The Future of Robotic Space Exploration

Dr. Leon Alkalai, JPL Fellow

Briefing to UCLA CS1

November 15, 2019

Jet Propulsion Laboratory
California Institute of Technology

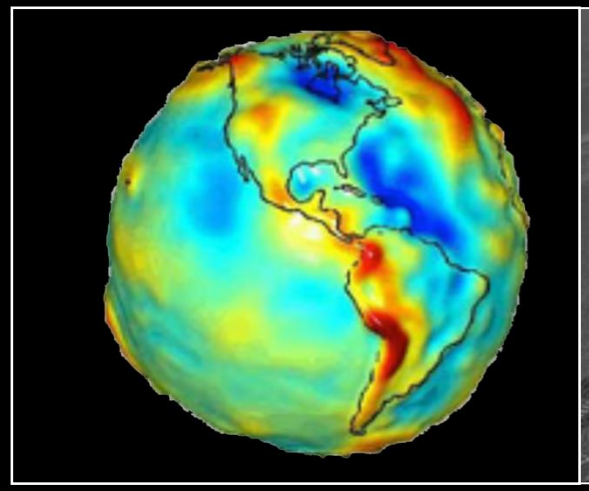
From Caltech students testing rockets to exploring the planets and beyond …

Caltech students (1936)

Missiles (1940s)

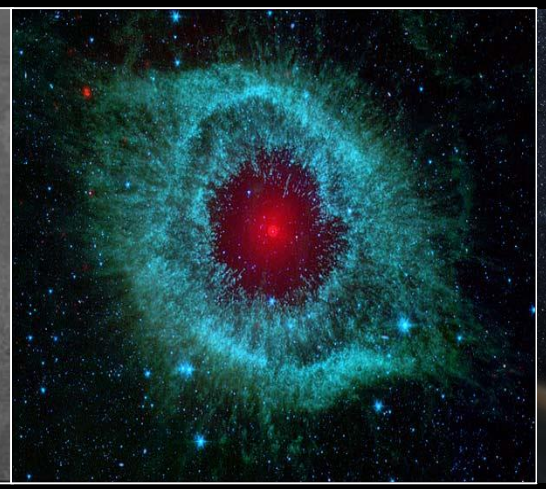
Explorer 1 (1958)

Voyager 1 & 2 (1977 – present)

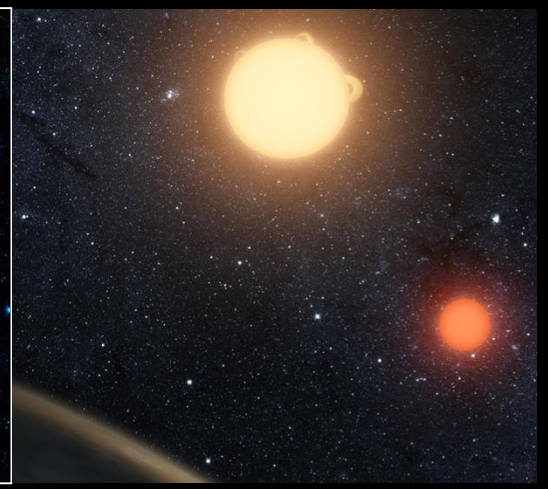


Earth Science
(1978 – now)

Mars Exploration Rovers
(2004 – present)



Spitzer Space Telescope
(2004 – present)



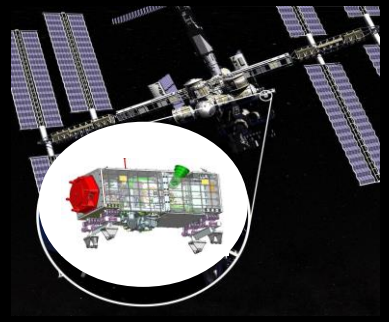
Exoplanet Exploration
(2009 – present)

NASA's Jet Propulsion Laboratory
California Institute of Technology

Caltech

Upcoming Missions

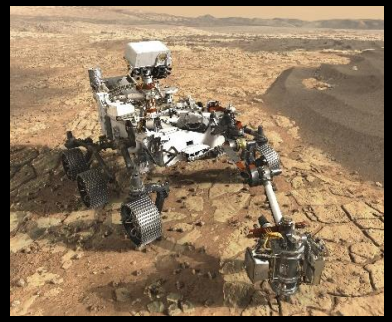
2019



OCO-3

COSMIC-2A

2020

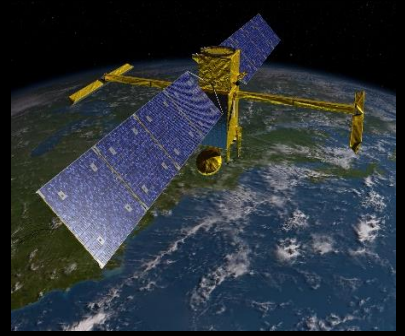


Mars 2020

Mars Helicopter

2021

NISAR

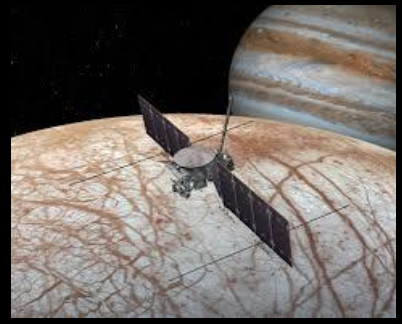


SWOT

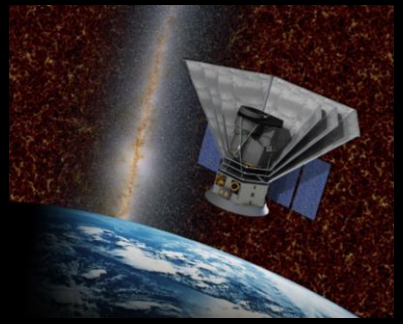
2022

Psyche / DSOC

2023

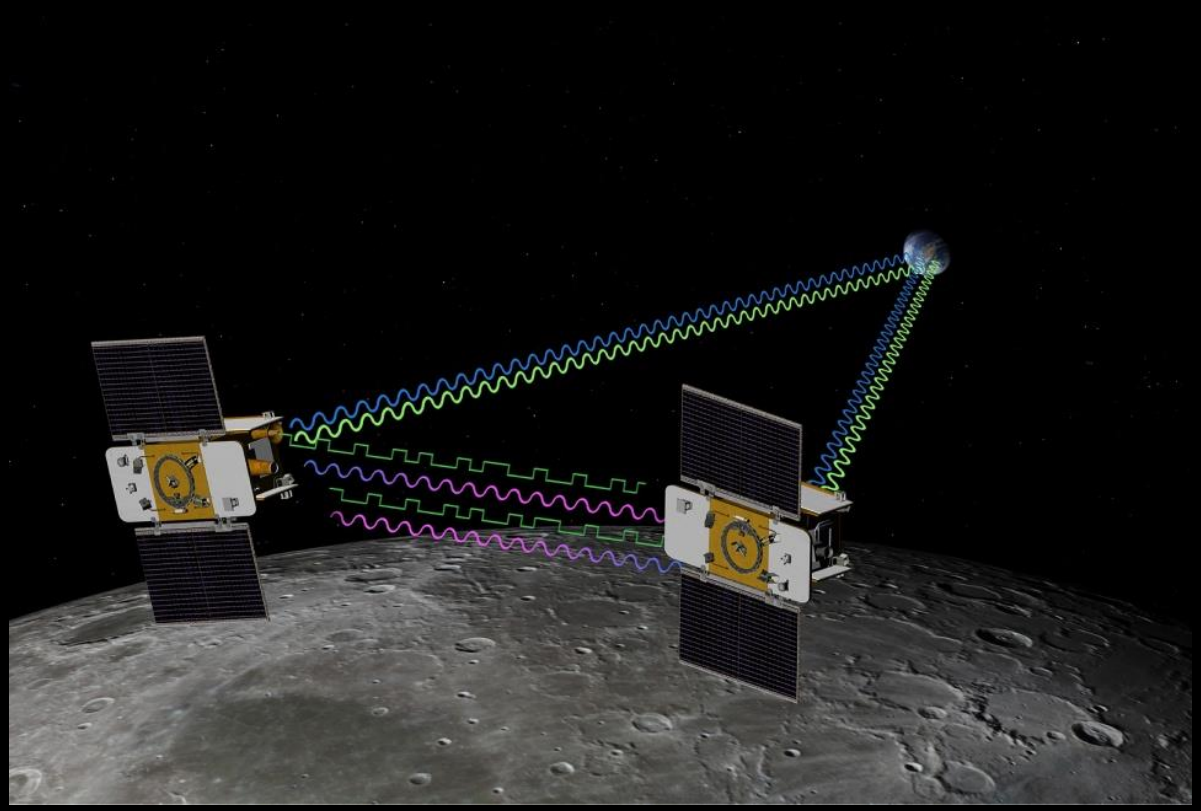


Europa Clipper



SPHEREx

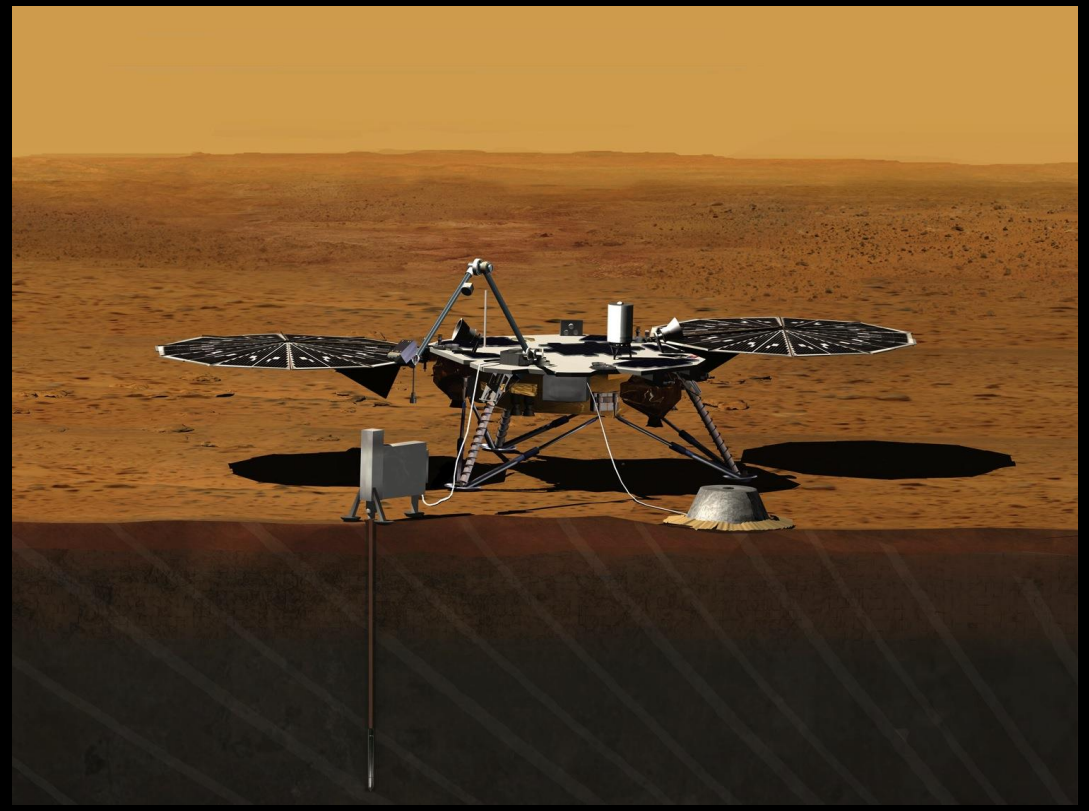
Dr. Leon Alkalai, JPL Fellow



GRAIL launched 9/10/2011:
NASA Discovery Program -11
Competition Winner

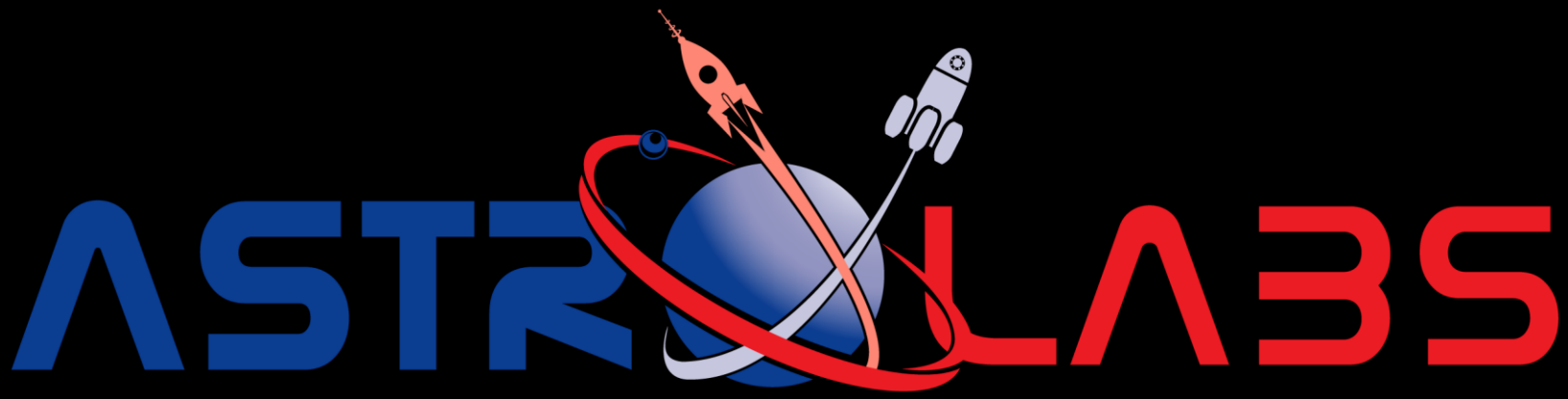
"*NASA Distinguished Individual Achievement Medal for the Successful Formulation of GRAIL, and for winning the NASA Discovery-11 Competition*" (C. Elachi, L. Alkalai, J. Grunsfeld)

Dr. Leon Alkalai, JPL Fellow



InSight launched 5-5-2018
Landed on Mars 11-26-2018
NASA Discovery Program -12, Competition Winner

"NASA Exceptional Public Achievement Medal" for exceptional achievement in formulation of the INSIGHT project, resulting in a successful commissioning on Mars." October 29, 2019

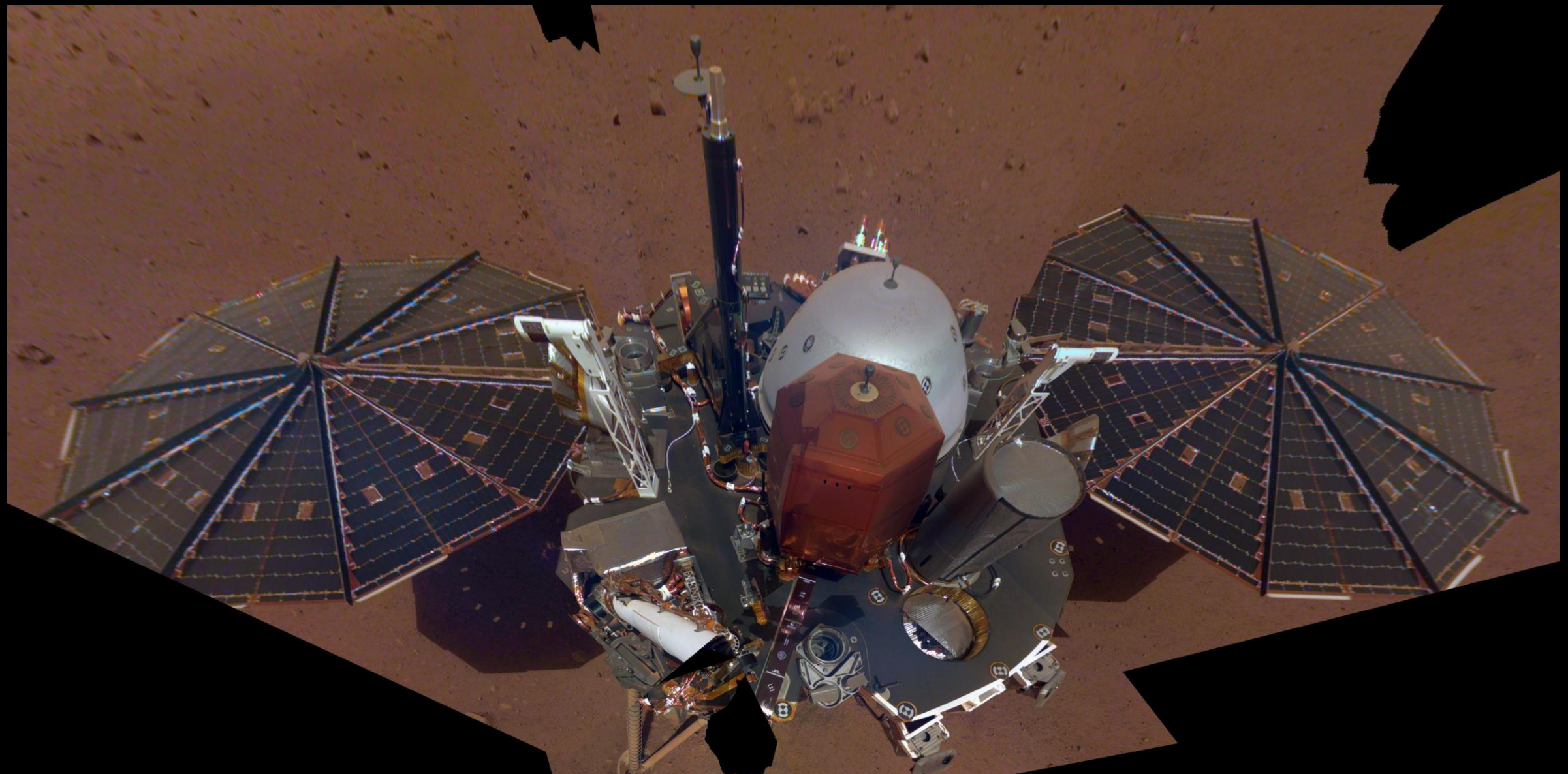


Dr. Leon Alkalai, Founder

Where Space Innovation and Start-up incubation meets Private Investments

InSight

First Selfie



https://jpl.nasa.gov/sip

JPL QUESTS

Long-term endeavor in support of the JPL Vision to "explore space in pursuit of scientific discoveries that benefit humanity"

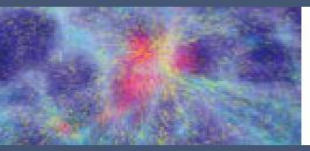
Understand how Earth works as a system and how it is changing

Help pave the way for human exploration of space

Understand how our Solar System formed and how it is evolving

Understand how life emerged on Earth and possibly elsewhere in our Solar System

Understand the diversity of planetary systems in our Galaxy



Understand how the Universe began and how it is evolving

Use our unique expertise to benefit the nation and planet Earth

JPL THRUSTS

Cross-cutting initiatives designed to support our culture of innovation and the pursuit of our Quests

Creating the Laboratory of the future

Innovating what we do and how we do it

Inspiring the world through our stories

FUTURE CAPABILITIES

Development and infusion of advanced technical capabilities into our future missions in pursuit of our Quests and in support of creating the Laboratory of the future

JPL engineer tests one of the two Mars Cube One (***MarCO***) small satellite spacecrafts launched together with the ***InSight*** mission to Mars in May 2018. The twin spacecrafts are the first ever deep-space small satellites, which will fly by Mars in November 2018 and provide additional telecommunications coverage for the ***InSight*** landing on Mars, scheduled for November 26, 2018.

QUESTS

EARTH SCIENCE & APPLICATIONS

MARS EXPLORATION

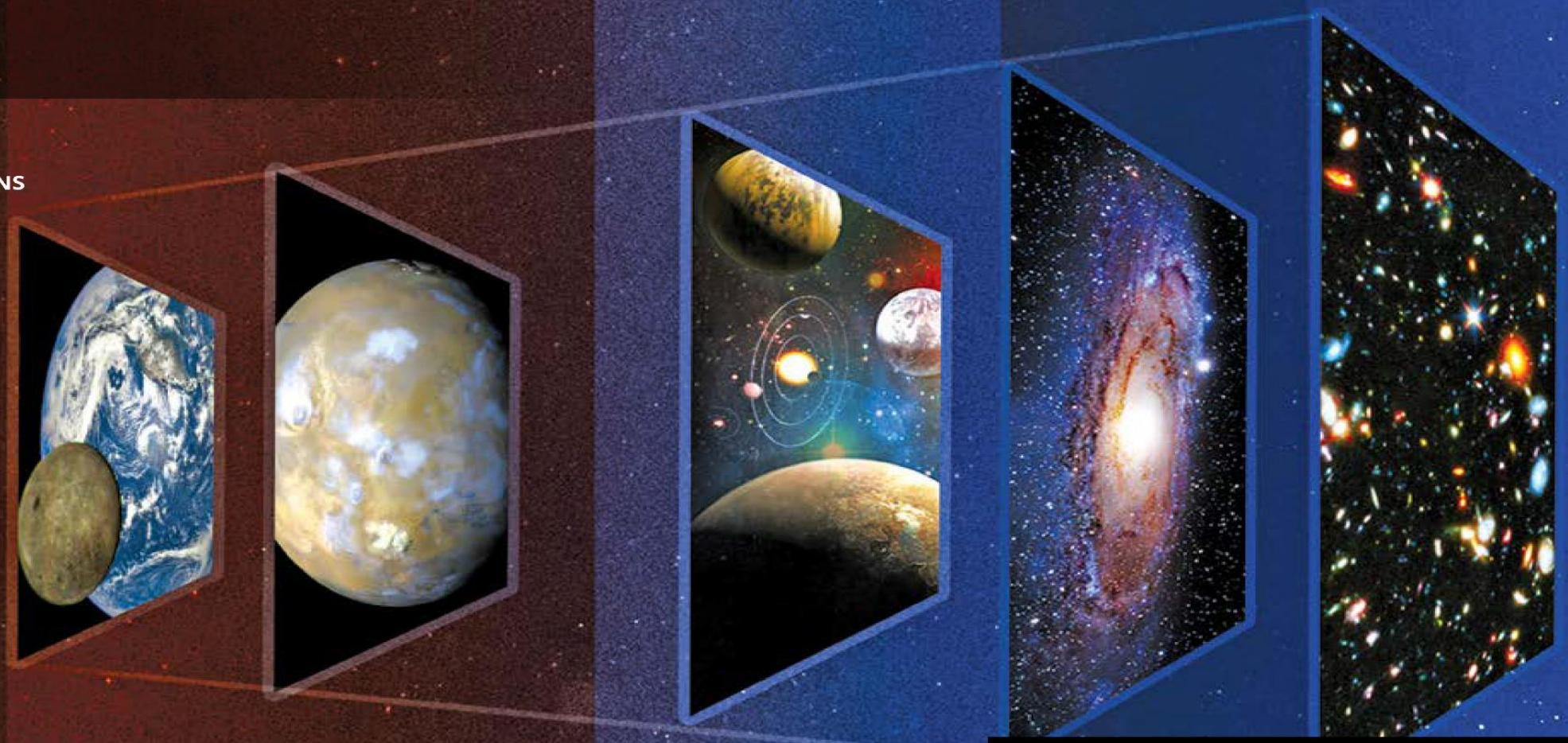
SOLAR SYSTEM EXPLORATION

ASTRONOMY & PHYSICS

INTERPLANETARY NETWORK

ADDRESSING NATIONAL CHALLENGES & CATALYZING ECONOMIC GROWTH

BENEFITS TO NATIONAL SECURITY



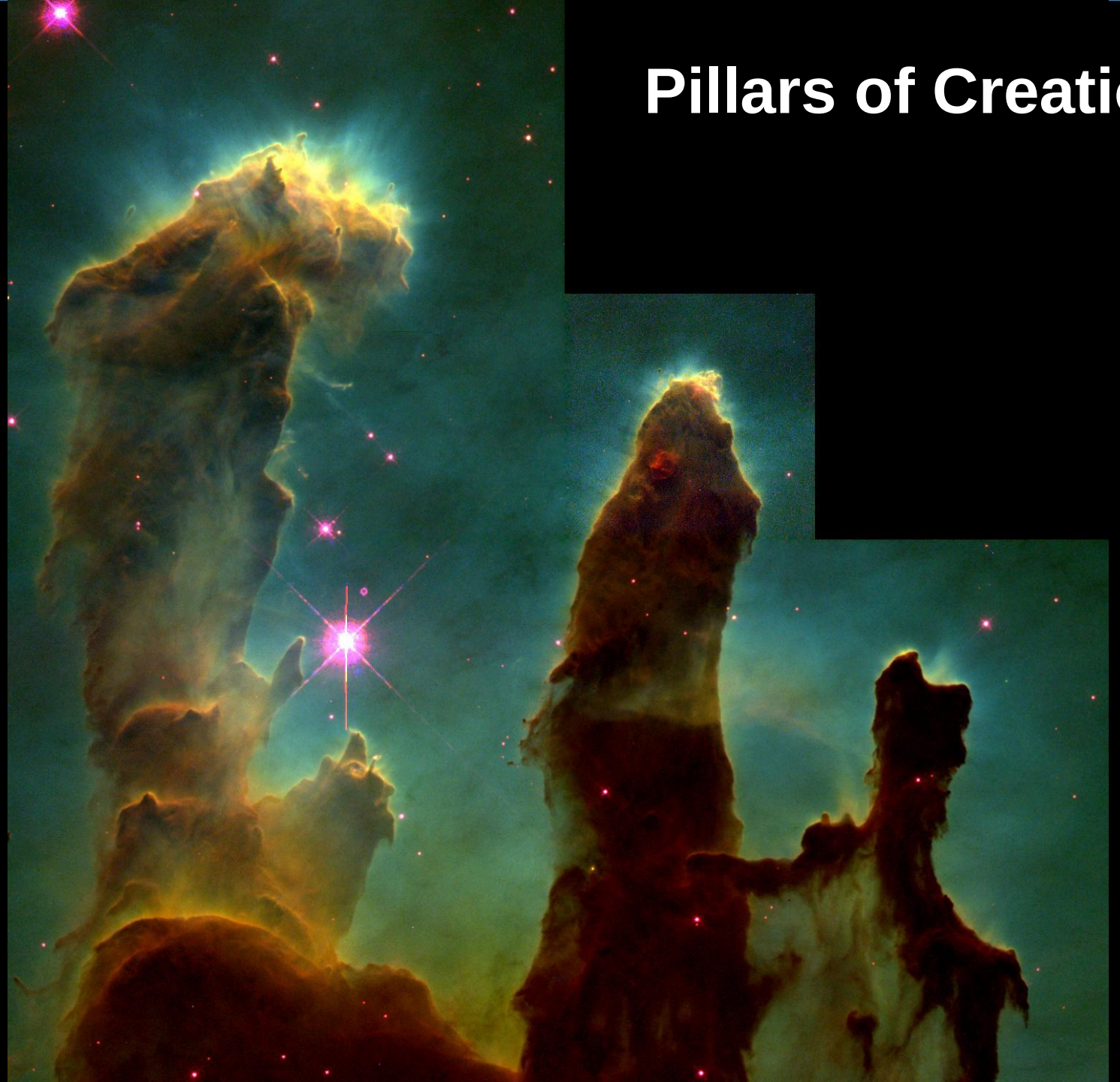
QUESTS: Pursue a diverse and bold set of science missions
Consistent with NASA's goal to "expand human knowledge through new scientific discoveries," JPL will work closely with the NASA Science Mission Directorate to understand the Sun, Earth, our Solar System, and the Universe.

Understand how Earth works as a system and how it is changing

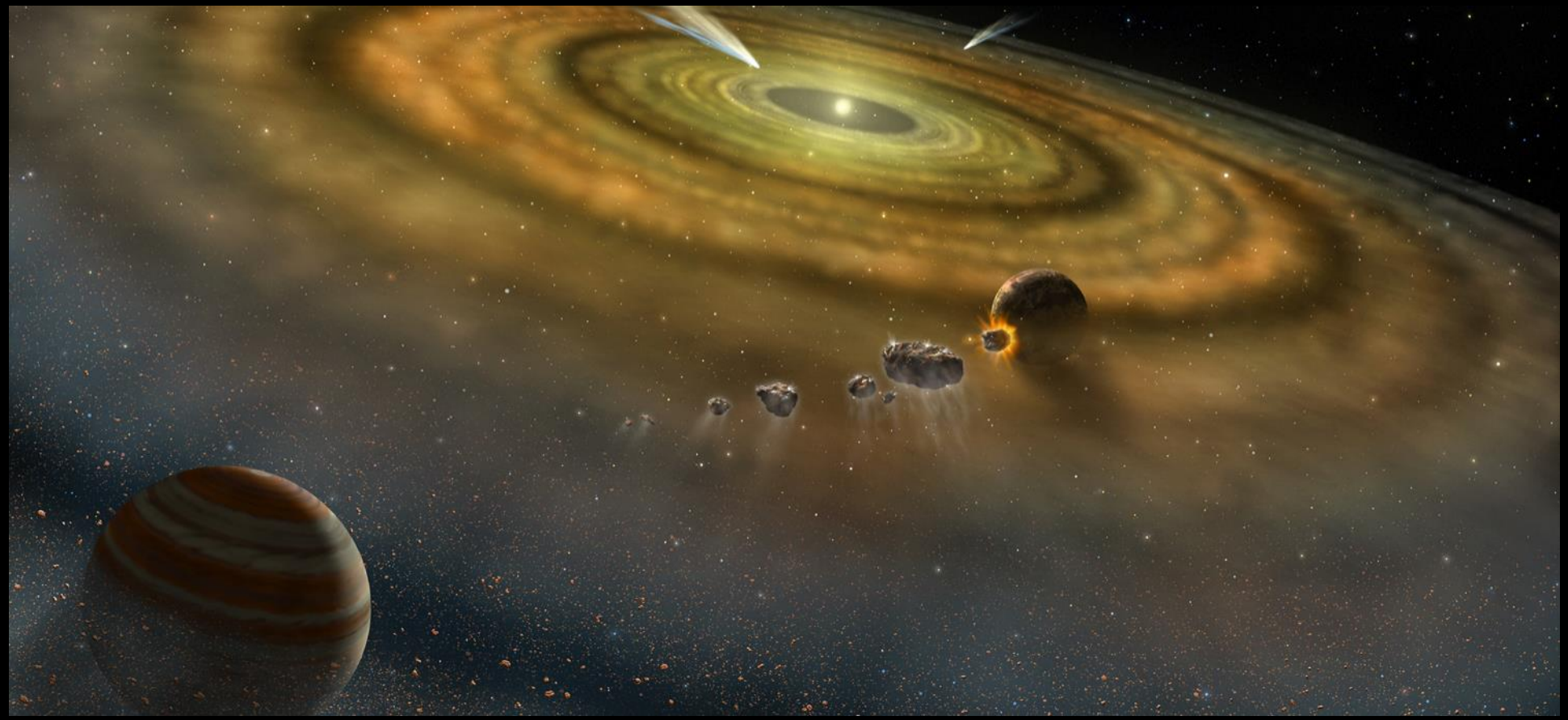
The History, evolution and future state of our Solar System

We visited all the planets in our Solar System

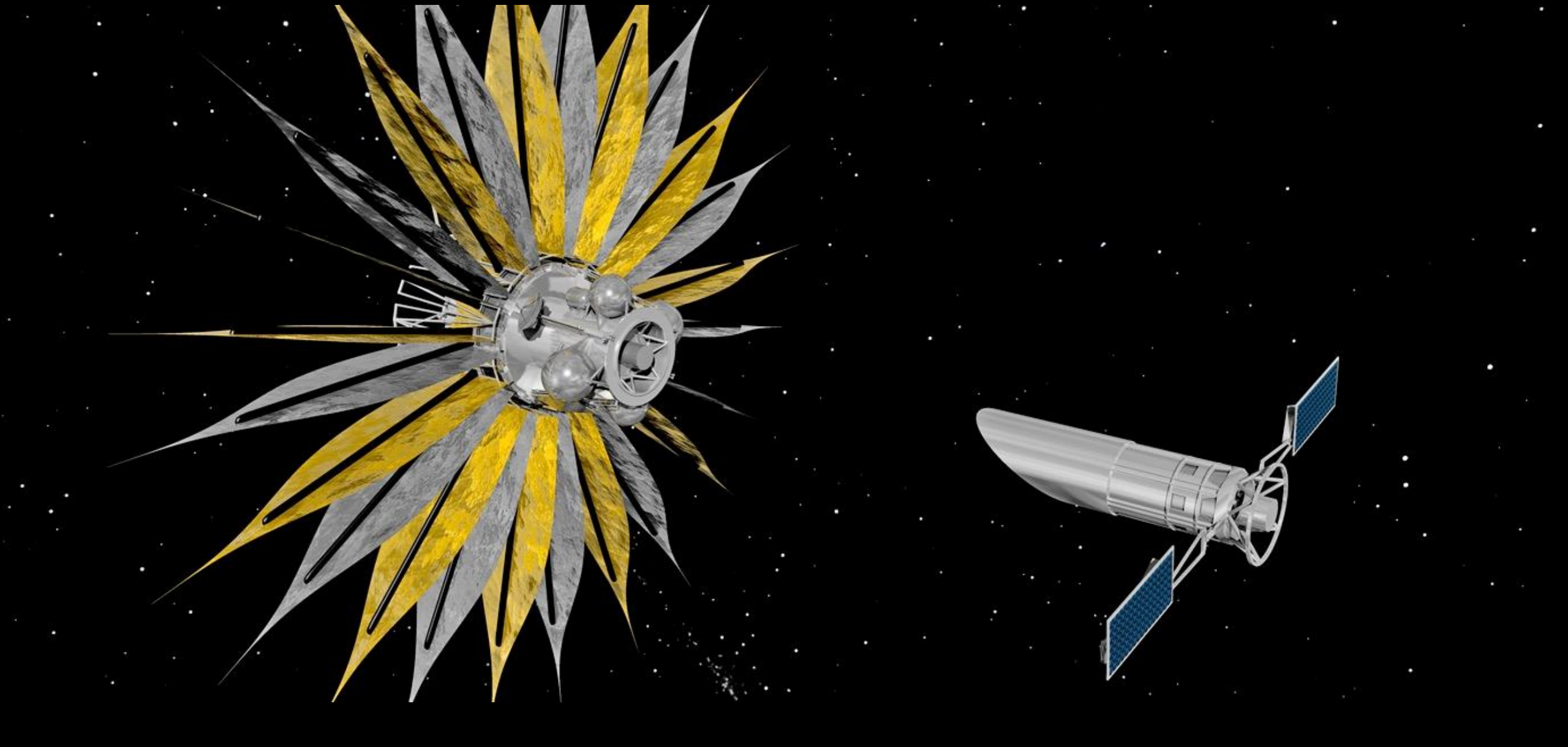
Pillars of Creation



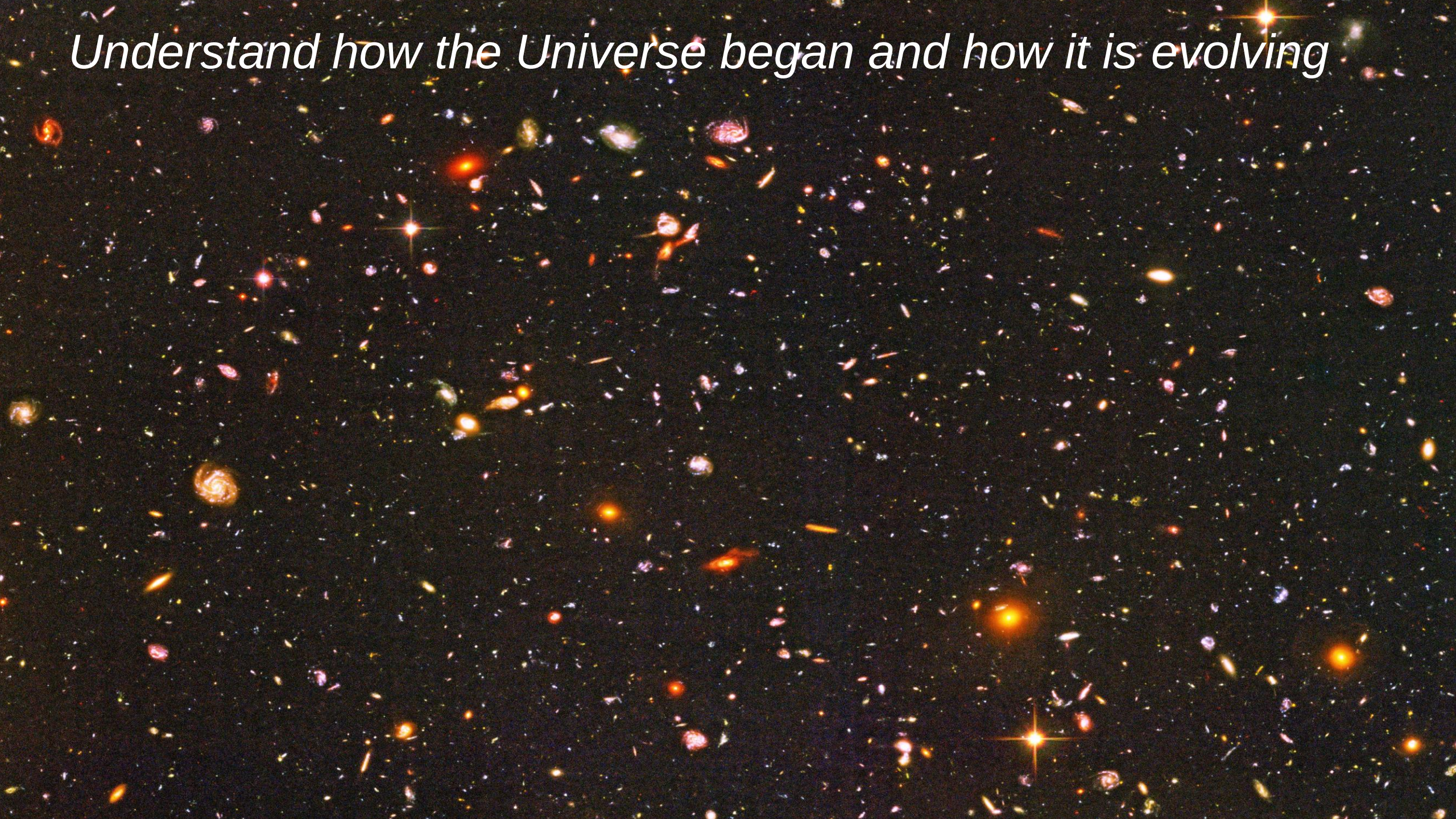
Is there life beyond Earth?



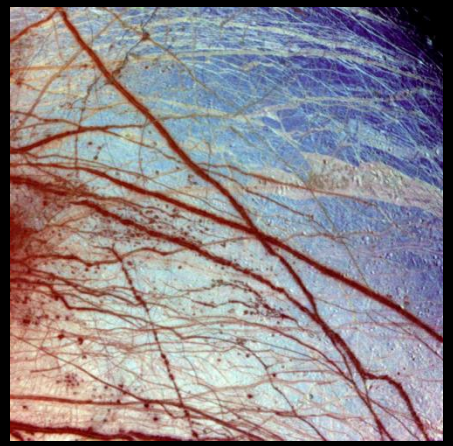
Understand the diversity of planetary systems in our Galaxy?



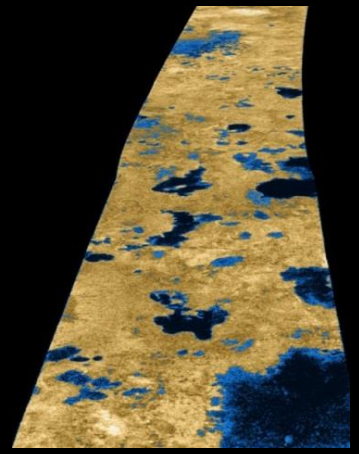
Understand how the Universe began and how it is evolving



The Future Destinations in our Solar System

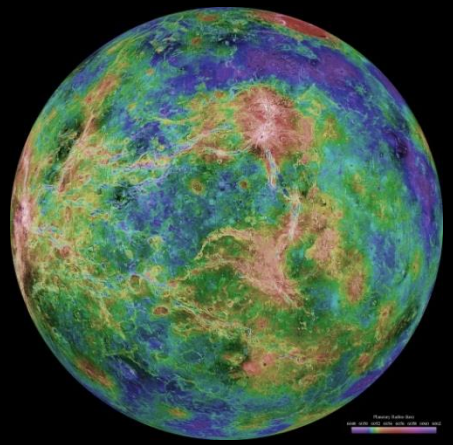


Europa

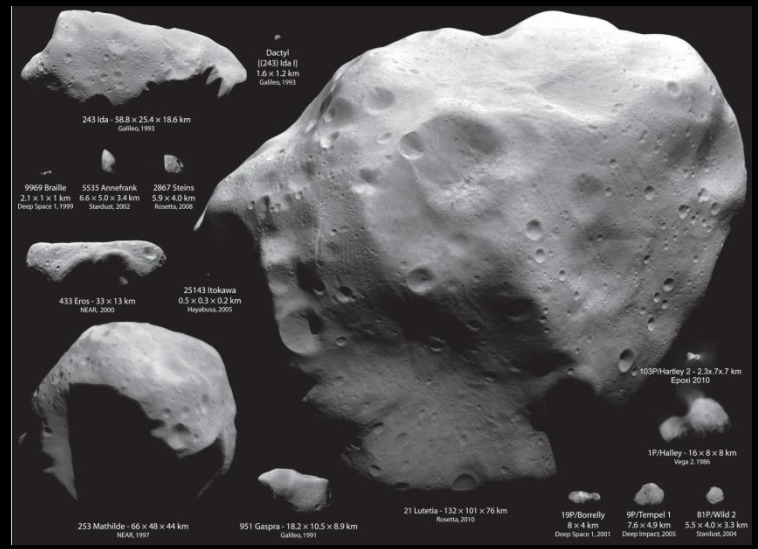


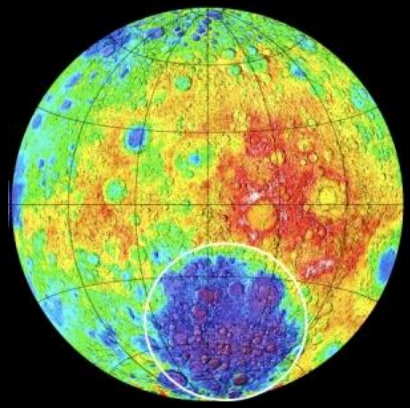
Titan

Enceladus



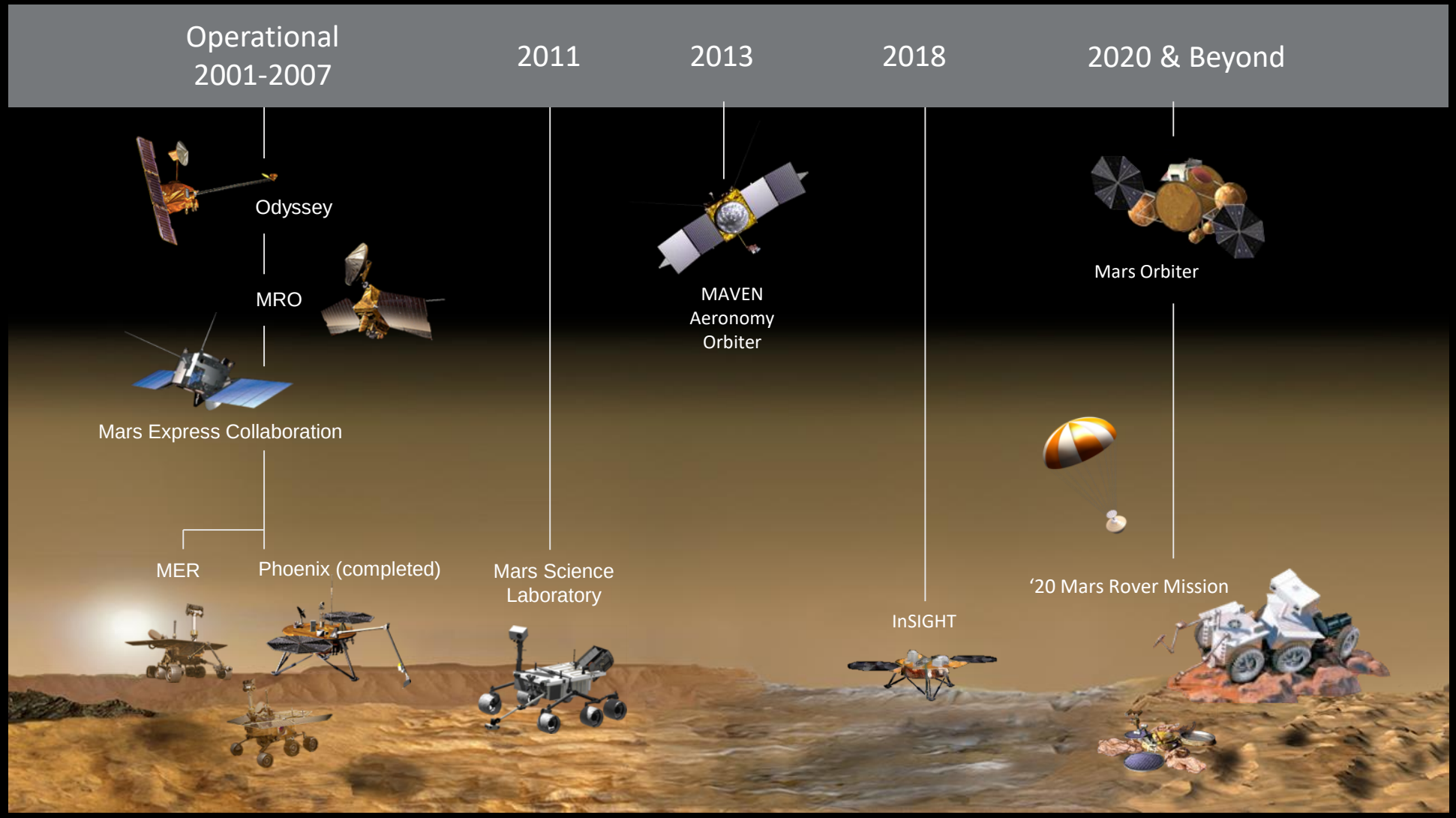
Venus



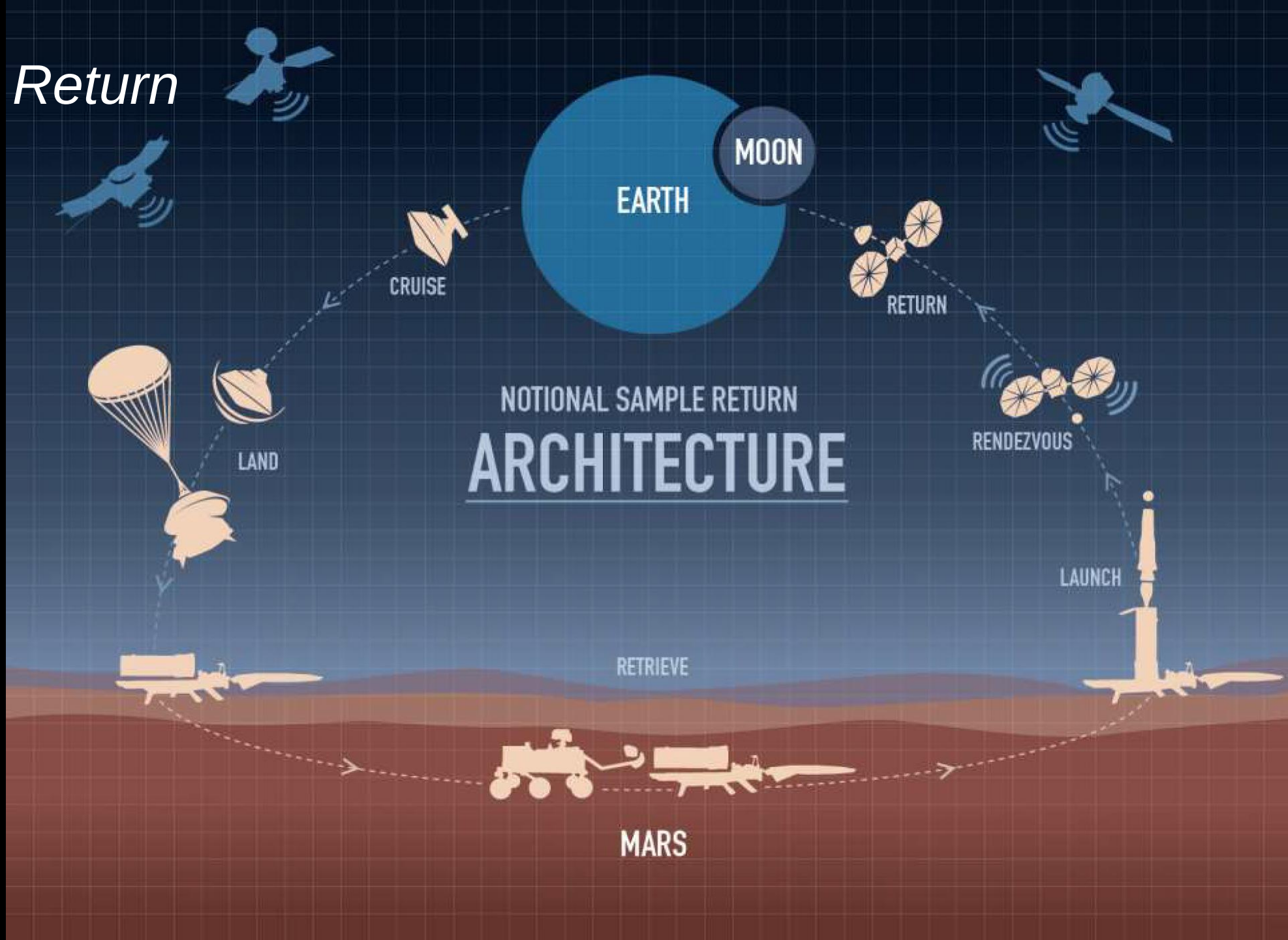


Moon:
South Pole-Aitken Basin

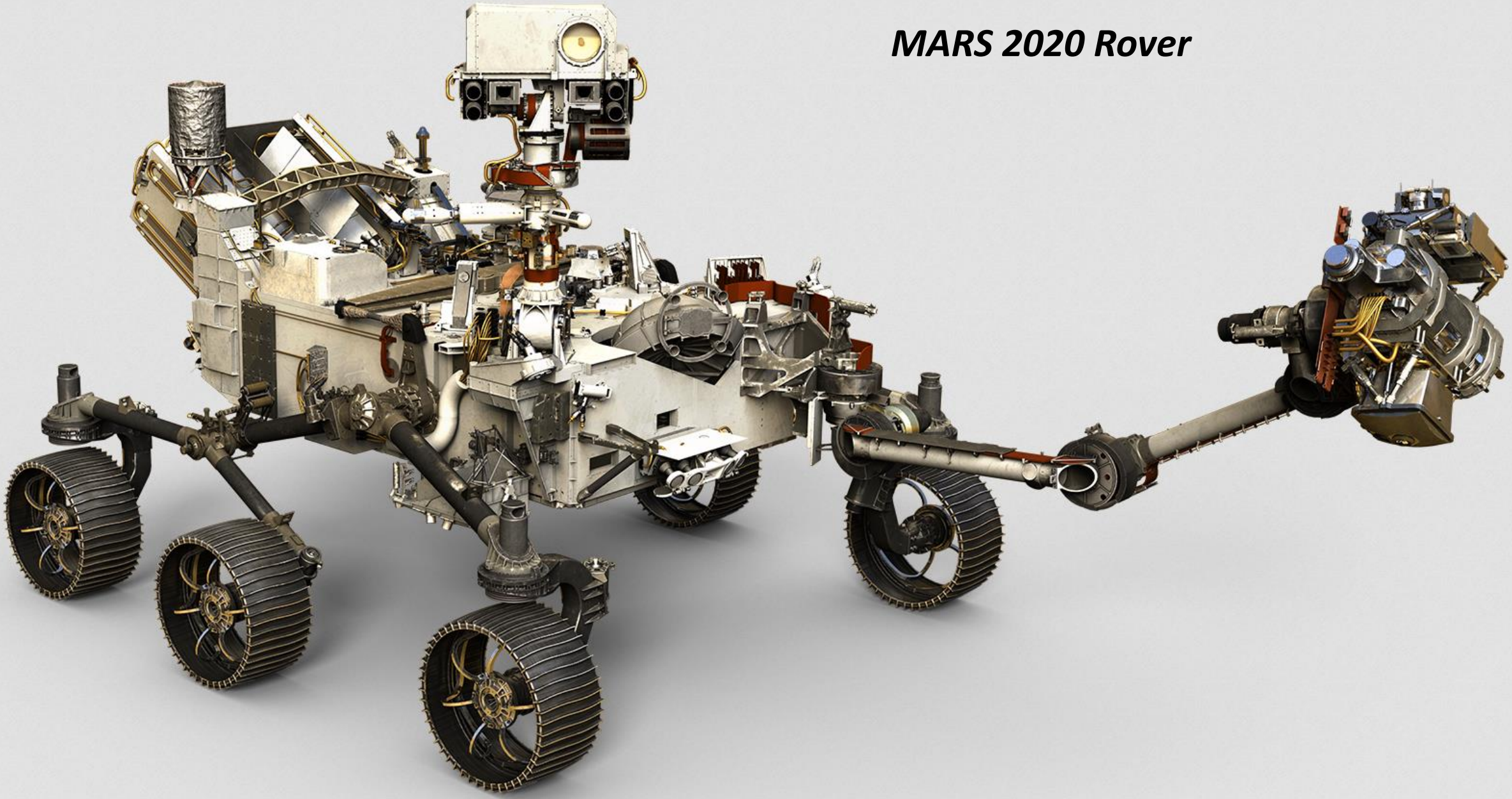
Mars Exploration Program



Mars Sample Return



MARS 2020 Rover



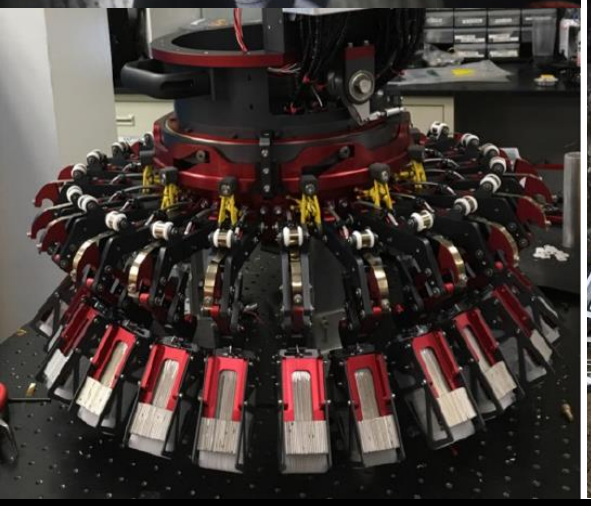
MARS HELICOPTER
TECHNOLOGY DEMONSTRATION

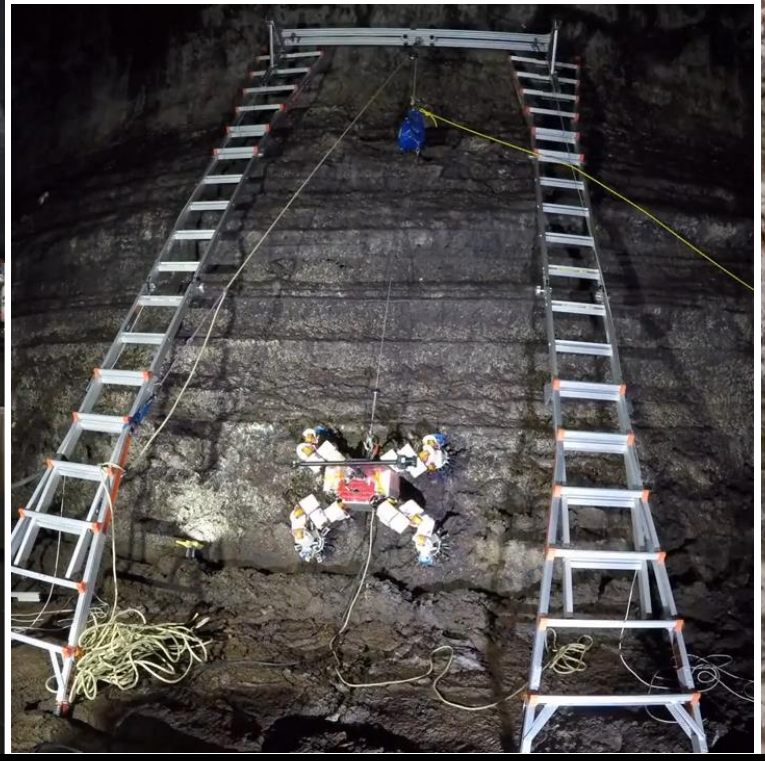
Surface Mobility 2: Untethered Steep Terrain Access

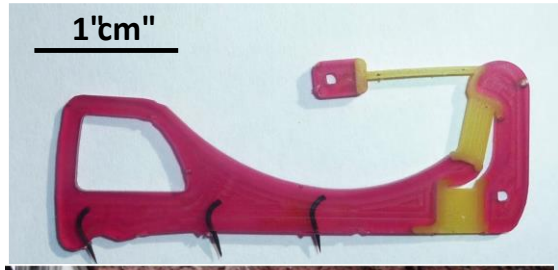
Lemur Climbing Robot

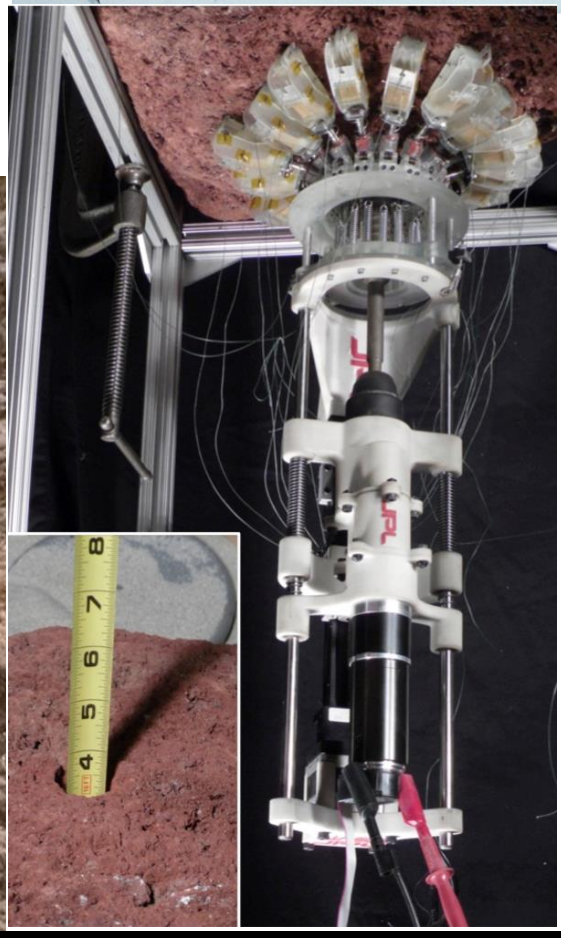
[PI: Aaron Parness]

- Prototype of walking system with 7 DoF limbs
- Radially retracting spiny end effectors have been matured through (canceled) NASA Asteroid Retrieval Mission project
- Grasp force can support robot, and also react optional drill for rock.
- Climbing of natural cave surfaces has been demonstrated.
- Extension of concept to ice is being explored for outer planet moons mobility.









In-Space Applications

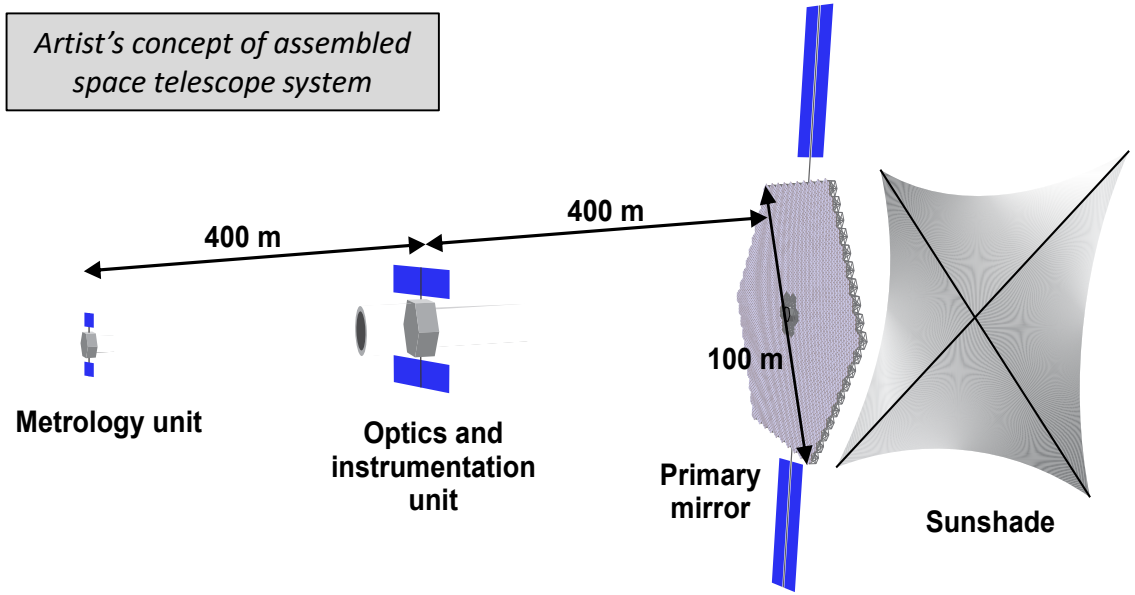
Telescope Assembly

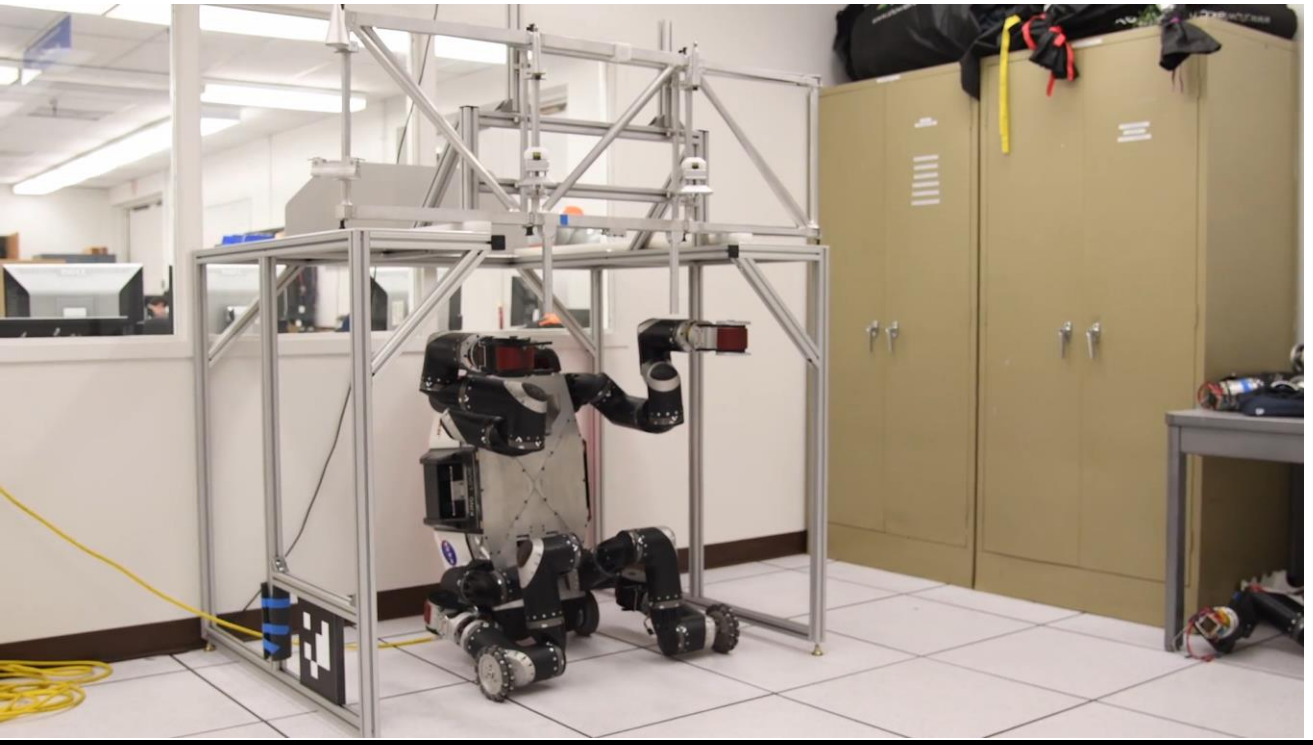
[PI: Rudra Mukherjee]

Developed and demonstrated prototype system for:

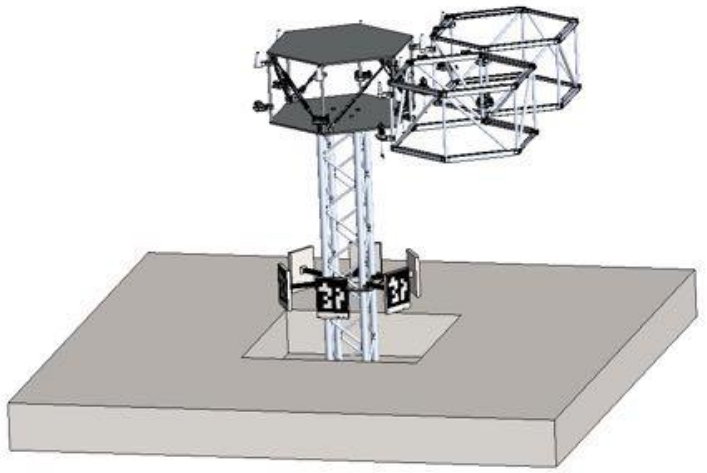
- Segmented mirror truss
- 3m truss in a closed kinematic loop
- Deployable “Deployable Truss Modules”
- autonomous assembly
- Robosimian platform
  - Force controlled manipulation
  - Visual feedback through AprilTags.

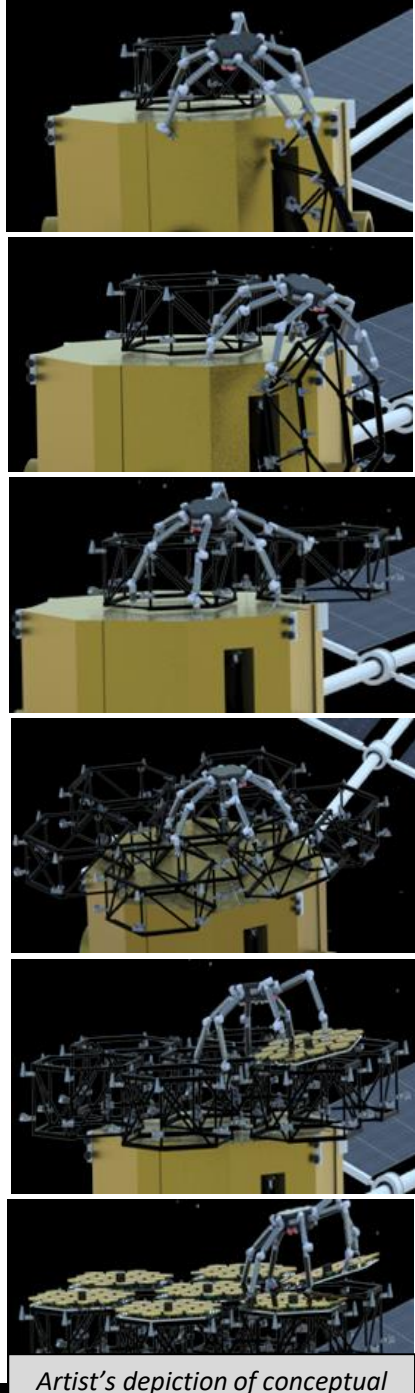
Artist’s concept of assembled space telescope system



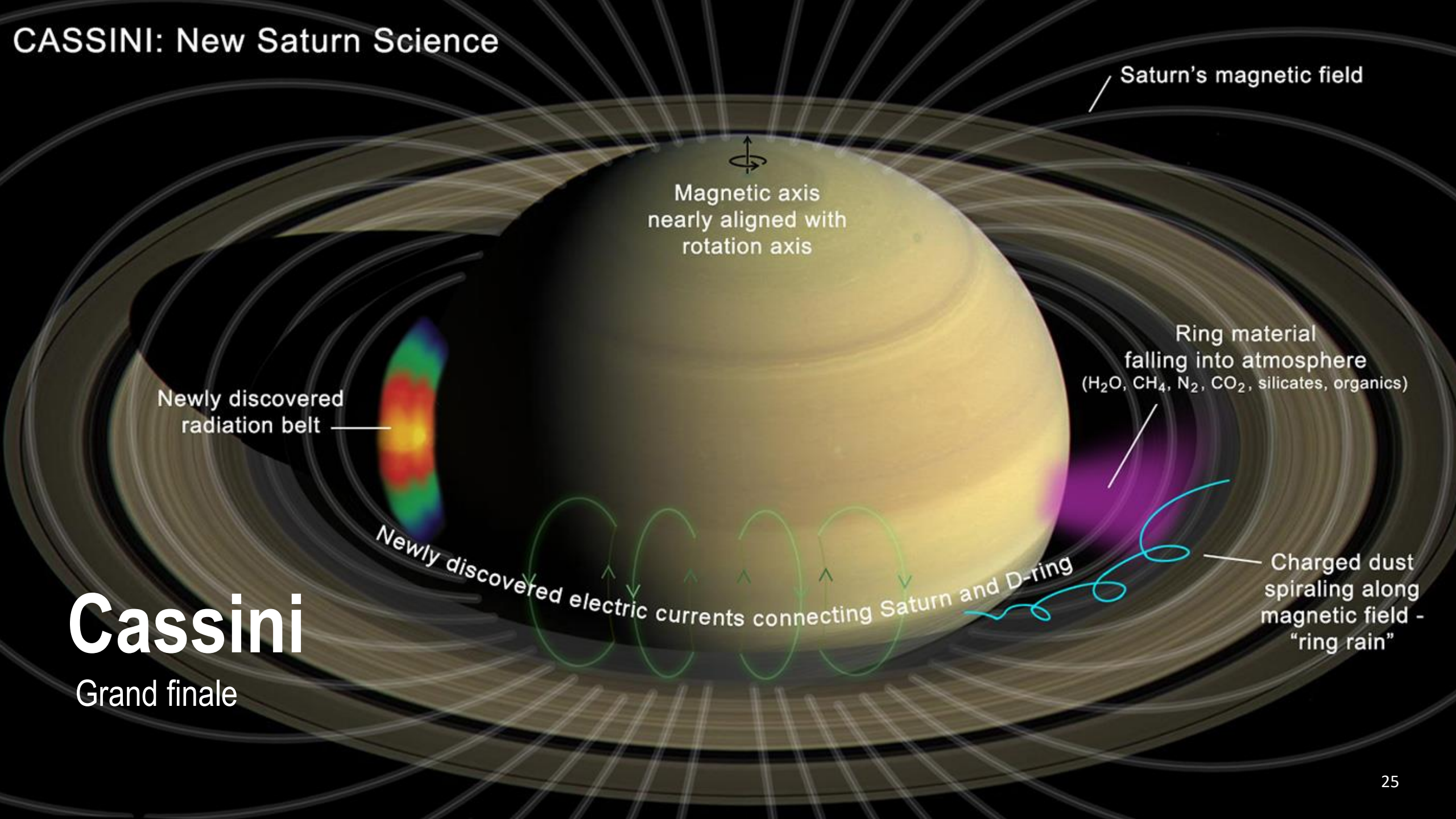


Artist’s depiction of prototype demonstration set-up.





Artist’s depiction of conceptual assembly process.



Cassini

Grand finale

Cassini/Huygens studies Saturn, Enceladus' geysers, and Titan's lakes

Spectrum of Satellite Development

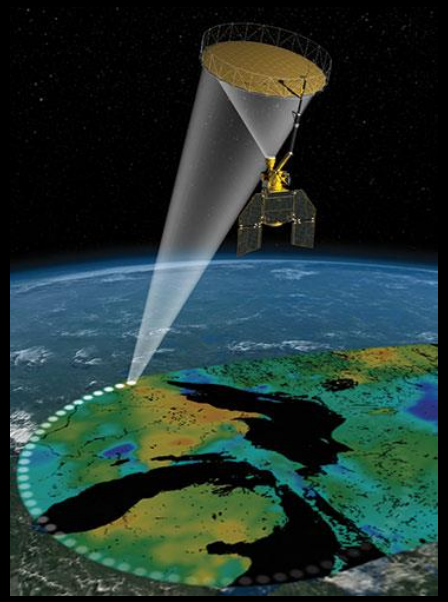
Small satellites are a growing component of space exploration

U-Class (CubeSat) / MicroSat

CP-6
10 – 50 cm (linear)
1 – 100 kg
5 – 50 W
$1 – 30 million (2015)

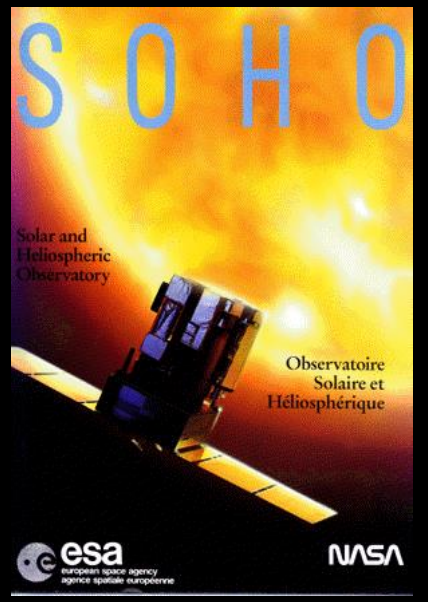
MiniSat / ESPA-Class

LCROSS
2 meters (linear)
585 kg (dry mass)
600 W
$79 million (2009)



Medium-Class

SMAP
9.7 meters (linear)
944 kg
550 W (radar peak)
$916 million (2015)



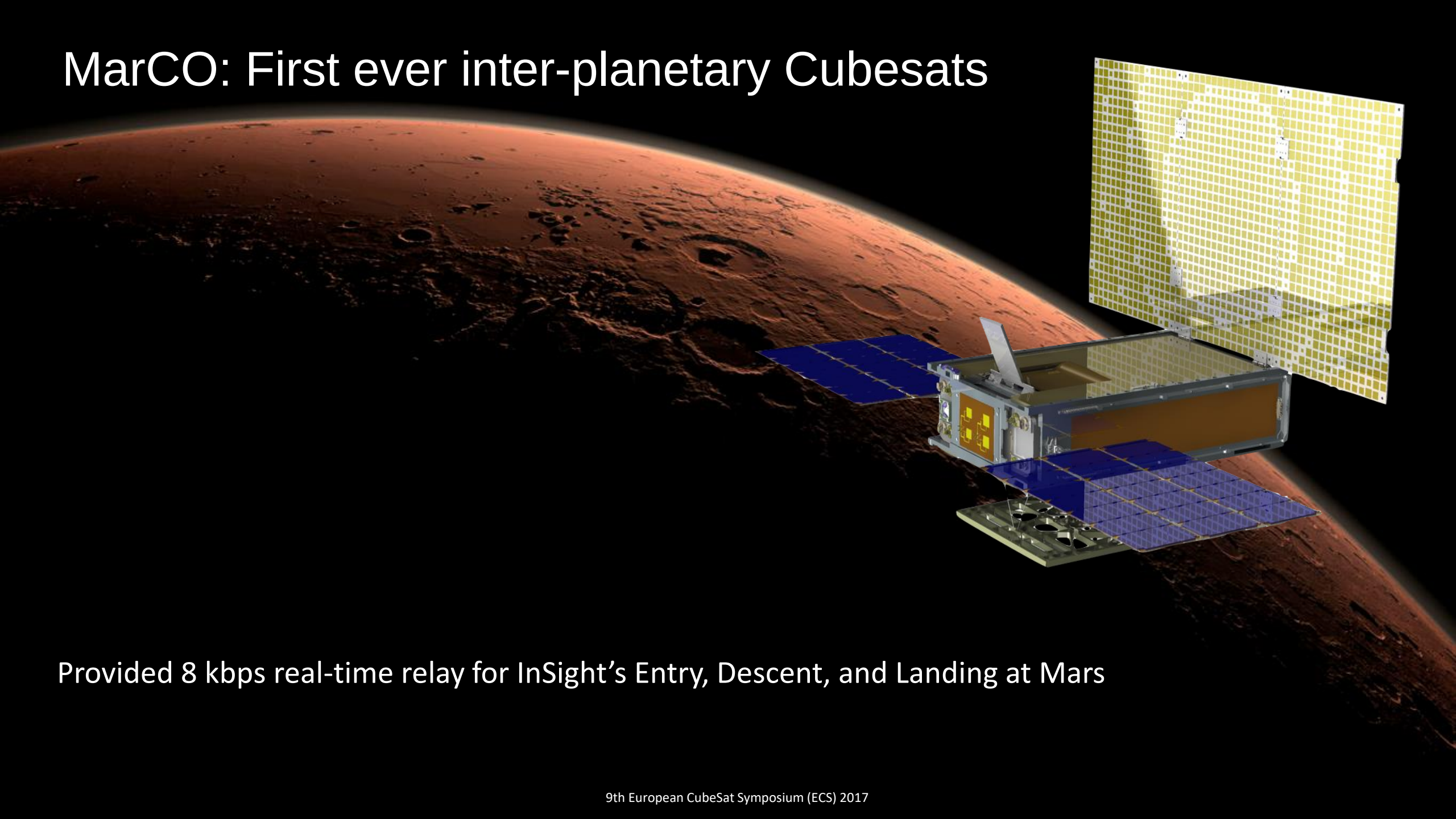
Large-Class

SOHO
4.3 meters (linear)
1850 kg
1,500 W
$1,100 million (1995)

Flagship-Class

Aura
17.37 meters (linear)
2,967 kg
4,600 W
$785 million (2004)

MarCO: First ever inter-planetary Cubesats

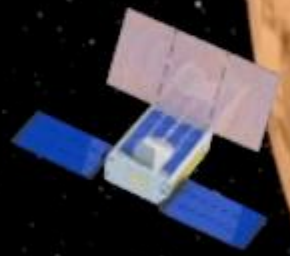


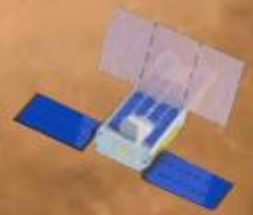
Provided 8 kbps real-time relay for InSight’s Entry, Descent, and Landing at Mars

MarCO

Mars Cube One

First Interplanetary CubeSat Mission



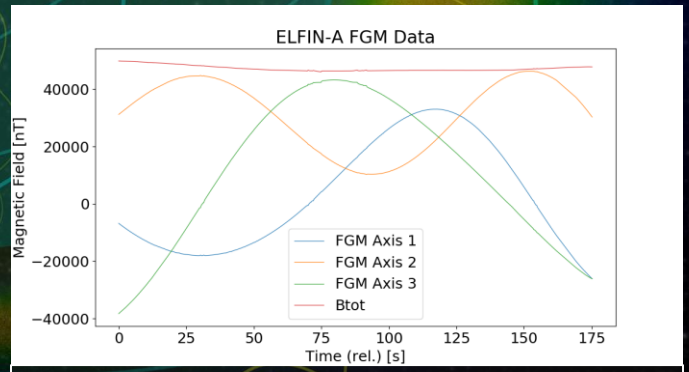


Jet Propulsion Laboratory
California Institute of Technology

ELFIN

Studying how energetic electrons escape the Van Allen Belts and fall to Earth

ELFIN-A/B will give the first pitch angle spectra of precipitating energetic i+,e-, spatio-temporal disambiguation, and i+,e- spectra from EMIC wave scattering

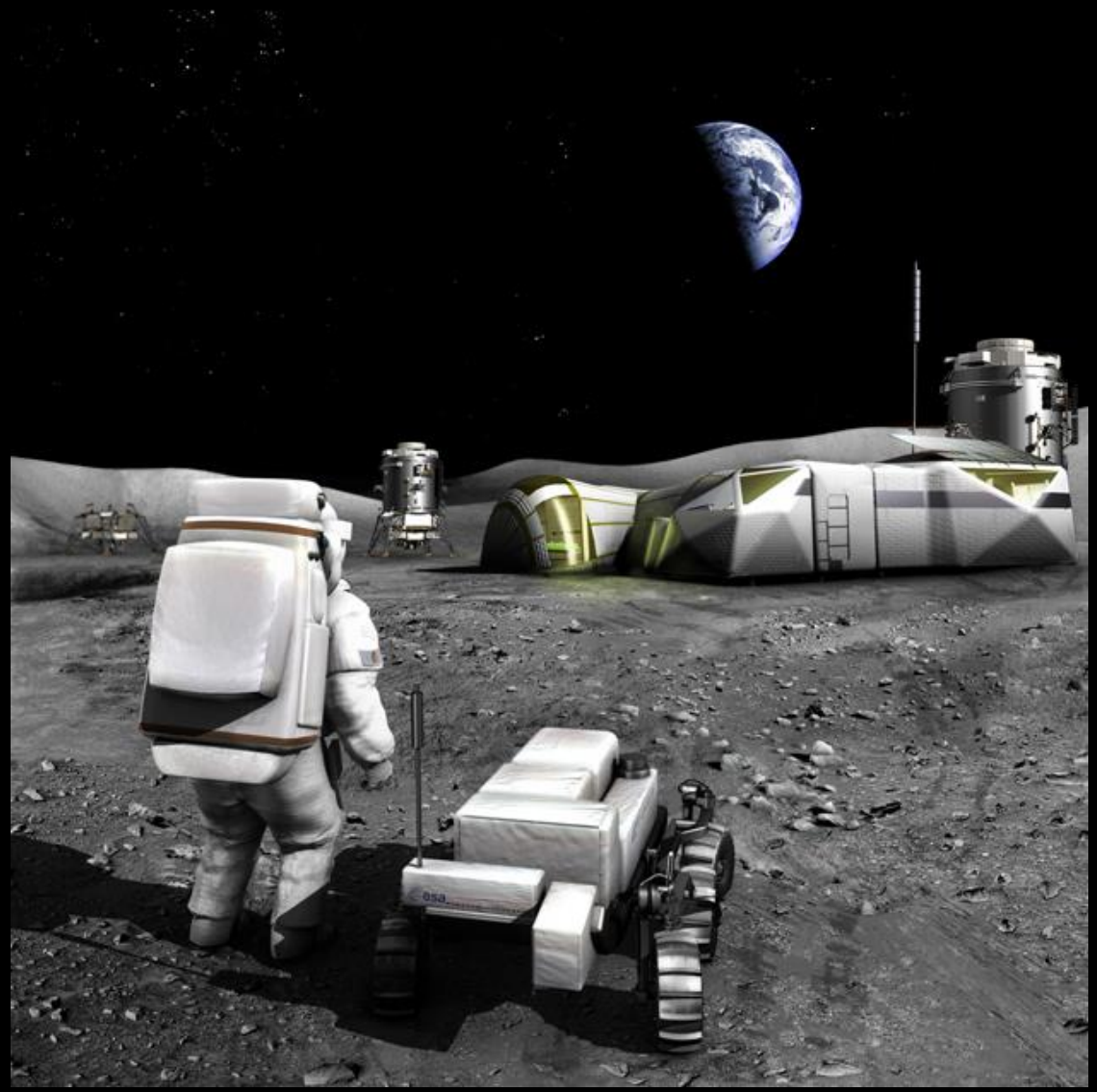


ELFIN-A on-orbit flux gate magnetometer data


John
onsight

Enable scientists to work together on Mars from their offices.

Thank you



JPL Caltech

Dare Mighty Things