COSMIC IMPACTS AND EVOLUTION

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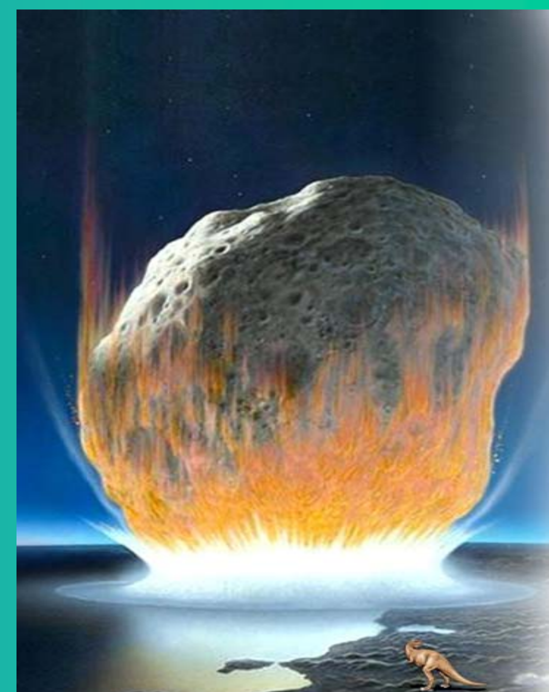


Tunguska Impact

Impact in Russian Siberia
June 1908

Destroyed more than
1000 square kilometers
of forest

Airburst with estimated
energy 10-15 megatons

Collision with small
stony asteroid (60 m)

Tunguska today

Tunguska in the New Millennium

Tunguska Blast is a powerful dietary supplement originating from the meterorical events of 1908 in Tunguska, Russia that created an oasis of fertility where herbs and plants grow at four times their normal rate and to as much as three times their normal size.

Mass Extinctions

"Sudden" extinctions in the fossil record of more than half of all species, often coincident with large environmental changes

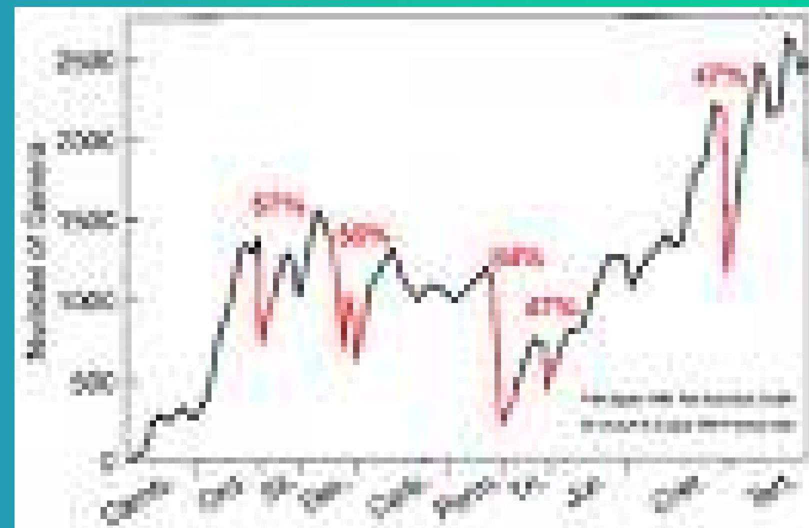
Time-scale may not be well defined

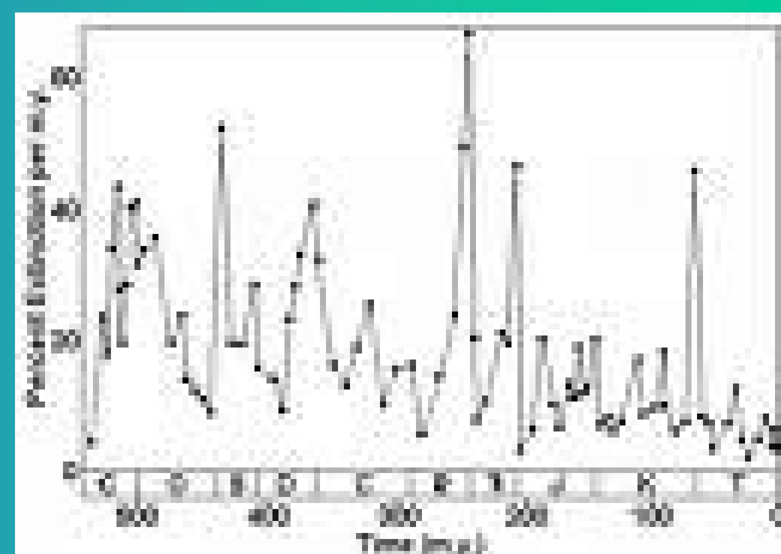
Usually followed by rapid speciation

Five big mass extinctions in past 500 million years

Largest is end-Permian, 251 million years ago, >90% loss

Most recent is end-Cretaceous, 65 million years ago





Cretaceous-Tertiary Boundary

First identified (1980) by rare metal iridium.

Global boundary layer contains record of extinction event.

The End-Cretaceous Impact

Most recent mass extinction, 65 million years ago

Defined precisely in fossil record by marine microfossils

Coincident with ejecta from Chicxulub (200 km crater)

Caused by impact with 10-15 km asteroid or comet

Atmospheric heating of back-falling debris created global firestorm

Stratospheric dust produced global impact winter

New Perspectives on Natural Selection

Classical Darwinian perspective is one of competition and adaptation to gradual changes.

Fossil evidence for mass extinctions and punctuated equilibrium indicates some periods of very rapid evolutionary change (extinction and speciation).

Cosmic impacts are truly catastrophic: Dinosaurs went extinct in an hour!

Life must cope with both gradual and catastrophic changes.

Ability to survive a cosmic impact favors special factors, such as small size for animals or fire-resistant seeds for plants (not just bigger, faster, smarter).

Congressional Statement 1991

The House Committee on Science and Technology believes that it is imperative that the detection rate of Earth-orbit-crossing asteroids must be increased substantially, and that the means to destroy or alter the orbits of asteroids when they do threaten collisions should be defined and agreed upon internationally. The chances of the Earth being struck by a large asteroid are extremely small, but because the consequences of such a collision are extremely large, the Committee believes it is only prudent to assess the nature of the threat and prepare to deal with it.

NASA Authorization Bill, 1991

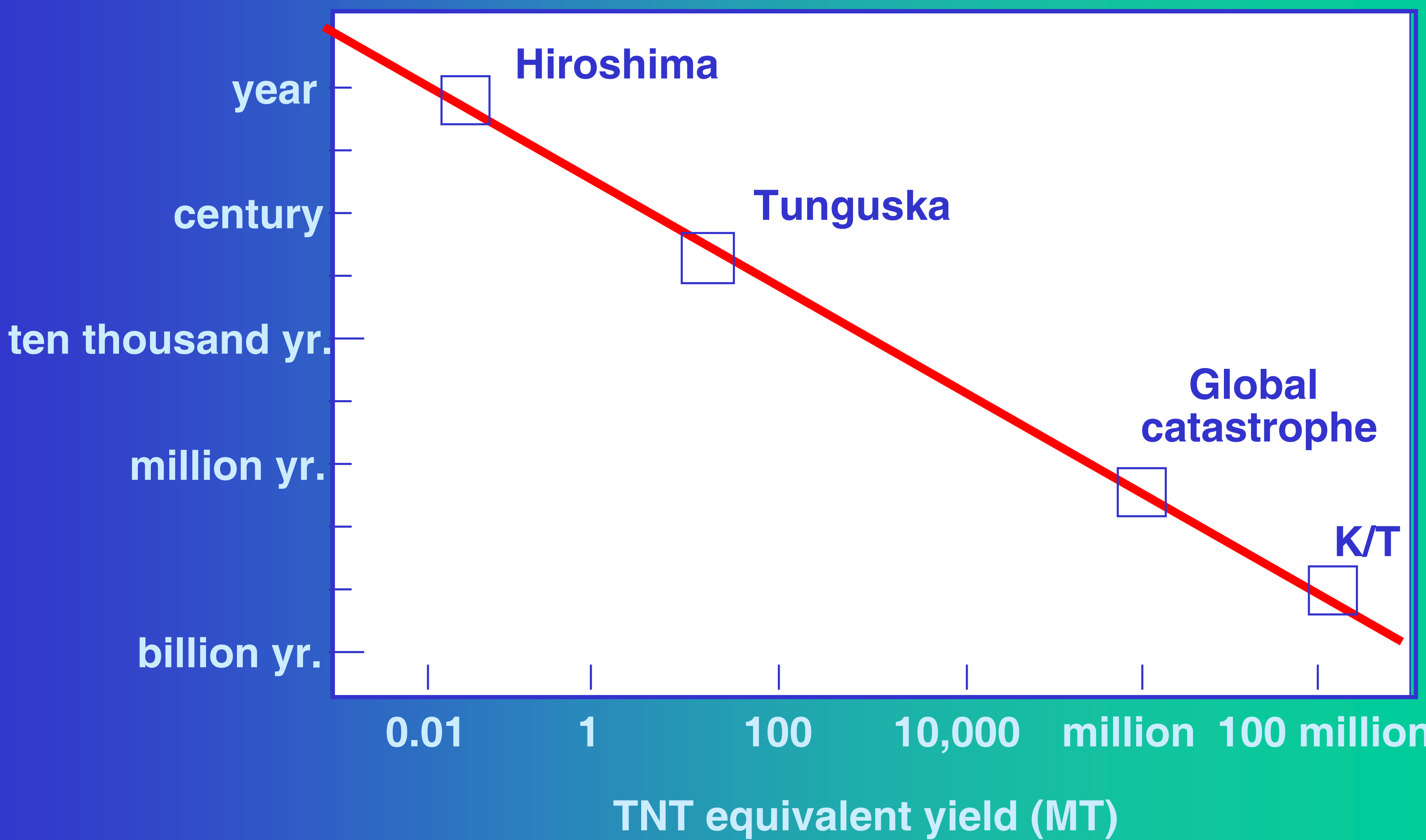
EROS Asteroid 433

Morrison August 2006

Hayubusa at Itokawa

First spacecraft encounter with a very small (sub-kilometer) Near-Earth Asteroid

Terrestrial Impact Frequency



Morrison August 2006

Comparison with Other Risks

Statistical risk of death from impacts is about 1 in 4 million per year, or about 1:50,000 lifetime risk
- Comparable with other natural hazards
- Well above threshold for government regulation

Severity of disasters (billions of people killed) is greater than any other *known* hazard we face
- Places this disaster in a class by itself

Average interval between major disasters (million yrs) is larger than for other hazards
- Hard to take seriously (the giggle factor)

Robust Conclusions from Hazard Analysis

Cosmic impacts represent an extreme example of the class of hazards with low probability but high consequences.

The statistical risk from impacts is larger than the one-in-a-million lifetime risk of death often used as a threshold for governmental or regulatory interest.

Unlike other natural hazards, impacts can kill billions and endanger survival of civilization.

Impacts can, in principle, be avoided by deflection to alter the orbit of the projectile.

The initial step in any mitigation scheme is discovery & prediction.

Manicouagan
Crater, Quebec

The Problem with Statistics

The impact hazard is the most extreme example of risks with very low probability but very large consequences. Statistically, it could happen any time, but that doesn't help us mitigate the risk.

The hazard that concerns us -- a possible impact within the next few centuries -- is actually a deterministic threat. An asteroid on a collision course passes close to the Earth repeatedly before it hits.

The Spaceguard Survey can find any threatening asteroid and provide decades warning.

If we look, we can have plenty of warning.
If we don't carry out a survey, we will have no warning.

Meteor Crater
Arizona

Spaceguard Survey

Survey to find asteroids capable of causing a global catastrophe

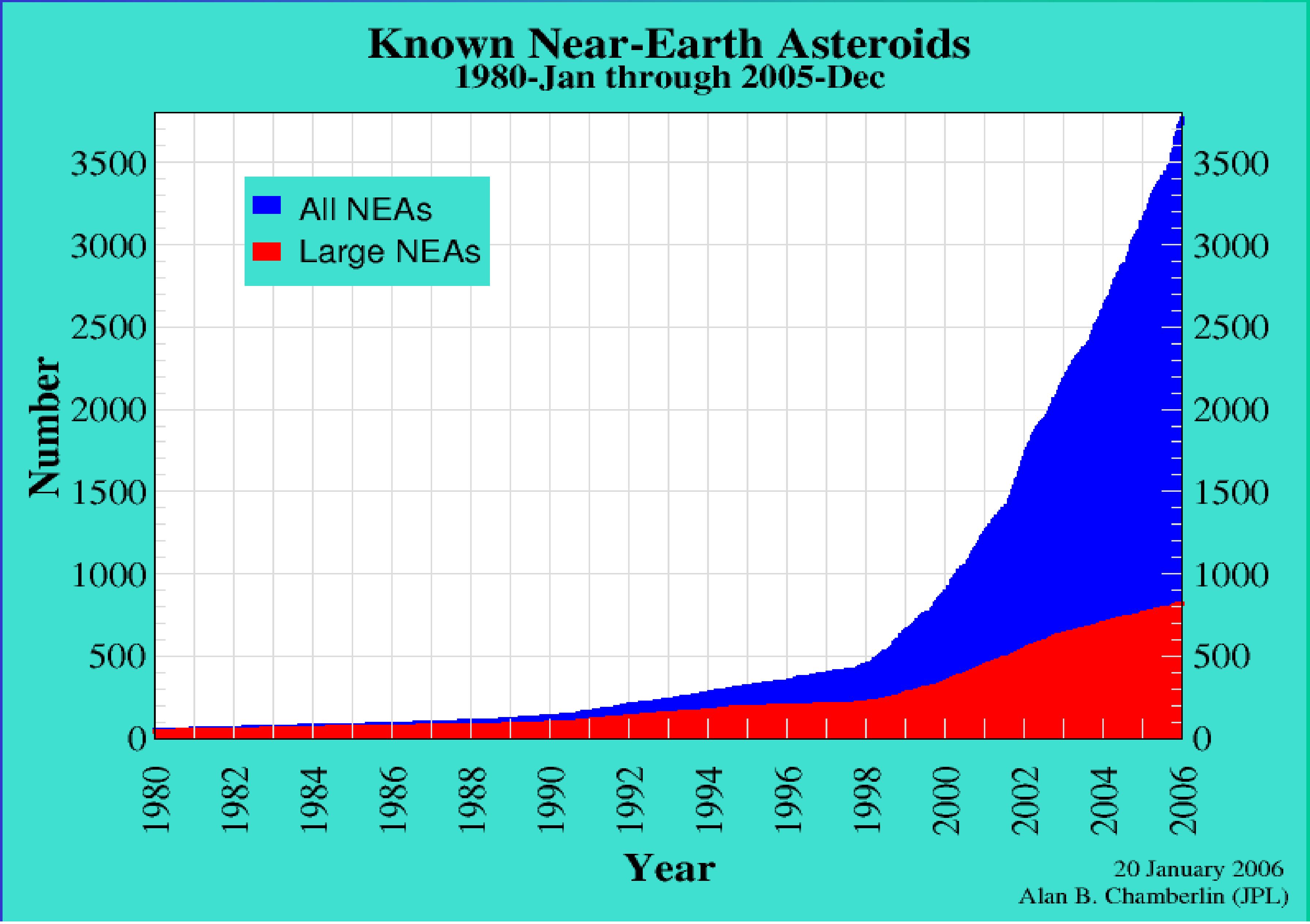
Asteroid orbits permit decades of warning

Most asteroids are being discovered by just 4 small (1-m) telescopes with NASA and USAF support

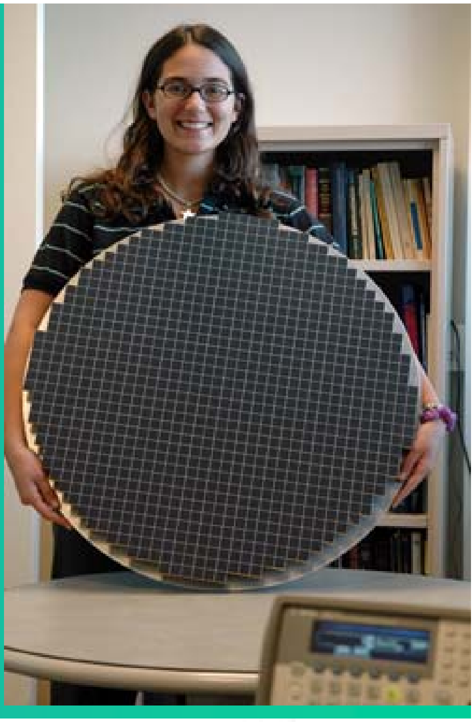
NASA's Spaceguard Goal is to find 90% of NEAs > 1 km diameter by end of 2008

LINEAR telescope, New Mexico

Spaceguard Discovery Progress



Spaceguard Deep Survey



Current Spaceguard Survey will eliminate 90% of impact risk by end of this decade.

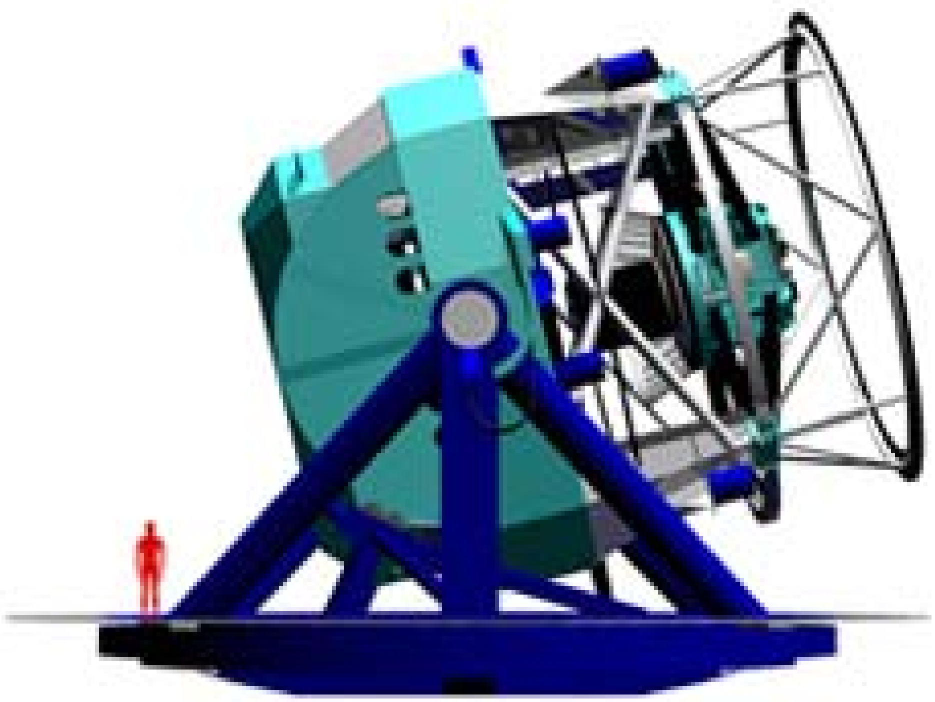
To eliminate 99% of risk, we must extend the survey to fainter asteroids.

Eliminating the next 9% is more expensive than the first 90%.

In 2006, Congress assigned responsibility to NASA to find and track 90% of NEAs > 140 m by 2020.

Proposed Large Synoptic Survey Telescope (LSST) can do the job.

Space-based surveys are also being considered.



LSST design

Apophis: A Real Threat?

Near-Earth Asteroid Apophis is the best current example of a possible impactor. Initial orbits (December 26, 2004) suggested 2% impact chance on Friday, April 13, 2029.

Current orbit still admits of a very small chance (less than one in 20,000) of impact on April 13, 2026.

Rusty Schweickart

Planetary Defense

- Impacts are the only natural hazard that can, in principle, be eliminated.
- We could develop the technology to change asteroid orbits.
- Earth moves its own diameter in 6 minutes -- thus to avoid a collision we need only change the arrival time of the asteroid by 6 minutes.
- Technologies considered to change orbits include ballistic impact, nuclear explosives, low-thrust rocket engines.

Deep Impact, Comet Tempel 1

Issues in Planetary Defense

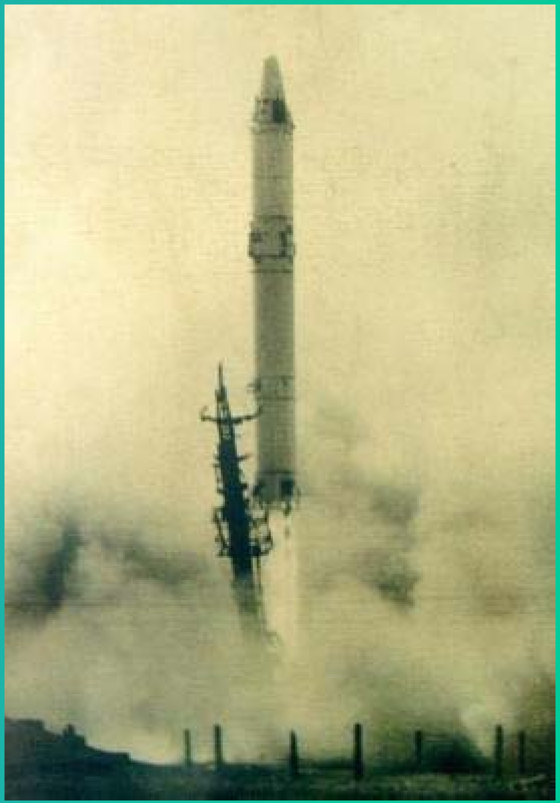
- Should we develop this technology now? Or wait until a specific threat is identified?

- Should the U.S., as the world's only superpower, assume responsibility, or should this be an international effort?

- How much should we spend to protect our planet?

- Who can we trust with this responsibility?

- How do we ensure that asteroid defense systems are not misused?



Sagan and the Deflection Dilemma

Sagan was concerned about the impact hazard and the risk of a catastrophic end of civilization.

He was equally concerned about the risk of developing nuclear defenses against asteroids.

He even suggested that the technology of changing asteroid orbits could be used to direct an otherwise benign asteroid to hit us as a doomsday weapon.

Sagan called this problem "the deflection dilemma."

The Marsh of Camarina

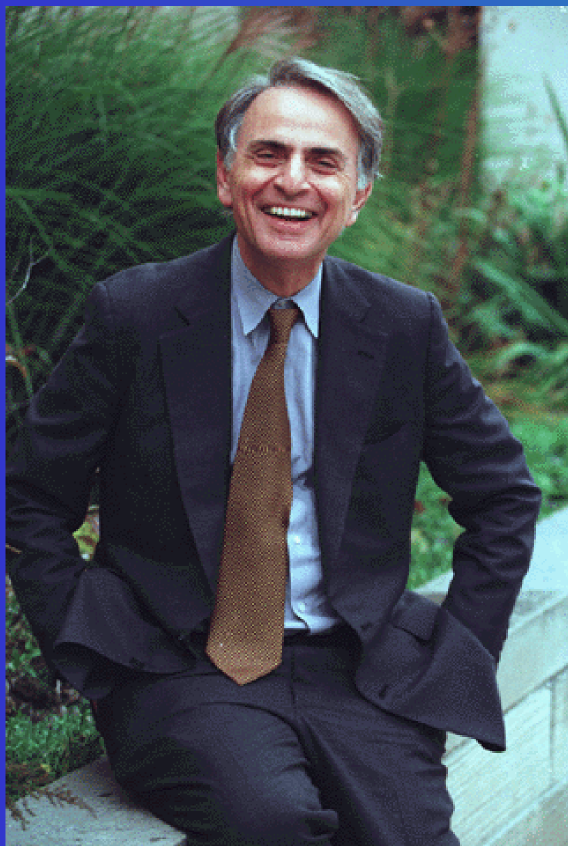
In *Pale Blue Dot*, Sagan illustrated the risk of unintended consequences with the story of Camarina, a Greek city-state in Sicily (5th century BCE).

To solve a public health problem, they drained the marsh surrounding their city.

Enemies, seeing that the protective marsh was gone, attacked them.

The Camarinans were all killed or enslaved, and their city razed.

Sagan on Impacts and Civilizations



"Since hazards from asteroids and comets must apply to inhabited planets all over the Galaxy, if there are such, intelligent beings everywhere will have to unify their home worlds politically, leave their planets, and move small nearby worlds around. Their eventual choice, as ours, is spaceflight or extinction."

Pale Blue Dot (1994)

More Information

NASA NEO hazard website:
impact.arc.nasa.gov

NASA NEO Program Office:
neo.jpl.nasa.gov

B612 Foundation
www.b612foundation.org

NASA Astrobiology Institute:
nai.arc.nasa.gov