DART Mission Overview
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New White House Guidance released on 20 June 2018


DART is the first mission in NASA’s new Planetary Defense Program line!
DART is targeting the Didymos system in October, 2022

Didymos is a well-characterized asteroid that approaches close to Earth, enabling ground-based observations of impact demonstration.

The secondary (“Didymoon”) is realistic scale
- Small enough to deflect kinetically and measure result
- Smaller NEOs represent a more frequent threat to Earth

Didymos B is much smaller than the Deep Impact target.

Preliminary shape model of the Didymos primary from combined radar and light curve data, diameter ~780 m. The secondary (not imaged) may be more elongated.

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Diameter</td>
<td>780 m ± 10%</td>
</tr>
<tr>
<td>Secondary Diameter</td>
<td>163 m ± 18 m</td>
</tr>
<tr>
<td>Total System Mass</td>
<td>(5.278 ± 0.54) × 10^{11} kg</td>
</tr>
<tr>
<td>Component Bulk Density</td>
<td>2,100 kg m^{-3} ± 30%</td>
</tr>
<tr>
<td>Primary Rotation Period</td>
<td>2.2600 ± 0.0001 h</td>
</tr>
<tr>
<td>Component Separation</td>
<td>1180 ±40/-20 m</td>
</tr>
<tr>
<td>Secondary Orbital Period</td>
<td>11.920 ±0.004/-0.006 h</td>
</tr>
<tr>
<td>Spectral Class</td>
<td>S</td>
</tr>
</tbody>
</table>

Deployed Configuration

Stowed Configuration

Low Voltage Solar Array

NEXT on gimbal, with Top Hat off

High Voltage Solar Array

NEXT Top Hat

HGA on gimbal

Battery

PAF

DRACO (inside PAF)

Mass Margin = 25%
Power Margin = 25%
NASA’s Evolutionary Xenon Thruster (NEXT) began as a technology development project

NEXT-C project’s objective is to transition the NEXT technology to flight and create a commercially available product (Managed by NASA GRC)

The NEXT-C project is producing two flight qualified thrusters and two Power Processing Units (PPUs). A single thruster and PPU (with simulators, testbeds, test data & documentation) are GFE to the DART project.

Flight project preparing to support a mission(s) with GFE flight hardware delivery in early 2019

DART is the first flight of NEXT and will qualify it for future deep space missions

<table>
<thead>
<tr>
<th>Performance Characteristics</th>
<th></th>
</tr>
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<tbody>
<tr>
<td>Thruster Power, kW</td>
<td>0.5 – 6.9</td>
</tr>
<tr>
<td>Specific Impulse, sec</td>
<td>2500 - 4200</td>
</tr>
<tr>
<td>Thrust, mN</td>
<td>25 - 235</td>
</tr>
<tr>
<td>Thrust –to-Power, mN/kW</td>
<td>32 - 48</td>
</tr>
<tr>
<td>Thruster Efficiency</td>
<td>0.32 – 0.7</td>
</tr>
<tr>
<td>Lifetime - Xenon Throughput, kg</td>
<td>&gt; 600</td>
</tr>
</tbody>
</table>
Baseline heliocentric transfer trajectory delivers DART to Didymos in Oct 2022

- The baseline is a design reference
  - Occurs at Launch Period Open: Jun 2021
  - It’s designed to the worst-case launch direction for that date
  - NEXT-C enabled asteroid flyby: 06 Mar 2022
  - Impact: 05 Oct 2022
  - Mission Duration: ~15 months

- DART uses the NEXT-C to thrust for roughly 140 days in 3 arcs
  - DART drifts ahead of Earth and changes its inclination to impact Didymos in its 2022 apparition
  - The impact occurs below the ecliptic plane

- OpNavs are used to design sets of 3 and 4 chemical TCMs for final targeting prior to Flyby and SMART Nav

- Low thrust allows impact geometry to be optimized
Path To Terminal Guidance
2022 Intercept (~10.9M km; 6.8M miles from Earth)*

Autonomous Navigation and Targeting

1. Launch
2. Cruise / Calibration
3. Target Detection / Coarse Acquisition
4. Deploy 6U CubeSat
5. Scene Classification
6. Target Selection
7. Homing Until Intercept
8. Impact Assessment

* 15 months total flight time

**Autonomous Navigation and Targeting**

1. Launch
- Low Energy Escape
  - <Jun 15 – Oct 15 2021>
  - <10^8 km from target>

2. Cruise / Calibration
- Flyby of PHA allows sensor calibration and control-gain tuning
  - <7 months until impact>
  - <10^8 km from target>
- Weeks prior to impact, seeker detects primary
  - <30 days until impact>
  - <10^7 km from target>

3. Target Detection / Coarse Acquisition
- Seeker counts and classifies closely spaced objects
  - <3 hours until impact>
  - <65,000 km from target>
- With sufficient confidence, seeker selects target and locks on
  - <1.5 hours until impact>
  - <32,000 km from target>

4. Deploy 6U CubeSat
- 6U CubeSat releases and executes a separation maneuver to trail DART
  - <~10 hours until impact>
  - <~216,000 km from target>

5. Scene Classification
- Seeker detects primary
  - <7 months until impact>
  - <10^8 km from target>

6. Target Selection
- Weeks prior to impact, seeker detects primary
  - <30 days until impact>
  - <10^7 km from target>

7. Homing Until Intercept
- Pro-Nav executes precision engagement and is robust to target uncertainties
  - <Executed until final 2 minutes>
  - <6.0 km/s Impact>
- Earth tracking & 6U CubeSat images quantify intercept success
  - <Up to 3 months>

8. Impact Assessment
- Earth tracking & 6U CubeSat images quantify intercept success
  - <Up to 3 months>
Didymos Encounter

**Timeline not to scale**

- **30 days**
  - DRACO detects the Didymos system

- **7 days**
  - DSN coverage enables real-time downlink

- **12 hrs**
  - Begin pre-terminal phase

- **4 hrs**
  - Begin terminal phase

**DRACO achieves the 50 cm/pixel requirement ~17 sec (100 km) before impact**

(Didymos B: ~300 pix @ 50 cm/pix)

Higher resolution images will continue to be acquired in the final seconds of the mission.
Post-Impact Observability over Fall 2022

Ground-based observations after impact are critical to achieving DART Level 1s

Lightcurve change easily measurable in matter of weeks

Radar opportunity in 2022 (DART-3 & 4B)

- Earth close approach on October 4
  - Encounter distance will be 0.071 au (1.5 x the 2003 close approach)
- Goldstone target: Sep 25 – Nov 18
  - Maximum SNR 1/4th as strong as 2003
- Arecibo target from Oct 24 – Jan 04
  - Maximum SNR 1/3rd as strong as 2003
- Resolutions: 2x coarser than in 2003
  - Goldstone: 150 m/pixel
  - Arecibo: 30 m/pixel
- Using GBT to receive Goldstone signals will improve resolution to 75 m/pixel
**Post-Impact**

**2022 Observing Campaign**

Selected telescopes expected to be available, baseline support of bolded observatories

<table>
<thead>
<tr>
<th>Facility</th>
<th>Telescope(s)</th>
<th>Location(s)</th>
<th>Capability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magellan</td>
<td>2 x 6.5m</td>
<td>SH: Chile</td>
<td>Optical and NIR imaging &amp; spectroscopy</td>
</tr>
<tr>
<td>Las Campanas</td>
<td>1 x 2.5m</td>
<td>SH: Chile</td>
<td>Optical imaging &amp; spectroscopy</td>
</tr>
<tr>
<td>DCT</td>
<td>1 x 4.3m</td>
<td>NH: Arizona</td>
<td>Optical &amp; NIR imaging &amp; low res spectroscopy</td>
</tr>
<tr>
<td>MRO</td>
<td>1 x 2.4m</td>
<td>NH: New Mexico</td>
<td>Optical imaging, Optical low res spectroscopy</td>
</tr>
<tr>
<td>LCOGT</td>
<td>11 x 1m, 2 x 2m</td>
<td>NH: 1 x 2m, 3 x 1m, SH: 1 x 2m, 8 x 1m</td>
<td>Optical imaging, Optical low res spectroscopy</td>
</tr>
<tr>
<td>IUCAA</td>
<td>1 x 2.0m</td>
<td>NH: India</td>
<td>Optical imaging</td>
</tr>
<tr>
<td>AAO</td>
<td>1 x 3.9m</td>
<td>SH: Australia</td>
<td>NIR imaging &amp; spectroscopy</td>
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<tr>
<td>SAAO</td>
<td>1 x 11.0m, 1 x 1.9m</td>
<td>SH: South Africa</td>
<td>Optical imaging &amp; low res spectroscopy</td>
</tr>
<tr>
<td>IRTF</td>
<td>1 x 3.0m</td>
<td>NH: Mauna Kea</td>
<td>Low &amp; high res IR spectroscopy</td>
</tr>
<tr>
<td>Keck</td>
<td>2 x 10.0m</td>
<td>NH: Mauna Kea</td>
<td>Low &amp; high res Optical &amp; IR spectroscopy, AO</td>
</tr>
<tr>
<td>Gemini</td>
<td>2 x 8.0m</td>
<td>NH: Mauna Kea, SH: Chile</td>
<td>Optical and IR imaging &amp; spectroscopy, AO</td>
</tr>
<tr>
<td>WHT</td>
<td>1 x 4.2m</td>
<td>NH: Canary Islands</td>
<td>Optical &amp; IR imaging &amp; spectroscopy, AO</td>
</tr>
<tr>
<td>ESO</td>
<td>4 x 8.2m, 1 x 3.6m, 1 x 3.5m</td>
<td>SH: Chile</td>
<td>Optical &amp; IR imaging &amp; spectroscopy, AO, IR high res spectroscopy</td>
</tr>
<tr>
<td>GTC</td>
<td>1 x 10.4m</td>
<td>NH: Canary Islands</td>
<td>Optical imaging, Optical low res spectroscopy</td>
</tr>
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</table>
First mission to **measure asteroid deflection** by constraining the “ejecta momentum amplification factor” of a kinetic impactor, **as well as the initial conditions** (impact conditions, target’s properties).

First mission to fly **NASA’s NEXT-C** solar electric propulsion technology.

First mission (with another spacecraft, if available) to **study a binary asteroid system, its origins and interior structure**.

Contributes valuable data to many disciplines, i.e., planetary defense, science, human exploration and resource utilization.