A woman with curly hair, wearing a light-colored long-sleeved shirt and dark pants, stands in a desert landscape, holding a large, glowing, metallic sphere with both hands. The sphere has a textured, crystalline surface with bright red and orange highlights. The background shows a vast, arid desert with mountains under a cloudy sky at dusk or dawn. The overall tone is dramatic and surreal.

Defining the Problem

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~10 km NEO
65 million yrs ago

- K-T extinction event
- Mega-tsunami
- Crater 170-300 km
- Extinguished 75% of all non-avian life on Earth



Comet fragments
1994

- Comet Shoemaker-Levy 9 hit Jupiter
- 21 fragments, some as large as 2 km in diameter
- 60 km/s
- 6 million megatons of TNT equivalent (entire arsenal of earth)



45 m NEO impact
50,000 years ago

- Arizona desert
- Nickel-iron meteorite
- 20 km/s
- 2.5 megatons of TNT
- Crater about 1 mile wide and 570 ft deep



40 m airburst
1908

- Tunguska, Russia
- Moving at 15 km/s
- Fragmented at a height of about 10 km
- 5 megatons TNT equivalent
- Destroyed 2000 sq km of forest



20 m airburst
2013

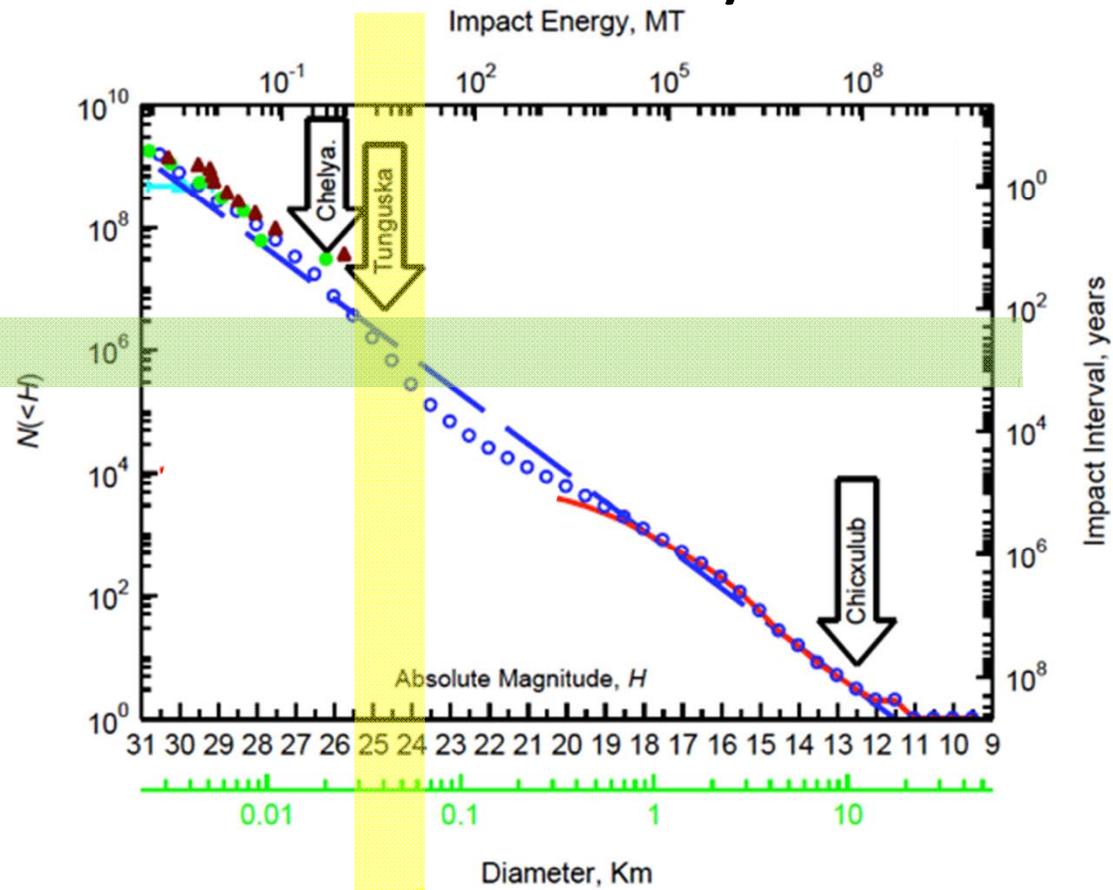
- 20-25 km above Chelyabinsk, Russia
- ~19 km/s
- Energy equivalent of 300-500 kT of TNT (about 30 Hiroshima bombs)
- Injured over 1,600 people and resulted in an estimated billion rubles in property damage

Tunguska-Type NEO (45 M airburst) Can Devastate a Major City

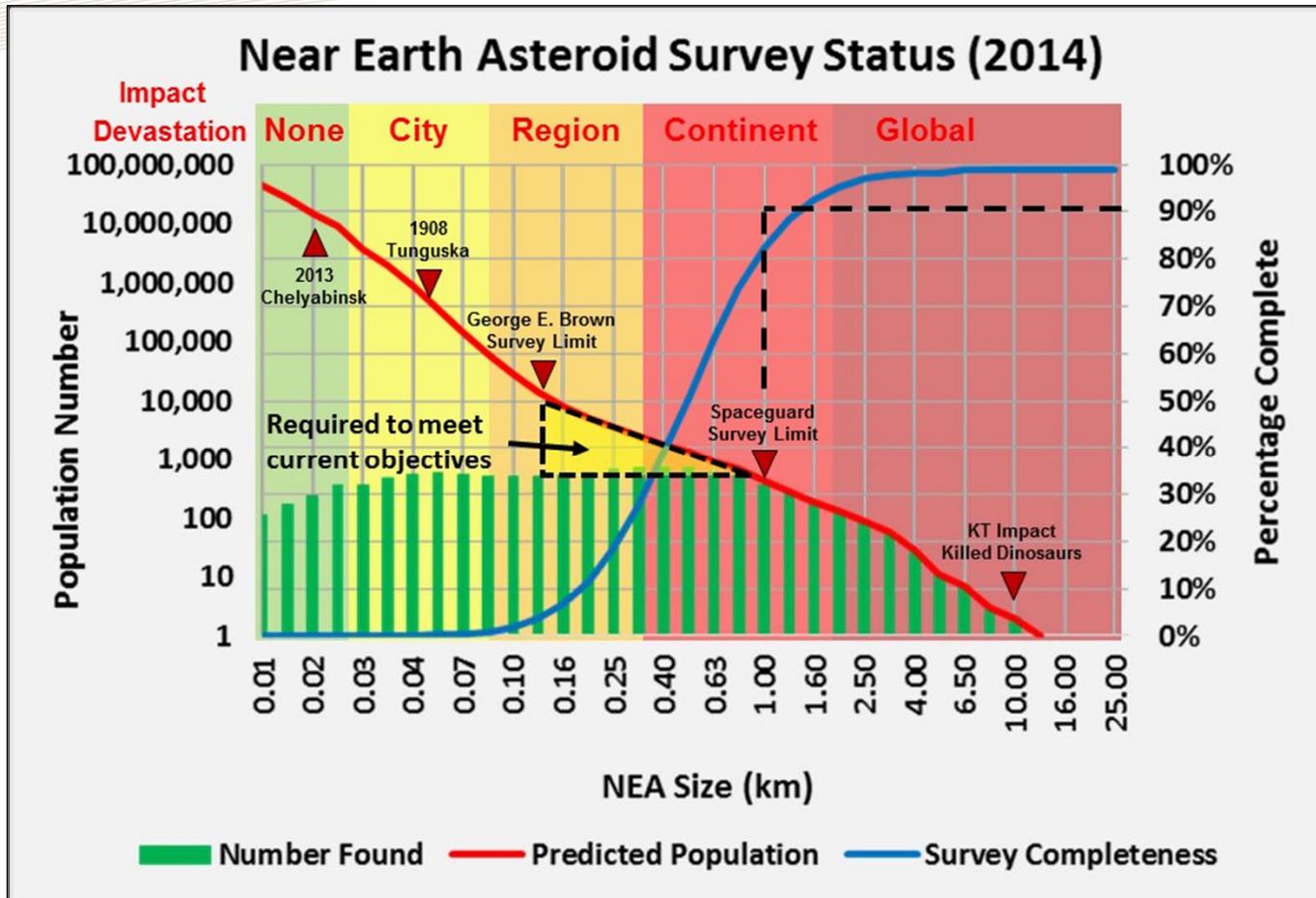
- Total Energy: 100 kT – 20 MT
- End result could be a large airburst or a major impact depending on the diameter and composition
 - Chelyabinsk dissipated most of its energy at a high enough altitude to cause minor damage
 - Tunguska event knocked down 2,000 sq. mi. of trees
 - Airburst destruction dependent on altitude, which is dependent on composition and size
- Damage is local – no expected systemic or secondary effects



About a Million “City Killer” NEOs



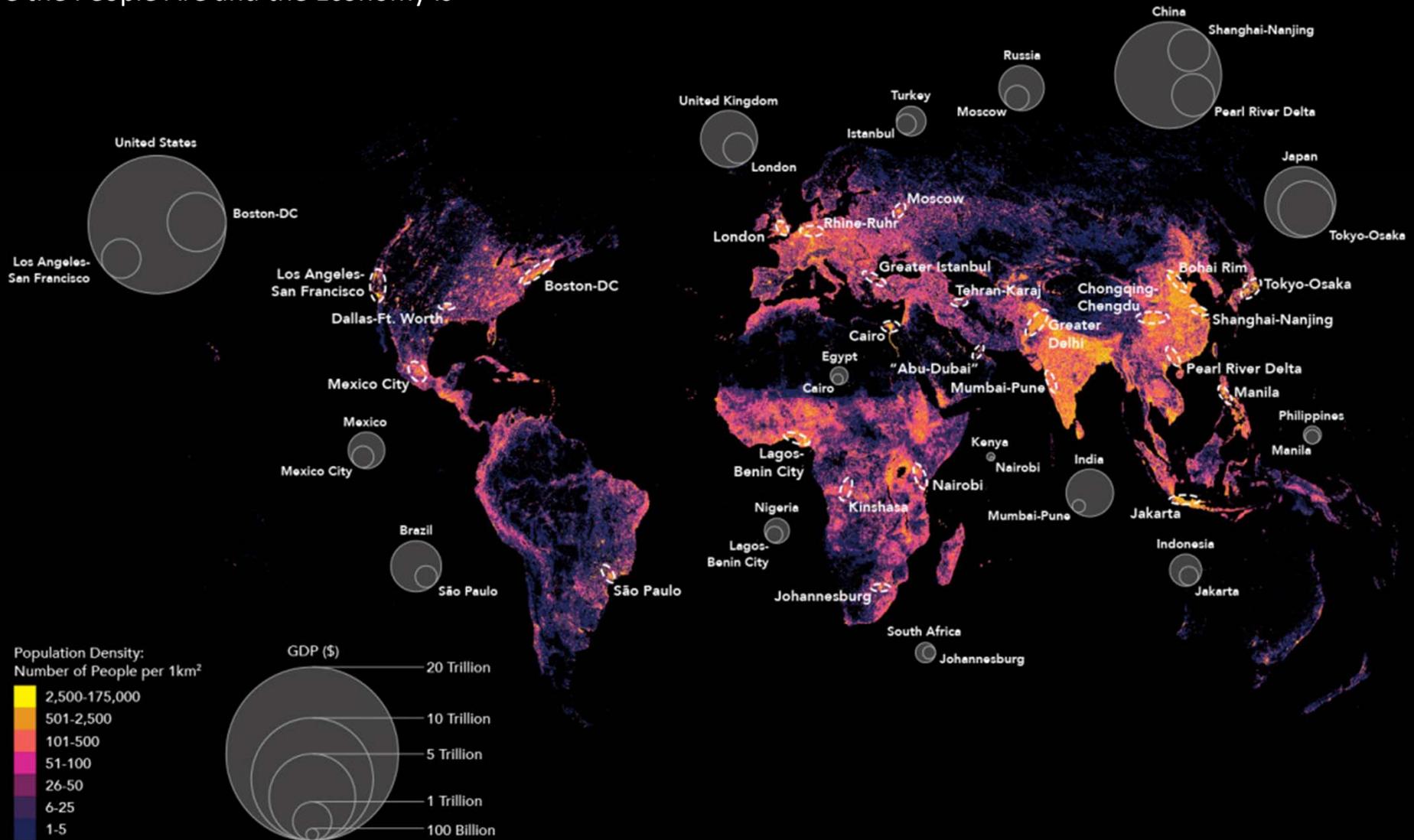
We Do Not Know Where They Are



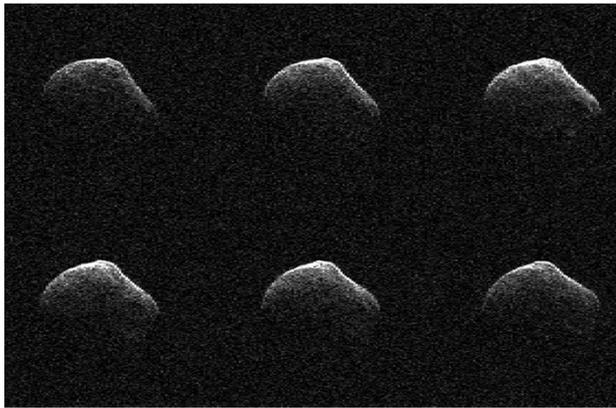
Arrive More Frequently

Characteristic Diameter of Impacting Object	Approximate Average Impact Interval (years)	Estimated Number	Energy Released (Megatons TNT)	Estimated Damage or Comparable Event
25–30 m	100-200	> 1.3 million	2	Fireball, airburst, shockwave, minor damage
50 m	2,000	—	10	Local damage comparable to that of largest existing thermonuclear weapon
140 m	30,000	13,000–20,000	~500	Destruction on regional/national scale
300–500 m	~100,000	—	≤10,000	Destruction on continental scale
1 km	700,000	980–1,000	80,000	Global effects, many millions dead
10 km	100 million	4	80 million	Complete extinction of the human species

Where the People Are and the Economy Is



It's not Just about Detection: Characterization is KEY



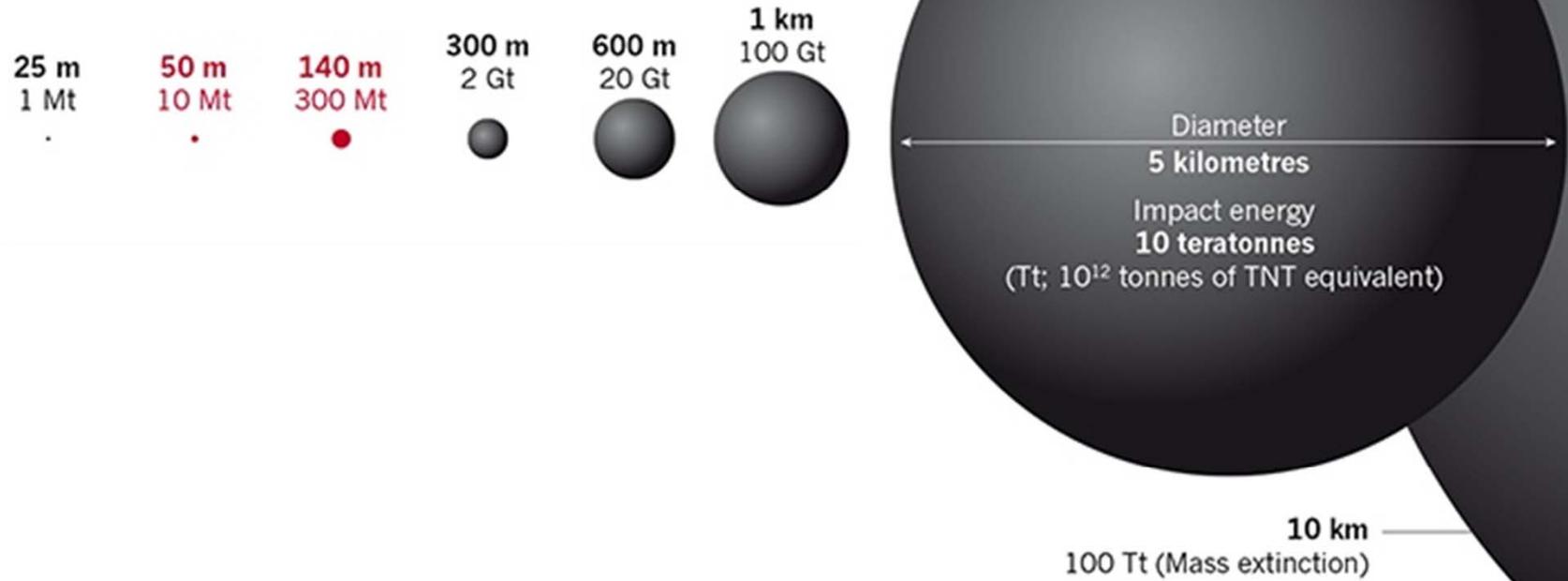
Radar images of comet P/2016 BA14 taken on March 23, 2016, using an antenna of NASA's Deep Space Network

Illustration from 2016

- P/2016 BA14 first detected as an asteroid in January 2016 and then reclassified as a comet. Presumed to be 125 m.
- In March, BA14 came within 2.2 million miles of Earth, 9 times the Earth-moon distance - the third closest comet flyby in recorded history
- As it came closer, radar estimated size as 1 kilometer.
- **We were off by almost an order of magnitude!**

<http://www.jpl.nasa.gov/news/news.php?feature=6180>

BACKUP SLIDES



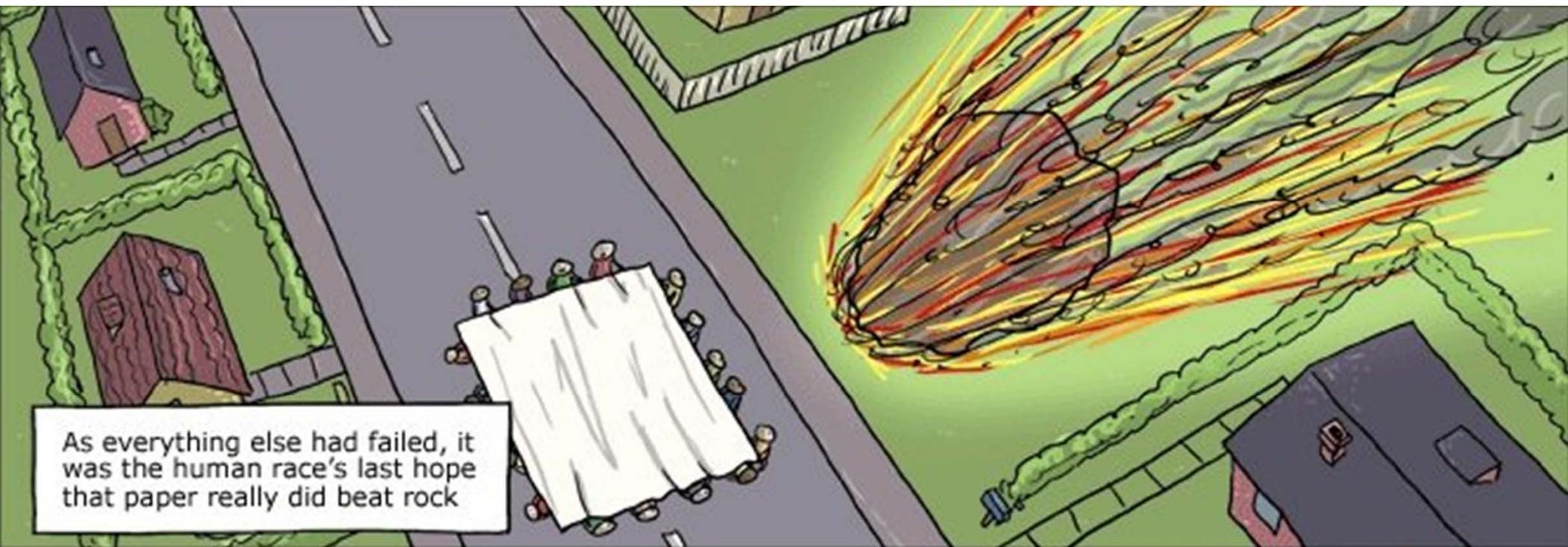
How to Avoid Asteroid Scares



“Let's go burn down the observatory so this will never happen again.”

-Moe the bartender, after Springfield narrowly avoids being destroyed by a comet, from “Bart's Comet.”





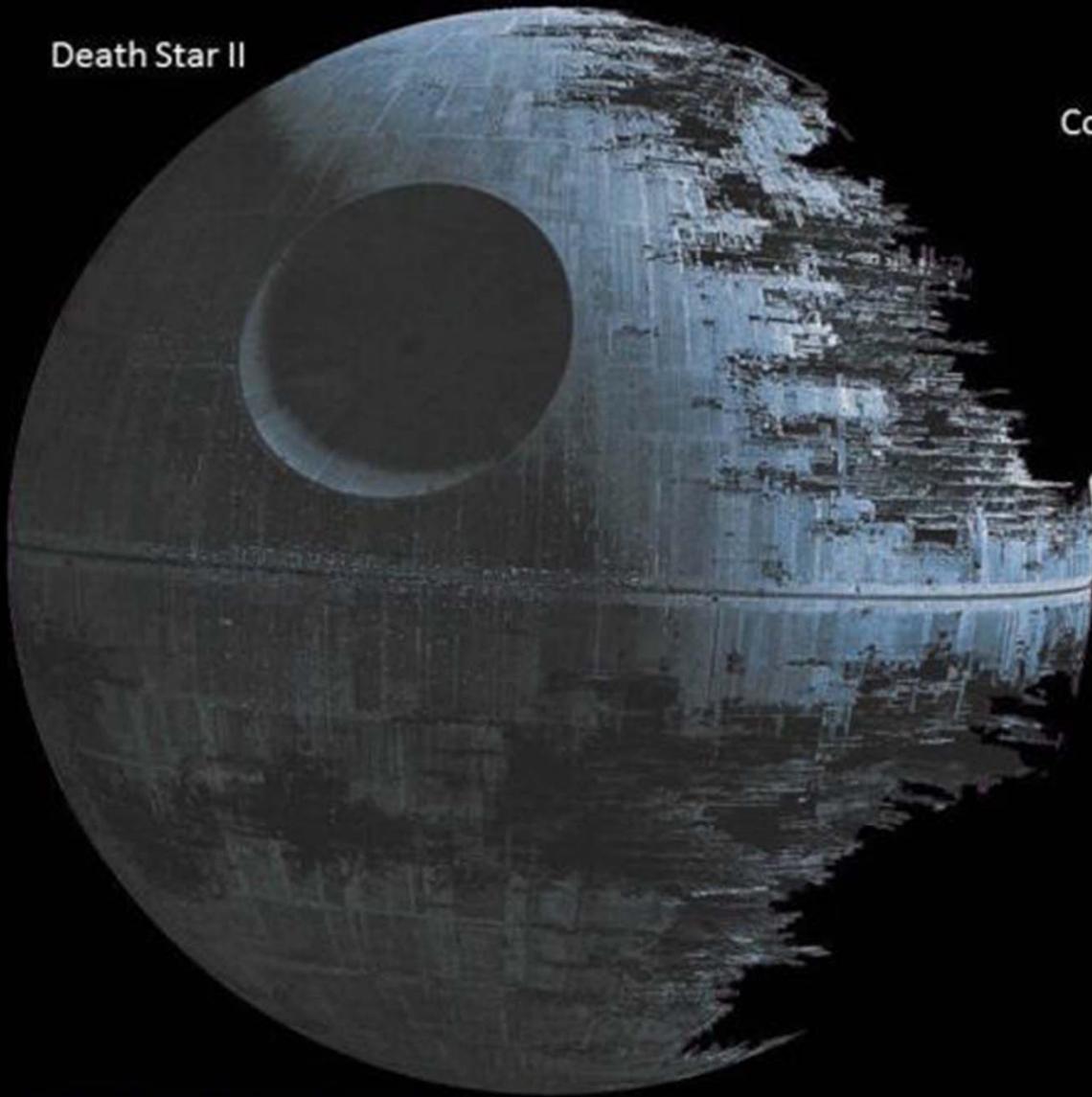
As everything else had failed, it was the human race's last hope that paper really did beat rock



Comet 67P/C-G
— which
the Philae probe
landed on in
November 2014
is absolutely tiny:
just 3.5 miles
wide.

But
superimposed on
Los Angeles, it's
pretty big

Death Star II



Comet 67P

Superimposed
on the Death
Star, not so
much...

Hypothetical scenario



150-400 m asteroid discovered April 2015, probability of Earth impact in 2022 is 1%

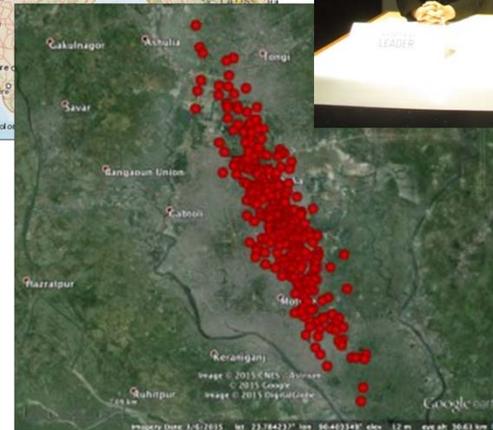


- April 2016, impact probability in September 2022 is 43%; seven deflection missions (4 by the US, one each by Europe, Russia and China) planned, 6 implemented
- India adds a nuclear disruption

- January 2022, deflection missions only partially successful
- Impact corridor moved from South China Sea to somewhere over the Indian subcontinent



August 3, 2022 (1 month prior)
Expected impact in Dhaka Bangladesh



<http://neo.jpl.nasa.gov/pdc15/>

Previous Mass Extinctions



Ordovician-Silurian mass extinction



Triassic-Jurassic mass extinction



Late Devonian mass extinction



Cretaceous-Tertiary mass extinction



Permian mass extinction

?

Source: http://www.bbc.co.uk/nature/extinction_events