National Aeronautics and Space Administration

Orlando Math Circle, Orlando, FL

How Math and Physics Unlock the Code of Our Universe

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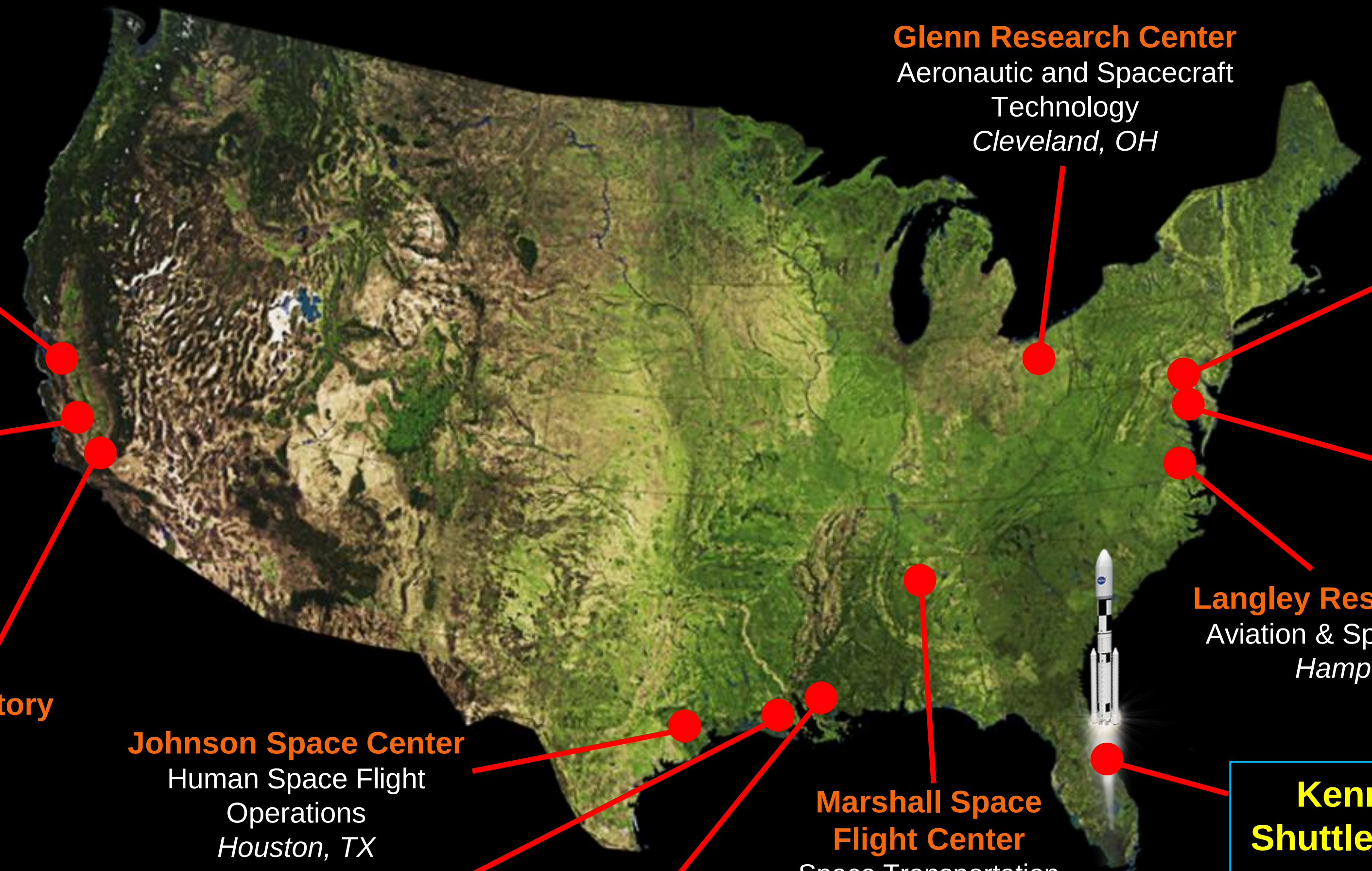
National Aeronautical and Space Administration (NASA)
Kennedy Space Center, Florida, USA

September 8, 2017

One NASA

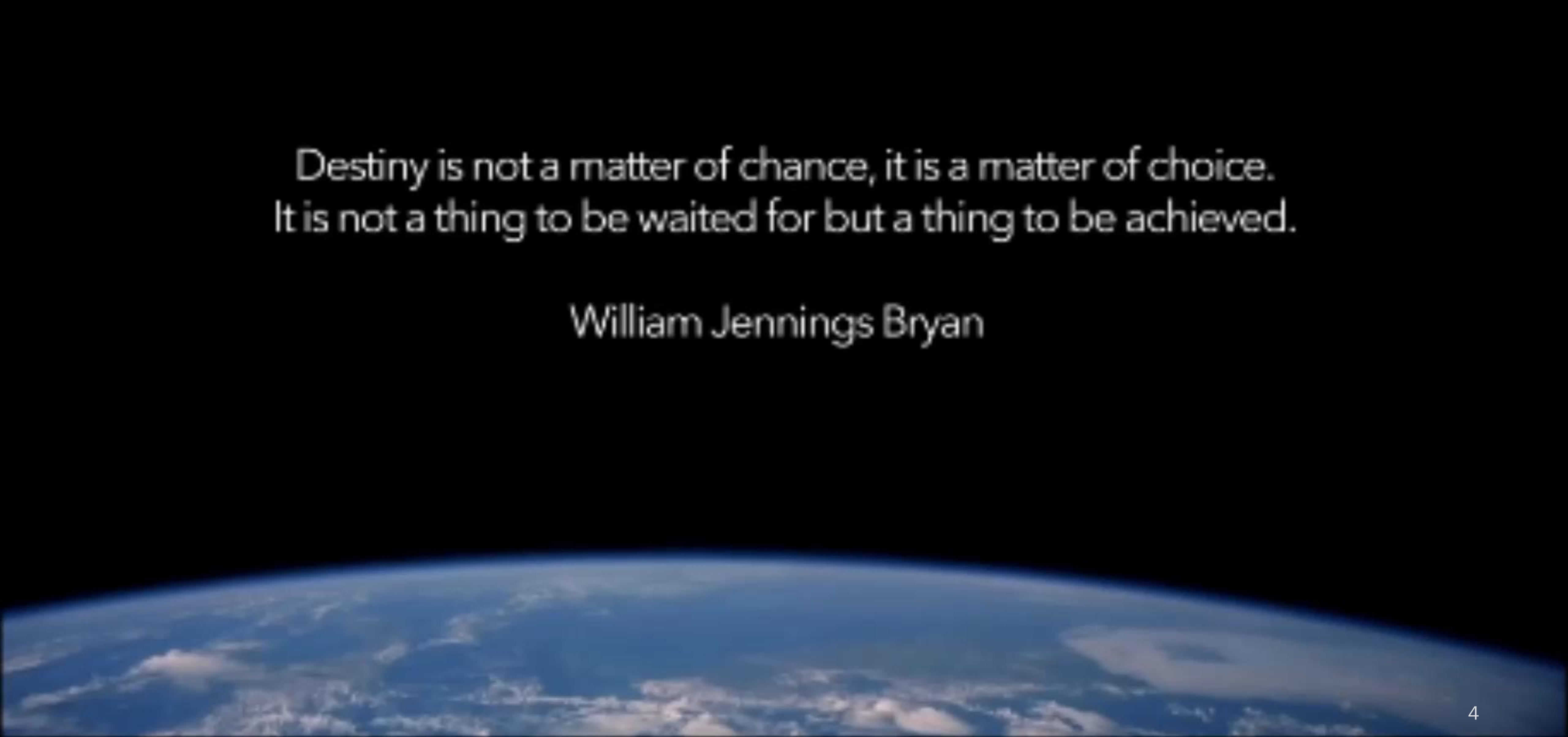
National Aeronautics and Space Administration

National Aeronautics and Space Administration Created by Congress in 1958



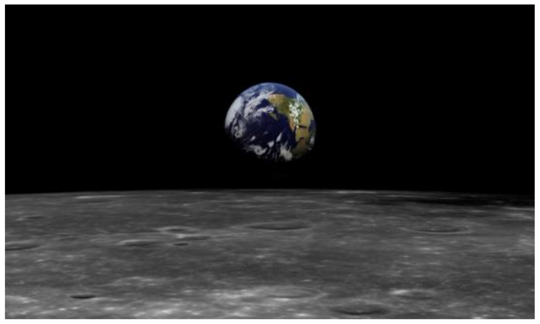
www.nasa.gov

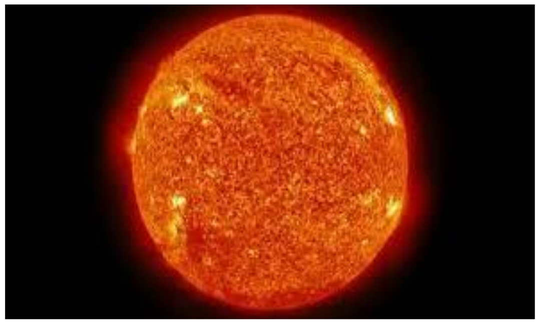
NASA Overview (2:39)

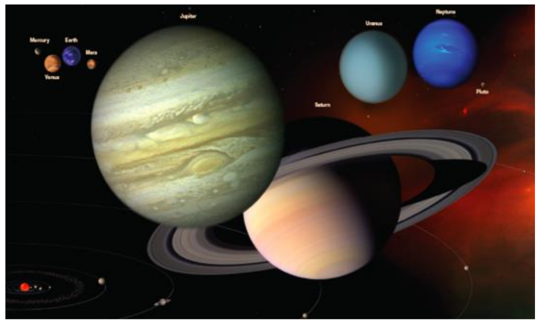


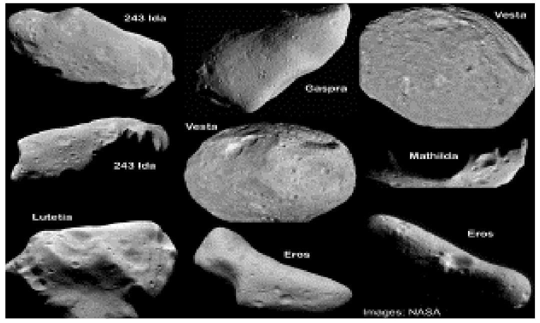
NASA – Explore, Discover, and Innovate


The Earth


The Moon


The Sun


Planets

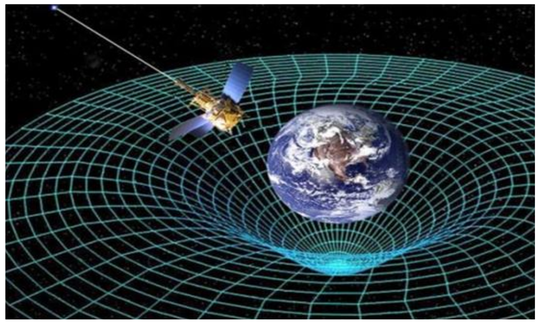


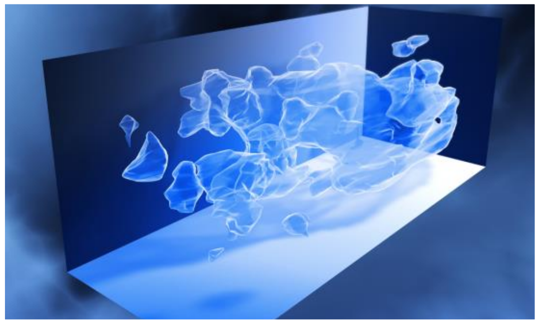
Dwarf Plane Asteroids

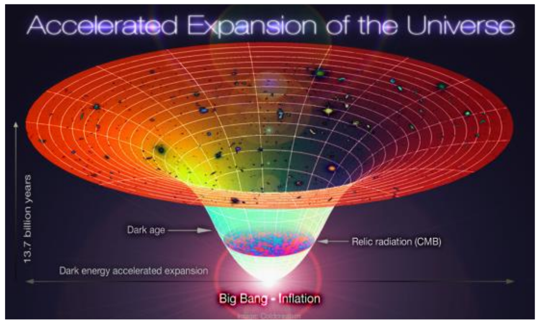

Comets


Stars & Galaxies


Search for Life & Exoplanets


Gravity


Dark Matter



Dark Energy


Black Holes

STEM Education – Foundation of Modern Society

S	• Science
T	• Technology
E	• Engineering
M	• Mathematics

STEM Relationships

Engineering

(create world)

- Converts science into technology and
- Converts technology into useful products

Technology

(use knowledge)

- Technologies (products and processes) are the result of engineered designs.
- They are created by technicians to solve societal needs and wants.

Science

(gain knowledge)

- Study the laws of nature
- Foundation of all technologies

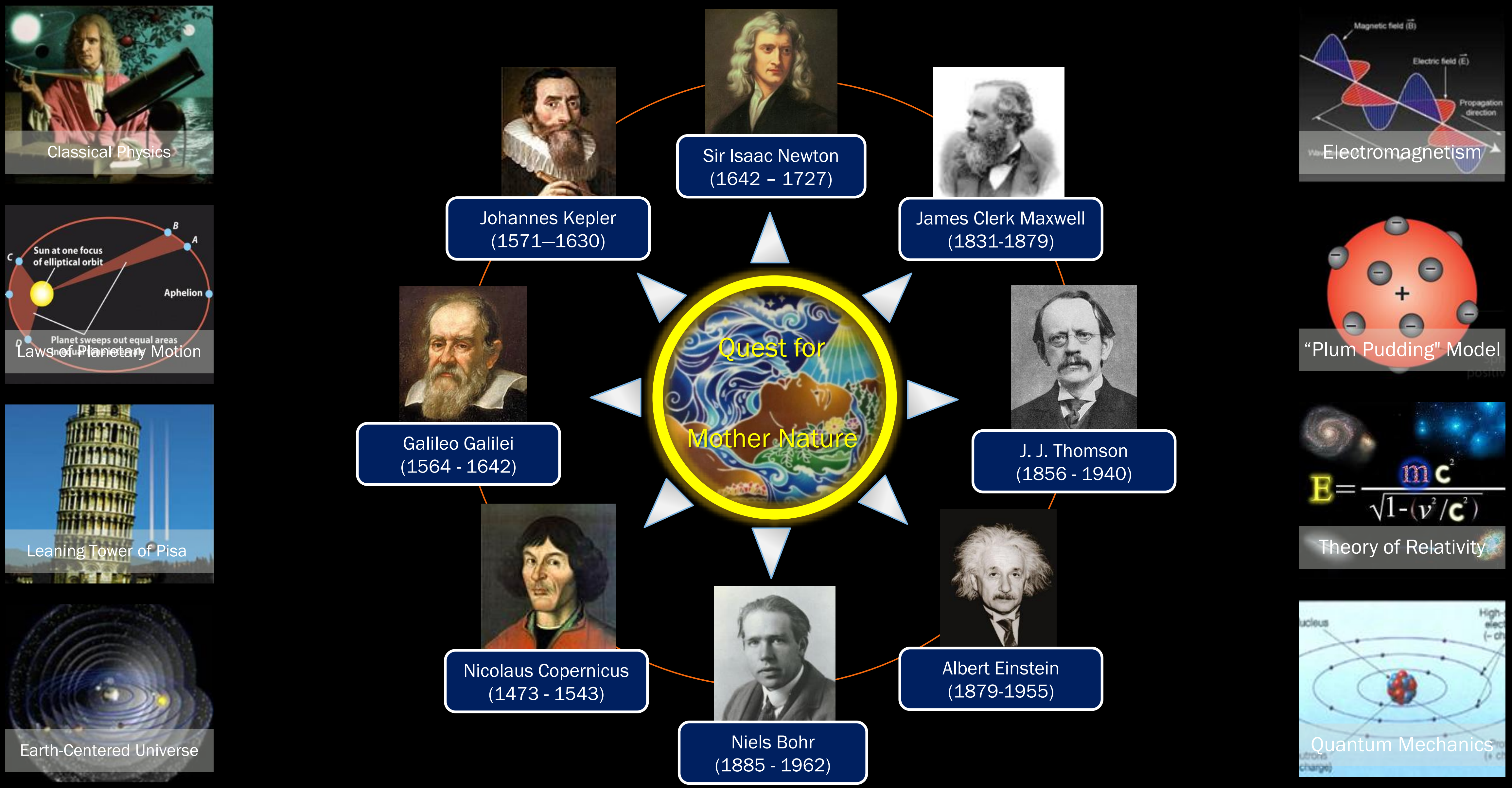
Mathematics

(describe knowledge)

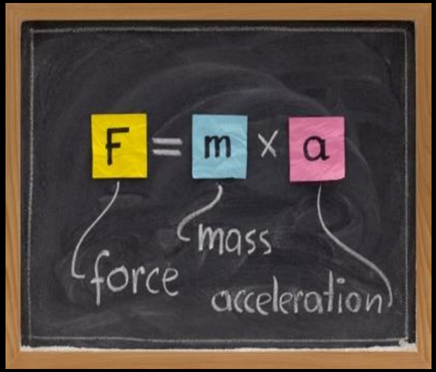
- Study laws of numbers
- Foundation of all sciences

Who Is Your Favorite Mathematician?

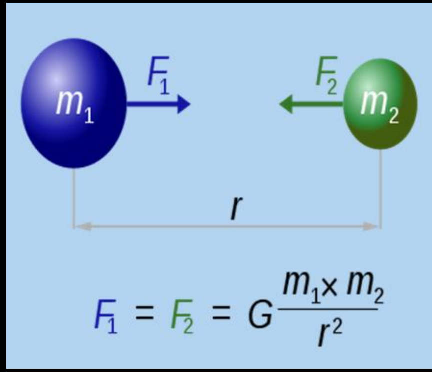
The Forefathers of Scientific Revolutions



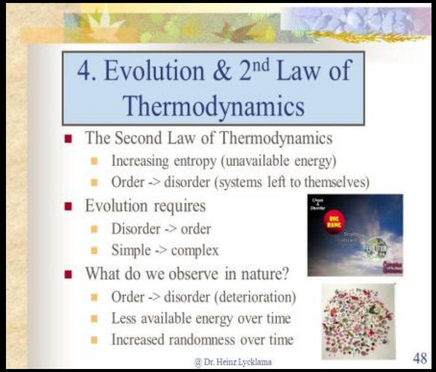
Most Important Equations That Shaped the World



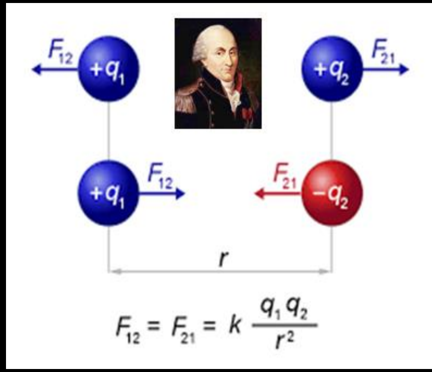
Newton's laws of motion



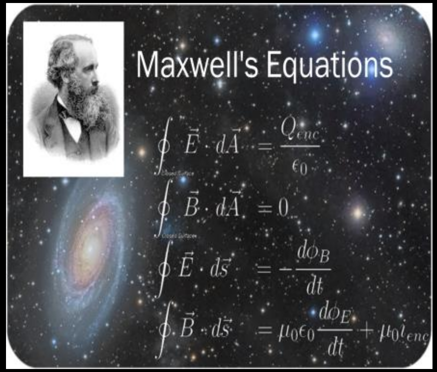
Newton's law of universal gravitation



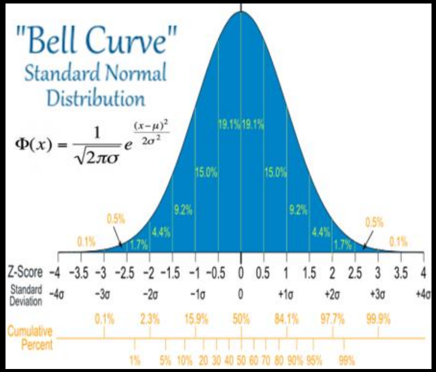
The second law of thermodynamics



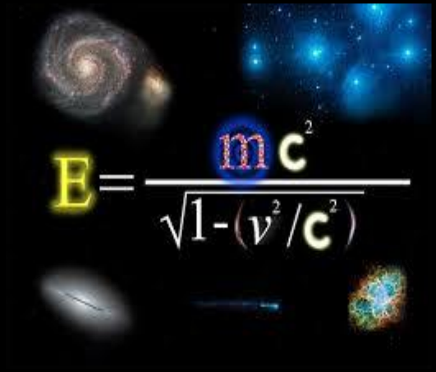
The Coulomb's law



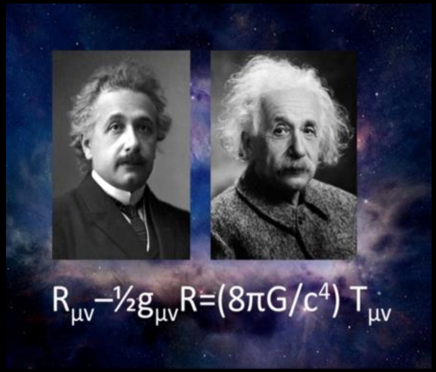
Maxwell’s Equations



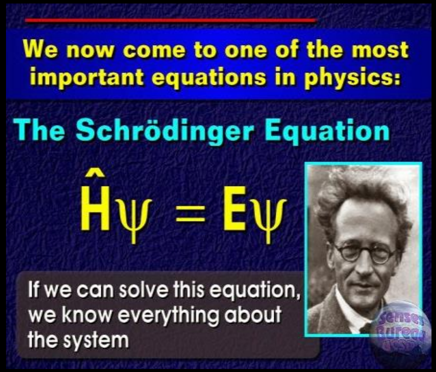
The Statistical Equation



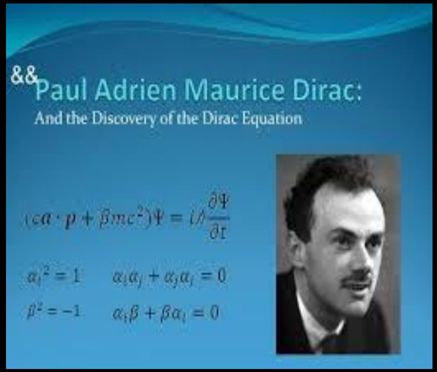
Einstein's special relativity



Einstein's general relativity



The Schrödinger equation

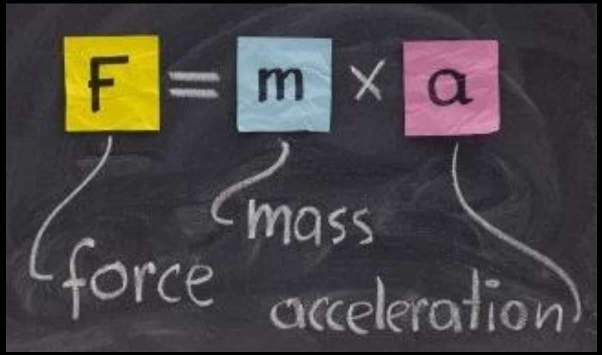


The Dirac equation

Newton's Equations

Three Laws of Motion

- 1st Law: (Law of Inertia)
  - Objects at rest stay at rest;
  - Objects in motion stay in motion
- 2nd Law: (Cause of Change)

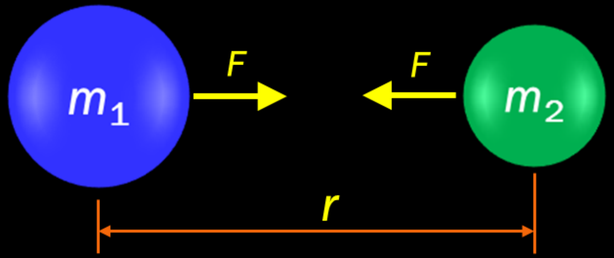


- Third Law: (Action & Reaction)
  - For every action there is an equal and opposite reaction

Law of Universal Gravitation

- A particle attracts every other particle in the universe: (an inverse-square law)

Sir Isaac Newton
(1642 – 1727)



$$F = G\frac{m_1 m_2}{r^2}$$

Maxwell's Equation

Maxwell's Equation

- Gauss' Law for Electricity

$$\vec{\nabla} \cdot \vec{E} = \frac{\rho}{\varepsilon_0}$$

- Gauss' Law for Magnetism

$$\vec{\nabla} \cdot \vec{B} = 0$$

- Faraday's Law of Induction

$$\vec{\nabla} \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$

- Ampere's Law

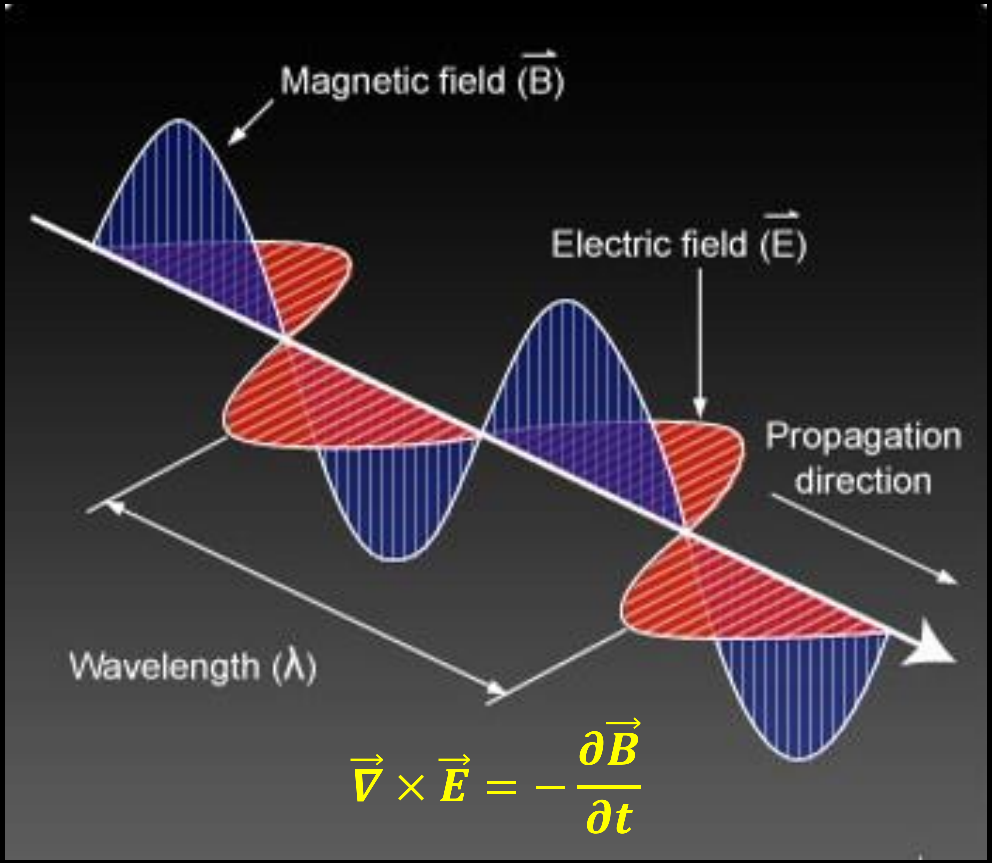
$$\vec{\nabla} \times \vec{B} = \mu_0 \vec{J} + \mu_0 \varepsilon_0 \frac{\partial \vec{E}}{\partial t}$$

(Maxwell's displacement)

James Clerk Maxwell
(1831-1879)
Scottish physicist

Electromagnetic Field

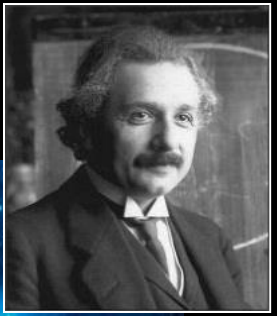
- Electric field is oscillating magnetic field



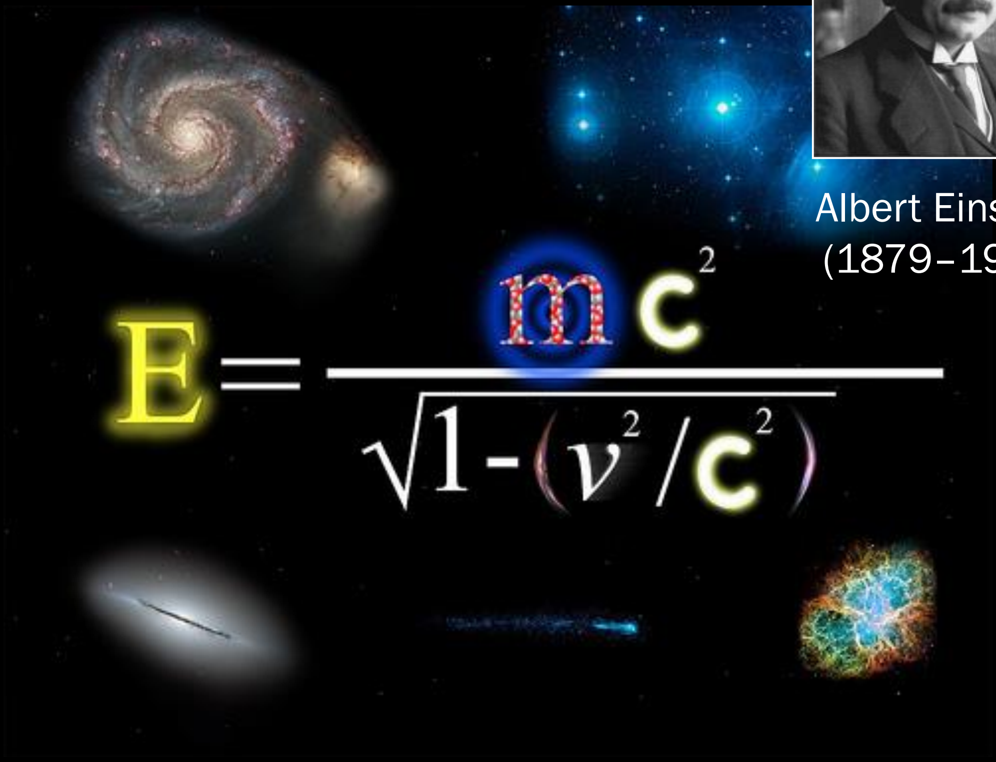
Einstein's Equations

Special Relativity

- "THE FASTER YOU MOVE,
  THE HEAVIER YOU GET."

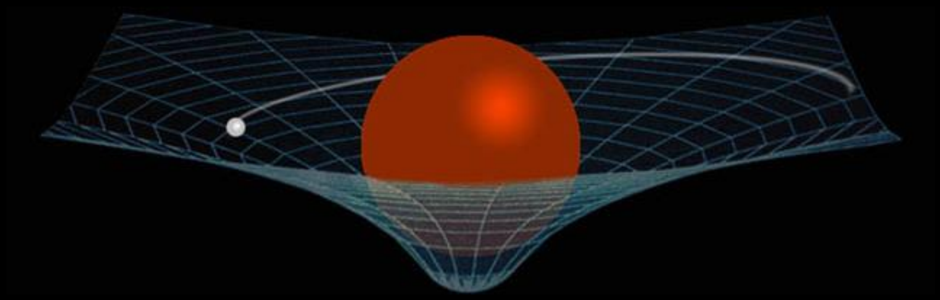


Albert Einstein
(1879–1955)



General Relativity

- "Matter tells space how to curve, and space tells matter how to move."

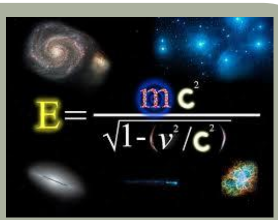


$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R + g_{\mu\nu} \Lambda = \frac{8\pi G}{c^4} T_{\mu\nu}$$

$R_{\mu\nu}$ = Ricci curvature tensor
$g_{\mu\nu}$ = Metric Tensor (symmetric 4x4)
Λ = Cosmological Constant
$T_{\mu\nu}$ = Stress Energy Momentum Tensor

Physics at Extreme Conditions

Special Relativity (1905)



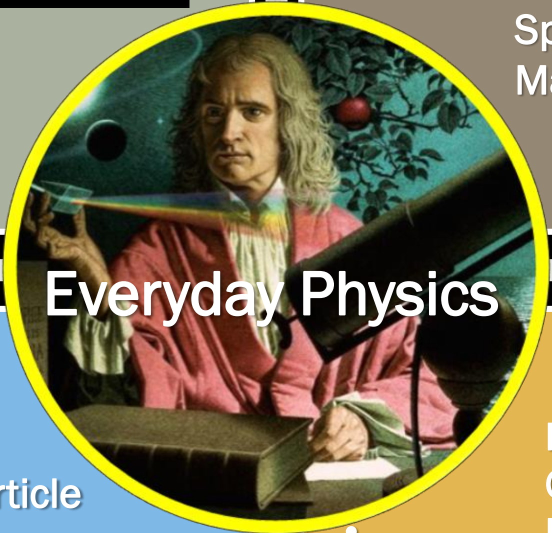
- Space & time related by LT
- Time dilation (Clock run slow)
- Length contraction
- Mass-energy mutually convertible

Near speed of light (~3x10^8 m/s)

General Relativity (1915)

- Very massive objects
- Bend space-time (gravity)
- Space/universe expanding
- Massive objects can collapse to black hole

Very Massive



Fast

Massive

Quantum Mechanics (~1913)

- Light behaves as both wave and particle
- Electrons also behave both wave and particle
- All have wave-particle duality
- Particles in two places at same time
- Probability/uncertainty

Very Fast & Small (~3x10^{-9} m)

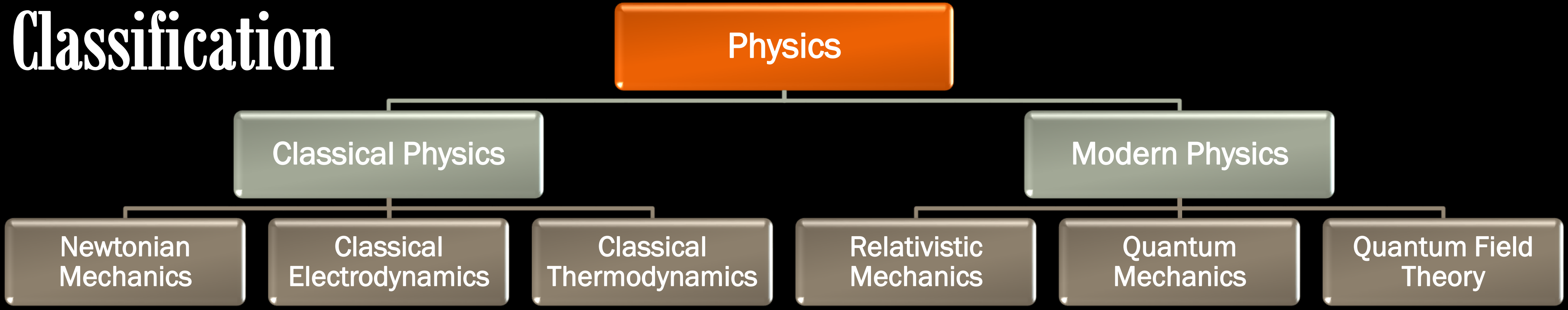
Quantum Field Theory

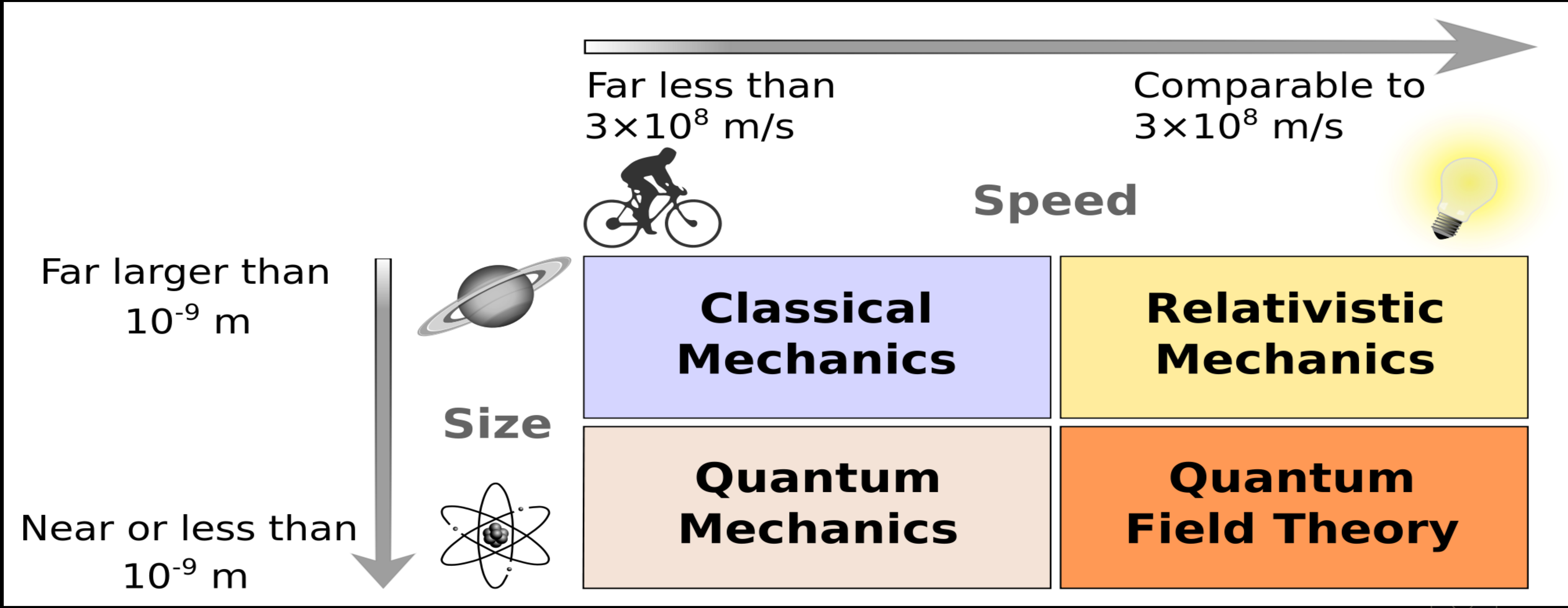
- Relativistic Quantum Mechanics
- Quantum gravity
- Black holes

Very Small, Fast & Massive

Very Small

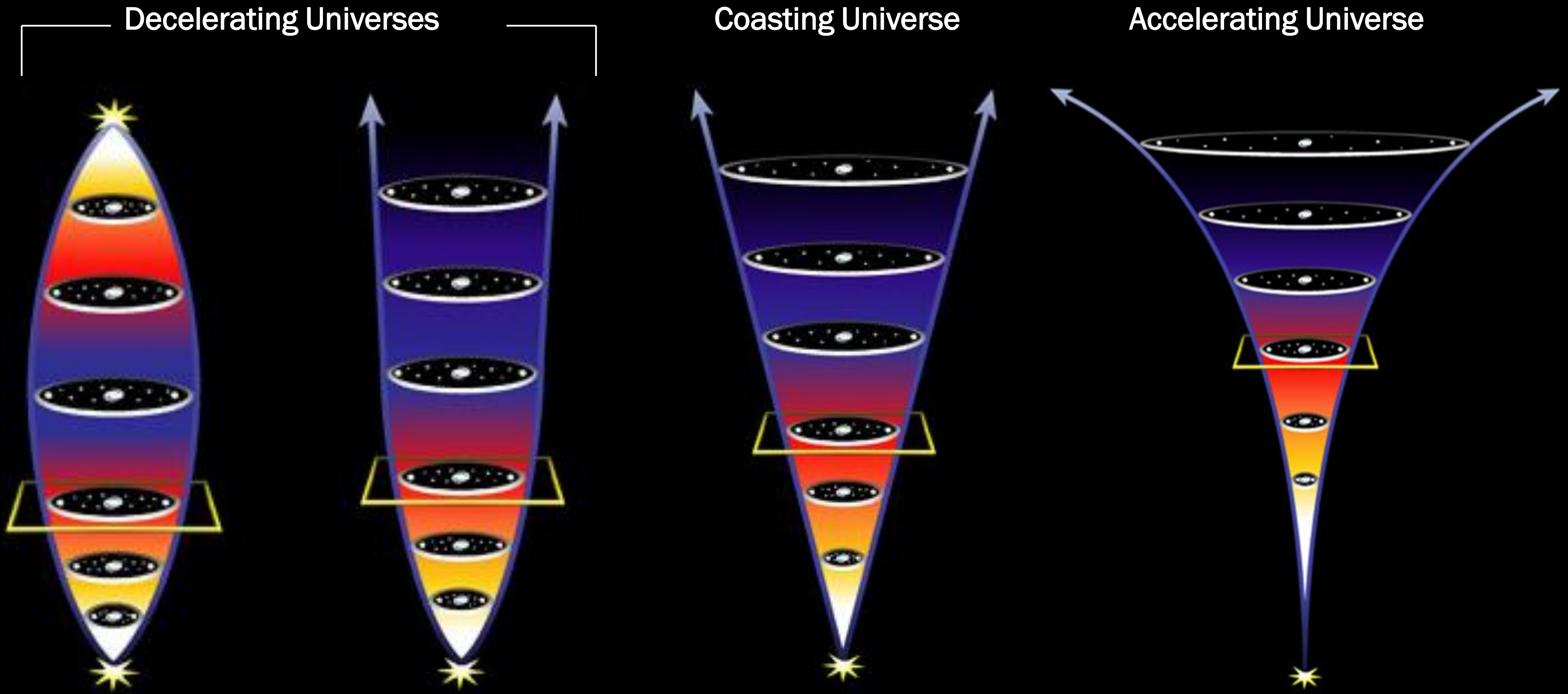
Classification



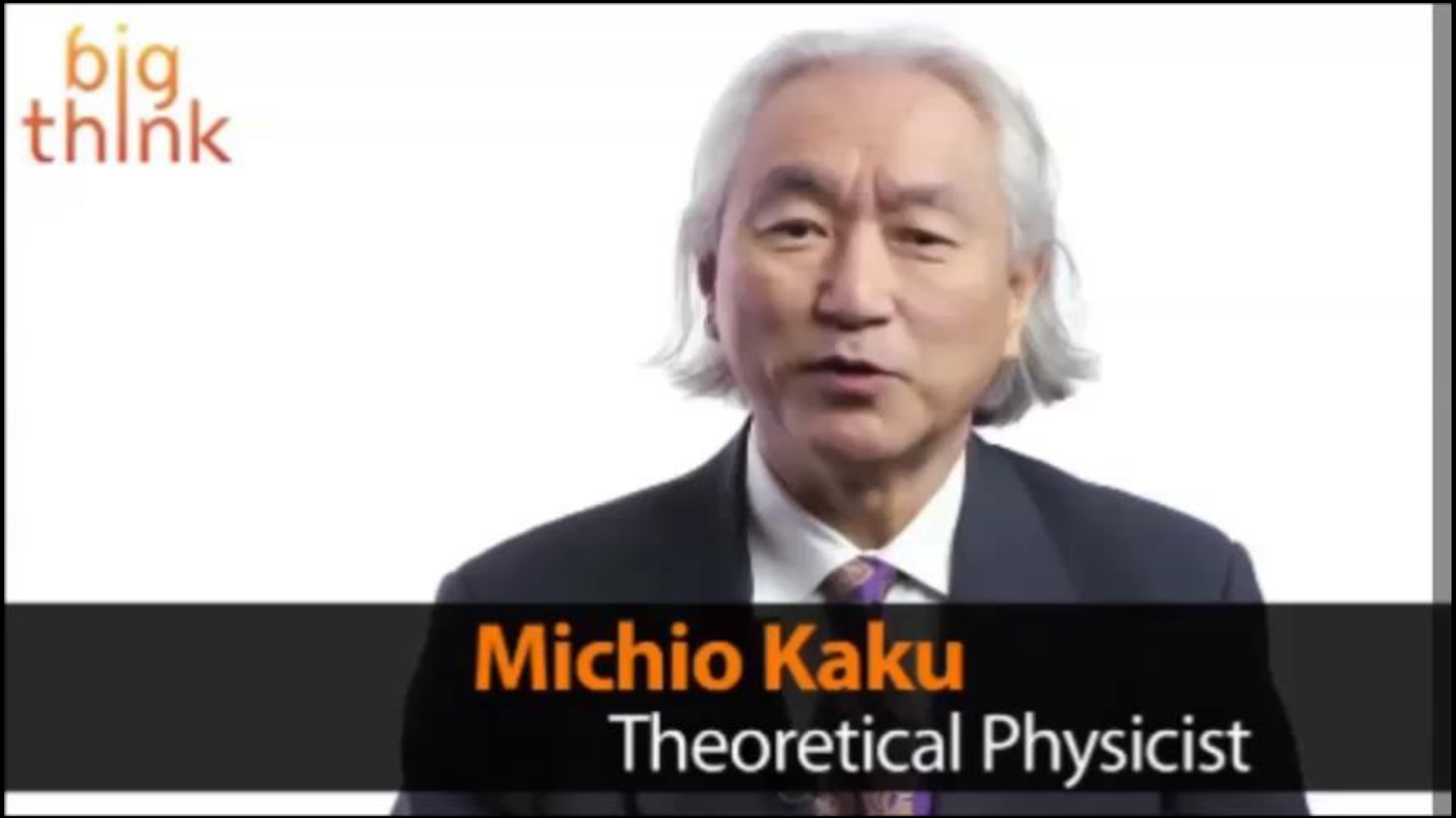


Hubble Biggest Discovery: Accelerating Expansion of Universe (1:29)

Possible Types of the Expanding Universe

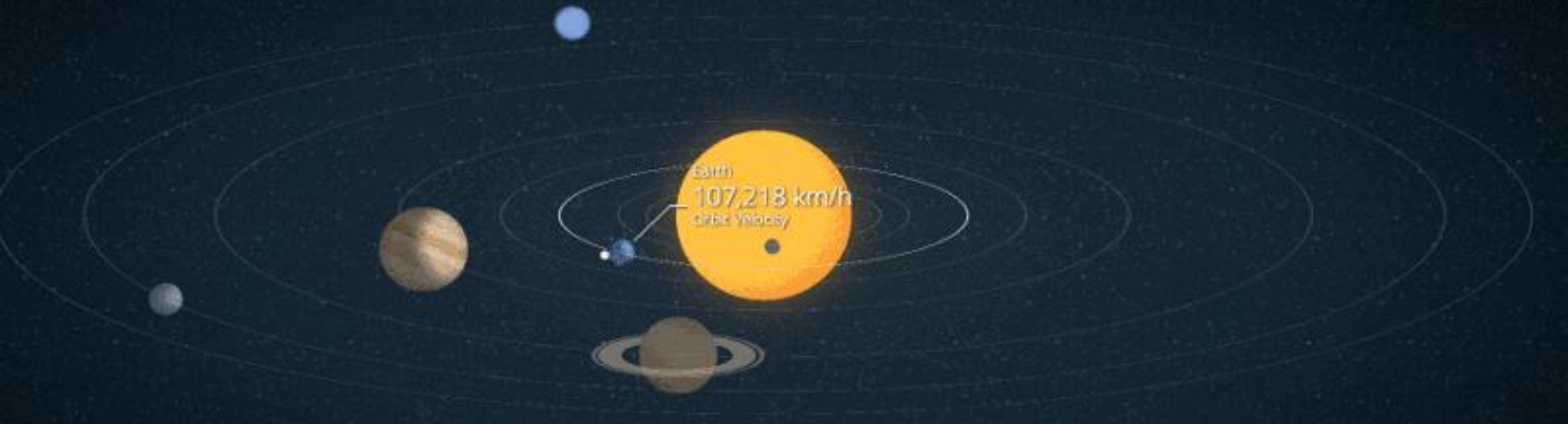


Michio Kaku on Quantum Mechanics (1.04)

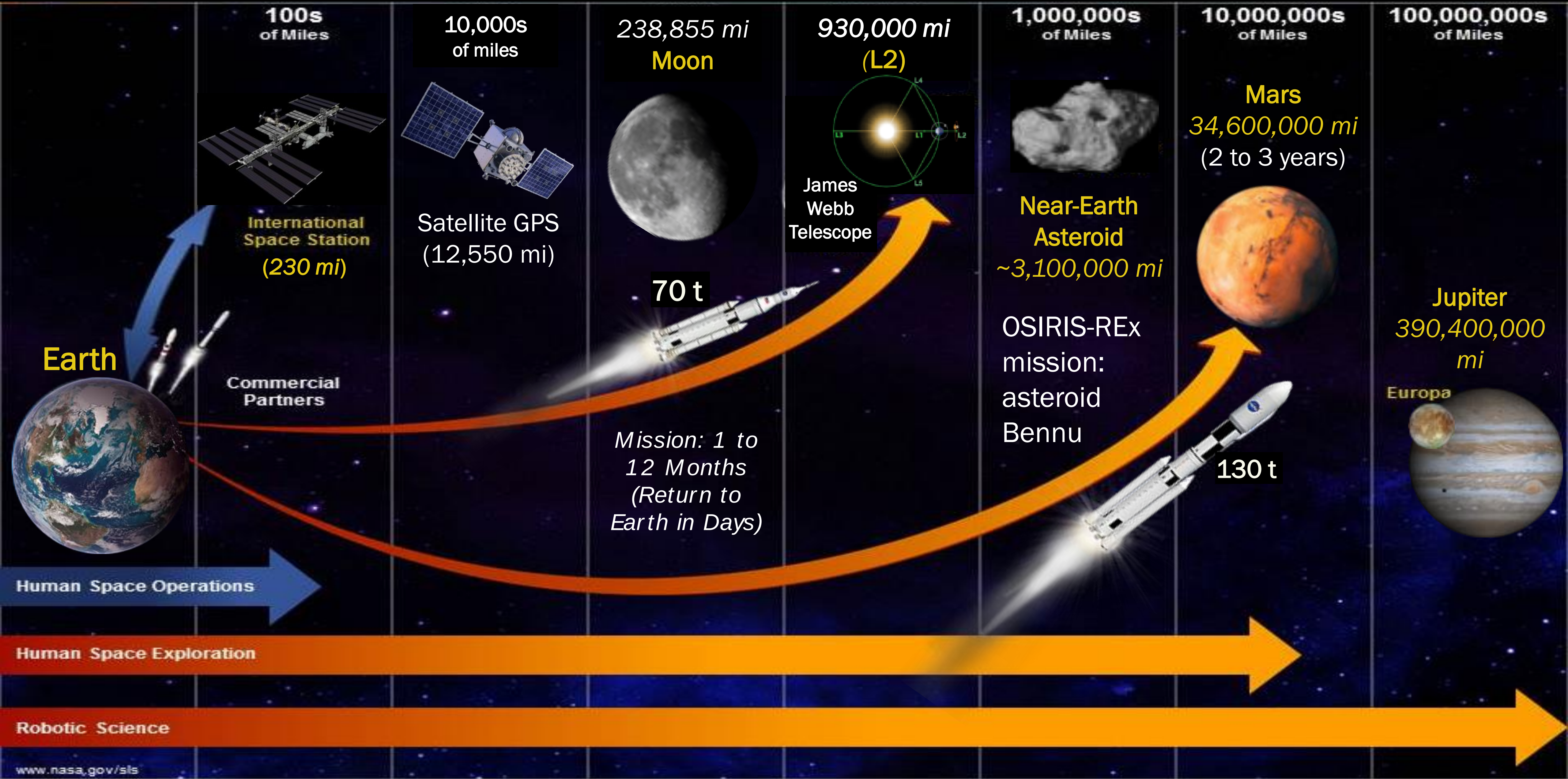


Views of the Universe: Ptolemy vs. Copernicus (2:31)

How Does Solar System Work?



The Future of Space Exploration

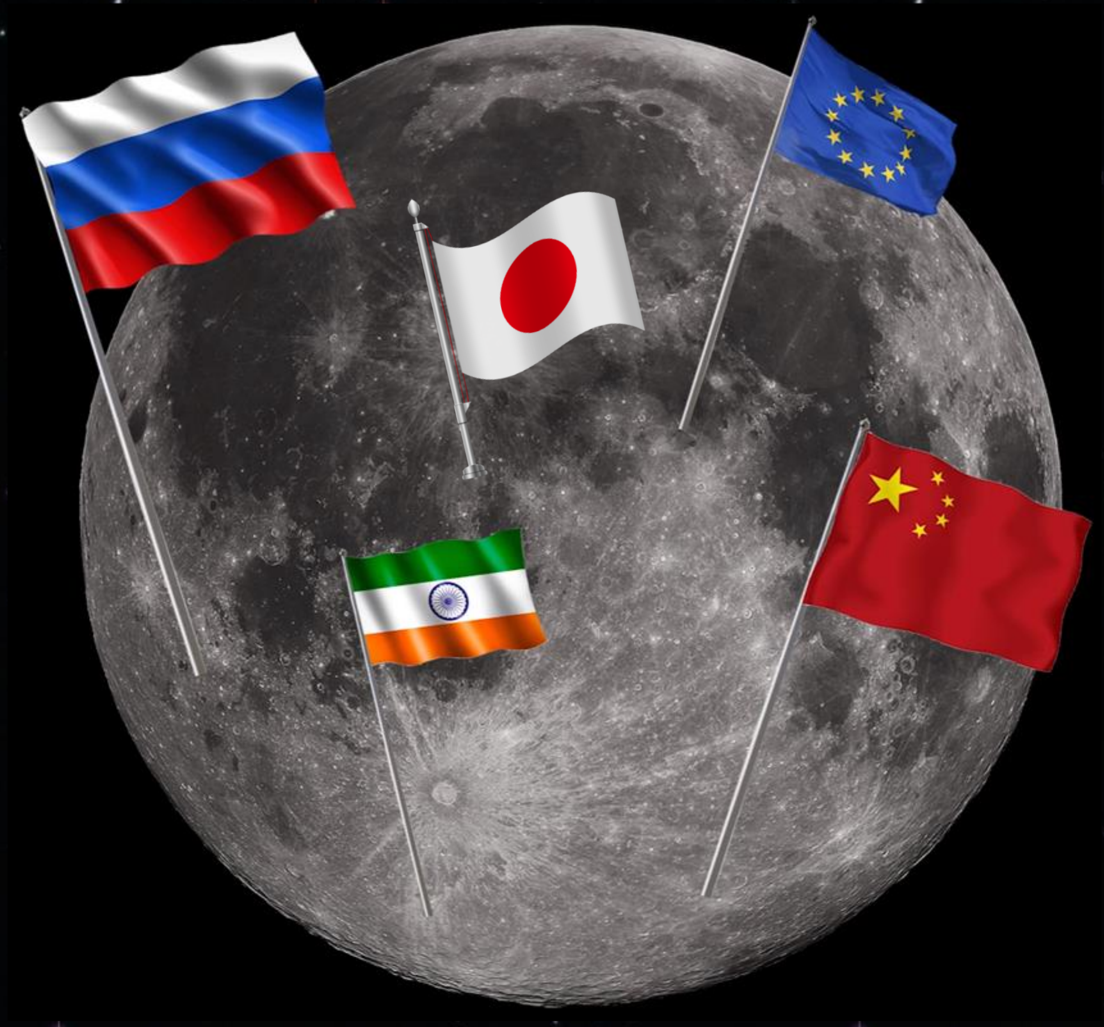


NASA's Earth Observatories

International Space Station (Since 1998)

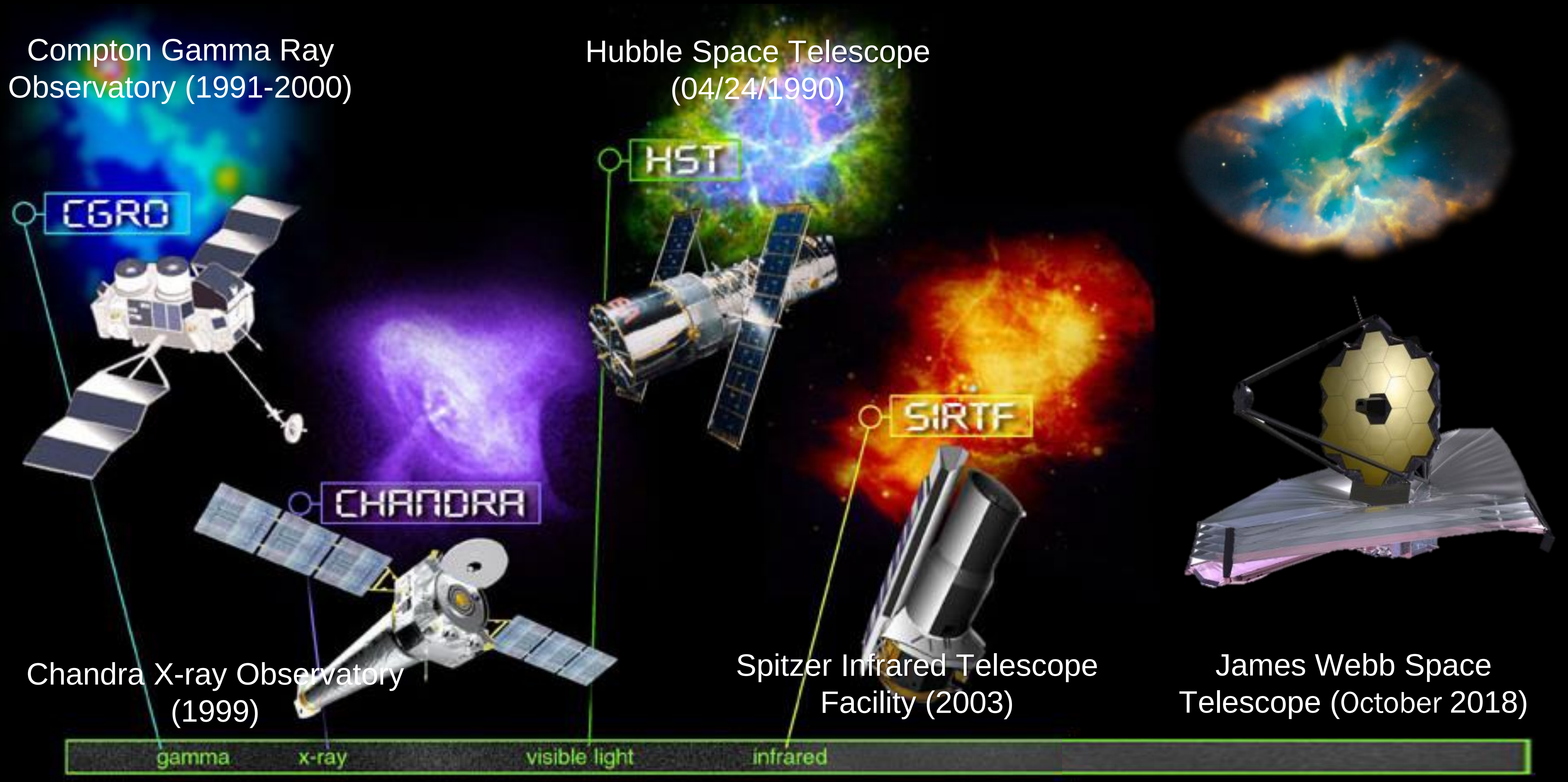
The Race to the Moon

The Mars



The Moon

NASA's Great Observatories



Compton Gamma Ray Observatory (1991-2000)

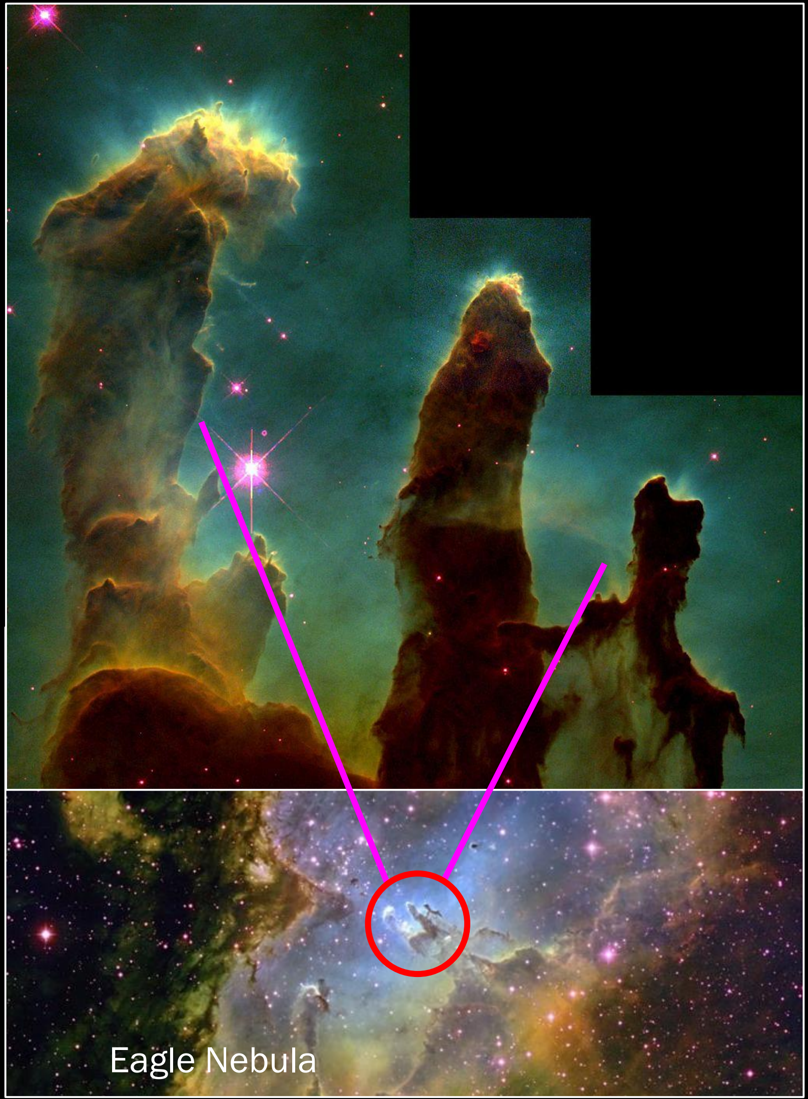
Hubble Space Telescope (04/24/1990)

Chandra X-ray Observatory (1999)

Spitzer Infrared Telescope Facility (2003)

James Webb Space Telescope (October 2018)

Hubble: Pillars of Creation - Eagle Nebula



1995 · WFPC2 · Visible

2015 · WFC3 · Visible

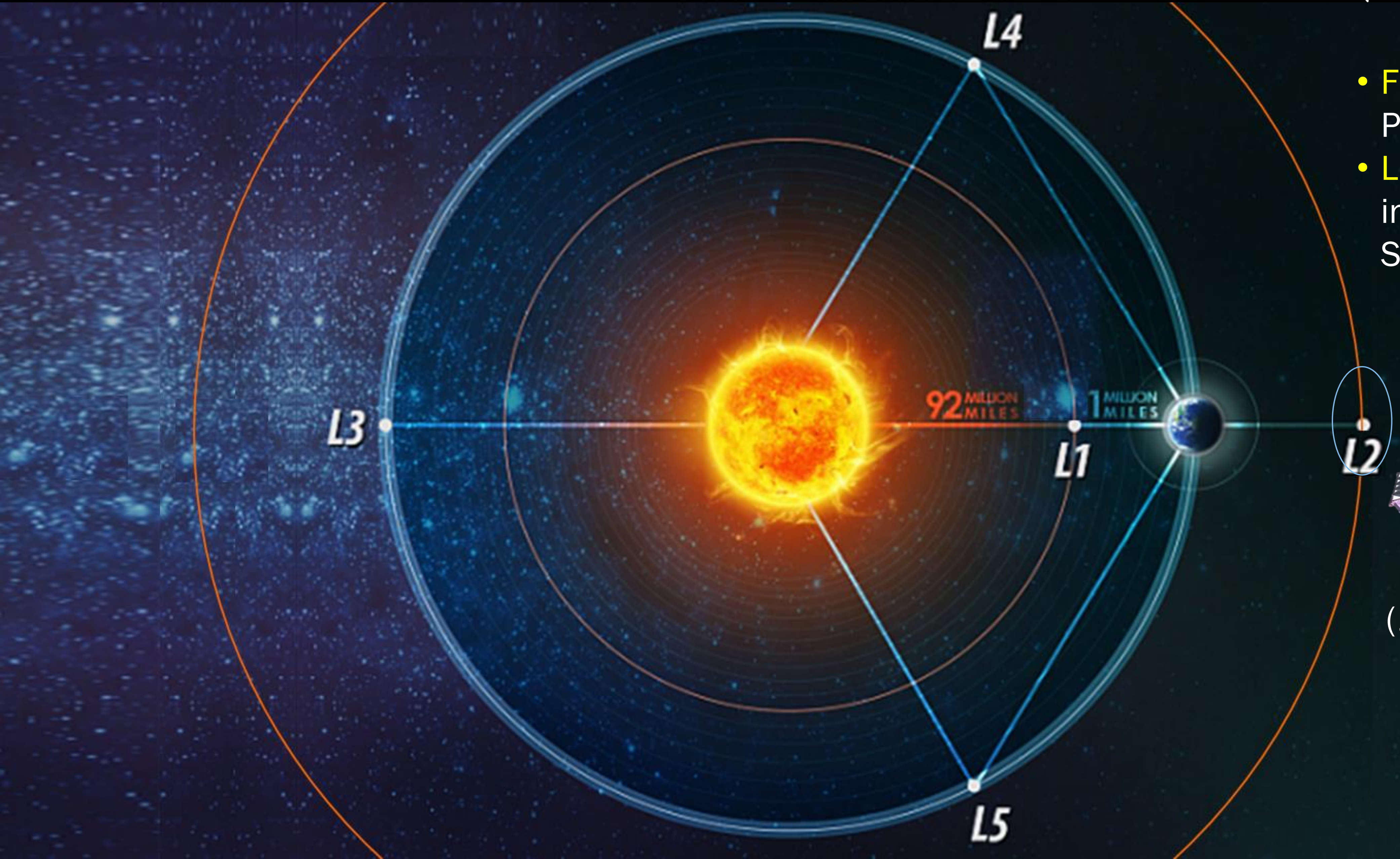
2015 · WFC3 · Infrared

JWST Vital Facts

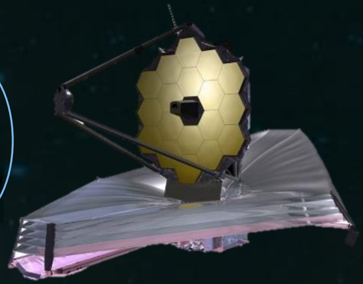
JWST:	Infrared Observatory
Launch Date:	October 2018
Launch Vehicle:	Ariane 5 ESA
Mission Duration:	5 - 10 years
Orbit from Earth:	1.5 million km @ L2
Prim. Mirror OD:	6.5 m (HST: 2.4 m)
Sensitivity:	100x Hubble
Wavelength:	0.6 - 28.5 microns (HST: 0.8 to 2.5 μm)
Temperature:	<50 K (HST: 77 K)
Gold Coating:	100 nm (HST: 65 nm Al)
Surface area:	25 m^2 (6x HST)
Cost:	$8.8 billion

James Webb Space Telescope will be launched in October 2018

JWST will orbit around Lagrangian Point 2 (L2)

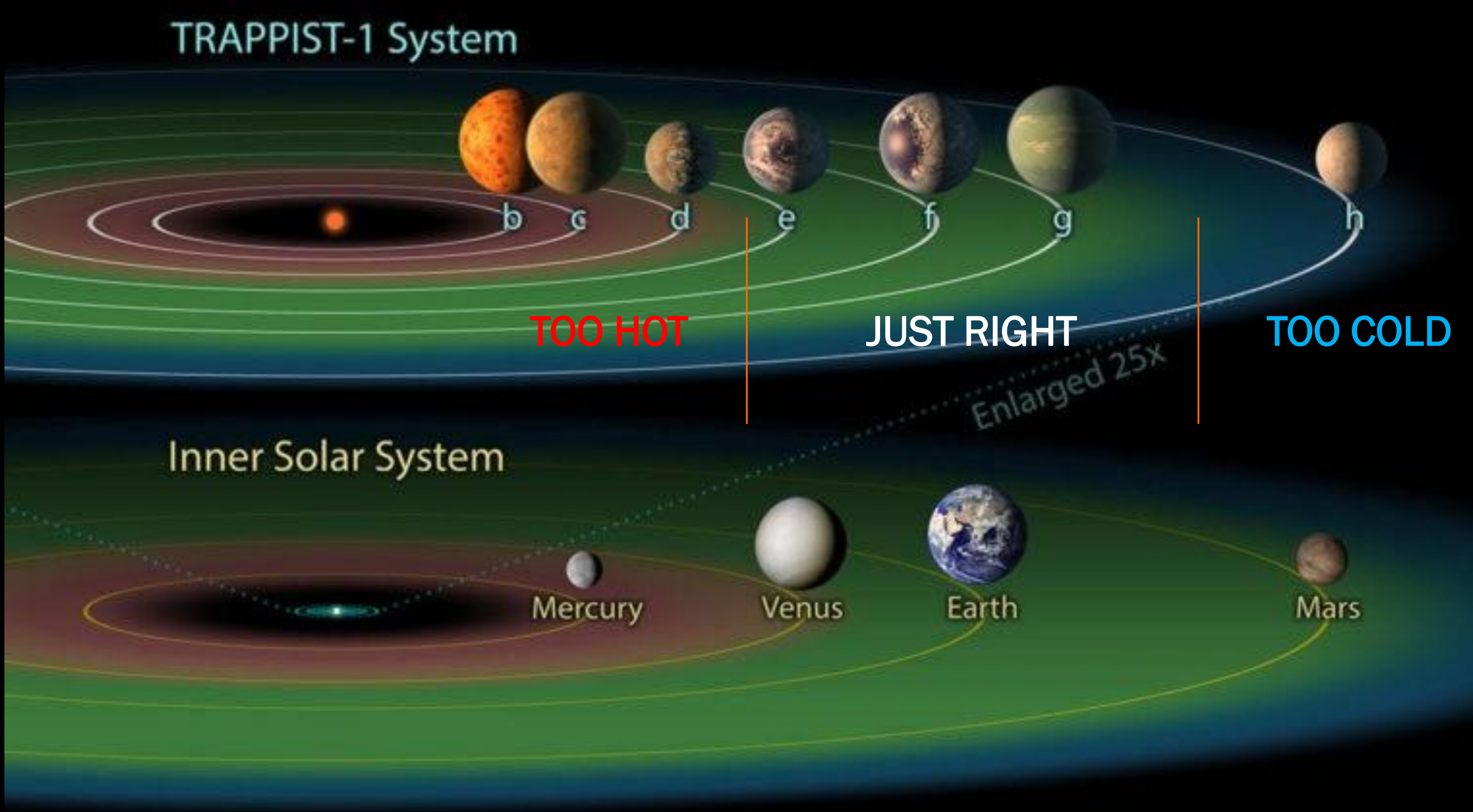


- Five Lagrangian Points (LPs)
- LP: Objects will stay in place relative to Sun & Earth.



930,000 miles
(1.5 million miles)
from Earth

Spitzer Space Telescope Discovered 7 Earth-size Planets



TRAPPIST-1 star
(an ultra-cool dwarf)

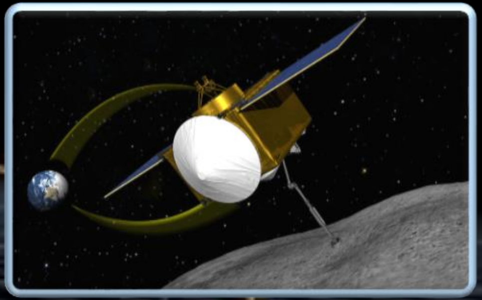
About 40 light-years from Earth

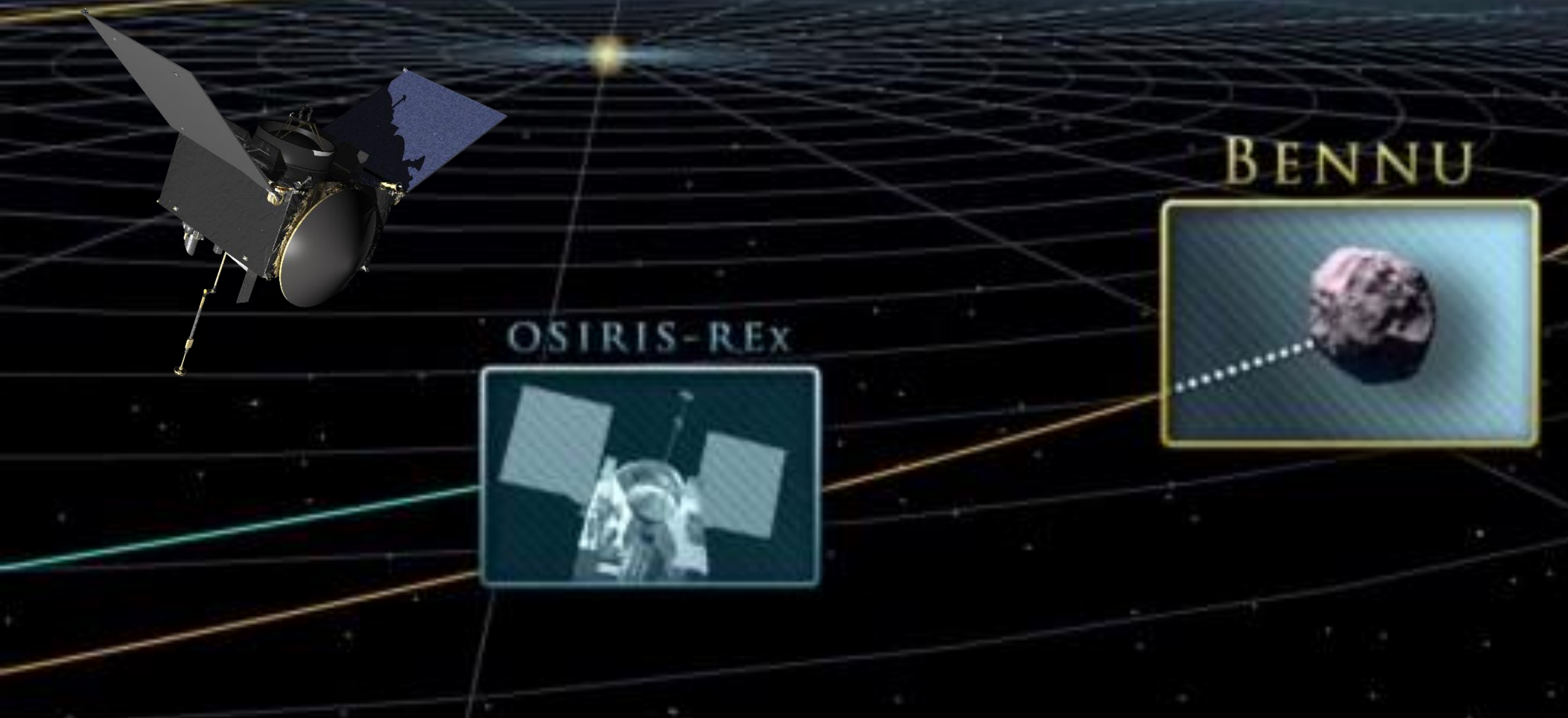
Spitzer Space Telescope has revealed the first known system of seven Earth-size planets around a single star

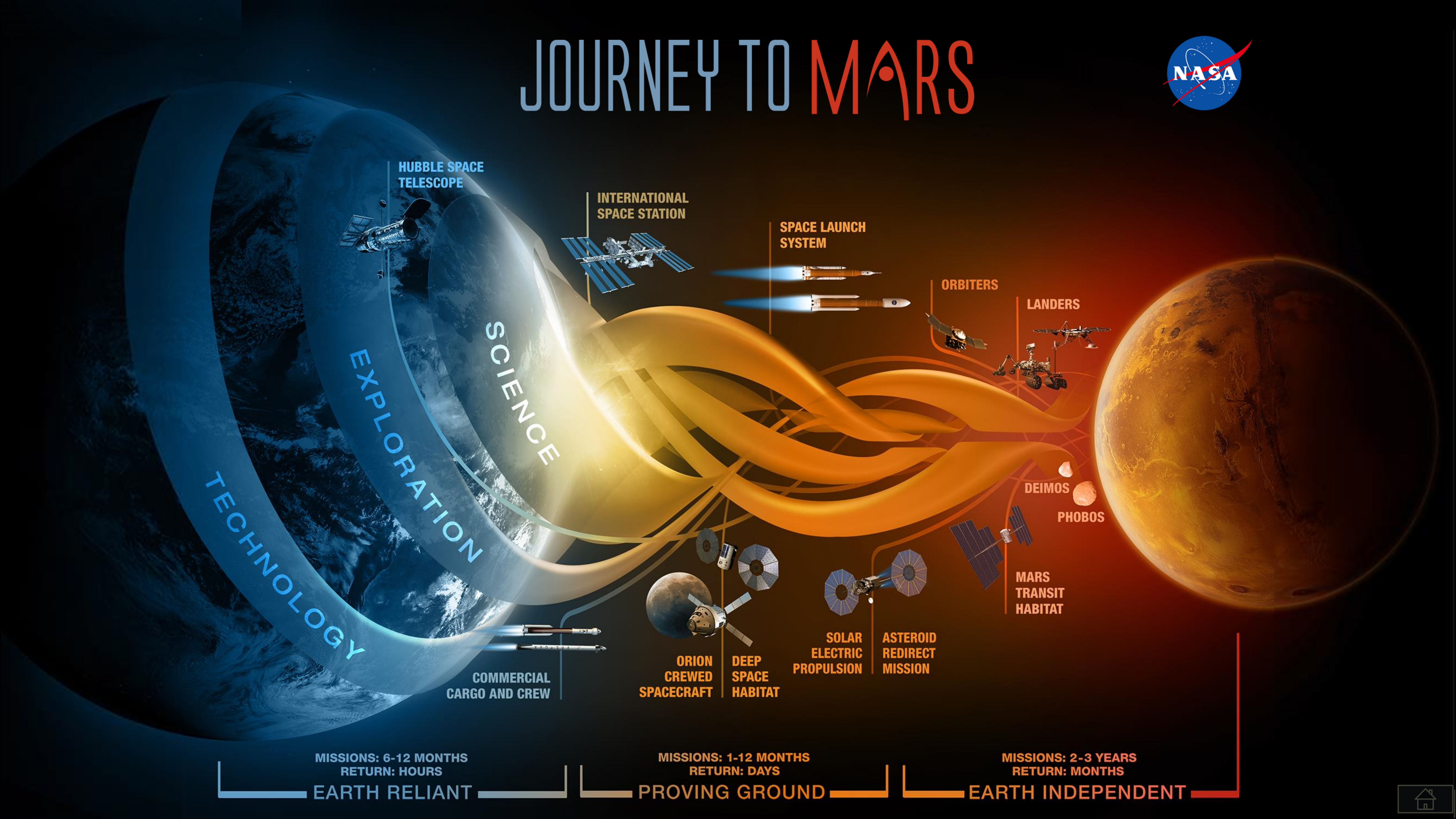
NASA's OSIRIS-Rex Asteroid Mining Mission

- Launch date: Sept. 8, 2016
- Reach the asteroid Bennu in 2018
- Return a sample to Earth in 2023

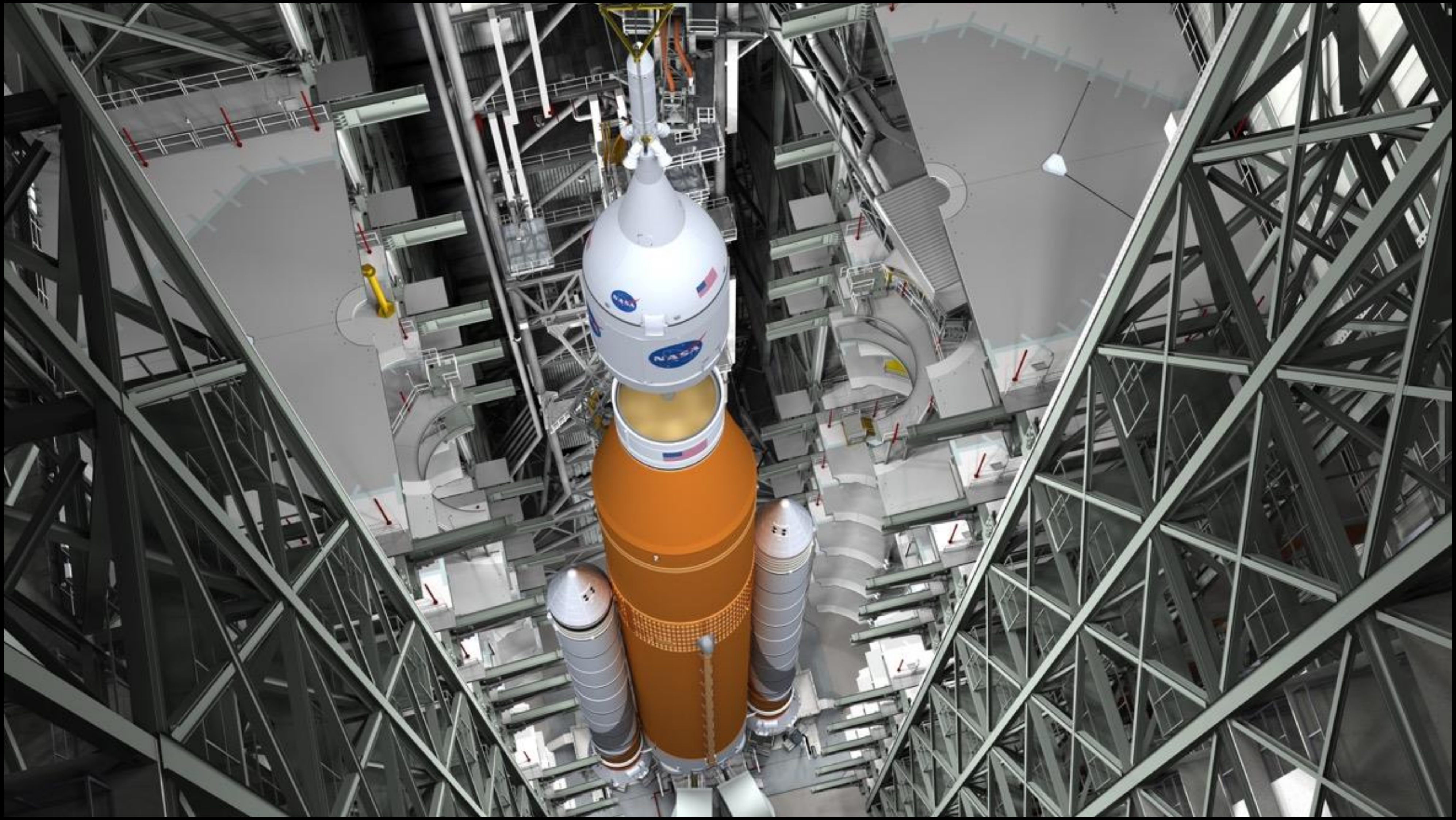
Sample Return



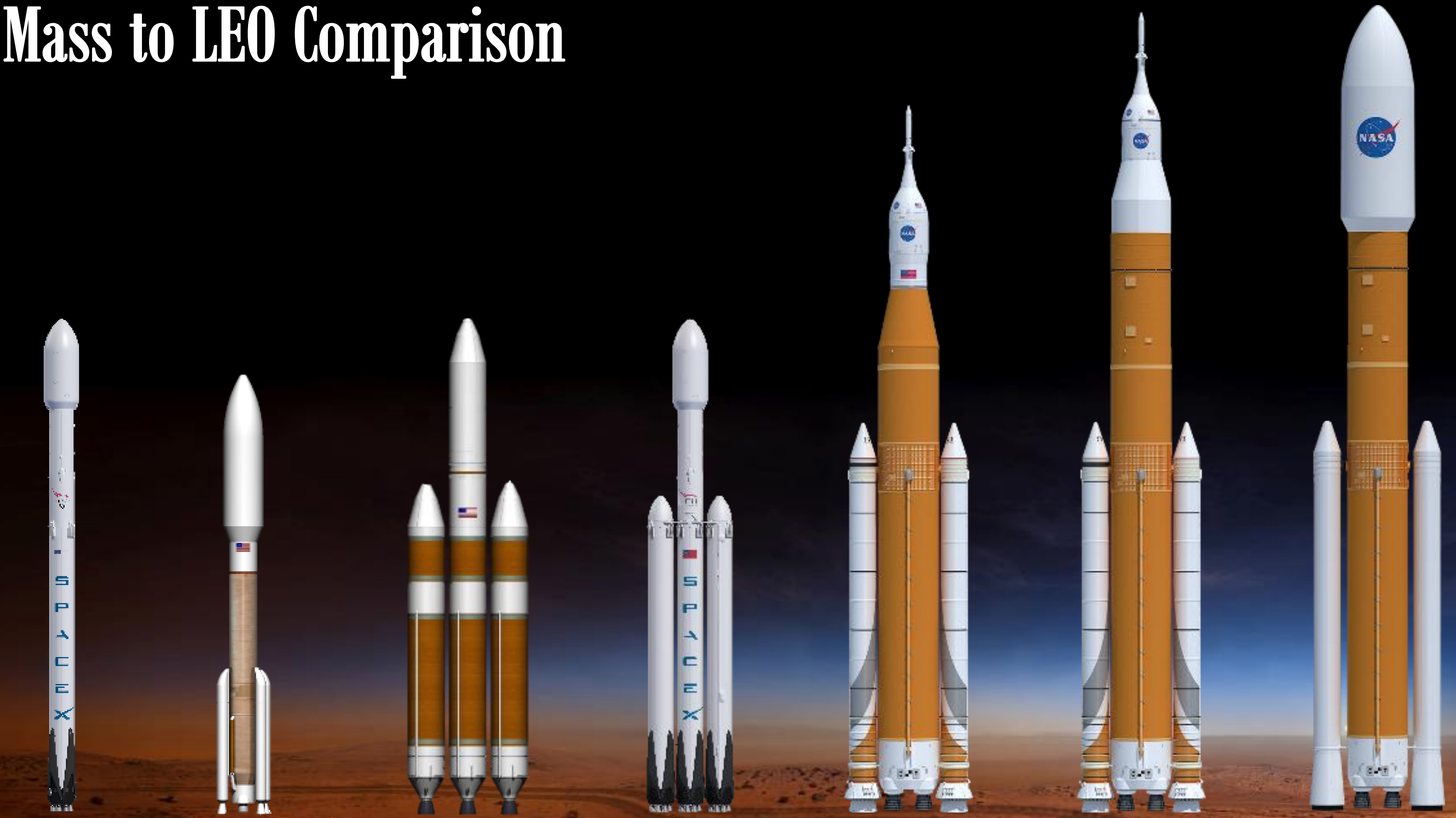



JOURNEY TO MARS
NASA
HUBBLE SPACE TELESCOPE
INTERNATIONAL SPACE STATION
SPACE LAUNCH SYSTEM
ORBITERS
LANDERS
SCIENCE
EXPLORATION
TECHNOLOGY
DEIMOS
PHOBOS
MARS TRANSIT HABITAT
COMMERCIAL CARGO AND CREW
ORION CREWED SPACECRAFT
DEEP SPACE HABITAT
SOLAR ELECTRIC PROPULSION
ASTEROID REDIRECT MISSION
MISSIONS: 6-12 MONTHS
RETURN: HOURS
EARTH RELIANT
MISSIONS: 1-12 MONTHS
RETURN: DAYS
PROVING GROUND
MISSIONS: 2-3 YEARS
RETURN: MONTHS
EARTH INDEPENDENT

SPACE LAUNCH SYSTEM (SLS) AT KSC



Mass to LEO Comparison



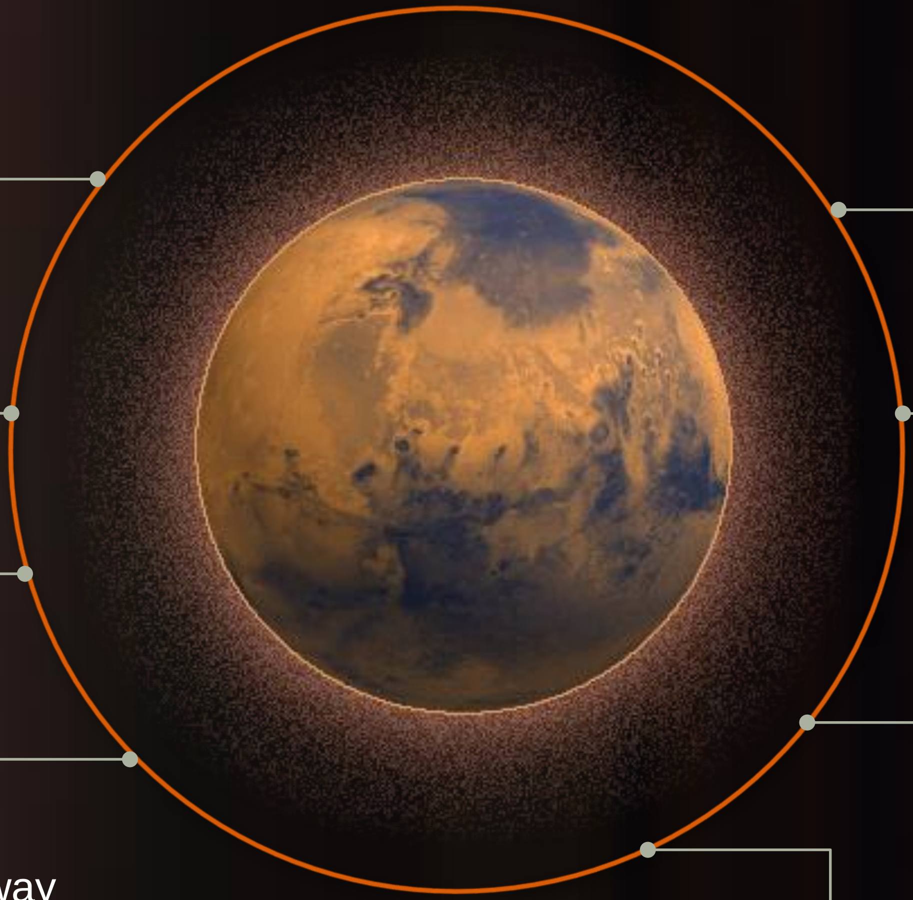
Falcon 9	Atlas V (551)	Delta IV H	Falcon 9H	SLS Block 1	SLS Block 1B	SLS Block 2
13 mT	18 mT	28 mT	53 mT	70 mT	105 mT	130 mT

Human Exploration of Mars is Hard

20-30 tons
Ability to land large payloads needed

130 tons
Heavy-lift mass means **multiple** launches per mission

13.5 km/s Earth re-entry speed



Reliable in-space transportation:
Total continuous transportation power

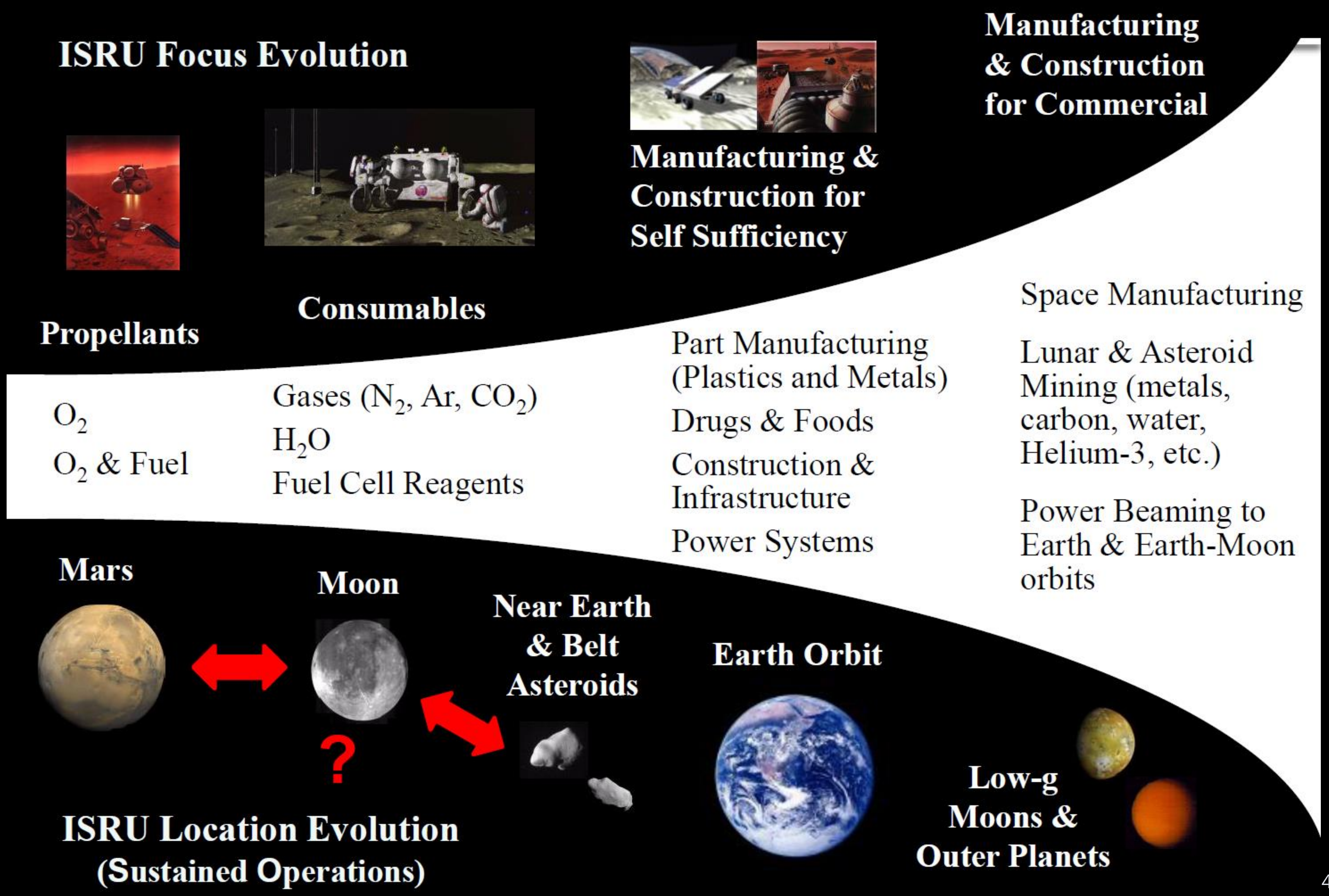
Thin atmosphere and dusty conditions for surface operations.

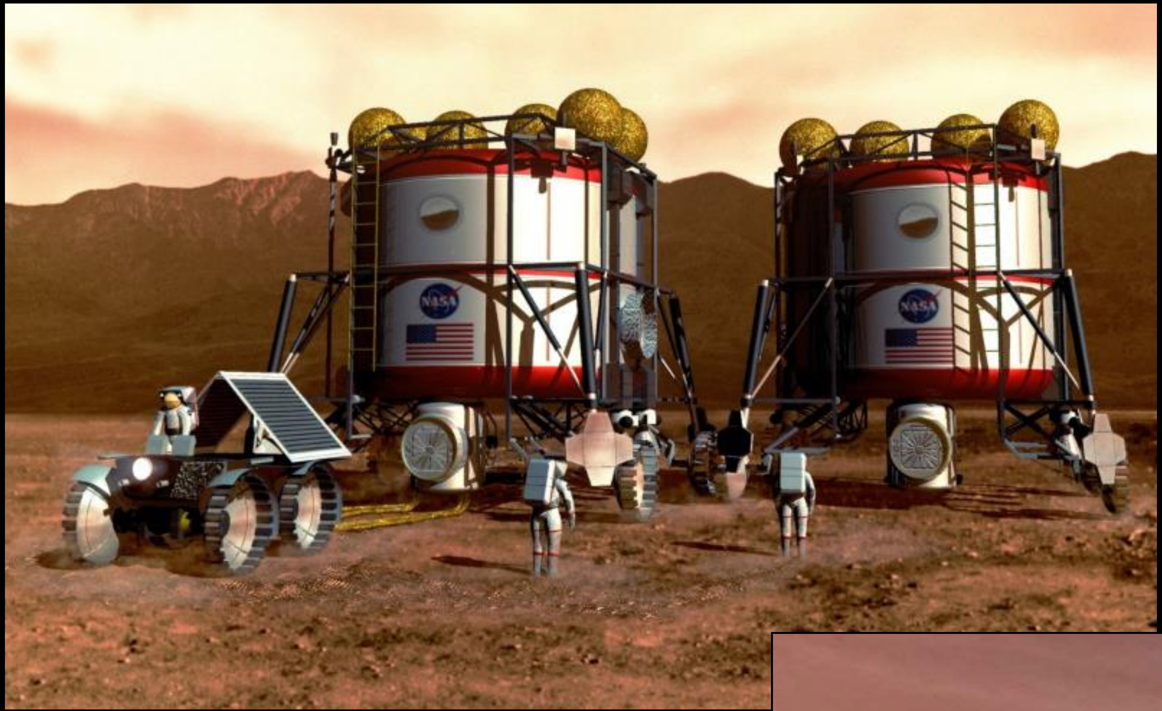
44 minute max two-way communication delay
2-week blackout every 26 months when Earth and Mars are on opposite sides of the sun

800-1100 days away from Earth in micro gravity and high levels of radiation

20 tons of oxygen needed for ascent to orbit: In-Situ Resource Utilization (ISRU)

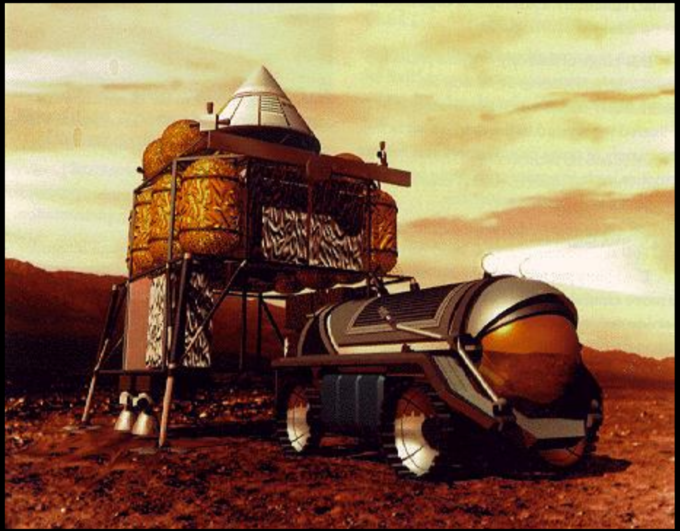
In-Situ Resource Utilization (ISRU)





NASA image

Pat Rawlings, “Distant Shores”, commissioned by NASA

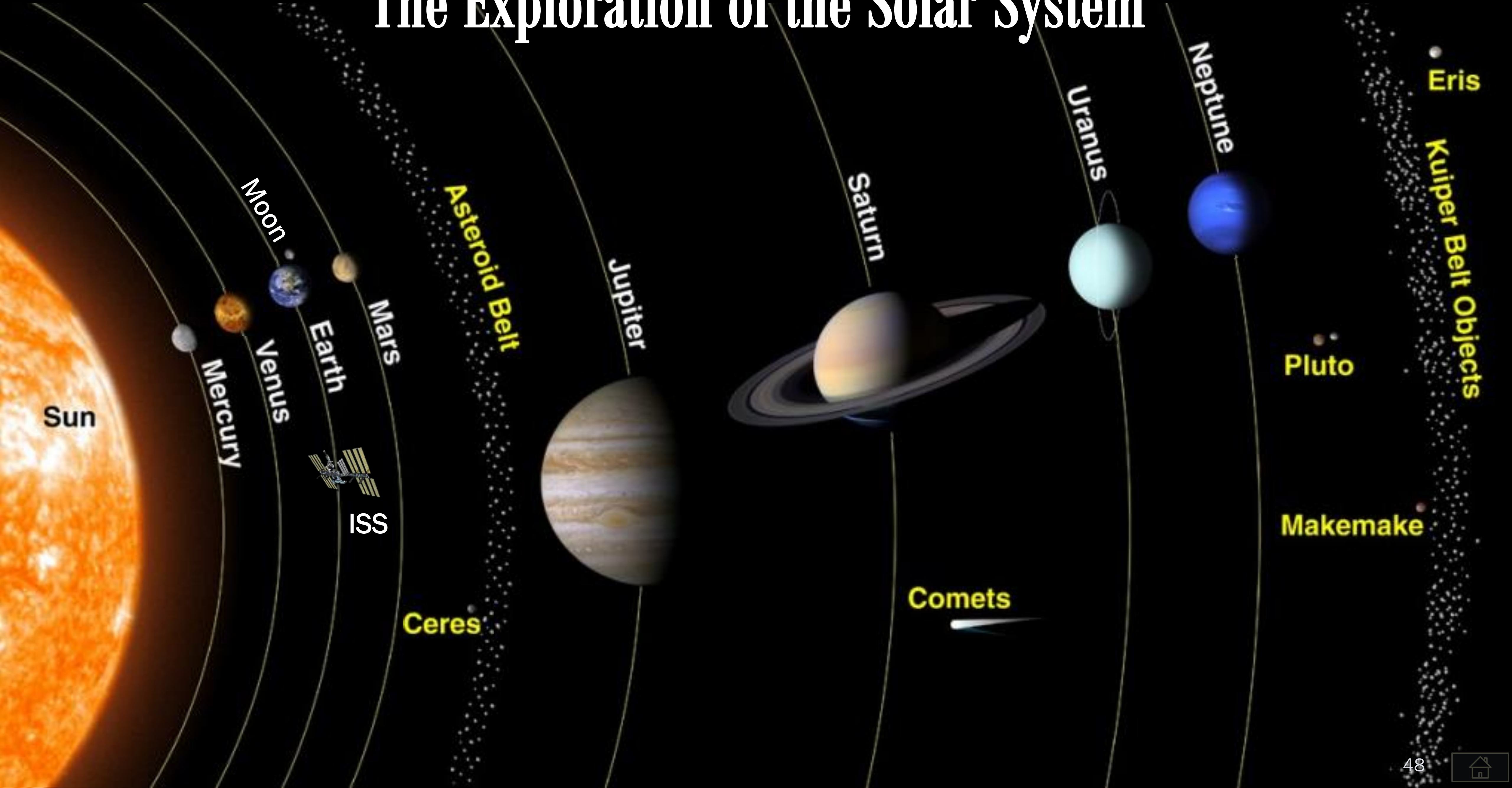


NASA image

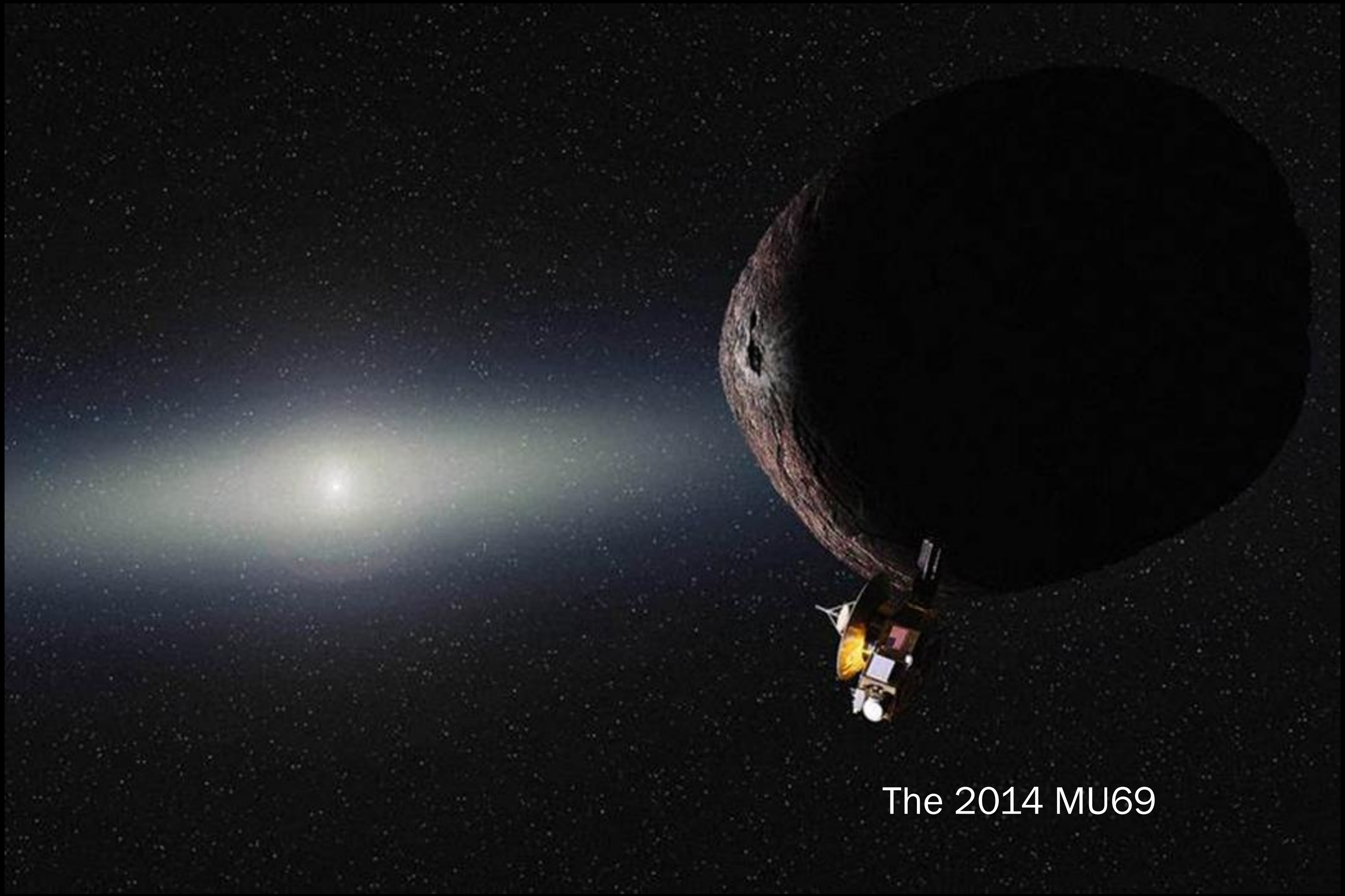
Pat Rawlings, “Commuter”, commissioned by Science Applications International Corporation (SAIC)

In-Situ Resource Utilization (ISRU)

The Exploration of the Solar System

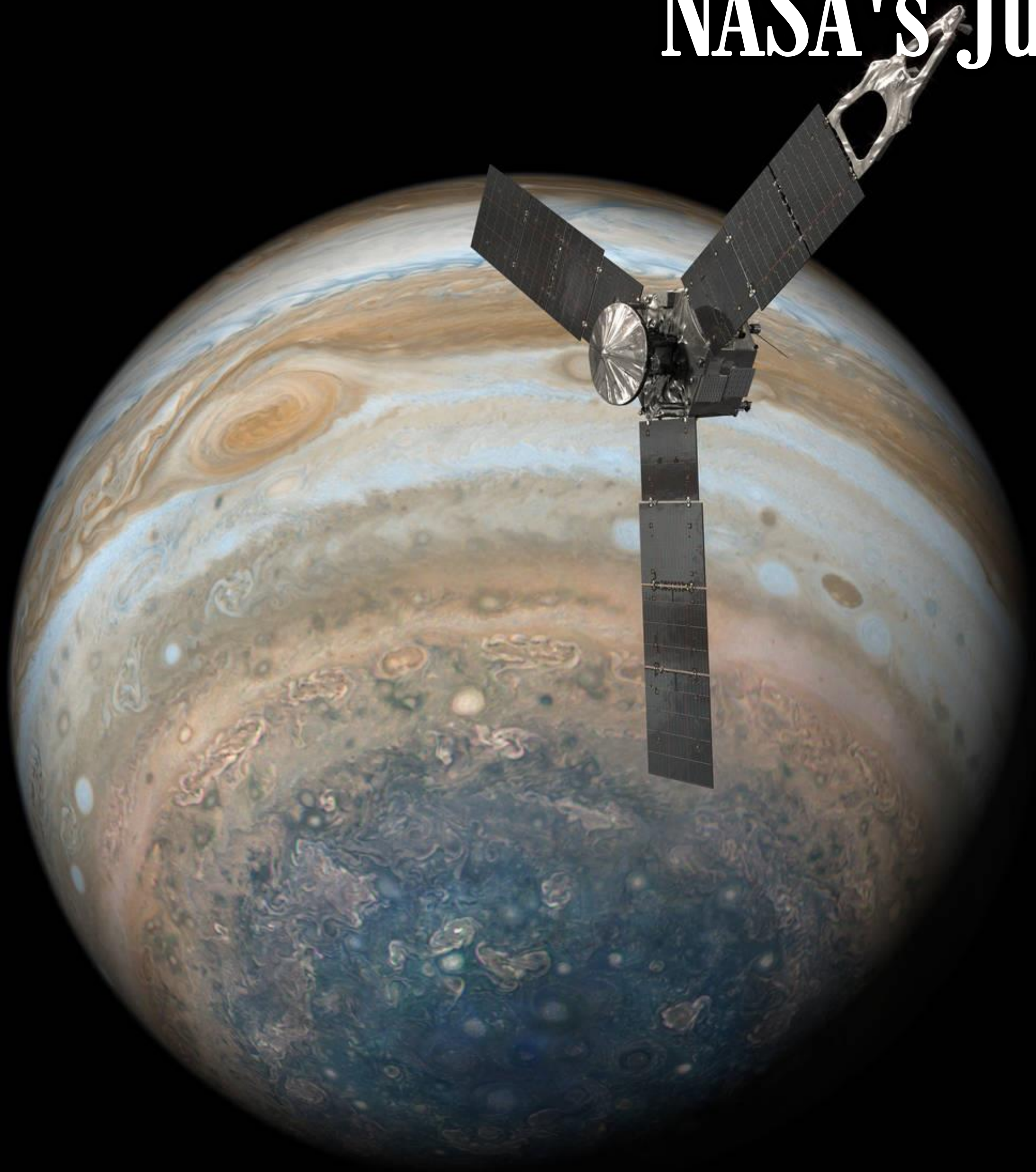


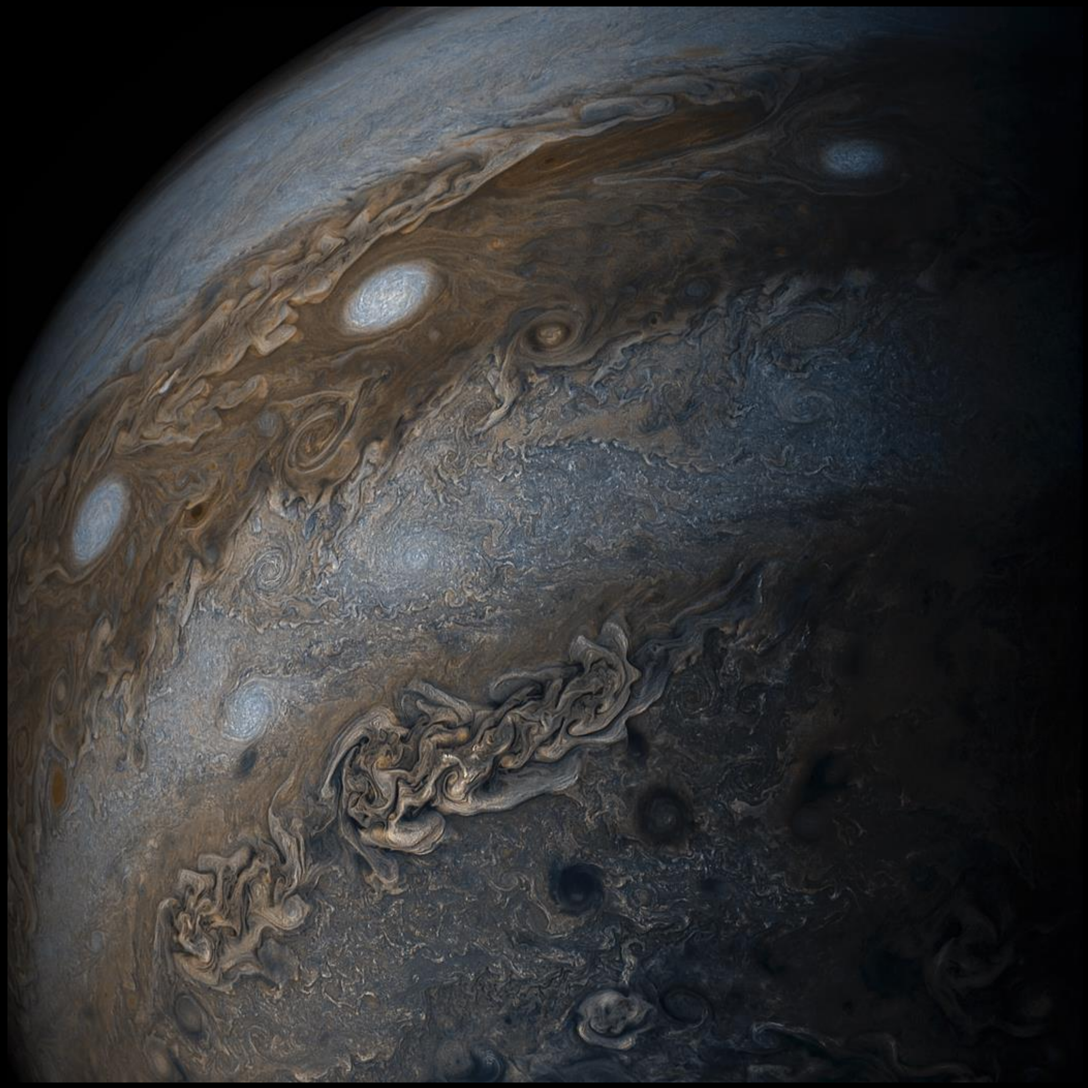
New Horizons Spacecraft Flyby “2014 MU69” in 2019



On New Year’s Day 2019, New Horizons will zoom past a Kuiper Belt object known as 2014 MU69

NASA's Juno Spacecraft



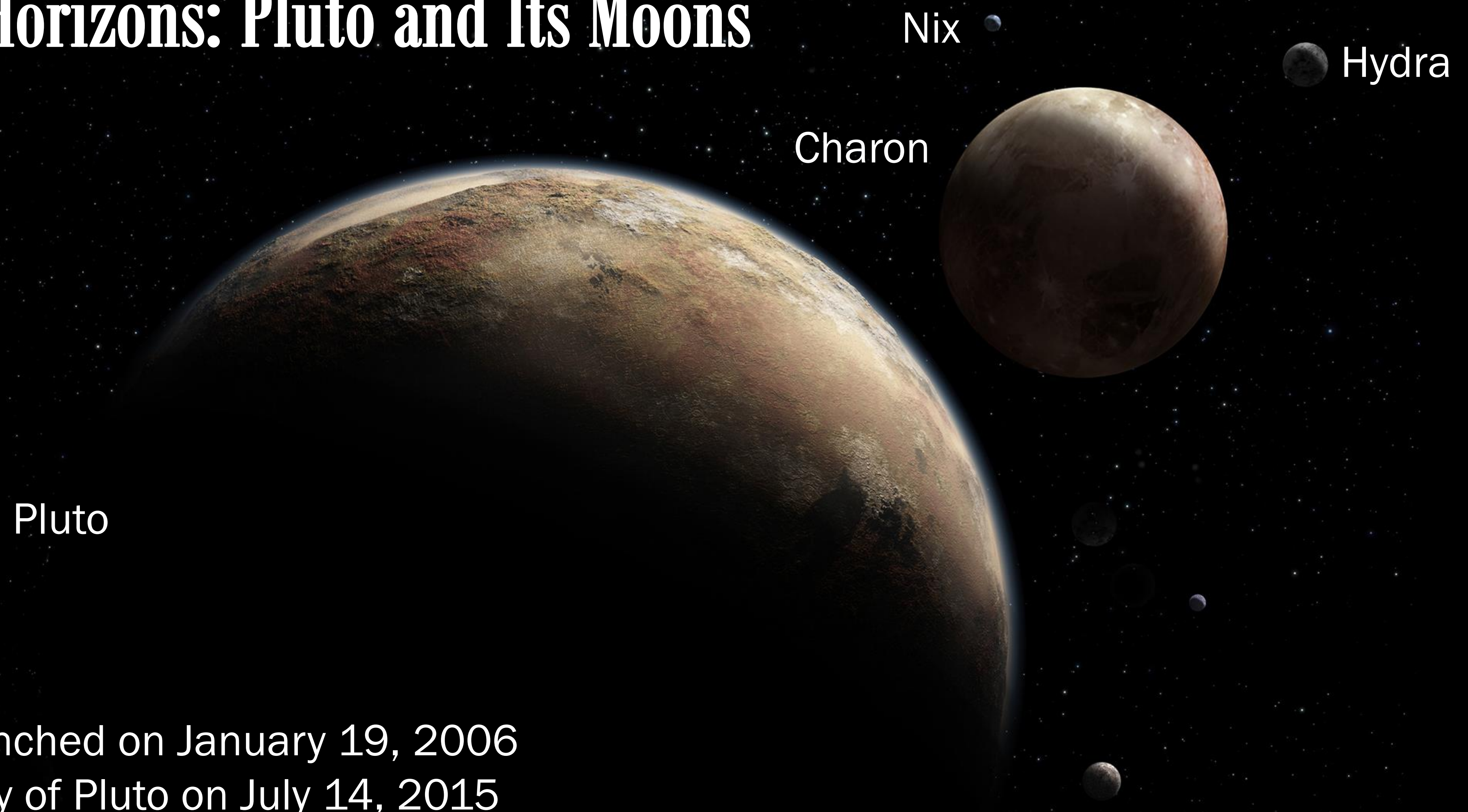


Launched on Aug. 5, 2011; Entered Jupiter orbit on Jul. 4, 2016

Cassini: The Grand Finale

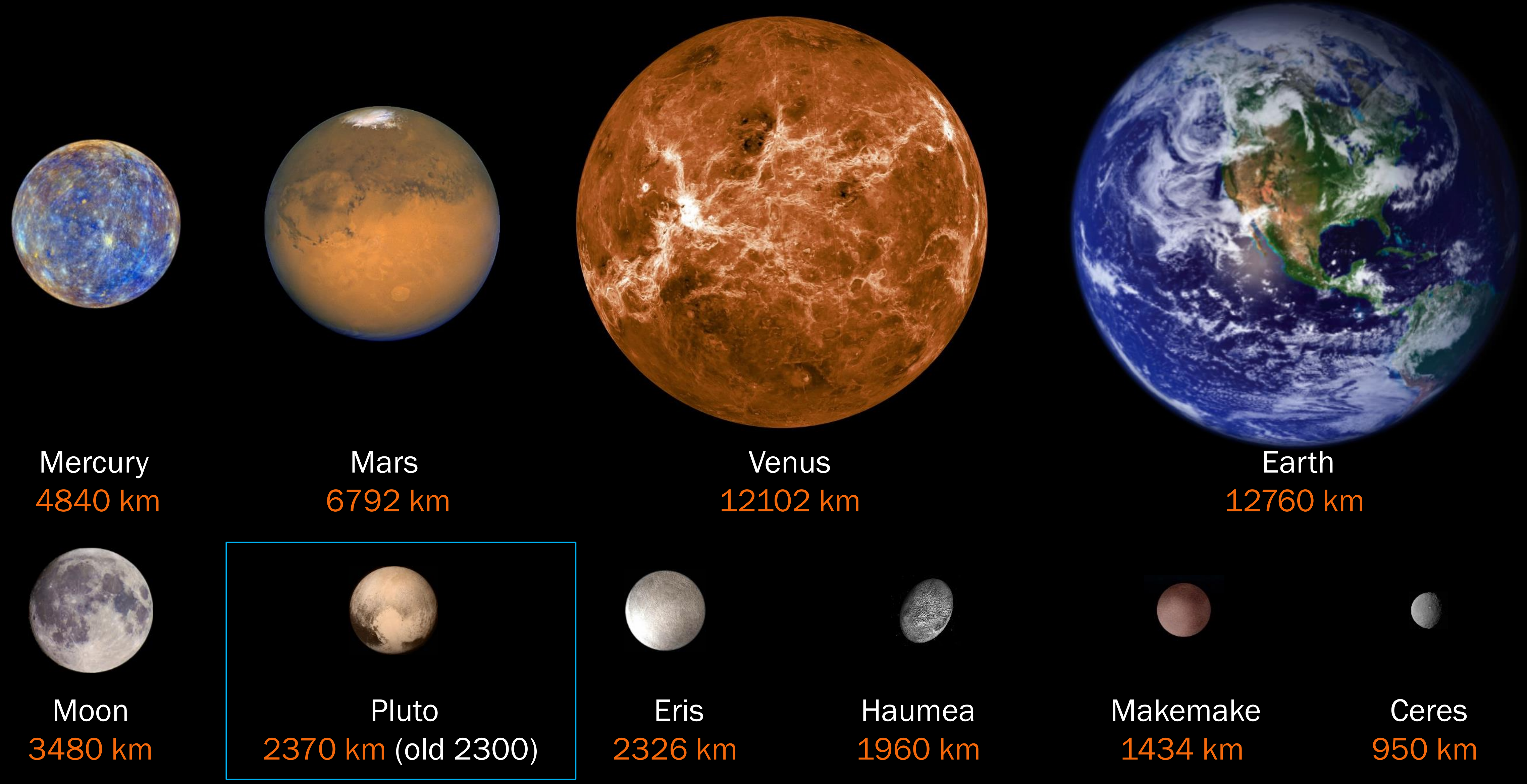
Launch Date: October 15, 1997 - End of Mission: 15 Sep 2017

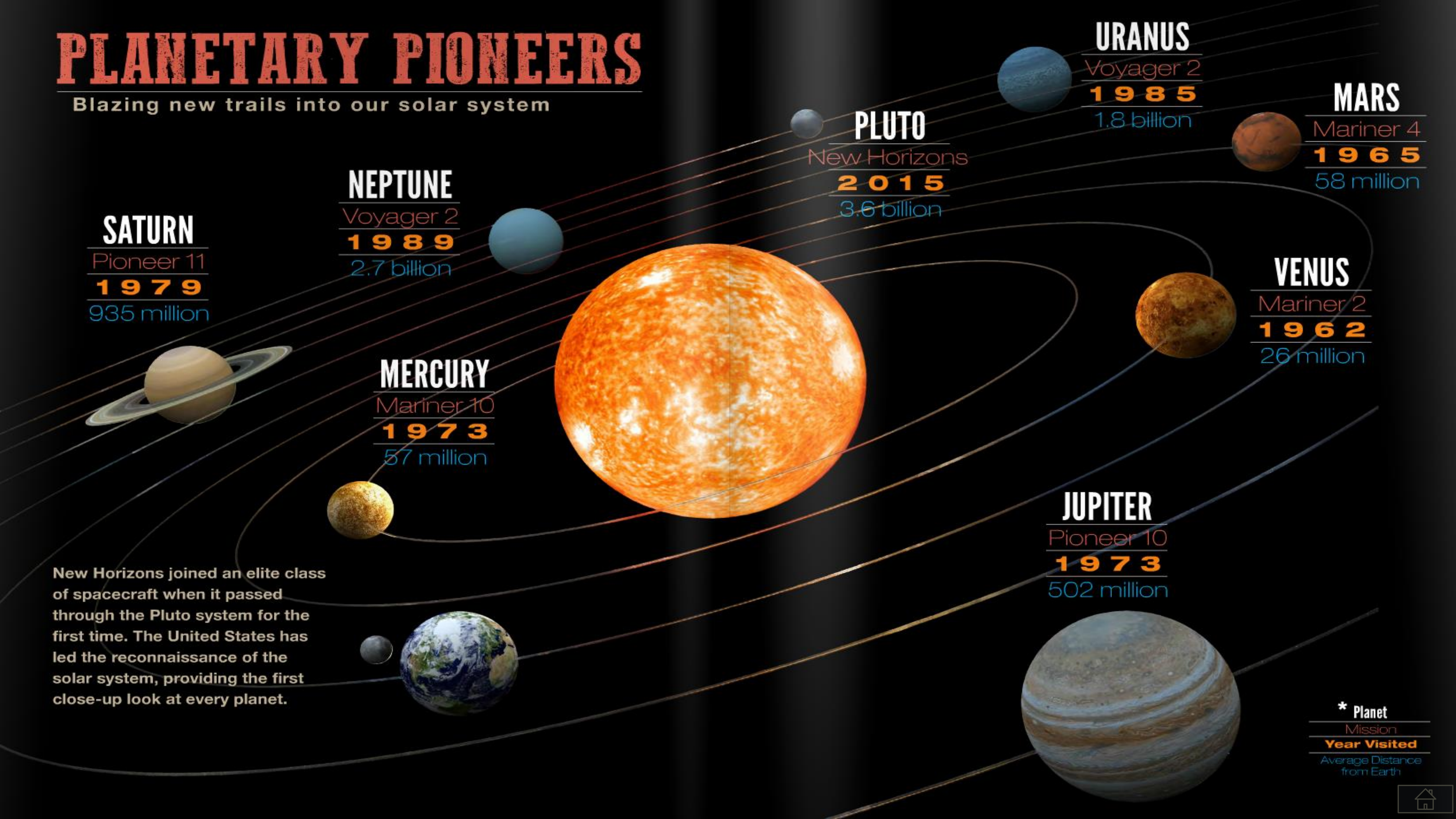
New Horizons: Pluto and Its Moons



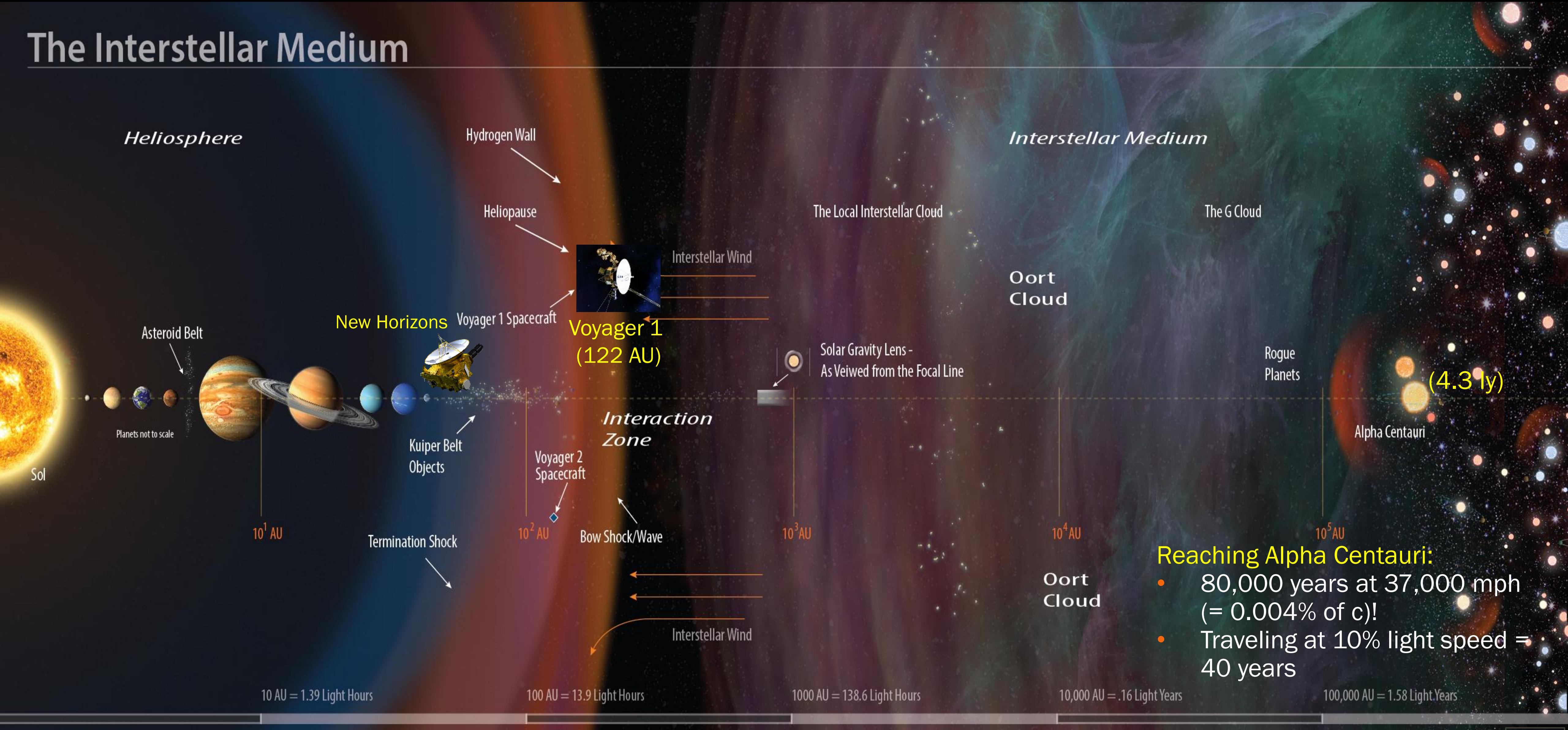
- Launched on January 19, 2006
- Flyby of Pluto on July 14, 2015
- Ten years and three billion miles

Sizes of Planets & Dwarf Planets




PLANETARY PIONEERS
Blazing new trails into our solar system
URANUS
Voyager 2
1985
1.8 billion
MARS
Mariner 4
1965
58 million
PLUTO
New Horizons
2015
3.6 billion
NEPTUNE
Voyager 2
1989
2.7 billion
SATURN
Pioneer 11
1979
935 million
VENUS
Mariner 2
1962
26 million
MERCURY
Mariner 10
1973
57 million
JUPITER
Pioneer 10
1973
502 million
New Horizons joined an elite class of spacecraft when it passed through the Pluto system for the first time. The United States has led the reconnaissance of the solar system, providing the first close-up look at every planet.
* Planet
Mission
Year Visited
Average Distance from Earth

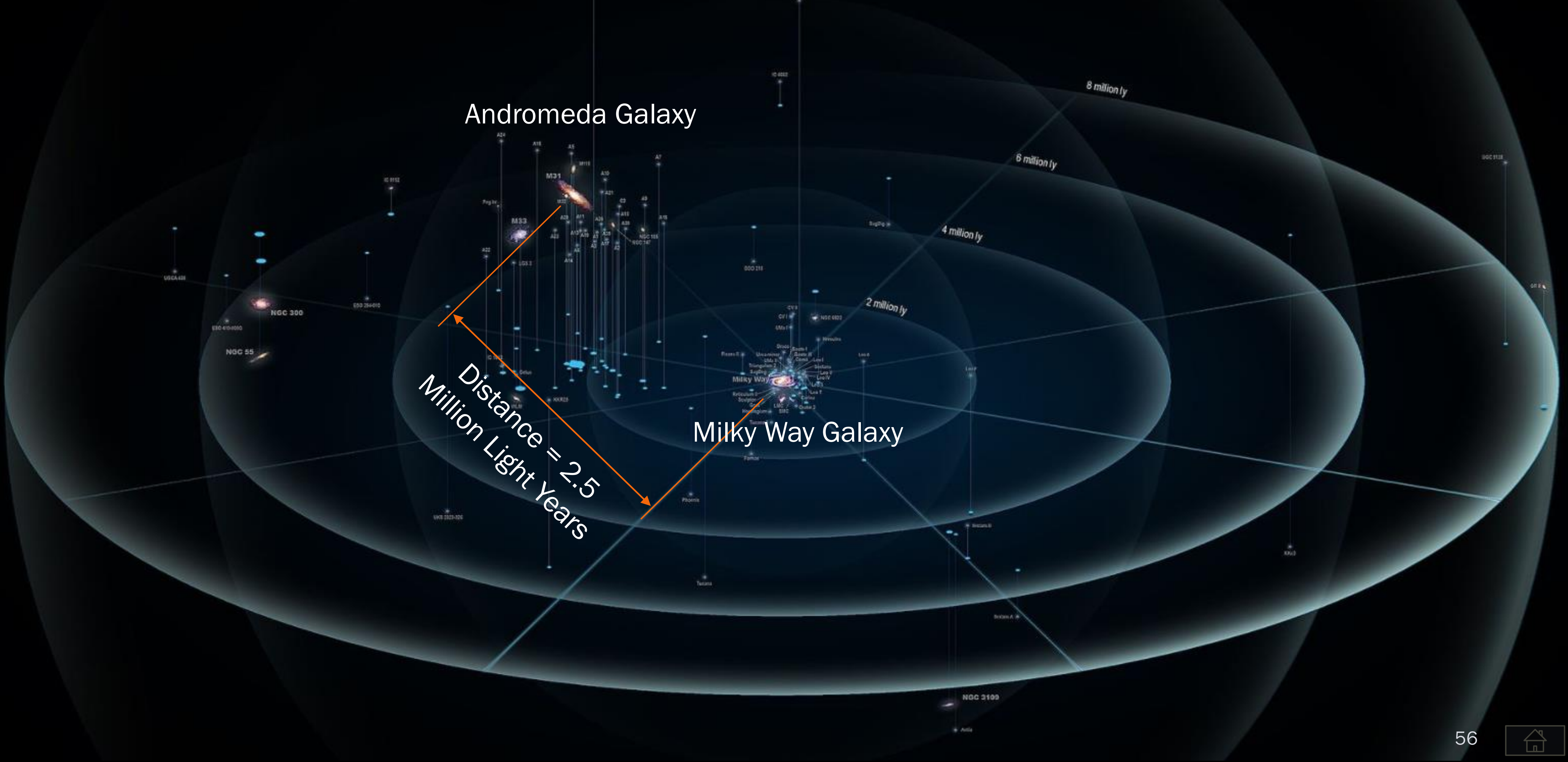
Interstellar Travel to Alpha Centauri (Nearest Star)



Reaching Alpha Centauri:

- 80,000 years at 37,000 mph (= 0.004% of c)!
- Traveling at 10% light speed = 40 years

Intergalactic Travel to Andromeda



Building America's Premier Spaceport

LANDING AND RECOVERY

Building America's Premier Spaceport


THANK
YOU