



The Future of Robotic Space Exploration

Dr. Leon Alkalai, JPL Fellow

Briefing to UCLA CS1

November 15, 2019



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



Caltech students (1936)



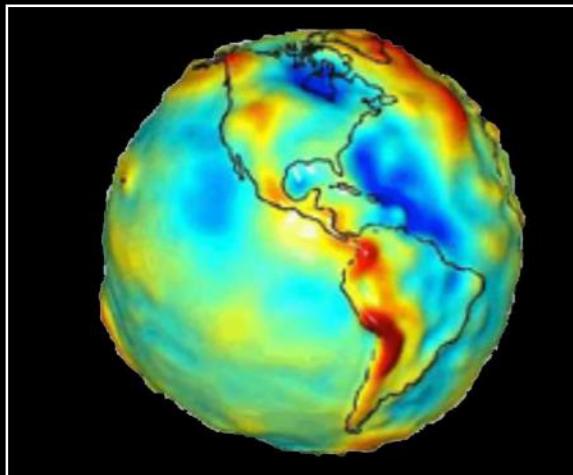
Missiles (1940s)



Explorer 1 (1958)



Voyager 1 & 2 (1977 – present)



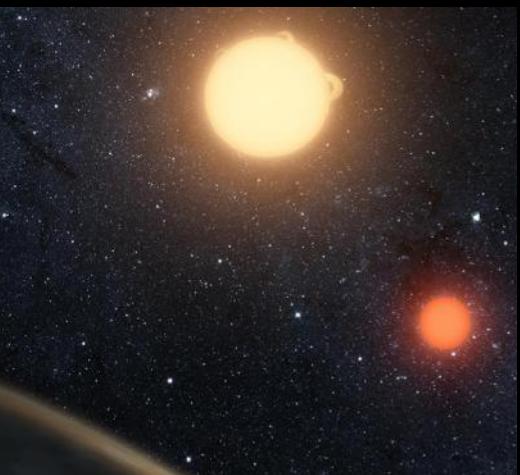
Earth Science
(1978 – now)



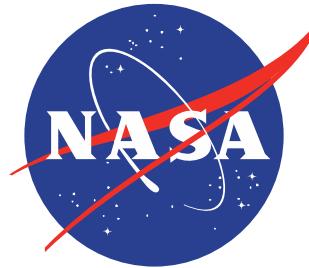
Mars Exploration Rovers
(2004 – present)



Spitzer Space Telescope
(2004 – present)



Exoplanet Exploration
(2009 – present)



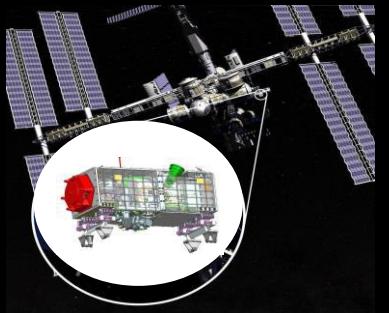
**NASA's Jet Propulsion Laboratory
California Institute of Technology**

Caltech



Upcoming Missions

2019



OCO-3



COSMIC-2A

2020



Mars 2020

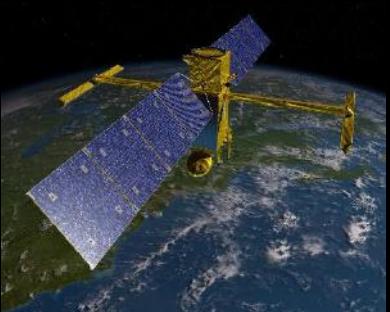


Mars Helicopter

2021



NISAR

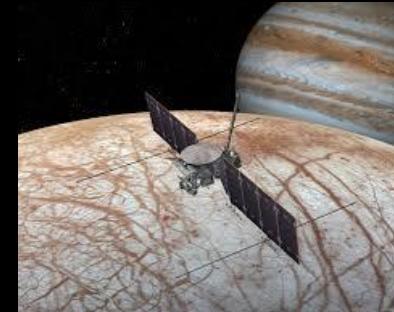


SWOT

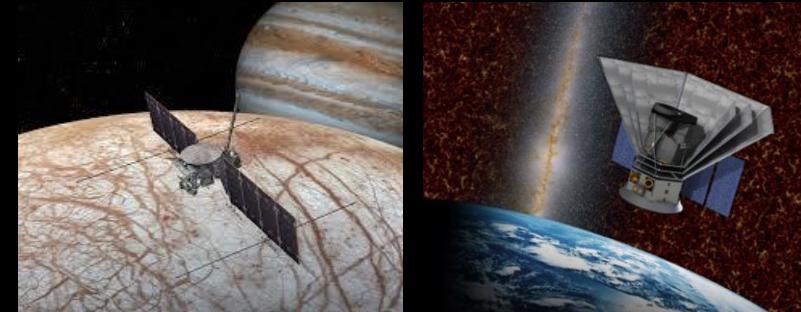
2022



Psyche / DSOC

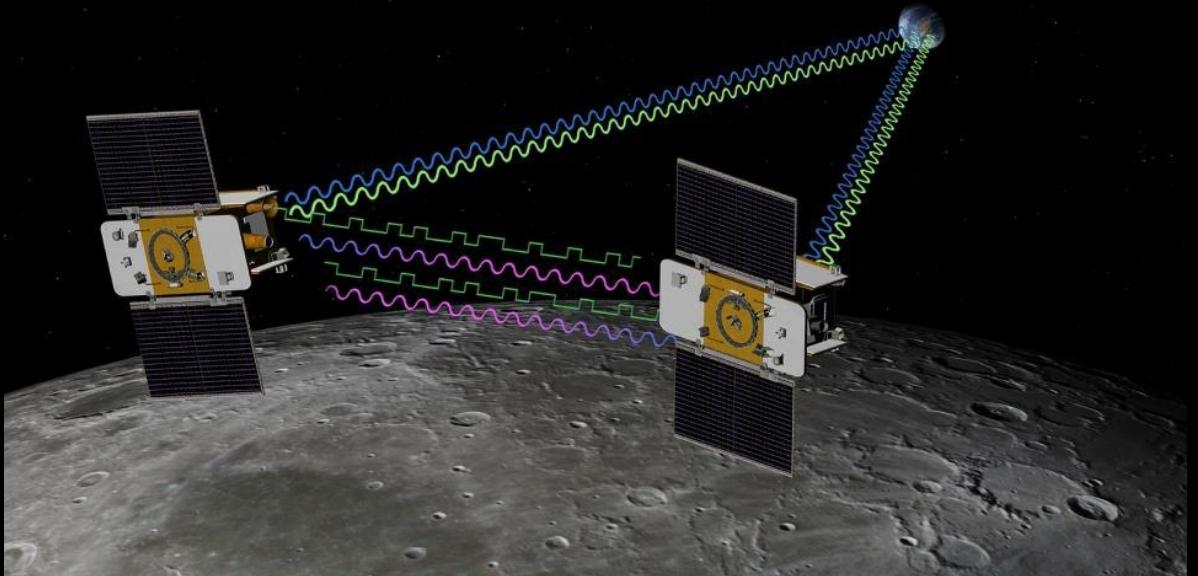


Europa Clipper



SPHEREx

Dr. Leon Alkalai, JPL Fellow

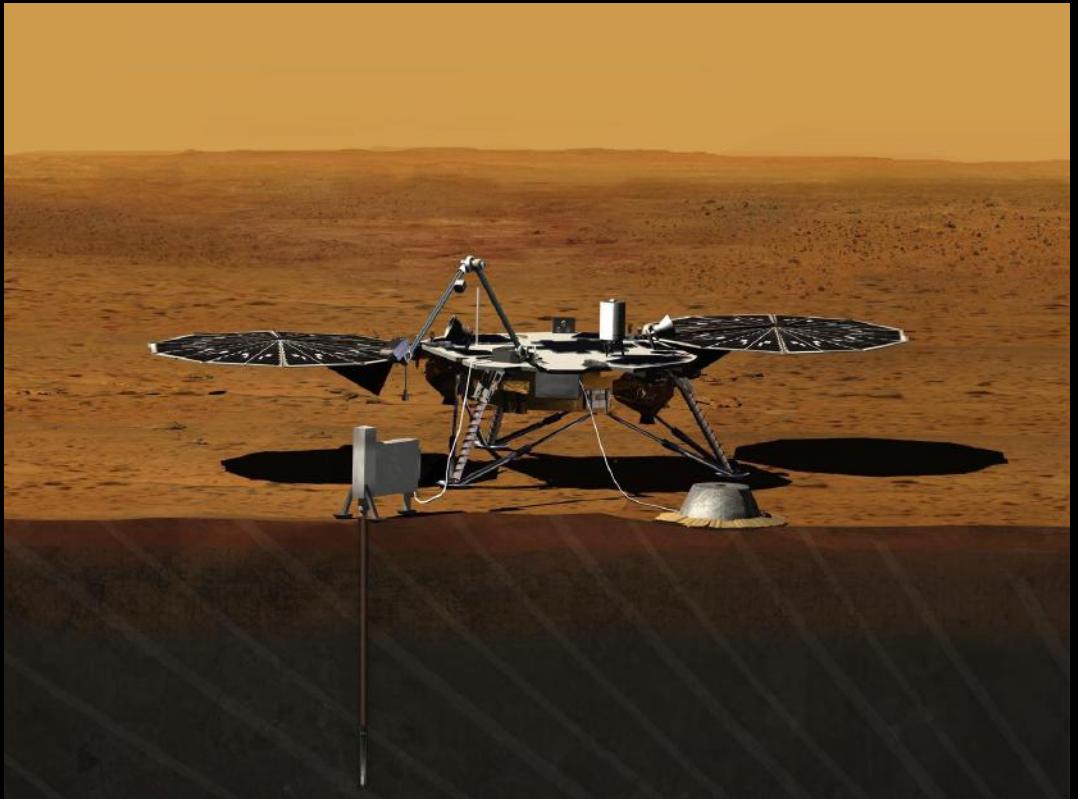


GRAIL launched 9/10/2011:
NASA Discovery Program -11
Competition Winner



*"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)*

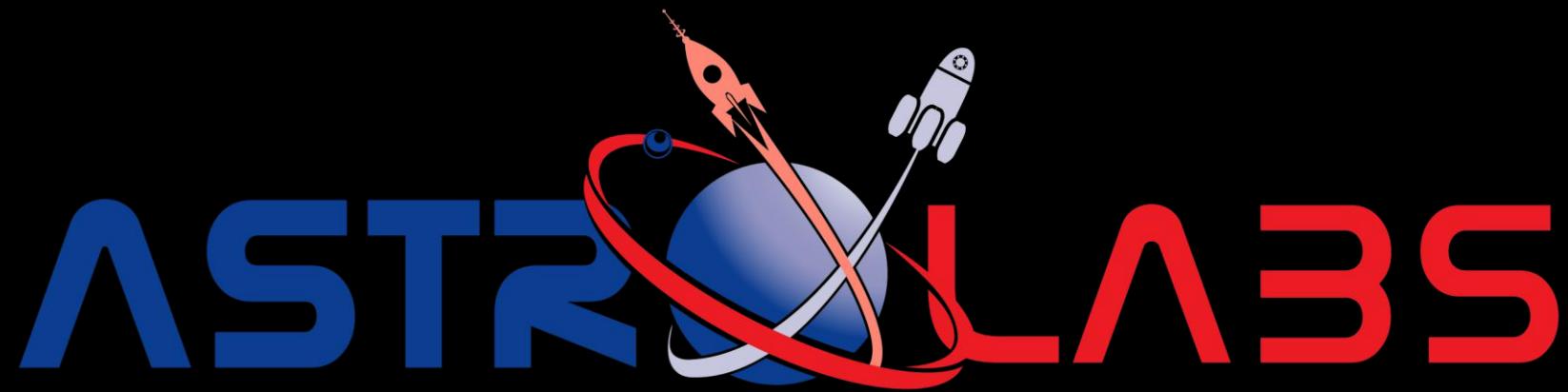
Dr. Leon Alkalai, JPL Fellow



*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*

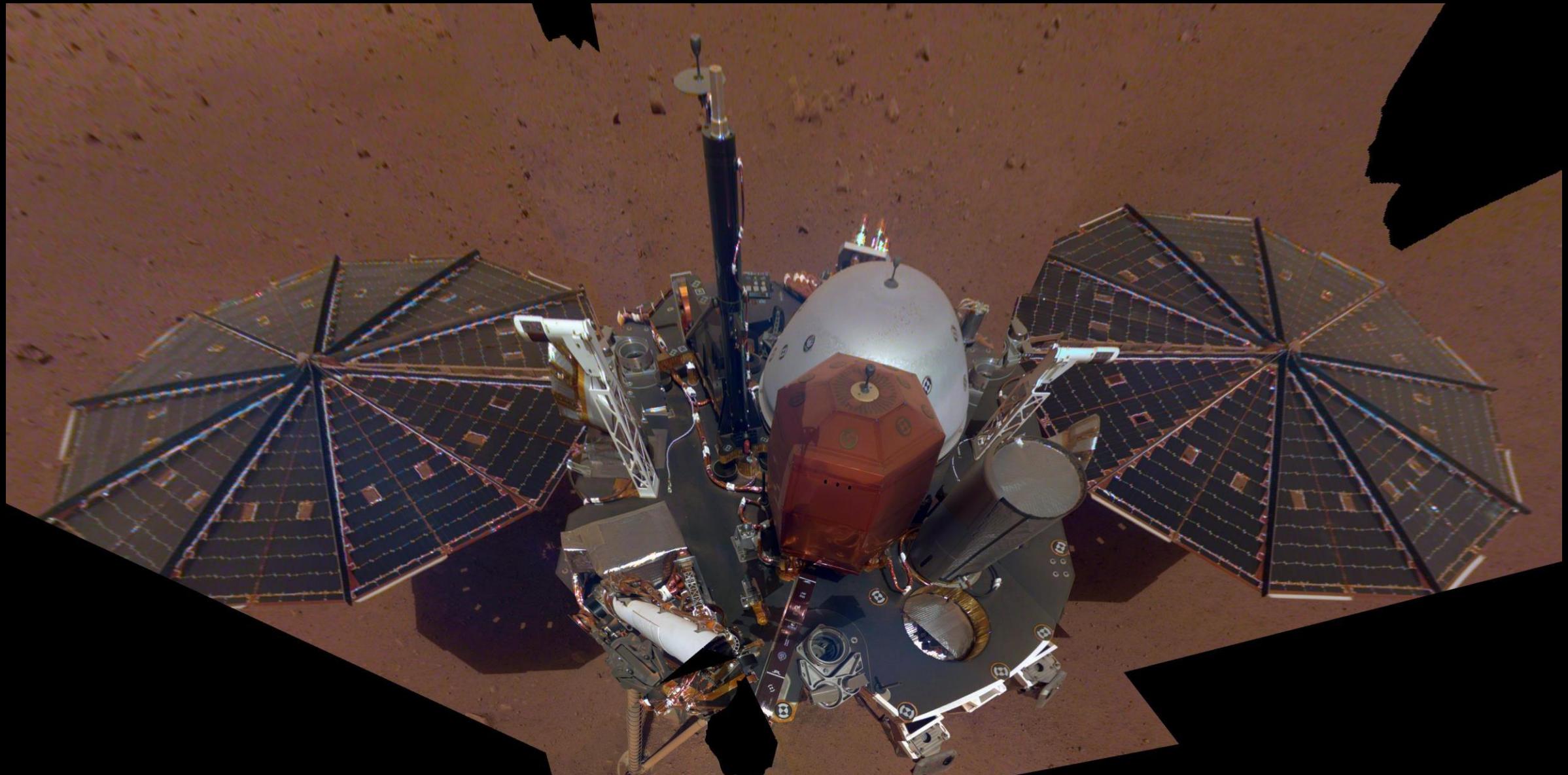


Dr. Leon Alkalai, Founder

Where Space Innovation and Start-up incubation meets
Private Investments

InSight

First Selfie





JPL Strategic Implementation Plan 2018

<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 spacecrafsts 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

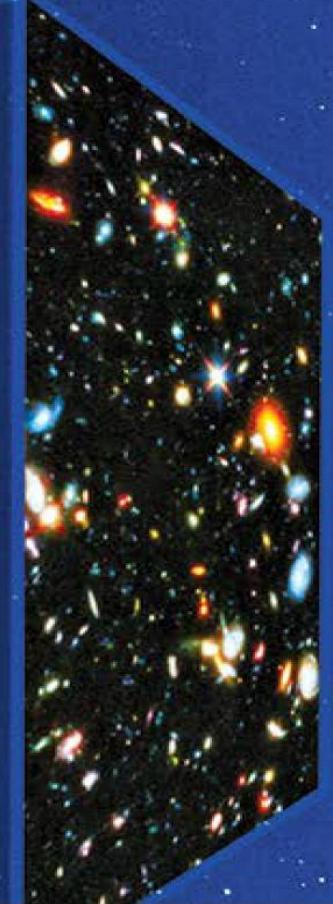
SOLAR SYSTEM EXPLORATION

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

Thriving on Our Changing Planet

A Decadal Strategy for Earth Observation from Space



#EarthDecadal

*The National
Academies of*

SCIENCES
ENGINEERING
MEDICINE

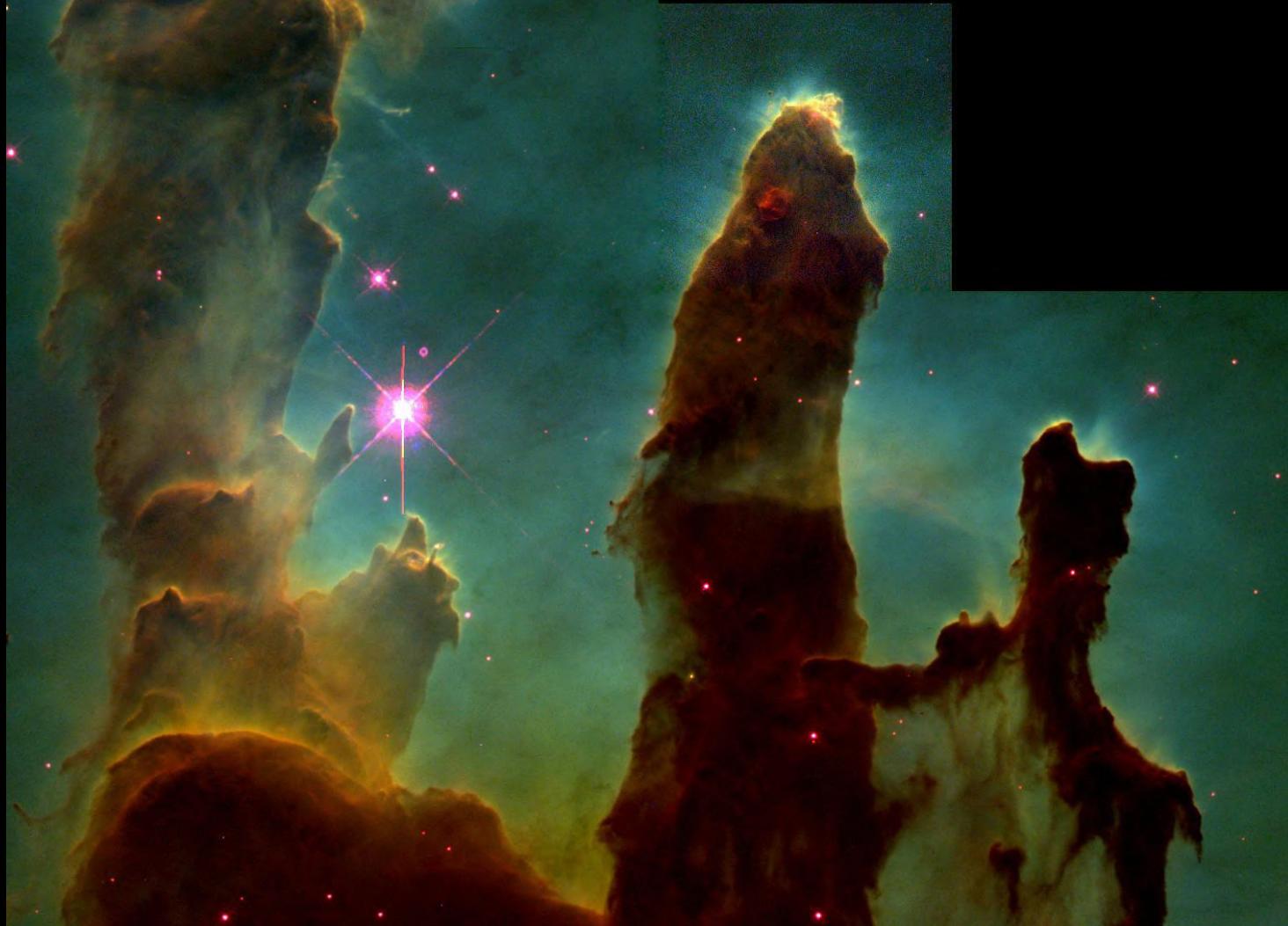


The History, evolution and future state of our Solar System

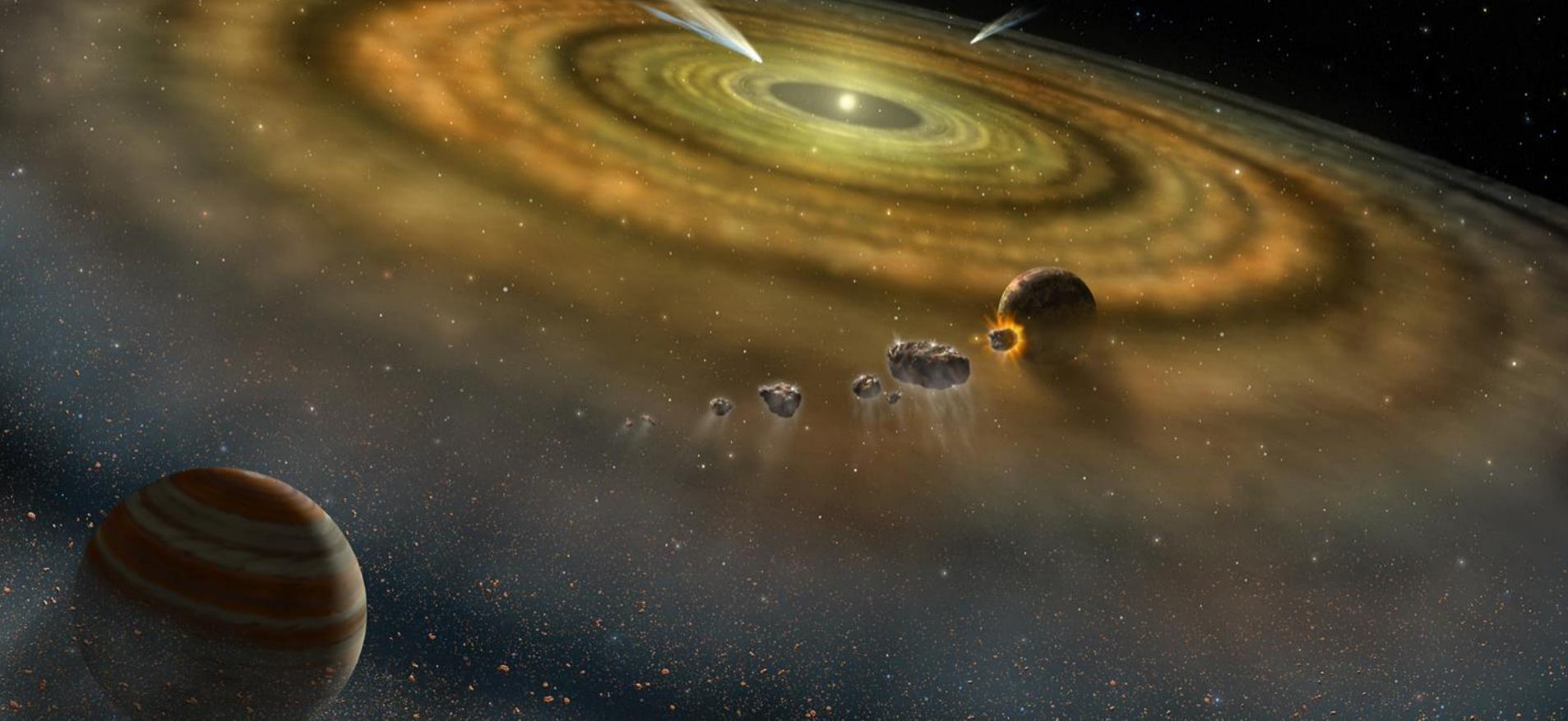
We visited all the planets in our Solar System



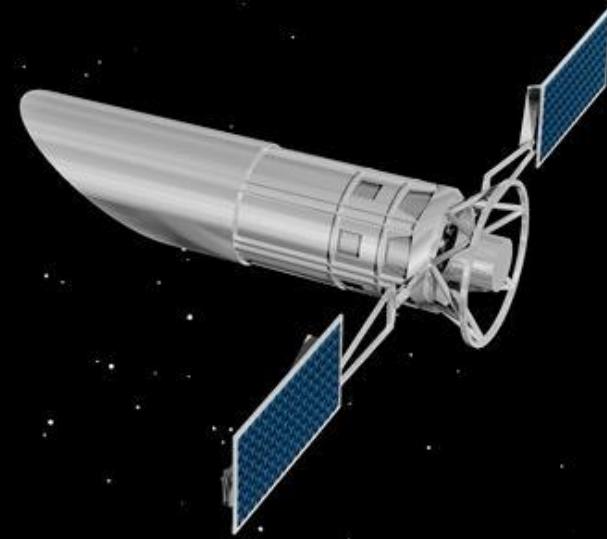
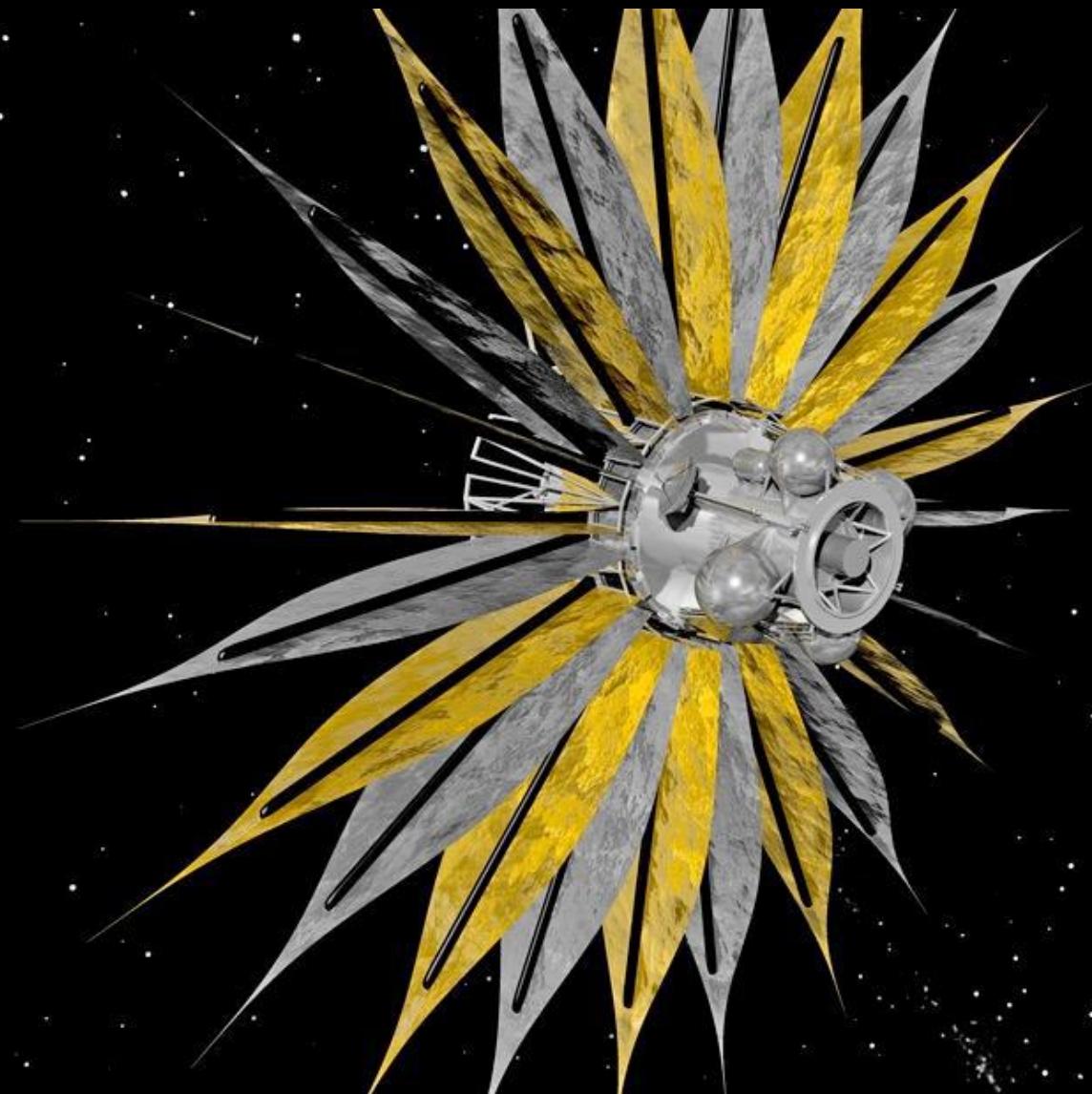
Pillars of Creation



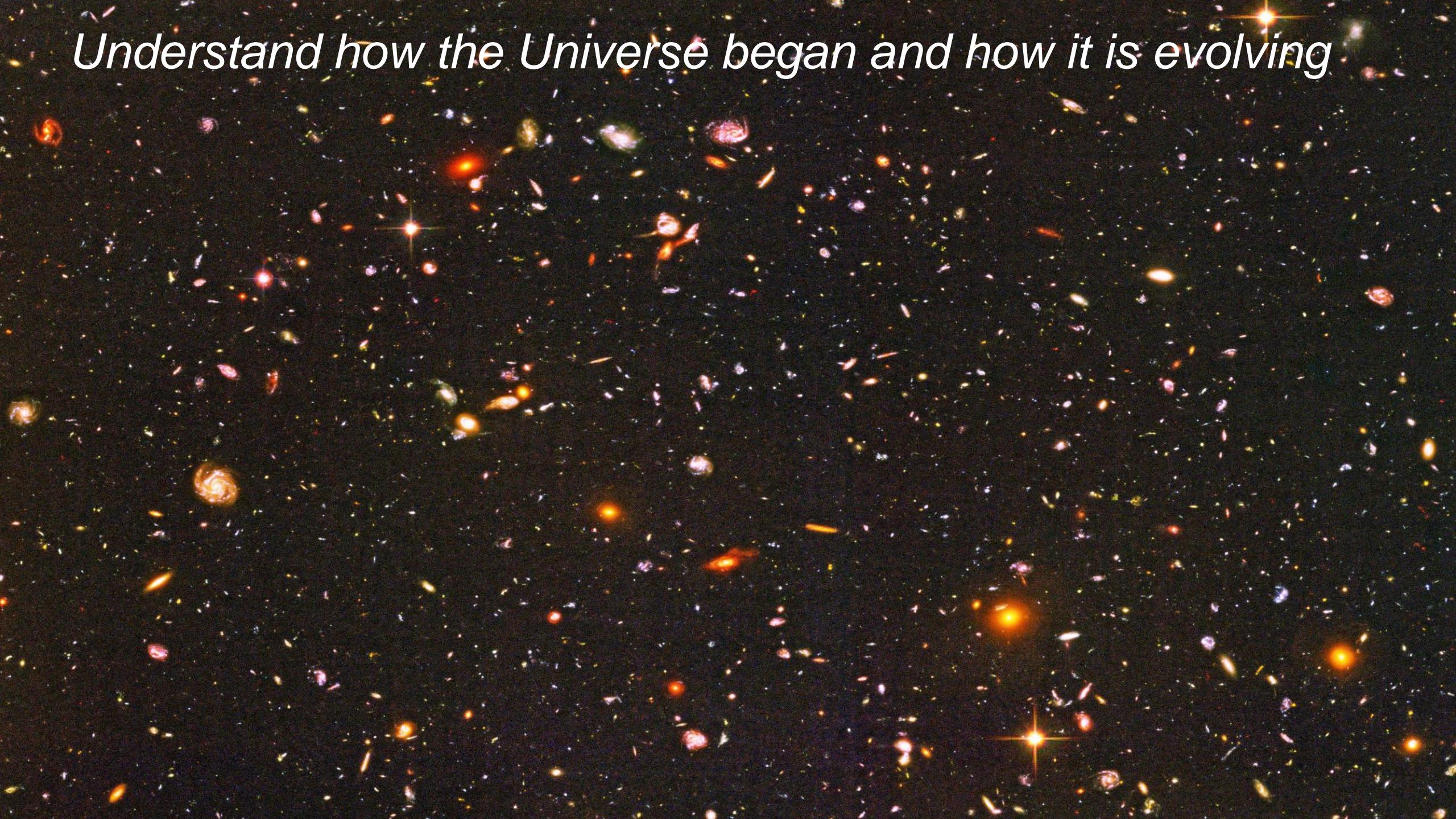
Is there life beyond Earth?



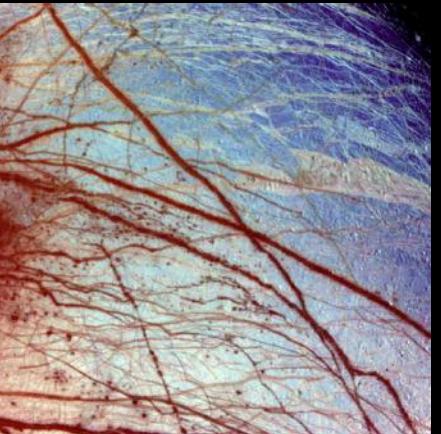
Understand the diversity of planetary systems in our Galaxy?



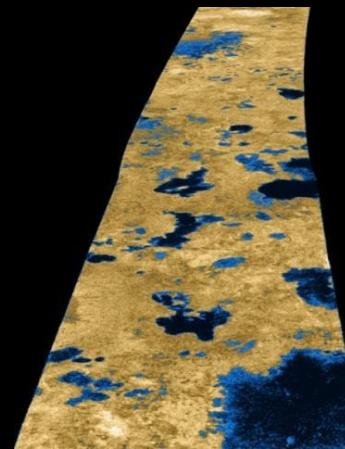
Understand how the Universe began and how it is evolving



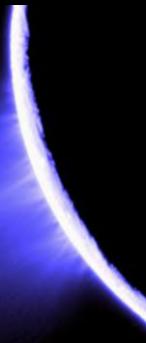
The Future Destinations in our Solar System



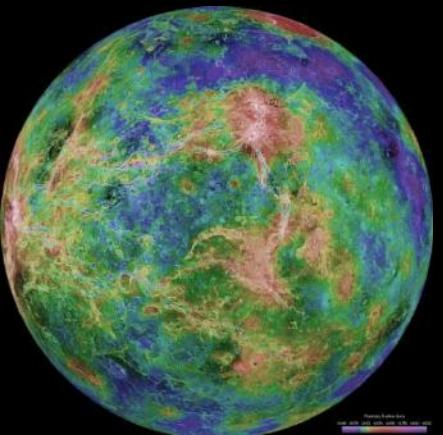
Europa



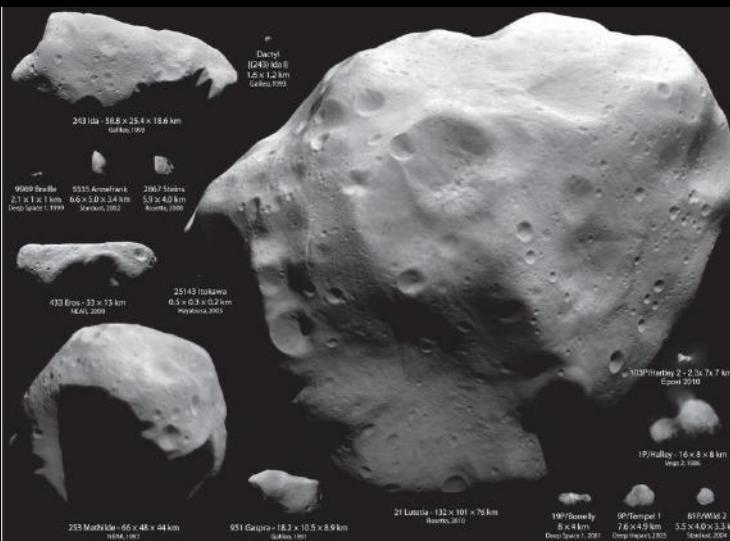
Titan



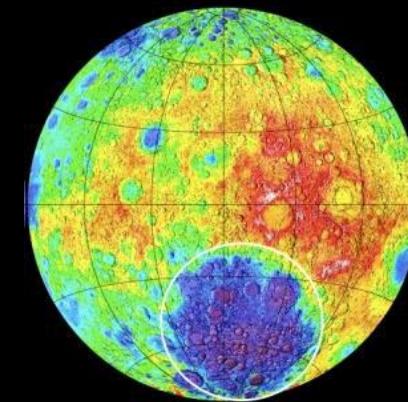
Enceladus



Venus

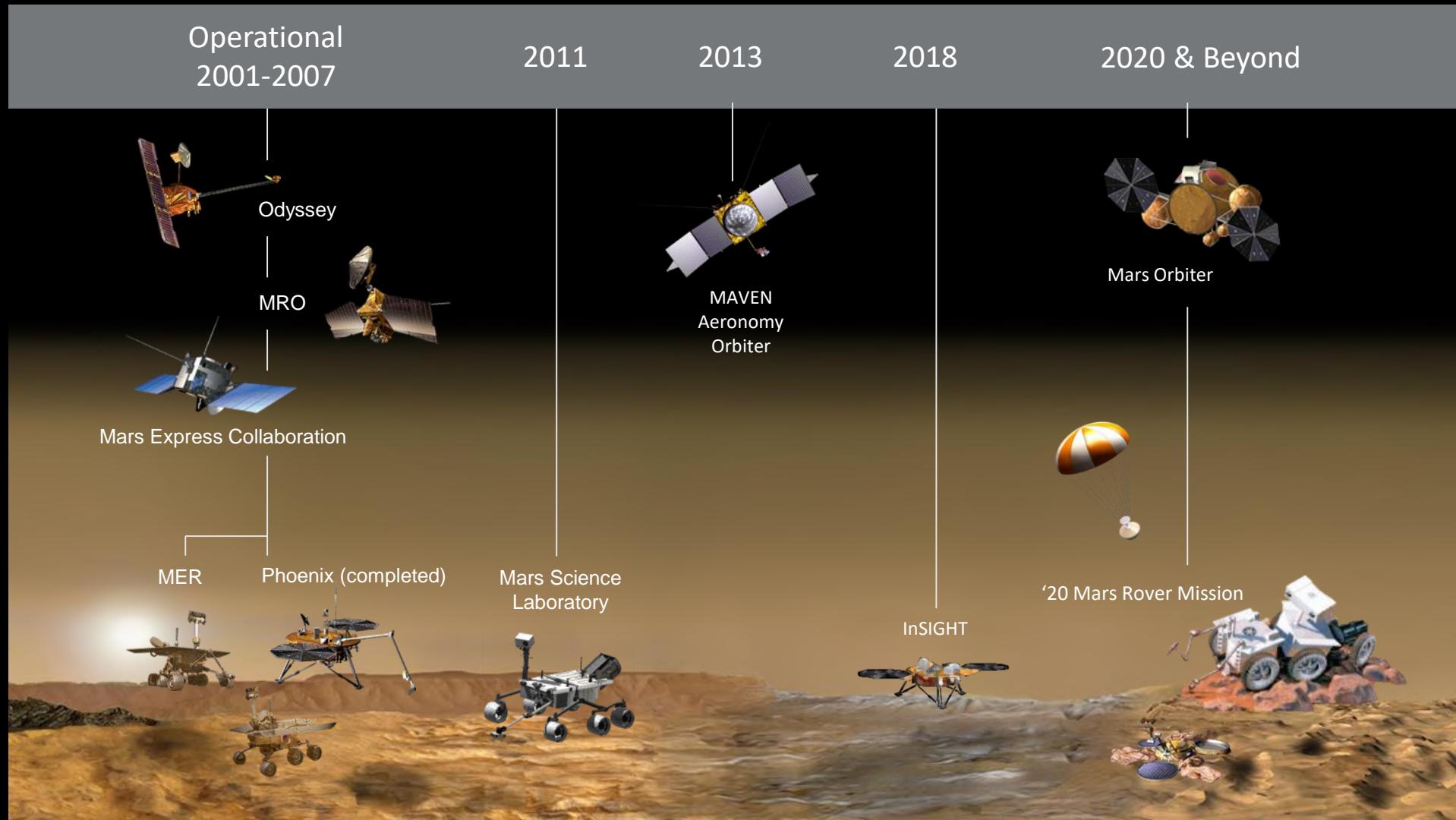


L. Alkalai, JPL

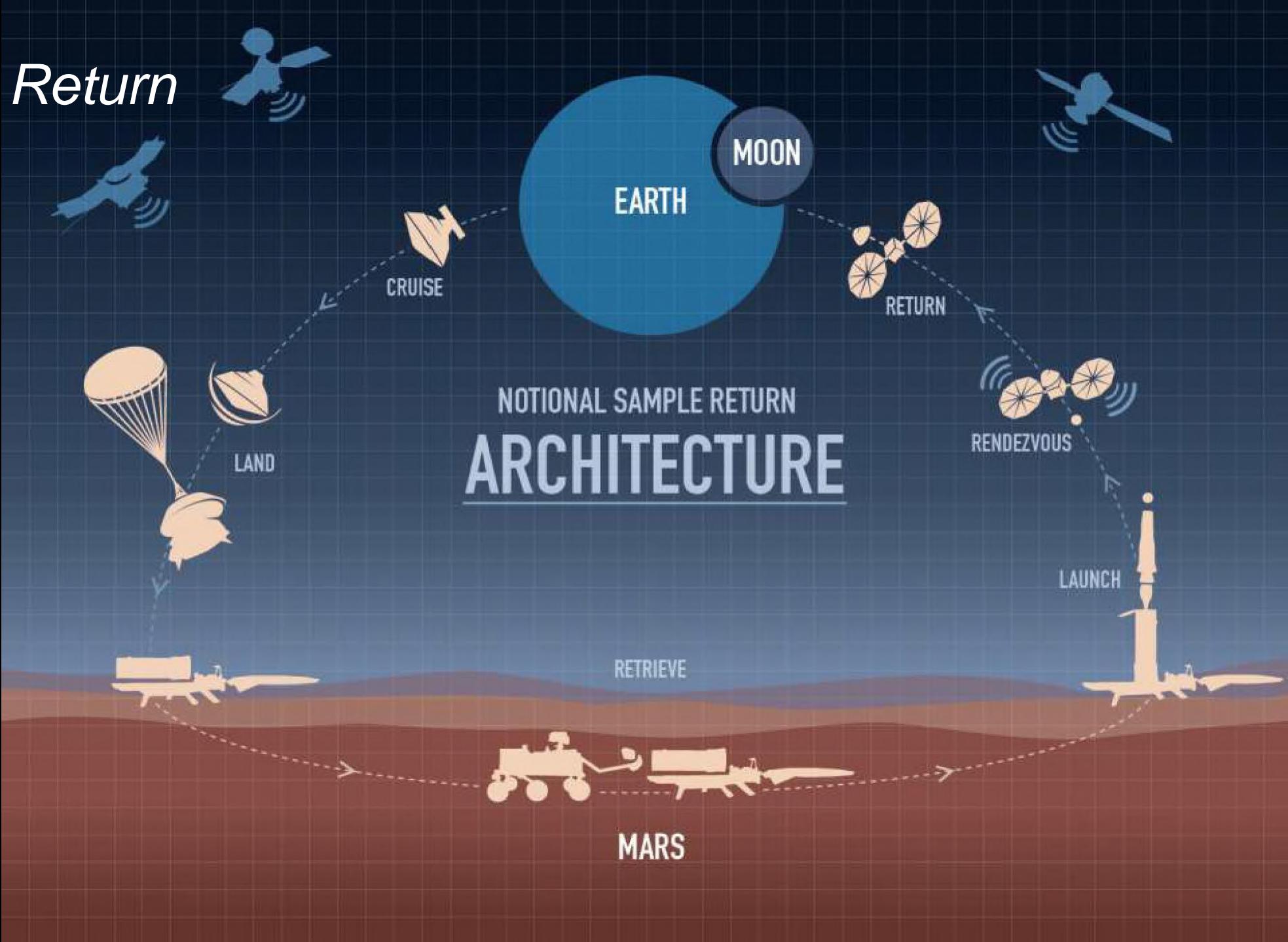


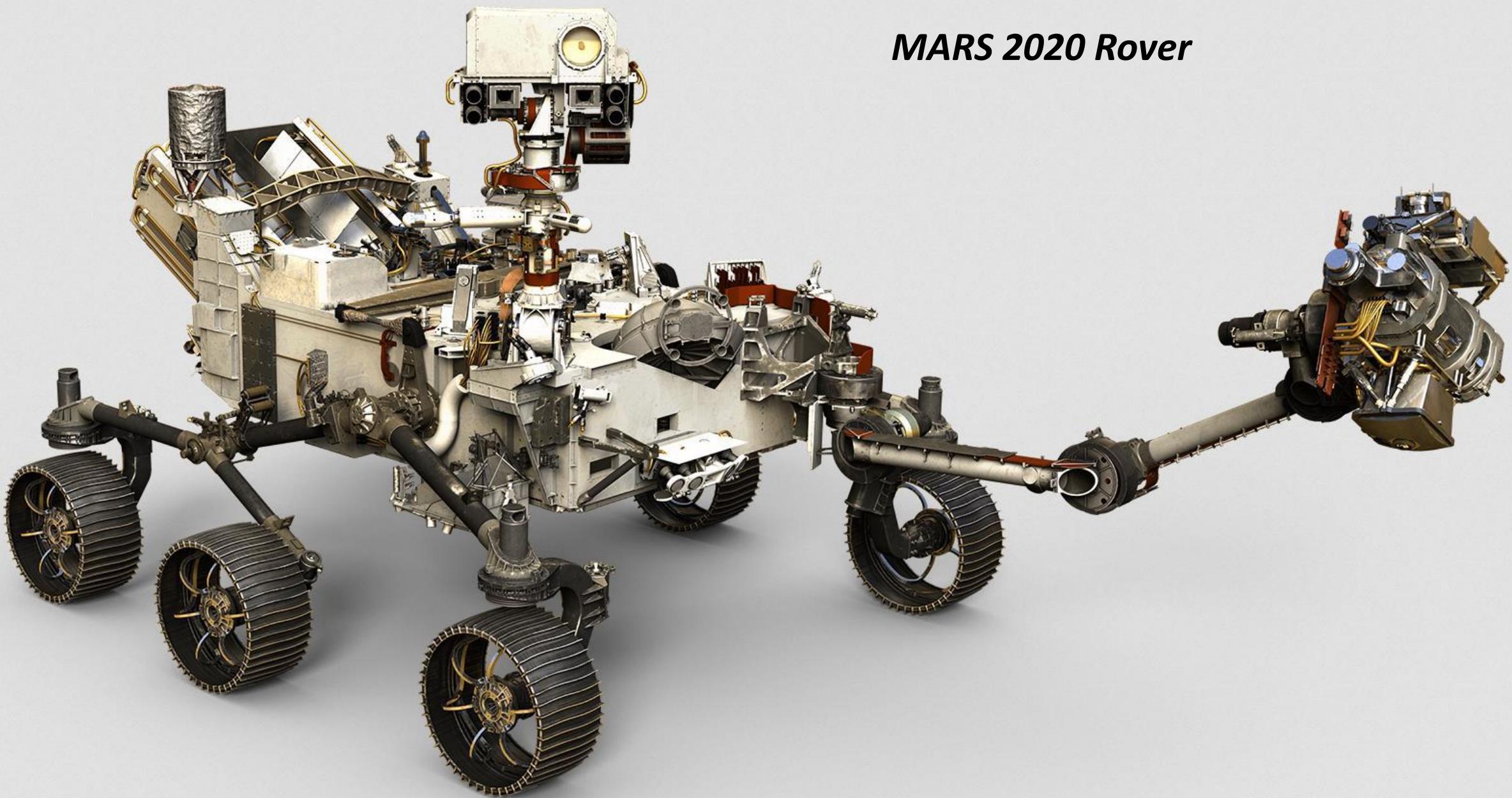
Moon: South Pole-Aitken Basin

Mars Exploration Program



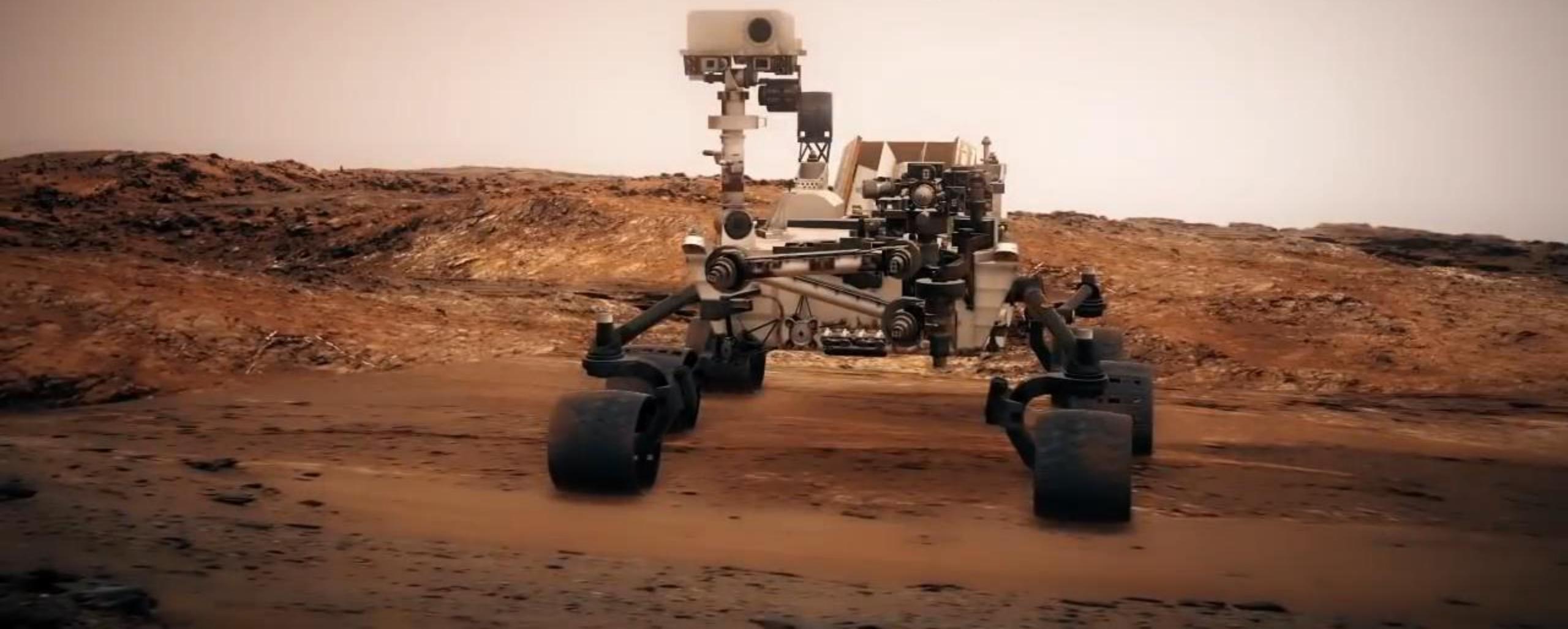
Mars Sample Return





MARS 2020 Rover

MARS HELICOPTER TECHNOLOGY DEMONSTRATION

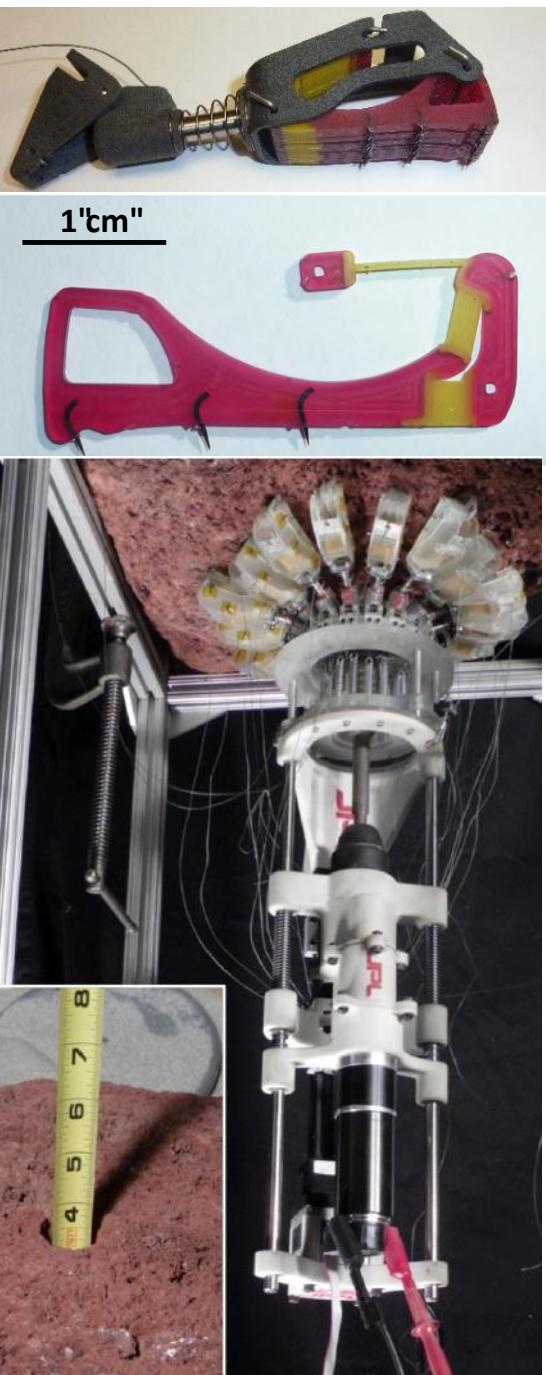
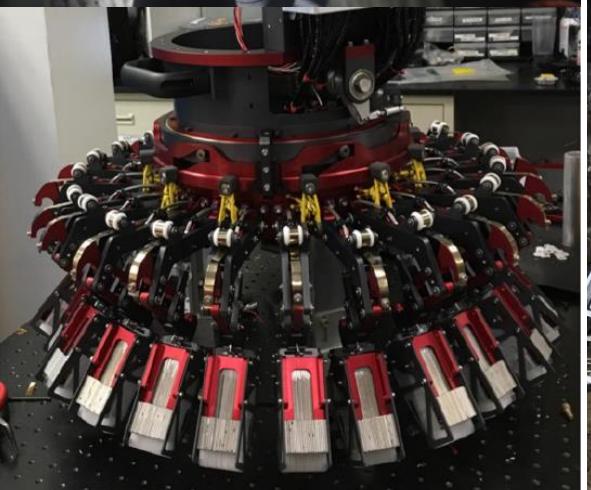


Surface Mobility 2: Untethered Steep Terrain Access

Lemur Climbing Robot

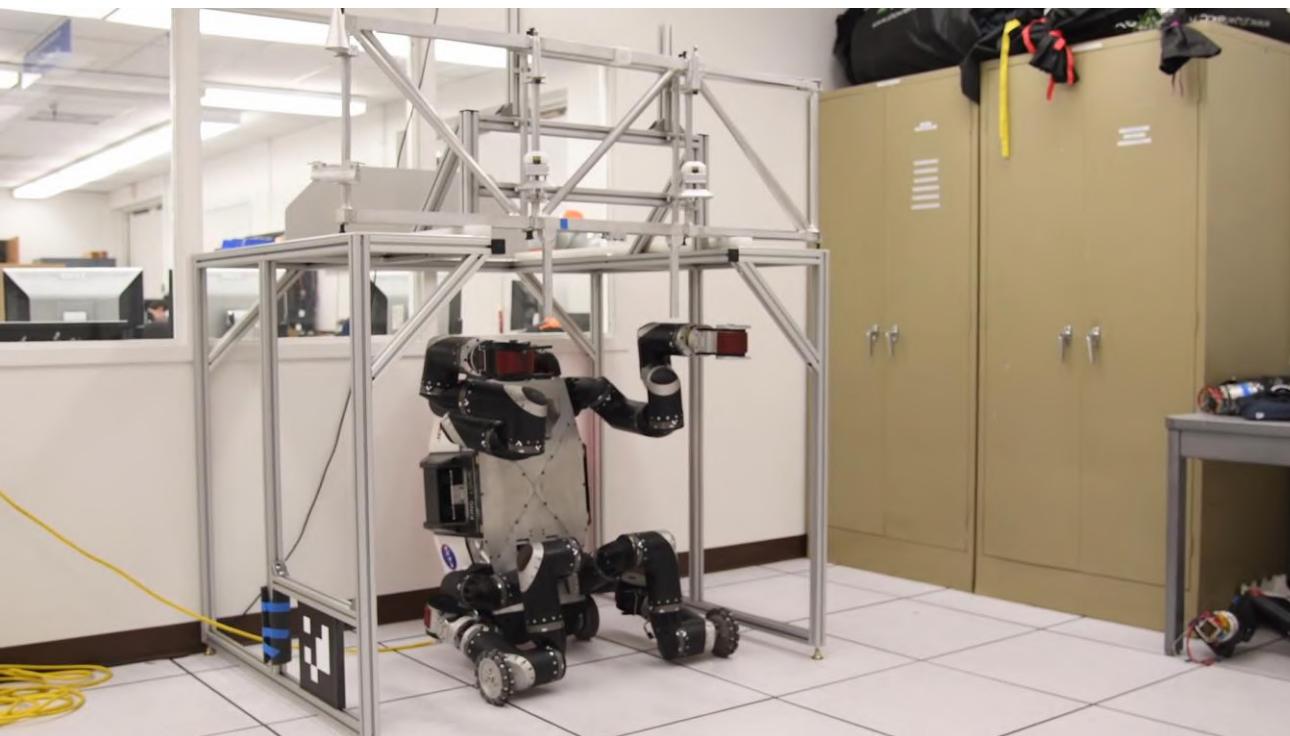
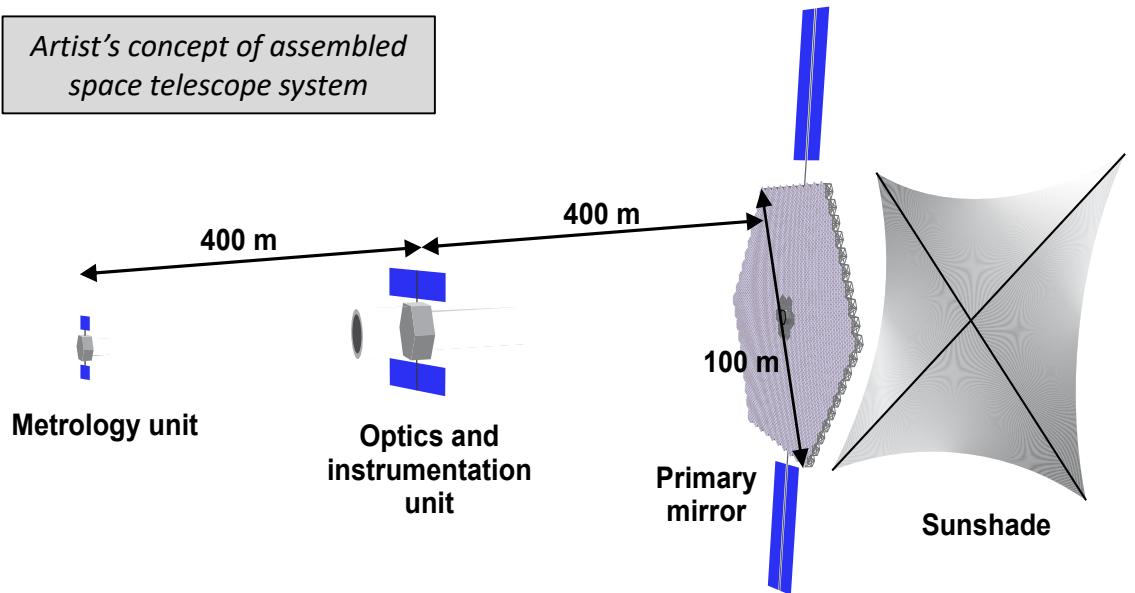
[PI: Aaron Parness]

- 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.



Predecisional information, for planning and discussion only.

Artist's concept of assembled space telescope system



Predecisional information, for planning and discussion only.

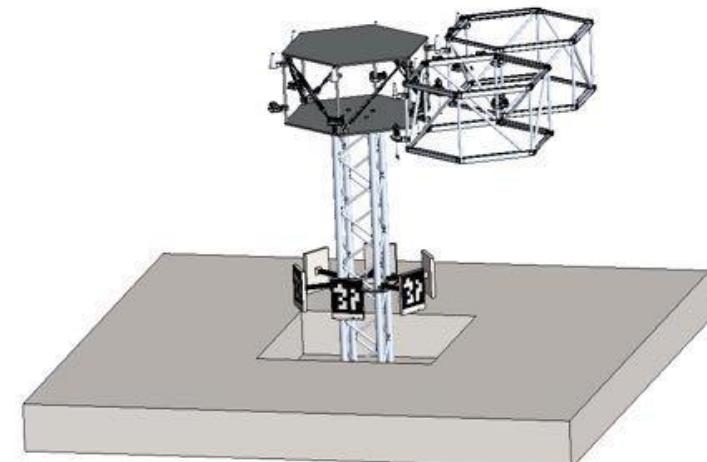
In-Space Applications Telescope Assembly

[PI: Rudra Mukherjee]

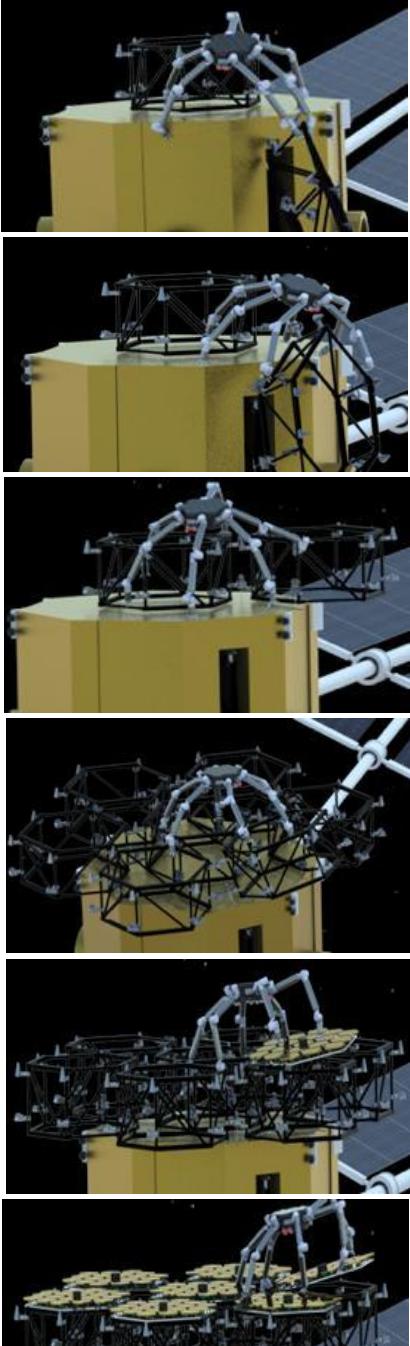
Developed and demonstrated prototype system for:

- 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 depiction of prototype demonstration set-up.

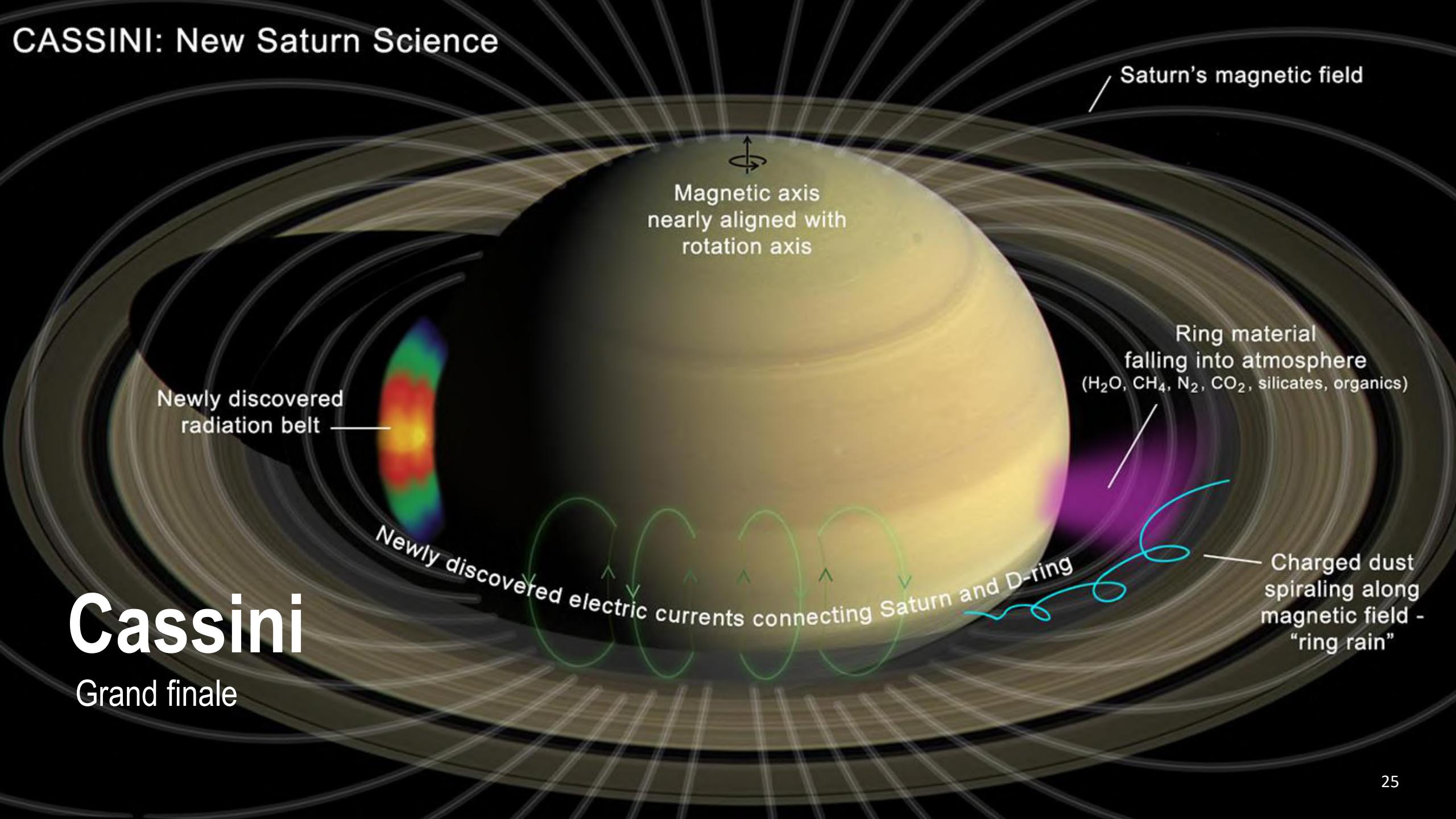


Artist's depiction of conceptual assembly process.



CASSINI: New Saturn Science

Cassini
Grand finale



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



Spectrum of Satellite Development

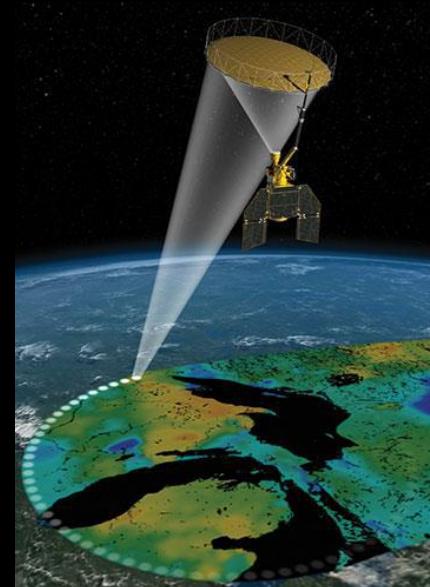
Small satellites are a growing component of space exploration



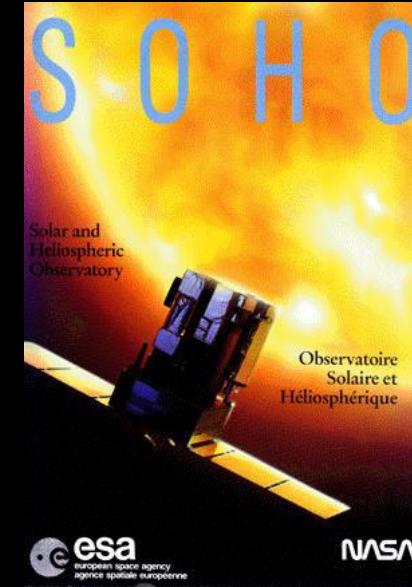
U-Class (CubeSat) / MicroSat



MiniSat / ESPA-Class



Medium-Class



Large-Class



Flagship-Class

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

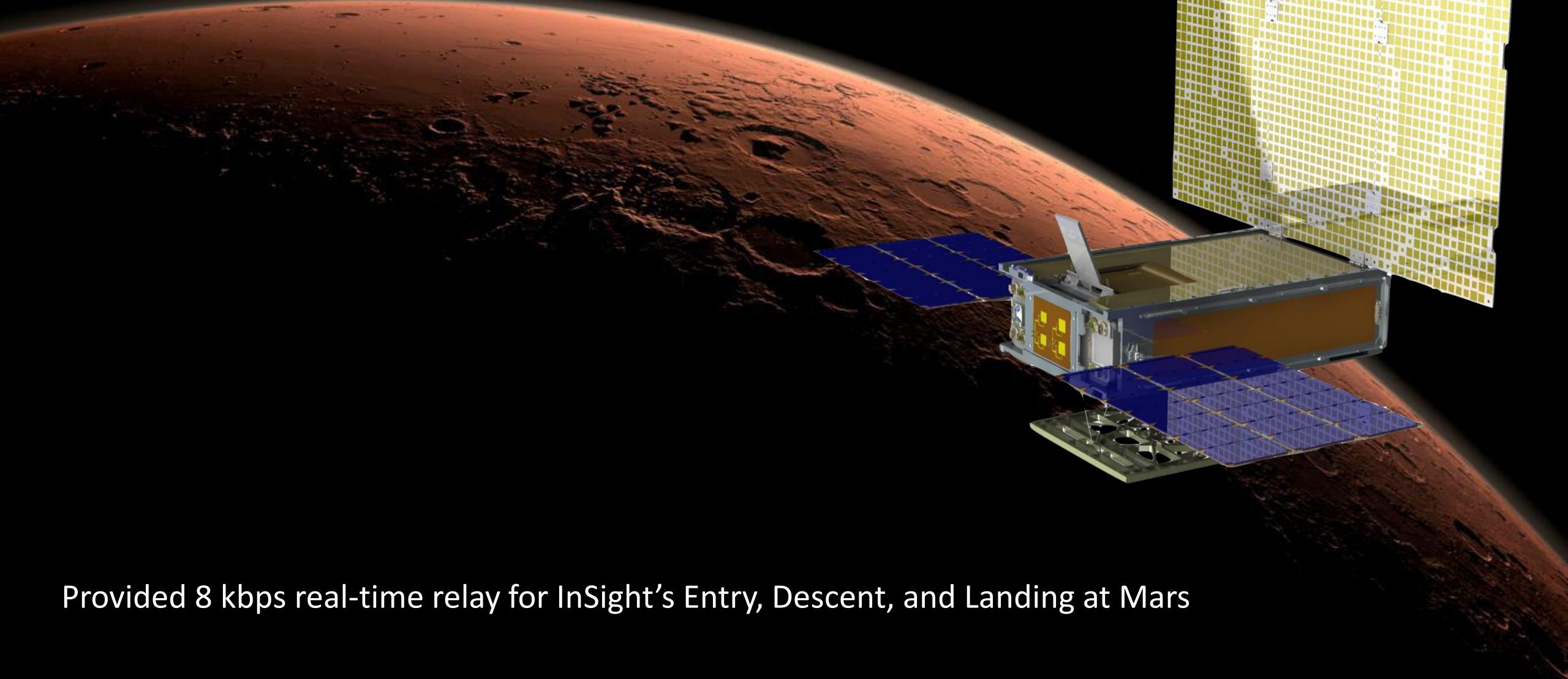
LCROSS
2 meters (linear)
585 kg (dry mass)
600 W
\$79 million (2009)

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

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

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

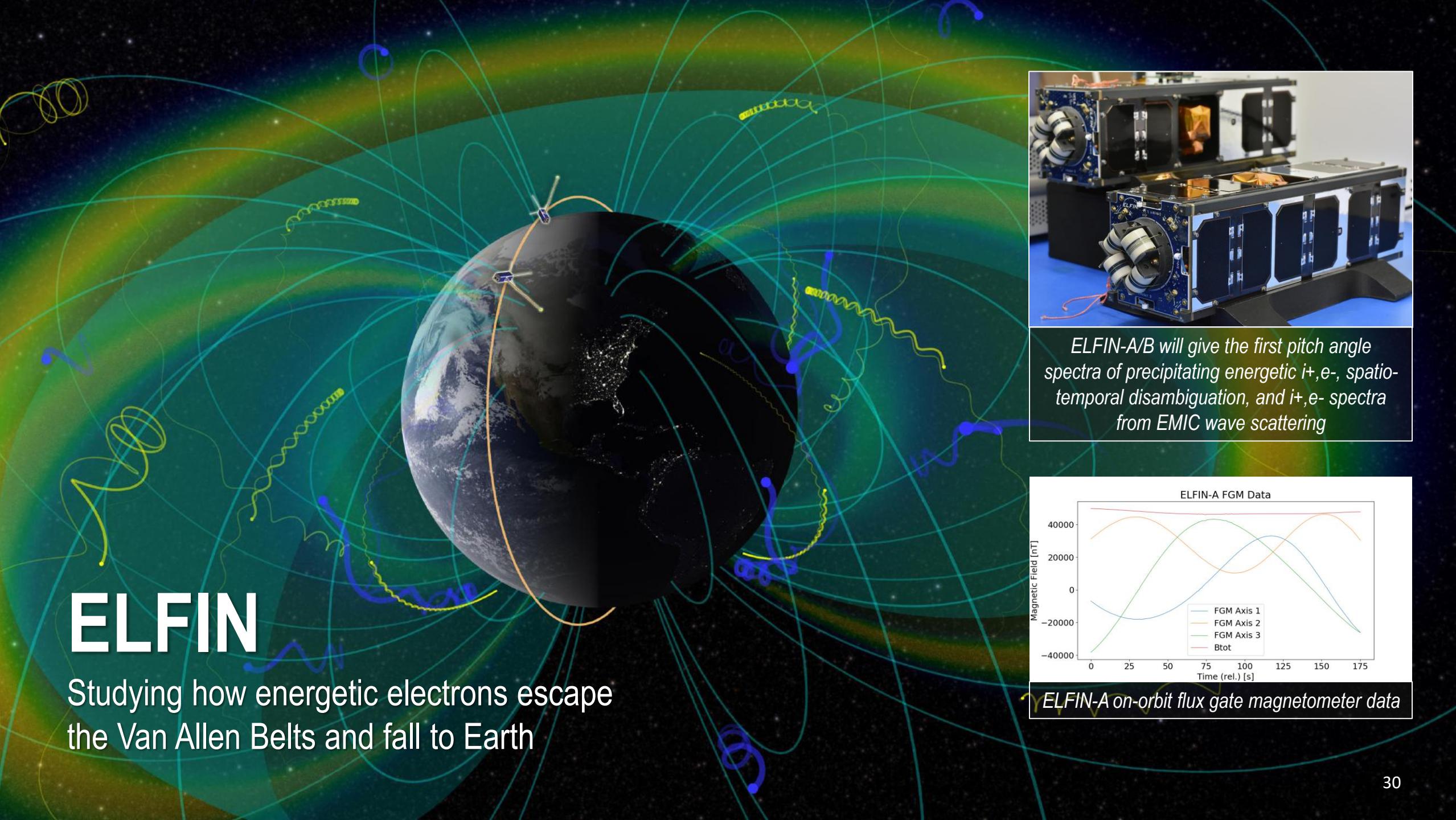
First Interplanetary CubeSat Mission



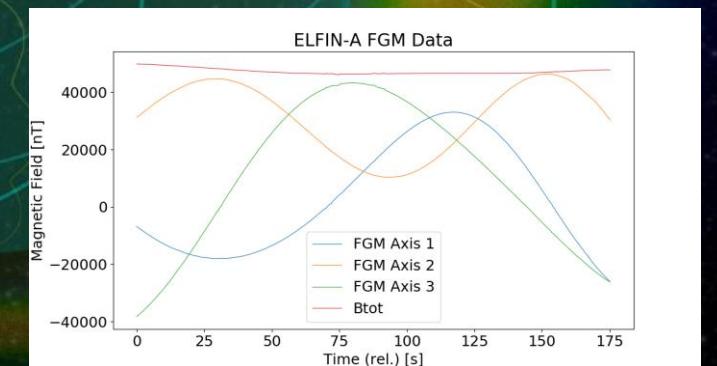
Jet Propulsion Laboratory
California Institute of Technology

ELFIN

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

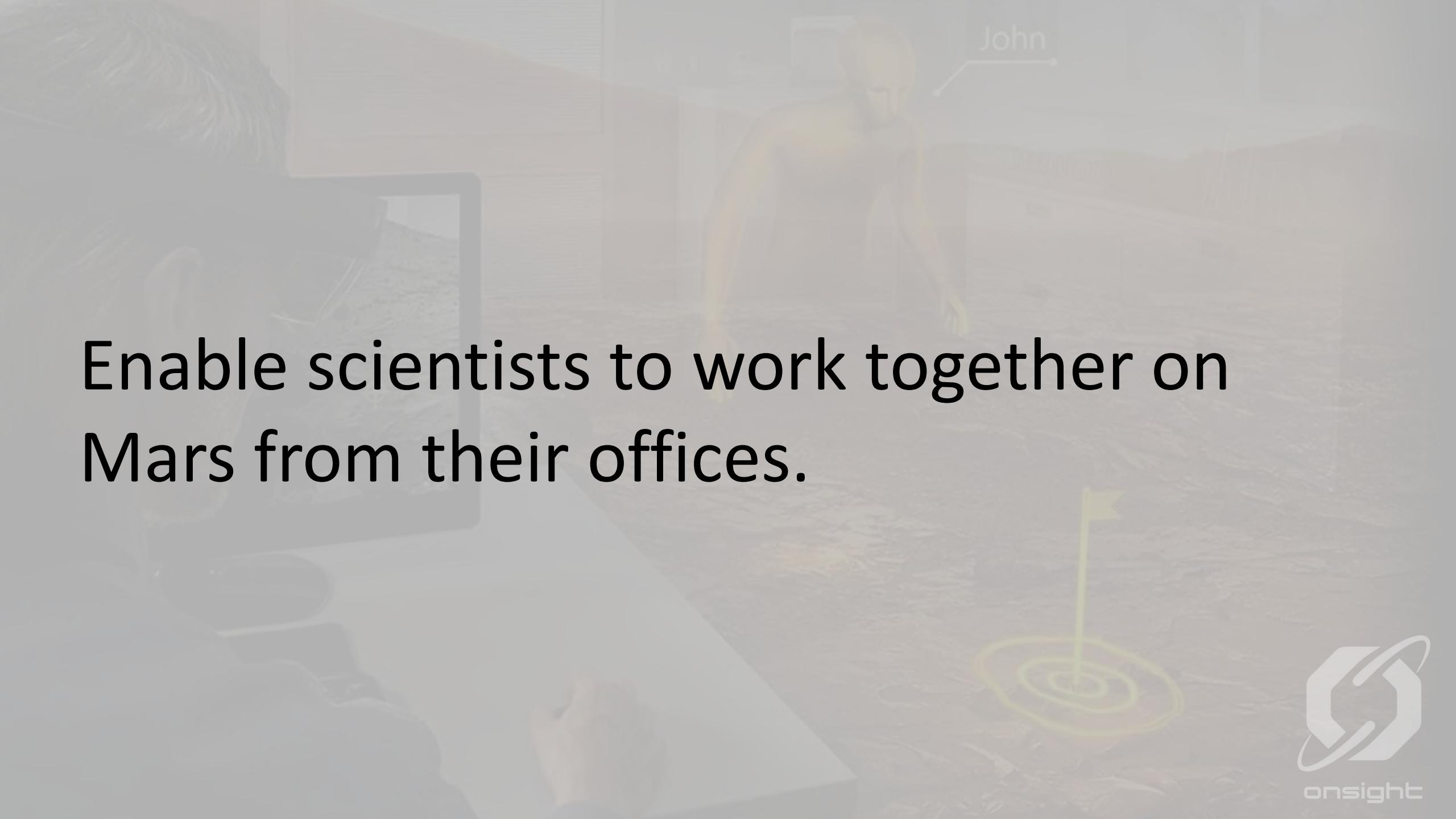


ELFIN-A/B will give the first pitch angle spectra of precipitating energetic i^+, e^- , spatio-temporal disambiguation, and i^+, e^- spectra from EMIC wave scattering



ELFIN-A on-orbit flux gate magnetometer data

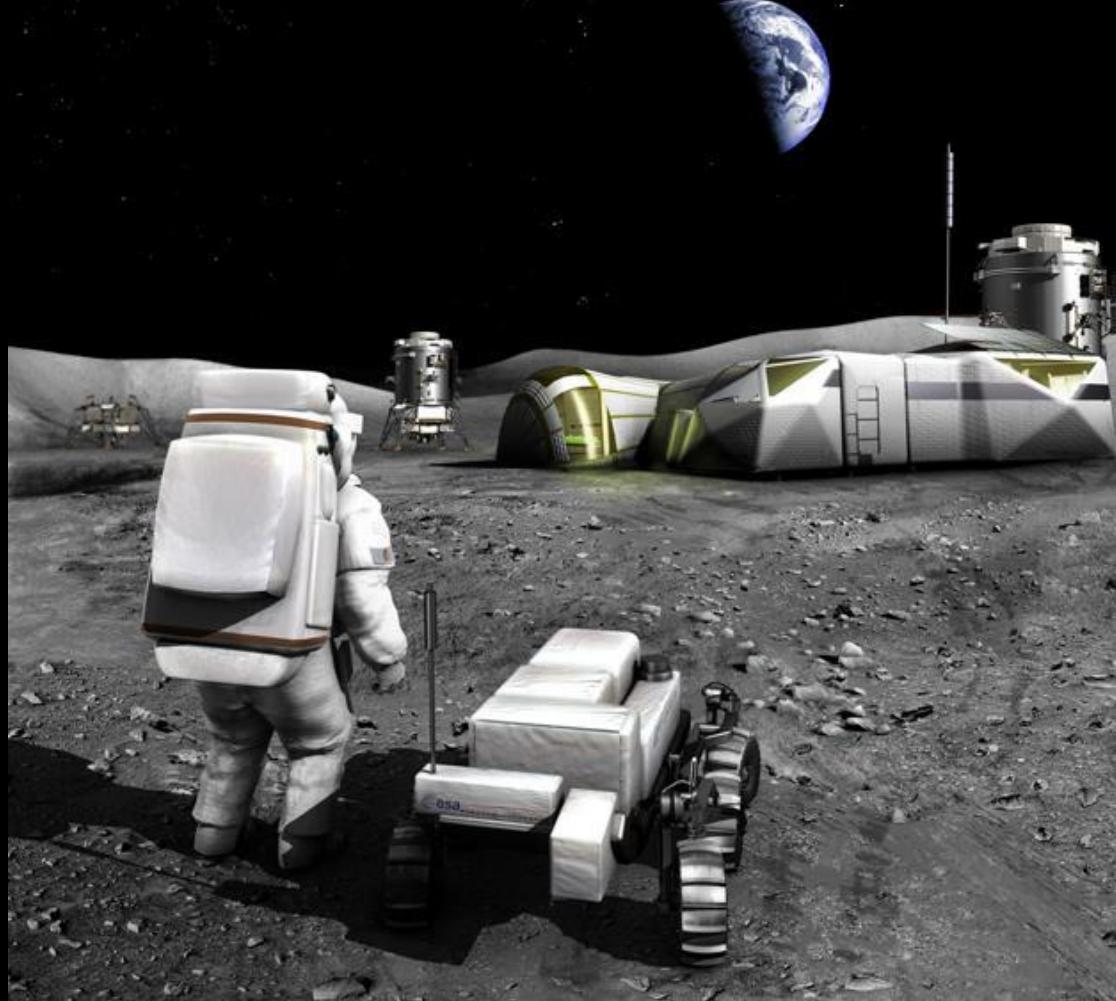


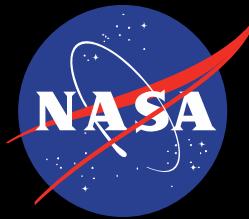
A grayscale photograph showing a group of people in a simulated Mars environment. In the foreground, a woman with long hair is looking at a tablet device. Behind her, another person is wearing a full-body spacesuit. A third person, labeled "John" with a yellow arrow, is standing further back. The background shows a vast, rocky landscape under a clear sky.

Enable scientists to work together on
Mars from their offices.



Thank you





JPL Caltech

Dare Mighty Things