# Risk, Opportunity, and Space

Dean W McCall, Ed.D.

Nov 16, 2021

Asteroid 4660 Nereus

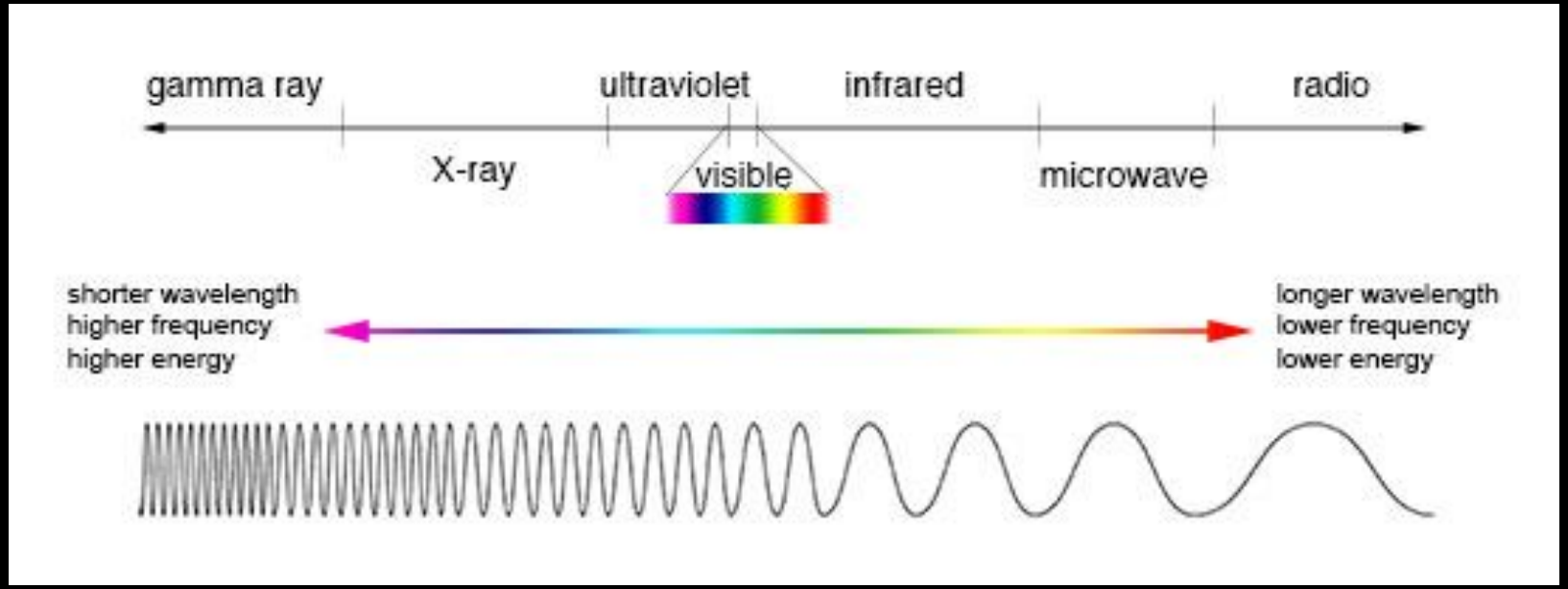
https://bgr.com/science/nasa-is-tracking-a-1000-foot-tall-asteroid-thats-headed-towards-earth/

# Agenda

- A few fundamentals so we’re on the same page
- Space-related examples
- Quick update on JWST
- Note: presentation includes links to source information

This is interactive -- please ask questions

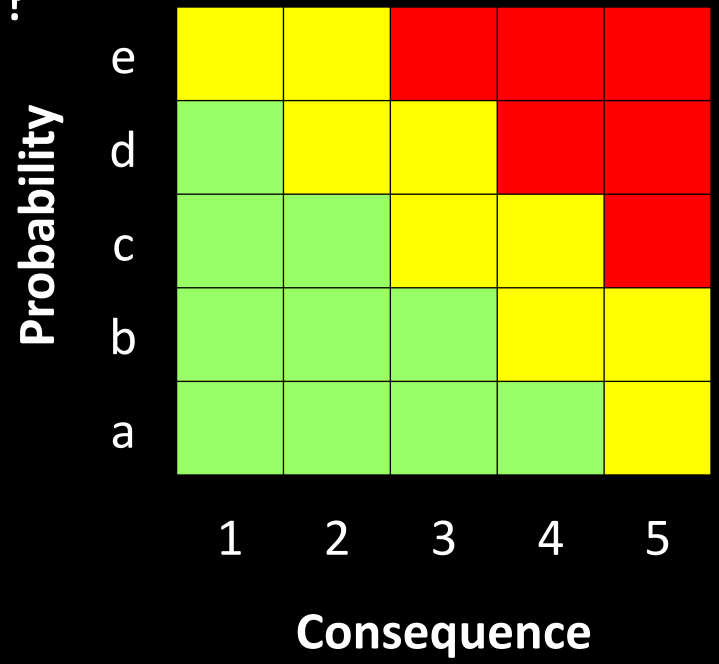
# Technical Fun: Electromagnetic Spectrum




- Remote Sensing (space telescopes, etc.)
  - Gamma-ray and X-ray: see active galaxies, the remnants from massive dying stars, accretion of matter around black holes (i.e., the most energetic objects)
  - Visible light and near-visible light (ultraviolet and infrared)
  - Longer-wavelength: see dark, cool, obscured objects, dusty star-forming regions, dark cold molecular clouds, primordial radiation (e.g., Big Bang)

# What is “Risk”?

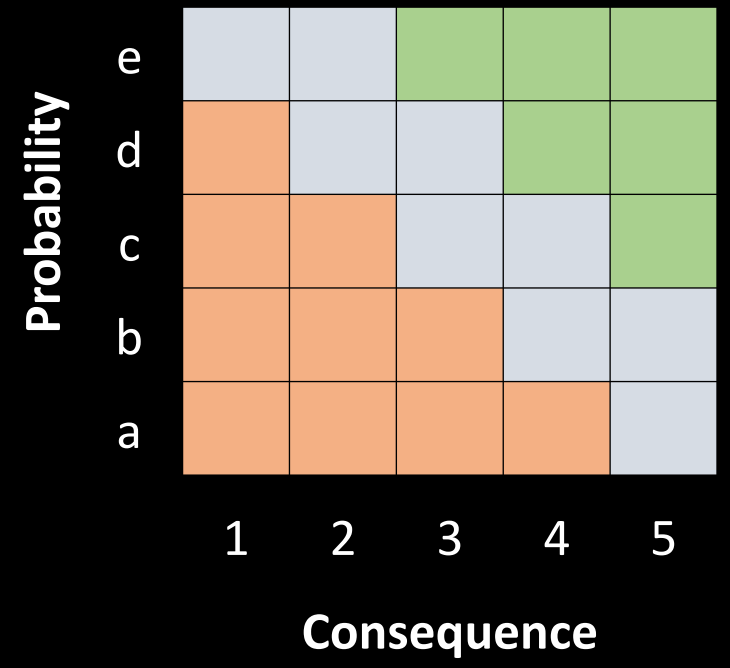
- Risk: Potential problem with consequences that may or may not manifest
  - What might go wrong, how likely, how much will it hurt?
  - IF <threat> occurs THEN <consequence>
- Handling: What do we do about it?
  - Avoid
  - Transfer
  - Control
  - or Accept




https://www.lockheedmartin.com/content/dam/lockheed-martin/eo/documents/suppliers/training-2017-risk-opportunity-mgmt.pdf

# What is “Opportunity”?

- Opportunity: Potential enhancement with consequences that may or may not manifest
  - What might go right, how likely, how much will it help?
  - IF <benefit> occurs THEN <consequence>
- Handling: What do we do about it?
  - Enhance
  - Share
  - Exploit
  - or Ignore



# Risk and Opportunity Management

- Process of
  - identifying program risks and opportunities
  - assessing them for potential action
  - implementing action plans
  - monitoring those plans to completion

# How Do Risk and Opportunity Apply in Space?

- R&O applies
  - to the fate of the human race
    - Potential NEO impacts
    - Earth sciences, including
      - Climatology
      - Geophysics
      - Heliophysics
    - Technologies that are purposed into sociological cornerstones
  - to the space missions themselves
    - Human safety
    - Return on Investment (ROI)
  - to scientific pursuit
    - Quantum physics
    - Energy
    - Cosmological evolution

# Chelyabinsk, Feb 15, 2013

Consequence

- Small asteroid – 56 feet in diameter, 11,000 tons, 40,000 mph
- Explosion – air burst -- was the equivalent of 470,000 tons of TNT
  - 30-40x the bomb dropped on Hiroshima
- Part of Asteroid 2014 UR116

https://www.space.com/33623-chelyabinsk-meteor-wake-up-call-for-earth.html

# Tunguska (Siberia), 6/30/1908

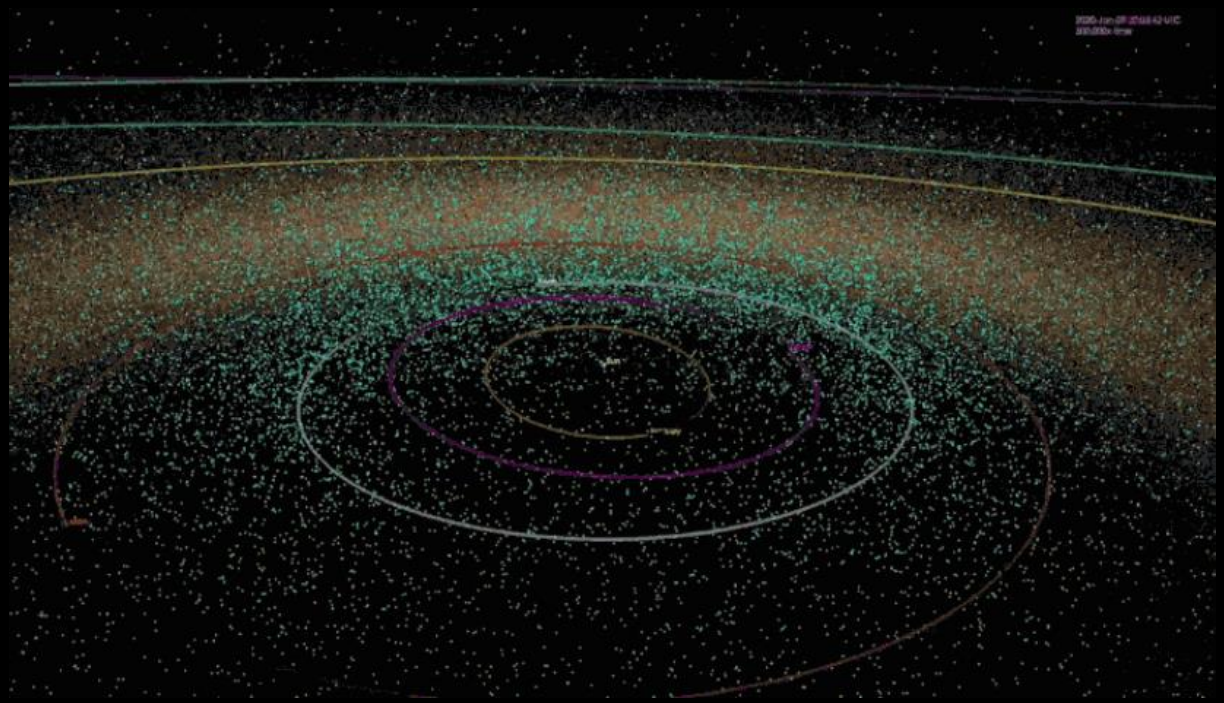
Consequence

- Flattened 825 sq miles of forest

# Other Asteroids

Likelihood

- “To date, NASA has identified approximately 27,000 NEOs, of which about 9,800 measure at least 459 feet (140 m) in diameter and 890 measure 0.6 mile (1 km) in diameter”



https://www.livescience.com/surprise-asteroid-flyby
https://earthsky.org/space/mapping-the-threat-of-small-near-earth-asteroids/
https://earthsky.org/space/asteroid-tracking-center-for-near-earth-object-studies/

# SO, What Do We Do?

*Avoid*
~~*Transfer*~~
*Control*
~~*Accept*~~

**Handling**

- Survey the sky
  - NEOWise, NEO Surveyor
  - LUCY mission to study Trojan asteroids in Jupiter orbit
  - NASA's Center for Near-Earth Object Studies (CNEOS)
- Get asteroid data
  - OSIRIS-REx (Origins-Spectral Interpretation-Resource Identification-Security-Regolith Explorer) bringing back asteroid Bennu sample in 2023
  - Deep Impact mission (2013) to comet Tempel 1
- Test potential solutions
  - NASA’s DART (Double Asteroid Redirection Test) mission to Asteroid Didymos
    - Late 2021 launch
    - Crash into moonlet, see what if any alteration to trajectory
- Simulations

https://www.livescience.com/surprise-asteroid-flyby
https://www.space.com/what-would-happen-asteroid-hit-earth-dart-video
https://solarsystem.nasa.gov/missions/deep-impact-epoxi/in-depth/

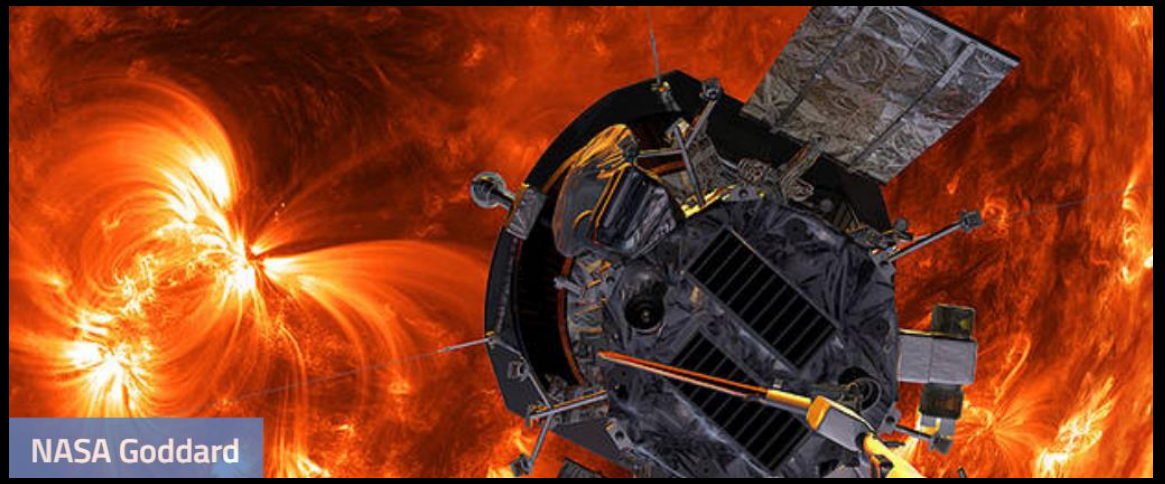
# Psyche Mission

Handling (Opportunity)

- 2022 launch to asteroid 16 Psyche to study what appears to be the exposed nickel-iron core of an early planet between Mars and Jupiter
  - Better understand earth's core without digging
- Possible vast quantities of gold, platinum, diamond worth quadrillions
- Too far to bring back samples, but
  - Recent study shows over ten asteroids that could be captured and brought to near-earth orbit with existing technology
  - Potential mining depending on content

https://www.jpl.nasa.gov/missions/psyche
https://www.news18.com/news/buzz/gold-mining-in-space-nasas-psyche-spacecraft-to-study-asteroid-worth-10000-quadrillion-2795127.html
https://www.space.com/asteroid-mining-bring-space-rocks-to-earth

# Parker Solar Probe




- Flies through the sun's atmosphere
  - Multiple passes, successively closer
  - 9th approach on 8/9/2021
    - 330,000 mph, 6.5 million miles from surface
  - 430,000 mph, 2,500° F at closest approach
- Measures solar wind, solar particles, heat, radiation, magnetics, chemistry
  - Space weather prediction
  - Add to quantum physics body of knowledge
    - Better understand fusion energy
- Did you know: Sun's atmosphere is thousands of degrees hotter than its surface

https://www.nasa.gov/content/goddard/parker-solar-probe-humanity-s-first-visit-to-a-star
https://science.nasa.gov/heliophysics

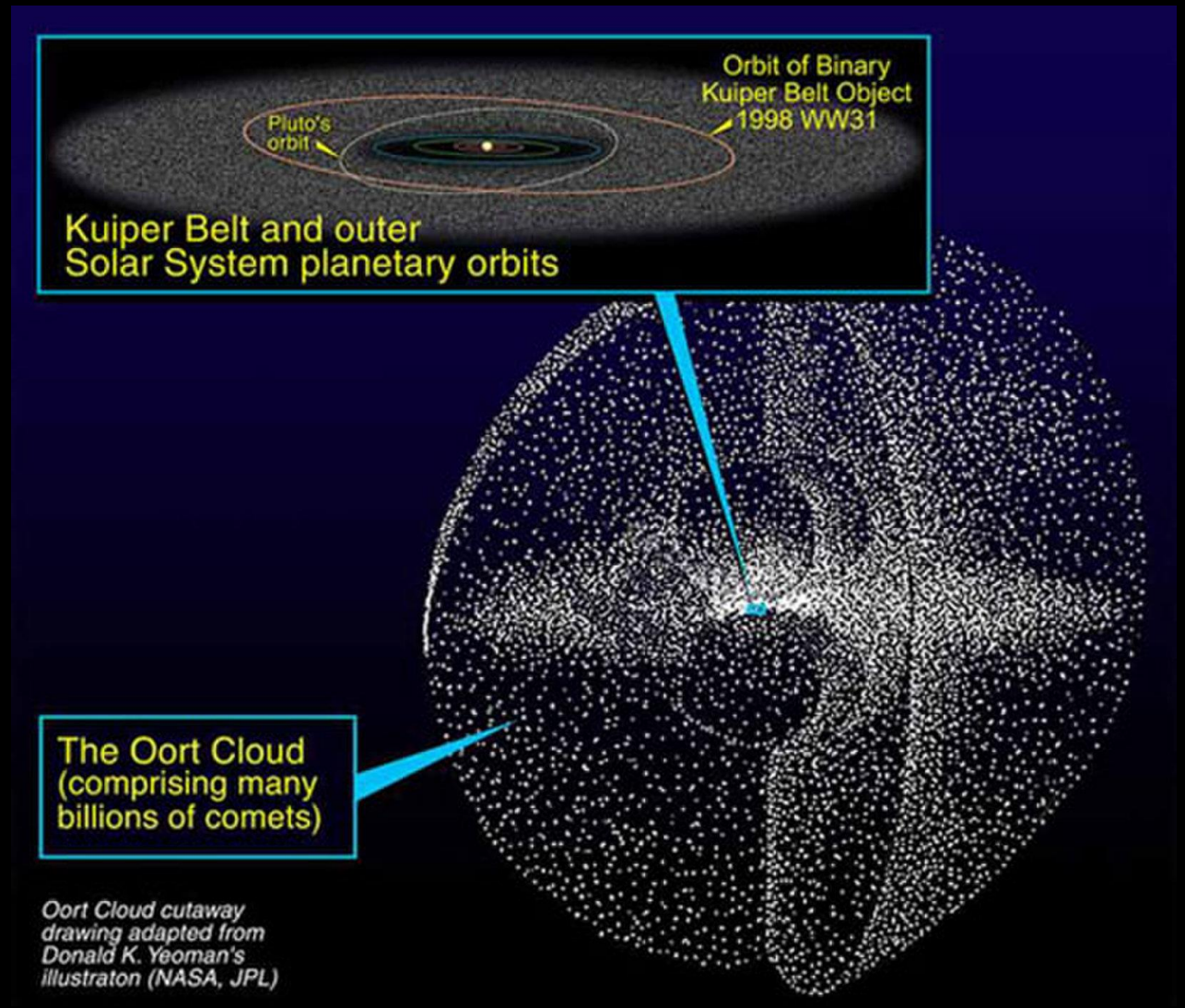
# Solar *System*

- Sun
- Inner planets
- Asteroid belt
- Outer planets
- Kuiper belt
- Oort cloud

*Is Pluto a planet?*
*Why or why not?*

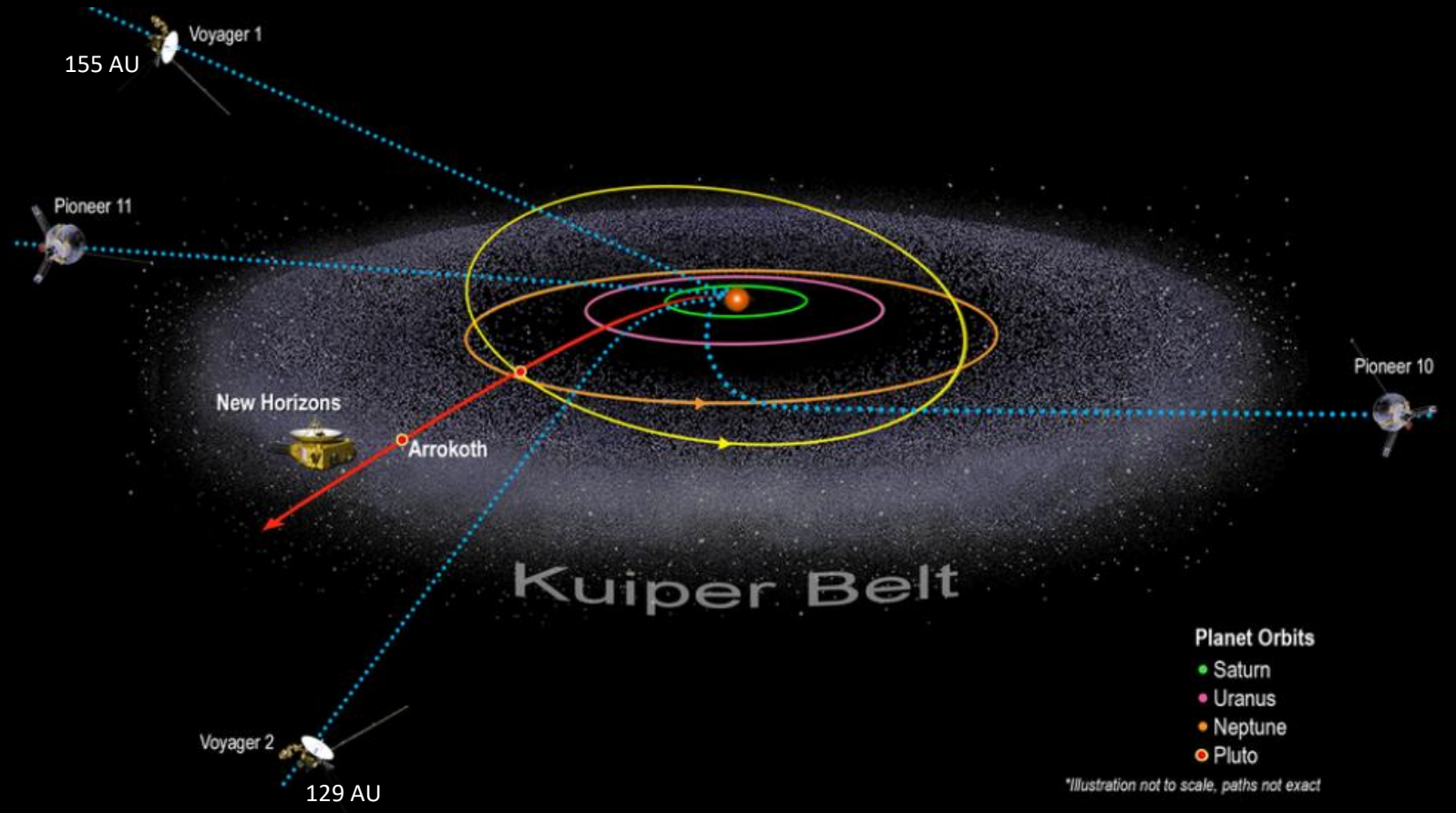
*Read: H***ow I Killed Pluto and Why It Had It Coming**

https://www.amazon.com/How-Killed-Pluto-Why-Coming/dp/0385531087/ref=sr_1_1?ie=UTF8&qid=1513036505&sr=8-1&keywords=how+i+killed+pluto+and+why+it+had+it+coming



# Solar System Exploration

- New Horizons, Pioneer 10 & 11, Voyager 1 &2 are more than 50 AU* from the sun
- Voyager 1 and 2 are now in interstellar space, beyond the heliopause, still sending data

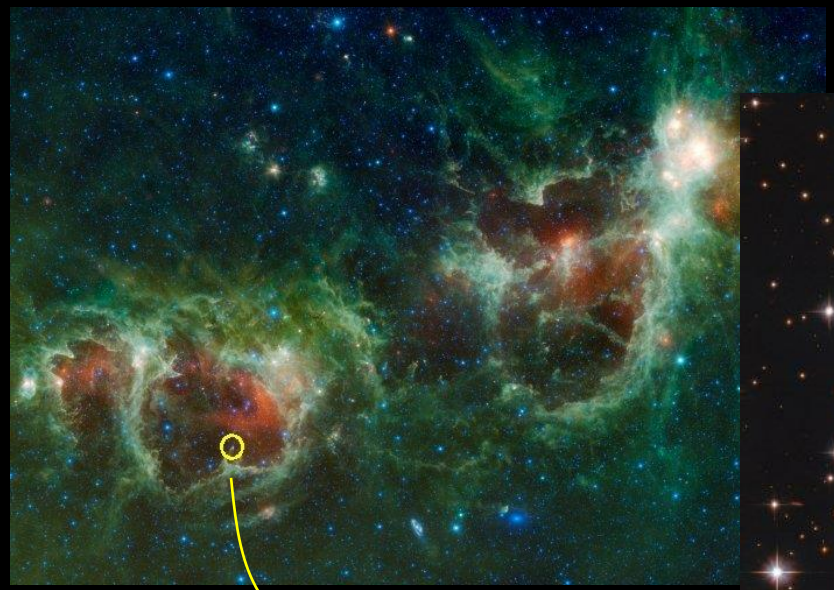



* 1 AU is the average distance of Earth to the Sun, or approximately 93 million miles

https://voyager.jpl.nasa.gov/mission/status/
https://gizmodo.com/new-horizons-captures-goosebump-inducing-image-as-it-ap-1846698155

# Star Birth

- J025157.5+600606 in the Soul Nebula
- FrEGGs - Free-floating Evaporating Gaseous Globules
- https://www.sciencealert.com/this-stellar-nursery-snapped-by-hubble-shows-a-star-still-being-born
- Also see https://www.sciencealert.com/the-most-detailed-image-yet-of-the-carina-nebula-will-blow-your-mind



# Distant Objects

- Hubble Space Telescope image of the spiral galaxy NGC 4603, which lies over 100 million light-years away in the constellation of Centaurus
- https://scitechdaily.com/hubble-snaps-a-stunning-close-up-of-a-magnificent-spiral-galaxy/

# Stellar Cannibalism

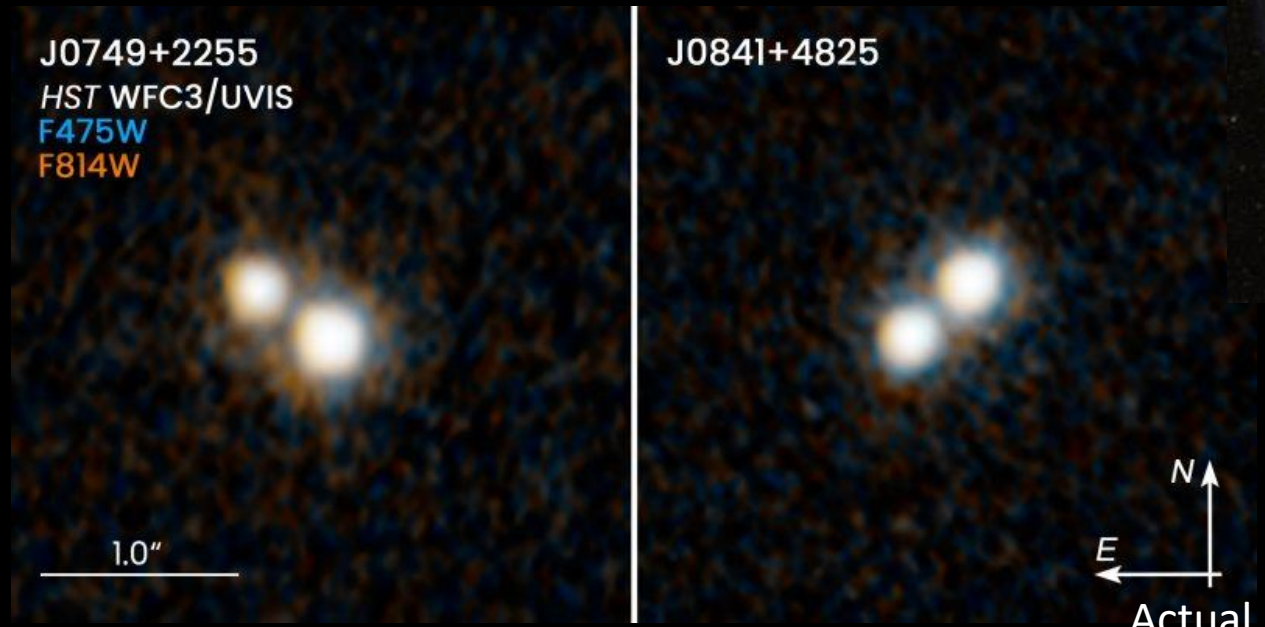
- The Milky Way's core has a black hole and a cluster of tens of millions of stars around it
- 7% of the stars orbit around the black hole at a different velocity and axis of rotation
  - ..and have a vastly different metal content
- Implies that an external entity was "swallowed"
  - Victim may have been another globular cluster.  Or a dwarf galaxy!


Infrared image of the central region of the massive cluster of stars at the Milky Way's core, about 27,000 light-years away

https://www.sciencenews.org/article/milky-way-most-massive-star-cluster-ate-smaller-cluster

# Double Quasars in Merging Galaxies

- 10-billion year-old quasars
- Huge amounts of energy thought to be related to black holes



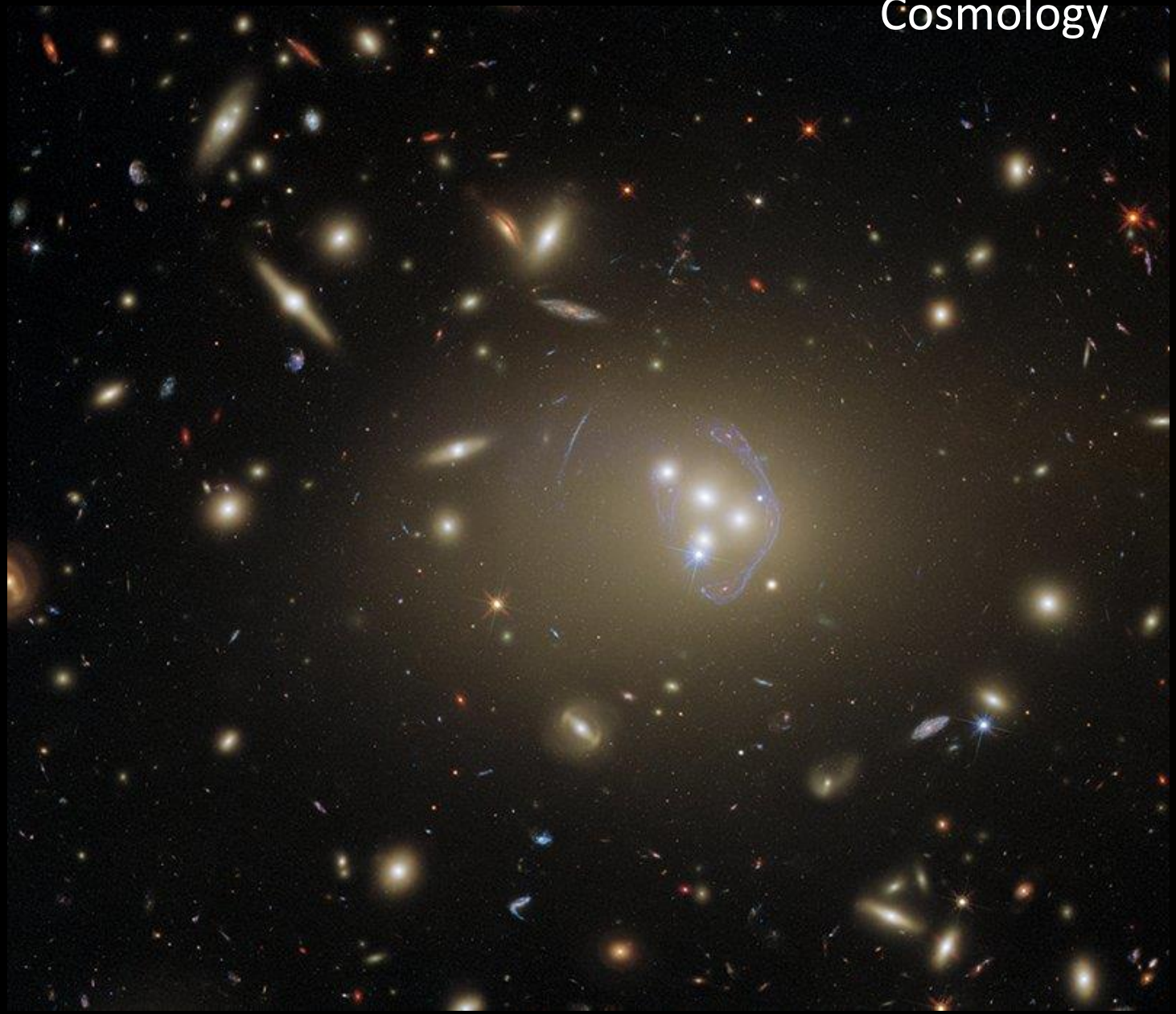

Actual images

Artist concept

- https://earthsky.org/space/double-quasar-black-holes-merging-galaxies/
- https://earthsky.org/space/double-quasar-black-holes-merging-galaxies/

# Distant Objects

- Hubble captures a cluster of hundreds of galaxies of different shapes and sizes, some 1.4 billion light-years* away
- https://www.sciencealert.com/this-hubble-image-of-a-galaxy-cluster-is-just-incredible

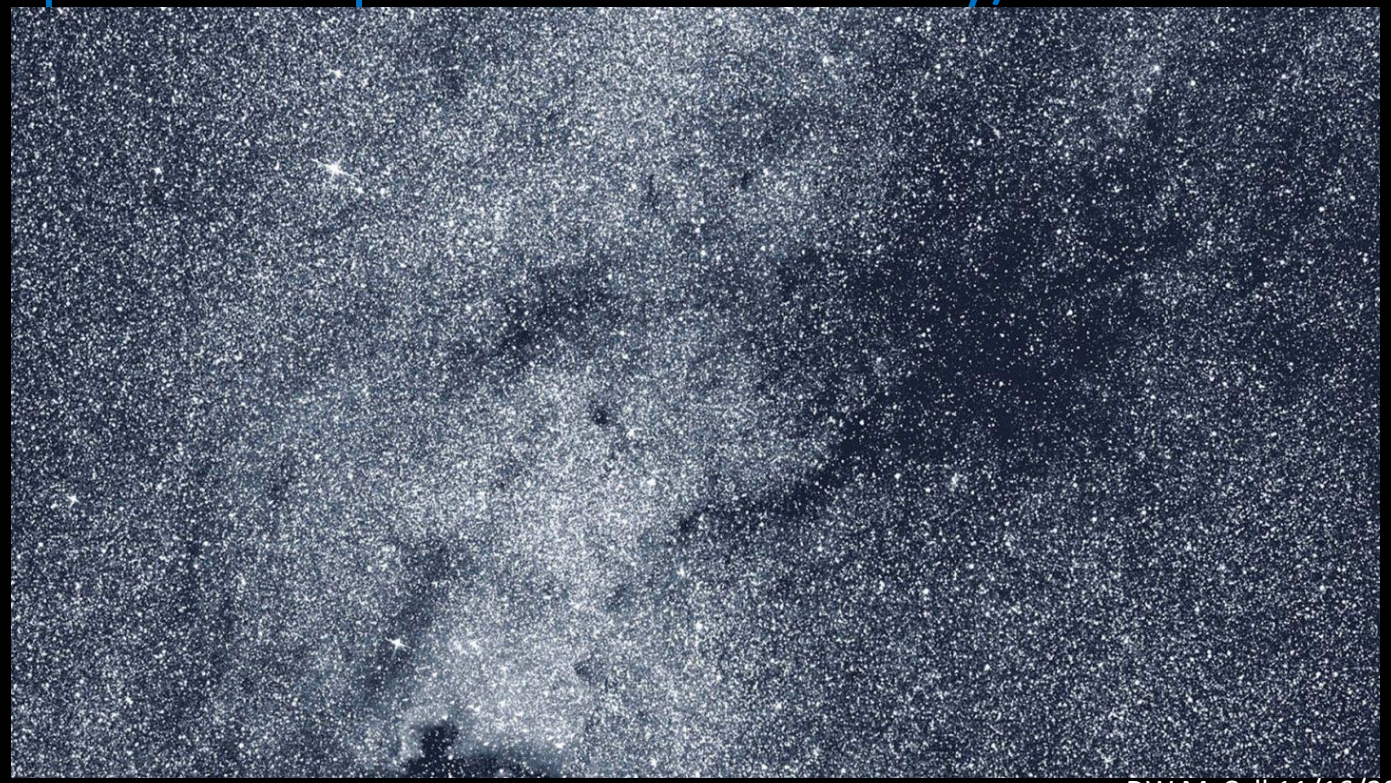


* 1 ly = 5,878,600,000,000 miles
(I am approx. 0.00000000000000193 ly tall)

Risk? or Opportunity?

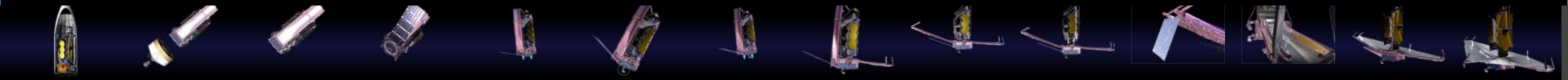
# We Are (probably) Not Alone

- TESS (Transiting Exoplanet Survey Satellite) maps the northern sky
- Nearly 100 confirmed planets and over 1,000 exoplanet candidates
- https://bgr.com/science/tess-photo-exoplanet-hunter-survey/

# JWST (James Webb Space Telescope) update

- Currently
  - In launch prep in Kourou, French Guiana
  - Planned launch date 12/18/2021
- Infrared observations
  - Improved view over Hubble; sees more
- Excellent overview at https://jwst.nasa.gov/content/webbLaunch/assets/documents/WebbMediaKit.pdf



https://jwst.nasa.gov/content/webbLaunch/index.html

# Links

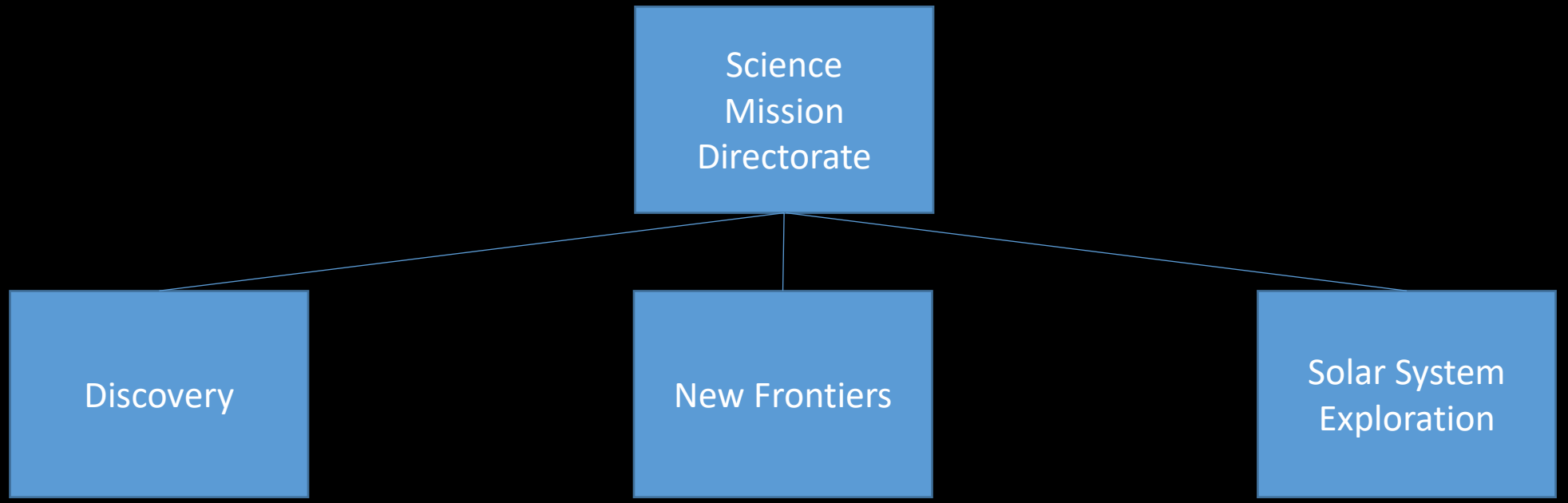
- NASA Missions A-Z https://www.nasa.gov/missions
- Launches and Landings https://www.nasa.gov/launchschedule/
- NASA Budget https://www.nasa.gov/news/budget/index.html

# Backup

# Space Observatories

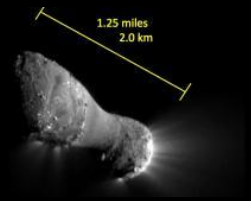
- Gamma-ray
  - Fermi -- dark matter, black holes and spinning pulsars
  - Swift -- gamma-ray bursts; cosmic explosions
- X-ray
  - Chandra -- quasars; clouds of gas and dust and particles sucked into black holes
- Ultraviolet
  - GALEX -- formation of galaxies: shape, brightness, size and distance
- Visible
  - Kepler – exoplanets
  - Hubble -- deep space objects
- Infrared
  - Spitzer -- distant galaxies, black holes; comets in our solar system
  - Herschel -- look for water both in nearby comets and faraway dust clouds; peer into star nurseries
- Microwave
  - Planck -- remnants of the first light to shine freely in the universe, the Cosmic Microwave Background (CMB)

# Planetary Missions - NASA



# Example Programs

- Discovery Programs
  - Deep Impact
    - Primary mission
      - Ram a spacecraft into comet Tempel 1, measure the ejecta
      - 370 kg at roughly 10.2 km/s => 19 Gigajoules or roughly 4.8 tons of TNT
      - https://www.nasa.gov/mission_pages/deepimpact/mission/index.html#.WibWNUqnGUk
    - Repurposed (extra) mission: EPOXI
      - Extrasolar Planet Observations and Characterization (EPOCh) and Deep Impact eXtended Investigation (DIXI), a flyby of comet Hartley 2
      - https://planetarymissions.nasa.gov/missions/EPOXI/overview

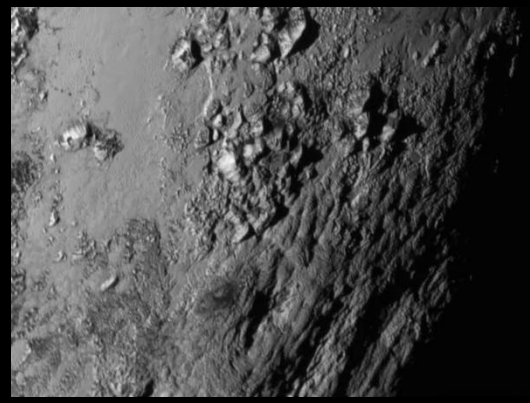


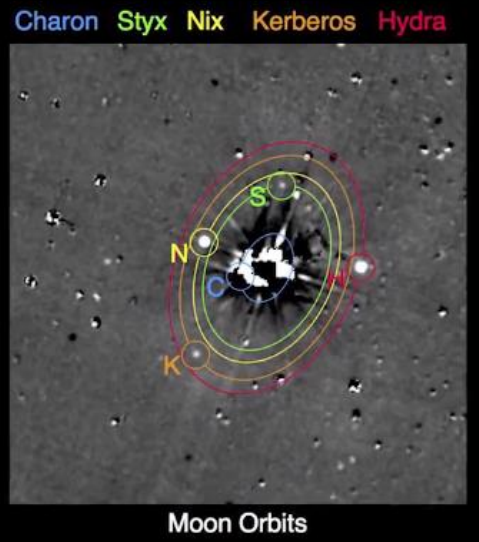

- Kepler:
  - Discover hundreds of Earth-size and smaller planets in or near the habitable zone in our region of the Milky Way galaxy
  - Determine the fraction of the hundreds of billions of stars in our galaxy that might have such planets
  - Second Mission: K2
  - https://www.nasa.gov/mission_pages/kepler/overview/index.html

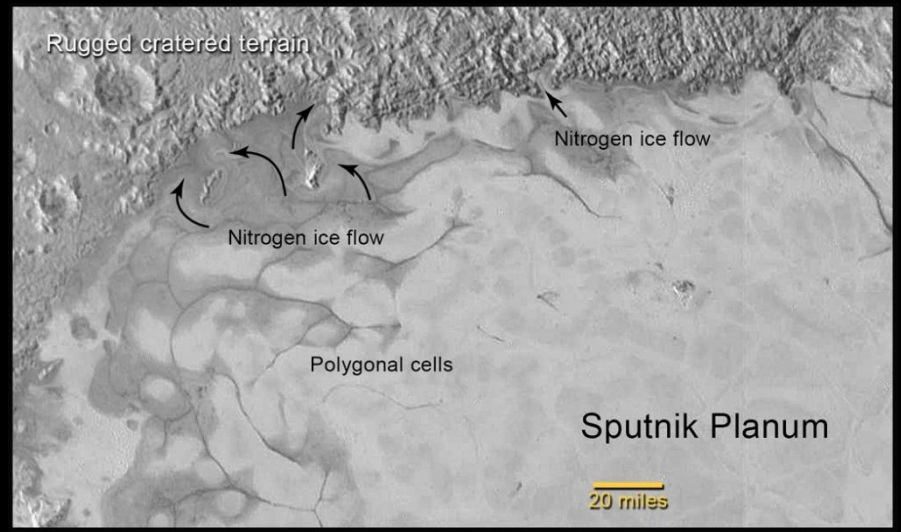
**Kepler mission:**
Candidate exoplanets: 4,496
Confirmed exoplanets: 2,337
Confirmed exoplanets less than twice Earth-size in the habitable zone: 30
**K2 mission:**
Candidate exoplanets: 515
Confirmed exoplanets: 178

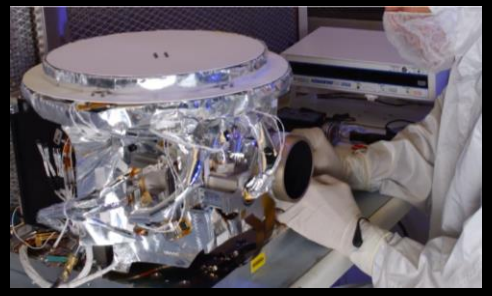
# Example Programs

- New Frontiers Programs
  - New Horizons
    - Primary mission
      - Obtain a close look at Pluto and its moon(s)
      - https://planetarymissions.nasa.gov/missions/New%20Horizons/overview
    - 2nd part of mission
      - Visit a Kuiper Belt Object beyond Pluto
      - https://planetarymissions.nasa.gov/missions/New%20Horizons/overview
    - Ralph instrument
      - Joint project of Southwest Research Institute (SwRI), Ball Aerospace and GFSC (NASA's Goddard Space Flight Center)
      - Color and black-and-white maps of Pluto's surface and temperature
      - Mapped the presence of nitrogen, methane, carbon monoxide, water and other materials





# Example Programs

- Explorers Program
  - MIDEX: Widefield Infrared Survey Explorer (WISE)
    - Launched December 14, 2009; primary mission complete in 2011, placed in hibernation
      - All-sky survey: three-quarters of a billion objects, including remote galaxies, stars and asteroids
    - Reactivated September 2013, renamed NEOWISE
      - New primary mission: identify the population of potentially hazardous near-Earth objects (NEO)
      - Secondary mission: characterize more distant populations of asteroids and comets to provide information about their sizes and compositions
    - https://www.nasa.gov/feature/jpl/nasa-s-asteroid-hunting-spacecraft-a-discovery-machine

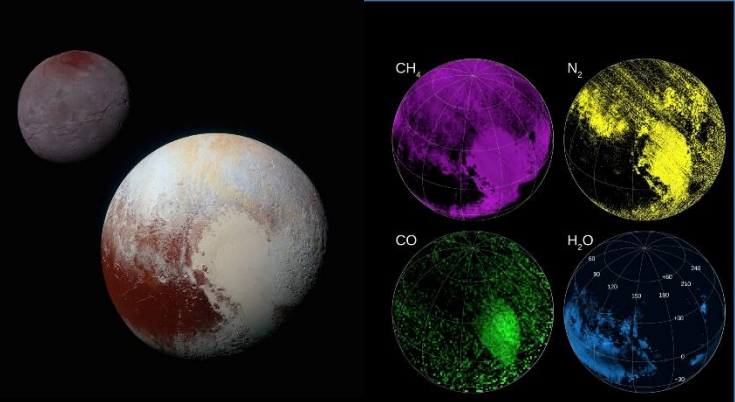
  - SMEX: Imaging X-Ray Polarimetry Explorer (IXPE)
    - Nov 2020 launch
    - Study X-ray production in objects such as neutron stars and pulsar wind nebulae, as well as stellar and supermassive black holes
    - https://wwwastro.msfc.nasa.gov/ixpe/index.html

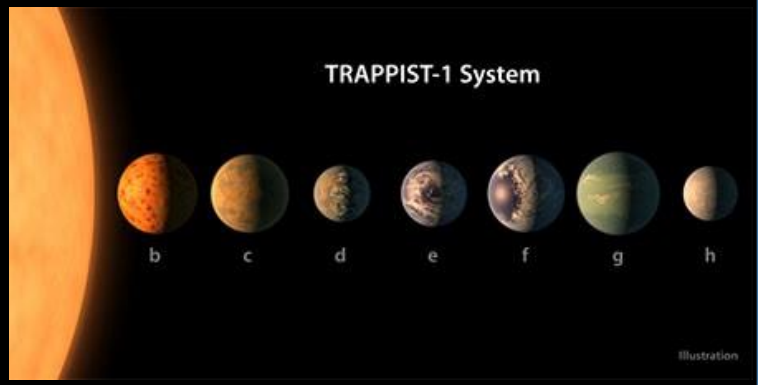
# NASA Research Centers

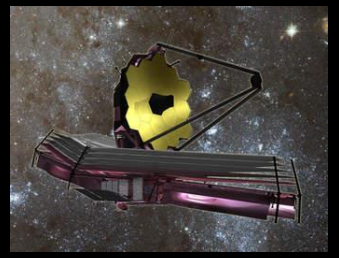
- Ames: IT, fundamental aeronautics, bio and space science technologies
- Armstrong: Flight research
- Jet Propulsion Laboratory: Robotic exploration of the solar system
- Johnson: Human space exploration
- Stennis: Rocket propulsion testing and remote sensing technology
- Kennedy: Prepare and launch missions around the Earth and beyond
- Marshall: Space transportation and propulsion technologies
- Glenn: Aeropropulsion and communications technologies
- Goddard: Earth, the solar system, universe observations, and space communications and navigation
- Langley: Aviation and space research
- Wallops Flight Facility: Suborbital Research Programs

# Ball Contributions to Missions

- James Webb Space Telescope optics
- New Horizons – Pluto close-ups – Ralph instrument, camera
- Spitzer Space telescope
  - Cryogenic Telescope Assembly (CTA)
    - The telescope, and two of the three science instruments embedded within the CTA: the Infrared Spectrograph and the Multiband Imaging Photometer.
- Hubble Space Telescope
  - Two star trackers, five major leave-behind equipment subsystems
  - Each of the five science instruments now operating on the telescope were Ball-designed and built.
  - *Ball also fixed the early problem with the imaging system*
- Kepler/K2 – exoplanet discoveries; Ball built the observatory
- Deep Impact
- Worldview spacecraft
- NPP spacecraft



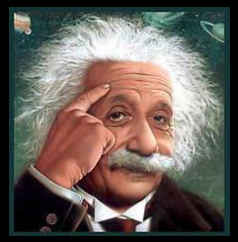



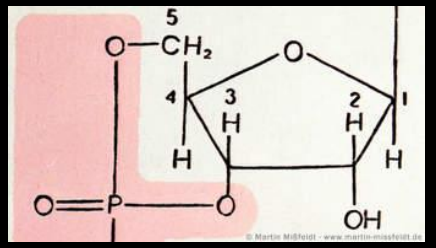
# What it Takes

- Systems Engineering*
  - Systems Thinking applied to Engineering
  - Addresses complexity
  - Initially driven by the Apollo program
  - Four key facets
    - Technical
    - Rational/Logical
    - Social
    - Intuitive
  - Quality, cost, schedule, risk
    - Optimized trade space

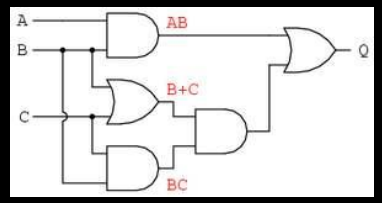
- Math
- Physics



- Chemistry




- Logic




- Coding

* …and several other types of engineering

# Space Environment

- Extreme temperatures
- Vacuum
- Little to no gravity: “zero-g”
- High radiation (solar & cosmic)
  - Big challenge for human space flight
- Debris (meteoroids, manmade)

# Launch Environment

- High vibrations & noise
- High g-forces
- Molecular heating
- Outgassing
- Failures
  - 3 out of 85 launches in 2016
  - 8.08% historically
  - 6.68% in the past 20 years

https://www.youtube.com/watch?v=M7wBN-U2KXI

# Spacecraft Anatomy

| | Car | Spacecraft |
|---|---|---|
| **Mission** | get there | telecommunications, science, intelligence |
| **Payload** | You, cargo | RF (radio frequency), optical, UV/IR/gamma/etc. |
| **Power** | Alternator, battery | Solar cells, battery |
| **Propulsion** | Engine | Thruster |
| **Fuel** | gas, diesel | MMH, NTO, Xe |
| **Structure** | metal, composite, plastic | metal, composite, plastic |
| **Materials** | low cost | exotic & high cost |
| **Guidance & Control** | You | Autonomous Guidance, Navigation & Control |
| **Sensors** | You, gauges | light sensors, accelerometers |
| **Actuators** | steering, brakes | thrusters, reaction wheels, magnetic torquers |
| **Temperature control** | heater, radiator | heater, radiator |
| **Wiring** | wire harness | wire harness, fiber |
| **Repair** | accessible | not physically accessible once flying |
| **Cost** | $Thousands | $Millions |

# McCall Background

- Hughes Space & Communications 1988-2000
- Boeing Satellite Systems 2000-2012
- Ball Aerospace 2012-2017
  - Manager, Space Systems
- Cogestalt Group LLC  2017-present
  - CEO

- BS in Computer & Electrical Engineering
- MS in Electrical Engineering
- MBA
- Ed.D., Organizational Leadership