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Asteroid Impact Mission: relevance to asteroid mining

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Abstract

The Asteroid Impact Mission (AIM) is the European (ESA) component of the Asteroid Impact & Deflection Assessment (AIDA) mission in collaboration with NASA. The objectives of AIDA are: (1) to perform a test of asteroid deflection using a kinetic impactor with the USA (NASA) component DART (Double Asteroid Redirection Test), and (2) with AIM, to investigate the binary near-Earth asteroid Didymos, in particular its secondary and target of DART, with data of high value for mining purposes.

1. Introduction

The Asteroid Impact Mission (AIM) is a small mission of opportunity whose objectives are to investigate a binary asteroid, to observe the outcome of a kinetic impactor test and thus, to provide extremely valuable information for mitigation, mining and science purposes [1, 2]. It is part of the Asteroid Impact & Deflection Assessment (AIDA) mission, in which the second component is the USA (NASA) Double Asteroid Redirection Test (DART) mission, which aims to send an artificial projectile to perform an asteroid deflection test and to observe the outcome from ground–based observatories [3] as well as from AIM. The AIM/AIDA target is the binary Near-Earth Asteroid (NEA) (65803) Didymos (1996 GT), in particular the secondary component and target of the DART mission, called hereafter Didymoon. A simplified version of AIM has been studied, called AIM-D^2 for AIM-Deflection Demonstration, which keeps the main objectives and is capable of providing crucial data for the interpretation of the DART impact. This modified mission concept provides the opportunity to reduce risk and cost by simplifying the spacecraft design and operational concept [2]. The payload is restricted to the AIM Framing Camera and the Cubesat ASPECT (Asteroid SPECTral Imaging), although optional payloads remain to be considered. They include a high-frame-rate camera to observe the plume generated by the DART impact, a hyperspectral camera for the analysis of the chemical composition and a LIDAR. A Radio Science Experiment (RSE) will also be performed. The mission will provide for the first time data from a new world, i.e., a binary asteroid and the smallest asteroid ever visited. In effect, the secondary is only 163 ± 18 meters in diameter. This size is actually among the most relevant ones to asteroid mining.

2. Relevance to asteroid mining

Asteroid mining, which needs appropriate tools for material extraction, relies currently on our poor knowledge of asteroid properties, in particular the mechanical properties at the surface and sub-surface, including regolith/dust properties. Moreover, a better understanding of the response of asteroid material to an external action in the appropriate low-gravity environment is strongly needed. Finally, a better knowledge of the composition of asteroids is needed, as it is not clear yet that meteorite material is representative of material in space, and spectral observations from the ground only provide disk-integrated information on the first microns of an asteroid surface. This prevents us from determining potential compositional heterogeneities within an asteroid. Extrapolating to an entire asteroid the abundance of rare materials in meteorites is unproven. AIM-D^2 is a crucial step in this ambitious adventure (see Table 1) that could eventually lead to successful asteroid mining. In effect, for the first time, AIM-D^2 will explore an asteroid of less than 200 hundred meters in diameter, sending us high-resolution images of its surface, telling us whether it is made of bare rock or granular material (including depth and grain size distribution down to the camera resolution limit), and measuring its global physical properties (shape, mass, density). All space missions that will allow us to obtain images and consequently access the detailed physical properties of an asteroid are very precious to enable us to cope with these bodies efficiently. Two sample-return missions underway, Hayabusa2 (JAXA) and OSIRIS-REx (NASA), will allow us to improve greatly our understanding of primitive asteroids in the size range 400–900 meters, in the coming years, and their preparation already showed how difficult it is to define the design of a proper sampling tool and the best sampling strategy when the knowledge of the target is still poor. The space mission Hayabusa (JAXA) showed us that getting back a sample is a real adventure and that we still have much to learn. The Rosetta space mission to a comet also showed how difficult it is to land in an unknown environment under low-gravity conditions. These experiences already allowed us to assess the difficulties associated with small-body investigations and to be better prepared for the next missions. AIM-D^2 will allow us to make another step performing measurements of the geophysical properties of the smallest asteroid ever visited. In addition, AIM-D^2 observations of the DART impact and outcome will provide fundamental information on the surface and subsurface mechanical properties and on the response of such a small body to an external action (here, an impact). Equipped with filters on the camera and with the Cubesat ASPECT, AIM-D^2 will also allow us to compare information on the compositional heterogeneity of the surface and ground truth for Earth-based observations. Another important aspect of AIM-D^2 is the size of Didymoon, which is very relevant for asteroid mining. In effect, asteroid mining relies on the abundance of targets to exploit. Big (km-size and larger) objects are rare, in particular if we account for their accessibility from Earth. Very small objects (below 100 meters in size) are very numerous, however they cause technical difficulties because of their extremely low gravity and their tendency to have a high spin rate, making it technically challenging to cope with them. Bodies of size of a few hundred meters are thus extremely interesting as they remain small enough to be numerous (some 10,000 are estimated to exist in the near-Earth space), but large enough to decrease the mentioned difficulties. Therefore, any data on bodies of this size, like AIM-D^2 will obtain, is of high value for asteroid mining. Moreover, as the target of the AIM-D^2 mission is a binary asteroid, we will have the opportunity to study two asteroids in the same mission! Although the investigations of the primary asteroid will likely not be as detailed as for the secondary, AIM-D2 will study the binary dynamical environment and should also be able to provide information about the morphology and surface properties of the primary. Given that almost one sixth of asteroids larger than 200 meters are expected to be binary, this information is very important for future asteroid exploration and resource utilization. Thus, all this information and the experience gained by AIM-D^2 on close proximity operations are precisely what is needed to make a big step towards actual asteroid mining.

Table 1: Mining Technology Demonstration and knowledge gained

Goals	Measurements
Close proximity operations around a 163 m-size asteroid	Mass Physical properties
Observing the response of a small asteroid to an external action (impact) and revealing the internal composition	Crater size/morphology Crater interior properties Ejecta properties
Deployment of and communication with the first interplanetary Cubesat at close proximity	Spectral properties In-situ charaterization

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