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Overview of ASTEROID IMPACT PHENOMENOLOGY

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Protecting Earth from Asteroids

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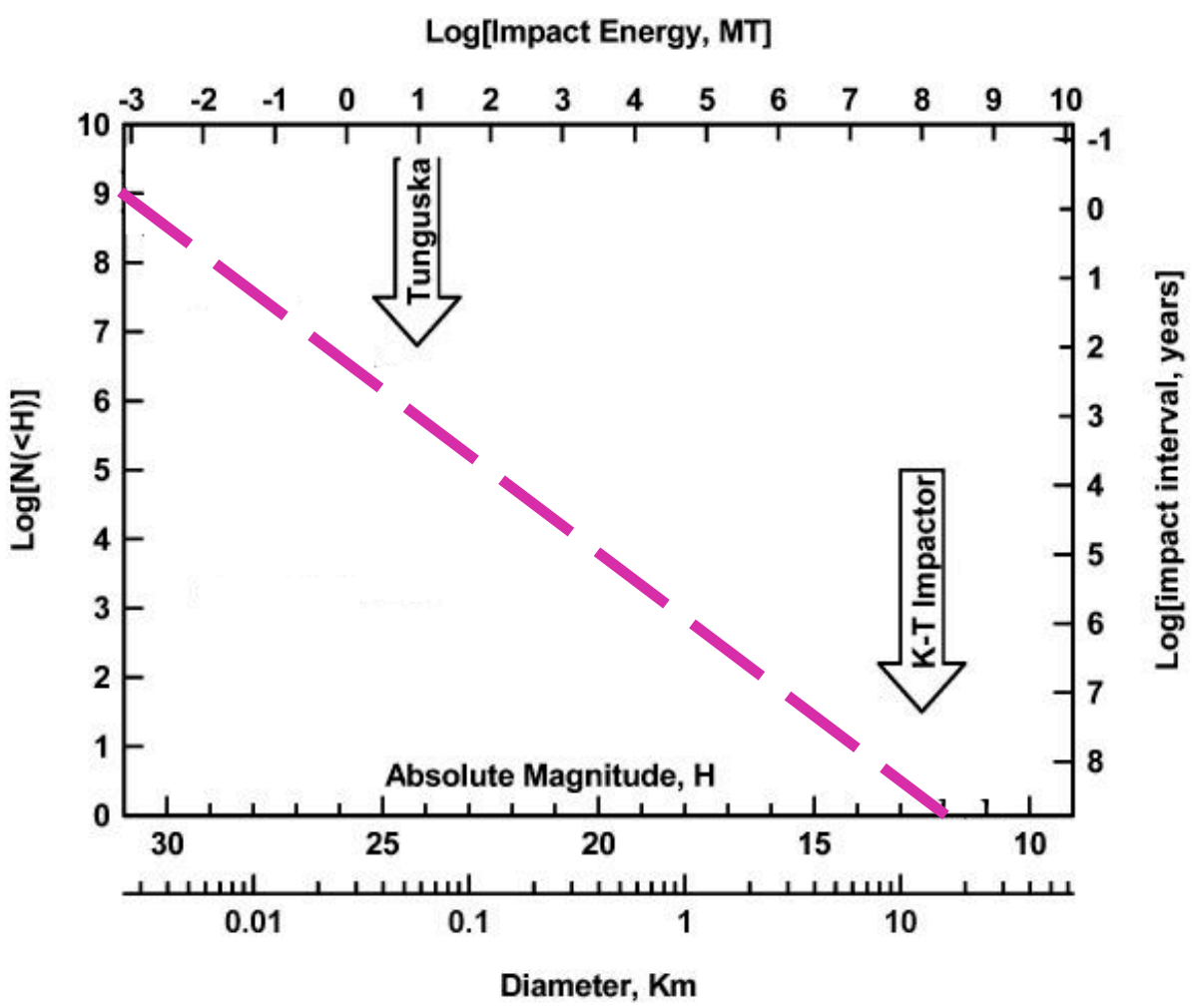
Sizes and Energies of NEAs… and How Often They Hit



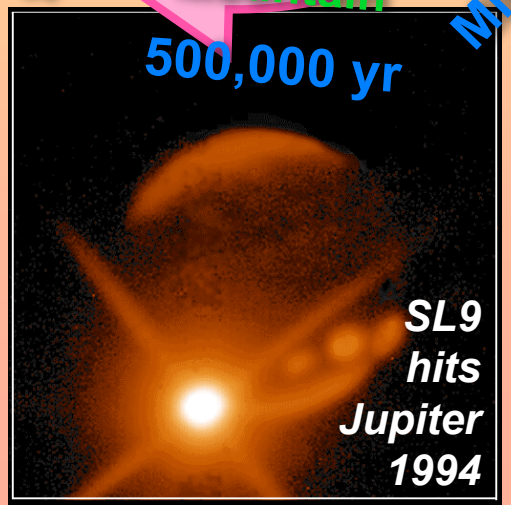
- Destructive energy ~½ mass x velocity^2
- Most NEAs hit with v = 12 to 30 km/sec, so energy differs by factor of 6 or less
- Sizes on diagram span factor of 10,000, so masses (and impact energies) span a factor of a million millions!
- So the effects of impact vary enormously depending on size of impacting asteroid

Sizes and Impact Frequencies of NEOs

Smallest, most frequent

Second
Dust
Boulder
Week
100 Myr
15 km
Mountain
500,000 yr
Building
Millennium

Huge, extremely rare



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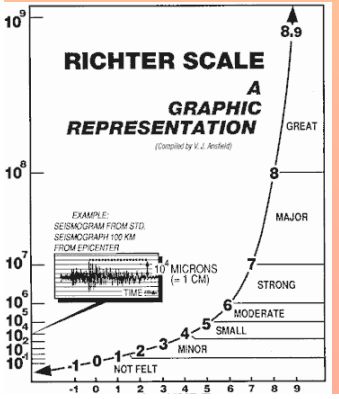
Impacts of Practical Concern

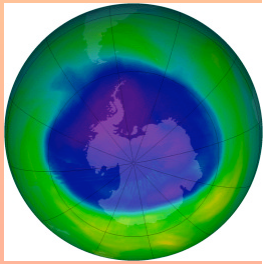
OBJECT DIAM.	IMPACT ENERGY	CHANCE PER 100 YR	WARN?	CHARACTER OF DAMAGE
>3 km	1.5 mil. MT	<1 in 50,000	Y	Global climate disaster, most killed, civilization destroyed
>1 km	80,000 MT	0.02%	Y?	Devastation of large region or an entire ocean rim
>300 m	2,000 MT	0.2%	?	5 km crater; huge tsunami or destruction of small nation
>100 m	80 MT	1%	N?	Exceeds greatest H-bomb; 1 km crater; locally devastating
>30 m	2 MT	40%	N	Stratospheric explosion; possible damage within ten km
>10 m	100 kT	6 per century	N	Aerial burst, little damage below (e.g. broken windows)
>3 m	2 kT	2 per year	N	Blinding flash, could be mistaken for atomic bomb

Environmental Consequences of Civilization-Threatening Impact



- **Total destruction in near-crater zone**
  - Destruction zone 30 times the size of the asteroid
- **Tsunami ("tidal waves")**
  - Inundation of shores of impacted ocean

- **Stratospheric dust obscures sun**
  - Sudden global climate change threatens agriculture
- **Widespread fires**
  - Re-entering ejected material broils Earth's surface
- **Poisoning of the biosphere**
  - Sulfates, nitric acid, ozone layer destroyed



- **Earthquakes**
  - Modest effects compared with everything else

Consequences from Four Classes of Impacts

- [Extremely unlikely mass-extinction event]
  - [Global environmental apocalyptic catastrophe]
- Unlikely impact by NEA hundreds of meters to couple of kilometers in size
  - Ocean impact: Tsunami *[Gisler; Ward]*
  - Land impact: Cratering explosion, blast wave, fires, etc.
  - Global climate change, threatens agriculture
- Distinctly possible 10-200 MT airburst *[Boslough]*
- Smaller impacts (or predicted impacts): likely during next decades
  - Harmless in terms of direct effects, but over-reactions could cause harm

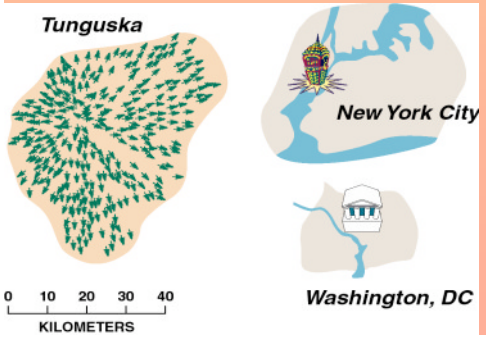
Consequences of Land Impact by 200 meter to 2 km Asteroid

- ***Consequences are well understood from nuclear bomb tests and studies of terrestrial and lunar impact craters.***
- **Crater rim ~15 times diameter of NEA; total destruction zone twice as big (4 – 40 km from ground-zero)**
- **Explosion fireball: 3rd deg. burns 10 – 100 km from ground-zero; firestorm 30 – 300 km from ground-zero**
- **Air-blast, overpressure destroys all structures 10 – 100 km away; poorly-built structures destroyed** (within minutes) **by winds, earthquake, falling debris up to 70 – 700 km from ground-zero**
- **Ozone layer destroyed globally by NEAs >500 m diameter**
- **Atmospheric pollution (sulfate aerosols, nitric acid rains, injection of dust and water into atmosphere); "year without summer" for NEAs ~1 km diameter, global agricultural disaster ("impact winter") possible for NEAs >2 km diameter** (land or ocean impact)**.**

The Consequences in Perspective…

Meteorite punctured roof in Canon City, CO

- **Most of the effects are individually familiar (fire, wind, falling debris, seismic shaking…)**
  - **Disaster responders face nothing truly alien**
  - **Synergy of many different effects in first 10 minutes**
- **Warning versus no warning (time and location)**
  - **Deaths and injuries dramatically reduced with warning**
  - **Property damage can be lessened somewhat**
  - **Even with no warning, human beings can reduce exposure by taking cover (within seconds to minutes) if they have been educated to recognize what's happening** (Indian Ocean tsunami analogy)
- **Impact disasters: local/regional versus global**
  - **Like Katrina, earthquakes, or wars, unaffected cities or nations can provide emergency response…**
  - **…Unless the consequences are global**



Secondary Consequences from Small, Likely Events

- The time-averaged mortality from NEA impacts is similar to that from terrorism over the past 2 decades (including Sept. 11th 2001)
- Public and national over-reaction (stock market, homeland security hysteria, Iraq war) after 9/11 could be replicated by a modest but unexpected impact disaster
- An otherwise harmless but brilliant bolide (fireball) could be mistaken for an atomic attack, causing a dangerous response
- Even sensational journalism or a mistaken prediction about a possible future impact could be disruptive

OVER KASHMIR? OVER ISRAEL? HOW WOULD THE GENERALS RESPOND?

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That's it, Folks…

Comet McNaught

Now let's consider consequences from other kinds of NEA impacts:

…airbursts

…tsunami

…and the human costs of impacts

This comet, one of the brightest in the last century, came by a couple of months ago…reminding us that Earth really exists in a cosmic shooting gallery.