Update on Planetary Defense

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Asteroid Deflection: Kinetic Impactor (KI)

Double Asteroid Redirection Test

The first test of an asteroid deflection technique, by impacting a spacecraft into an asteroid.
DART Mission Goals:
- Target the binary asteroid Didymos system
- Impact Dimorphos and change its orbital period
- Measure the period change from Earth

IMPACT: 26 Sep 2022

PERIOD CHANGE: ~32 minutes

Earth-Based Observations
6.8 million miles (0.07 AU) from Earth at DART impact

DART Spacecraft
15,000 miles per hour

Dimorphos
160 meters
11.92-hour orbital period

Didymos
780 meters
1,180-meter separation between centers

DART – Double Asteroid Redirection Test
ATLAS South Africa (University of Hawai'i/NASA PDCO)
<table>
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<tr>
<th>Continent</th>
<th>Location</th>
<th>Organization/Institute</th>
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<tr>
<td>Africa</td>
<td>South Africa (South Africa)</td>
<td>ATLAS project, HQ at U. Hawai'i.</td>
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<tr>
<td>North America</td>
<td>United States (United States)</td>
<td>Bill and Eileen Ryan: Magdalena Ridge Obs. NM Tech</td>
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<tr>
<td>South America</td>
<td>Chile (Chile)</td>
<td>T. Lister, J. Chatelain, E. Gomez / Las Cumbres Observatory</td>
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<td>Europe</td>
<td>Romania (Romania)</td>
<td>Popescu: Astronomical Institute of the Romanian Academy</td>
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<td>Asia</td>
<td>Israel (Israel)</td>
<td>Ofek/Polishook, Weizmann Institute of Science.</td>
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<td>Antarctica</td>
<td>Concordia (Concordia)</td>
<td>Abe/Guillot: Antarctic Search for Transiting ExoPlanets Project</td>
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And this is just a snapshot! There is so much more than this and telescopes continue to provide new data daily.
Webb, Hubble Capture Detailed Views of DART Impact

These images, Hubble on the left and Webb on the right, show observations of the Didymos-Dimorphos system several hours after NASA's Double Asteroid Redirection Test (DART) intentionally impacted the moonlet asteroid.

Credit: Science: NASA, ESA, CSA, Jian-Yang Li (PSI), Cristina Thomas (Northern Arizona University), Ian Wong (NASA-GSFC); image processing: Joseph DePasquale (STScI), Alyssa Pagan (STScI)
Hubble Captures Detail in Debris Trail
This imagery from NASA's Hubble Space Telescope from Oct. 8, 2022, shows the debris blasted from the surface of Dimorphos 285 hours after the asteroid was intentionally impacted by NASA's DART spacecraft on Sept. 26. The shape of that tail has changed over time. Scientists are continuing to study this material and how it moves in space, in order to better understand the asteroid. Credits: NASA/ESA/STScI/Hubble
Imaging from LICIACube

Credits: ASI/NASA
Distance [km]: 777
Measuring result of the impact from Earth: new orbit for Dimorphos
Observations after DART impact show orbit change

- Prior to DART’s impact, it took Dimorphos 11 hours and 55 minutes to orbit its larger parent asteroid, Didymos.
- Since DART’s intentional collision with Dimorphos on Sept. 26, astronomers have been using telescopes on Earth to measure how much that time has changed.
- Now, the investigation team has confirmed the spacecraft’s impact altered Dimorphos’ orbit around Didymos by 32 minutes, shortening the 11 hour and 55-minute orbit to 11 hours and 23 minutes.
- This measurement has a margin of uncertainty of approximately plus or minus 2 minutes.
Observations after DART impact show orbit change

Dimorphos eclipses:  
- Expected from 11 hr 55 min orbit  
- Observed from 11 hr 23 min orbit

Observations for Sept. 27 to Oct. 6:
- Sept. 27: Observed from 11 hr 23 min orbit
  - Relative brightness: 100%  
- Sept. 28: Expected from 11 hr 55 min orbit
  - Relative brightness: 96%
- Sept. 29: Observed from 11 hr 23 min orbit
  - Relative brightness: 104%
- Sept. 30: Expected from 11 hr 55 min orbit
  - Relative brightness: 96%
- Oct. 1: Expected from 11 hr 55 min orbit
  - Relative brightness: 100%
- Oct. 2: Observed from 11 hr 23 min orbit
  - Relative brightness: 104%
- Oct. 3: Expected from 11 hr 55 min orbit
  - Relative brightness: 96%
- Oct. 4: Observed from 11 hr 23 min orbit
  - Relative brightness: 104%
- Oct. 5: Expected from 11 hr 55 min orbit
  - Relative brightness: 96%
- Oct. 6: Expected from 11 hr 55 min orbit
  - Relative brightness: 100%

Credit: NASA/Johns Hopkins APL/Astronomical Institute of the Academy of Sciences of the Czech Republic/Lowell Observatory/JPL/Las Cumbres Observatory/Las Campanas Observatory/European Southern Observatory Danish (1.54-m) telescope/Northern Arizona University
2022 WJ1 - Warned Impact on Nov. 19, 2022, 08:27 UTC (3:27 AM EST)

- First observed by the Catalina Sky Survey
- Placed on the NEO Confirmation Page by the Minor Planet Center
- Impact probability and corridor calculated within minutes by the Center for Near-Earth Object Studies (CNEOS) Scout system.
- Additional observations by the Catalina Sky Survey and Farpoint Observatory, Northeast Kansas Amateur Astronomers' League allowed Scout to narrow the impact location to Southern Ontario, Canada
- Observations by the community continued and ground observers were notified
2022 WJ1 - Warned Impact on Nov. 19, 2022, 08:27 UTC (3:27 AM EST)

Cosmographia animation courtesy of Davide Farnocchia (JPL/CNEOS)
The fireball was photographed by Rob Weryk, member of the Pan-STARRS team at the University of Western Ontario.

Over 50 witness reports on the American Meteor Society website
https://fireball.amsmeteors.org/members/imo_view/event/2022/8984
Probable meteorite fall detected by NEXRAD Doppler weather radar

https://ares.jsc.nasa.gov/meteorite-falls/events/grimsby-ontario

Ground track based on JPL/CNEOS impact location estimates as a function of the altitude in the atmosphere that the object could have disintegrated (courtesy R. Seaman UA/Catalina Sky Survey)

2022 WJ1 - Warned Impact on Nov. 19, 2022, 08:27 UTC (3:27 AM EST)
At ≤1 meter in size, 2022 WJ1 was a much smaller object than NASA is tasked to detect and warn about since objects of that size easily disintegrate after they impact Earth’s atmosphere.

This real-world event exercised capabilities and gave confidence that NASA/JPL/CNEOS impact prediction models are adequate to inform response to the potential impact of a larger object.

The success of this real-world exercise was due to routine rapid reporting and orbit determination by NASA-funded projects.

This is the sixth impact tied to observations obtained of a natural object while it was still in space (4th for Catalina Sky Survey).
*Potentially Hazardous Asteroids come within 7.5 million km of Earth orbit

NASA's search started in 1998

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George E Brown NEO Survey Goal

**NEAs:**
- 30,752 all
- 10,316 >140m
- 858 >1km

**PHAs:**
- 2,317 all
- 152 >1km

**NECs:** 118
Progress: 140 Meters and Larger
Total Population estimated to be ~25,000

NEO Survey Status as of 30 Sep 2022

George E Brown NEO Survey
Goal: (tasked in 2005)
Find at least 90% of NEOs
140 meter and larger
within 15 years

At the current assets’ discovery rate, it will take more than 30 years to complete the survey. New capabilities in development will cut that time in half.
NEO Surveyor

- Space-based infra-red telescope
- Objectives:
  - Find 65% of Potentially Hazardous Asteroids (PHAs) >140 m in 5 years
    (>90% in 10 years)
  - Estimate object sizes

- Preliminary Design Review (PDR) took place in September 2022
- The Project passed KDP-C and entered Phase C on Nov. 29, 2022