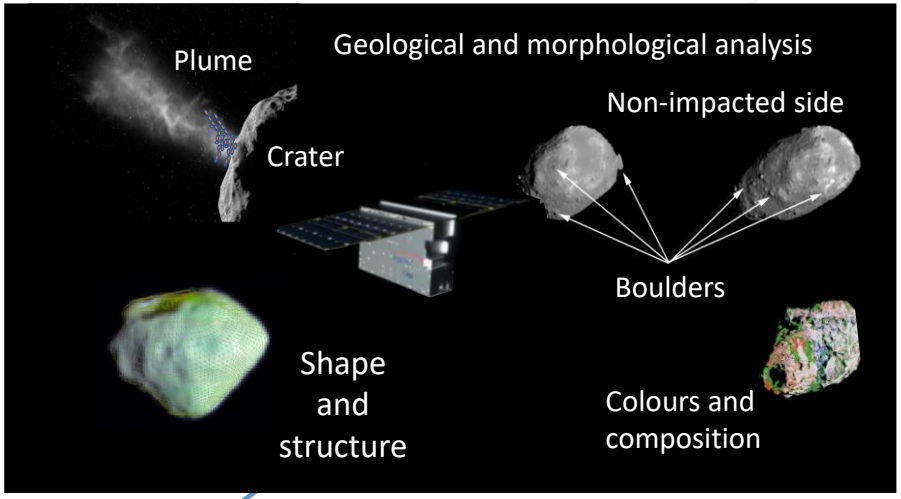
Earth-based
observations

LICIACube mission profile



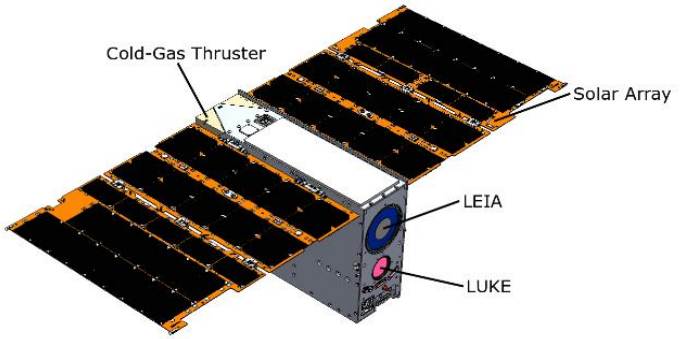
LICIACube scientific objectives

- **Testify** the DART **impact**;
- Obtain multiple images of the **ejecta plume,** over a span of time and phase angle to:
  - Allow measurement of the motion of the slow (< 5 m/s) ejecta, at spatial scale better than 5 m/pixel, with the possibility to distinguish the movements of the slowest particles;
  - Allow estimation of the plume structure, measuring the evolution of the dust distribution;
- Obtain multiple images of the **DART impact site** with a sufficient resolution to allow measurements of the size and morphology of the crater;
- Obtain multiple images of Dimorphos showing the **non-impact hemisphere**, hence increasing the accuracy of the shape and volume determination.



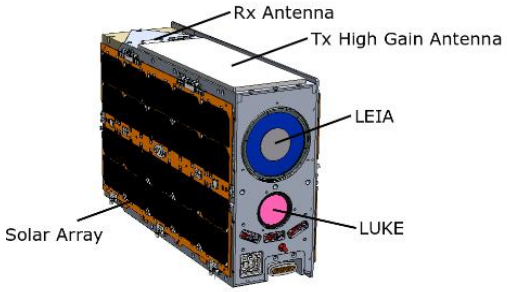
LICIACube design, at a glance

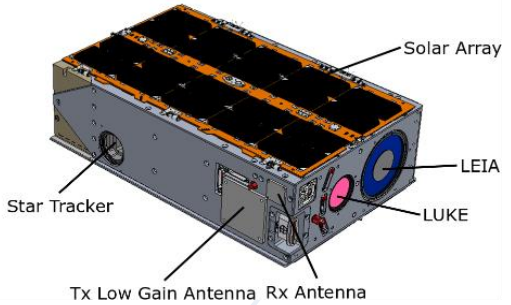
Orbit: Heliocentric (~10M km from the Earth)
Mass: 14 kg
Volume: 6U+
366 mm x 239 mm x 116.2 mm (stowed)
911.5 mm x 366 mm x 239 mm (deployed)

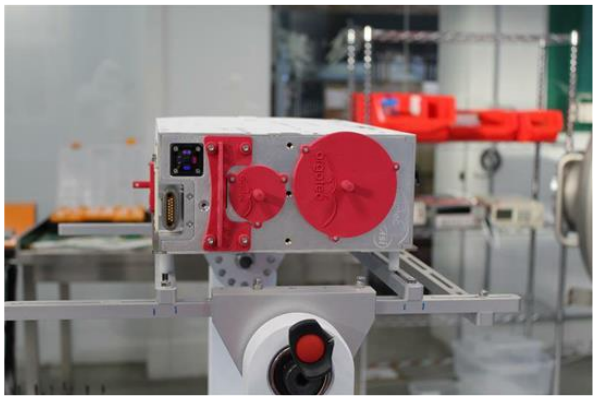


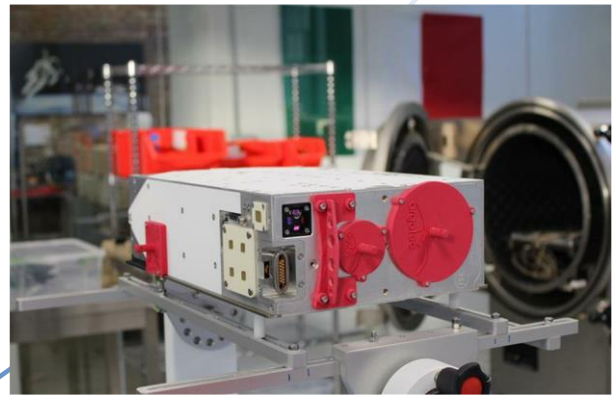
LEIA: a catadioptric camera with spatial scale at C/A (~55km) 1.38 m/px

LUKE: a camera with a RGB Bayer pattern filter

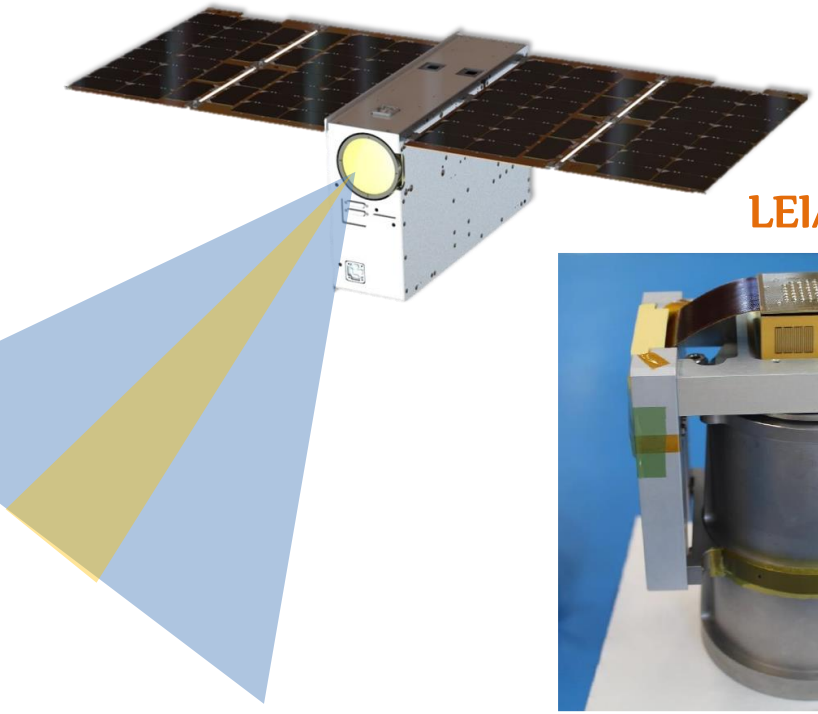








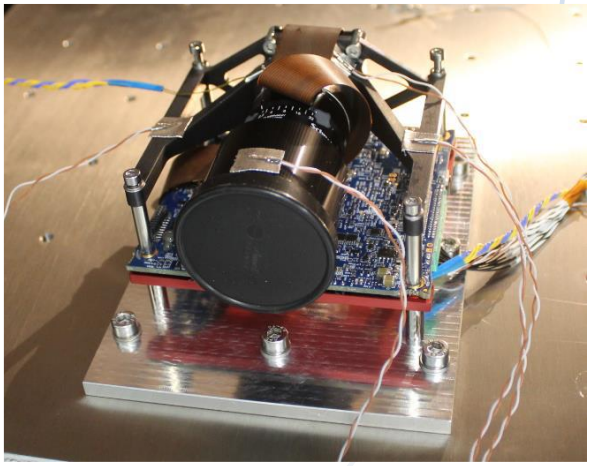
LICIACube Payloads



LEIA

Liciacube Explorer
Imaging for Asteroid

LUKE

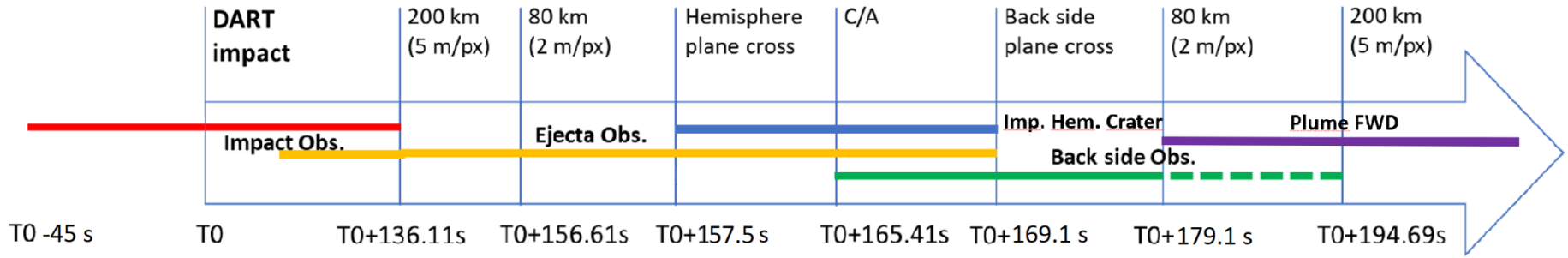


Liciacube Unit Key Explorer

	Focal length (mm)	FoV (°)	IFoV (μrad/px)	Spat. scale at 55.2km (m/px)
LEIA	222.55	± 2.06	24.71	1.38
LUKE	70.5	±5	78	4.31

LICIACube Timeline

Phase	Start	End	LEIA	LUKE
1 – DART Impact	-45 s to T0	T0+136.11 s	yes	Not operative
2 - Ejecta Observation	-25 s to T0	T0 + 169.1 s	yes	yes
3 - High resolution (surface properties/crater) observation	T0 + 157.5 s	T0 + 169.1 s	yes	yes
4 – Non-impact hemisphere observation	T0 + 165.41s	T0 + 179.1 s	yes	yes
5 – Plume evolution in forward scattering	T0 + 179.1 s	T0 + 600 s	yes	yes



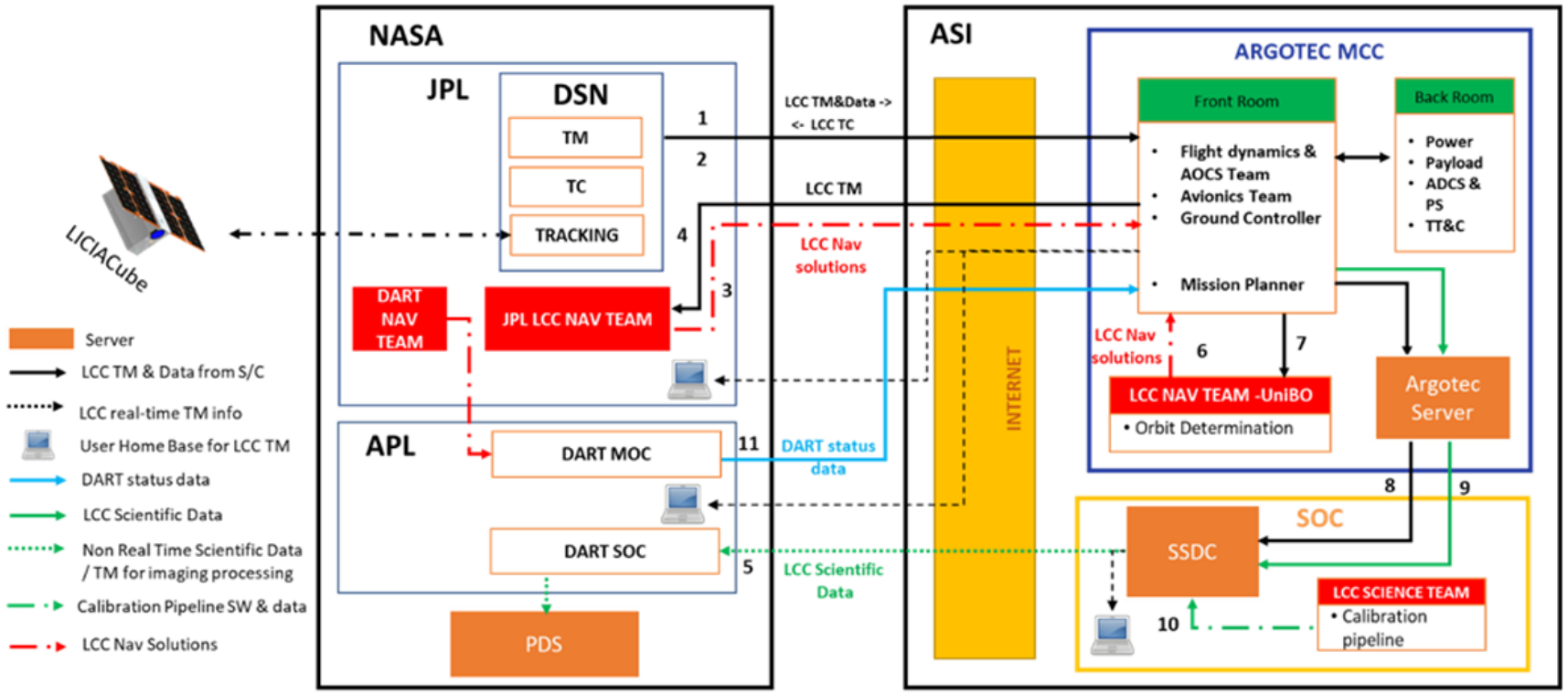
LICIACube integration and launch!

August 2021: Integration on DART at JHU – APL, Baltimore, MD

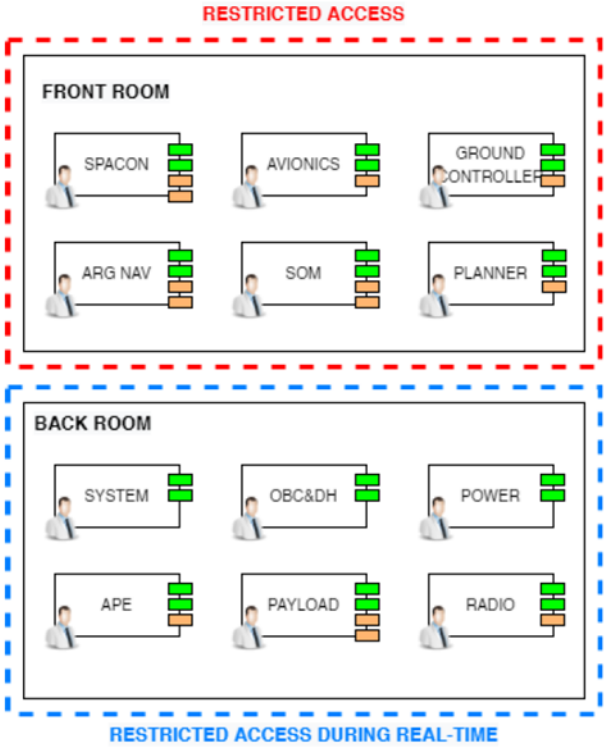
24th November 2021: DART and LICIA Launch – Vandenberg Air Force Base, CA

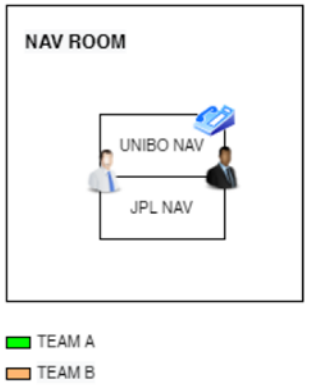
LICIACube GS architecture

A quite articulated **Ground Segment architecture** was implemented: Antennas terminals are part of the DSN, while the **Mission Control Centre** was located in Turin (Argotec) and the **Science Operation Centre** in Rome (ASI)



GS and Operations readiness



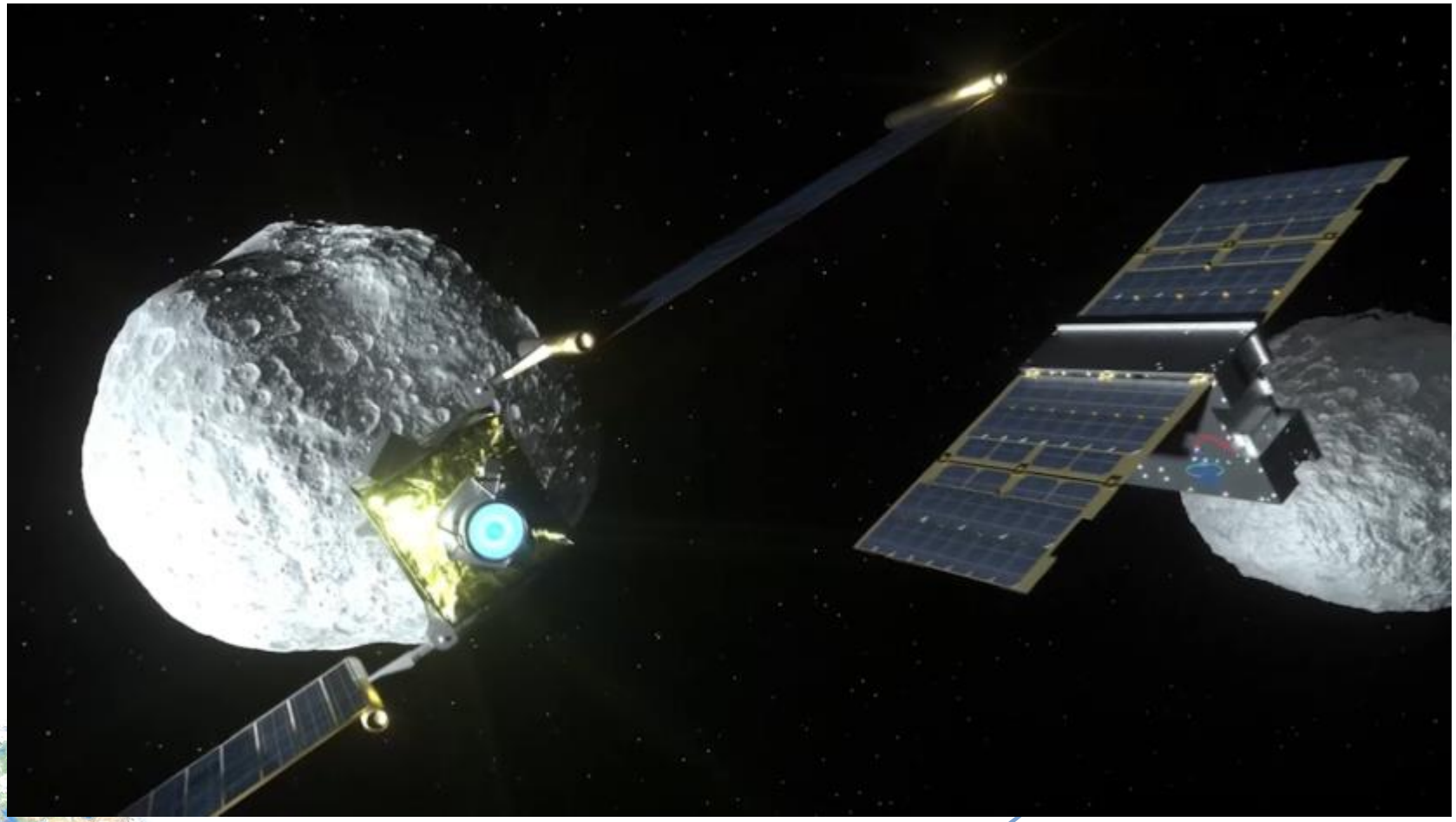


- **MCS** based on commercial software
- **Custom software** (MARGOT) for data processing and visualization developed by ARGOTEC.
- Flight Operations Procedures (**FOP**) validated by the FCT during SVT.

- **Operational features** (timeline, connectivity and data sharing) an End-to-end dry run simulation of the Ops phase planned completed before LICIACube separation
  - The same GS-MCC has been used also for ArgoMoon mission, the Italian cubesat that took part in the NASA Artemis 1 mission, in mid November 2022

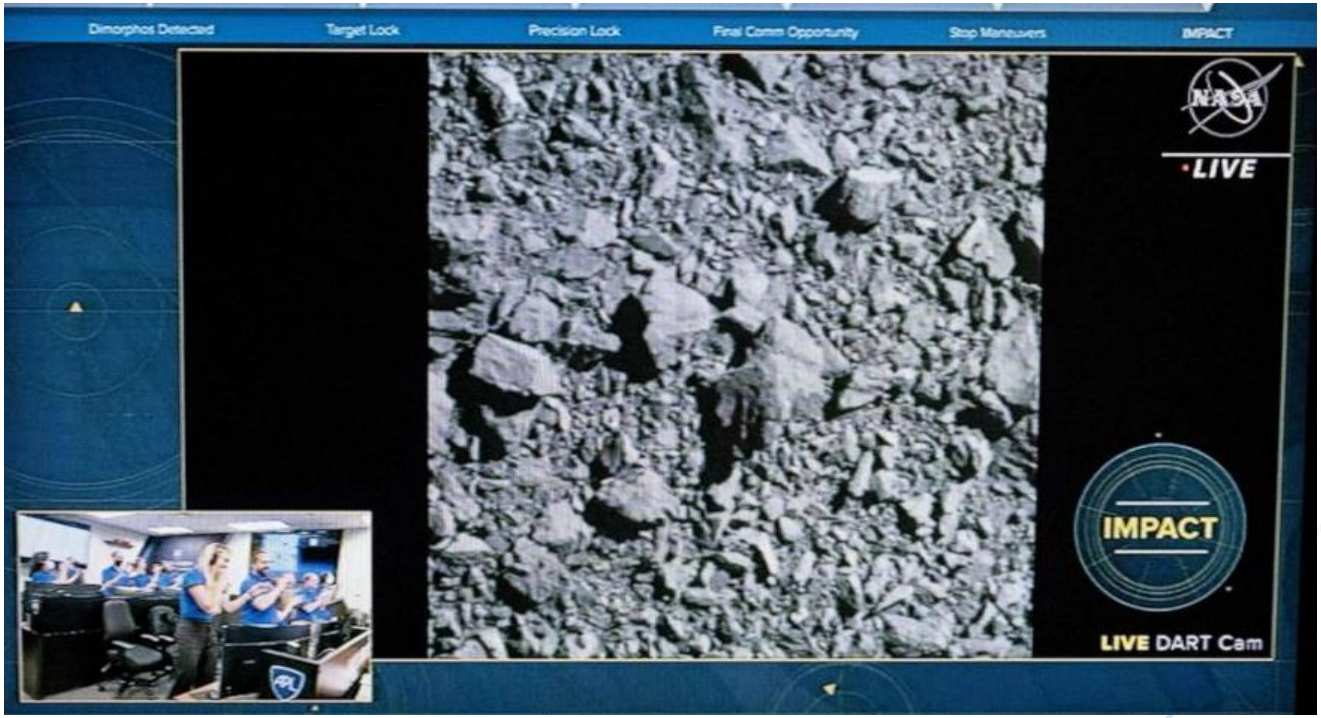
LICIACube separation from DART

23:14 UTC on September 11th, 2022 LICIACUbe separated from DART and started operating autonomously



DART's impact on Dimorphos

At 23:16 UTC on September 26th, 2022, the DART spacecraft impacted Dimorphos at the speed of about 6.1 km/s



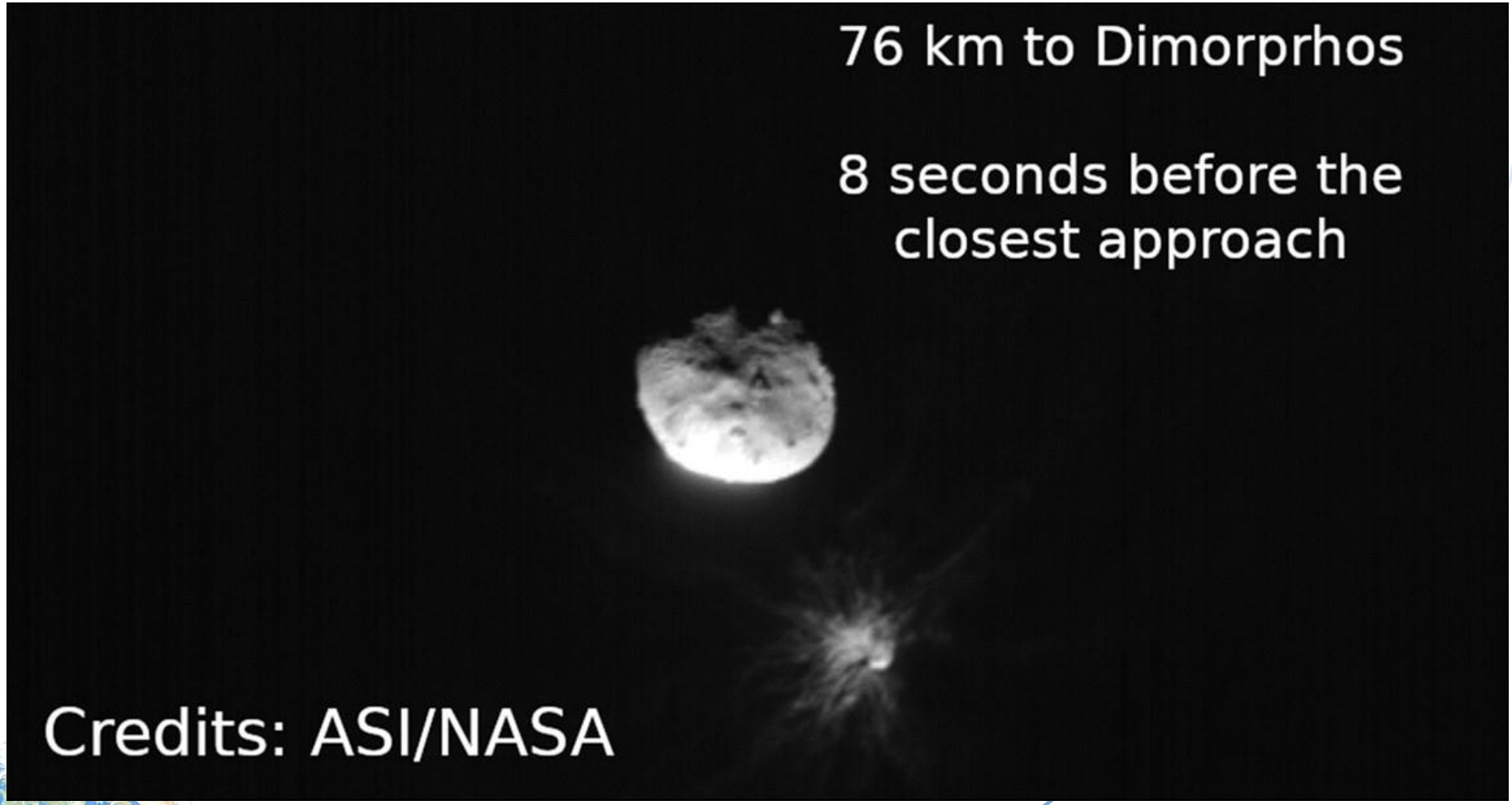
About 3 minutes later, LICIACube passed at a minimum distance of about 58 km from Dimorphos (closest approach, CA) and acquired a total of 426 scientific images

LICIACube first images

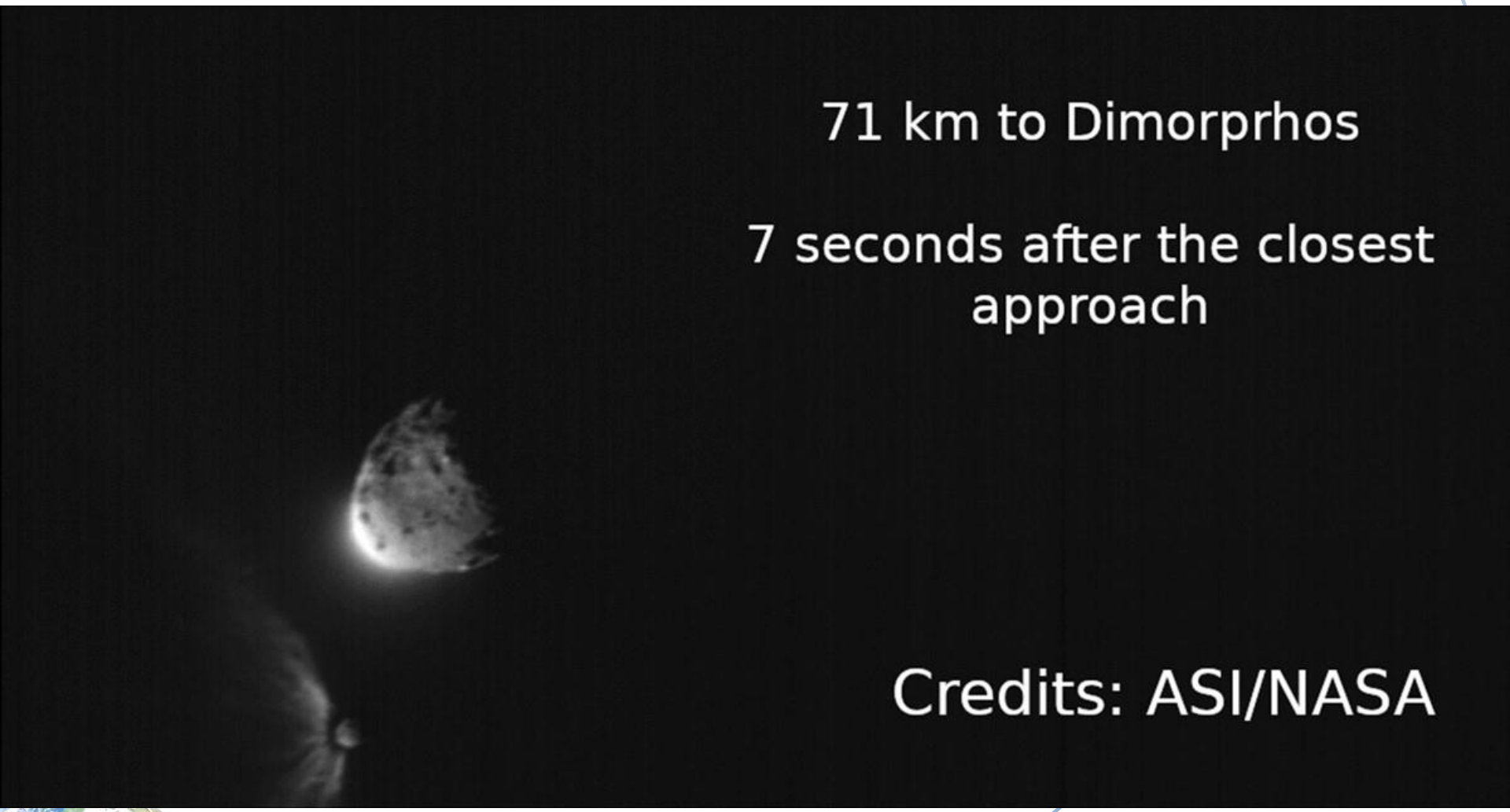
At 02:14 UTC on September 26th 2022, the first images have been downloaded at LICIACube MCC

The first visual reporting

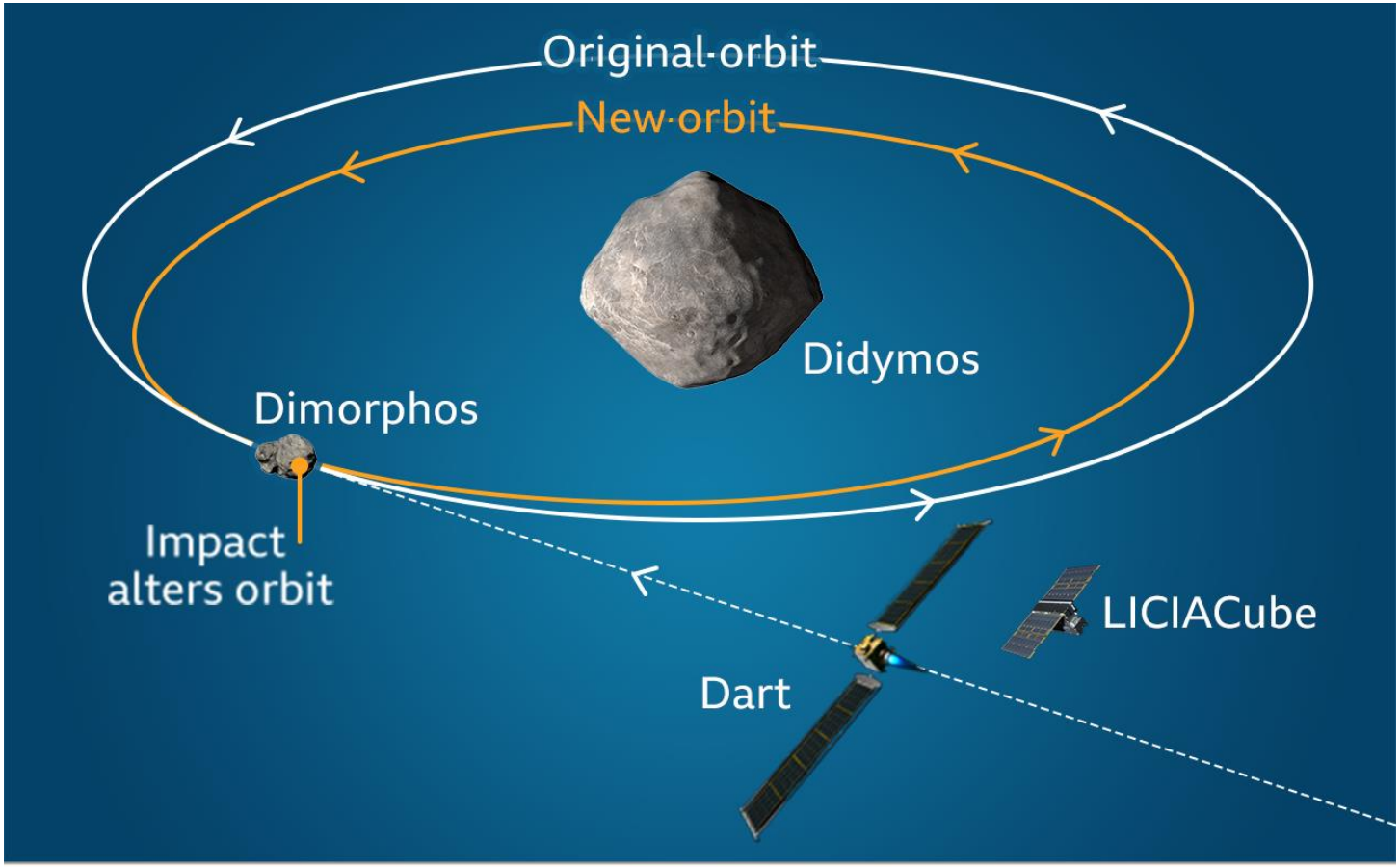
Data analysis in progress



Data analysis in progress



Captured images



Source: Nasa, Johns Hopkins Applied Physics Laboratory

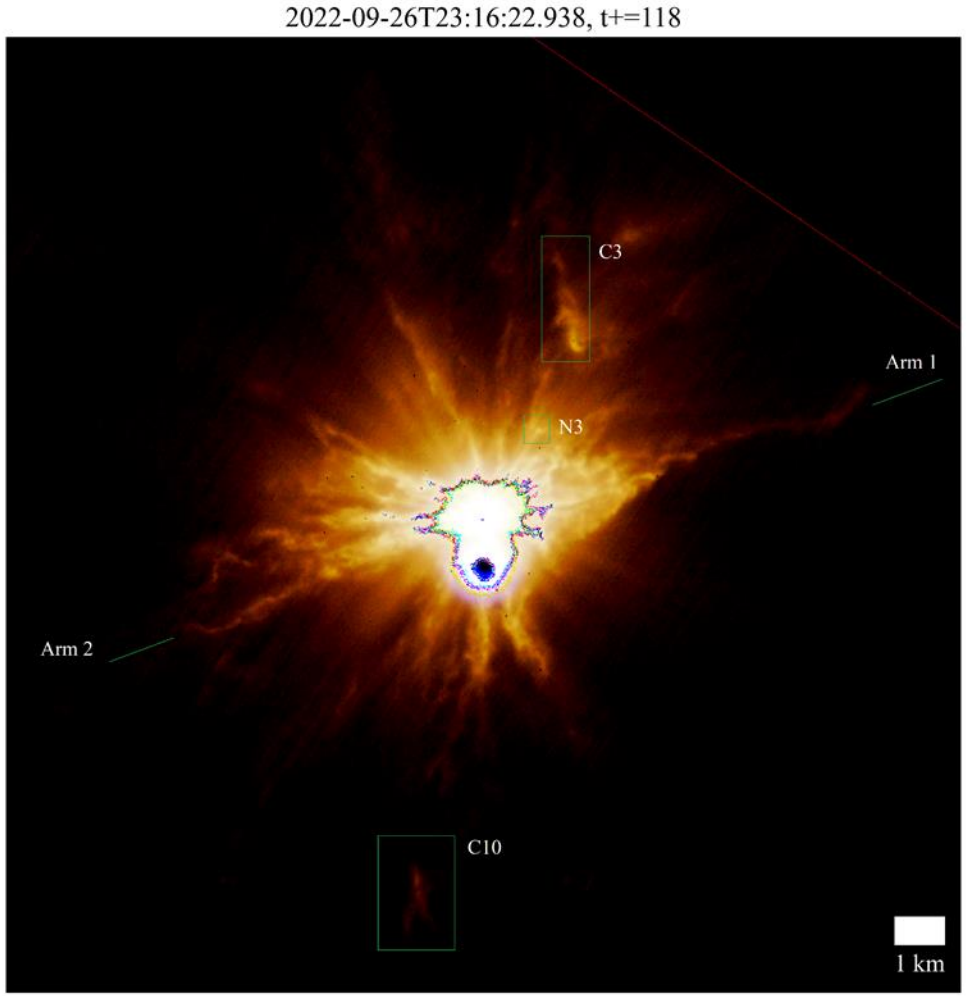
BBC

On October 11th 2022, NASA announced the complete success of the DART mission, confirming that the spacecraft's impact altered Dimorphos' orbit around Didymos by 33 minutes

Data analysis in progress

The LICIACube images show that the DART impact on Dimorphos generated a cone of ejected surface material with a large aperture angle (140±4°).

This plume has a complex and inhomogeneous structure, characterized by non-radial filaments, dust grains, and single and clustered boulders that allows us to deeply investigate the nature of the ejecta and the structure of Dimorphos



Further scientific investigations in progress !

Conclusions

- LICIACube participated in the NASA DART mission, concluded on September 26th, with the crash on the surface of the asteroid (65803) Dimorphos.
- Measurements from the LICIACube flyby constrain the shape of the target, and quantitatively characterize the ejecta and their early evolution velocities (ranging from a few tens of m/s up to about 500 m/s), providing also pivotal input for measuring the momentum transferred to Dimorphos and so contributing to confirm the DART success as Planetary Defense initiative.
- LICIACube obtained several **records**: it was the third cubesat (first European) to perform an interplanetary mission and the first satellite to fly by a binary asteroid; it is also the first Italian mission operating in Deep Space.
- LICIACube success confirmed the potential for small probes even in deep space exploration, as extremely powerful, flexible and sustainable platforms that can be used to complement the missions usually assigned to larger spacecrafts. In fact, few weeks later another Italian 6U cubesat, derived from the same LICIACube design, named ArgoMoon participated in the NASA Artemis 1 mission as one of the ten secondary payloads on board of the Space Launch System at its maiden flight