

Collisions in Space: The Threat of Asteroid Impacts

Dr. Melissa N. Hayes-Gehrke
Astronomy Dept.
University of Maryland

Mid-Atlantic Senior Physicists
Group
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Chelyabinsk meteor, Feb. 15, 2013



Image from asterisk.apod.com/viewtopic.php?t=30724

Talk Outline

- What we've learned from past impacts
- Which asteroids pose an impact threat?
- What could we do to stop an impact?

Comet Shoemaker-Levy 9
impact sites on Jupiter, 1994

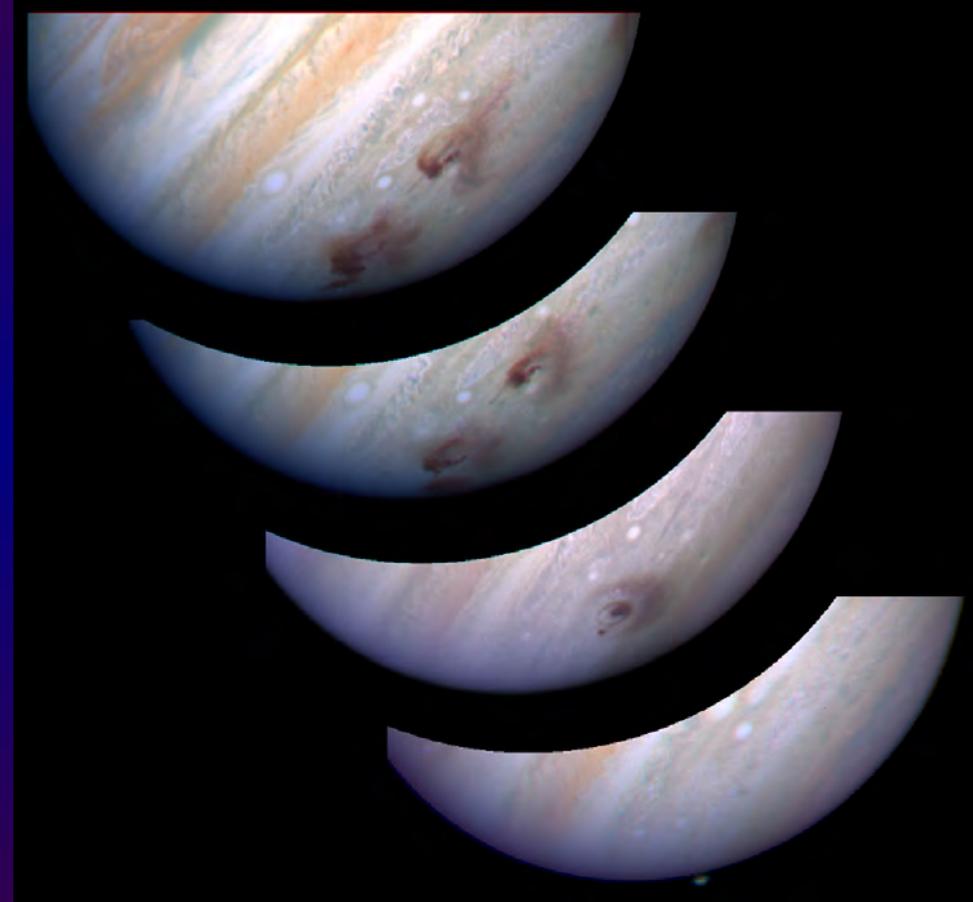


Image by JPL/NASA/STScI

What We've Learned from Past Impacts

- Meteor Crater
- Tunguska
- K-T Impact
- Shoemaker-Levy 9
- Chelyabinsk

Meteor Crater



Image copyright M.N. Hayes-Gehrke

About 50,000 years ago, a 50-m metallic asteroid impacted the surface in Arizona at about 12 km/s, creating Meteor Crater.



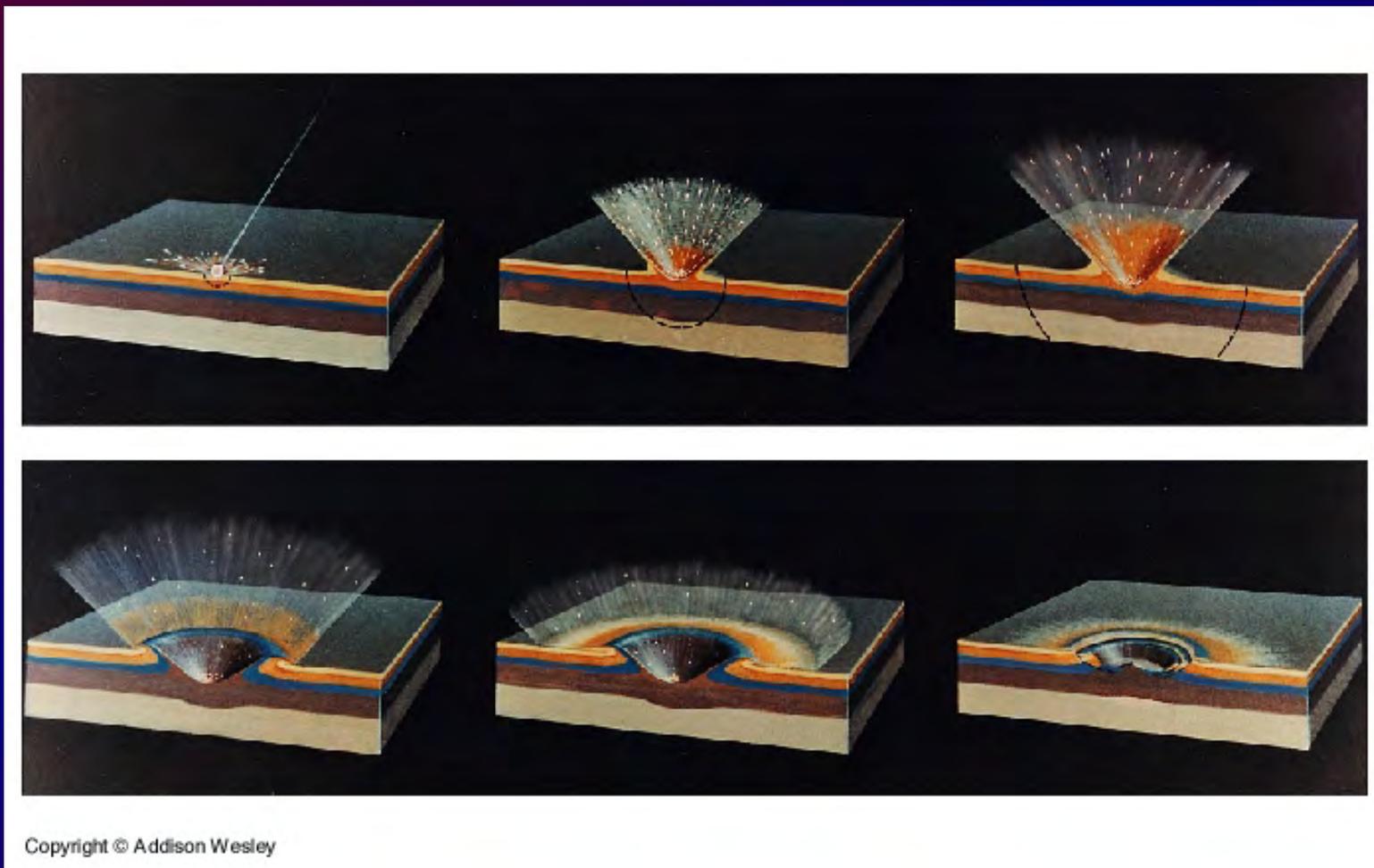
Approx.
1.5 km
across,
175 m
deep

Image by D. Roddy

From late 1800s to mid-1900s,
Meteor Crater's impact origin was
debated.



By studying Meteor Crater, scientists have learned the basics of crater formation.



In 1908, a 40-m meteoroid entered the Earth's atmosphere over Tunguska, Siberia, and was visible as a bright fireball.



artist's
conception

Image copyright William K. Hartmann

It entered the Earth's atmosphere at 15 km/s and fragmented explosively 8 km above the surface.



artist's
conception

The airburst created a huge fireball and shockwave, which flattened 2200 km² and ignited a huge forest fire.

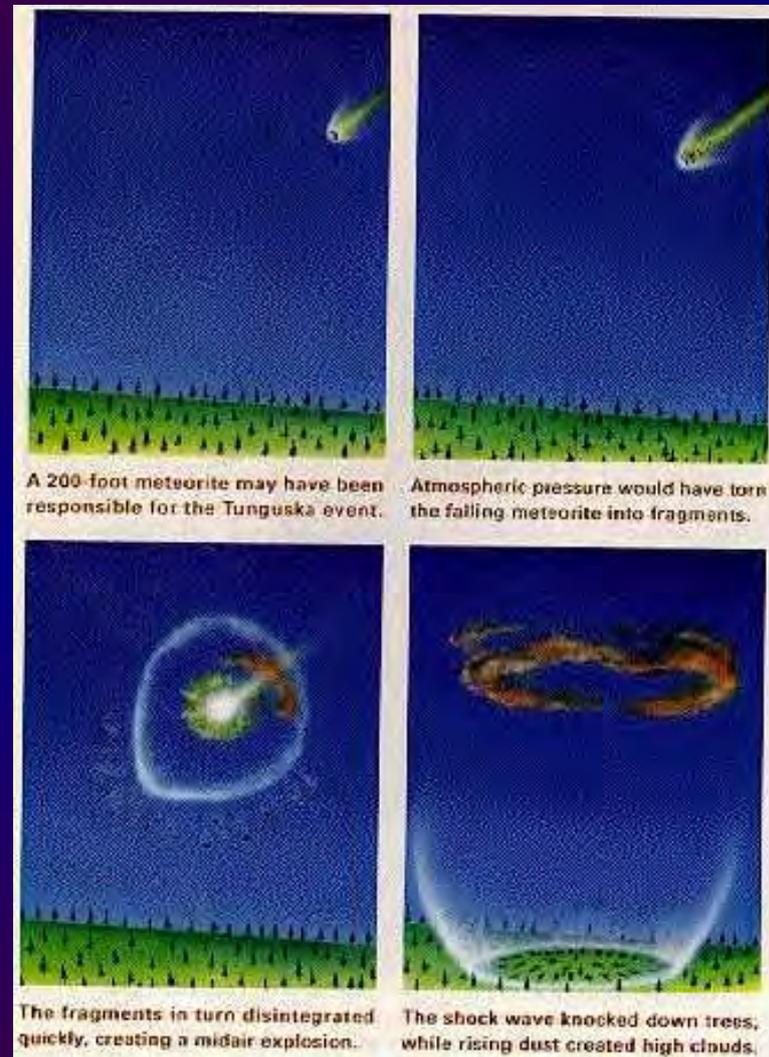


Image from
<http://members.aol.com/mrb26/>

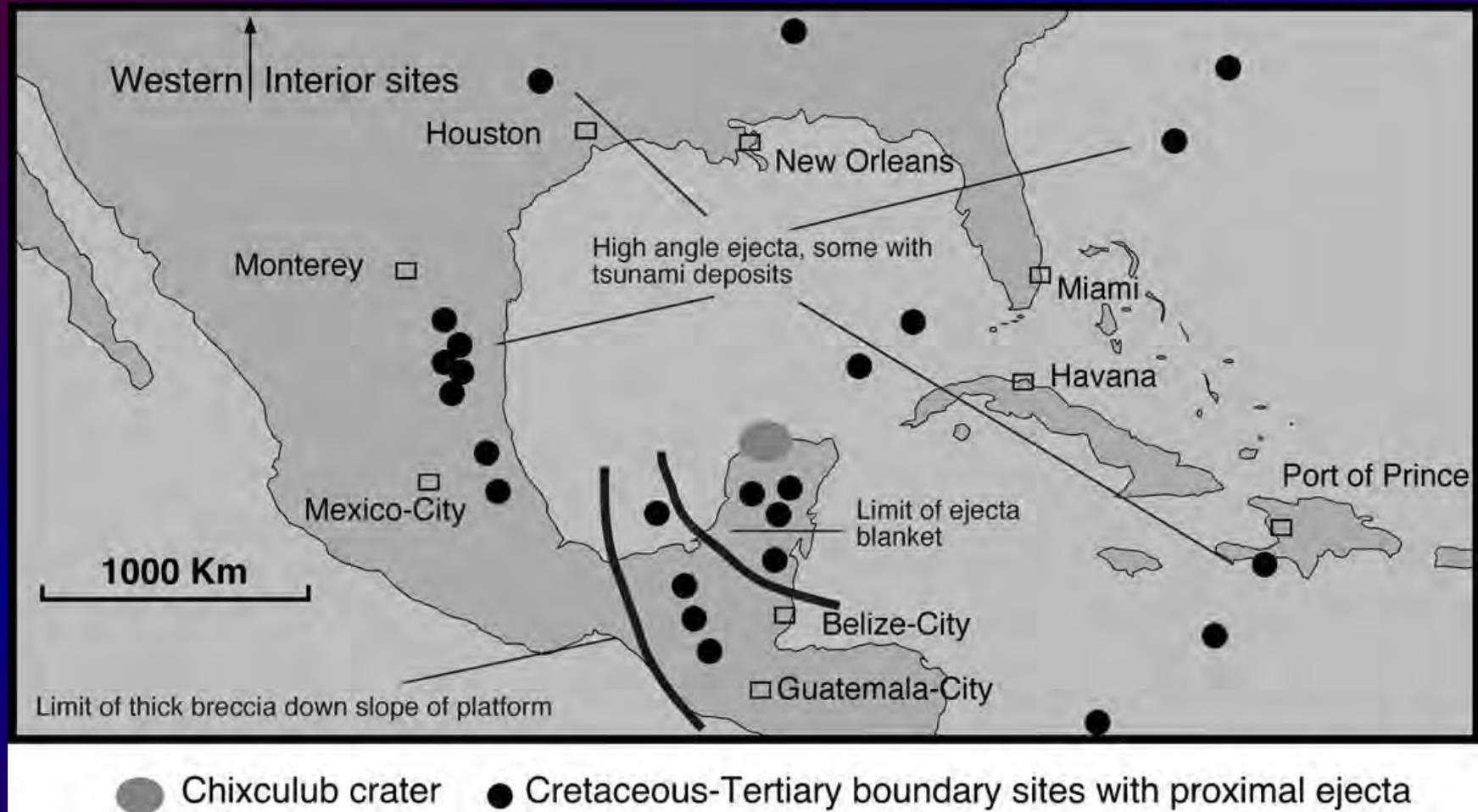
By studying the Tunguska event, scientists learned that an impactor does not have to hit the surface in order to be destructive.



felled trees
photographed by
Leonid Kulik,
1927

Image from Tunguska Page of Bologna Univ, <http://www-th.bo.infn.it/tunguska/>

About 65 MY ago, an asteroid hit the Earth's surface on the Yucatan peninsula at 50 km/s in what has been named the K-T impact.



The 10 km asteroid created in impact crater about 170 km across.

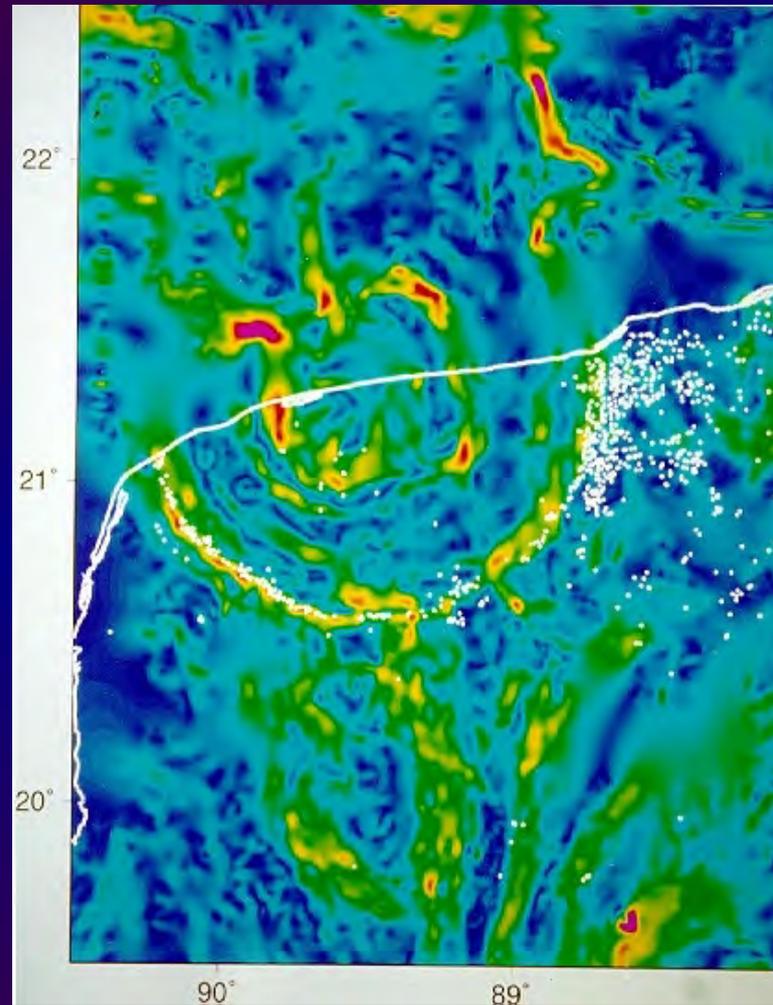
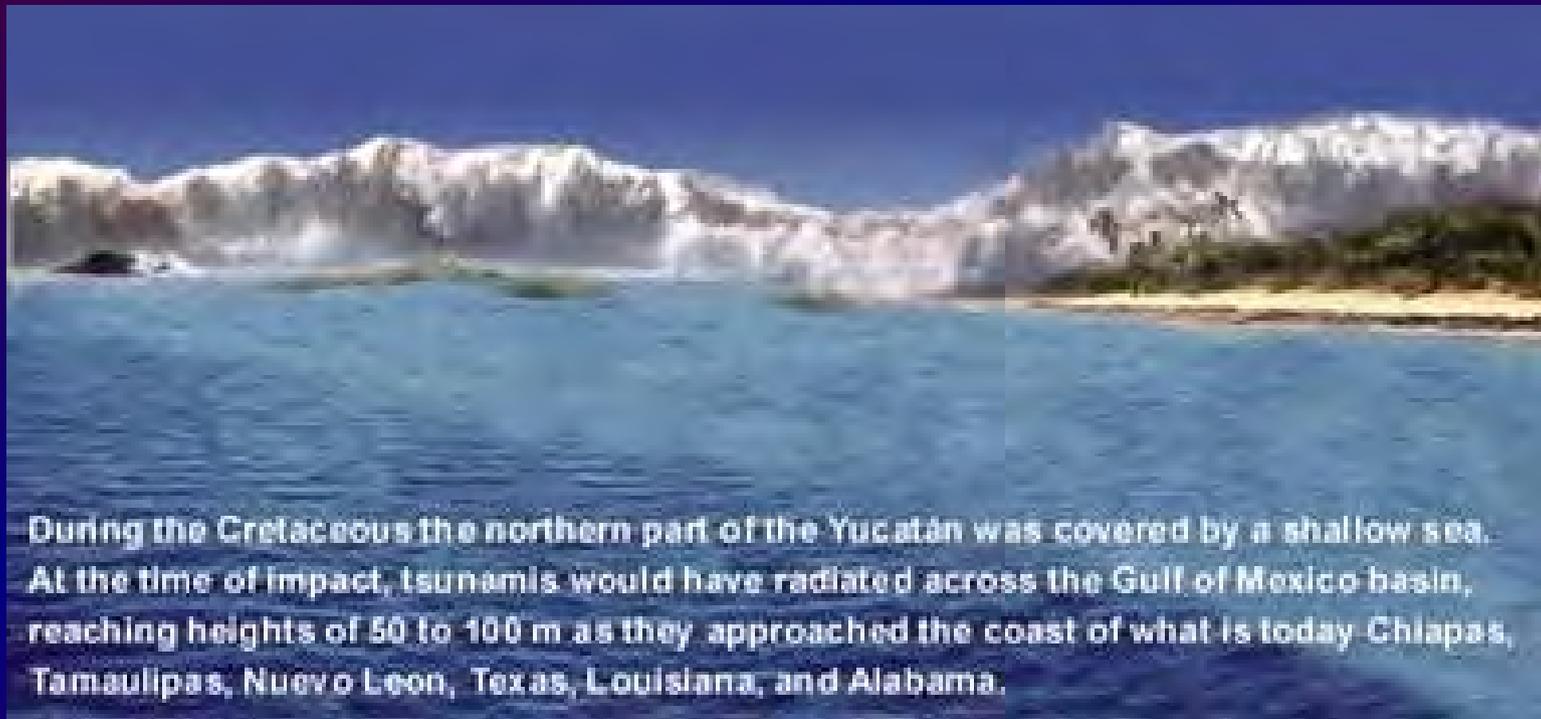


Image from Geological Survey of Canada

The heat and shockwave of the impact caused damage for thousands of miles, plus an earthquake, tsunamis and firestorm.



During the Cretaceous the northern part of the Yucatán was covered by a shallow sea. At the time of impact, tsunamis would have radiated across the Gulf of Mexico basin, reaching heights of 50 to 100 m as they approached the coast of what is today Chiapas, Tamaulipas, Nuevo Leon, Texas, Louisiana, and Alabama.

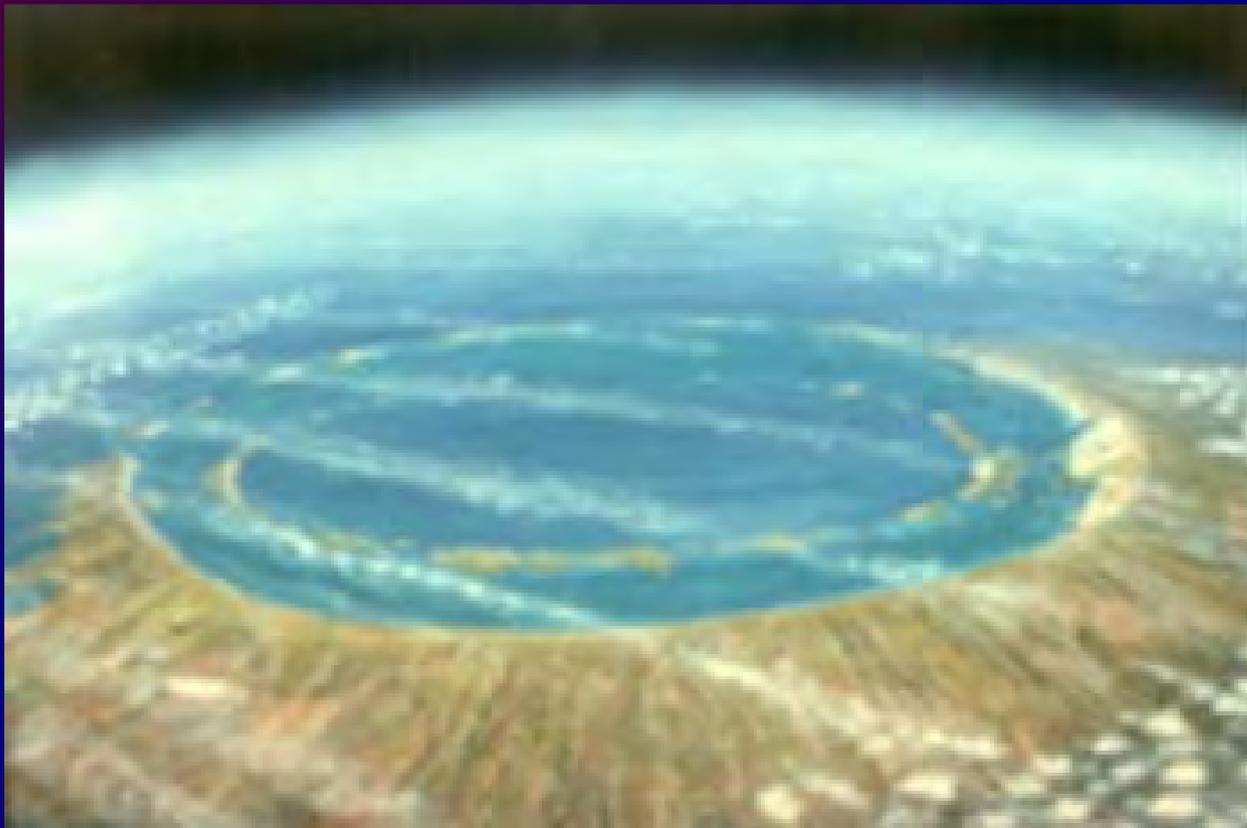
artist's
con-
ception
of
100 m
tsunami

Climate change caused by dust, soot, and gases ejected into the air caused the extinction of 50% of all plant and animal species, including the dinosaurs.



gray layer is
K-T
boundary near
Trinidad, CO

By studying the K-T impact, scientists have learned about the world-wide effects of a large impact.



artist's conception
of Chicxulub
crater after
1000 yrs

Image by William K. Hartmann

In July 1994, about two dozen pieces of the broken-up Comet Shoemaker-Levy 9 impacted Jupiter.

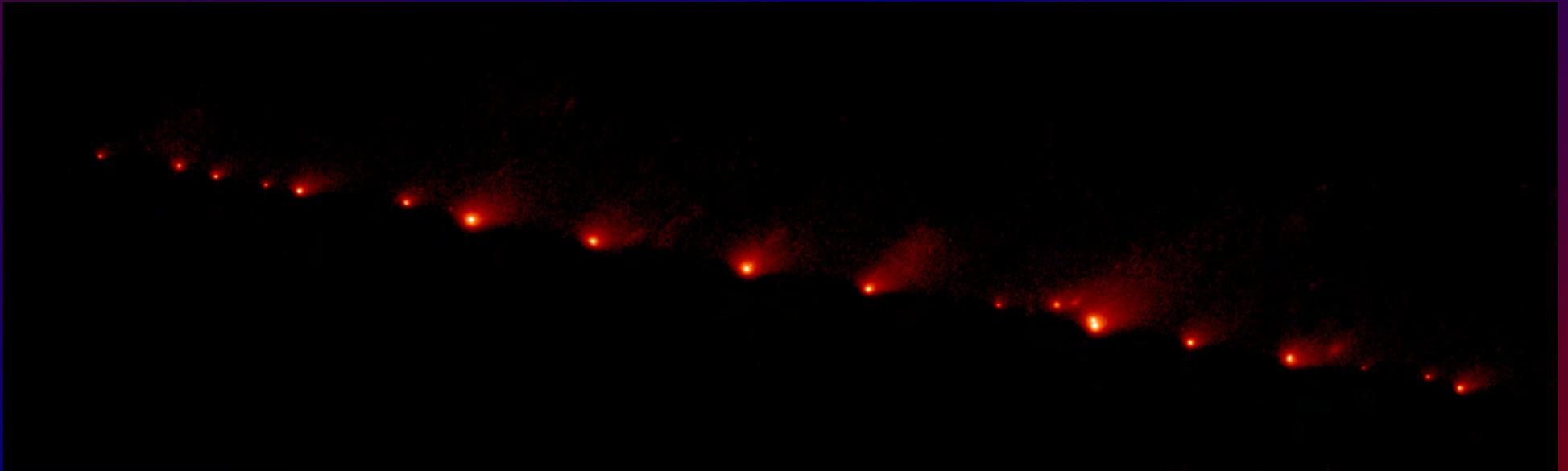
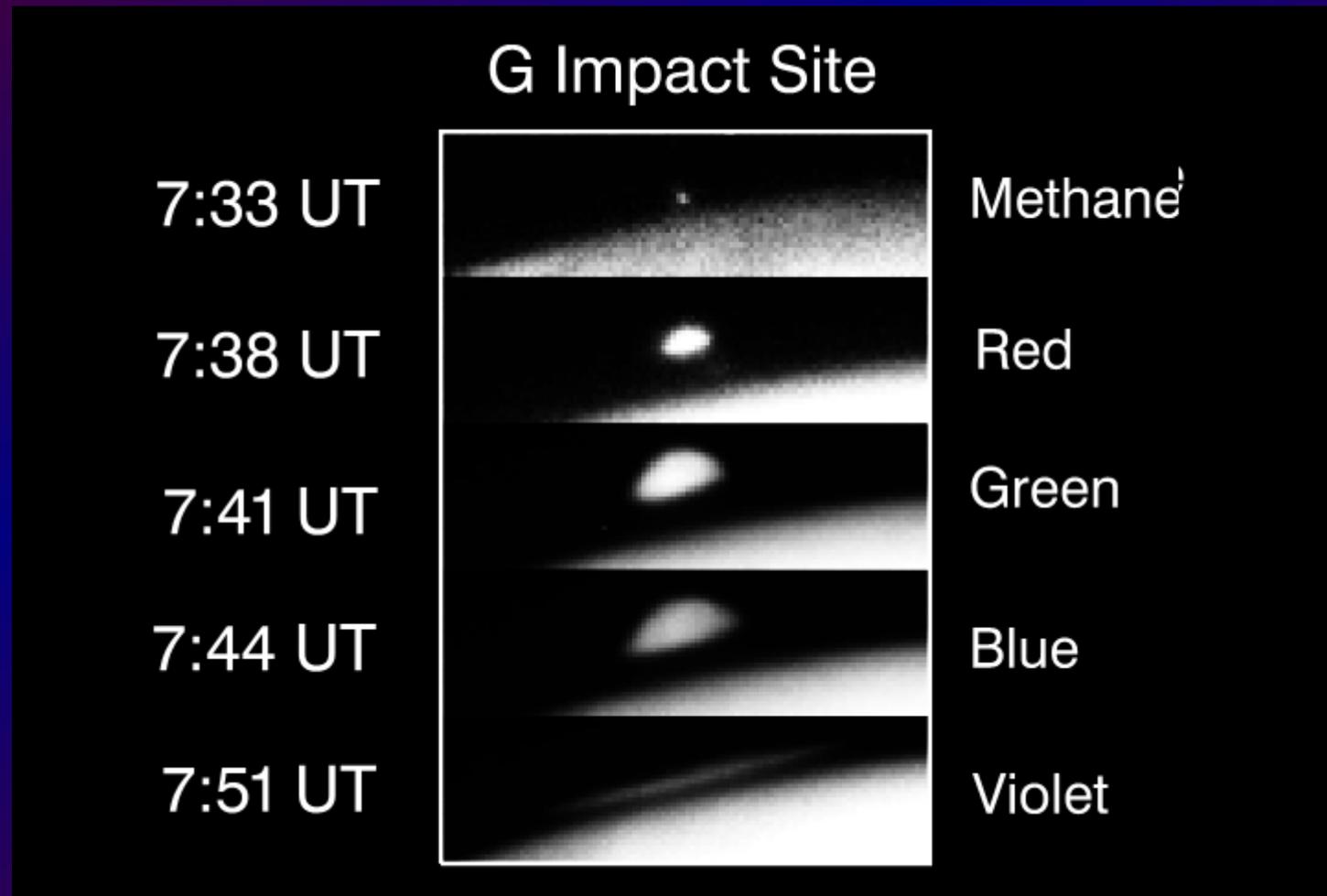
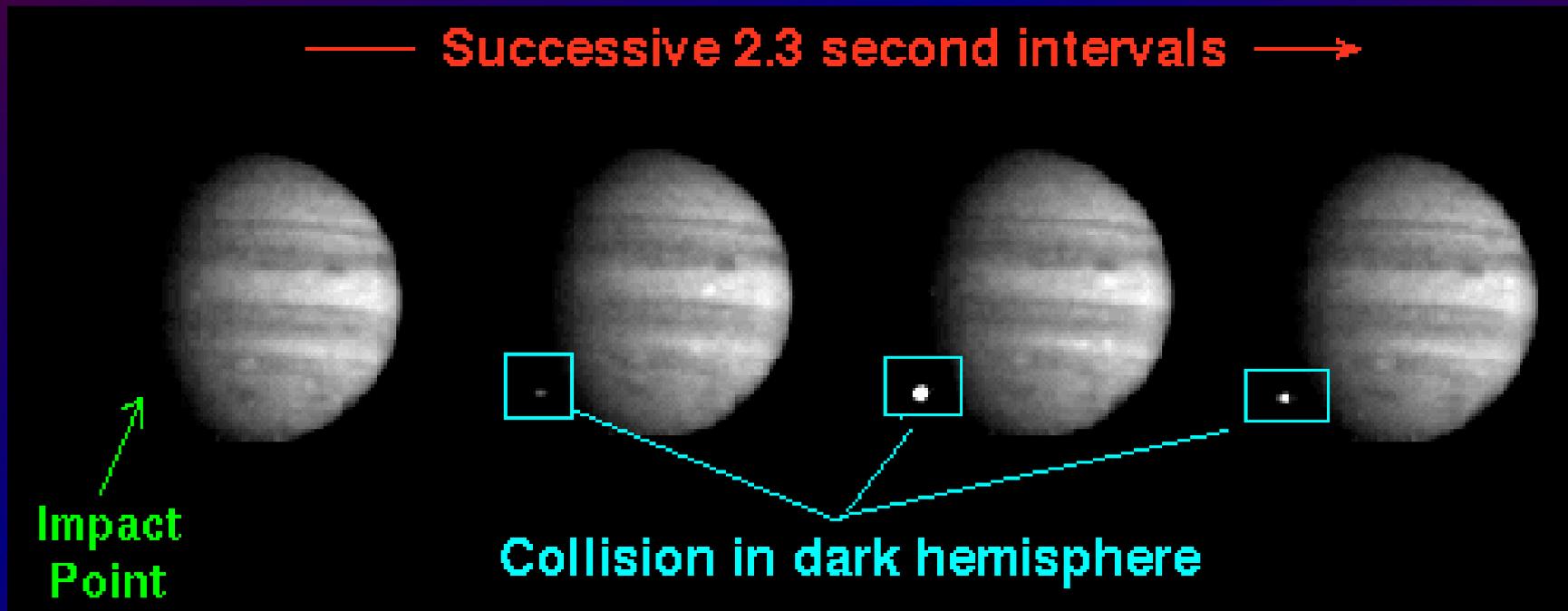


Image by NASA, ESA, H. Weaver, E. Smith

As the comet pieces fragmented in airbursts in Jupiter's atmosphere, many of them created fireballs and spread dark plumes of material in the atmosphere.

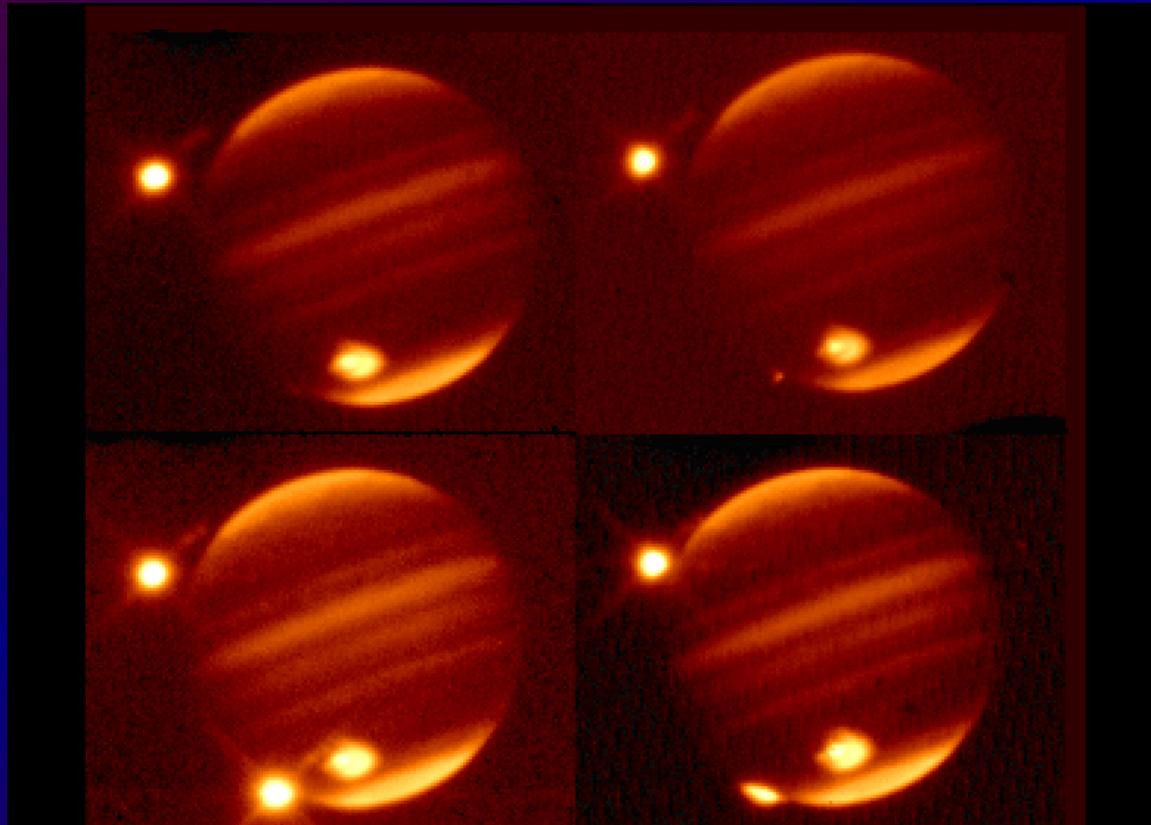


Because the impacts had been predicted with ample warning, an unprecedented number of observations were made, even though the actual impacts occurred out of sight from Earth.



images
from
Galileo
spacecraft

From this impact, scientists and the public learned that large impacts are still occurring in the solar system today.



Impact of Fragment H of Comet Shoemaker-Levy 9 on Jupiter
Infrared image in the 2.3 micron methane band taken using MAGIC
on the 3.5-m telescope, Calar Alto Observatory, Spain, 18/07/94



MPLA

On Feb. 15, 2013, a 20 m meteoroid entered the Earth's atmosphere above Chelyabinsk, Russia and was visible as a fireball brighter than the Sun.



Image from asterisk.apod.com/viewtopic.php?t=30724

It entered the Earth's atmosphere at about 20 km/s (45,000 mph) and fragmented explosively about 30 km above the surface.



**Dashcam
videos**

About 76% of the meteor fragments vaporized, creating an airburst and shockwave.



Image by AP Photo/Chelyabinsk.ru

Some people nearest the fireball were sunburned, many more felt the heat of the airburst, and some experienced temporary blindness or eye pain.



image is overexposed by the brightness of the airburst

Under the path of the fireball, people were blown off their feet by the shockwave, which also caused structural damage and collapse of some nearby buildings.



collapsed roof
of a factory

glass damage map

Buildings as far away as 120 km (75 mi) had shattered windows from the shockwave.

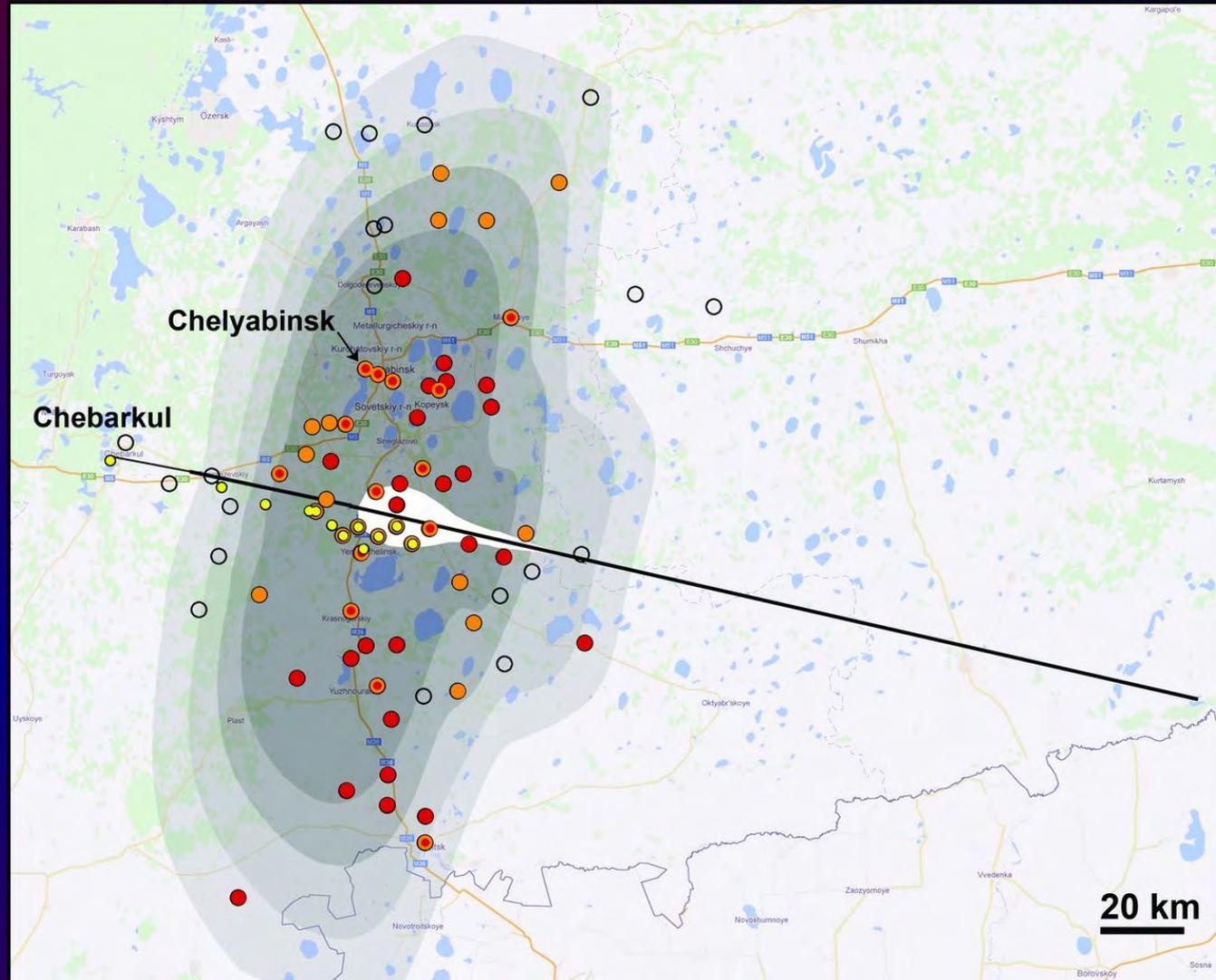


Image from Popova et al. Science 2013

About 1500 people sought treatment after the airburst, mostly for injuries from shattered glass.



shattered
windows in
Chelyabinsk
Drama
Theater

A few hundred meteorites have been recovered from the airburst.

map of the location of some meteorites and track of meteor

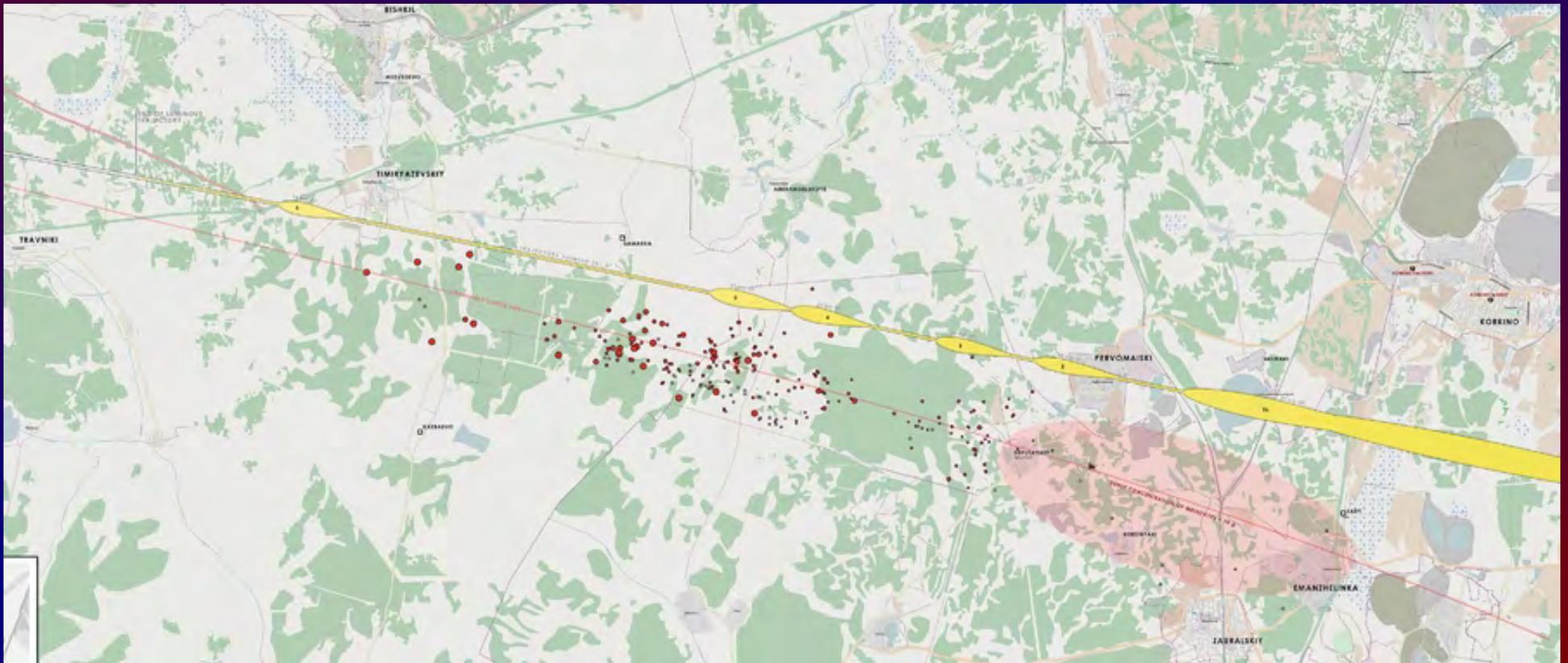
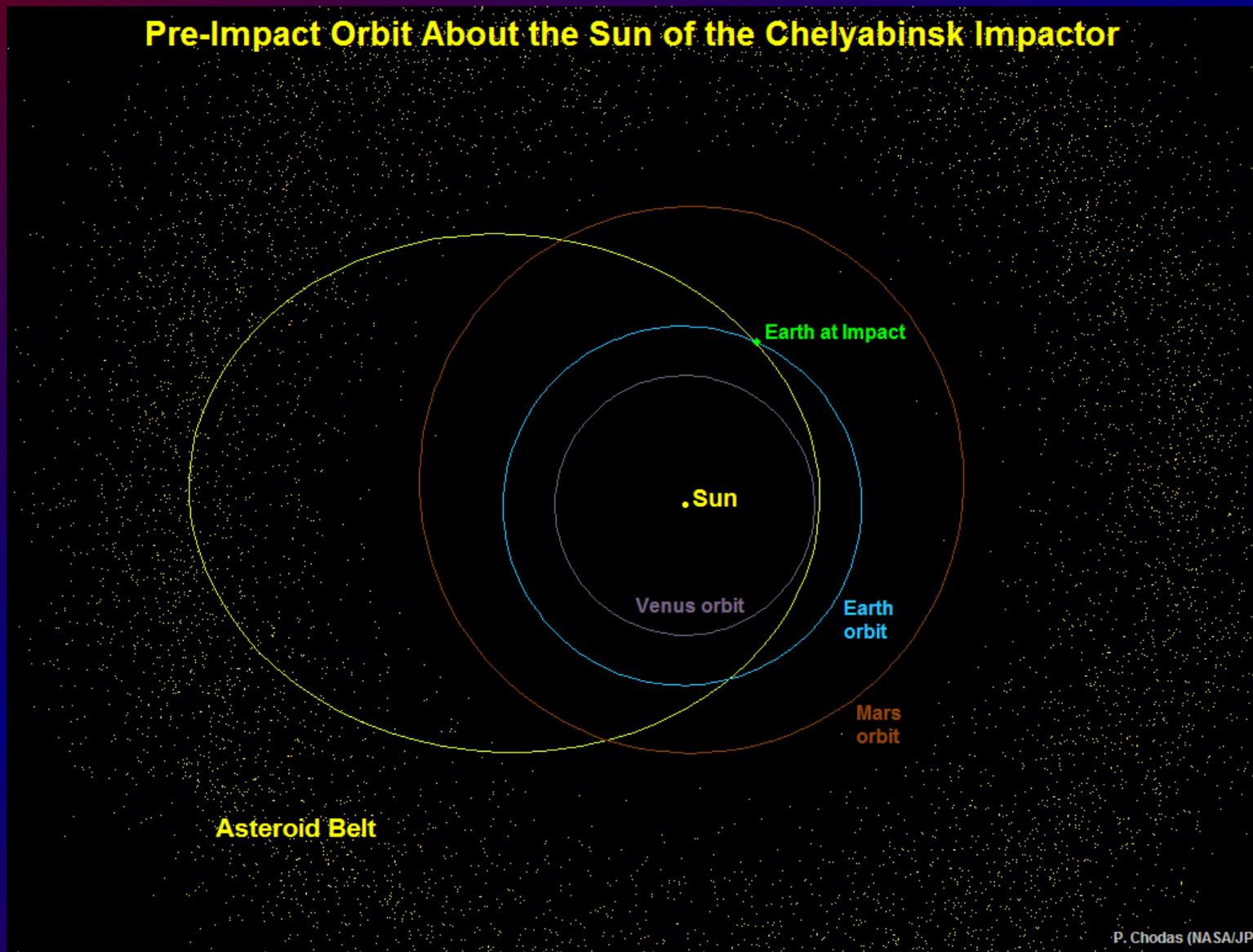


Image by Svend Buhl

The meteorites indicate that the original meteoroid was a rocky asteroid.



Using video footage, astronomers have been able to determine the meteoroid's orbit before impact.



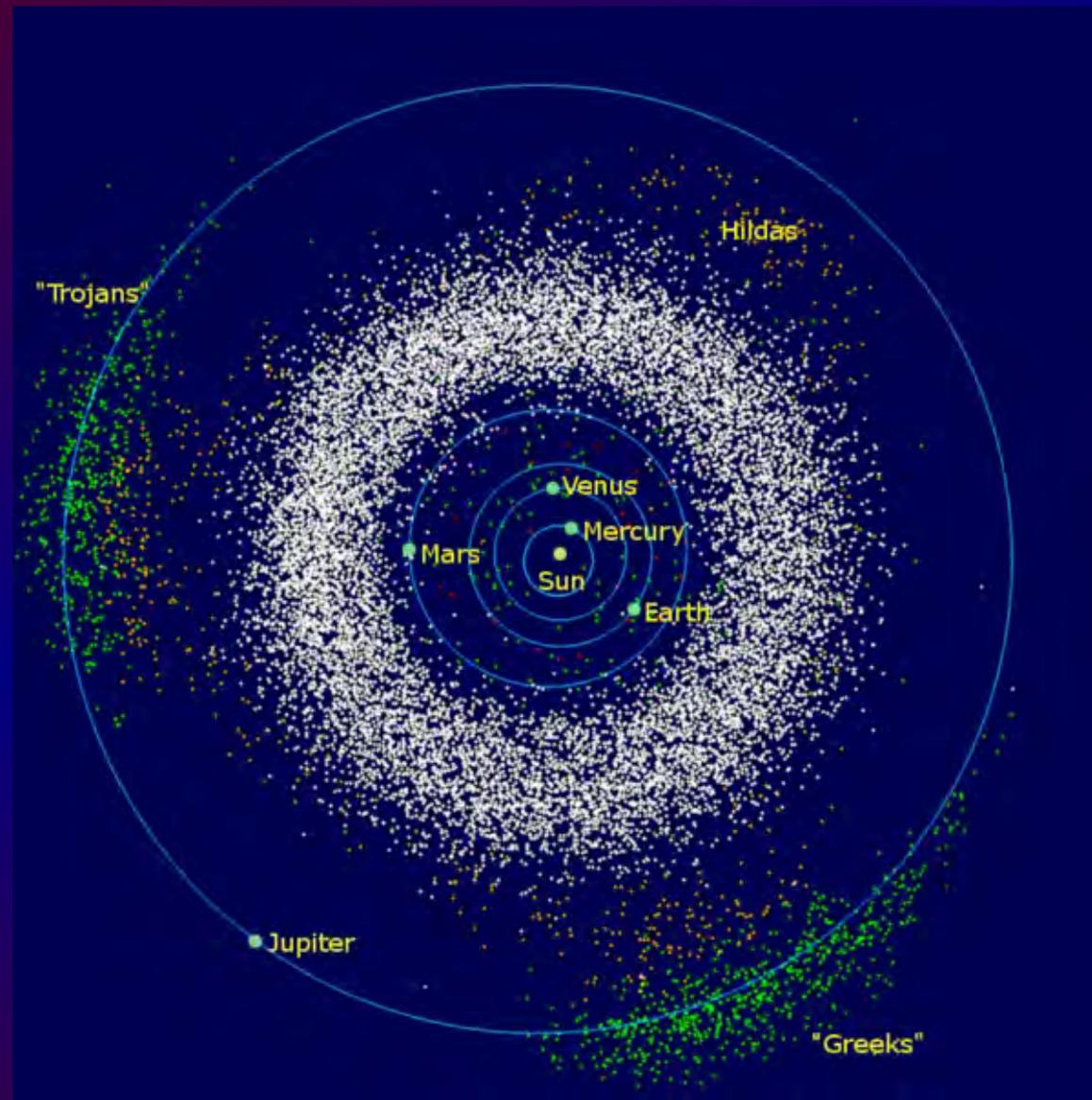
From the Chelyabinsk airburst, scientists have learned a lot about how airbursts occur and their effects.



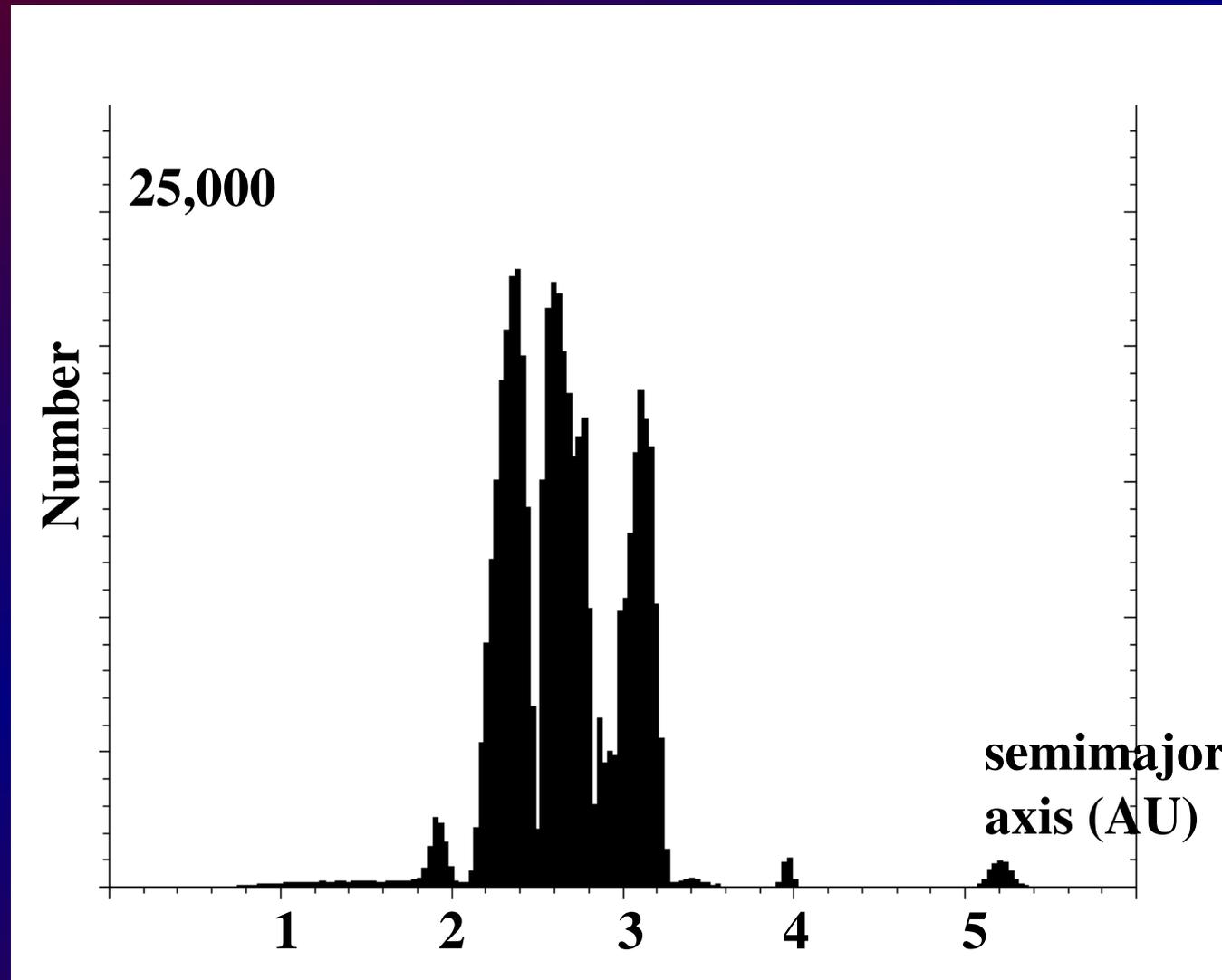
The Chelyabinsk airburst also brought the threat of asteroid impacts to the public's attention.



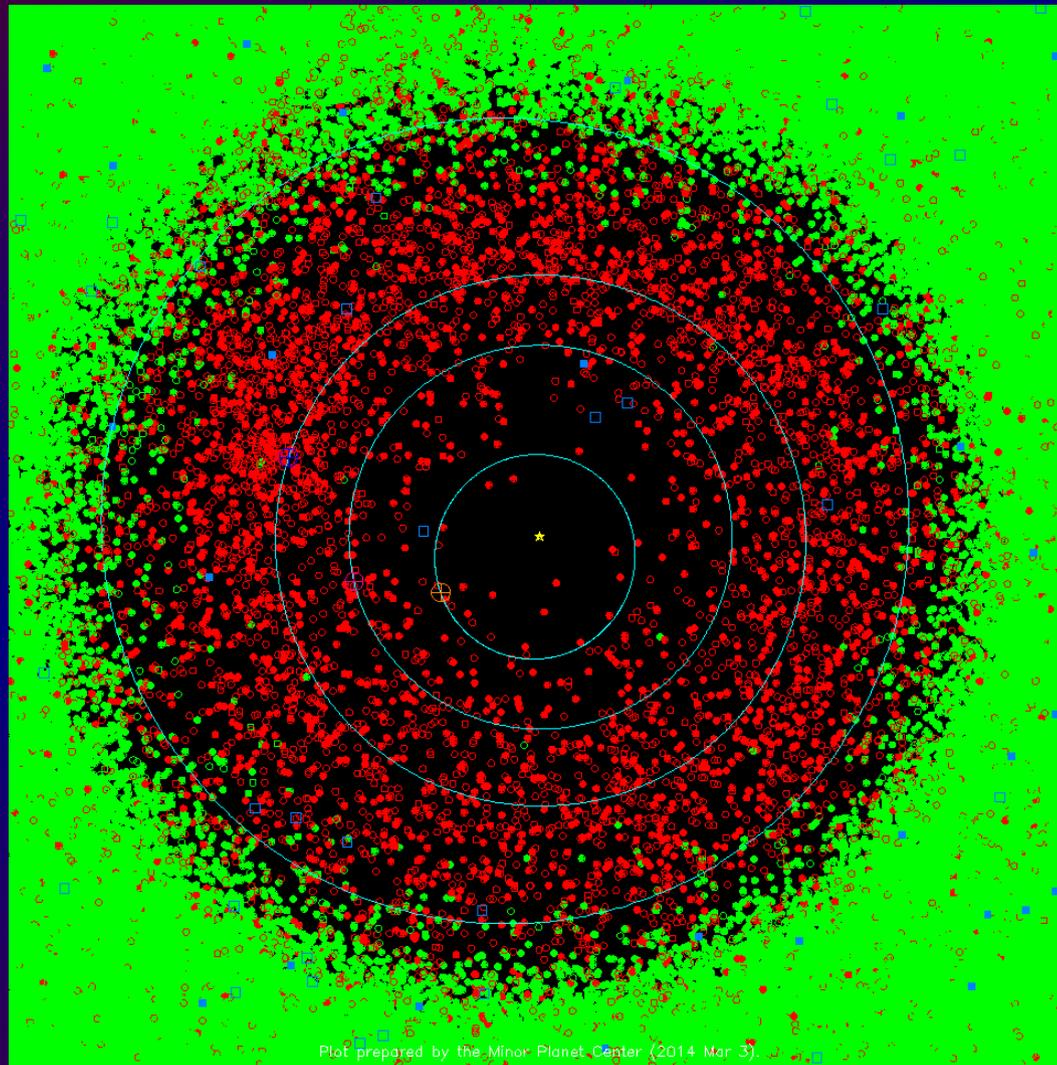
Which asteroids are a threat to impact the Earth?



As of Sep. 2, 2014,
654,249 asteroids have been discovered
and about 2/3 have official numbers.



The asteroids that could possibly impact the Earth are near-Earth asteroids, which have perihelia less than 1.3 AU.

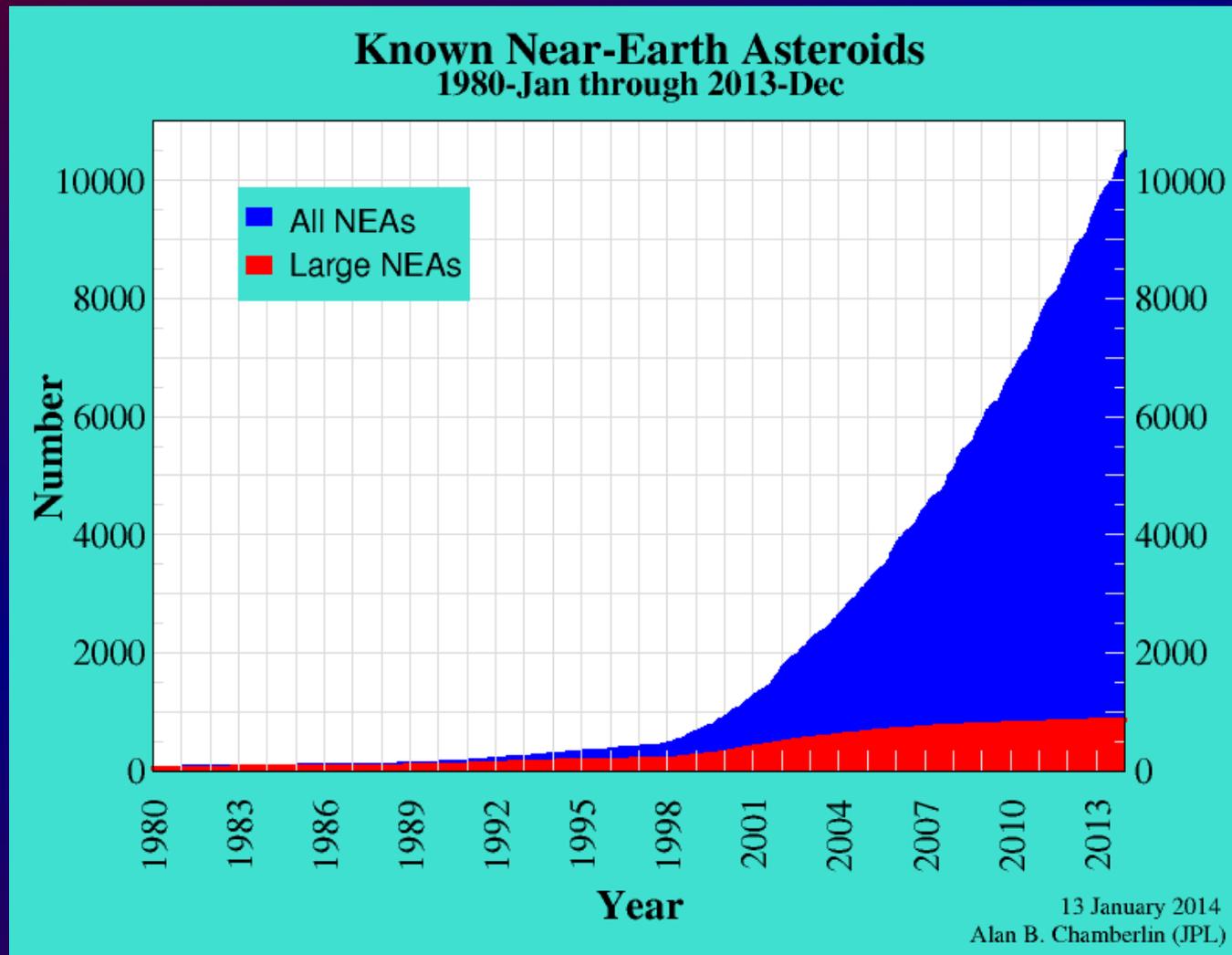


red: near-Earth asteroids

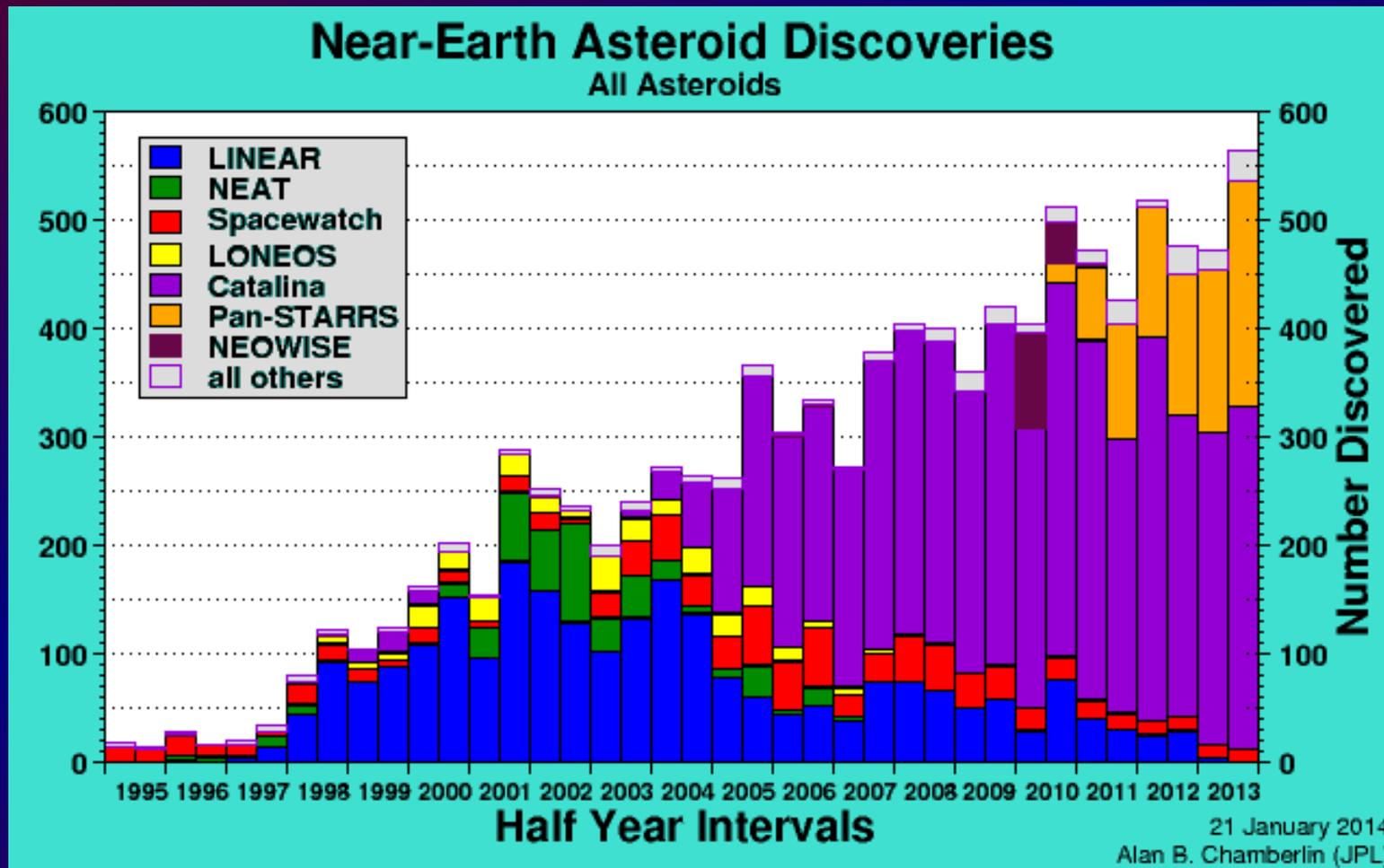
green: main-belt asteroids

Image copyright
Minor Planet Center

By the end of 2013, about 10,500 near-Earth asteroids had been discovered.



Telescopic surveys are continuing to search for the estimated 500,000 near-Earth asteroids that exist.



By studying known asteroid populations and past impacts on the Earth and other worlds, scientists have estimated the frequency of impacts of different sizes.

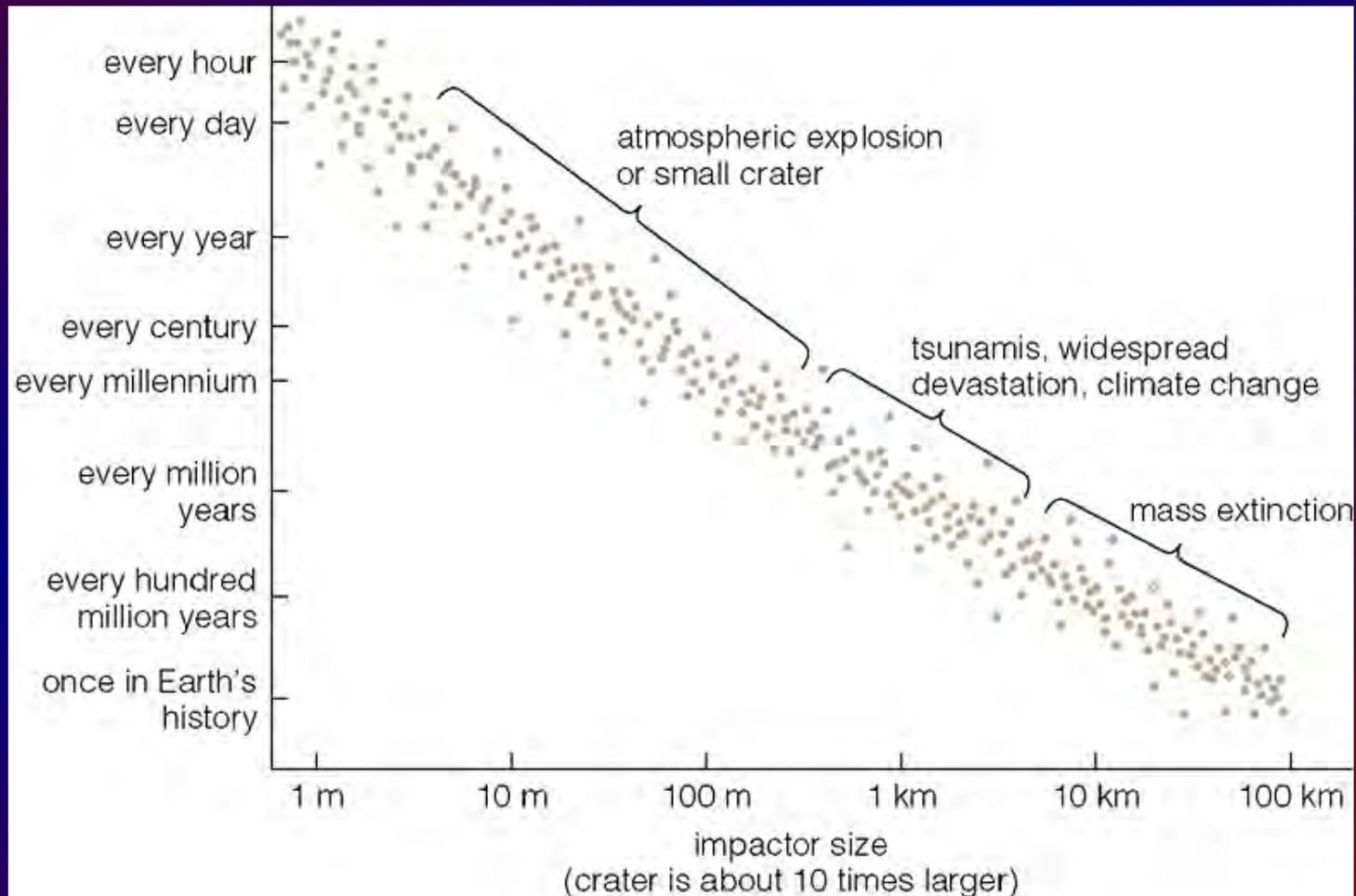


Image
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Pearson
Education Inc

These types of statistics help scientists and policy makers decide what types of impacts are likely and plan for them.

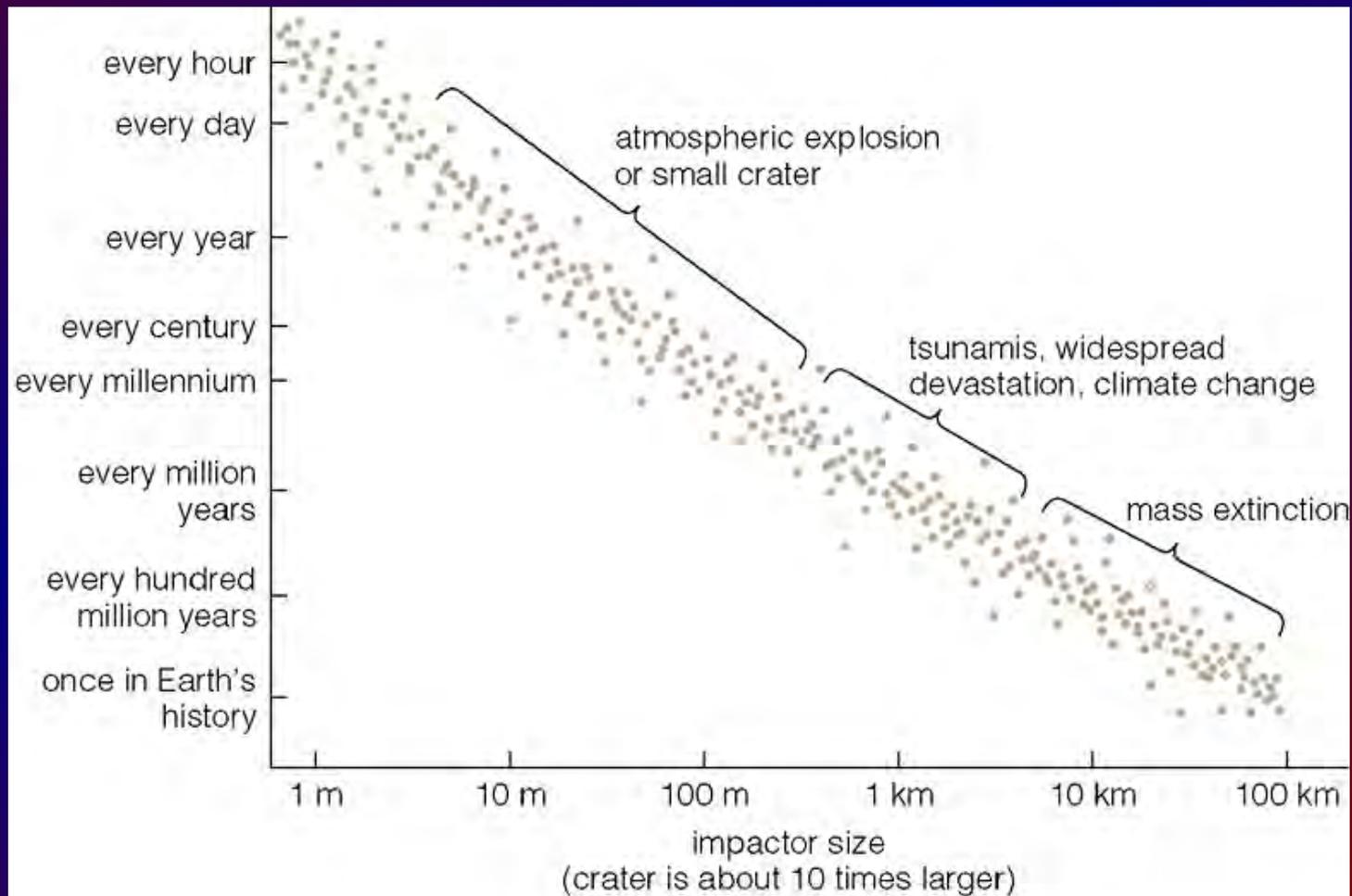
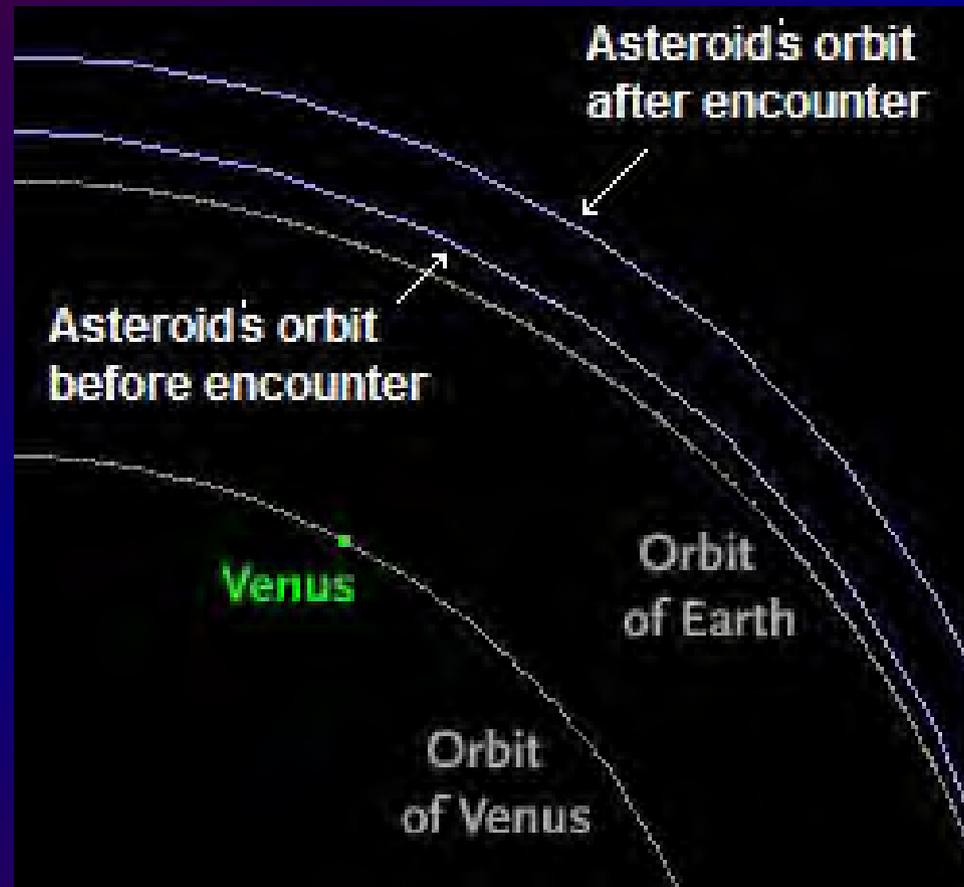


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Since it is inevitable that the Earth will be impacted by an asteroid in the future, what could we do to stop an impact?



All plausible defense methods involve deflecting the asteroid: changing its orbit so that it misses the Earth.



near-Earth
asteroid 2011
MD's close pass
by the Earth in
2011 changed its
aphelion distance
from 1.05 AU to
1.1 AU

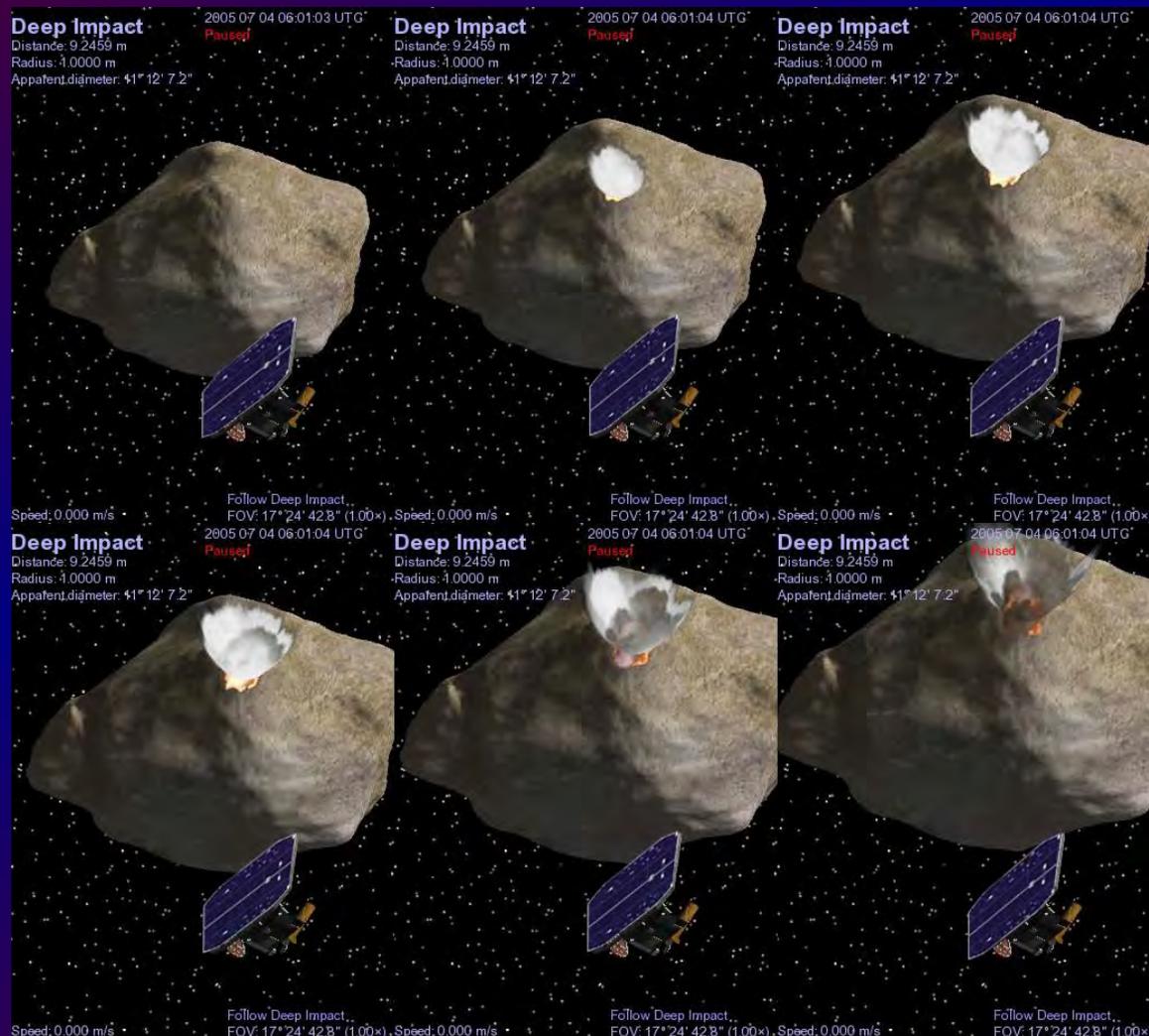
Image by NASA/JPL

One method of deflecting an asteroid would be to hit it with a kinetic impactor – ram it with a spacecraft.



artist's
conception of
a kinetic
impactor
deflection
mission

A small-scale test of such a deflection was successfully conducted by the Deep Impact mission to Comet Tempel 1 in 2005.



simulation of
the Deep
Impact impact

Images by Jestr and
Jack Higgins

A similar deflection strategy would be to explode a nuclear weapon on or near the asteroid's surface in order to change its orbit.



Image from space.com

A more controlled method to deflect an asteroid would be to push it slowly off-course with a spacecraft.



artist's
conception of
a spacecraft
pushing an
asteroid

Image from Schweickart
et al. 2006

Another controlled deflection method would be to pull the asteroid off-course using the gravitational force between it and a spacecraft.



artist's
conception
of a gravity
tractor

All of the deflection techniques take time, so it is crucial to have as much warning time as possible before an impact.

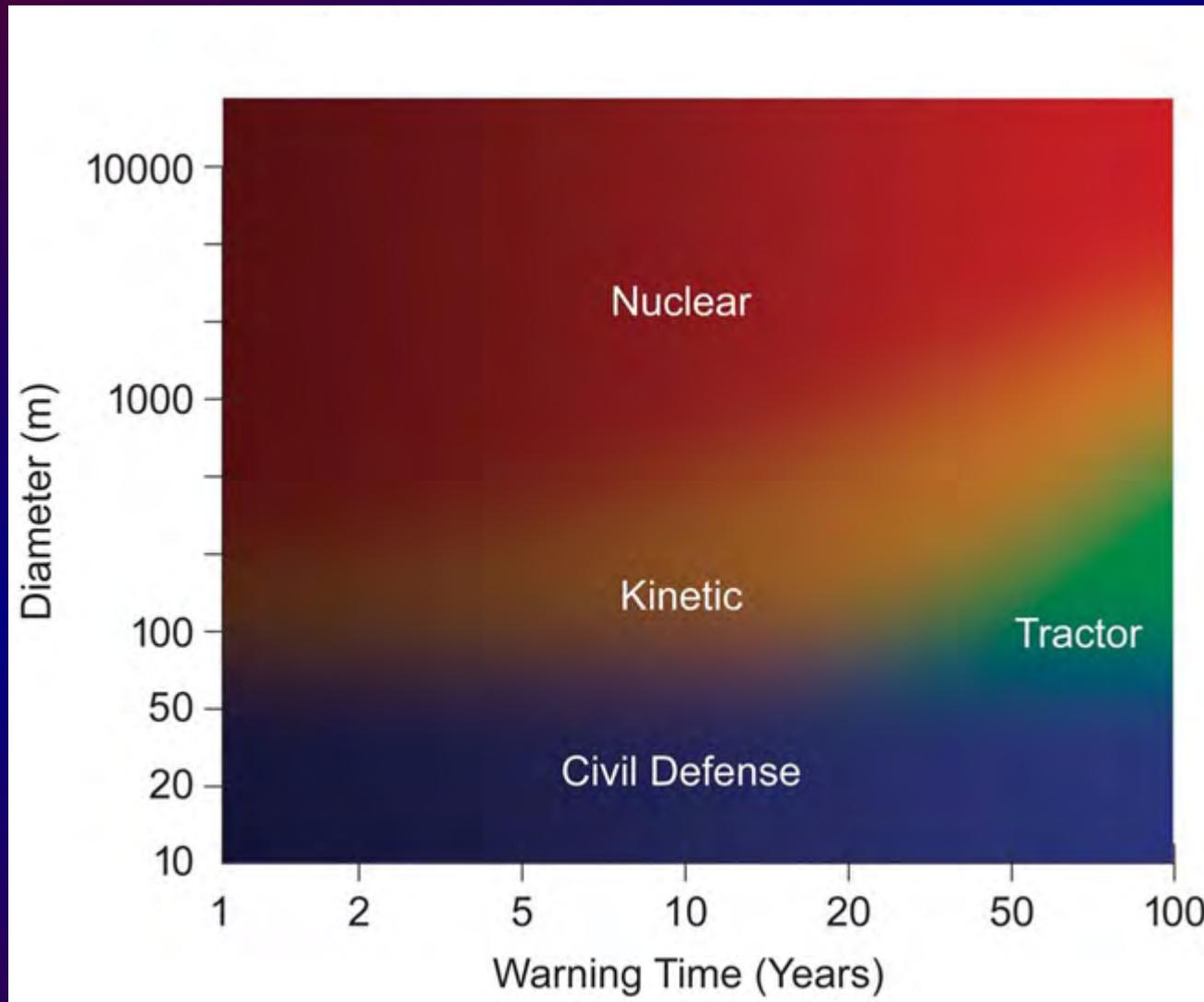


Image from
the NEOShield
Project

Currently, the US does not have any specific deflection plan prepared.

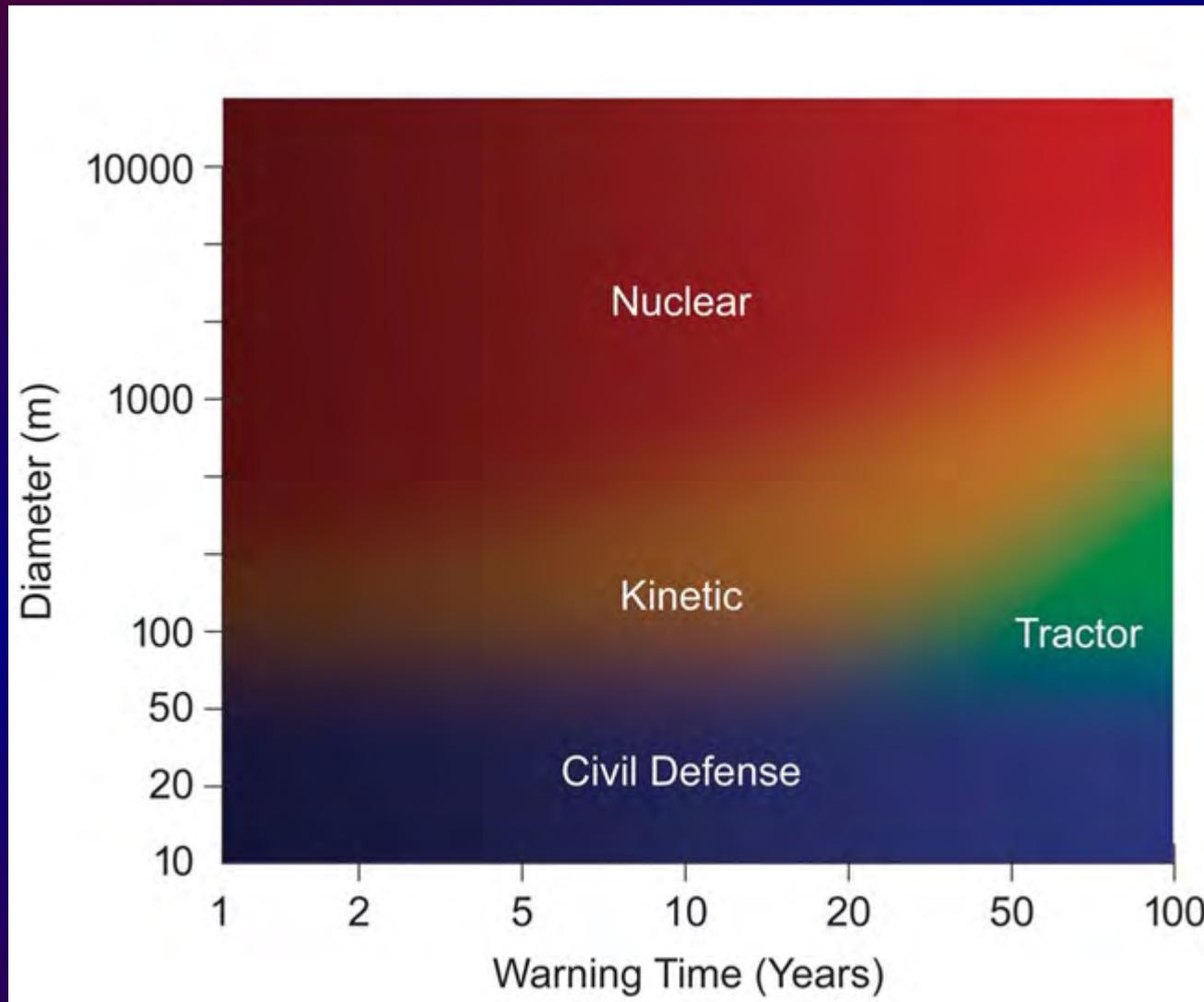
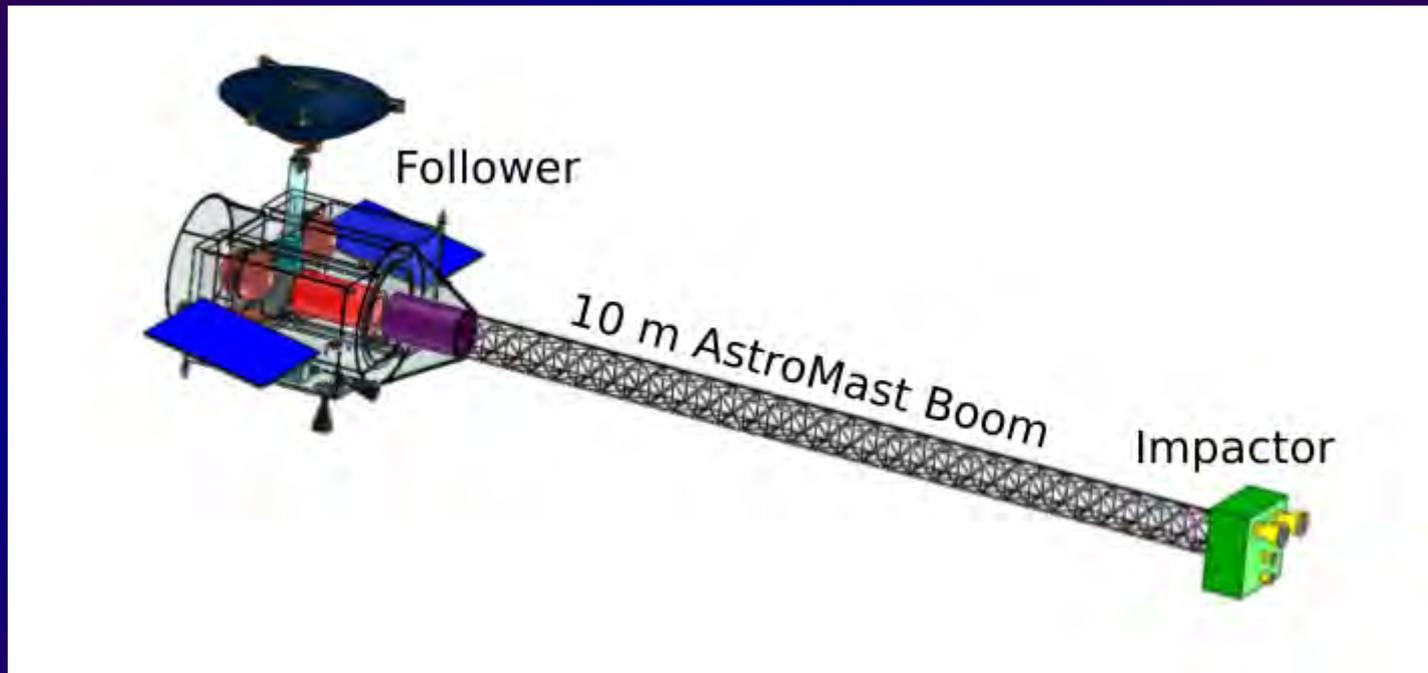


Image from
the NEOShield
Project

A research group working at Iowa State University and Goddard Space Flight Center have been researching a Hypervelocity Asteroid Intercept Vehicle (HAIV) to prevent an impact.



We know asteroids have impacted the Earth in the past, and we know there are still asteroids in the solar system that could impact us, so it makes sense to be prepared.



Wolfe Creek
impact crater
in Australia,
870 m across,
less than
300,000 yrs old