Asteroid Impact Mission (AIM)

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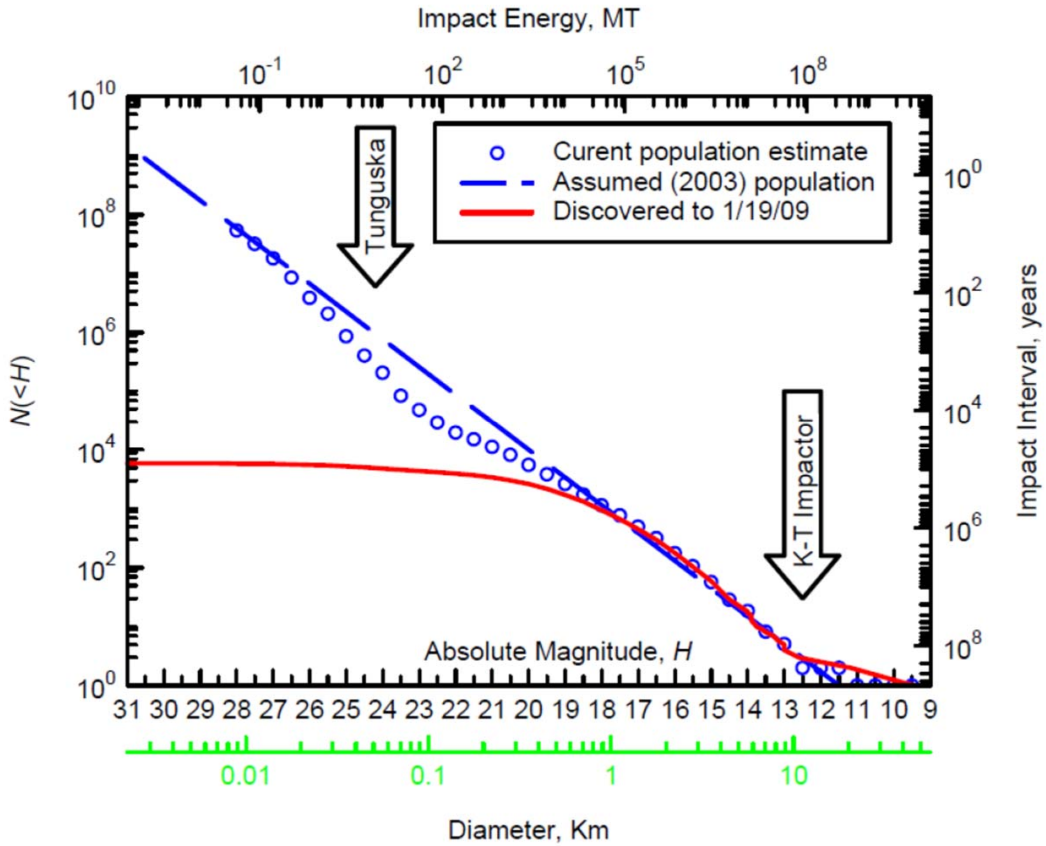
The Asteroid Hazard



Earth is continually bombarded by cosmic objects, most of which are small, but some are hazardous

Background and motivation

- ESA has studied the role of space missions with respect to the NEO Impact hazard since 2002 (Don Quijote) in the General Studies Programme.
- In line with DG´s strategy (ESA´s Agenda 2015) work now focuses on international cooperation, precursor missions and In Orbit Demonstration (IOD) of enabling technologies and operations.
- The mission and IOD studies are run within the GSP in D/TEC, while NEO hazard assessment, data policy and operations are led by D/HSO; coordination with D/SRE is in place as required.

to Sun

The history of the AIDA cooperation

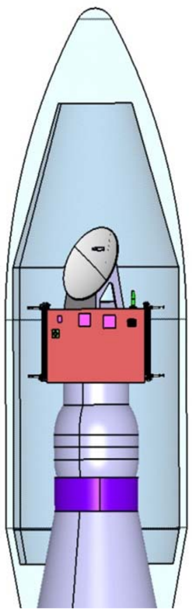
- APL-ESA-OCA-DLR contacts on mission of opportunity on earlier ESA “Don Quijote¨ work
- Goal: **jointly demonstrate asteroid deflection by kinetic impact.**
- AIDA (Asteroid Impact and Deflection Assessment) will send two spacecraft to the binary asteroid 65803 Didymos
  - Asteroid impactor
  - Asteroid rendezvous

→ **AIDA = AIM + DART**

The mission concept AIDA = AIM + DART

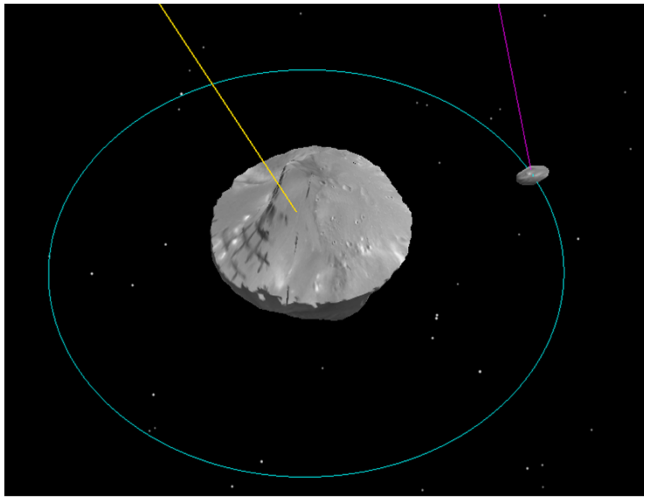
1st goal : Redirect secondary component of 65803 Didymos, and measure the binary´s orbital period variation from ground and space

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



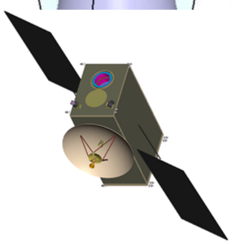
AIM: Physical characterization by close-approach spacecraft

DART: intercept spacecraft

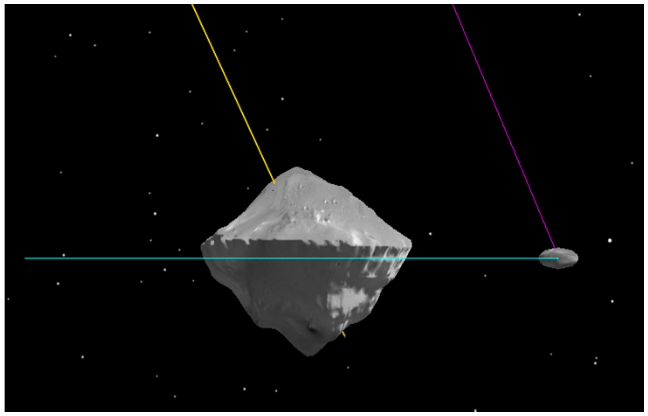


Separate spacecraft + Ground-based optical / radar validation of the test

Both mission are independent - but results boosted if operated together



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



Overlapping Goals of NEO Missions

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

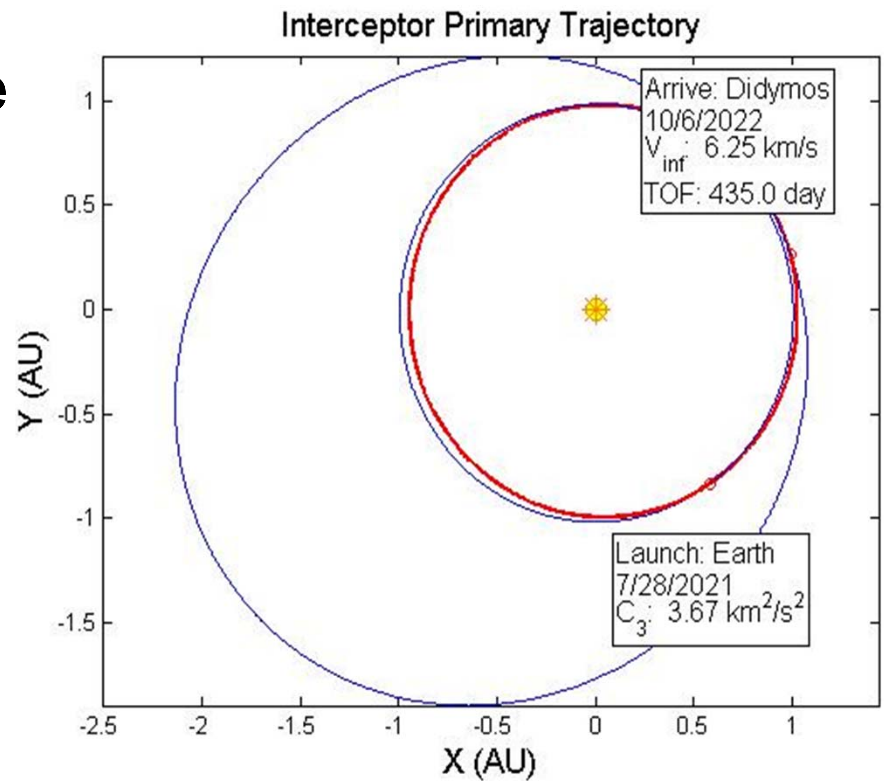
Resource Utilization
Geology, surface properties
Density, internal structure
Sub-surface properties
Composition (mineral, chemical)

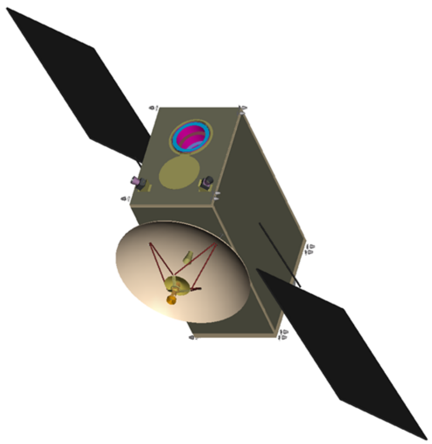
AIDA "firsts"

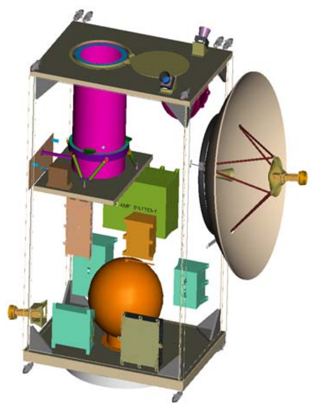
Themes	Comments
First demonstration of capability to deflect an asteroid and measure the trajectory change	Both capabilities, to deflect and to measure the deflection, are required to assure that mitigation reduces (and does not increase) an impact hazard
First rendezvous with a binary asteroid	Binary systems are an important component of Solar System small body population; as a consequence, many double Earth impacts have taken place during Earth´s history
First characterization of tons-scale impacts on an asteroid	Impact of 1.5 Ton TNT. Most asteroids, including close binaries, are believed to be rubble piles, but we don't know how they would respond to large scale hypervelocity impacts.
First active probing of internal structure and measurements of surface geotechnical properties	Although Didymos is not necessarily a human exploration target, these measurements expand our knowledge base of asteroid surfaces and help prepare for human operations on them.

DART, 2022 Didymos Intercept

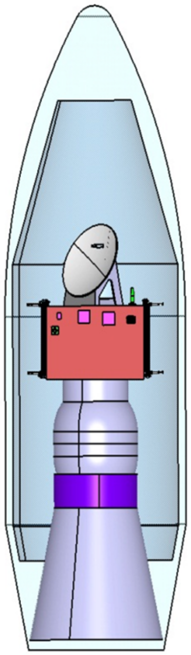
- DART trajectory remains near 1 AU from Sun, Earth distance < 0.11 AU at impact in 2022.
- Impact event occurs under excellent Earth-based viewing conditions including radar. Impact velocity 6.25 km/s





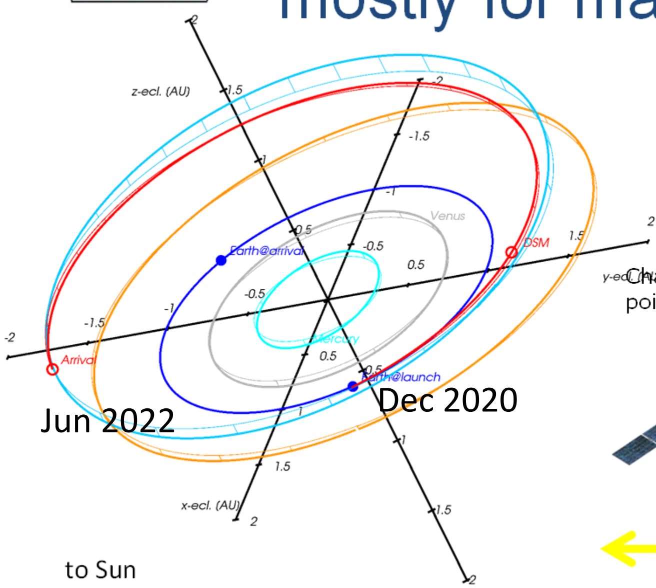


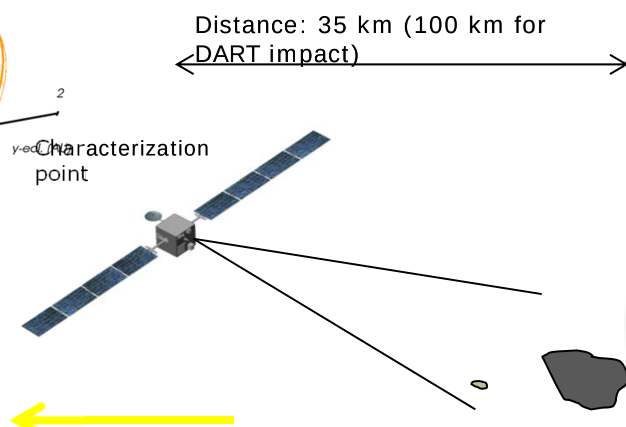
AIM, 2022 Didymos Prospector

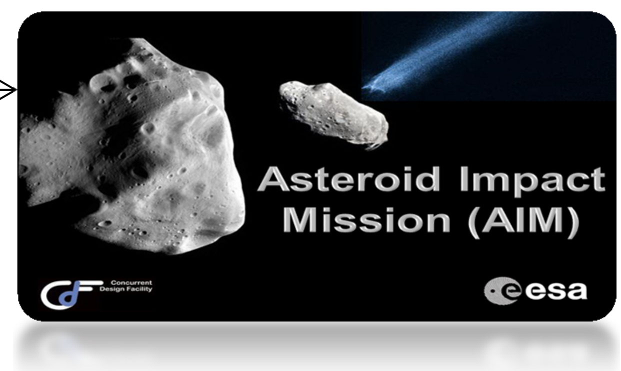


Mission statement: Determine a binary asteroid dynamics and assess its interior, while demonstrating spacecraft technologies and operations to advance small planetary missions.

Mission concept: a simple rendez-vous spacecraft, high TRL system involving selected development mostly for mass reduction. Cost target 150M€



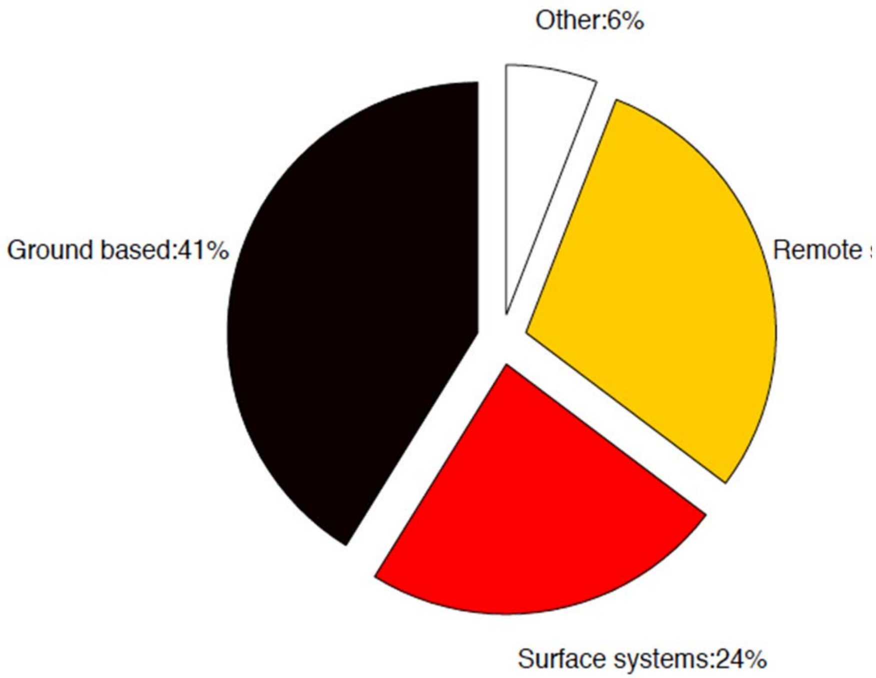


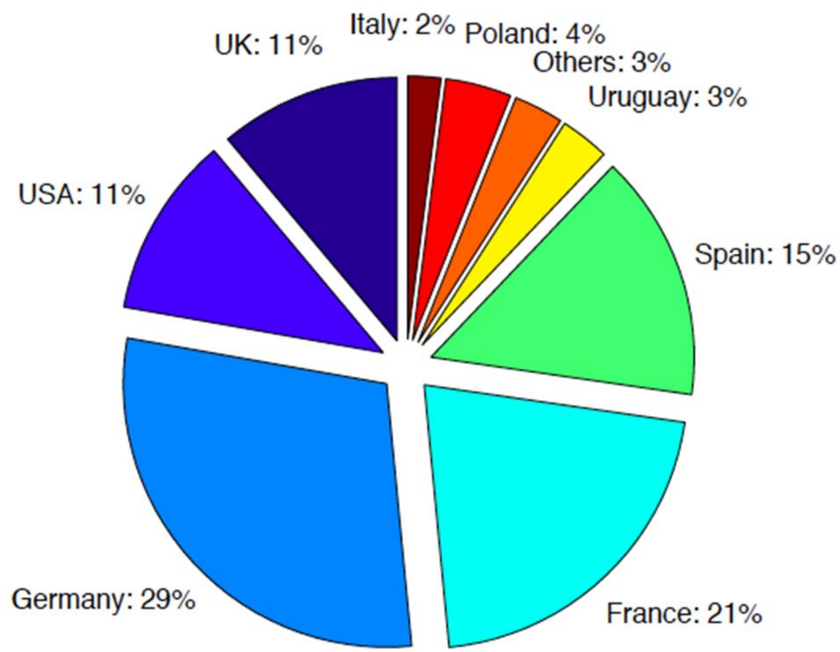


AIM Payload Objectives in Priority

P#	Parameter	Relevance to goal	Possible measurement / is it a must to have?
1	• Moonlet size, mass, shape, density	• Mass key to momentum, size to shape, volume, gravity to internal structure, operations	• Mass from binary orbit, shape model from CAM (or LIDAR), a must
2	• Dynamical state (binary, moonlet Rotation state)	• Key to determine momentum	• Ground-based photometry & radar, in-space visual observations (CAM)
3	• Surface properties, topology, roughness, shallow subsurface	• Material mechanical properties, surface thermal inertia, context for ejecta generation (¨beta factor¨)	• CAM for surface features (and LIDAR) • TIR for surface roughness (must)
4	• Deep subsurface, internal structure, gravity. chem. composition	• Interior affects absorption of impact energy, “data point” for study of asteroid mitigation. Gravity for operations. Chemical composition for context for ¨beta factor¨.	• Radar or seismic probing beneficial if a simple implementation can be found (low mass and system impact) • Drift-bys might help estimate gravity field • CAM VIS photometry to derive spectral type, IR spectrometer mineralogy

AIDA Call for Experiment Ideas





Proposals for both ground and space-based experiments from co-Pis around the world
This information has been used by ESA to help understand interests

AIM Deep Space Technology Test

Objective: provide a flight opportunity Deep space Optical Terminal (DOT)

Rationale: to demonstrate **deep-space optical communications** relevant to interplanetary and L2 missions (e.g. Euclid, Plato,...)

Ground terminal for a Lunar/L2 scenario (0.4m, incl. Uplink)

Strong heritage in Europe Laser communication terminal RUAG (OPTEL 80 ISL, Gbps rates over distances of 80,000 km. TESAT (Alphabus LCT) for GEO-LEO and space-ground.

NASA has tested LADEE´s LLCD (622 Mbps down/20 Mbps up from the Moon using ESA´s OGS)

Reference data	(2016 Frame)
Data return	17.3 Tbit in 180 mins
Space terminal power	140 W
Space terminal mass	30 kg
Space terminal volume	15 lt (modem inside platform) + 30 cm x 30 cm (external optical head)
Ground network	2 stations in different hemispheres with 4m antenna (or 2x 2.8m)

Target: 267 Mb/s from 0.42 AU. Max range 2.3 AU

AIM S/C Preliminary Considerations

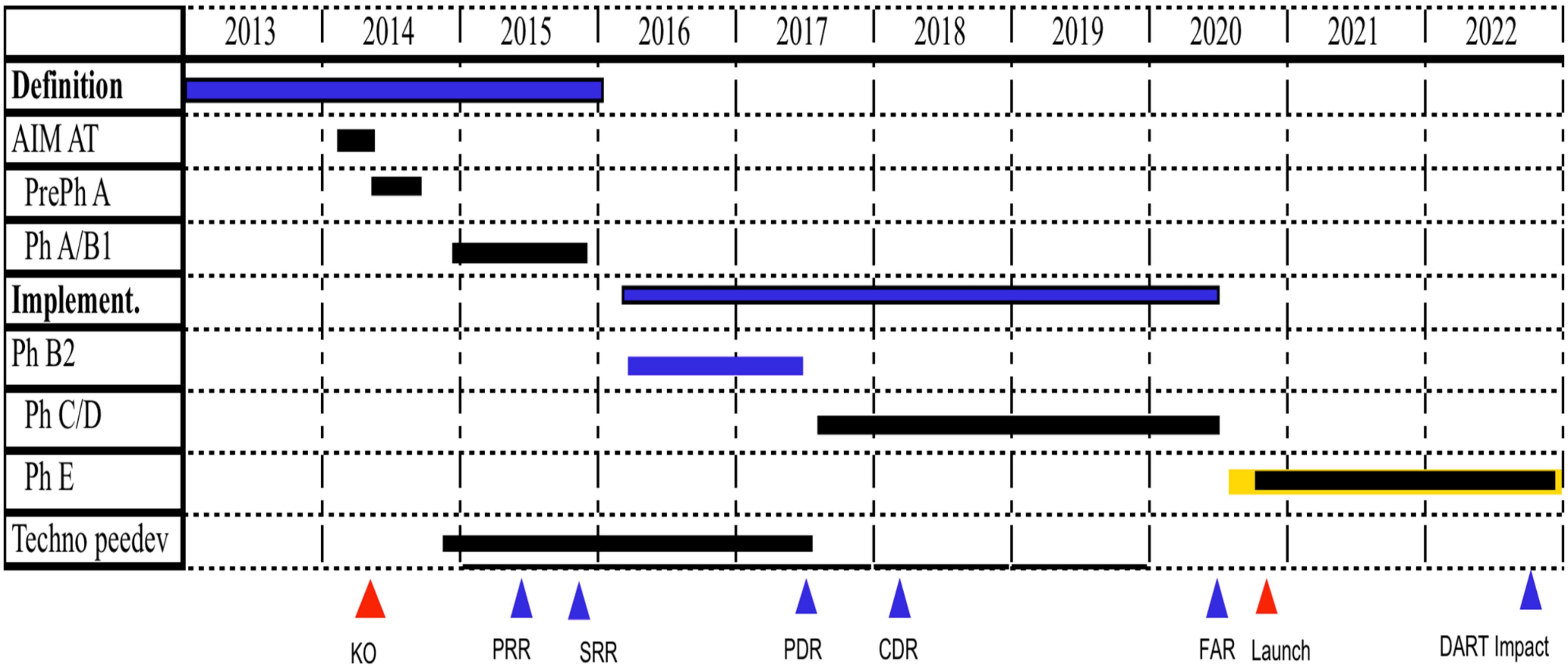
- **ESA internal studies are currently ongoing**
- Max. heliocentric distance is 2.3 AU but s/c can be designed to operate around 1 AU as there are not very demanding power or telecom needs at maximum heliocentric distance (s/c hybernation).
- Intense operations only some months around Oct 2022.
- Simple communications due to relatively low range (as close as 0.11 AU during impact even), optical communication as a technology test.
- Transfer time and cost drive the choice of chemical propulsion; total s/c delta-v is modest (about 1 kms)
- Simple concept, no unneeded sophistication in s/c bus, e.g. no mechanisms (fixed HGA and solar arrays).
- Deployment of surface payloads from fail-safe hyperbolic flyby –no need for challenging close-range operations.

The AIDA Opportunity

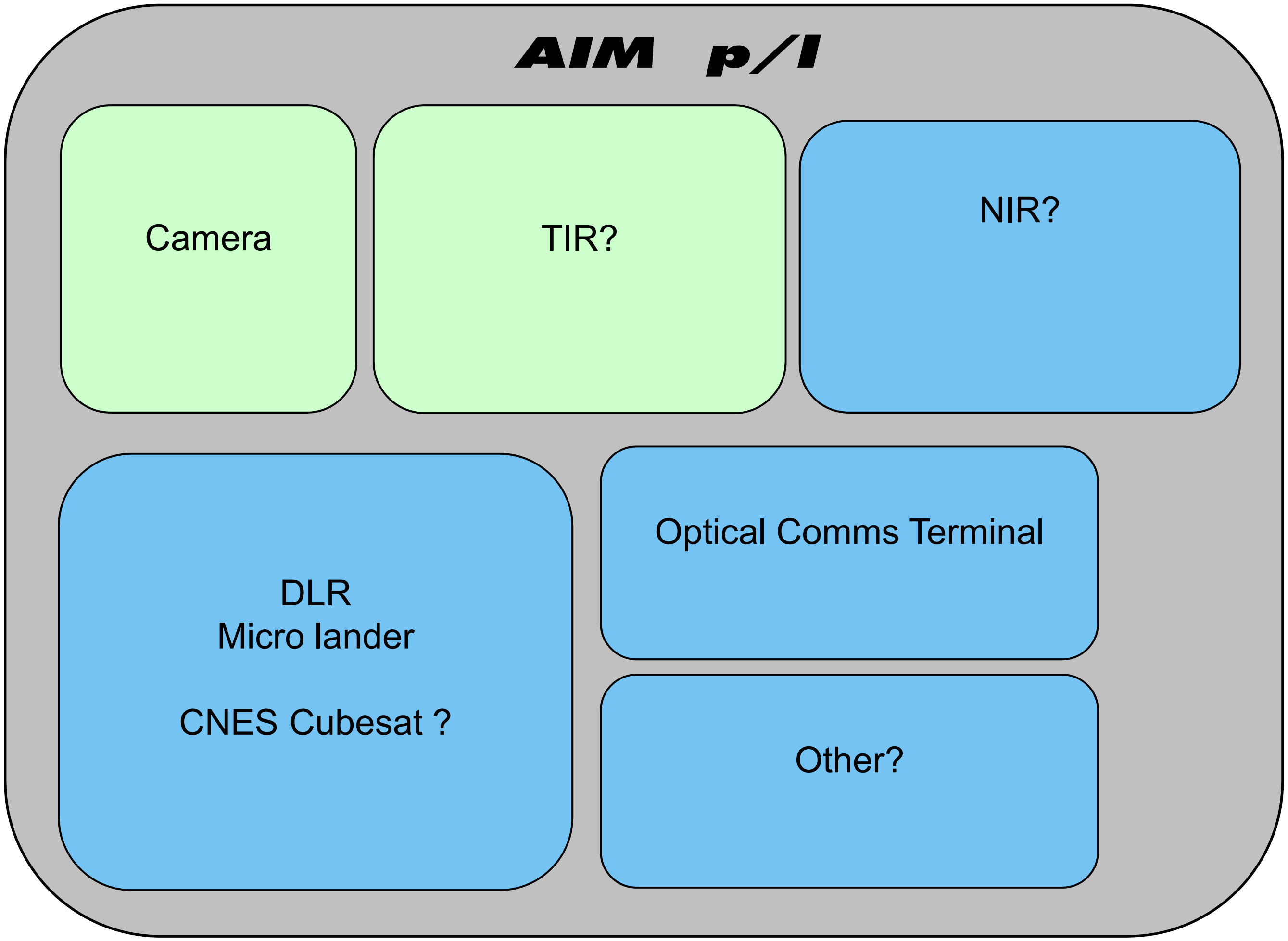
- Didymos is a well characterised binary and sizes of components are just right -850 m & 150 m diam.- to enable a kinetic deflection test.
- Close approach to Earth in 2022 (range 0.11 AU), excellent radar observation opportunity, best till 2042.
- Ground-based measurements: radar and photometry enabling impact determination with $\Delta p/p<10\%$
- DART and AIM, two short missions (TOF 435 and 600 d, launch in ´21 and `20, resp.), impact test on 06/10/22. AIM will have a privileged view on a exceptional test, one that will demonstrate Humanity´s ability to change the course of an asteroid for the first time in history.


esa
European Space Agency

AIM schedule



Payload Options



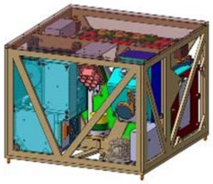
AIM candidate experiments

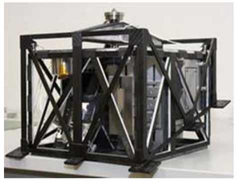
Objective: provide flight opportunities for microlanders and active experiments in addition to remote sensing instruments.

Rationale: study the asteroid shallow subsurface and internal structure

Small-scale pyrotechnic device: 0.41kg, 76mm x 40mm, 200J impact.

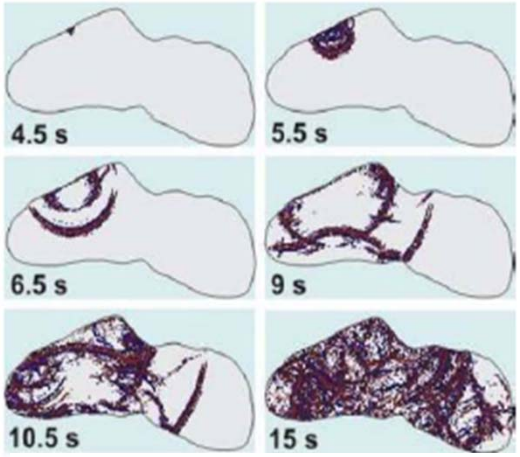
Medium-scale pyrotechnic device: 1.3kg, 133mm x 135mm, 200 kJ





Surface package heritage of 10kg-MASCOT design (DLR contribution to the JAXA Hayabusa-2 mission). **Seismic sensors** heritage based on CNES SEIS payload for InSight, cubesats, APL active sounding.

Impactor	Energy	Crater diameter
Small-scale	200 J	25 cm
Medium-scale	200 kJ	108 cm



Propagation of a seismic wave in Eros