

IAA-PDC-23-01-42
NASA's DART SMART Nav – Performance in Flight

Michelle Chen⁽¹⁾, Mark Jensenius⁽²⁾, Peter Ericksen⁽³⁾,
Carolyn Sawyer⁽⁴⁾, Steve Jenkins⁽⁵⁾, Musad Haque⁽⁶⁾,
Dmitriy Bekker⁽⁷⁾, and Nishant Mehta⁽⁸⁾

⁽¹⁾The Johns Hopkins University Applied Physics Laboratory, 11100 Johns Hopkins Road, Laurel MD 20723, USA, 240-228-4682, michelle.chen@jhuapl.edu

⁽²⁻⁸⁾The Johns Hopkins University Applied Physics Laboratory, 11100 Johns Hopkins Road, Laurel MD 20723

Keywords: DART, proportional navigation, optical navigation, onboard decision making, autonomous systems

Extended Abstract—

On 26 September 2022, the Double Asteroid Redirection Test (DART) spacecraft impacted Dimorphos at 23:14:24.183 ± 0.004 UTC, successfully executing NASA's first-ever planetary defense test. During the last four hours of the mission, the DART spacecraft maneuvers were performed autonomously using the onboard Small-body Maneuvering Autonomous Real-Time navigation (SMART Nav) system. SMART Nav's function was to detect the Didymos system with images acquired by the Didymos Reconnaissance and Asteroid Camera for Optical navigation (DRACO) instrument, identify Dimorphos when it became visible, and guide the spacecraft to impact Dimorphos at its center of figure.

Prior to 26 September 2022, the DART team had theories of what the Didymos system could look like, but the resolved images of the Didymos system were taken for the first time less than two hours from impact. In order to develop an algorithm that would be robust to this uncertainty, the Guidance, Navigation, and Control (GNC) team developed an extensive simulation environment that was utilized to test the SMART Nav algorithm under a variety of perturbations. This simulation allowed the team to run numerous Monte Carlo analyses, providing confidence in SMART Nav's robustness. The Monte Carlo analyses also offered visibility into the predicted performance of SMART Nav on 26 September.

The team, however, did not rely just on simulation alone. Opportunities were taken in-flight to test SMART Nav on the DART spacecraft. As SMART Nav is comprised of different algorithms distributed across DRACO's field programmable gate array (FPGA) and

the single board computer (SBC), a variety of in-flight tests were identified that enabled testing of these different functional components and characterization of DRACO and its effect on SMART Nav. Following completion of each in-flight test, the simulation was updated to better reflect the flight system performance, additional Monte Carlo analyses were run to refine the estimated probability of impact, and as needed, parameters were updated to improve flight performance for the next in-flight test. The ability to close the loop with simulation, hardware-in-the-loop test environments, and then with the spacecraft itself yielded a spectacular impact on 26 September.

