Planetary Defense: An Overview

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Background

- Considerable work over the last several years on understanding the threat, proposing actions
- 2004, 2007, 2009, 2011 Planetary Defense Conferences discussed
  - *What we know about the threat to Earth from asteroids and comets*
  - *Consequences of impact*
  - *Techniques for deflection and disruption*
  - *Deflection mission design*
  - *Disaster mitigation*
  - *Political, policy, legal issues associated with mounting a deflection mission*
  - *Details and videos at www.planetarydefense.info, www.pdc2011.org*
- Highlights from 2011 IAA Planetary Defense Conference presented later in this briefing

The Threat

Larger Meteor Events

- 10 to 20 meteor impact events occur worldwide each day
- 2 to 5 events/ day with potential for discovery by people
- Injury has occurred, but rare

October 9, 1992

March 27, 2003: Chicago (Park Forrest)

- **27 March 2003, 05:50 UT (12:50 AM local time)**
- **Southern suburbs of Chicago**
- **Camera in stationary squad car parked about 150 km away**
- **Five structures damaged**
- **Object estimated to be ~2 m in diameter, weigh ~7 tons**

Credit: Sgt. Kile - South Haven Indiana Police Department
Prof. Peter Brown - University of Western Ontario
Dr. Dee Pack - The Aerospace Corporation
Video courtesy of University of Western Ontario, South Haven Indiana Police Department, and The Aerospace Corporation

Chicago (Park Forest) Impact, March 27, 2003

- Video image courtesy of ABC News, Channel 7, Chicago, IL.

Events

1.2 kilometer BARRINGER (OR METEOR) CRATER, Arizona, was created about 49,000 years ago by a small nickel-iron asteroid (Photo by D.J. Roddy and K.Zeller, USGS)

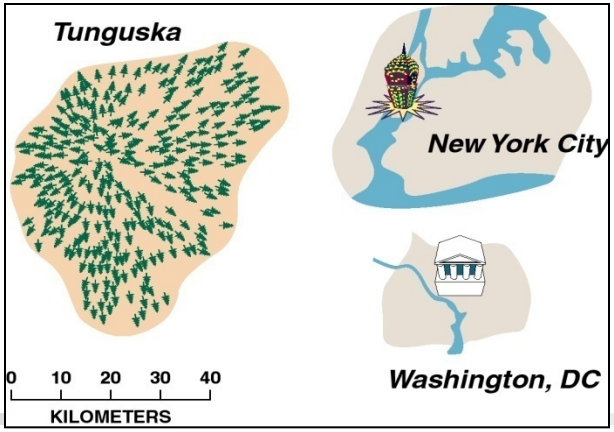


Image courtesy Clark Chapman

June 30, 1908: Tunguska, Siberia

- Airburst of ~30 m diameter object at ~6 km altitude
- 2-15 MT explosion
- Two deaths
- Leveled and ignited 2000 km^2 of forest

August 13, 1930: Brazil

- Multi-megaton explosive equivalent
- Very remote area

Asteroid Discovery Video

- Locations of known asteroids beginning 1980
  - *Earth-crossers (red)*
  - *Earth approachers (Perihelion less than 1.3AU) (yellow)*
  - *All others (green)*
- Widefield Infrared Survey Explorer (WISE) discoveries become available in 2010
- Video courtesy of Scott Manley, Armaga Observatory
- asteroid_discovery_04-11-H.264.mov

History of Known Asteroid & Comets

2006

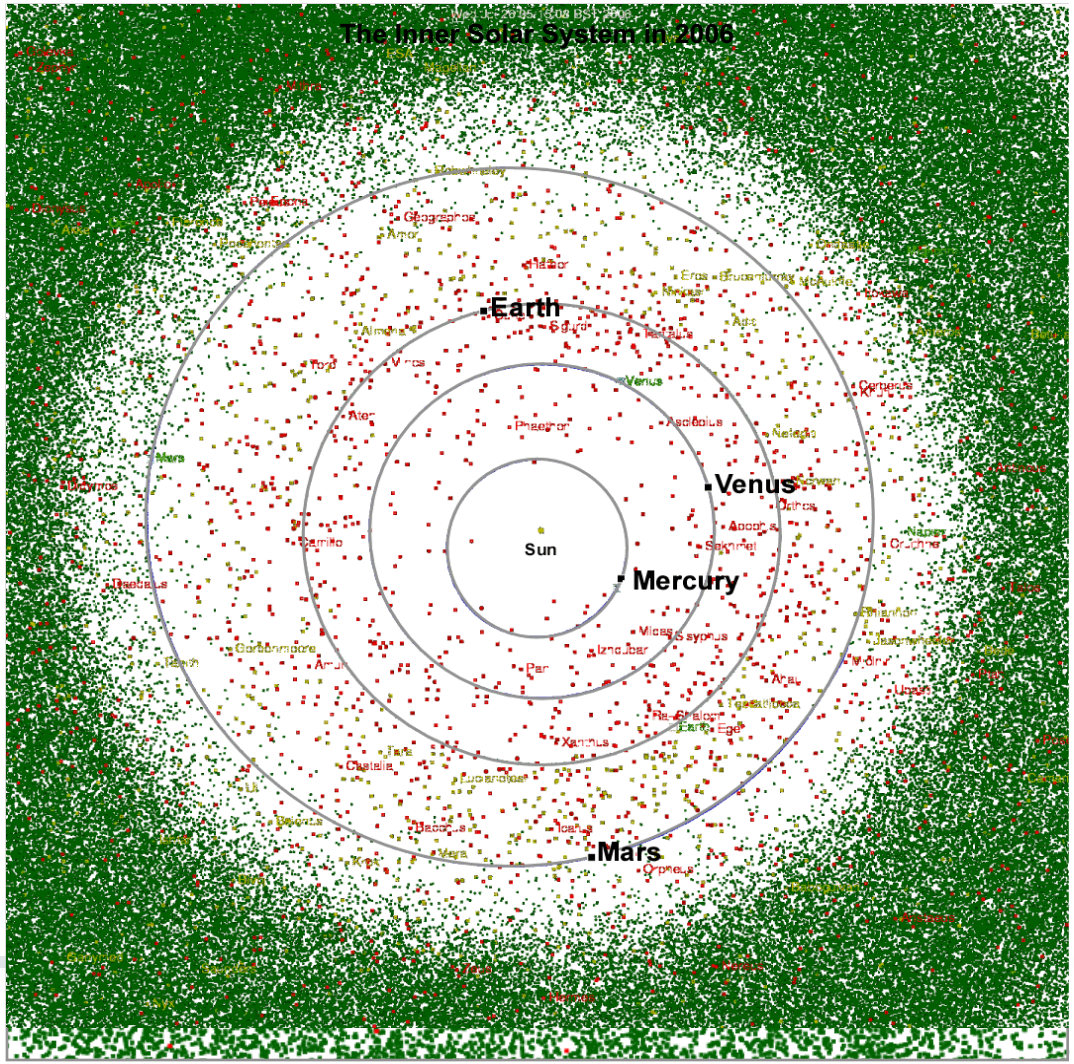
Earth Crossing

Outside Earth's Orbit

NEO: Near Earth Object:--Perihelia <1.3 AU

PHO: Potentially hazardous asteroid or comet--pass within 0.05 AU of Earth's orbit

PHA: Potentially hazardous asteroid



Known

- **350,000 minor planets**
- **4500 NEOs**
- **~1200 PHOs**

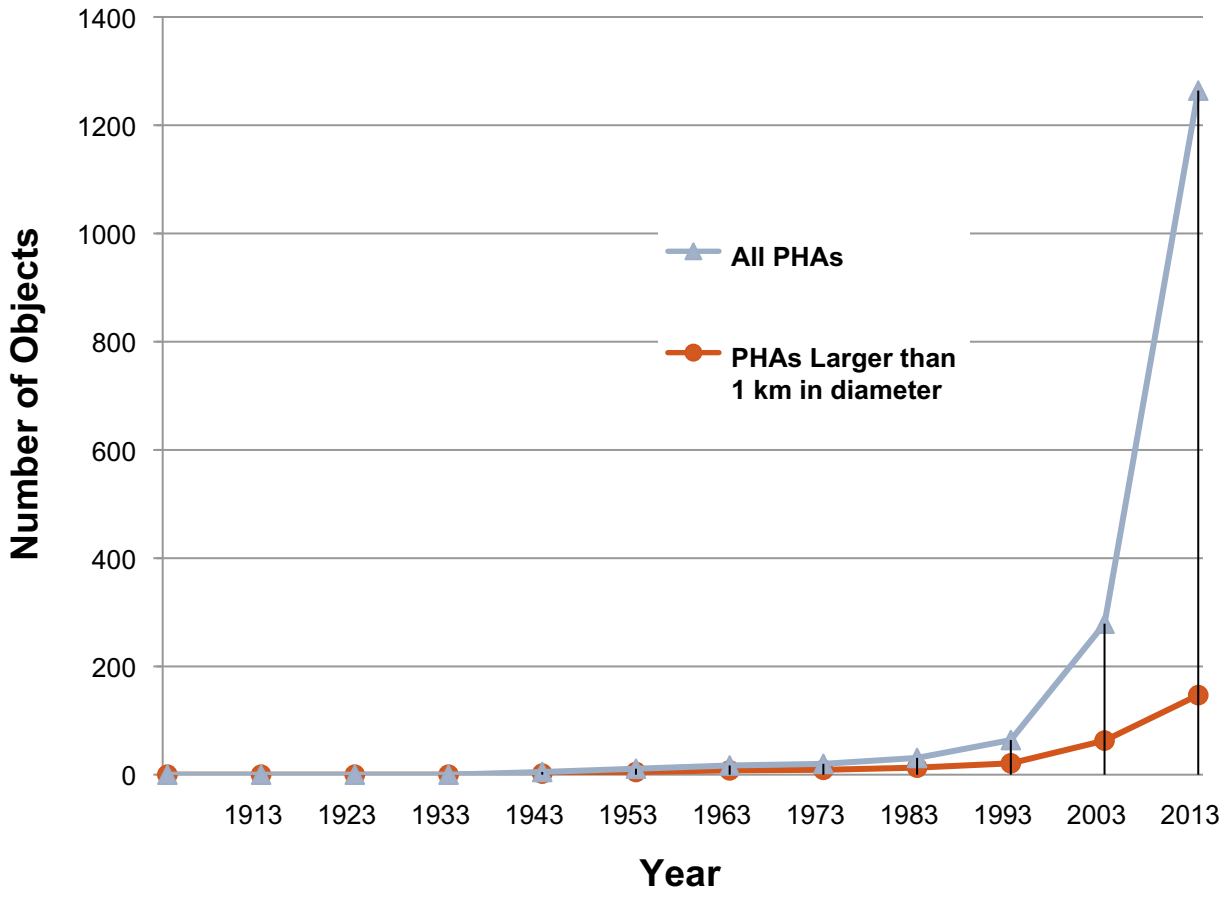
New Survey Will Likely Find

- **100,000+ NEOs (> 140m)**
- **20,000+ PHOs**

Scott Manley

Armagh Observatory

How many have been detected?

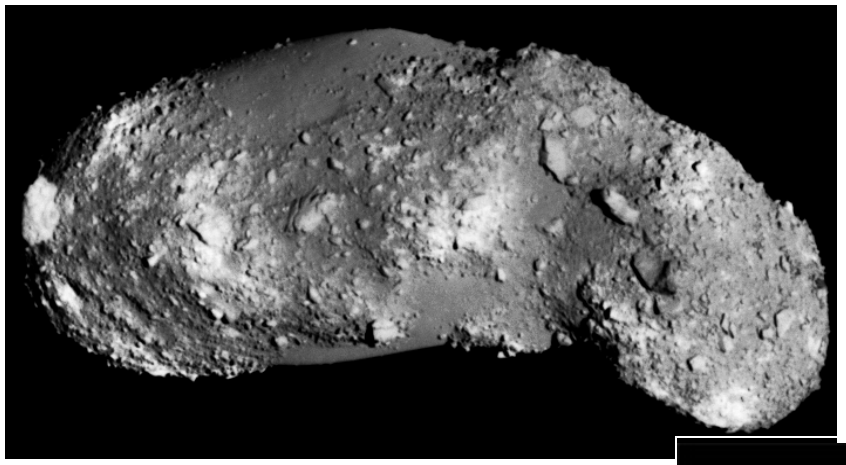


Congressionally mandated effort to find and catalog 90% of NEOs larger than 1 km by 2008

Current U.S. funding ~$4 Million/year for discovery and tracking

Comets ~ 1% of overall threat
Orbits of comets difficult to predict accurately

What do they look like?

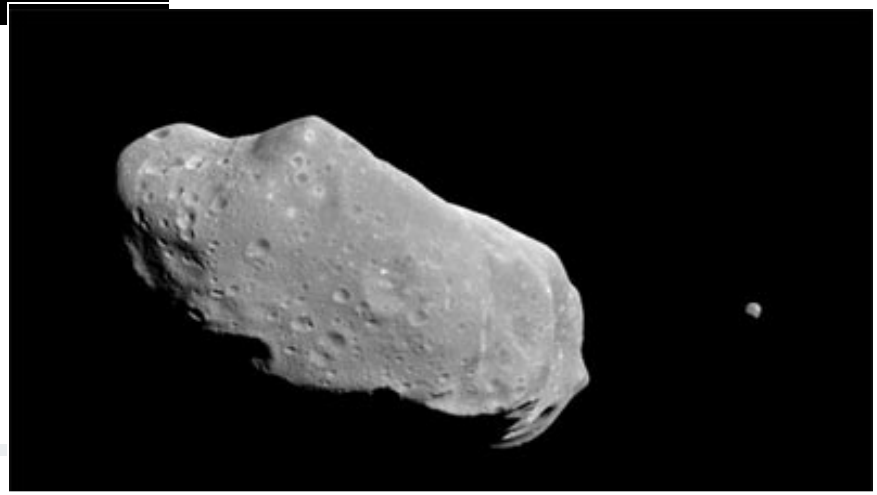


Asteroid Itokawa

500 x 300 x 200 meters

Photo courtesy JAXA

Photo courtesy NASA



Asteroid Ida and its moon Dactyl

Ida: 54 x 24 x 15 km

Dactyl: 1.4 km diameter

What sizes cause problems?

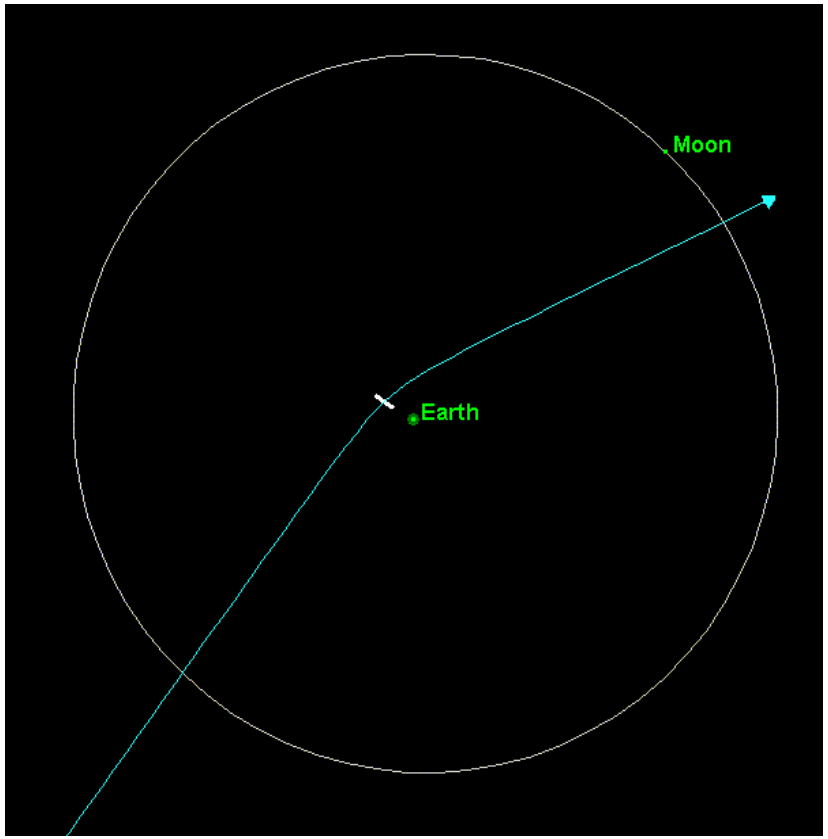
Characteristic Diameter of Impacting Object	Type of Event	Approximate Impact Energy (MT)	Approximate Average Impact Interval (Years)
25 m	Airburst	1	200
50 m	Local Scale	10	2000
140 m	Regional Scale	300	30,000
300 m	Continent Scale	2,000	100,000
600 m	Below Global Catastrophe Threshold	20,000	200,000
1 km	Possible Global Catastrophe	100,000	700,000
5 km	Above Global Catastrophe Threshold	10,000,000	30 million
10 km	Mass Extinction	100,000,000	100 million

from "Defending Planet Earth: Near-Earth Object Surveys and Mitigation Strategies Final Report," National Research Council, The National Academies Press, 2010 (available at http://www.nap.edu)

How likely is an impact?

- The probability of a “dinosaur-killer” impact~**1 in one million** this century
- The probability of a civilization-ending impact is ~ **1 in 1000** this century
- The probability of a small or Tunguska-class impact (near the lower size for penetration of the atmosphere, but still large enough to destroy a city) is ~**1 in 10** this century.

Coming Events



Apophis trajectory changed by Earth's gravity during close approach in 2009 (Paul Chodas, NASA/JPL)

2029--Asteroid 2004 NM4 (Apophis) will pass 4.7 Earth radii (30,000 kilometers, or 18,600 miles) from Earth's surface

- *~300 meters in diameter*
- *Impact energy ~ 850 megatons (~150 times more powerful than Tunguska)*
- *1 in 250,000 chance of impacting Earth in 2036*

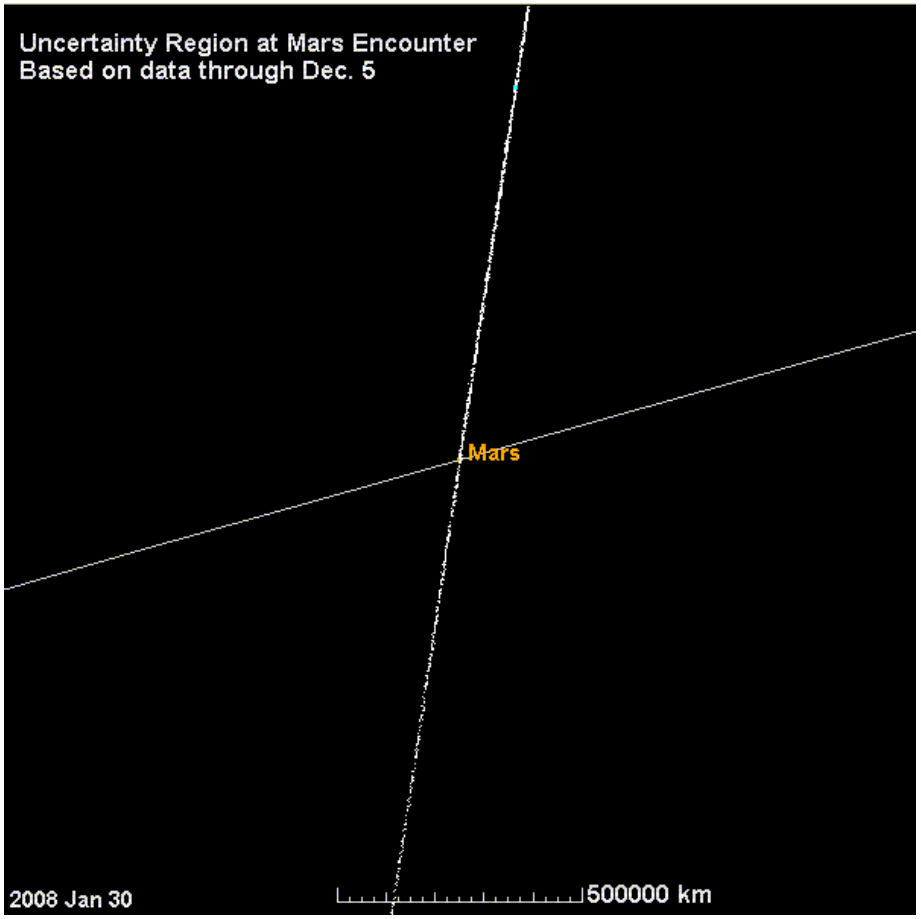
2048--Asteroid 2007 VK184

- *~130-meter diameter*
- *1 in 3000 chance of impact*
- *Impact* energy ~150 MT

2052--Asteroid 2011 AG5

- ~140-meter diameter
- 1 in 4000 probability of impact
- Impact energy ~100 MT

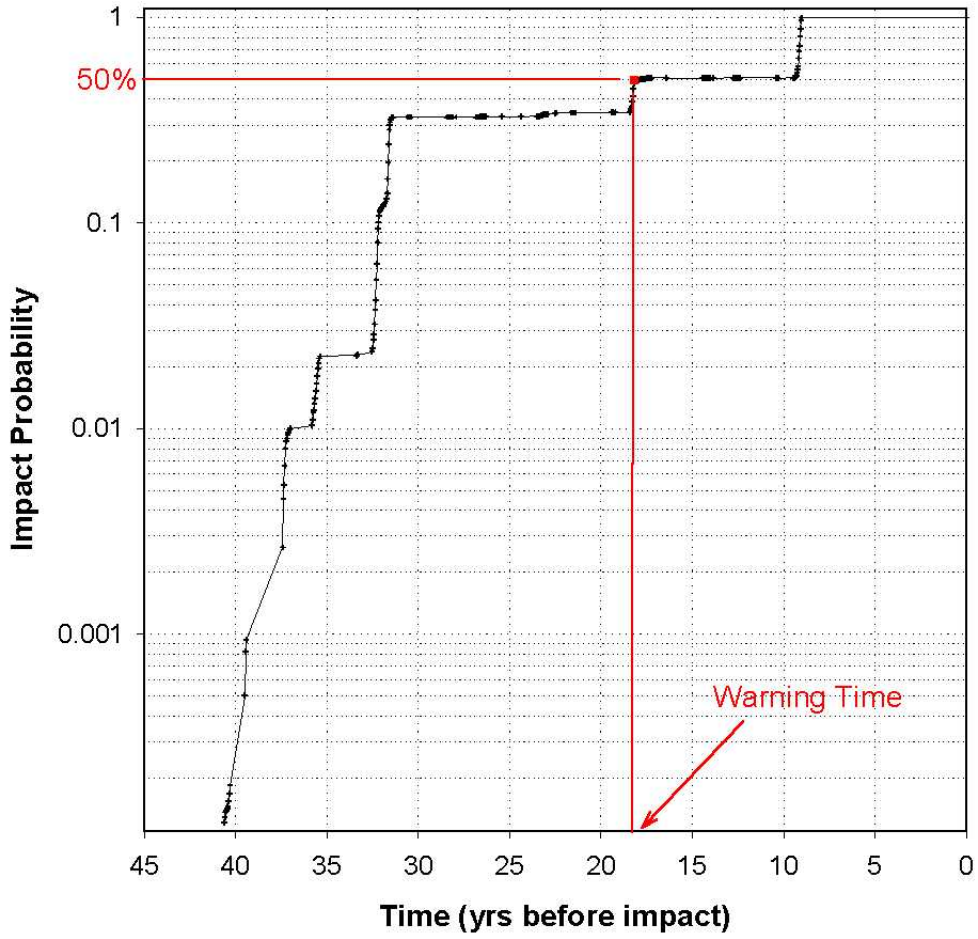
Mars Encounter, January 30, 2008



- Asteroid 2007 WD5 discovered late November 2007 (2 months before possible Mars impact)
- ~50 meters in diameter
- Initial probability of Mars impact ~1 in 350
- Increased to 1 in 75
- Increased to 1 in 25
- Late January: 1 in 10,000
- Could be similar for Earth encounter

Image reprinted courtesy of NASA/JPL

How much warning?



Warning time depends on size

- *Larger objects (900-350m): reach 50% impact probability 5-7 years after discovery*
- *Smaller objects*
  - Warning time decreases as size decreases
  - Some not seen at all

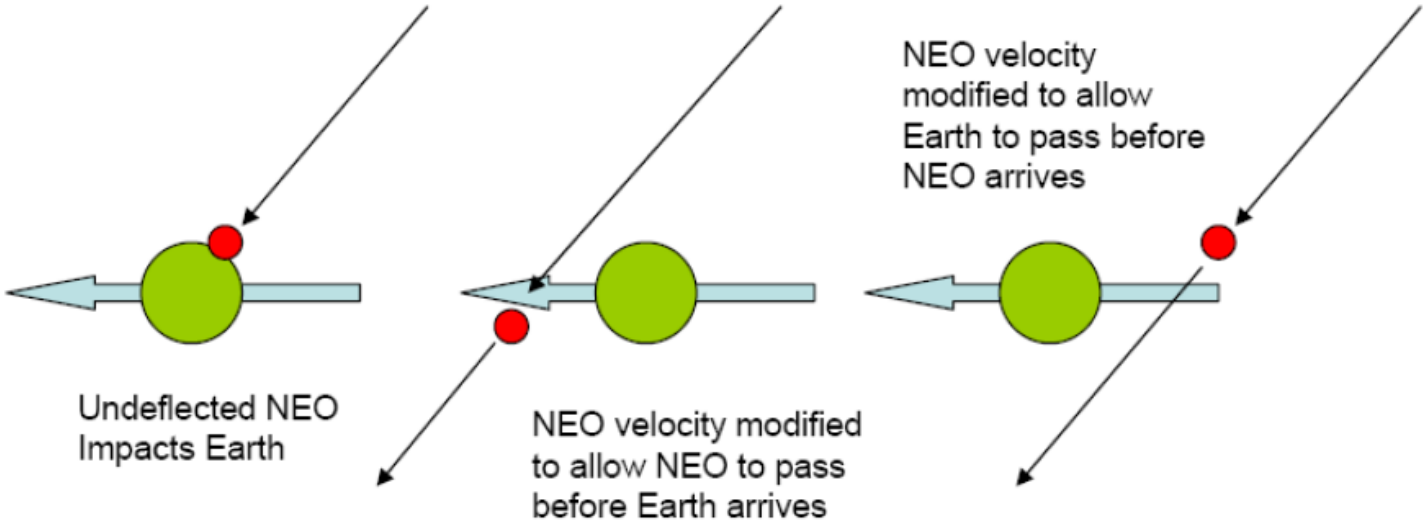
Paul Chodas, "NEO Warning Times for NEAs and Comets," 2007 Planetary Defense Conference.

Issues

- When is action required?
- Who makes the decision to act or not act?
- Who pays for the deflection effort?
- What information is needed to be able to make effective decisions?
- How are international efforts coordinated?
- What is cost-effective strategy for maintaining capabilities?
- Are nuclear explosives acceptable?
- How will the public and decision makers react to false alarms?

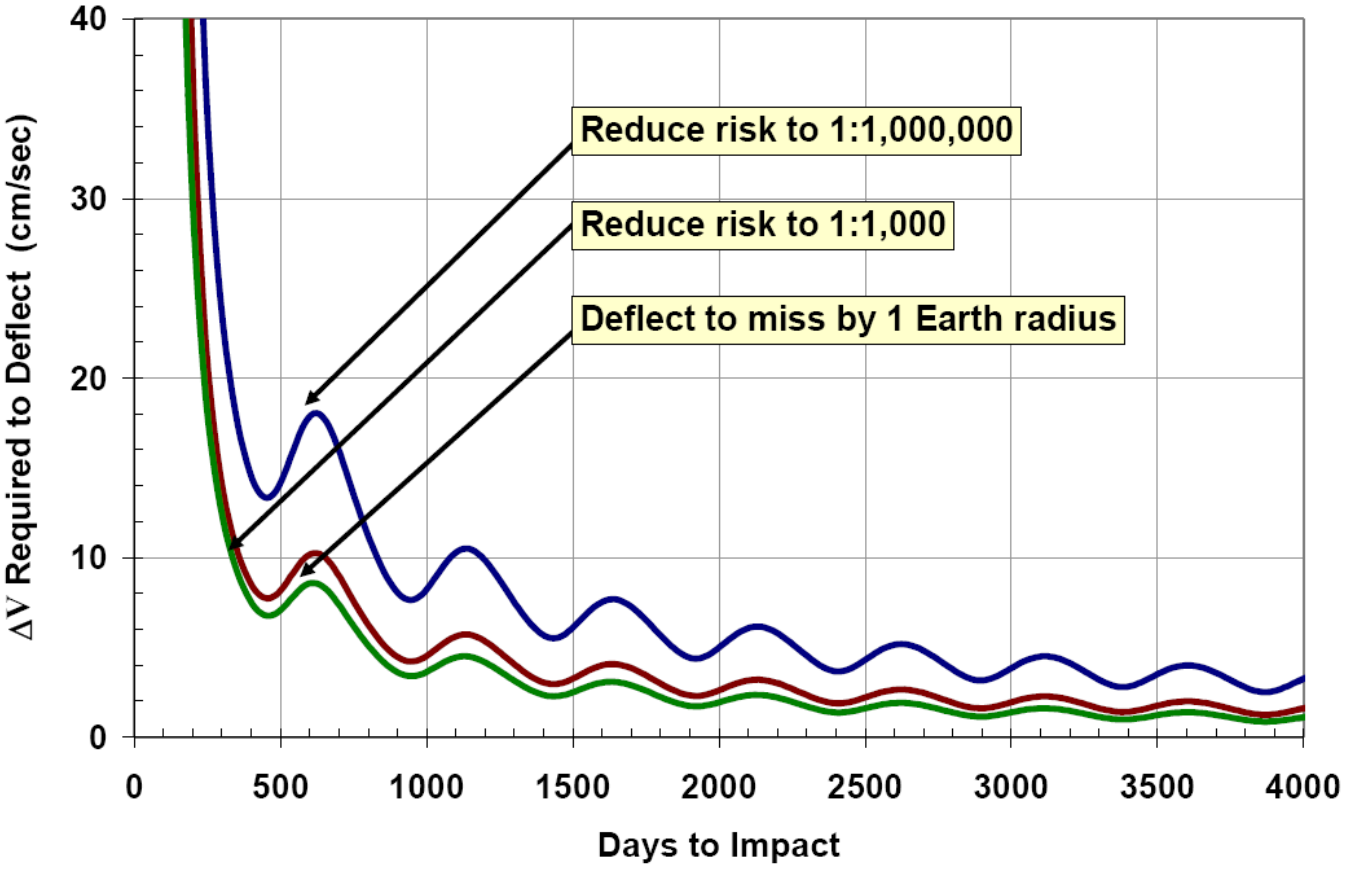
Deflection

Deflection Basics



Objective: Apply velocity change so that NEO arrives when Earth is not there

Impulse Required vs. Time



Deflection Options

- Slow-push techniques
  - *Provide velocity increment over extended period*
- Impulsive
  - *Instantaneous velocity increment*

Slow Push: Gravity Tractor

- Station-keep very close to NEO
- Gravitational attraction slowly pulls NEO
- Requires long warning times

Image courtesy Dan Durda, FIAAA

Slow Push: Mass Driver

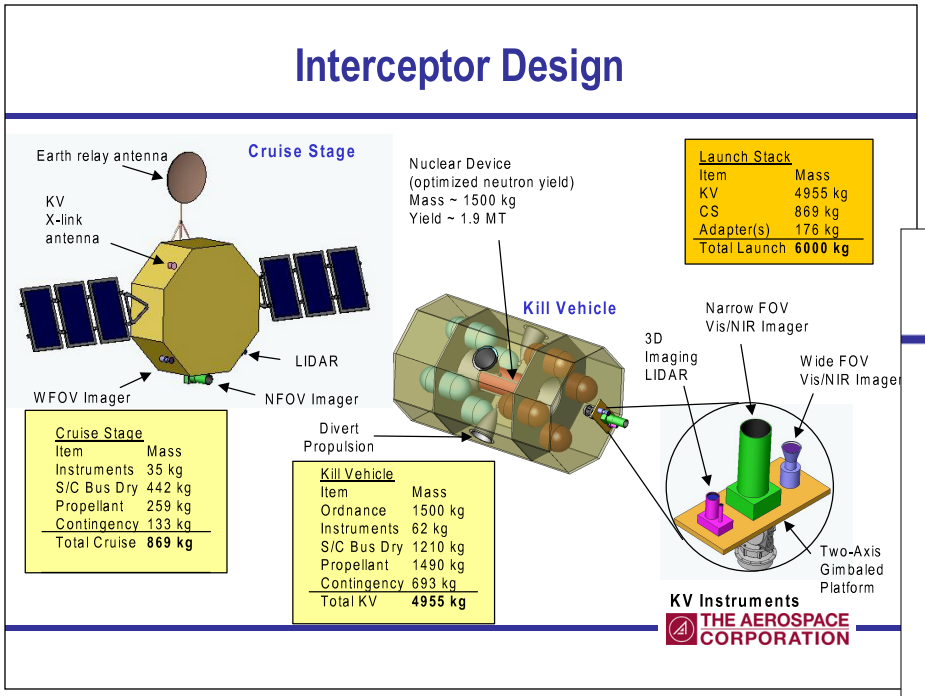
- Land on NEO
- Mine NEO material and eject at high speed
- Use multiple devices

Impulsive: Kinetic Impact

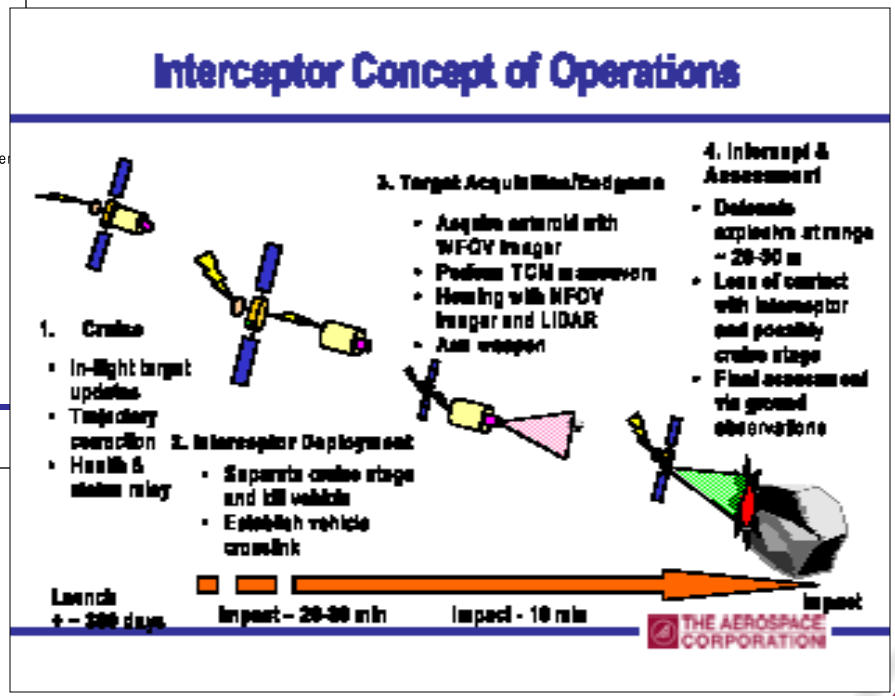
Photograph reprinted courtesy of NASA

- High-velocity impact
- Similar to “Deep Impact” mission
- Instantaneous momentum change
- Ejecta from impact crater amplifies effectiveness

Impulsive: Stand-Off Nuclear Explosive



- Detonation above surface
- Less chance of fragmenting NEO
- Use multiple interceptors



- Political and policy issues

2011 IAA Planetary Defense Conference

- Held in Bucharest, Romania
- Sponsored by International Academy of Astronautics (IAA); 18 additional co-sponsors, including NASA, ESA, JAXA, ISRO, ROSCOSMOS, ROSA, The Planetary Society, The Aerospace Corporation, Secure World Foundation
- 160 attendees
- Shows increasing international recognition of threat of NEO impacts
- UN COPUOS (Action Team 14) developing framework for international decision-making and coordinated action in event threatening object discovered

Highlights from 2011 IAA PDC: Threats

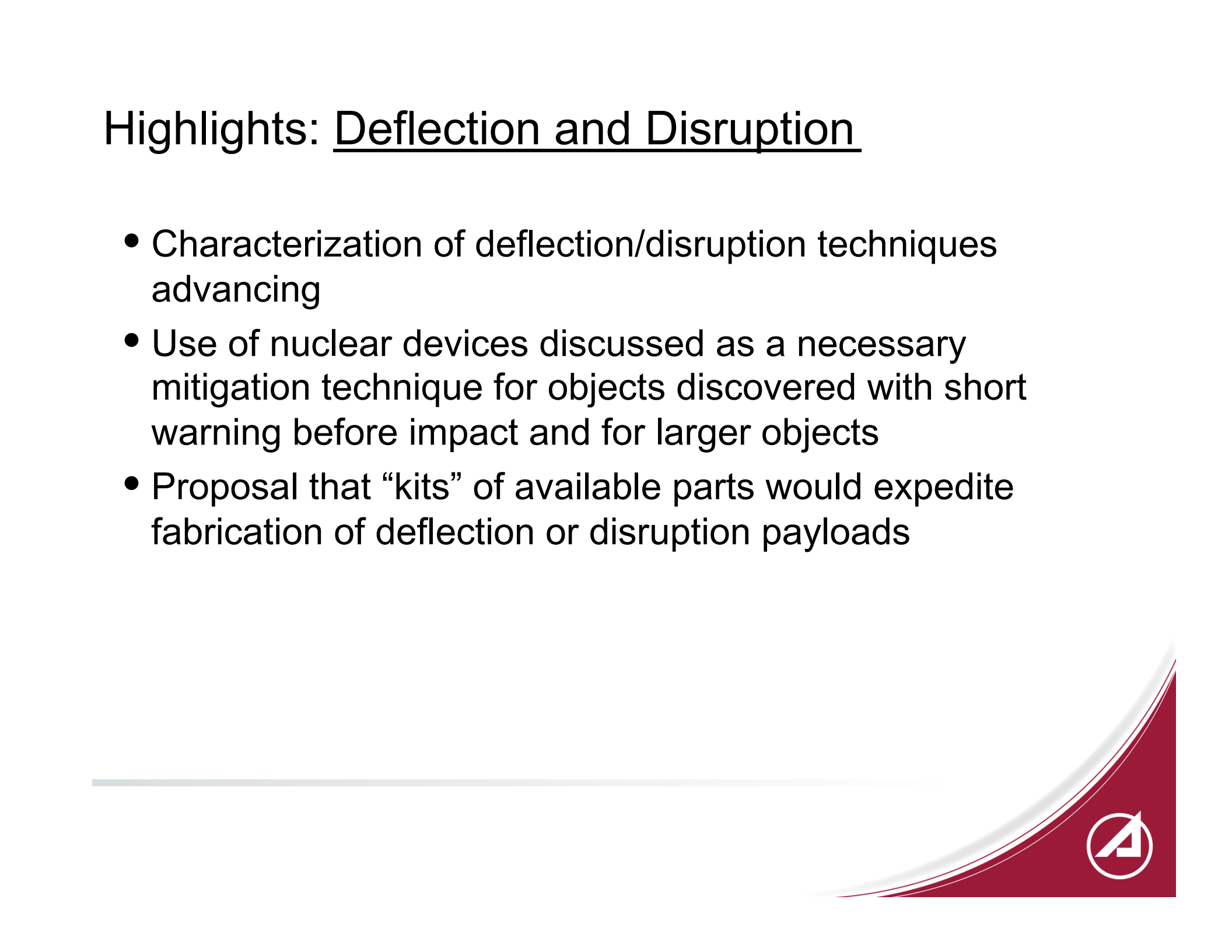
- No threats yet identified for this century from objects larger than 1km
- Recognition that most frequent damaging threat is from smaller NEOs (e.g., less than 50 m diameter)
- Approximately 350 NEOs discovered with small but non-zero probability of impact this century
- Two known objects with diameters over 100m have impact probabilities of ~1/4000 in the 2050 timeframe (impact energy >100 MT)
- Recognition that Tunguska-class disaster could currently occur with no or little warning given available search and detection assets
- New wide sky search systems could provide 1-3 month warning time for 30-50m diameter object (Tunguska-class)

Highlights: Discovery and Characterization

- Estimate that there are 990±35 NEOs greater than 1km in diameter
- ~80% of objects larger than 140 m but smaller than 1KM are undiscovered
- Funding increased for discovery, tracking resources (e.g., funding provided by the European Commission, NASA support for Arecibo)
- Making significant progress on discovering NEOs >300 m in diameter (~45% completion)
- Increased understanding of keyholes and how deflection efforts vary if act before or after keyhole passage
- Potential for human missions to gather data that will minimize uncertainty for planetary defense efforts

Highlights: Deflection and Disruption

- Characterization of deflection/disruption techniques advancing
- Use of nuclear devices discussed as a necessary mitigation technique for objects discovered with short warning before impact and for larger objects
- Proposal that “kits” of available parts would expedite fabrication of deflection or disruption payloads



Highlights: Civil Defense

- Civil defense (evacuations, etc.) should include responses to the possibility of objects discovered with short warning times
- Public understanding of the NEO risk and effects can be increased via “teaching moments”
- Increase focus on civil defense/emergency management issues at future conference

Highlights: Public Education

- New interactive web tools being developed to help public understand mission design
- A survey of students indicates interest in asteroid impacts, planetary defense
- Suggestion that topics of past impacts and planetary defense might be included in the geography curriculum in schools, be highlighted at planetariums, and also include societal implications of an impact

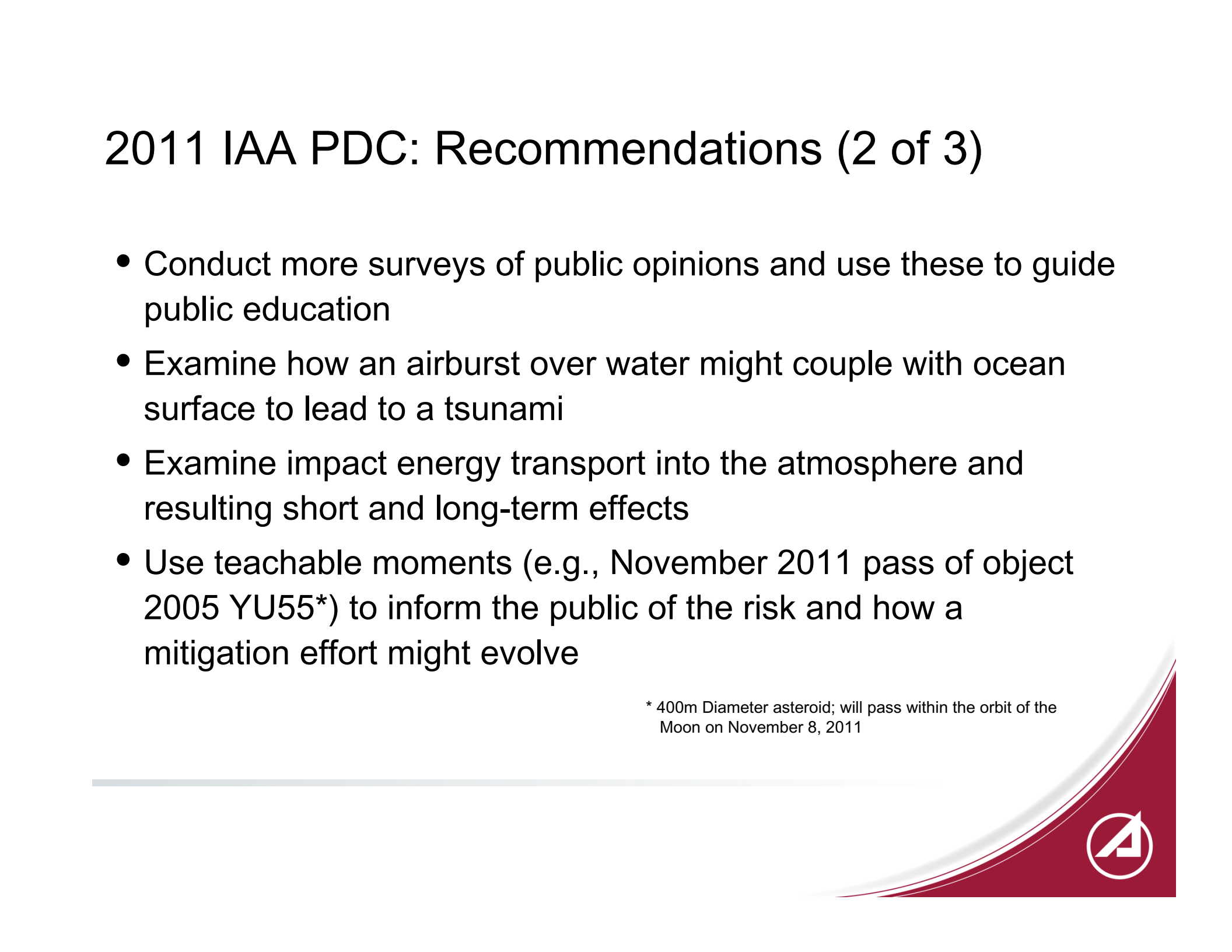
2011 IAA PDC: Recommendations (1 of 3)

- Develop deflection/disruption options, civil defense plans for the most probable impact threats of smaller NEOs with a short warning times
- Conduct flight validation/demonstration of key technologies for deflection/disruption options
- Encourage other nations to participate in planetary defense and present status at future conferences
- More governments should make funds available for planetary defense studies and civil defense exercises
- Put a sensor interior to Earth's orbit to discover NEOs with Earth-like and interior orbits and orbits with perihelia that take them close to the sun

2011 IAA PDC: Recommendations (2 of 3)

- Conduct more surveys of public opinions and use these to guide public education
- Examine how an airburst over water might couple with ocean surface to lead to a tsunami
- Examine impact energy transport into the atmosphere and resulting short and long-term effects
- Use teachable moments (e.g., November 2011 pass of object 2005 YU55*) to inform the public of the risk and how a mitigation effort might evolve

* 400m Diameter asteroid; will pass within the orbit of the Moon on November 8, 2011



2011 IAA PDC: Recommendations (3 of 3)

- Consider system of university and amateur telescopes that could increase follow-up after new discoveries, detect short warning threats
- Determine what resources should be maintained over the long term to assure adequate deflection/disruption/civil defense actions are available when required
- Consider quick reassignment of general purpose missions to planetary defense for short warning time threats
- Pay attention to and resolve related policy and legal issues
- Work to better leverage funding to NASA, ESA, Russian, other space efforts for progress on planetary defense-related programs
- Continue evolution of framework for international decisions and coordinated action

Next Meeting: 2013

1.2 kilometer BARRINGER (OR METEOR) CRATER, Arizona, was created about 49,000 years ago by a small nickel-iron asteroid (Photo by D.J. Roddy and K.Zeller, USGS; Reprinted courtesy of USGS)

2013 IAA Planetary Defense Conference

will be hosted by

NASA

in

Flagstaff, Arizona.

Will include

tour of

Meteor Crater

Summary

- Interest increasing worldwide
- Recognition that greatest near-term threat is from smaller objects
- Possible that planetary defense mission may be required this century
- Many opportunities for research
- 2013 IAA Planetary Defense Conference will provide latest information on asteroids & comets and help identify paths toward effective planetary defense

Current Status

- Need to continue efforts to discover and track smaller objects
- Need to watch and characterize objects that pose known threats (characterization reduces uncertainty of deflection effort)
- Need complete conceptual campaign/mission designs
- Need to test deflection methodologies and characterize effectiveness

Overview of Threat to Earth from Asteroids and Comets

- >350 asteroids known as of today with non-zero but small probability of impacting Earth in next 100 years
  - *–2>1 km diameter*
  - *–131>30 m diameter*
- Many more yet to be discovered
- Recognition that small objects represent greatest risk of impact
- ~1 in 5 chance of Tunguska-class (30-meter asteroid) entry this century
- Two known objects with diameters >100m have impact probabilities ~1 in 4000 in 2050 timeframe (may be reduced by additional tracking); impact energy ~150 MT

Tunguska

Photo: Leonid Kulik Expedition, 1927

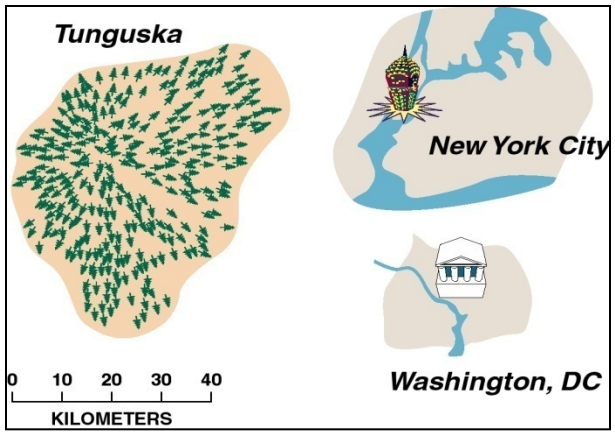
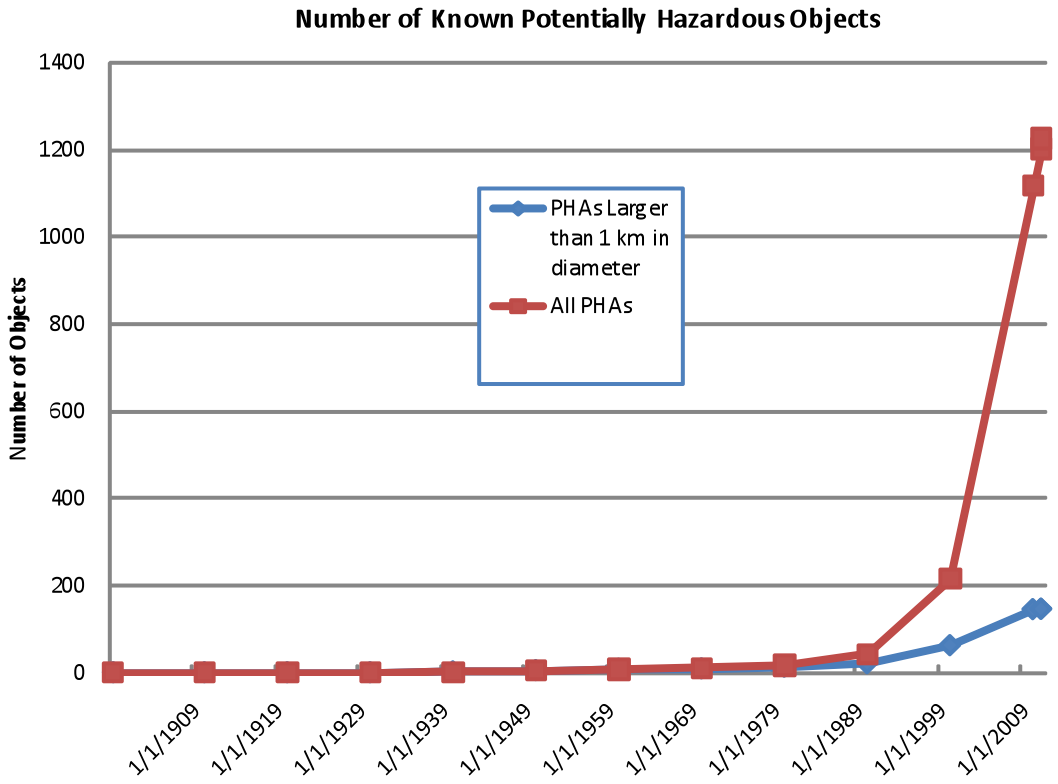


Image courtesy Clark Chapman

June 30, 1908: Tunguska, Siberia

- Airburst of ~30 m diameter object at ~6 km altitude
- 2-15 MT explosion
- Two deaths
- Leveled and ignited over 2000 km^2 of forest
- Most powerful natural explosion in recent history

How many have been detected?



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

Congressionally mandated effort to find and catalog 90% of NEOs larger than 1 km by 2008

Comets ~ 1% of overall threat

Orbits of comets difficult to predict accurately

Definitions:

NEO: Near Earth Object:--Perihelia <1.3 AU

PHO: Potentially hazardous asteroid or comet--pass within 0.05 AU of Earth's orbit

PHA: Potentially hazardous asteroid