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
→ **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 “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.
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<tr>
<th>#</th>
<th>GOAL</th>
<th>COMMENT</th>
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</table>
| 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 TECHNOLOGY RESEARCH OBJECTIVES
### AIM (alone) PRIMARY SCIENCE OBJECTIVES

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

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>RELEVANCE</th>
<th>SUPPORTING INSTRUMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>S#6 Didymoon post-impact characterisation</td>
<td>Changes due to impact</td>
<td>All</td>
</tr>
<tr>
<td>S#7 Didymain characterisation</td>
<td>Origin of the system</td>
<td>VIS, TIRI, HFR, LFR</td>
</tr>
<tr>
<td>S#8 Impact ejecta</td>
<td>Properties of ejected dust</td>
<td>VIS, TIRI, HFR</td>
</tr>
<tr>
<td>S#9 Ambient dust</td>
<td>Dust in Didymos environment</td>
<td>VIS, TIRI, HFR</td>
</tr>
<tr>
<td>S#10 Chemical and mineralogical composition</td>
<td>Asteroid classification, origin of the system</td>
<td>VIS (TBC), TIRI, MASCOT-2 lander</td>
</tr>
</tbody>
</table>
AIM MISSION SCENARIO

PAYLOAD
- VIS
- Mascot-2 + LFR
- HFR
- Hyperspec/TIRI
- Optel-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)**
- **TIR Imager (TIRI)**
- **MASCOT-2 incl. LFR, DACC, CAM, MARA**

Options under study:
- Hyperspectral camera
- European Lidar

Built-in AIM S/C (subsystem)
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)
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 cm³.

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)

- **2015**
  - **PM1** KO+2
  - **PM2** KO+4
  - **PM3/OMC** KO+6

- **2016**
  - **PRR** KO+9
  - **PM4** PRR+3
  - **ISRR** PRR+6

**ESTEC**
- 19 March
- 8 & 13 May
- 3 & 6 July
- 21 & 22 Sept
- 12 - 29 Jan
- 8 & 11 April
- 11 July - 13 Sept

**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**

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

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

- WISDOM
  - 30 April (KO)
  - 14 Sept (MTR)
  - 7 Jan (SPR)
  - 4 Mar (Final review)

- Aalto-1, Picasso, Xatcobeo, HumSat-D, Optos, SEAM...
  - SRR (29 Jun)
  - 14 Dec (SDR)

- MERTIS, CAMIR, Hypercube...
  - 9 Oct (KO)
  - 17 Nov (KUDOS)
  - 8 Feb (PM1)

- CIVA, X-CAM, Clupi...
  - 10 June (Final review)

**AFTER AIM**

- Exploration
- Mars, human exploration, L-missions
- Planetary exploration
- Earth observation, lunar explo
- RDV & docking EOP, planetary
- CubeSats, Exploration

**ESA CDF Study (July)**

**EXPLORATION**

- Exploration
- Mars, human exploration, L-missions
- Planetary exploration
- Earth observation, lunar explo
- RDV & docking EOP, planetary
- 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, optical 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
**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)