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ASTEROID IMPACT MISSION (AIM) & DEFLECTION ASSESSMENT: AN OPPORTUNITY TO UNDERSTAND IMPACT DYNAMICS AND MODELLING

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Abstract

ESA's Future Preparation and Strategic Studies Office has carried out the Asteroid Impact Mission (AIM) study with the objective of defining an affordable and fully independent mission element that ESA could contribute to an Asteroid Impact Deflection Assessment campaign (AIDA), a joint effort of ESA, JHU/APL, NASA, OCA and DLR. The mission design foresees two independent spacecraft, one impactor (DART) and one rendezvous probe (AIM). The target of this mission is the binary asteroid system (65803) Didymos (1996 GT): one spacecraft, DART, would impact the secondary of the Didymos binary system while AIM would observe and measure any the change in the relative orbit. For this joint project, the timing of the experiment is set (maximum proximity of the target to Earth allowing for ground-based characterisation of the experiment) but the spacecraft are still able to pursue their missions fully independently. This paper describes in particular the AIM rendezvous mission concept.

1. AIM objectives

The AIDA/AIM rendezvous spacecraft (see Figure 1) would be under responsibility of ESA. It would arrive before APL's DART impactor spacecraft in order to characterize the binary asteroid, and have the chance to observe the impact as well as the resulting ejecta and crater. The main objectives of the rendezvous spacecraft are therefore to:

- Determine the binary asteroid orbital and rotation state;
- Analyse size, mass and shape of both binary asteroid components;
- Analyse geology and surface properties;
- Observe the impact crater and derive collision and impact properties.

The assessment considered two scenarios, one that includes the DART mission and an impact on the Didymos moonlet and one without an impact, concentrating on an asteroid characterisation campaign and AUTONAV tests.

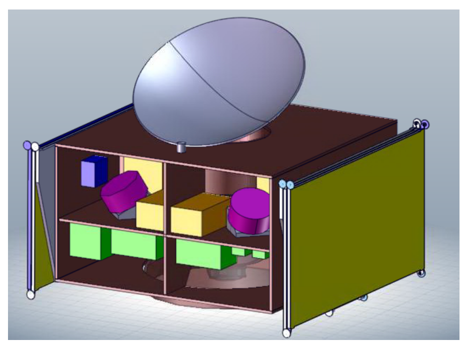

Figure 1: AIM spacecraft in stowed configuration

2. Mission scenario

The AIDA rendezvous mission is designed to be compatible with the VEGA launch vehicle, which would require an additional low-cost "kick motor" (e.g. STAR-48) to perform the 1 km/s Earth escape burn. Within the study all major design trade-offs have been carried out. Given the demanding mass envelope imposed by the use of the VEGA launch vehicle, the selection of the spacecraft propulsion technology (chemical vs. electrical) was of particular importance. The analysis considered mostly the reference interplanetary trajectory (direct transfer or including swing-bys) and the resulting mass at arrival. The requirement was for the spacecraft to arrive two months before the DART impactor spacecraft. Due to the low values of the arrival mass at the asteroid, chemical propulsion was discarded. The resulting baseline trajectory involves an Earth swing-by and assumes a performance of a SNECMA PPS-1350 Hall-effect thruster, the one demonstrated by ESA's SMART-1 lunar mission.

Table 1: SEP interplanetary transfer

Launch	**19/08/2019**
Escape velocity [km/s]	1.0
Declination [deg]	-14.46
Escape mass [kg]	400
Earth swing-by	**07/11/2020**
Infinite velocity at SB [km/s]	5.44
Vel. at pericentre [km/s]	10.8
Pericentre altitude [km]	2854
Arrival	**01/08/2022**
Final mass [kg]	324
SEP delta-v [km/s]	2.9
Xenon consumption [kg]:	73
Hydrazine consumption [kg]:	5
Thruster on time [d]:	213
Total impulse [10^6kg m/s]:	1.05

Upon arrival, the spacecraft would perform continuous observations from a serious of fixed "station points" relative to the asteroid inertial frame and at a safe distance, out of the sphere of influence of both Didymos components. In order to be able to image the two bodies for precise measurements of the orbital state, distances of 13.5 to 17 km were considered for the first characterisation point. The impact of the impactor spacecraft will be observed from a second characterisation point at 100 km distance to avoid any damage by debris generated from the impact ejecta.

4. Strawman payload

A strawman payload for the characterisation of the asteroid consists of a Narrow Angle Camera (NAC), a Micro Laser Altimeter, a Thermal IR Imager and a NIR spectrometer. The NAC combines navigation and science purposes, allowing to observe both the impact and the impact crater while measuring the orbital and rotational state, as well as the asteroid's shape. The Micro Laser Altimeter should have an operational range higher than 10 km for precise shape model. The Thermal IR Imager would provide surface temperature and thermal inertia data, the NIR spectrometer would allow instead a global mapping of the surface mineralogy. It is to be noted that no Radioscience Experiment is foreseen as the momentum transfer due to DART's impact can be inferred from the change in orbital period of the secondary around the primary NEA both measurable from the AIM spacecraft and from ground (by means of lightcurve measurements).

Table 2: AIM strawman payload.

Instrument	Mass (kg)	Power (W)	FOV (deg)	Aperture (mm)
NAC	2.0	0.75	5.3 x 5.3	14.2
Micro Laser Altimeter	2.5	4	0.003	30
Thermal IR Imager	1.5	1	4	40
NIR spectrometer	1.5	7	4	38

6. Summary and Conclusions

The mission goal for ESA's Asteroid Impact Mission study was to characterise the components of a binary asteroid, especially from the dynamical point of view. The mission concept focuses on the monitoring aspects, that is the capability to determine in-situ the key physical properties of a binary asteroid playing a role in the system's dynamic behaviour. A low-cost small-class spacecraft design was identified that would increase Europe's competitiveness through the development of new technologies also relevant to other missions, in particular in the area of autonomous guidance, navigation and control. When coupled to the DART impactor mission, and assuming both spacecraft are targeting the same object (Didymos) around its 2022 close Earth encounter, the mission objectives can be addressed in full: object characterisation, impact test, and momentum transfer assessment.

Acknowledgements

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