Introduction: On Feb. 15, 2013, an exceptionally close approach to Earth by the small asteroid 2012 DA14 was eagerly awaited by astronomers around the world, but a different small asteroid unexpectedly impacted Earth over Chelyabinsk, Russia the same day without warning. The Chelyabinsk meteor released several hundred kilotons TNT of energy and injured over 1500 people. This dramatic reminder of the asteroid impact hazard re-emphasized the importance of discovering hazardous asteroids and learning how to mitigate the hazards. The Asteroid Impact & Deflection Assessment (AIDA) mission will be the first demonstration of a mitigation technique to protect the Earth from a potential asteroid impact, by performing a spacecraft kinetic impact on an asteroid to deflect it from its trajectory.

AIDA is an international cooperation entering Phase A study at NASA and ESA, consisting of two mission elements: the NASA Double Asteroid Redirection Test (DART) mission and the ESA Asteroid Impact Mission (AIM) rendezvous mission. The primary goals of AIDA are (i) to test our ability to perform a spacecraft impact on a potentially hazardous near-Earth asteroid and (ii) to measure and characterize the deflection caused by the impact. The AIDA target will be the binary asteroid (65803) Didymos, with the deflection experiment to occur in October, 2022. The DART impact on the secondary member of the binary at ~6 km/s will alter the binary orbit period, which can be measured by Earth-based observatories. The AIM spacecraft will characterize the asteroid target and monitor results of the impact in situ at Didymos. AIDA will return fundamental new information on the mechanical response and impact cratering process at real asteroid scales, and consequently on the collisional evolution of asteroids with implications for planetary defense, human spaceflight, and near-Earth object science and resource utilization. AIDA will return unique information on an asteroid's strength, surface physical properties and internal structure. Supporting Earth-based optical and radar observations, numerical simulation studies and laboratory experiments will be an integral part of AIDA.

AIDA=AIM+DART: The target of the AIDA mission will be a binary asteroid, in which the NASA DART mission will target the secondary, smaller member in order to alter its orbit around the primary. The resulting period change can be measured to within 10% by Earth-based observations. The asteroid deflection will be measured to higher accuracy, and additional results of the DART impact, like the impact crater, will be studied in great detail by the AIM mission. AIDA will return vital data to determine the momentum transfer efficiency of the kinetic impact and key physical properties of the target asteroid. The two mission components of AIDA, DART and AIM, are each independently valuable, but when combined they provide a greatly increased knowledge return.

The main objectives of the DART mission, which includes the spacecraft kinetic impact and Earth-based observing, are to:

- Impact the secondary member of the Didymos binary system during its close approach to Earth in October, 2022
- Demonstrate asteroid deflection by kinetic impact and measure the period change of the binary orbit resulting from the impact
- Determine the impact location on the target asteroid, the local surface topography and the geologic context

DART is targeted to impact the smaller secondary component of the binary system [65803] Didymos, which is already well characterized by radar and optical instruments [1,2]. The impact of the >300 kg DART spacecraft at 6.27 km/s will produce a velocity change on the order of 0.3 mm/s, which leads to a significant change in the mutual orbit of these two objects, but only a minimal change in the heliocentric orbit of the system. This is because the target’s velocity change from the impact is significant compared to its orbital speed ~15 cm/s, although it is quite small compared to the heliocentric orbit speed ~23 km/s. Thus the change in the binary orbit is relatively easy to measure compared with the change in the heliocentric orbit. To maximize the orbit change, the impact should be close to the moon’s perihelion [3, 4], although the eccentricity of the Didymos secondary is very low.

The momentum transfer from the kinetic impact depends on momentum carried away by ejecta that are not retained by the moon’s gravity [5]. The momentum transfer is parameterized by $\beta$, which is the ratio of momentum transferred to the incident momentum. Complete transfer of the kinetic impactor momentum to the target is indicated by $\beta=1$. Numerical simulations of asteroid fragmentation resulting from the impact of a kinetic impactor as well as numerical integrations of the momentum carried away by impact ejecta,
accounting for gravitational bending of ejecta trajectories, yielded similar \( \beta \) estimates of 1.28 to 2.52 for a variety of low strength, high strength, low cohesion and high cohesion target materials [6,7].

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 \(~0.5\)%, 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, 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 consists of a high-resolution visible imager to support the primary mission objective of impacting the target body through its center. The DART imager is required to support optical navigation on approach and autonomous navigation in the terminal phase. The imager is derived from the New Horizons LORRI instrument [8] which used a 20 cm aperture Ritchey-Chretien telescope to obtain images at 1 arc sec resolution. The DART imager will determine the impact point within 1% of the target diameter, and it will characterize the pre-impact surface morphology and geology of the target asteroid and the primary to \(<20\) cm/px.

The ESA AIM mission will use a small spacecraft demonstrating a number of technologies including deep-space optical communication and inter-satellite network in deep-space with a number of CubeSats deployed in the vicinity of the Didymos system and lander on the surface of the secondary.

The AIM mission objectives are to:
- Characterize the Didymos secondary component by analyzing its dynamical state, mass, geophysical properties, surface and subsurface structure.
- Demonstrate deep-space optical communication technology and perform inter-satellite communication network with CubeSats and lander.
- Deploy the MASCOT-2 lander on Didymos secondary asteroid and sound its interior structure.

When AIM is operated together with DART, the mission covers supplementary objectives:
- Determine the momentum transfer resulting from DART’s impact by measuring the dynamical state of Didymos after the impact and imaging the resulting crater.

- Study the shallow subsurface and deep-interior structure of the secondary after the impact to characterize any change.

Hence, AIM will measure the size and shape of the impact crater and will image the ejecta plume, providing valuable data to validate impact models.

AIM is a small mission of opportunity to explore and demonstrate new technologies for future science and exploration missions while addressing planetary defense and asteroid science objectives. The AIM payload consists of remote sensing instruments, a landed package and technology demonstrations. A Visual Imaging System (VIS) is part of the guidance, navigation and control system of the spacecraft. The AIM strawman payload also includes a Thermal IR Imager (TIRI), a monostatic High-Frequency Radar (HFR), a bistatic Low-Frequency Radar (LFR), the Optel-D optical communication terminal, the MASCOT-2 lander, and CubeSats opportunity payloads (COPINS).

Thus, AIM will determine the Didymos secondary asteroid orbital and rotation state, size, mass and shape and analyze geology and surface properties. In the AIDA mission together with the DART kinetic impact, AIM will observe the impact crater and derive collision and impact properties.

Mission Designs: The DART spacecraft, the interceptor, can be launched on a small class launch vehicle for the baseline mission in December 2021 to impact Didymos in Oct 2022, targeted to the secondary member of the binary system. There are multiple intercept opportunities for both the 2022 and 2024 close approaches providing program flexibility. For all AIDA mission options, the interceptor is on a low-energy trajectory and the impact occurs close to Earth.

The AIM launch opportunity is identified in Oct 2020 with a transfer duration of around 19 months (i.e. arriving in mid-2022). This trajectory is based on a launch with a Soyuz 2.1b/Fregat MT from Kourou allowing a 21-day launch window and will lead the spacecraft to a maximum Sun distance of up to 2.2 AU and a maximum Earth range of 3.2 AU.

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