NEAR EARTH OBJECTS

A DATA VISUALIZATION JOURNEY AND WARNING

Who Are We?

We are a group of three students from the University of Michigan-Flint:

Kedree Proffitt: Physics and Data Science Dual Major

Landon Rollins: Computer Science

Zach Whitney:

We are all part of Dr. Halil Bisgin's class: Introduction to Data Visualization (CSC 302) for Summer 2022

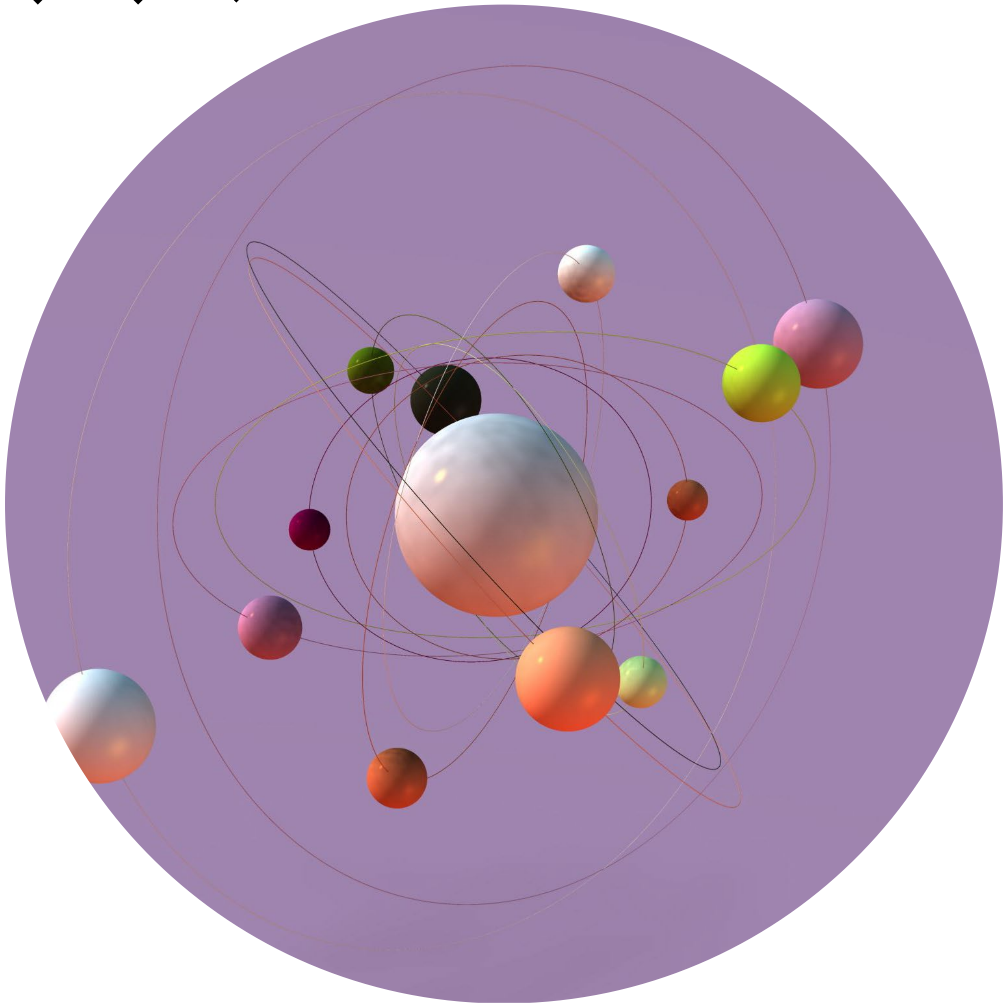
What is This?

This presentation is the showcase of countless hours of research, writing, data obtaining, cleaning, and most importantly visualization. This also serves as our collective final for this accelerated summer class.

We have done our project on near Earth objects with a focus on asteroids. Little knowledge of physics or asteroids is needed; we will provide what is necessary.

WHAT ARE NEOS

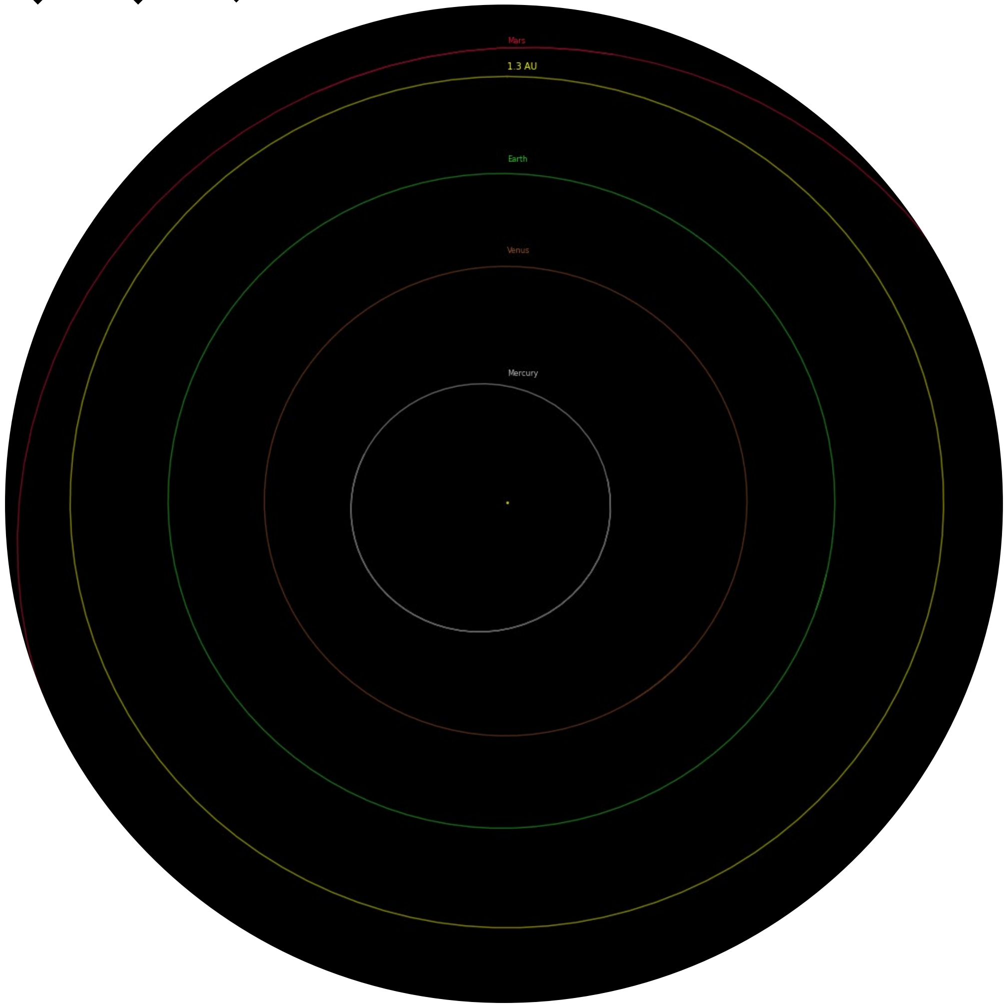
WHAT ARE NEAR EARTH OBJECTS?



Space Objects

- Objects are classified in various ways which we will explain
- Small bodies such as asteroids and comets are basically small planets (minor-planets)
- Can range from rock sized to a kilometer or larger, about 11 football fields

Near Earth Objects



- NASA has a simple definition for near earth objects, the object must have a perihelion distance of 1.3 AU or less (1 AU is the distance from the Earth to the Sun)
- In English: object at closest approach to the sun comes within 1 + 0.3 distance of Earth orbit. Due to the funky way orbits work this basically means within 0.3 AU of the Earth

THE NATURAL QUESTIONS WE POSE

WHAT IS IT THAT WE CARE ABOUT

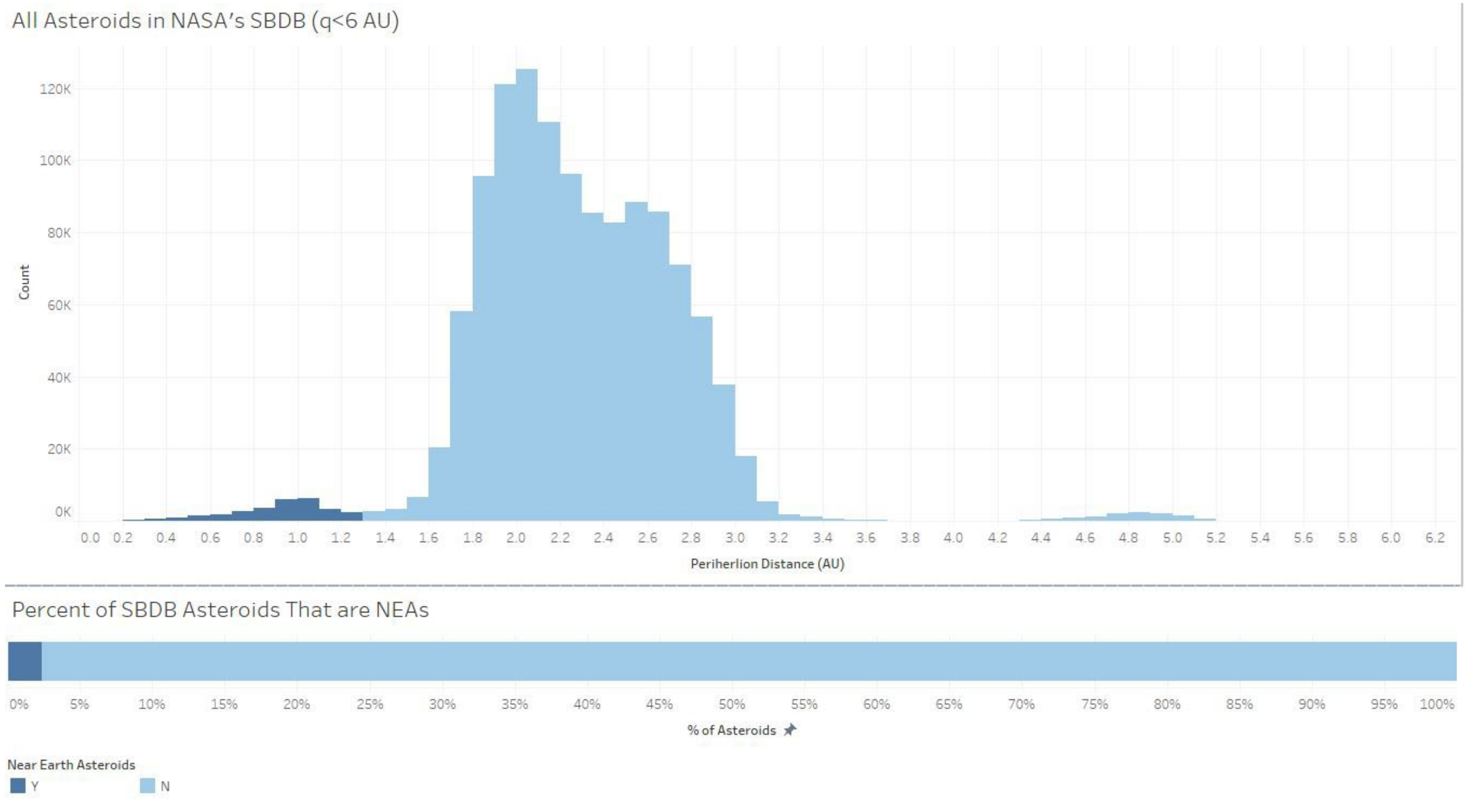
YET KNOW SO LITTLE ABOUT

The Natural Questions we Pose on NEOs:

- How many are out there?
- How many are close to us?
- How are they classified?
- How many are considered dangerous?
- Will we collide with them soon?
- How certain are we?
- Have we found them all?
- How do we increase our certainty?
- How much money does NASA get to find them?
- How does this compare to other agencies, the past and future?

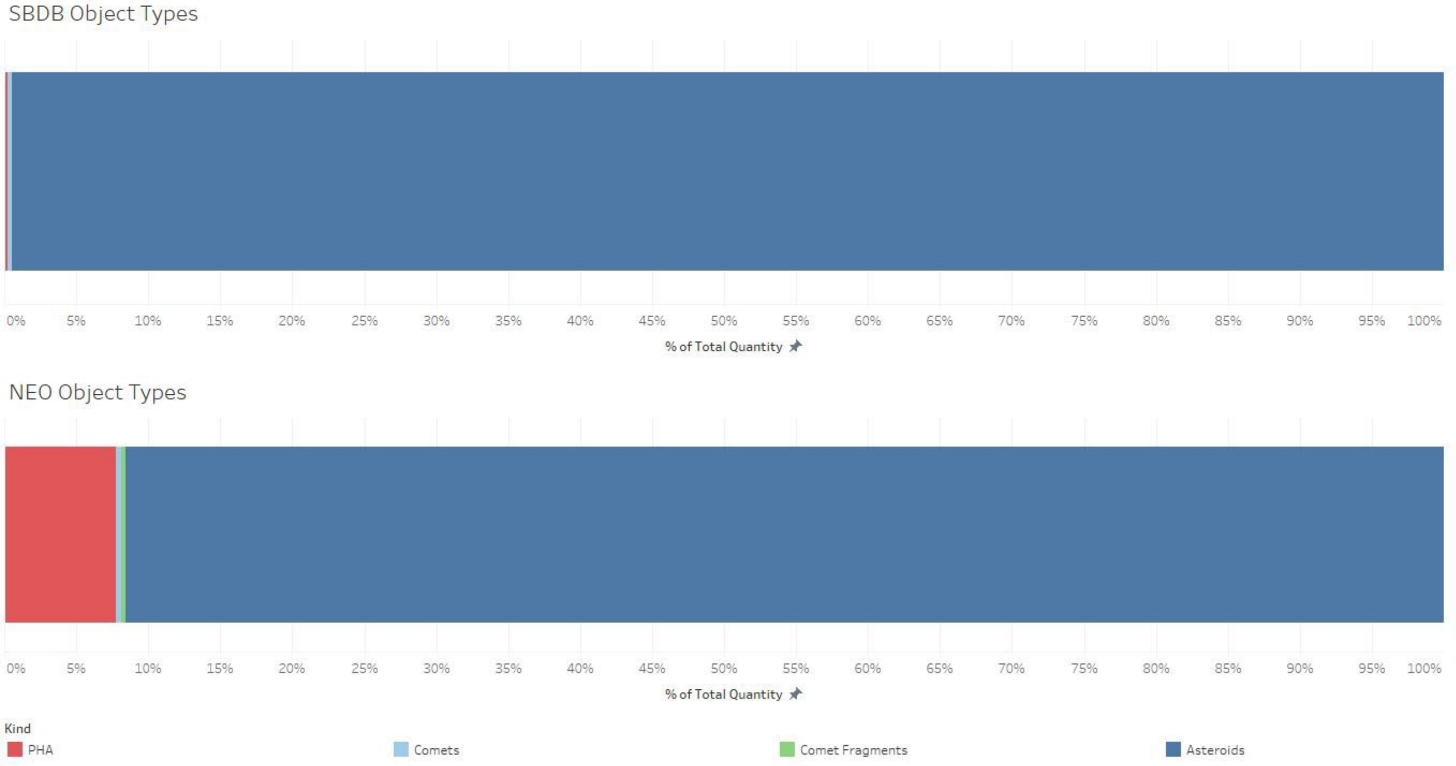
How many are out there?

- NASA has a database with every small body known
- The vast majority of objects are asteroids, with some being comets or fragments
- The right diagram shows all asteroids in the SBDB according to their distance
- The darker portion are the ones considered “near Earth”
- Most asteroids are very far away!
- NASA lists about 1.22 million asteroids



How many are close to us?

- NASA lists 29,406 NEAs as of 8/15/2022
- Along with 194 comets / comet fragments
- A significant portion of asteroids are classified as PHAs, what does this mean?

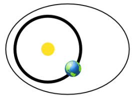


Group	Definition	Description
NECs	q<1.3 au P<200 years	Near-Earth Comets
NEAs	q<1.3 au	Near-Earth Asteroids
Atiras	a<1.0 au Q<0.983 au	NEAs whose orbits are contained entirely with the orbit of the Earth (named after asteroid 163693 Atira).
Atens	a<1.0 au Q>0.983 au	Earth-crossing NEAs with semi-major axes smaller than Earth's (named after asteroid 2062 Aten).
Apollos	a>1.0 au q<1.017 au	Earth-crossing NEAs with semi-major axes larger than Earth's (named after asteroid 1862 Apollo).
Amors	a>1.0 au 1.017<q<1.3 au	Earth-approaching NEAs with orbits exterior to Earth's but interior to Mars' (named after asteroid 1221 Amor).
PHAs	$MOID$<=0.05 au H<=22.0	Potentially Hazardous Asteroids: NEAs whose Minimum Orbit Intersection Distance (MOID) with the Earth is 0.05 au or less and whose absolute magnitude (H) is 22.0 or brighter.

How are they classified?

Amors

Earth-approaching NEAs with orbits exterior to Earth's but interior to Mars' (named after asteroid (1221) Amor)



$a > 1.0$ AU
1.017 AU $< q < 1.3$ AU

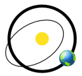
Apollos

Earth-crossing NEAs with semi-major axes larger than Earth's (named after asteroid (1862) Apollo)

$a > 1.0$ AU
$q < 1.017$ AU

Atens

Earth-crossing NEAs with semi-major axes smaller than Earth's (named after asteroid (2062) Aten)



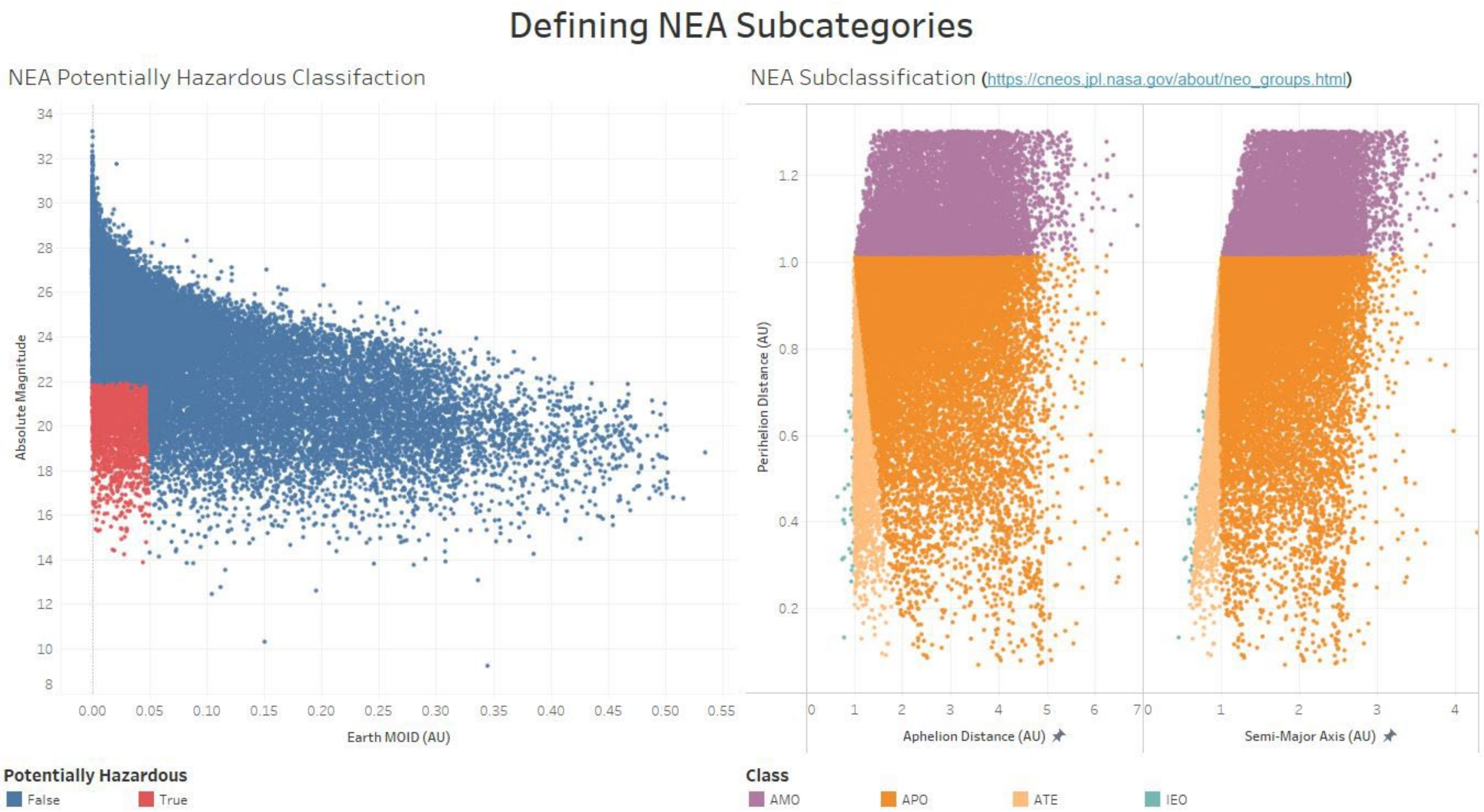
$a < 1.0$ AU
$Q > 0.983$ AU

Atiras

NEAs whose orbits are contained entirely within the orbit of the Earth (named after asteroid (163693) Atira)

$a < 1.0$ AU
$Q < 0.983$ AU

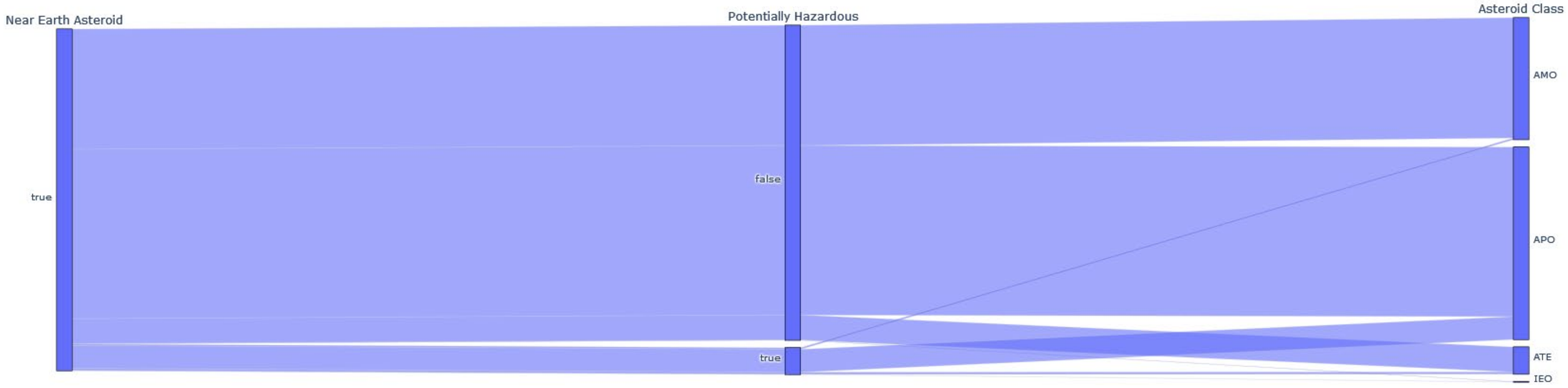
(q = perihelion distance, Q = aphelion distance, a = semi-major axis)

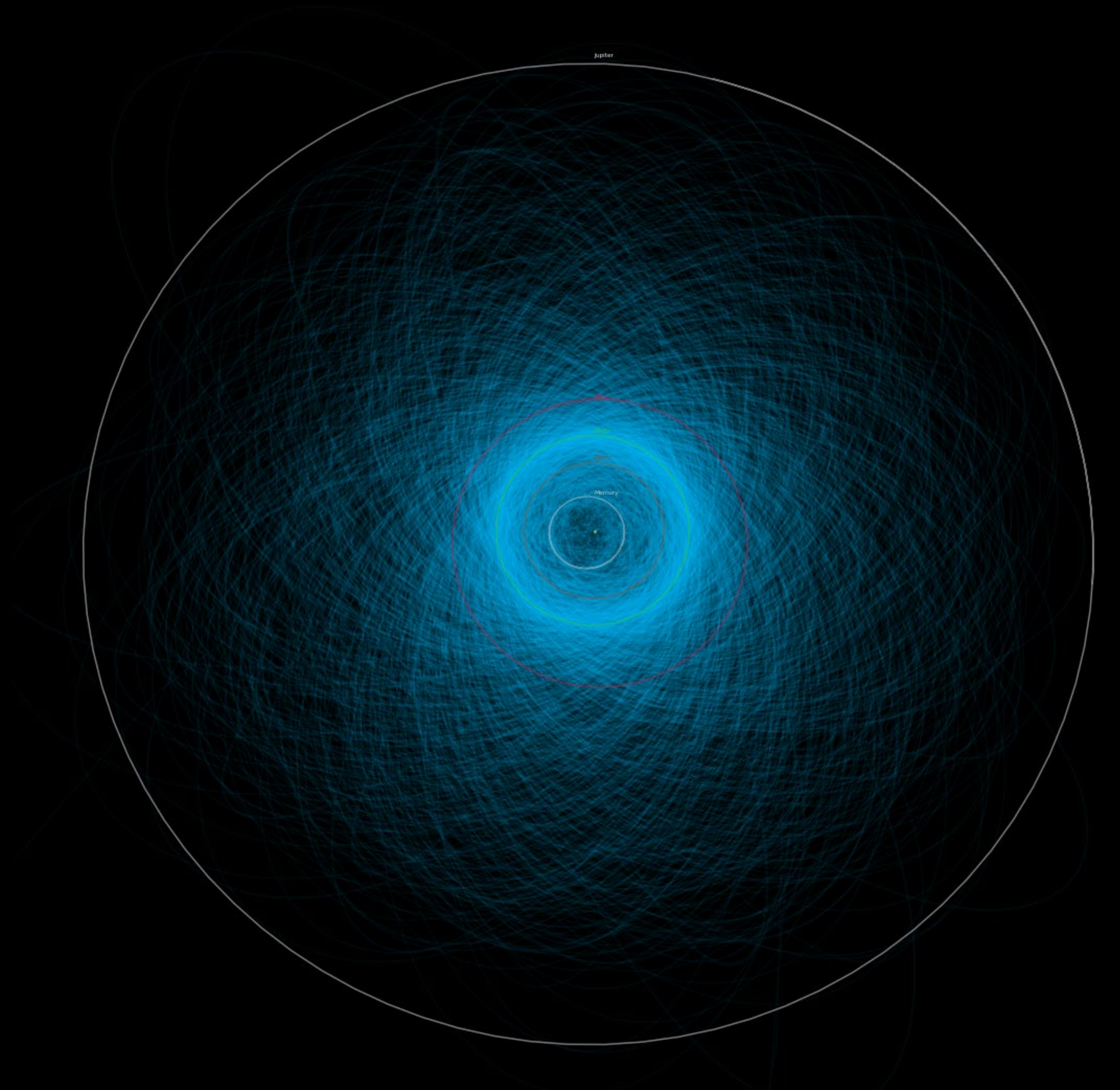


Left two graphics from: https://cneos.jpl.nasa.gov/about/neo_groups.html

How many are considered dangerous?

As you may have seen in the last slide, an NEA is considered a PHA if it has a MOID of 0.05 AU or less and an absolute magnitude of 22 or less, basically meaning it comes close to us and its assumed to be pretty big.
Out of the 28,863 in our dataset (some were excluded for various reasons) 2,252 were PHAs, you can see what asteroid class they belonged to as well below.





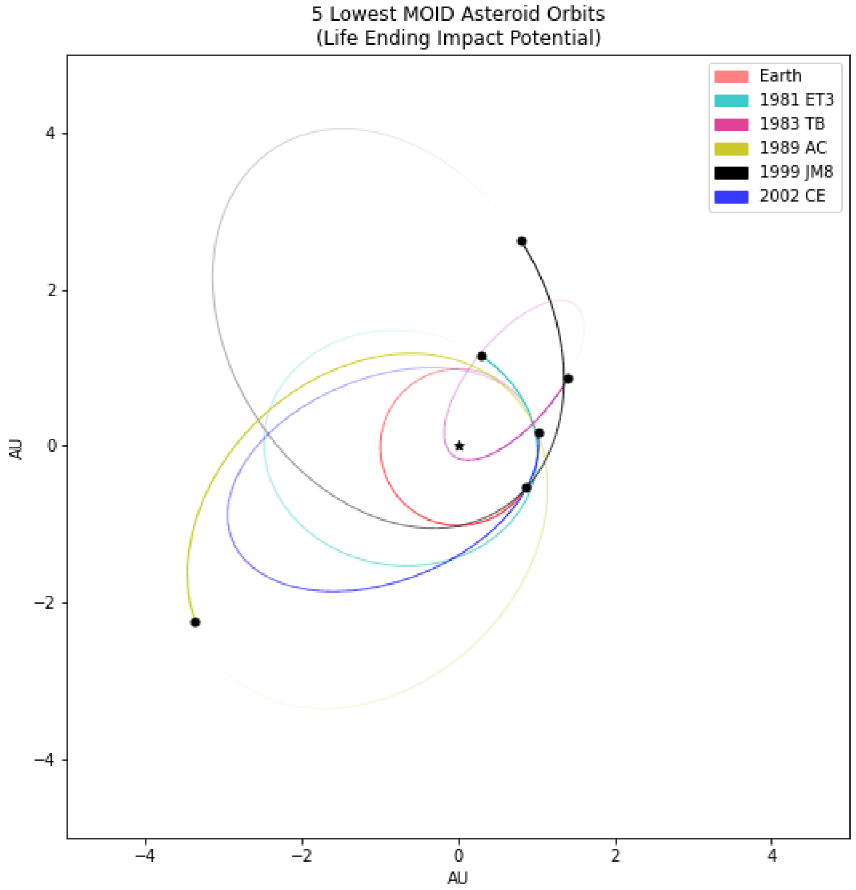
Here is a simulation of all PHA orbits made by our team using NASA’s SBDB PHA orbital data and PyAstronomy for the calculations. This was directly inspired by a now outdated graphic made by NASA which had about 14,000 asteroids at the time. The green ellipse is the Earth’s orbit, each blue ellipse is a PHA.

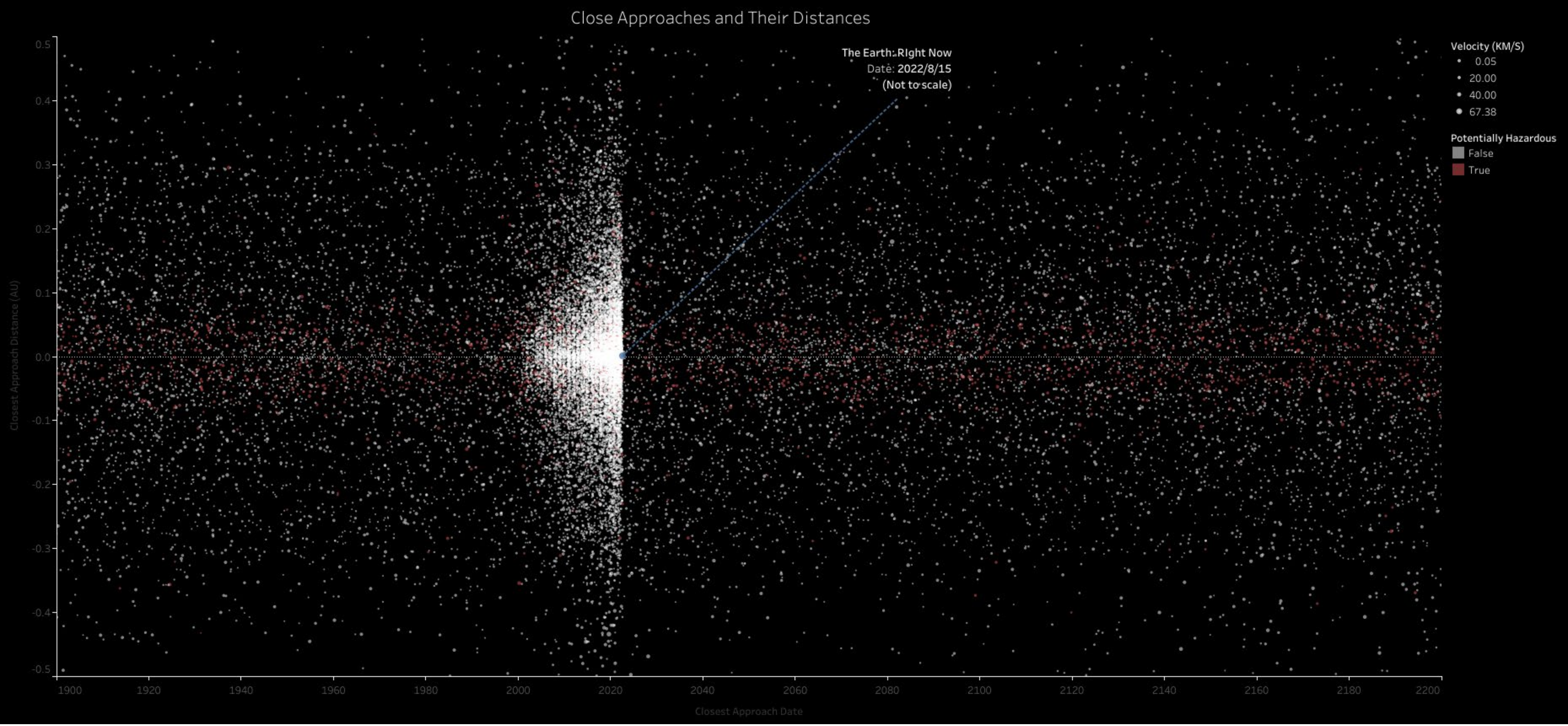
Inspiration:

https://www.jpl.nasa.gov/images/pia17041-orbits-of-potentially-hazardous-asteroids-phas

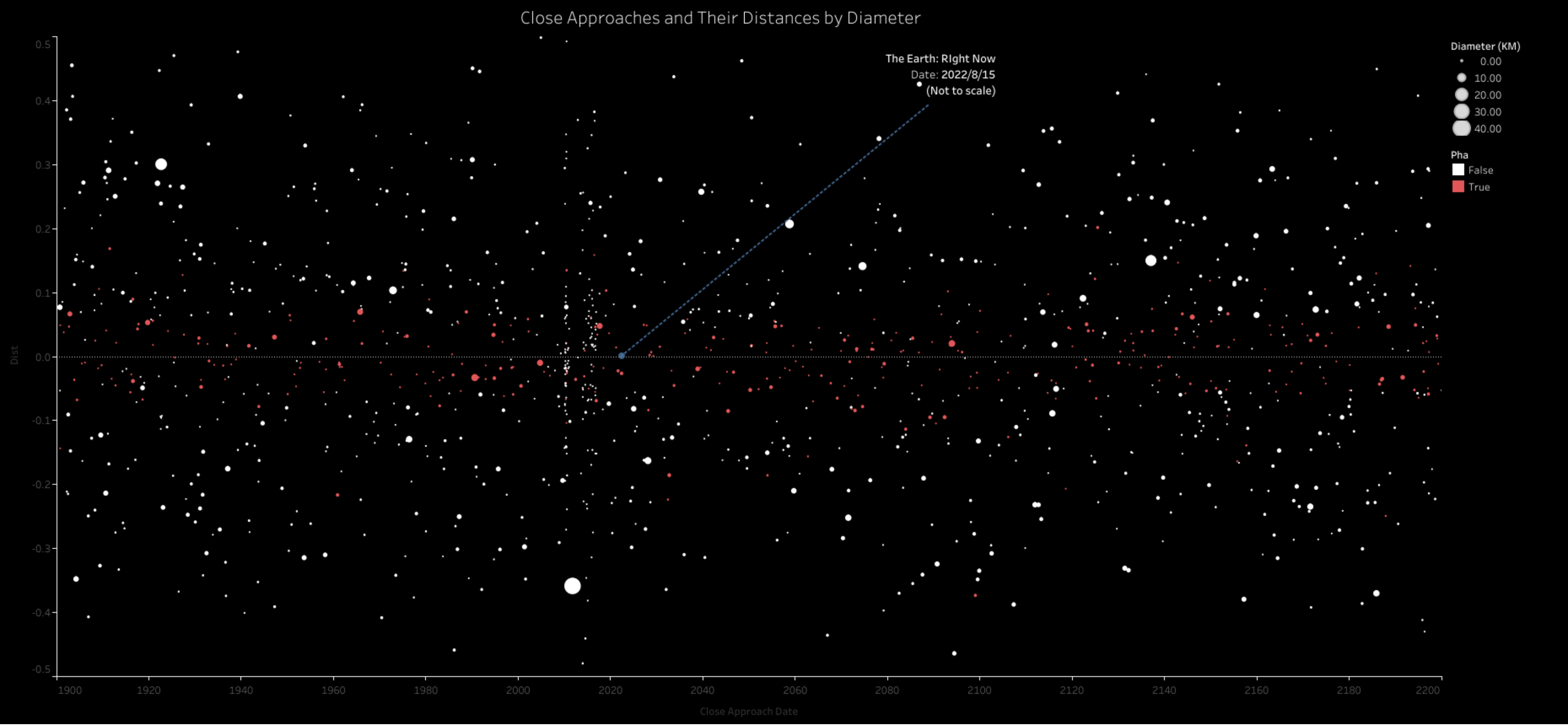
Will we collide with them soon?

- This is a tricky question, we collide with asteroids commonly, but they almost always burn away in the atmosphere.
- When it comes to dangerous asteroids, we do not know for sure, but of the asteroids we can see, they do not predict a dangerous impact for at least 100 years.
- The single highest cumulative probability for impact is 5% by 2100, but this is only for one asteroid, there are many others.





The above is every NEA's closest approach to the Earth, this does not include repeat flybys, only the closest. The center blue dot is the Earth at this very time, the X-axis is time, left of the blue dot is the past, the right is the future. The Y-axis represents how close the asteroid approaches the Earth, positive and negative is arbitrary and random. The dot size is its relative velocity at that time and the color is its PHA status.



The above is very similar to the previous slide only that the size of the dots is the known diameter of the asteroid, there are significantly less as many asteroids do not have a known size as we do not know their albedo which currently is used to estimate size along with absolute magnitude.

How certain are we?

- NASA defines NEO orbit certainty in a complex way, from 0-9. That's not the complex part, its logarithmic.
- It is defined as the "anticipated longitudinal uncertainty in the minor planet's mean anomaly after 10 years."
- The necessary data is entered into the formula, and the result is rounded into an integer between 0-9.
- 0 represents great certainty and 9 essentially means they have absolutely zero idea where it will be in 10 years due to the way arc seconds work.

$$r = (\Delta\tau \cdot e + 10 \cdot \frac{\Delta P}{P}) \cdot 3600 \cdot 3 \cdot \frac{k_o}{P}$$

Δτ: uncertainty in the perihelion time in days

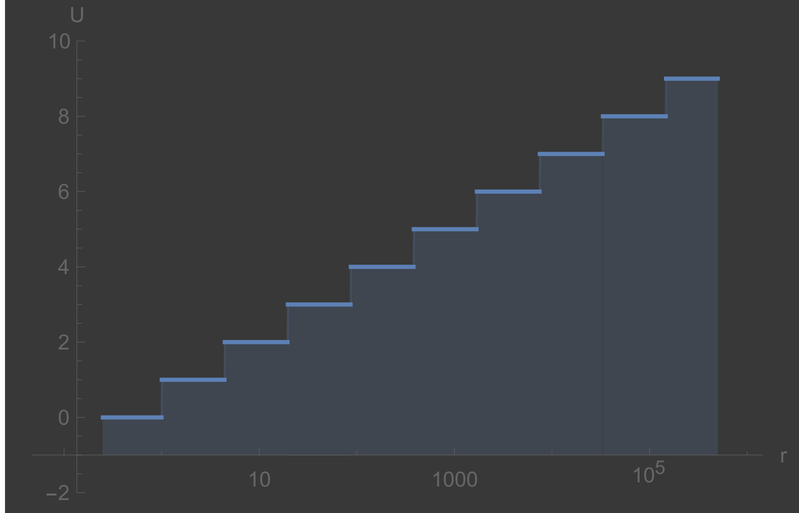
e: eccentricity of the determined orbit

P: orbital period in years

ΔP: uncertainty in the orbital period in days

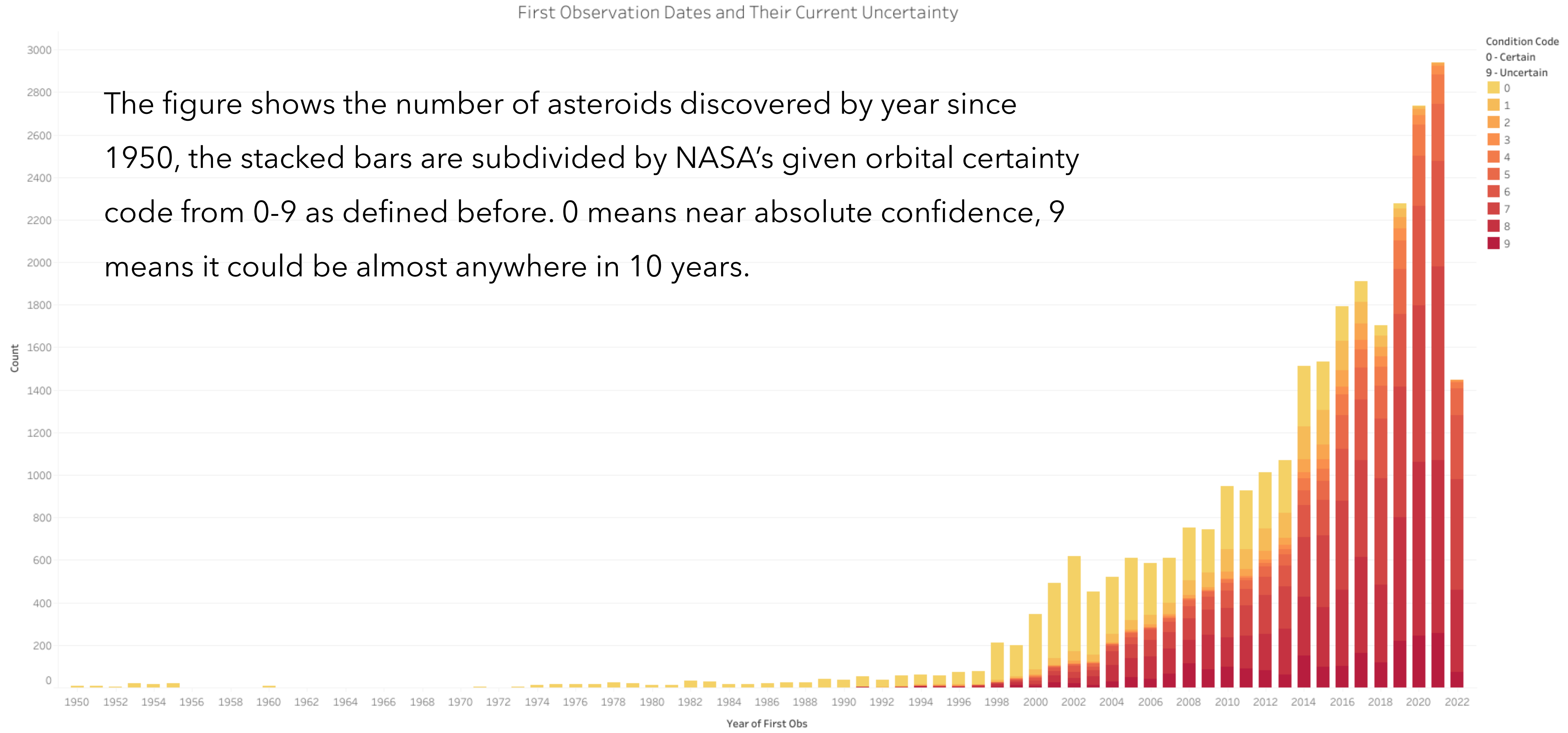
k_o: $0.01720209895 \cdot \frac{180}{\pi}$, Gaussian gravitational constant, converted to degrees

U	Runoff Longitude runoff per decade
0	< 1.0 arc second
1	1.0–4.4 arc seconds
2	4.4–19.6 arc seconds
3	19.6 arc seconds – 1.4 arc minutes
4	1.4–6.4 arc minutes
5	6.4–28 arc minutes
6	28 arc minutes – 2.1°
7	2.1°–9.2°
8	9.2°–41°
9	> 41°

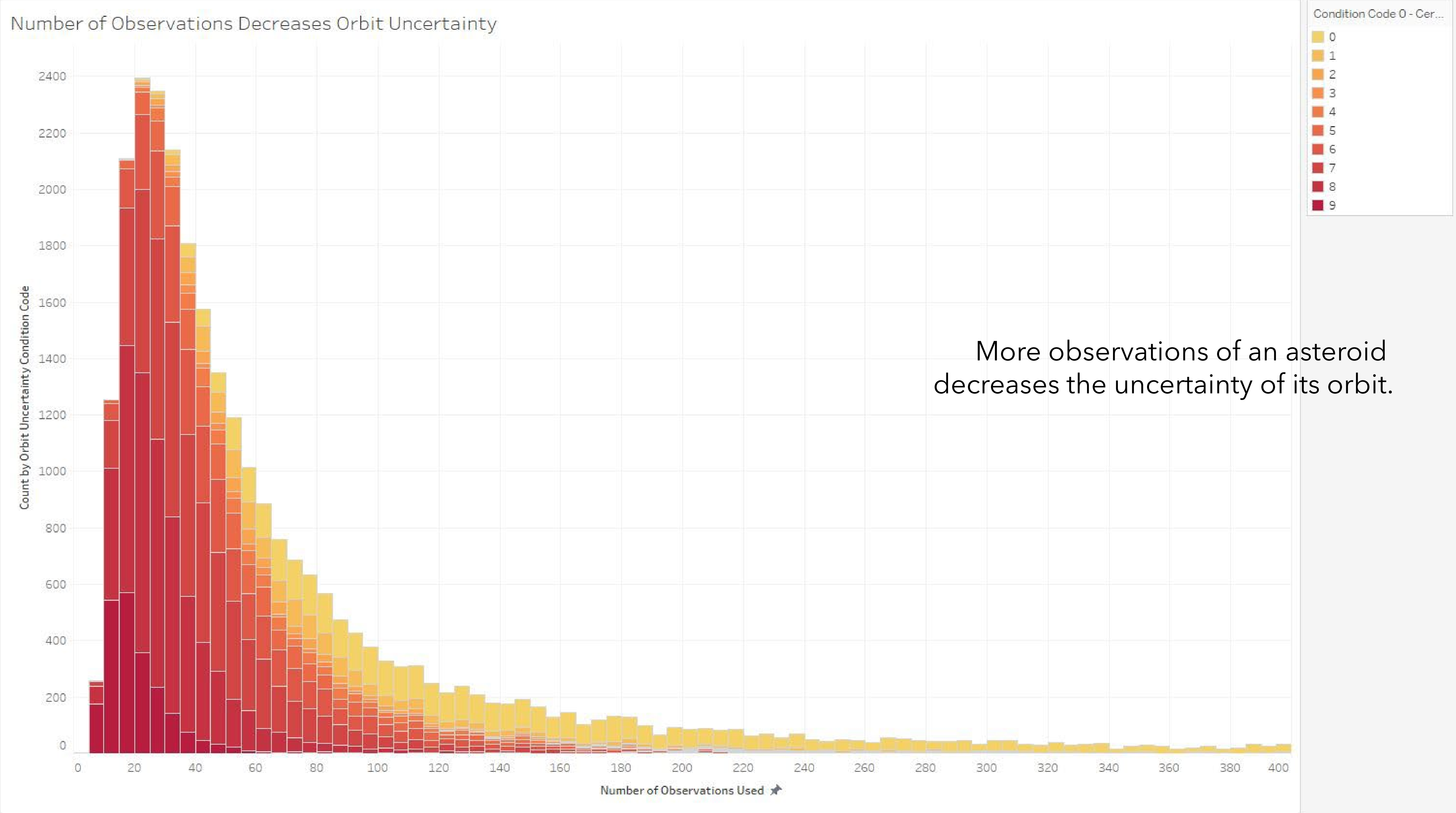


Source: https://en.wikipedia.org/wiki/Uncertainty_parameter

The figure shows the number of asteroids discovered by year since 1950, the stacked bars are subdivided by NASA's given orbital certainty code from 0-9 as defined before. 0 means near absolute confidence, 9 means it could be almost anywhere in 10 years.



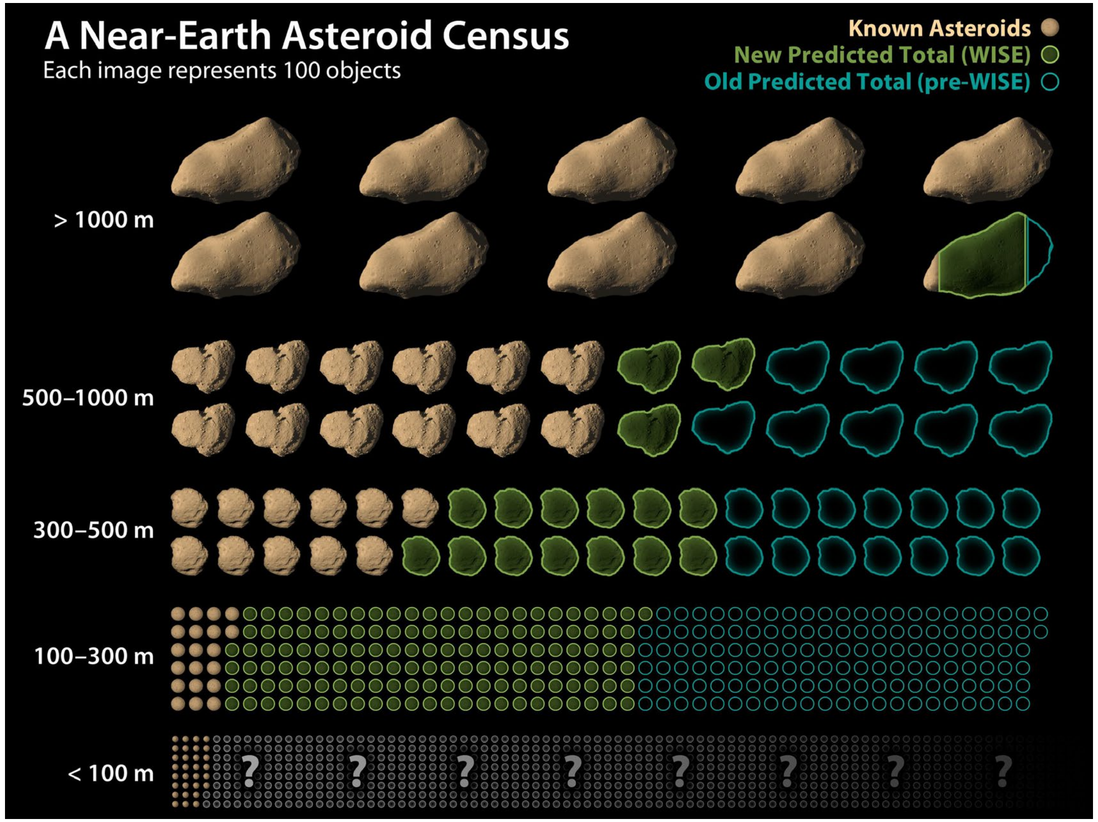
The average uncertainty increases with year of first observation which might be counter-intuitive. Surely better technology means less uncertainty, so what gives?

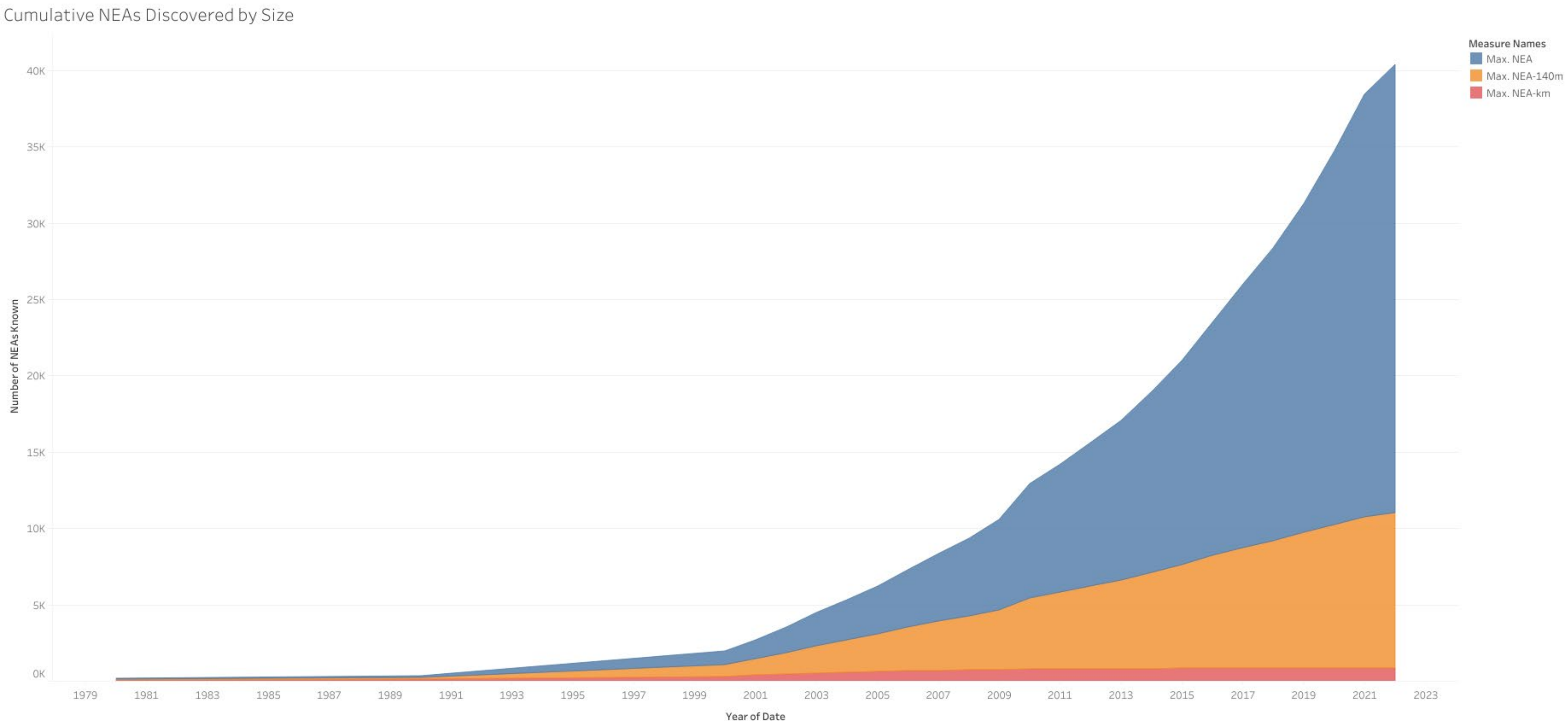


More observations of an asteroid decreases the uncertainty of its orbit.

Have we found them all?

- Certainly not! NASA claims to have found 90%+ of NEAs sized 1km or more.
- The brown out of green is the current number of known asteroids out of the green estimated total.
- Only about 25% of 140m+ asteroids are estimated to have been found.





The figure above shows the cumulative NEA asteroid count over the years, it is easy to see that the 1km asteroids have slowed down considerably indicating that we have found most of them.

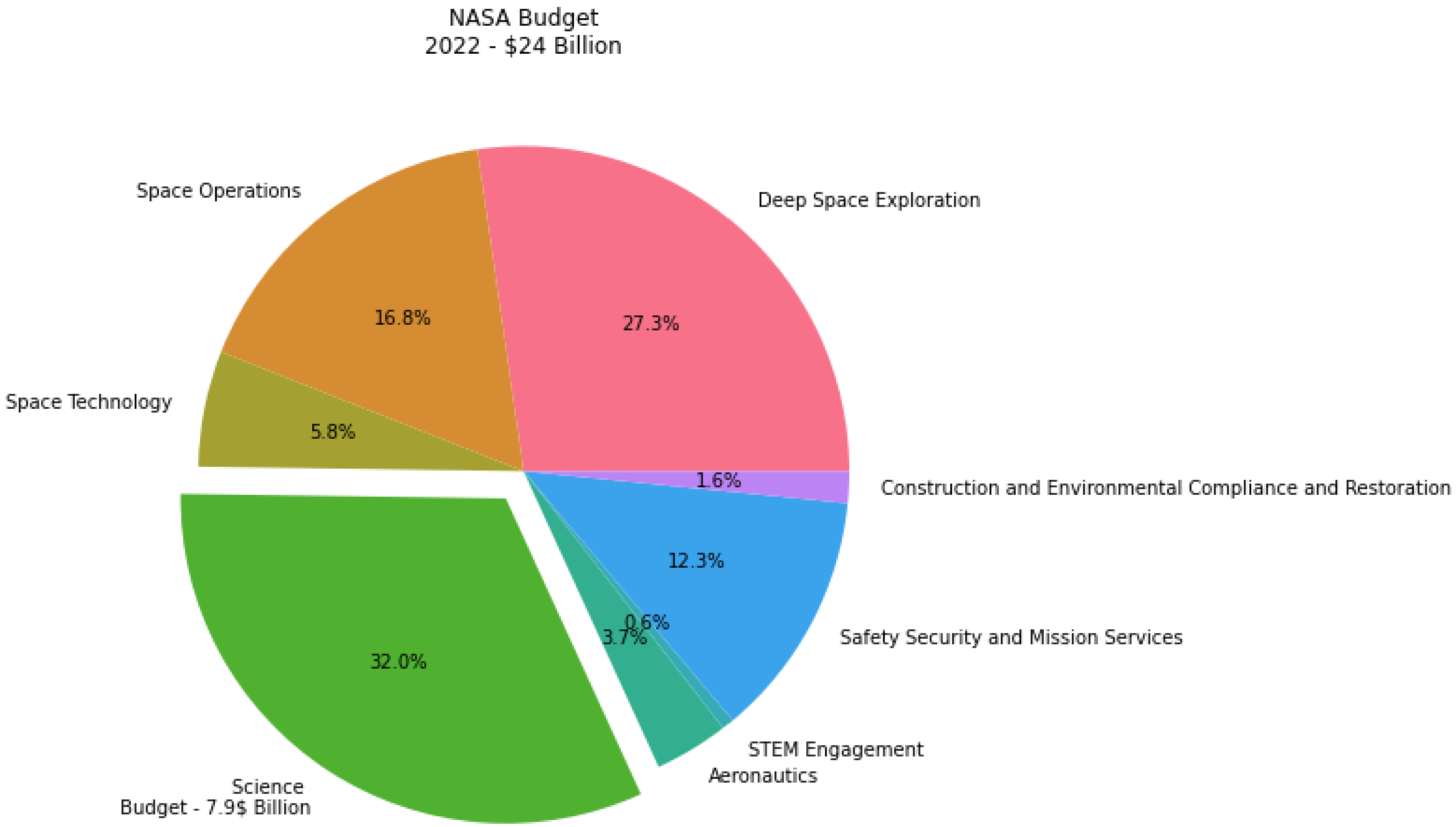
Diameter of Impacting Asteroid	Type of Event	Approximate Impact Energy (MT)	Average Time Between Impacts (Years)
5 m (16 ft)	Bolide	0.01	1
10 m (33 ft)	Superbolide	0.1	10
25 m (80 ft)	Major Airburst	1	100
50 m (160 ft)	Local Scale Devastation	10	1000
140 m (460 ft)	Regional Scale Devastation	300	20,000
300 m (1000 ft)	Continent Scale Devastation	2,000	70,000
600 m (2000 ft)	Below Global Catastrophe Threshold	20,000	200,000
1 km (3300 ft)	Possible Global Catastrophe	100,000	700,000
5 km (3 mi)	Above Global Catastrophe Threshold	10,000,000	30 million
10 km (6 mi)	Mass Extinction	100,000,000	100 million

We can see above why 1km and 140m asteroids are targets by congress and NASA, they represent jumps in devastation levels.

https://trumpwhitehouse.archives.gov/wp-content/uploads/2021/01/NEO-Impact-Threat-Protocols-Jan2021.pdf

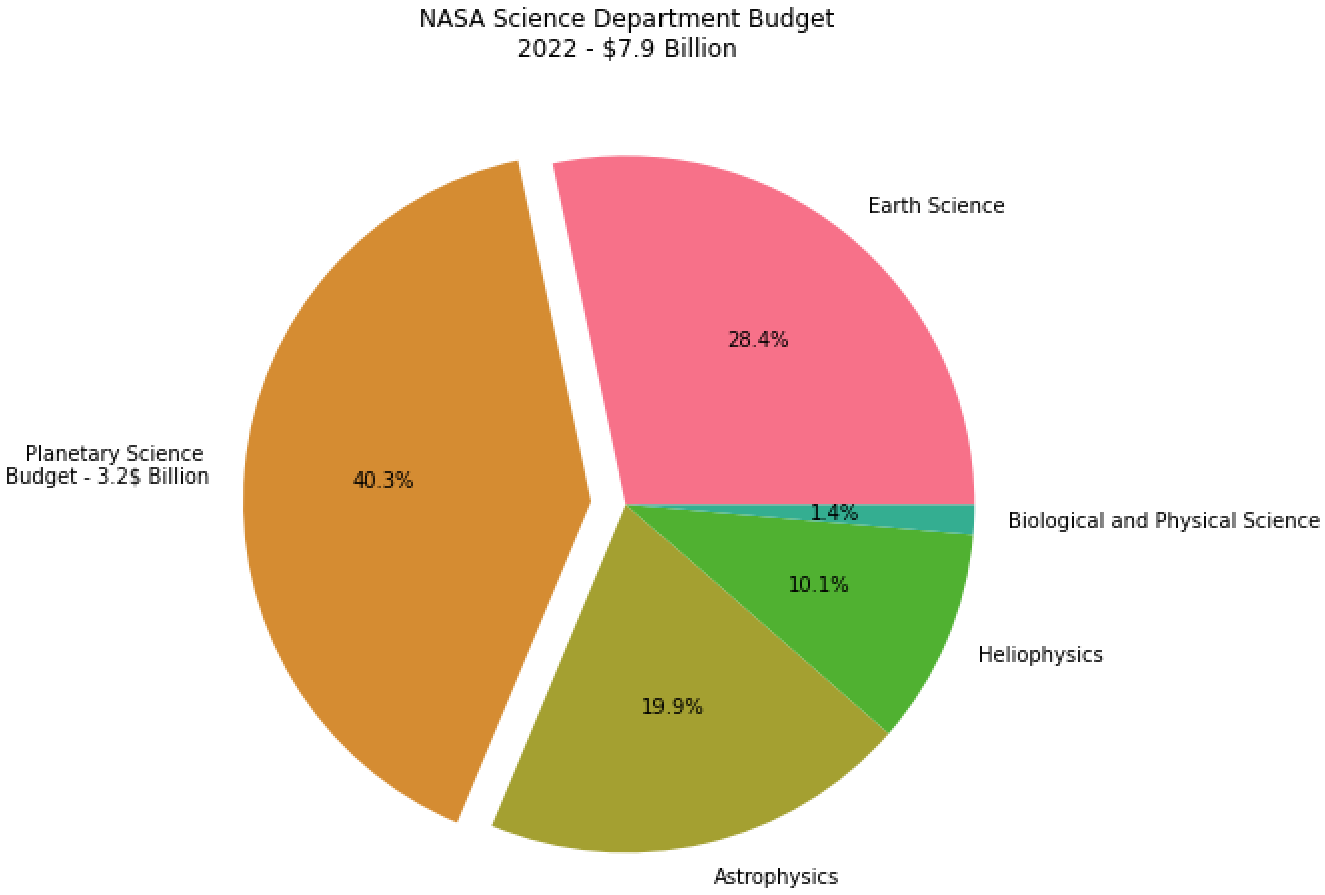
How much money does NASA get to find them?

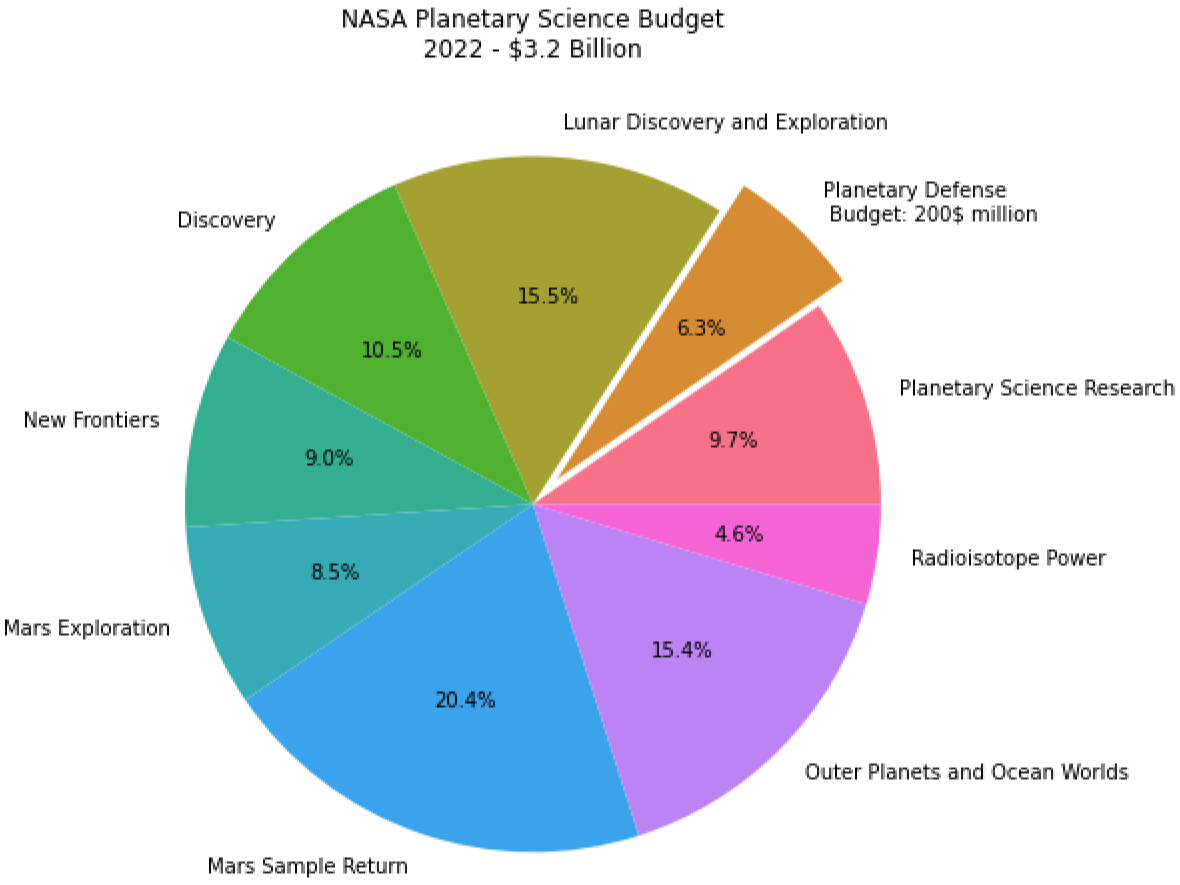
- The total NASA budget in 2022 was 24$ billion.
- This must be shared with between every department in NASA however, which includes everything from deep space exploration, to environmental restoration and engaging in STEM activities.
- The budget for NEO surveying can be found within the science department of NASA.
- This department receives the largest amount of the budget, at 7.9$ billion, but we must go deeper to find the actual budget for NEO surveying.



How much money does NASA get to find them?

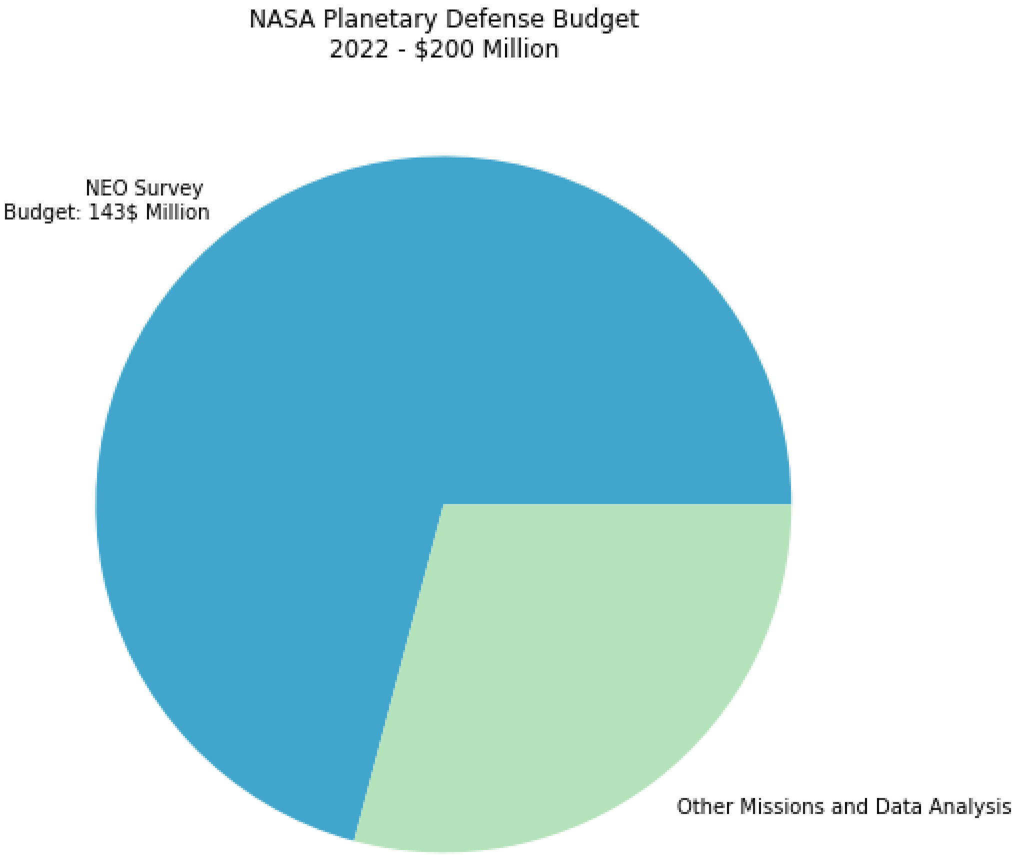
- Here we see the breakdown for the Science department's budget (7.9$ billion) and located within that is the Planetary Defense department (3.2$ billion), where NEO Surveying is located.
- As we can see there are many departments in which NASA must share the budget between, and by the time we reach the Planetary Defense department the budget is only 200$ million.





How much money does NASA get to find them?

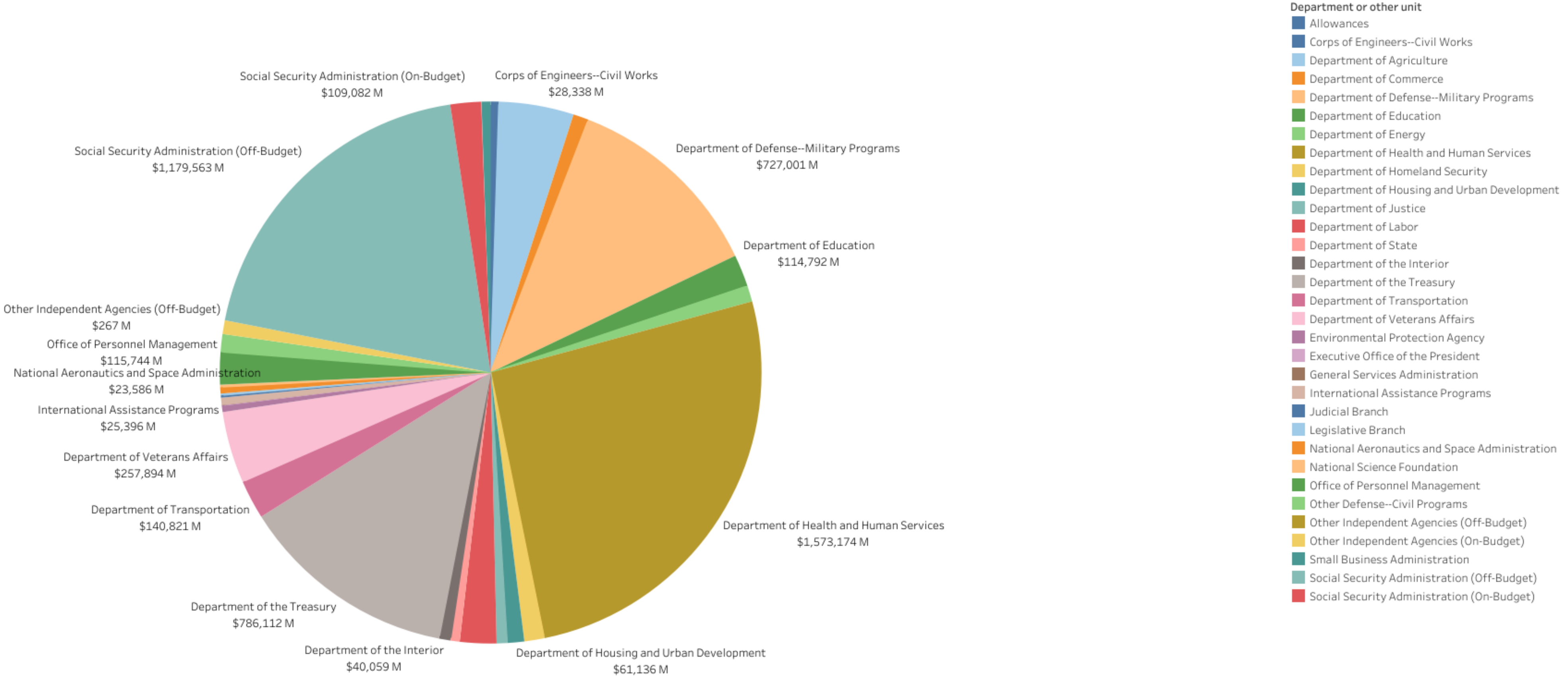
- Here we finally reach the budget for NEO Surveying, at 143$ million. While it is a small department in an organization that deals with advanced researching and exploration, it is the largest department in the Planetary Defense department.
- Still the budget only makes up a small percentage of the total NASA budget, despite the department's potential importance in keeping us all safe.



How does this compare to other agencies, the past and future?

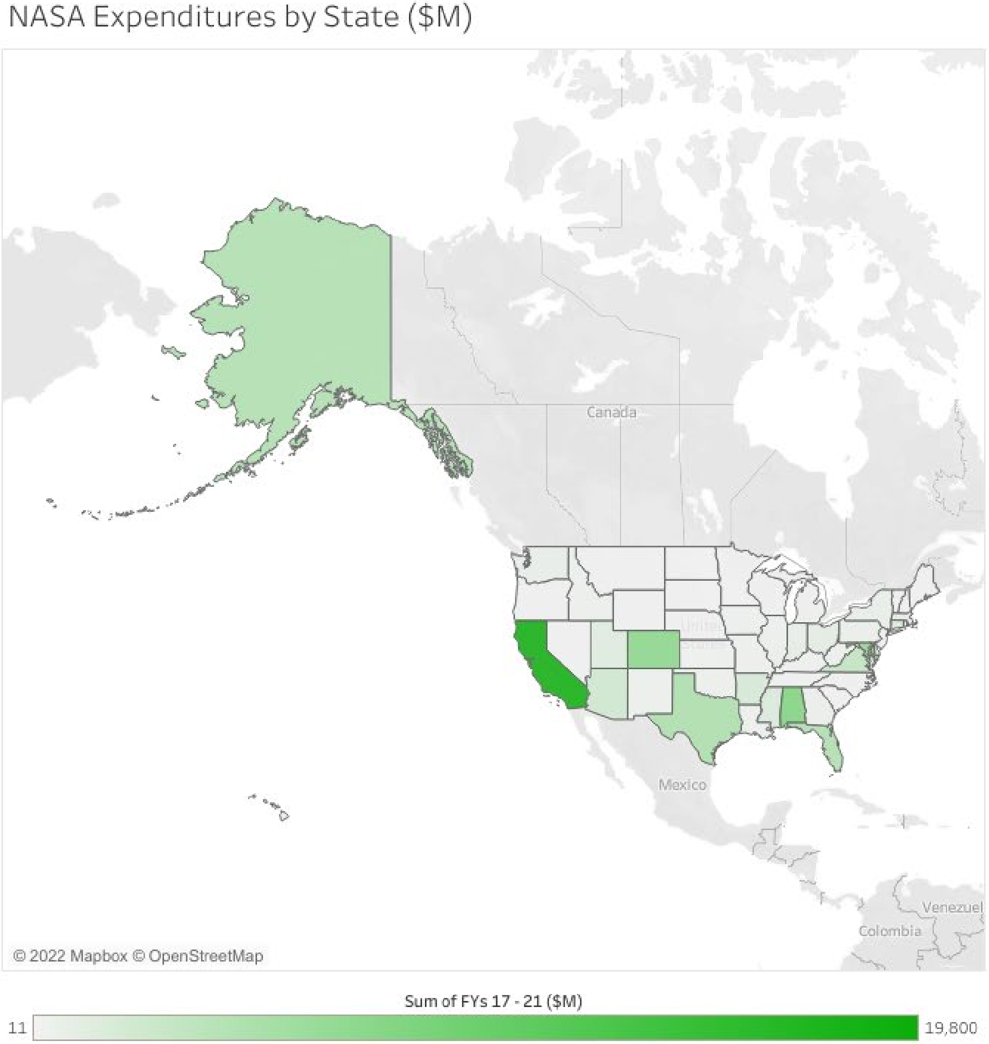
- NASA had a budget in 2022 of roughly 24 billion USD
- This is about 0.5% of the total federal budget

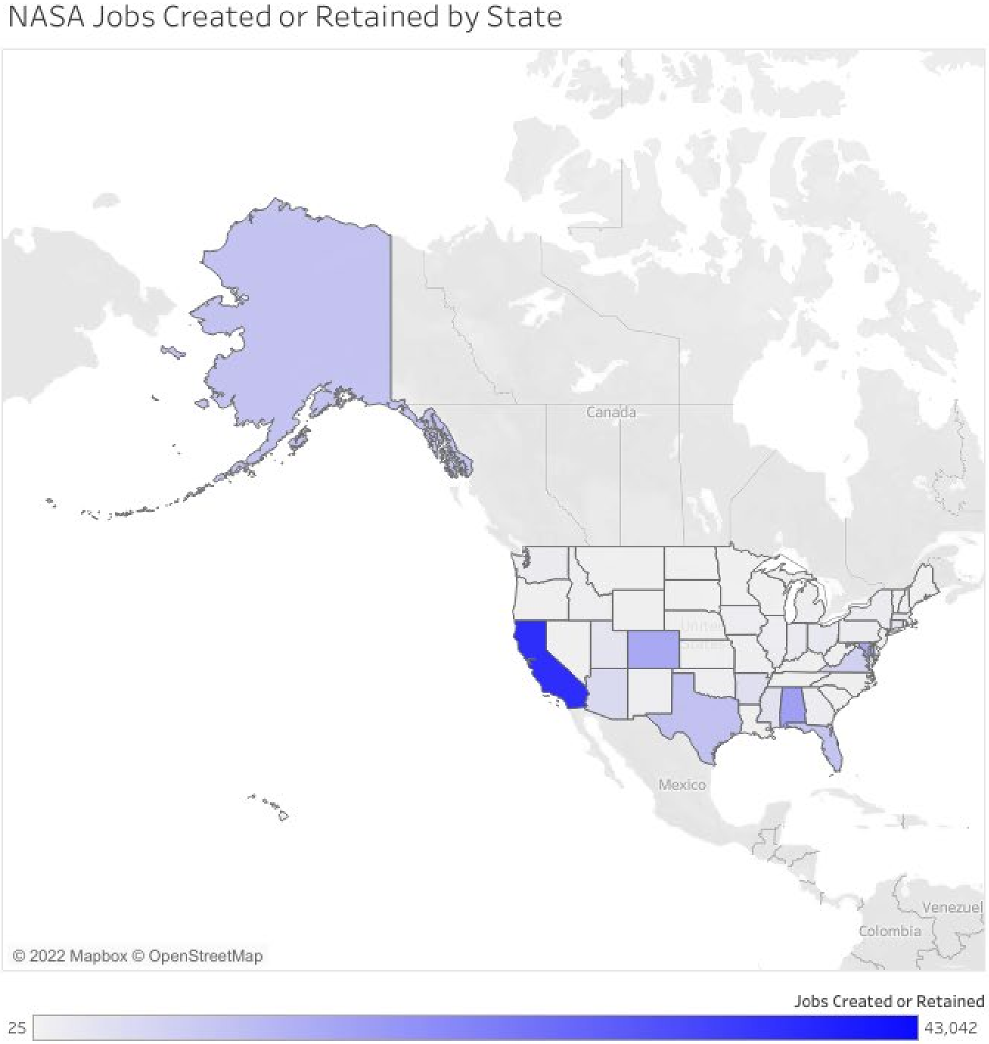
National Budget by Agency (2022 in $M)



How does this compare to other agencies, the past and future?

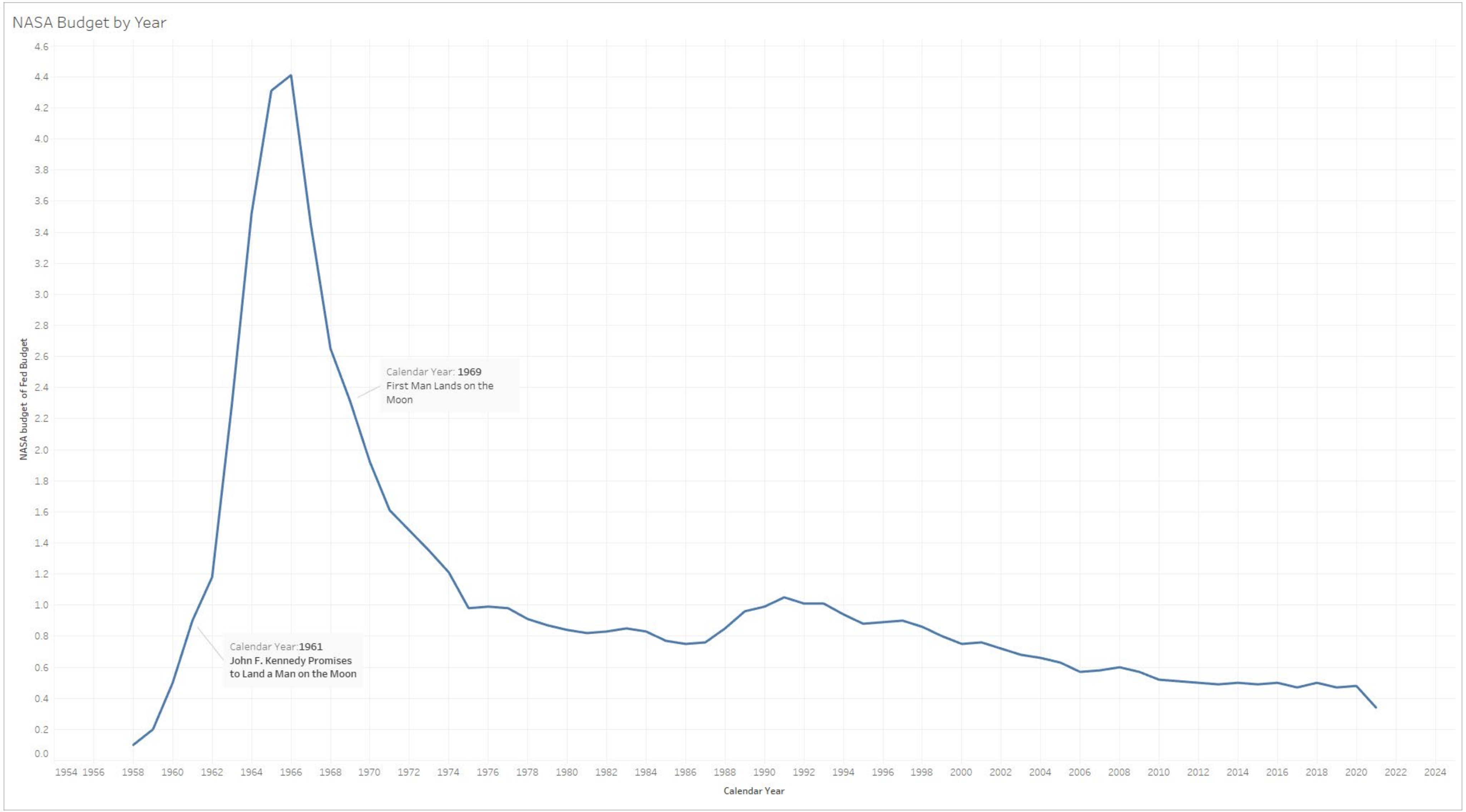
- This budget is used not only for space exploration and research, but also gets put back into the economy through goods and services bought from businesses
- In addition to this it also must hire people to work for NASA and in effect creates jobs





How does this compare to other agencies, the past and future?

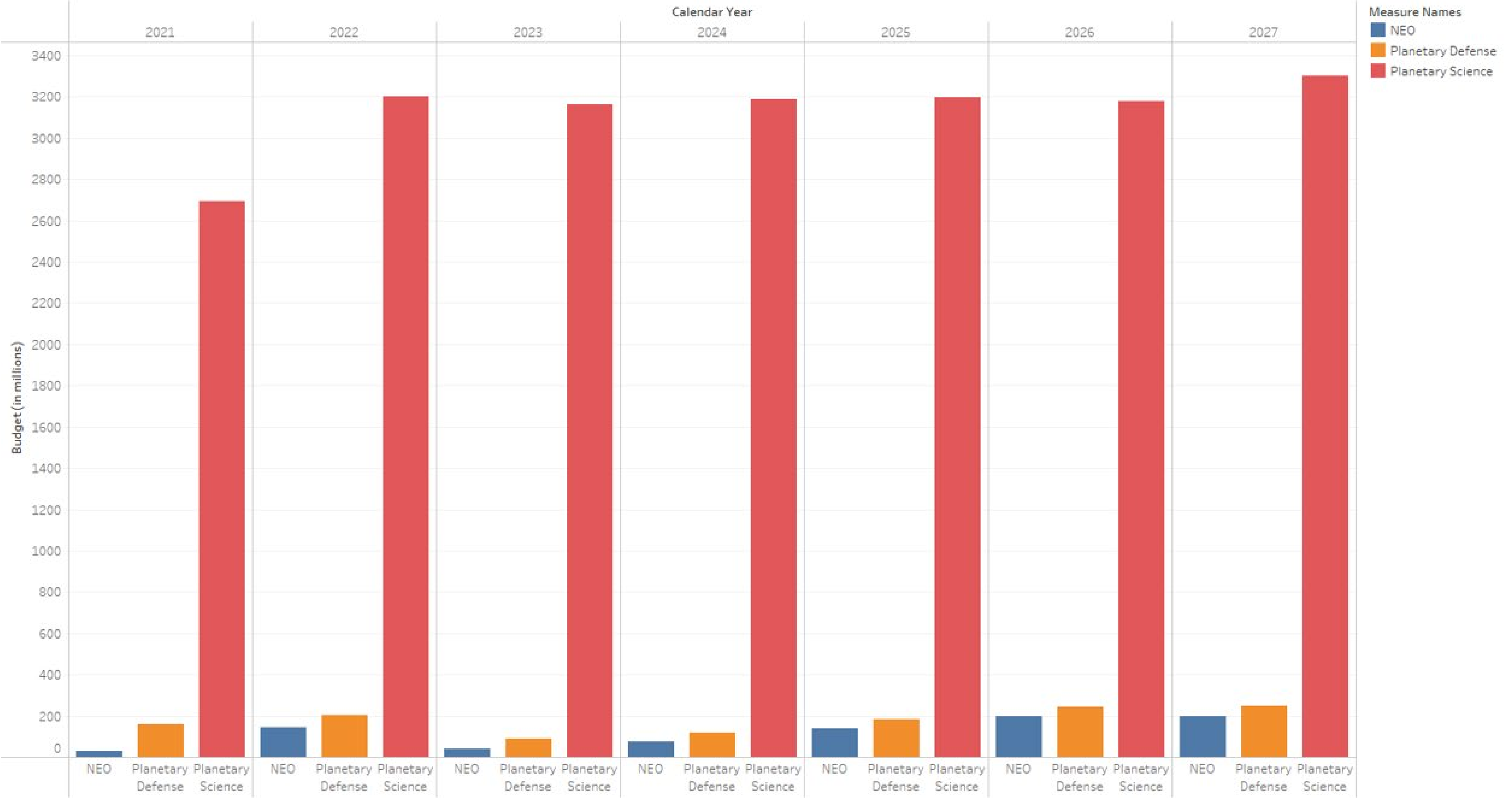
- NASA's budget grew rapidly after it's foundation in 1958, this was due to the space race of the 60s
- NASA's budget as a percentage of the total federal budget has since been on a decline since the mid to late 60's



How does this compare to other agencies, the past and future?

- NASA's budget for discovering NEO's is located within the Planetary Defense department, which itself is located with the Science department
- At roughly 143$ million in 2022 it only makes up a fraction of that budget, but is expected to start gradually increasing starting in 2023

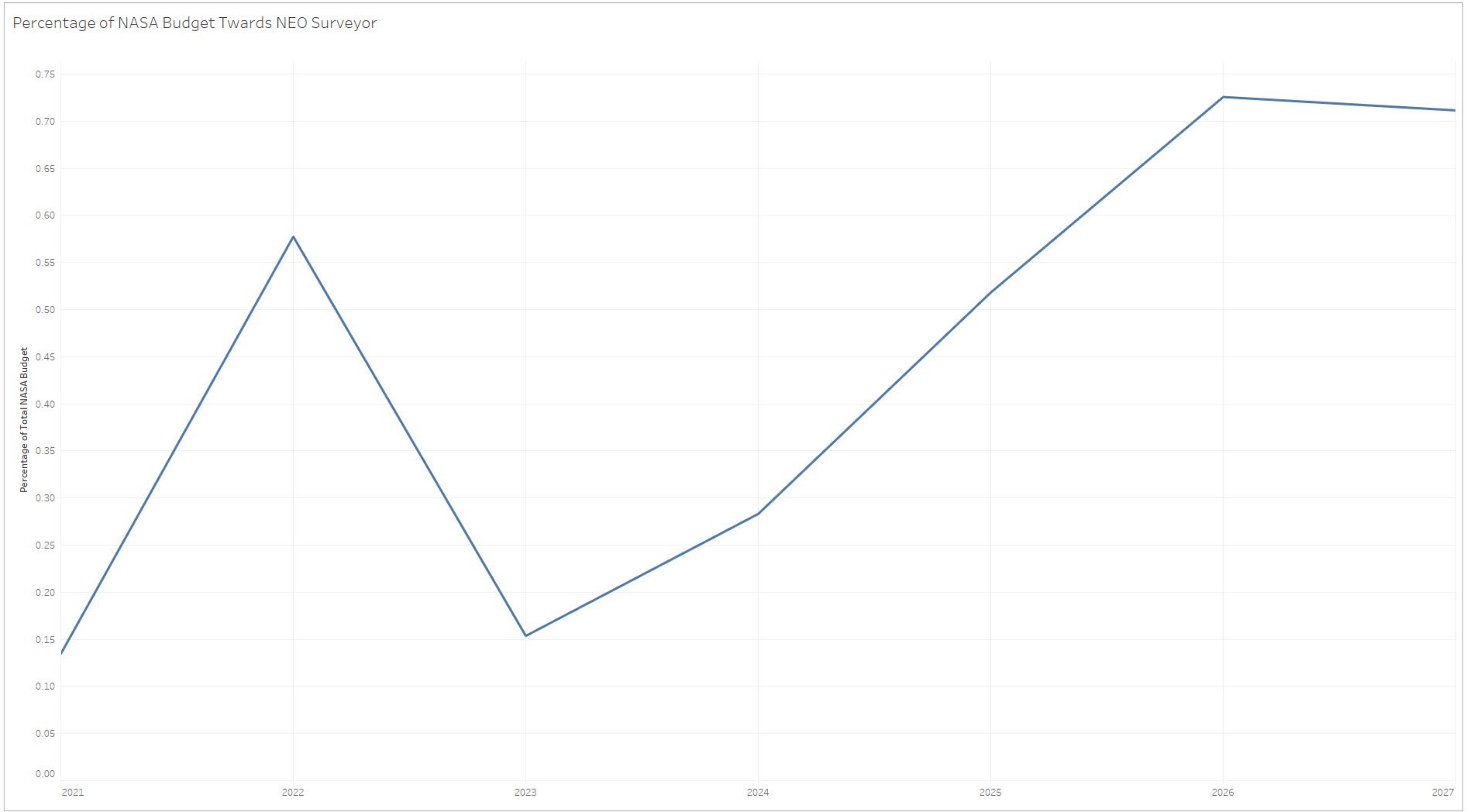
NEO Budget compared to Total NASA Budget



NEO, Planetary Defense and Planetary Science for each Calendar Year. Color shows details about NEO, Planetary Defense and Planetary Science.

How does this compare to other agencies, the past and future?

- The percentage of the total NASA budget put towards NEO surveying is even smaller, sitting at a recent high of only 0.57% in 2022
- This budget is expected to gradually increase starting in 2023 however, reaching a high of 0.73% in 2026



One last Question, What do *we* do?

- Can we afford to pay for telescopes that will provide safety and ease of mind for millions world-wide? Or do we roll the dice and ignore the potential problem?
- This question falls mainly upon congress, not the millions of Americans they represent or even the President! The president merely suggests the budget and is entirely beholden to what congress wants as the President can only deny a budget, not push it through.
- If you feel the urge to do something, either out of fear or out of courage please consider contacting a local representative!
- Literally just three dollars from every American could fund a space telescope which would provide safety for the world.