LICIACUBE

MISSION SCENARIO AND DATA EXPLOITATION

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INTRODUCTION

"LICIACube – the Light Italian Cubesat for Imaging of Asteroids" is managed by the Italian Space Agency (ASI) and will be part of the NASA DART mission, with the aim of i) documenting the DART impact's effects on the secondary member of the (65803) Didymos binary asteroid system, ii) characterizing the shape of the target, and iii) performing dedicated scientific investigations on it.

The LICIACube team gathers together national research centres, academies, and private sector acting in Italy in the space domain.

DART, the NASA Double Asteroid Redirection Test will be the first mission demonstrating the applicability of the kinetic impactor to change the motion of an asteroid in space and prevent the impact of Earth with a hazardous object (Cheng et al. 2018).

After being launched in 2021, in autumn 2022 the DART spacecraft will impact Dimorphos, the secondary member of the (65803) Didymos binary asteroid. With a mass of 650 kg and an impact velocity of about 6.6 km/s, DART is expected to change the binary orbital period of the 160-m Dimorphos by about 10 minutes, an effect that can be easily measured by ground-based telescopes.

LICIACube will be launched with DART, hosted as piggyback during the interplanetary cruise, and released ten days before the impact in the proximity of the Didymos system, on it autonomous path towards the target (Dotto et al. 2021, Capannolo et al. 2019).

After commissioning phase and braking and correction maneuvers LICIACube will approach the target and will perform the scientific phase during the asteroid's fly-by.

After the Dimorphos fly-by, LICIACube will downlink the obtained images directly to Earth.

The architecture of the LICIACube Ground Segment is based on the Argotec Mission Control Centre, antennas of the NASA Deep Space Network and data archiving and processing, managed at the ASI Space Science Data Center where images are planned to be integrated in the MATISSE tool (Zinzi et al, 2016; 2019] for visualization and analysis.

LICIACUBE SPACECRAFT OVERVIEW

LICIACube is a cubesat 6U, of about 14 kg of mass, developed by Argotec and equipped with two different payloads name LEIA and LUKE.

LEIA (Liciacube Explorer Imaging for Asteroid) is a catadioptric camera composed of two reflective elements and three refractive elements. The optics is designed to work in focus between 25 km and infinity and the detector is a CMOS sensor with 2048x2048 pixel. The latter is equipped with a Panchromatic filter centered at 650nm±250nm.

LUKE (Liciacube Unit Key Explorer), is the Gecko imager from SCS space, a camera with an RGB Bayer pattern filter, designed to work in focus between 400 m to infinity.

	Focal length (mm)	FoV (°)	IFoV (µrad/px)	Spat. scale at 55.2 km (m/px)
LEIA	220	± 2.06	25	1.38
LUKE	70.55	±5	78	4.31

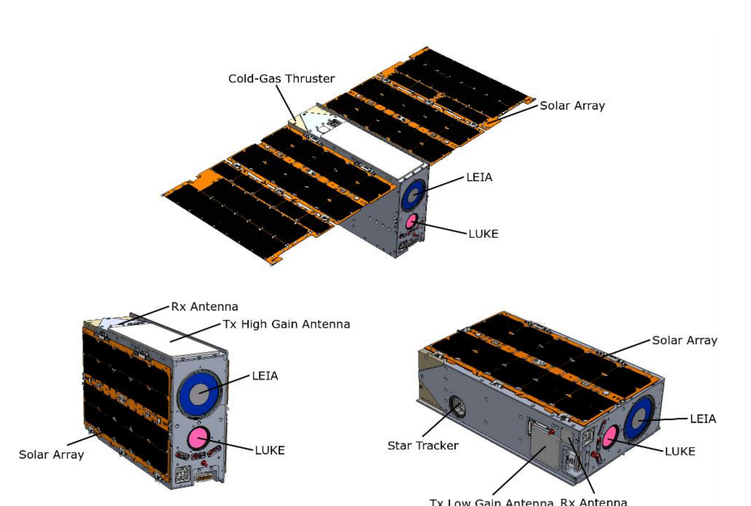


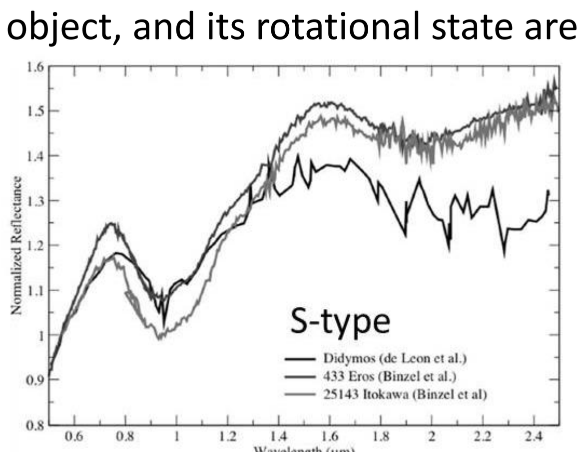
Fig. 1. 3D view (also with deployed Solar Array, top) of the LICIACube spacecraft, with the two payloads LEIA and LUKE onboard (see text).

OUR TARGET: DIDYMOS AND DIMORPHOS

The target of LICIACube is the (65803) Didymos system, a binary NEA classified as potentially hazardous asteroid (PHA).

Didymos is classified as an S-type (De Leon et al. 2010) and spectroscopically consistent with ordinary chondrites, with an affinity for L/LL-type meteorites (Dunn et al. 2013)

The primary object seem to have a "spinning top" shape and a bulk density compatible with known bulk density range for S-type objects (2000 – 2700 kg m^{-3}). The bulk density of Dimorphos, the secondary object, and its rotational state are not constrained.



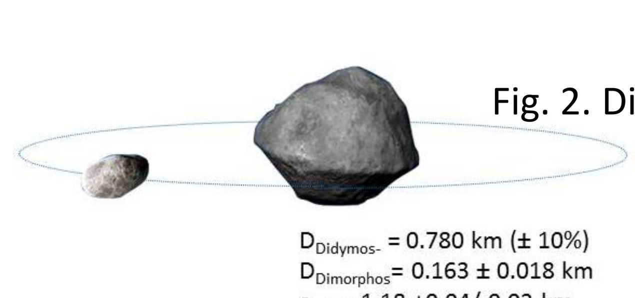


Fig. 2. Didymos and Dimorphos

SCIENCE OBJECTIVES AND ACQUISITION STRATEGY

The scientific objectives of LICIACube are:

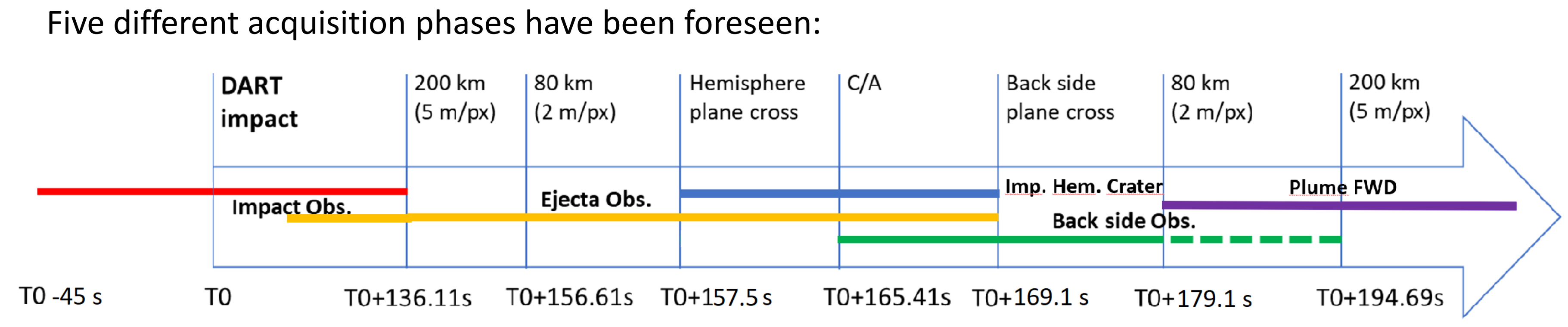
- Testify the DART impact;
- Obtain multiple images of the ejecta plume taken over a span of time and phase angle in order to:
  - Allow measurement of the motion of the slow ejecta:
  - Allow estimation of the structure of the plume, measuring the evolution of the dust distribution;
- Obtain multiple images of the DART impact site 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.

The science objectives constrain the operations of the LICIACube scientific payloads in order to:

- have data acquisition redundancy;
- cover the possible uncertainty on the real brightness of the objects in the field of view of the cameras;
- increase the dynamic range of the detectors on board the payloads;

As a general approach each planned observation will be formed by a sequence of three images acquired at the maximum frame rate possible with different integration times.

Five different acquisition phases have been foreseen:



DART impact observation (red phase in figure): LEIA will presumably witness the impact as an increase of the target luminosity. LUKE: Will be not operative.

Ejecta observation (yellow phase in figure): LEIA will observe the plume developed after the DART impact. LUKE, due to its larger FoV, will have a better view of the plume global expansion. In this phase LEIA and LUKE shall work simultaneously.

High resolution (surface properties, crater) observation (blue phase in the figure): LEIA will reach the best spatial resolution. LUKE will continue to operate and acquire images of the plume and possibly of the Dimorphos surface. LEIA and LUKE shall work simultaneously.

DATA EXPLOITATION

During the LICIACube fly-by we will perform a radio science experiment, exploiting the information carried by radio link between the S/C and the Earth focused on the precise orbit determination, and providing an assessment of the accuracies achievable in the estimation of the scientific parameters of interest, like the masses and the extended gravity field of Didymos.

Images acquired by LEIA and LUKE will allow us to constrain the physical properties of Dimorphos.

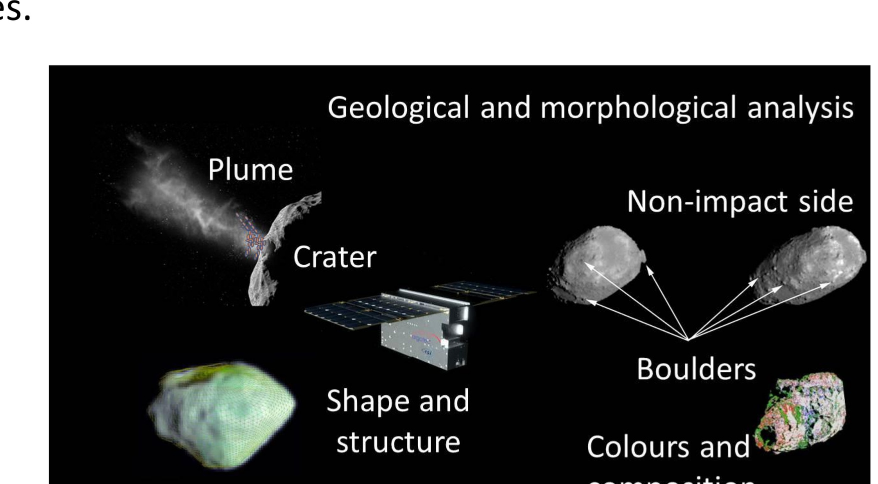
High-resolution images will allow us to study the surface morphology of Dimorphos and the presence of boulders/large blocks on its surface. By comparing pre- and post-impact surface areas we will have the unique opportunity to witness how the boulders size-frequency distribution and density changed as a result of the DART impact.

The LUKE data will give us also the opportunity to investigate the composition of Dimorphos throughout spectrophotometric analyses. So we will be able

- to map the surface composition of the object,
- to derive the surface heterogeneity at the observed scale
- to investigate the effects, on the asteroid surface materials, produced by the shock and those due to space weathering

To properly interpret the multi-color data acquired by LUKE, we will take profit from laboratory experiments on different minerals and meteorites, to investigate the variation of surface colors due to grain size, space weathering and at different temperatures. To better interpret the obtained data, we are also developing a model of the dust dynamics of the plume evolution considering the physical properties of the material which composes the target, and taking also into account analytical models of ejecta from asteroid physical properties. We are also developing and testing a model on in-house simulated ejecta clouds, to perform realistic simulations of the ejecta evolution over different timescale. Our team will also perform a 3D reconstruction of the target using all the acquired images.

Fig. 3. LICIACube Data Exploitation



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