Planetary Defense Coordination Office Brief

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Program Executive / Planetary Defense Officer
Science Mission Directorate
NASA HQ

March 9, 2016

Planetary Defense Coordination Office

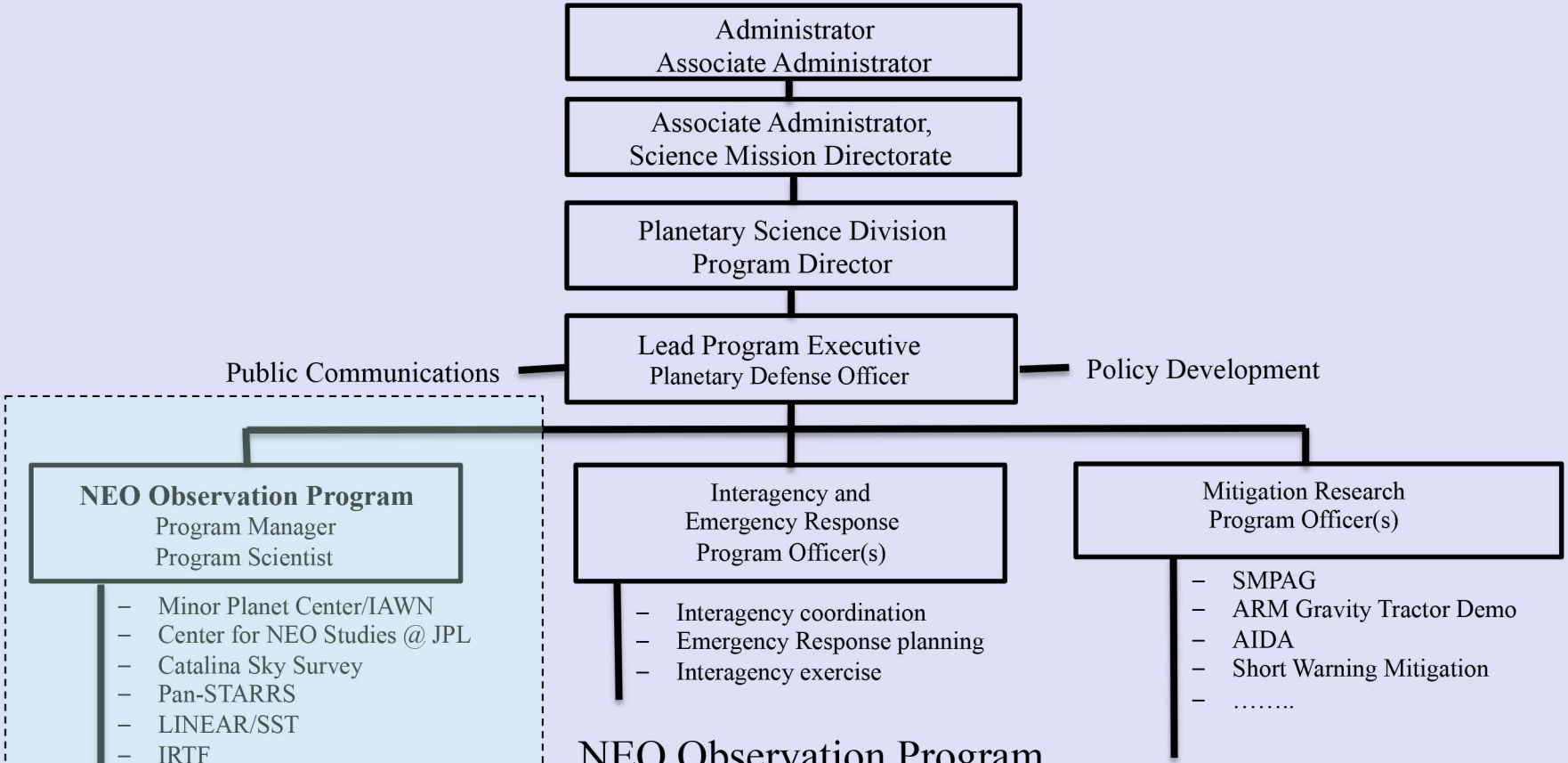
This new office was recently established at NASA HQ to coordinate planetary defense related activities across NASA, and coordinate both US interagency and international efforts and projects to address and plan response to the asteroid impact hazard.

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

Planetary Defense Coordination Office

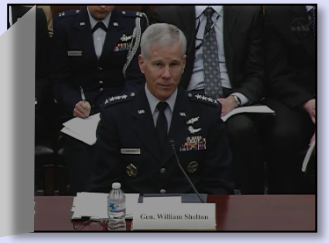


NEO Observation Program

- ❑ Officially established as a research program
- ❑ Formalized program documentation
- ❑ PDCO also includes emergency response and mitigation elements
- ❑ PDCO Staffing at ~5.0 FTE

National Interest in Asteroid Hazard

Congressman Lamar Smith (R-Texas) — Chairman of U.S. House of Representatives Committee on Science, Space, and Technology



General William Shelton — then-Chief of the U.S. Air Force Space Command

"The Administration places a high priority on tracking asteroids and protecting our planet from them, as evidenced by the five-fold increase in the budget for NASA's NEOO program since 2009. The United States has an effective program for discovering larger NEOs, but we need to improve our capabilities for the identification and characterization of smaller NEOs."

John Holdren, Director, Office of Science and Technology Policy, Science advisor to President Barack Obama

National Space Policy, June 28 2010 – "Pursue capabilities, in cooperation with other departments, agencies, and commercial partners, to detect, track, catalog, and characterize near-Earth objects to reduce the risk of harm to humans from an unexpected impact on our planet and to identify potentially resource-rich planetary objects." https://www.whitehouse.gov/sites/default/files/national_space_policy_6-28-10.pdf

Administration guidance was provided in OSTP Letter to Congress dated 15 October, 2010, as Response to Section 804 of NASA Authorization Act of 2008
https://www.whitehouse.gov/sites/default/files/microsites/ostp/ostp-letter-neo-senate.pdf

NEO Observations Program

Detection and tracking of natural objects – asteroids and comets – that approach within 28 million miles of Earth's orbit

US component to International Asteroid Warning Network

Has provided 98% of new detections of NEOs since 1998

Began with NASA commitment to House Committee on Science in May 1998 to find at least 90% of 1 km and larger NEOs

- That goal reached by end of 2010

NASA Authorization Act of 2005 increased scope of objectives:

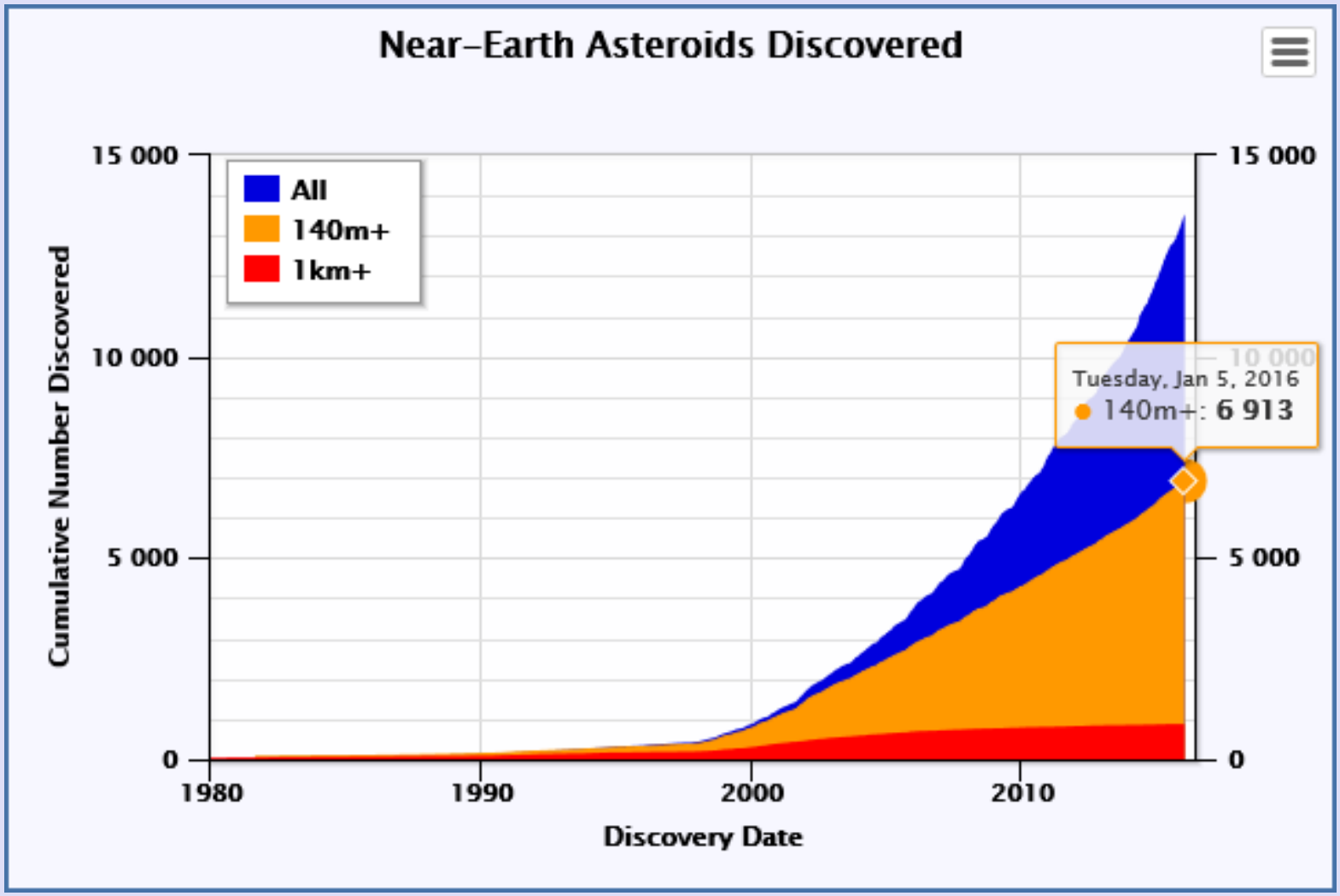
- Amended National Aeronautics and Space Act of 1958 ("NASA Charter") to add:

  ''The Congress declares that the general welfare and security of the United States require that the unique competence of the National Aeronautics and Space Administration be directed to detecting, tracking, cataloguing, and characterizing near-Earth asteroids and comets in order to provide warning and mitigation of the potential hazard of such near-Earth objects to the Earth.''

- Made NEO detection, tracking and research 1 of 7 explicitly stated purposes of NASA!
- Provided additional direction:

  "…plan, develop, and implement a Near-Earth Object Survey program to detect, track, catalogue, and characterize the physical characteristics of near-Earth objects equal to or greater than 140 meters in diameter in order to assess the threat of such near-Earth objects to the Earth. It shall be the goal of the Survey program to achieve 90 percent completion of its near-Earth object catalogue within 15 years [by 2020]"

Known Near Earth Asteroid Population



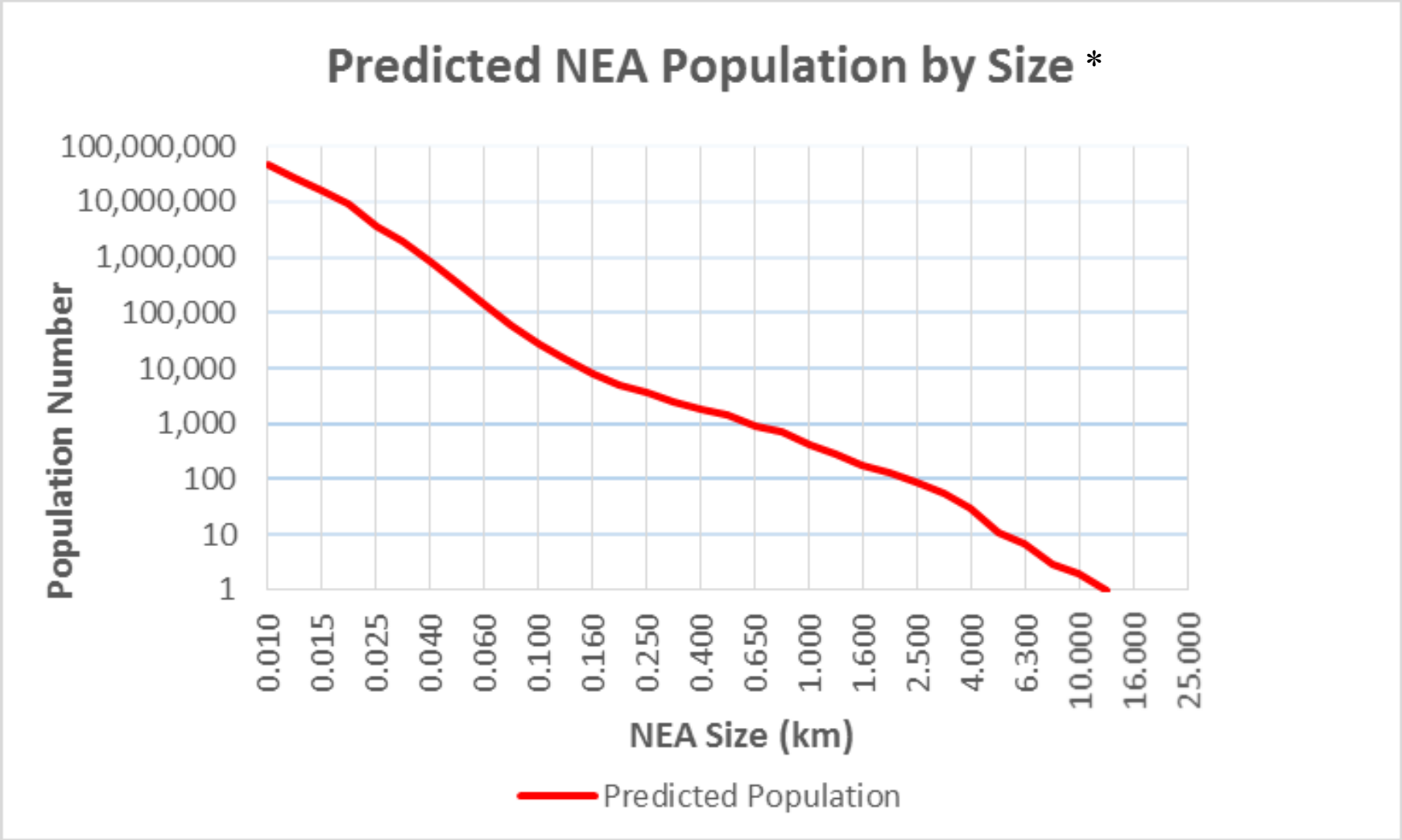
As of 12/31/15
13,514

Also 105 comets

1649 Potentially Hazardous Asteroids
Come within 5 million miles of Earth orbit

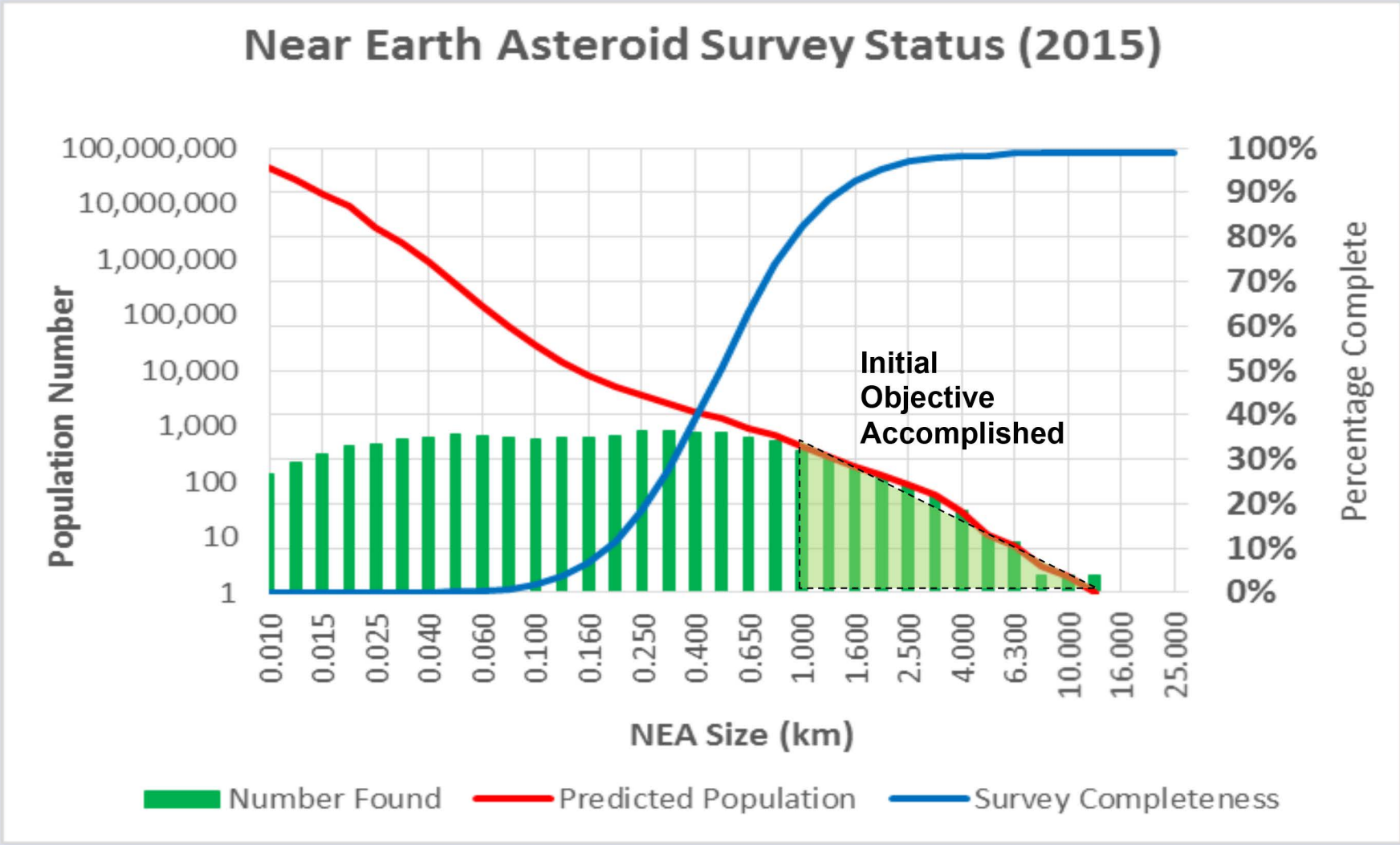
879
153 PHAs

Near Earth Asteroid Survey Status

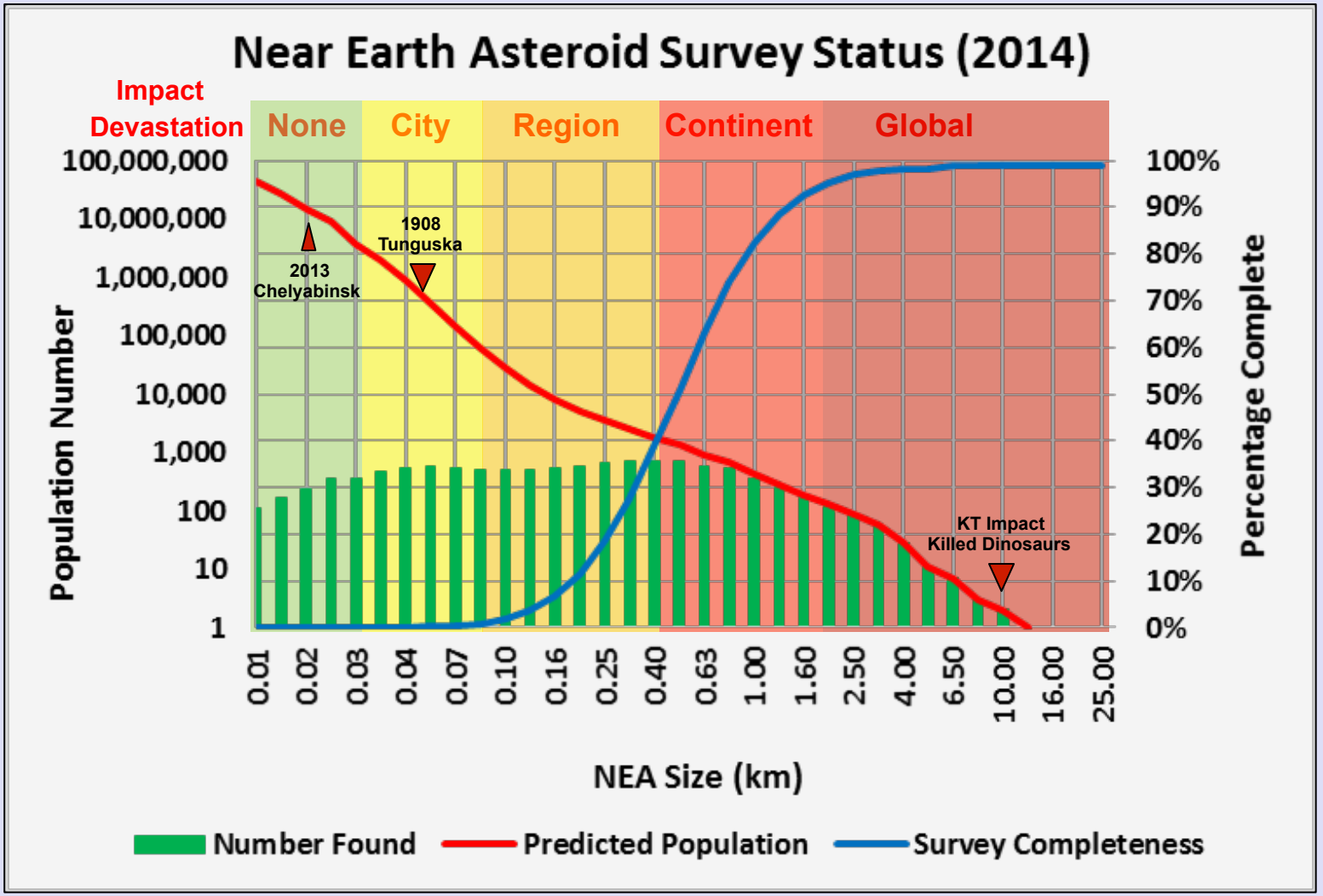


*Harris & D'Abramo, "The population of near-Earth asteroids", Icarus 257 (2015) 302–312, http://dx.doi.org/10.1016/j.icarus.2015.05.004

Near Earth Asteroid Survey Status

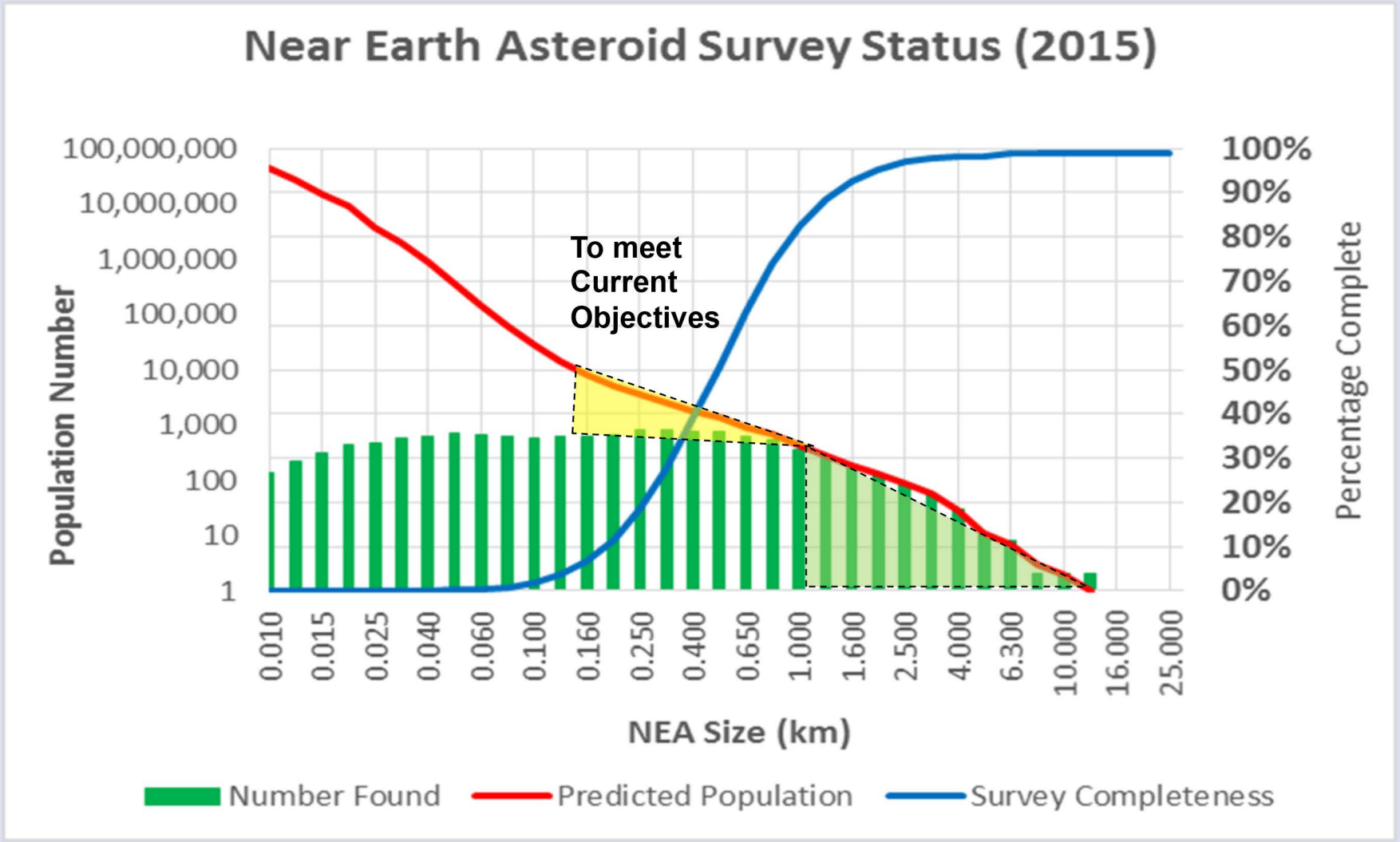


Near Earth Asteroid Survey Status



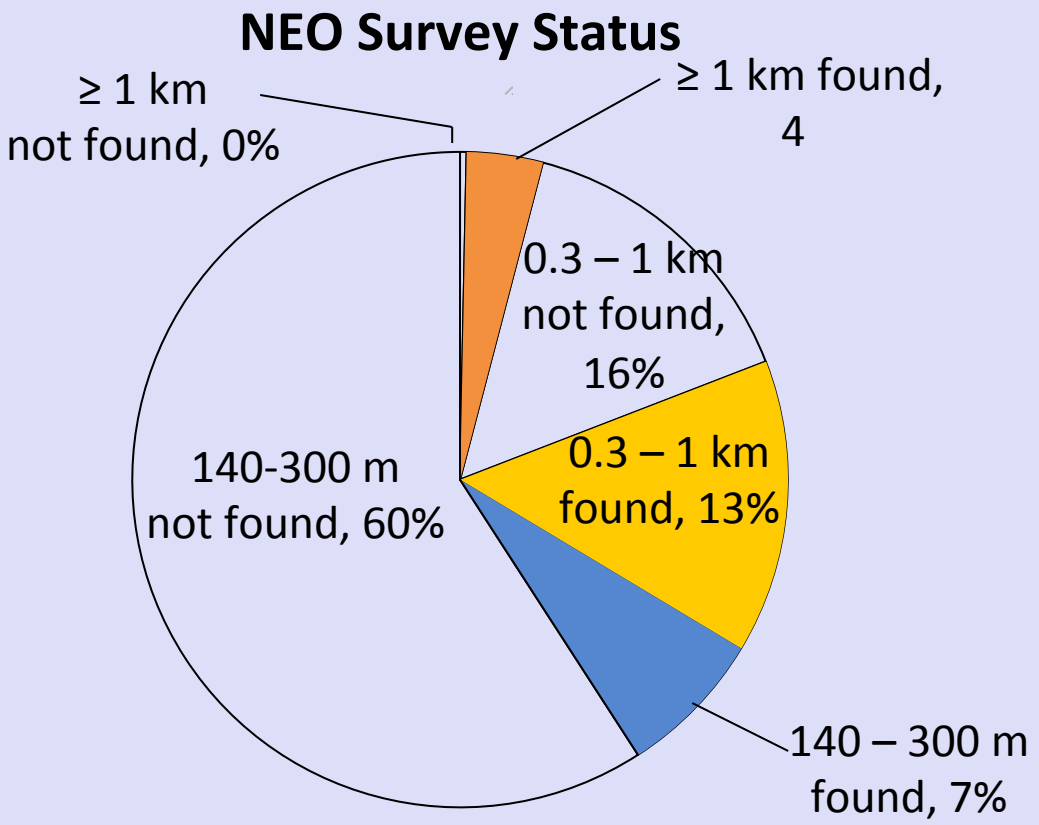
Study to Determine the Feasibility of Extending the Search for Near-Earth Objects to Smaller Limiting Diameters
Report of the Near-Earth Object Science Definition Team, August 22, 2003, http://neo.jpl.nasa.gov/neo/neoreport030825.pdf

Near Earth Asteroid Survey Status



Near Earth Asteroid Survey Status Alternative Graphic

Population ≥ 140 meters in estimated size ~25,500 = 100%



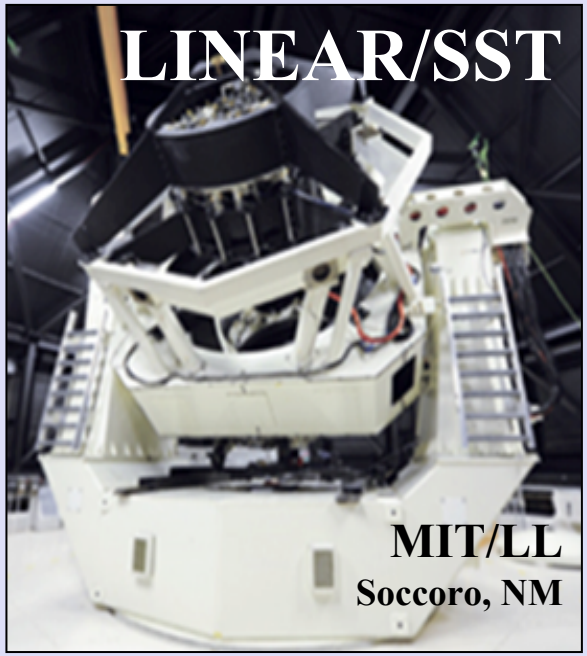
NASA's NEO Search Program
(Current Survey Systems)

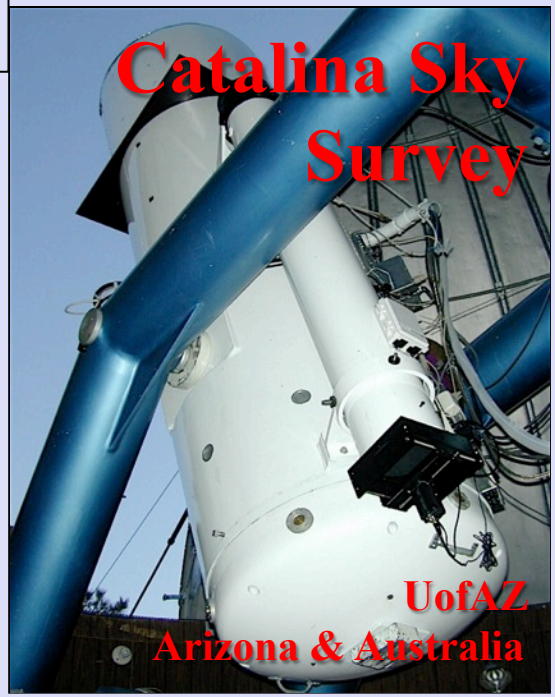
Minor Planet Center (MPC)
- IAU sanctioned
- Int'l observation database
- Initial orbit determination

http://minorplanetcenter.net/

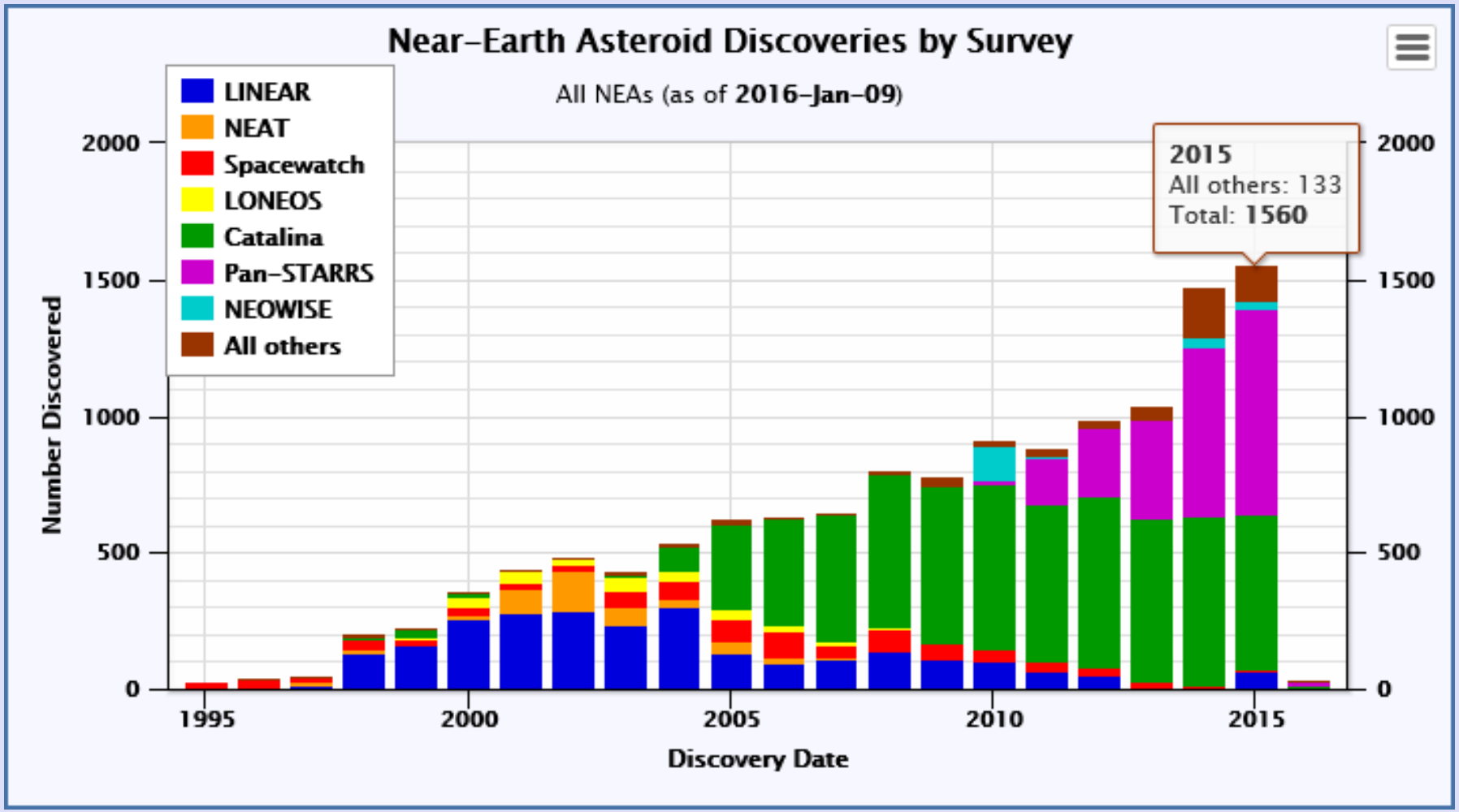
Center for NEO Studies @ JPL
- Program coordination
- Precision orbit determination
- Automated SENTRY

http://neo.jpl.nasa.gov/



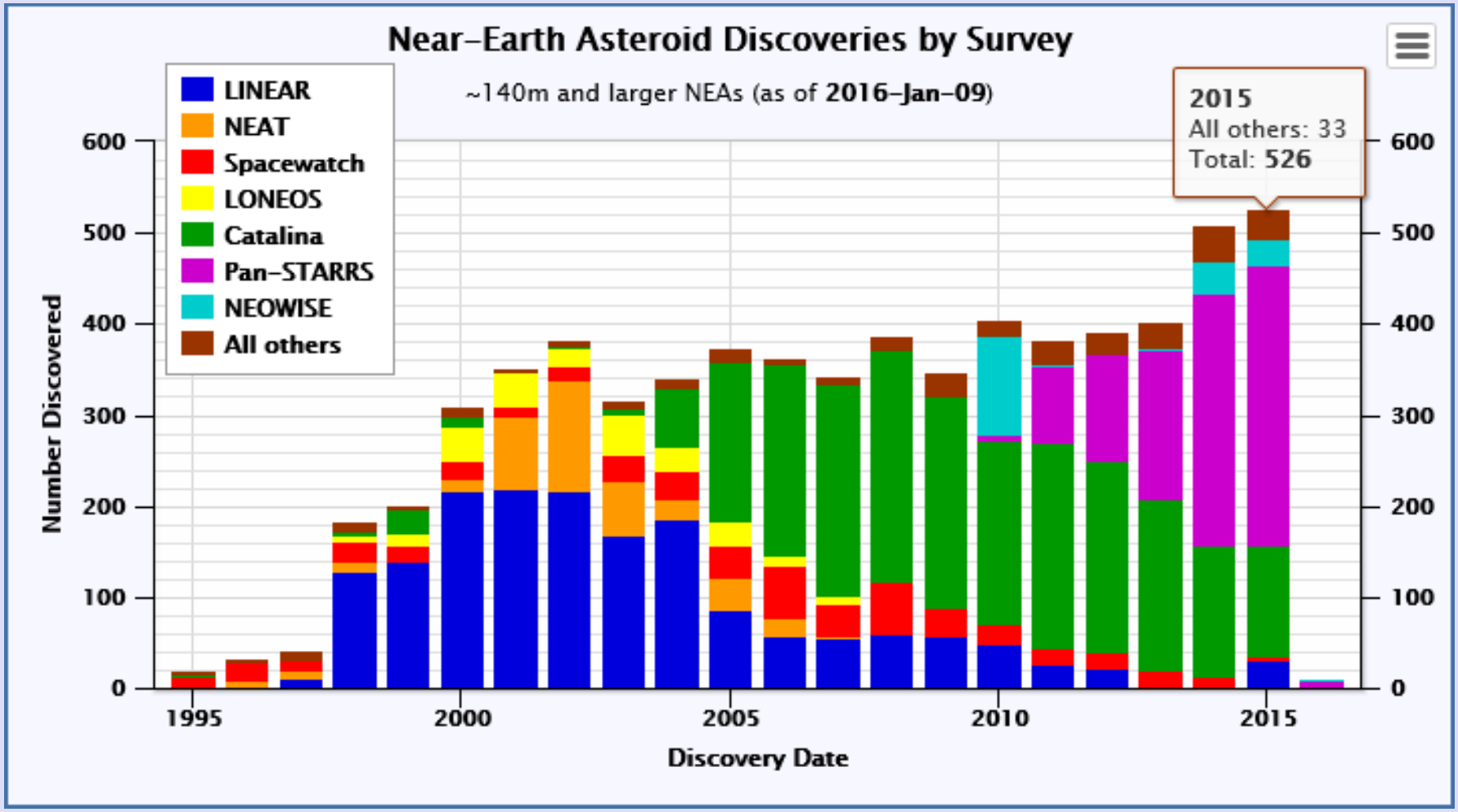


Growth in Capability



As more capable telescopes are added, discoveries include more <140m NEOs

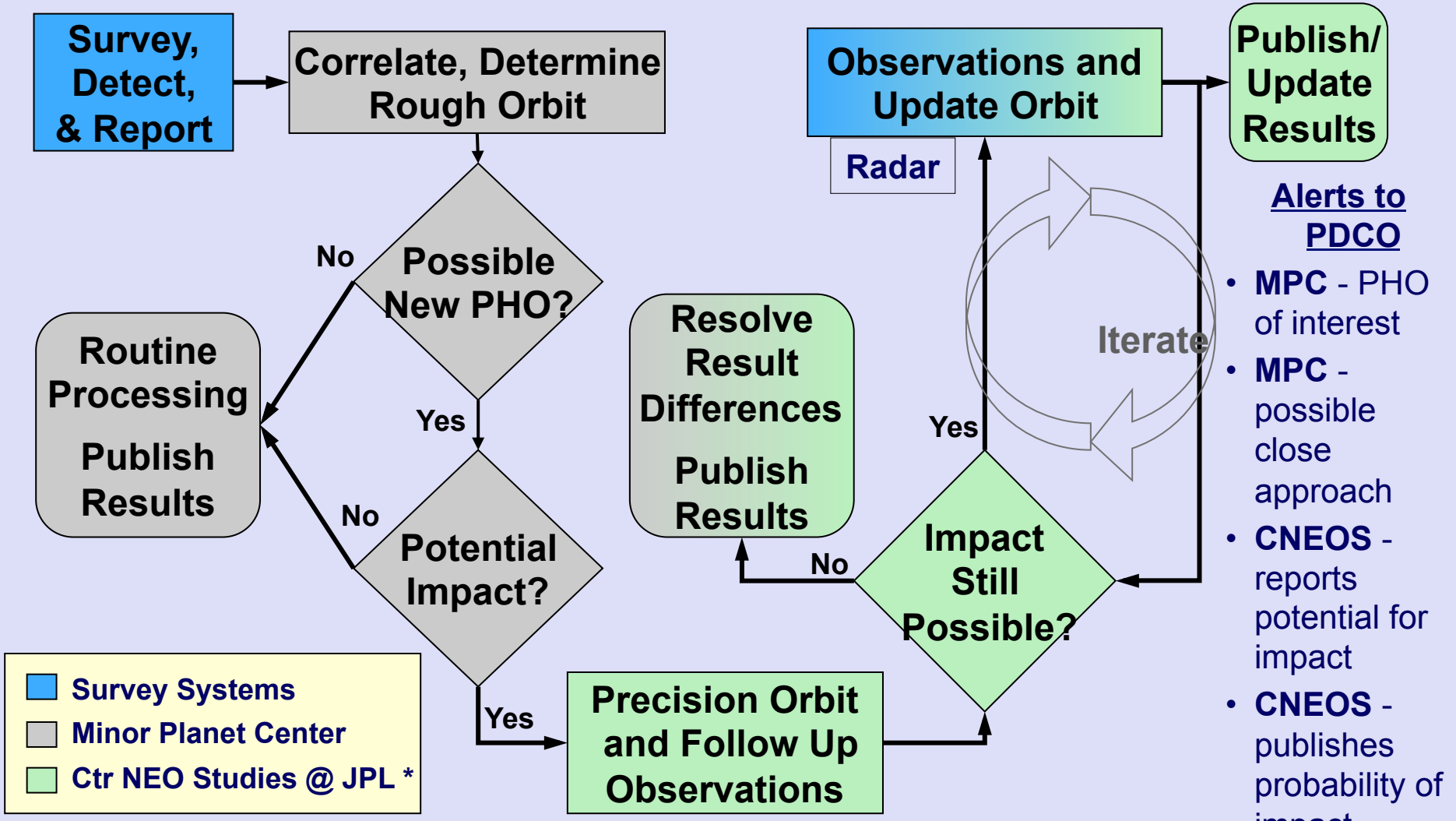
Discoveries for Current Objective



Planetary Defense Coordination Office

Rapid Notification Process

NEOO Survey and Alert Process

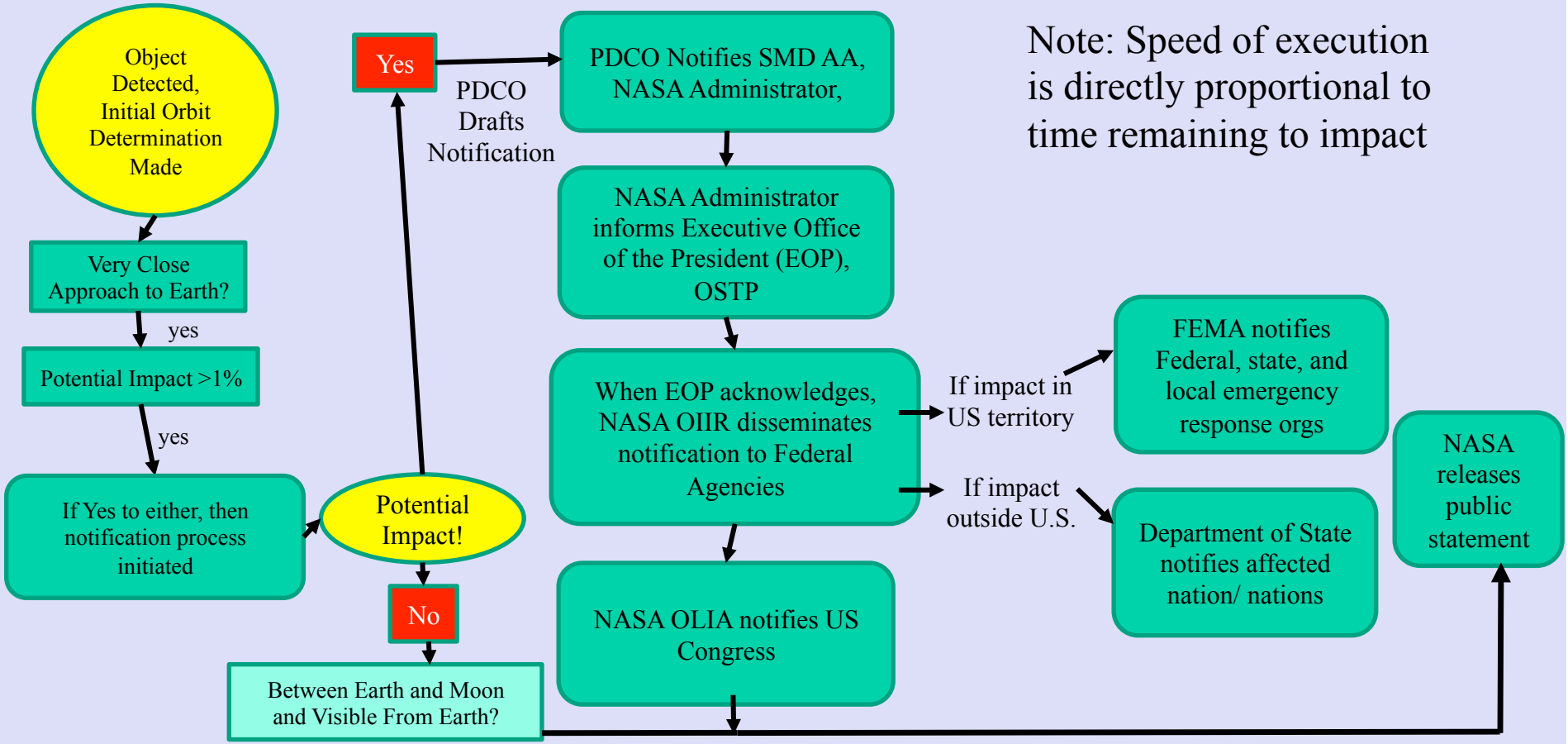


Alerts to PDCO

- **MPC** - PHO of interest
- **MPC** - possible close approach
- **CNEOS** - reports potential for impact
- **CNEOS** - publishes probability of impact

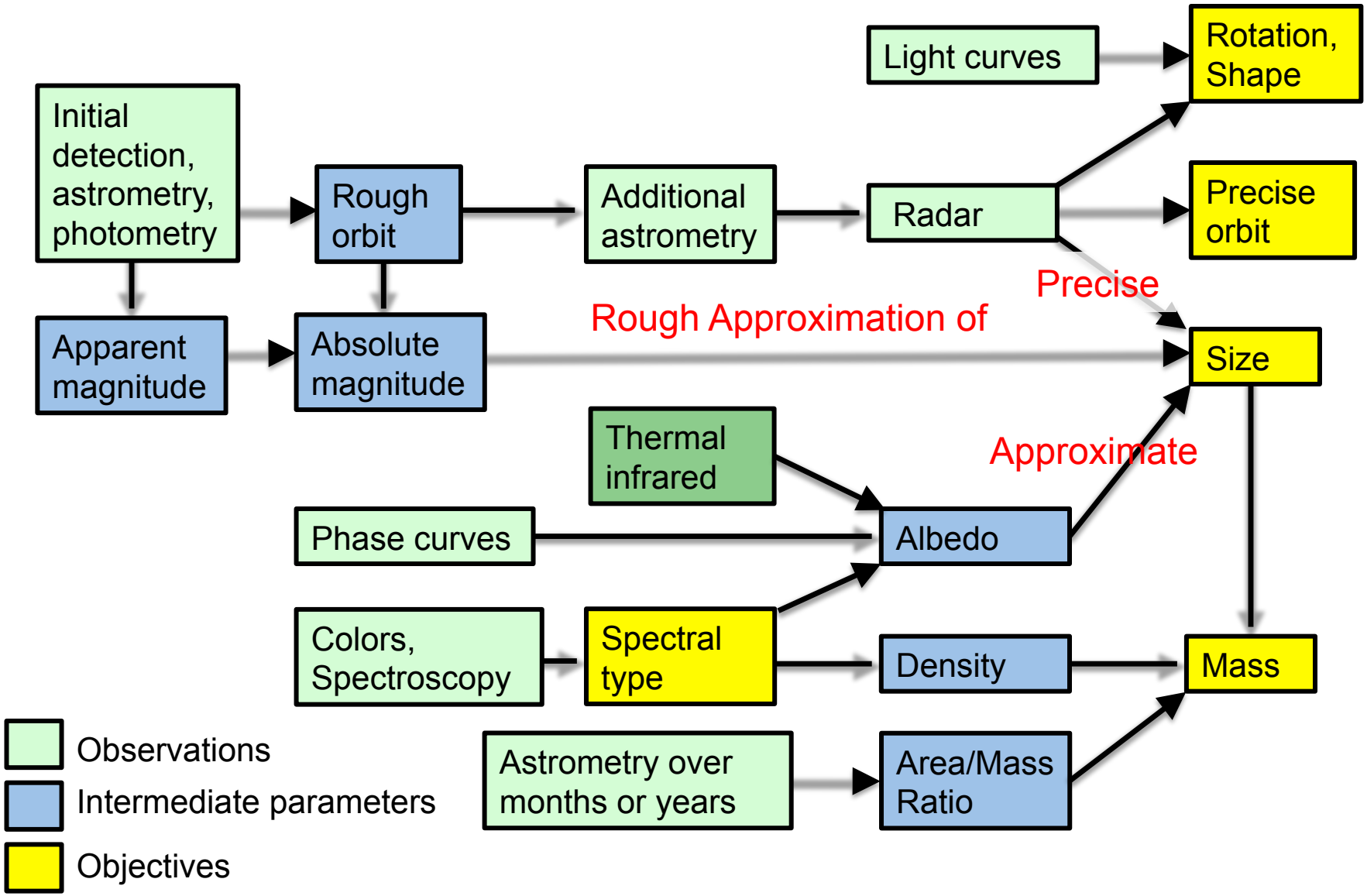
* In parallel with NEODyS

Planetary Defense Coordination Office
Potential Impact Notification Process



Note: Speed of execution is directly proportional to time remaining to impact

Characterization Process

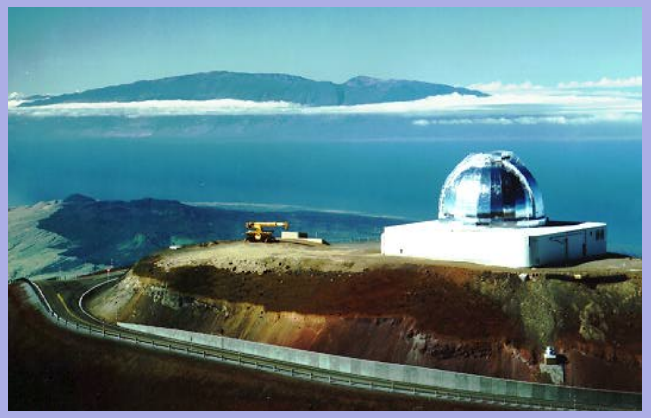


Primary NEO Characterization Assets and Enhancements

Radar (Goldstone and Arecibo)

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

Arecibo Observatory



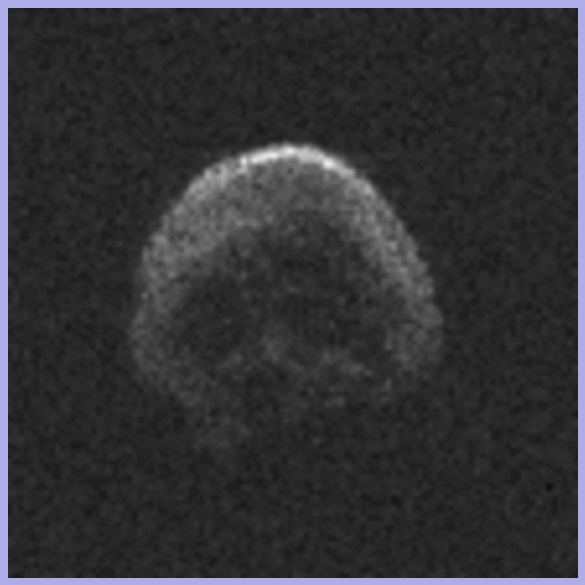
NASA Infrared Telescope Facility (IRTF)

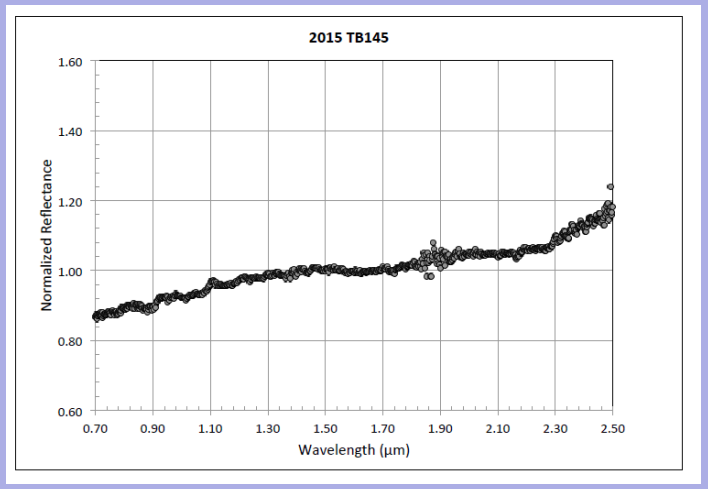
- Increased call-up for Rapid Response
- Improving operability/maintainability
- Improve Instrumentation for Spectroscopy and Thermal Signatures

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

2015 TB145 - Halloween Asteroid Fly-by "The Great Pumpkin"





- Discovered by Pan-STARRS on October 10
- Close Approach of 1.3 Lunar Distance predicted for October 31
- Immediately drew some media attention – "Discovered only 3 weeks before it may hit"
- IRTF observations determined object is likely a dead comet that has shed volatiles

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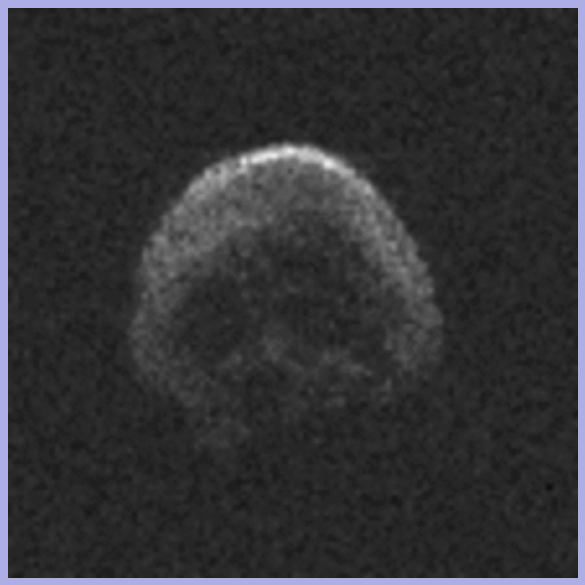

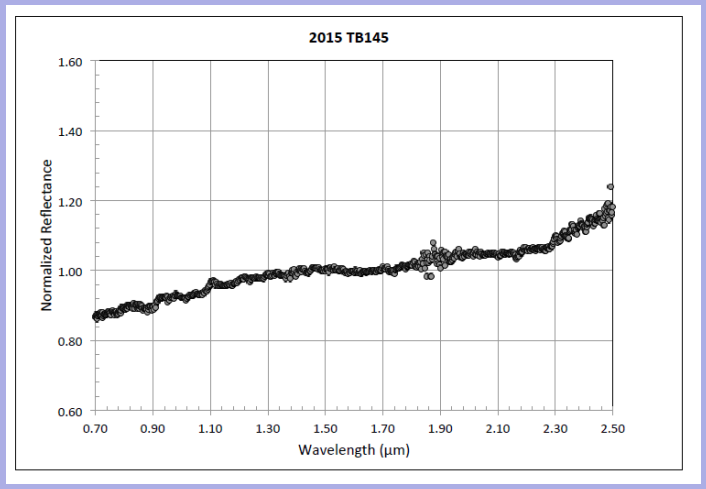

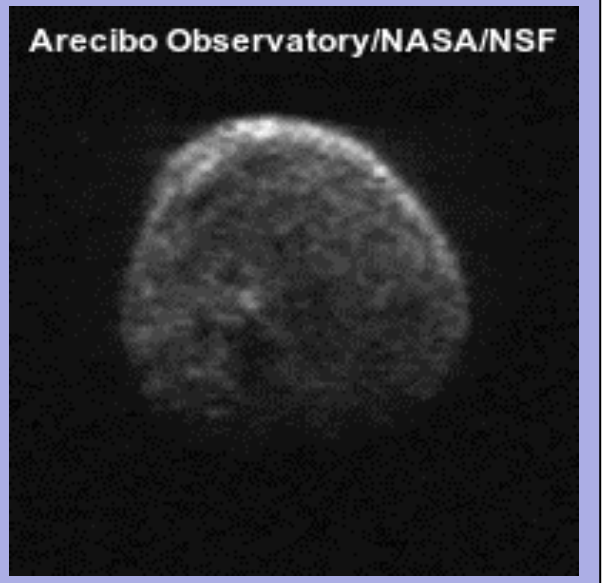

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- IRTF observations determined object is likely a dead comet that has shed volatiles
- Observed by Arecibo and then bi-static with Greenbank receiving from Goldstone transmission
- Object is roughly spherical in shape and approximately 2,000 feet (600 meters) in diameter
- Resolution is ~4 meters

Coordinated Rapid Response to a New Near-Earth Asteroid Discovery and Flyby

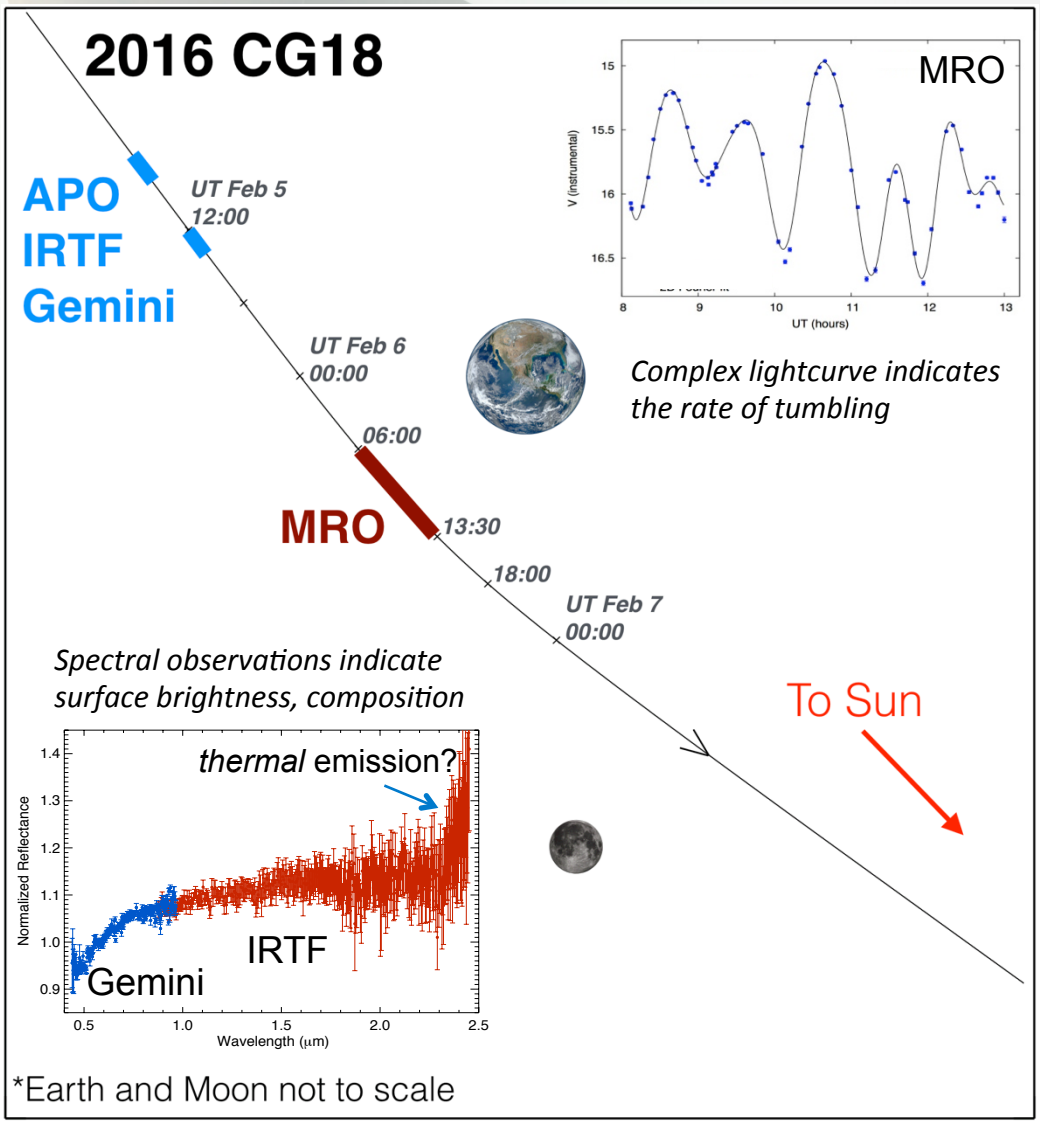
The near-Earth asteroid 2016 CG_{18} was discovered by the Catalina Sky Survey on Feb 3, 2016 and flew by the Earth three days later at less than half the distance to the Moon. A coordinated response by astronomers was made from several observatories:

- NASA's Infrared Telescope Facility (IRTF)
- Gemini North Observatory
- Magdalena Ridge Observatory (MRO)
- Apache Point Observatory (APO)

IRTF and Gemini target-of-opportunity spectroscopic observations give clues to the composition and surface brightness. Light curve observations from APO and MRO show that **this 4-9 meter object is an unusually slow tumbler for an object of its size, possibly the slowest measured to date at ~2 hours per revolution**

This campaign tested rapid response observing protocols and coordination for difficult, fast moving objects in preparation for future time-critical events similar to the discovery and impact of 2008 TC_3. This effort also added critical data to the catalog of physical properties for potential Earth impactors as well as spacecraft-accessible targets for future exploration.

Observations & data analysis: N. Moskovitz (Lowell Obs.), D. Polishook (Weizmann Inst.), M. Hinkle (NAU), B. Ryan (MRO), M. Brucker (Adler), K. Nault (Adler), V. Reddy (PSI), B. Burt (Lowell)



Comet Catalina (C/2013 US10) Outbound

Comet Catalina (C/2013 US10) was discovered on 31 Oct 2013 by the 0.7-m Schmidt telescope of the Catalina Sky Survey. It is a dynamic 'new' comet from the Oort cloud.

As these icy bodies approach the inner part of the solar system, the Sun's radiation causes the volatiles sublimate and vaporize – creating the fuzzy coma and tails.

Chris Schur obtained this 54-sec exposure on 1 Jan 2016 as Comet Catalina passed within ½° of the orange giant star Arcturus.

NASA's NEO Observations Program funds several surveys, including the CSS & NEOWISE This is the 0.7-m Schmidt, located in the Catalina Mtns, north of Tucson, Arizona.

The ion tail points directly away from the Sun whereas the wispy dust trail curls towards the comet's orbital path.

Arcturus

to the Sun

(Image: Stellarvue SV80 astrograph, Canon XTi, ISO 400)

NEOWISE imaged the comet on 28 Aug 2015, a few months before perihelion. Five co-added images show its motion across the sky.

NEOWISE 'sees' in two IR wavelengths: 3.4 & 4.6 μm; color-coded as cyan and red, respectively. The copious quantities of gas and dust spewed by the comet appear red in this image because they are very cold, much colder than the background stars.

Planetary Defense Coordination Office
at
NASA

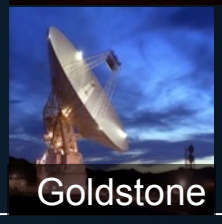
Asteroid Redirect Mission: Three Main Segments

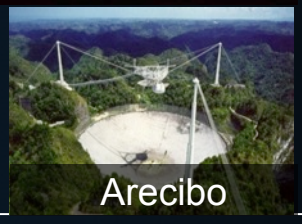
IDENTIFY

Ground and space based assets detect and characterize potential target asteroids


Pan-STARRS


NEOWISE

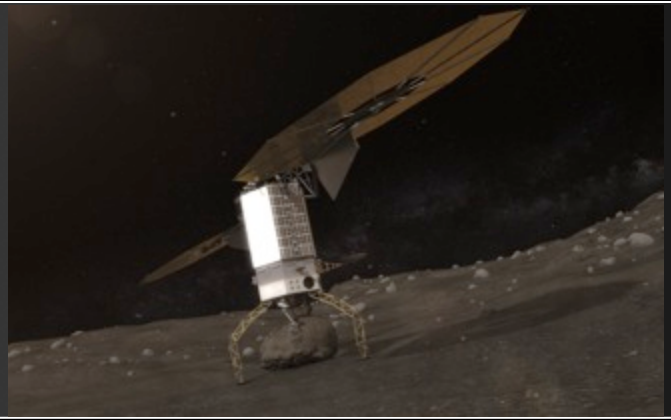

Goldstone

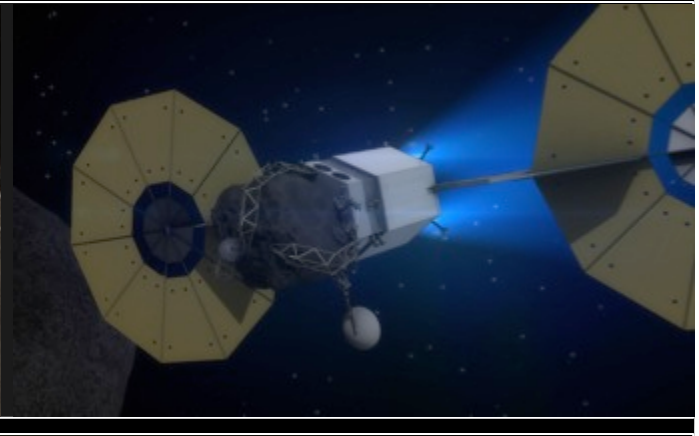

Arecibo


Infrared Telescope Facility

REDIRECT

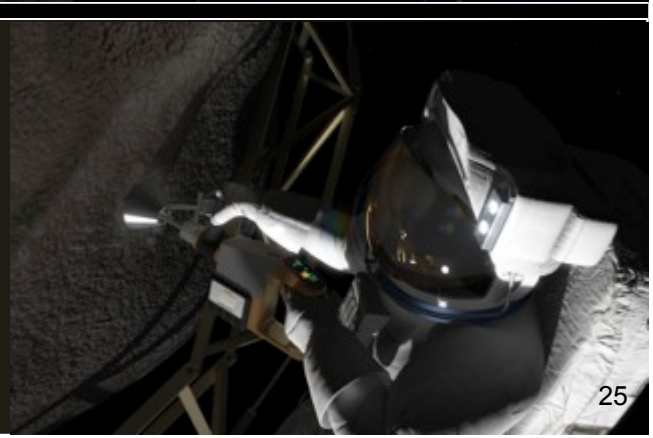
Solar electric propulsion (SEP) based system redirects asteroid to cis-lunar space.





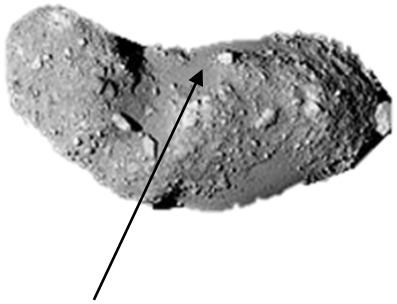
EXPLORE

Crew launches aboard SLS rocket, travels to redirected asteroid in Orion spacecraft to rendezvous with redirected asteroid, studies and returns samples to Earth



Current Candidate Parent Asteroids

ITOKAWA

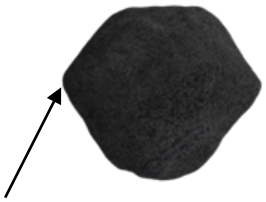


Muses C –
Hayabusa landing

BENNU

Radar –
OSIRIS-REx target

2008 EV5



Radar – boulders and extremely pronounced bulge at equator suggests movement of loose material

1999 JU3

Expected valid target -
Hayabusa 2 target

Asteroids not to scale

Comparison of current candidate parent asteroids

	Itokawa	Bennu	2008 EV_5	1999 JU_3
Size	535 x 294 x 209 m	492 x 508 x 546 m	420 x 410 x 390 m	870 m diameter
V_∞	5.68 km/s	6.36 km/s	4.41 km/s	5.08 km/s
Aphelion	1.70 AU	1.36 AU	1.04 AU	1.42 AU
Spin Period	12.13 hr	4.297 hr	3.725 hr	7.627 hr
Type	S	B (C-grp volatile rich)	C (volatile rich)	C (volatile rich)
Precursor	Hayabusa (2005)	OSIRIS-REx (9/2016 launch,	None currently planned (boulders implied from	Hayabusa 2 (launched 12/4/2014,

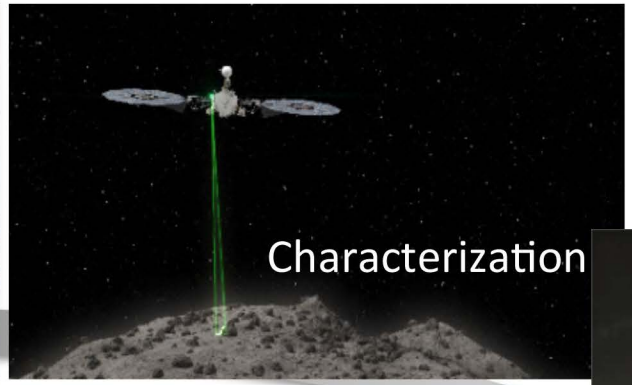
Reference ARRM Target

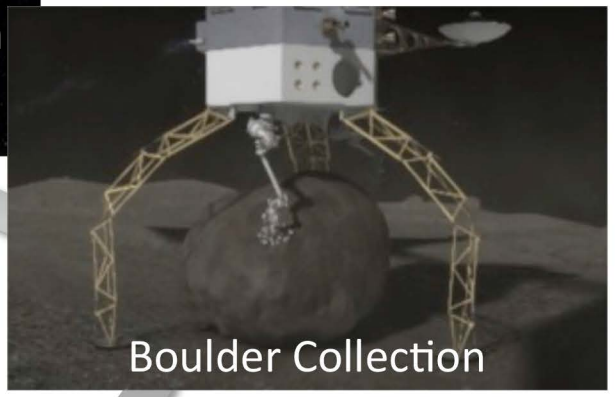
Capture Phase Overview
Asteroid Redirect Robotic Mission

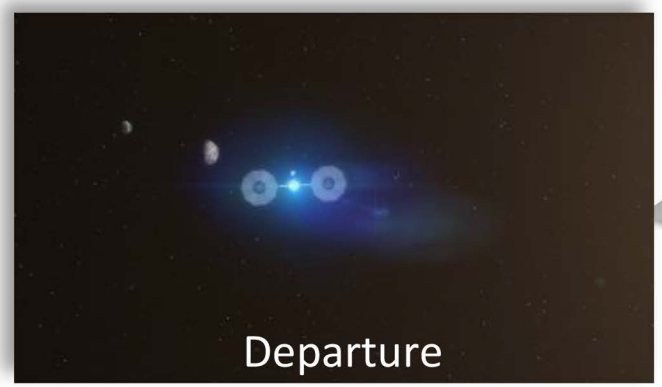
Approach
14 days

Characterization
85 days

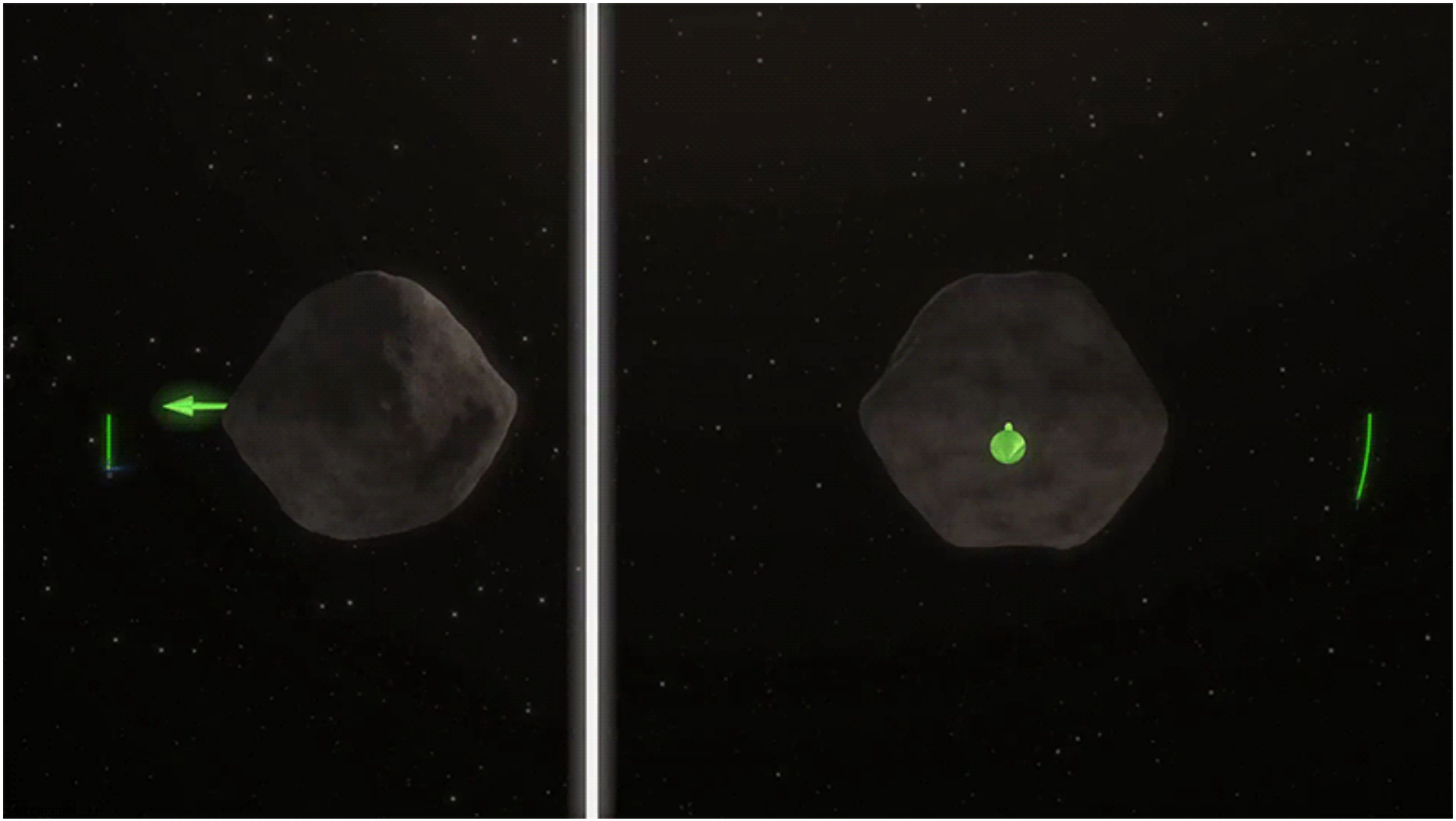
Boulder Collection
60 days + 30 day margin







Demonstration of Basic Asteroid Deflection Technique



Animated version also available here: http://www.nasa.gov/content/asteroid-redirect-mission-images?id=350296

Planetary Defense Coordination Office

Interagency Collaboration

Asteroid Threat Assessment Project (ATAP)

Ames Research Center

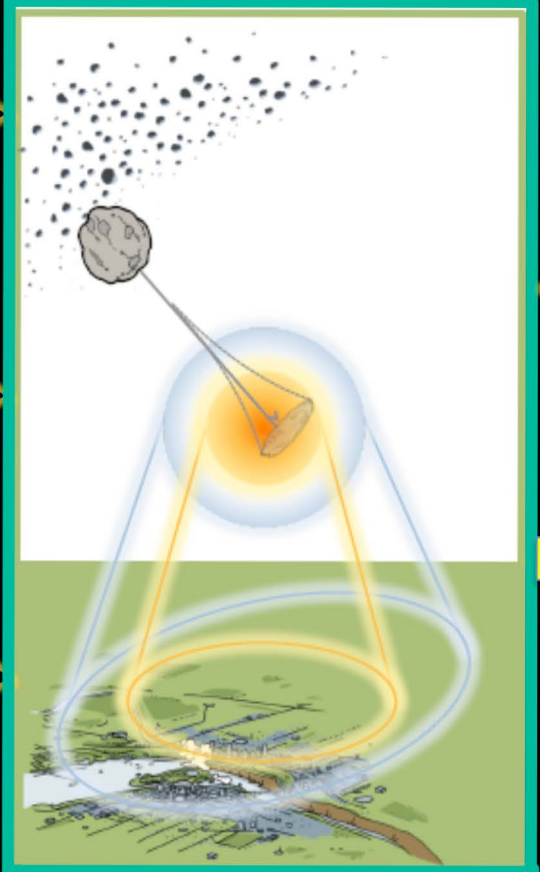
NASA

Characterization
- Physical Properties
- Orbital Trajectories JPL Web

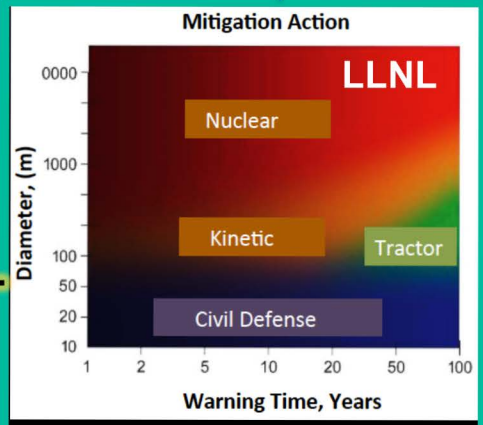
Atmospheric Entry & Airburst Modeling
- Entry Trajectories/Ablation
- Energy Deposition

Surface Impact Effects Modeling
- Ground Damage
- Tsunami Propagation

Physics-Based Impact Risk Modeling
- Quantitative Risk Metrics
- Sensitivity to Uncertainty



Impact Risk Assessment Tools



Deliverables
- Mitigation Decision Tools
- Near Real-Time Bolide Reporting System

US Gov. Surveillance System
- Light Curves: New 600 Plus Existing

Impact Emergency Response Exercise #2

EXERCISE

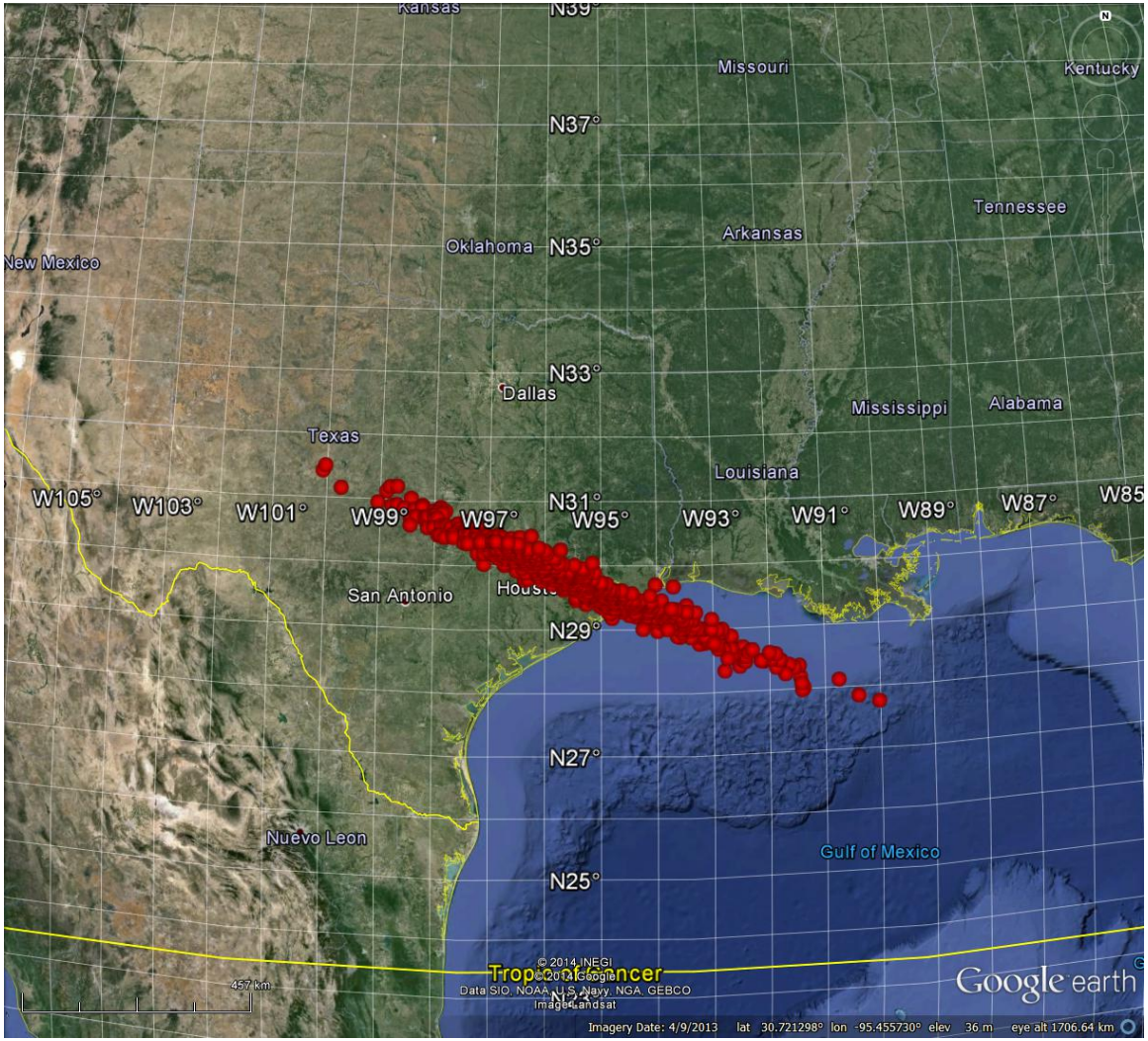
30 Days prior to Impact
Optical only tracking

40 to 60 meter object
Impact Probability 100%

Date/Time (UTC)
2021 Sep 5 17:02

Center Point
Latitude
29.7
Longitude
-95.3

Footprint size
1000 x 50 km
Major axis Azimuth (deg)
130



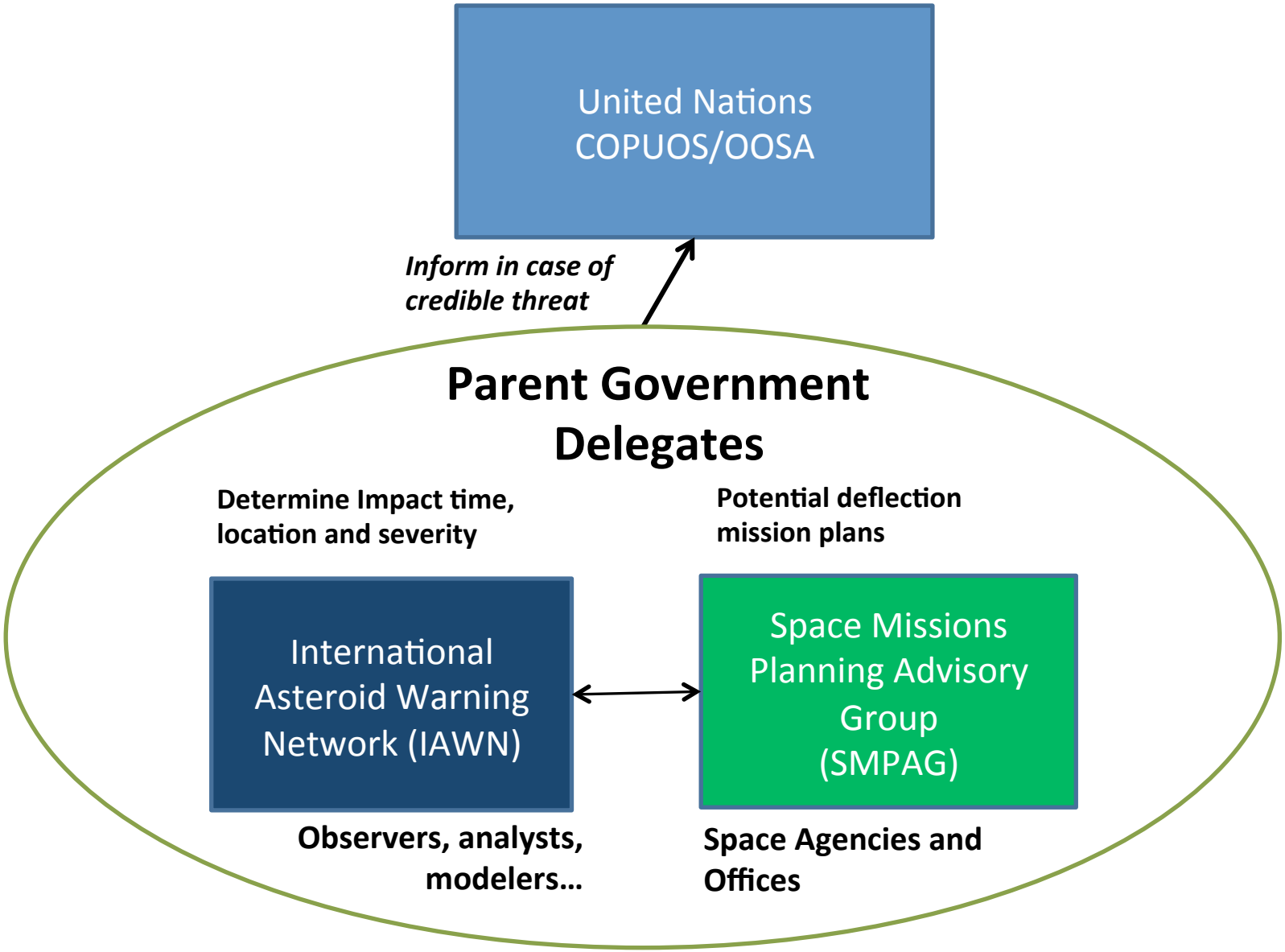
EXERCISE

Planetary Defense Coordination Office

International Collaboration

UN Office of Outer Space Affairs
Committee on Peaceful Uses of Outer Space

Overview for NEO Threat Response



Signatories to IAWN

National Institute of Astrophysics, Optics & Electronics

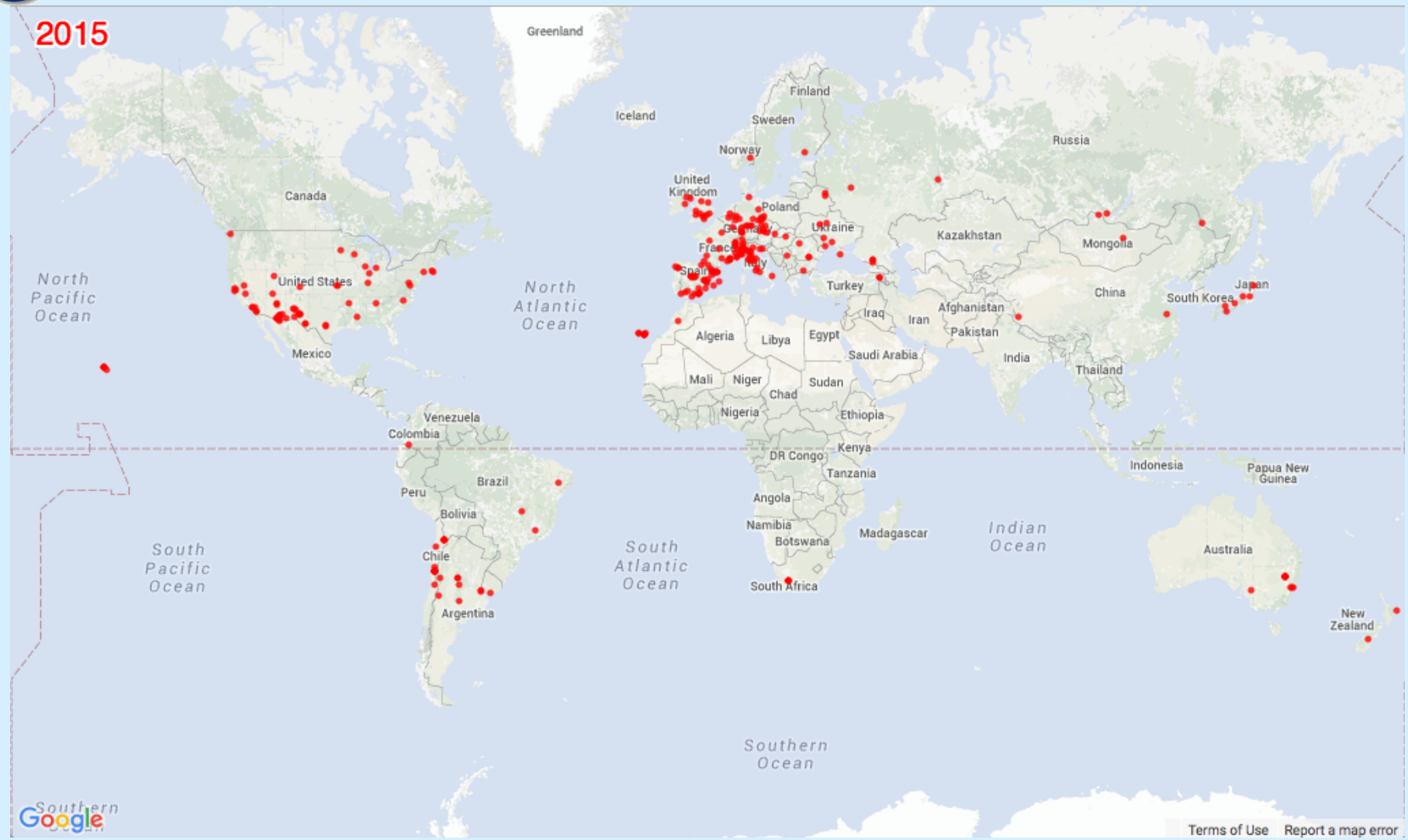
European Southern Observatory (ESO)

Peter Birtwhistle *(amateur follow-up observer, United Kingdom)*

Korean Astronomy Space Science Institute (KASI)

and, NASA

International Asteroid Warning Network



Received ~20.6 Million Observations from 39 countries in 2015
(and one in space!)

Asteroid Impact & Deflection Assessment (AIDA)

- The AIDA is a mission concept to demonstrate asteroid impact hazard mitigation with a kinetic impact spacecraft to deflect an asteroid
- AIDA would be a joint US and European mission:
  - European rendezvous spacecraft, the Asteroid Impact Monitor (AIM) mission
  - US kinetic impactor, the Double Asteroid Redirection Test (DART) mission
- NASA has agreed with ESA to enter parallel formulation concept studies in 2016
- The AIDA mission would intercept the secondary member of the binary Near-Earth Asteroid Didymos in October, 2022

AIDA = AIM+DART

AIDA