NASA
Near-Earth Object Observations (NEOO) Program

Lindley Johnson
Near Earth Object Program Executive
Planetary Defense Coordination Office
NASA HQ

October 5, 2015

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 Spaceguard Survey effort

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:

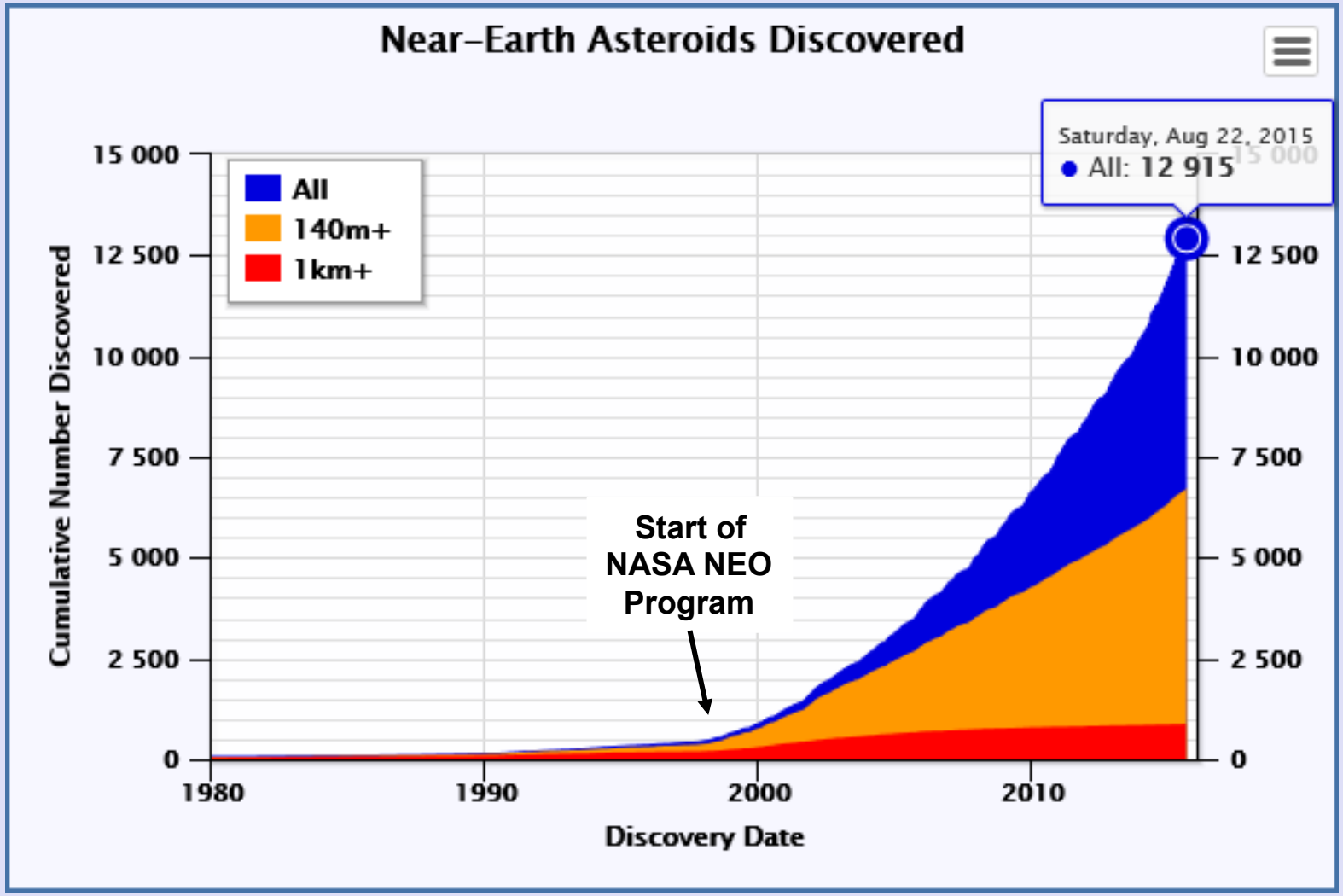
- Amended National Aeronautics and Space Act of 1958 ("NASA Charter") to add:

  ''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.''

- Makes NEO detection, tracking and research 1 of 7 major purposes stated for 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 09/25/15 13,035

Also 104 comets

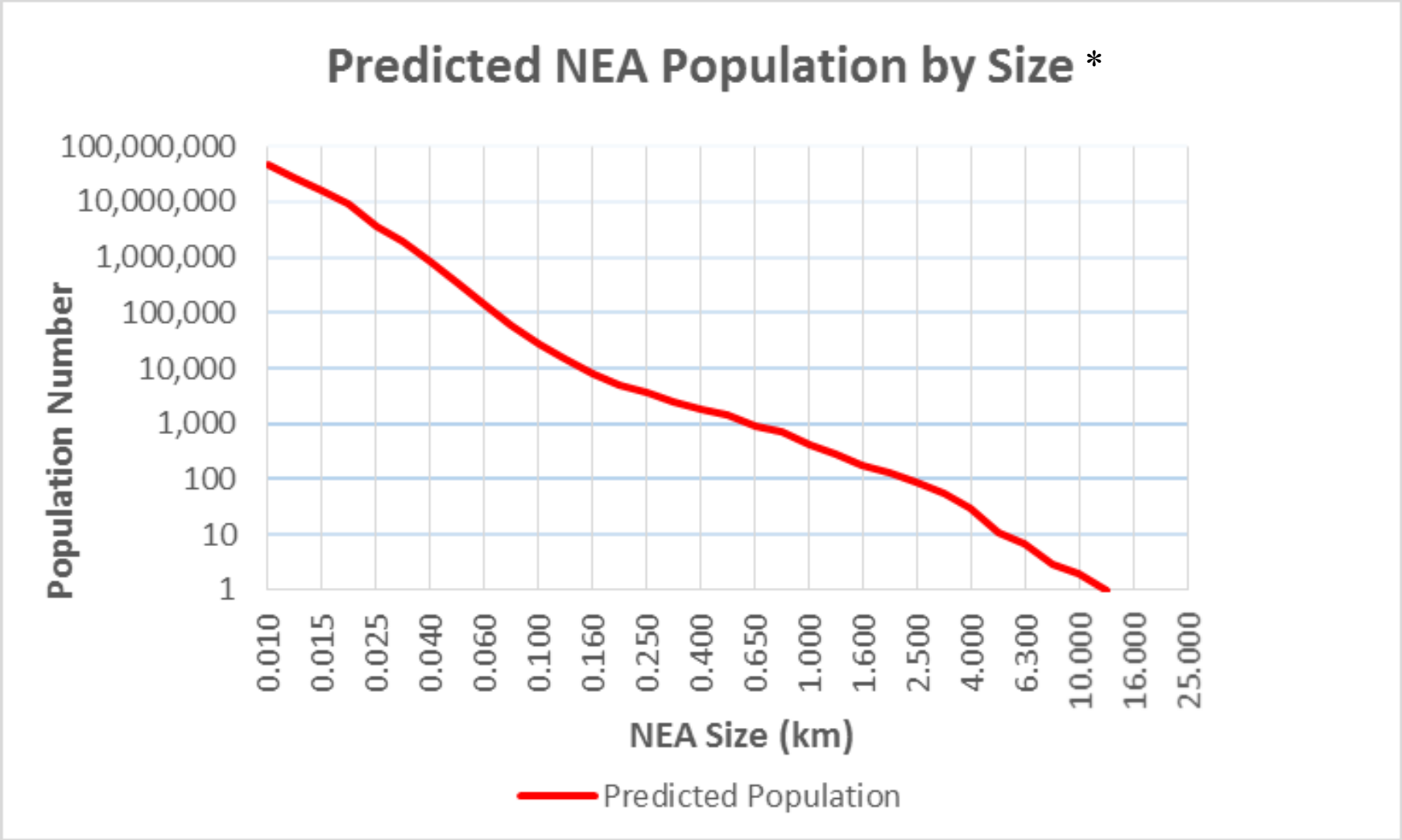
1623 Potentially Hazardous Asteroids

Come within 5 million miles of Earth orbit

876

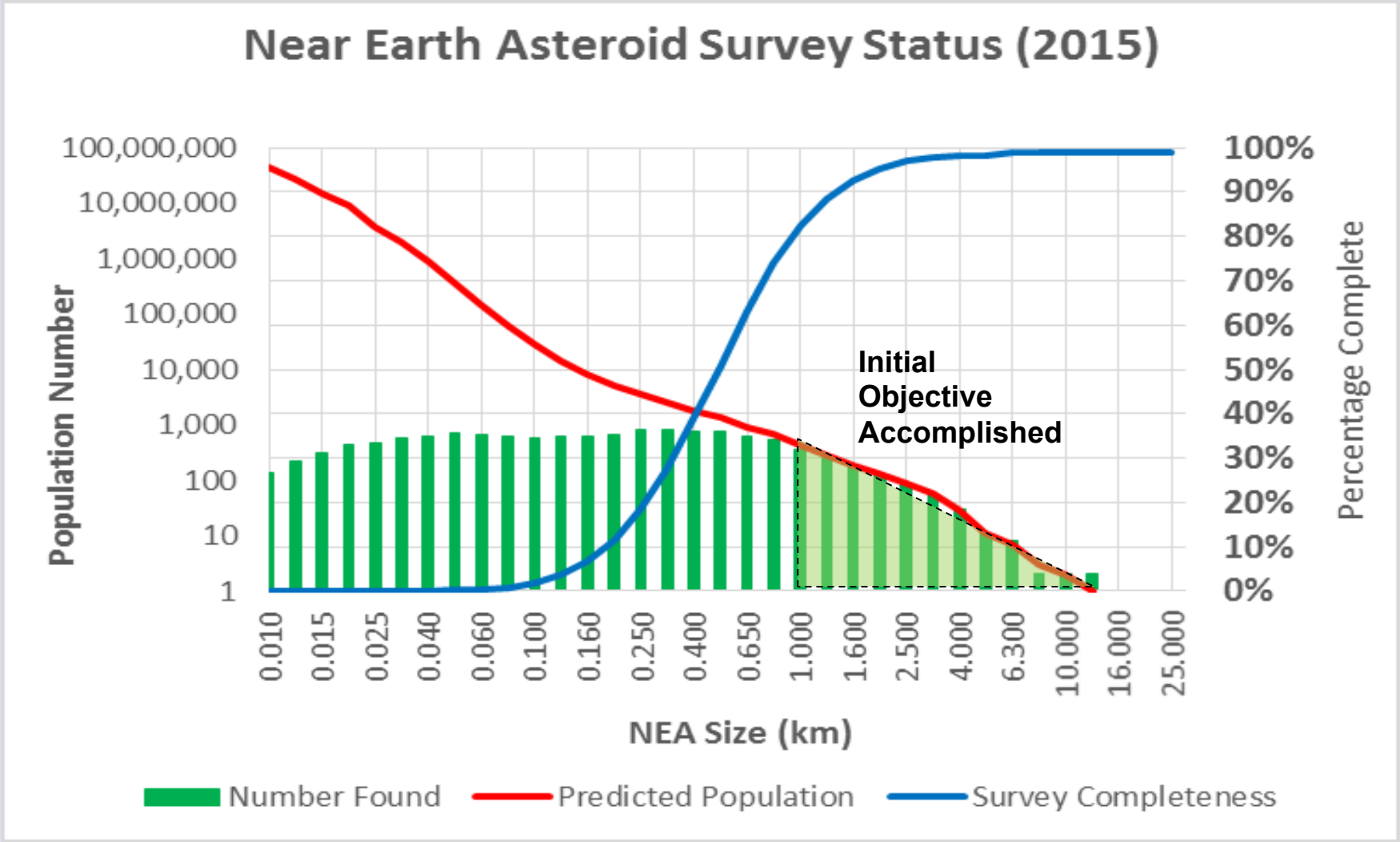
154 PHAs

Near Earth Asteroid Survey Status

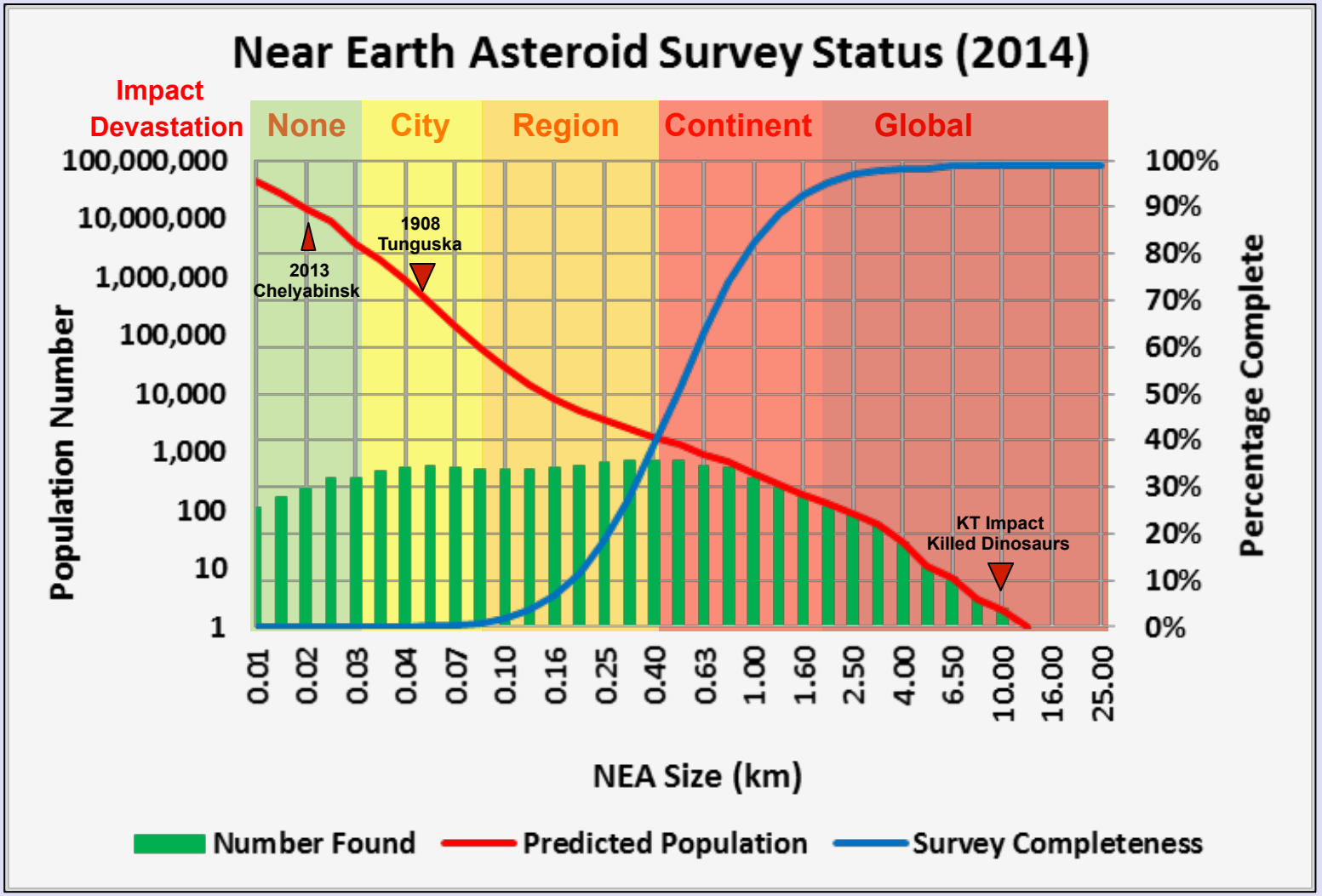


*Harris & D'Abramo, "The population of near-Earth asteroids", Icarus 257 (2015) 302–312, http://dx.doi.org/10.1016/j.icarus.2015.05.004

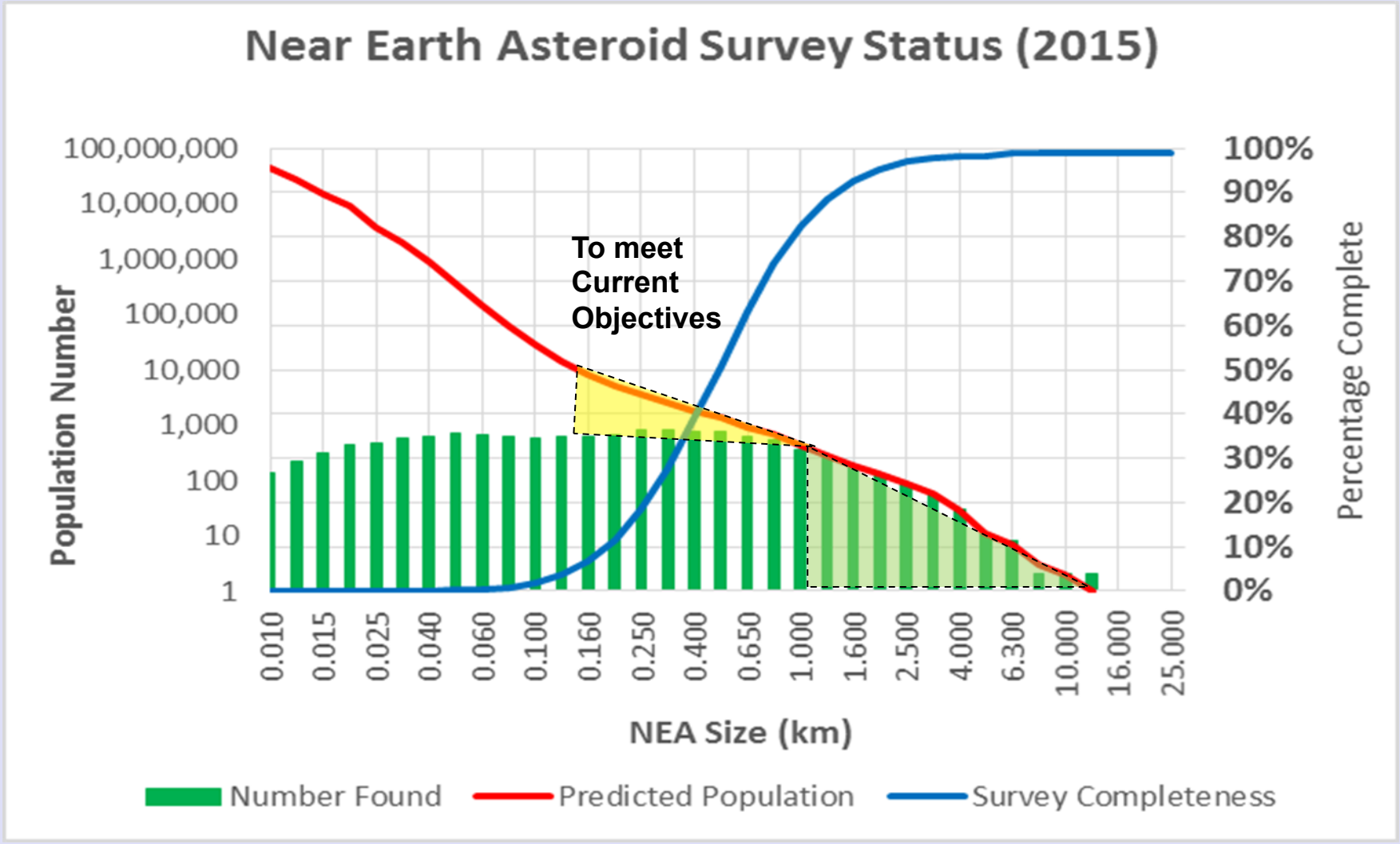
Near Earth Asteroid Survey Status



Near Earth Asteroid Survey Status

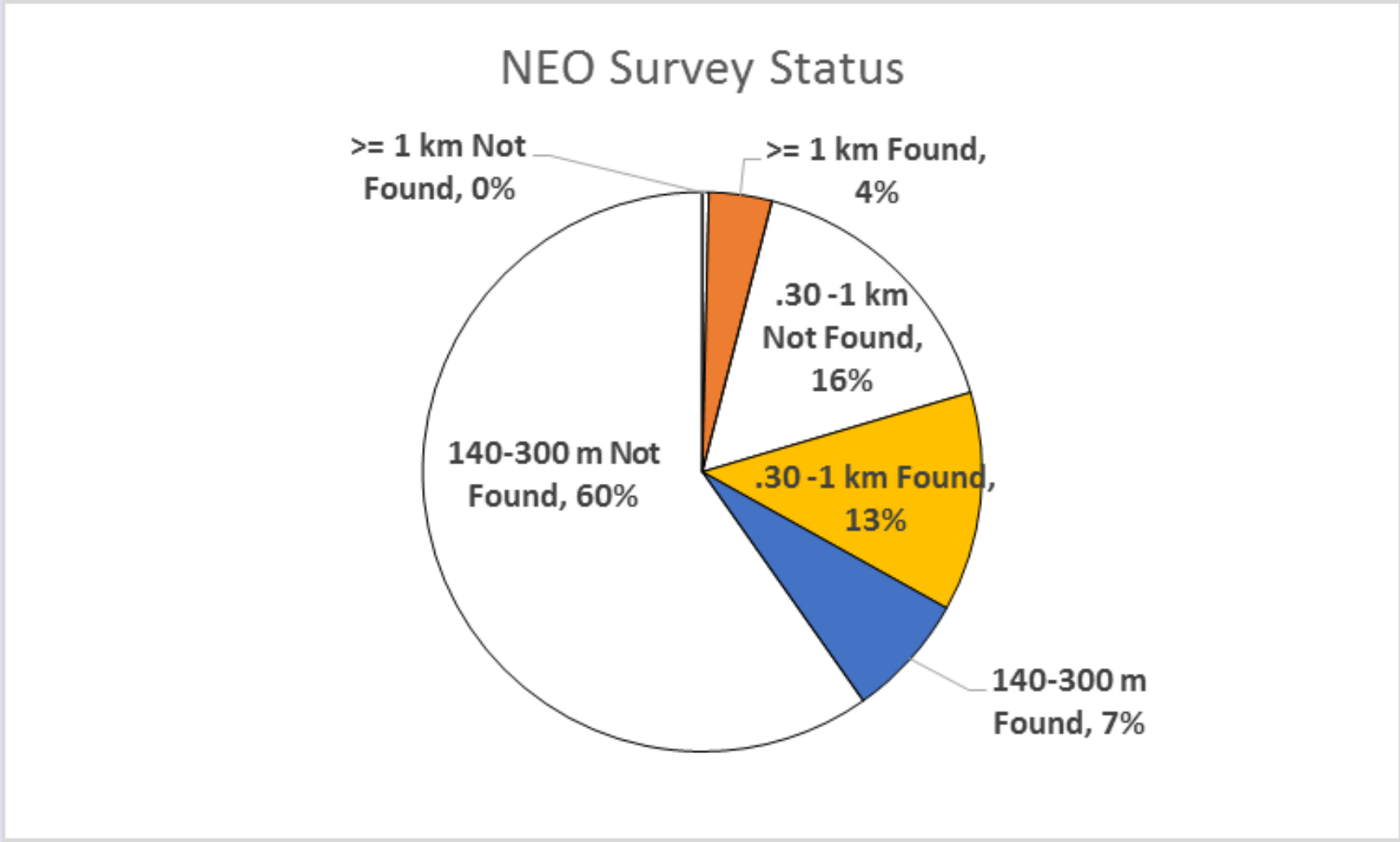


Near Earth Asteroid Survey Status



Near Earth Asteroid Survey Status Alternative Graphic

Population >= 140 meters in estimated size = 100%



NASA's NEO Search Program

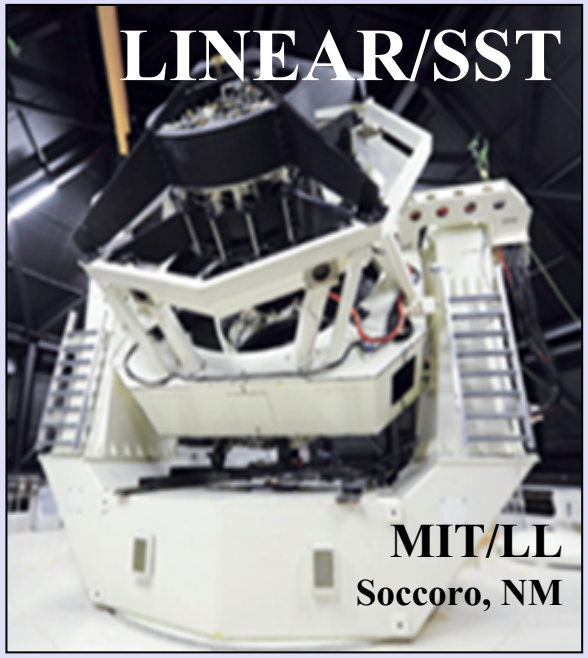
(Current Survey Systems)

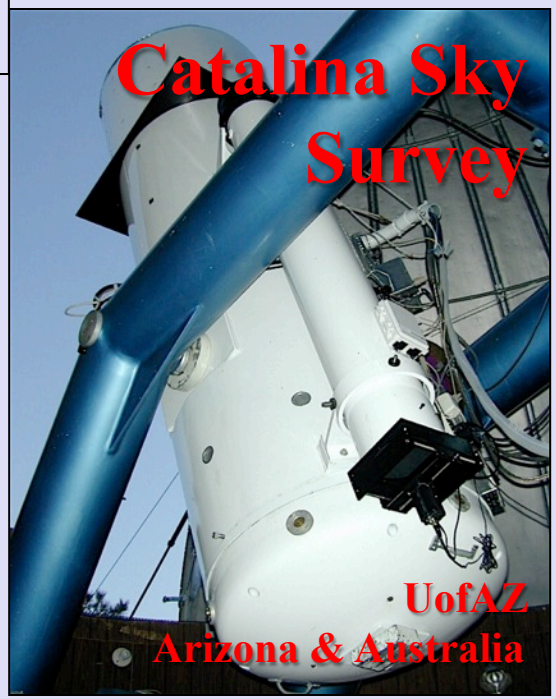
Minor Planet Center (MPC)
- IAU sanctioned
- Int'l observation database
- Initial orbit determination

http://minorplanetcenter.net/

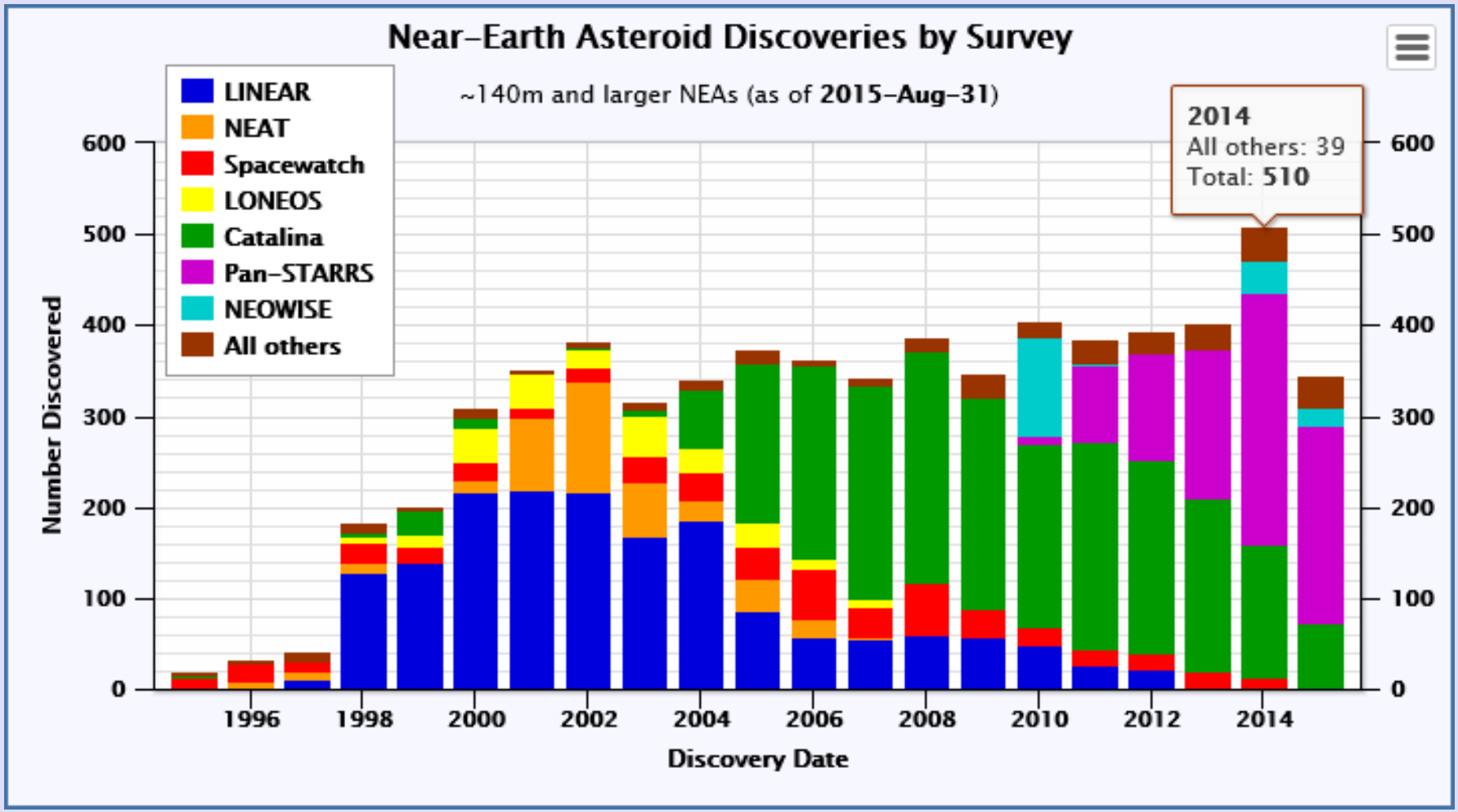
Center for NEO Studies @ JPL
- Program coordination
- Precision orbit determination
- Automated SENTRY

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





Discovery of ≥140 meter Asteroids



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

Physical Characterization of NEAs

- **Radar** is essential for obtaining an accurate estimate of size and shape to within ~2 m, as well as rotation state.
- Ground-based and space-based **IR** measurements are important for estimating albedo and spectral class, and from these an approximate density can be inferred.
- **Light curves** are important to estimate shape and rotation state.
- **Long-arc high-precision astrometry** is important for determining the area-to-mass ratio.
- Mass is estimated from size and shape using an inferred or assumed density, and it should be constrained by the estimate of the area-to-mass ratio. Even so, mass may only be known to within a factor of 3 or 4.
- Composition can only be roughly assessed via analogy to spectral class.

Assumed albedo
ρ = 0.04

Assumed albedo
ρ = 0.34

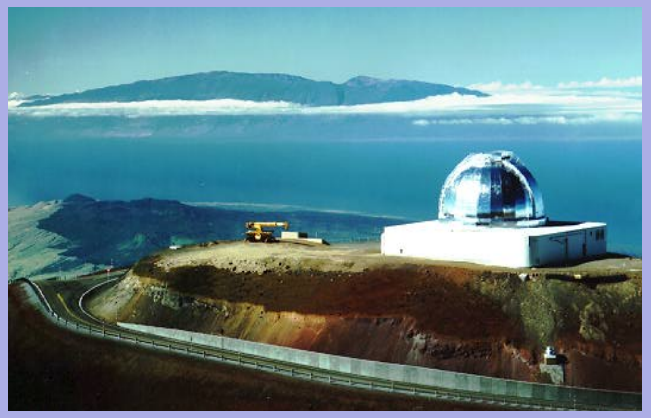
Primary NEO Characterization Assets and Enhancements

Radar (Goldstone and Arecibo)

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


Goldstone Radar


Arecibo Observatory



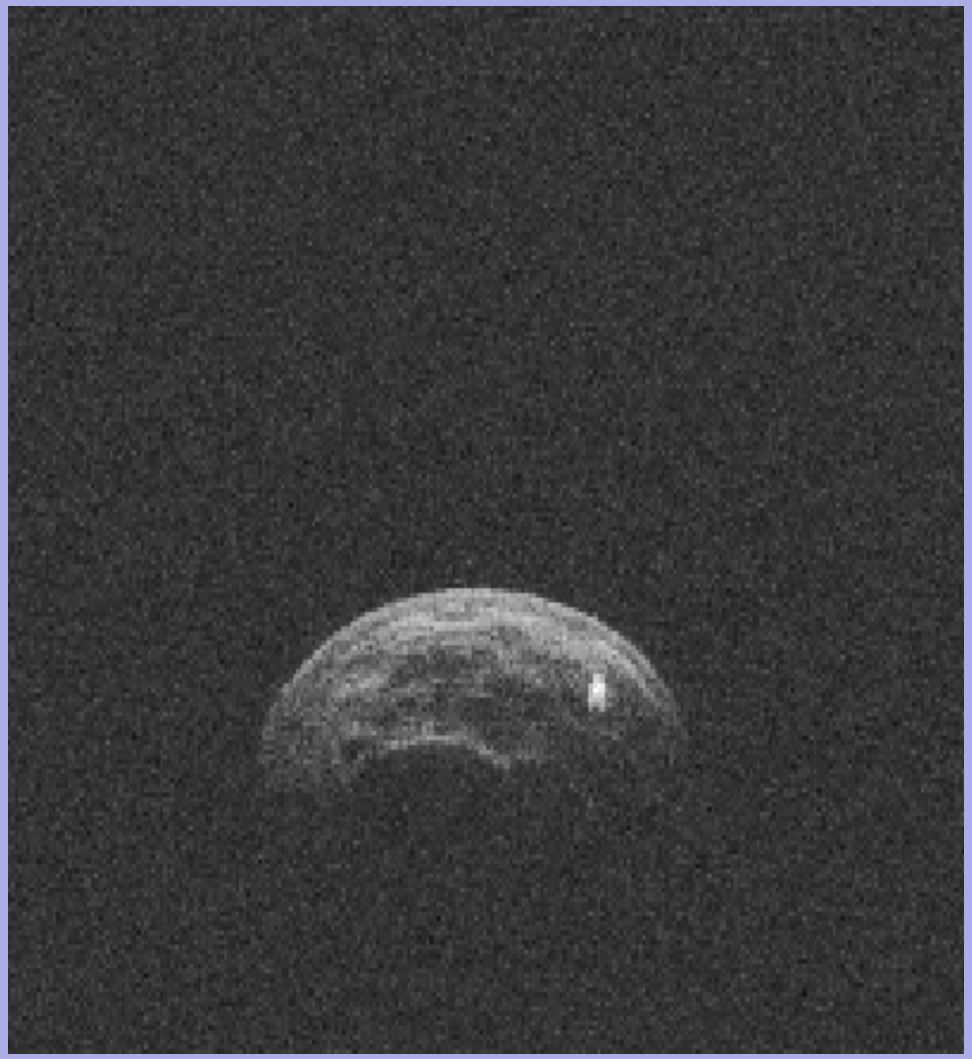
NASA InfraRed Telescope Facility (IRTF)

- 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

Radar Images of Asteroid 2004 BL86, Jan. 26, 2015



- Earth close approach of about 3.1 lunar distances
- The asteroid has a moon!
- Main Asteroid is about 330 meters across; satellite is about 70 meters across (it's small and blurry size in the image is an artifact of the processing)
- Radar pulses were transmitted from Goldstone, received at Greenbank
- Resolution is ~4 meters

High Resolution Radar Imagery of Venus

Planetary radar has been often been utilized to obtain radar images of the Moon, Mercury, Venus and innumerable near-Earth asteroids. Maxwell Montes was the first significant 'radar bright' feature first observed in 1967 by Arecibo. Located on the Ishtar Terra highlands, this mountain rises ~11 kilometers above the surrounding plains.

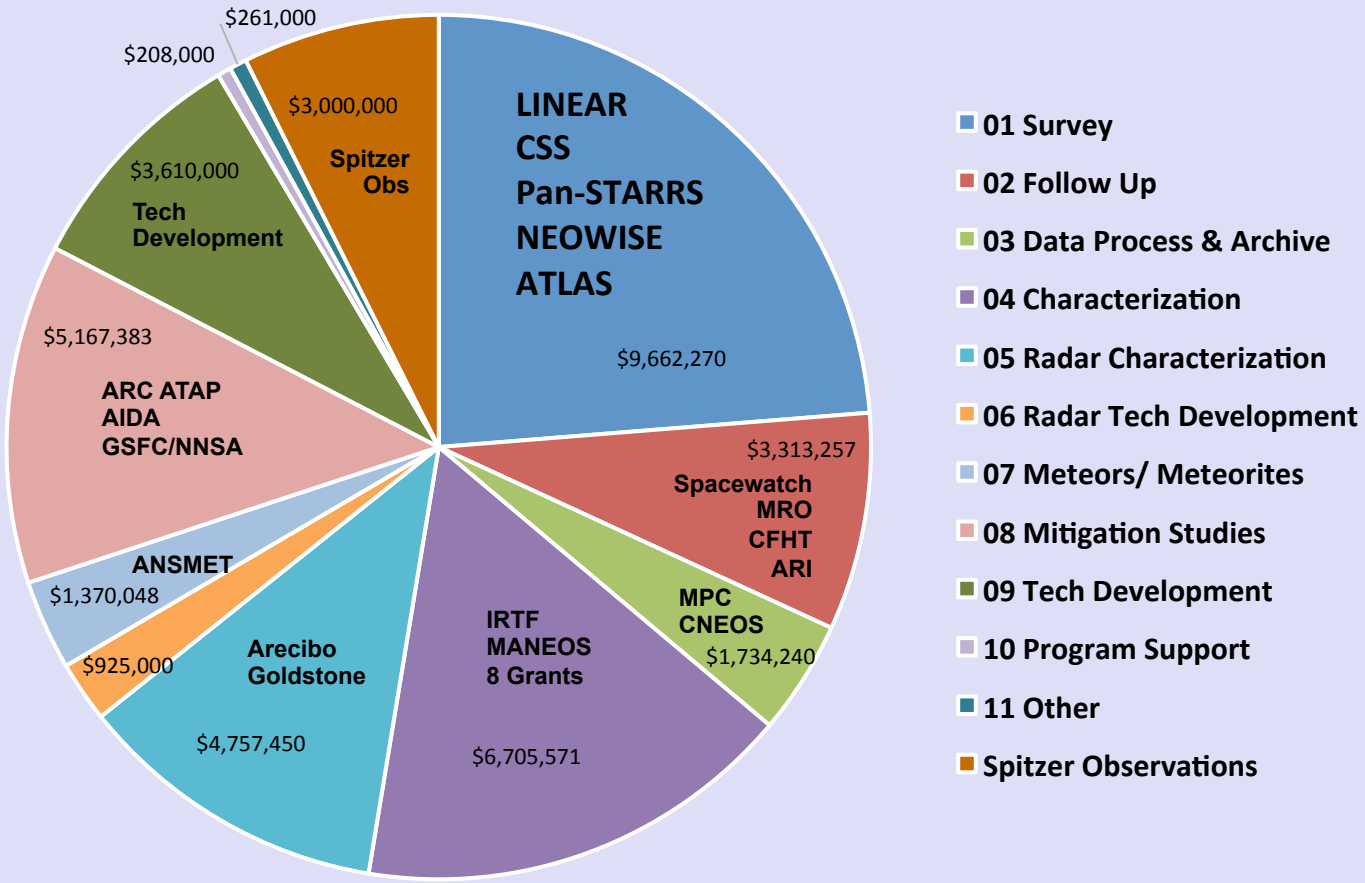
300 m radio observatory, Arecibo, PR

On 12 August 2015, just three days prior to Venus' inferior conjunction [and closest point to the Earth, ~41 million km] scientists used the planetary radar of the Arecibo Observatory to take this radar image of the northern hemisphere of Venus. At such close approaches, the achievable imaging resolution is ~1 km. This direct radar mapping can be used to look for changes that might indicate new lava flows.

Maxwell Montes

Campbell et al., Smithsonian Institution

NEO Program FY2015 ($40M)



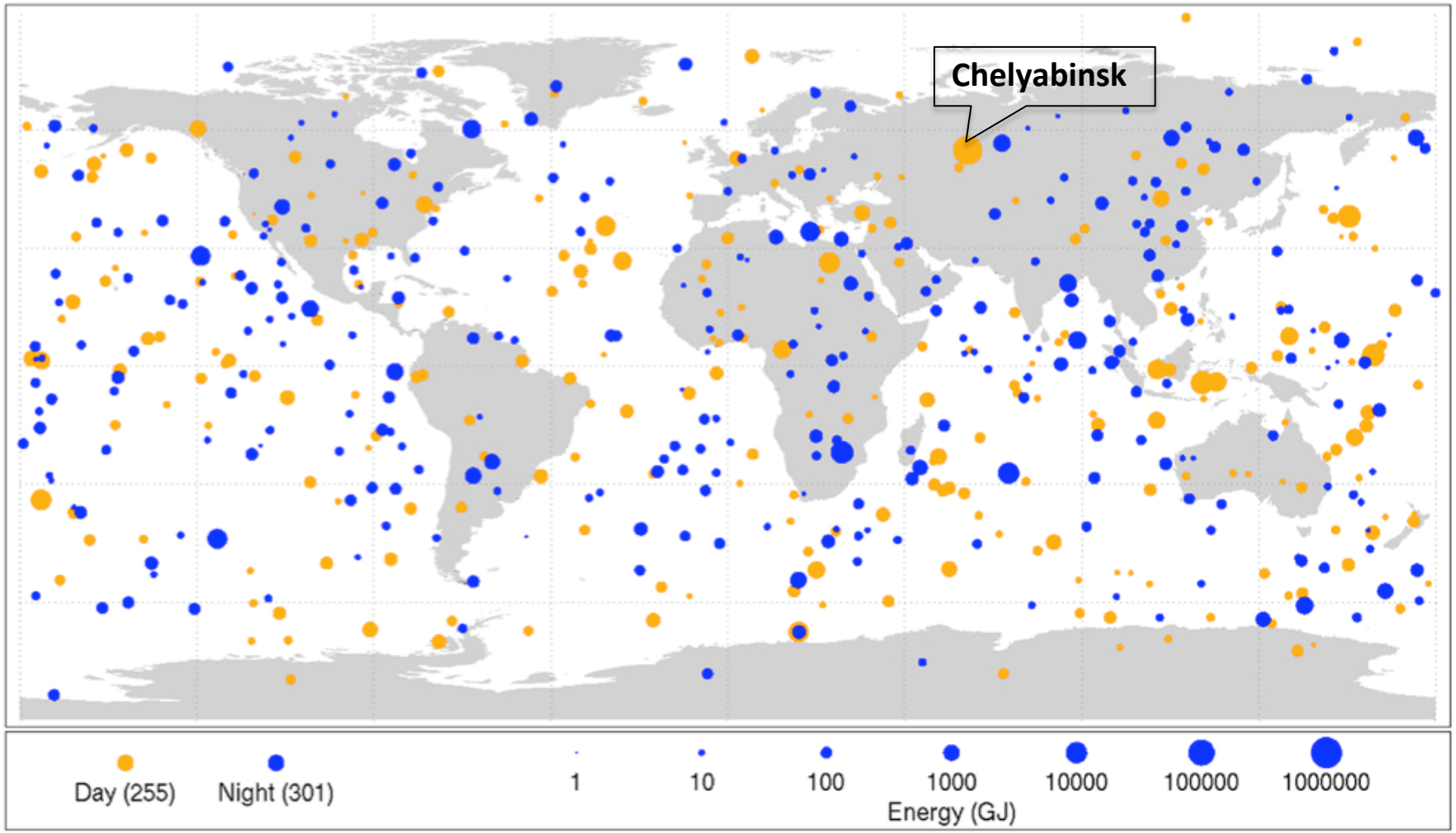
Bolides or “Fireballs”

- Natural objects entering Earth’s atmosphere
  - Large meteoroids = small asteroids
  - Larger than 1 meter in size
- Entry velocity much higher than re-entering space debris
- Characteristic ionization trail and detonation
- Chelyabinsk Event largest and most documented in recent decades

February 15, 2013
1613 citizens injured
~$30 million damages

Bolide Events 1994 – 2013

Small Asteroids that Disintegrated in Earth's Atmosphere



This diagram maps the data gathered from 1994-2013 on small asteroids impacting Earth's atmosphere and disintegrating to create very bright meteors, technically called "bolides" and commonly referred to as "fireballs". Sizes of orange dots (daytime impacts) and blue dots (nighttime impacts) are proportional to the optical radiated energy of impacts measured in billions of Joules (GJ) of energy, and show the location of impacts from objects about 1 meter (3 feet) to almost 20 meters (60 feet) in size.

Value of Bolide Data

- Current US systems can quickly differentiate between an asteroid impact and a nuclear event
  - An asteroid impact has very similar but distinct characteristics with knowledgeable analysis compared to a nuclear detonation
  - In a crisis situation, the mis-typing of an asteroid impact as a nuclear event could have destabilizing consequences
- This information is also useful to emergency responders
  - "Near real-time" assessment of an impact could rapidly inform civil emergency response services
  - Tracking a larger asteroid into an ocean or coastal area may enable a timely tsunami warning to be issued
- Also useful to scientists:
  - Improve asteroid population models, infer characteristics of the object
    - Original justification for existing NASA-AFSPC MOA
  - Rapid recovery of pristine meteorites for analysis – "free sample return"
  - Input to impact effects & threat models

"NEO Research Organization"