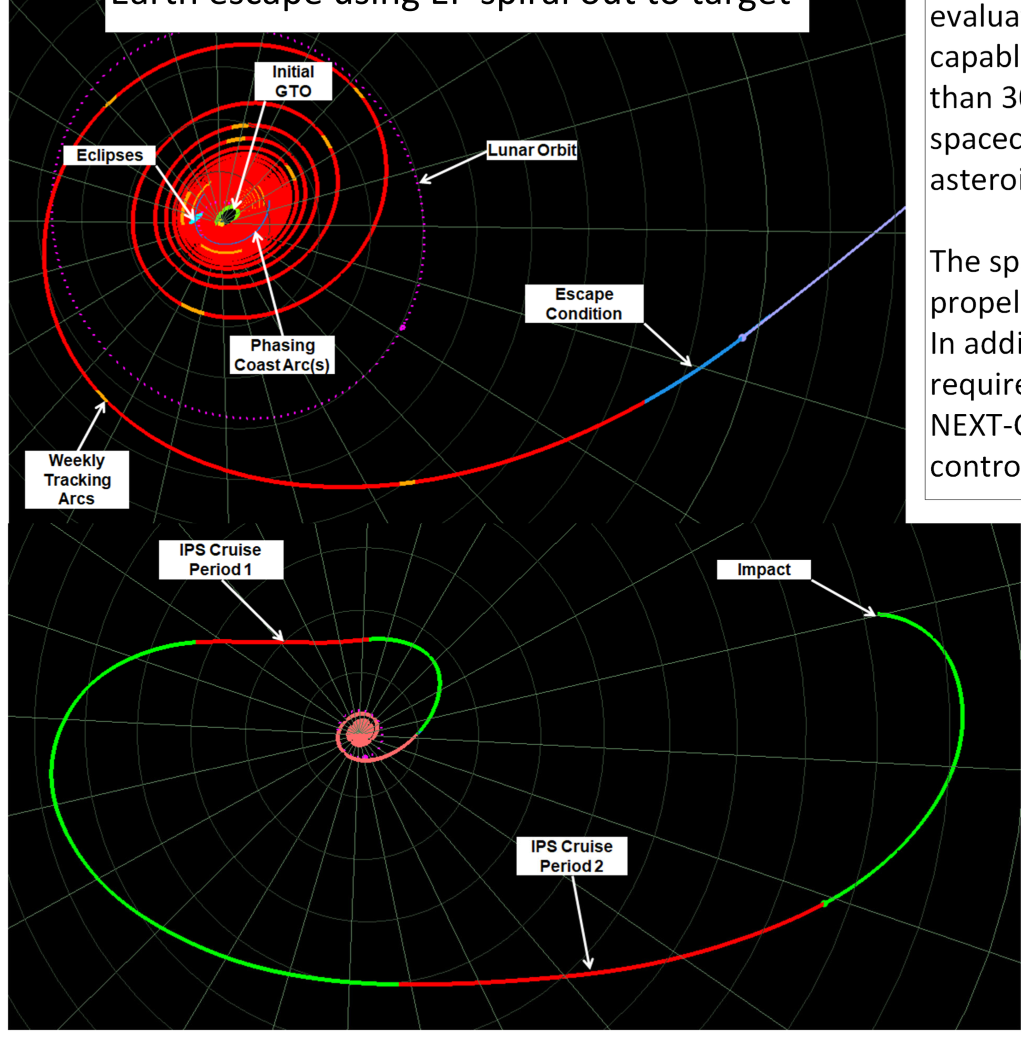
Solar electric propulsion (SEP) has been shown to offer mass efficient solutions to changing a spacecraft's trajectory. From basic orbit raising in near Earth applications to deep space maneuvers that move a spacecraft between multiple objects, SEP enables a spacecraft to have operational flexibility. In combination with a chemical, divert propulsion system, a spacecraft equipped with SEP has capability to meet new potentially hazardous asteroids and offer options such as a flyby observer to a kinetic deflector, similar to DART.

The NEXT-C Ion Propulsion System is one type of SEP system that offers a wide range of performance options that include high thrust to input power, or high Isp to input power operating conditions. The system's operational flexibility means that it is responsive to multiple mission scenarios involving potentially hazardous asteroids. As an example, a spacecraft with this type of SEP could be parked in high Earth orbit with the goal of offering a quick response to these types of asteroids by escaping out with a high thrust maneuver before utilizing the high Isp to cruise to intercept the asteroid.

For the DART mission, the NEXT-C Ion Propulsion System was demonstrated for the first time in flight on December 18, 2021 as part of the spacecraft's commissioning phase. The system was operated for just over two hours of total firing time before being manually commanded to shutdown. The spacecraft was able to provide sufficient input power for the thruster to achieve steady thrust and Isp during its operating period. The spacecraft supplied xenon to the thruster at a higher than anticipated rate but was stable throughout operation. The higher flow rate was due to higher pressure at the inlet to the flow controllers, which is downstream of the pressure regulator. The thermal control of the feed system and spacecraft was initiated several hours before the start of the thruster operation to ensure that the feed system temperatures were stable.

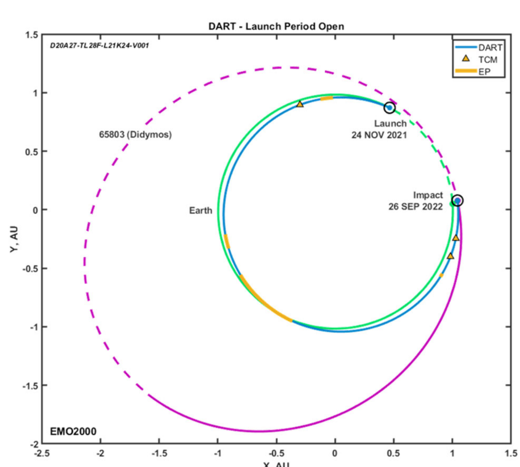
The spacecraft attitude control during NEXT-C operation was an open question prior to operation as there was a large analytical range of the amount of hydrazine required to maintain the spacecraft attitude control. The guidance and control system maintained the spacecraft in a stable orientation that did not consume excess amounts of hydrazine in the process. Compared to pre-launch analysis, the hydrazine consumption was on the lower end of the estimated range, only 38.6% of pre-launch nominal value. This hydrazine usage value was extrapolated out for steady state operation following the initial heating period for the ion optics.

Earth escape using EP spiral out to target

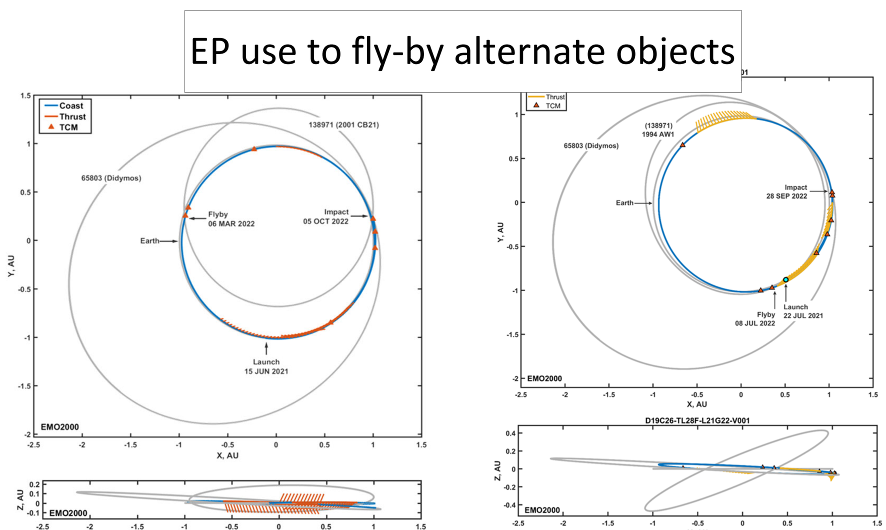


Near Earth orbit raising to an escape trajectory using NEXT-C was evaluated early in the DART mission and was shown to be capable of putting a spacecraft on an intercept trajectory in less than 300 days. Additional firings of less than 120 days put the spacecraft on the correct trajectory for an incept with the target asteroid.

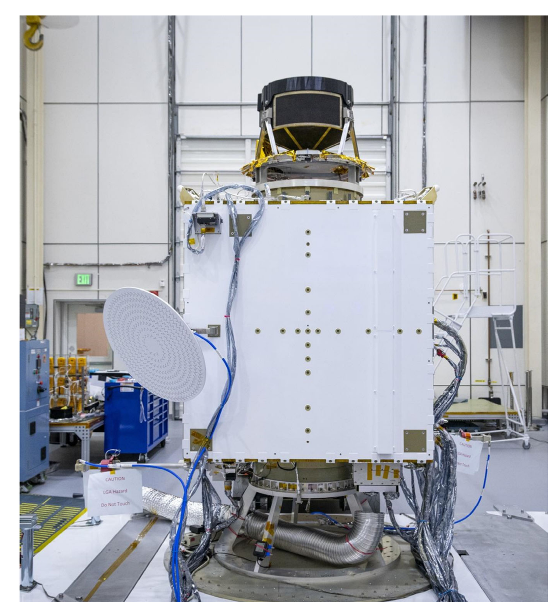
The spacecraft was sized to accommodate sufficient xenon propellant to complete this spiral maneuver and the thrust arcs. In addition, the hydrazine system was initially sized to meet required budget for maintaining spacecraft orientation during NEXT-C operation and for terminal phase divert and attitude control functions.

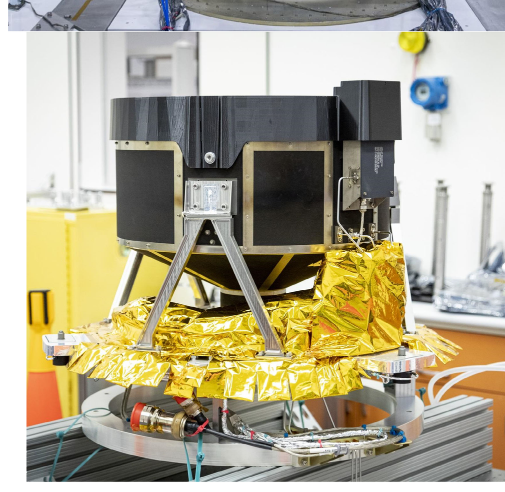


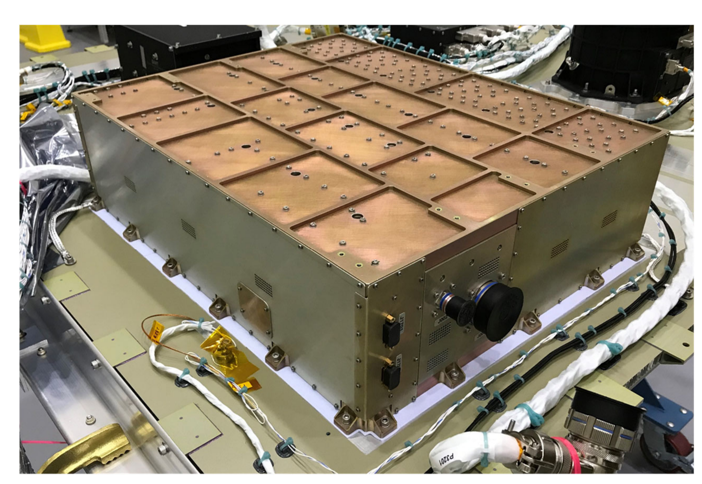
EP use to fly-by alternate objects



During the DART cruise phase, targets of opportunity for fly-bys were identified. Using NEXT-C to divert to these objects was evaluated and was within the propellant budget allocations to achieve. The trajectory adjustments would have altered the arrival time at Dimorphos by only a few days had they been executed.

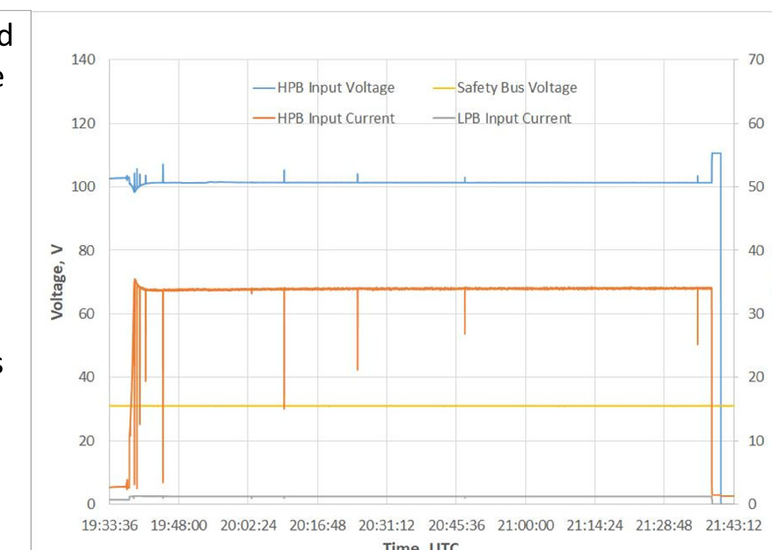


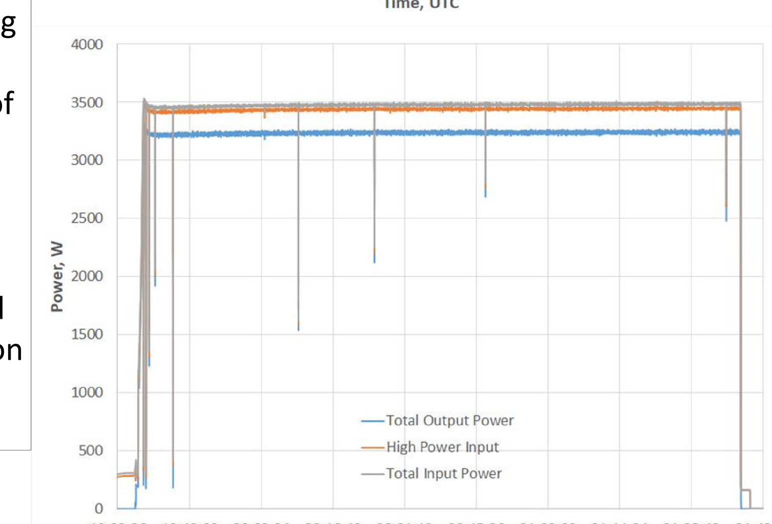




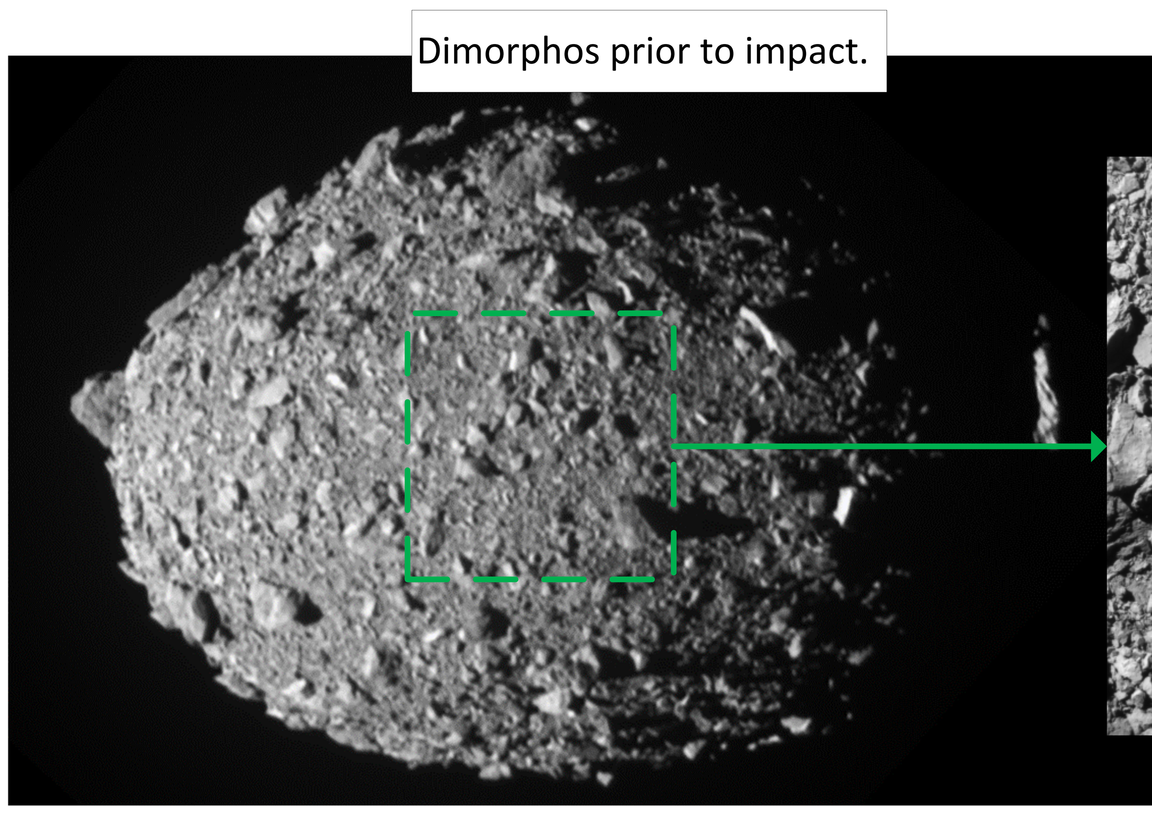
NEXT-C flight demonstration indicated that thrust and Isp performance were nominal and varied by less than 1% from ground tests. PPU operation indicated that the spacecraft input power was nominal throughout the operation period. PPU efficiency during this period was slight above ground and the dissipated power was well below the capability of the spacecraft thermal design.

The spacecraft guidance and control maintained overall spacecraft pointing during the NEXT-C operation period without consuming excess amounts of hydrazine. The amount of hydrazine consumed was less than 40% of the nominal result of pre-launch analysis. This indicated that the thruster could have been operated for longer period of time before the hydrazine allocation for this part of the mission was used.





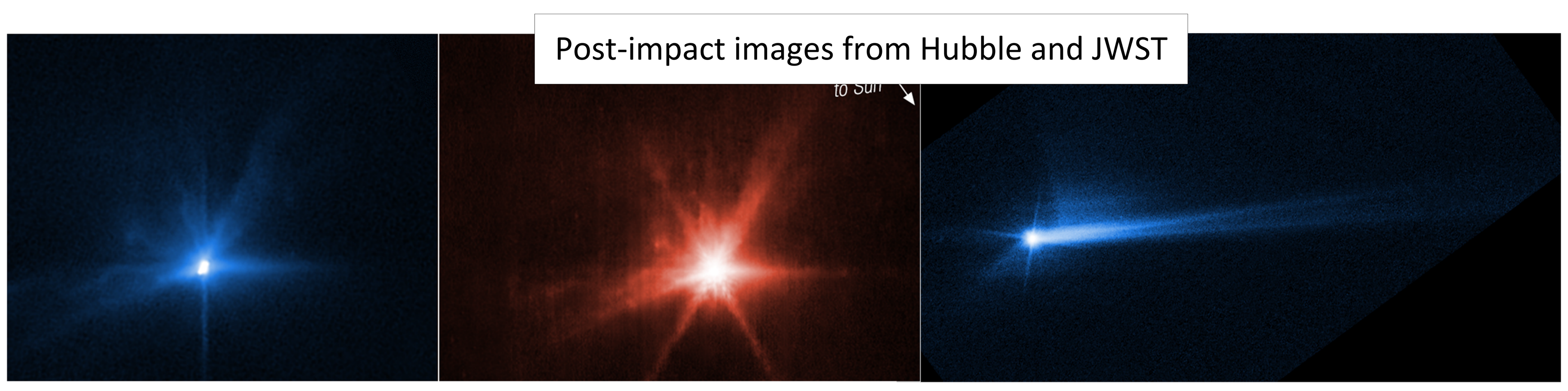
Dimorphos prior to impact.



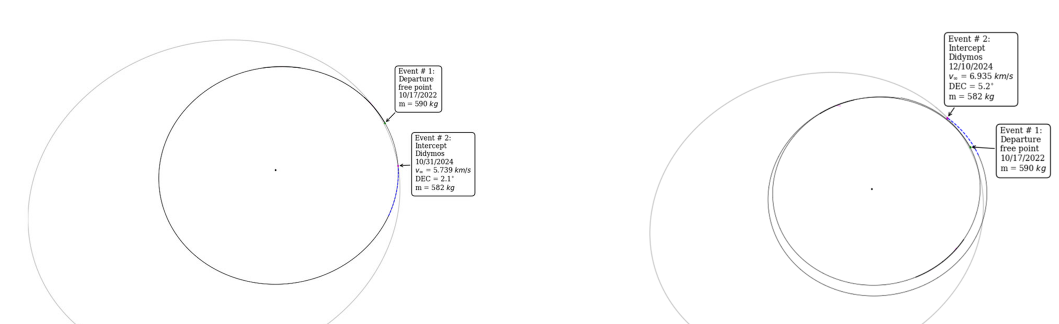
2 seconds prior to impact.

DART successfully impacted Dimorphos on September 26, 2023.

Post-impact images from Hubble and JWST

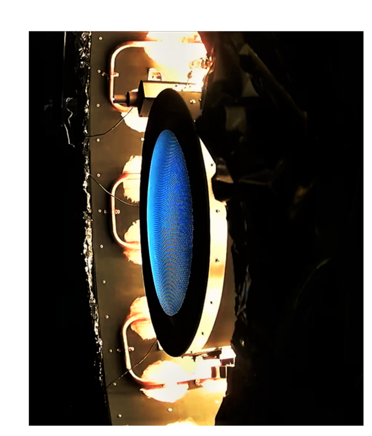


Contingency operations were evaluated in the event that the spacecraft missed Dimorphos on the first attempt. Trajectories were identified that would allow for a second attempt by using NEXT-C in two thrusting arcs. The amount of propellant needed to complete the maneuvers was within the remaining quantities onboard and would not impact the ability to complete a second terminal approach. Fortunately, DART did not have to execute this contingency.



Options for a 2 year return to Dimorphos

NEXT-C was demonstrated as part of the DART mission. The system operated in a manner consistent with ground testing with little deviation from the ground performance. The flexibility and capability range offered by NEXT-C would allow for future missions to consider multiple intercept options either from an Earth parking orbit or while in flight to targets of opportunity. The ability to divert a spacecraft from one trajectory to another mid-cruise is a useful capability for planetary defense missions. Future missions can consider this technology as a viable option for mission execution.



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