

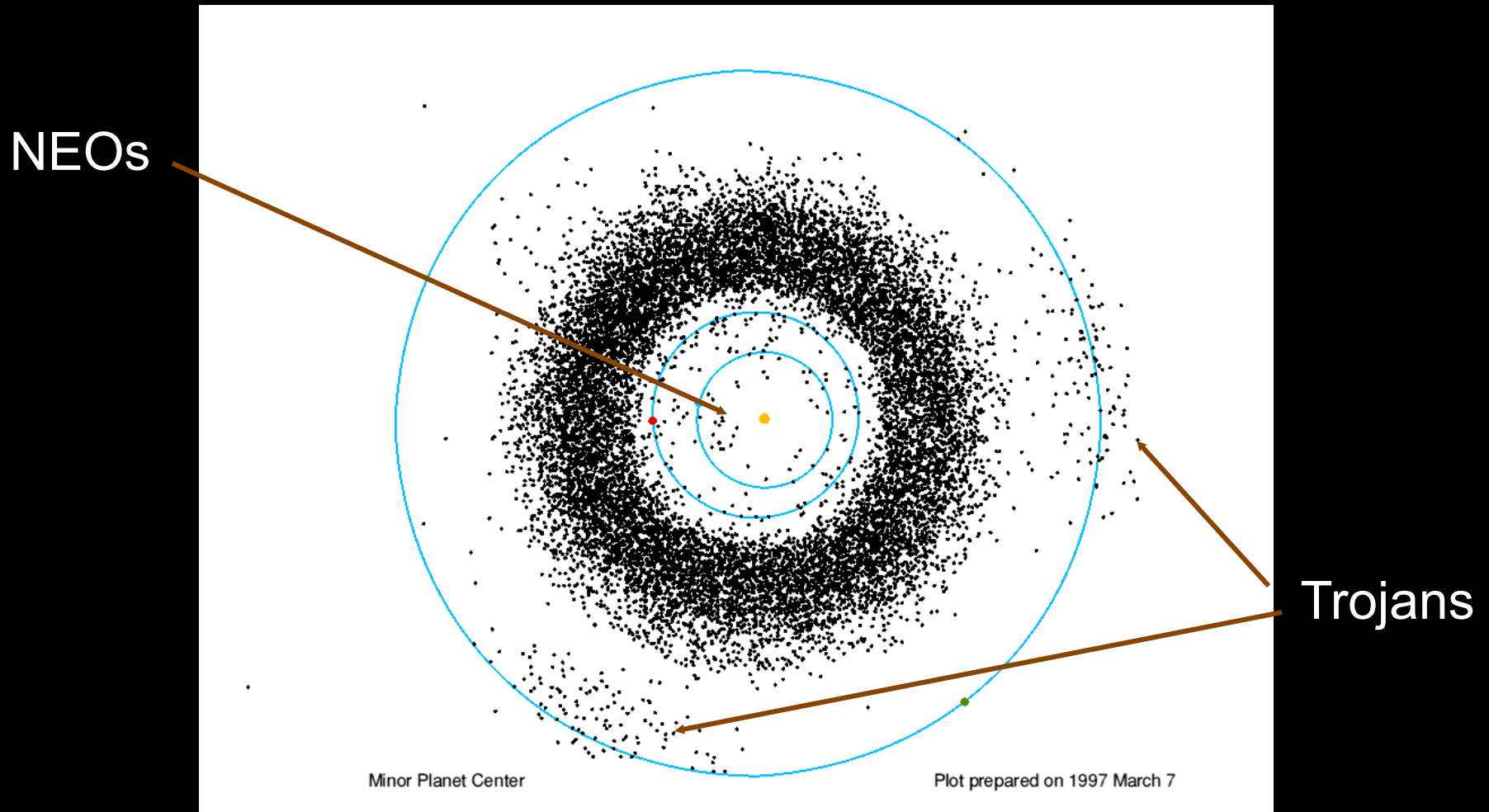
The Asteroid Threat to Earth

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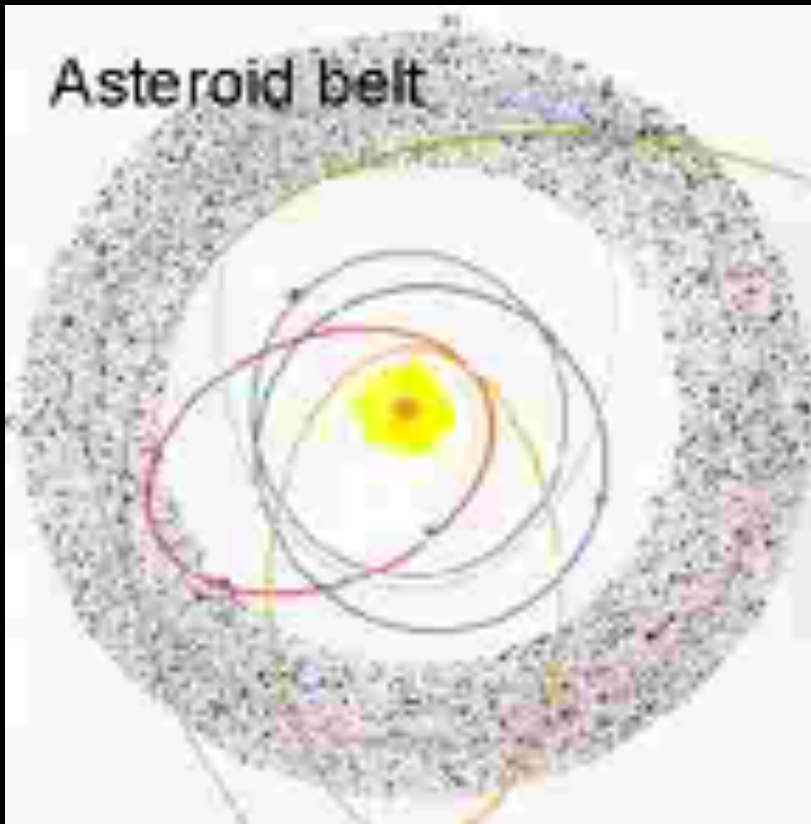
Asteroids in the Inner Solar System



Hollywood's Asteroid Belt



The Real Asteroid Belt

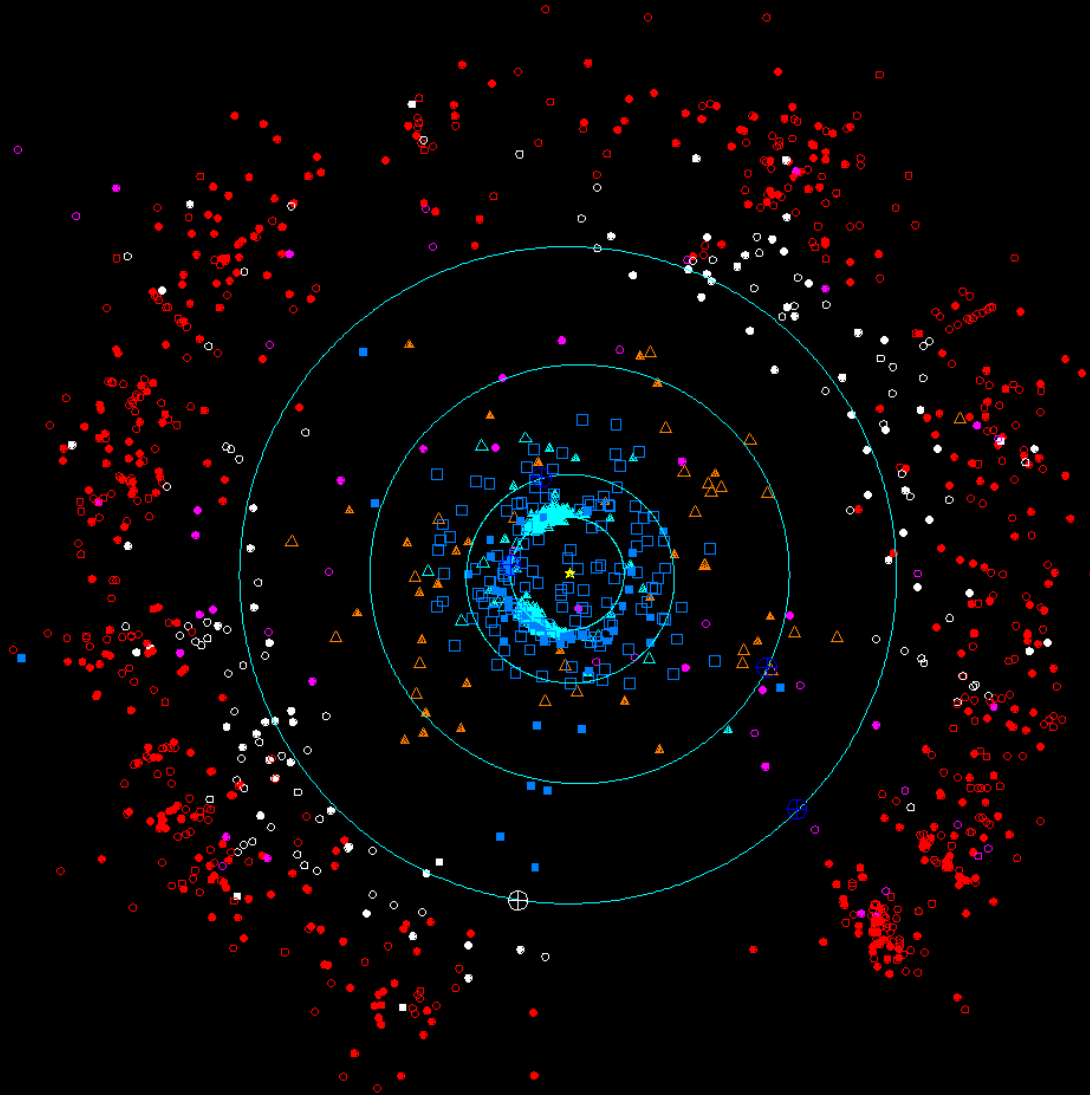


- Many thousands of asteroids...
- Spaced about a million miles apart!

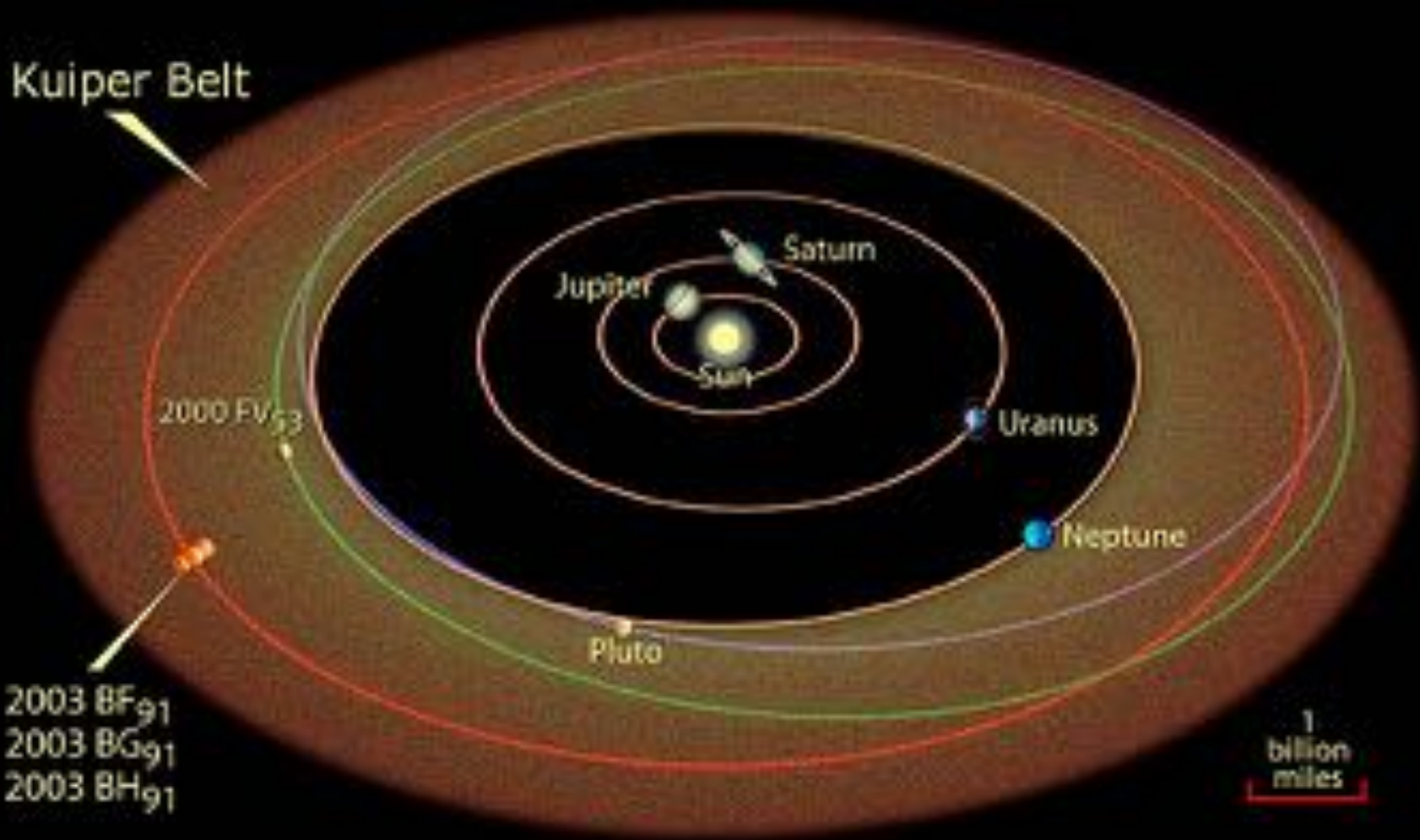


500 million miles

Asteroids in the Outer Solar System



Plot prepared by the Minor Planet Center (2004 Jul 6).



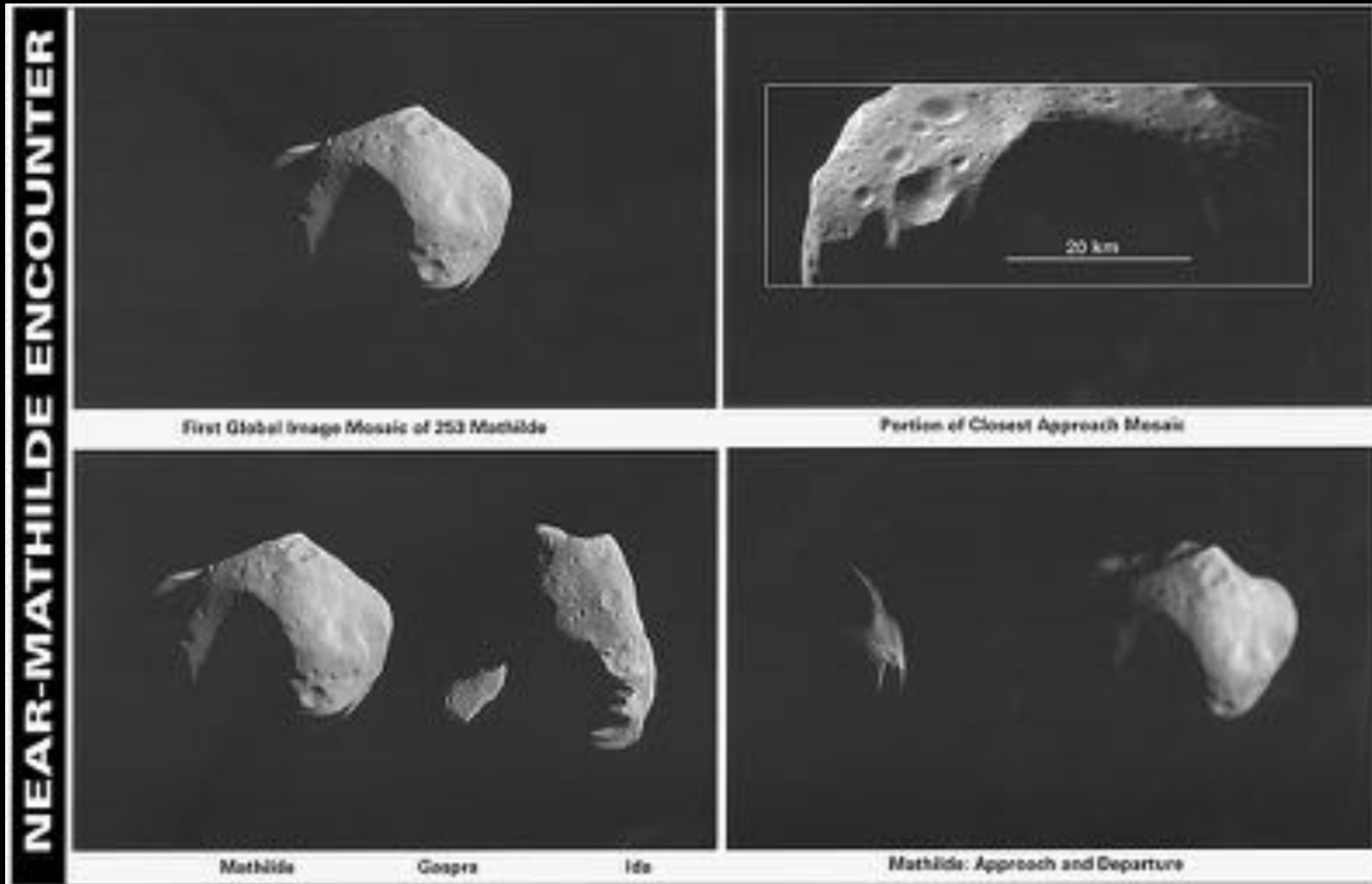
Asteroid Types

- Largest class (40%) are called C-type for carbonaceous. Very dark.
- S-type (stony) (30%). Brighter with albedo~0.15. Contain pyroxen and olivine.
- D and P-types (5-10%) Dark and reddish. Could be very primitive bodies with no proposed meteoritic analog.
- M-type (M=metal). Iron rocks.
- E-type. Enstatite asteroids, near inner edge of belt. Very high albedo.

My Favorite Type...

- U-type. Weird and unclassified.

C Type - Mathilde

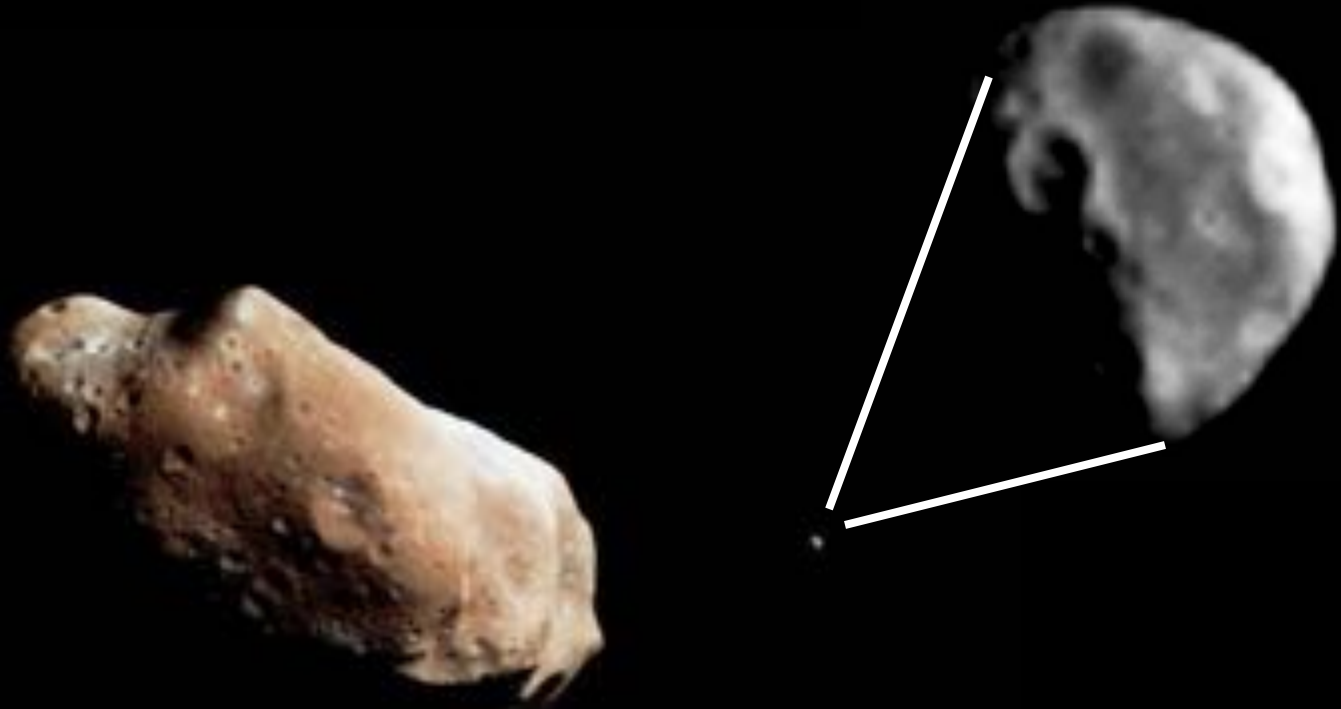


S Type - Gaspra



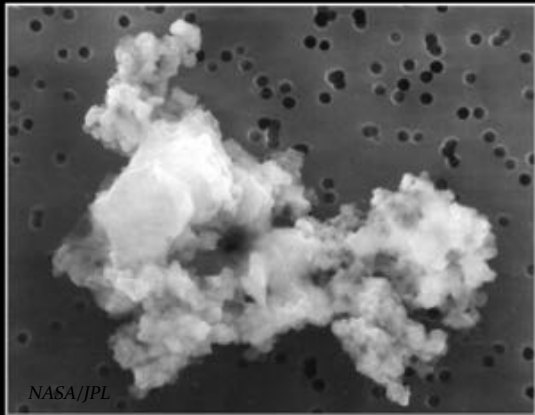
February 12, 2018

Some Asteroids Have Moons!



Ida and Dactyl

Terminology



Meteoroids

- Chunks of rock and ice out in space.
- About the size of a boulder or smaller.
- Smaller than an asteroid (< 1 meter diameter).



Meteors

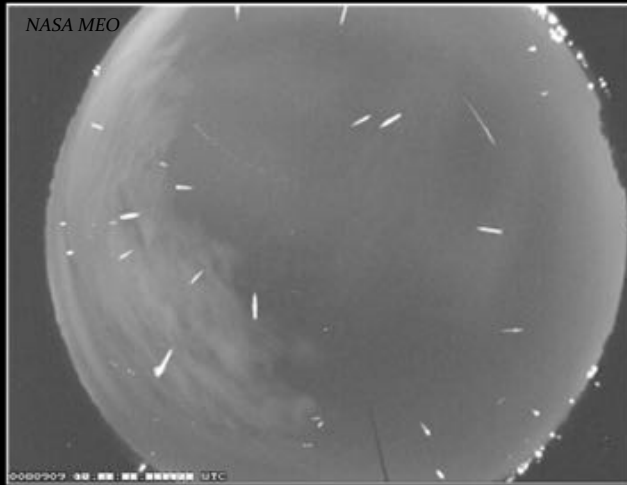
- Streaks of light or ionization produced as a meteoroid *ablates*, or burns up, in the Earth's atmosphere.
- Commonly called a 'shooting star' or 'falling star'.



Meteorites

- What is left of the meteoroid if it survives the trip through the atmosphere and hits the Earth.
- Made of silicate minerals and/or iron-nickel.

Terminology



Fireballs or Bolides

- Bright meteors.
- Peak magnitude brighter than Venus,
 $m_{\text{app}} = -4$.



Superbolides

- VERY bright meteors.
- Peak magnitude brighter than the full Moon,
 $m_{\text{app}} = -17$.

Famous meteorite falls

Peekskill, NY – 1992

Witnessed by
thousands

16 video recordings
during HS football
games

Damage: 12.4 kg
meteorite struck a
Chevy Malibu

Total meteorite mass:
12.5 kg

Type: Ordinary
chondrite, H6

Initial size: 50-100 cm,
2-15 metric tons

Speed: 15 km/s

Peak Mabs: -13



Park Forest, IL – 2003

Hundreds of eye
witnesses

A handful of video
recordings

Damage: 2 houses &
fire station struck by
meteorites

Total meteorite mass:
>18 kg

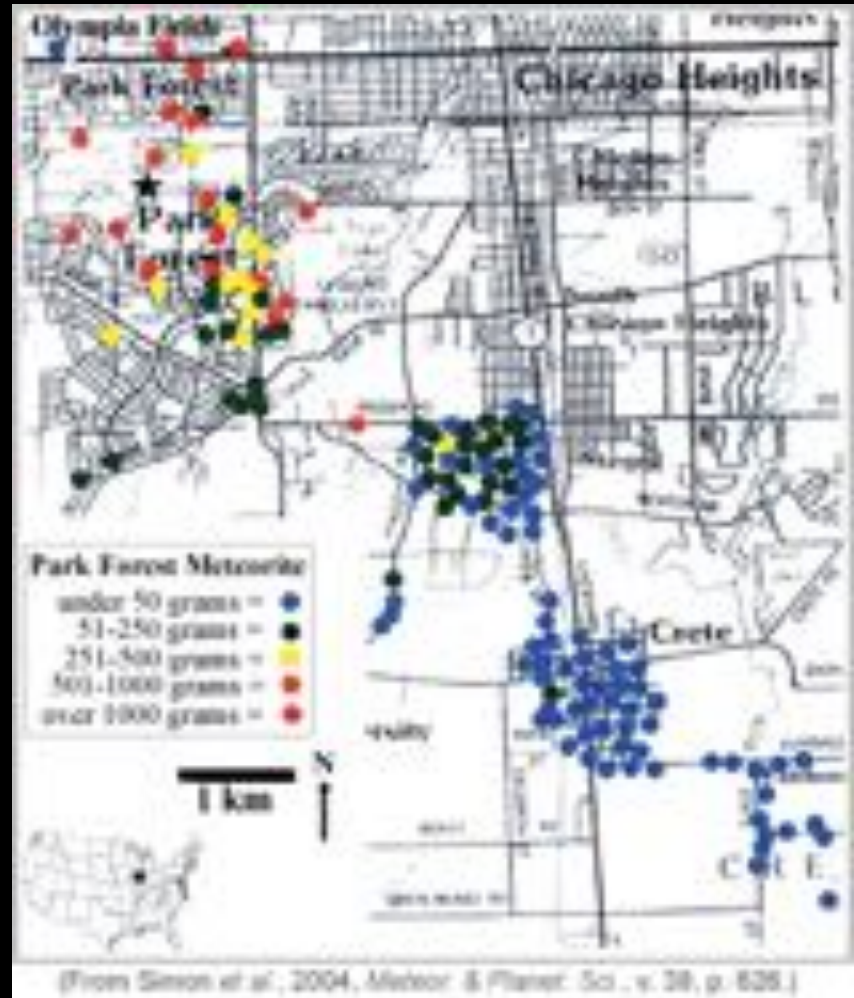
Type: Ordinary
chondrite, L5

Initial size: 1.8 m
(11,000 kg)

Speed: 19 km/s

Peak Mabs: -22







638g individual of Park Forest found by Rich and Larry Atkins

CIVILIZATION II

BY STEPHEN WATTS

KEEP AWAY

CIVILIZATION II

THE COMPLETE HISTORY OF THE WORLD FROM 4000 BC TO THE PRESENT



1988

AMERICAN PAPER

Meteorites hitting humans

- Sylacauga (Hodges) – On November 30, 1954, a 3.9 kg fragment crashed through the roof of a house, ricochet off a big wood radio, and struck Ann Hodges, who was napping on a couch. Her side was badly bruised.
- Tortona, Italy manuscript dated to 1677 states that a Milanese friar was killed by a stone “projected from the clouds.”
- On August 14 1992, a small boy in Mbale, Uganda was struck by a 3g meteorite fragment, which had been first slowed by banana tree leaves. No injury.



Big Rocks in Space – Coming to Your Planet Soon!

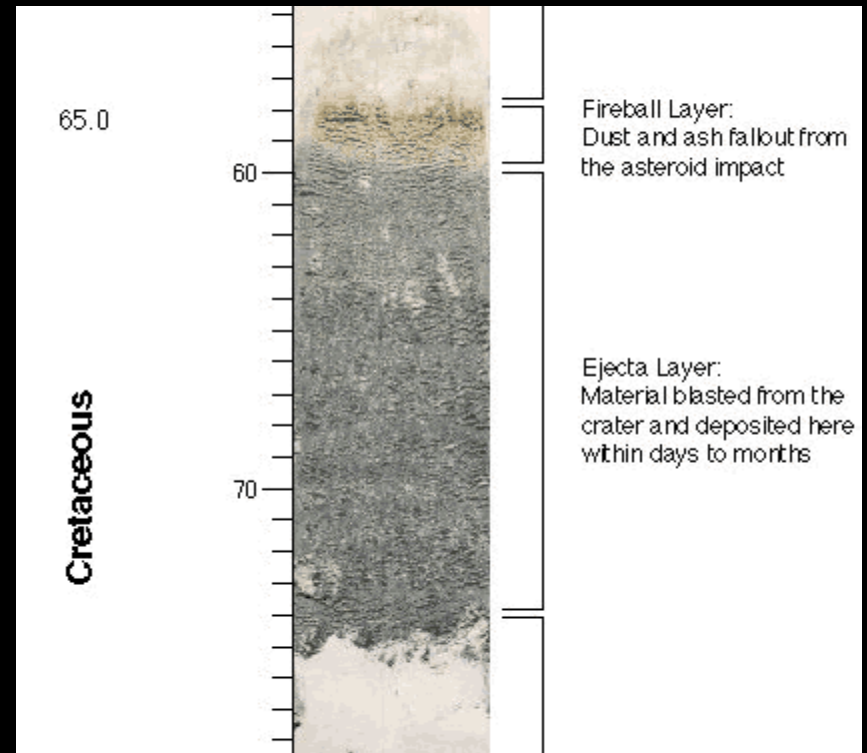


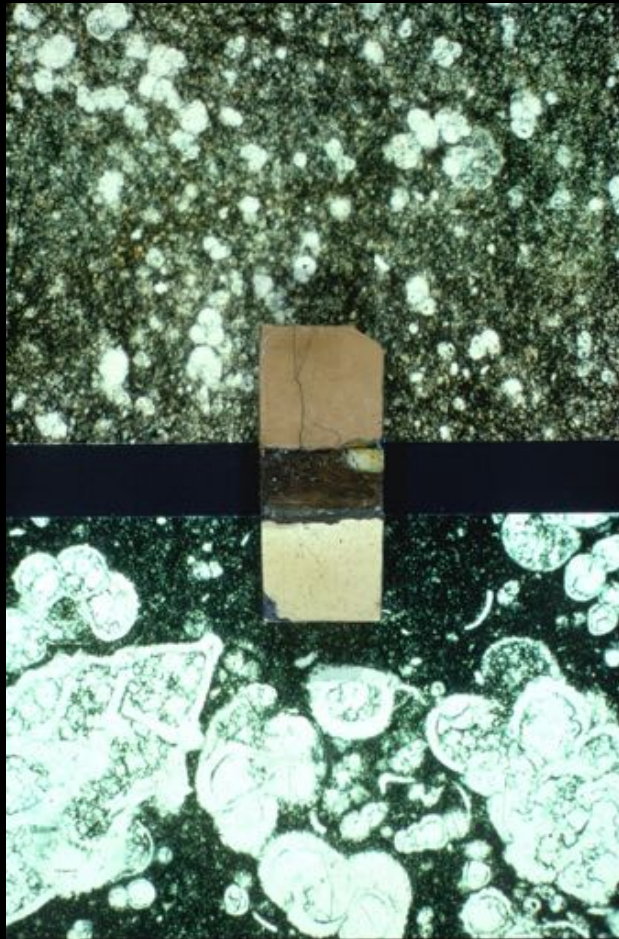
Types of Near Earth Asteroids

- **Atens** – Objects with average distances smaller than that of Earth.
- **Amors** – Objects with average distances between those of Earth and Mars.
- **Apollos** – Objects whose orbits cross that of Earth.
- **Potentially Hazardous Asteroid (PHA)** – Asteroids bigger than 200 meters that approach within 7.5 million miles.

The K-T Event

- Mass extinction at the end of the Cretaceous – 70% of all species went extinct, including the dinosaurs.
- In 1980, Walter Alvarez hypothesized that an impact might be responsible. Extra-terrestrial abundance of Iridium found in core samples.





Marine fossils after K-T

K-T boundary

Marine fossils before K-T

- Impactor was at least 10 km in diameter.
- Crater identified in Yucatan (1990) – Chicxulub, a 180 km ring structure.
- Worst possible place to hit – shallow sea of continental shelf.



Barringer Crater, Arizona



Tunguska

- June 30, 1908 –
7:17 AM local time,
60 km S of
Tunguska:

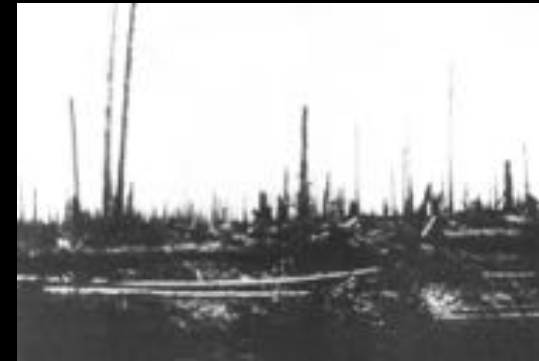
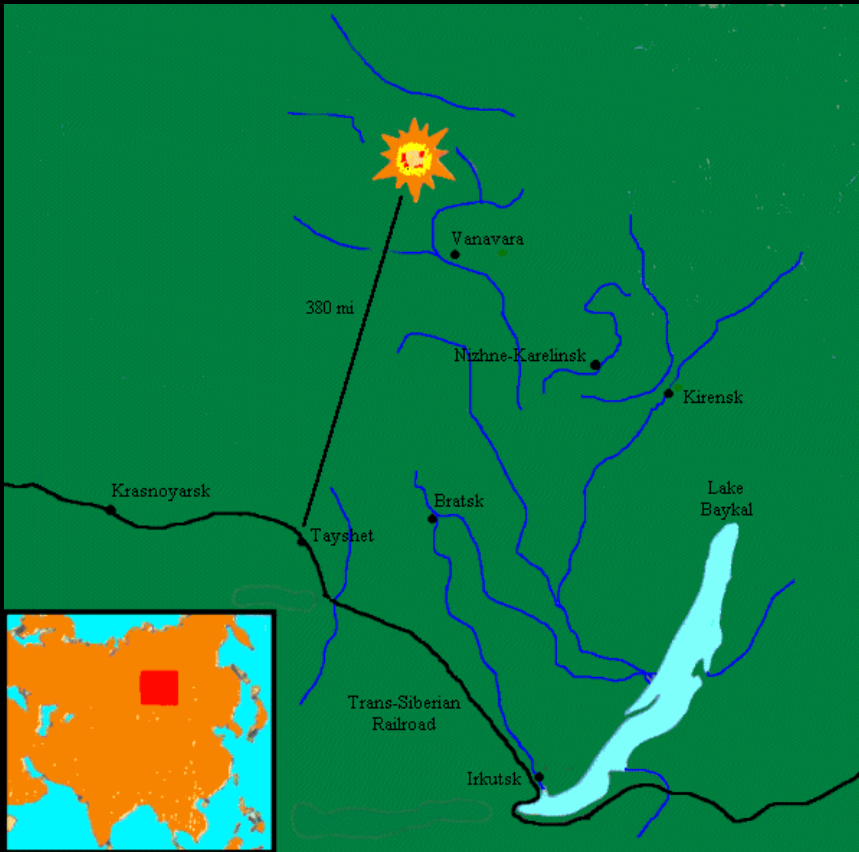


"I was sitting on the porch of the house at the trading station, looking north. Suddenly in the north...the sky was split in two, and high above the forest the whole northern part of the sky appeared covered with fire. I felt a great heat, as if my shirt had caught fire... At that moment there was a bang in the sky, and a mighty crash... I was thrown twenty feet from the porch and lost consciousness for a moment.... The crash was followed by a noise like stones falling from the sky, or guns firing. The earth trembled.... At the moment when the sky opened, a hot wind, as if from a cannon, blew past the huts from the north. It damaged the onion plants. Later, we found that many panes in the windows had been blown out and the iron hasp in the barn door had been broken."

- Small asteroid 50-60 meters in diameter vaporized at an altitude of about 6 km.
- Resultant explosion equivalent to 5-15 megaton airburst – at perfect altitude for maximum damage on ground.



- 800 square miles devastated.
- Some injuries, but no fatalities due to sparse population of Siberia





Tunguska in 1938 Aerial Survey



**And then came 9:20 AM on February 15,
2013**







Play

15.02.2019 17:22:56



Damage



Over 4000 buildings
damaged



11



Over 1600 people
injured by glass
& debris



AP Photo / Boris Kaulin



©RIA Novosti / Pavel Lisitsyn

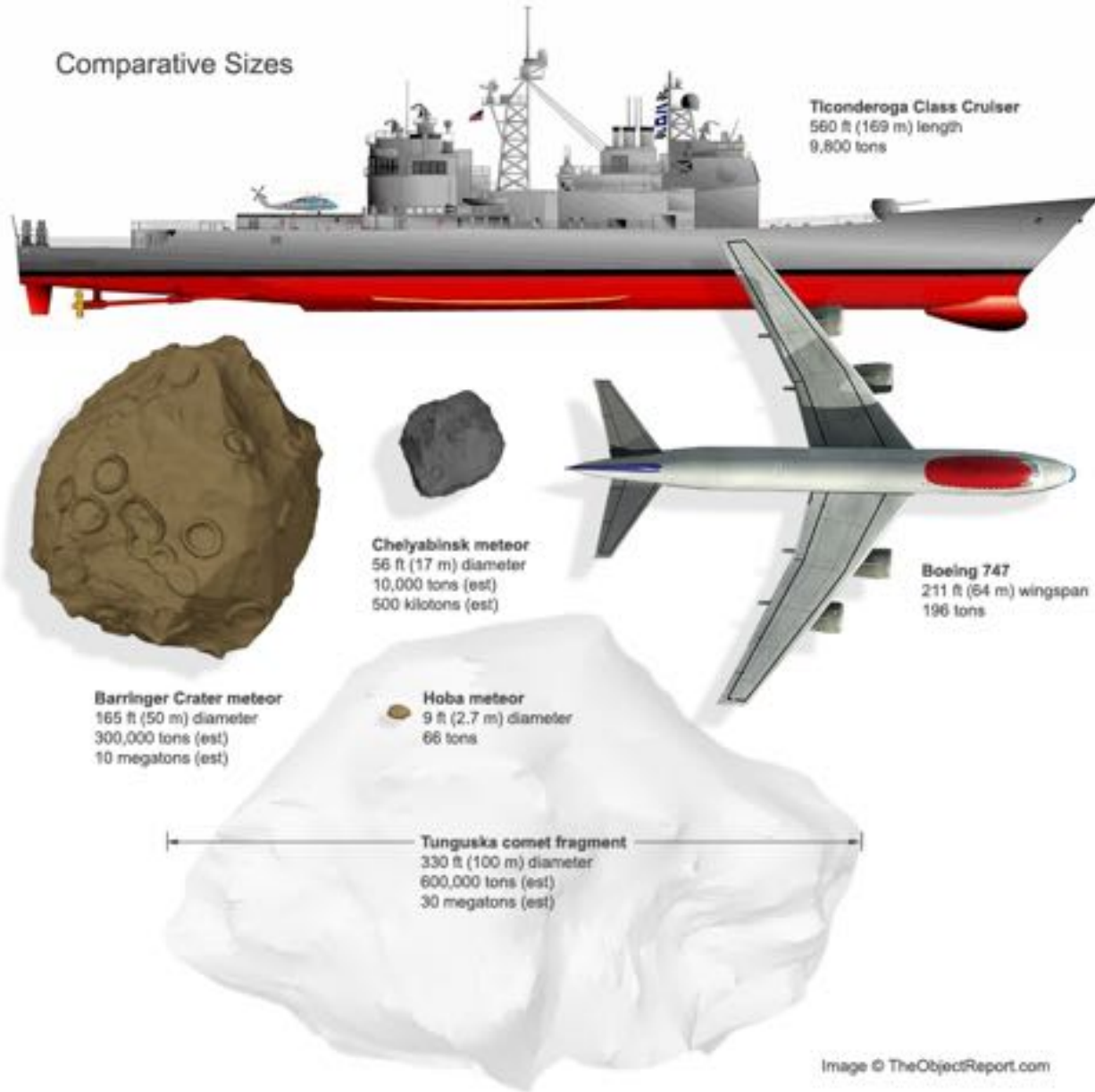


If you see the flash, duck and cover!

Chelyabinsk Properties

Energy	470 kilotons at altitude of 30 km (19 miles) near Chelyabinsk (54.8° N, 61.1° E)
Speed	18 km/s (40,300 mph)
Mass/size	~12,000 tons 20 m (66 ft)
Composition	Ordinary chondrite (LL5)

Comparative Sizes



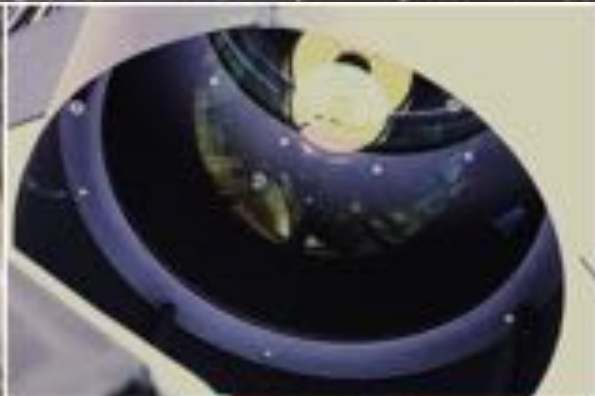
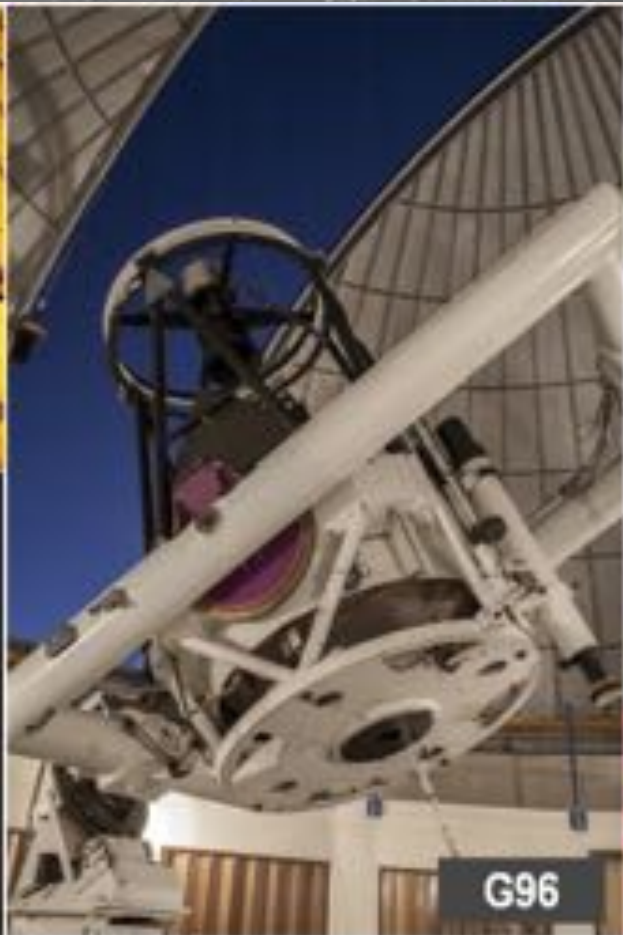
Keeping an eye on big rocks

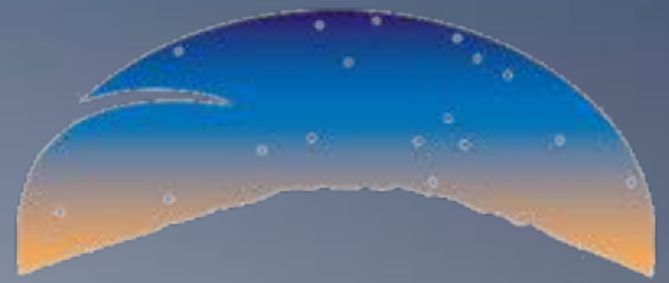
- Spaceguard survey tasked NASA to find 90% of near-Earth objects (NEOs) greater than 1 km in diameter within 10 years (1998-2008).
 - ◆ Completed - >90% found
- Brown NEO survey – find 90% of 140 m diameter NEOs within 15 years (2005-2020).
 - ◆ 140 meters is near limit of atmospheric protection
 - ◆ Probably won't meet deadline – too few resources
- Chelyabinsk shifted focus to even smaller objects (20-50 m diameter “city killers”), as these occur roughly once or twice in a human lifetime.



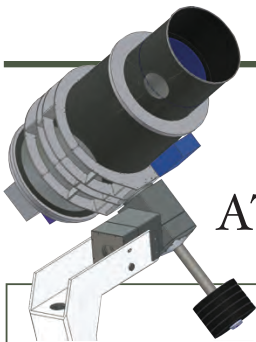
Catalina Sky Survey

ABOUT US »



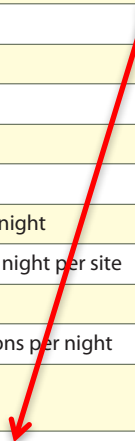


Pan-STARRS



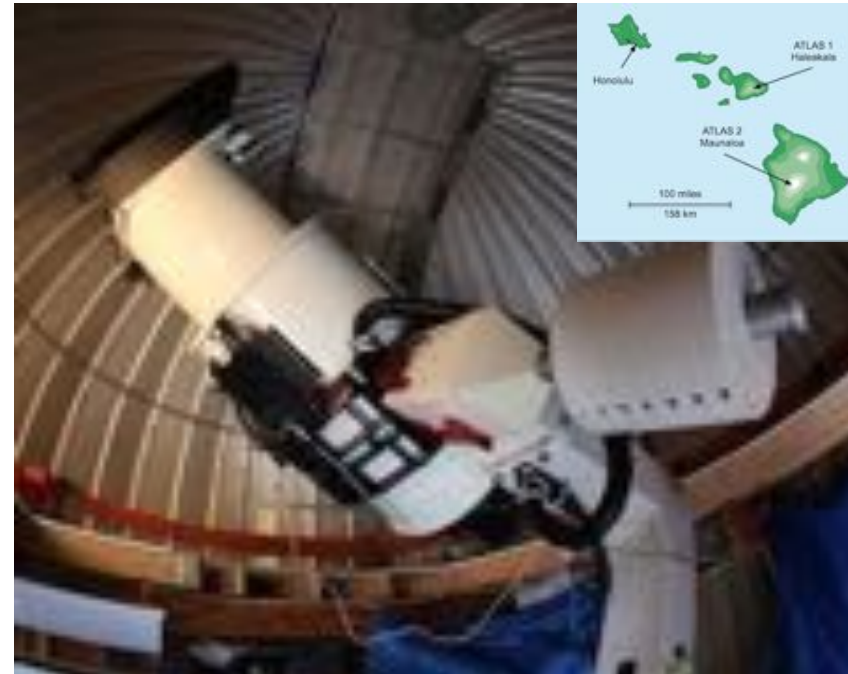
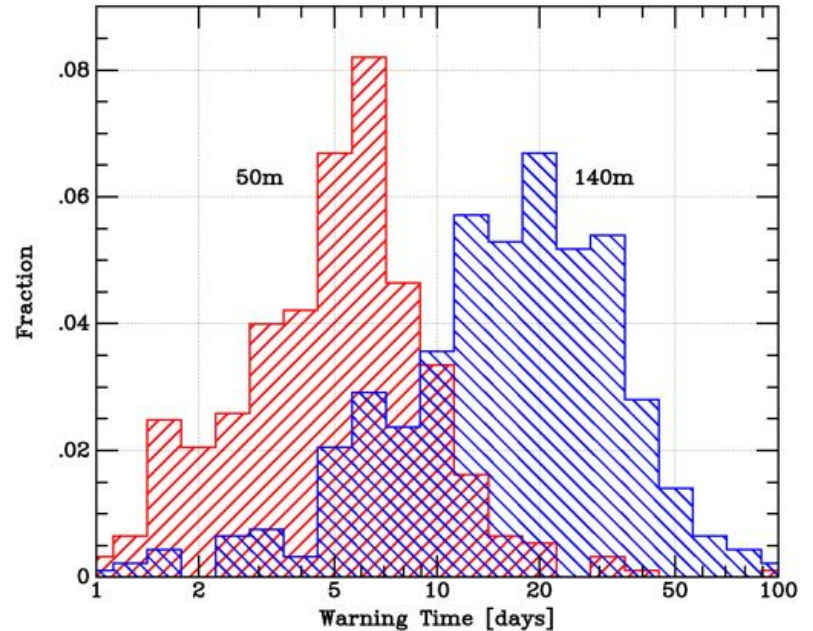
ATLAS Technical Specifications

Number of observatories	Initially 2, goal 6 or more
Site separation	100 miles (160 km)
Telescope field of view	7.4°
Detector	10.5k x 10.5k CCD
Pixel scale	1.86"
Nominal exposure time	30 seconds
Sensitivity	Magnitude 20
Time between revisits each night	About 1 hour
Total number of images per night per site	1000
Total data rate per site	150 GB per night
Number of asteroid detections per night	Up to 25,000 asteroids
Impact warning time	About a week for 50 meter diameter impactor About a month for 140 meter diameter impactor

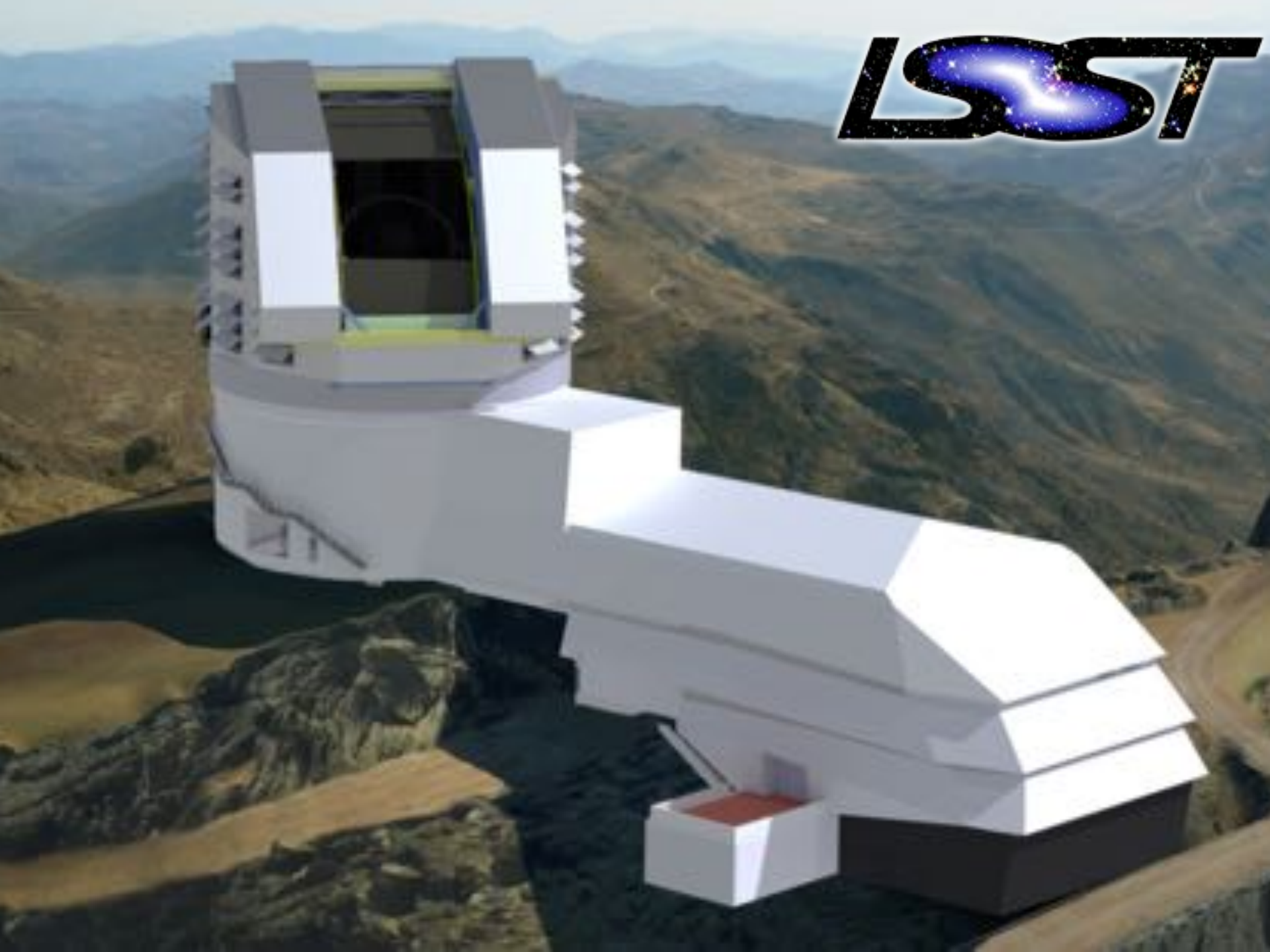


Can scan entire sky visible from Hawaii in 700 pointings

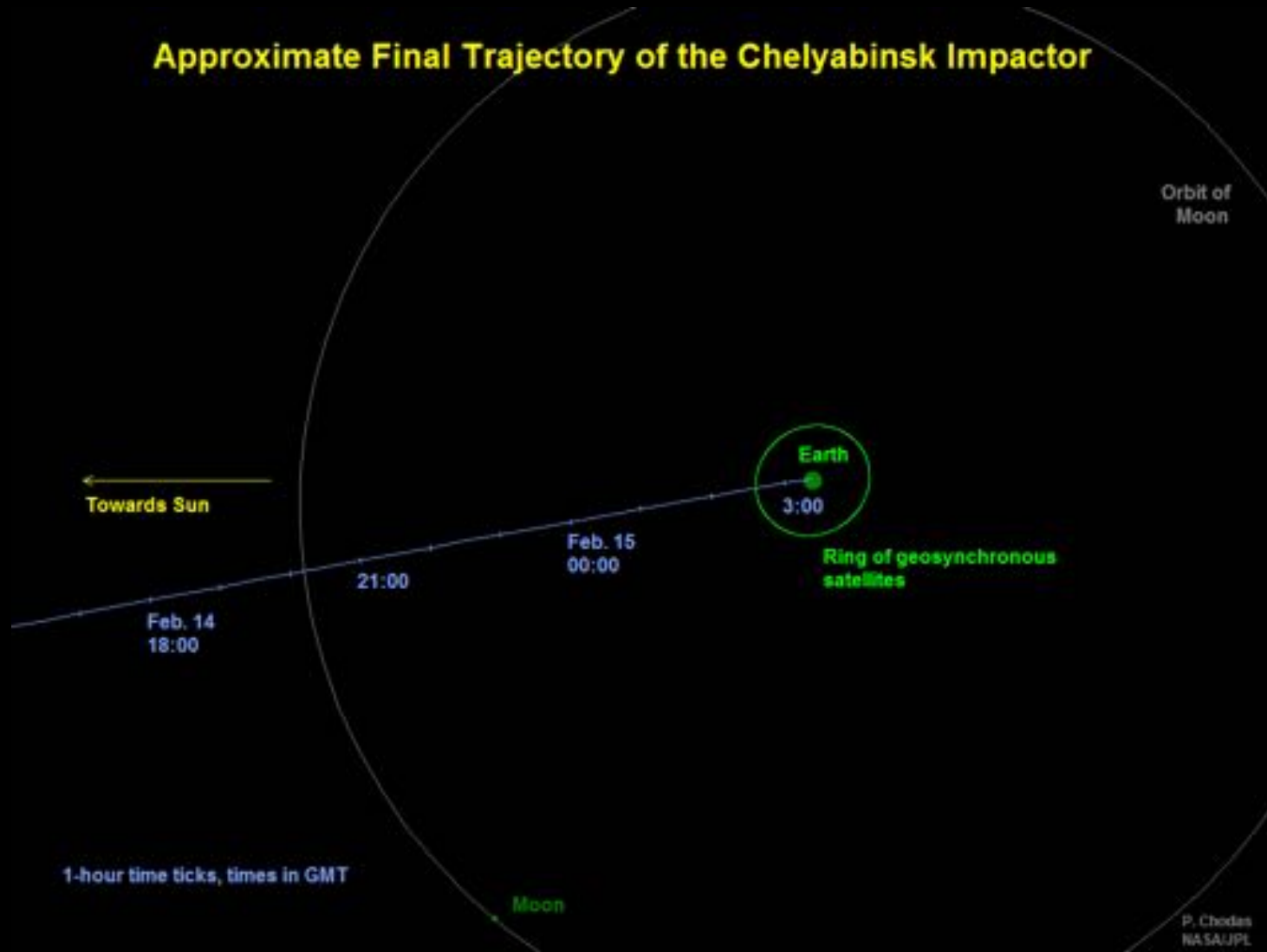
At 30 sec per exposure, can do this 2x per night



LSST



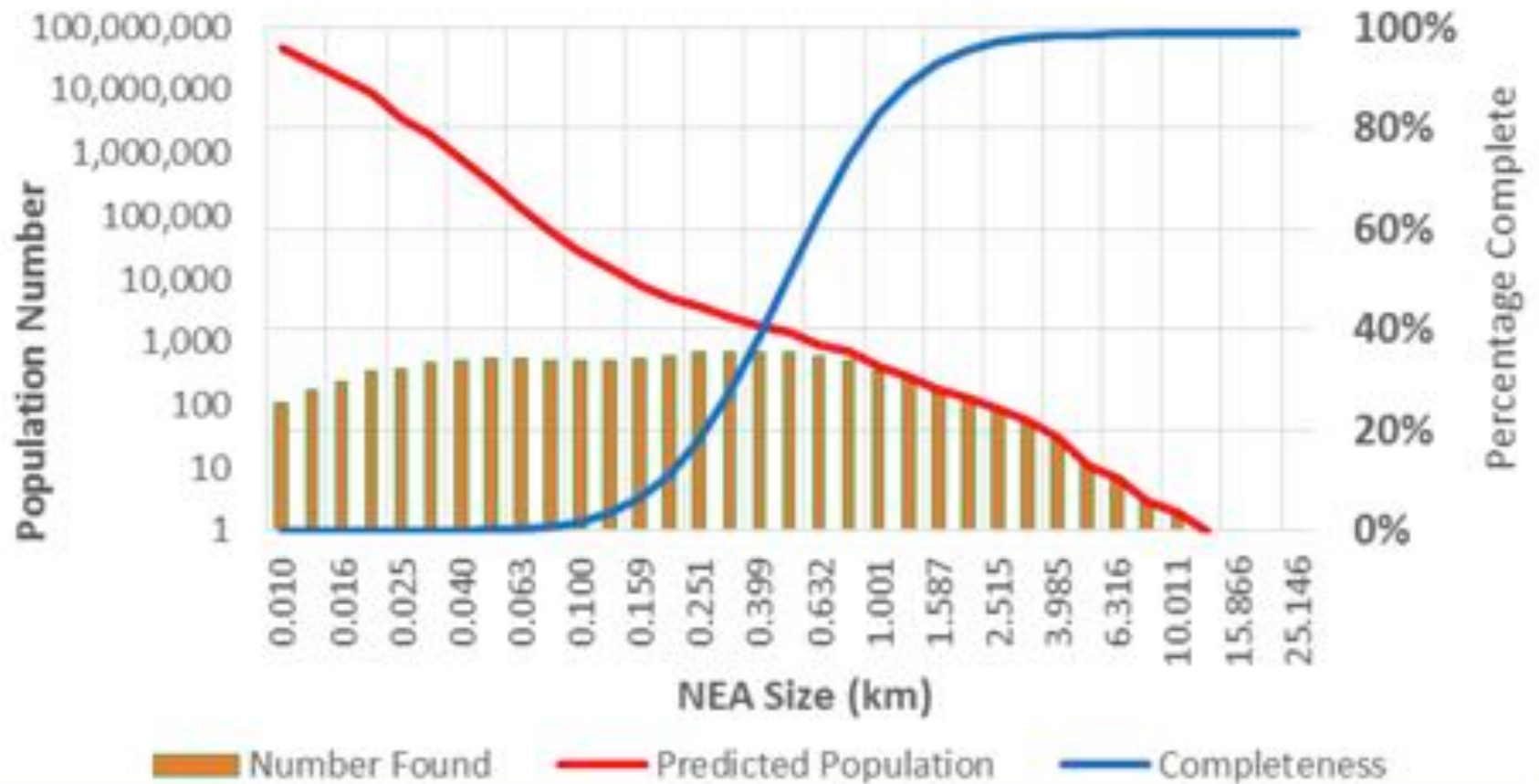
We can't see close to the Sun

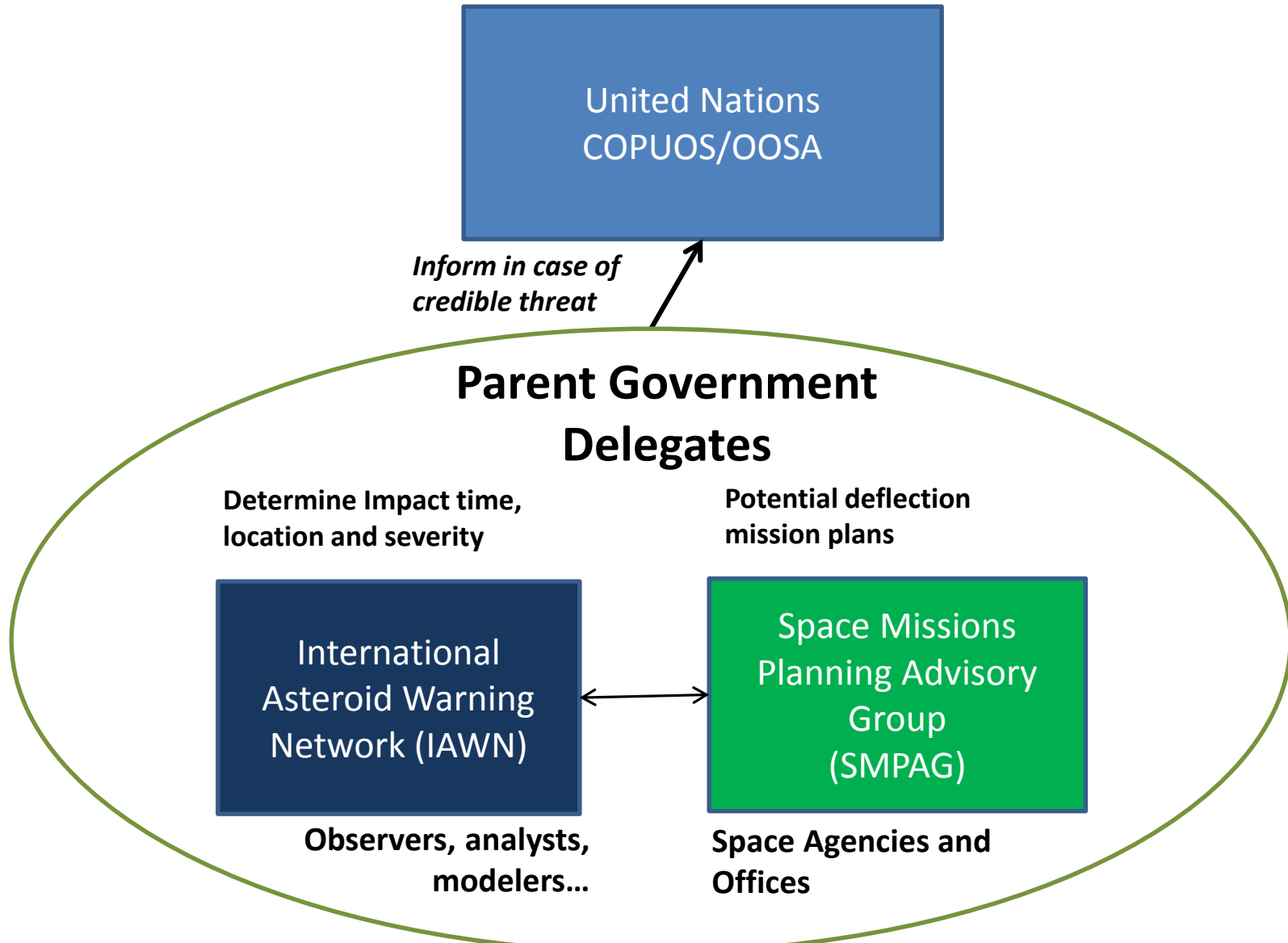




Near Earth Asteroid Survey Status

NEA SURVEY COMPLETENESS





*<http://www.oosa.unvienna.org/oosa/en/COPUOS/stsc/wgneo/index.html>

Purpose of IWAN

- Maintain, support, and enhance existing ground-based observation facilities that currently perform discovery and physical characterization of NEOs
- Develop international rapid all-sky search capacity, geared towards discovering small, imminent impactors
- Build ground-based facilities to globally survey larger areas of sky to fainter magnitudes
- Develop a well-positioned space-based infrared survey to discover objects much faster than the current rate
- Establish an international communication policy and procedures regarding close approaches and impact risks
- Coordinated by a steering committee
- Formally established by the UN in December of 2013

Existing Worldwide Observing Network



In 2014

Received ~15 Million Observations from 239 Observatories in 31 countries
(and one in space!)

IAWN status, Feb 2015, L. Johnson

SMPAG

- The purpose of the SMPAG is to prepare for an international response to a NEO impact threat through the exchange of information, development of options for collaborative research and mission opportunities and NEO threat mitigation planning activities.
- Formally established in February 2014; Terms of reference finalized in June 2014
- ESA current chair
- Membership is open to all national space agencies or governmental or inter-governmental entities that coordinate and fund space activities and are capable of contribution to or carrying out a space based NEO mitigation campaign (Must be nominated and voted upon by SMPAG)
- Each member must provide own funds for SMPAG work

● Current members of SMPAG are:

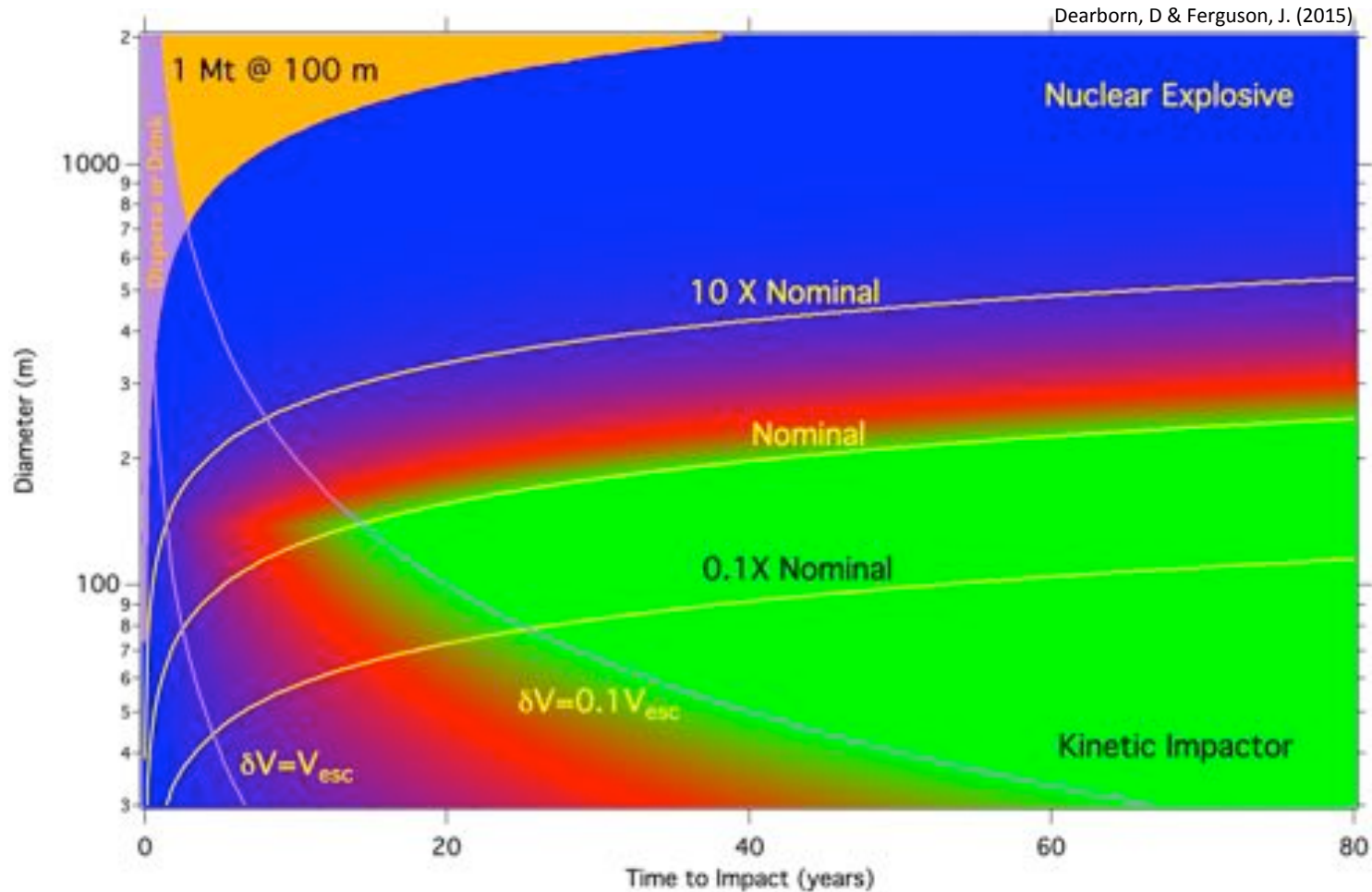
- AEM (Mexico)
- ASI (Italy)
- Belspo (Belgium)
- CNES (France)
- DLR (Germany)
- ESA
- ISA (Israel)
- JAXA (Japan)
- KASI (Republic of Korea)
- NASA (USA)
- ROSA (Romania)
- ROSCOSMOS (Russian Federation)
- SSAU (Ukraine)
- SUPARCO (Pakistan)
- UKSA (UK)
- IAWN (ex officio)

U.S. Policy:

**If larger than 50 m, deflect;
otherwise evacuate impact zone**

50 meter diameter object has an
impact energy of ~10 megatons

Hit it or Nuke it?



10 ton impactor at 20 km/s

- “Physics package” detonated some distance away from asteroid surface
- Deposited energy ablates fraction of surface
- Debris, gas, etc. ejected from asteroid provide impulse, deflecting object



Possible Impact Locations



EXERCISE



QUESTIONS?