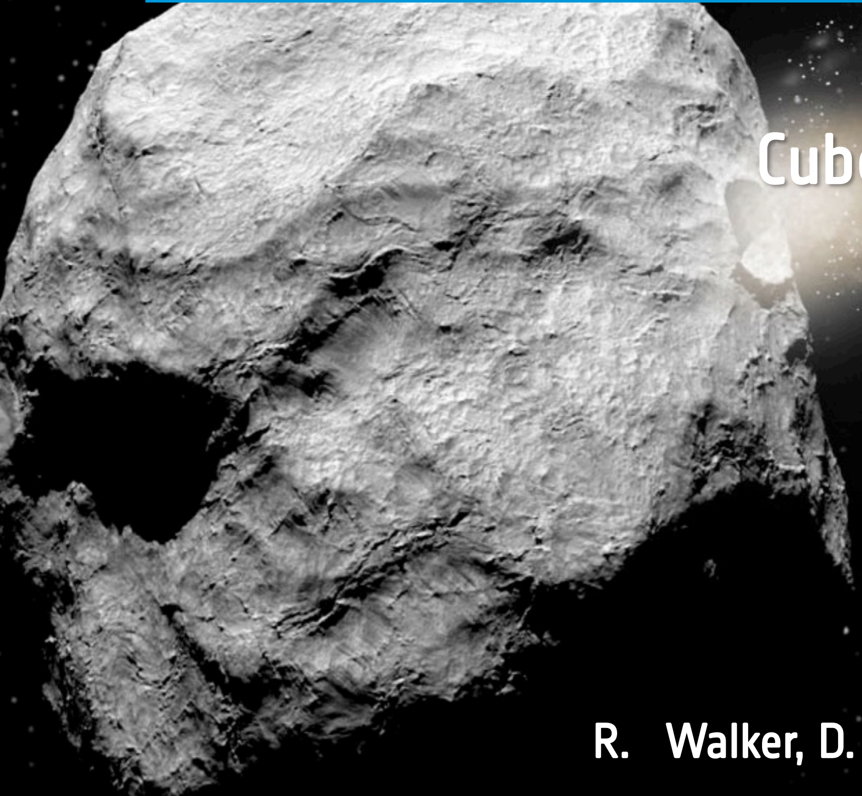
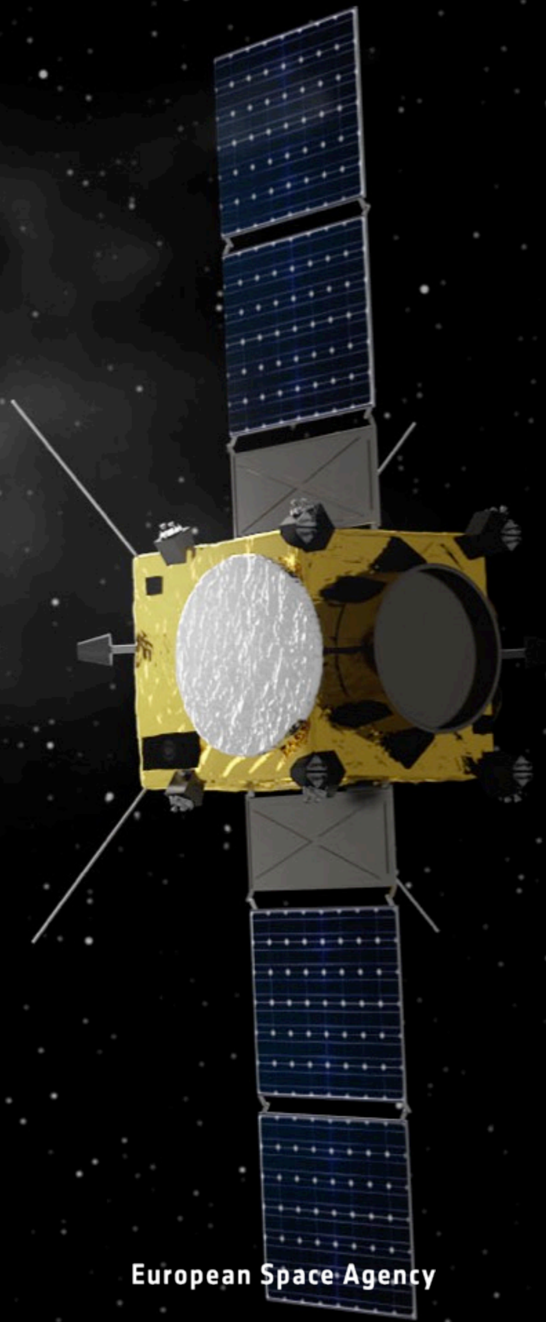
→ ASTEROID IMPACT MISSION



CubeSat Opportunity Payload Inter-satellite Network Sensors (COPINS)

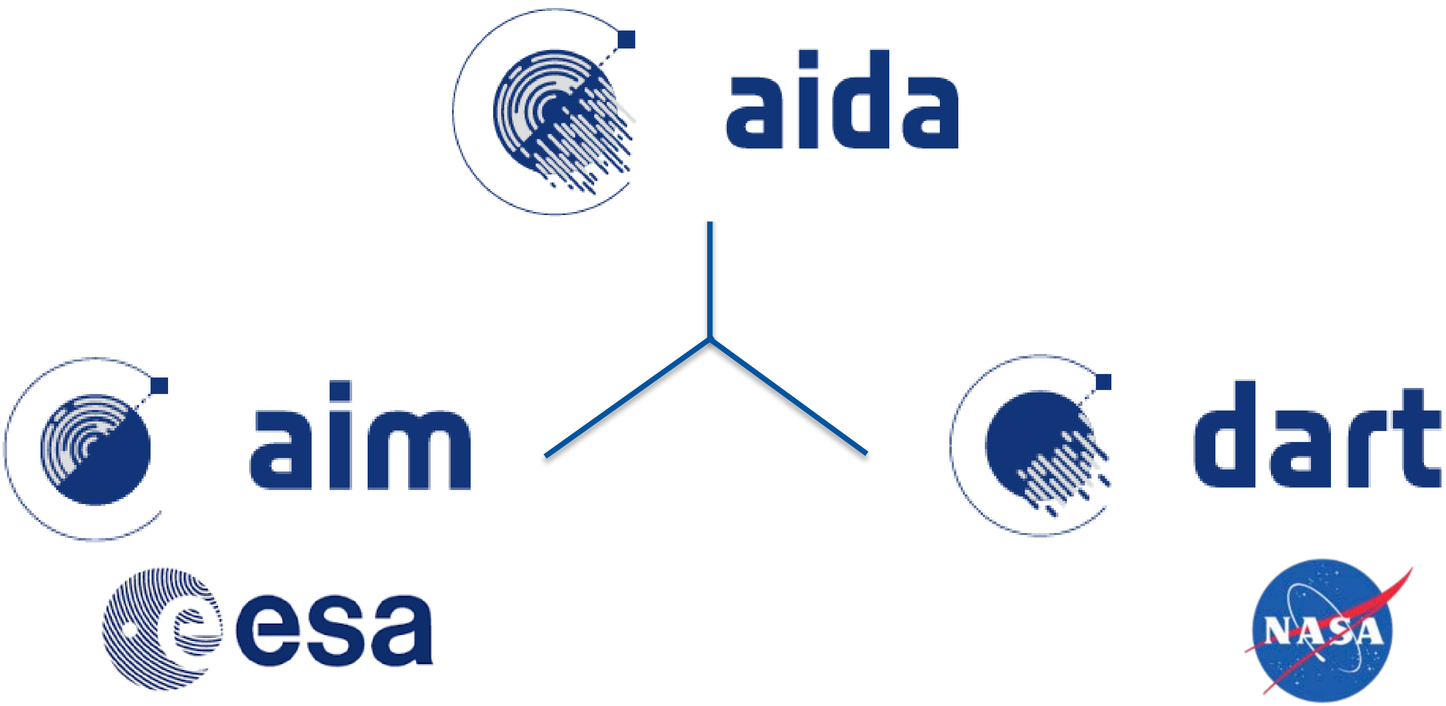


R. Walker, D. Binns, I. Carnelli, M. Keuppers, A. Galvez

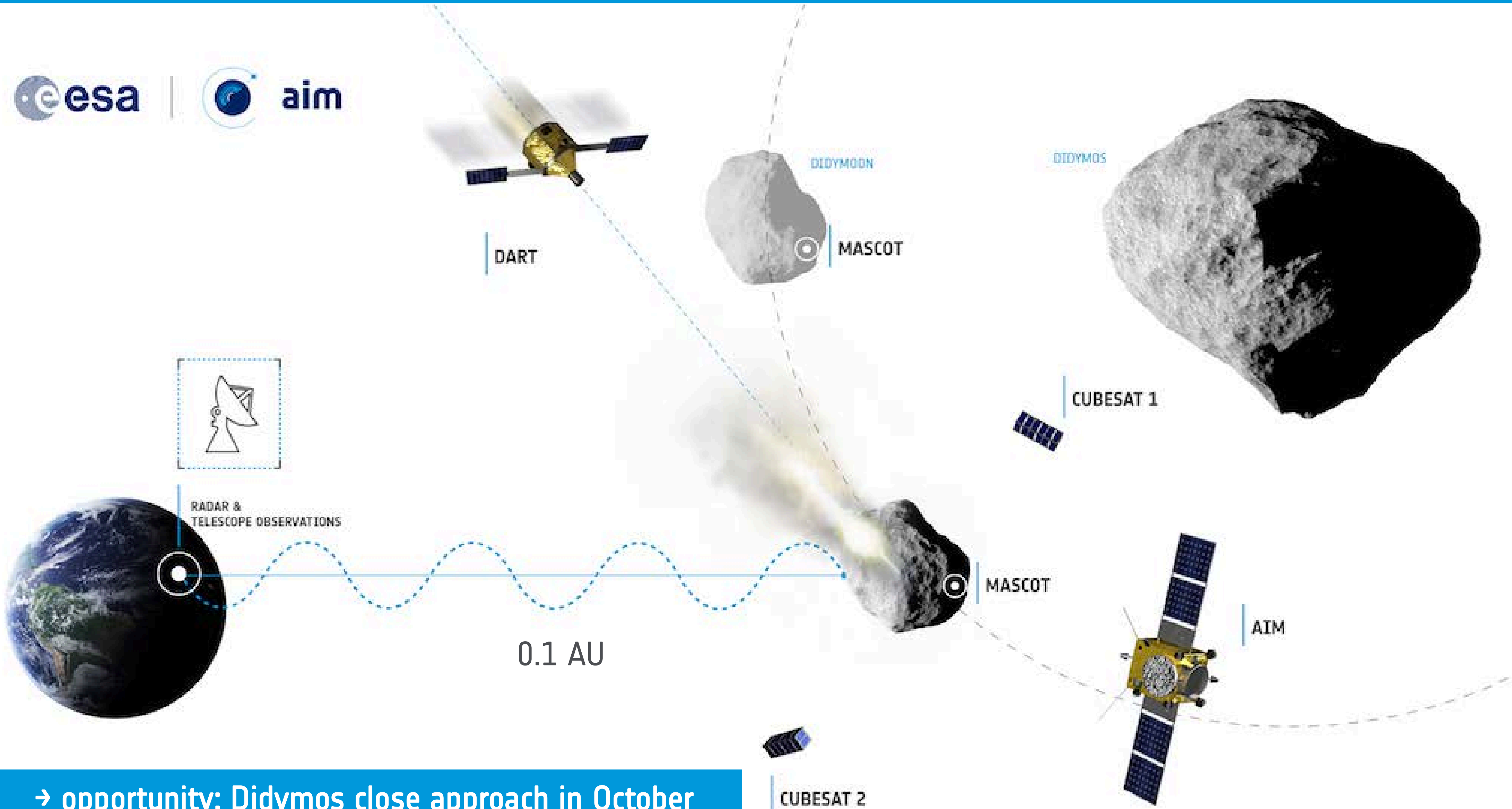
European Space Agency

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 in October 2022 asteroid, target and impact date are fixed

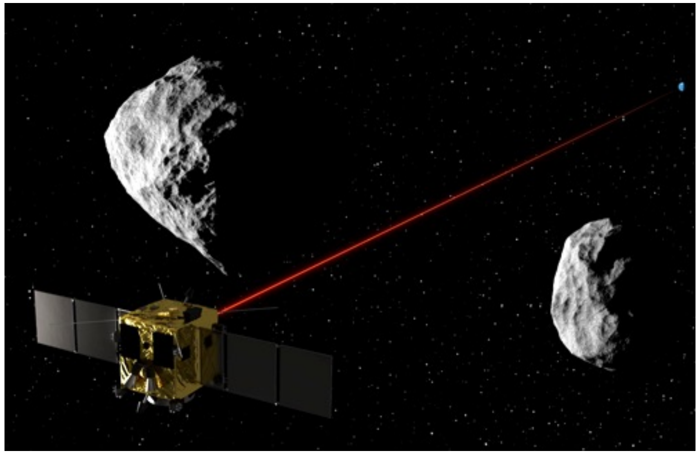
ASTEROID IMPACT MISSION (AIM)

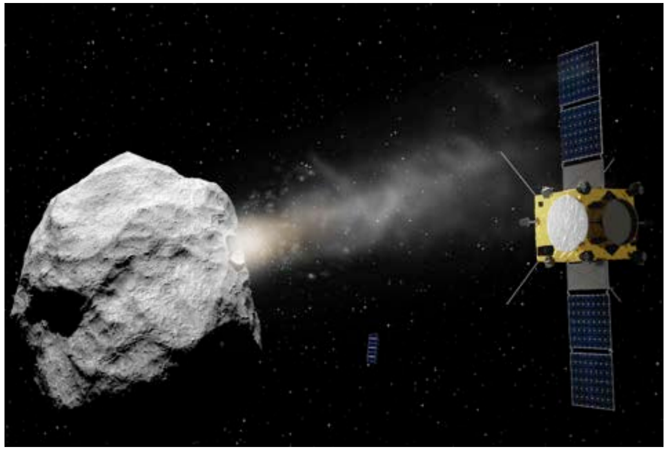
Small mission of opportunity to explore and demonstrate technologies for future deep-space missions while addressing planetary defense objectives and performing asteroid scientific investigations.

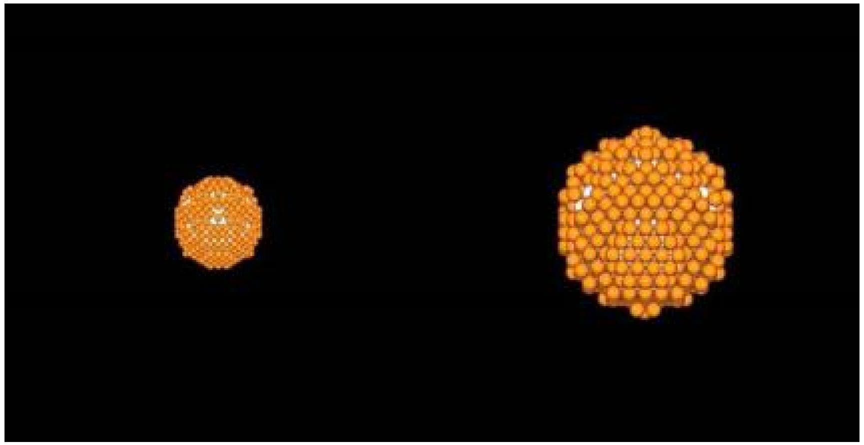
TECHNOLOGY DEMONSTRATION

ASTEROID IMPACT MITIGATION

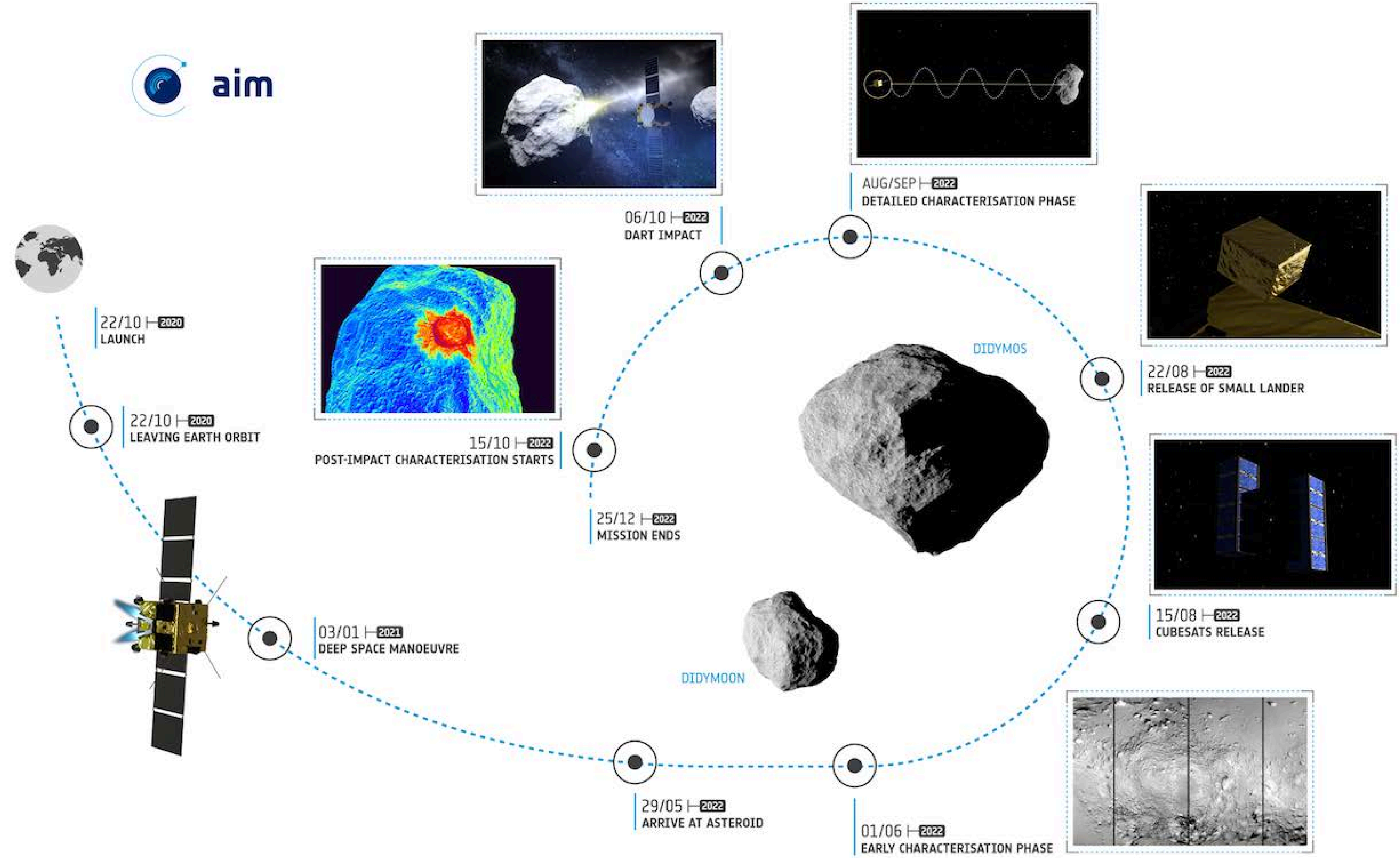
SCIENCE



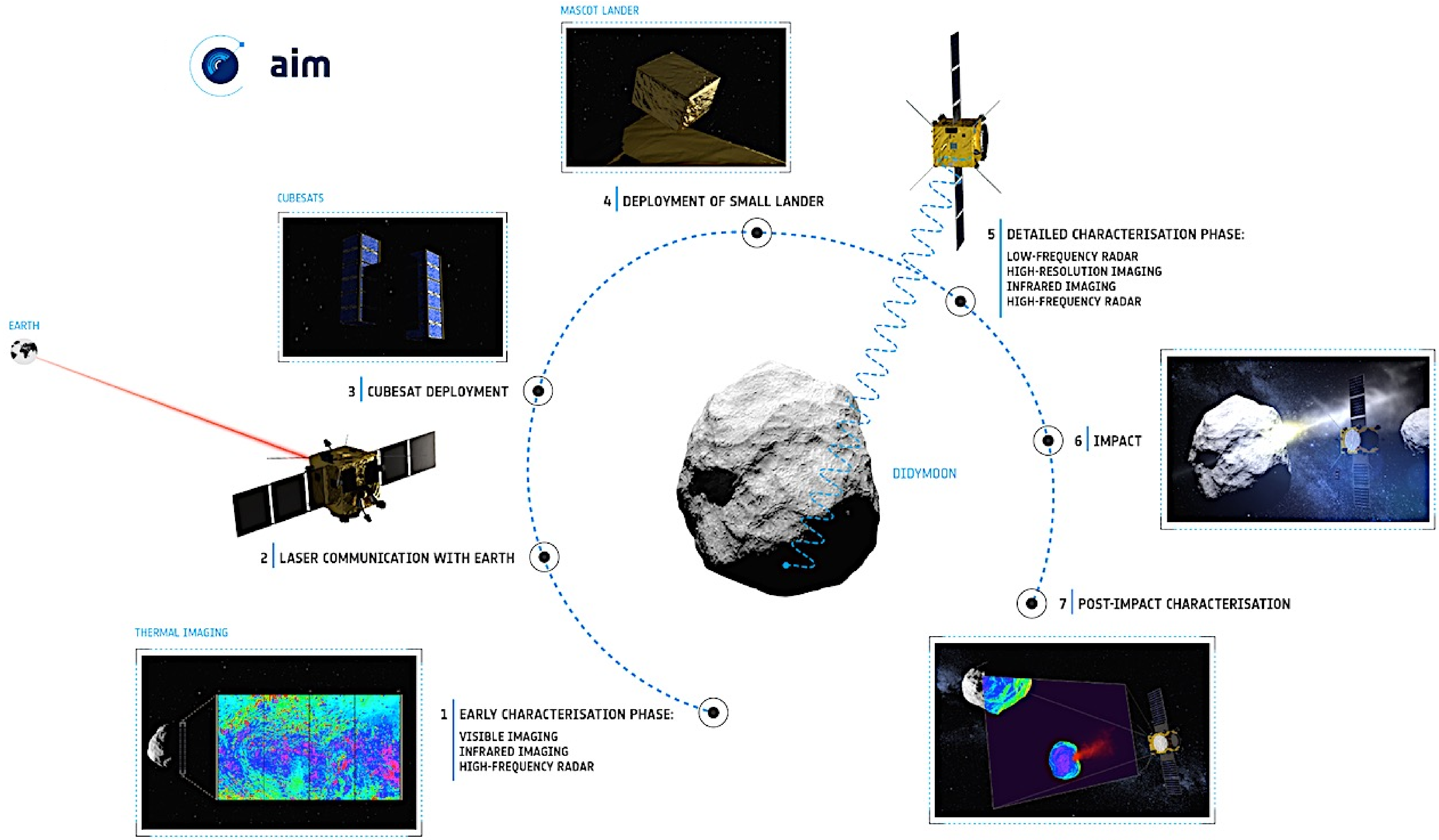




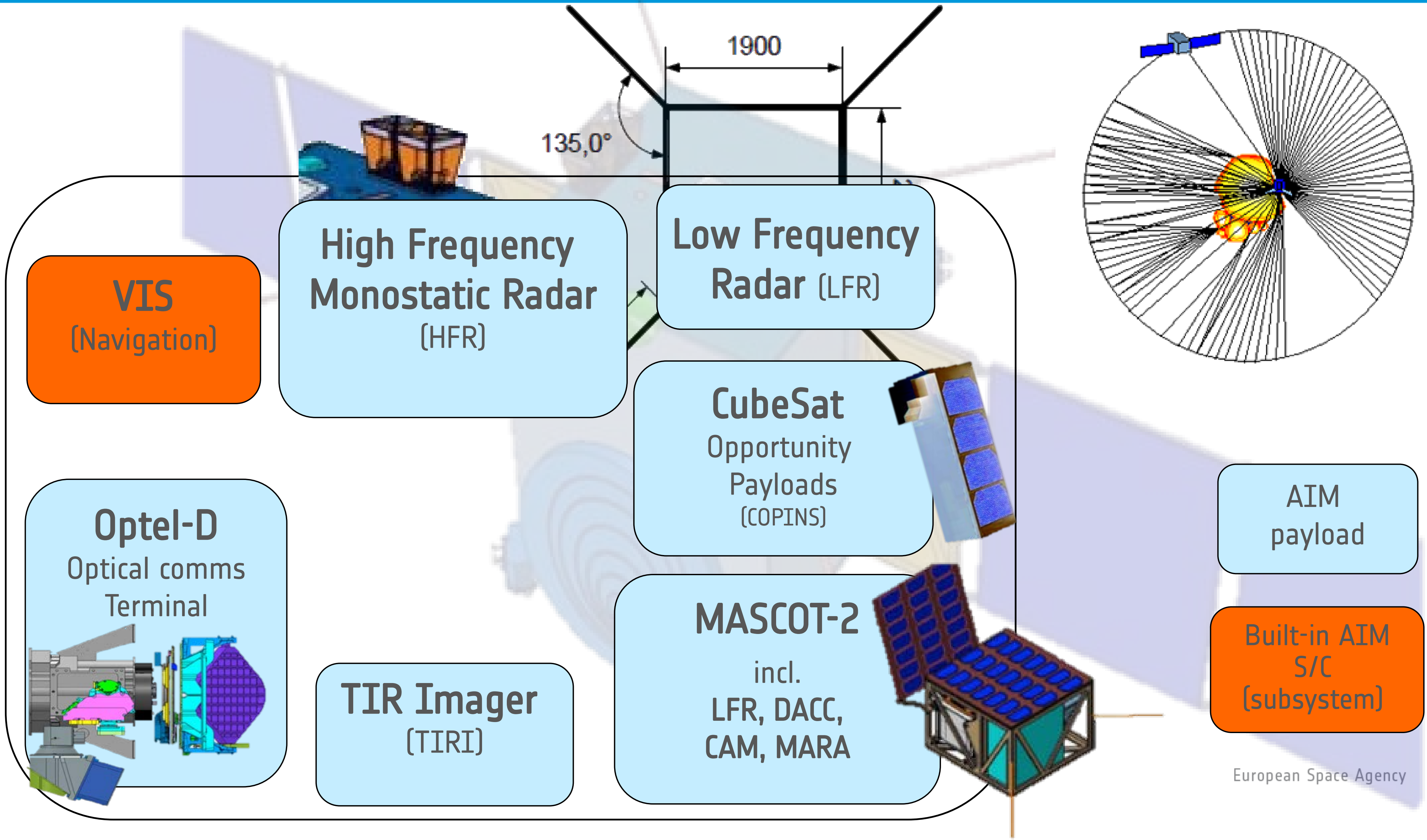
AIM MISSION SCENARIO



AIM CLOSE PROXIMITY OPERATIONS SCENARIO



AIM PAYLOAD


1900
135,0°
VIS
(Navigation)
High Frequency Monostatic Radar
(HFR)
Low Frequency Radar (LFR)
CubeSat
Opportunity Payloads
(COPINS)
Optel-D
Optical comms Terminal
TIR Imager
(TIRI)
MASCOT-2
incl.
LFR, DACC, CAM, MARA
AIM payload
Built-in AIM S/C (subsystem)
European Space Agency

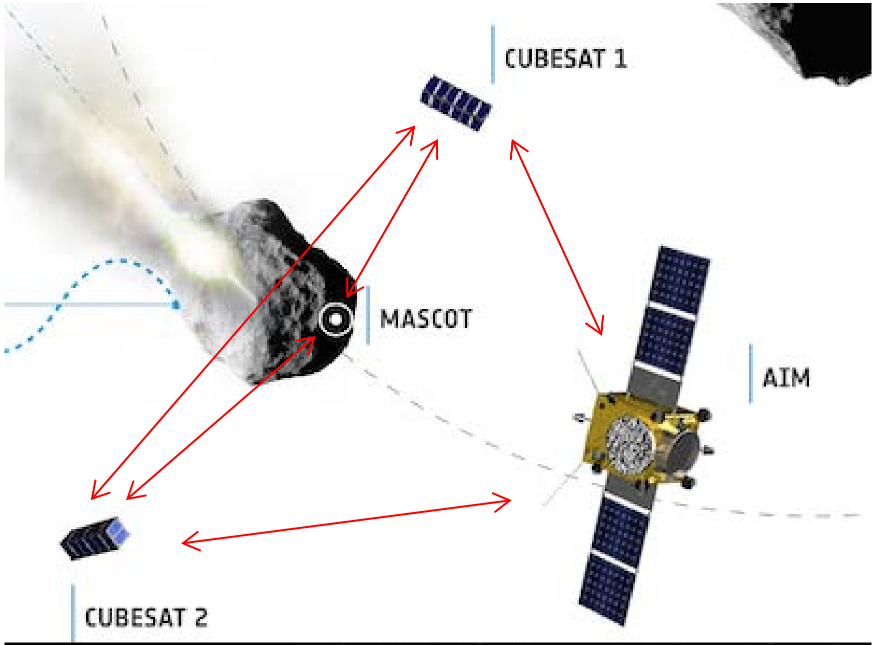
COPINS OBJECTIVES & CONSTRAINTS

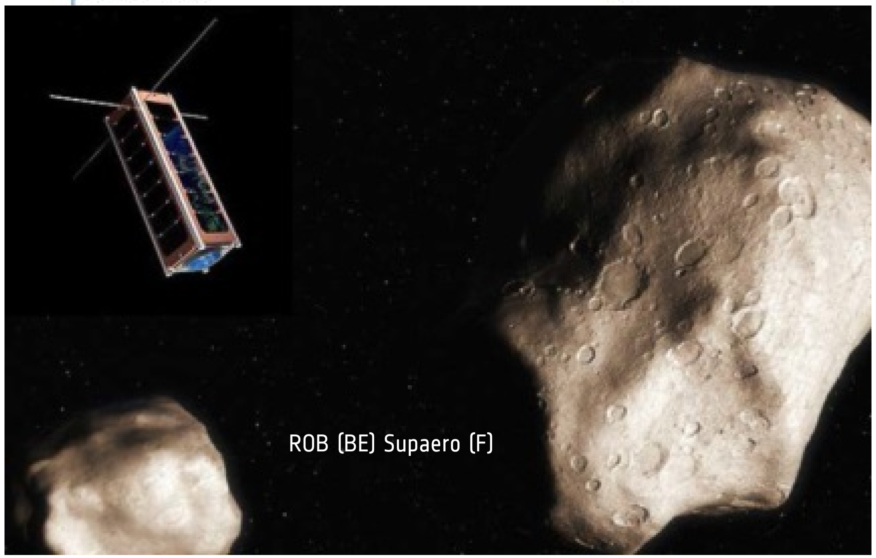
Technology Demonstration Objectives:
- Inter-satellite Networking of sensors in deep space between AIM, CubeSats & MASCOT-2 lander
- Low-velocity deployment and autonomous operation of multiple spacecraft in close proximity to Didymos
- Driver for Tech Miniaturisation (optics, RF etc...)

Science Objectives:
- Remote sensing and in-situ measurements
- Contribution to AIM mission objectives
- Complementary to other AIM payloads

Constraints:
- 2 x 3U CubeSat deployers => up to 6U available
- Total Mass <9 kg
- 3 months operations + 1 year storage during cruise
- S-band ISL unit and antenna(s) provided by ESA:
  - o Up to 0.5 Mbps data rate over 10 km range
  - o 1 m ranging between network nodes

o Space-ground data limit: 1 kbps for COPINS part





CONCEPT OF OPERATIONS

Deployment:
- Injection into stable orbit around Didymoon or onto landing trajectory (same as MASCOT-2)
- Separation velocity << Didymos escape velocity (!)

Close proximity operations:
- Orbiters: orbit acquisition and maintenance manoeuvres
- Landers: surface operations in adverse illumination/thermal environment
- Measurements before/during/after impact
- Post-impact survivability TBC (AIM at extended range)

Major Technical Challenges:
- Full autonomy between AIM-Earth daily comms windows
- Inter-satellite data networking between COPINS and AIM independent of relative position/attitude, line-of-sight
- Autonomous GNC relative to AIM and Didymos:
  - Range-only measurements wrt AIM
  - Optical tracking of Didymos centres of brightness
  - Manoeuvres in low gravity field

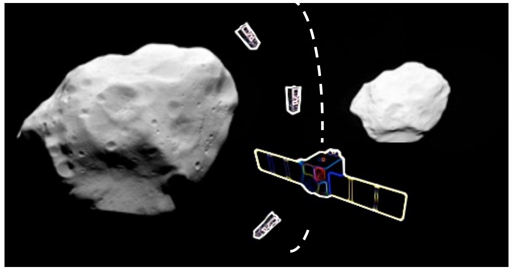
VTT/Aalto (FI)

COPINS DEFINITION PROCESS

STEP 1: science & technology evaluation

Q3 2015

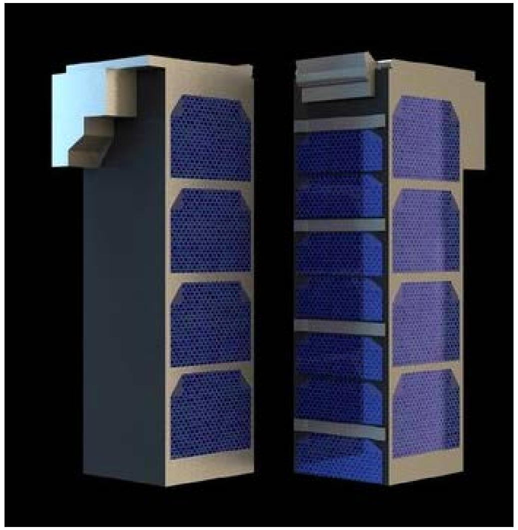
- Evaluate science opportunities offered by CubeSats using ESA SysNova scheme -> technical challenge in open competition
- 5 parallel studies awarded for COPINS mission concept definition



STEP 2: mission consolidation

Q3 2016

- Review of COPINS mission concept studies -> Sysnova winner(s)
- Completion of supporting technology studies
- Perform ESA CDF study
- Define platform & payload technology developments



STEP 3: implementation

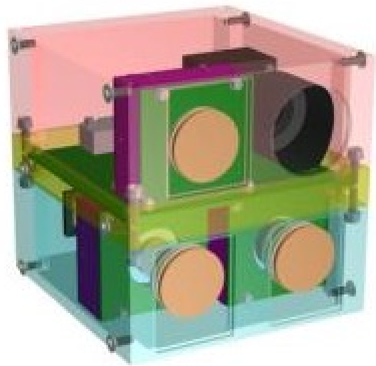
- Confirm ESA MS support and release COPINS AO for CubeSat selection, implementation & FM delivery — Q1 2017
- Development of ISL & COPINS deployers
- Integration of CubeSat FMs with deployers & delivery to AIM — Q4 2019

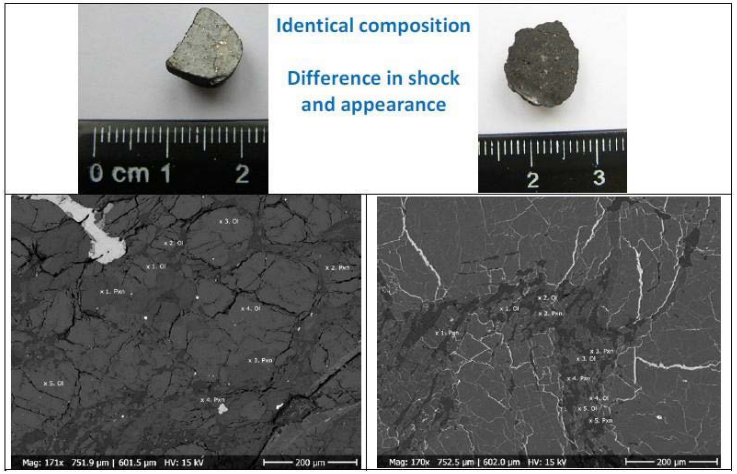
Concept Study #1:
ASPECT (VTT, Uni. Helsinki, Aalto Uni. FI)

Asteroid Spectral Imaging (ASPECT) Mission Concept

"Composition of the Didymos asteroid and the effects of space weathering and shock metamorphism in order to gain understanding of the formation and evolution of the Solar System."

- Measure of reflectance spectra
- Space Weathering
- Shock experiment
- Plume Observations
- Spectral observations *and* modelling





The network of molten metal and sulfide veins in the dark-colored lithology acts as the darkening agent (Kohout et al. 2014).

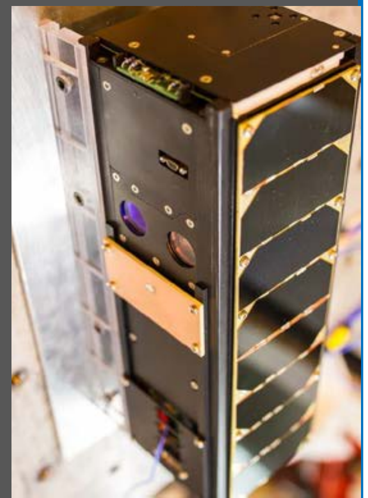
Proposed Payloads

Imaging Spectrometer

- VIS: 500-900 nm, 20 bands, 1 m GSD
- NIR: 900-1600 nm, 20 bands, 2 m GSD
- SWIR: 1600-2500nm, 20 bands, 1 pixel
- FoV 6^0
- 96 x 96 x 100 mm, 900g, 7 W
- TRL 6
- Aalto-1 heritage, space qualified

CubeSat Mission Design

- 3U CubeSat
- 4.5 kg, 10 W gen.
- < 1^0 Pointing accuracy
- Star tracker & wheels
- Aalto 1&2 heritage
- 4 km alt. deployment, orbit around binary
- Propulsion DV 1 m/s for orbit maintenance & RW offloading

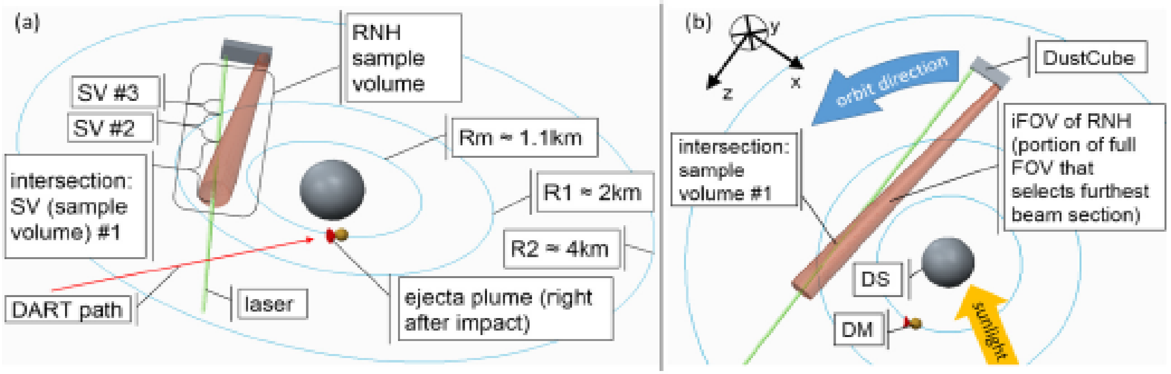


Concept Study #2: DustCube (Uni. Vigo, Uni. Bologna, MICOS)

DustCube Mission Concept

“Complementing the sensing capabilities of AIM, to better characterize the ejected dust plume after impact. Over a full scattering angle range, retrieval of size, shape, and refractive index of the grains.”

- Size, shape, refractive index and concentrations of ejected dust
- Constrain mineralogical composition
- Compliment the demonstration of the end to end optical communications system TEX
- Aid the study of interplanetary dust evolution.
- Measure the BRDF of the asteroid surface



Proposed Payloads

In-situ Nephelometer (TRL2/3)

- Heritage from PI-Neph
- CCD Camera FOV 45^0

Remote Nephelometer (TRL 3)

- CCD camera 2^0 FoV, 500x500 pixels
- Avalanche Photodiode for ToF
- Laser diode 780-905 nm, 2 W power

CubeSat Mission Design

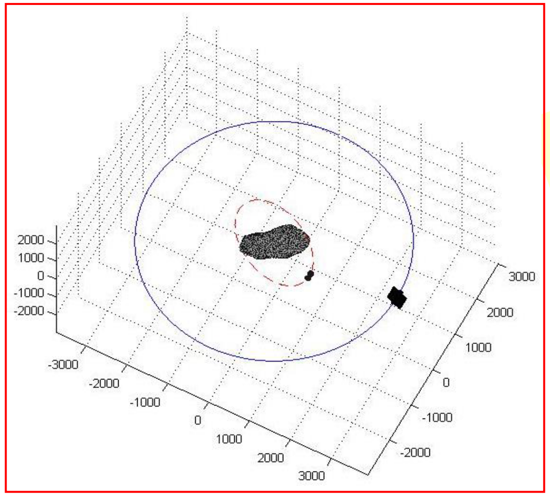
- 3U CubeSat
- Xatcobeo and HumsatD heritage
- Cold gas propulsion for 2 m/s DV
- 2 deployable solar panels
- Optical IR rel. navigation wrt asteroid
- Star tracker & Reaction wheels
- 4.2 kg, 5 W generation
- Deployed by AIM into 3-5 km orbit, transfer to L4/L5 orbit pre-impact, DRO 280 m alt. post-impact

Concept Study #3:
CUBATA (GMV, Uni. La Sapienza, INTA)

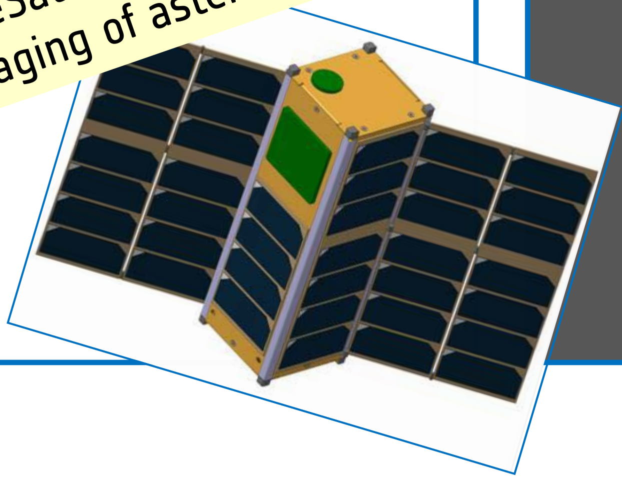
CUBATA Mission Concept

"Measurement of the gravity field of the Didymos system before and after the impact and the observation of the DART impact."

- Determine the gravity field of the Didymos system before and after the impact.
- Observe the impact from DART from a short range and its effects
- Determine the velocity field of the ejecta



- Doppler tracking between CubeSats
- Imaging of asteroids



Proposed Payloads

Camera Payload

- FoV 36^0, 320g
- 1 m resolution at 1 km, 5-10 fps
- OPTOS CubeSat heritage

Radio Payload

- Cube-Cube LoS tracking
- S-Band Transponder, 250g, <10W
- Ultra-Stable Oscillator, 200 g, 4W

CubeSat Mission Design

- 2 x 3U CubeSats
- Deployed approx. 4-5 km alt. polar
- Ops: Sun-synch terminator orbit 1.5 km
- 30° phase angle between s/c
- 45° shift in orbit plane for impact obs
- Propulsion system DV 1.5 m/s
- Star tracker + wheels, 1 deg APE
- Optical navigation relative to asteroid
- 4 Deployable solar panels 24W
- 4.5 kg

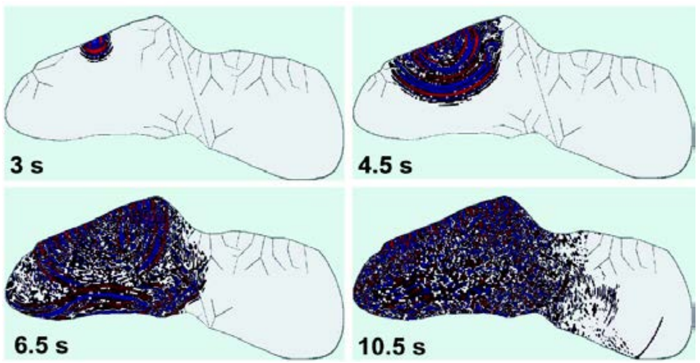
Concept Study #4: AGEX (ROB, ISAE Supaero, Emxys, Antwerp Space)

Asteroid Geophysical Explorer (AGEX) Mission Concept

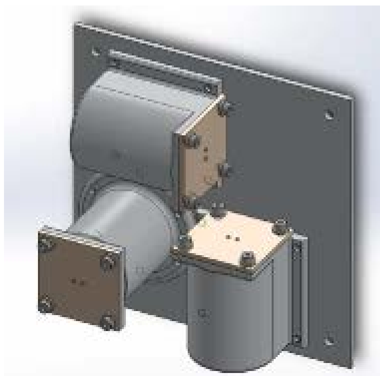
"Determination of dynamical state, geophysical surface properties, subsurface structure and the assessment of the DART impact on the asteroid dynamic properties."

- Mechanical properties of the surface material
- Seismic properties of the sub-surface (<10m)
- Rotational kinematics prior to the DART impact
- Surface gravity -> constraint on the bulk mass and density
- Global scale accelerations/surface motions from DART impact

Seismic wave propagation post-impact



Geophones



Proposed Payloads

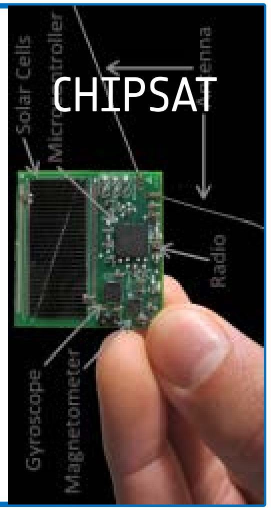
3-axis seismometer
- Commercial geophones (TRL 4)
- 5-250 Hz, 80 ng noise floor

Accelerometers (TRL 6)

3-axis Gravimeter (TRL 2/3)
- 0.05 mGal sensitivity

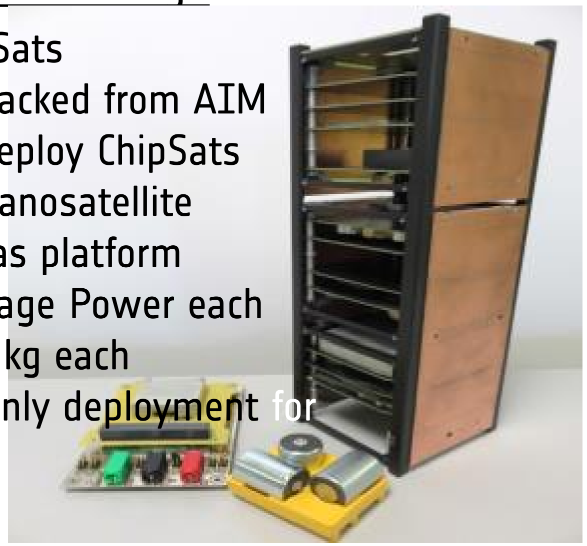
Budgets: 1.3 kg, 2W, 0.9U

30 chipsats deployed over surface



CubeSat Mission Design

2 x 3U CubseSats
- Lander, tracked from AIM
- Orbiter: deploy ChipSats
- NAOSat nanosatellite selected as platform
- 6 W Average Power each
- Around 3 kg each
- Ballistic only deployment for landing

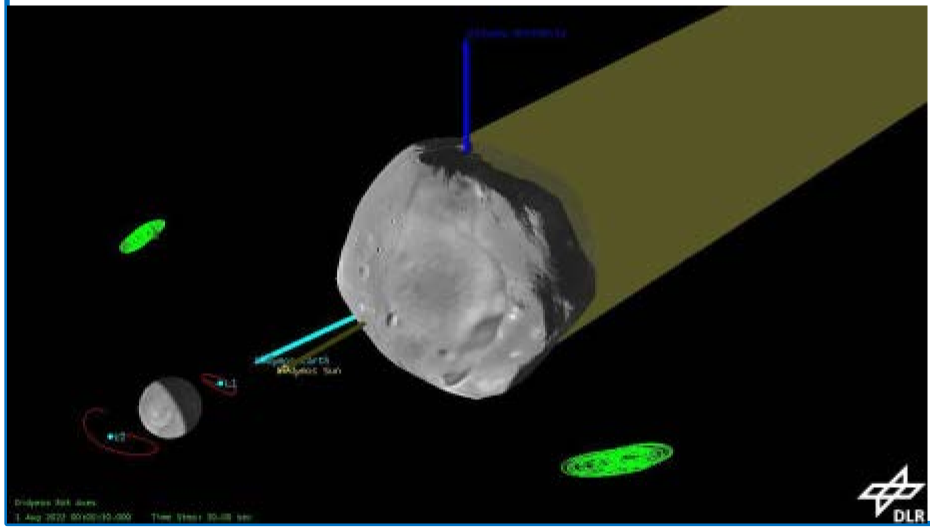


Concept Study #5: PALS (Swedish Institute of Space Physics, KTH, DLR, IEEC, AAC Microtec)

PALS (Payload of Advanced Little Satellites) Mission Concept

"The CubeSats will characterise the magnetization, the main bulk chemical composition and presence of volatiles as well as do super-resolution surface imaging of the Didymos components impact ejecta."

- Magnetization of primary and secondary.
- Composition of volatiles around primary and secondary.
- Composition of volatiles released from the DART impact site.
- Super-resolution surface imaging from close range
- DART impact and plume observations at close range.



Proposed Payloads

Hugin:

- Narrow Angle Camera (TRL 5-7)
- Volatile Composition Analyser (TRL 4)

Munin:

- Fluxgate Magnetometer (TRL 5)
- Video Emission Spectrometer (TRL 5-7)

Payload volume: 1U / CubeSat

CubeSat Mission Design

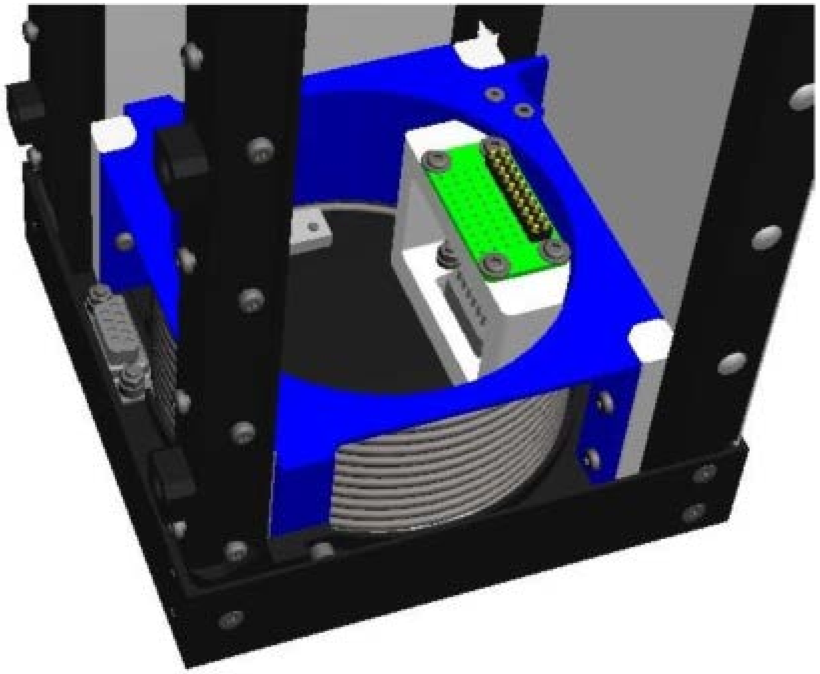
2 x 3U CubeSats (Hugin & Munin)

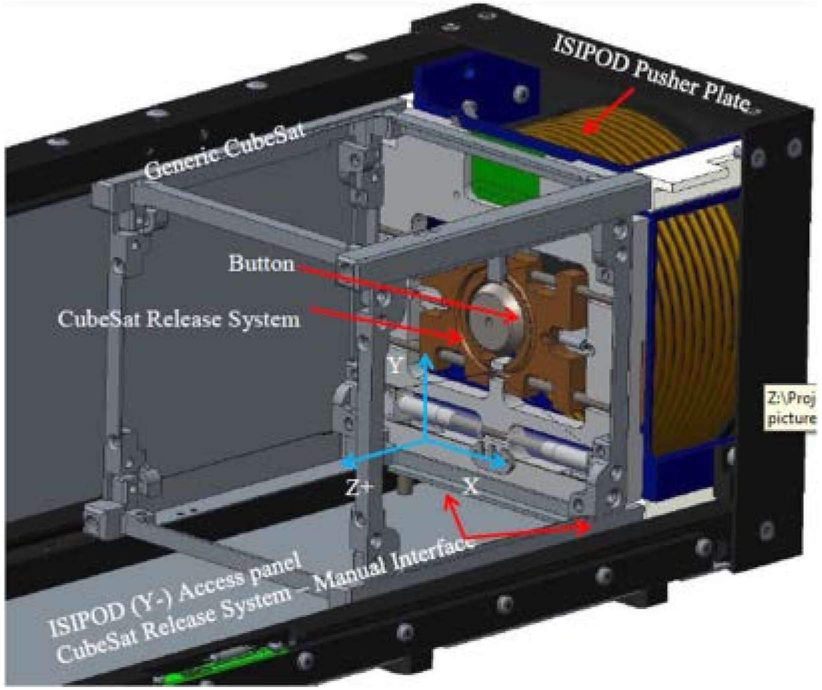
- Tour of Lagrange points
- Propulsion: 12.5 m/s DV
- AOCS: Star tracker + wheels
- Optical relative navigation
- Magnetic cleanliness
- 2m boom for magnetometer
- 4 Deployable solar panels
- SEAM/SPARC bus heritage
- Mass 4.5 kg; 15W power

Low-velocity Deployer Technology Study

Required functions:

- Accommodation/radiation shielding of 3U CubeSat during cruise
- Provision of power/telemetry interfaces to CubeSat during cruise
- Separation of CubeSat at low-velocity: 2-5 cm/s (+/- 1 cm/s)





Design concept:

- Adaptation of the ISIPOD deployer (ISISpace NL) with LEO heritage
- Release system on pusher plate activated after spring extension

Conclusions

1. COPINS payload on the proposed ESA AIM mission will enable European CubeSats to venture into deep space for the first time & become the first CubeSats to explore an asteroid

2. Piggyback on a larger ESA mission avoids severe technical challenges of propulsion and communications associated with deep space CubeSats

3. COPINS CubeSats support the AIM mission objectives and enhance the overall mission return in complement with the other payloads, by subjecting them to higher risk scenarios (post-impact)

4. Validation of Inter-satellite Links and deep space autonomous operations of multiple nano-spacecraft with a larger s/c in a "mother + daughters" architecture is expected to pave the way for other innovative robotic exploration/science mission concepts

Coming soon: LUnar Cubesats for Exploration (LUCE)

esa

ESA SysNova Challenge #4

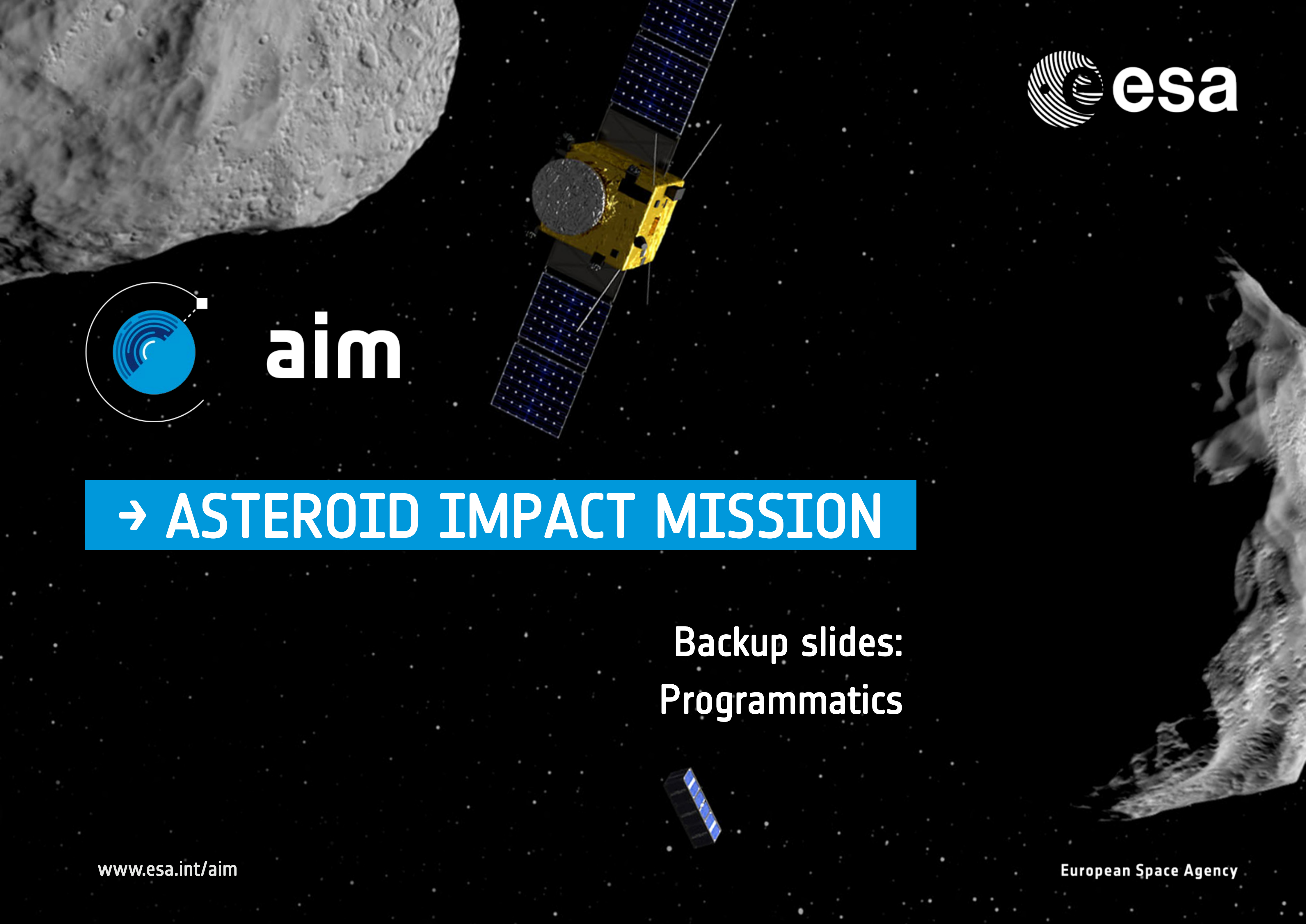
- Open competitive ITT
- Expected Q3 2016
- Proposals from joint academic/industry teams
- New mission concepts involving Nano-sats/CubeSats operating either individually or in (mini)constellations
- Multiple parallel study contracts to be awarded (6 months duration)
- Prize: CDF study for the winner(s)

Objectives:

- Generate lunar exploration Cubesat/Smallsat mission concepts, demonstrating what can be done to support lunar exploration objectives
- Engage and bring together the European Cubesat community with the lunar exploration science and technology community
- Identify key platform and instrument technology needs and drivers for lunar Cubesats
- Support the European community to be able to respond to future lunar Cubesat opportunities (e.g. SLS/Orion, commercial)

Themes:

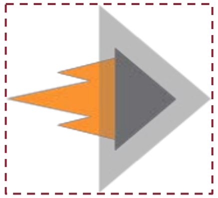
1. Resource prospecting
2. Investigations into the environment and effects
3. Fundamental scientific research
4. Demonstrating new technologies and operational capabilities


esa
aim
→ ASTEROID IMPACT MISSION
Backup slides:
Programmatics
www.esa.int/aim
European Space Agency

AN OPPORTUNITY

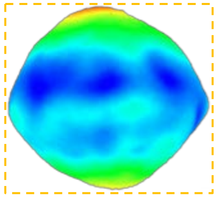
→ SPEED

Fast "return on investments", 2 years from launch (Ariane 6.2)
Asteroid operations: 6 months, favourable for operations
Demonstrate new platform-payload-operations teams integrated approach (schedule-driven optimization)



→ TECHNO

New technology "firsts" applicable to future exploration and science missions based on activities already funded in ESA: laser comm, on-board autonomy, cubesats, advanced GNC
New industries to demonstrate capabilities in deep-space



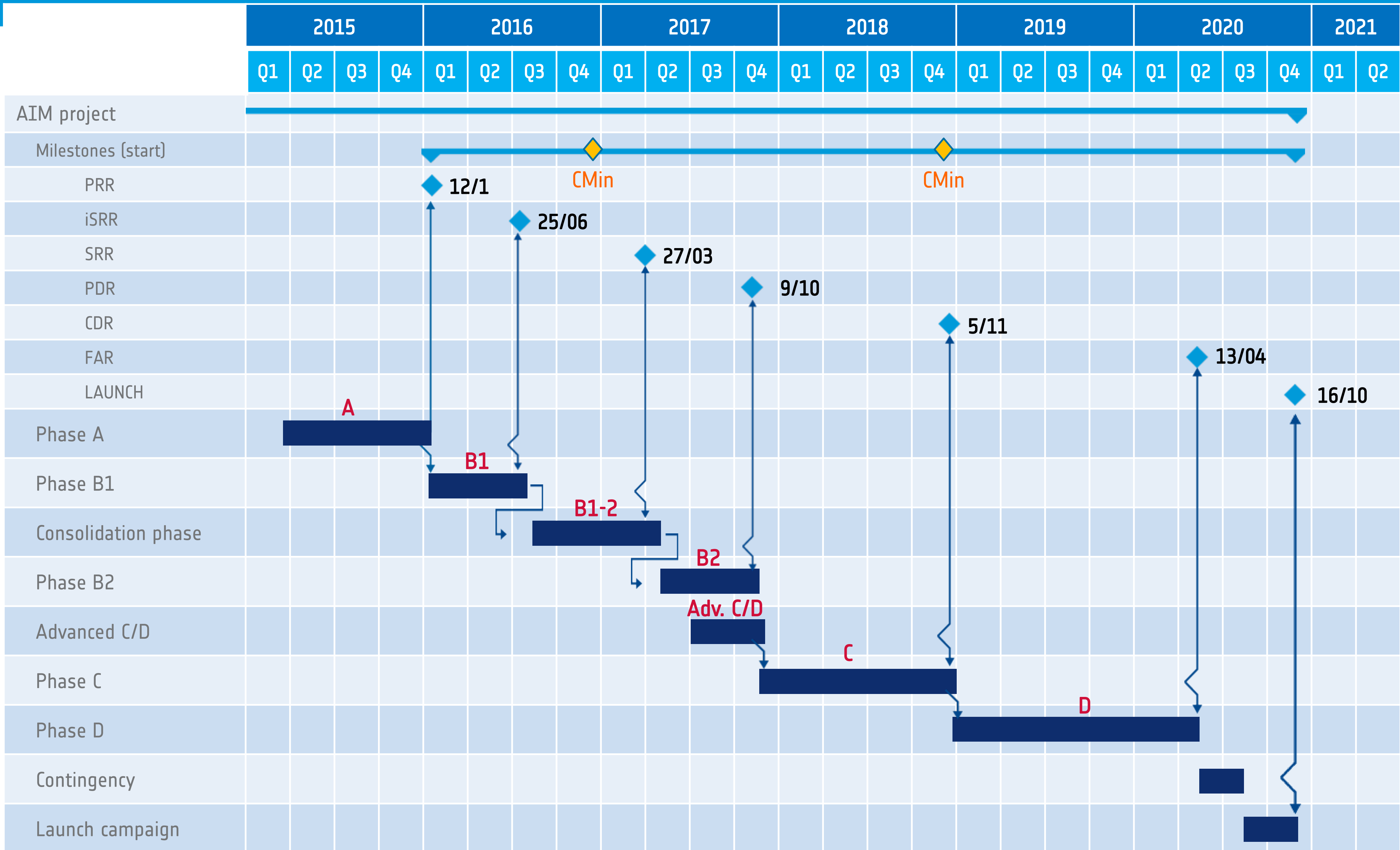
→ SCIENCE

Answer fundamental questions on Solar System formation
Study impact dynamics beyond laboratory scale
Probe the interior structure of NEOs (first time)
Provide "ground-truth" for radar, optical, meteorites analyses

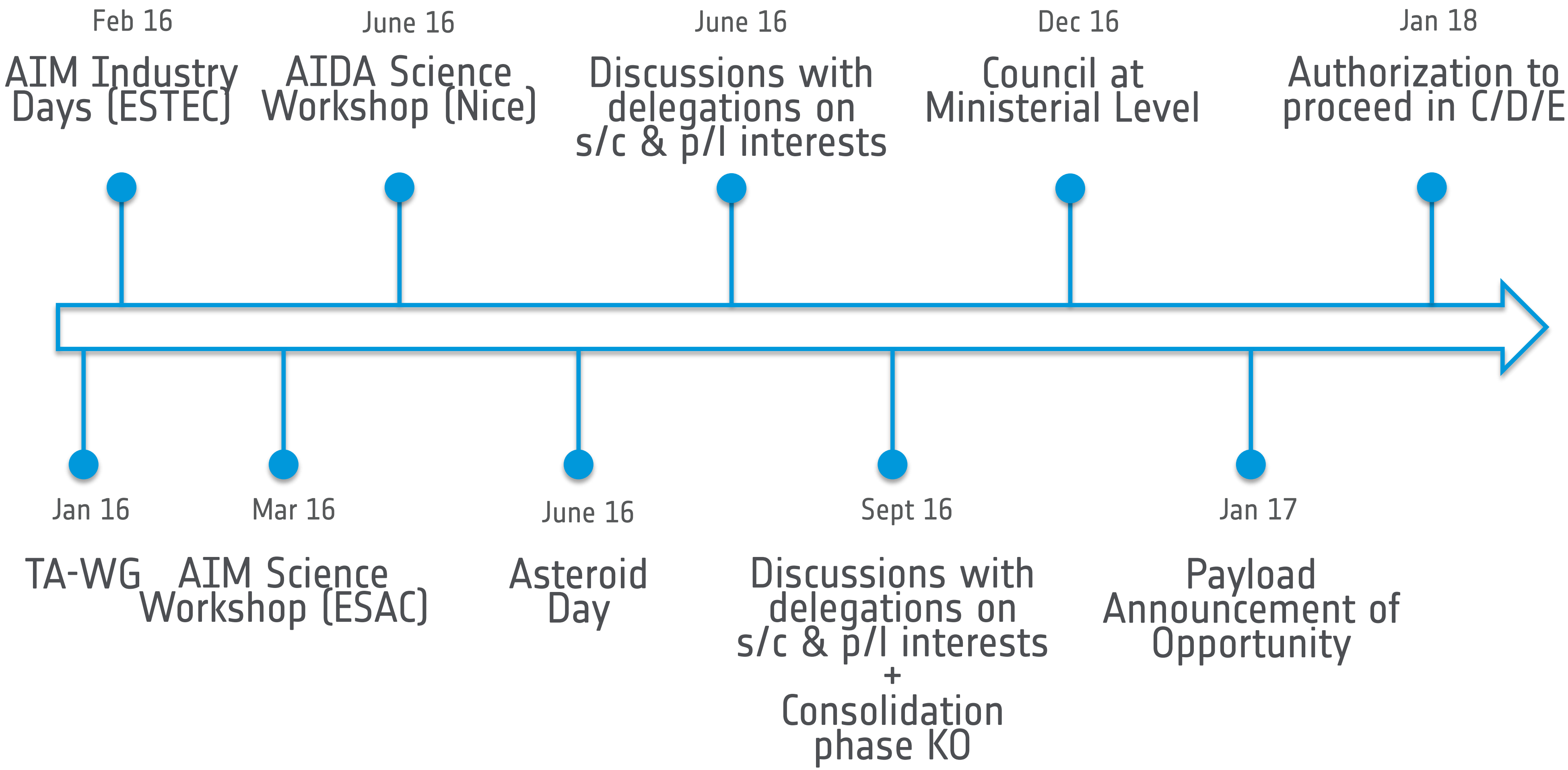
→ INSPIRATION

Addressing planetary defence objectives
Public engagement and outreach similar to Rosetta
Opportunity to provide visibility to space programmes

AIM SCHEDULE



WAY FORWARD


Feb 16
AIM Industry Days (ESTEC)
June 16
AIDA Science Workshop (Nice)
June 16
Discussions with delegations on s/c & p/l interests
Dec 16
Council at Ministerial Level
Jan 18
Authorization to proceed in C/D/E
Jan 16
TA-WG
Mar 16
AIM Science Workshop (ESAC)
June 16
Asteroid Day
Sept 16
Discussions with delegations on s/c & p/l interests + Consolidation phase KO
Jan 17
Payload Announcement of Opportunity