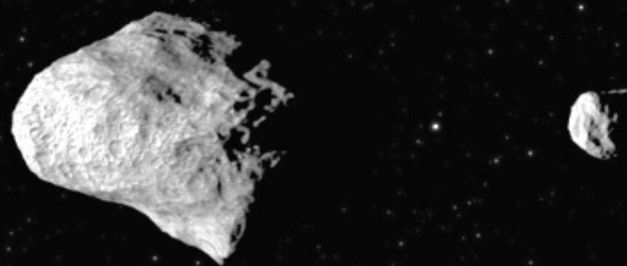
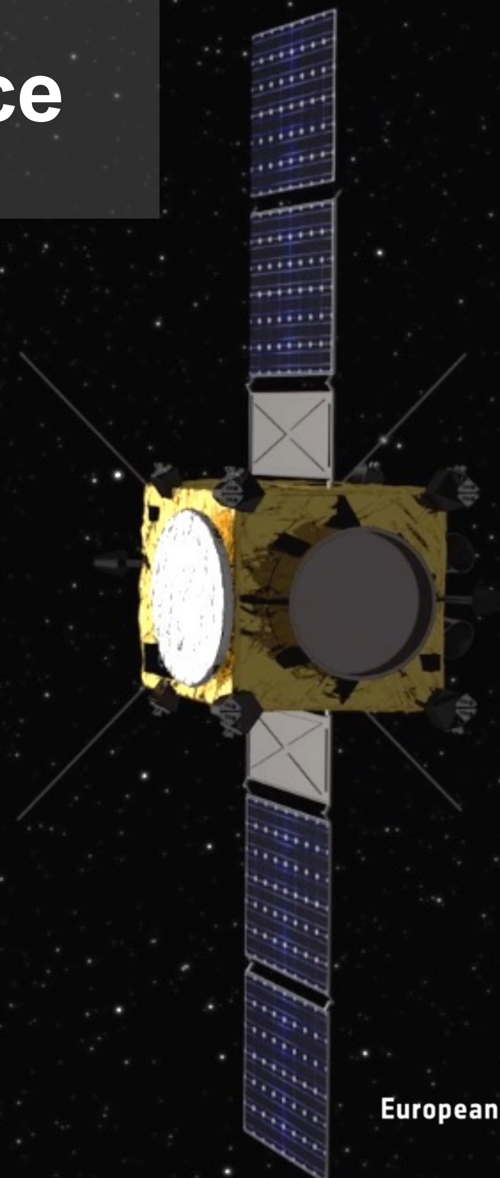
Science by Cubes opportunities to increase the Asteroid Impact Mission science return





Ian Carnelli project manager
Michael Kueppers project scientist
Andres Galvez payload manager
Roger Walker cubesat specialist
… and the ESA team

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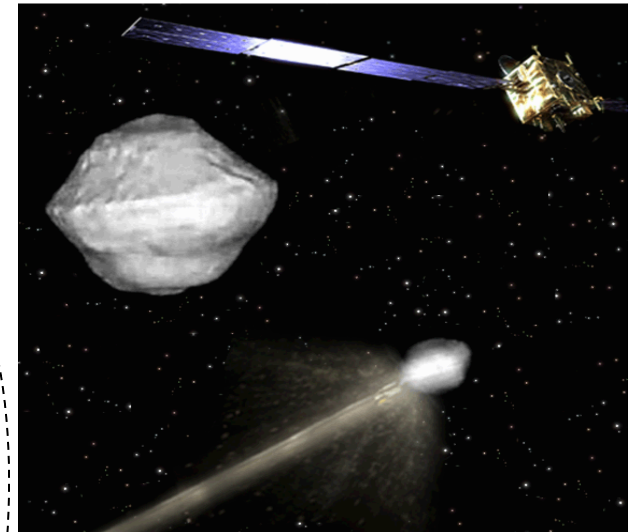
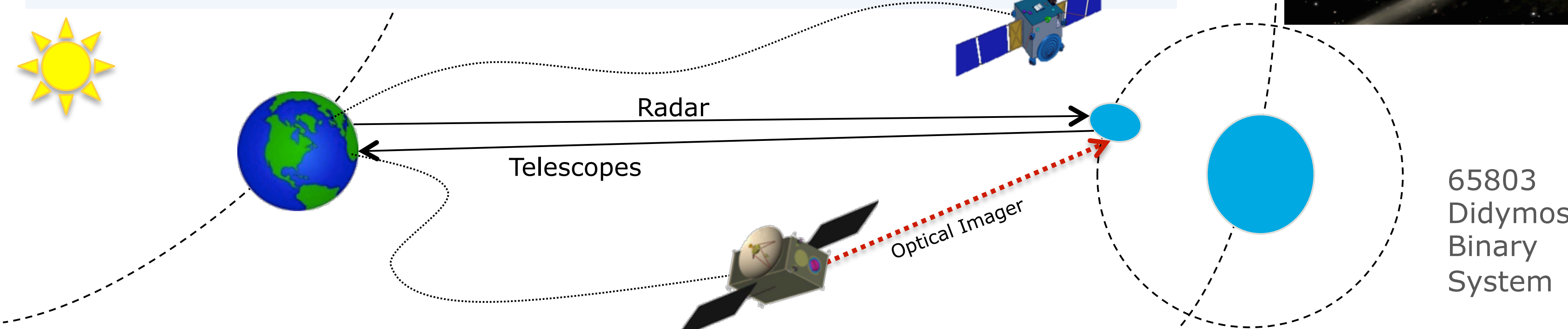
European Space Agency

AIDA cooperation

In 2011, contacts between ESA, JHU/APL, DLR and OCA resulted in a simpler operational concept, based on two modest missions that are operated in coordination, the result was **AIDA.**



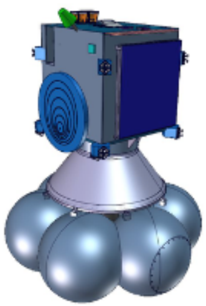


Two **independent** and **self-standing** mission developments: the USA-led Double Asteroid Redirection Test (**DART**) and the European-led Asteroid Impact Mission (**AIM**). Its goal is to demonstrate the ability to modify the orbital path of the secondary asteroid of the 65803 Didymos binary system and obtain scientific and technical results that can be applied to other targets and missions.

AIDA = AIM + DART

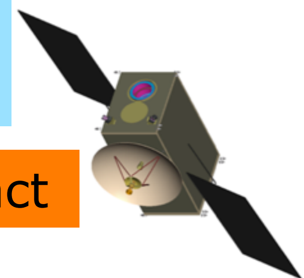
1st goal: Redirect secondary component of Didymos, and measure the deflection by monitoring the binary´s orbital period change

2nd goal: Measure all scientific and technical parameters allowing to interpret the deflection and extrapolate results to future missions or other asteroid targets



AIM: Physical characterization by close-approach & lander

DART: Deflection by kinetic impact



Dual test validation by AIM spacecraft + ground-based optical/radar facilities

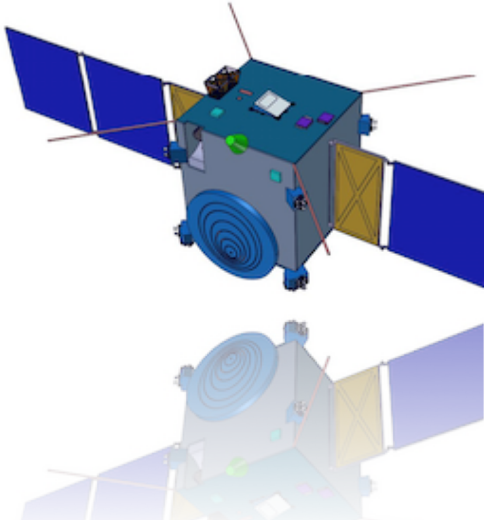
Both mission are independent but results boosted if flown together

Impact date (October 2022) and target (Didymos) are fixed.

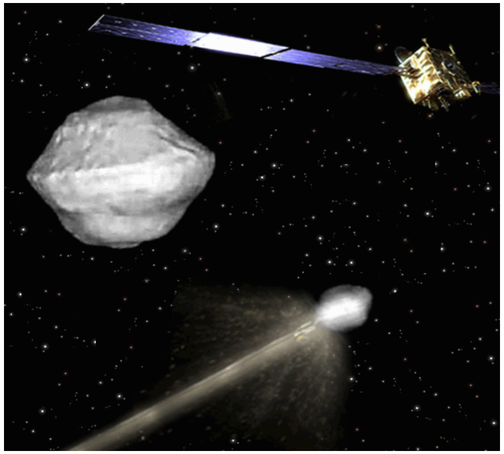
Asteroid Impact Mission (AIM)

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

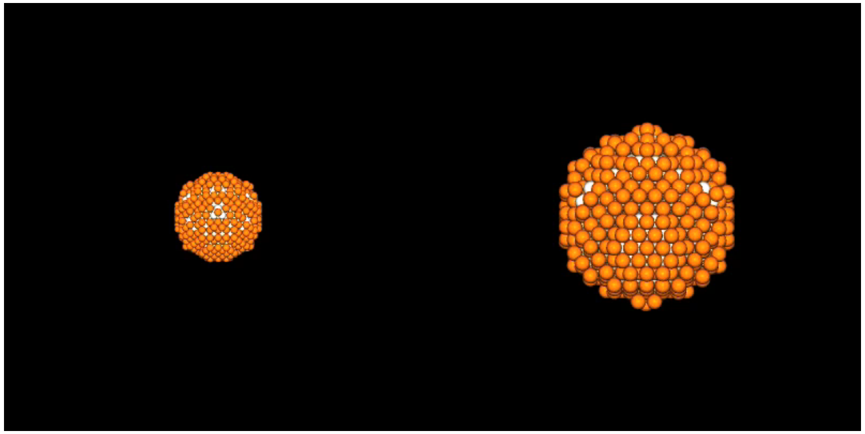
Technology demonstration



Asteroid impact mitigation

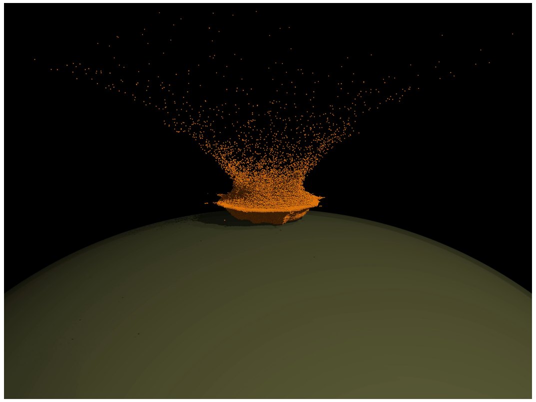


Science

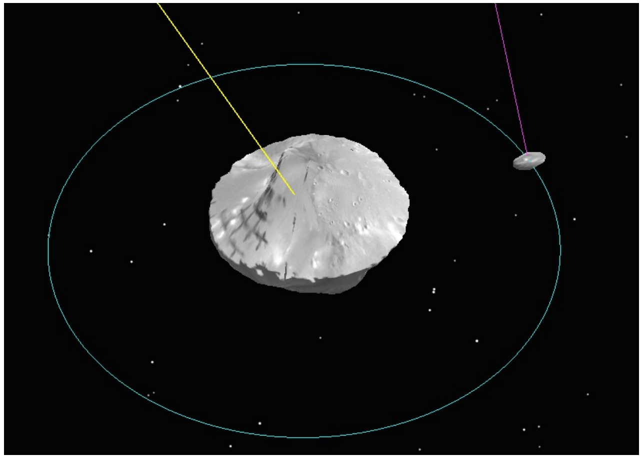


AIM "firsts"

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 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**

AIM primary science objectives

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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 Lander (?)
S#4 **Deep-internal structure of the moonlet**	Interpretation of impact Origin of binary	Low Frequency Radar (LFR)

AIM secondary science objectives

Parameter	Relevance	Supporting instruments
S#5 **Didymoon post-impact characterisation**	Changes due to impact	All
S#6 **Didymain characterisation**	Origin of the system	VIS, TIRI, HFR, LFR
S#7 **Impact ejecta**	Porperties of ejected dust	VIS, TIRI, HFR
S#8 **Ambient dust**	Dust in Didymos environment	VIS, TIRI
S#9 **Chemical and mineralogical composition**	Asteroid classification, origin of the system	VIS (TBC), TIRI, MASCOT-2 lander
S#10 **Comparison to observations from earth**	Ground truth for other asteroids	VIS, TIRI, HFR

Overlapping Goals of NEO Missions

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Planetary Defense

Deflection demonstration and characterization
Orbital state
Rotation state
Size, shape, gravity
Geology, surface properties
Density, internal structure
Sub-surface properties
Composition (mineral, chemical)

Science

Orbital state
Rotation state
Size, shape, gravity
Geology, surface properties
Density, internal structure
Sub-surface properties
Composition (including isotopic)

AIDA

Deflection demonstration and characterization
Orbital state
Rotation state
Size, shape, gravity
Geology, surface properties
Density, internal structure
Sub-surface properties

Human Exploration

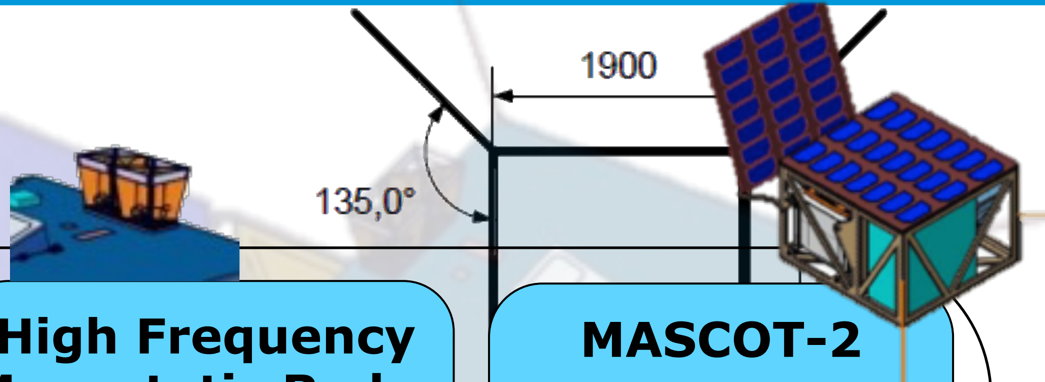
Orbital state
Rotation state
Size, shape, gravity
Geology, surface properties
Density, internal structure
Composition (mineral, chemical)
Radiation environment
Dust environment

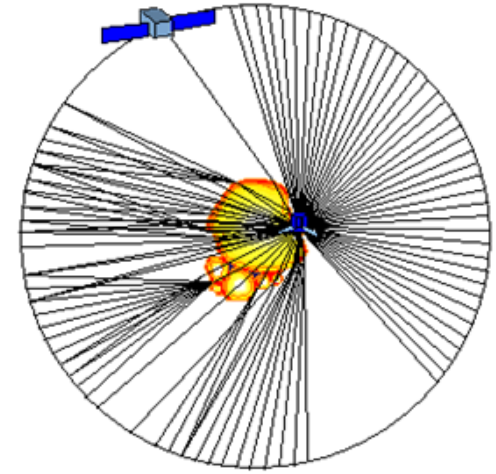
Resource Utilization

Geology, surface properties
Density, internal structure
Sub-surface properties
Composition (mineral, chemical)

(P. Abell)

AIM Model Payload



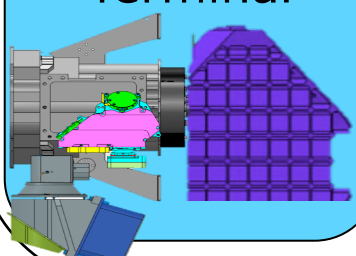


VIS
(Navigation)

High Frequency Monostatic Radar
(HFR)

MASCOT-2
+
Low Frequency bistatic Radar
(LFR)

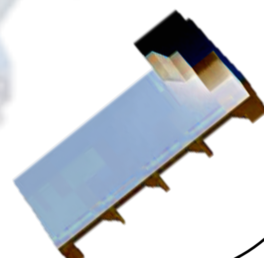
Optel-D
Optical comms Terminal



Radio Science Experiment
(TT&C s/s)

Cubesat
Opportunity Payloads
(COPINS)

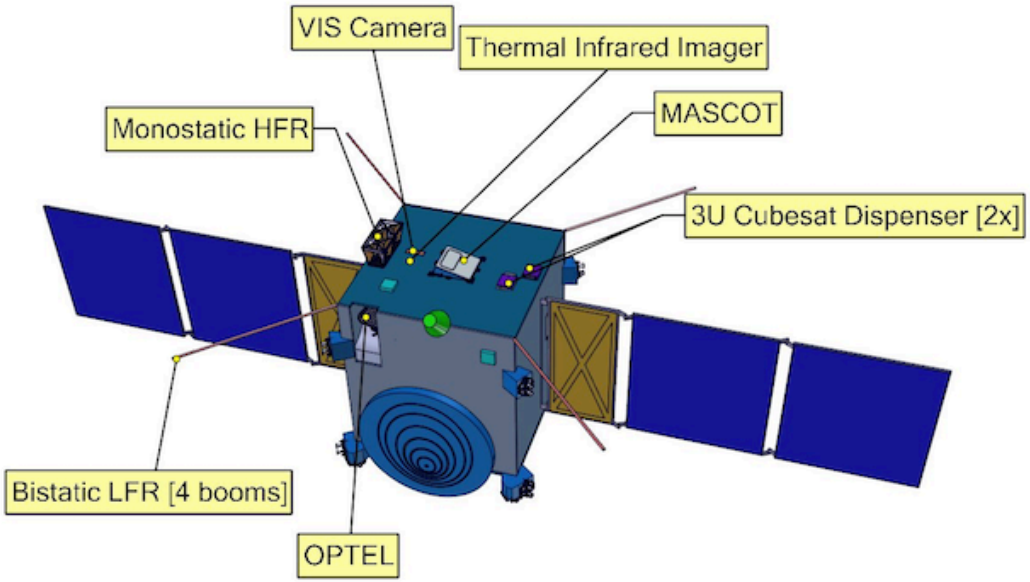
TIR Imager
(TIRI)

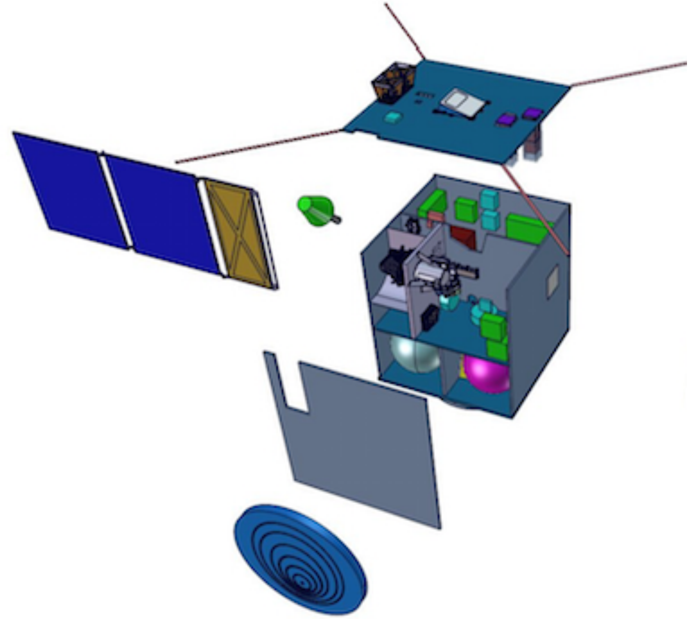


Built-in AIM S/C (subsystem)

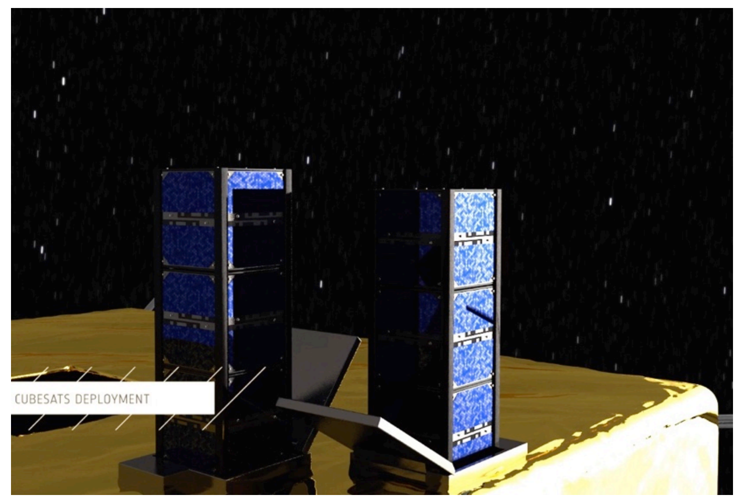
AIM payload

AIM main elements

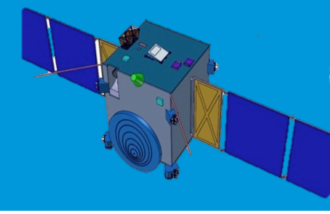


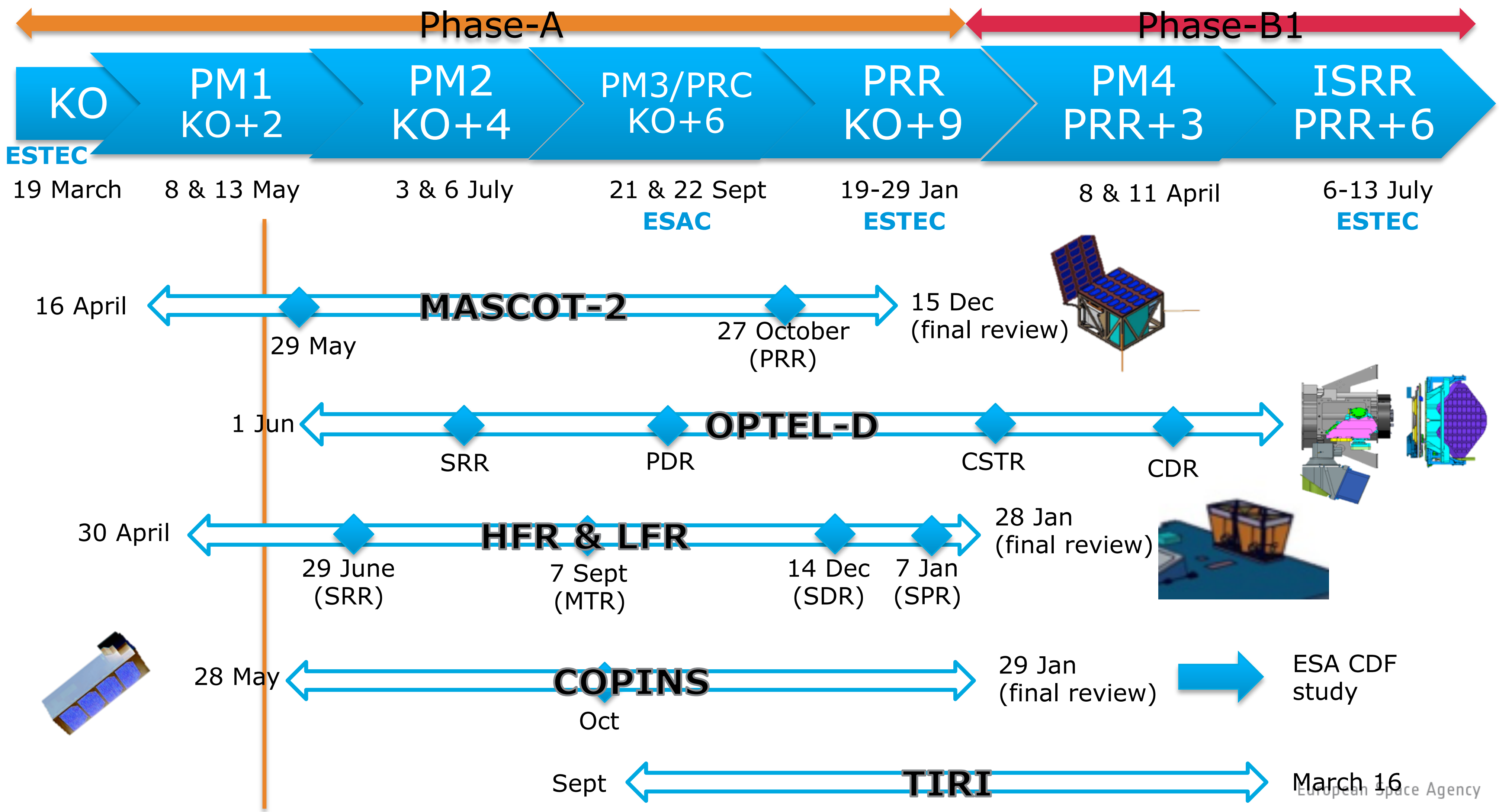


Technology Payload	Mass
OPTEL-D (Optical comms terminal)	39.3
MASCOT-2 (incl. low-frequency radar)	13
COPINS	13.2
Asteroid Research Payload	**Mass**
Thermal Infrared Imager	3.6
Monostatic High Frequency Radar	1.7
Bistatic Low Frequency Radar (Orbiter)	1.2
Visual Imaging Camera	2.4



Platform & payload activities 2015-2016



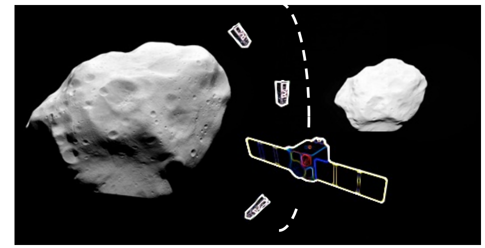


CubeSats Opportunity Payloads (COPINS): definition process

STEP 1: science evaluation

3Q 2015

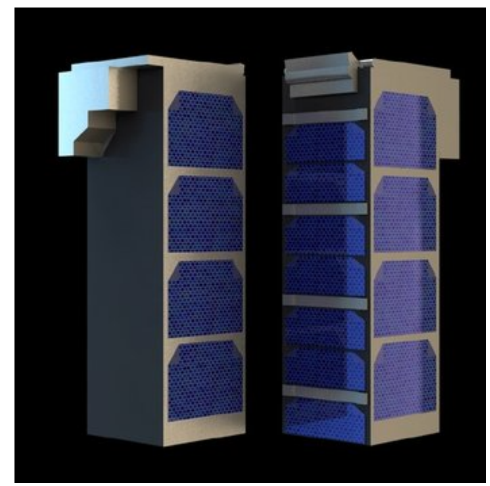
- Evaluate science opportunities offered by CubeSats using ESA SysNova scheme -> challenge
- Assess technology development needs to support science objectives



STEP 2: technical consolidation

1Q 2016

- Review/combine interesting mission options
- Perform ESA internal analysis on platform and payload technology readiness
- Define platform technology development



STEP 3: Implementation

4Q 2016
2Q 2017

- Confirm ESA MS support and match funding with technology readiness for integration by 2Q 2019
- Advance techno developments in 2016 for implementation in 2017

STEP 1: science evaluation (SysNova challenge approach)

CHALLENGE

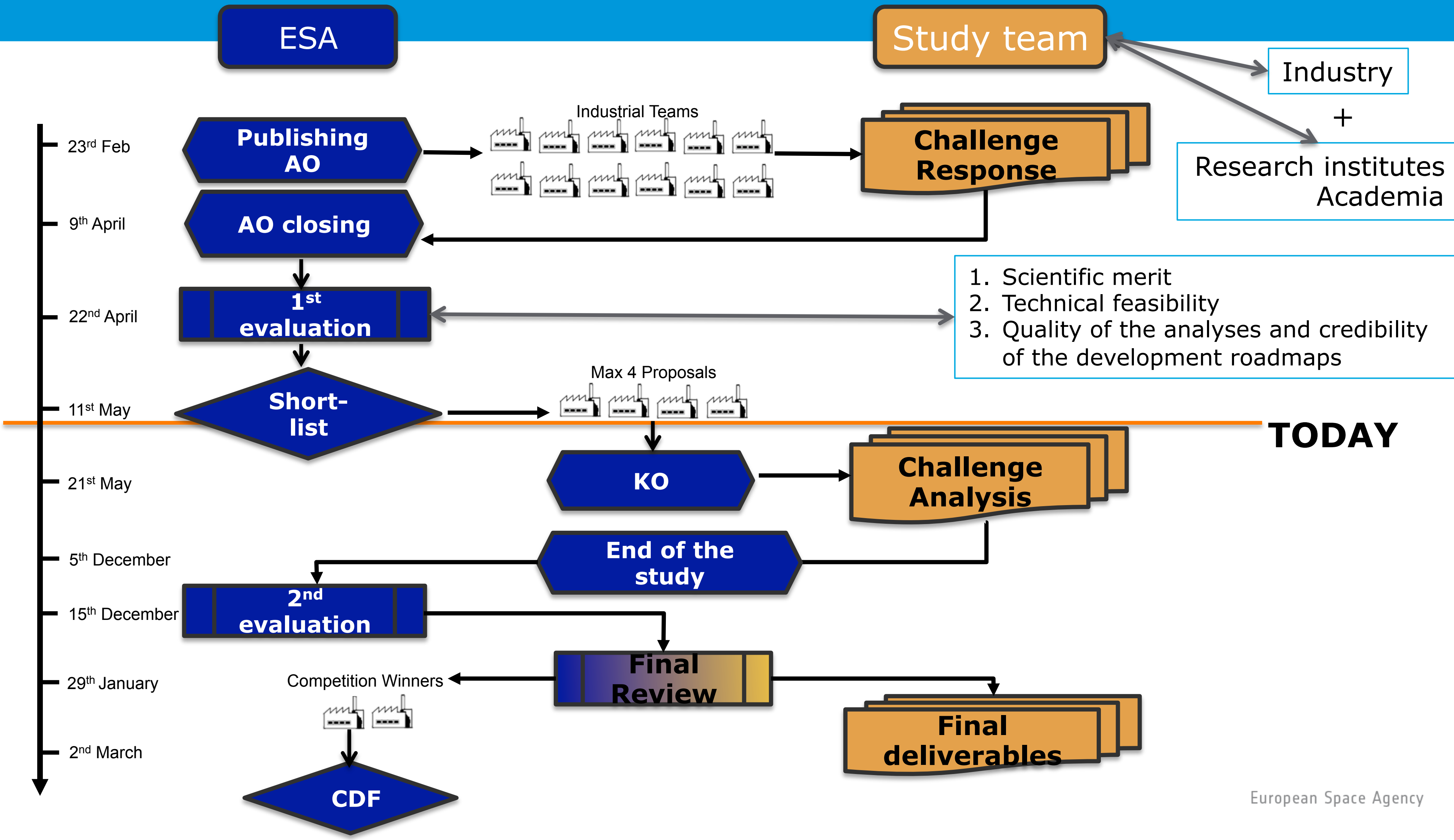
investigate concepts exploiting distributed networked or single CubeSat systems in order to provide significant contributions to the AIM asteroid research and mitigation assessment objectives.

Constraints:

1. Total volume: 2 x 3U CubeSat deployers, total of **6 units** for all CubeSats in the COPINS payload
2. Total Mass: up to **9 kg**
3. Size: up to 3U for each CubeSat
4. Design lifetime: storage during **interplanetary cruise + 3 months operations**
5. Inter-satellite link: **S-band ISL** unit and antenna(s) provided by ESA
6. Item and carried on each CubeSat with the following characteristics (TBC):
   a. <200 g transceiver mass + 2 antennas of 60 g each for omni-directional coverage
   b. 1 W receive and 3 W transmit electrical power consumption
   c. Full duplex
   d. Data rate (two-way) of up to 1 Mbps with main AIM spacecraft
   e. Total data volume of up to 1 Gbit allocated for the whole mission
   f. 3 months maximum data relay duration by AIM

8. Separation conditions: **0.5-2 m/s** velocity provided by deployer (under assessment)

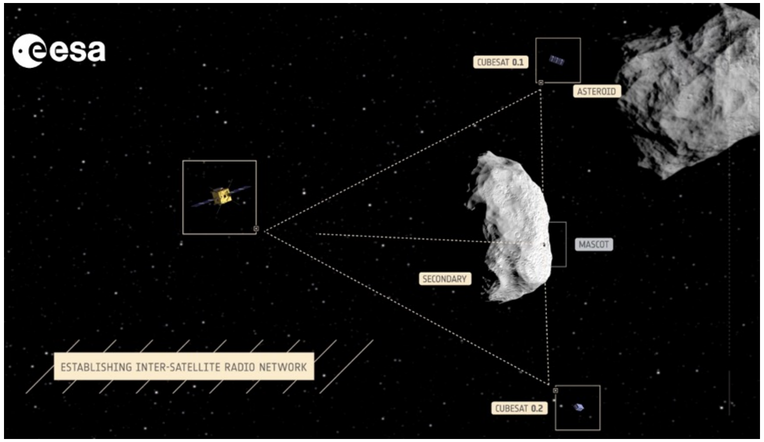
STEP 1: science evaluation (SysNova challenge approach)



STEP 1: science evaluation (SysNova challenge approach)

Asteroid surface science

- Geophones / seismometers for sounding interior structure exploiting DART impact
- Visual cameras for regolith properties
- Multi-band imager
- Mass spectrometers
- Gravimetry
- Retroreflectors
- Thermocouples for measuring moment of inertia



Asteroid proximity science

- Retroreflectors
- Visual cameras for close-proximity impact monitoring
- Volatiles
- Dust monitors to address dust environment through nephelometers
- Radioscience to sound the gravity field
- Ejecta plume tomography
- Optical astrometry (for satellite path reconstruction)
- X-ray fluorescence
- Volatiles thermogravimetry (fine dust and water vapour)
- Magnetometers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