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AIDA: The Asteroid Impact & Deflection Assessment Mission

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Abstract

The Asteroid Impact and Deflection Assessment (AIDA) mission, a joint effort of ESA, JHU/APL, NASA, OCA, and DLR, is the first demonstration of asteroid deflection and assessment via kinetic impact. AIDA consists of two independent but mutually supporting mission elements, one of which is the asteroid kinetic impactor and the other is the characterization spacecraft. These two missions are, respectively, JHU/APL's Double Asteroid Redirection Test (DART) and the European Space Agency's Asteroid Investigation Mission (AIM) missions. As in the separate DART and AIM studies, the target of this mission is the binary asteroid [65803] Didymos in October, 2022. For a successful joint mission, one spacecraft, DART, would impact the secondary of the Didymos system while AIM would observe and measure any change in the relative orbit. AIM will be the first probe to characterise a binary asteroid, especially from the dynamical point of view, but also considering its interior and subsurface composition. The mission concept focuses on the monitoring aspects i.e., the capability to determine in-situ the key physical properties of a binary asteroid playing a role in the system's dynamic behavior. DART will be the first ever space mission to deflect the trajectory of an asteroid in a measurable way.- It is expected that the deflection can be measured as a change in the relative orbit period with a precision better than 10%. The joint AIDA mission will return vital data to determine the momentum transfer efficiency of the kinetic impact [1,2].

1. Introduction

AIDA follows the previous Don Quijote mission study performed at phase A level by ESA in 2005 – 2007 [3], whose objectives were to demonstrate the ability to modify the trajectory of an asteroid, to measure the trajectory change, and to characterize physical properties of the asteroid. Don Quijote involved an orbiter and an impactor spacecraft, with the orbiter arriving first, measuring the deflection by radio tracking, monitoring the impact and making additional characterization measurements. Unlike Don Quijote, AIDA envisions an impactor spacecraft to intercept the secondary member of a binary near-Earth asteroid, with additional ground-based observations to measure the deflection. In the joint AIDA mission, DART combines with the ESA AIM mission which will rendezvous with the asteroid. Each of these missions has independent value, with greatly increased return when combined. Both DART and AIM are low cost missions. In the case of DART, cost would be under $150 million US including launch. For AIM, the mission cost would be 150 M€ (including launch but excluding payload instruments, as it is usually the case in ESA missions).

2. Asteroid Investigation Mission

The main objectives of the AIDA rendezvous spacecraft, AIM, are to:

- Determine binary asteroid orbital and rotation state
- Analyse size, mass, and shape of both components of the binary asteroid
- Analyse the geology and surface/subsurface properties of the binary system

When AIM is operated together with DART the mission would also cover a supplementary objective:

- Observe the impact outcome (crater and ejecta properties) and derive the impact response of the object as a function of its physical properties.

AIM is designed to be compatible with a small launcher such as VEGA, which would require an additional upper stage to perform the Earth escape burn. On arrival, the spacecraft would perform continuous observations from the vicinity of several "station points": fixed points relative to the asteroid inertial frame and at a safe distance, outside the sphere of influence of both Didymos components.

2.1 AIM Strawman Payload

The strawman payload mounted AIM could consist of a Narrow Angle Camera, a Micro laser Altimeter, a Thermal IR Imager, a NIR spectrometer. In addition to this, a camera for observation of the impact, a seismometer and the seismic sources would also be carried and deployed by the spacecraft.

3. Deflection Demonstration

DART is a self-standing element in the AIDA mission and will impact the smaller secondary component of [65803] Didymos. Didymos is a binary system, well-observed by radar and optical instruments. The impact of the >300 kg DART spacecraft at 6.25 km/s will change the mutual orbit of these two objects. By targeting the smaller, 150 m diameter member of the binary system, DART will produce a larger orbital deflection than if it targeted a more massive near-Earth asteroid.

The DART impact will be observable by ground-based radar and optical telescopes around the world, providing exciting opportunities for international participation in this first asteroid deflection experiment. The DART mission will use ground-based observations to make the required measurements of the orbital deflection, by measuring the orbital period change of the binary asteroid. The DART impact is expected to change the period by 0.5% – 1%, and this change can be determined to 10% accuracy within months of observations. The DART target is specifically chosen because it is an eclipsing binary, which enables accurate determination of small period changes by ground-based optical light curve measurements. In an eclipsing binary [4], the two objects pass in front of each other (occultations), or one object creates solar eclipses seen by the other, so there are sharp features in the lightcurves which can be timed accurately.

The DART payload is an imager based on the New Horizons Long Range Reconnaissance Imager, a 20-cm aperture, CCD camera. Payload objectives are: to support autonomous guiding to impact the target body through its center, to determine the impact point within 1% of the target diameter, and to characterize the pre-impact surface morphology and geology of the target asteroid and the primary to <20 cm/px.

3.2 DART Spacecraft

The DART mission uses a simple, , and low-cost spacecraft with a high-technology-readiness level to intercept Didymos. DART hosts no scientific payload other than an imager for targeting and data acquisition as described above. The spacecraft is single string, and most of the components are either rebuilds of previous APL designs or commercial off-the-shelf equipment. Terminal guidance to the target asteroid is accomplished using the imager for optical navigation and using autonomous guidance algorithms based on APL experience in development of the Standard Missile used on US Navy ships for air defense. A mono-propellant propulsion system is used for all Δv burns. Three-axis attitude control is performed using thrusters.

4. Summary and Conclusions

AIDA will combine the AIM and DART missions to provide the first demonstration of asteroid deflection at low cost, and the first in-depth investigation of a binary asteroid system, its response to an impact, its dynamics, as well as its surface/ subsurface composition and structure. The AIDA joint mission provides a full characterization and assessment of a kinetic impact and potential resources that might be present that would be of operational interest for future Robotic and Human Exploration.

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