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The Asteroid Impact Mission – Deflection Demonstration ($AIM-D^2$)

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Abstract

The Asteroid Impact Mission (AIM) is ESA's contribution to the international Asteroid Impact Deflection Assessment (AIDA) cooperation, targeting the demonstration of deflection of a hazardous near-earth asteroid. AIM will also be the first in-depth investigation of a binary asteroid and make measurements that are relevant for the preparation of asteroid resource utilisation. AIM is foreseen to rendezvous with the binary near-Earth asteroid (65803) Didymos and to observe the system before, during, and after the impact of NASA's Double Asteroid Redirection Test (DART) spacecraft. Here we describe the observations to be done by the simplified version Asteroid Impact Mission – Deflection Demonstration ($AIM-D^2$) and show that most of the original AIM objectives can still be achieved.

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]. It is part of the Asteroid Impact & Deflection Assessment (AIDA) mission, in which the second component is the 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 [2] as well as from AIM. AIDA will thus be the first test ever to use a kinetic impactor to detect an asteroid. 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. The original AIM design and objectives were studied during a Phase A/B1 that took place from March 2015 to August 2016 at ESA, however the mission did not receive full funding at ESA's ministerial conference in Dec. 2016. Here we discuss a simplified version of the mission, called AIM-D2 for AIM-Deflection Demonstration, which keeps the main mission 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. $AIM-D^2$ firsts

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. In addition, AIM-D2 will also carry, deploy and communicate with an interplanetary Cubesat, for the first time, which will also perform in-situ spectral observations. The satellite and its Cubesat will also observe for the first time a kinetic impactor deflection test and improve drastically our understanding of the impact process at asteroid scale, which will serve for the extrapolation to other cases, with many important implications on Solar System science.

3. $AIM-D^2$ payload

The $AIM-D^2$ mission profile and spacecraft are similar to those of the original AIM mission [1]. Spacecraft interfaces could be simplified and the mass reduced by down-selecting the payload to the most essential items:

- $AIM-D^2$ Framing camera. This is a flight spare of the DAWN framing cameras [3] and will be used for science imaging and Guidance, Navigation, and Control. The image scale is ~1m/pixel from a distance of 10 km.

- Asteroid SPECTral imaging (ASPECT) cubesat. This is a 3 U cubesat that will carry a Fabry-Perot spectrometer, working as a spectral imager from 0.5 µm to 1.6 µm and as a point spectrometer from 1.6 µm to 2.5 µm.

- Radio Science Experiment (RSE). Radio science makes use of existing hardware on the spacecraft to measure the gravity field of Didymos

4. AIM-D^2 relevance for mitigation of an asteroid impact

Although the probability of an asteroid impact on Earth during the coming years is low, the potential consequences to our society could be very severe. Small bodies are continually colliding with Earth, however, the vast majority of these objects are very small (below 10 m in size) and pose no threat to human activity. Larger impacts (1 km or more) occur far less often but, when they do occur, they can lead to a major natural catastrophe. Fortunately more than 90% of the asteroid population with diameter of 1 km or larger is known and poses no risk. On the intermediate size (100-500 m range), damage can still be of regional scale (a country or a continent) and we only know a small fraction of these objects while their impact frequency becomes high enough (centuries to millenia, i.e., within the duration of a civilization) that we must study how to protect ourselves from the threat they pose. Indeed, the impact of an asteroid is the only natural disaster we may be able to accurately predict and prevent. For this we need to (1) improve our knowledge of the geophysical properties of bodies in this size range, (2) test our ability to detect such a small asteroid, (3) complete the inventory of this population.

AIDA will allow us to address (1) and (2) for the first time. In terms of detection techniques, we will never know whether we are ready if no test is performed. AIM-D^2 images will thus tell us for the first time what a 163 m asteroid looks like (Didymoon) as well as what a 780 m body looks like (Didymos), with important information regarding the geophysical and surface properties of both bodies and therefore of a binary system. Moreover, DART will hit the smallest component, whose size is the most relevant one for mitigation purposes. With its geophysical characterization by AIM-D^2, AIDA will provide the first documented detection experiment. Such an experiment at actual asteroid scale is the only direct way to check our ability to use kinetic impactor techniques to detect a body of this size, and to validate/refine our numerical impact models that can then be used with higher confidence at such scales.

5. Science Return

The Science return of AIM-D^2 includes:

- First images of a binary asteroid in orbit.

- First images and in-situ compositional analysis of the smallest asteroid ever visited.

- Constraints for binary formation models.

- Understanding of physical/compositional properties and geophysical processes in low gravity, with implications for our understanding of small-body surface properties and their evolution.

- First documented impact experiment at asteroid scale, orders of magnitude beyond the scale accessible in laboratory.

- Validation of numerical simulations of hyper-velocity impacts that are used in planetary science (planet and satellite formation, impact cratering and surface ages, asteroid belt evolution).

- Constraints for collisional evolution models of small-body populations and planetary formation.

References

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