Executive Summary
Final report
Asteroid Impact Mission

Advisory Study

By

Dr. Patrick MICHEL
Lead of the AIM Advisory Team
Université Côte d'Azur, OCA, CNRS

October 27th, 2016

In this report, we describe the advisory study for both the Asteroid Impact Monitoring (AIM) as a stand-alone European mission and for AIM with its second component, the US Double Asteroid Redirection Test (DART) mission under study at NASA by the John Hopkins University Applied Physics Laboratory.

AIM is a rendezvous mission that focuses on the monitoring aspects i.e., the capability to determine in-situ the key properties of the secondary of the binary asteroid 65803 (1996GT) Didymos. DART consists primarly of an artificial projectile aims to demonstrate asteroid deflection. In the framework of the full AIDA concept, AIM will also give access to the detailed conditions of the DART impact and its outcome, allowing for the first time to get a complete picture of such an event, a better interpretation of the deflection measurement and a possibility to compare with numerical modeling predictions.

The mission goal for AIM is twofold. On one hand it will provide the opportunity to demonstrate, on the minimum expression of a deep-space mission, technologies related to autonomous navigation, on-board resources management, inter-satellite networks, optical communication and close proximity and landing operations. On the other hand it will characterise for the first time the secondary of a binary asteroid and demonstrate the technologies required by a simple monitoring spacecraft as well as establishing the suitability of binary asteroids as candidates for future explorations and asteroid deflection tests.

Both AIM and AIDA address issues that interest a large variety of communities, such as communities of researchers and engineers working on impact physics, planetary defense, seismology, geophysics (surface and internal properties), dynamics, mineralogy and resources, spectral and physical properties of small bodies, low-gravity environment and human exploration.

Figure 1 shows that AIM serves a wide range of objectives. Accompanied with DART it will also serve as a deflection demonstration and provide important knowledge on the impact process on asteroids.

The report describes the different tasks performed during this study. The first task has been to consolidate the AIM scientific objectives. The first activity in this task was to evaluate and refine all scientific objectives to enable a derivation of physical parameters to be measured by the AIM instruments and a quantification of the required measurement accuracies. The following activity led to the final mission objectives document called AD50, which describes the mission objectives for the AIM spacecraft and the objectives set for different payloads to achieve them. It contains information on both, scientific objectives (including those linked to asteroid hazard mitigation) and technological objectives. As a result of this work, it is considered that the AIM spacecraft will carry two AIM Framing Cameras (AFC), as part of the spacecraft guidance and navigation system. The payload would also feature ‘dual-use’ as science and technology payload that can gather data and provide navigation or positioning information, increase operations flexibility or enhance the mission performance in other ways. The additional payloads being studied include a Hyperspectral Imager (HYP), a Thermal InfraRed Imager (TIRI), a monostatic High Frequency Radar (HFR) and a bistatic Low Frequency Radar (LFR), a communications Optical Laser Terminal doubling as range-finder (OPTEL-D), a

Lidar (Planetary ALTimeter), an asteroid micro-lander (MASCOT-2) and two 3U cubesats (COPINS).

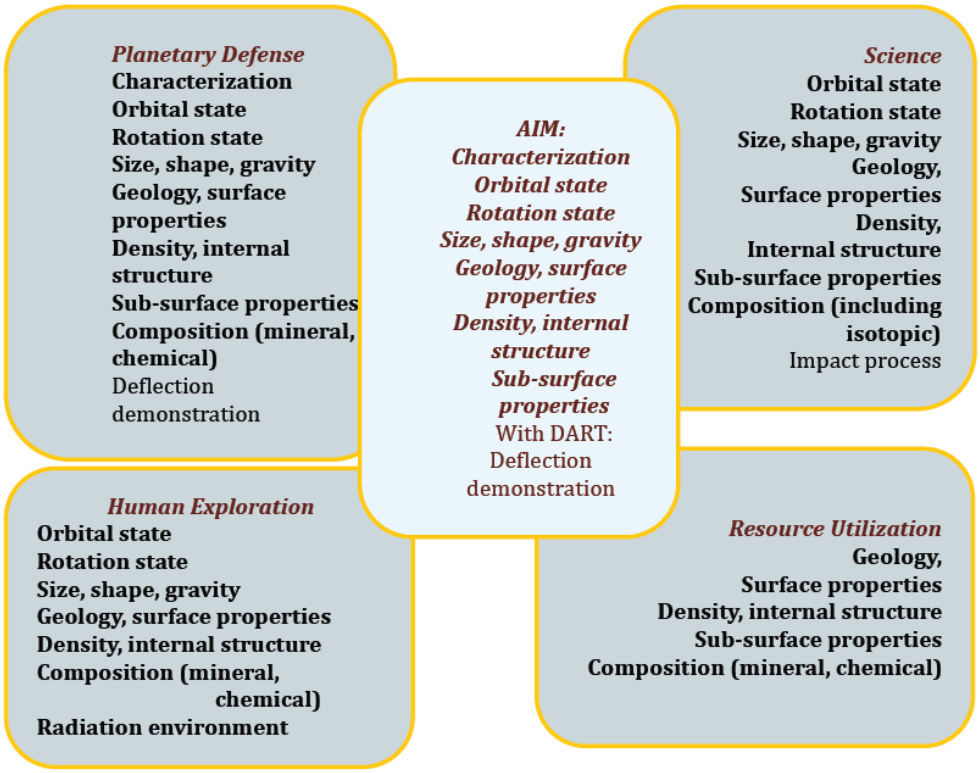

Figure 1: The full AIDA concept serves all NEO exploration stakeholders. The same applies to AIM as a stand-alone mission (bold characters), except for the deflection demonstration.

The second task was to review the instrument requirements, using as input the updated AIM scientific objectives. This task led to the AIM payload requirements document.

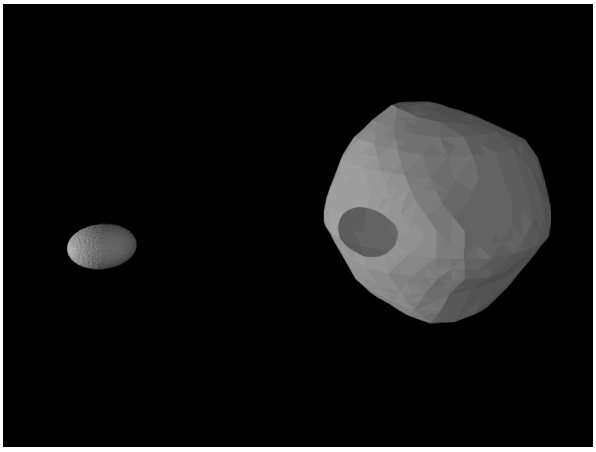

Figure 2: Preliminary shape model of the primary of Didymos obtained from combined modeling of the radar and photometry data from 2003, shown with Didymoon at scale with assumed ellipsoid axes.

The third task was to update the Didymos environmental model. Thanks to the different expertise represented in the AIM advisory team, in the areas of observations as well as small body dynamics and physical properties, it has been possible to define

a Didymos Reference Model that contains all the current knowledge regarding Didymos, in terms of physical parameters, dynamics and environment. Unfortunately, there are still many unknown regarding the binary properties, and big efforts have been made to provide the best estimates regarding the unknown parameters, based on modeling, dynamical considerations and knowledge from other observed binary systems. This task led to the Didymos Reference Model called AD3. Fig. 2 shows the shape model of Didymos defined during this activity and used in the AIM study.

The fourth task was to assemble and coordinate the AIM Advisory team, and to organize open meetings involving the relevant scientific community, to debate the results of the different tasks of the study, as well as to organize specific meetings with international partners that might be required in addition to the scientific workshops mentioned above. The AIM Advisoty team has been defined to include the relevant expertise for the mission study. AIM Advisory team meetings have taken place regularly in Nice at the Observatoire de la Côte d'Azur, to discuss the advances of the first three tasks, and other meetings took place during various international meetings. Two papers in peer-reviewed journal have been published by the team, one on AIM (Michel et a. 2016, Av. Space Res. 57, 2529-2547), the other on DART (Cheng, Michel, et al. 2016, Plan. Space Sci. 121, 27-35). AIM and AIDA (involving our US partner). Workshops open to the community have been organized during this contract. Some of them were specifically organized, such as the AIM workshop that took place at ESAC in March 2016 and the AIDA International Workshop that took place in Nice on June 1-3, 2016 (Fig. 3). Special sessions on AIM and/or AIDA have been organized during international congresses, such as the General Assembly of the European Geophysical Union in April 2016, in which the abstract call was open to the entire community. Other workshops or splinter meetings have been organized to update the community with the current status of the mission and to answer to questions during international congresses, such as the Asteroid Comet Meteor 2014 meeting in Finland in July 2014, the Planetary Defense Conference in Frascati in April 2015, the General Assembly of the International Astronomical Union in Hawaii (US) in August 2015, the Lunar and Planetary Science (LPSC) Congress in The Woodlands (Texas) in March 2015 and 2016, the Annual Meetings of the American Division of Planetary Science (DPS) in November 2015 and October 2016, etc … Finally Press conferences and Radio/TV interviews have been given during the study and articles in popular journals and newspapers have been written in different countries about the mission.

Figure 3: Picture at the AIDA International Workshop 2016 organized in Nice on June 1-3, 2016, involving more than 80 participants from both US and Europe.