Planetary Defense Coordination Office (PDCO)

Lindley Johnson

Program Executive / Planetary Defense Officer

Science Mission Directorate

NASA HQ

May 20, 2016

Planetary Defense Coordination Office

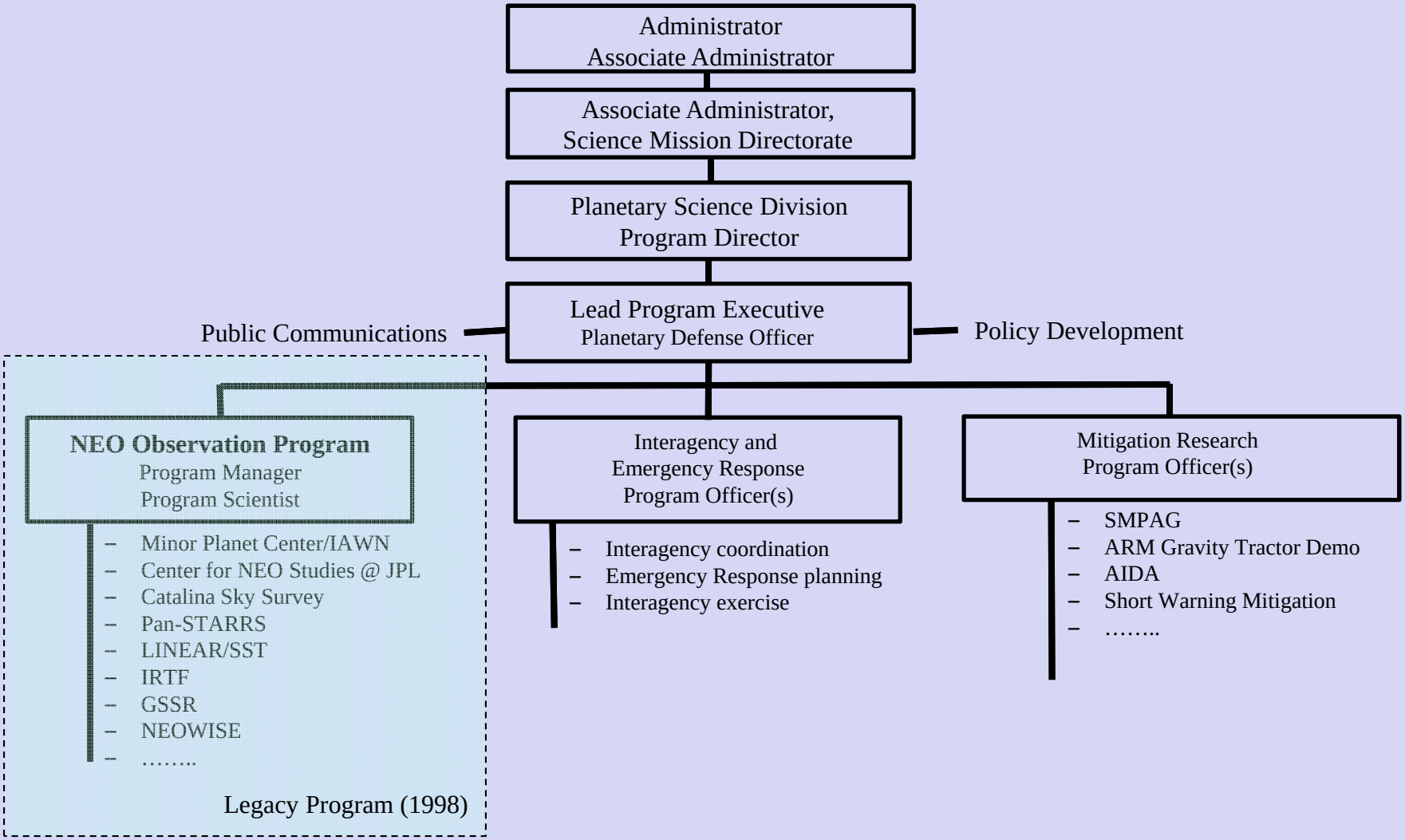
This new office was recently established at NASA HQ to coordinate planetary defense related activities across NASA, and coordinate both US interagency and international efforts and projects to address and plan response to the asteroid impact hazard.

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 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

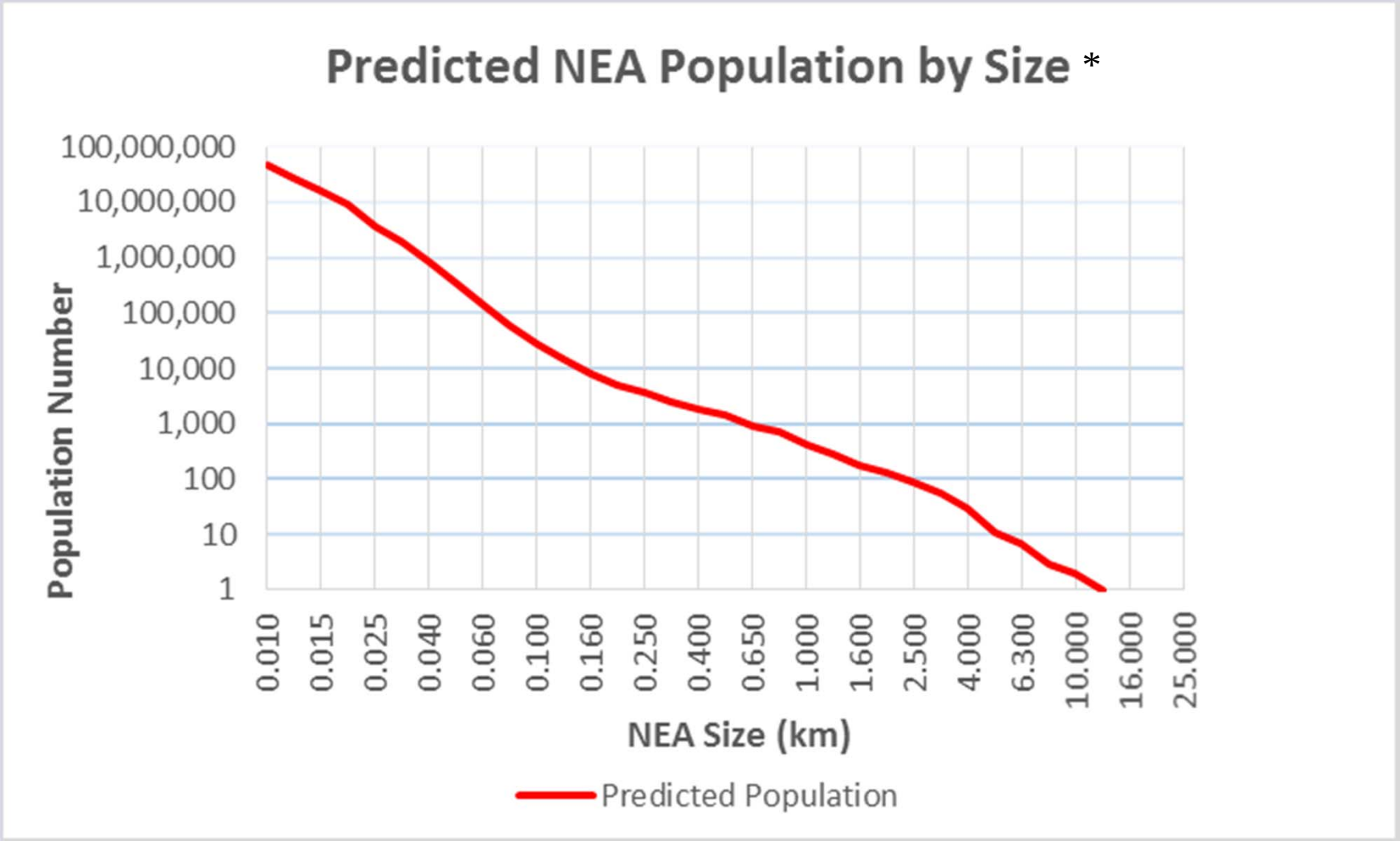
NASA Authorization Act of 2005 increased scope of objectives:

- 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:

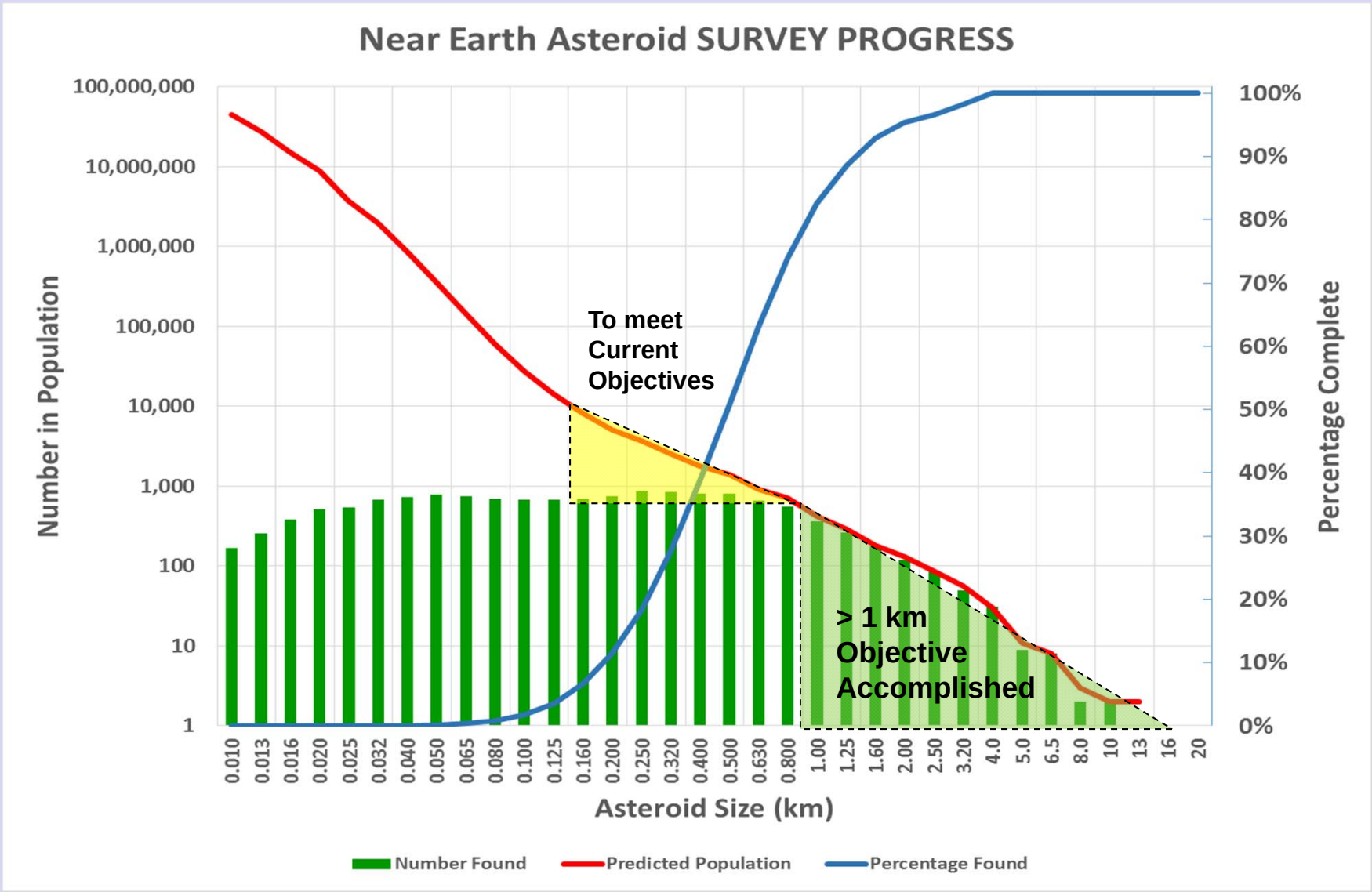
  "…plan, develop, and implement a Near-Earth Object Survey program to detect, track, catalogue, and characterize the physical characteristics of near-Earth objects equal to or greater than 140 meters in diameter in order to assess the threat of such near-Earth objects to the Earth. It shall be the goal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

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



NASA's NEO Search Program

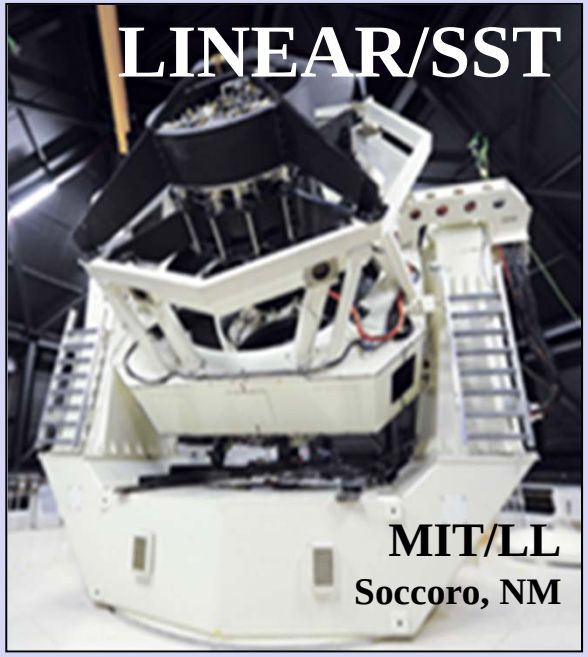
(Current Survey Systems)

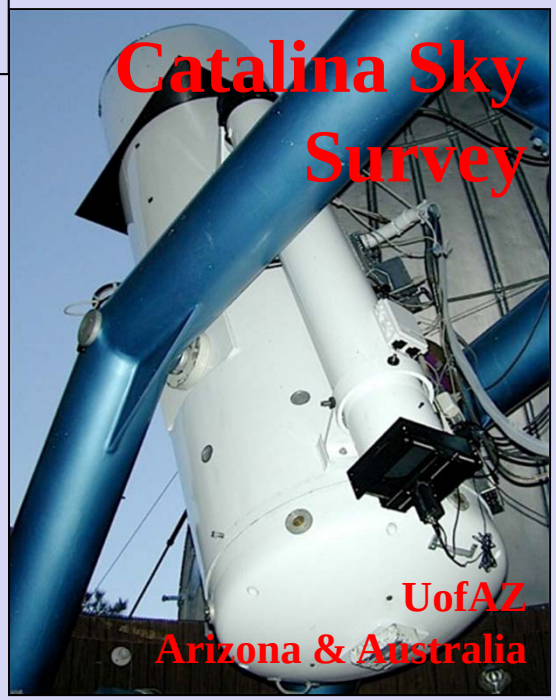
Minor Planet Center (MPC)
- IAU sanctioned
- Int'l observation database
- Initial orbit determination

http://minorplanetcenter.net/

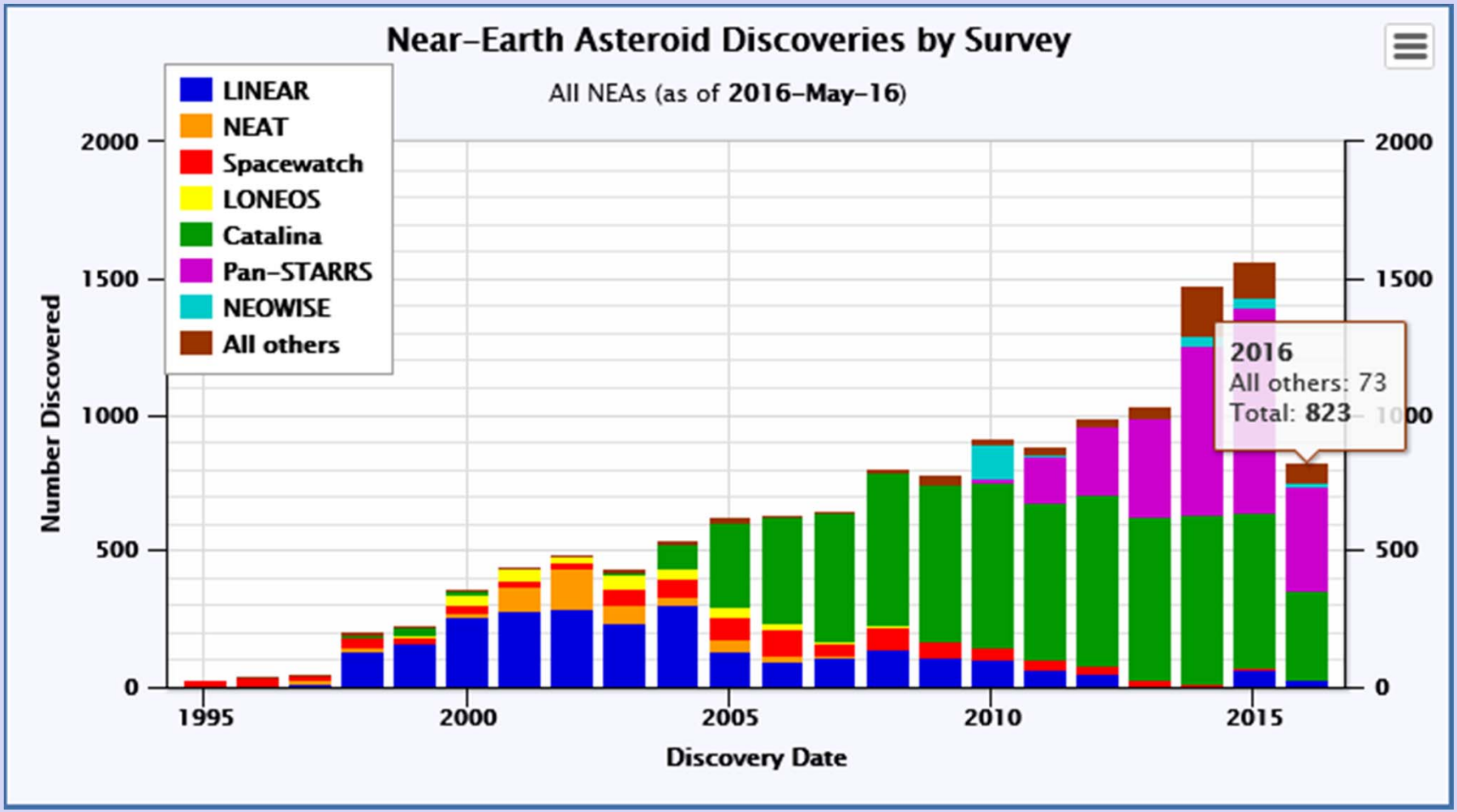
Center for NEO Studies @ JPL
- Program coordination
- Precision orbit determination
- Automated SENTRY

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



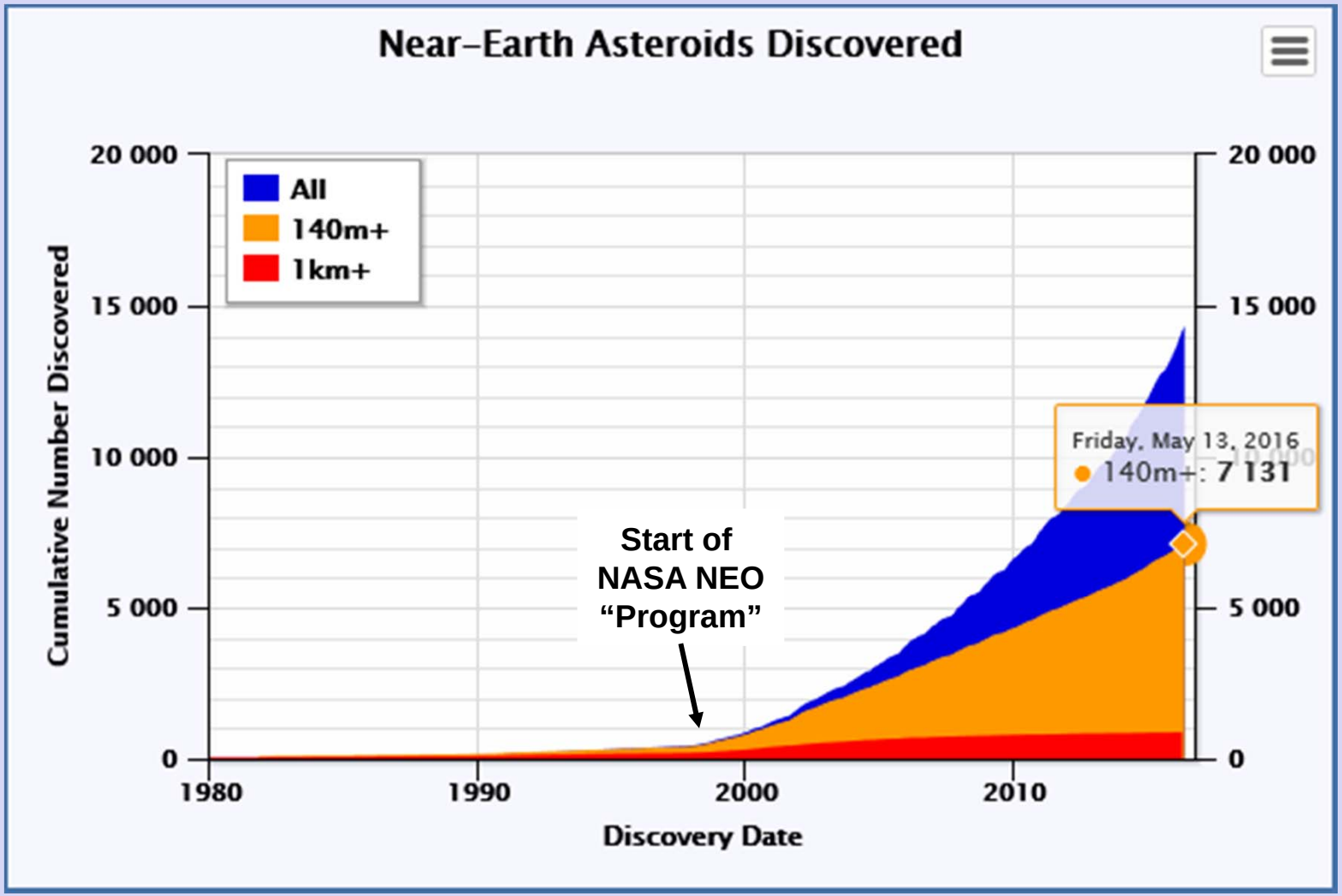


Growth in Capability



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

Known Near Earth Asteroid Population



As of 5/13/2016 14,340

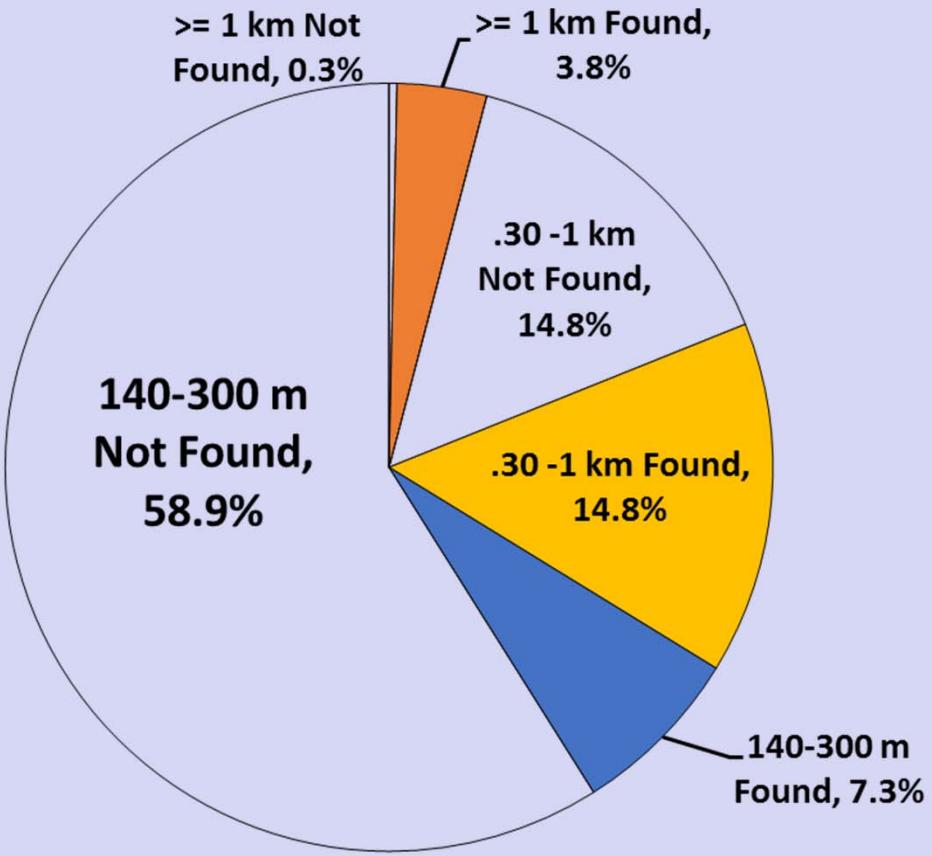
Also 106 comets

1698 Potentially Hazardous Asteroids
Come within 5 million miles of Earth's orbit

875
157 PHAs

Near Earth Asteroid Survey Status

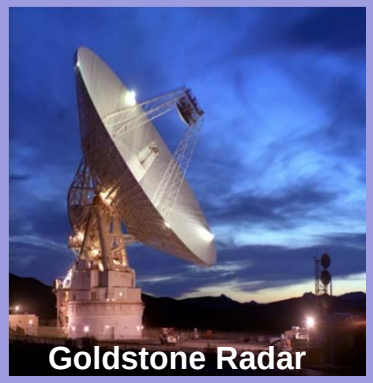
If Population >= 140 meters in estimated size is ~ 25,500 = 100%



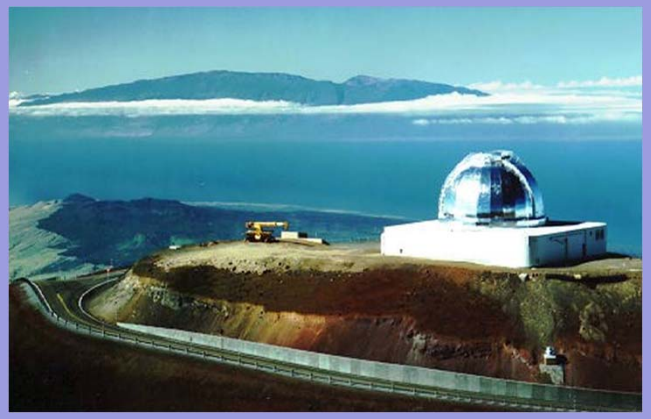
Primary NEO Characterization Assets and Enhancements

Radar (Goldstone and Arecibo)

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


Goldstone Radar


Arecibo Observatory

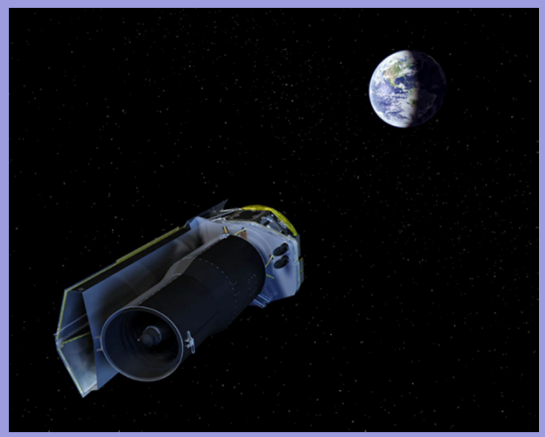


NASA InfraRed Telescope Facility (IRTF)

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

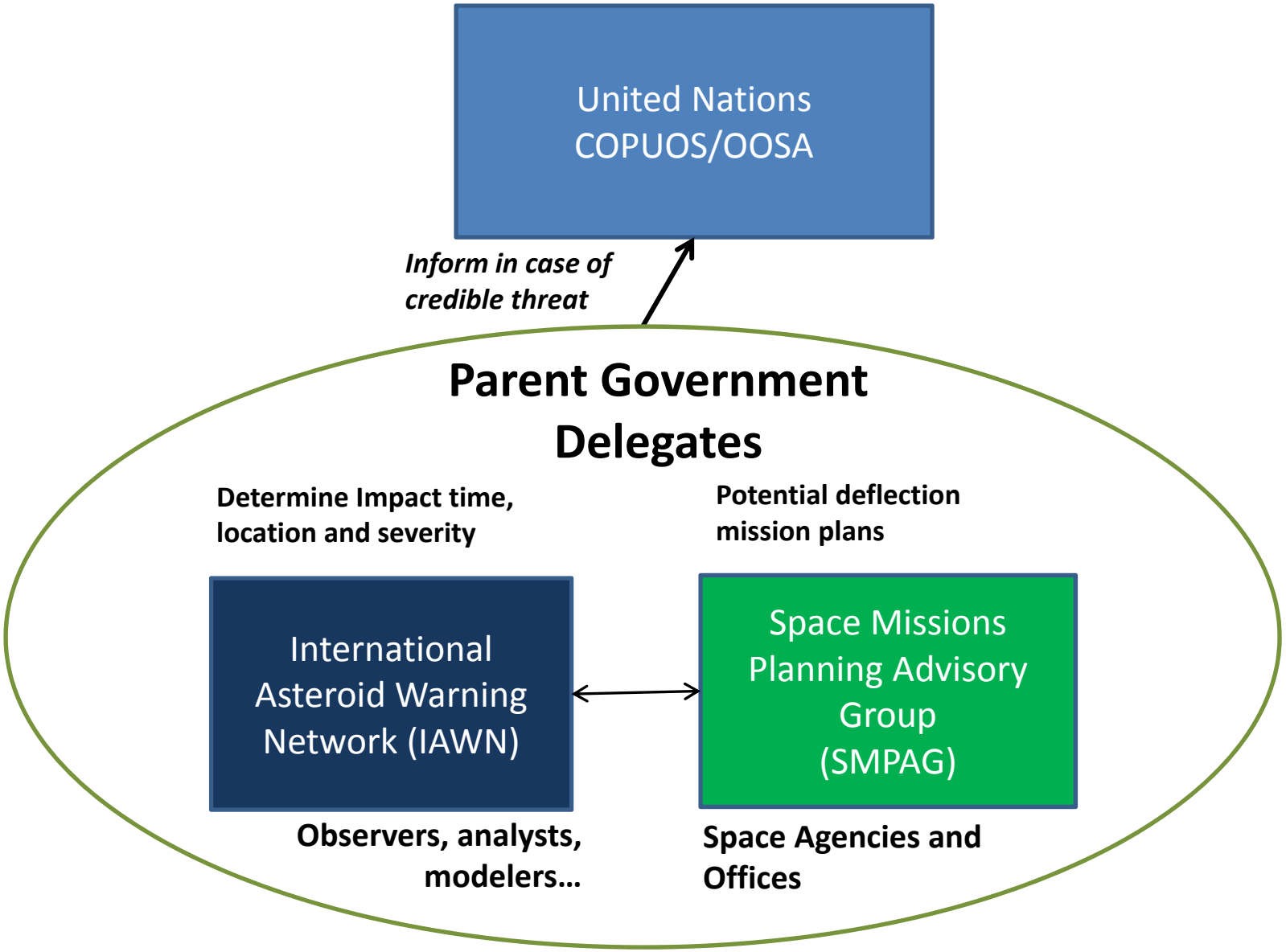
Spitzer Infrared Space Telescope

- 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

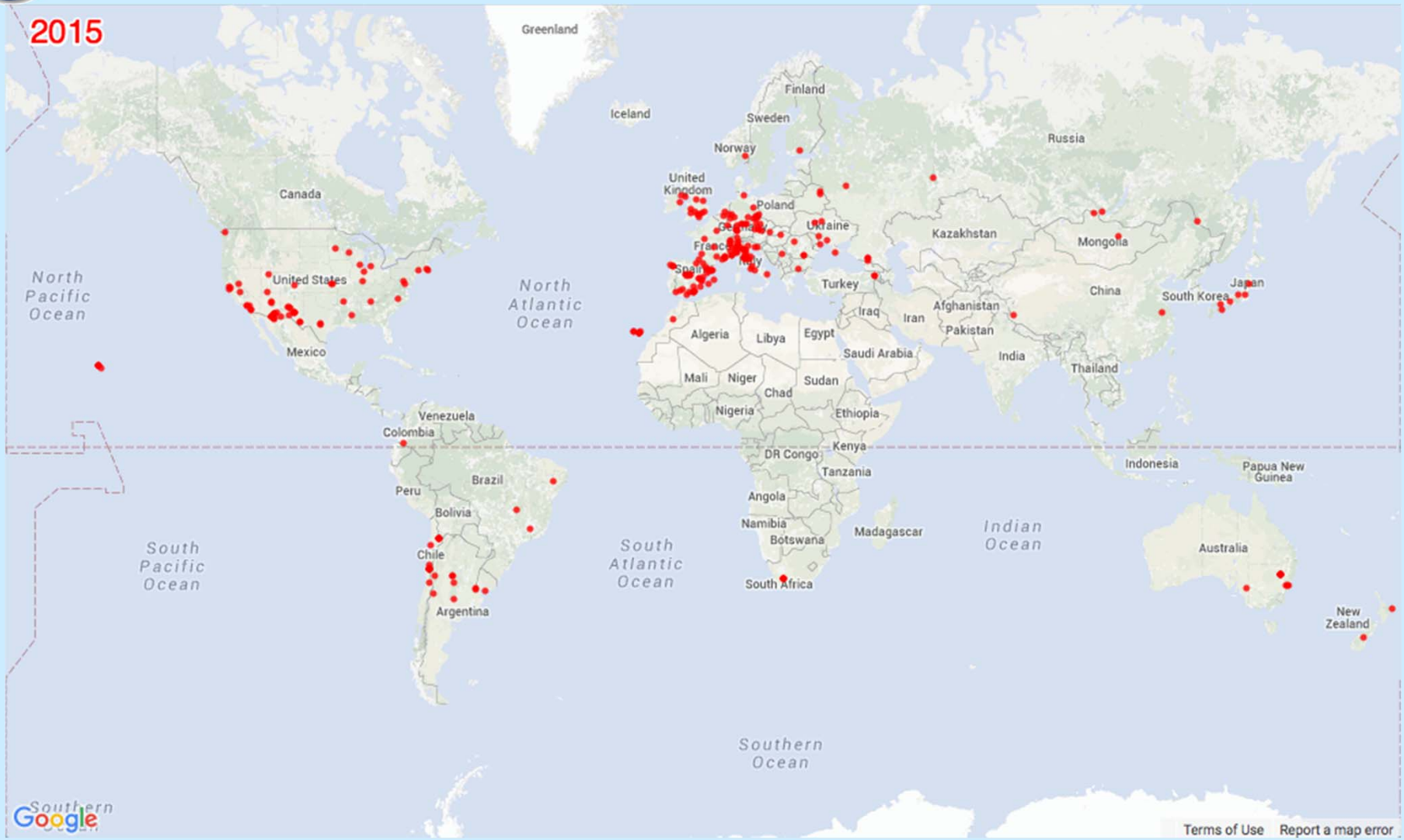


UN Office of Outer Space Affairs
Committee on Peaceful Uses of Outer Space

Overview for NEO Threat Response



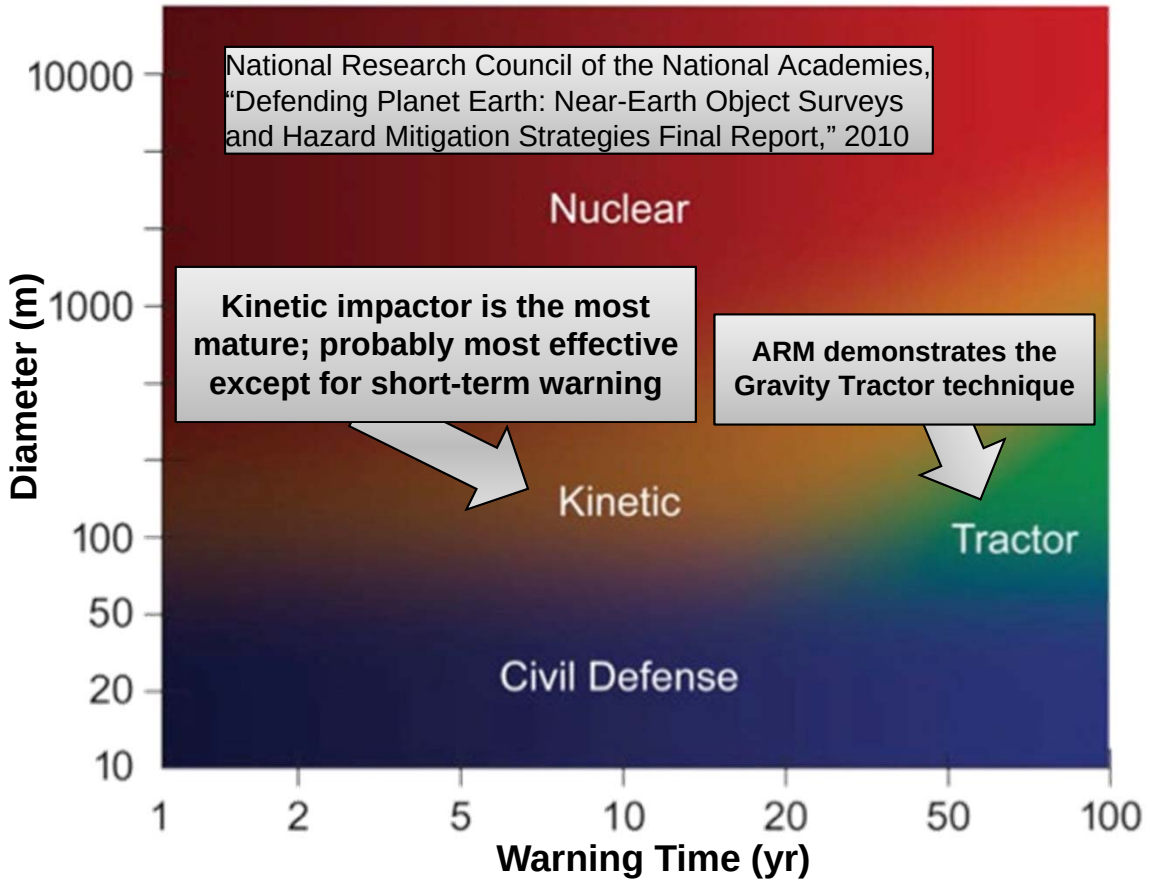
International Asteroid Warning Network



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

Options for In-space Deflection

- Multiple studies of impact threat deflection have cited three techniques as most viable: Kinetic Impactor, Gravity Tractor, Nuclear Explosive Device
- Making planetary defense credible requires a series of technology demonstrations and operational tests
  - **All techniques require some level of demonstration and validation before considered viable for implementation in impact emergency response**
  - **Requires ongoing program to reduce risks, validate performance models, prove out an integrated capability, and maintain readiness for potential operators and decision-makers**
- International participation in any asteroid mitigation / deflection campaign is highly desirable if not essential to overall acceptability



Short Warning NEO Mitigation Studies

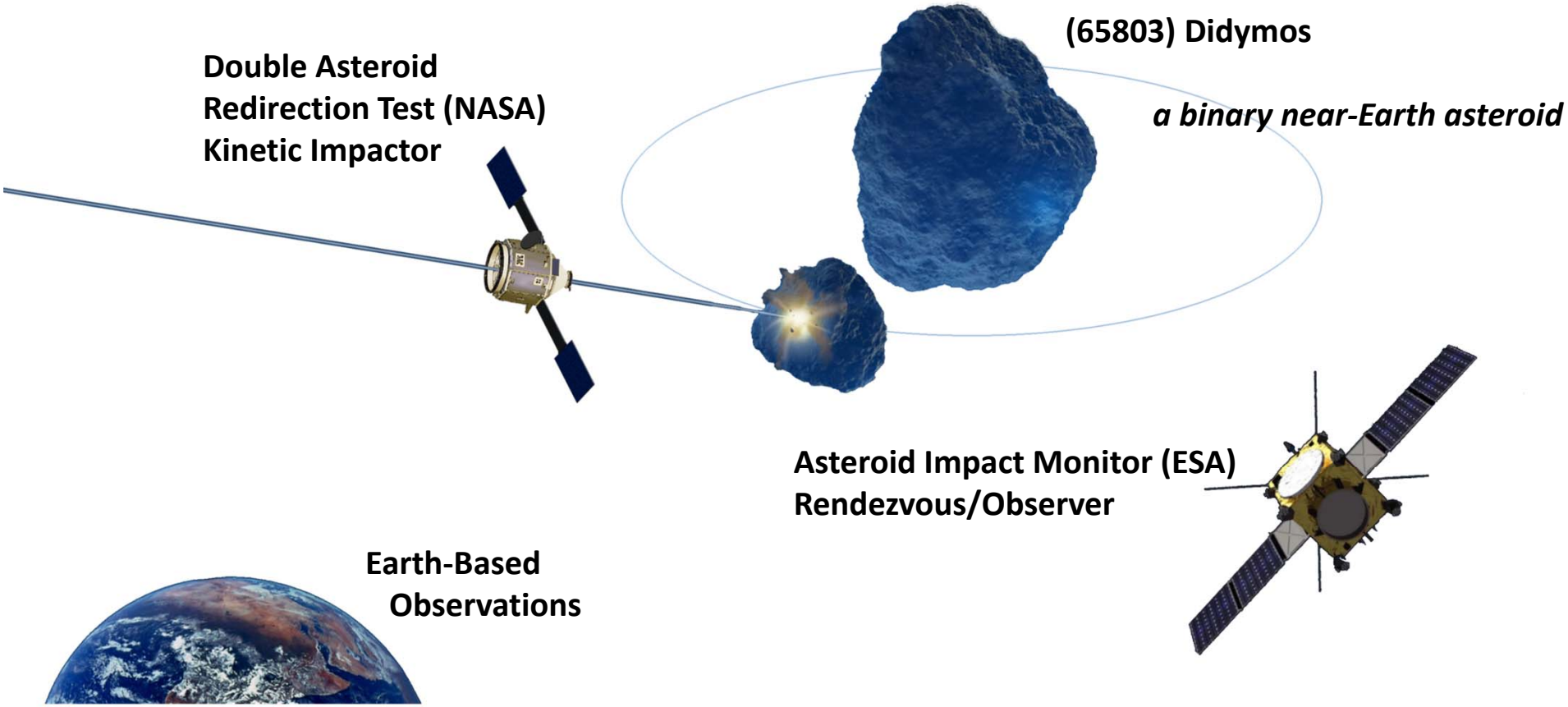
Joint NASA - DOE/NNSA Team
GSFC -Livermore-Los Alamos-Sandia
Objectives

- Investigate mitigation approaches for the class of potentially hazardous asteroids in the short time response scenario
- Impulse energies increase as time to impact lessens, so we computationally explore high energy momentum delivery approaches to deflection or disruption of the NEA threat
- Employ a full-system scenario analysis methodology for addressing the end-to-end mitigation mission design
- Parse the research into a series of case studies based on various design reference asteroid types
- Use probabilistic methods to describe the effectiveness of the proposed mitigation design reference mission

AIDA Mission Concept

Asteroid Impact Deflection Assessment (AIDA) Mission

- currently in parallel formulation studies with European Space Agency (ESA)



Asteroid Redirect Mission: Three Main Segments

IDENTIFY

Ground and space based assets detect and characterize potential target asteroids


Pan-STARRS


NEOWISE

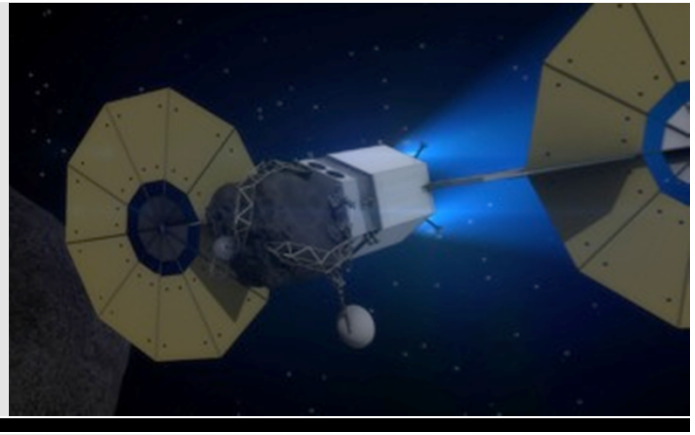

Goldstone


Arecibo


Infrared Telescope Facility

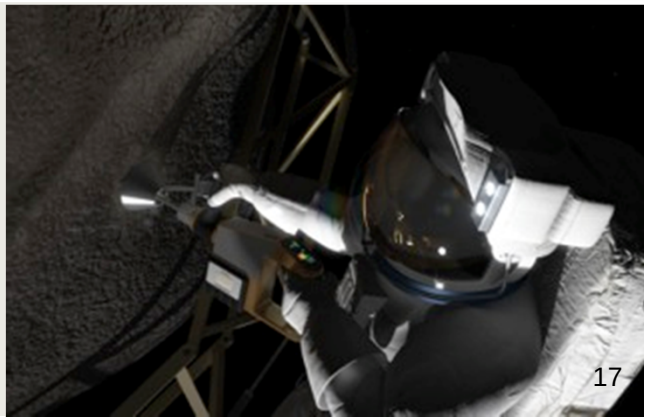
REDIRECT

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

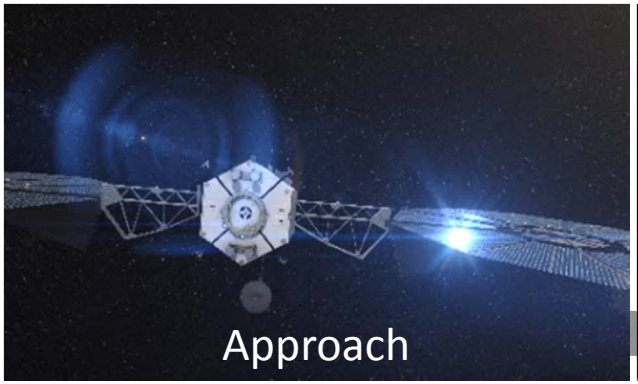


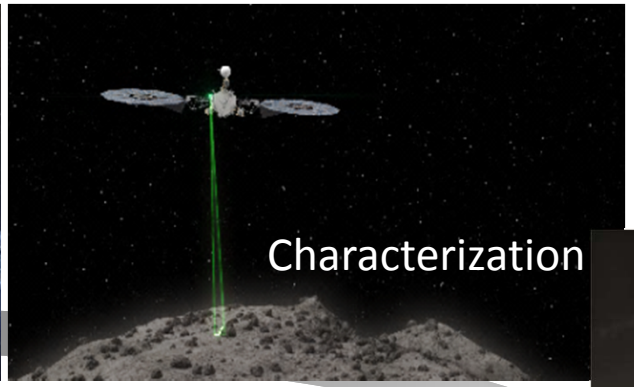
Capture Phase Overview
Asteroid Redirect Robotic Mission

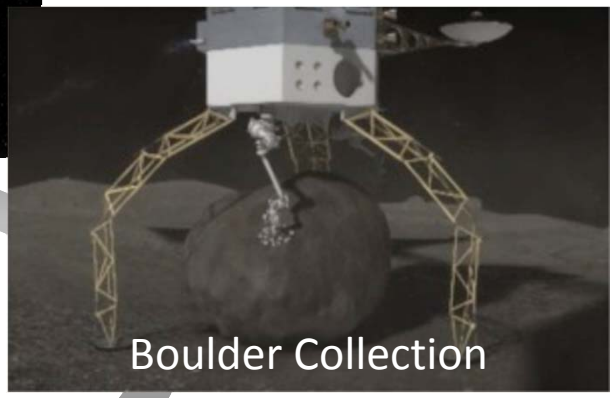
Approach
14 days

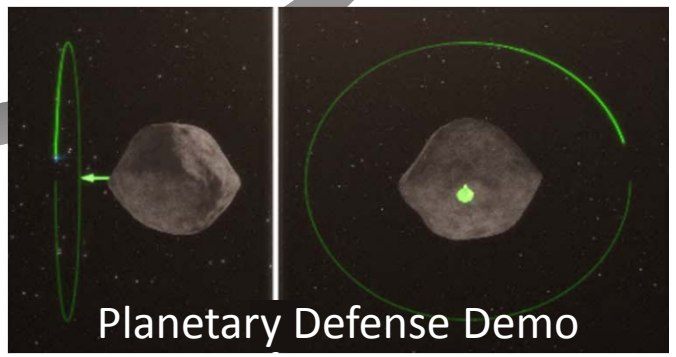
Characterization
85 days

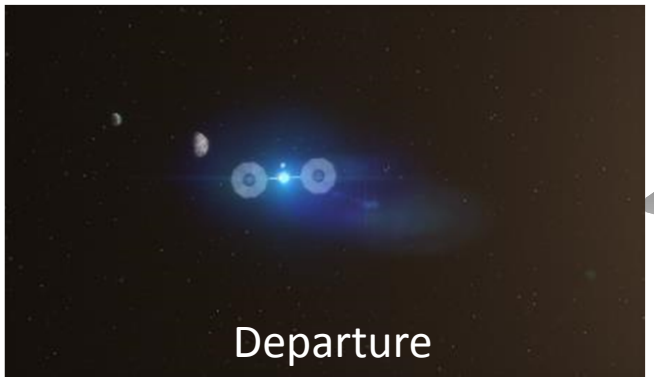
Boulder Collection
60 days + 30 day margin





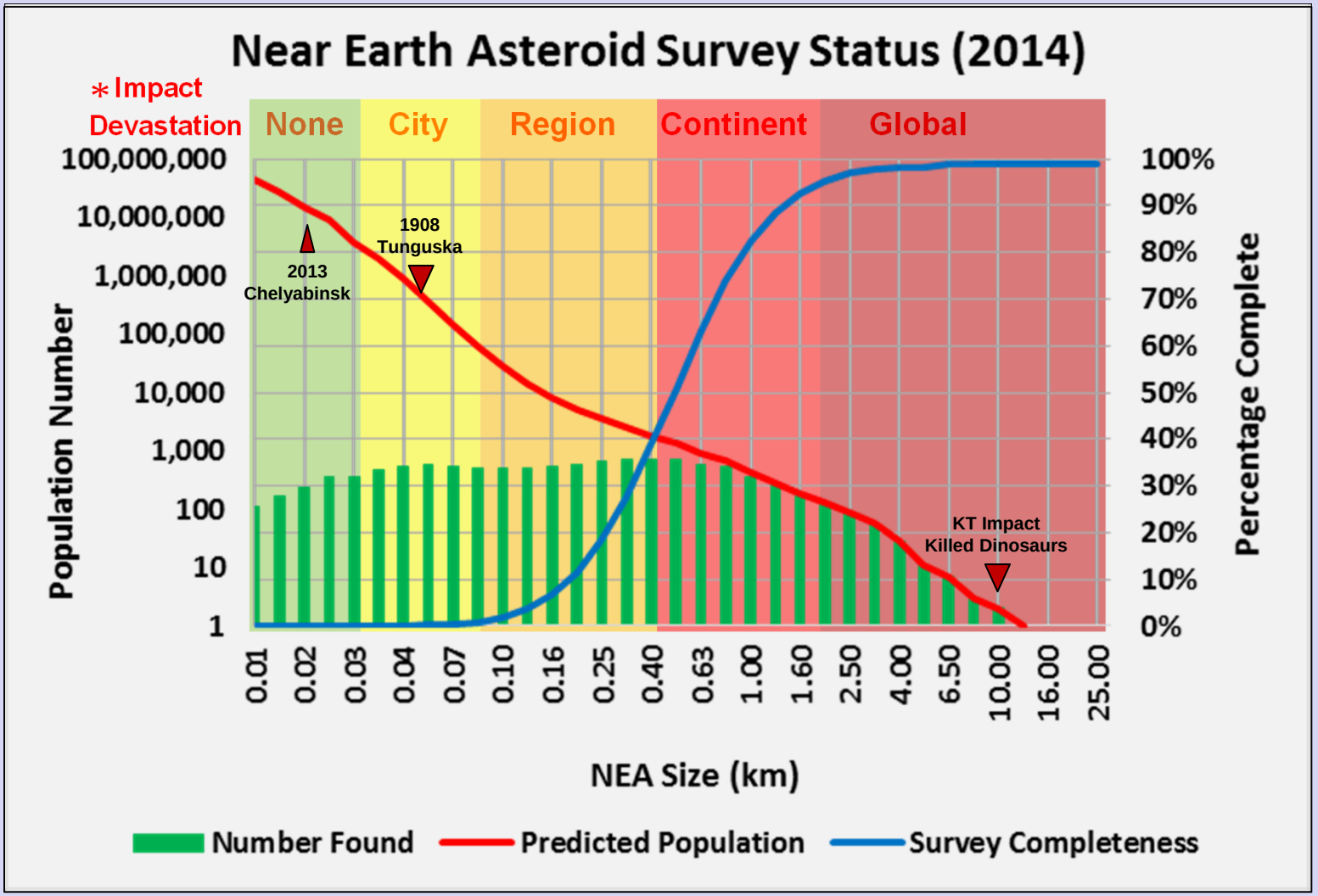






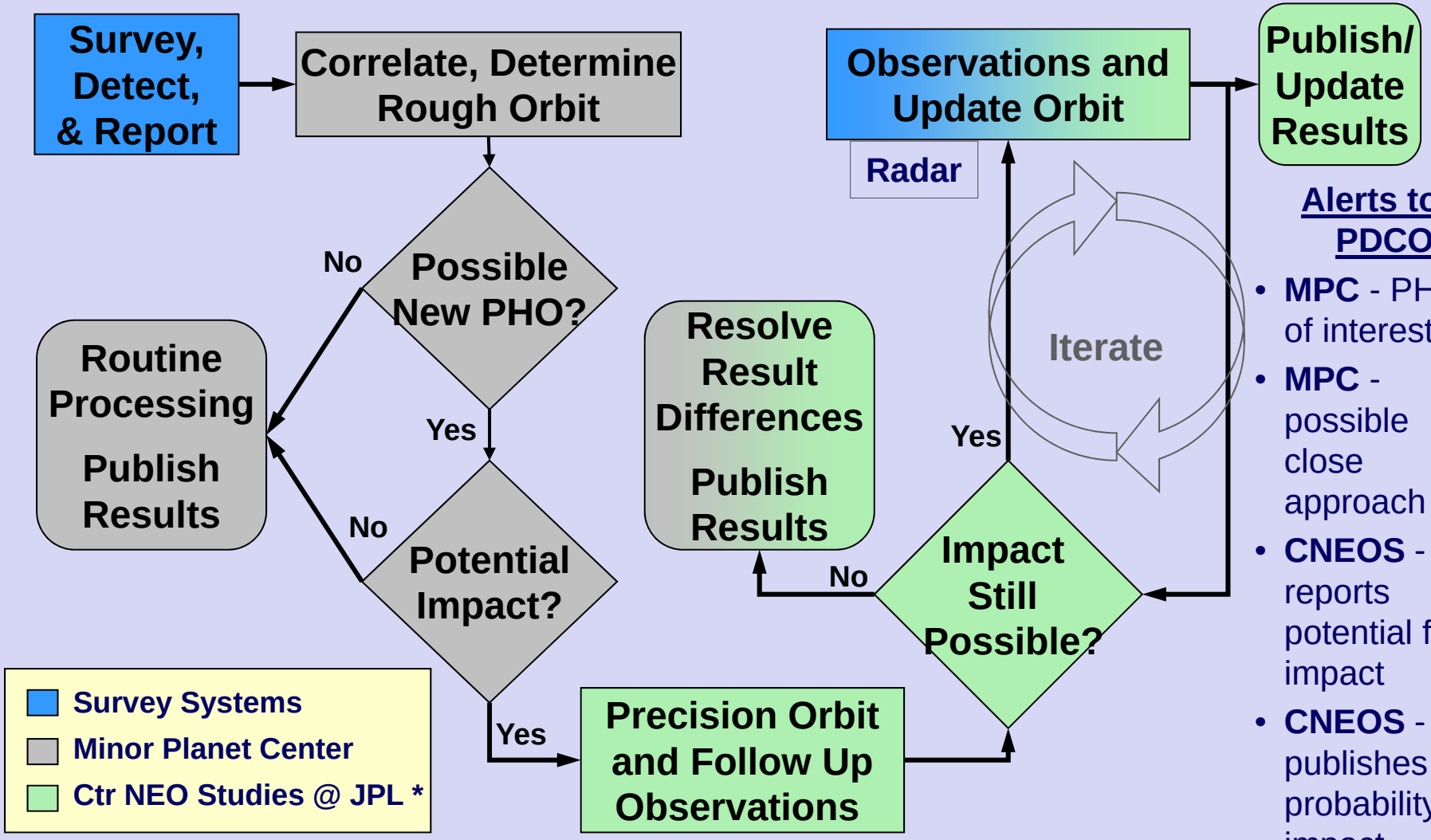
Background Slides

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

NEOO Survey and Alert Process

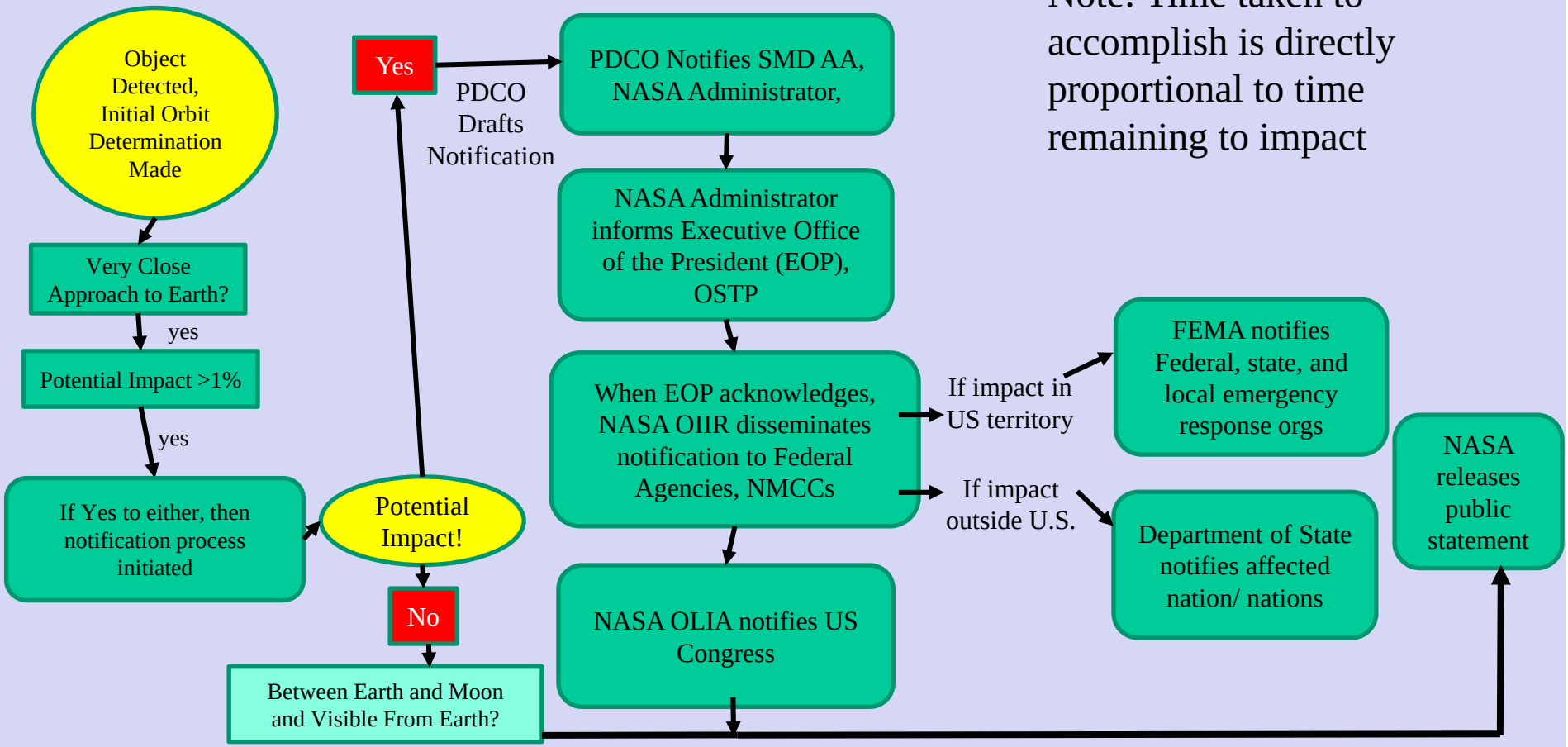


* In parallel with NEODyS

Alerts to PDCO

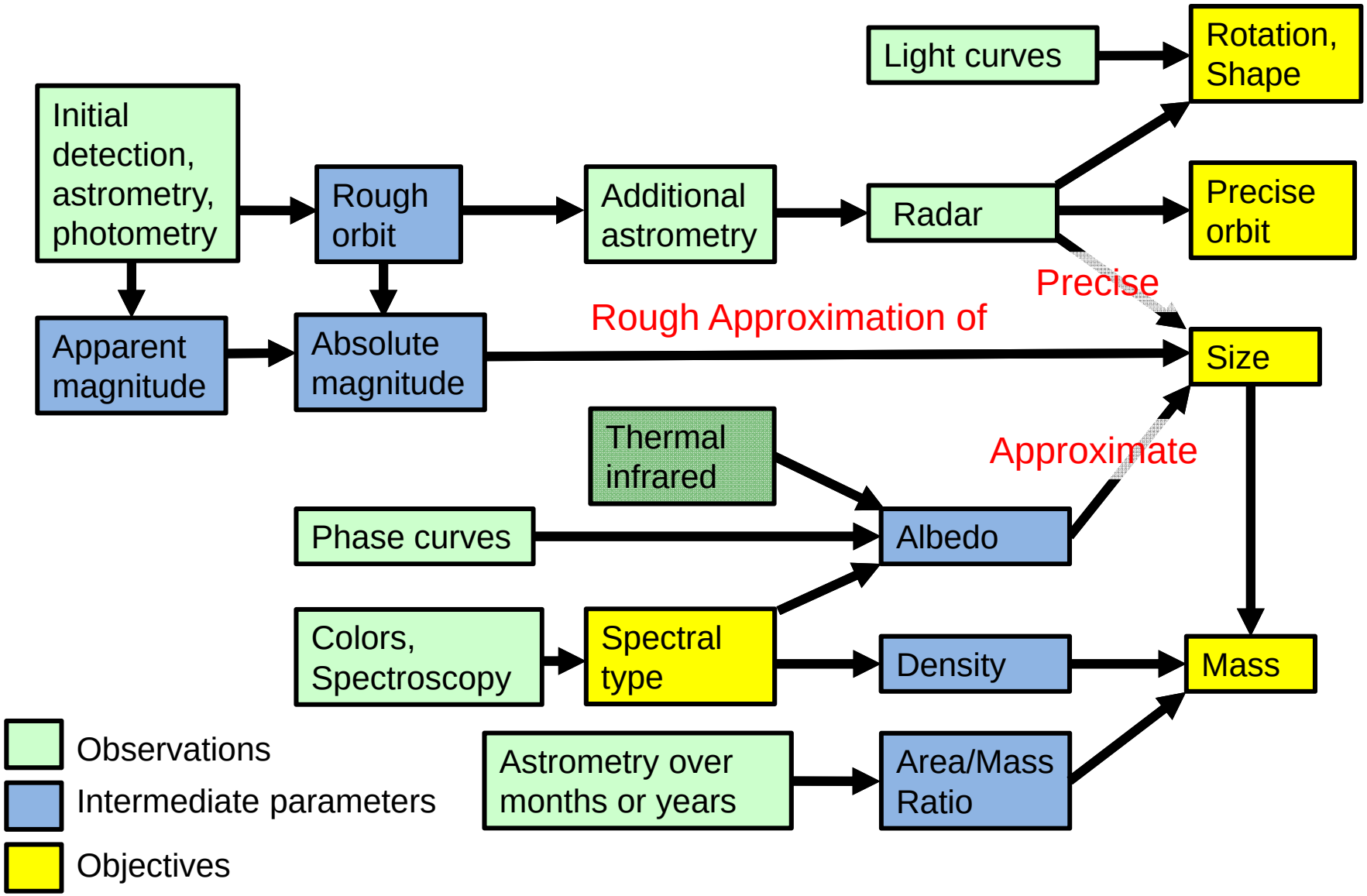
- **MPC** - PHO of interest
- **MPC** - possible close approach
- **CNEOS** - reports potential for impact
- **CNEOS** - publishes probability of impact

Planetary Defense Coordination Office
Potential Impact Notification Process

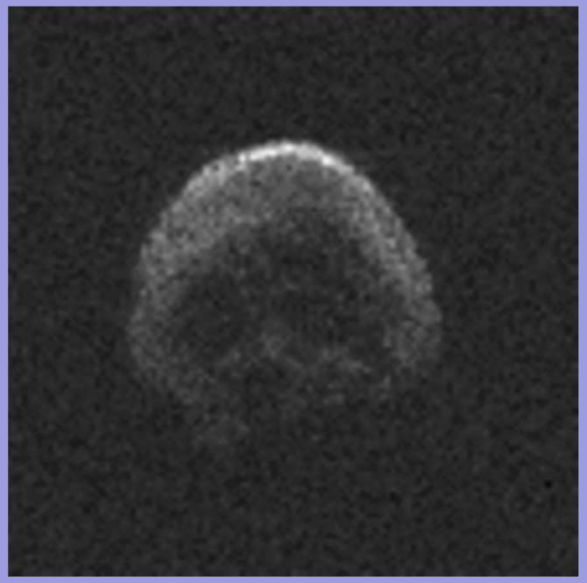


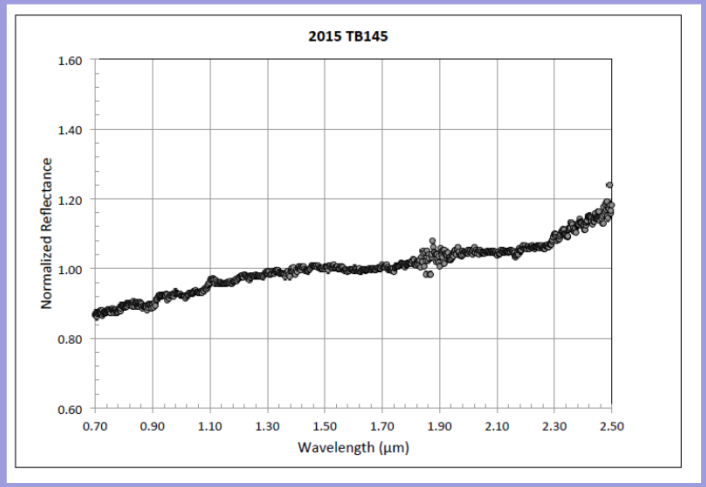
Note: Time taken to accomplish is directly proportional to time remaining to impact

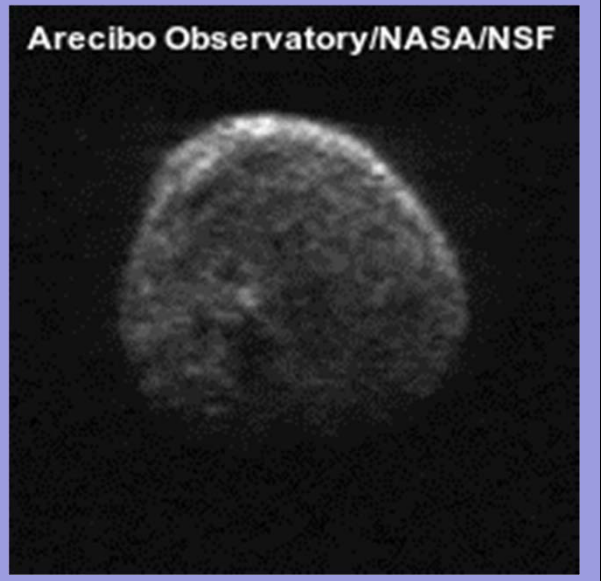
Characterization Process



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
- 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

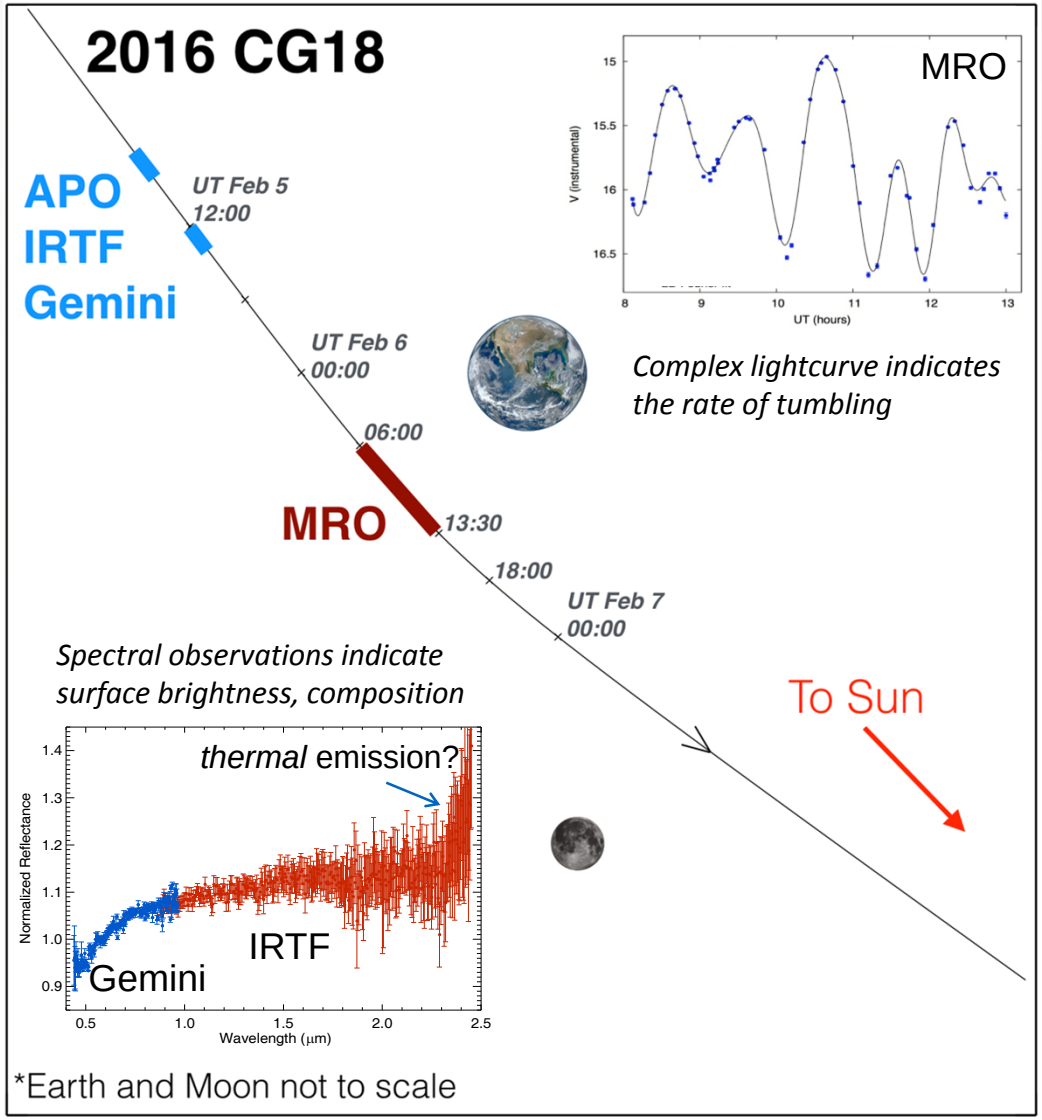
The near-Earth asteroid 2016 CG_{18} was discovered by the Catalina Sky Survey on Feb 3, 2016 and flew by the Earth three days later at less than half the distance to the Moon. A coordinated response by astronomers was made from several observatories:

- 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**.

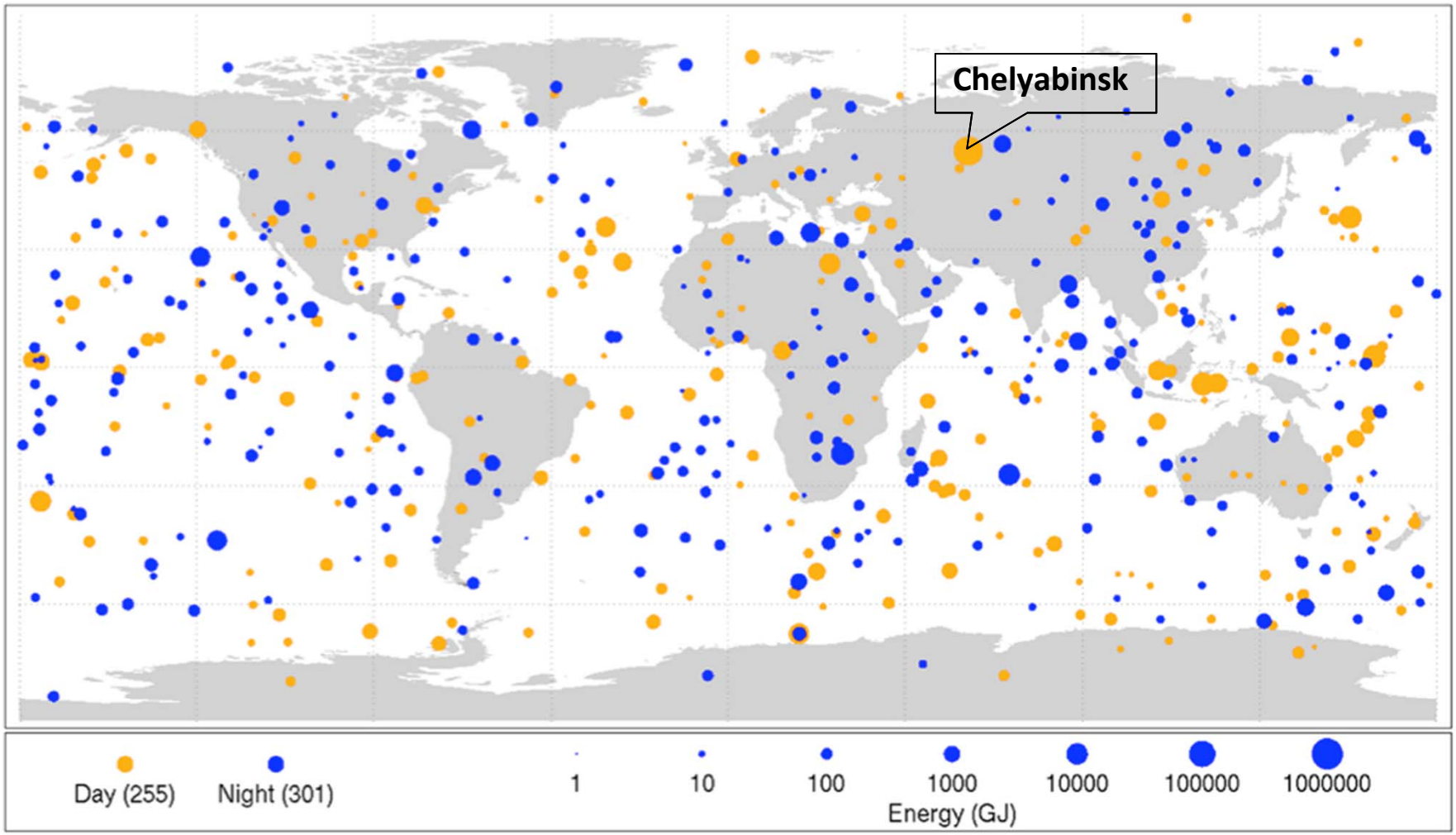
This campaign tested rapid response observing protocols and coordination for difficult, fast moving objects in preparation for future time-critical events similar to the discovery and impact of 2008 TC_3. This effort also added critical data to the catalog of physical properties for potential Earth impactors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



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.

Asteroid Threat Assessment Project (ATAP)

Ames Research Center

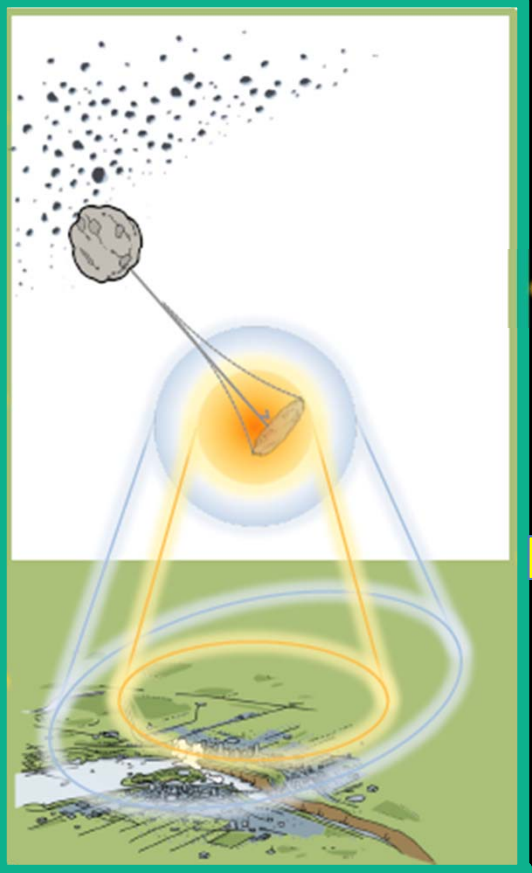
NASA

Characterization
- Physical Properties
- Orbital Trajectories JPL Web

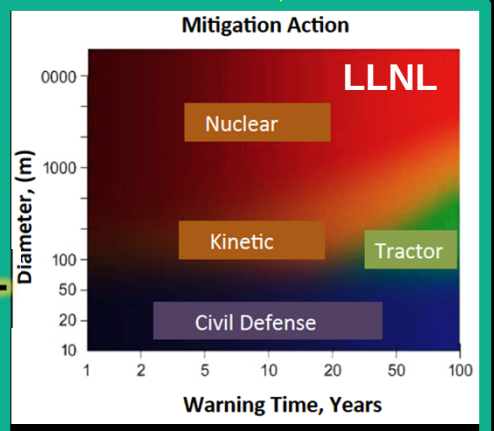
Atmospheric Entry & Airburst Modeling
- Entry Trajectories/Ablation
- Energy Deposition

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