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**Double Asteroid Redirection Test (DART) Phase D Mission Design & Navigation Analysis**

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##### ABSTRACT

NASA’s Double Asteroid Redirection Test (DART) mission is the first demonstration of kinetic deflection of an asteroid. DART uses terminal guidance to impact Dimorphos, which orbits Didymos, during its 2022 close-approach to Earth. The close range to Earth allows Earth-based observations to reconstruct the impact’s effect. Light-curve data will be used to measure the resulting change in orbit period of Dimorphos due to the momentum change associated with the impact experiment. This paper will discuss the current DART trajectory and its recent trade studies and key decisions leading up to launch.

DART will launch on a dedicated SpaceX Falcon 9 launch vehicle, which will inject DART onto a hyperbolic Earth-escape trajectory intersecting the Didymos system. DART launches from Vandenberg Air Force Base, which facilitates the high magnitudes of declination of launch asymptote necessary to achieve the required heliocentric inclination change.

Previous iterations of the mission design utilized NASA’s Evolutionary Xenon Thruster (NEXT-C) as the primary propulsion system. Following the Mission Critical Design Review, the decision was made for the NEXT-C thruster demonstration to be completely independent from the asteroid deflection demonstration. As a result, DART’s option to use NEXT-C for an opportunistic asteroid flyby was removed. The spacecraft now uses a direct trajectory to Didymos with no deterministic maneuvers (either chemical or low-thrust). NEXT-C will be used for two statistical trajectory correction maneuvers (TCMs) as well as a series of neutral burns, designed to allow it to be operated for a significant duration without altering the trajectory.

DART’s largest TCM is allocated for the cleanup of post-launch injection errors. In order to minimize this delta-V and save propellant, most missions perform the maneuver as soon as possible after launch. However, due to the geometry of DART’s trajectory, a low delta-V maneuver opportunity exists several months after launch. This later TCM not only saves propellant, but also allows more time for post-launch checkout activities.

The Navigation Team is responsible for determining the DART spacecraft trajectory and associated uncertainty through orbit determination techniques using radiometric tracking and, during approach, optical navigation (OpNav) data. Pre-launch, navigation’s error analysis serves to size and place TCMs for quantifying the TCM propellant budget and satisfying error requirements.

Since a significant portion of the interplanetary Delta-V will be expended to correct for injection errors, the injection accuracy has a significant impact on required cruise propellant. Setting the launch vehicle requirement in terms of what is called a Figure of Merit (FoM) ties the launch vehicle performance to the propellant budget. The FOM measures how the spread in the launch injection states maps to a spread in the TCM which cleans up the launch. We describe how this process was used and computed for DART.

For the end of the mission, the Navigation team driving requirement is to deliver the DART spacecraft with less than 15 km uncertainty when projected on the Didymos B-plane (1-sigma), and three seconds uncertainty in the time of flight (1-sigma). SMARTNav will then take over for the terminal engagement of the asteroid. To achieve this, a series of TCMs are strategically placed in the last 40 days of the mission. We describe modeling and analyses included in the approach phase.