Taking Pictures in Deep Space: ArgoMoon and LICIACube

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Argotec Small Satellites

Argotec designs and manufactures high-reliable rad-hard small satellite platforms able to **operate in different environments, from deep space to LEO**

The company developed a proprietary scalable satellite platform (from 6U up to 27U) called **HAWK**

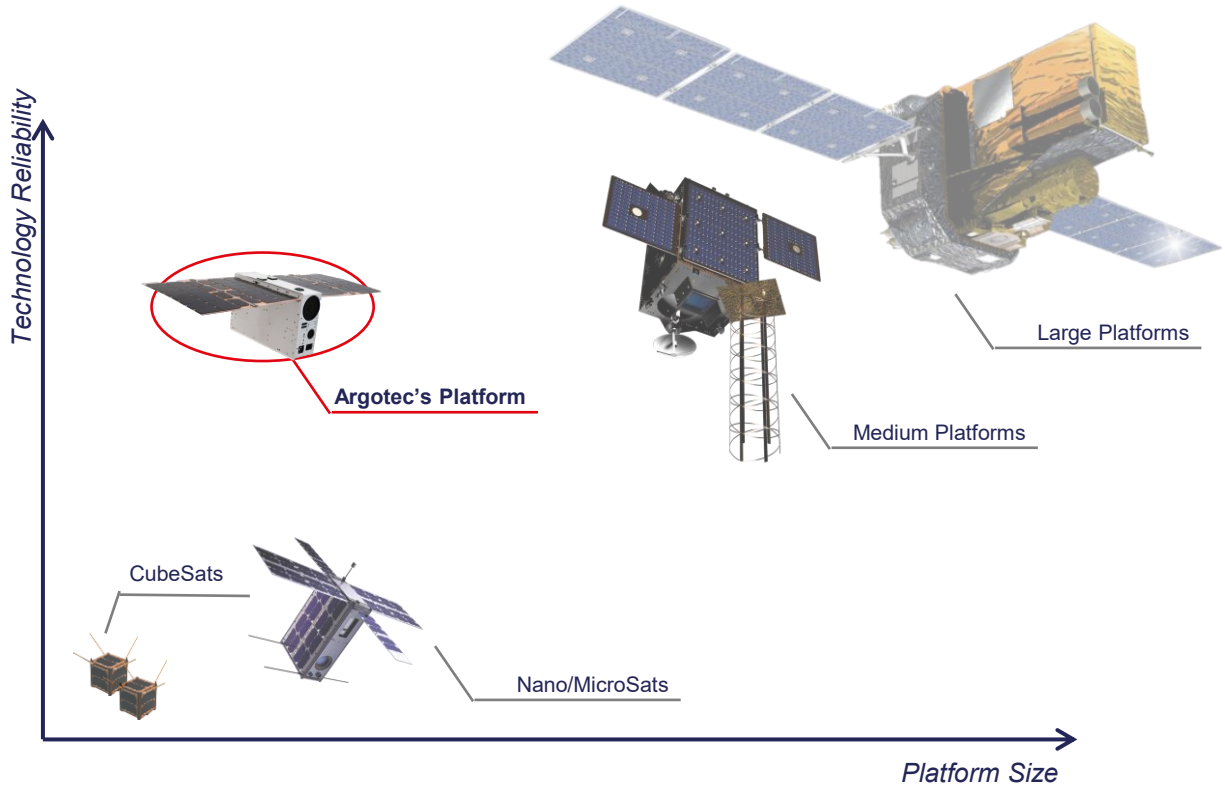
In 2022, Argotec became the only company in the world to have performed **two small satellites missions in deep space**

LICIACube
(DART)

ArgoMoon
(Artemis I)

The deep space missions are being operated from the company's Mission Control Center, the first European private control center to be **certified by NASA JPL** and **directly connected with NASA DSN and ASINet**

The **low platform cost** and **short development time** allow us to gain strategic advantages in terms of **fast time to market** and **high ROI**



HAWK in Deep Space

ArgoMoon and LICIACube

ArgoMoon

Argotec is part of the **ARTEMIS program** whose goal is the return of man on the lunar surface. Our small satellite platform was on board the **maiden flight** of the new **NASA SLS launcher**

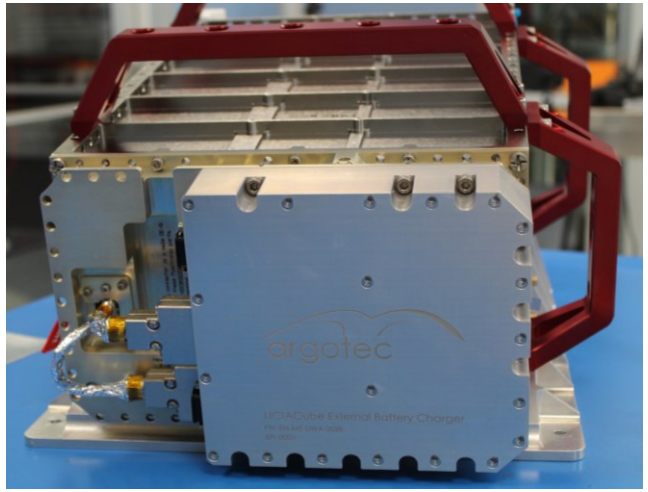
Artemis-1 took-off in November 2022

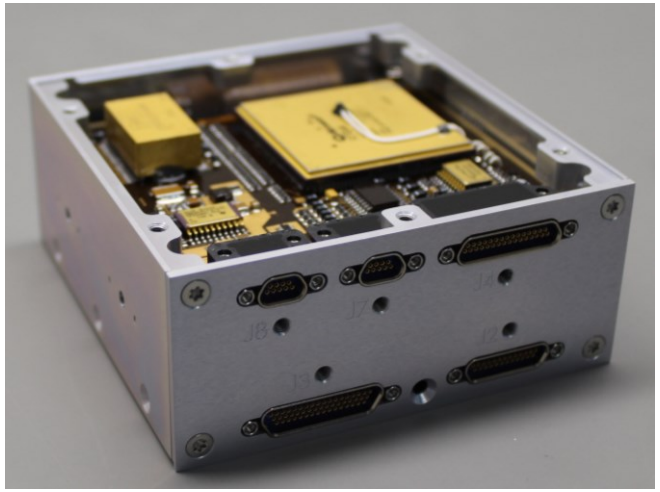
ArgoMoon - Overview

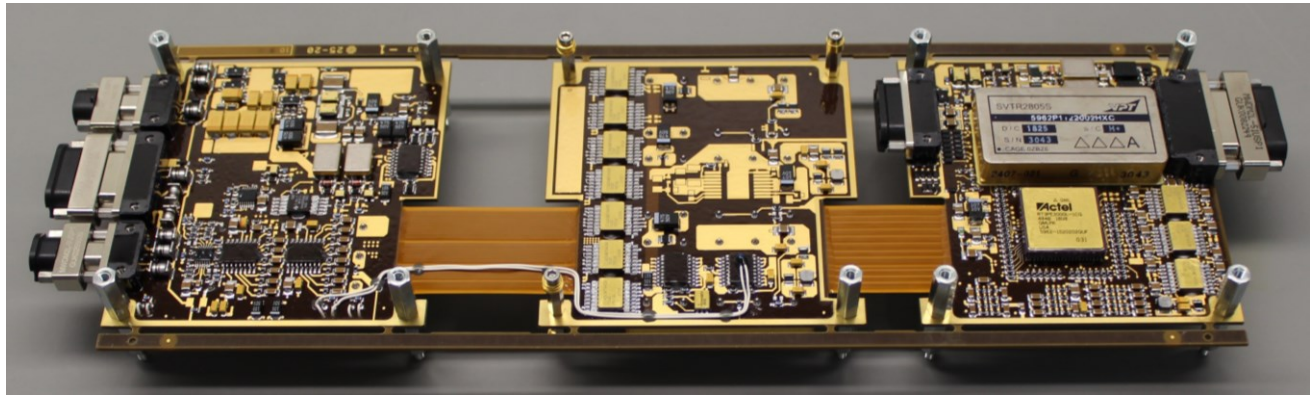
Mass	14 kg
Volume	36x24x11 cm (6U)
Downlink Band	X-Band @ 256 kbps
On-Board Storage	16 + 8 GB
SPA Generated Power	80W
Payload Power	Up to 30W available
Propulsion	ADN (Green Prop - Primary) Cold Gas RCS (R-134a)
Payload	±1.25° FoV Primary PL, 12Mpxl ±20° FoV Secondary PL, 12Mpxl Laser Rangefinder

HAWK Avionics Platform

- First **CubeSat-compatible** rad-hard avionics (**FERMI OBC**, **VOLTA PCDU**)
- Based on space-grade **SPARC-V8** dual-core **CPU** and **flash-based FPGAs**
- **1U** (10x10x10 cm) form factor (OBC + PCDU)
- **HW & SW mitigation mechanisms** for the rest of the satellite platform
- **Plug&Play External Battery Charger** to manage battery SoC, temperature and health monitoring during long cruises*



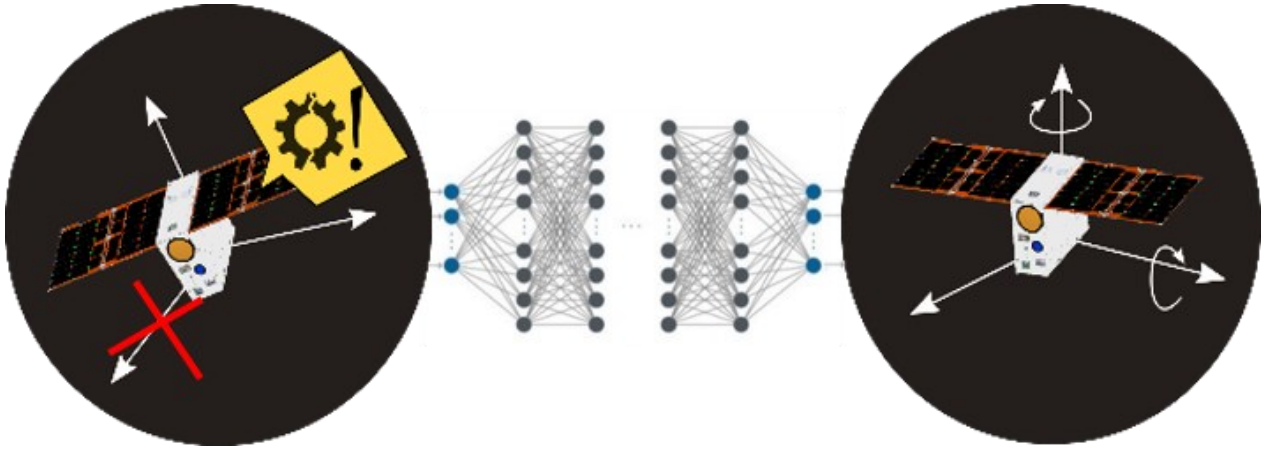




SW-Based Redundancy: REACT

ML-based subsystem to help the satellite **survive off-nominal condition**, without ground intervention

- An **adaptive attitude control system** for increased satellite autonomy
- Able to detect and react to **reaction wheels failures**
- Deep Reinforcement Learning to train light and fast **controllers based on neural networks**



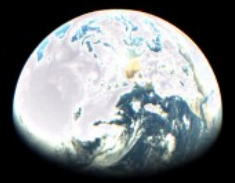
ID21 [PL2]
Epoch: 2022-11-21
Earth distance: 384101.7 km
Moon distance: 18380.7 km

Credits ASI/NASA

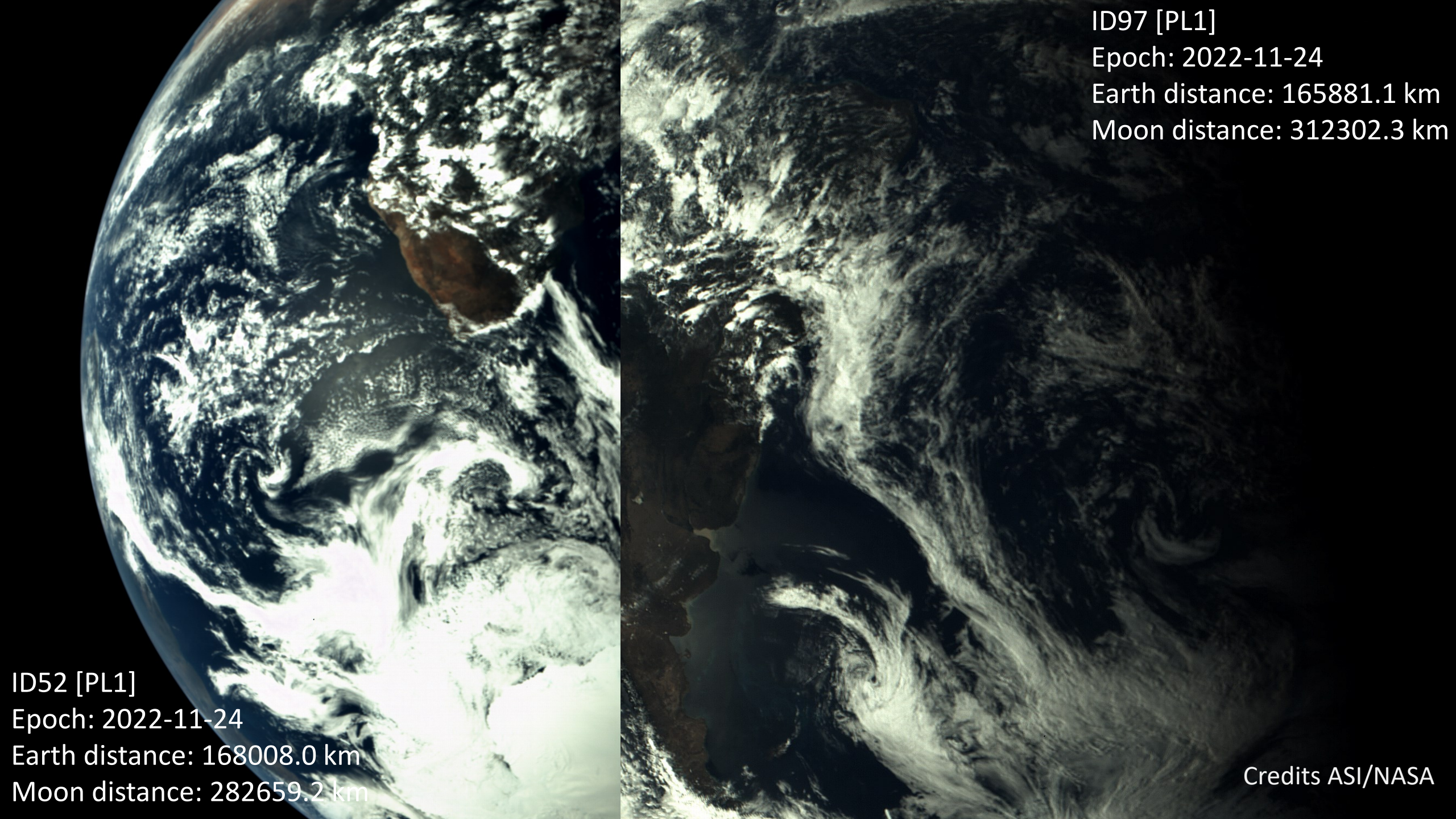
Credits ASI/NASA

ID23 [PL1]
Epoch: 2022-11-21
Earth distance: 384104.5 km
Moon distance: 18411.8 km

ID34 [PL2]
Epoch: 2022-11-24
Earth distance: 168634.8 km
Moon distance: 278618.9 km



Credits ASI/NASA


ID52 [PL1]
Epoch: 2022-11-24
Earth distance: 168008.0 km
Moon distance: 282659.2 km
ID97 [PL1]
Epoch: 2022-11-24
Earth distance: 165881.1 km
Moon distance: 312302.3 km
Credits ASI/NASA

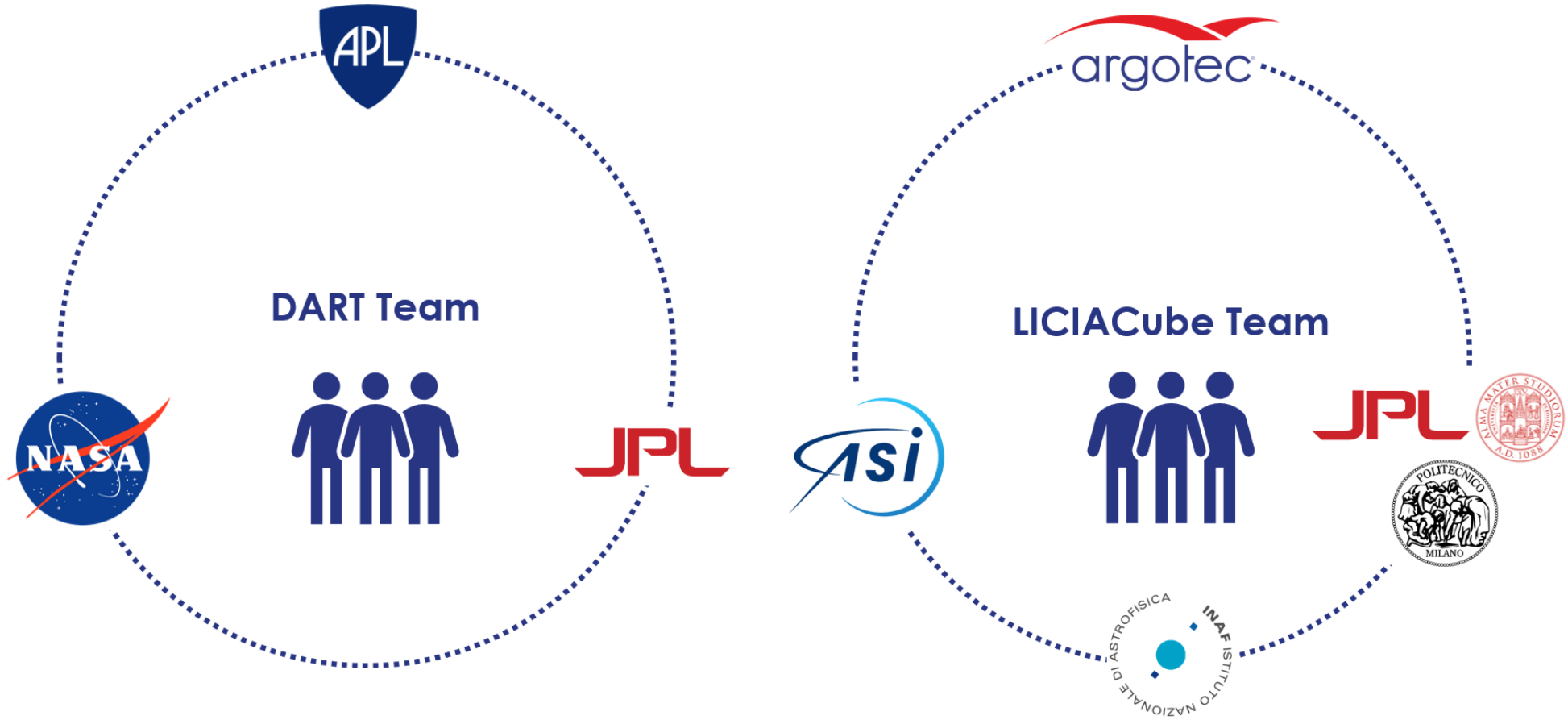
LICIACube

Argotec is onboard the **DART mission** in the framework of the **planetary defense program**

LICIACube has **witnessed the consequences of the impact** of the NASA's probe against the Dimorphos and will take pictures of the asteroid, the plume and the impact region

We **downloaded more than 600 photos** taken during the flyby

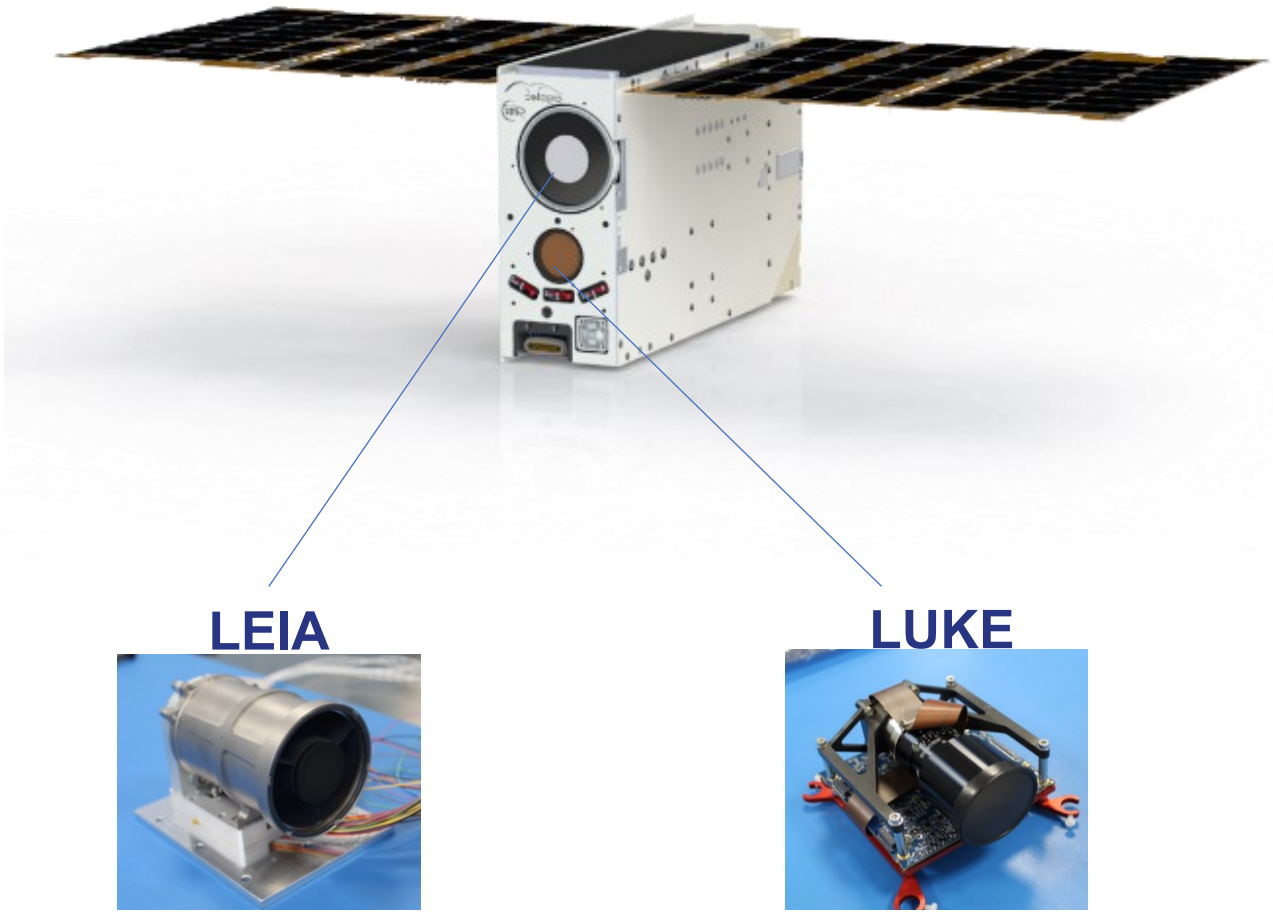
DART & LICIACube Teams



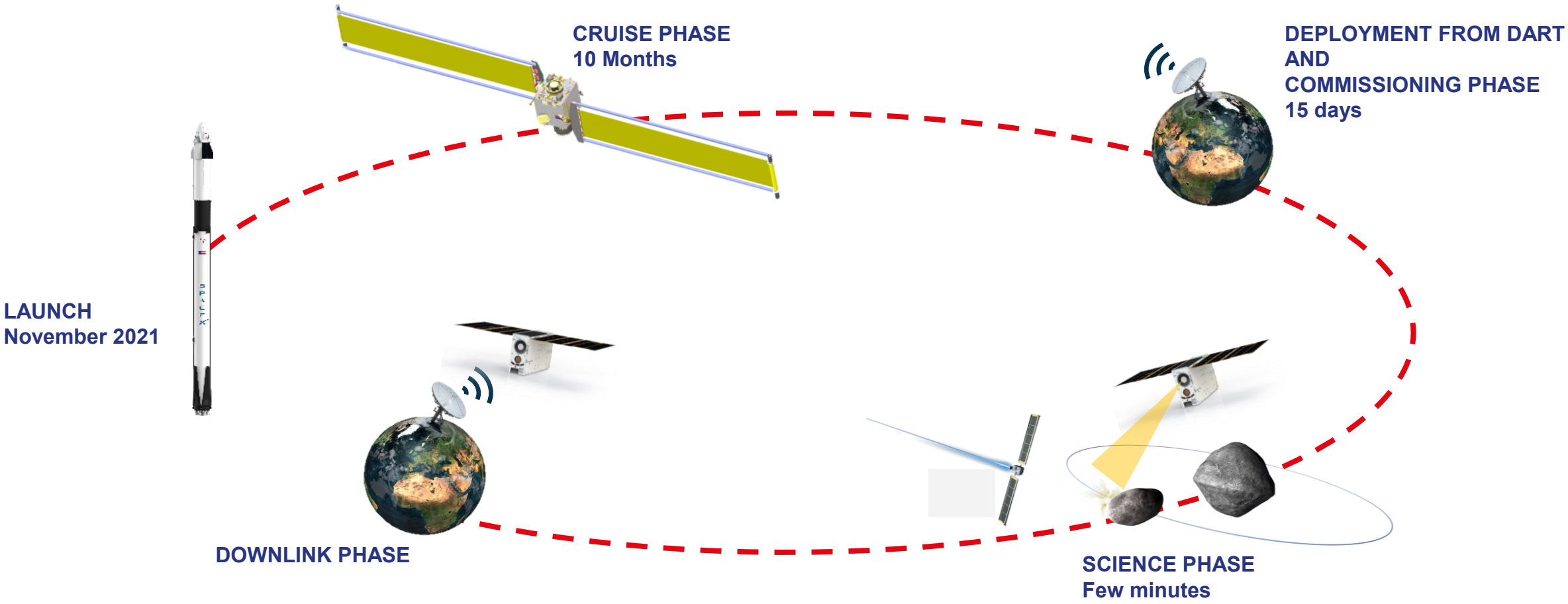
LICIACube - Overview

- Testify the DART impact
- Obtain multiple images of the non-impacted hemisphere of Dimorphos
- Obtain images of the ejecta plume and asteroid target to characterize color and spectral variations

Mass	13 kg
Volume	30x20x10 cm (6U)
Downlink Band	X-Band @ 256 kbps
Generated Power	80 W
Propulsion	Cold Gas (R-236fa)
Payload	±2.06° FoV Primary PL (B&W) ±5° FoV Secondary PL (RGB)
Distance at DART impact	1378 km (3.5 minutes behind)
Distance at Closest Approach	58 km
Pictures taken during Flyby	> 660 (Navigation + Science)
Distance from Earth	11 million km (during Fly-By)



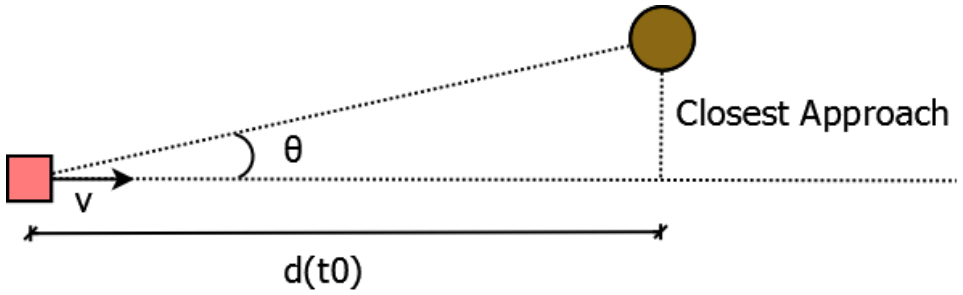
Mission Overview

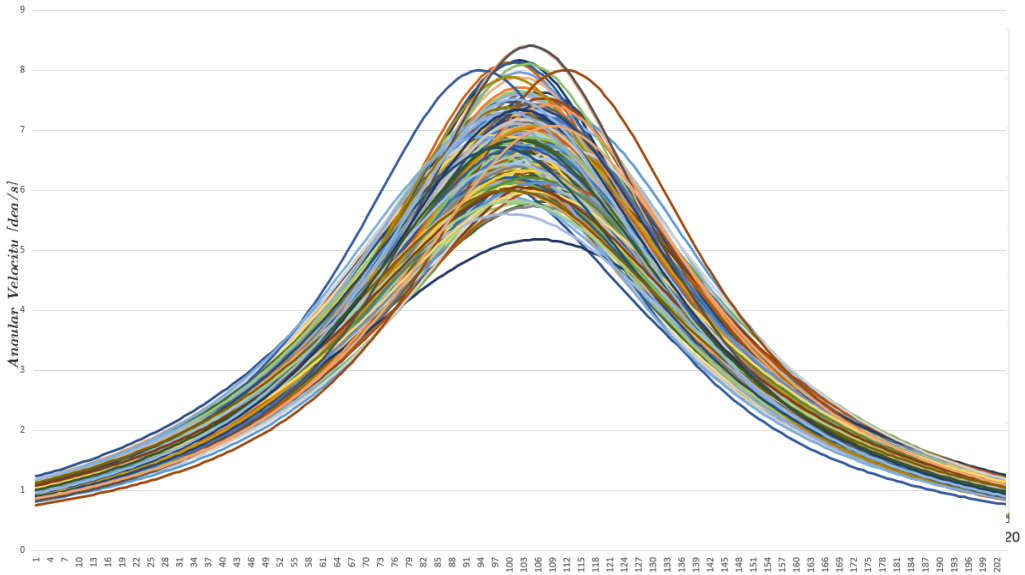


Mission Challenges

Main **challenges** of the mission

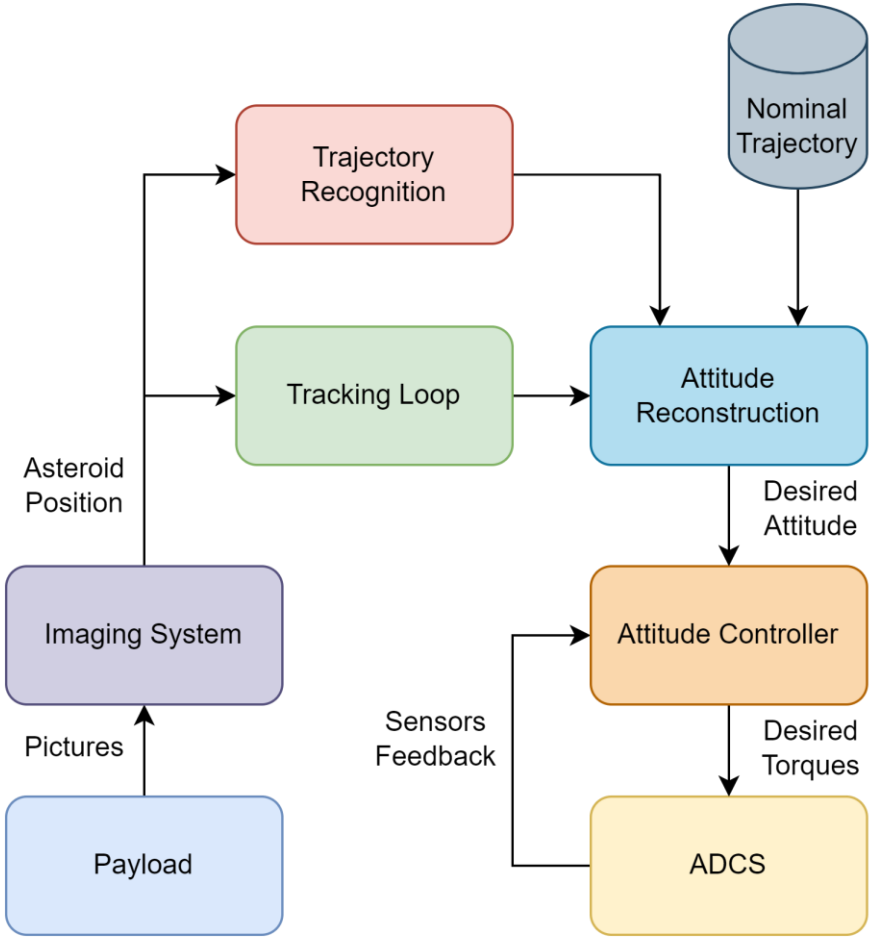
- Communications: RTLT **72 seconds** @ 11 Mkm
  → No real-time commanding
- Relative velocity: at closest approach (CA) ~7 km/s
  → Up to **10°/s body rate**
- **Trajectory uncertainties**: distance at closest approach is 50 km ± 15 km, closest approach instant affected by errors
  → Adaptive attitude control solution





Autonomous Navigation System

- **Payload** to acquire images of the target
- **Imaging System** to detect targets in the images and provide required corrections
- **Trajectory Recognition** to reconstruct the actual trajectory and adapt it using visual feedback
- **Tracking Loop** to adjust the attitude to center the target
- **Attitude Controller** to provide attitude control torques
- **ADCS** to measure the attitude and actuate the reaction wheels



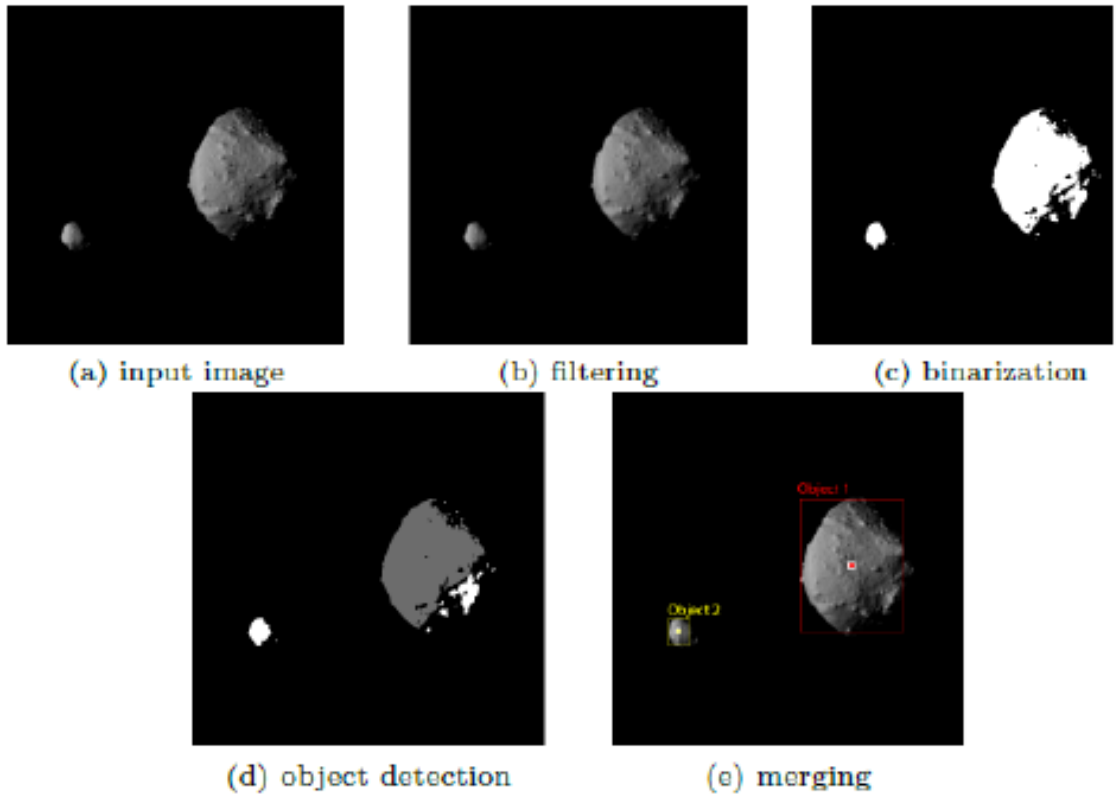
Imaging System

FPGA-implemented features

- Binning
- Low-Pass Filtering
- Color Depth Compression
- Histogram Calculation
- Binarization
- Labeling – First Pass

CPU-implemented

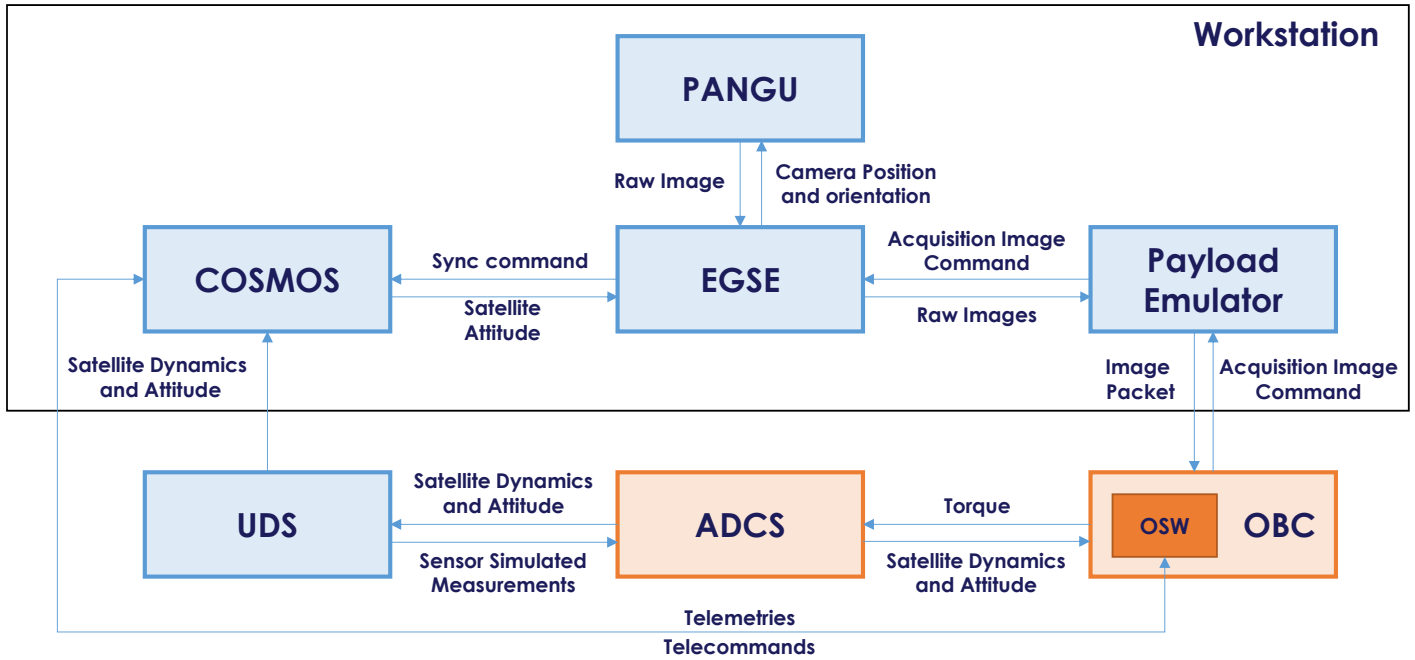
- Labeling – Second Pass
- Feature Extraction and Target Selection

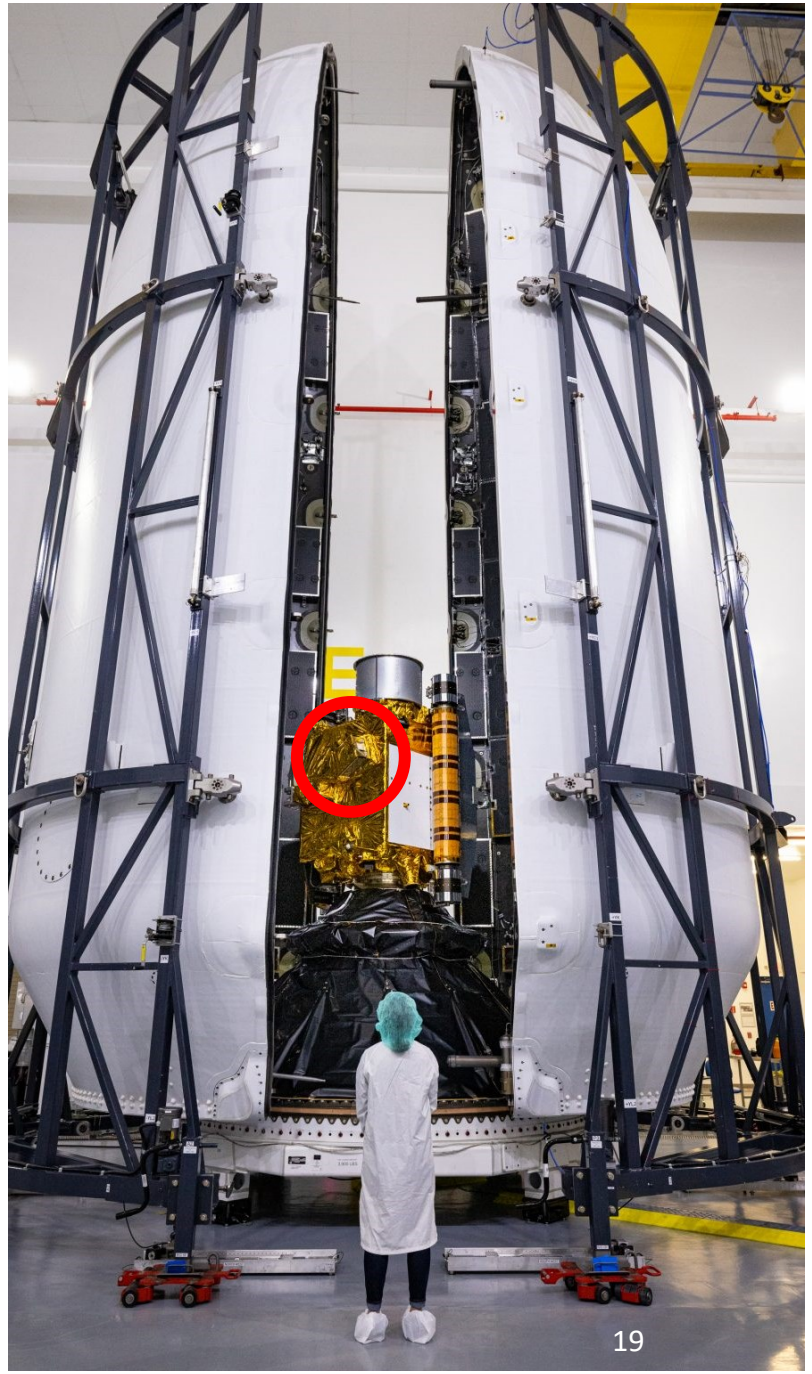


Validation

Hardware-in-the-Loop setup used to confirm functionality when the actual hardware comes in the equation:

- Realistic Payload-OBC interface using SpaceWire
- Image processing executed by the actual OBC HW+SW
- Attitude control by the real ADCS (with dynamics simulator)

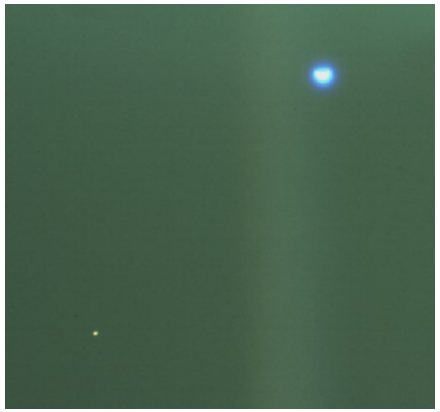




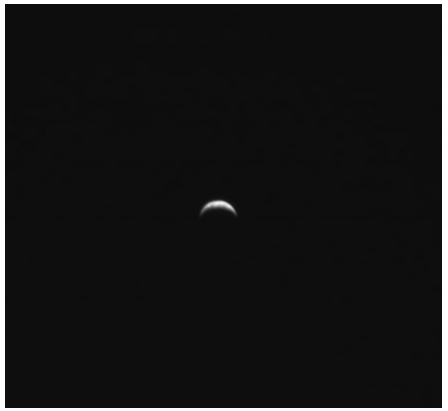
Commissioning & Calibration

- **Payload Calibration**:
  acquisition of known objects to set gain, integration, time, etc.

- **Attitude Calibration** (pointing):
  fine determination of cameras alignment



- Fly-by **dry-run** (with no target):
  measurement of inertias, torques, etc.



- Navigation parameters **optimization/tuning:**
  new run on SIL setup and upload of parameters to satellite

- **Fly-by execution**

Pictures Credits ASI/NASA

LICIACube Images

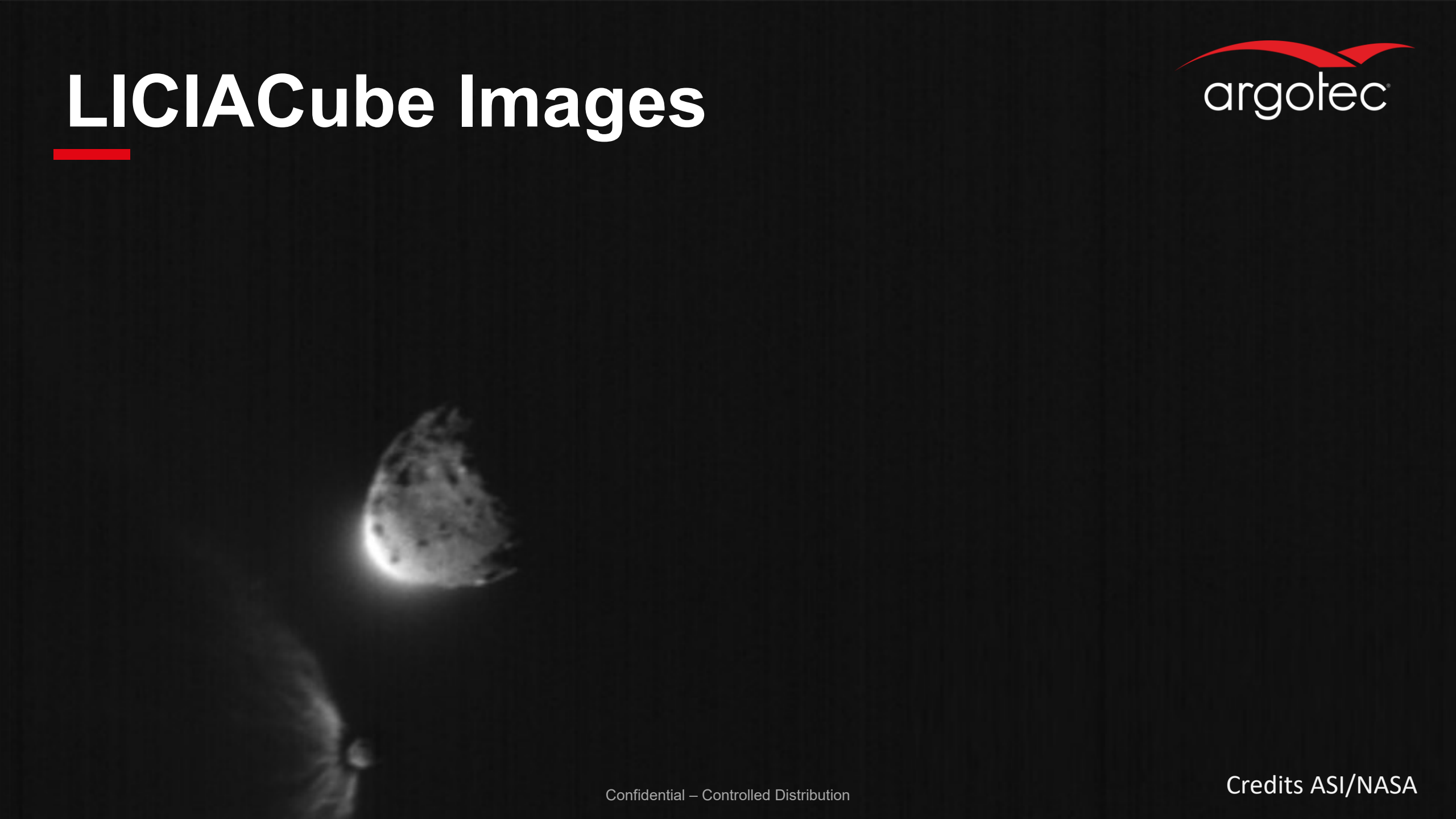
Earth rising captured by LICIACube camera at ***14 milion kilometers***

Credits ASI/NASA

LICIACube Images

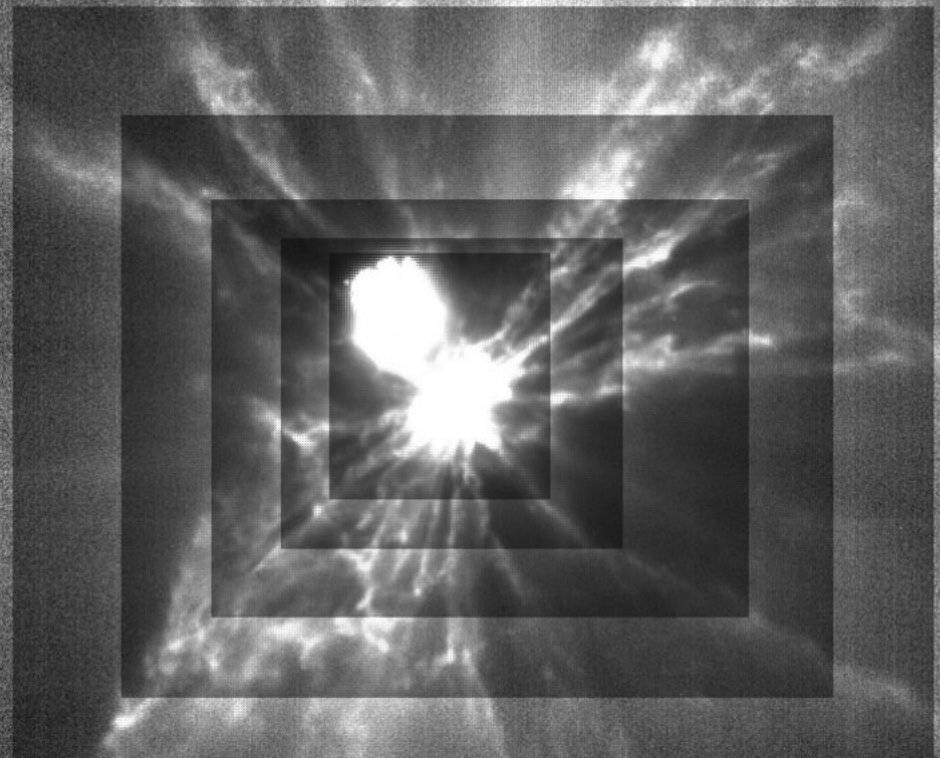
Credits ASI/NASA

LICIACube Images



Credits ASI/NASA

LICIACube Images



Credits ASI/NASA

Results

- Successful commissioning and operation after **10 months deep-space cruise** ☑
- Successful **autonomous navigation** and tracking of Dimorphos ☑
- **627 pictures** shot during fly-by and downloaded to ground ☑
- Meaningful pictures of **impact and ejecta plume** released to scientific community ☑

What's Next

Support to **next generation scientific missions**

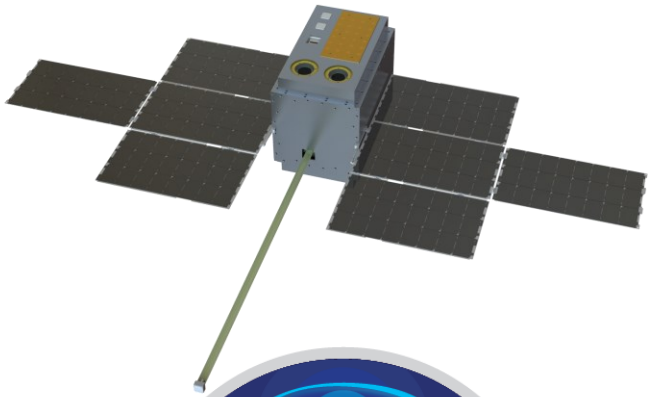
- **HENON**, space-weather monitoring with electric propulsion
- **LUMIO**, Moon far side monitoring

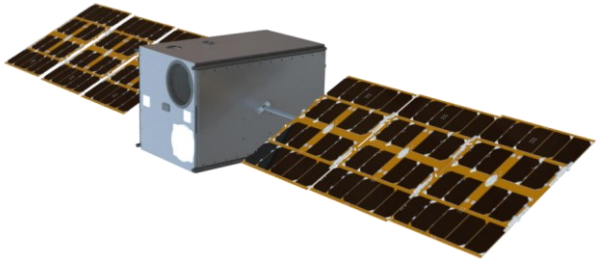
Constellations

- Earth, Moon and Mars

New avionics subsystems

- OBCs, PCDUs, radios and more



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THANK YOU