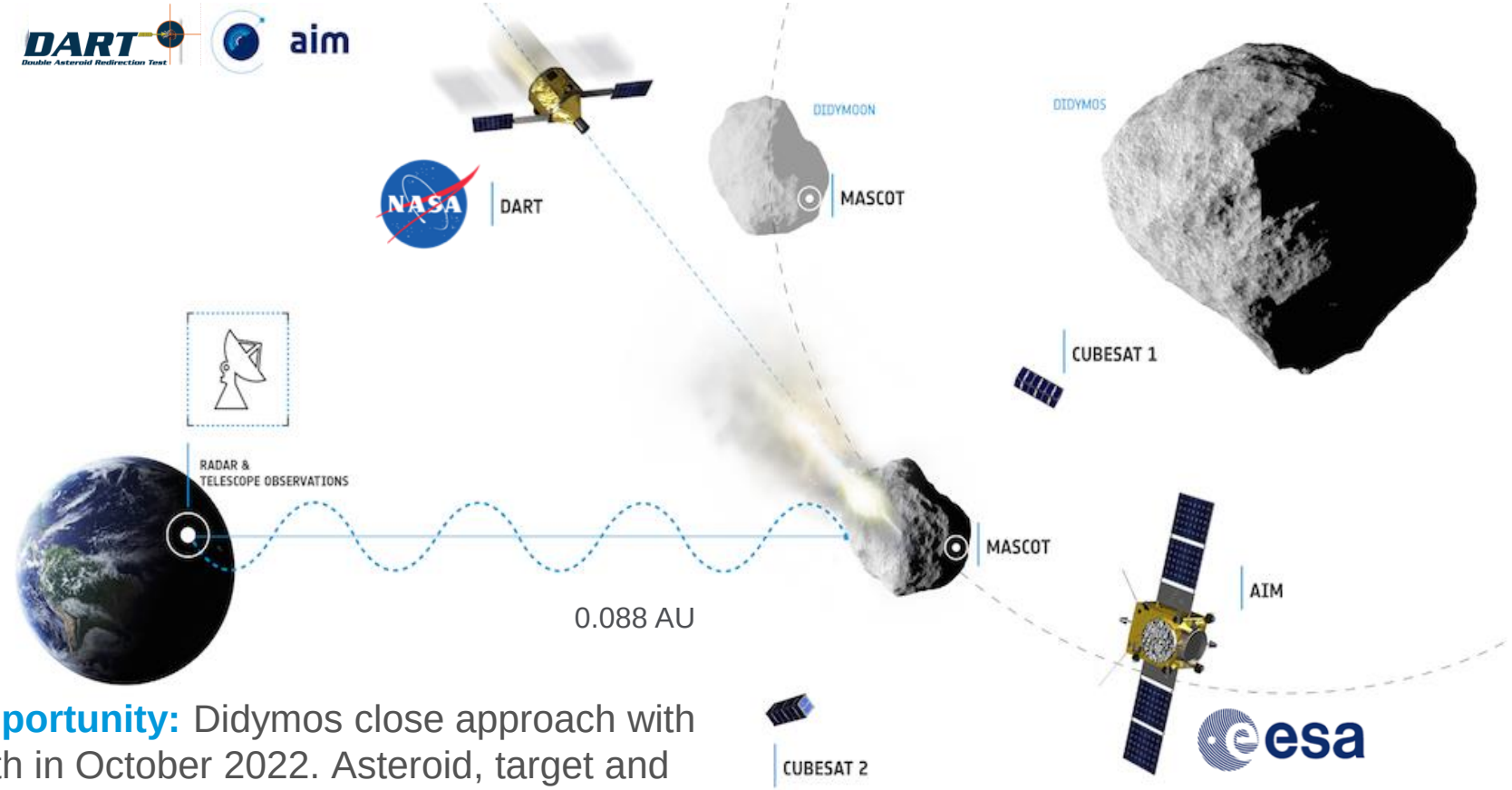
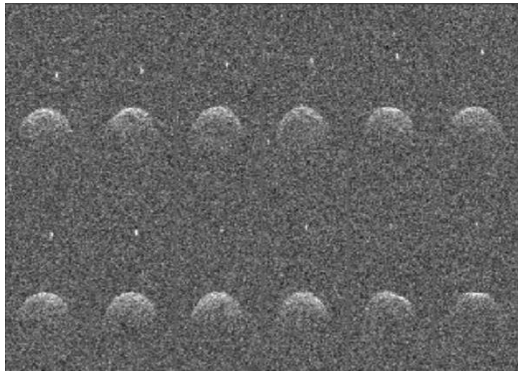
AIDA INTERNATIONAL COOPERATION

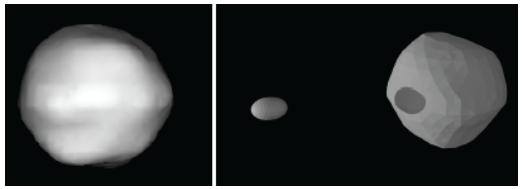


→ **opportunity:** Didymos close approach with Earth in October 2022. Asteroid, target and impact date fixed

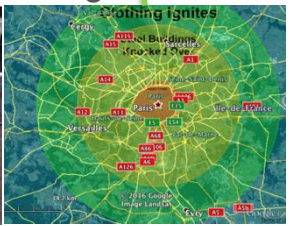
DIDYMOS: A PERFECT TARGET

- Asteroid observed by ground telescopes and radars
- Heliocentric orbit well known
- Shape and size of primary well known (not Didymoon)
- Orbit plane orientation to be confirmed in 1Q 2017 (observations planned with European observatories)
- Didymoon size representative of a potentially hazardous object (generating casualties independently





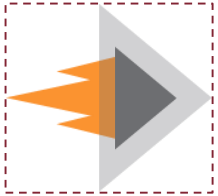
Chelyabinsk meteor (Feb 2013): 1500 injuries, 7200 damaged buildings



AIM: A UNIQUE OPPORTUNITY

→ SPEED

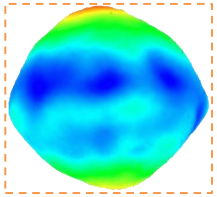
- Fast “return on investments” (2 yrs) + double return with DART
- Asteroid operations: 6 months to achieve all objectives
- Demonstrate approach integrating platform-payload-operations teams for faster implementation



→

- Technology “firsts” enabling future:
  LEO spacecraft architectures (swarms) and applications, debris-removal, sample-return, mining and human exploration missions
- Based on currently funded developments for:
  on-board autonomy, CubeSats, advanced GNC, laser comm
- New industries to demonstrate technical capabilities in deep-space, stepping stone to future missions (e.g. Cosmic Vision)

AIM: A UNIQUE OPPORTUNITY



→

- First mission to a binary body, Solar System formation
- Impact dynamics beyond laboratory scale
- Probe the interior structure of small bodies (first time)
- Provide “ground-truth” for observations (radar, optical, meteorites)

→

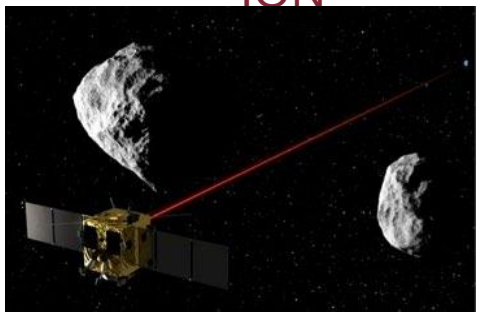
- First mission to demonstrate planetary defence
- Public engagement and outreach similar or even beyond Rosetta (DART impact event visible from ground)
- Opportunity to provide visibility to space programmes at large
- Opportunity to enhance governments’ support in space activities

ASTEROID IMPACT MISSION

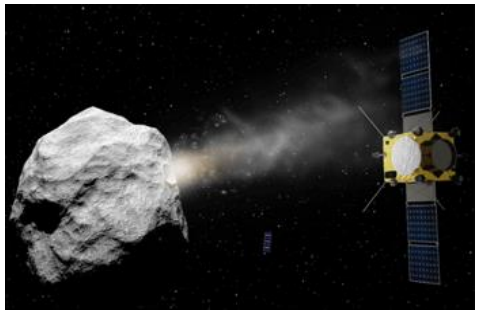
Interdisciplinary mission of opportunity to explore and **demonstrate technologies for future deep-space missions** while addressing **planetary defence objectives** and performing **asteroid scientific investigations**.

aim

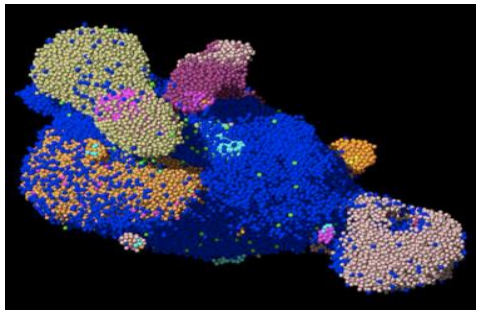
TECHNOLOGY DEMONSTRATION



ASTEROID IMPACT MITIGATION

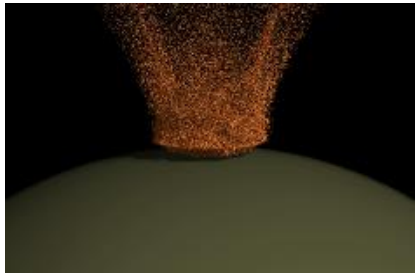


SCIENCE

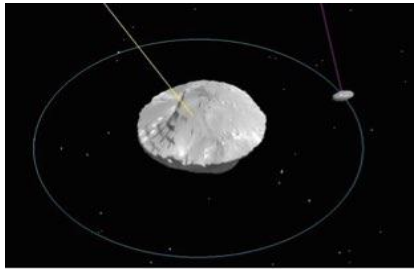


AIM "FIRSTS"

First mission to deploy **CubeSats** in deep-space and operate them through advanced **inter-satellite link** with embedded metrology, first semi-autonomous deployment of **micro-lander**, first demonstration of **interplanetary optical communication**



First mission to fully **measure** and **characterize asteroid** deflection, results enabling the validation of models to be applied to other asteroids if necessary.



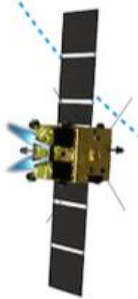
First mission to **study a binary asteroid,** its **origins** and sound the **interior structure** providing clues of its formation process.

AIM MISSION SCENARIO

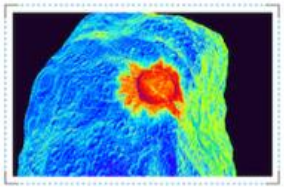
Ariane 6
maiden flight
under study

22/10 ⊢ 2020
LAUNCH

22/10 ⊢ 2020
LEAVING EARTH ORBIT



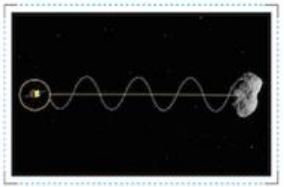
03/01 ⊢ 2021
DEEP SPACE MANOEUVRE



15/10 ⊢ 2022
POST-IMPACT CHARACTERISATION STARTS

06/10 ⊢ 2022
DART IMPACT

25/12 ⊢ 2022
MISSION ENDS



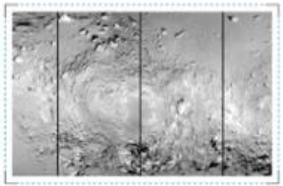
AUG/SEP ⊢ 2022
DETAILED CHARACTERISATION PHASE

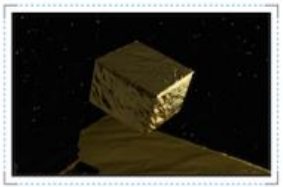
DIDYMOS

DIDYMOON

29/05 ⊢ 2022
ARRIVE AT ASTEROID

01/06 ⊢ 2022
EARLY CHARACTERISATION PHASE

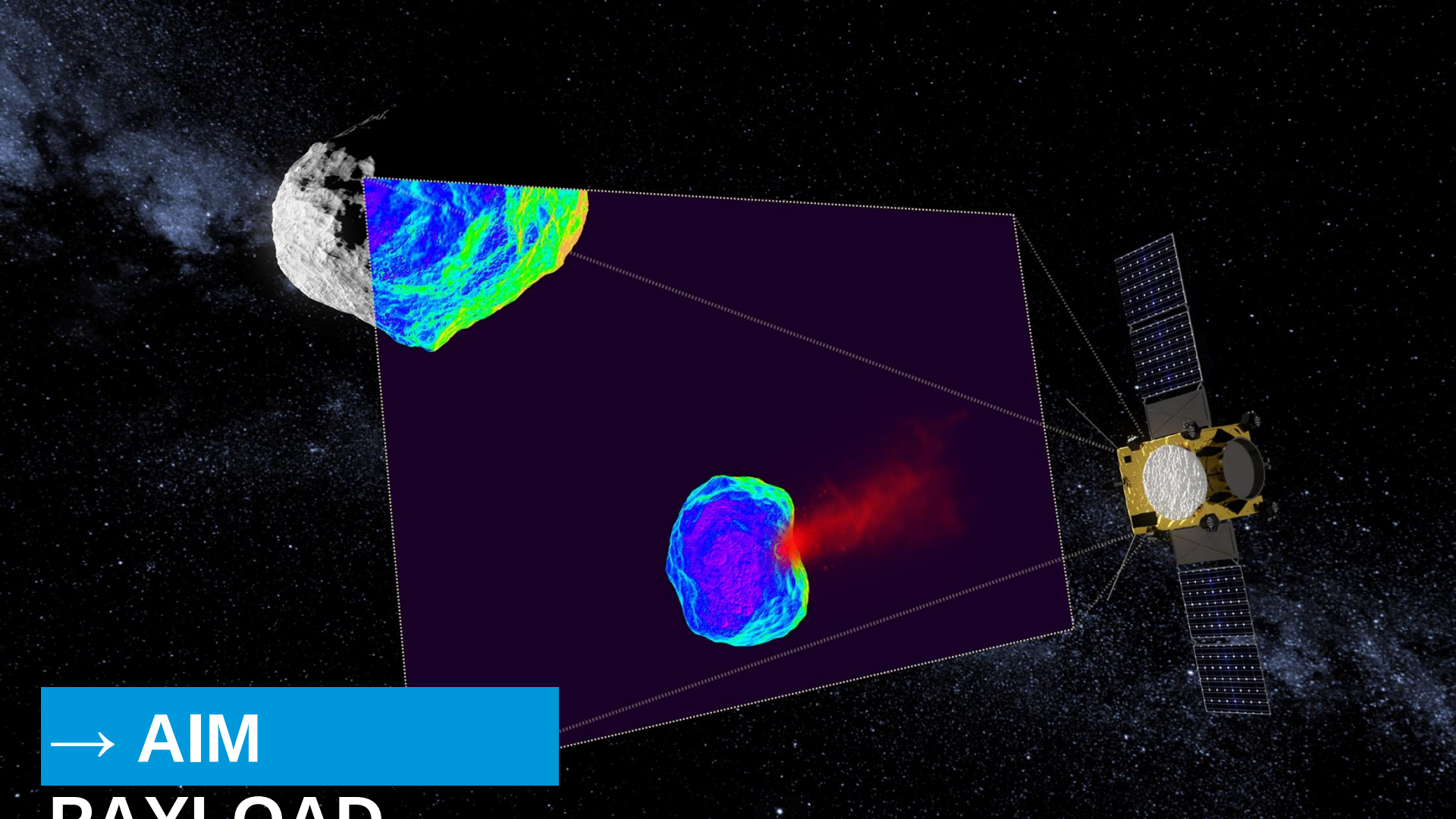




22/08 ⊢ 2022
RELEASE OF SMALL LANDER

15/08 ⊢ 2022
CUBESATS RELEASE

Direct escape
1.5 years cruse
0.5 years ops
Platform optimised for ops @0.4-0.08AU from Earth

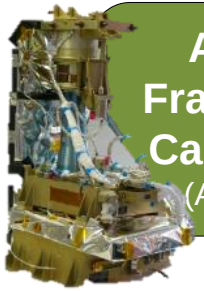


→ AIM

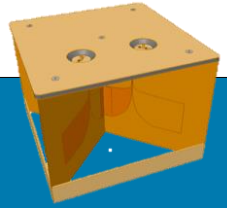
PAYLOAD

AIM REFERENCE PAYLOAD

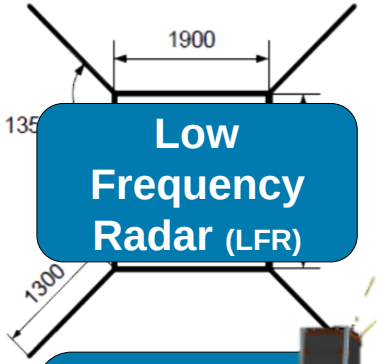
(consolidation phase)



AIM Framing Camera (AFC)

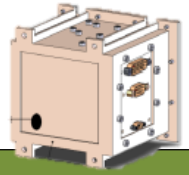


High Frequency



Low Frequency Radar (LFR)

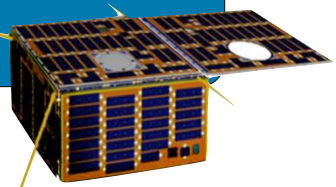
CubeSat (COPINS)



European Lidar (PALT)

Hyperspectral camera (HYP)

MASCOT-2



- Several options studied in detail to prepare for proper **interfaces** and **proximity operations**.
- Announcement for payload opportunities to be released in **Jan 2017** for any remaining mass following CM16 subscriptions by ESA Member States.

Legend: Potential provider companies (country)

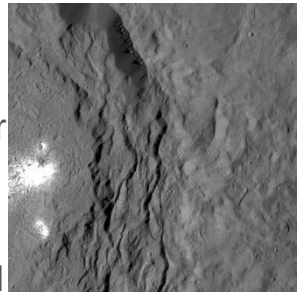
Built-in AIM S/C (GNC subsystem)

AIM Framing Cameras (AFC), Hyperspectral Imager

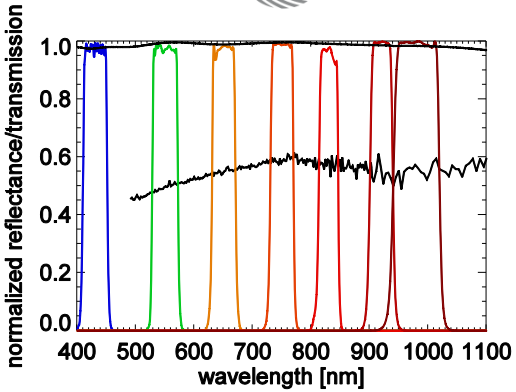
Flight Spares of the DAWN cameras

(5.5° FOV, 93.7 µrad/pixel, 400-1000 nm, 7 filters)

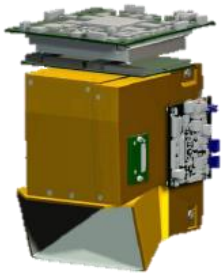
- spacecraft GNC system, provided by MPI for solar system research
- Used for spacecraft navigation but also science
- Navigation currently being tested at GMV with QM



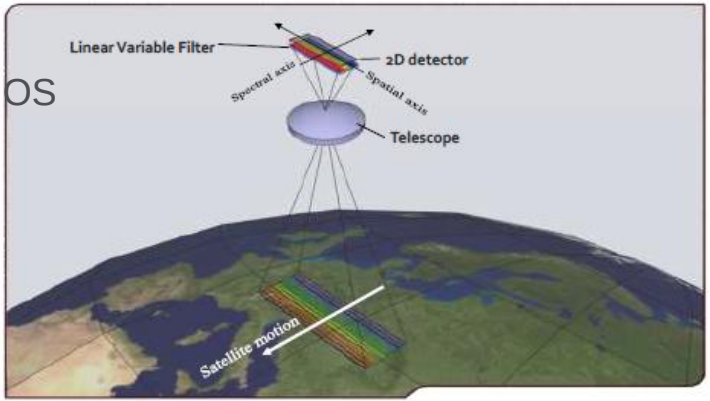
DAWN FC image of Ceres



Compact Hyperspectral imager

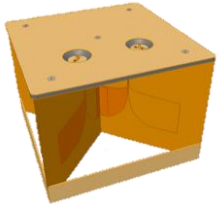


- Grating spectrometer or linear filter fixed on CMOS detector
- Large detector, 7 x 9 deg. FOV at 8 arcsec/pix
- Spectral resolution 5-10 nm
- Wavelength range 470-950 nm
- Developed for Earth observation



PLANETARY RESOURCES INC. (LUX), AMOS (BE), VITO (BE), COSINE (NL)

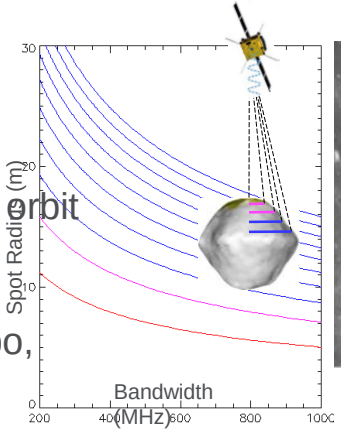
HIGH-FREQUENCY RADAR (HFR), LOW-FREQUENCY RADAR (HFR)

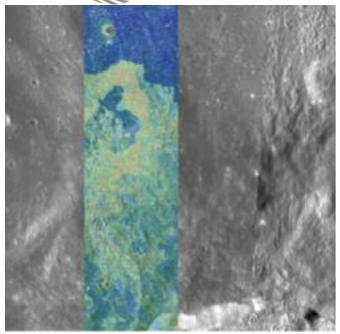


Stepped high-frequecy frequency radar

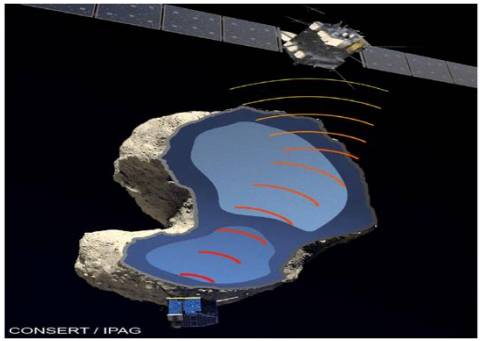
(300MHz to 2.4GHz, 108W power, 2.86kg, 37 x 37 x 27 cm3)

- determine structure and layering of shallow sub-surface
- support asteroid mass determination, shape modelling and orbit characterisation
- observe ejecta cloud
- support ground-based bi-static radar measurements Arecibo, Goldstone, SRT



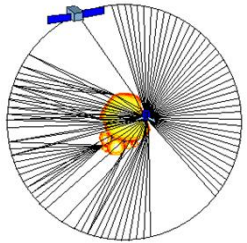


IPAG (FR), LATMOS (FR), Univ. Dresden (DE), ROB (BE), Antwerp Space (BE), Astronica (PL), CBK (PL)



Instrument design based on CONSERT (Rosetta)

- Spare components available and TRL6
- Radar type: Bistatic radar (between AIM and MASCOT-2)
- Carrier frequency: 60 MHz
- Bistatic operation through the secondary asteroid



IPAG (FR), LATMOS (FR), Univ. Dresden (DE), ROB (BE), Antwerp Space (BE), Astronica (PL), CBK (PL)

THERMAL IMAGER (TIRI), MASCOT-2 µLANDER

TIRI strawman design

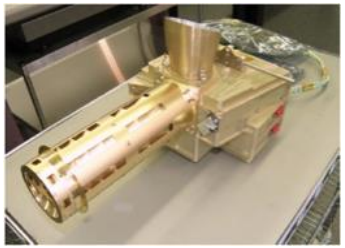
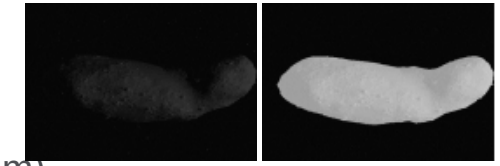


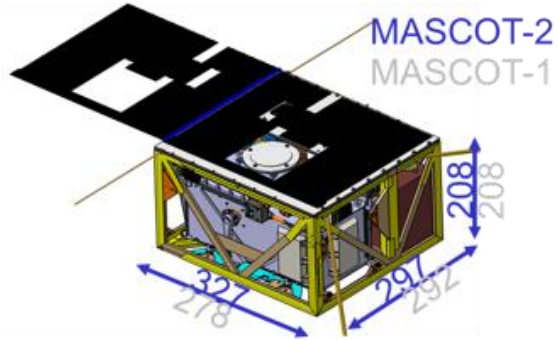
Figure: MERTIS

- Heritage: MERTIS (Bepi-Colombo), MAIR, HIBRIS, AMS
- Temperature range: 200 K – 450 K
- Spectral range: 8 µm – 13 µm (spectral resolution 0.3 µm)
- Spatial resolution (goal): 2 m @ 10 km
- Field of view: ~5 deg., similar to cameras
- Thermal and physical surface properties



VISUAL @ 5 km IR @ 5 km

COSINE (NL), GMV (PT), GMV (RO), SODERN (F), MPI (D), DLR (D)



MASCOT-2 µlander

- Development based on MASCOT-1 currently on JAXA's Hayabusa-2 mission
- Size: 33 x 30 x 21 cm
- Mass: 15 kg
- Deployable solar generator cover (supports orientation)
- 3 months operational lifetime
- Carries: µ-camera (CAM), low-frequency radar (LFR), radiometer

DLR (DE), SSC (SE), Cobham Gaisler (SE), CBK (PL), Astronika (PL), COSINE (NL), CGS (I), SELEX (I), POLIMI (I), Space-X (CH), CSEM (CH), MCSE (CH)

COPINS: A CASE FOR CUBESATS IN DEEP SPACE

ASPECT

- Vis-NIR imaging spectrometer
- Space Weathering
- Shock experiment
- Plume

VTT (FI), Univ. Helsinki (FI), Aalto Univ. (FI), CAS (CZ)

AGEX

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

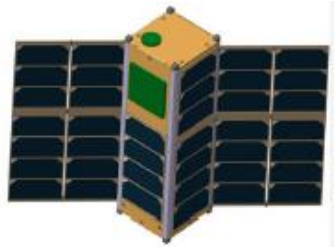
ROB (BE), ISAE (FR), Antw. Space (BE), EMXYS (ES)

PALS

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

IFR (SE), AAC (SE), DLR (DE), IEEC (ES), KTH (SE)

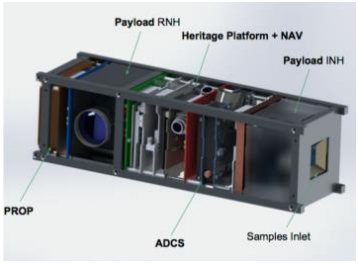
CUBATA



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

GMV (ES), Sapienza Univ. Roma (IT), INTA (ES)

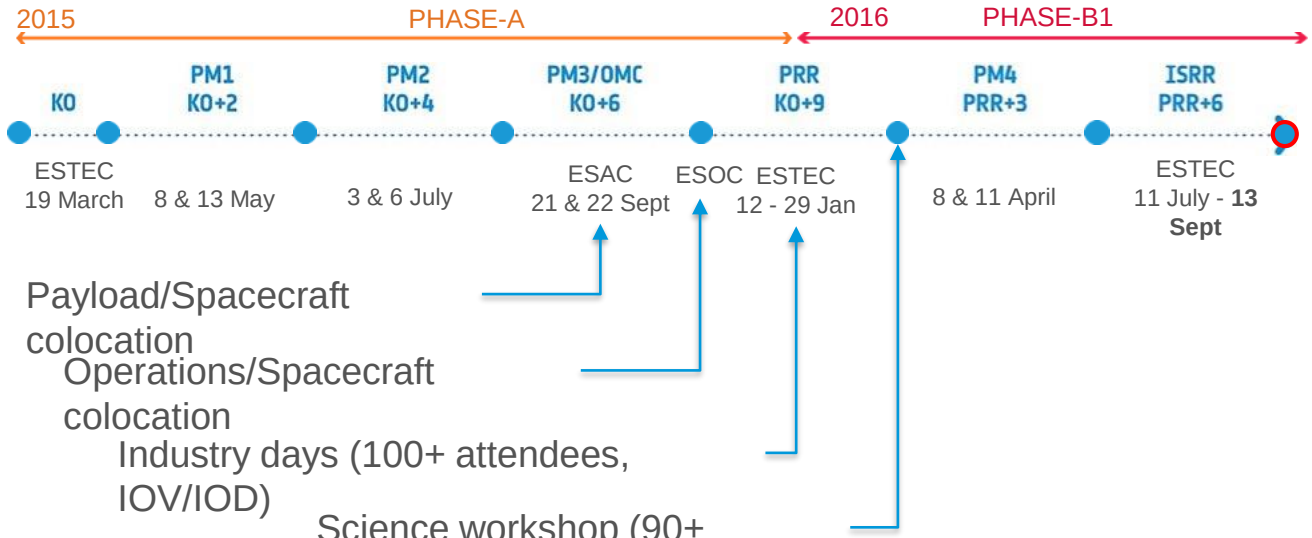
DUSTCUBE

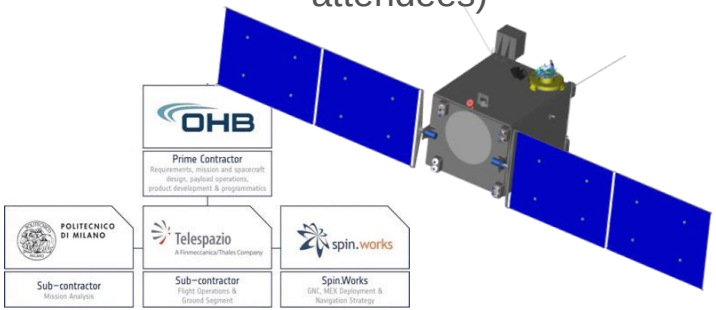


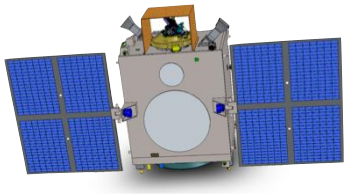
- Dust properties with Nephelometer
- Mineralogical composition
- Compliment com demo
- Reflectance of the

Univ. Vigo (ES), UniBO (I) Micos (CH), Univ. Bern (CH)

SYSTEM ACTIVITIES: PHASE B1 COMPLETED







- Preliminary feasibility confirmed

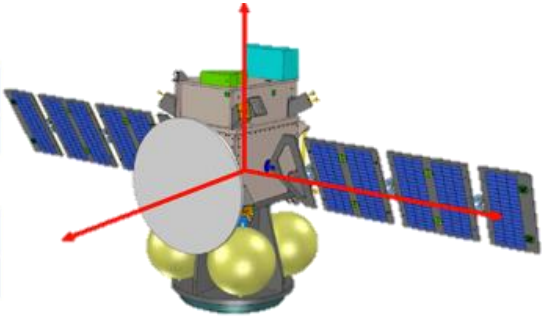
→ ENABLING APPROACH

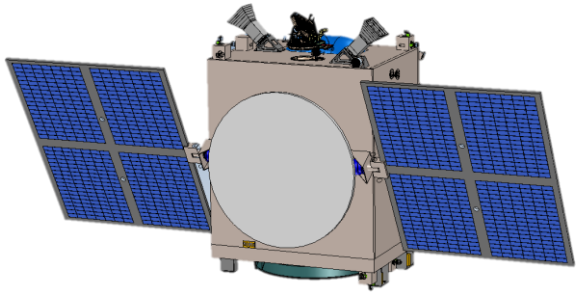
- Cost and schedule driven
- Platform and payload “integrated” teams
- Early OPS and FDyn teams support (Rosetta)
- Early GNC testing and validation in lab
- Reuse of flight spares (e.g. DAWN framing camera)

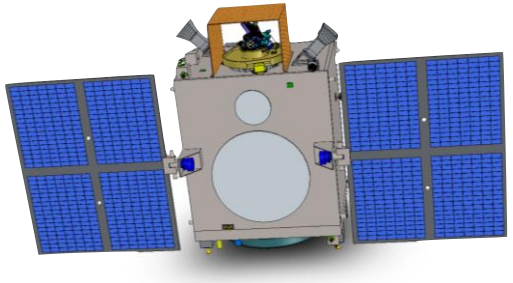
CURRENT SYSTEM DESIGN (B1)

QinetiQ
Prime Contractor
QinetiQ Space BE

gmv
Sub-contractor
GMV EE





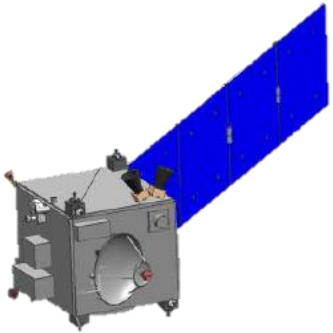


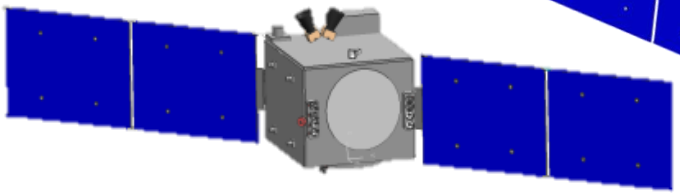
OHB
Prime Contractor
Requirements, mission and spacecraft design, payload operations, product development & programmatics

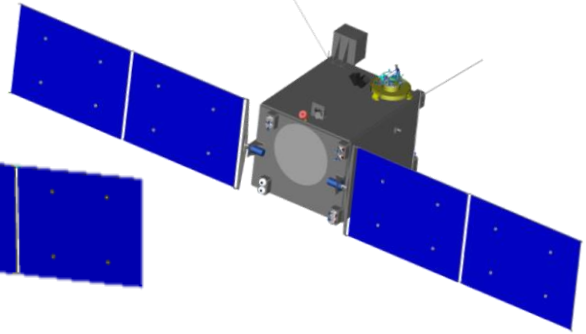
POLITECNICO DI MILANO
Sub-contractor
Mission Analysis

Telespazio
A Finmeccanica/Thales Company
Sub-contractor
Flight Operations & Ground Segment

spin.works
SpinWorks
GNC, MEX Deployment & Navigation Strategy







PAYLOAD ACTIVITIES: TOWARDS COMPLETION

→

2015

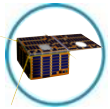
2016

→ AFTER

MASCOT
CONSERT

MASCOT–2 & LFR

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



Exploration

Optel-μ
LADEE

OPTEL–D

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

Mars, human exploration, L-missions

WISDOM

HFR

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

Planetary exploration

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

COPINS

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

ESA CDF Study (Jan 17)

Earth observation, lunar explo

MERTIS, CAMIR, Hypercube…

TIRI

Mar — Dec

RDV & docking

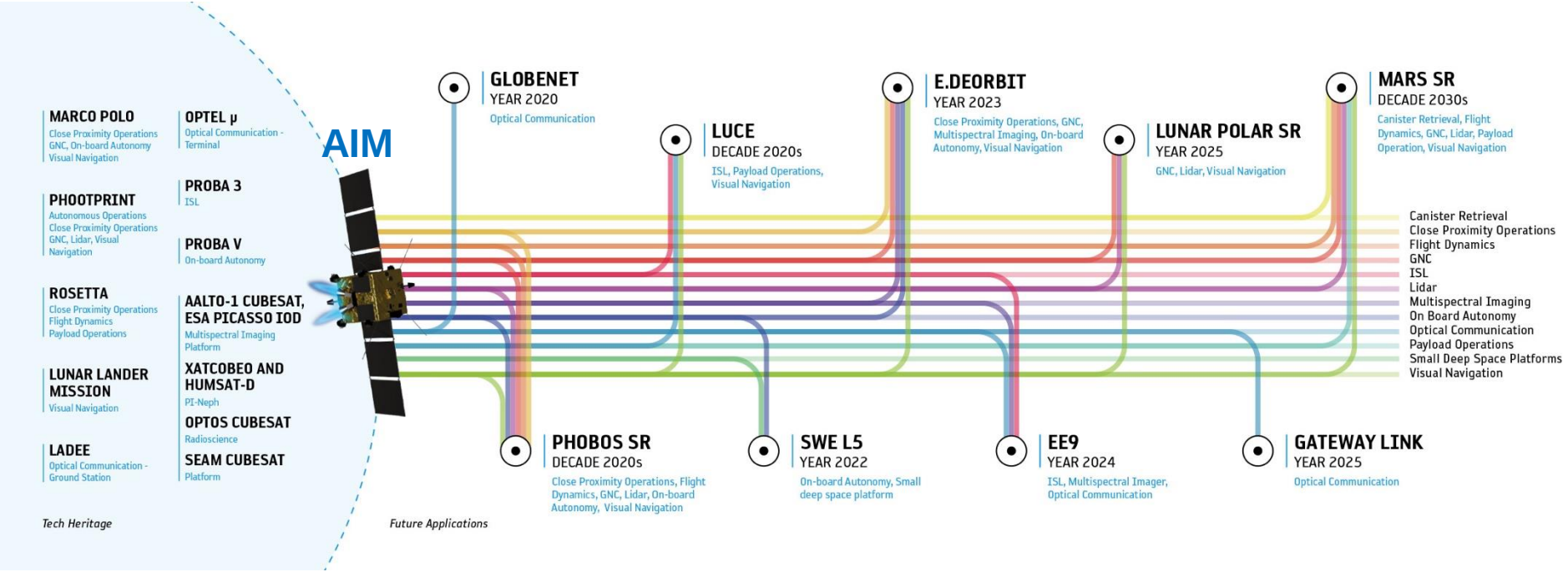
CIVA, X-CAM, Clupi…

μCAM

Jan — July

EOP, CubeSats, planetary Exploration

aim is…TECHNOLOGY OF THE FUTURE



aim is… INSPIRATION AND OUTREACH

(416.000 results on Google for "asteroid impact mission")

AIM sand art performance

Asteroid Day press conf AIM @ planetarii Astrofest (London, June 2016)

Science&Vie Magazine

AIM videogame

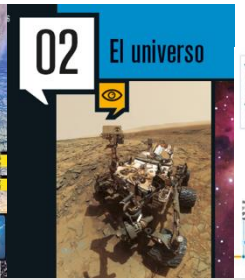
Design your asteroid" school contest

"Men vs Asteroid" Discovery Channel documentary

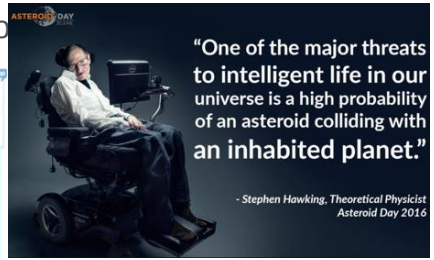
AD (Milan, 2016)

Asteroid Day (Bucharest, 2015)

CNN TV news



Science school book (Spain)

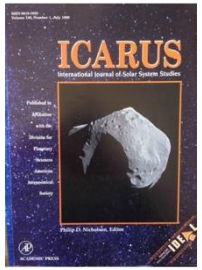


Stephen Hawking supporting A

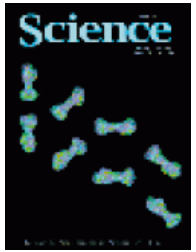
aim is… HIGH SCIENCE RETURN

Fly-by of Lutetia (Rosetta) in 2010:
- Special issue of Science
- 47 referred articles (source ADS)

Fly-by of Steins (Rosetta) in 2008:
- 33 referred articles (source ADS)



Fly-by of Mathilde (NEAR) in 1997:
- Special issue of Icarus
- 19 referred articles



Radar observations of Kleopatra:
- Cover of Science

Visit of Eros (NEAR) in 2000-2001:
- Special Issue of Science
- One book (Cambridge Press)
- 156 referred articles (source ADS)

Visit of Itokawa (Hayabusa) in 2005:
- Two Special Issues of Science
- 83 referred articles (source ADS)
- Three Hollywood-like movies

Visit of Ceres (DAWN) in 2015:
- Special Issues of Science
- 206 referred articles (source ADS) for Ceres and Vesta

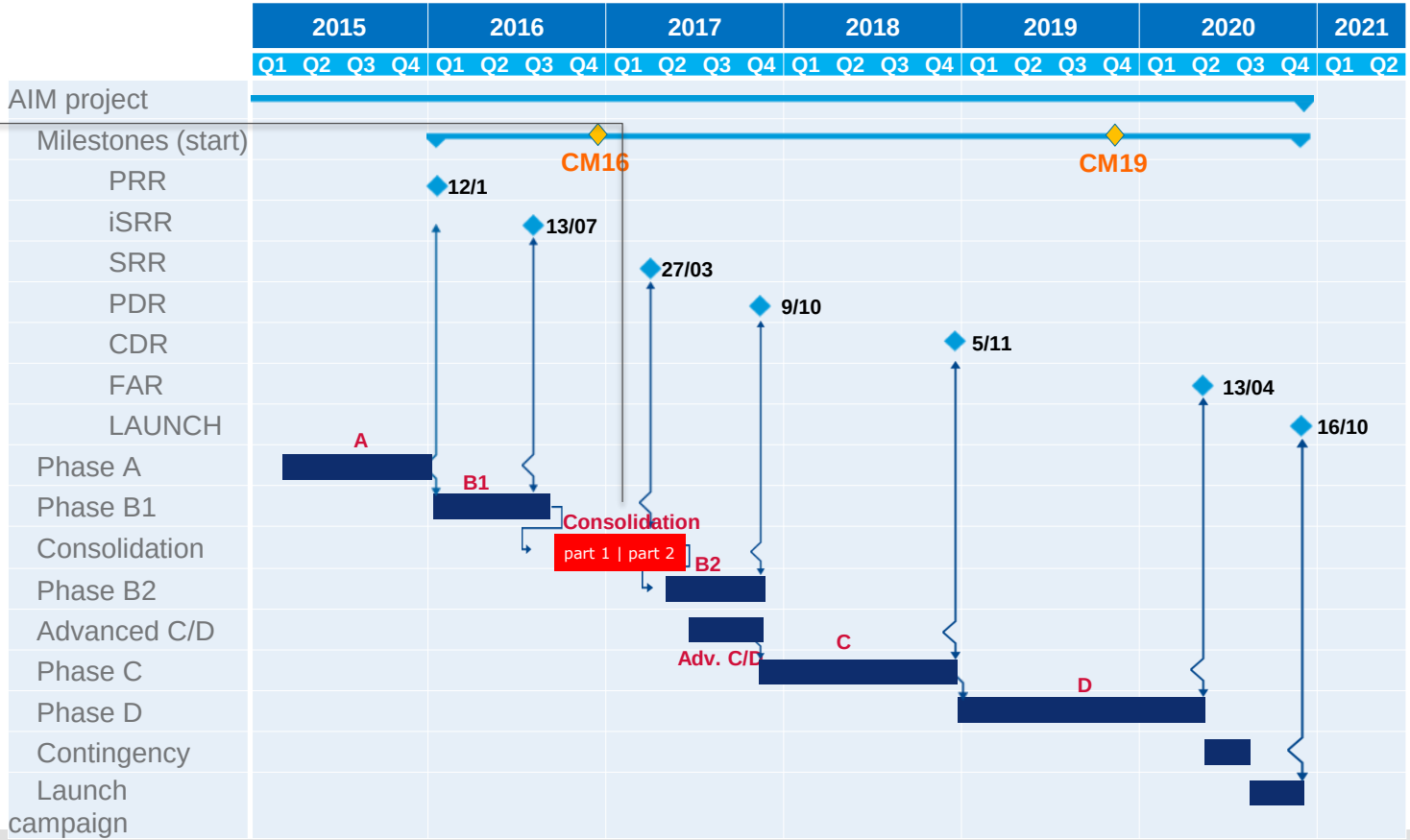
AIM SCHEDULE & STATUS

→ NEXT

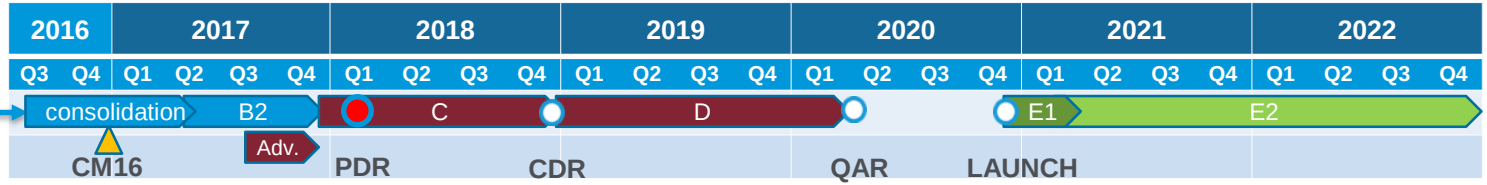
ITT Consolidation Phase published
(4.5M€)

- Spacecraft design consolidation
- Team organization
- Consolidation of CaC and implementation plan

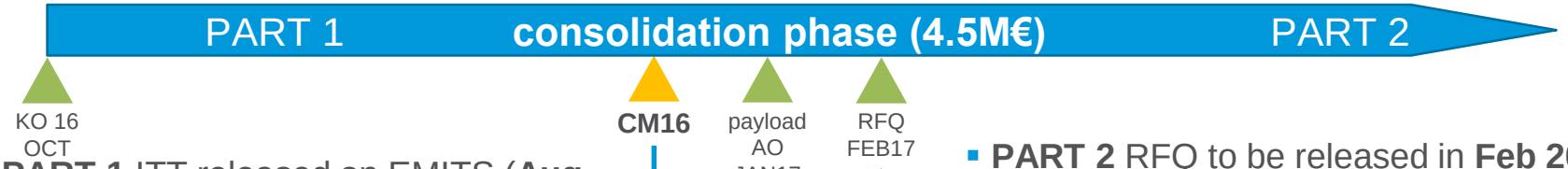
Supported by:
- Germany
- Belgium
- Spain
- Portugal
- Romania
- Poland



AIM CONSOLIDATION PHASE



Consolidation phase approved:



- **PART 1** ITT released on EMITS (**Aug 2016**)

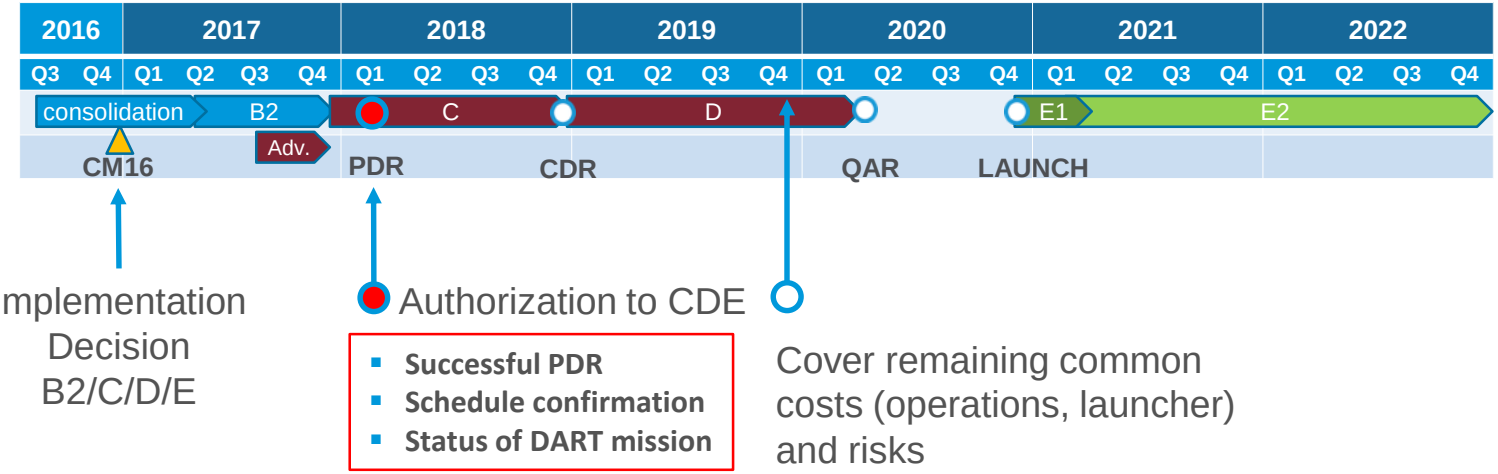
Consolidation of the spacecraft design down to equipment level, preliminary design of the GNC and associated FDIR algorithms, operations concept definition, program implementation definition, preliminary subco/suppliers identification, consolidation of cost estimates

Consolidation of MS interests following CM16 subscriptions

- **PART 2** RFQ to be released in **Feb 2017**, team consolidation **reflecting CM16 level subscriptions**
- KO planned **Apr** 17, covering activities up to Sep 2017 (pre-PDR)

Further consolidation of the spacecraft design down to equipment level, down-flow of requirements and specifications. GNC development. Industrial team consolidation also on the basis of the MS subscriptions. Identification of LLIs and critical pre-developments.

AIM IMPLEMENTATION



PHASE 1

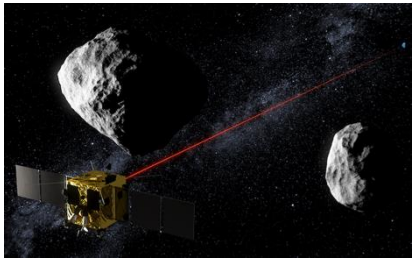
Phase 2

Completion of phase B2 activities up to PDR, finalization of LLI procurement

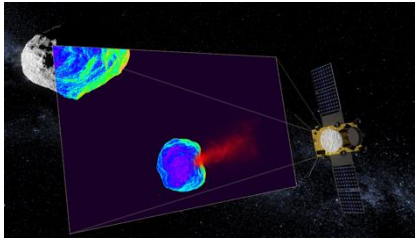
Spacecraft detailed design definition and successful critical design review (CDR), spacecraft production and ground qualification, successful qualification review (QR) and acceptance review (AR). Completion of Phase E activities.

CONCLUSIONS

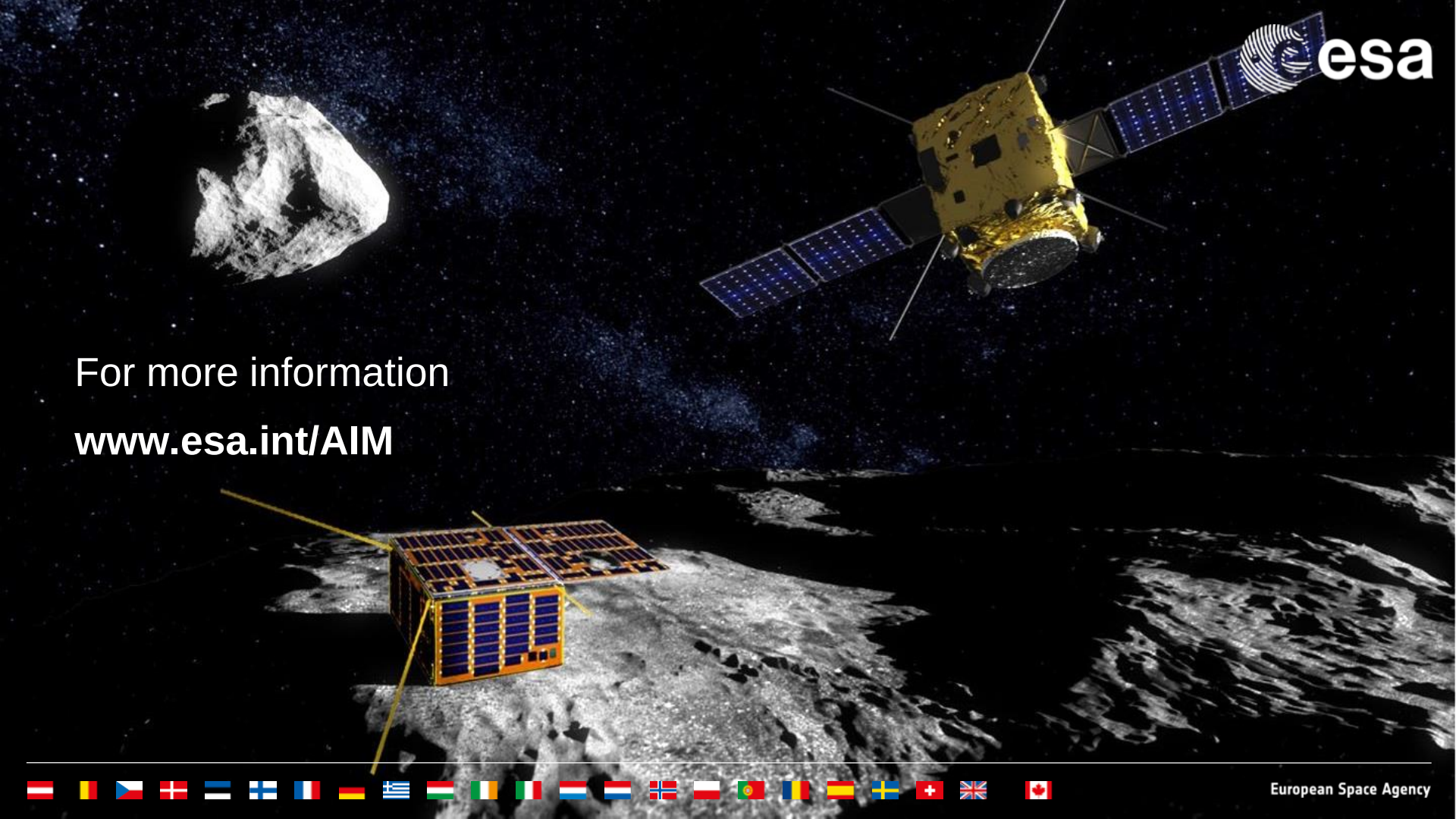
First mission to prove **asteroid deflection** with an experiment visible from ground, to reach a **binary asteroid** and to deploy small **CubeSats.** Great **inspiration for European citizens.**



Maintain European industry **leadership** in **GNC, complex proximity operations,** forefront of deep-space **optical communications,** first to **operate multiple-platforms** in close vicinity, demonstrate new approach for **fast missions in deep-space**.



Enabling future **space mission architectures** (swarms), **new applications** for Earth monitoring and services, capabilities for **autonomous operations**, demonstrate key technologies for **exploration missions**, **opportunity for new industries** to gain deep-space heritage.


esa
For more information
www.esa.int/AIM
European Space Agency