The ANIME mission and beyond: SmallSat exploration of near-Earth asteroids

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Interest in near-Earth asteroids (NEAs) has rapidly grown in recent decades. The motivation is threefold: first, their proximity allows us to discover and investigate small bodies down to the metre-size, thus enhancing our understanding of the mechanisms underlying planetary formation; second, such information is also critical to mitigate their threat of collision with the Earth; third, their near-future exploitation can exponentially expand the natural resources available to humankind.

Ground-based observations of thousands of NEAs have revealed the striking diversity existing within this population in terms of physical properties. So far, only a handful of NEAs have been visited by space missions: each of them provided unexpected discoveries and huge steps forward in our understanding of planetary sciences. Deep-space SmallSats represent a new frontier for the solar system exploration. After the success of the NASA/JPL MarCO mission in 2018 and of the ASI LICIACube mission which testified the impact of the NASA DART spacecraft onto asteroid Dimorphos in September 2022, several further deep-space SmallSat missions will take place in the next few years, e.g. in the framework of ESA HERA and NASA Artemis projects.

The "Asteroid Nodal Intersection Multiple Encounters" (ANIME) mission has been proposed by an Italian consortium led by INAF – Rome Observatory, and selected in 2021 by the Italian Space Agency (ASI) in the framework of a call for future CubeSat missions. ANIME aims to explore three near-Earth asteroids, selected by virtue of their peculiar and yet unexplored size and physical regimes, as well as their relevance in terms of planetary protection. The rationale behind the ANIME target selection and interplanetary trajectory design lies in encountering asteroids that have a nodal passage in the proximity of the Earth, considering their relative positions and velocities (Fig. 1). With a launch envisaged in the 2026-2028 timeframe, the 20-kg, 12U CubeSat ANIME will flyby two Potentially Hazardous Asteroids, and then rendezvous with asteroid 2000 SG344. The study of such 40-m-sized object will allow constraining the latest theories about planetary system formation scenarios, addressing questions about the monolithic vs. cohesive vs. rubble pile aggregation structure of small asteroids. Moreover, 2000 SG344 presents a very high impact risk, with multiple potential collision solutions with our planet during the course of the next century. It is also considered an excellent target for future human exploration thanks to its accessibility.

Multiple similar/identical SmallSats (to maximize mission return while minimizing costs and risks) could be launched profiting of the same or separate mission opportunities, and then reach their respective targets using electric propulsion and optimized interplanetary trajectories. Each SmallSat would flyby and/or rendezvous multiple NEAs, with encounters at the nodal points, to explore the diversity of such population. E.g., assuming an ANIME-like platform and mission durations capped at 3 years, many mission scenarios with similar performances can be identified with total $\Delta V < 3$ km/s. This outlines the strong implementation flexibility of such mission concept, as the definitive choice of target NEAs can be easily updated even at relatively late project phases, also considering the current exponential growth of NEA discoveries. This provides a huge flexibility in terms of mission scenarios, which can be adapted to varying constraints. The strategic relevance of ANIME and further SmallSat missions to NEAs also lies in the step forwards that will be taken in validating critical small spacecraft technologies for deep space exploration.

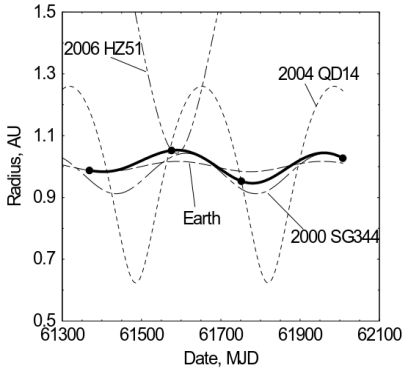

Figure 1. Reference ANIME trajectory for a launch in late 2026. Alternative flyby targets can be identified for different launch windows.