

Session: Ongoing and Upcoming Mission Highlights

**DART MISSION DESIGN AND NAVIGATION LESSONS LEARNED FOR FUTURE
PLANETARY DEFENSE MISSIONS**

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ABSTRACT

This paper summarizes the lessons learned by the Double Asteroid Redirection Test (DART) Mission Design and Navigation team most relevant to future planetary defense missions and studies. From the perspective of its trajectory and navigation, DART is a reasonable analog for an operational rapid reconnaissance flyby or kinetic impactor mission. Through DART's successful impact, we hope to retire some conservatism typical for hypothetical planetary defense scenarios.

The lessons related to mission design formulation include the dramatic trajectory flexibility imparted by electric propulsion, the significance of the arrival solar phase angle, and the availability of Vandenberg Space Force Base as a viable higher latitude launch site. For launch, we estimate the shortest reasonable timeline to complete the trajectory and navigation analysis in the event of short response time threat. We demonstrated some of these steps when asked to analyze a potential switch to Cape Canaveral Air Force Base and completed the analysis in only a few weeks.

The Navigation experience reinforced the importance of a trajectory that is not frequently perturbed with spacecraft thruster activities. DART's thruster-based attitude control introduced complexity and even risk, requiring changes to the planned approach phase schedule. DART also demonstrated a relatively new but increasingly common disturbance—CubeSat deployment. Despite being small, the reaction force imparted to DART from the deployment, and DART's corresponding attitude control response, together represented a relatively large uncertainty in the final days leading to impact. This risk was mitigated by adjusting the timing of the deployment and subsequent maneuvers.

Next, we summarize lessons related to optical navigation. Optical navigation turned out to be essential for characterizing the noise in the star tracker, which was used for

attitude knowledge during terminal guidance. This calibration is challenging and required processing hundreds of thousands of images. In future missions, the effort could be prevented by using a lower noise IMU or by processing stars and the asteroid target in the same images.

The result of six maneuvers, hundreds of thousands of optical navigation images, dozens of delta-DOR tracks, and nearly continuous approach phase DSN tracking was a 12-hour pre-impact uncertainty of 0.21×0.06 km (3 sigma). Although each encounter may be different, this point case demonstrates the feasibility of precision ground navigation for critical small body encounters. This suggests that future missions may be able to assume less conservative navigation uncertainties when evaluating potential small body engagements.

Comments:

If selected for presentation, we request that this come after the DART Navigation paper led by Julie Bellerose. This paper complements the overall Navigation findings.