7th IAA Planetary Defense Conference

26-30 April 2021, Online Event

Hosted by UNOOSA in collaboration with ESA

Session 1: Hera

Chairs: Mariella Graziano | Monica Lazzarin | Richard Moissl

Presenters: P. Michel | M. Küppers | F. Topputo | Ö. Karatekin

The ESA Hera mission: planetary defense and science return

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On behalf of the Hera Science Team

esa

hera

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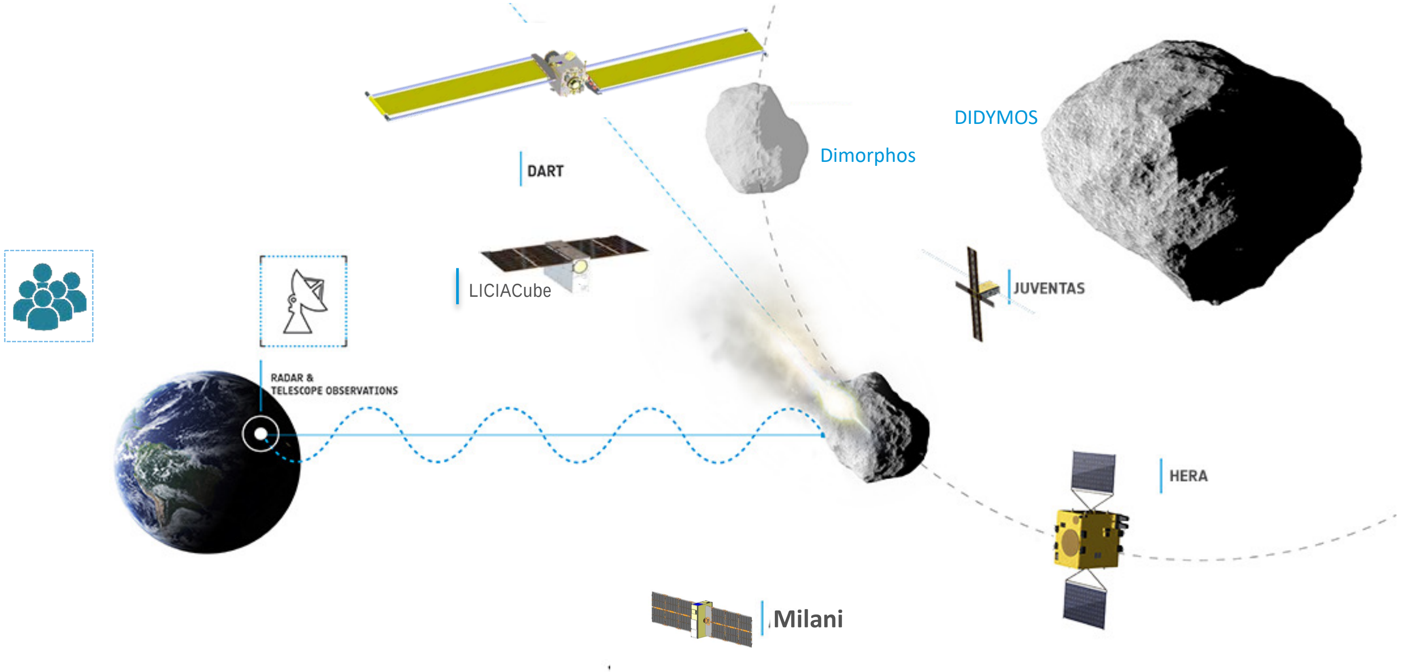
cnrs

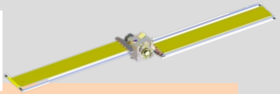
7th IAA Planetary Defense Conference

AIDA international collaboration



AIDA

DART

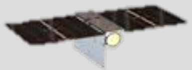


Synergy from

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

with

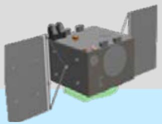
LICIACube



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

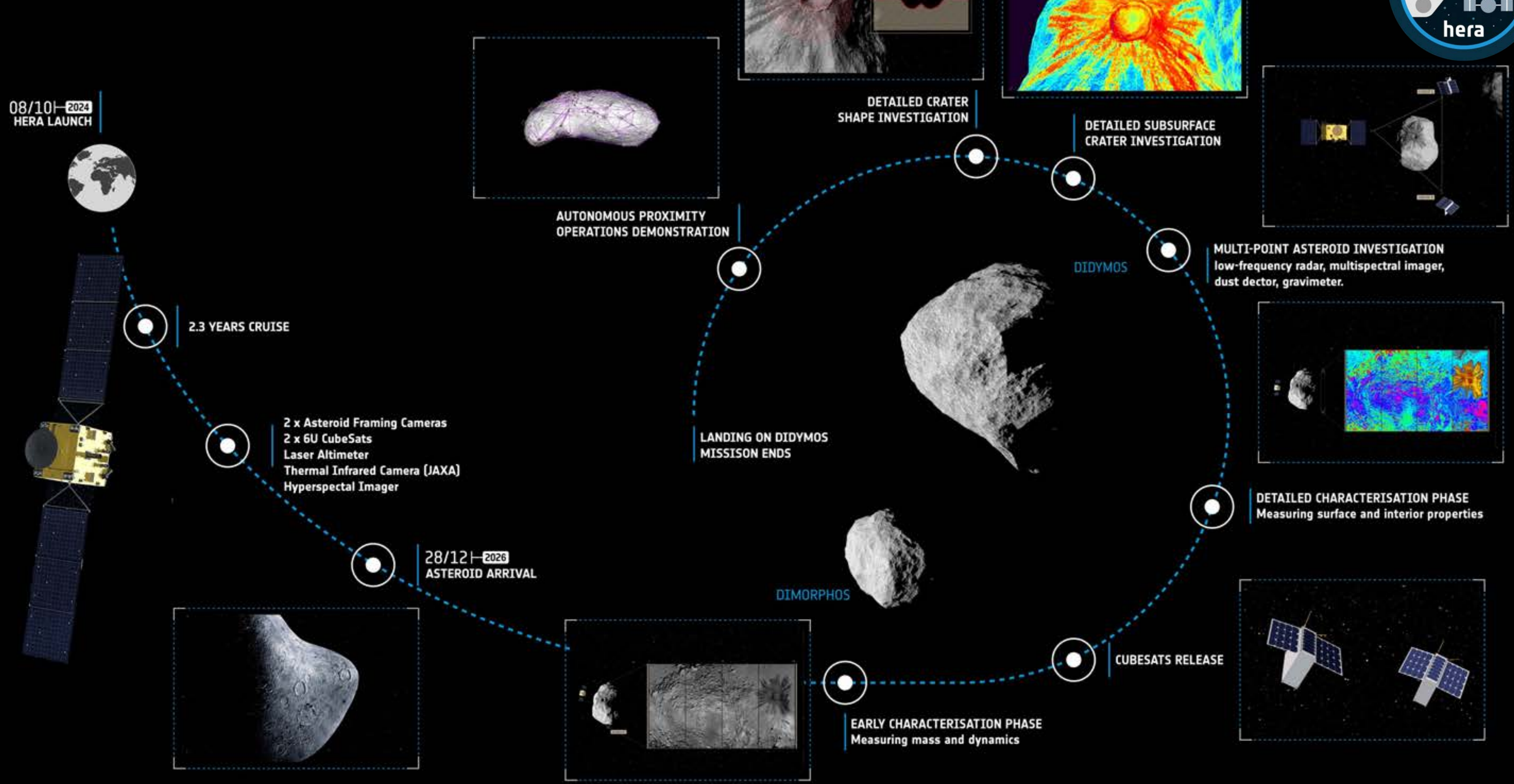
+

hera



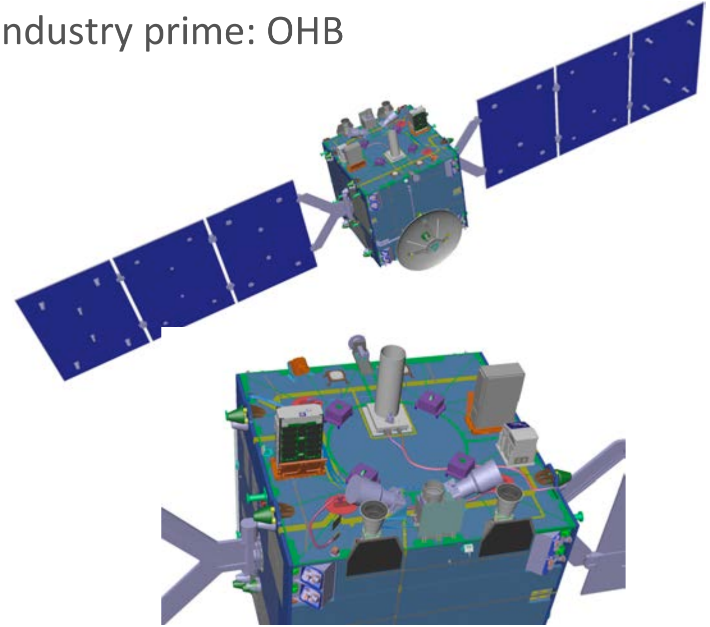
Mass of Dimorphos
Detailed dynamical characterization
Detailed investigation of final crater
Overall characterization of the asteroids

Hera mission scenario



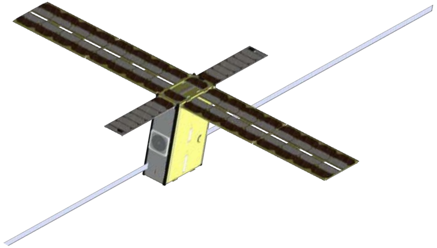
Hera spacecraft, payloads and 2 Cubesats

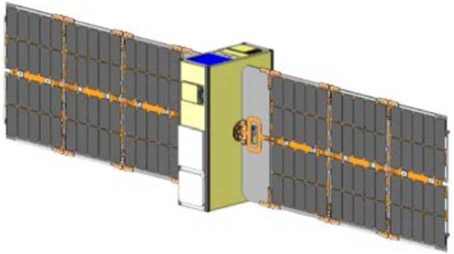
Industry prime: OHB



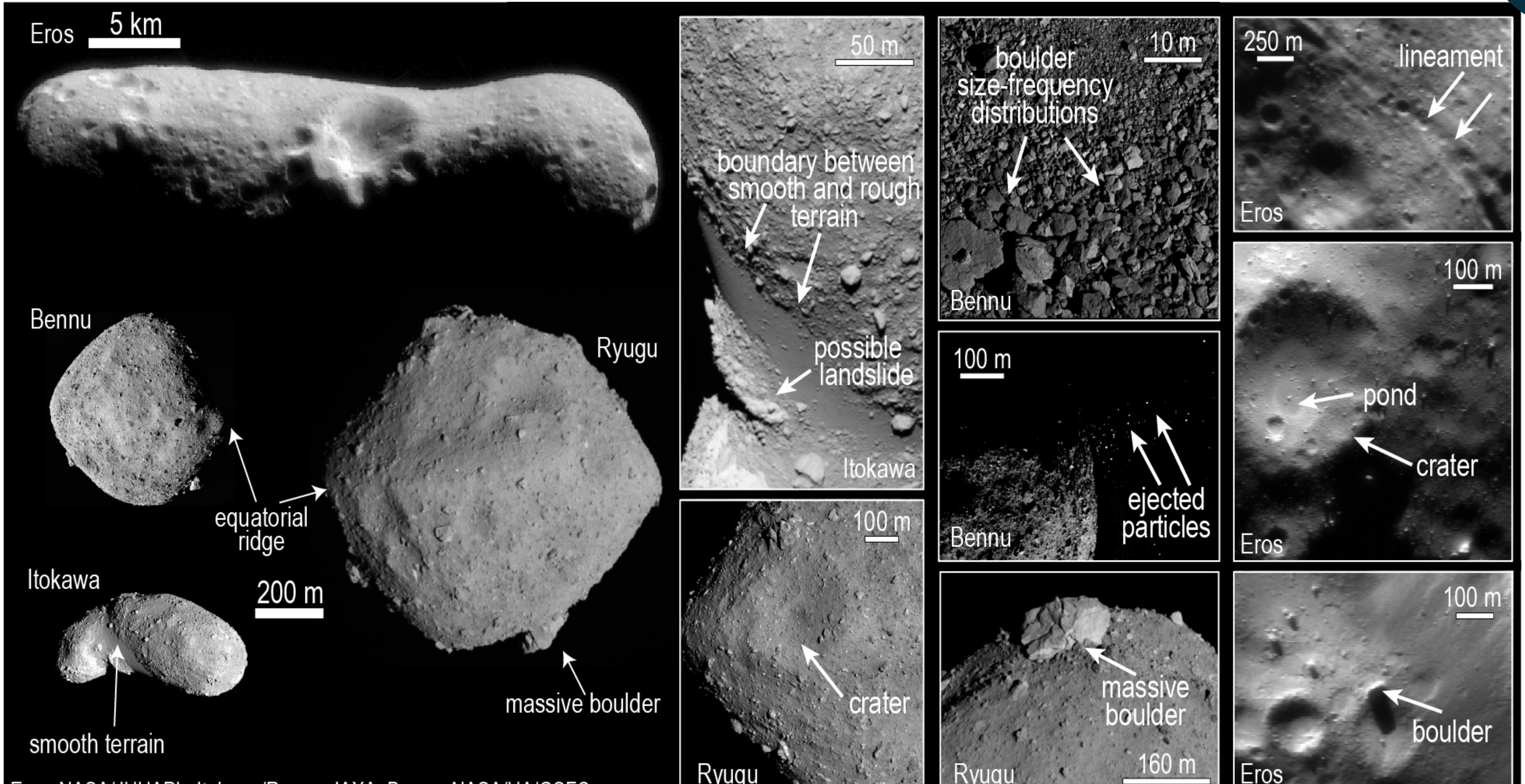
+ **ISL and RadioScience**

- **Asteroid Framing Camera**
- **LIDAR** (PALT)
- **Thermal Infrared Imager** (TIRI)
- **Hyperspectral Imager** (Hyperscout-H)
- **Juventas Cubesat** (internal structure, gravity field, surface properties)
- **Milani Cubesat** (Mineralogy, space weathering, dust detection, gravity field)



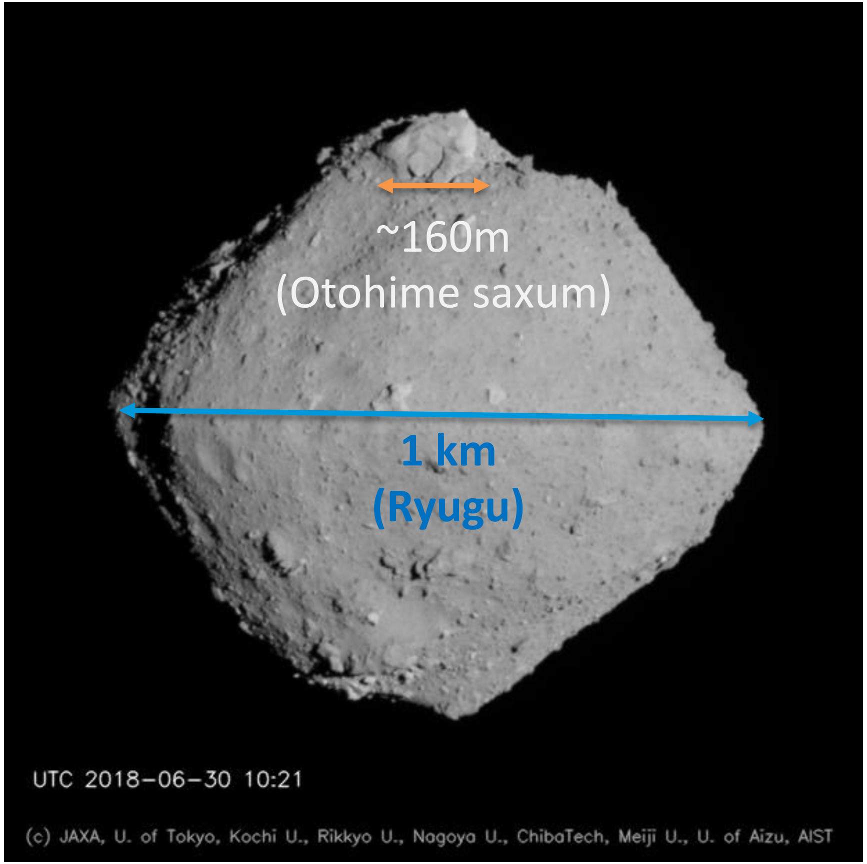


Asteroids:
An incredible and fascinating geological and compositional diversity



Eros: NASA/JHUAPL; Itokawa/Ryugu: JAXA; Bennu: NASA/UA/GSFC

Dimorphos vs Ryugu (Hayabusa2)

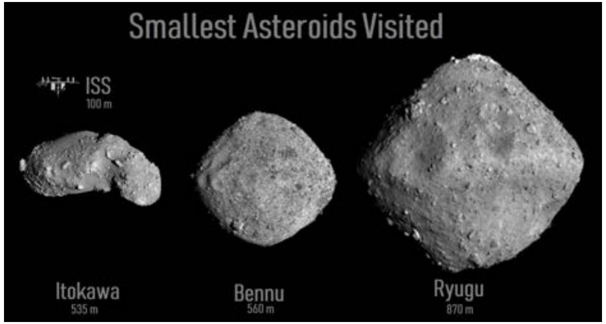


Hera mission firsts

- First rendezvous mission to a binary asteroid
- First characterization of an asteroid in an intriguing size range
- First radar sounding (internal structure) of an asteroid
- First full scale cratering physics experiment (with DART)

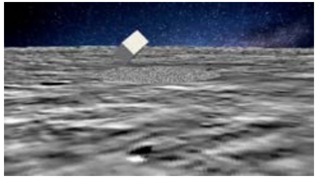
Hera in the context of Hayabusa2 and OSIRIS-REx

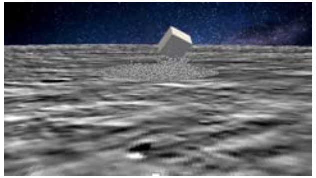
- **First detailed characterization and surface response of 2 primitive asteroids in different gravity conditions**
  - Ryugu is 900 meter wide
  - Bennu is 500 meter wide



Credits: NASA/Goddard/University of Arizona

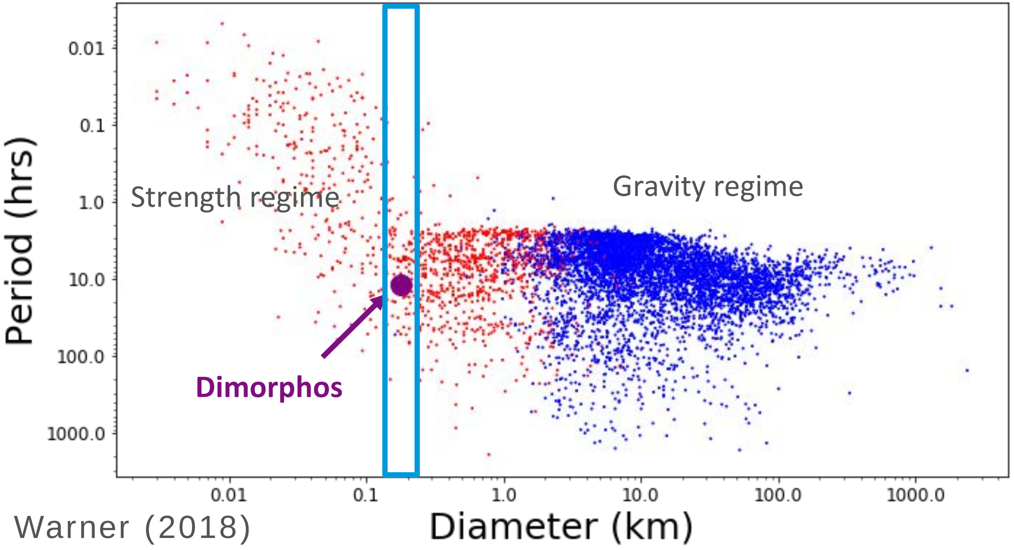
- **Dimorphos is ~ 3 times less wide than Bennu**
  - Another step in low gravity levels
  - **Possibility to understand how some processes scale with gravity down to the low-g of Dimorphos**



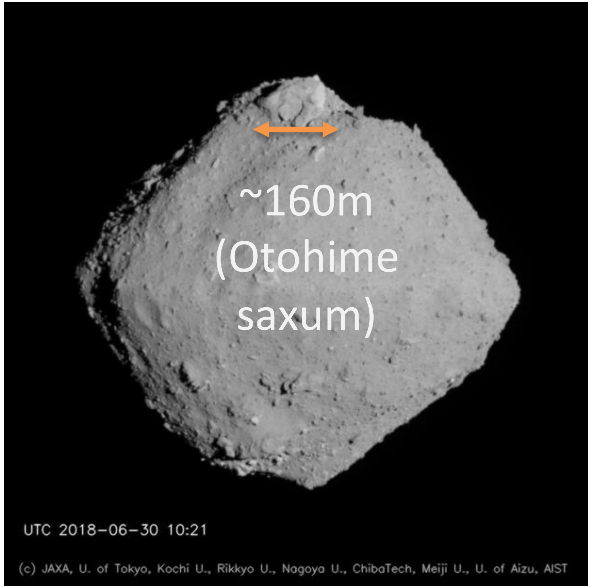


Dimorphos: in a very interesting size range

First detailed characterisation (including interior) of an asteroid at the transition between strength (cohesion) and gravity-dominated bodies

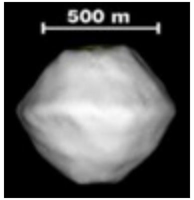


Warner (2018)

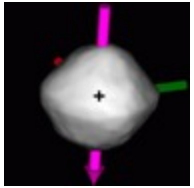


New knowledge in our understanding of asteroid geophysics and impact response (with DART)

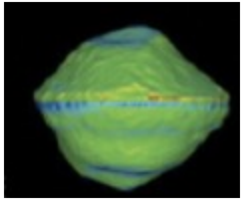
Didymos and the prevalence of « spinning tops »



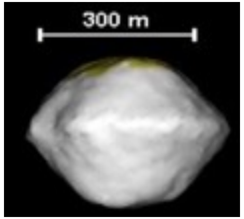
Triple Asteroid
1994 CC
Brosovic et al.
2011



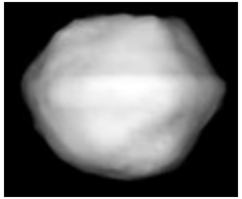
Single Asteroid
Bennu
Howell et al.
2008, ACM



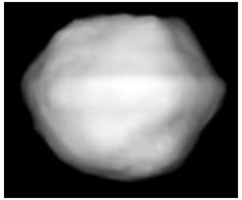
Binary Asteroid
1999 KW4
Ostro et al. 2005



Single Asteroid
2008 EV5
Busch et al.
2011

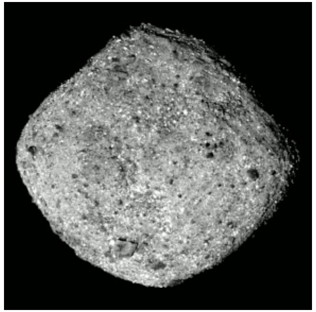


Triple Asteroid
1996 SN263
Becker et al.
2008



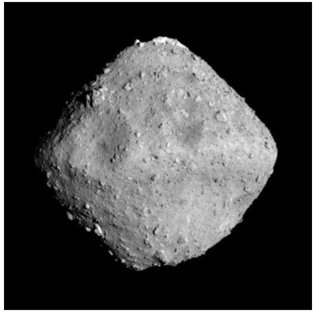
Binary Asteroid
2004 DC
Taylor et al.
2008, ACM

Bennu



Credit: NASA

Ryugu



Credit: JAXA, University of Tokyo, et al.

- Ryugu and Bennu are top shapes possibly formed early by disruption/reaccumulation !!! (Michel, P. & Ballouz R.-L. et al. 2020)
- **But both Ryugu and Bennu are single!**
- **What does a top shape binary primary look like?**

First detailed investigation of a binary asteroid

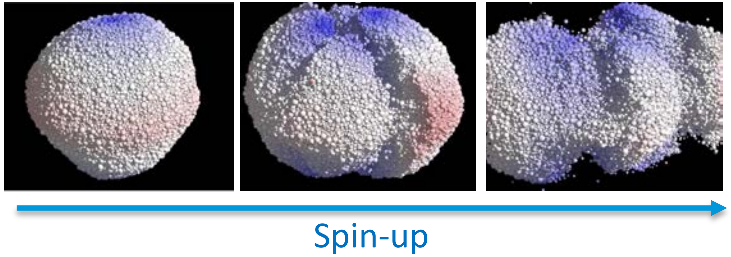
15 % of NEAs are binaries

- YORP mass shedding?
- Are Didymos and Dimorphos rubble piles?

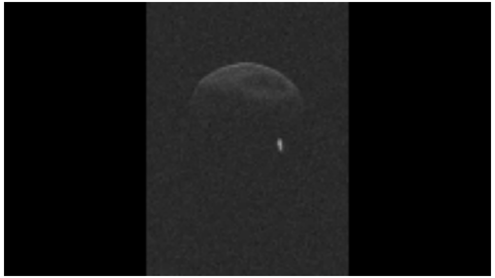
Key knowledge to understand Solar System accretion processes

- First asteroid visited near disruption limit
- Insights on formation or disruption of planets

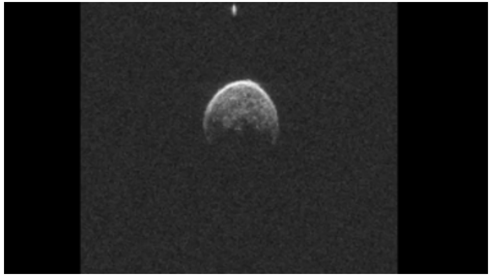
Didymos spin-up evolution



Zhang et al. 2021, Icarus 362

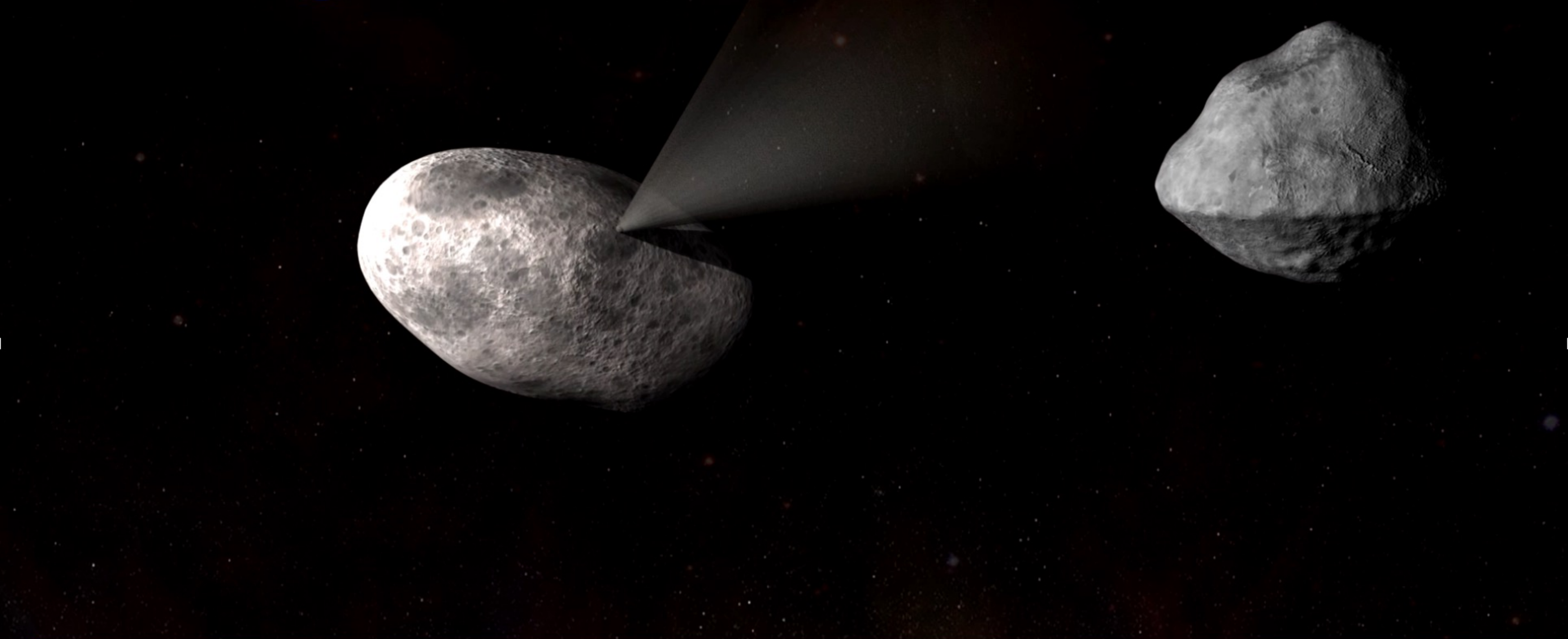


1998 QE2



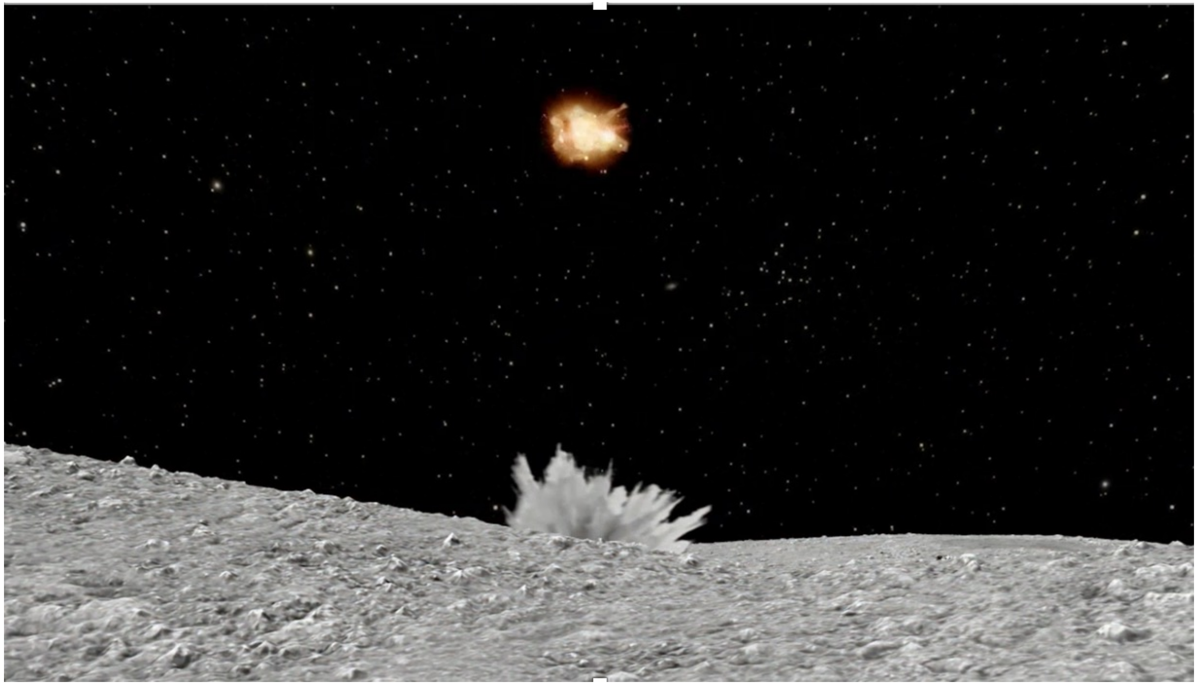
2004 BL86

2014 JO25



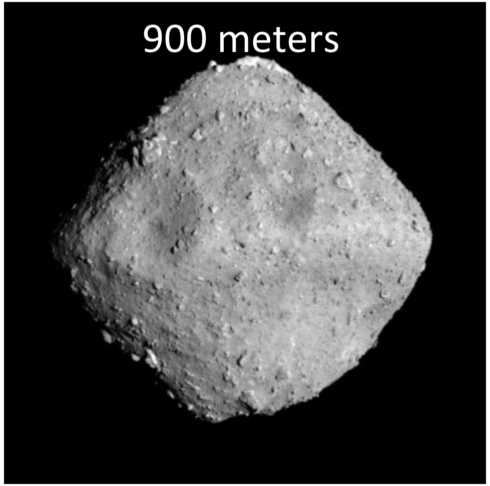
Hera will measure the outcome of a cratering impact at actual asteroid scale

Cratering physics: Hayabusa2 versus Hera



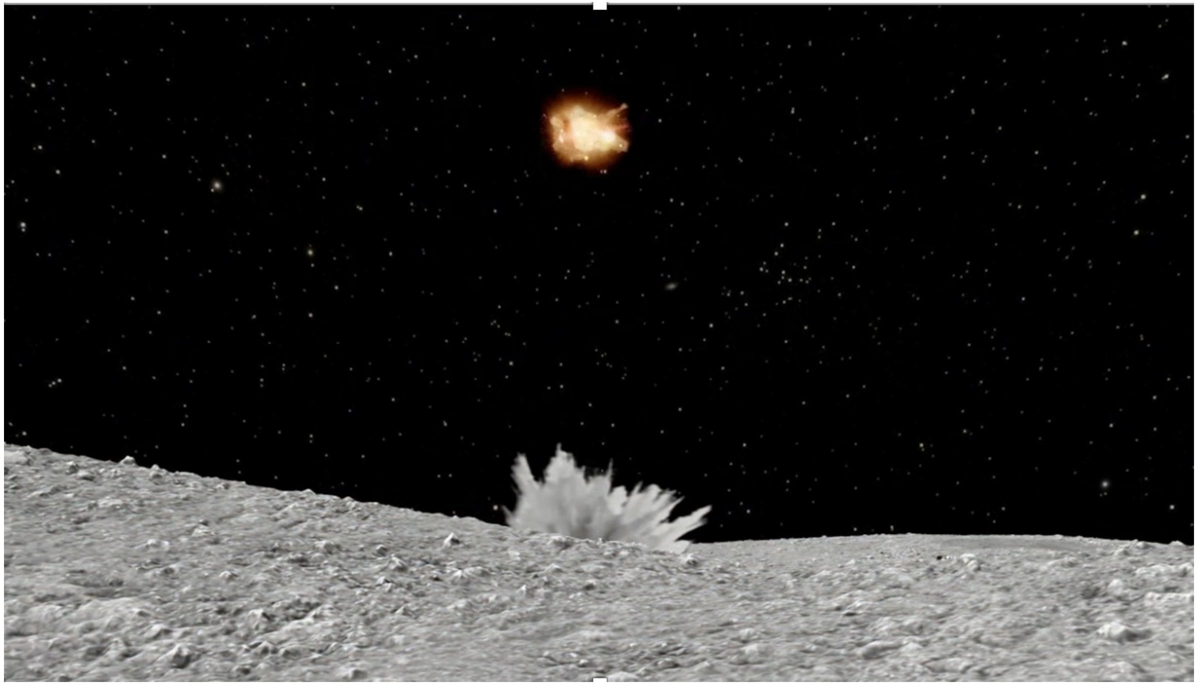
Hayabusa2 Small Carry-on Impactor
April 5, 2019

Arakawa et al. 2020, Science



Credit: JAXA, Univ. Tokyo et al.

Cratering physics: Hayabusa2 versus Hera



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Cratering physics: Hayabusa2 versus Hera

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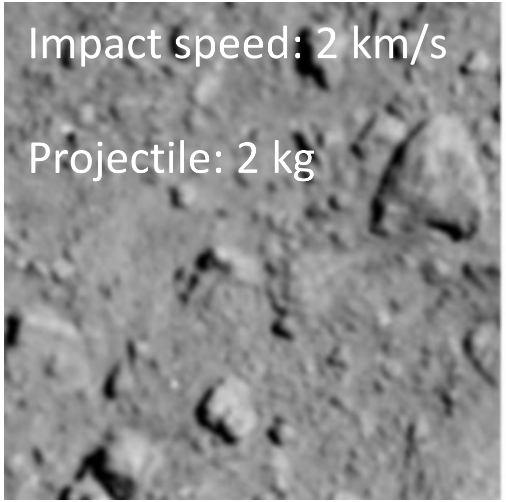
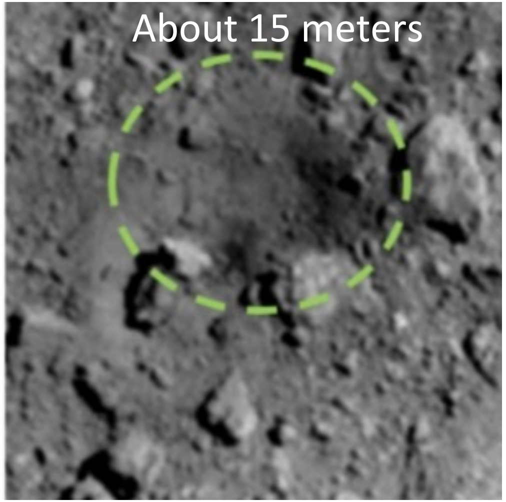
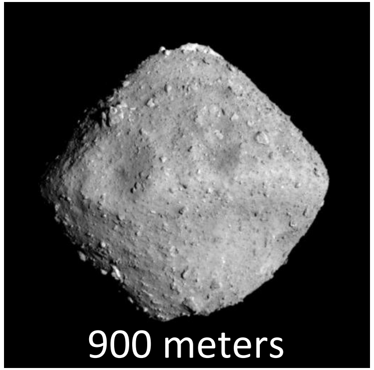






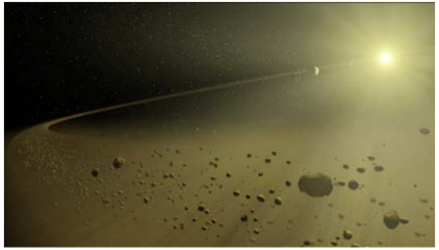
Credit: JAXA, Univ. Tokyo et al.

The large size of the crater can only be explain if the surface has no cohesion, which is a surprize! Strong implications on surface age

What about a 165 m-size body? And how does cratering scale with impact speed (from 2 to 6 km/s)?

Understanding collisions in space

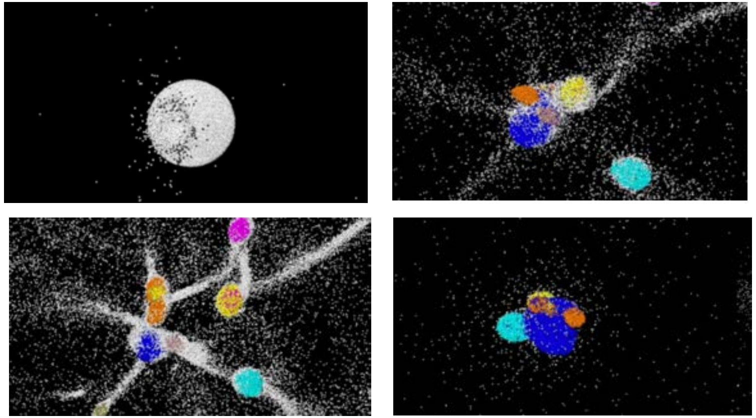
Planetesimal formation



Collisional accretion

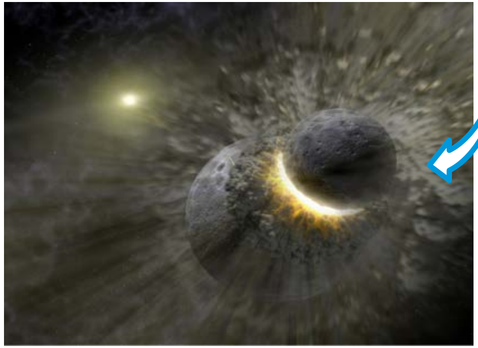
EARLY PHASES

Planet formation



Michel & Richardson 2013

Giant impacts



Asteroid families

Collisional disruption

LATE PHASES

Juventas 6U Cubesat

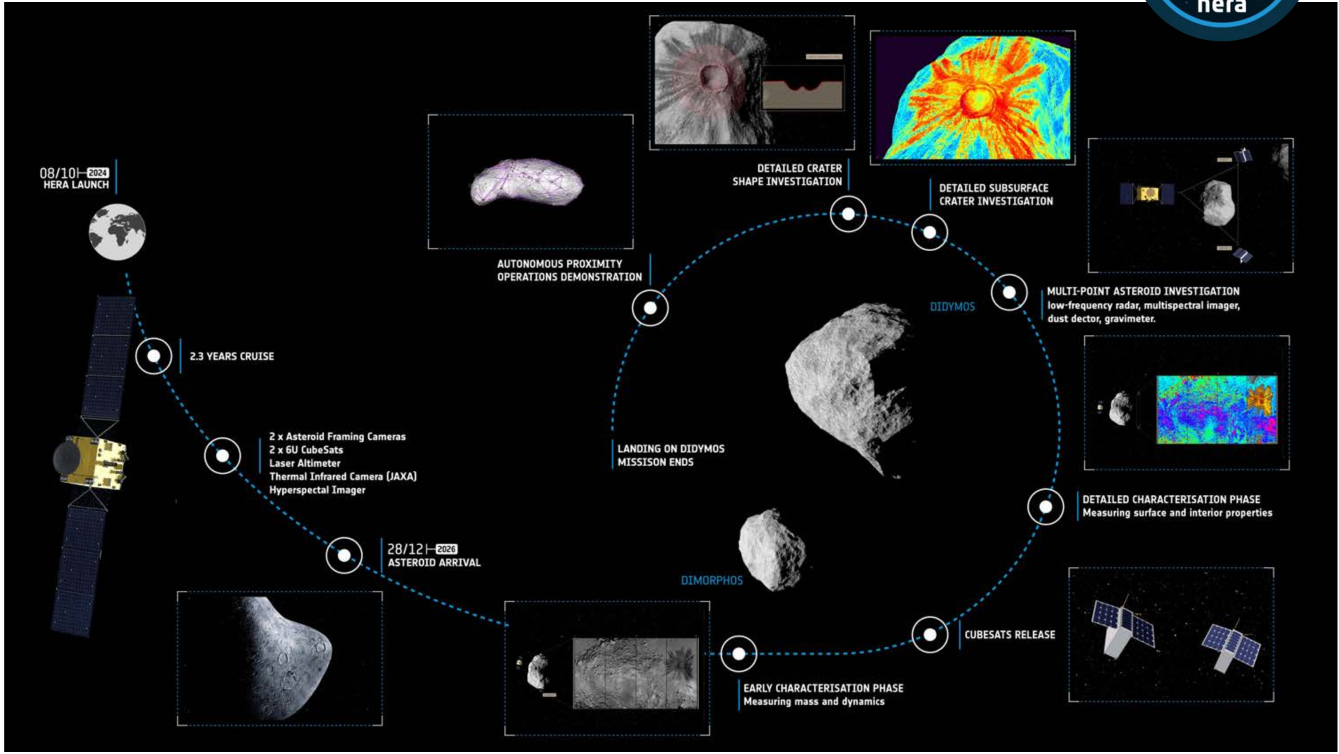
Landing on Dimorphos

- **Bouncing properties**
- **Mechanical properties**

Direct interaction with the surface is the only way to determine its often counter-intuitive response!

Hera: a mission of "firsts"

- First rendezvous with a binary asteroid and smallest asteroid ever visited
- First detailed measurements of asteroid cratering physics in the impact speed regime of asteroid collisions
- First deep-space Cubesats for very close asteroid inspection and first internal structure probing
- First Cubesat landing on a 160 m-size asteroid



Hera: planetary defense and science

Asteroids are fascinating:

- Sources of high interest of different communities (science, planetary defense, mining)
- Whichever is the primary objective to explore them (here, planetary defense), all those communities will benefit from the gained knowledge

Hera is fascinating:

- First binary asteroid rendezvous and full characterisation, including subsurface/interior properties, and documentation of an impact outcome with NASA DART
- European contribution to planetary defense, concretizing ESA's pioneering initiative in the early 2000s starting with the Don Quijotte concept
- Great team and community actively working for it, promising amazing discoveries!

European Commission
HORIZON 2020
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 870377.

Hera Science Team

Impacts simulation

Chairs:
Kai Wünnemann
Martin Jutzi

Mission PI:
Patrick Michel

Dynamics

Chairs: Menios Tsiganis
Adriano Campo Bagatin
Sébastien Charnoz

ESA Mission Manager:
Ian Carnelli esa

ESA project scientist:
Michael Küppers esa

Data Analysis Exploitation Interpretation

Chairs: Alain Hérique
Jean-Baptiste Vincent
Paolo Tortora
Ozgur Karatekin
Naomi Murdoch

Management Board:
S. Green
A. Fitzsimmons
M. Lazzarin
S. Ulamec

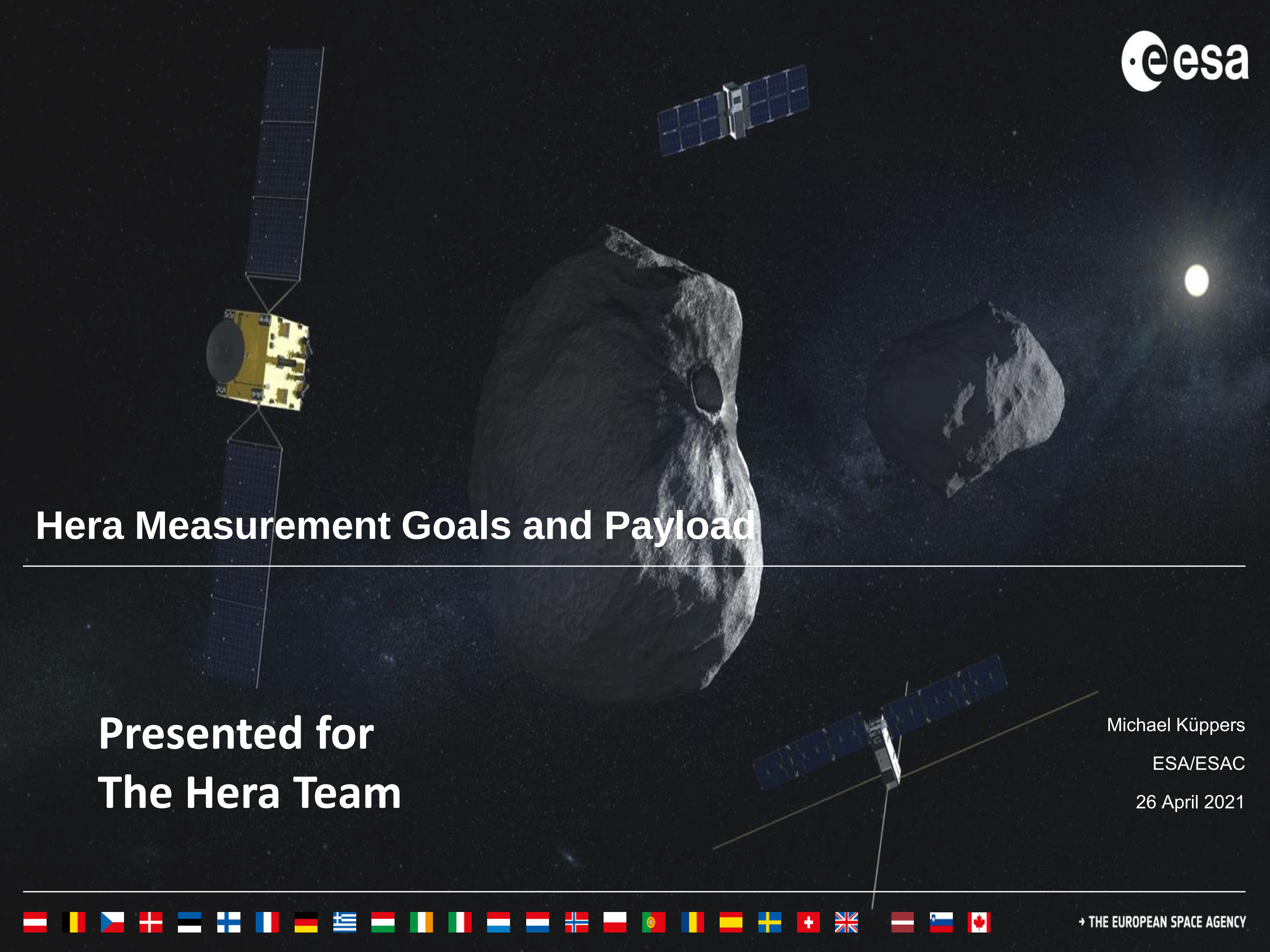
Ground-based observations

Chairs: Petr Pravec
Julia de Leon
Benoît Carry
Colin Snodgrass

+ Operation Group
+ Instrument PIs
+ International (US/Japan) members

Common AIDA (DART +Hera) Working groups


THANK YOU
0
360
esa
hera



Hera Measurement Goals and Payload

Presented for
The Hera Team

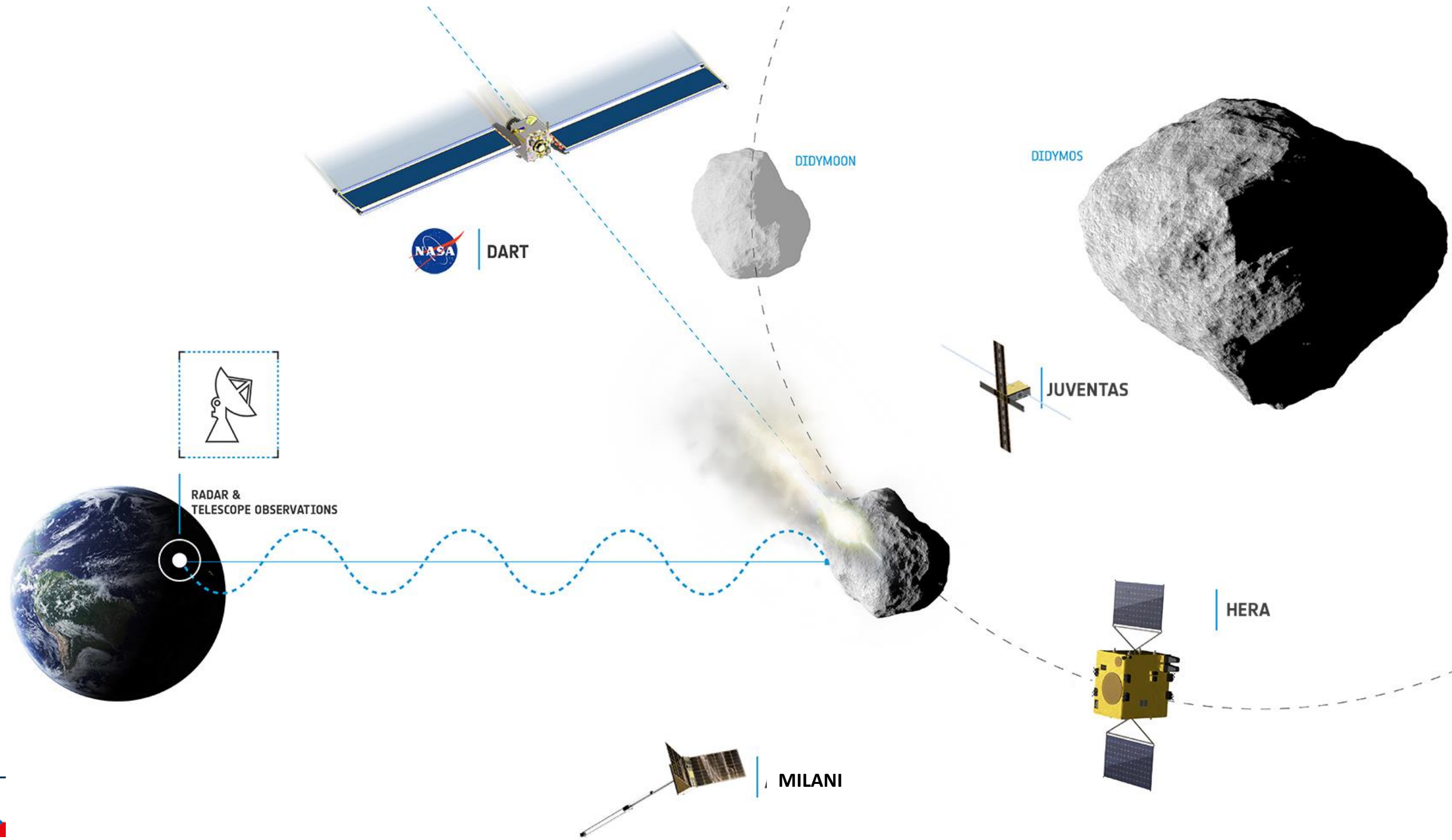
Michael Küppers

ESA/ESAC

26 April 2021

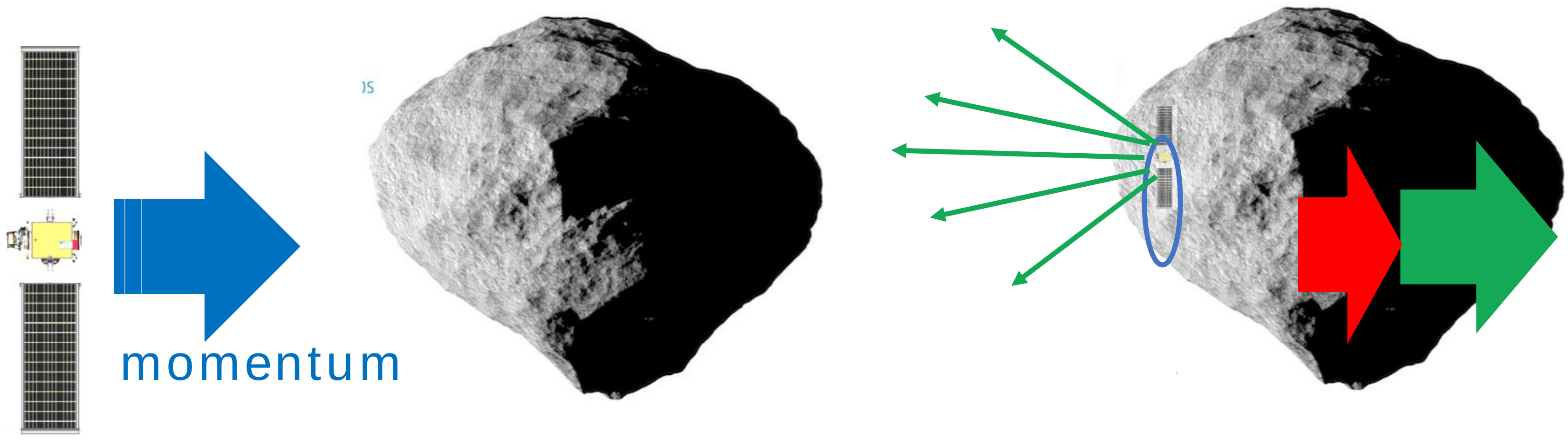
Goals of asteroid deflection

1. Demonstrate the deflection of the target -> DART, Groundbased
2. Measure the efficiency of the momentum transfer from projectile (DART) to target (Dimorphos) -> Hera, Groundbased
3. Characterize the target -> Hera



Momentum transfer (illustrative)

Dimorphos mass x ΔV = momentum + momentum (ejecta)
= momentum x $\boldsymbol{\beta}$

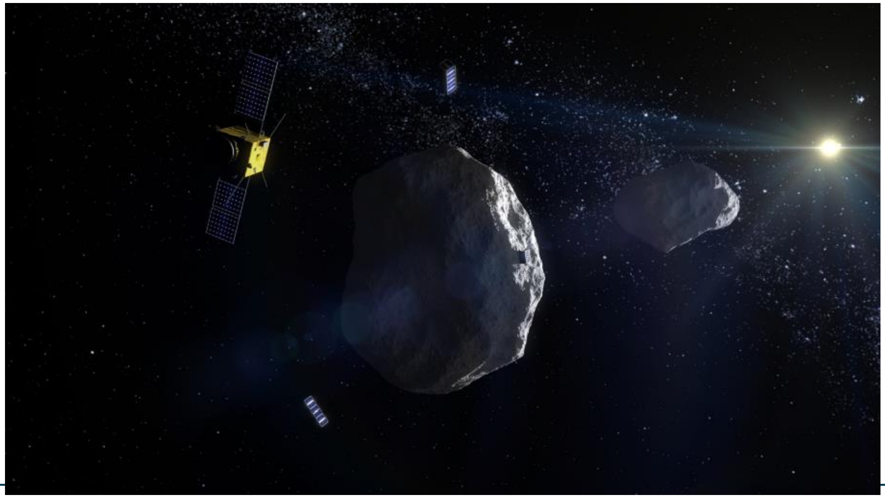


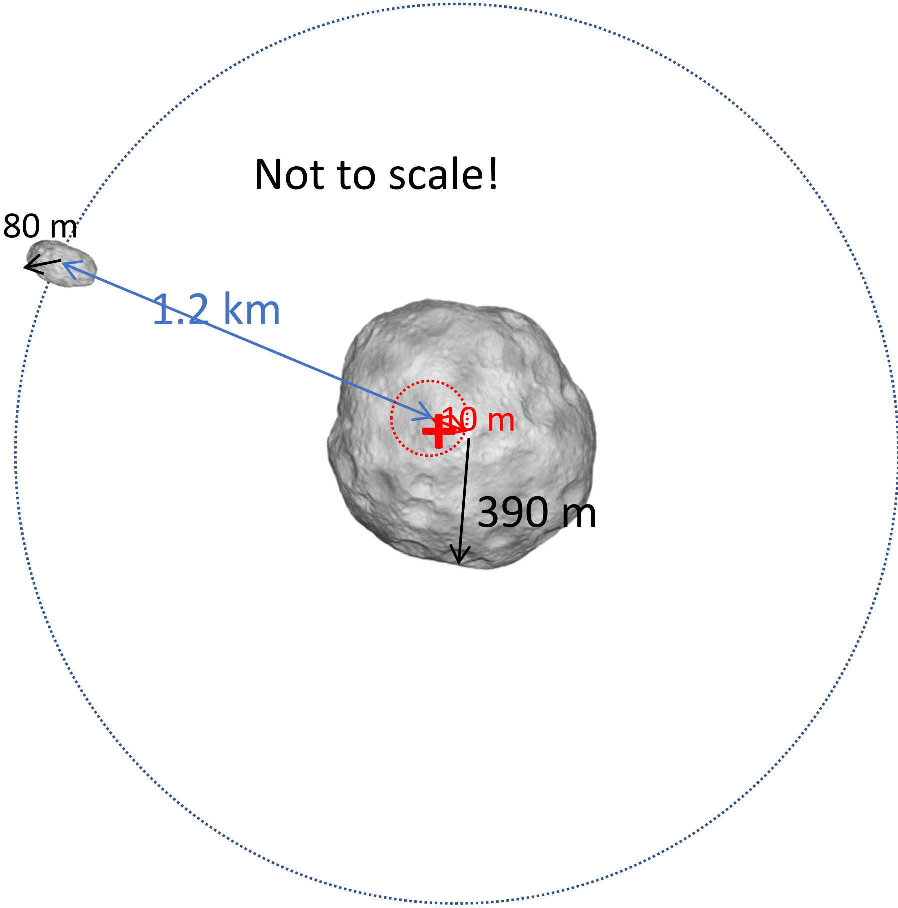
Efficiency $\boldsymbol{\beta} = \dfrac{\text{Dimorphos mass x } \Delta V}{\text{momentum}}$

2 unknowns in the momentum equation: Dimorphos mass and $\boldsymbol{\beta}$

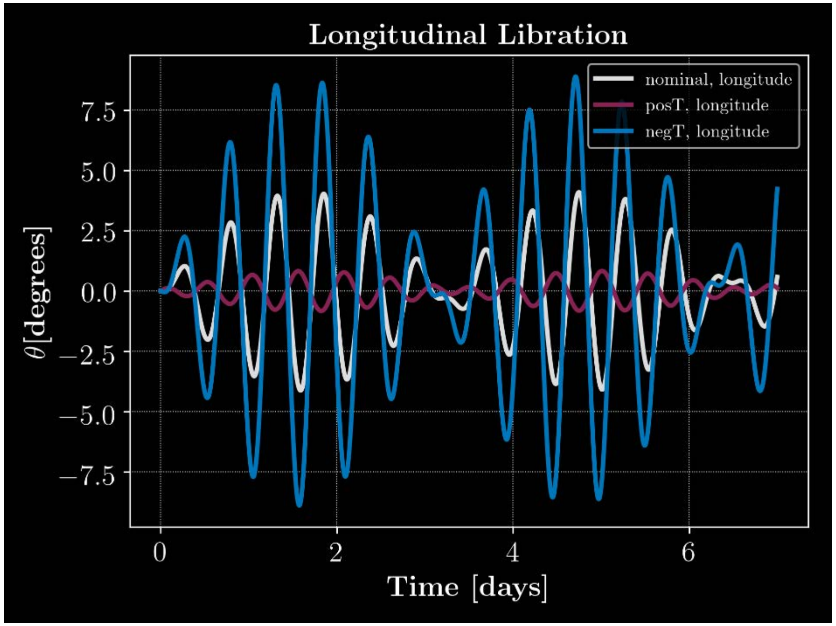
Hera Measurement Goal 1: Mass of Dimorphos

- Measurement of the "Wobble" motion of Didymos due to the gravity of Dimorphos
- Supporting observations by Radio Science (spacecraft deflection due to Dimorphos gravity)

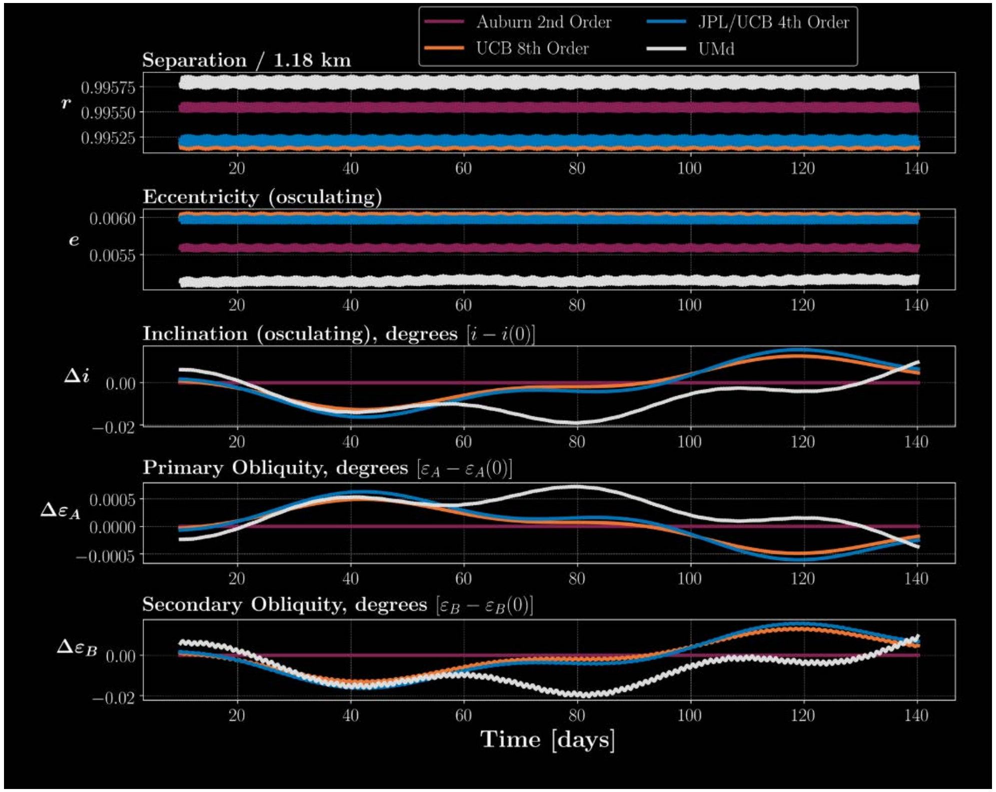




Measurement Goal 2: Dynamics of the Didymos system

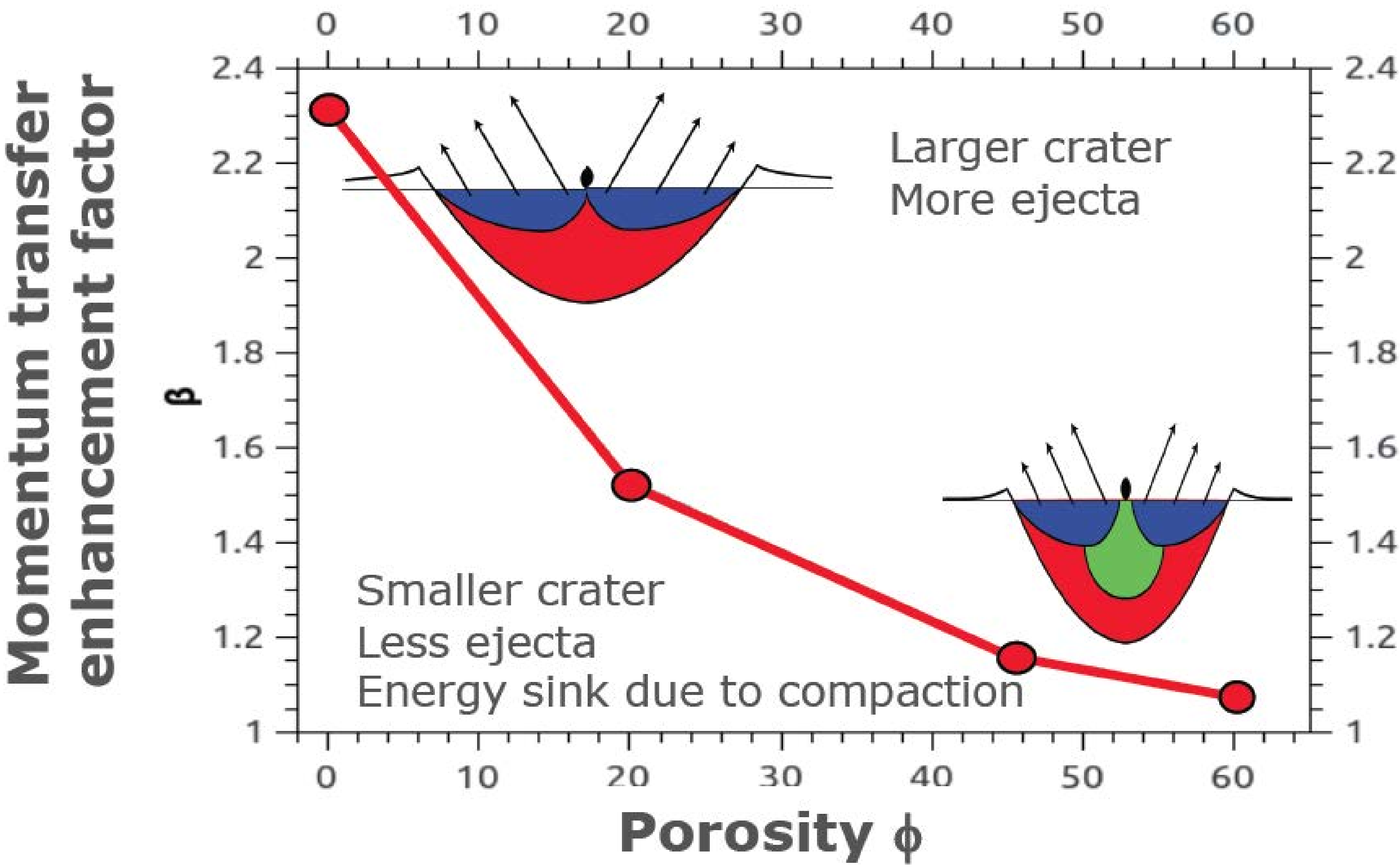


Source: Agrusa et al., Icarus 349, Art. 113849, 2020

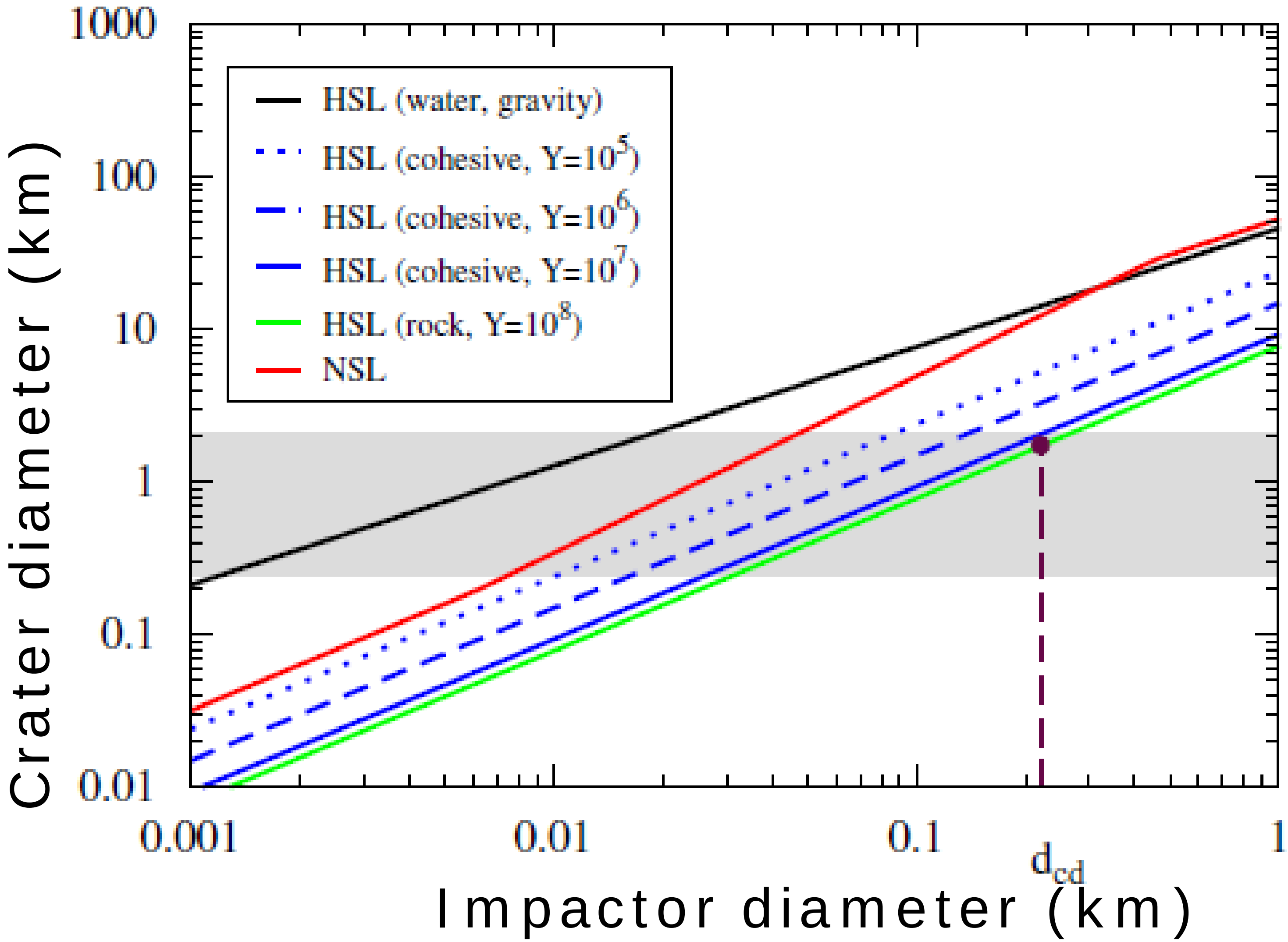


Additional contribution to β: Momentum transfer into rotational motion =>
Need for determination of orbital and spin parameters, including possible libration of Dimorphos induced by DART impact

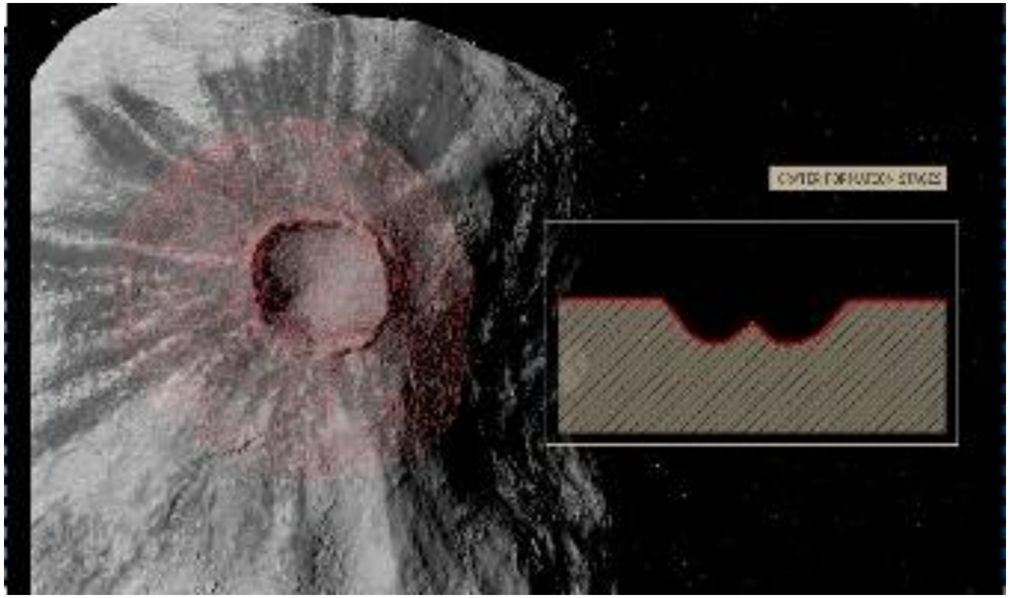
Hera Measurement Goal 3: Properties of Dimorphos (for scaling of the impact outcome to other objects)



Hera Measurement Goal 3: Properties (Example material strength)



Hera Measurement Goal 4: Shape and Volume of the Impact Crater, spectral comparison to bulk asteroid

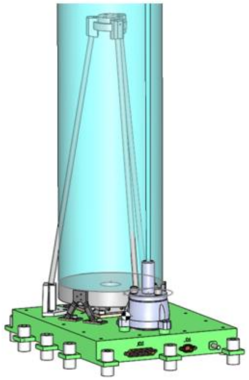


Unique opportunity to verify impact models and experiments as impactor and crater are both known!

Hera Payload

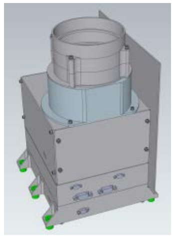
Asteroid Framing Cameras (AFC)

- Broadband, pan-chromatic visual imager
- 5.5 deg. FoV
- 1m / pixel from 10 km



Planetary Altimeter (PALT)

- Laser Range Finder
- Wavelength 1.5 µm
- footprint 1 mrad (1m from 1 km)
- operating frequency up to 10 Hz)



Thermal InfraRed Imager (TIRI)

- Contributed by JAXA,
- Wavelength range 7 -14 µm, 6 filters
- Field of view 13.3 X 10.6 deg.
- 2.3 m / pixel from 10 km

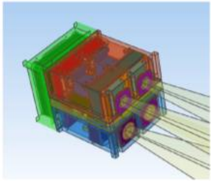
Hyperspectral Imager (Hyperscout-H)

- Visible spectral imager
- 15.5 X 8.3 deg. field of view (TBC)
- 1.3 m / pixel from 10 km
- Spectral range and resolution TBD

Hera Payload (2)

Milani Cubesat with

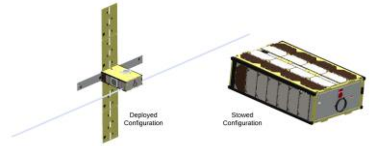
1. ASPECT: Visual and near-IR Fabry-Perot imaging spectrometer



- Spectral range 0.5 – 2.5 µm
- Spectral resolution <40 nm (visible < 20nm)
- 2 m/pixel from 10 km

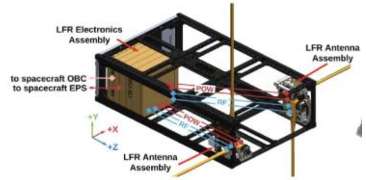
2. VISTA: Thermogravimeter

- Dust detector
- Composition analysis (water, organics)



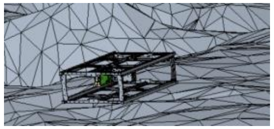
Juventas Cubesat with

1. Low-Frequency Radar (LFR)



- Frequency 50-70 MHz
- Resolution 10-15 m

2. Gravimeter (GRASS)

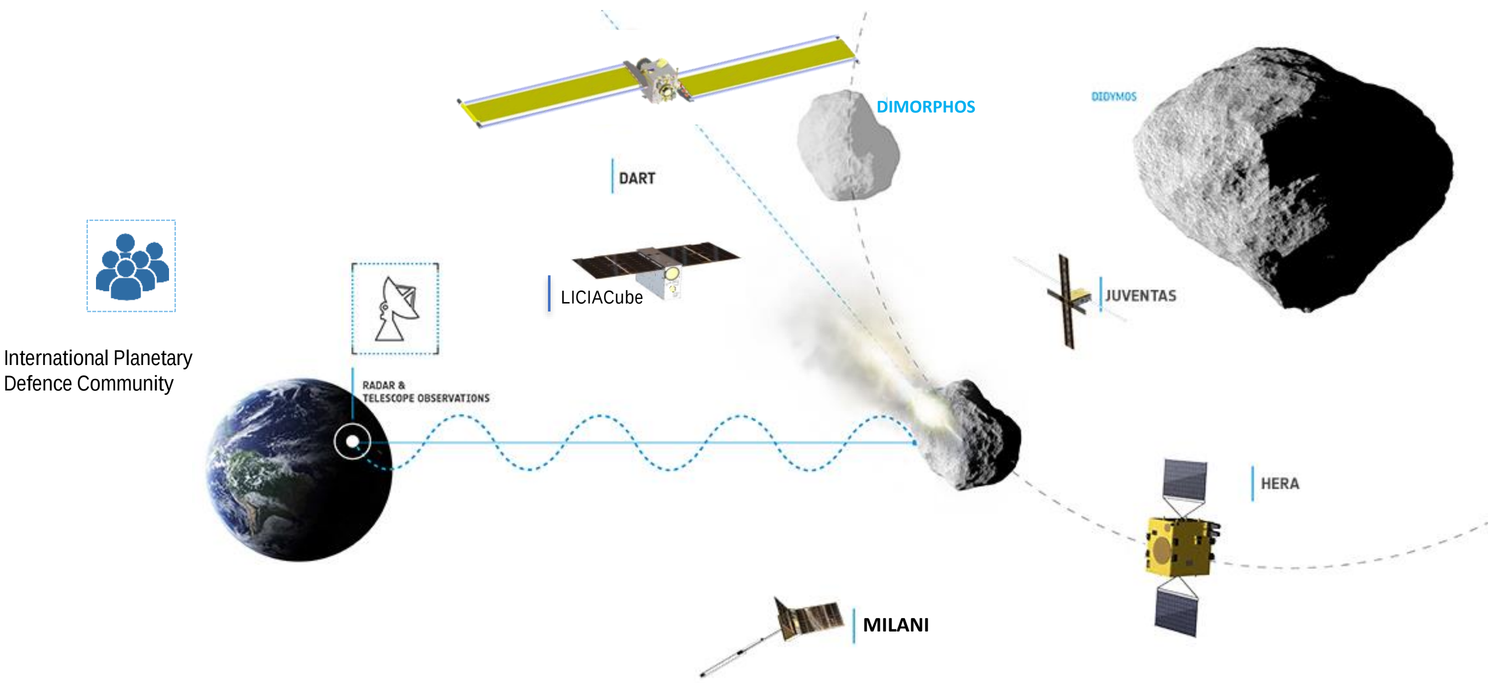


- Dynamic range $5 * 10^{-4}$ m/s
- Sensitivity $5 * 10^{-7}$ m/s

Radio Science Experiment

- Utilizes Hera->earth link and Intersatellite link Hera <-> cubesats

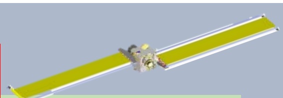
Summary: Asteroid Impact Deflection Assessment (AIDA)



AIDA

Synergy from

DART



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

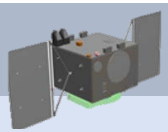
with

LICIACube

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

+

Hera



Mass of Dimorphos
Detailed dynamical characterization
Detailed investigation of final crater
Overall characterization of the asteroids

Thank You!

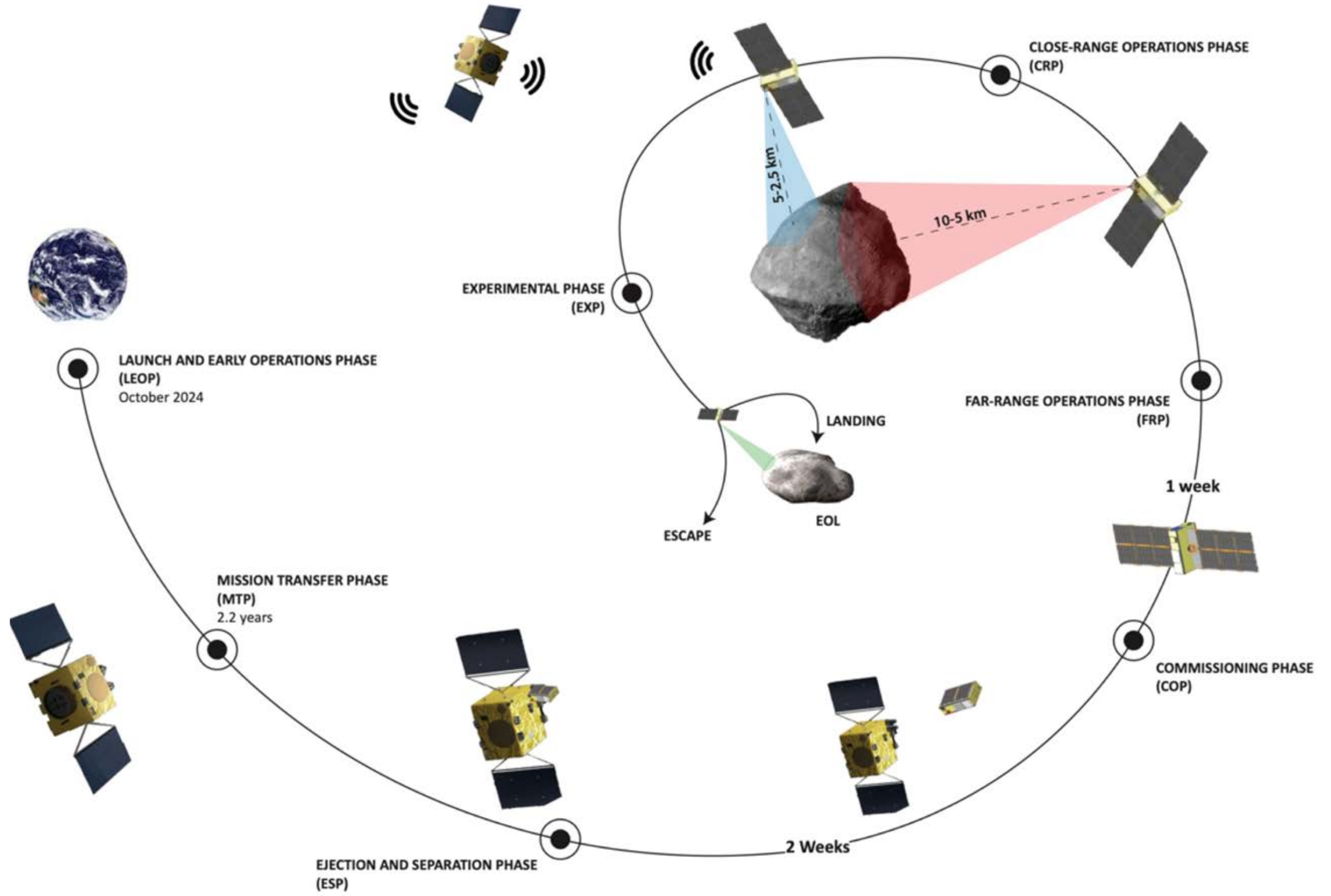
The Hera Milani CubeSat Mission

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?

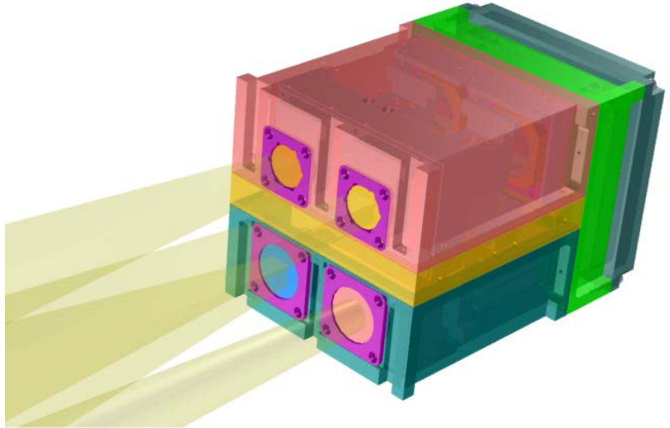
Obj ID	Objective
SO1	To support the determination of the **global properties** of Didymos asteroids
SO2	To determine **taxonomy and mineral composition** of Didymos asteroids
SO3	To detect areas of **oxidized silicates**
SO4	To characterize the sub-millimeter **microstructure** of the Didymos bodies 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

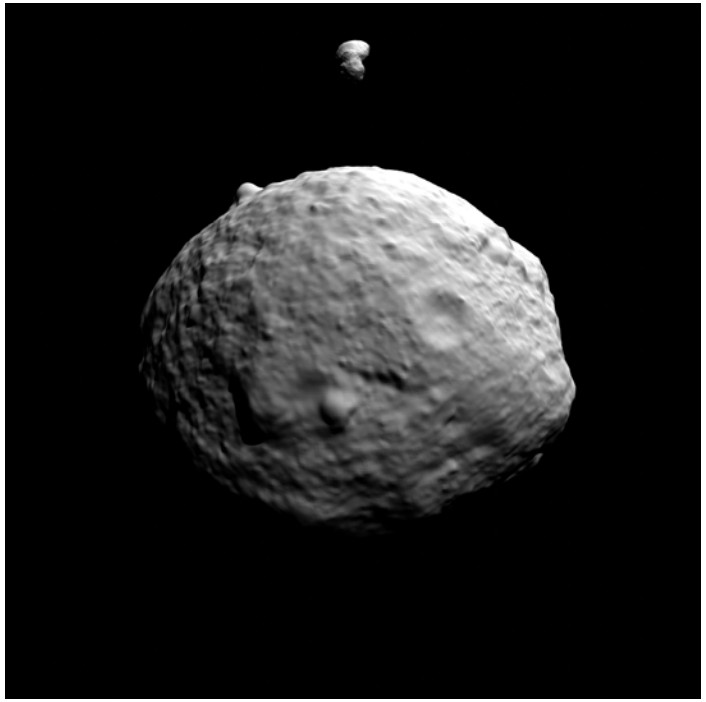
Primary objectives

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



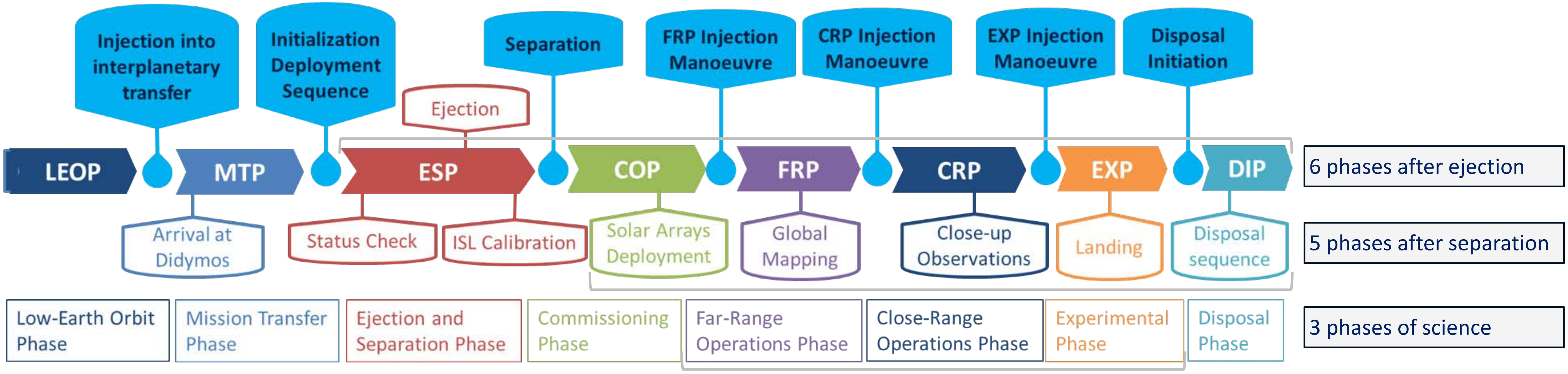


VISTA

- **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**

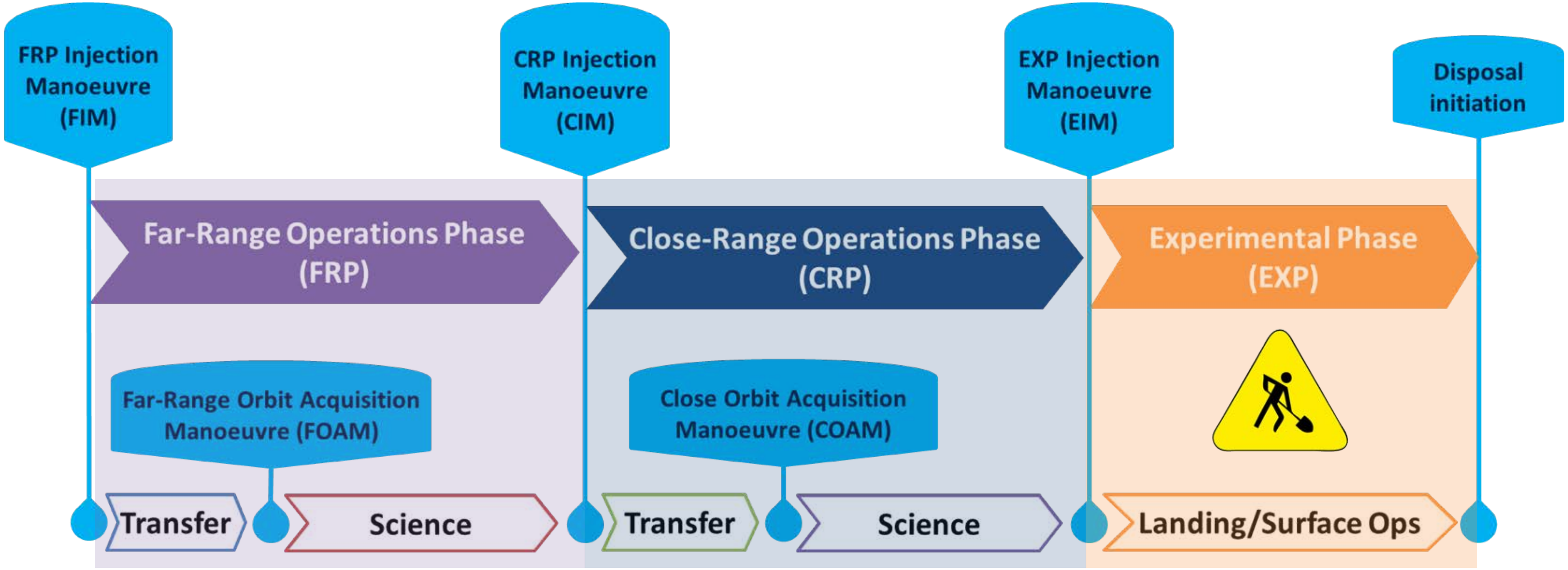
Sensor Type	**Quartz Crystal Microbalance (QCM)-based device**
Resonant Frequency [MHz]	10
Mass [g]	90
Volume [mm]	50×50×38
Sensitive area [cm^2]	1.5
Power [W] (Trange: 233K - 373K)	<1 W (peak, PE+crystals); 0.8 (mean)
Power [W] (Trange: 77K - 373K)	<4 (peak, PE+crystals+heater PE); 3.8 (mean)
Data rate [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)

Transfer
- 7 days (TBC)

Global Mapping
- 3 fly-by loops (7 days each) at 8-14 km

Close-Range Operations Phase (CRP)

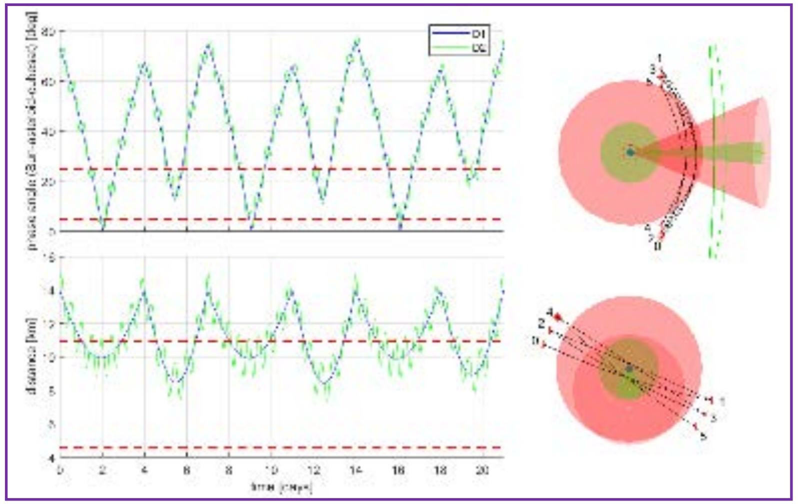
Transfer
- 7 days (TBC)

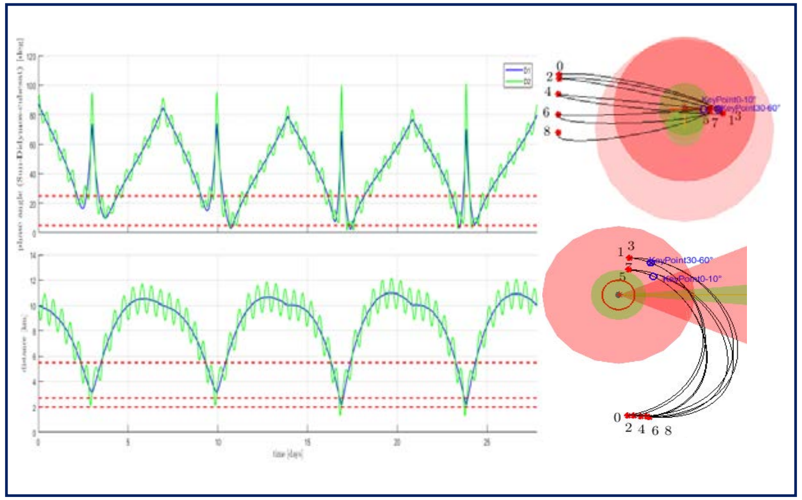
Close-up Obs.
- TBD fly-by loops (7 days each) at TBD km

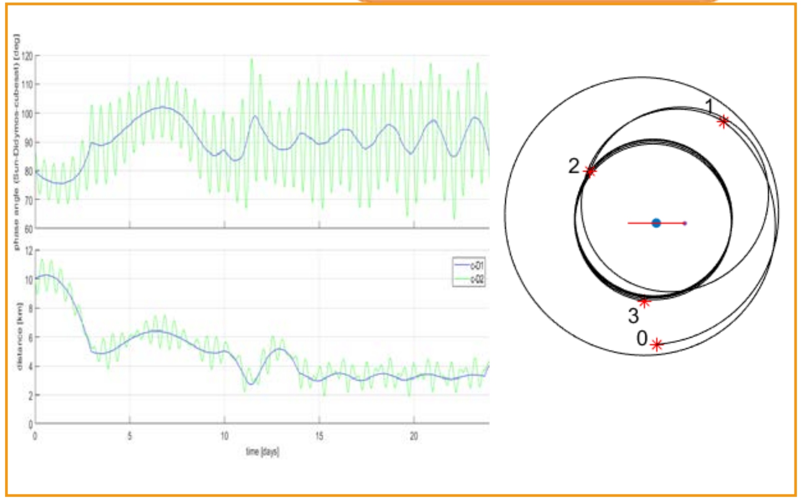
Experimental Phase (EXP)

Transfer
- TBD phasing arcs (3-4 days each)

Landing
- Controlled descent (TBD)
- Surface operations (TBD)

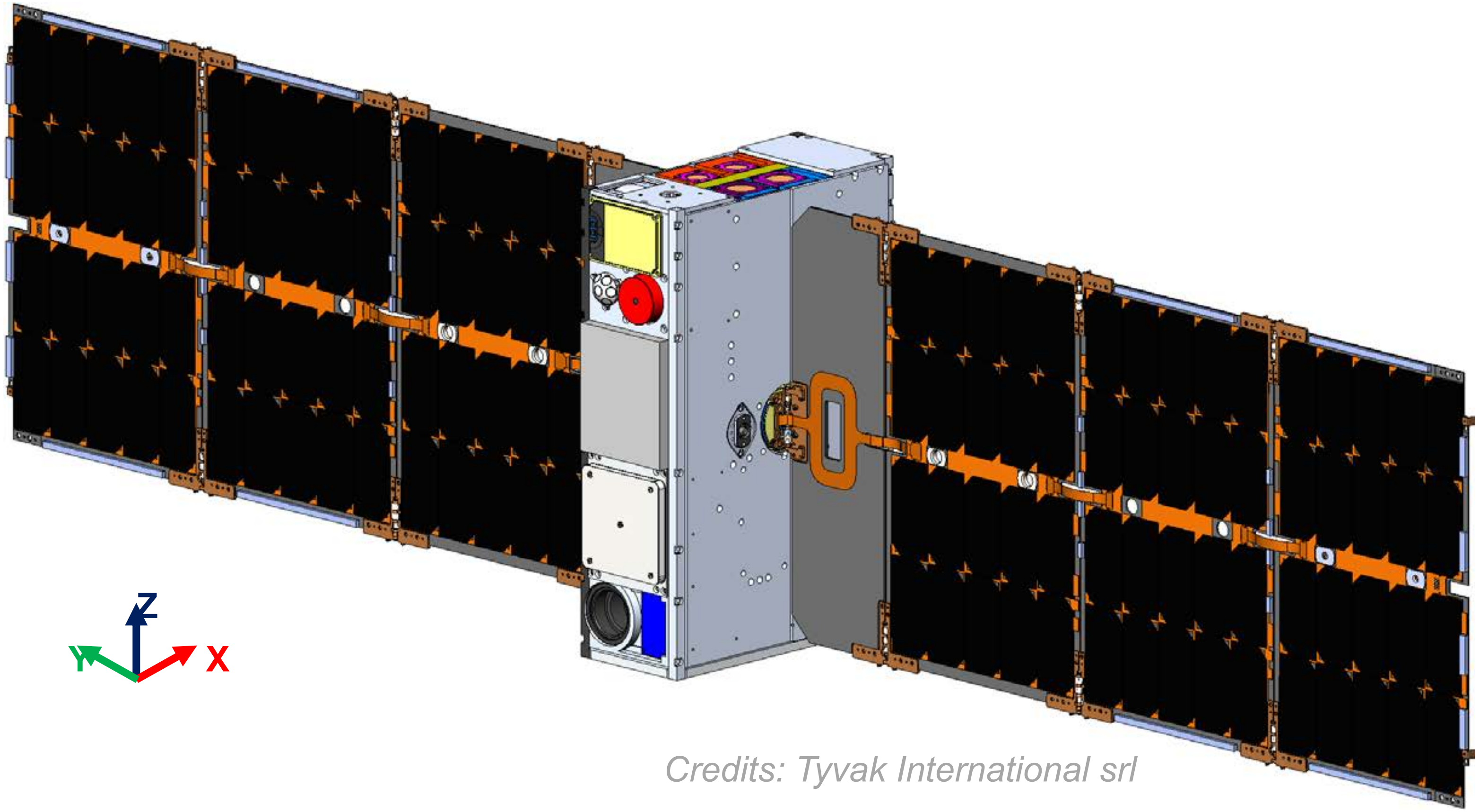






Milani CubeSat configuration

- **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)

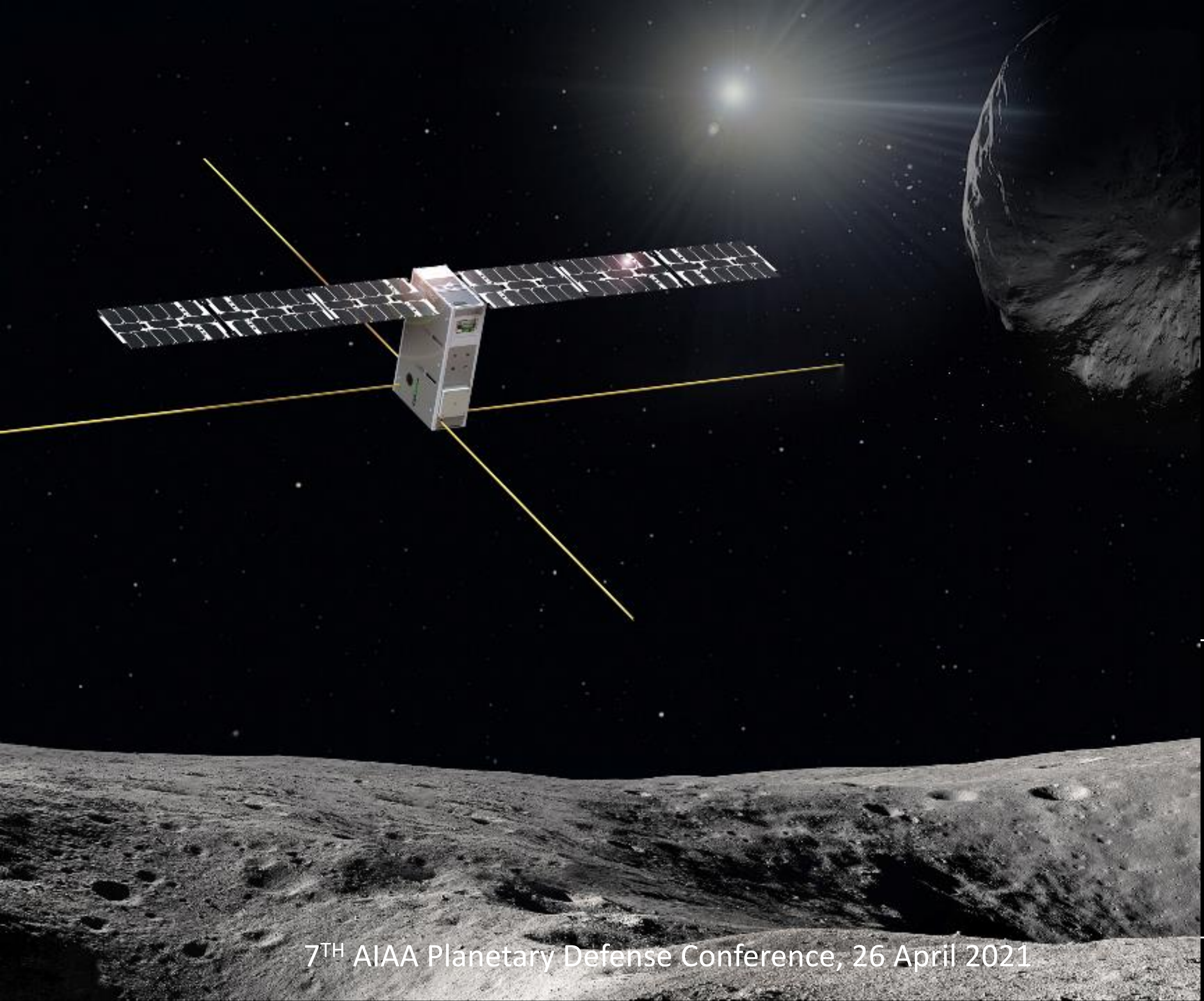
POLITO
Requirements and
environmental analysis
(Sabrina Corpino)

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)



7TH AIAA Planetary Defense Conference, 26 April 2021

JUVENTAS CUBESAT

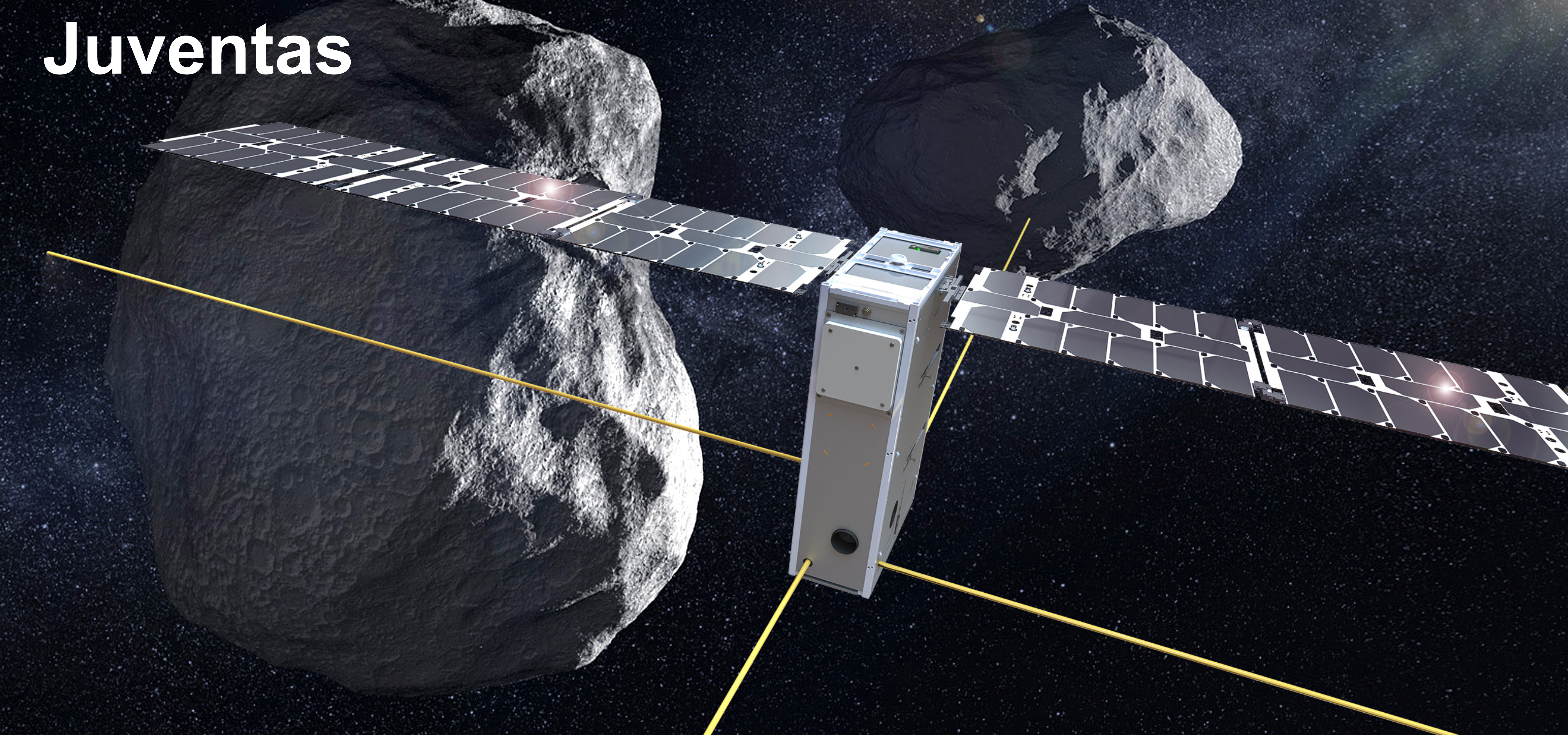
Ozgur Karatekin[1]

& Juventas team

Stefaan Van wal(2), Mehdi Scoubeau(2), Etienne le Bras(2), Victor Manuel Moreno(3), Alain Herique(4), Paolo Tortora (5), Birgit Ritter(1),, Michael Kueppers(6), Patrick Michel(7), Ian Carnelli(6), and Juventas team.

(1) *Royal Observatory of Belgium,* (2)*GomSpace,* (3)GMV (4)*IPAG,* (5)*Università Di Bologna*, (6)ESA, (7)Observatoire de la Côte d'Azur

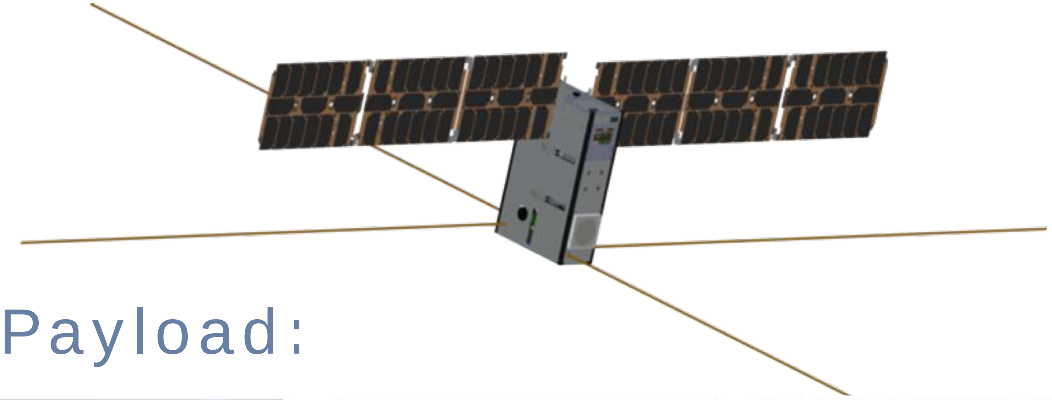
Juventas



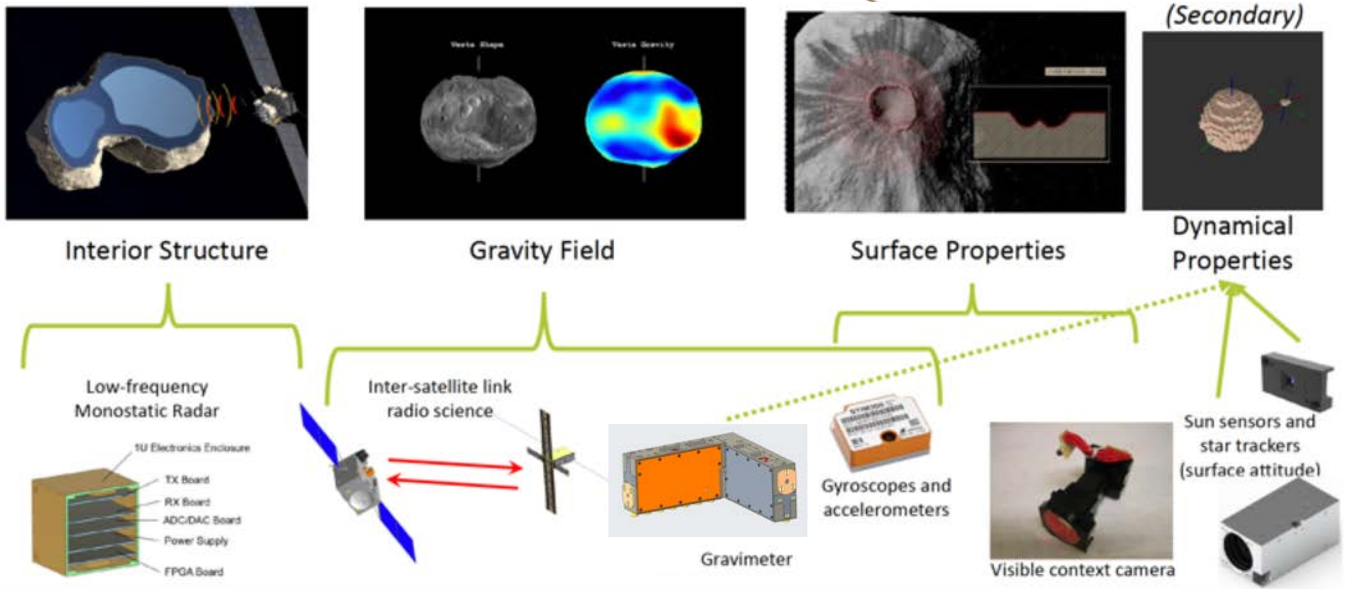
Juventas is a 6U-XL Cubesat developed as a daughter-craft to the Hera mothership for the purpose of contributing to asteroid research and mitigation assessment objectives of the Hera mission.

The Juventas CubeSat will complement the Hera mission, by providing scientific contribution towards the understanding of the formation processes of binary asteroids, their interior structure, surface properties, and dynamical properties:

Juventas



Payload:



Country	Company	Role
BE	Royal Observatory of Belgium	PI, landing science / gravimeter
BE	Spacebel	Operations partner (TBD)
CZ	Filip Zaplata	LFR digital
DK	GomSpace	Spacecraft platform subsystems
FR	Univ. Grenoble / IPAG	LFR design lead (Co-I), Rx chain
FR	CNES	Operations partner
DE	TU-Dresden	LFR Tx chain and antenna simulation
IT	U. Bologna	Radio Science (Co-I)
LU	GomSpace Luxembourg	Mission and system lead, ISL lead to OHB
LU	EmTroniX	LFR electronics
NL	ISIS	Deployer interface (procurement)
PL	Astronika	LFR antenna
RO	gmv	GNC subsystem
ES	Emxys	Gravimeter payload

See PDC presentations:

Alain Herique JuRa: the Juventas Radar on Hera to fathom Didymoon. *Wednesday, 1:15 pm*

Paolo Tortora Hera Radio Science Experiments through Ground-Based and Satellite-to-Satellite Doppler Tracking. *Wednesday, 1:15 pm.*

Birgit Ritter Surface Gravimetry on Dimorphos with GRASS on Juventas. *Friday, 7:30 pm.*

Juventas Science Matrix

Science Objective	Investigation	Measurements	Instruments	Mission Phase
SO#1: Gravity field of Dimorphos	Gravity field characterisation outside Brillouin sphere at least up to degree & order 2	Deflection during orbit measured with ranging, LoS to HERA (second CubeSat)	ISL radio link	Proximity operations
	Surface gravity	Surface acceleration	Gravimeter	Surface operations
	CubeSat descent / touchdown/bouncing	Dynamic recording of each event	GNC	Landing / Bouncing
SO#2: Internal structure of Dimorphos	Reconstruction of material density & largest monolithic object	Properties of (back-)reflection of transmitted signal	Low frequency radar	Proximity operations
SO#3: Surface properties of Dimorphos	Visible imaging	Inspection of Didymoon surface features and impact crater	Visible camera	Proximity operations, Surface operations
	Surface strength measurement	Rebounds from the surface	IMU	Landing / Bouncing
SO#4 (secondary) Dynamical properties of Dimorphos	Orbital analysis	Orbital analysis by ranging LoS to HERA (second CubeSat)	ISL radio link	Proximity operations
	Variable surface acceleration	Surface acceleration measurements over >1 orbit	Gravimeter	Surface operations
	Attitude and Time dependent surface illumination	Attitude and time dependent surface illumination	Star tracker, sun sensors	Surface operations
SO#5 (secondary) Surface/sub-Surface properties of Didymos	Reconstruction of material density & largest monolithic object	Properties of (back-)reflection of transmitted signal	Low frequency radar	Proximity operations

Juventas Mission Profile

Launch and Cruise

Juventas is transported to Didymos by Hera, stowed within a deployment canister. It is released at Didymos and undergoes a short commissioning period

Proximity Operations

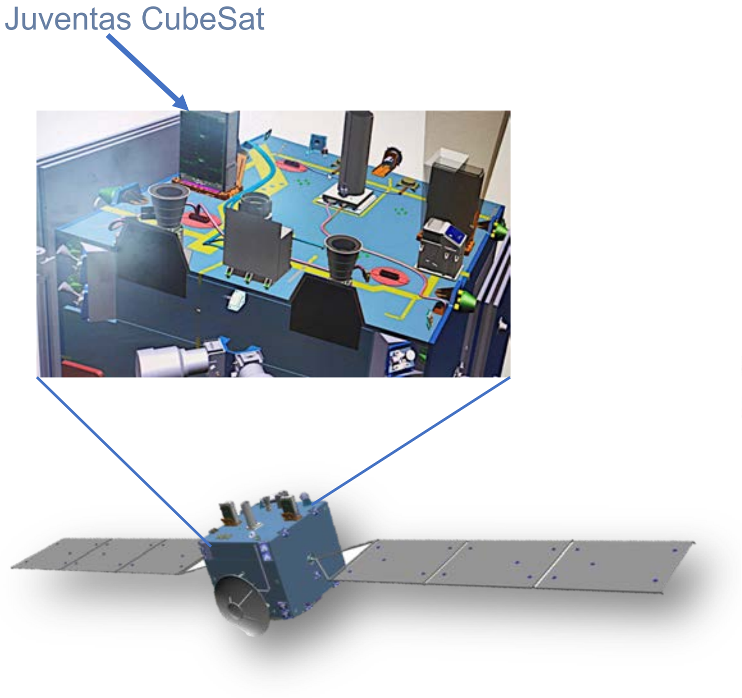
Radar & Radio Science Observations

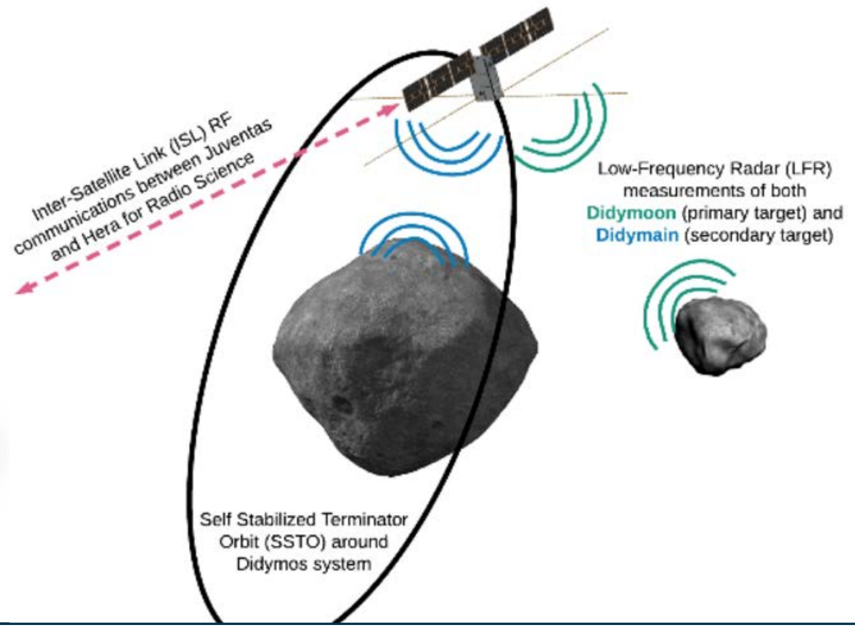
Juventas performs the main scientific observations with its low frequency radar payload to look inside the asteroid interior, and operate radio science experiments through the ISL link

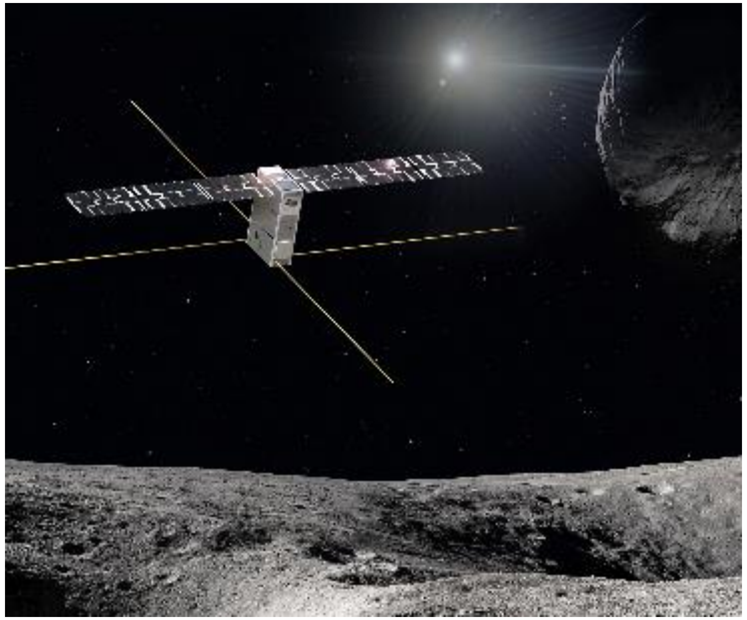
Surface Operations

Surface Mechanical Properties & Gravity

Juventas attempts to land on the surface of Didymoon, making measurements of the impact and bouncing events and then operating its gravimeter payload from the surface to understand dynamical properties of the asteroid system

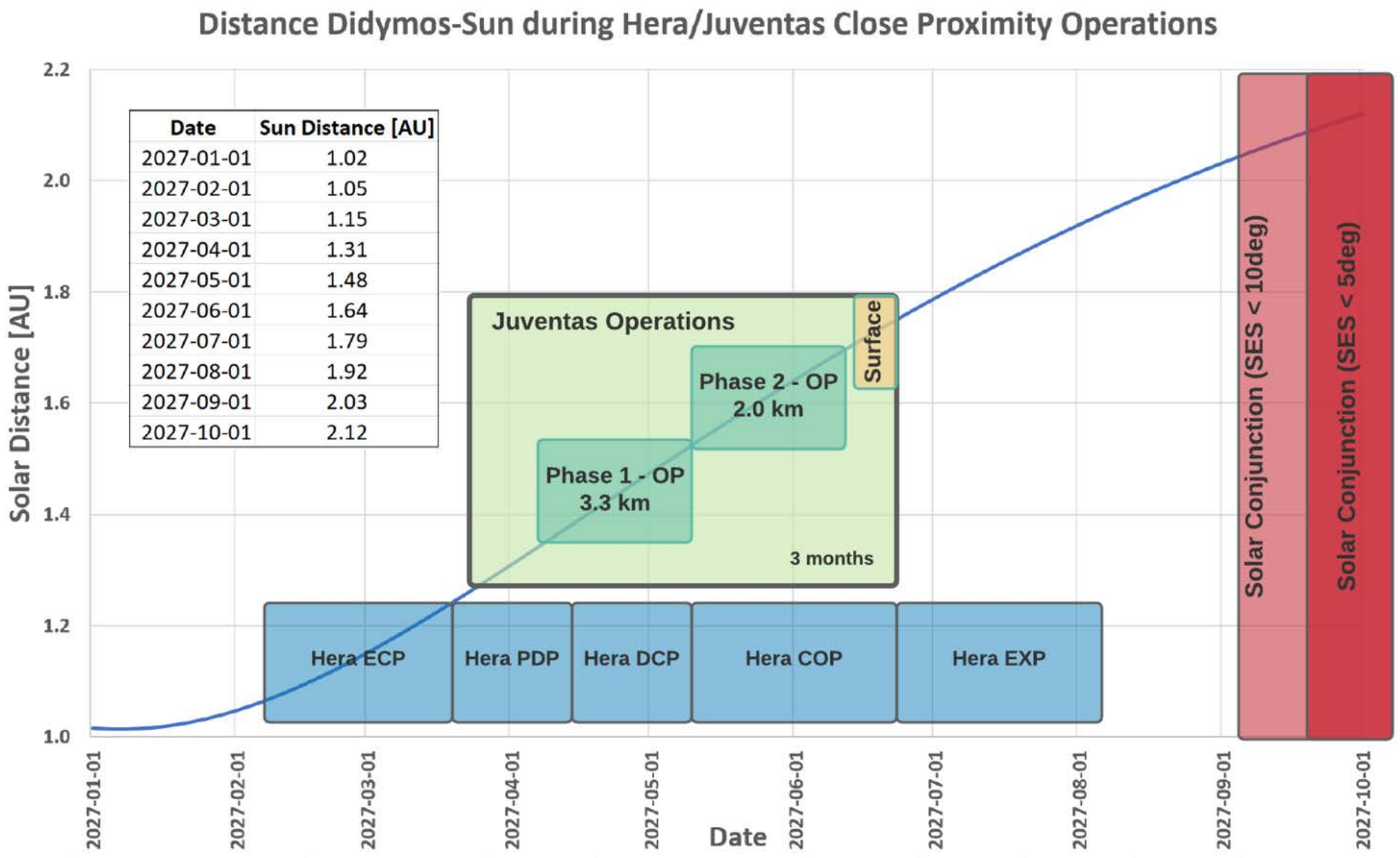






Mission Timeline

Scenario	LPO	LPC	Arrival	Cruise Duration
Baseline 2024	Oct 8, 2024	Oct 25, 2024	Dec 28, 2026	2.17 – 2.22 years



Date	Sun Distance [AU]
2027-01-01	1.02
2027-02-01	1.05
2027-03-01	1.15
2027-04-01	1.31
2027-05-01	1.48
2027-06-01	1.64
2027-07-01	1.79
2027-08-01	1.92
2027-09-01	2.03
2027-10-01	2.12

Proximity Operations

Self Stabilized Terminator Orbits

Equilibrium elliptical orbits perpendicular to sun direction due to high SRP perturbation

Two phases:

SSTO at 3.3 km
SSTO at 2.0 km

Attitude strategy:

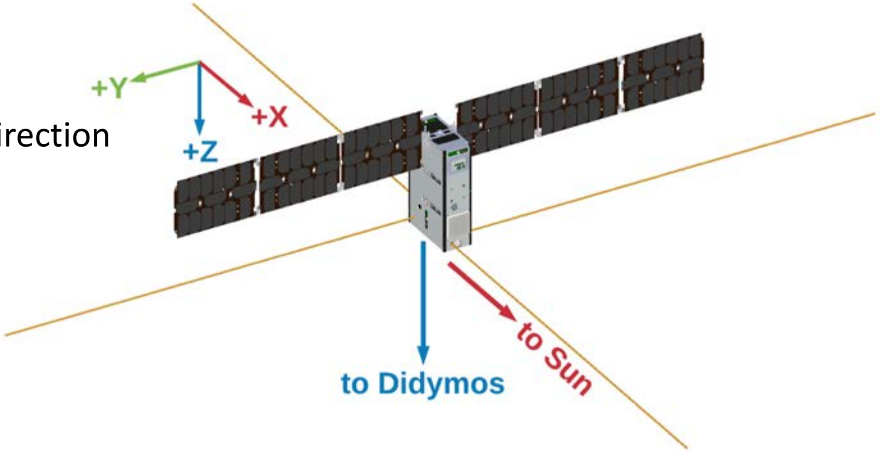
Camera + Altimeter pointing to Didymos
Solar panels rotated to maximize solar exposure 90º
ISL -X mainly facing HERA

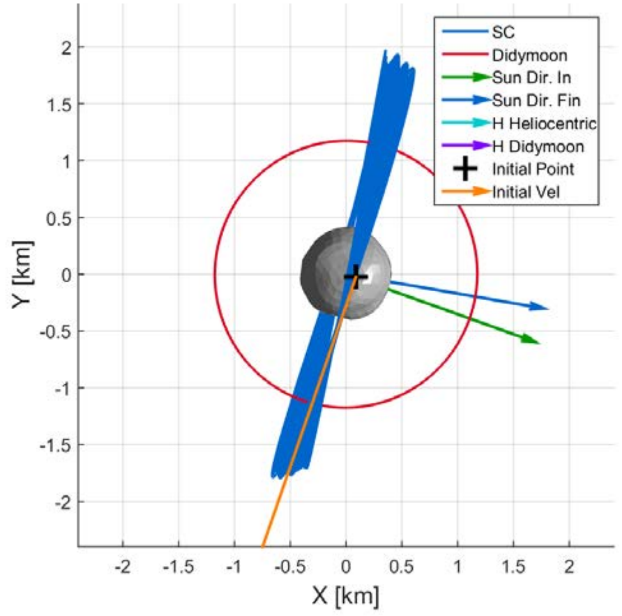
Science Observations

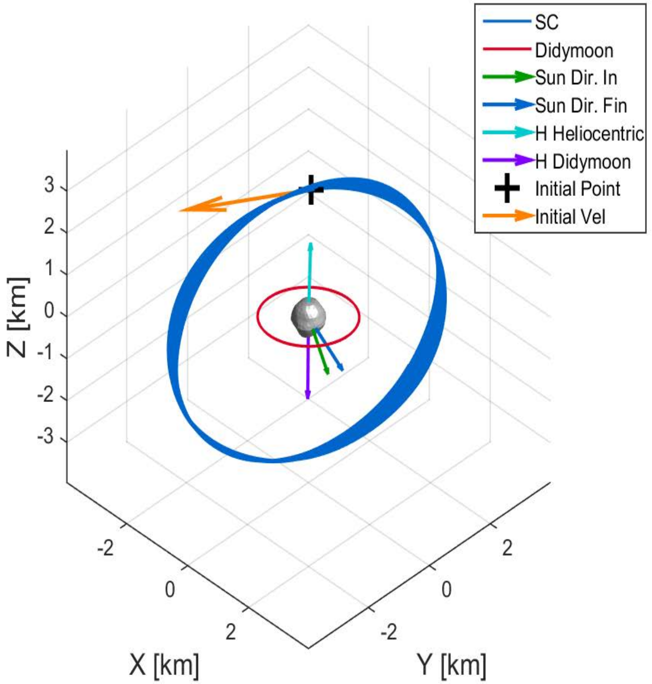
Radar observations
Radio science

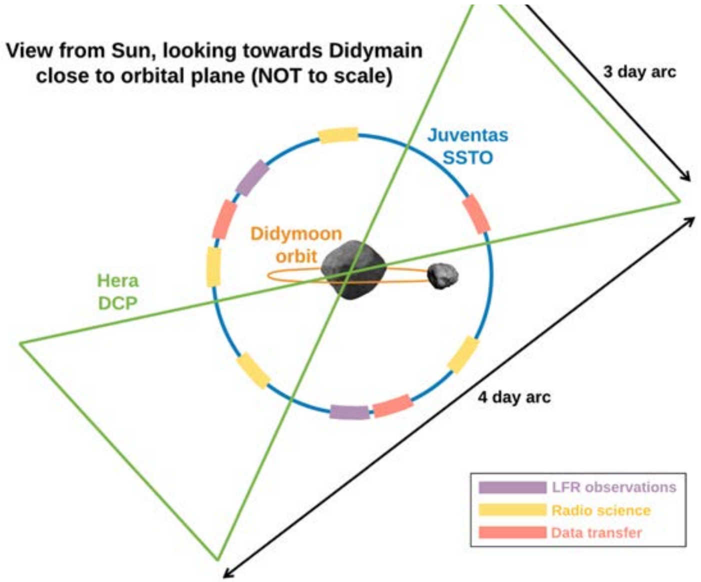
ISL communications

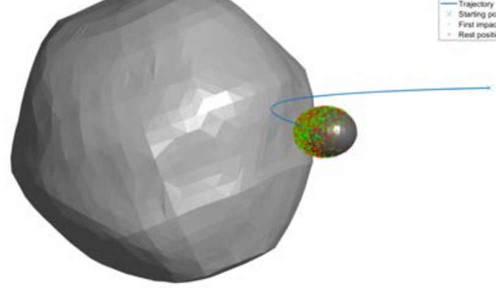
Near-continuous link
Scheduled data transfer with higher bit rate when favorable geometry

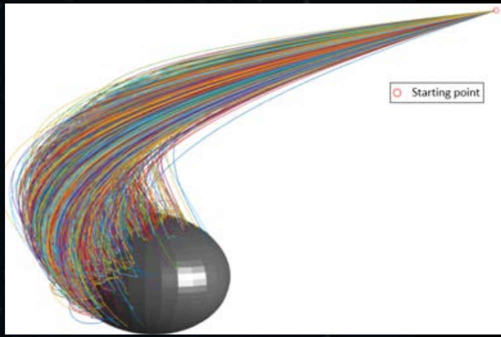




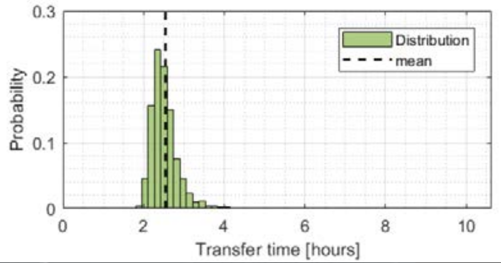




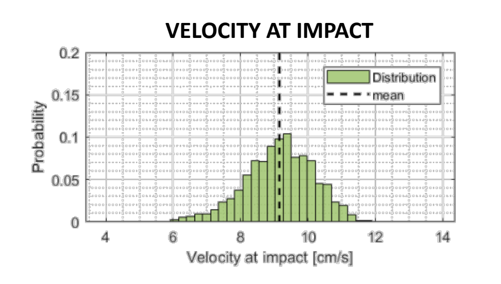




Starting point

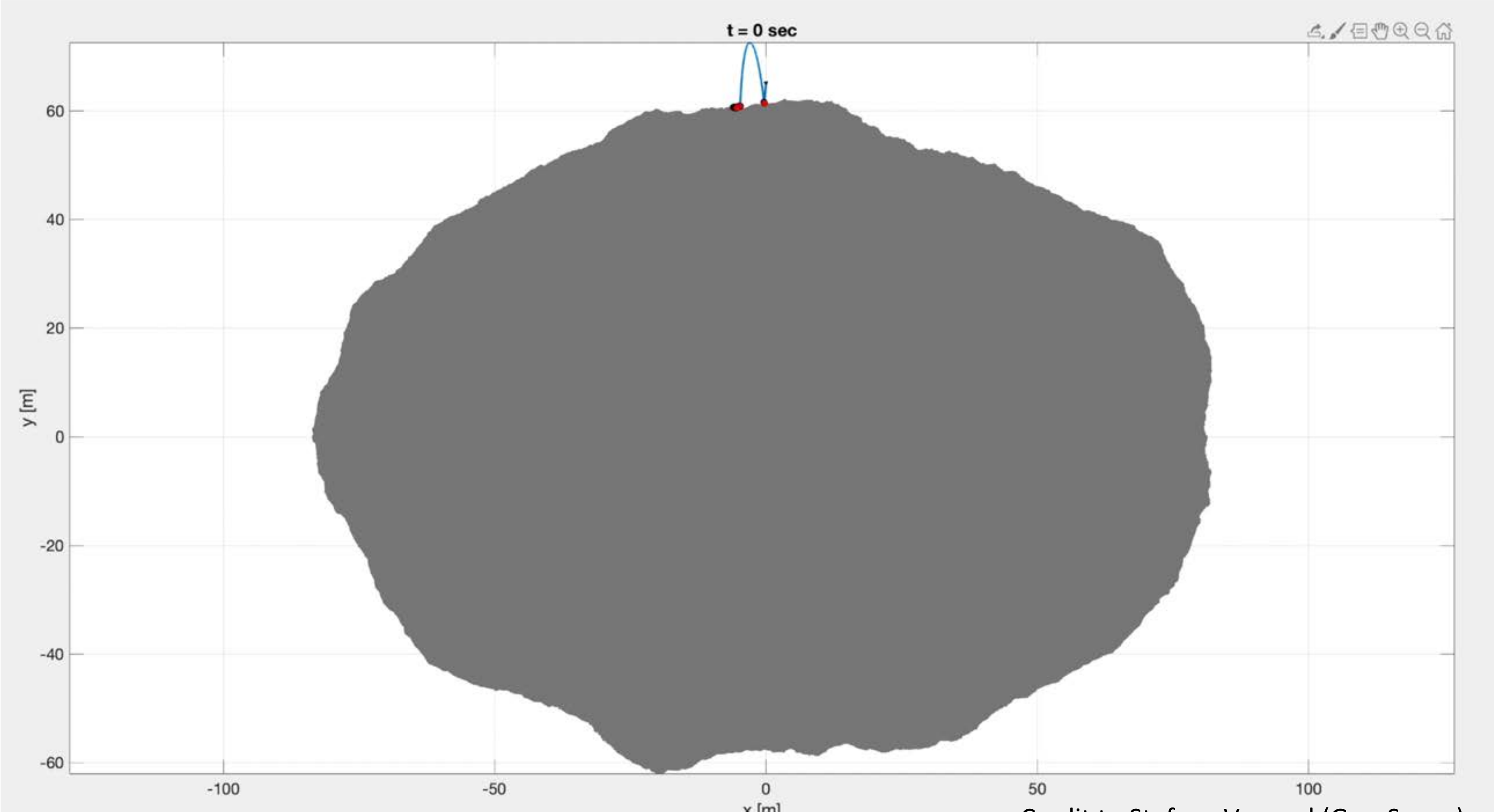


Distribution
mean
Probability
Transfer time [hours]

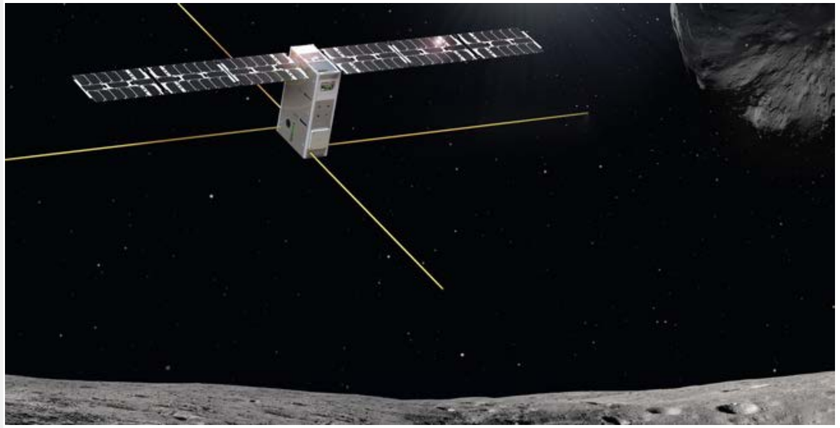


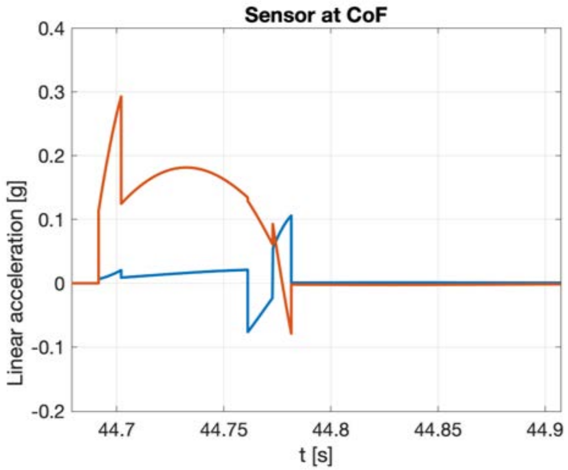
VELOCITY AT IMPACT
Distribution
mean
Probability
Velocity at impact [cm/s]

Surface touchdown & bounces



Credit to Stefaan Van wal (GomSpace)

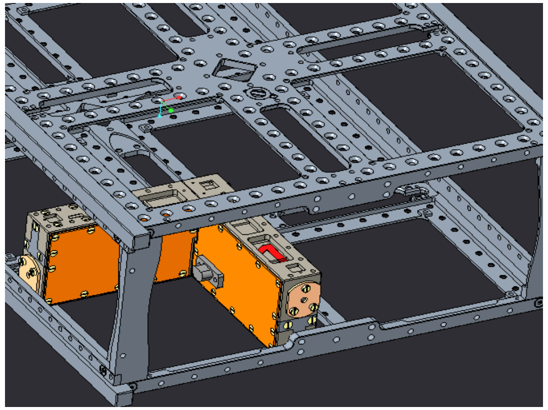


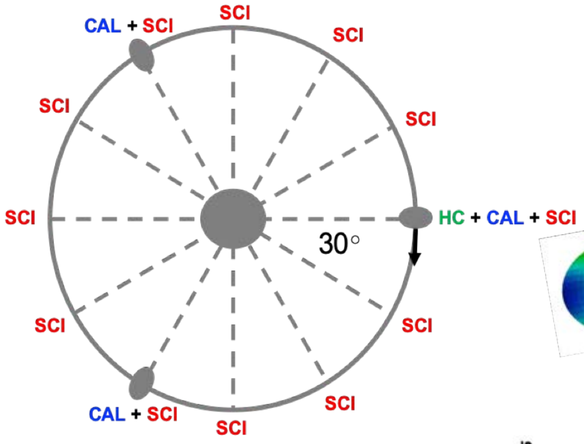


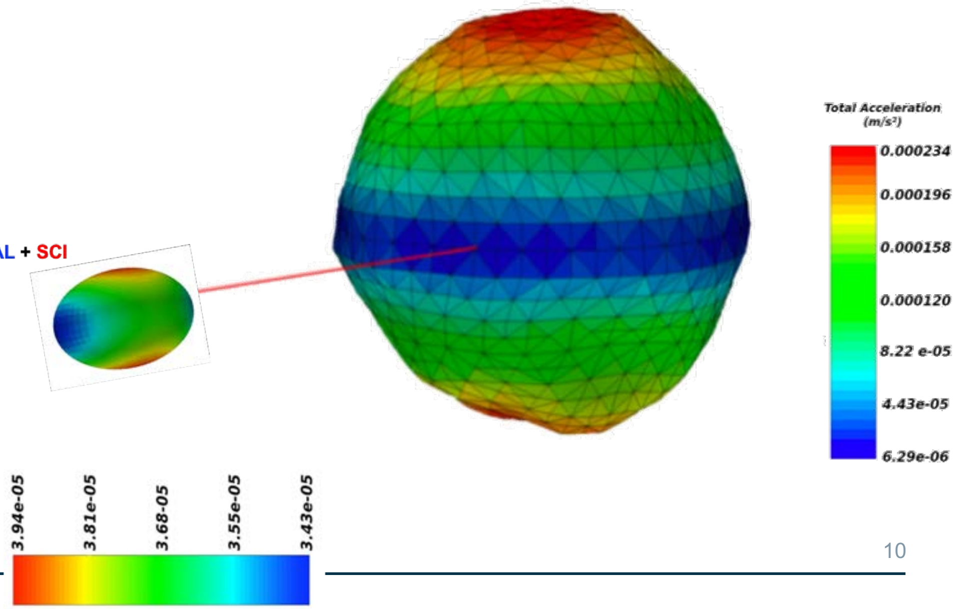
Science Objective	Investigation	Measurements	Instruments	Mission Phase
Surface Mechanical Properties	Surface strength measurement	Rebounds from the surface	IMU, ISL	Bouncing
Local (High degree) Gravity	CubeSat descent / touchdown/bouncing	Trajectory (Radio tracking, LR), dynamic recording of events	GNC, ISL	Descent / Bouncing

Surface Operations

- Gravimeter starts to operate after soft-landing of Juventas on the surface
- Gravimeter measurements at equally spaced measurements over a Didymoon orbit (every 30 degrees) to get dynamic variations
- Goal: survivability of 1 day = approx. 2 Didymoon orbits
- ISL link
- Surface attitude sensors
    - Star trackers, sun sensors
    - Navigation and context camera images from surface (TBC)







OBJECTIVES MAPPED TO HERA REQUIREMENTS

Hera ID	Hera Mission Requirement Description	Juventas Objective	Juventas Instrument/Measurement
Core Requirements for Planetary Deflection			
D1	Determine the mass of Dimorphos	SO1	ISL radio science Gravimeter
D2	Global properties of Dimorphos (size, global shape, volume, density, porosity)	SO1, SO2	LFR radar: density/porosity Accelerometers: porosity Gravimeter: surface gravity/density ISL radio science: gravity
D3	Size distribution of surface material	SO3	LFR radar Visible imaging (with navcam)
D4	Dynamical properties of the Didymos system	SO4	Gravimeter: Surface accelerations over a Didymoon orbit Attitude: landed attitude over Didymoon orbit using star trackers or sun sensors ISL radio science (via orbital analysis, TBC)
If DART is successful:			
D5	Shape and volume of the DART impact crater	SO3	Visible imaging (with navcam)
D6	Size distribution of excavated material	N/A	LFR radar (TBC)
Opportunity for Planetary Defence			
D7	Surface strength	SO3	Accelerometers: Surface strength from impact
D8	Interior structure of Dimorphos	SO2	LFR radar
D9	Composition of Dimorphos	SO3	LFR radar Accelerometers: Surface strength from impact
If DART is successful:			
D10	Transport of impact ejecta from Dimorphos to Didymos	N/A	

Alain Herique JuRa: the Juventas Radar on Hera to fathom Didymoon. *Wednesday, 1:15 pm*

Paolo Tortora Hera Radio Science Experiments through Ground-Based and Satellite-to-Satellite Doppler Tracking. *Wednesday, 1:15 pm.*

Birgit Ritter Surface Gravimetry on Dimorphos with GRASS on Juventas. *Friday, 7:30 pm.*

7th IAA Planetary Defense Conference

26-30 April 2021, Online Event

Hosted by UNOOSA in collaboration with ESA

Q&A

Session 1: Hera

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Break

Up next: Session 2 – Hayabusa2