
ASSESS
[Center for Near Earth Object Studies]

SEARCH, DETECT & TRACK
[Ground-based & Space-based Observations, IAWN]

MITIGATE
[DART, FEMA Exercises]

CHARACTERIZE
[NEOWISE, Goldstone, Arecibo, IRTF]

PLAN & COORDINATE
[SMPAG, PIERWG, Damien IWG]
Launch
July 22, 2021

IMPACT: September 27, 2022

DART Spacecraft
650 kg arrival mass
18.8 m × 2.4 m × 2.0 m
6.65 km/s closing speed

Didymos-B
163 meters
11.92-hour orbital period

65803 Didymos
(1996 GT)
1,180-meter separation between centers of A and B

Didymos-A
780 meters, S-type
2.26-hour rotation period

Earth-Based Observations
0.07 AU range at impact
Predicted ~10-minute change in binary orbit period

• Target the binary asteroid Didymos system
• Impact Didymos-B and change its orbital period
• Measure the period change from Earth
DART: Key Technologies

DART will demonstrate key technologies for future NASA missions.

**Autonomous SmartNav system**
SmartNav autonomously directs DART to impact Didymos-B, leveraging decades of missile guidance algorithms developed at APL

**NEXT-C Ion Propulsion Engine**
DART will be the first flight of NASA’s Evolutionary Xenon Thruster-Commercial (NEXT-C) ion propulsion engine

**Roll Out Solar Arrays (ROSA)**
Powered flight, demonstrated on ISS previously

**Coresat Avionics**
Integrated system-on-a-chip FPGA processing

**Transformational Solar Arrays**
Concentrators, providing 5x times power of current state-of-the-art solar arrays, great at Jovian distances

**Radial Line Slot Array**
Planar low cost high efficiency high gain antenna
DART Engineering Challenges

EASY!
DART Spacecraft

mass: NLT 700 kg
power: ~5000 W

DRACO
(with cover on)

LICIACube

NEXT-C cover
(top hat)

Hydrazine Thrusters

NEXT-C Ion thruster

High Gain Antenna (RLSA)

Roll Out Solar Arrays (ROSA)

18 m
Hypervelocity impact at ~7 km/s

Required to stream images back real time, including last image within 7 sec of impact

Typically feeding images to the radio (3); for OpNavs and flyby, will be storing additional images on recorder (1,2)

Challenge in processing images from DRACO, feeding them to GNC to target and guide to the asteroid, and to the radio, ~ every second
DART Challenges - Through the Eyes of DRACO

60 min: ~24,000 km
A: ~6.5 pix
B: ~1.4 pix
A-B surfaces: ~6 pix

4 min: ~1,600 km
A: 99 pix
B: 21 pix

2 min: ~800 km
A: 197 pix
B: 41 pix
A-B surfaces: 179 pix

SmartNav simulation
(Mean ecliptic +z = up)
Testing SMART Nav

How do we test SMART Nav and make sure that it works?

- On ground in simulations (see next talk)
- Also in flight, using Jovian moons

We also have new technology, NEXT-C, that enables a flyby of a binary asteroid, 1994 AW1

Launch with $C_3 \approx 4-5 \text{ km}^2/\text{s}^2$

Low Thrust doesn’t start until \( \approx 30 \) days after launch.

Option: Use NEXT-C to add flyby and adjust arrival.

Demonstrate NEXT-C

Ballistic Transfer

1994 AW1

However, it comes with its own set of challenges...
DART Challenges – NEXT-C Implementation (1/2)

NEXT-C: Thruster and PPU

NEXT-C accommodation drives much of spacecraft design
- NEXT-C is controlled by flight software application housed in avionics
- Top Hat protects thruster from contamination by launch vehicle
- 2-axis Gimbal Assembly moves thruster to account for center of mass offset and thrust misalignment

Thruster emits ions and Molybdenum, charging and modifying S/C surfaces

Power Processing Unit (PPU)
- Thermally, dissipates ~300 W while operating; when off, make-up heaters are used
- Heat pipes distribute heat away from S/C panel
- Requires both high voltage and low voltage power
DART Challenges – NEXT-C Implementation (2/2)

S/C has high voltage bus for NEXT-C and low voltage bus for other spacecraft components

Need ~4500 W for operating NEXT-C system – results in large solar arrays
To keep SA lightweight and to provide clear fields of view to sensors, Roll Out Solar Arrays (ROSA) are used
But they introduce additional challenges for DRACO

Direction of thrust for NEXT-C can vary dramatically from thrust arc to thrust arc

Need to gimbal Solar Arrays to ensure that power was available
Low Gain Antennas need to cover ~4p sr

Fault management system constantly monitors NEXT-C operations

PPU has internal fault detection and correction; when faults occur, it ‘phones’ home
Ensures HV shutdown is performed correctly
Light Italian CubeSat for Imaging Asteroids

LICIACube

A very capable 6U CubeSat provided by Agenzia Spaziale Italiana (ASI)

CubeSat contractor: Argotec

Based on Argomoon CubeSat that will be flying on EM-1 mission

In process of solidifying payload, but Narrow Angle Camera at the least (goal of 1 m/pixel resolution imagery)

Released 5 days prior to impact

Current conops includes flyby of Didymos ~ 4 min after DART impact and downlinking data after event
Conclusions

DART mission simultaneously achieves planetary defense, technology demonstration, and asteroid science objectives.

Principal goal of DART is to accomplish kinetic deflection of a Near Earth Asteroid that could be observed from the ground.

First flight demonstration of the NEXT-C engine provides substantial flexibility in the trajectory design, but drives many features of the DART spacecraft.

To enable the high-velocity impact with Didymos-B, DART relies on proven proportional navigation techniques used heavily in the missile defense community as the basis for SMART Nav.

DART is on its way to be launched in July of 2021. Go DART!
Didymos B

Didymos A

Original Orbit

New Orbit

IMPACT

Spacecraft

Earth-based observations

DART