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

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Roger Walker cubesat specialist
... and the ESA team
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

1\textsuperscript{st} goal: Redirect secondary component of Didymos, and measure the deflection by monitoring the binary’s orbital period change

2\textsuperscript{nd} 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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Relevance</th>
<th>Supporting instruments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>S#1 Didymoon size, mass, shape, density</strong></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 Didymoon dynamical state</strong></td>
<td>Momentum transfer, Indirect constraints on interior structure (?)</td>
<td>VIS</td>
</tr>
<tr>
<td><strong>S#3 Geophysical surface properties, topology, shallow subsurface</strong></td>
<td>Composition, mechanical properties, thermal inertia =&gt; Interpretation of impact</td>
<td>VIS, Thermal Infrared Imager (TIRI), High Frequency Radar (HFR), Accelerometer on Lander (?)</td>
</tr>
<tr>
<td><strong>S#4 Deep-internal structure of the moonlet</strong></td>
<td>Interpretation of impact, Origin of binary</td>
<td>Low Frequency Radar (LFR)</td>
</tr>
<tr>
<td>Parameter</td>
<td>Relevance</td>
<td>Supporting instruments</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
<td>-----------------------------------------------</td>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>S#5 Didymoon post-impact characterisation</td>
<td>Changes due to impact</td>
<td>All</td>
</tr>
<tr>
<td>S#6 Didymain characterisation</td>
<td>Origin of the system</td>
<td>VIS, TIRI, HFR, LFR</td>
</tr>
<tr>
<td>S#7 Impact ejecta</td>
<td>Properties of ejected dust</td>
<td>VIS, TIRI, HFR</td>
</tr>
<tr>
<td>S#8 Ambient dust</td>
<td>Dust in Didymos environment</td>
<td>VIS, TIRI</td>
</tr>
<tr>
<td>S#9 Chemical and mineralogical composition</td>
<td>Asteroid classification, origin of the system</td>
<td>VIS (TBC), TIRI, MASCOT-2 lander</td>
</tr>
<tr>
<td>S#10 Comparison to observations from earth</td>
<td>Ground truth for other asteroids</td>
<td>VIS, TIRI, HFR</td>
</tr>
</tbody>
</table>
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)

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

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

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

P. Abell
AIM Model Payload

- VIS (Navigation)
- High Frequency Monostatic Radar (HFR)
- MASCOT-2 + Low Frequency bistatic Radar (LFR)
- Radio Science Experiment (TT&C s/s)
- Cubesat Opportunity Payloads (COPINS)
- Optel-D Optical comms Terminal
- TIR Imager (TIRI)
- Built-in AIM S/C (subsystem)
- AIM payload
## AIM main elements

### Technology Payload

<table>
<thead>
<tr>
<th>Payload</th>
<th>Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPTEL-D (Optical comms terminal)</td>
<td>39.3</td>
</tr>
<tr>
<td>MASCOT-2 (incl. low-frequency radar)</td>
<td>13</td>
</tr>
<tr>
<td>COPINS</td>
<td>13.2</td>
</tr>
</tbody>
</table>

### Asteroid Research Payload

<table>
<thead>
<tr>
<th>Payload</th>
<th>Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal Infrared Imager</td>
<td>3.6</td>
</tr>
<tr>
<td>Monostatic High Frequency Radar</td>
<td>1.7</td>
</tr>
<tr>
<td>Bistatic Low Frequency Radar (Orbiter)</td>
<td>1.2</td>
</tr>
<tr>
<td>Visual Imaging Camera</td>
<td>2.4</td>
</tr>
</tbody>
</table>
Platform & payload activities 2015-2016

Phase-A

KO
- PM1 KO+2
- 19 March
- 8 & 13 May

PM2 KO+4
- 3 & 6 July

PM3/PRC KO+6
- 21 & 22 Sept
- ESAC

PRR KO+9
- 19-29 Jan
- ESTEC

PM4 PRR+3
- 8 & 11 April

ISRR PRR+6
- 6-13 July
- ESTEC

Phase-B1

MASCOT-2
- 16 April
- 29 May
- 27 October (PRR)
- 15 Dec (final review)

OPTEL-D
- 1 Jun
- SRR
- PDR
- CSTR
- CDR

HFR & LFR
- 29 June (SRR)
- 7 Sept (MTR)
- 14 Dec (SDR)
- 7 Jan (SPR)
- 28 Jan (final review)

COPINS
- 28 May
- Oct

TIRI
- Sept

28 Jan (final review)

ESA CDF study

European Space Agency
CubeSats Opportunity Payloads (COPINS): definition process

STEP 1: science evaluation
- Evaluate science opportunities offered by CubeSats using ESA SysNova scheme -> challenge
- Assess technology development needs to support science objectives

STEP 2: technical consolidation
- Review/combine interesting mission options
- Perform ESA internal analysis on platform and payload technology readiness
- Define platform technology development

STEP 3: Implementation
- 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)

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
7. Separation conditions: 0.5-2 m/s velocity provided by deployer (under assessment)
STEP 1: science evaluation (SysNova challenge approach)

Industry + Research institutes Academia

1. Scientific merit
2. Technical feasibility
3. Quality of the analyses and credibility of the development roadmaps

23rd Feb
Publishing AO

9th April
AO closing

22nd April
1st evaluation

11th May
Short-list

21st May

5th December
2nd evaluation

15th December
End of the study

29th January
Final Review

2nd March
CDF

Challenge Analysis

Max 4 Proposals

Challenge Response

Final deliverables

TODAY
**Asteroid surface science**
- Geophones / seismomters 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