Near-Earth Object Observations Program

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NEOO Program Manager
Planetary Defense Coordination Office
NASA HQ
June 13, 2018
Planetary Defense Coordination Office

- Near-Earth Object Observations Program
- Interagency and International Partnerships
- Mitigation Research

NASA’s NEO Search Program
(Current Survey Systems)

**LINEAR/SST**
- MIT/LL
- 3.5 m
- Moving to Australia

**Catalina Sky Survey**
- U of AZ
- 1.5 m
- 0.7 m
- Arizona

**NEOWISE**
- JPL
- 0.4 m
- Sun-synch LEO

**Pan-STARRS**
- U of HI
- 1.8 m
- Haleakala, Maui

**ATLAS**
- U of HI
- 0.5 m
- Mauna Loa, HI

www.nasa.gov/planetarydefense
The International Astronomical Union

Minor Planet Center

http://minorplanetcenter.net/

- Receives positional measurement of small bodies from observations made all over the world (and beyond)
- Responsible for identification, designation and initial orbit computation
- Now operating under the Planetary Data System’s Small Bodies Node

- Computes high-precision orbits of near-Earth objects
- Performs long-term analyses of possible future orbits of hazardous asteroids (Sentry) and computes orbits for new potential asteroid discoveries to determine any impact hazard (Scout)
- Predicts the impact time, location and geometry in the event of a predicted impact
Near-Earth Asteroids Discovered

Most recent discovery: 2018-Jun-08

- **NEAs:**
  - 18242 all
  - 8182 >140m
  - 893 >1km

- **PHAs:**
  - 1909 all
  - 155 >1km

- **NECs:** 107

*Potentially Hazardous Asteroids come within 7.5 million km of Earth orbit*
NEOs >140 meters

Near-Earth Asteroid Discoveries by Survey
~140m and larger NEAs (as of 2018–Jun–12)

- Linear
- NEAT
- Spacewatch
- LONEOS
- Catalina
- Pan-STARRS
- NEOWISE
- NEAT
- All others

190 so far in 2018
539 discoveries in 2017

https://cneos.jpl.nasa.gov/stats/

Alan Chamberlin (JPL/Caltech)
NEOs >1 km

Near-Earth Asteroid Discoveries by Survey
~1km and larger NEAs (as of 2018–Jun–12)

https://cneos.jpl.nasa.gov/stats/

Alan Chamberlin (JPL/Caltech)
Planetary Defense Coordination Office

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Near Earth Asteroid Population and Survey Progress - 2017

<table>
<thead>
<tr>
<th>Impact Devastation</th>
<th>None</th>
<th>City</th>
<th>Region</th>
<th>Continent</th>
<th>Global</th>
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<tbody>
<tr>
<td>Number in Population</td>
<td>100,000,000</td>
<td>10,000,000</td>
<td>1,000,000</td>
<td>100,000</td>
<td>10,000</td>
</tr>
</tbody>
</table>

- 1908 Tunguska
- 2013 Chelyabinsk
- George E. Brown Survey Limit
- Spaceguard Survey Limit
- KT Impact Killed Dinosaurs

Number Found

Asteroid Size (km)

Percentage Complete

www.nasa.gov/planetarydefense
NEO Population - 140 meters and larger

NEO Survey Status Jan 2010
- 140-300 m Not Found, 67.9%
- 0.30-1 km Found, 8.4%
- 0.30-1 km Not Found, 13.9%
- >= 1 km Not Found, 3.3%
- >= 1 km Found, 5.9%

NEO Survey Status Jan 2018
- 140-300 m Not Found, 58.5%
- 0.30-1 km Found, 13.8%
- 0.30-1 km Not Found, 8.5%
- >= 1 km Not Found, 3.6%
- >= 1 km Found, 15.4%
Primary NEO Characterization Assets and Enhancements

Radar (Goldstone and Arecibo)
- Increased time for NEO observations
- Streamlining Rapid Response capabilities
- Increased resolution (~4 meters)
- Improve maintainability

NASA Infrared Telescope Facility (IRTF)
- Increased call-up for Rapid Response
- Improving operability/maintainability
- Improve instrumentation for spectroscopy and thermal signatures

Spitzer Infrared Space Telescope
- Orbit about Sun, ~176 million km trailing Earth
- In extended warm-phase mission
- Characterization of comets and asteroids
- Thermal signatures, albedo/sizes of NEOs
- Longer time needed for scheduling
Discovery and Impact of 2018 LA on June 2, 2018

- Discovered by the Catalina Sky Survey
- <3 meters in size
- ~8 hours prior to impact
- Additional observations from ATLAS-MLO
2018 LA

- The Minor Planet Center and JPL’s Center for NEO Studies (CNEOS) warned PDCO of potential impact
- CNEOS calculated impact corridors with available data

Evolution of JPL/CNEOS impact solutions

- Bolide over Botswana (~3.5 seconds, -27 magnitude)
ORIGINAL CCTV Footage of Asteroid 2018 LA (ZLAF9B2)
https://www.youtube.com/watch?v=SrzSwBp7i3M
Credit: Barend Swanepoel and Vicus van Zyl
Comprehensive Test Ban Treaty Organization (CTBTO) infrasound sensors also detected the bolide
2018 LA

• This was a much smaller object than NASA is tasked to detect and warn about

• This real-world event allowed us to exercise capabilities and gave some confidence that the impact prediction models are adequate to inform response to the potential impact of a larger object

• In the 20-year history of NASA’s Near-Earth Object Observations Program, this is the third time an object has been discovered and an impact solution calculated prior to an impact
2008 TC3 – impact over Sudan
2014 AA – impact over the middle of the Atlantic Ocean
2018 LA – impact over Botswana

...all discovered by Catalina Sky Survey astronomer Richard Kowalski
Planetary Defense Coordination Office

Lindley Johnson
Planetary Defense Officer
Planetary Defense Coordination Office
NASA HQ
June 13, 2018
Established in January 2016 at NASA HQ, this office coordinates planetary defense related activities across NASA, and coordinate both US interagency and international efforts and projects to address and plan response to the asteroid impact hazard.

**Planetary Defense Coordination Office**

**Mission Statement:**

Lead national and international efforts to:

- Detect any potential for significant impact of planet Earth by natural objects
- Appraise the range of potential effects by any possible impact
- Develop strategies to mitigate impact effects on human welfare
The Planetary Defense Coordination Office (PDCO) is responsible to:

• Ensure early detection of potentially hazardous objects (PHOs) – asteroids and comets whose orbits are predicted to bring them within 0.05 AU of Earth’s orbit - and characterize PHOs of size large enough to affect Earth’s surface to provide warning of potential impact effects if not deflected or mitigated
• Provide timely and accurate communications about PHOs and any potential impact
• Lead research into potential asteroid deflection and impact mitigation technologies and techniques
• Provide lead coordination role in U.S. Gov’t planning for response to an actual impact threat (e.g., planetary science and deep space mission expertise for Federal Emergency Response Team).

The PDCO:

• Manages NASA’s Near-Earth Object Observations Program to obtain best data available
• Coordinates NEO observation efforts conducted at ground-based observatories sponsored by the National Science Foundation and space situational awareness facilities of the USAF
• Participates in federal agency exercises to plan and develop appropriate impact response
• Conducts collaborative research on mitigation techniques with interagency and international partners
### NEO Close Approaches 2018 < 1 Lunar Distance - through May

<table>
<thead>
<tr>
<th>Object</th>
<th>CA Date</th>
<th>CA Distance LD</th>
<th>au</th>
<th>Est. Diameter</th>
<th>Object</th>
<th>CA Date</th>
<th>CA Distance LD</th>
<th>au</th>
<th>Est. Diameter</th>
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<tbody>
<tr>
<td>2018 AH</td>
<td>2018-Jan-02 04:25</td>
<td>0.77</td>
<td>0.00199</td>
<td>84 m - 190 m</td>
<td>2018 GY3</td>
<td>2018-Apr-10 04:23</td>
<td>0.78</td>
<td>0.00201</td>
<td>7.9 m - 18 m</td>
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<td>2018 BW</td>
<td>2018-Jan-15 15:13</td>
<td>0.43</td>
<td>0.00112</td>
<td>6.4 m - 14 m</td>
<td>2018 GD2</td>
<td>2018-Apr-12 16:42</td>
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<td>0.00201</td>
<td>3.4 m - 7.7 m</td>
</tr>
<tr>
<td>2018 BR1</td>
<td>2018-Jan-16 13:22</td>
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<td>0.00088</td>
<td>3.3 m - 7.5 m</td>
<td>2018 GE3</td>
<td>2018-Apr-15 06:41</td>
<td>0.50</td>
<td>0.00129</td>
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<tr>
<td>2018 BD</td>
<td>2018-Jan-18 15:43</td>
<td>0.10</td>
<td>0.00026</td>
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<td>2018 HW1</td>
<td>2018-Apr-21 22:53</td>
<td>0.89</td>
<td>0.00229</td>
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<tr>
<td>2018 BF3</td>
<td>2018-Jan-19 03:00</td>
<td>0.63</td>
<td>0.00162</td>
<td>17 m - 38 m</td>
<td>2018 HV</td>
<td>2018-Apr-22 17:07</td>
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<td>2018 BC</td>
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<td>0.73</td>
<td>0.00189</td>
<td>3.5 m - 7.8 m</td>
<td>2018 KW1</td>
<td>2018-May-23 11:57</td>
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<td>0.00100</td>
<td>3.1 m - 6.9 m</td>
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<tr>
<td>2018 BX</td>
<td>2018-Jan-19 23:00</td>
<td>0.73</td>
<td>0.00188</td>
<td>4.0 m - 9.0 m</td>
<td>2018 KY2</td>
<td>2018-May-26 05:25</td>
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<td>0.00200</td>
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<td>2018 BL11</td>
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<td>0.79</td>
<td>0.00203</td>
<td>5.8 m - 13 m</td>
<td>2018 BN6</td>
<td>2018-Jan-24 09:29</td>
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<td>2018 CS1</td>
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<td>2018 FL29</td>
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<td>0.00148</td>
<td>2.6 m - 5.7 m</td>
<td>2018 FE3</td>
<td>2018-Mar-18 07:12</td>
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<td>0.00098</td>
<td>9.7 m - 22 m</td>
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<td>0.00187</td>
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<td>2018 FZ3</td>
<td>2018-Mar-23 16:19</td>
<td>0.50</td>
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<tr>
<td>2018 FK5</td>
<td>2018-Mar-30 13:28</td>
<td>0.39</td>
<td>0.00100</td>
<td>5.8 m - 13 m</td>
<td>2018 GR11</td>
<td>2018-Apr-07 07:52</td>
<td>0.69</td>
<td>0.00177</td>
<td>5.3 m - 12 m</td>
</tr>
</tbody>
</table>

And 2018 LV4 at 0.86 LD on June 15 (13-30m)
Planetary Defense Coordination Office Status

- Over 18,000 near-Earth objects (NEOs) discovered and confirmed to date
  - Over 8,000 NEOs greater than 140 meters in size
  - Over 1,900 NEOs are Potentially Hazardous Asteroids

- White House National Near-Earth Object Preparedness Action Plan to be released late June 2018 by the Detecting and Mitigating the Impact of Earth-Bound Near-Earth Objects (DAMIEN) Interagency Working Group

- 2017 NEO Science Definition Team reassessed NEO search and characterization given current technology and understanding of the NEO population. Of the estimated 25,000 NEOs 140 meters or larger in size (that can cause regional damage), 1/3 have been found. Space-based assets will be needed to complete the catalog.

- FY19 budget request includes an enhanced Planetary Defense program for near-Earth object detection and mitigation
PDCO Past Events

- January 16, 2018: Tunguska Revisited Workshop
- January 29, 2018: UNCOPUOS/IAWN/SMPAG
- February 12, 2018: IRTF Future Directions Workshop
- February 14, 2018: 2012 TC4 post-exercise meeting
- February 15, 2018: NEOO Program meeting
- February 15, 2018: Chelyabinsk anniversary (2013)
- February 27-28, 2018: NEOCam MDR/SRR
- April 10-12, 2018: DART PDR

PDCO Upcoming Events

- June 20, 2018: UNISPACE+50
- June 22, 2018: DART KDP-C DPMC
- June 30, 2018: Tunguska anniversary (1908)
- October 18, 2018: Space Mission Planning Advisory Group - SMPAG
- October 19, 2018: International Asteroid Warning Network - IAWN
PDCO Mission Projects

NEOWISE

- Continues in extended NEO survey operations

NEOCam: Near-Earth Object Camera

- Infrared survey telescope optimized for meeting congressional mandate to find and characterize NEOs down to 140 meters in size
- Continues in extended Phase A
- Passed SRR/MDR on February 28, 2018

DART: Double Asteroid Redirection Test

- Demonstration of kinetic impactor technique
- Target - Moon of 65803 Didymos
- Launch period opens June 2021, impact October 2022
- Passed mission-level PDR on April 12, 2018
- KDP-C scheduled for June 22, 2018
Sentry Object 2018 LB1

2018 LB1 -- Earth Impact Risk Summary (orbit details off)

<table>
<thead>
<tr>
<th>Torino Scale (maximum)</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Palermo Scale (maximum)</td>
<td>-1.58</td>
</tr>
<tr>
<td>Palermo Scale (cumulative)</td>
<td>-1.58</td>
</tr>
<tr>
<td>Impact Probability (cumulative)</td>
<td>3.5e-5</td>
</tr>
<tr>
<td>Number of Potential Impacts</td>
<td>3</td>
</tr>
<tr>
<td>Impact Search Technique</td>
<td>LOV</td>
</tr>
</tbody>
</table>

V_{\text{Impact}} = 14.81 \text{ km/s} 

V_{\text{Infinity}} = 9.76 \text{ km/s} 

H = 20.0

Diameter = 0.340 km

Mass = 5.2e+10 kg

Energy = 1.3e+3 Mt

All above are mean values weighted by impact probability

Analysis based on 45 observations spanning 23,805 days (2018-May-18.425541 to 2018-Jun-12.23056)

Impact Table (these results were computed on 2018-Jun-12)

<table>
<thead>
<tr>
<th>Date (yyy-mm-dd.dd)</th>
<th>Distance (r_{Earth})</th>
<th>Width (r_{Earth})</th>
<th>Sigma Impact</th>
<th>Sigma LOV</th>
<th>Stretch LOV (r_{Earth})</th>
<th>Impact Probability</th>
<th>Impact Energy (Mi)</th>
<th>Palermo Scale</th>
<th>Torino Scale</th>
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<tr>
<td>2032-08-06.51</td>
<td>1.20</td>
<td>1.41e-1</td>
<td>1.425</td>
<td>-0.84205</td>
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