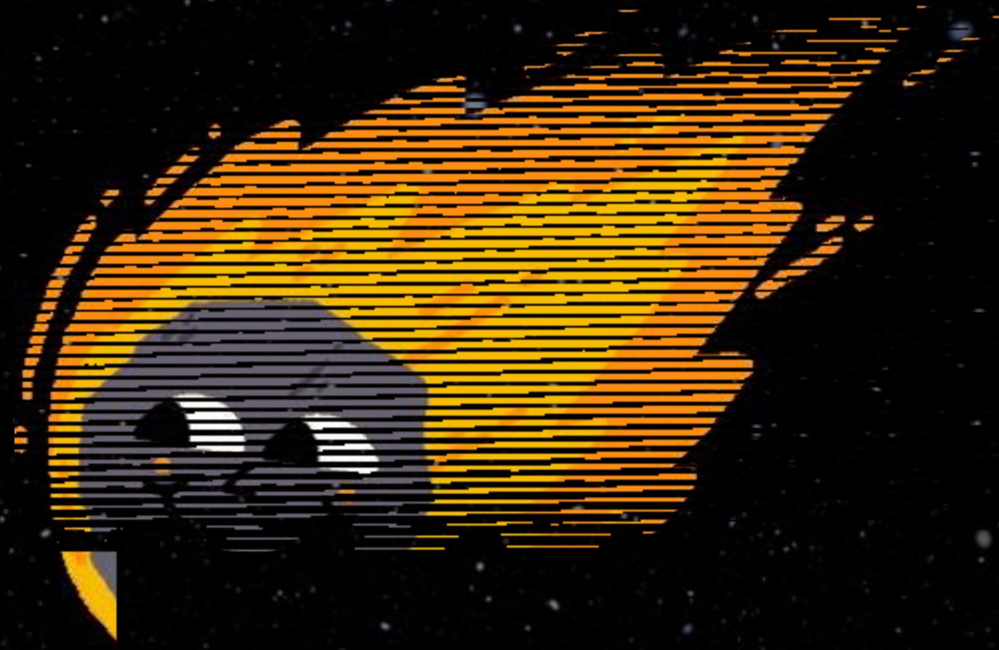
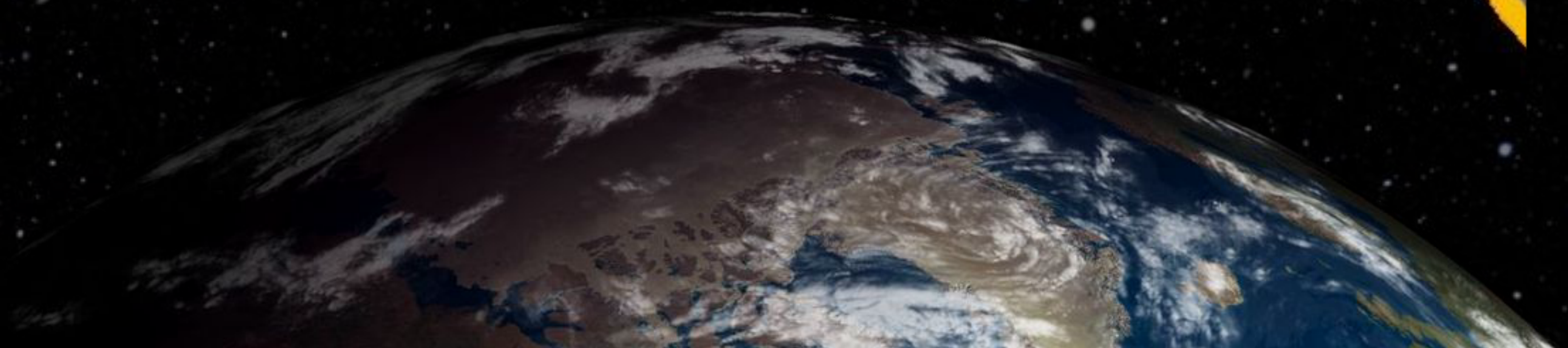
Asteroid Deflection

By Ulrik Bucksteg-Neuhoff, Max Curtis, and Jordan Budd





NASA fears “dino-killer” size asteroid may hit Earth in next decade!!!

Figure 1-1: Illustration of an asteroid impacting Earth. Retrieved from: https://www.nhm.ac.uk/discover/how-an-asteroid-caused-extinction-of-dinosaurs.html

1. What’s the damage?
2. How common are asteroid impacts?
3. How can we find asteroids before impact?
4. Can we prevent an impact?

Terminology

Near-Earth Objects (NEOs)

- Asteroids, comets, or meteoroids that orbit within 1.3 AU of the Sun (Chapman, 2004, para 10)
  - Comets comprise of <1% of impact risk (Chapman, 2004, para 3)
  - Concern is focused on asteroids
- 20% of NEOs are classified as potentially hazardous objects (PHOs) passing within 0.05 AU of Earth's orbit (Chapman, 2004, para 11)

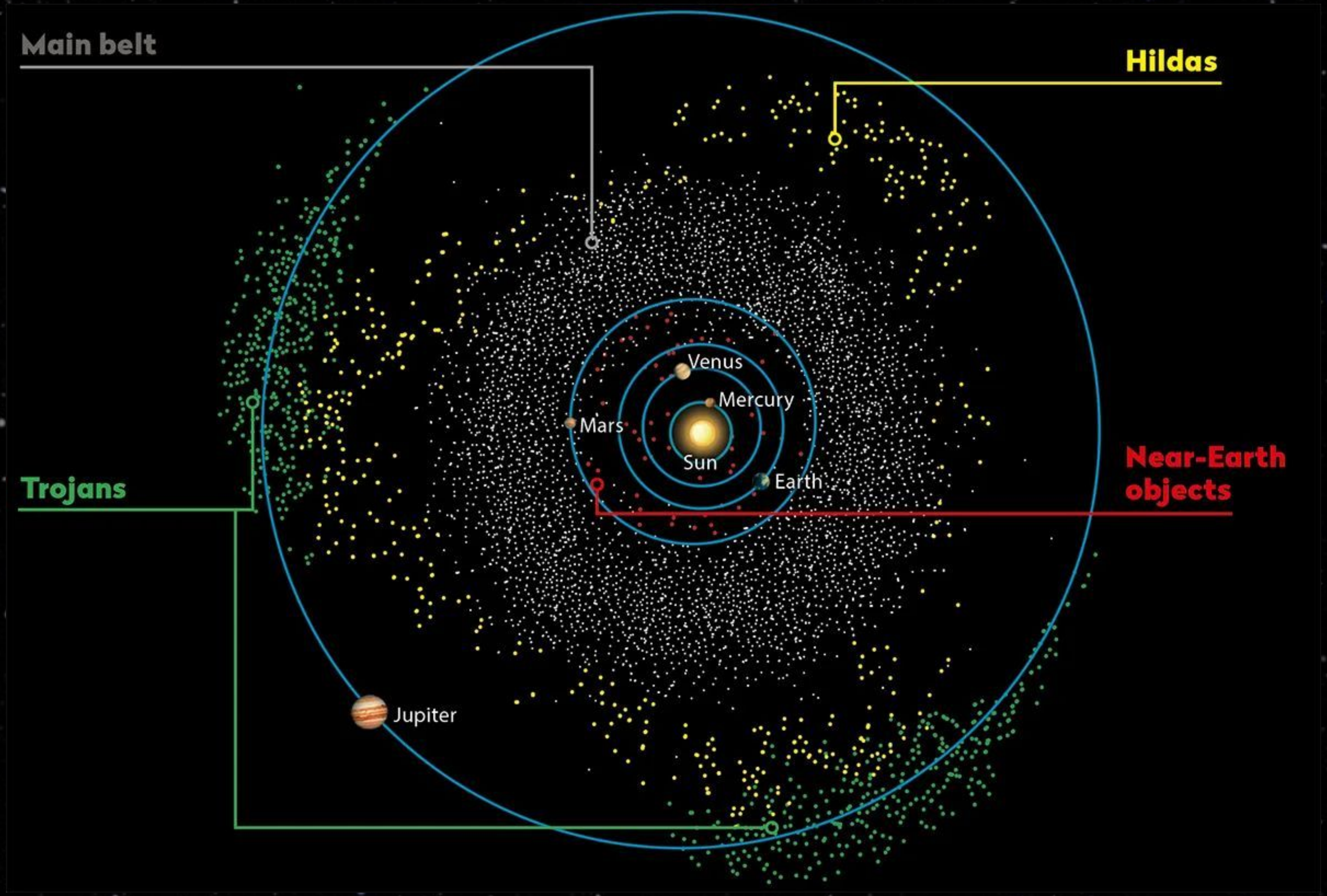


Figure 1-2: Diagram of asteroids in the solar system showing the location of NEOs. Retrieved from: https://www.skyatnightmagazine.com/advice/find-observe-photograph-planet-killer-asteroids

What’s the damage?

Tunguska Event

- 1908 in Tunguska, Russia (Hou et al., 1998, para 1)
- ~ 60 m in diameter (Hou et al., 1998, para 3)
- Meteor air burst (Hou et al., 1998, para 3)
- Felled ~ 2150 km² of forest (Hou et al., 1998, para 1)

~ 23 Nanaimos affected!

Figure 1-3: Felled trees in Tunguska, Russia. Retrieved from: https://www.nasa.gov/history/115-years-ago-the-tunguska-asteroid-impact-event/

Chicxulub Asteroid

- ~ 66 mya (Desch et al., 2021, para 1)
- 10 km asteroid forming 200 km crater

  (Desch et al., 2021, para 2)
- Lead to extinction of 75% of all species

  (Desch et al., 2021, para 28)

  - Earthquakes & megatsunamis
  - Mass wildfires
  - Atmospheric dust causing a global winter
  - Destruction of ozone layer
  - Global warming
  - (Chapman, 2004, para 21)

Figure 1-4: Location of impact of Chicxulub asteroid. Retrieved from: https://www.jsg.utexas.edu/news/2016/11/dino-killing-asteroid-made-rocks-behave-like-liquid-and-could-have-provided-habitat-for-new-life/

How common are asteroid impacts?

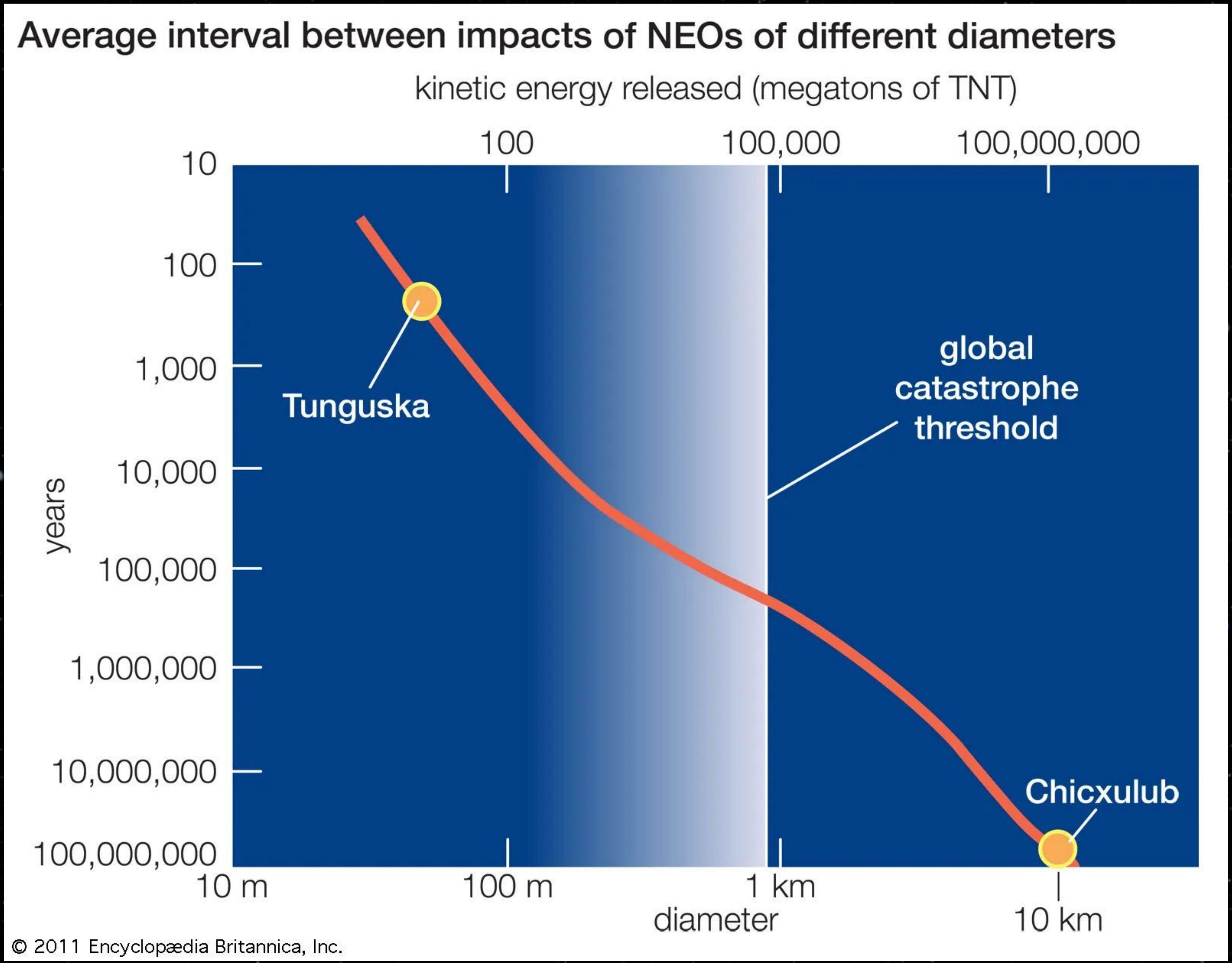


Figure 1-5: Years between impacts of NEOs of varying sizes. Retrieved from: https://cdn.britannica.com/54/96854-050-5D85A684/objects-impacts-times-Earth-size-sizes-amounts-1908.jpg

How can we find asteroids before impact?

Discovery

- The first detection methods were used to discover Asteroids. c

- In 1781, Uranus is discovered using the Titius Bode Law (University of Minnesota, n.d.)

- Titius Bode Law: orbital radius of planets given by
  - **$R_n = 0.1 + 0.3 * 2^n$, where n = -inf, 0, 1, 2, 3…**
- predicted another planet between mars and Jupiter
  (NASA, 2019)

- The first ever asteroid, Ceres, was discovered in 1801 by Giuseppe Piazzi
  - Classed as a planet upon discovery
    (NASA, 2019)

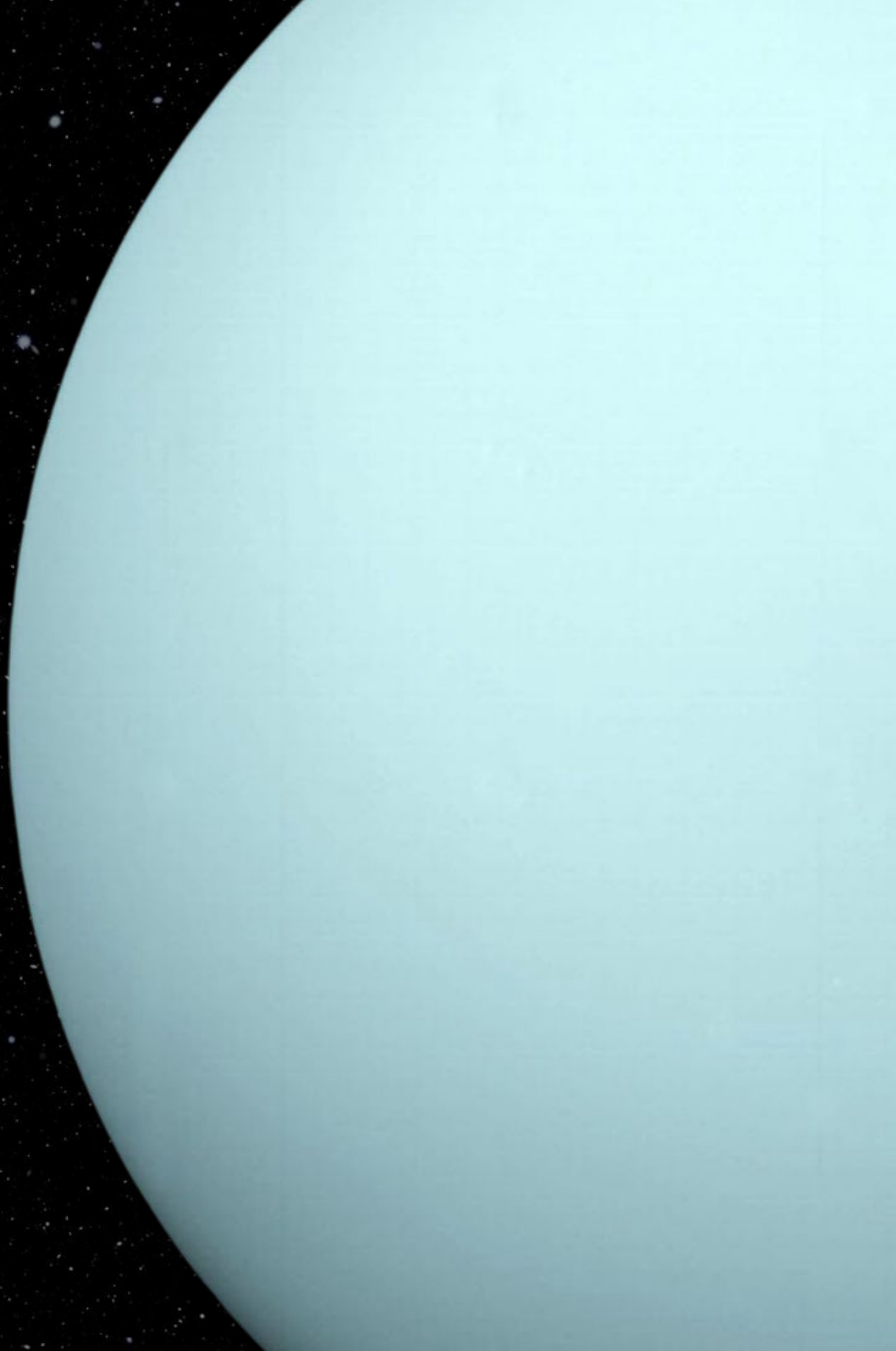
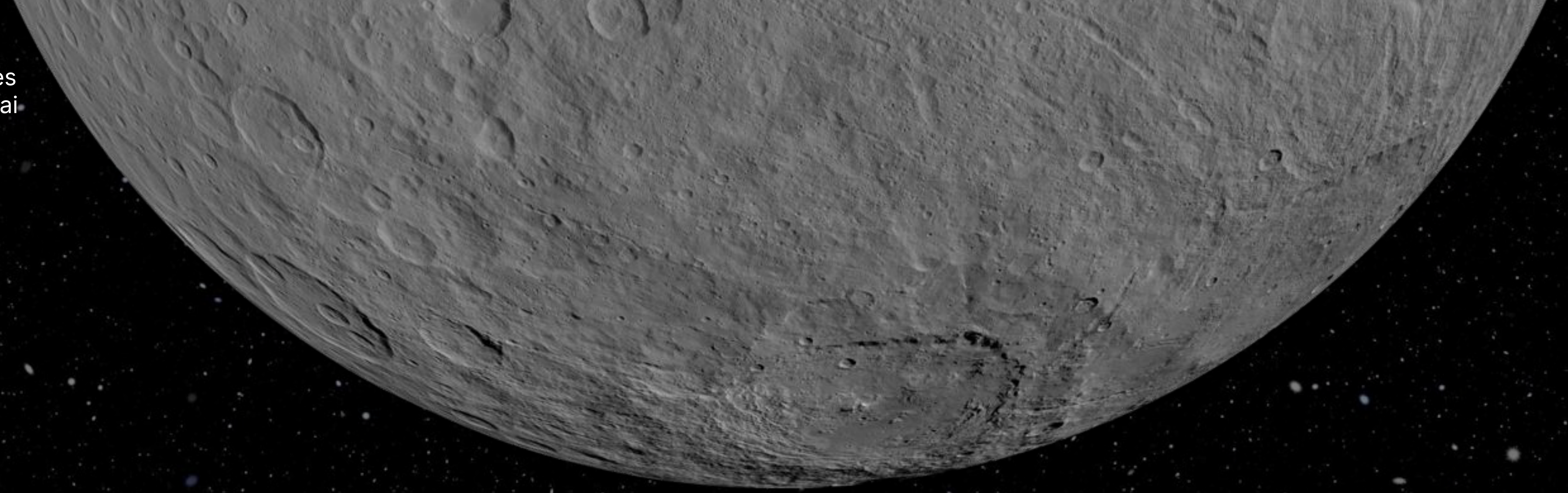


Figure 2-1: CERES, retrieved from: https://www.usgs.gov/media/images/ceres-dawn-framing-camera-mosaic



Asteroid Classification

- Second asteroid, Pallas, discovered by Heinrich Olbers in 1802 (NASA, 2019)

- William Herschel placed both Ceres and Pallas into a new class: **Asteroids**

Photographic Plates

- Introduced in 1850's

  (Jet Propulsion Laboratory [JPL], 2022)

- Light sensitive chemicals exposed to sky

- Photograph developed

  (Jet Propulsion Laboratory [JPL], 2022)

- First method to record observations directly

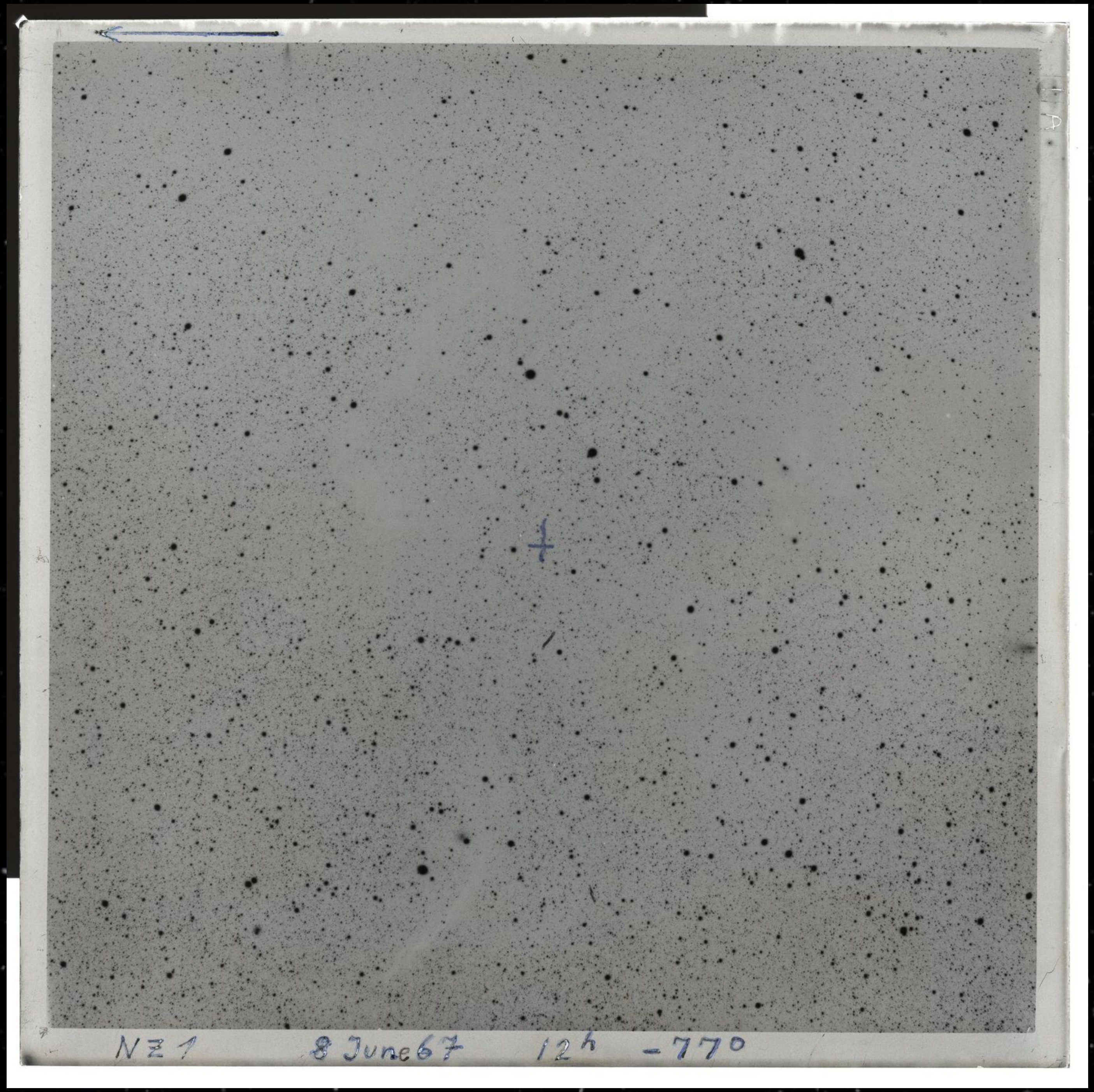


Figure 2-2: Photographic Negative from 1967, retrieved from: https://www.fau.eu/2022/07/news/research/web-archive-with-astronomical-photographic-plates-goes-online/

PCAS

- **Planet-Crossing Asteroid Survey (PCAS)**
  - performed at California Palomar Observatory in 1973 (NASA, 2019)

- **Eleanor "Glo" Helin** and **Eugene Shoemaker** from
  - **California Institute** of **Technology**

- Objective: determine orbits to estimate quantities of NEO classes

- Asteroid classes based on orbital patterns (NASA, 2019)

Amors (safe)

Apollos (High risk)

Athens (Avg risk)

Atrias (very low risk)

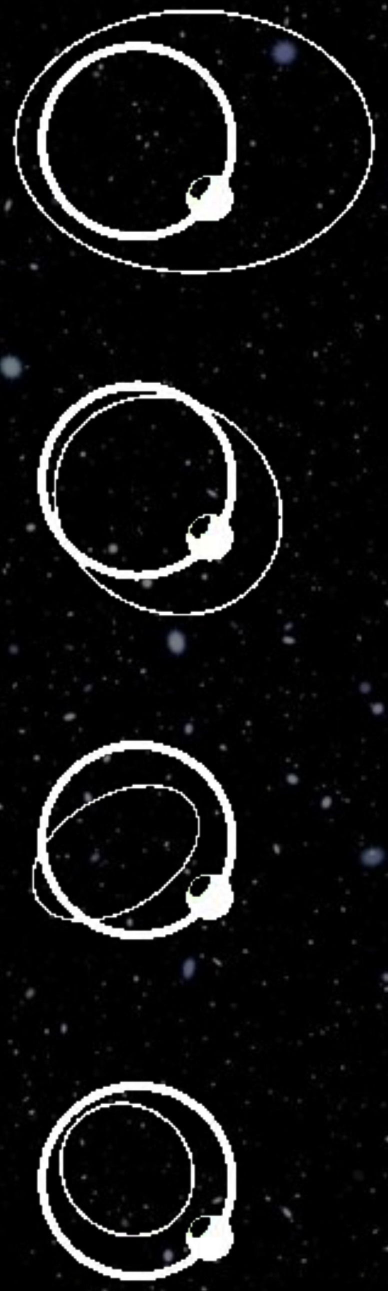


Figure 2-3: Asteroid Classes, retrieved from: https://cneos.jpl.nasa.gov/about/neo_groups.html

PCAS Early Method

- Used Photographic Plates
  - 8.75° circle(field) of sky captured onto one plate
    (NASA, 2019)

- 0.48-meter **Schmidt telescope** imaged **8-10 fields** per night
  - each with 10 minute then 20 minute exposure

- 20 minute exposure checked for trails, 10 minute exposures used for verification.
  (NASA, 2019)

- Results phoned to International Astronomical Union's Minor Planet Center (MPC)

- MPC would alert worldwide observers via telegram

Figure 2-4: Eleanor Helin with Schmidt Telescope, retrieved from: https://www.nasa.gov/history/history-publications-and-resources/nasa-history-series/a-history-of-near-earth-objects-research/

PCAS Evolution

- 1981: introduced more efficient method.
  - Used **stereo microscope** and more sensitive film

- 2 six-minute exposures, 30 minutes apart.
  - images compared for differences

(NASA, 2019)

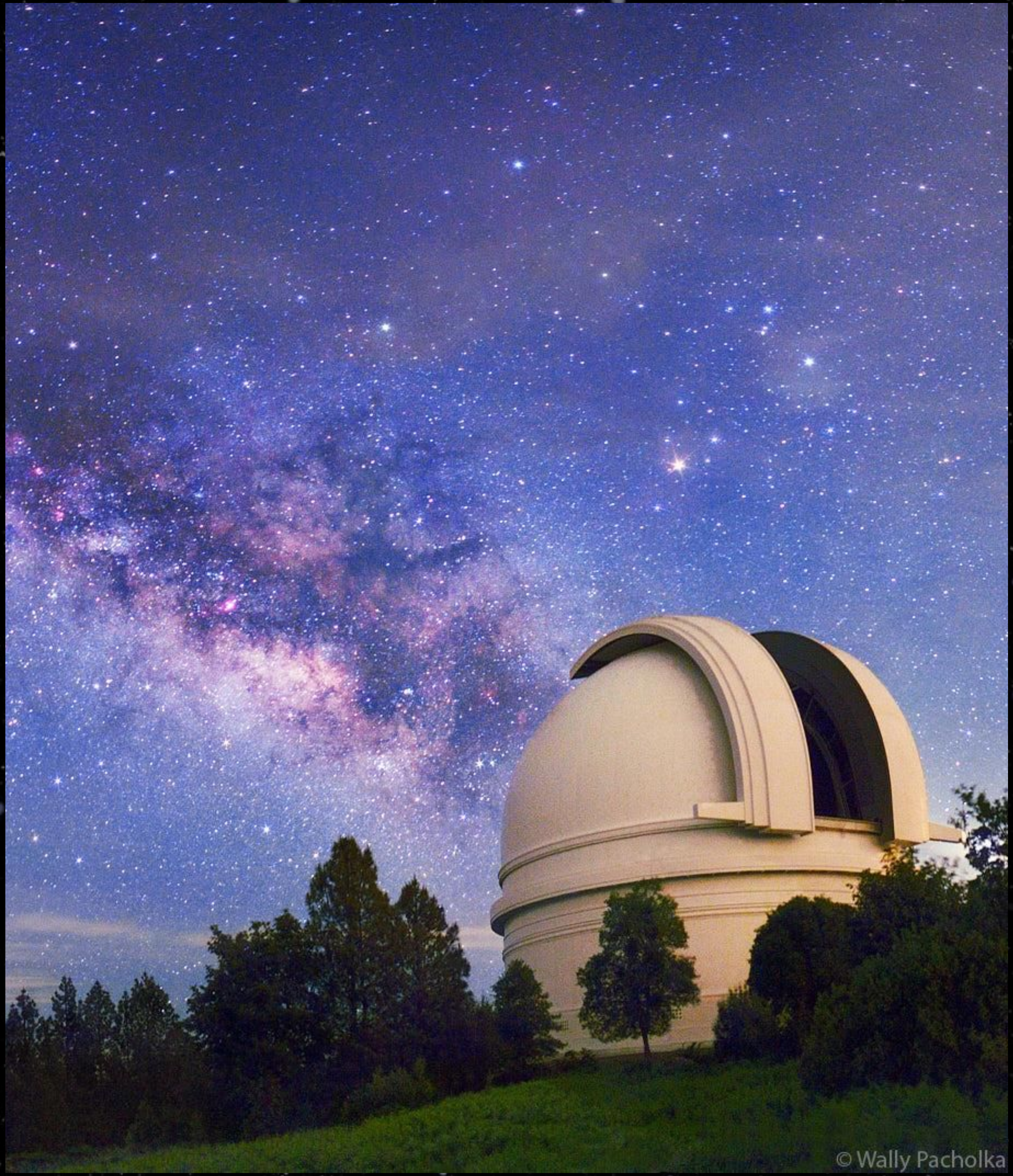


Figure 2-5: Palomar Observatory in California, retrieved from: https://www.astropics.com/photo/palomar-observatory-milky-way/

Charge-Coupled Devices (CCD)

- Silicon chip covered in **photosites**

- Each **photosite** represents a pixel in an image.
-

- Photosites generate electric charges based on intensity of light

  (GlobalSpec, n.d.)

- Still primary method of astronomical imaging today

  (NASA, 2019)

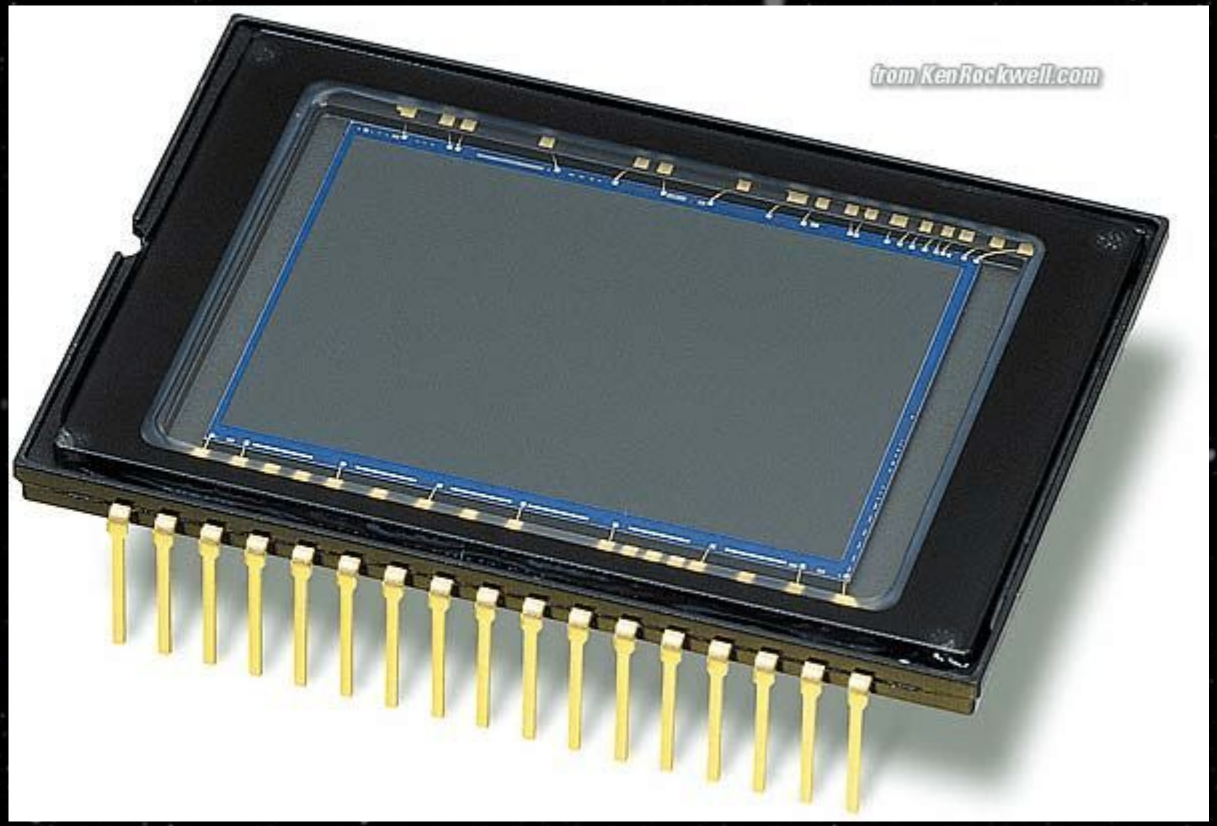


Figure 2-6: CCD Sensor, retrieved from: https://www.globalspec.com/learnmore/video_imaging_equipment/video_cameras_accessories/ccd_cameras

Spacewatch

- Started in 1980 by Tom Gehrels and Robert McMillan
    - at University of Arizona Lunar and Planetary Lab

- Objective: track NEO’s that pose a potential threat

- pioneered the use of **Charge-Coupled Device** (CCD) technology

- Project Still operational today
    - Most activity and significance 80s-00s

(NASA, 2019)

COLLEGE OF SCIENCE
LUNAR & PLANETARY LABORATORY

Figure 2-7: University of Arizona Lunar and Planetray Lab Logo, retrieved from: https://spacewatch.lpl.arizona.edu/

Torino Scale

- Adopted by NASA in 1999
- Charts risk posed by potential asteroid impacts
- Kinetic Energy is is TNT equivalent
- Distances are diameter of asteroid

(Jet Propulsion Laboratory [JPL], n.d.)

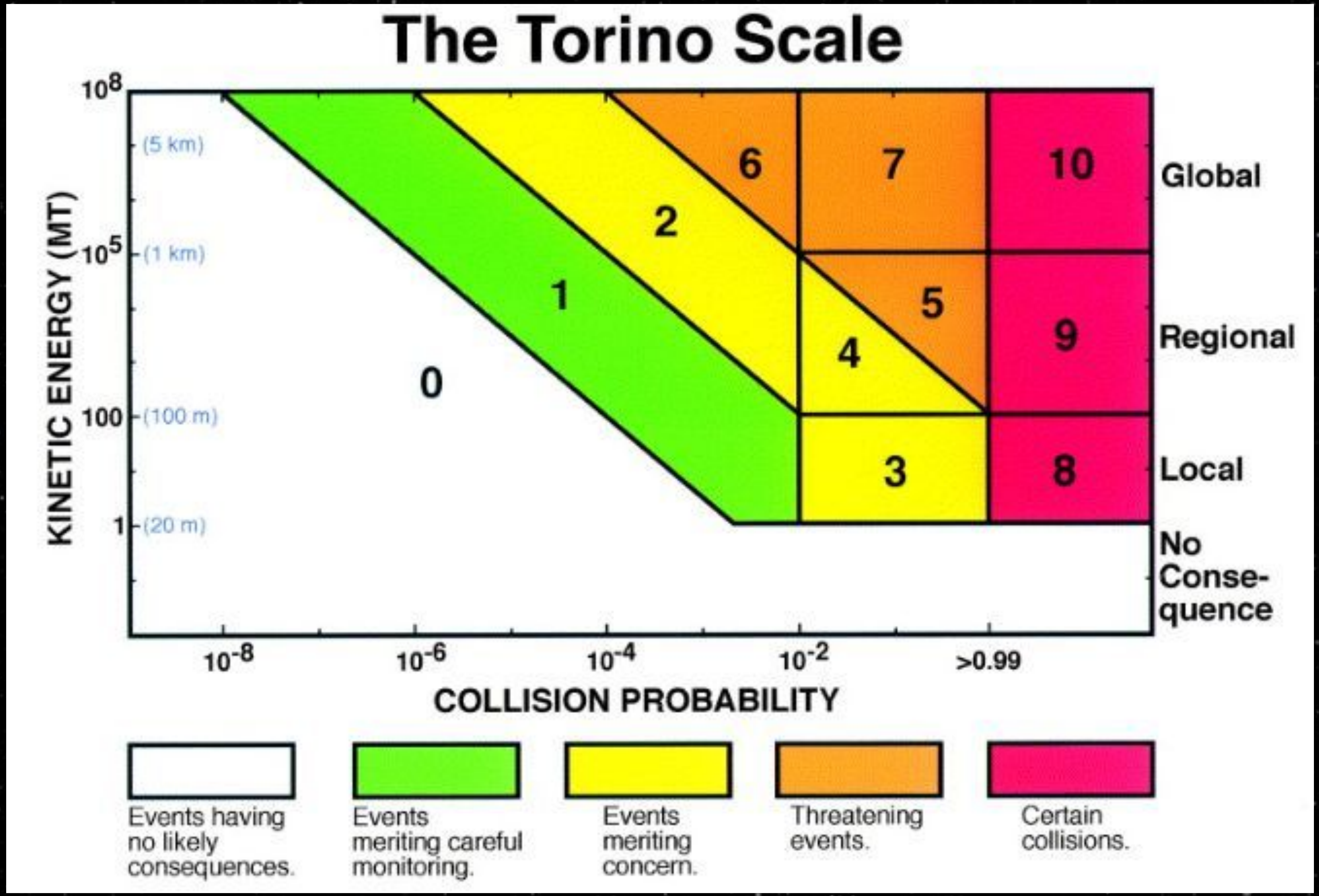


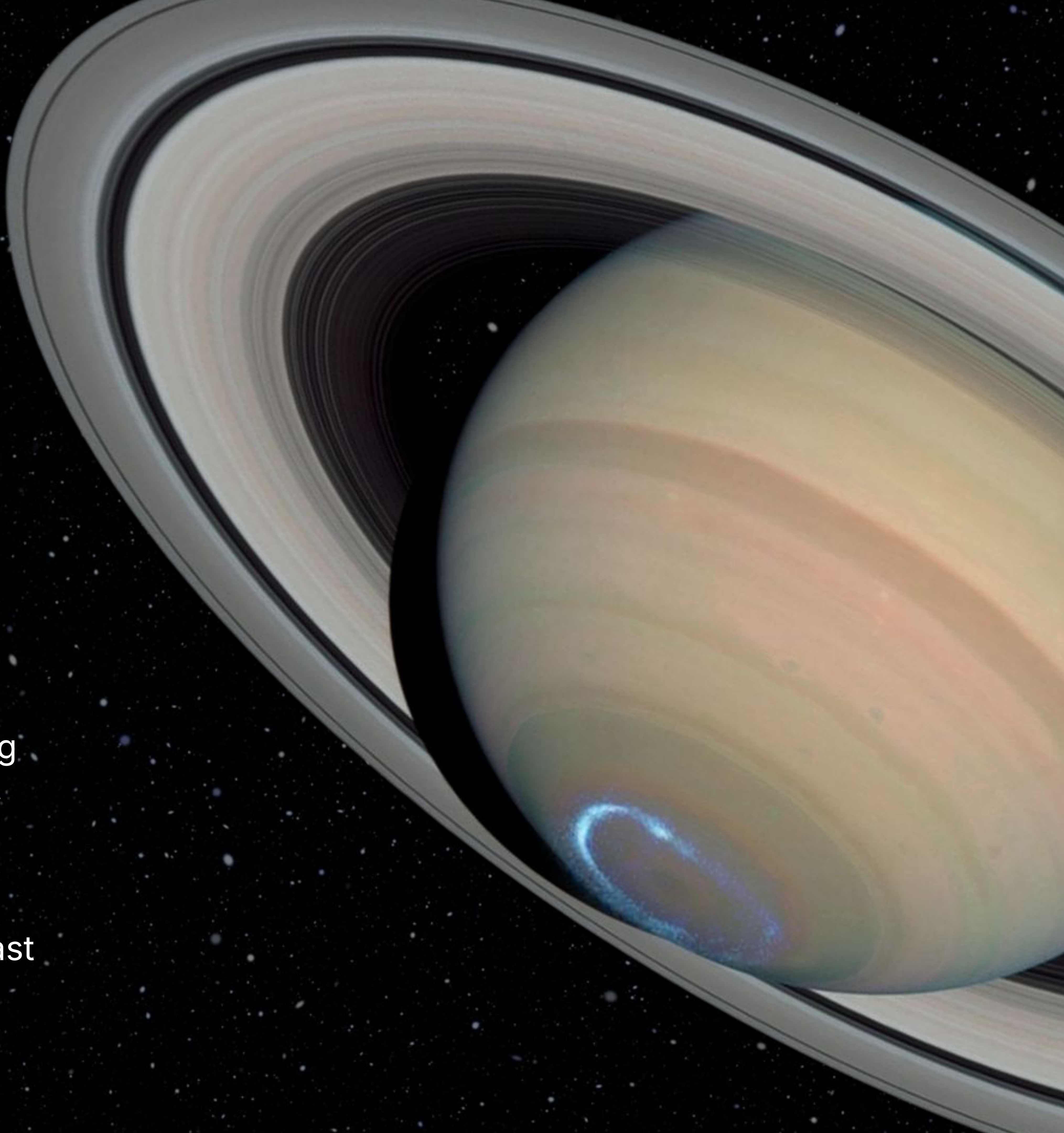
Figure 2-8: Torino Scale, retrieved from: https://www.researchgate.net/figure/The-Torino-Scale-created-by-Professor-Richard-P-Binzel-with-the-Massachusetts-Institute_fig4_289485833

Can we prevent an impact?

DART mission

DART Mission

- The Mission: NASA’s **Double asteroid redirection test** (NASA, 2023)
- The target: Dimorphos is a smaller asteroid orbiting a larger asteroid, Didymos (NASA, 2023)
- Impacted asteroid Dimorphos on Sept 26, 2022, having an impact velocity of 6.6 km/s or 23,760 km/h (Daly et al., 2023)
- Primary goal: Reduce the orbit of the asteroid by at least 73 seconds (NASA, 2023)



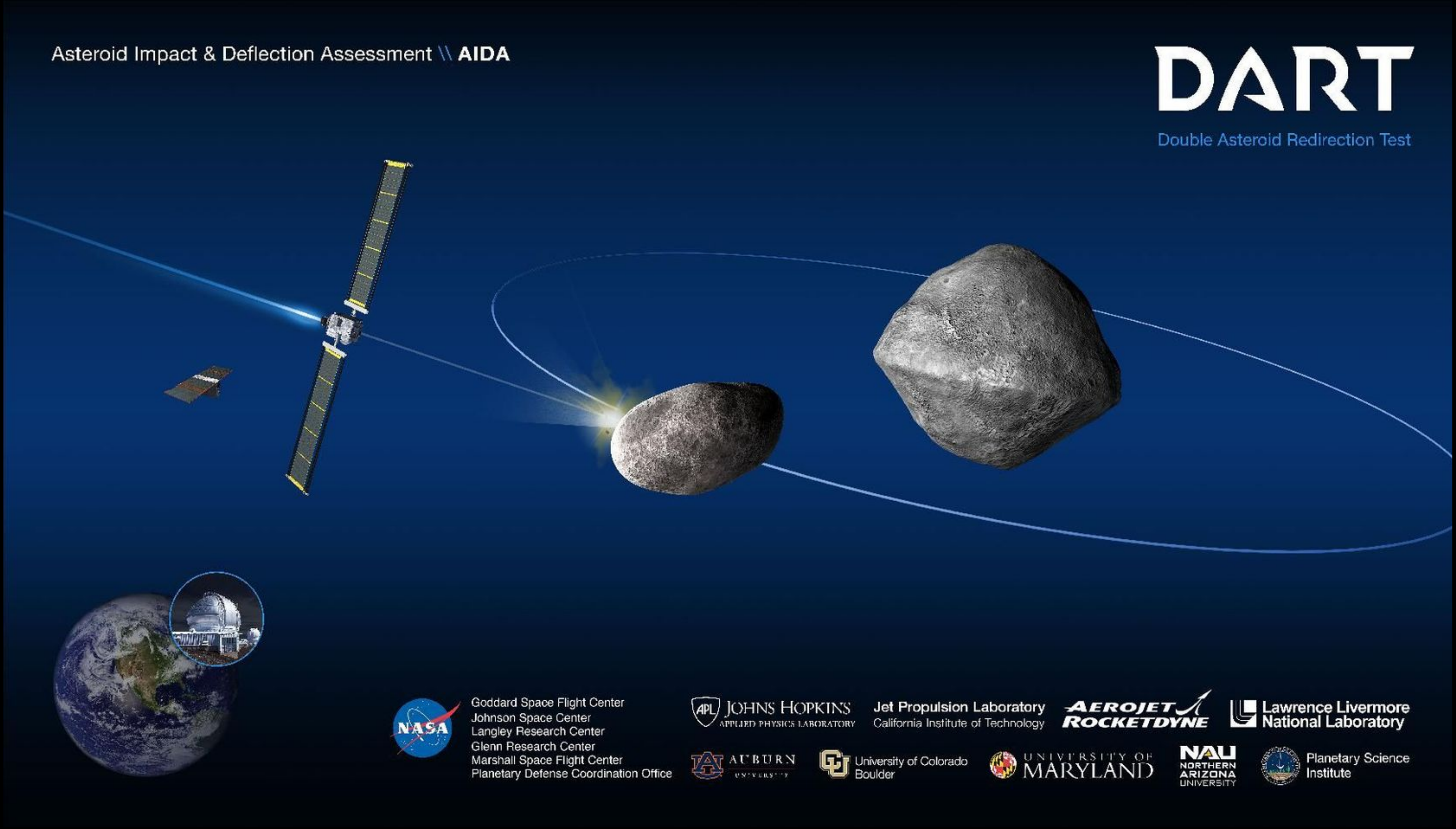


Figure 3-1: Conceptual image of mission, retrieved from: https://www.eoportal.org/satellite-missions/dart-asteroid#overview

Results of Mission

- Actual Result: Reduced the orbit by **33 minutes** (1980 seconds) (NASA, 2024)
- Shifted the entire binary systems path around the sun by 0.15 seconds (NASA, 2024)
- This speed change proves that a tiny nudge can deflect an asteroid if done early enough
- Visual confirmation provided by the LICIACube

The "Witness" (LICIACube)

- Name: Light Italian CubeSat for imaging of Asteroids
- What it is: A 6U CubeSat (roughly size of a shoebox) built by the Italian Space Agency (ASI) (NASA, 2024)
- Primary goal: document, and analyze the impact of the DART spacecraft. (NASA, n.d.)

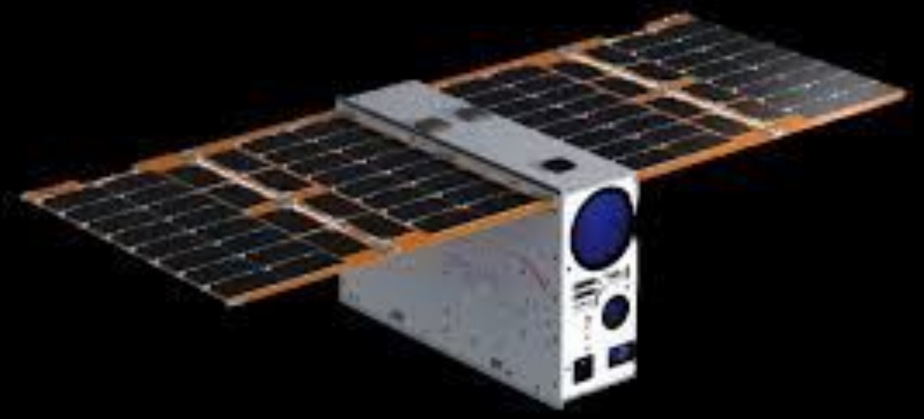


Figure 3-2: LIDIACUBE retrieved from: https://www.nanosats.eu/sat/liciacube

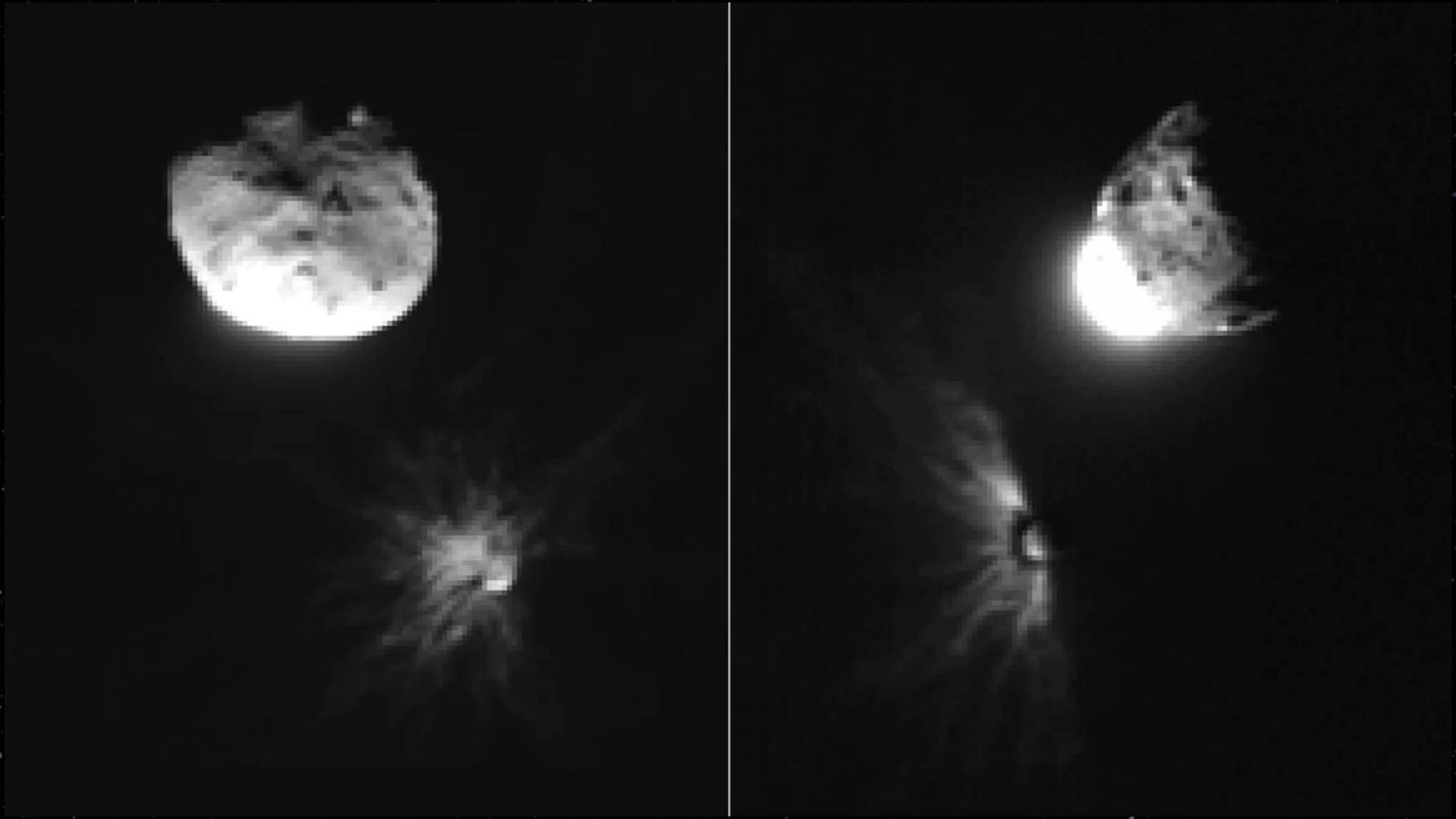


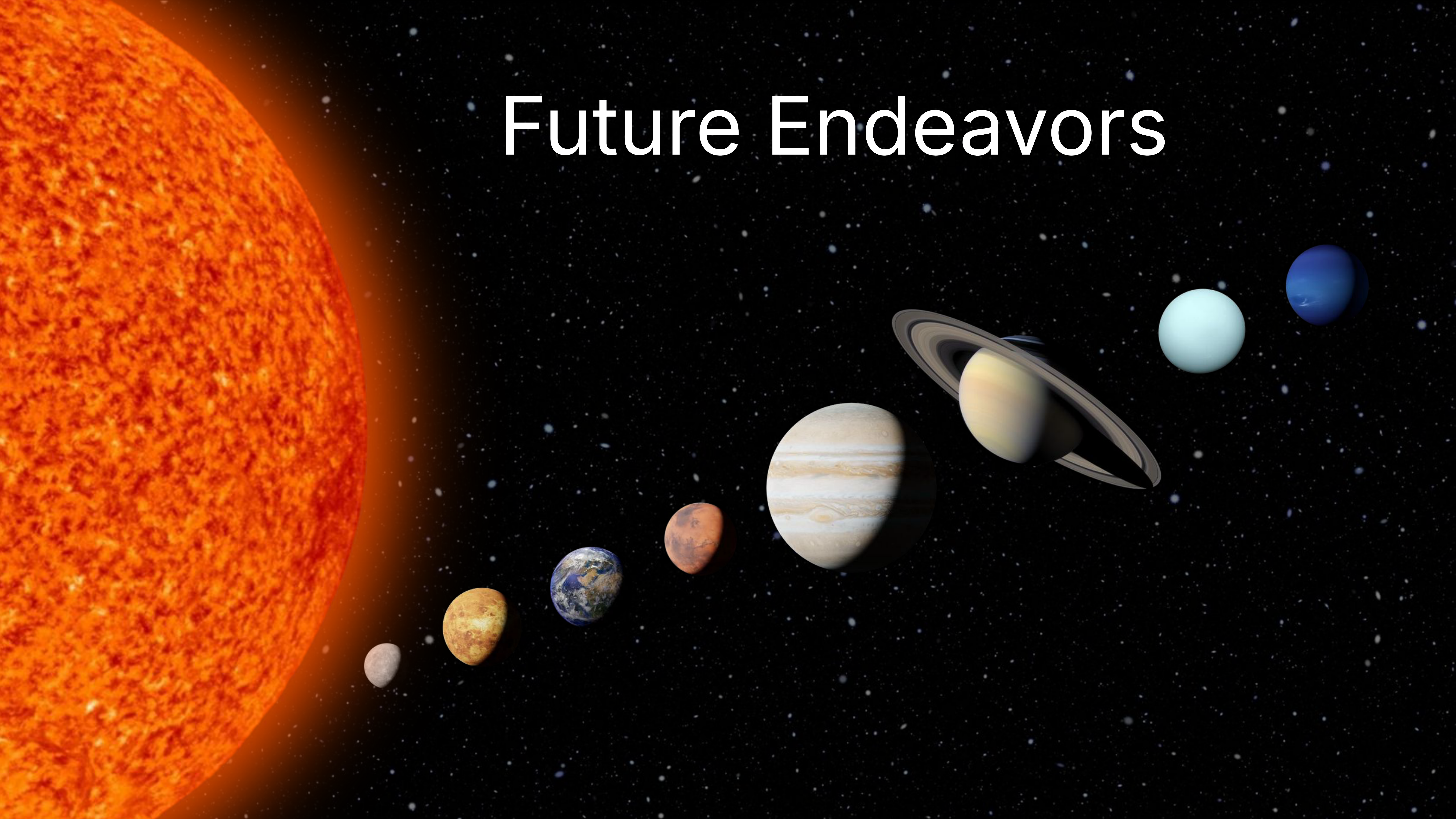
Figure 3-3: Impact of DART caught by LIDIACube retrieved from:
https://science.nasa.gov/missions/close-up-views-of-nasas-dart-impact-to-inform-planetary-defense/

The B factor

- Momentum Enhancement (B) measures the thrust from escaping debris (ejecta) (NASA, 2024)
- Ejecta used in measurement of pictures taken by LICIDA to determine effects
- DART achieved a B factor of 2.2+, meaning the debris doubled the missions effectiveness. (NASA, 2024)

$$\beta = \frac{\Delta \text{Momentum}_{\text{Asteroid}}}{\text{Momentum}_{\text{Spacecraft}}}.$$

Future Endeavors



ESA's HERA

- Primary Goal: Conduct a detailed post-impact survey of Dimorphos (NASA, 2024)

- Launched in October 7, 2024 (NASA, n.d.)
- Arrival: November 2026 (NASA, 2024)

- Duration: planned 6+ months orbiting and analyzing the asteroid (NASA, 2024)

- Juventas and Milani CubeSats onboard

Figure 3-4 HERA: retrieved from: https://www.esa.int/ESA_Multimedia/Sets/Hera_images/%28result_type%29/images

Future Endeavors

- Neo Surveyor: space-based infrared Telescope designed to find “Dark Asteroids” (Mainzer et al., 2023)
- The Goal: Find potential threatening asteroids within 10 years (Mainzer et al., 2023)
- Gravity tractor: A heavy spacecraft “hovering” near an asteroid to pull if off its course using gravity (NASA, 2023)
- Nuclear Ablation: A blast near the asteroid to vaporize the surface and create thrust (NASA, 2023)

Figure 3-5: Neo Surveyor retrieved from: https://science.nasa.gov/mission/neo-surveyor/

Thank you!

Max Curtis

Jordan Budd

Ulrik Bucksteg-Neuhoff