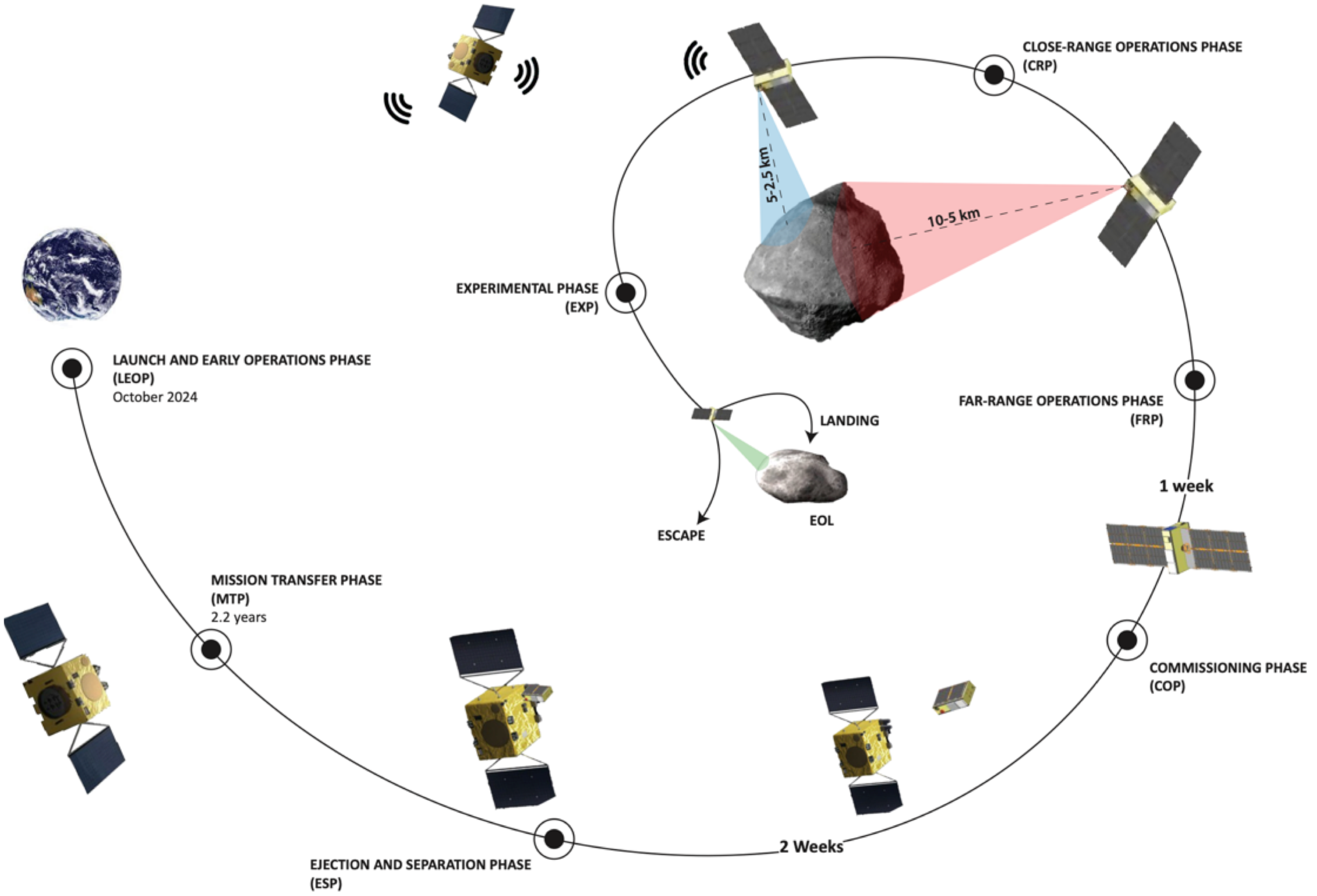
The Hera Milani CubeSat Mission

Planetary Defense Conference

26th April 2021

F. Topputo and the Milani Team

Milani mission concept



Milani mission objectives

STM

- How to provide complementary observations to the Hera planetary defence mission of retrieving information about Didymos asteroids?
- How to support the Hera deep-space Radio science Experiment?
- How to enhance the overall science return of the mission?

TTM

How to enable key mission capabilities of CubeSats for deep space applications?

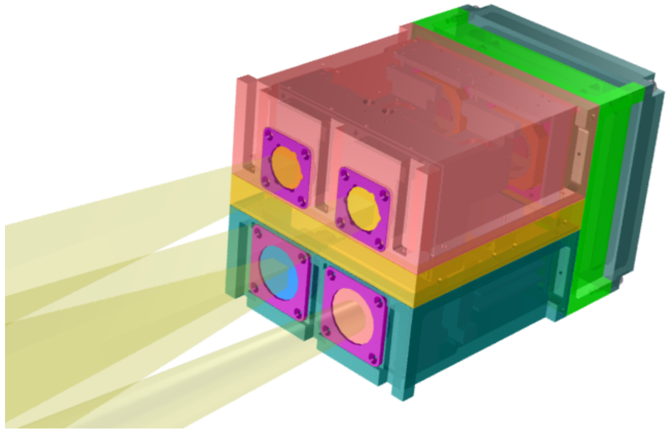
Obj ID	Objective
SO1	To support the determination of the **global properties** of Didymos asteroids
SO2	To determine **taxonomy and mineral composition** of Didymos asteroids
SO3	To detect areas of **oxidized silicates**
SO4	To characterize the sub-millimeter **microstructure** of the Didymos bodies surface
SO5	To map the distribution of the fall-back **ejecta** on Didymos asteroids.
SO6	To compare mature and freshly **exposed material** at global scale
SO7	To characterize the **crater** caused by DART impact
SO8	To detect the **shock-darkening** (if any) of the freshly exposed material within the crater
SO9	To support Hera **Gravity Field** measurements enhanced by ISL network
SO10	To detect inorganic materials, **volatiles** (e.g. water) and light organics
TO1	To provide **ISL communication** with Hera
TO2	To provide **relative positioning**
TO3	To measure the effects of the asteroid environment on **key hardware**
TO4	To validate **autonomous navigation** algorithms

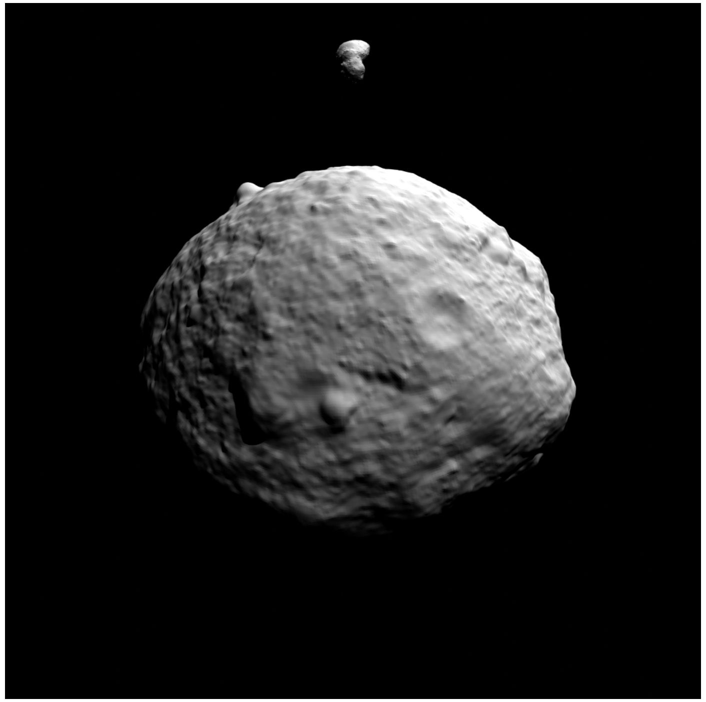
Primary objectives (SO1–SO4, SO9–SO10)

ASPECT

- **Spectral imager (500 – 2500 nm)**
- **4 channels**

Parameter	VIS channel	NIR1 channel	NIR2 channel	SWIR channel
Field of View [deg]	10° x 10°	6.7° x 5.4°	6.7° x 5.4°	5° circular
Spectral range [nm]	500–900	850–1275	1225 –1650	1600–2500
Image size [pixels]	1024 x 1024	640 x 512	640 x 512	1 pixel
Pixel size [µm]	5.5 µm x 5.5 µm	15 µm x 15 µm	15 µm x 15 µm	1 mm
No. spectral bands	Ca. 14	Ca. 14	Ca. 14	Ca. 30
Spectral resolution [nm]	< 20 nm	< 40 nm	< 40 nm	< 40 nm



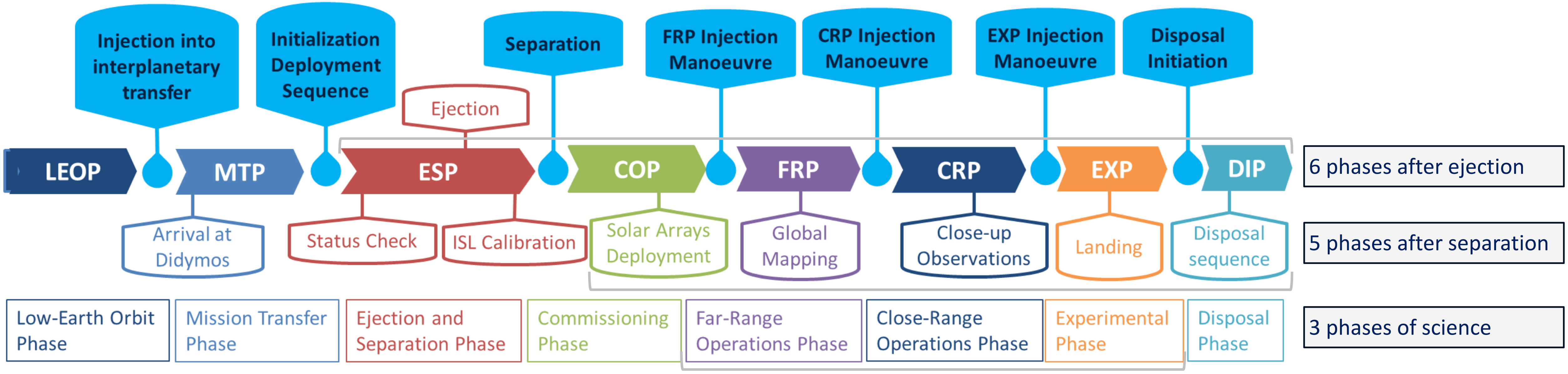


VISTA

- **Micro-thermogravimeter**
- **Detects dust particles (<5-10 µm), volatiles (e.g., water) and light organics**
- **Monitors the molecular contamination (to support other instruments/subsystems)**
- **Composed of quartz crystals, TCS, Proximity Electronics**

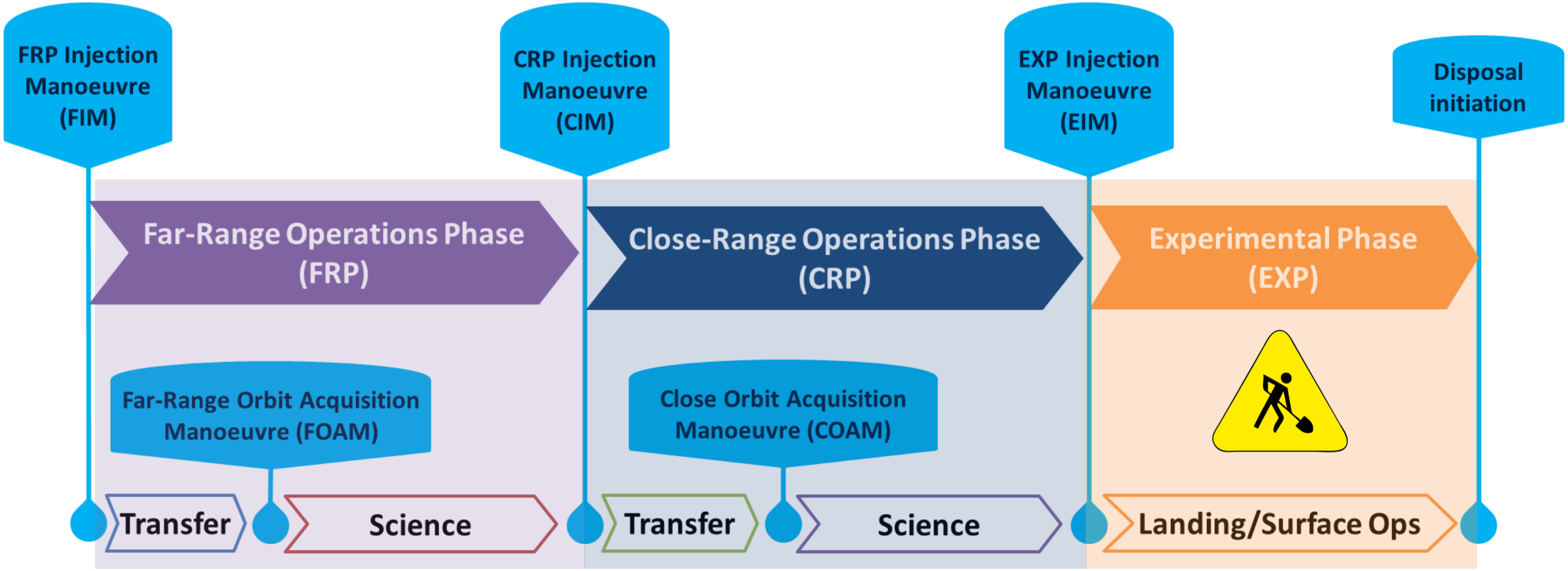
Sensor Type	**Quartz Crystal Microbalance (QCM)-based device**
Resonant Frequency [MHz]	10
Mass [g]	90
Volume [mm]	50×50×38
Sensitive area [cm^2]	1.5
Power [W] (Trange: 233K - 373K)	<1 W (peak, PE+crystals); 0.8 (mean)
Power [W] (Trange: 77K - 373K)	<4 (peak, PE+crystals+heater PE); 3.8 (mean)
Data rate [bit/measurement]	54
Particles size detection range	from 5-10 µm to sub-µm particles
Operational temperature range [K]	from 233 to 350K (PE components)
Crystal working temperature range [K]	from 123 to 473K
Non-operational temperature range [K]	from 77 to 403K
Channels (read-out and controlled)	3 RTDs and 1 frequency; 2 heaters control
Methods/Technique used	1.Dust and contaminants accumulation (passive mode) 2.TGA cycles (active mode)

Milani mission design



Phase	Start		End	
	Event	Date	Event	Date
LEOP	Launch of Hera mission	Oct 2024	Injection into interplanetary transfer	End of 2024
MTP	Injection into interplanetary transfer	End of 2024	Deployment Initialization Sequence	Mar 2027
ESP	Deployment Initialization Sequence	Mar 2027	**Separation**	**15/03/27**
COP	Separation	15/03/27	FIM (FRP Injection Manoeuvre)	23/04/27
FRP	FIM (FRP Injection Manoeuvre)	23/03/27	CIM (CRP Injection Manoeuvre)	17/04/27
CRP	CIM (CRP Injection Manoeuvre)	17/04/27	EIM (EXP Injection Manoeuvre)	09/05/27
EXP	EIM (EXP Injection Manoeuvre)	09/05/27	Disposal Initiation	01/06/27 (TBC)
DIP	Disposal Initiation	01/06/27 (TBC)	EoL	02/06/27 (TBC)

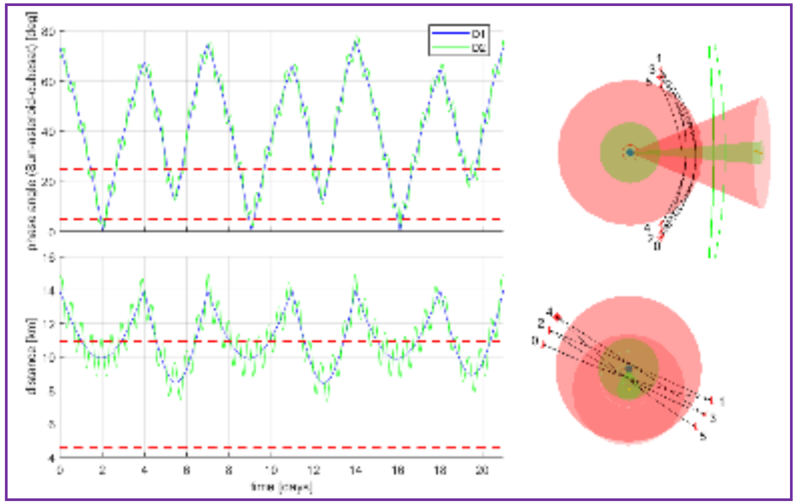
Milani scientific phases

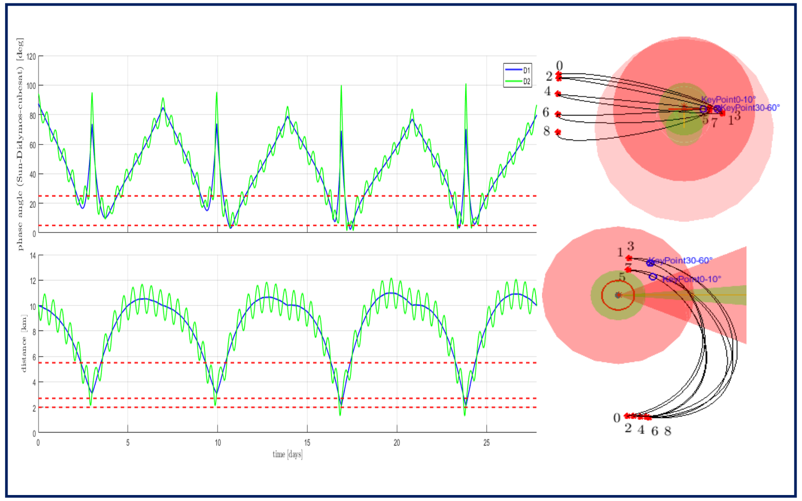


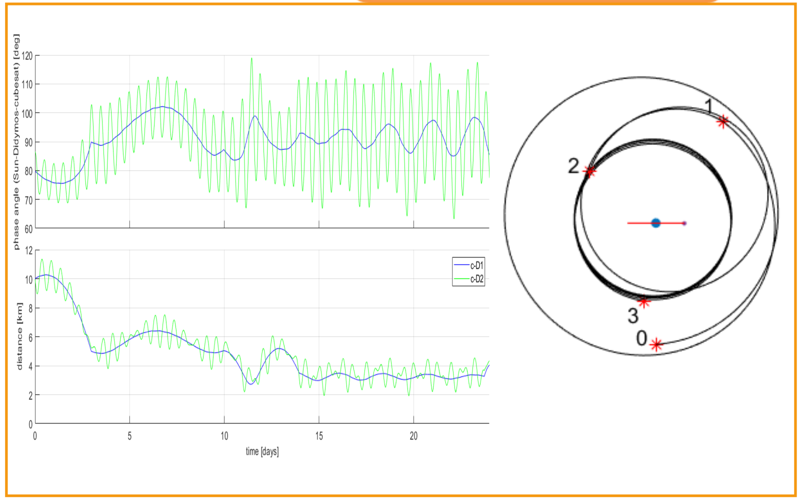
	Mapping of D1 and D2	Mapping of D2, impact crater (hi-res)	
Resolution Req	**≤ 2 m/px** (for both D1 and D2)	• **≤ 1 m/px** (mapping D2) • **≤ 50 cm/px** (selected features of D2)	**Enhanced science, technological demonstrations, landing attempt**
Phase Angle Req	• 5-25 deg (global coverage of D1, D2) • 0-60 deg (surface microstruct. of D1, D2)	• 5-25 deg (global coverage of D2) • 0-10 and 30-60 deg (crater imaging) • 0-60 deg (surface microstruct. of D1, D2)	

Milani mission profile

Far-Range Operations Phase (FRP)		Close-Range Operations Phase (CRP)		Experimental Phase (EXP)	
Transfer	**Global Mapping**	**Transfer**	**Close-up Obs.**	**Transfer**	**Landing**
• 7 days (TBC)	• 3 fly-by loops (7 days each) at 8-14 km	• 7 days (TBC)	• TBD fly-by loops (7 days each) at TBD km	• TBD phasing arcs (3-4 days each)	• Controlled descent (TBD) • Surface operations (TBD)

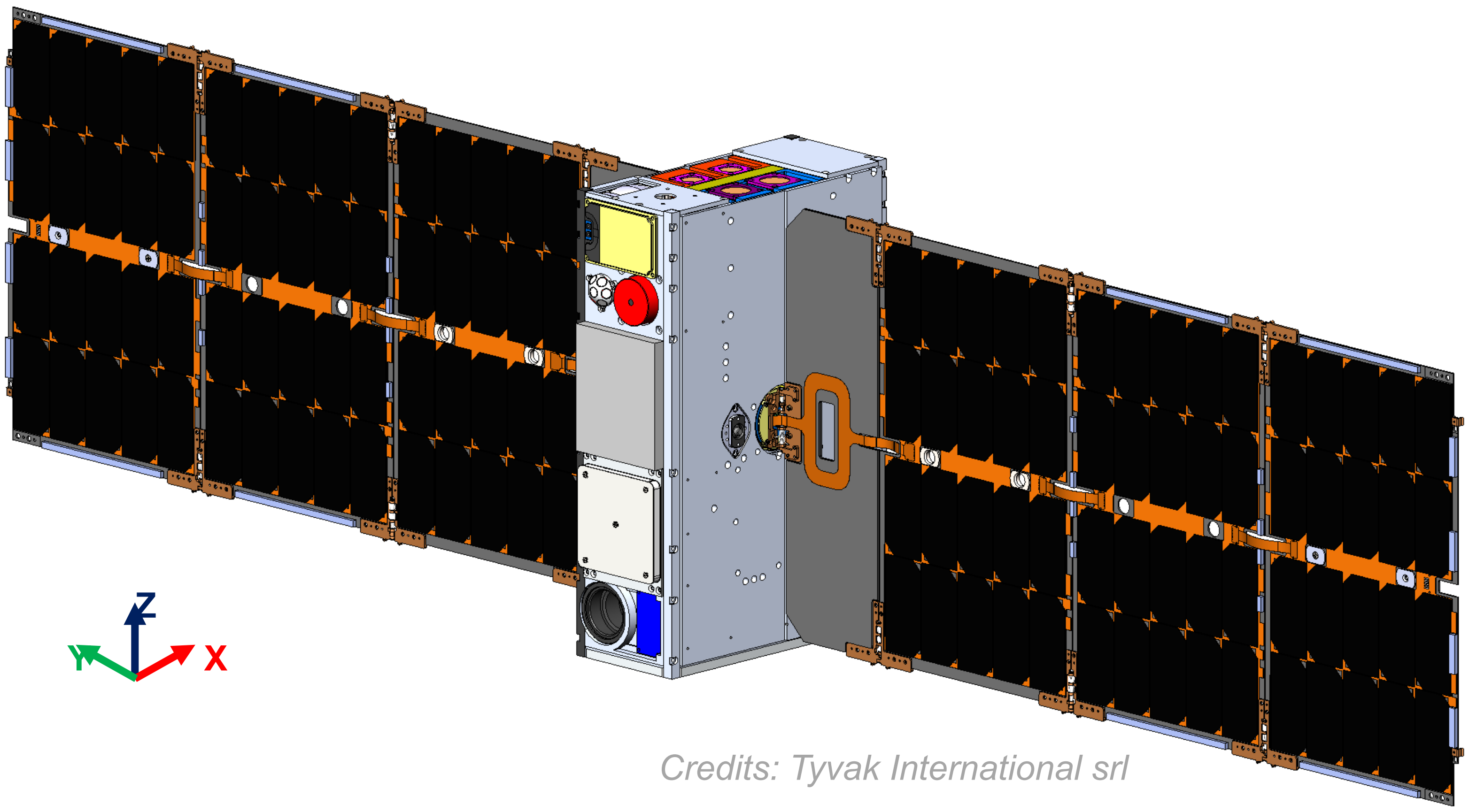






Milani CubeSat configuration

- **System Architecture**
  - Based on Trestles 6U bus
  - Mission Specifics:
    - Payloads: ASPECT + VISTA
    - Navigation Camera
    - LIDAR
    - Propulsion System
    - Inter-Satellite Link (ISL) Radio
    - Umbilical Interface to HERA mothercraft
      - CubeSat IF Board (CIB)
      - External CRS
      - Life Support Interface Board (LSIB)



Credits: Tyvak International srl

Milani consortium

ESA
CUSTOMER

TYVAK INTERNATIONAL
PRIME CONTRACTOR
Space Segment Developer
(Margherita Cardi)

POLIMI
Mission and GNC design
(Francesco Topputo)

ALTEC
Space-to-Ground Interface
(Alessandro Bellomo)

VTT
ASPECT Payload Provider
(Antti Näsilä)

Istituto Nazionale di AstroFisica
VISTA Payload Provider
(Ernesto palomba)

Czeck Institute Geology
DPU software
requirements & testing
(Tomas Kohout)

University of HELSINKI
ASPECT Calibration
(Tomas Kohout)

POLITO
Requirements and
environmental analysis
(Sabrina Corpino)

CIRA
Environmental Test
(Vincenzo Quaranta)

REAKTOR SPACE LAB
ASPECT DPU Provider
(Tuomas Tikka)

HULD
Software Development
(Tomáš Cinert)

Brno University of Technology
ASPECT on board
algorithms
(Tomas Kasparek)