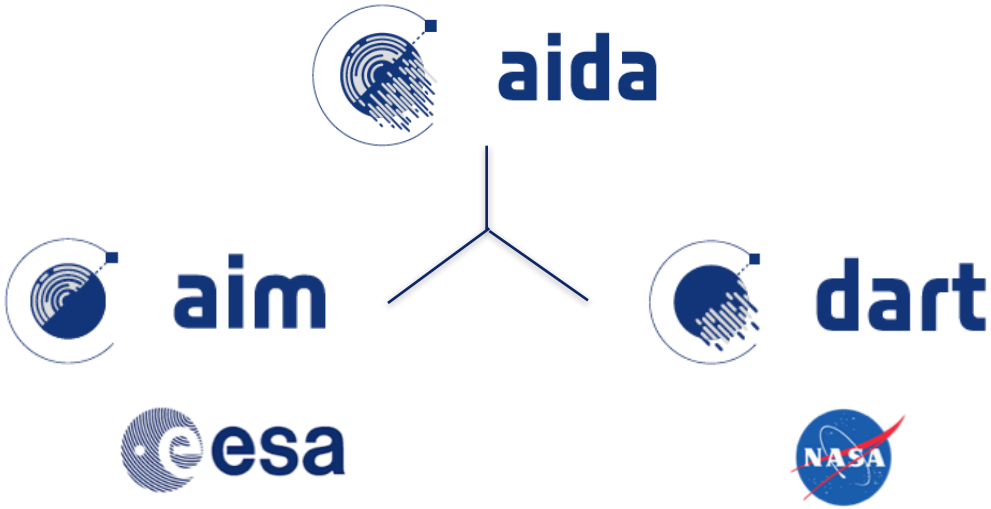
→ASTEROID IMPACT MISSION

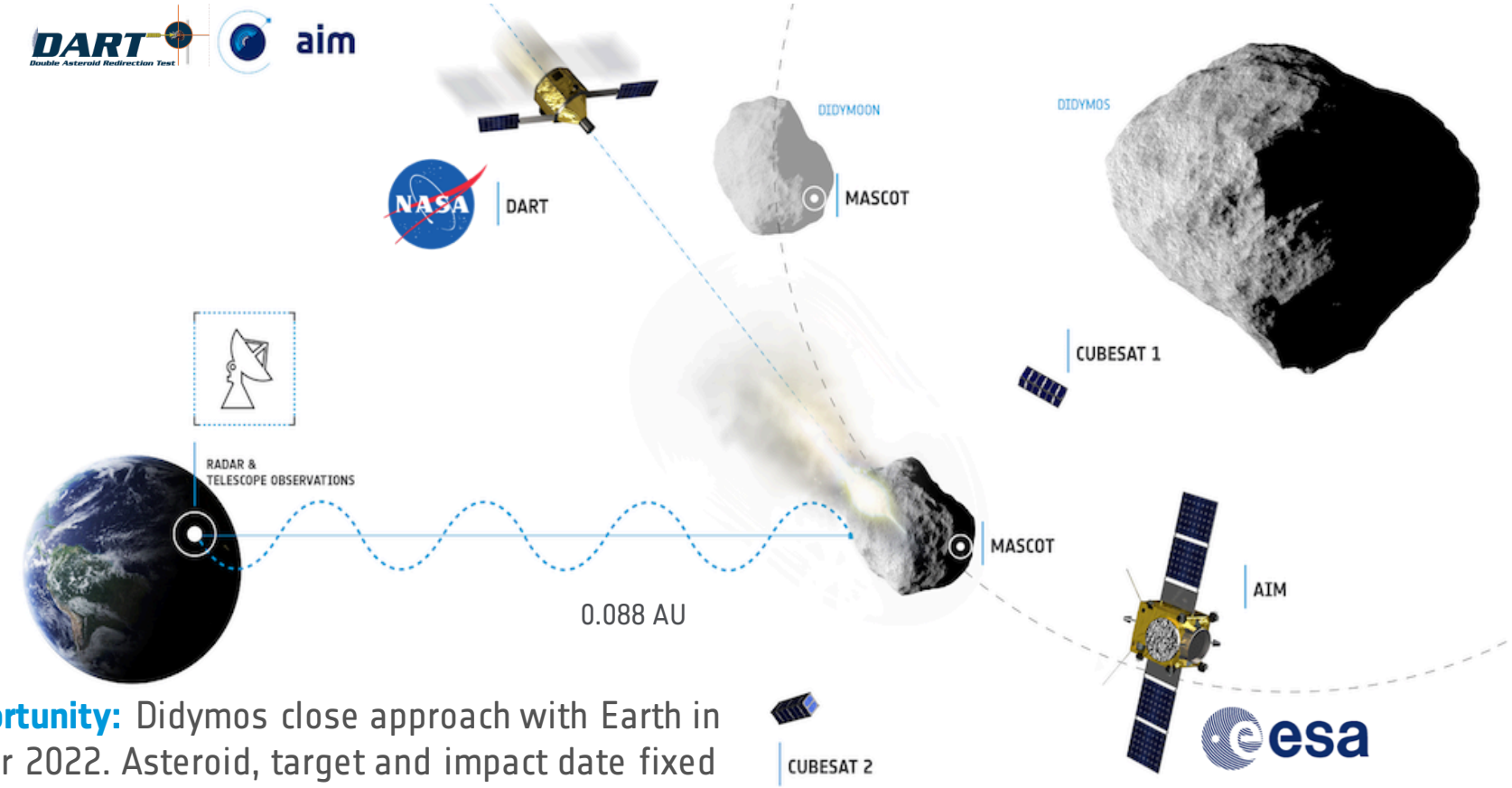
AIDA COOPERATION Asteroid Impact & Deflection Assessment

Two **simple**, **independent** and **self-standing** mission developments operated in coordination:

- demonstrate the ability to **modify the orbital path of Didymoon** and measure the deflection by monitoring the binary`s orbital period change
- measure all scientific and technical parameters to **interpret the deflection** and extrapolate results to future missions or other asteroid targets



AIDA COOPERATION



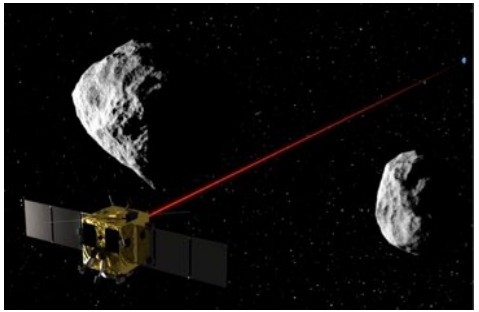
→ **opportunity:** Didymos close approach with Earth in October 2022. Asteroid, target and impact date fixed

ASTEROID IMPACT MISSION

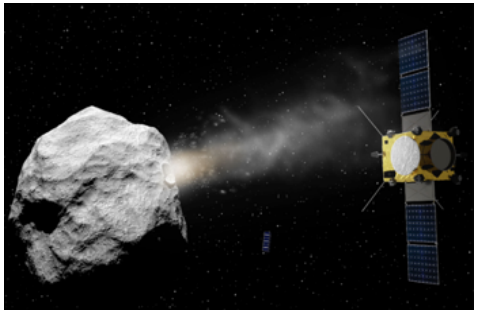
Small mission of opportunity to explore and **demonstrate technologies for future deep-space missions** while **addressing planetary defence objectives** and **performing asteroid scientific investigations**.

aim

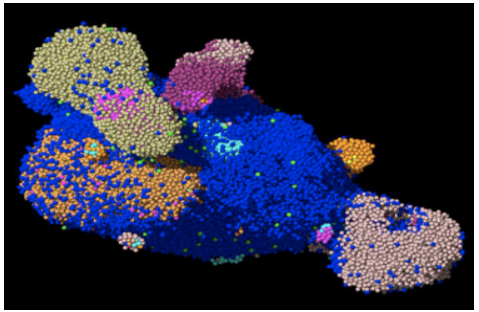
TECHNOLOGY DEMONSTRATION



ASTEROID IMPACT MITIGATION

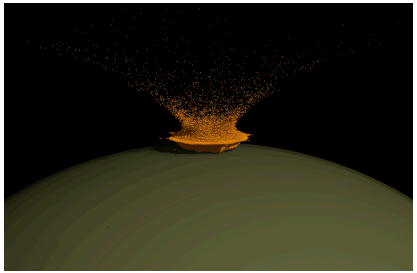


SCIENCE

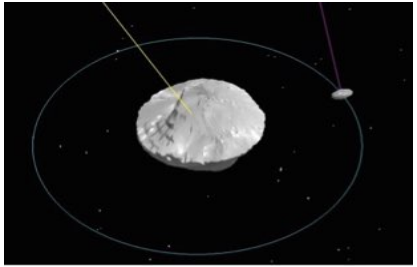


AIM “FIRSTS”

First mission to demonstrate **interplanetary optical communication** and **deep-space inter-satellite links with CubeSats** and a **lander** in deep-space.



First mission to **measure** and **characterize asteroid deflection** by determining the “ejecta momentum amplification factor” of a kinetic impactor.



First mission to **study a binary asteroid,** its **origins** and sound the **interior structure** providing clues of its formation process.

AIM TECHNOLOGY RESEARCH OBJECTIVES

#	GOAL	COMMENT
T#1	**Demonstrate semi-autonomous asteroid landing and extended operations on Didymoon**	• Demonstrate landing on small (1630 m) asteroid and inter-satellite link in deep-space • Test long-lived payload operation i.e. transmission radar, surface imaging, radiometry.
T#2	**Infra-Red Instrument Navigation Aid** *(IRINA)*	• To demonstrate the use of an IR instrument potential to support rendezvous phases
T#3	**Qualify an end-to-end 2-way deep-space optical communications system**	• Primary goal transmit full asteroid 1m resolution map before DART arrival (goal, transmit images of the impact) • Components and operations representative of terminal developed for commercial applications. • Maximum platform independence: inertial pseudo-star pointing, mirror-stabilization, power-limited modes 135 W nominal @ 0.11 AU and 50 w power limited mode @ 3.3 AU max distance
T#4	**Demonstrate deep-space inter-satellite communication network**	• Deploy up to two 3U cubesats (or any combination of units) • Demonstrate inter-satellite link network between AIM, COPINS and MASCOT-2

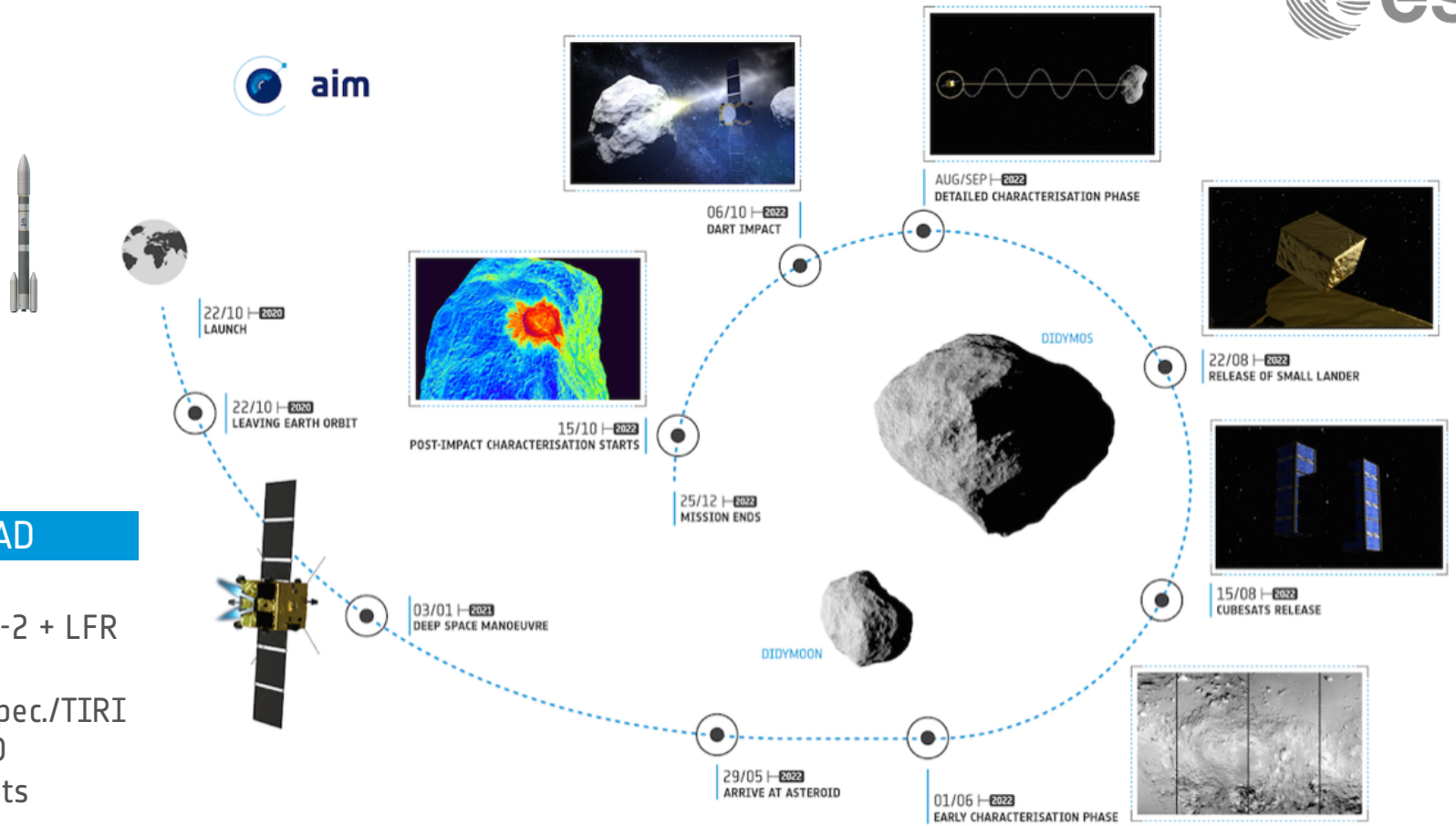
AIM (alone) PRIMARY SCIENCE OBJECTIVES

PARAMETER	RELEVANCE	SUPPORTING INSTRUMENTS
S#1 **Didymoon size, mass, shape, density**	Mass => momentum size => shape, volume, gravity density => internal structure	Camera (VIS), LIDAR (OPTEL-D), radio tracking
S#2 **Didymoon dynamical state**	Momentum transfer Indirect constraints on interior structure	VIS
S#3 **Geophysical surface properties, topology, shallow subsurface**	Composition, mechanical properties, thermal inertia =>Interpretation of impact	VIS, Thermal Infrared Imager (TIRI), High Frequency Radar (HFR), Accelerometer on MASCOT
S#4 **Deep-internal structure of the moonlet**	Interpretation of the impact Origin of binarity	Low Frequency Radar (LFR)
S#5 **Optical, IR, Radar calibration**	Simultaneous ground and space-based measurements to calibrate ground-based observations and extrapolate to other objects observed from the ground.	VIS, TIRI, HFR

AIM (with DART) SECONDARY SCIENCE OBJECTIVES

PARAMETER	RELEVANCE	SUPPORTING INSTRUMENTS
S#6 **Didymoon post-impact characterisation**	Changes due to impact	All
S#7 **Didymain characterisation**	Origin of the system	VIS, TIRI, HFR, LFR
S#8 **Impact ejecta**	Porperties of ejected dust	VIS, TIRI, HFR
S#9 **Ambient dust**	Dust in Didymos environment	VIS, TIRI, HFR
S#10 **Chemical and mineralogical composition**	Asteroid classification, origin of the system	VIS (TBC), TIRI, MASCOT-2 lander

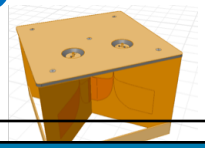
AIM MISSION SCENARIO

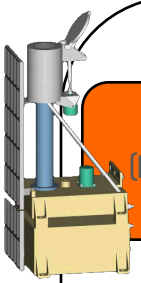


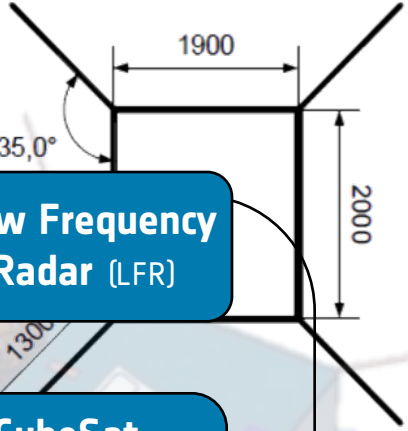
→ PAYLOAD

- VIS
- Mascot-2 + LFR
- HFR
- Hyperspec./TIRI
- OpteI-D
- CubeSats

AIM PAYLOAD







VIS
(Navigation)

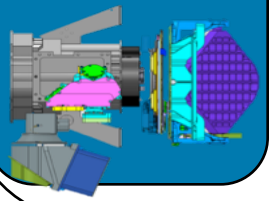
High Frequency Monostatic Radar
(HFR)

Low Frequency Radar (LFR)

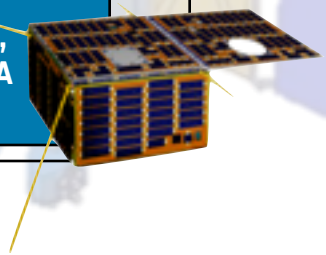
CubeSat
Opportunity Payloads
(COPINS)

Radio Science Experiment
(TT&C s/s)

Optel-D
Optical comms Terminal



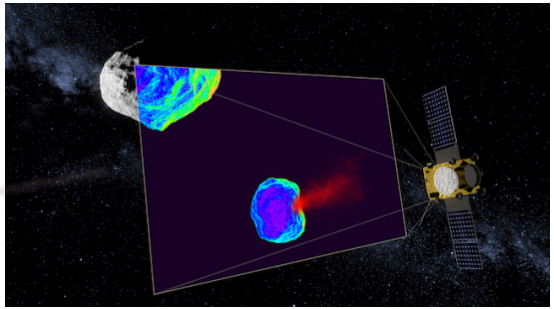
MASCOT-2
incl.
LFR, DACC, CAM, MARA



TIR Imager
(TIRI)

Built-in AIM S/C (subsystem)

AIM payload



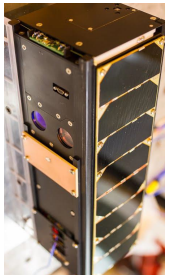
Options under study

Hyperspectral camera

European Lidar

COPINS – A case for cubesats in deep space

ASPECT



- Space Weathering
- Shock experiment
- Plume Observations
- Spectral observations

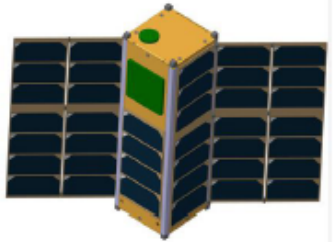
AGEX

- Mechanical properties of surface material
- Seismic properties of sub-surface
- Determine kinematics prior and after DART

PALS

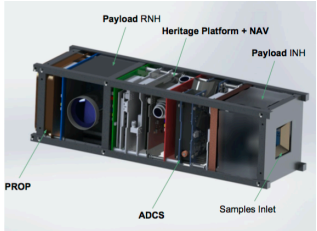
- Characterize magnetization
- Composition of volatiles
- Volatiles released from DART impact
- Super-resolution imaging
- DART collision and plume observation

CUBATA



- Gravity field
- Observe DART impact
- Perform seismology
- Velocity field of the ejecta

DUSTCUBE

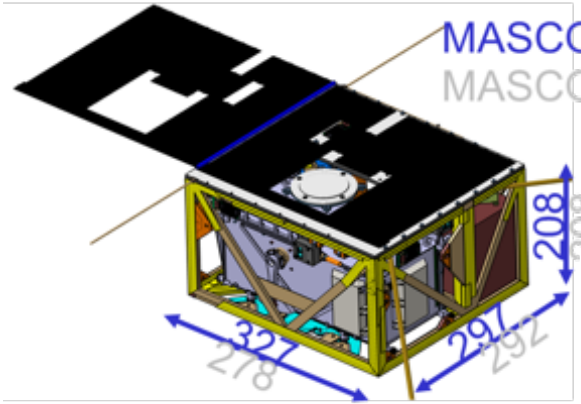


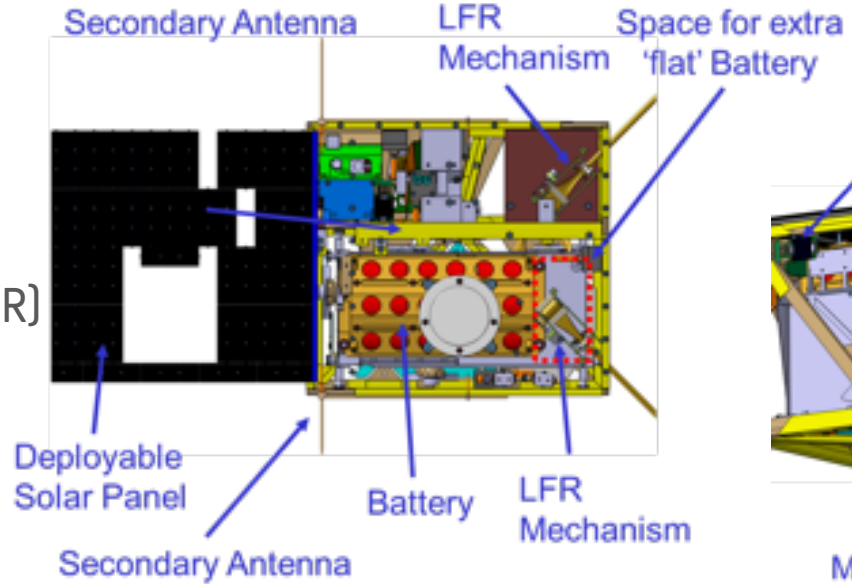
- Size, shape and ejected dust analysis
- Mineralogical composition
- Compliment com demo
- Measure the BRDF of the asteroid surface

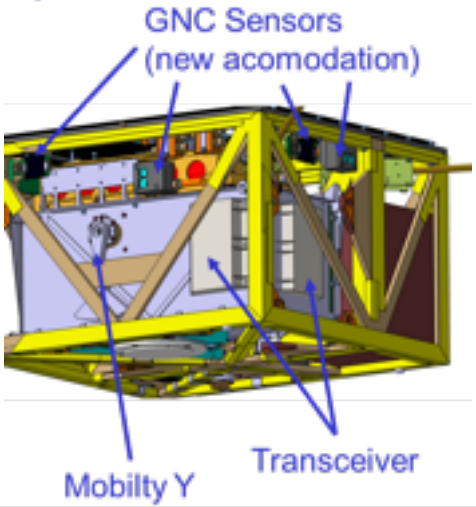
MASCOT-2 LANDER

MASCOT-2 developed by DLR based on MASCOT lander currently on Japanese Hayabusa-2 mission

- Size: 33 x 30 x 21 cm
- Deployable solar generator cover (supports orientation)
- Mass: 15 kg
- 3 months operational lifetime
- Carries:
  - Camera (CAM)
  - Low-frequency radar (LFR)
  - Radiometer (MARA)
  - Accelerometer (DACC)

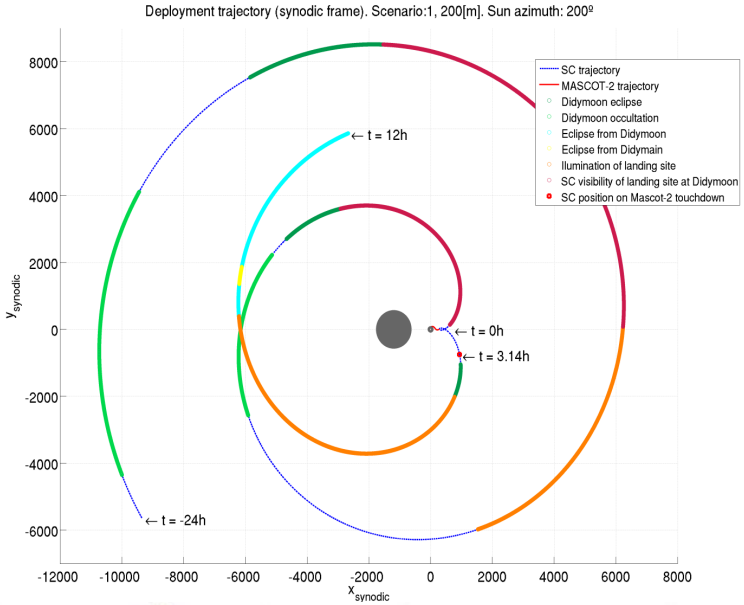


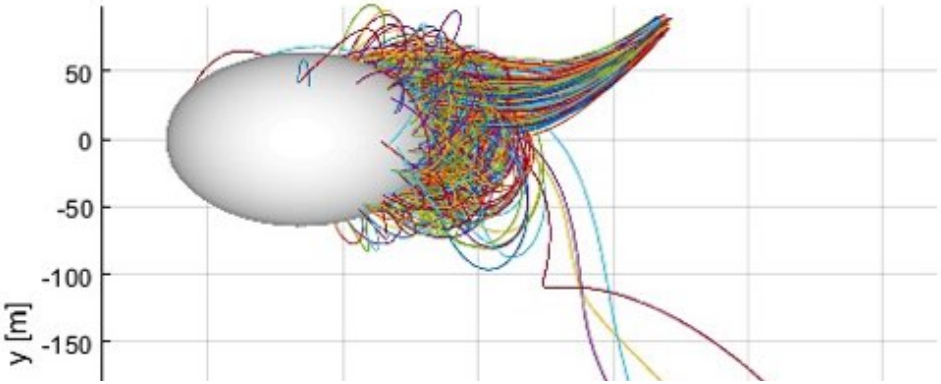




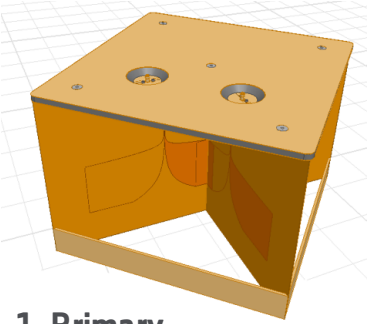
MASCOT-2 RELEASE

- The main perturbation due to the uncertainty on Didymos gravity field
- The minimum touchdown velocity from outside Didymoon SOI 5.14 cm/s
- Robust landing solutions have TD velocities on the order of 6 cm/s
- Uncertainty on first touch down dispersion depends mainly on uncertainty on release velocity
- No targeting possible when releasing from outside SOI
- 86% landing probability from 200m with 10 m relative
  position error, 1 cm/s, 0.9 restitution coeff.

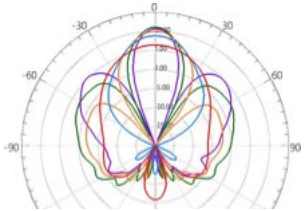


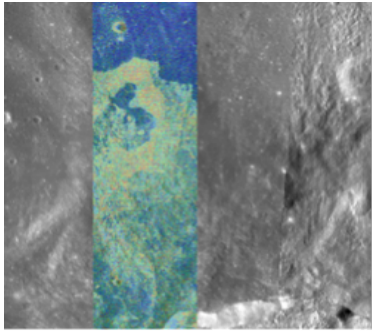


HIGH-FREQUENCY RADAR

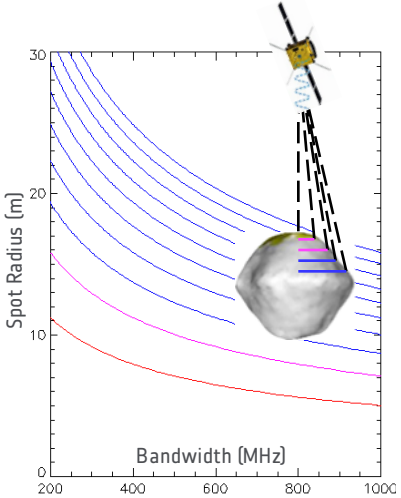


Stepped frequency radar ops from 300MHz to 2.4GHz (potentially extended to 3GHz) based on WISDOM heritage, 108W power, 2.86kg, 200Gb, 37 x 37 x 27 cm^3.

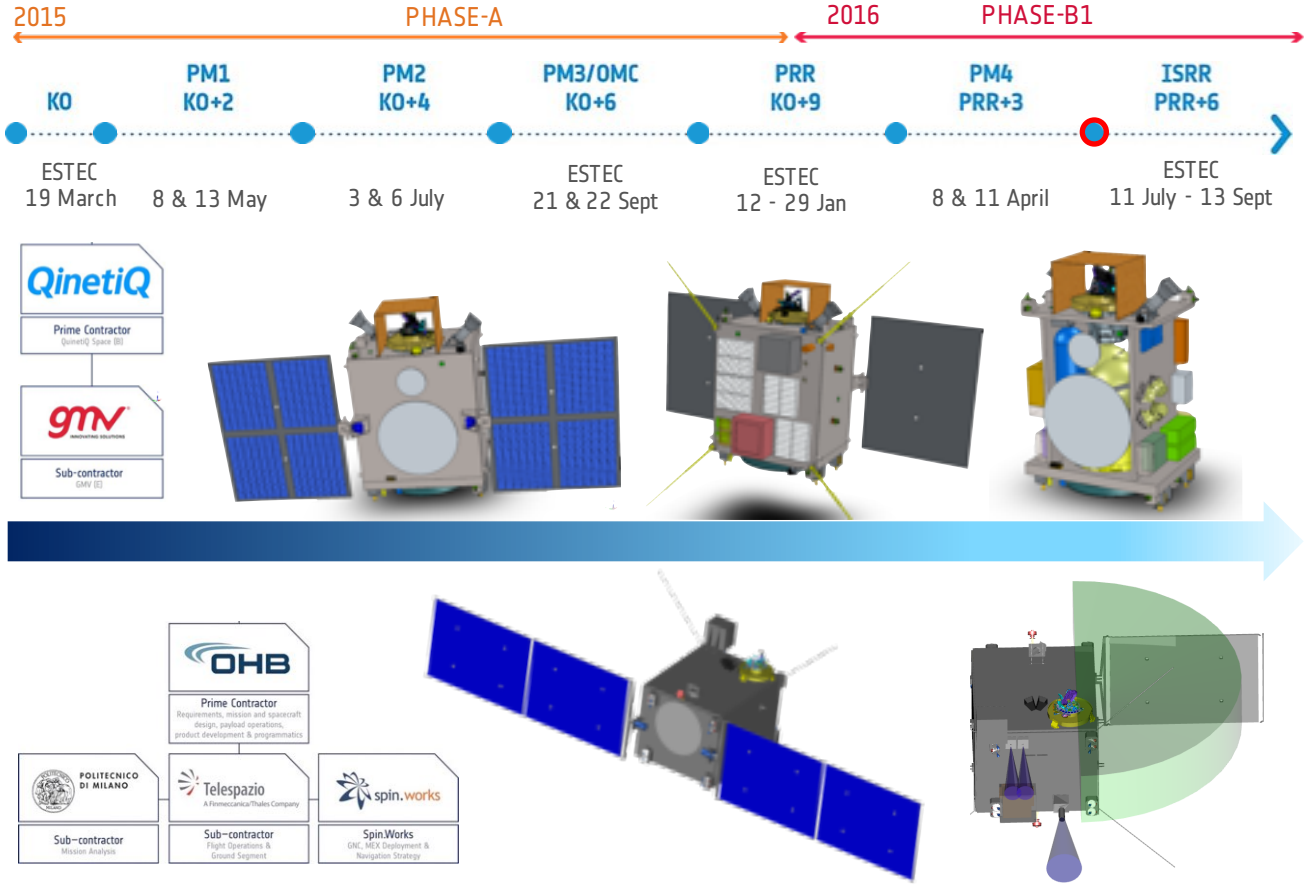




1. **Primary**
   - determine **structure and layering of shallow sub-surface**
   - **map the spatial variation of the regolith texture** related to the size and mineralogy of the constituent grains and macro-porosity
   - study **2-D distribution of geomorphological elements** (rocks, boulders, etc.) embedded in the subsurface
   - estimate the **dielectric permittivity** of the sub-surface material
2. **Secondary**
   - support asteroid **mass determination, shape modelling and orbit characterisation**
   - support **ground-based bi-static radar measurements** Arecibo, Goldstone, SRT
   - **observe ejecta cloud**
   - search for the presence of **particles surrounding Didymoon**
3. **Tertiary**
   - **altimeter** for GNC and collision (requiring onboard near real-time processing)



CURRENT SYSTEM ACTIVITIES (B1)



→ ENABLING APPROACH

- Cost and schedule driven
- Platform and payload "integrated" teams
- Early OPS and FDyn teams support
- Early GNC testing and validation in lab
- Reuse of flight spares (e.g. DAWN NavCAM)
- Leveraging on previous techno developments for Marco Polo/-R, Phobos SR, Lunar Lander…

CURRENT PAYLOAD ACTIVITIES

→ HERITAGE — 2015 — 2016 — → AFTER AIM

MASCOT–2 & LFR

MASCOT
CONSERT

15 April (KO) — 29 May (PM1) — 22 Jul (MCR) — 2 Oct (CEF) — 26 Oct (PM2) — 22 Jan (PRR) — 25 Feb (Final review)

Exploration

OPTEL–D

Optel-μ
LADEE

1 Oct (KO) — 27 Jan (SRR) — 8 Apr (PDR) — 17 Jun (CSTR) — 26 Aug (CDR) — 30 Sep (FP)

Mars, human exploration, L-missions

HFR

WISDOM

30 April (KO) — SRR (29 Jun) — 14 Sept (MTR) — 14 Dec (SDR) — 7 Jan (SPR) — 4 Mar (Final review)

Planetary exploration

COPINS

Aalto-1, Picasso, Xatcobeo, HumSat-D, Optos, SEAM...

9 Oct (KO) — 17 Nov (KUDOS) — 8 Feb (PM1) — 10 June (Final review)

ESA CDF Study (July)

Earth observation, lunar explo

TIRI

MERTIS, CAMIR, Hypercube...

Mar — Dec

RDV & docking EOP, planetary

μCAM

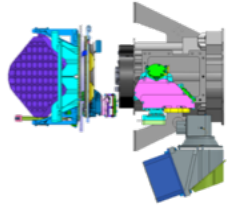
CIVA, X-CAM, Clupi...

Jan — July

CubeSats, Exploration

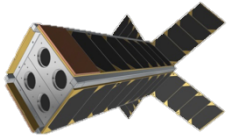
ONGOING TECHNOLOGY

→ Optical comm



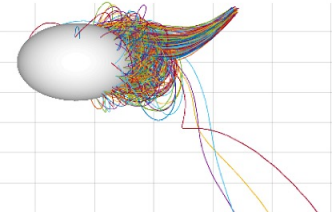
- EBB preliminary testing based on Optel-µ components
- OGS in Tenerife based on developments for LADEE
- TDAs already ongoing: steering mirror, tracking camera, µ-pointing assembly, pulse laser transmitter, otical fiber amplifier
- Multi-purpose laser (altimeter, comm, imager) under detailed study

→ Cubesats

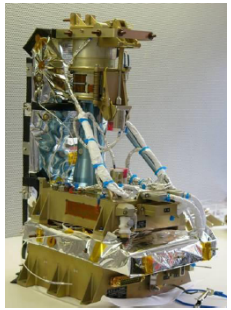


- 5 concepts under study based on TRL (LEO heritage, incl. payload) and scientific return (complementarity to AIM)
- Low-speed CubeSat deployer testing (synergies with LEO)
- Flexible inter-satellite link with embedded ranging defined
- Advanced µ-camera design

→ GNC



- NavCam HIL test at robotic facility in Madrid
- Autonomy concepts for lander delivery, high-fidelity navigation analysis
- FDIR based on sensor data fusion
- Optical/infrared navigation
- Drop-tests & surface interaction modelling



AIM SCHEDULE

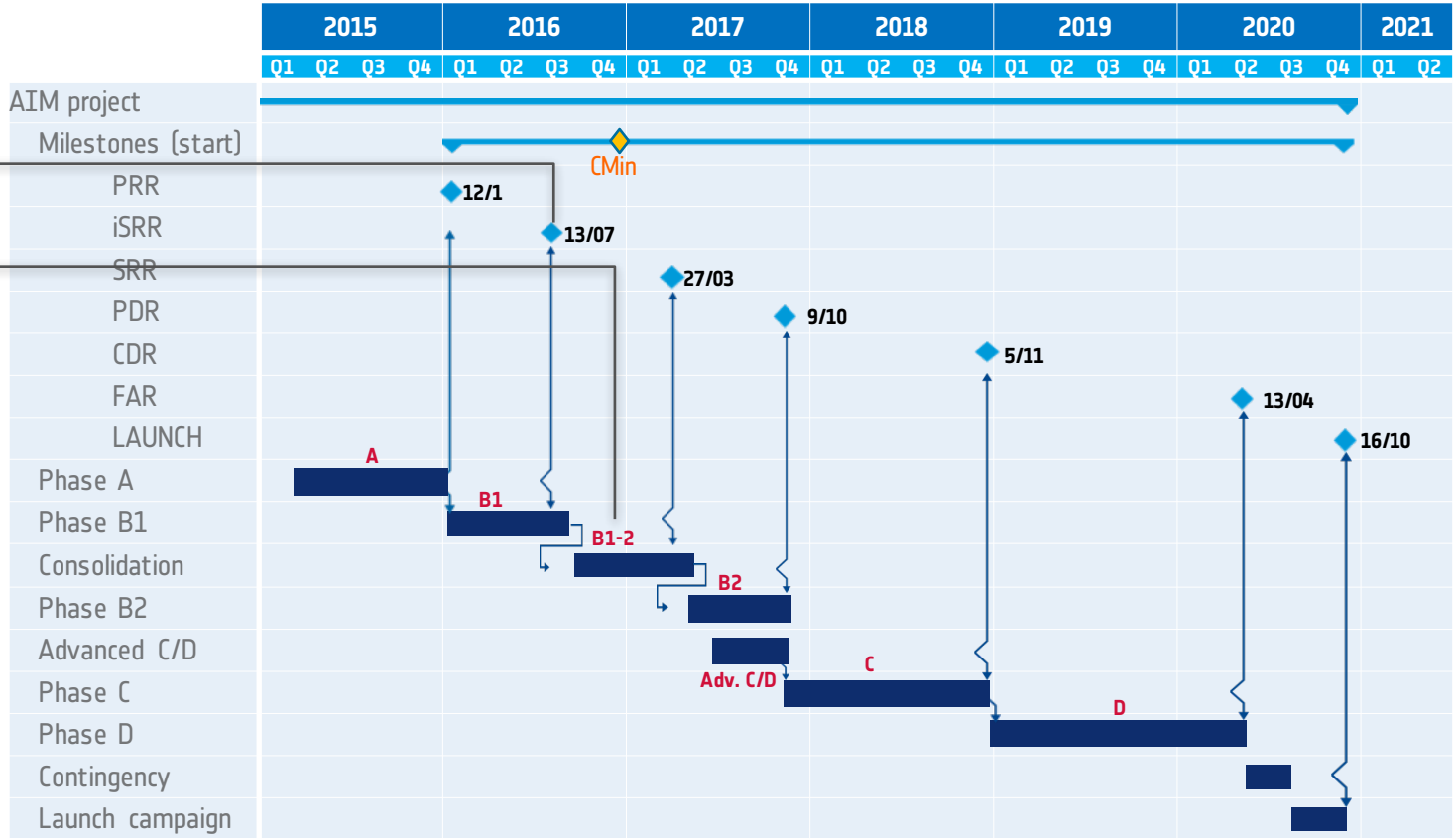
→ NEXT STEPS

B1 iSRR in July

ITT consolidation phase release in June:

- finalize s/c design
- build consortium
- single team, GNC, payload…

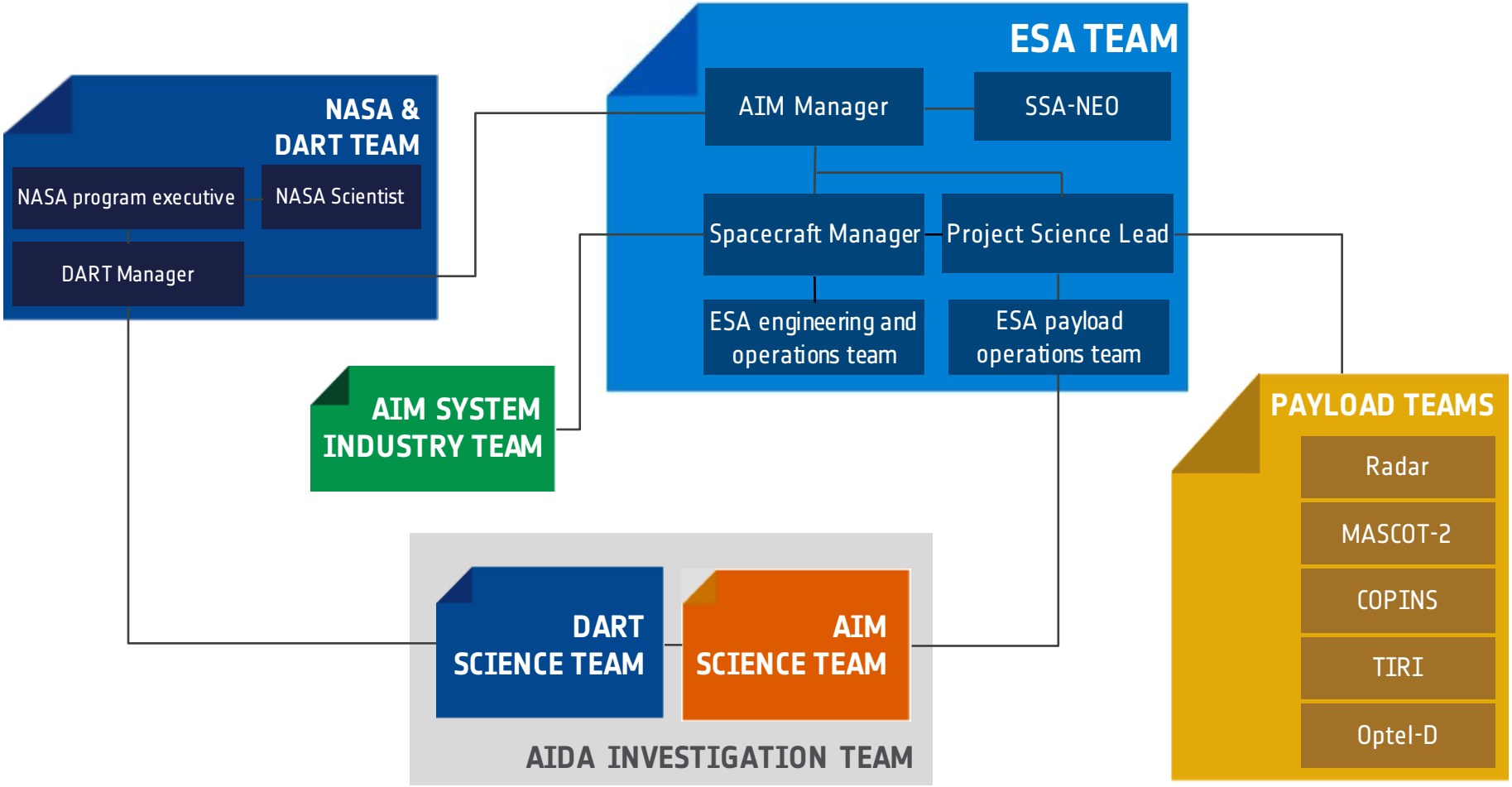
preliminary MS feedback on potential interest for payload opportunities is welcome



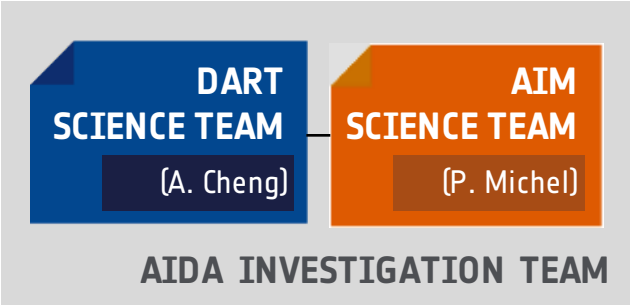
For more information

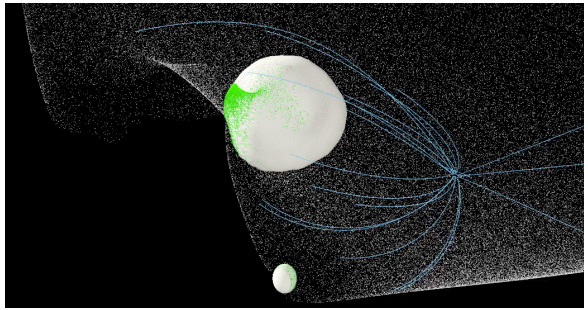
www.esa.int/AIM

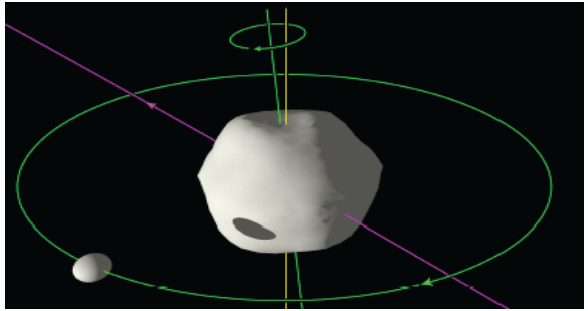
ian.carnelli@esa.int


ESA TEAM
AIM Manager
SSA-NEO
Spacecraft Manager
Project Science Lead
ESA engineering and operations team
ESA payload operations team
NASA & DART TEAM
NASA program executive
NASA Scientist
DART Manager
AIM SYSTEM INDUSTRY TEAM
PAYLOAD TEAMS
Radar
MASCOT-2
COPINS
TIRI
Optel-D
DART SCIENCE TEAM
AIM SCIENCE TEAM
AIDA INVESTIGATION TEAM

AIDA INVESTIGATION TEAM







W1 Modelling and simulation of impact outcomes
(A. Stickle/JHU-APL, P. Miller/LLNL, R Schwartz/OCA)

W2 Remote sensing observations
(A. Rivkin/JHU-APL, P. Pravec/Ondrejov Obs.)

W3 Dynamical and physical properties of Didymos
(D. Richardson/Univ. Maryland, K. Tsiganis/Univ. Thessaloniki, A. Bagatin/Univ. Alicante)

W4 Science proximity operation
(S. Ulamec/DLR, O. Barnouin/JHU-APL)