



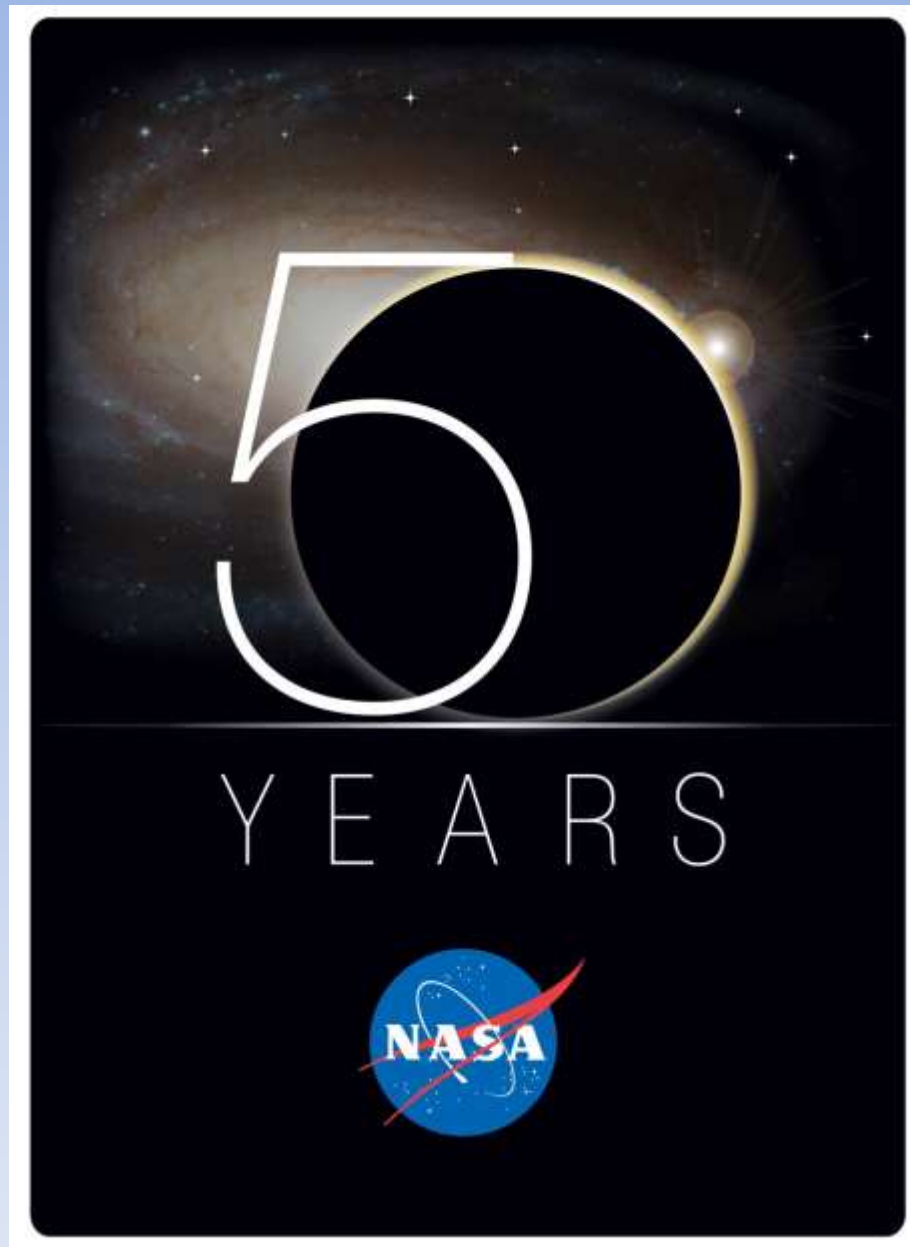
# **NASA and Future Human Exploration of the Solar System**

**Presentation to the  
AEE NORTHERN OH CHAPTER**

**Bryan Palaszewski  
NASA Glenn Research Center  
Cleveland, OH  
12/6/18**

# Introduction

- **Why space flight?**
- **The Space Act and Technology Development.**
- **Human exploration of space (in the past).**
- **Transitions.**
- **New Space Launch System.**
- **Robotic Mars Exploration.**
- **Pluto and New Horizons.**
- **Concluding remarks.**





# **Why Space Flight?**

## **The National Aeronautics and Space Act (1958)**

- **(1) The expansion of human knowledge of the Earth and of phenomena in the atmosphere and space;**
- **(2) The improvement of the usefulness, performance, speed, safety, and efficiency of aeronautical and space vehicles;**
- **(3) The development and operation of vehicles capable of carrying instruments, equipment, supplies, and living organisms through space;**
- **(4) The establishment of long-range studies of the potential benefits to be gained from, the opportunities for, and the problems involved in the utilization of aeronautical and space activities for peaceful and scientific purposes;**
- **(5) The preservation of the role of the United States as a leader in aeronautical and space science and technology and in the application thereof to the conduct of peaceful activities within and outside the atmosphere;**

# **Why Space Flight?**

## **The National Aeronautics and Space Act (1958)**

- **(6) The making available to agencies directly concerned with national defense of discoveries that have military value or significance, and the furnishing by such agencies, to the civilian agency established to direct and control nonmilitary aeronautical and space activities, of information as to discoveries which have value or significance to that agency;**
- **(7) Cooperation by the United States with other nations and groups of nations in work done pursuant to this Act and in the peaceful application of the results thereof;**
- **(8) The most effective utilization of the scientific and engineering resources of the United States, with close cooperation among all interested agencies of the United States in order to avoid unnecessary duplication of effort, facilities, and equipment; and**
- **(9) The preservation of the United States preeminent position in aeronautics and space through research and technology development related to associated manufacturing processes.**



APOLLO

4

YEARS

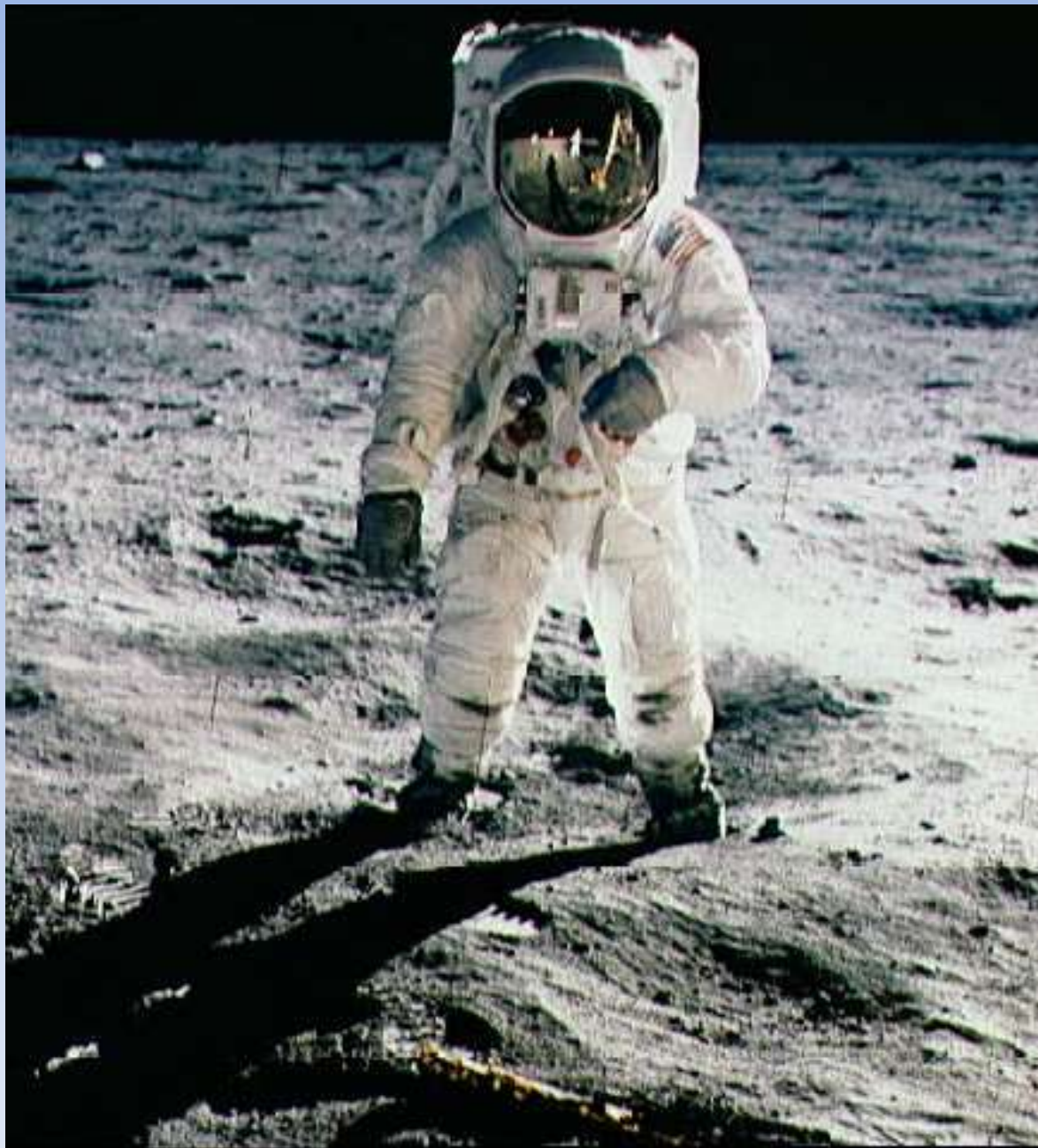
The logo features the word "APOLLO" in a stylized, white, sans-serif font. The letter "O" is replaced by a circular image of the Moon, and the final "O" is replaced by a circular image of the planet Mars. A white swoosh underline passes through the center of the "O"s. Below "APOLLO" is the number "50" in a large, white, sans-serif font. To the right of "50" is the text "NEXT GIANT LEAP" in a smaller, white, sans-serif font. The entire logo is set against a dark blue space background with numerous white stars and a nebula-like glow.

NEXT GIANT LEAP









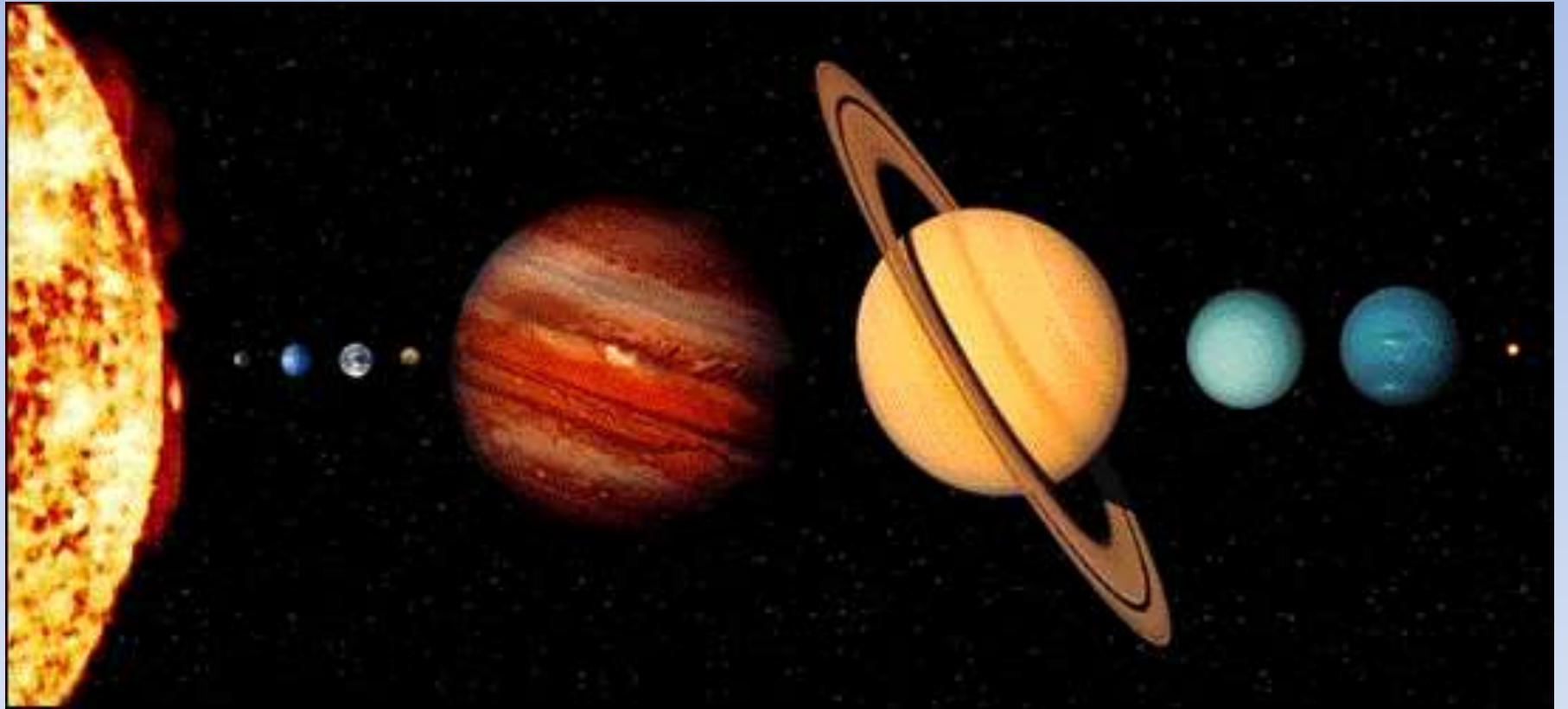


*NASA Remembers*  
**Neil Armstrong**



**1930 - 2012**

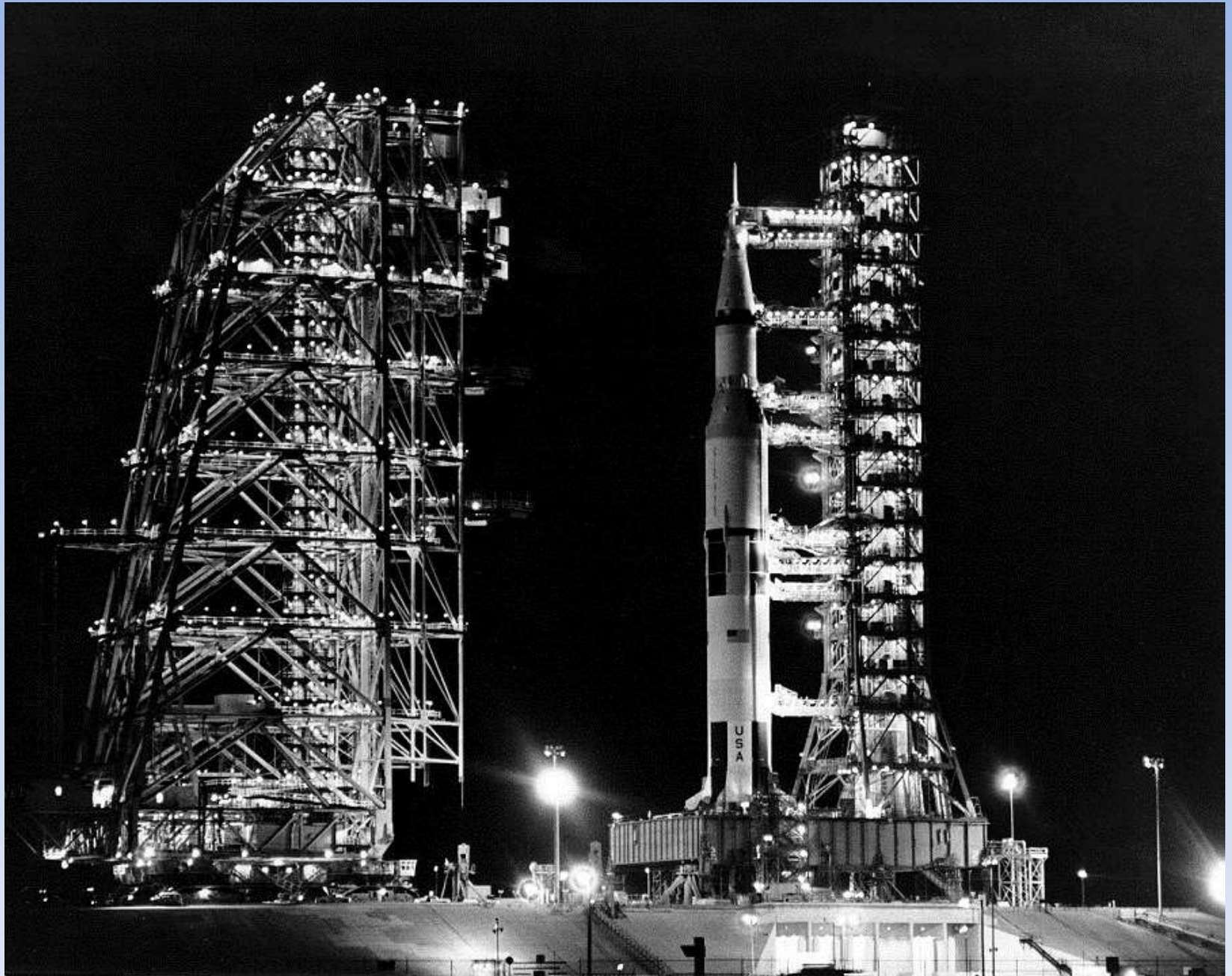




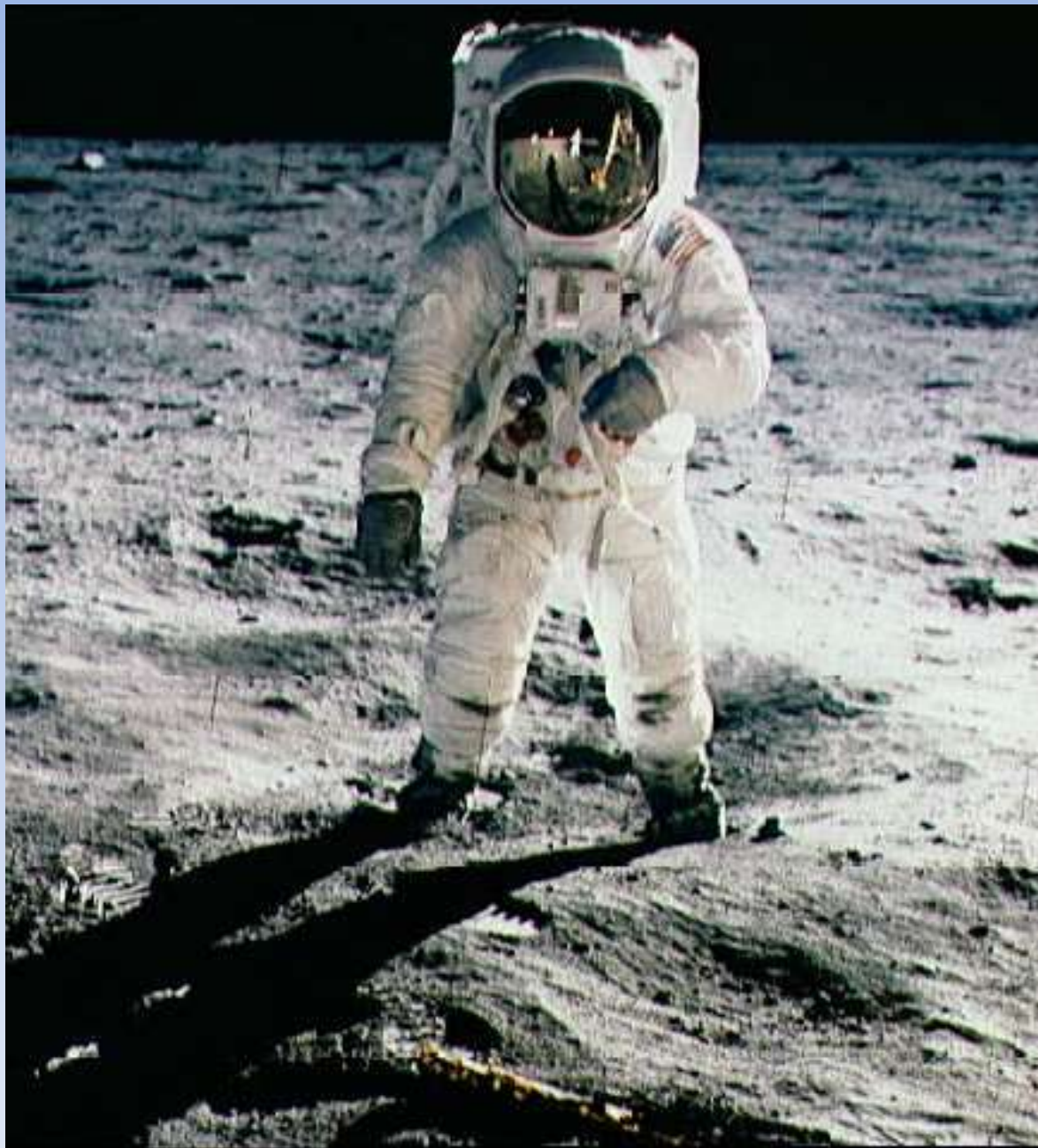


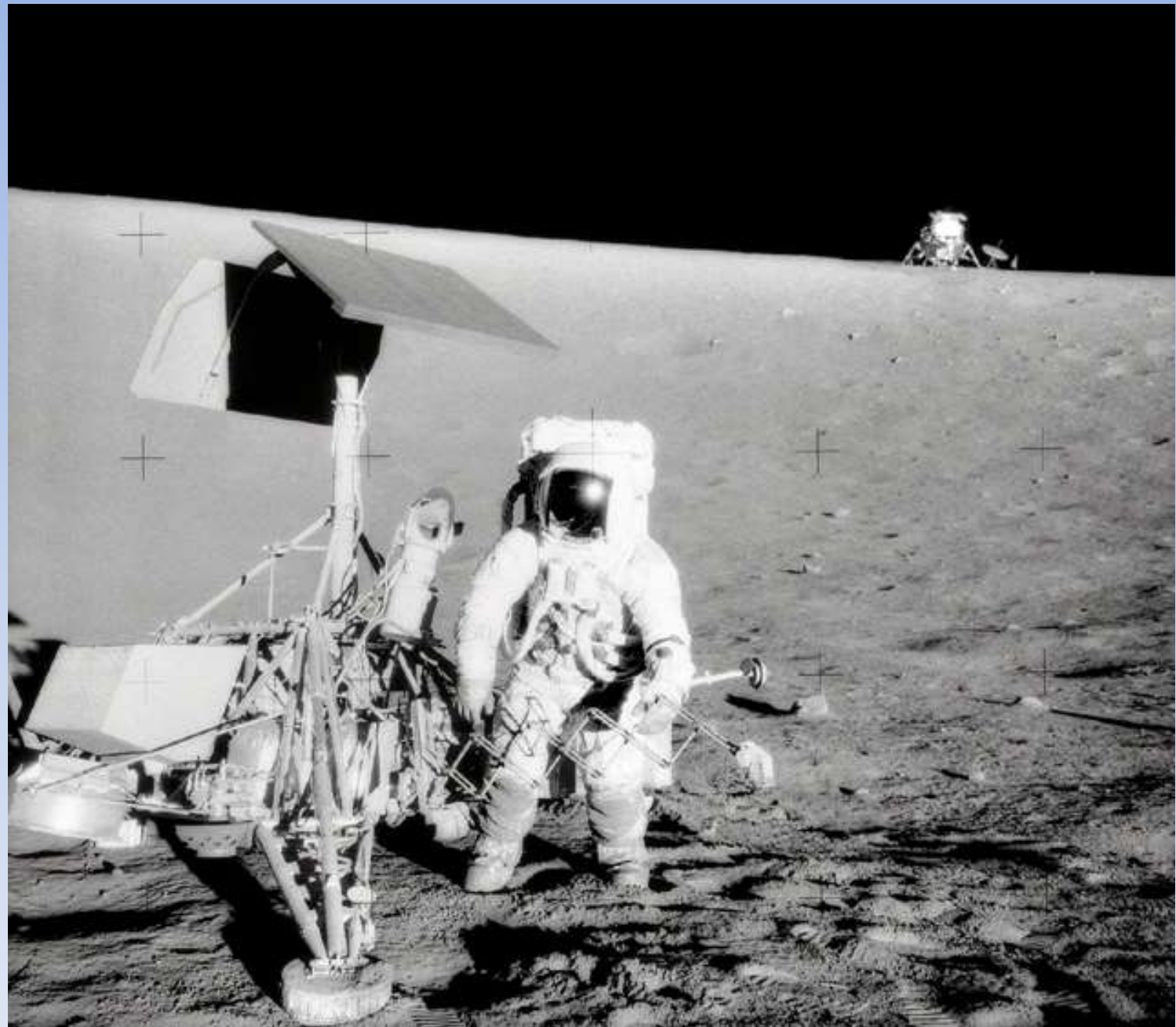


























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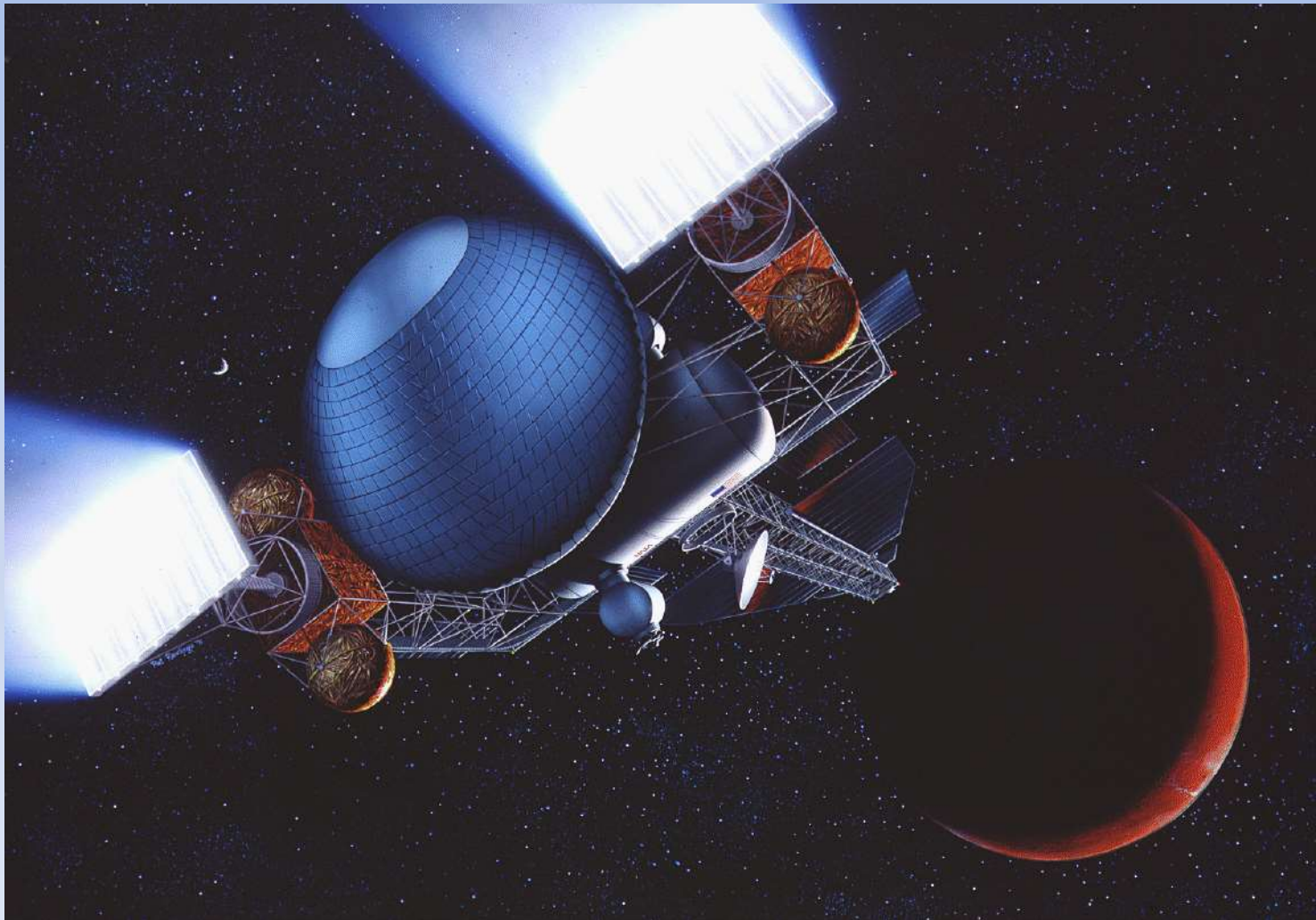


ISS021E032749

# Nuclear Thermal Rocket For Piloted Mars- Asteroid Missions



# Nuclear Electric Propulsion for Piloted Mars - Asteroid Missions



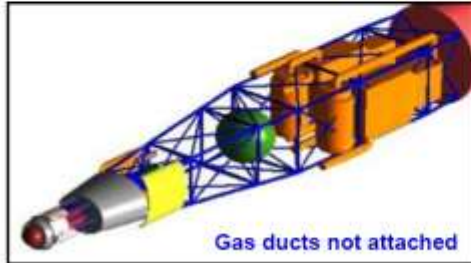


# JUPITER ICY MOONS ORBITER

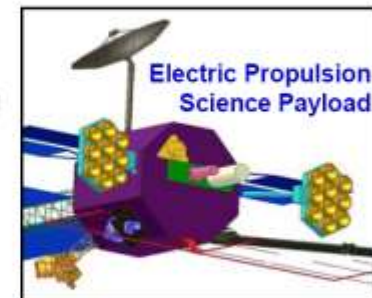
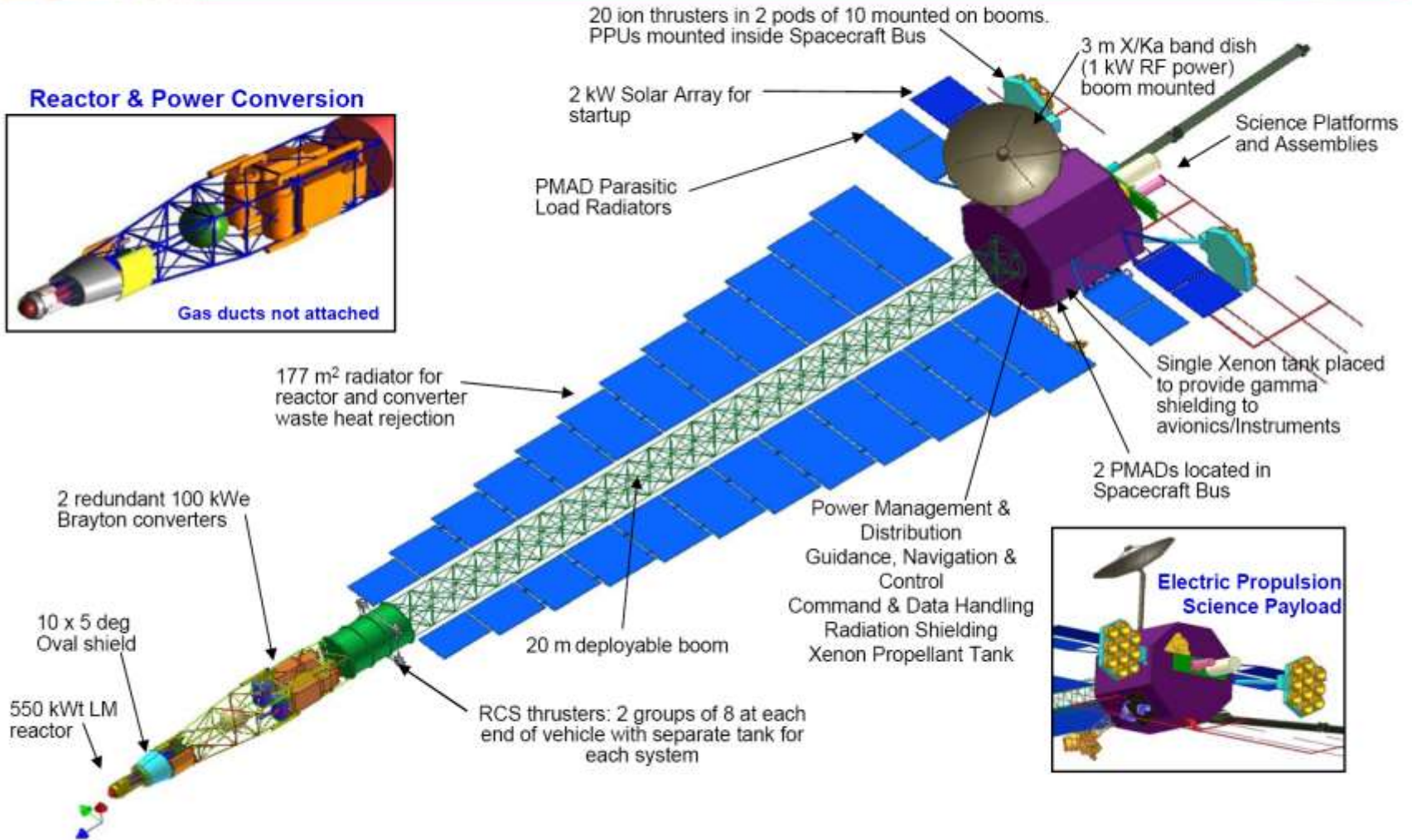
(An element of Project Prometheus)

## Preliminary Government Study Configuration

### Reactor & Power Conversion

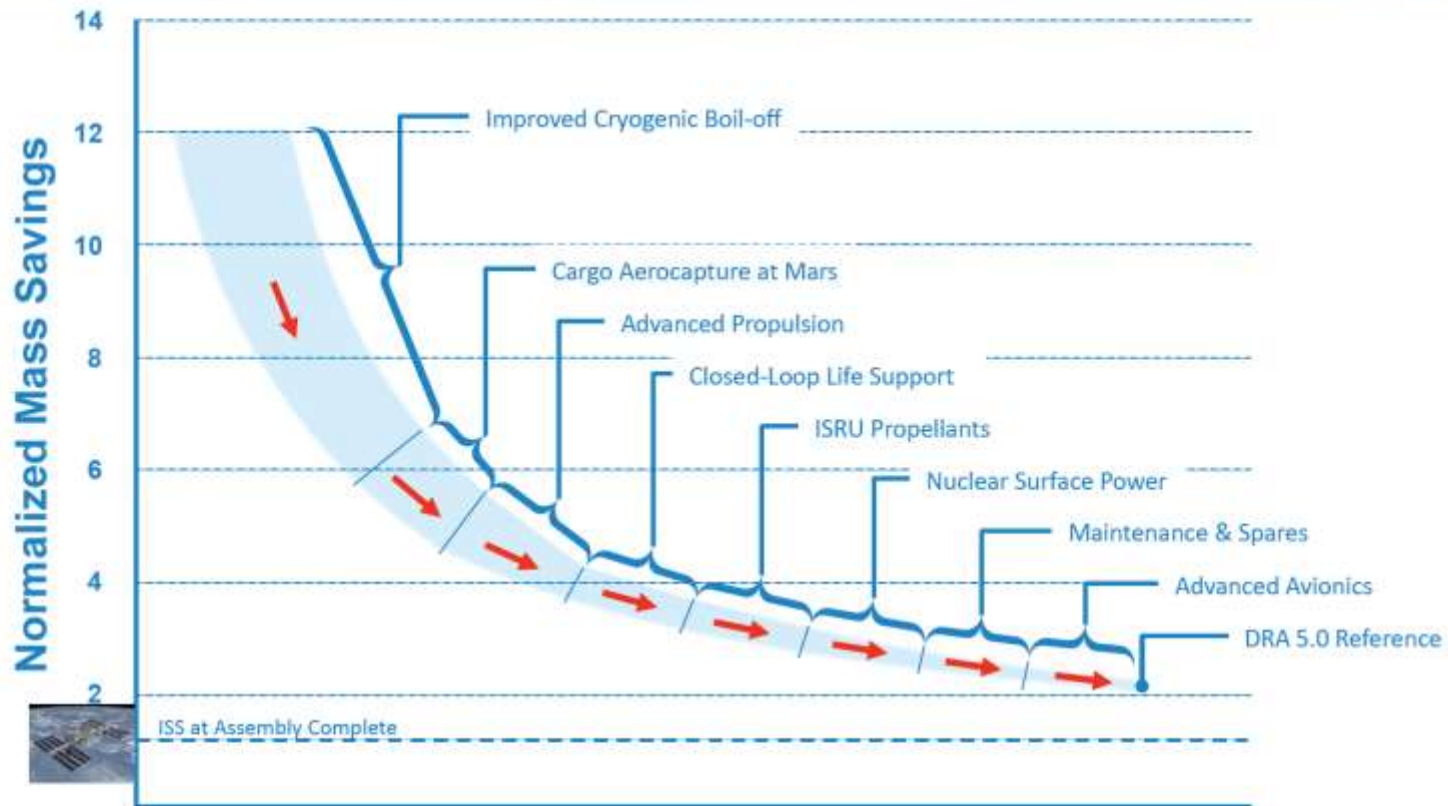


Gas ducts not attached



Electric Propulsion Science Payload

# The Value of Technology Investments Mars Mission Example



- Without technology investments, the mass required to initiate a human Mars mission in LEO is approximately twelve times the mass of the International Space Station (ISS)
- Technology investments of the type proposed in the FY2011 budget request are required to put such a mission within reach







# A New Rocket to Rival Saturn V

NASA plans to use the Space Launch System (SLS) to launch astronauts and heavy payloads into Earth orbit and beyond.



**CREW MODULE** (above) is larger than the Apollo Command Module developed in the 1960s

## Orion Multi-Purpose Crew Vehicle (MPCV)

**ESCAPE TOWER** fires to jettison the capsule away from the booster in the event of an emergency during launch

**CREW MODULE** holds four astronauts

**HERMAN TRACKS**

**SERVICE MODULE** carries fuel, solar power panels and equipment

**CORE STAGE** has the same diameter as the space shuttle's external tank. Its five RS-25D/E engines — modified versions of the shuttle's main engines — are fueled by liquid hydrogen and liquid oxygen

**STRAP-ON BOOSTERS** are similar to the shuttle's boosters, but are longer because they have additional solid fuel aboard

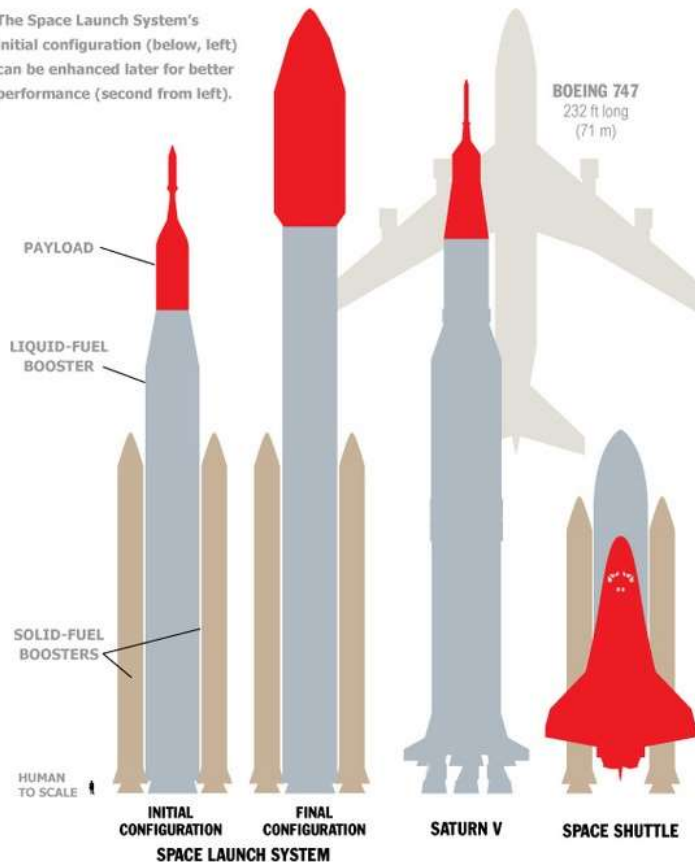
At liftoff, SLS fires its five liquid-fueled main engines and two solid-fueled boosters

An advanced version of the SLS would include an additional **UPPER STAGE** with a single J-3X engine derived from engines used on the Saturn V moon rocket. The engine burns liquid hydrogen and liquid oxygen



# How SLS Stacks Up Against Other Rockets

The Space Launch System's initial configuration (below, left) can be enhanced later for better performance (second from left).



	INITIAL CONFIGURATION	FINAL CONFIGURATION	SATURN V	SPACE SHUTTLE
Country	United States	United States	United States	United States
Years of operation	first launch planned for 2017	to be determined	1967-1973	1981-2011
Destinations	Earth orbit, deep space	Earth orbit, deep space, asteroids, moon, Mars	Earth orbit, moon	Earth orbit
Fuel type	solid fuel, LH2/LOX	solid fuel, LH2/LOX	kerosine, LH2/LOX	solid fuel, LH2/LOX
Height	320 ft (97.5 m)	400 ft (122 m)	363 ft (110 m)	184 ft (56.1 m)
Lift capability	70-77 metric tons	up to 130 metric tons	130 metric tons	24.4 metric tons
Thrust	8.4 million lbs (3.8 million kg)	9.2 million lbs (4.2 million kg)	7.5 million lbs (3.4 million kg)	7.8 million lbs (3.54 million kg)

LH2 = liquid hydrogen fuel  
 LOX = liquid oxygen oxidizer  
 Solid fuel = aluminum perchlorate composite mixture

SOURCES: NASA, LOCKHEED MARTIN

KARL TATE / © SPACE.com

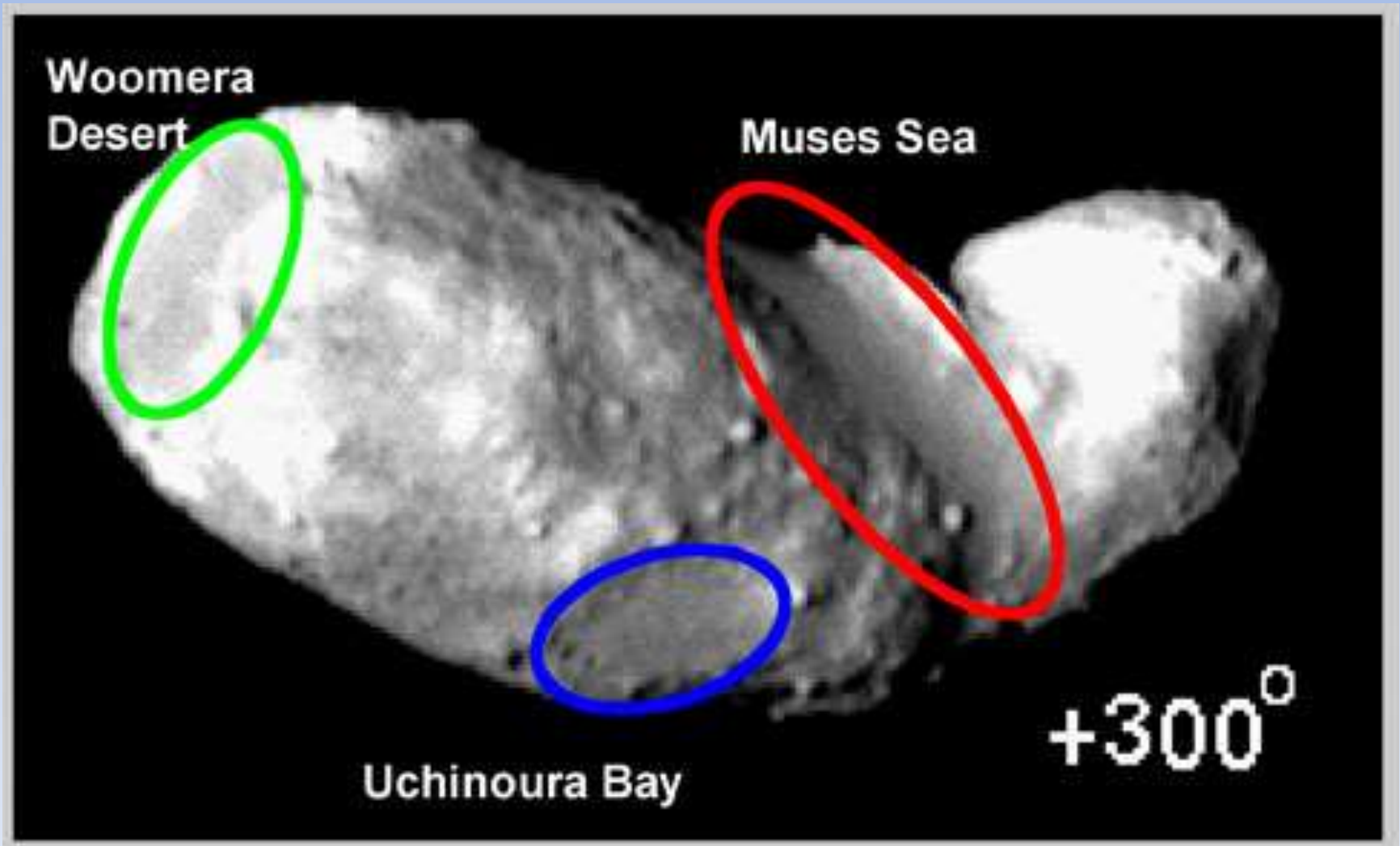
# Hayabusa Visiting Asteroid Itokawa



# Hayabusa Visiting Asteroid Itokawa



# Hayabusa Visiting Asteroid Itokawa



# Hayabusa 2 Visiting Asteroid Ryugu



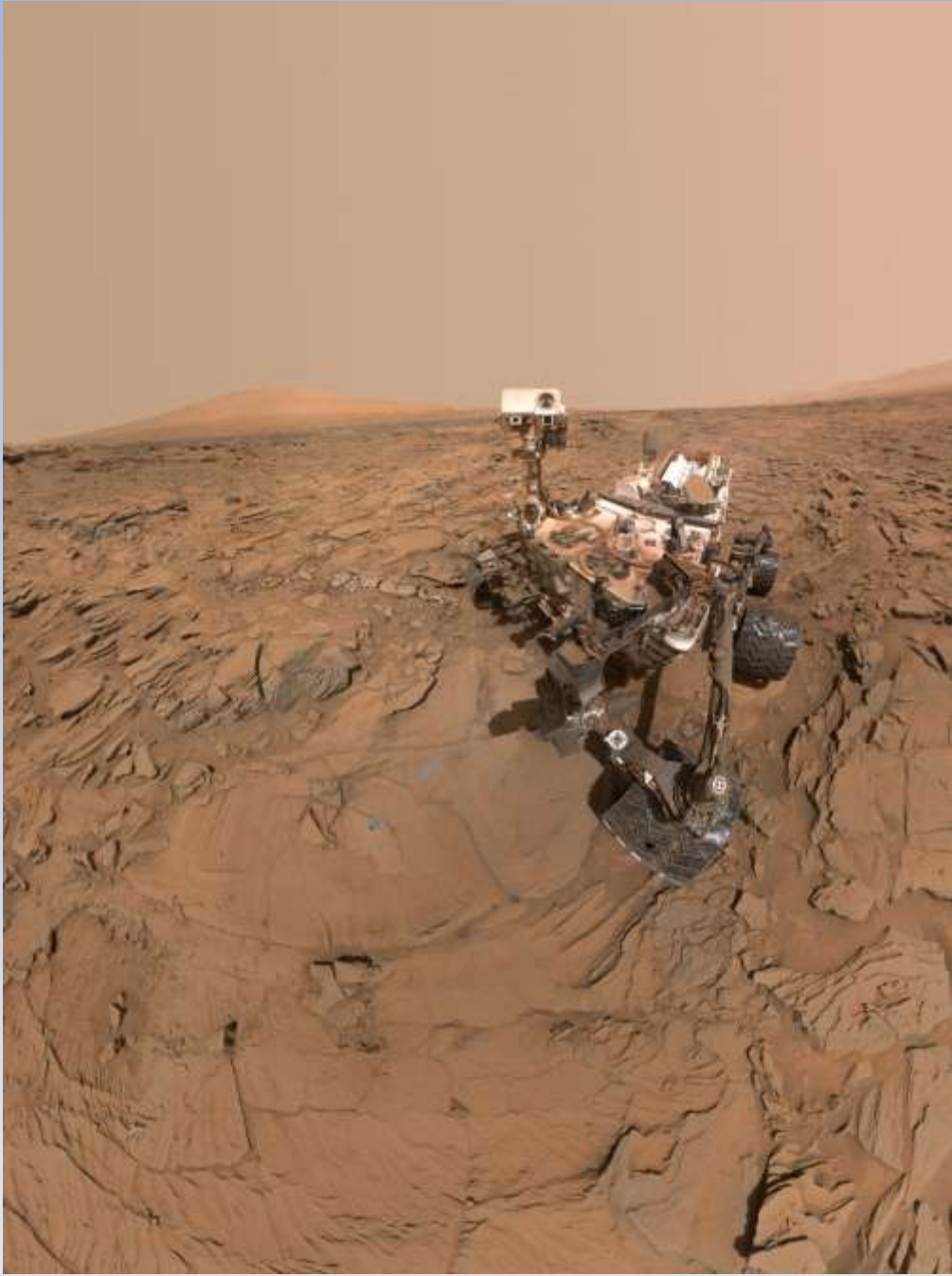




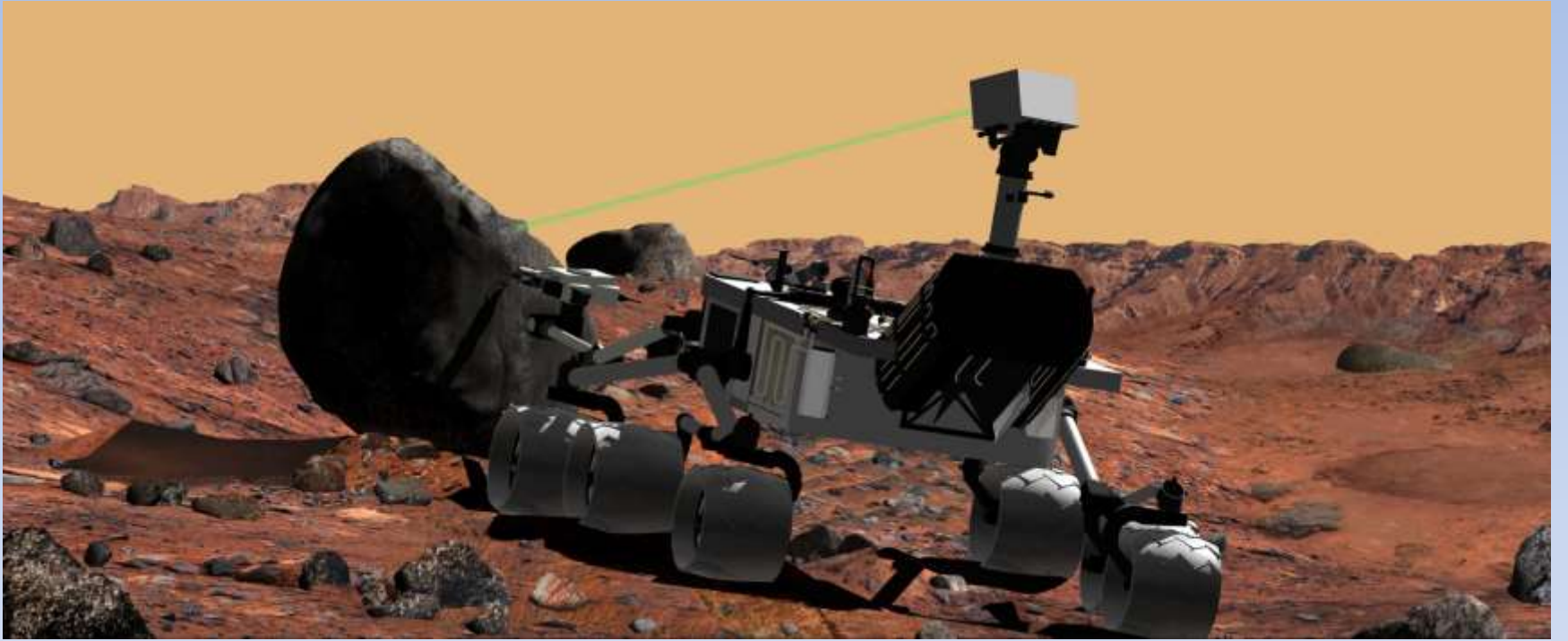
# Economic Analysis of 2-km M-Class Metal Rich Asteroid

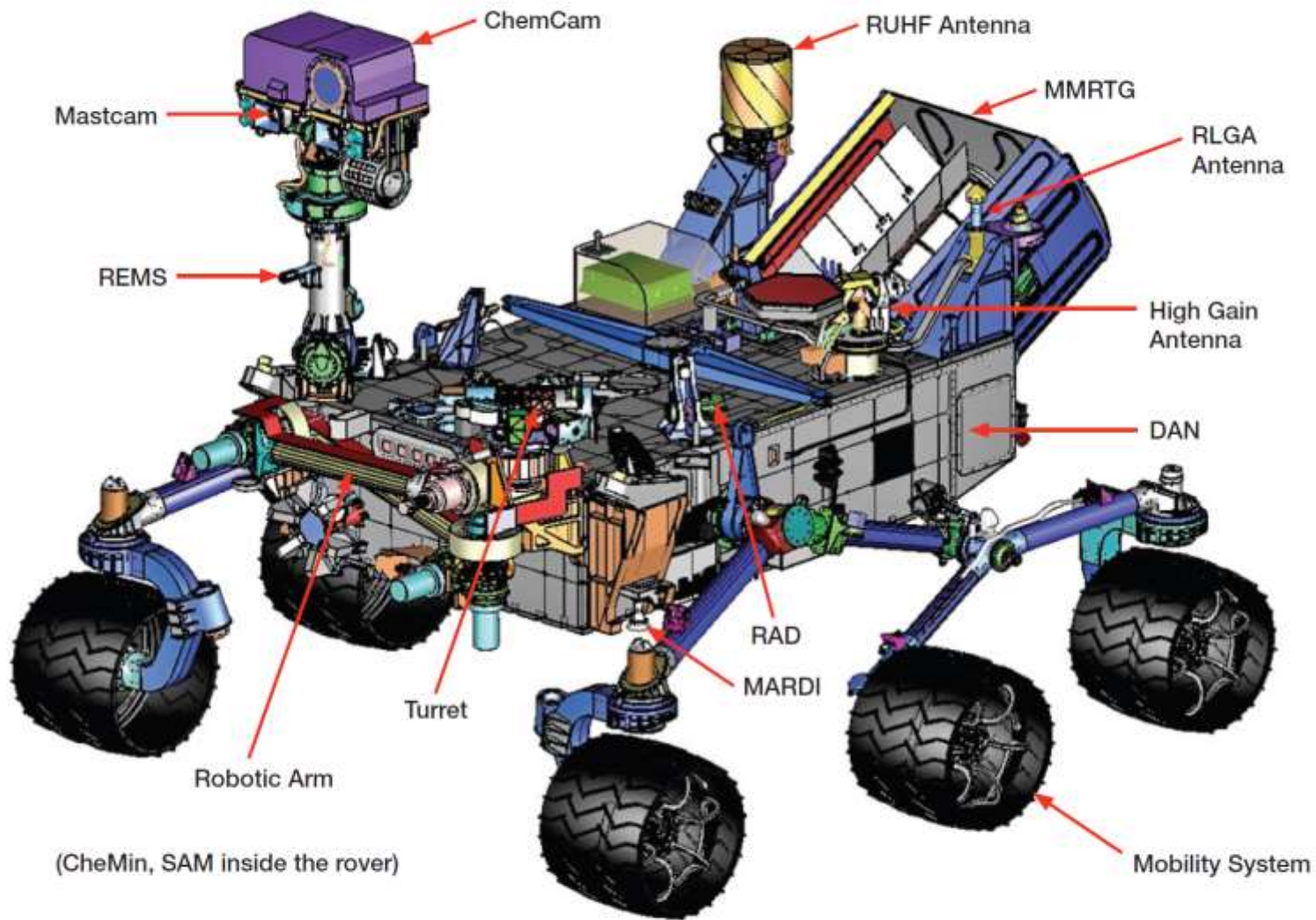
Component	Fraction of metal by mass	Mass	Estimated value (\$/kg)	Estimated dollar value (\$ trillions)
Iron	0.89	$2.7 \times 10^{13}$	0.1	3
Nickel	0.10	$3.0 \times 10^{12}$	3	9
Cobalt	0.005	$1.5 \times 10^{11}$	25	4
Platinum-group metals	15 ppm	$4.5 \times 10^8$	20,000	9
Total value				25

# **Mars Science Laboratory**



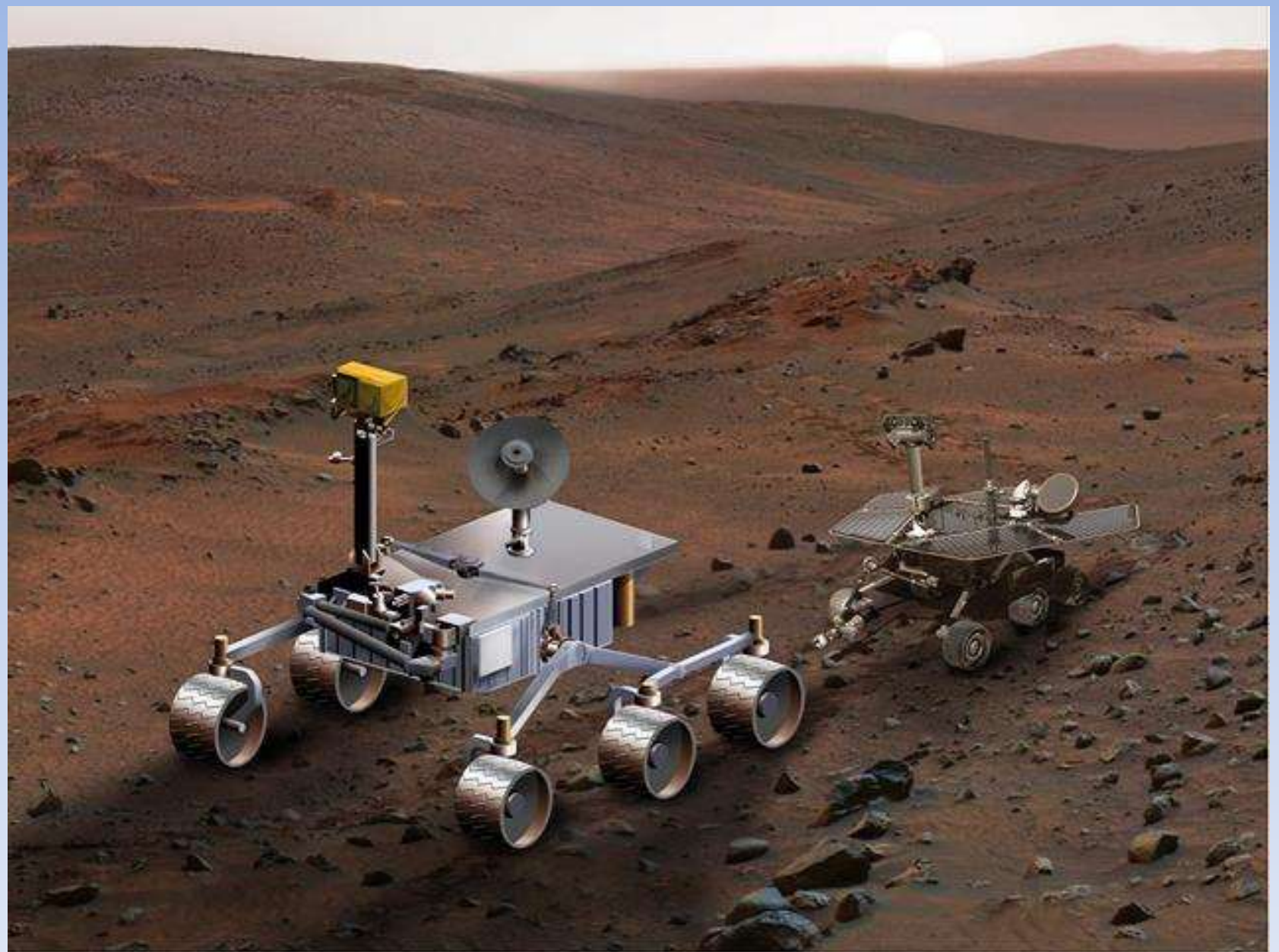




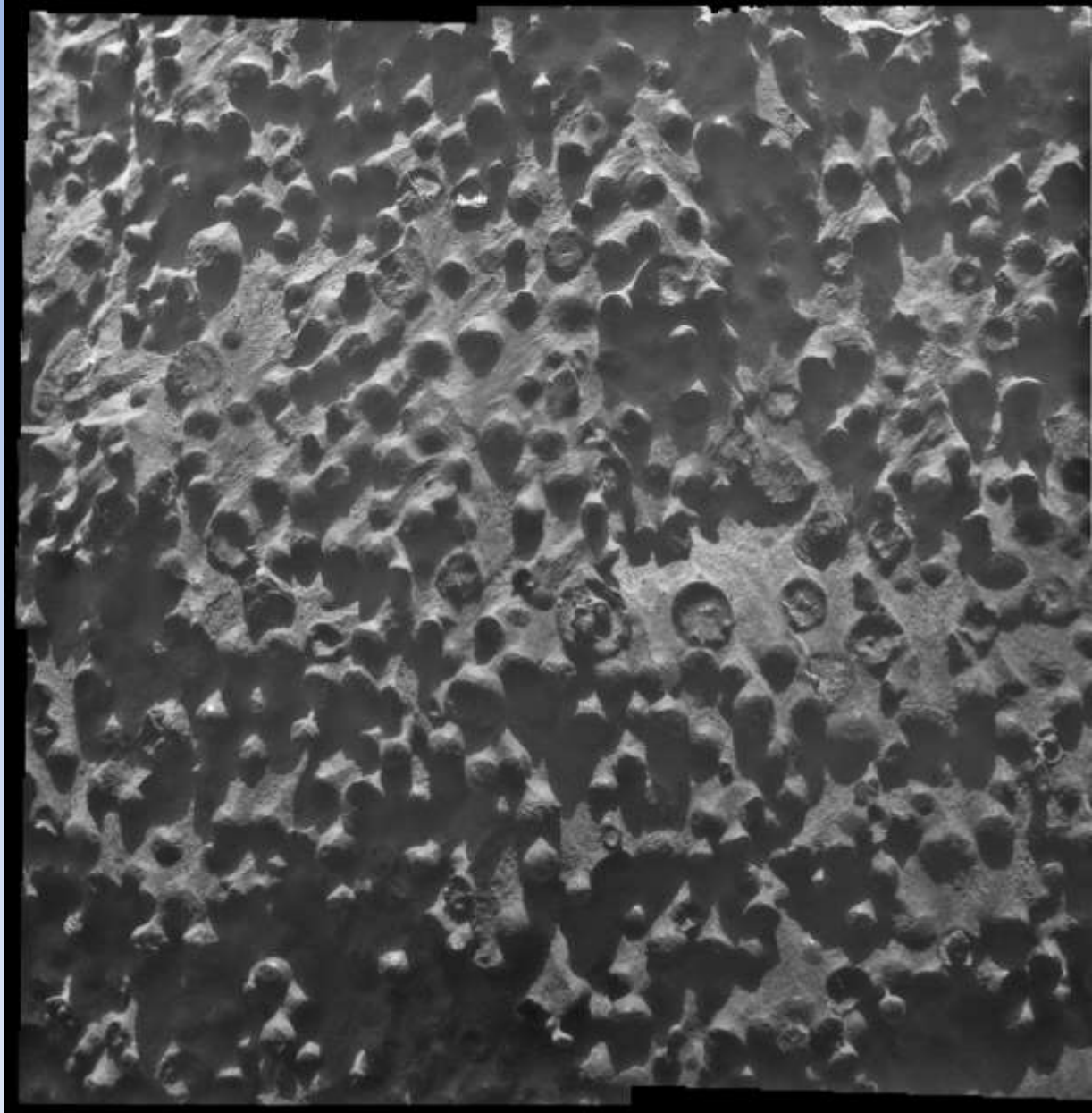


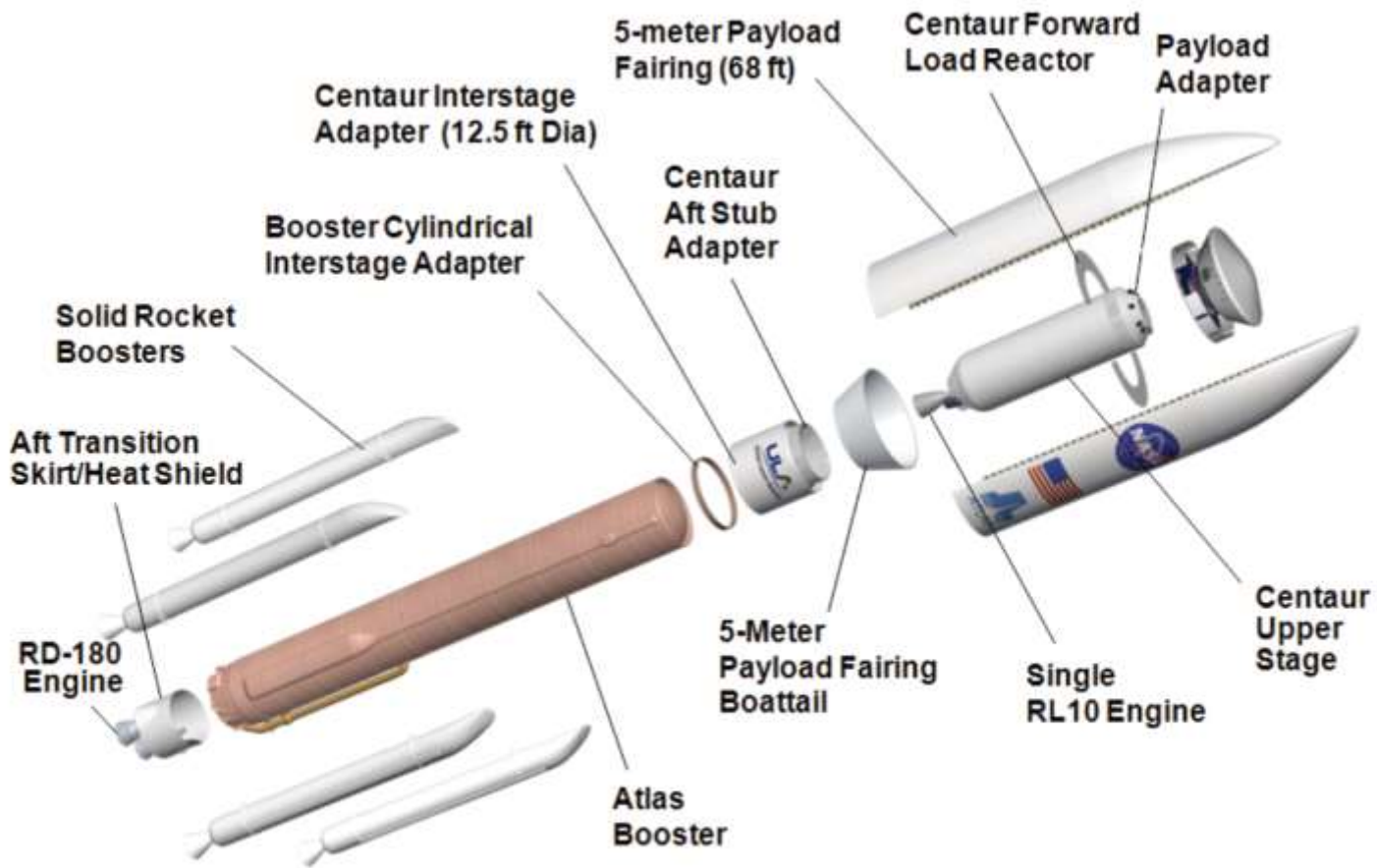
Curiosity Mars Rover







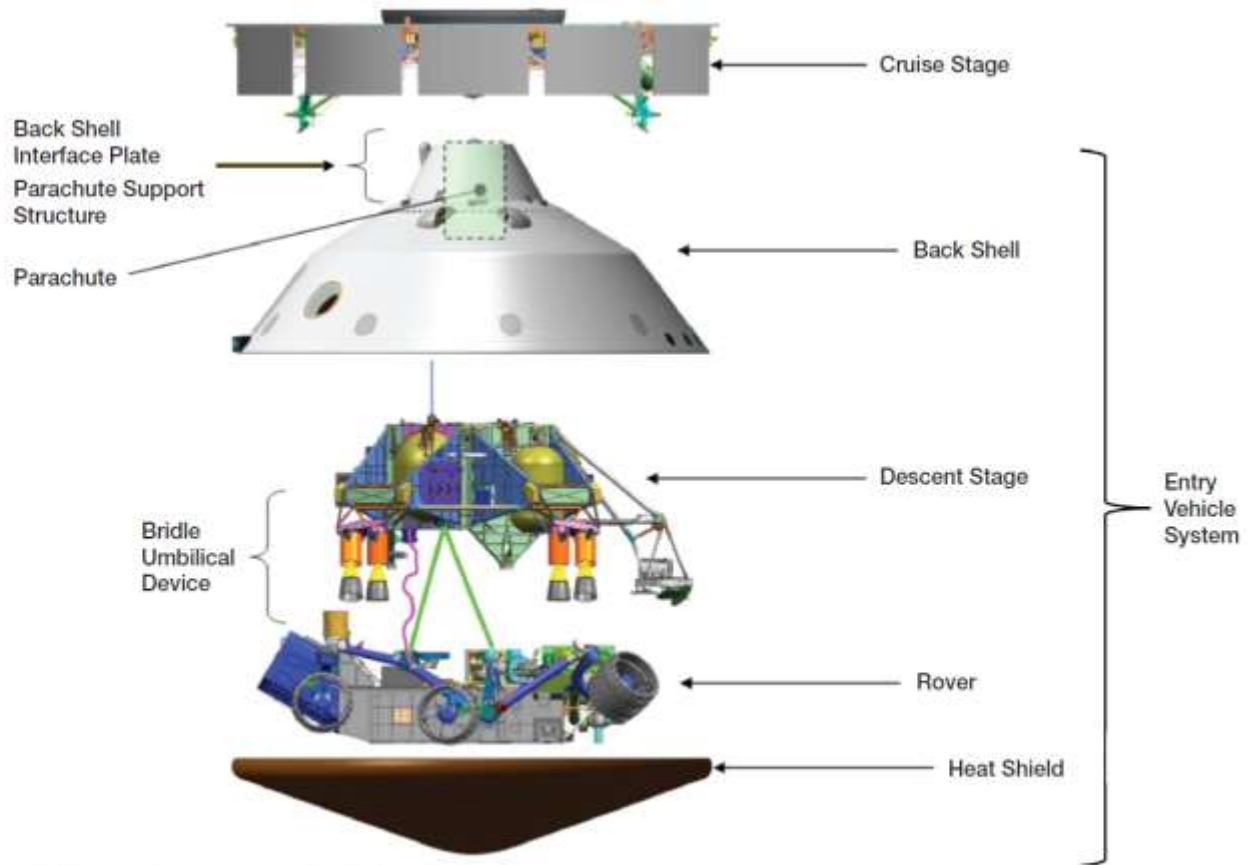




*Atlas V 541 launch vehicle, expanded view*

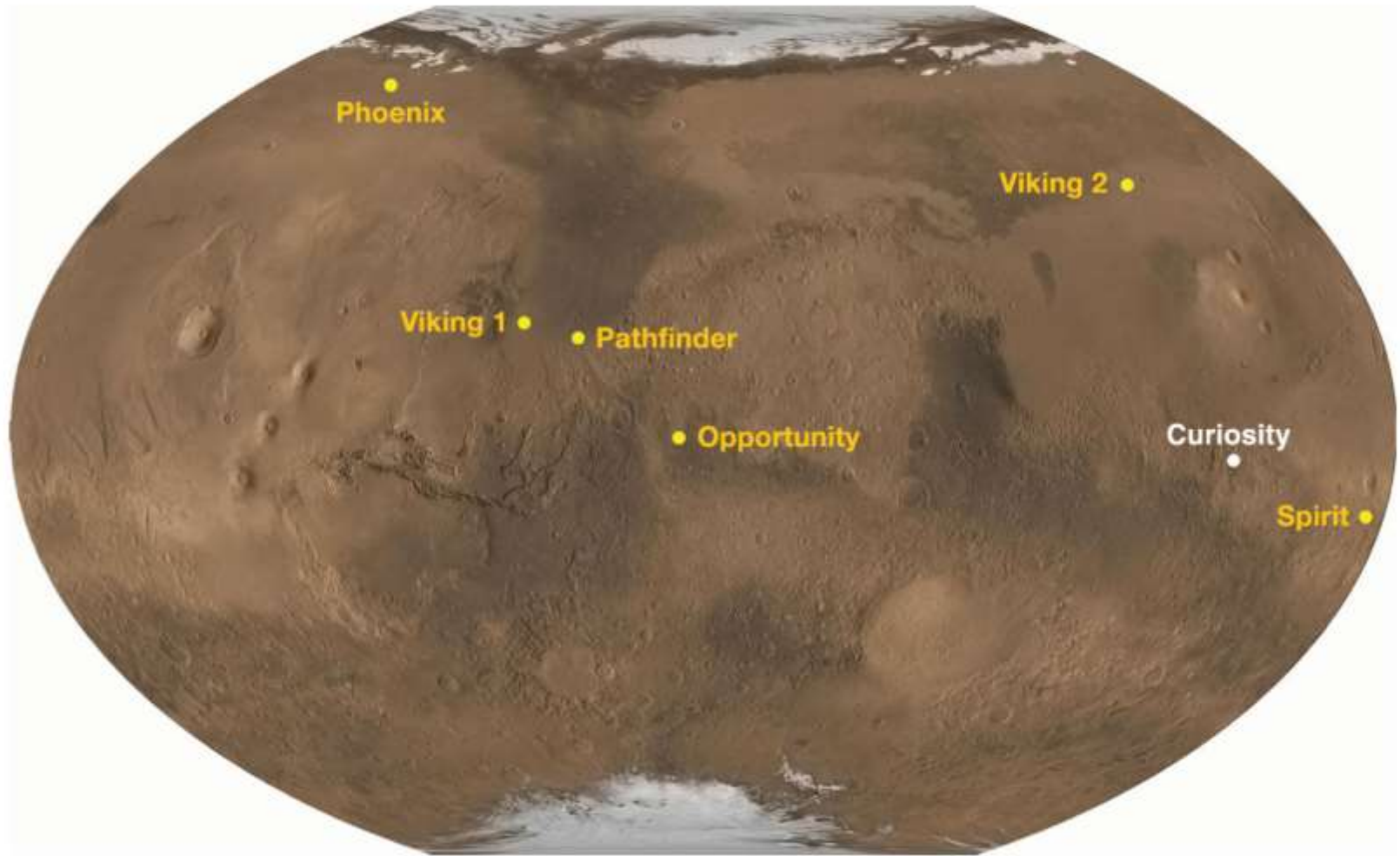






*Mars Science Laboratory flight system, expanded view*

*Locations of landing sites for Curiosity and previous Mars rovers and landers*

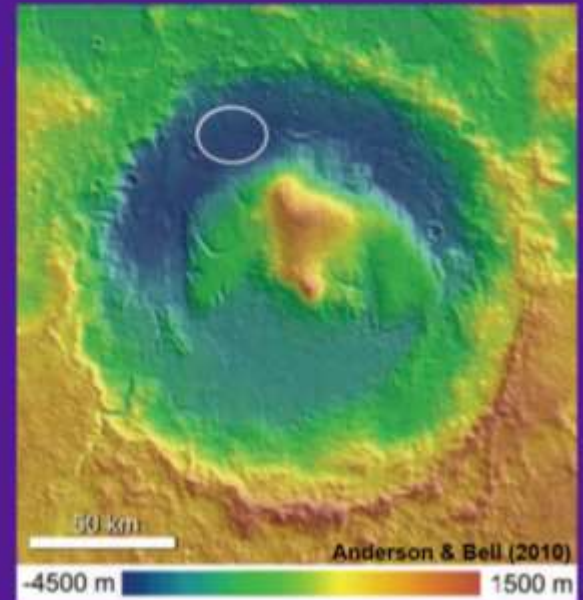


# Proposed MSL Field Site In Gale Crater



## Landing ellipse

- very low elevation (−4.5 km)
- shown here as 25 x 20 km
- alluvium from crater walls
- drive to mound



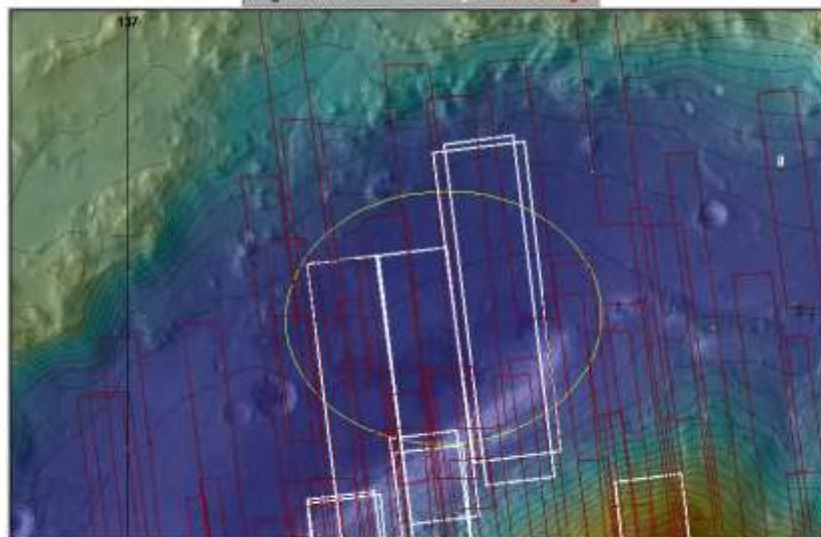


### MSL Landing Site Images Gale Crater

Primary Site: 4 49°S, 137 42°E  
Elevation: -4451 m Target: Layered Sulfates, Phyllosilicates



Image Outlines: [HIRISE Images](#) [MOC Images](#)



HIRISE Images Link To...  Thumbnail Image  Browse Image  Browse Color Swath  Web Page  Online Viewer

View...  HIRISE  MOC Links Open In...  New Page  This Page

#### HIRISE Images Near Landing Ellipse

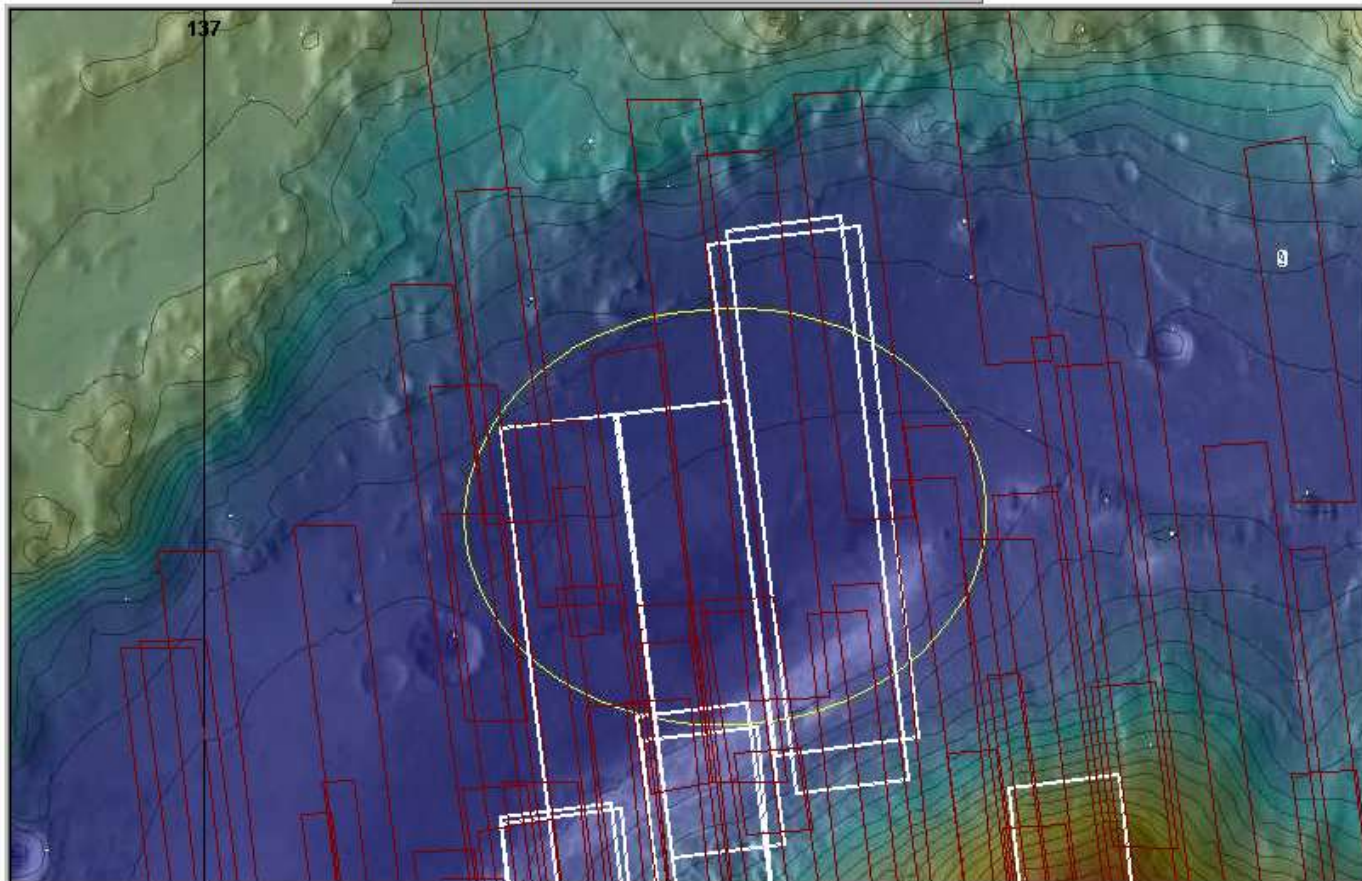
Image	Latitude	Longitude	Description	Online Viewer	Image	Latitude	Longitude	Description	Online Viewer
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## MSL Landing Site Images Gale Crater

Primary Site: 4.49°S, 137.42°E  
Elevation: -4451 m Target: Layered Sulfates, Phyllosilicates

Image Outlines: [HiRISE Images](#) [MOC Images](#)



HiRISE Images Link To...

Thumbnail Image

Browse Image

Browse Color Swath

Web Page

Online Viewer

View...  HiRISE  MOC

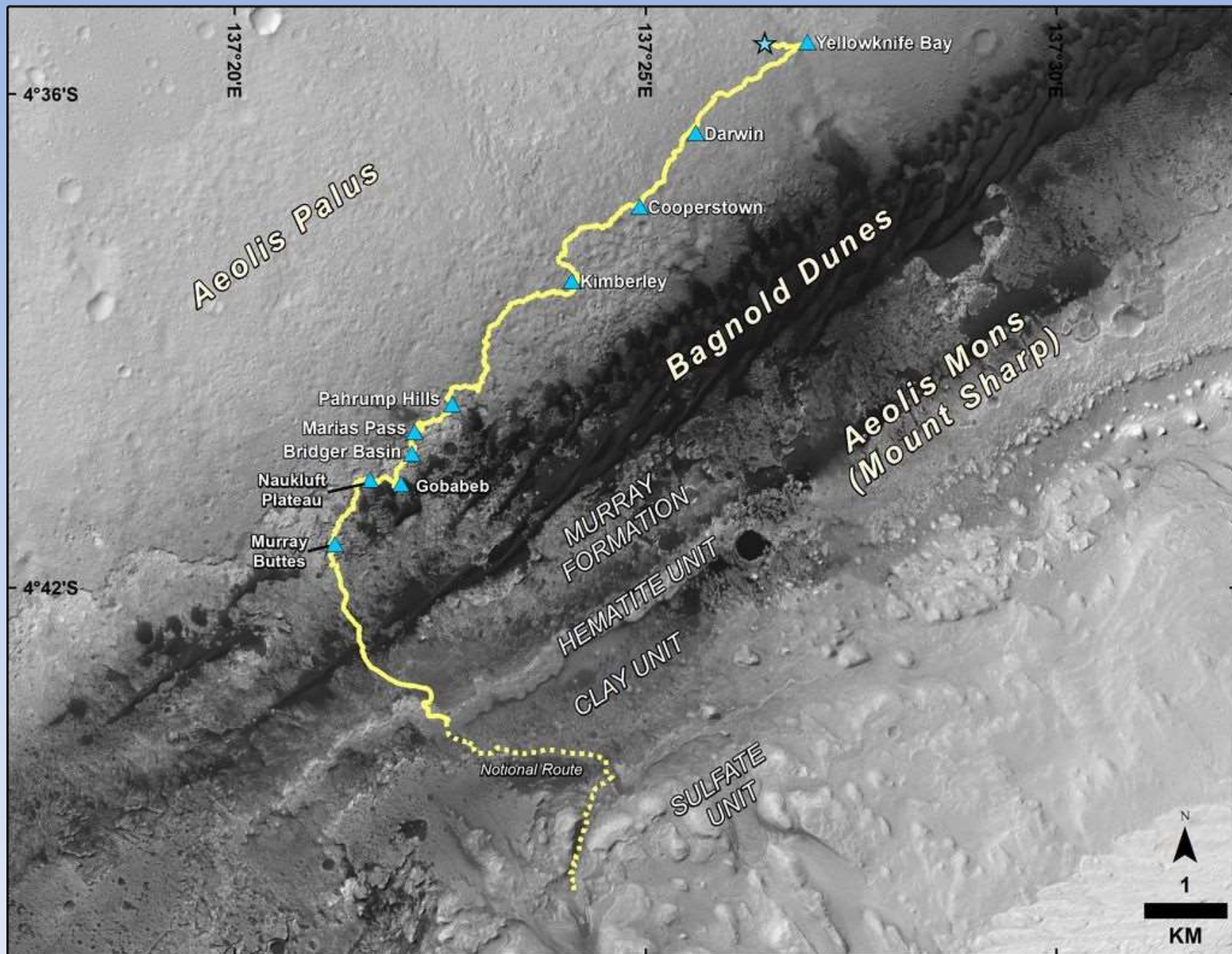
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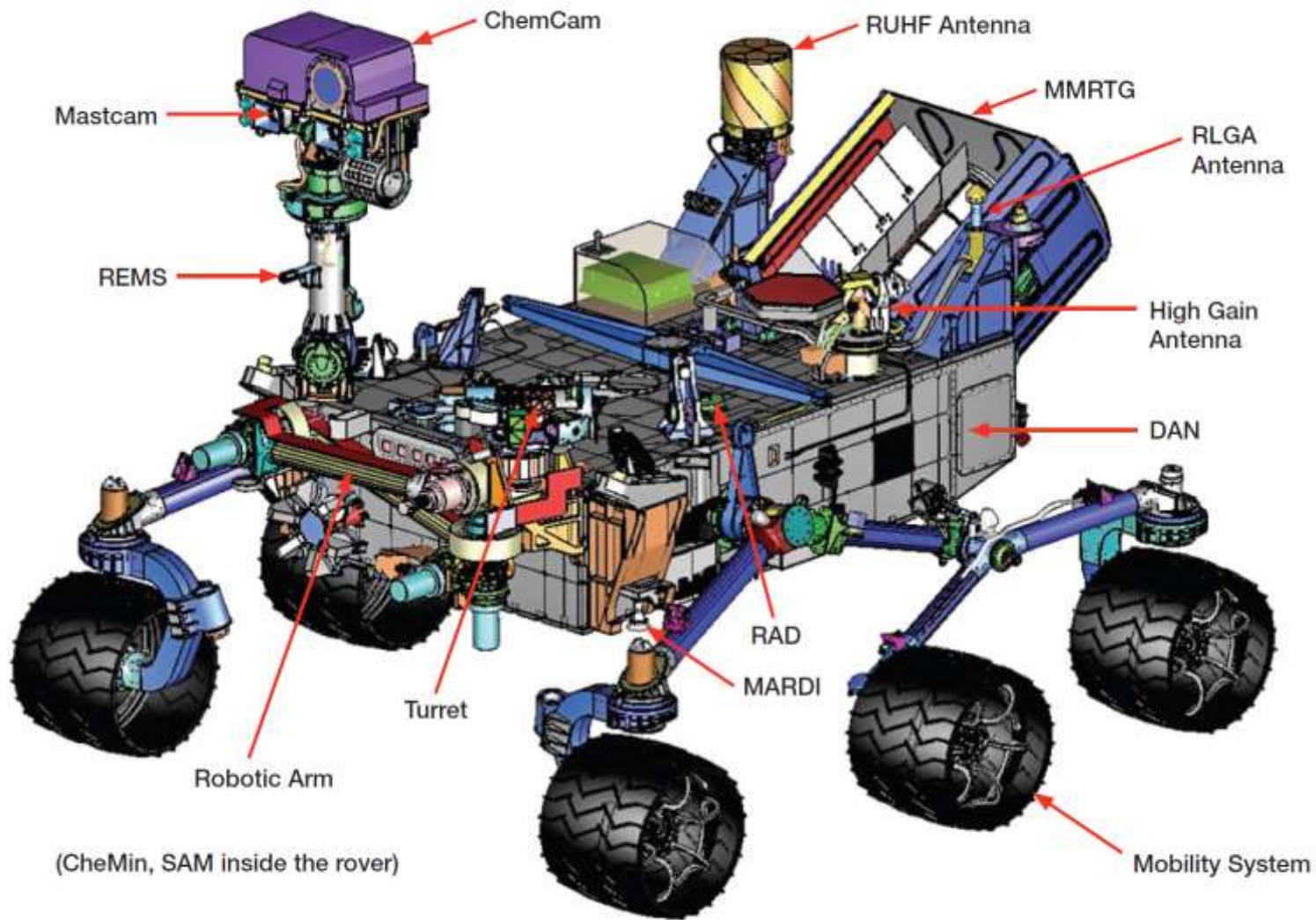
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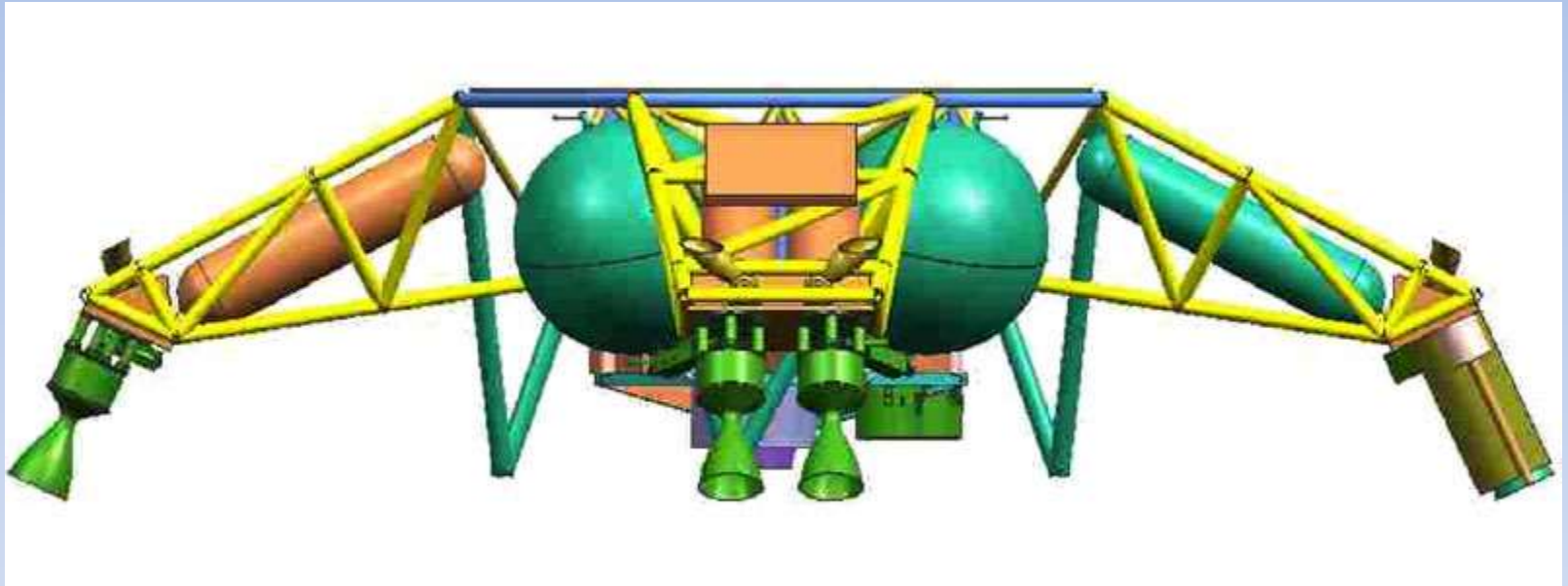
**Edge Along Gale Crater Interior Mound, NASA / JPL / University of Arizona**



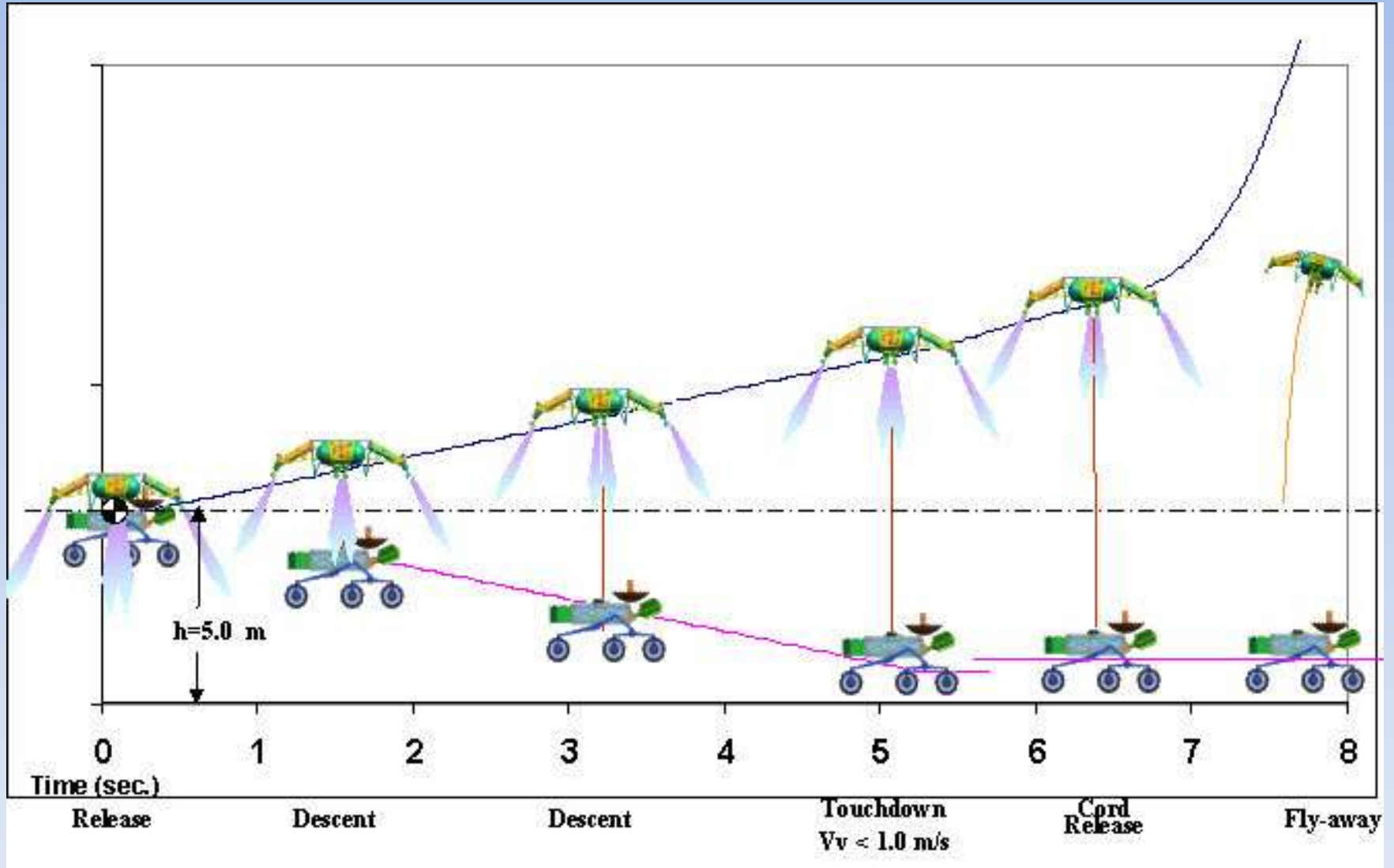


Curiosity Mars Rover





# Sky Crane Operations





Mission update from NASA-JPL via telecon





Landing Site  
Glenelg

Base of Mount Sharp

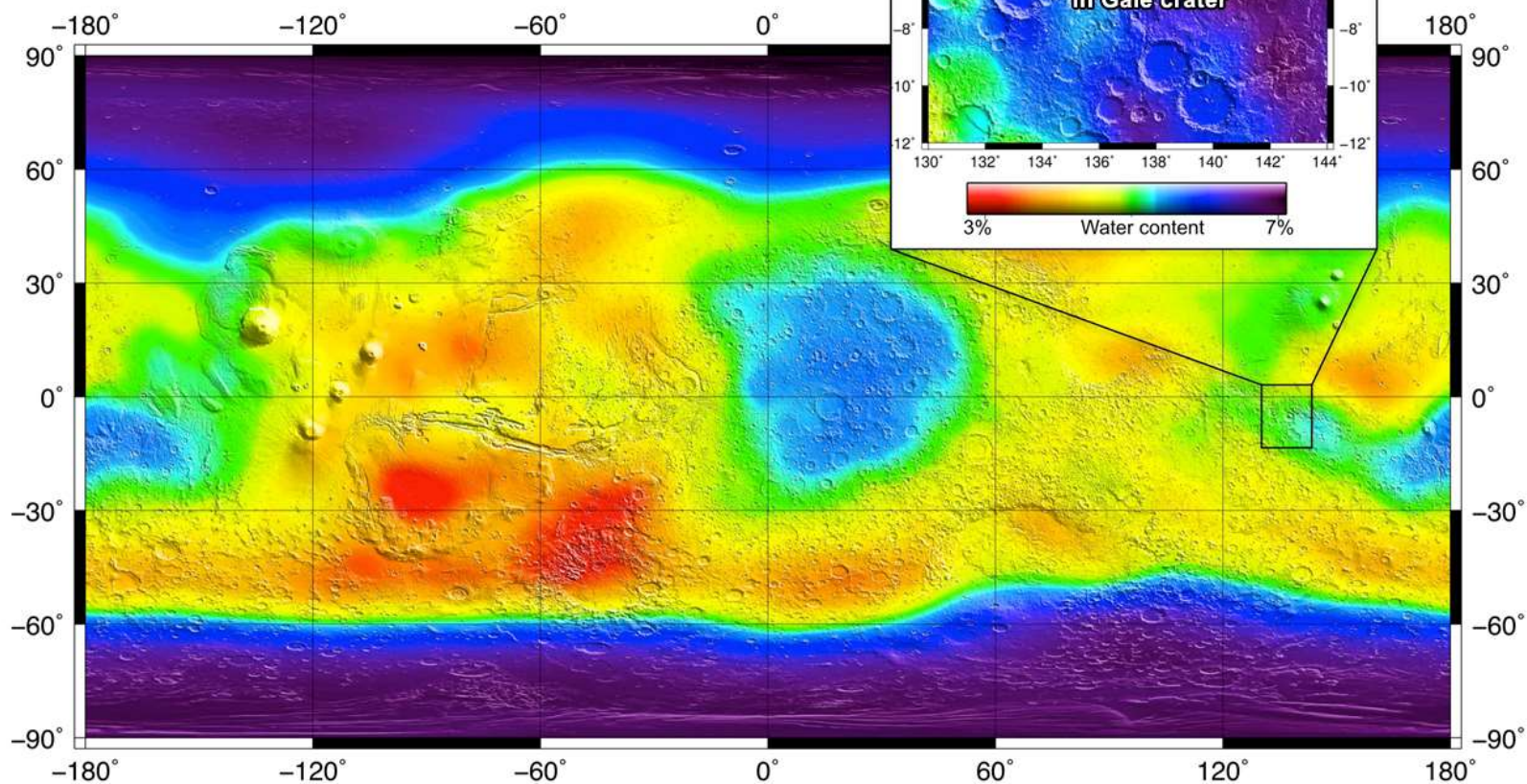
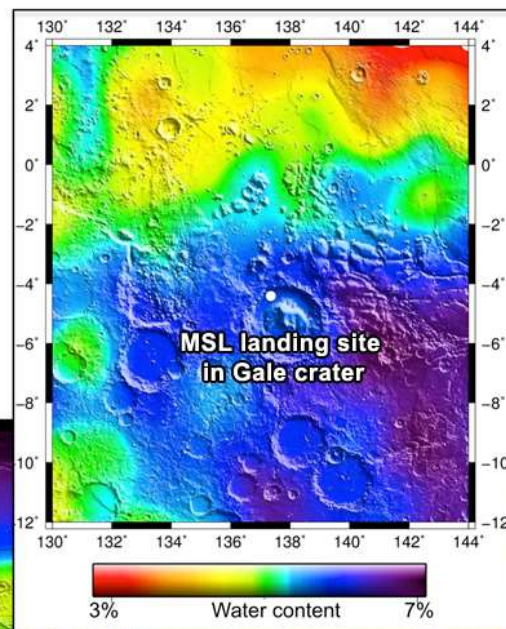
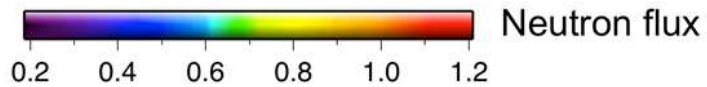
Lower Reaches of Mount Sharp

Mission update from NASA-JPL via telecon

USTREAM  
LIVE

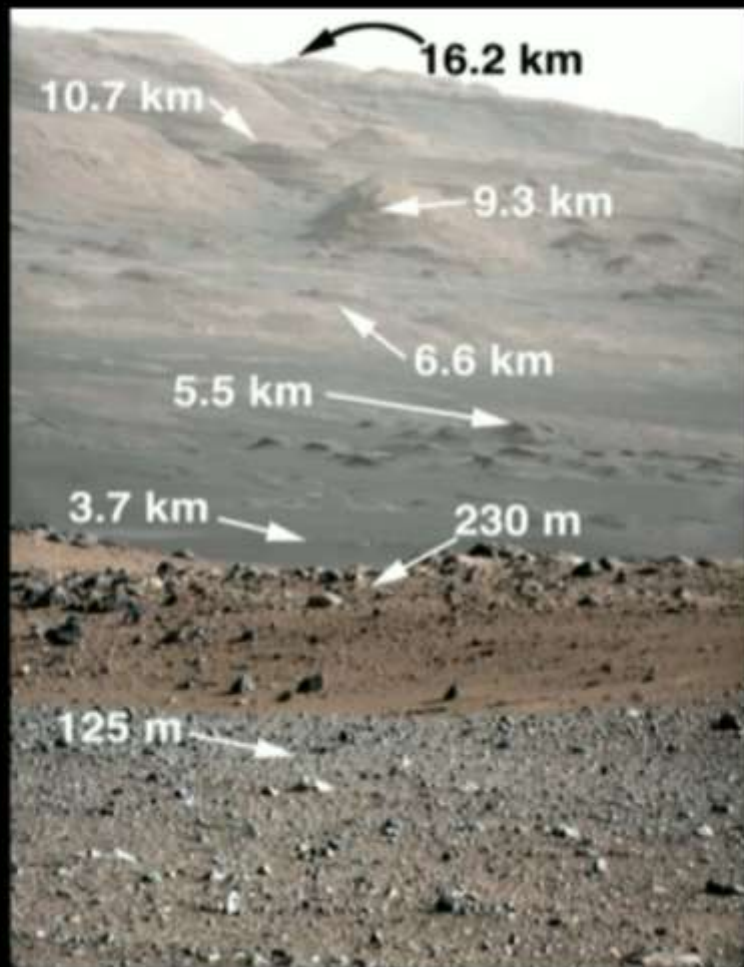






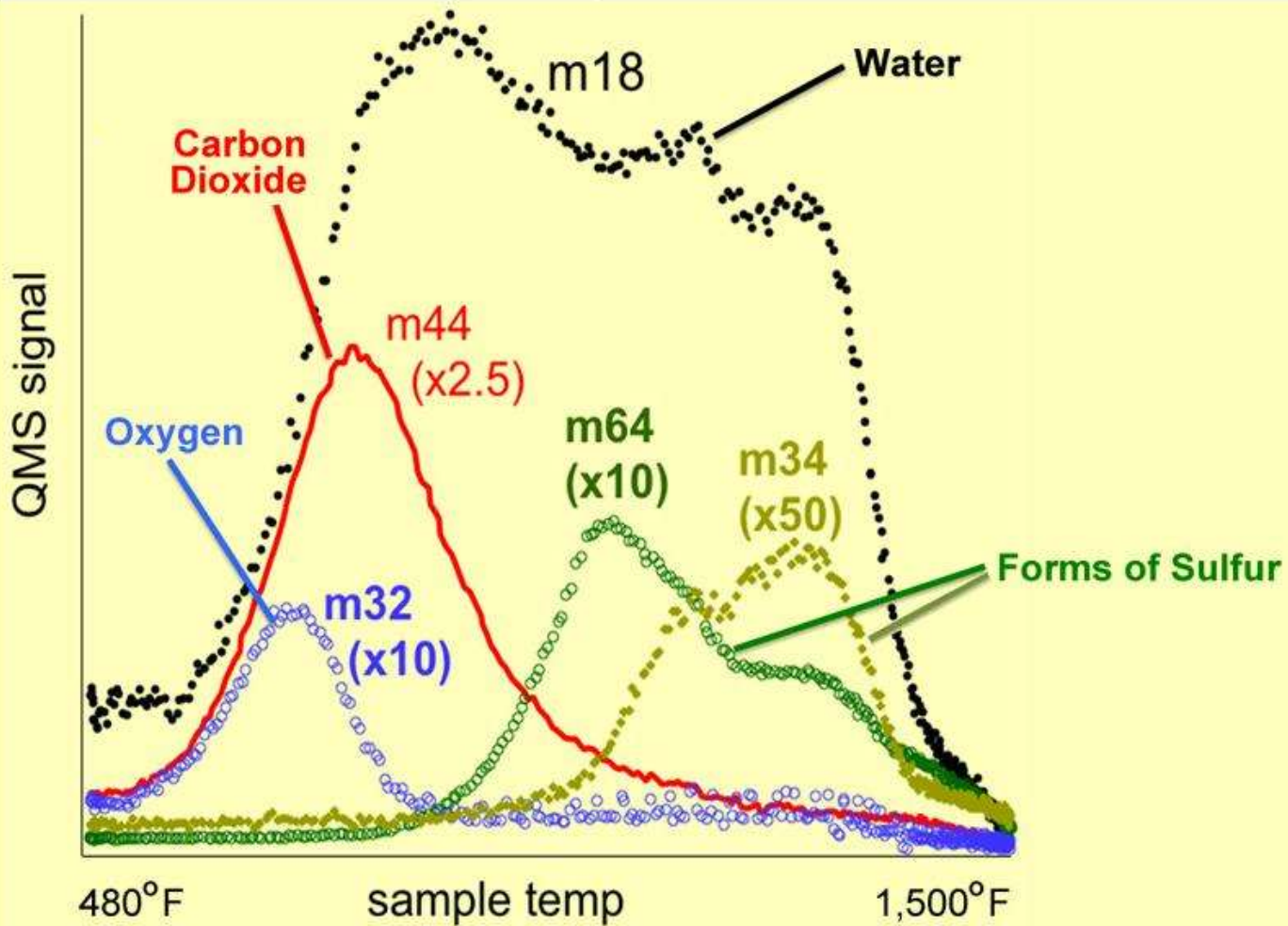


NASA HD

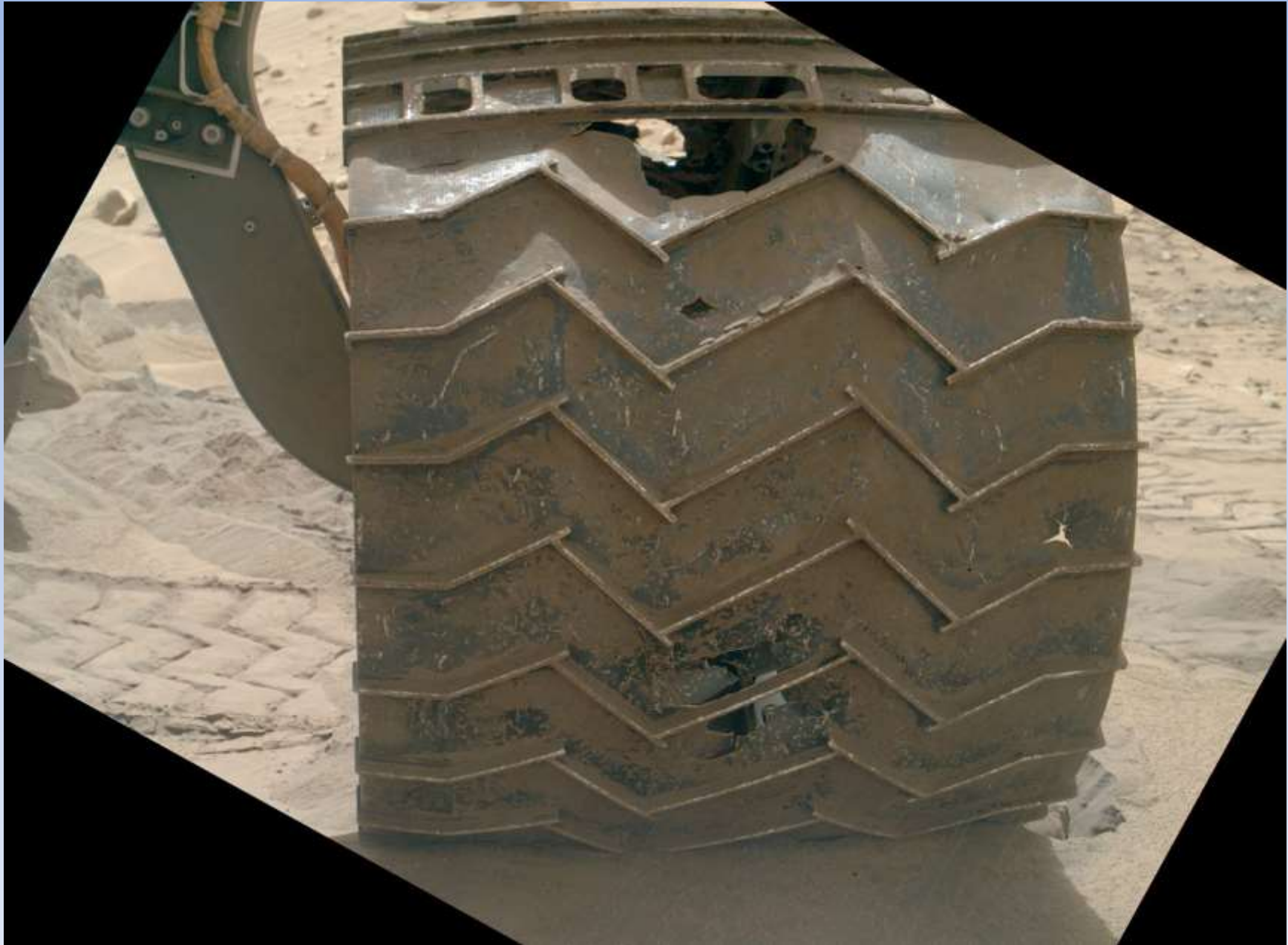




# Major gases released from the bedrock called "John Klein" and analyzed by the SAM instruments







# **Making Humans a Multiplanetary Species**

**Elon Musk, SpaceX**

**at the**

**67<sup>th</sup> International Astronautical Congress (IAC)**

**09-27-2016**

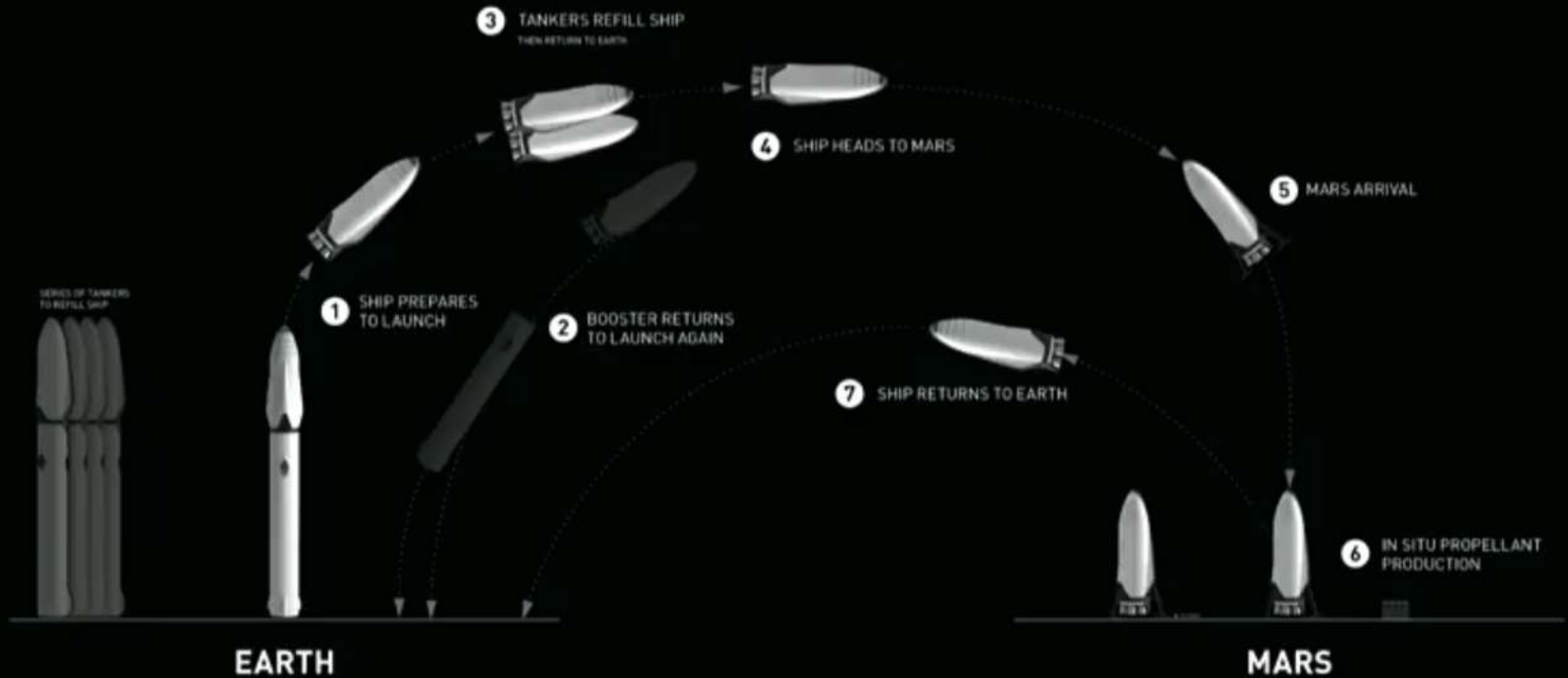
# SYSTEM ARCHITECTURE

## TARGETED REUSE PER VEHICLE

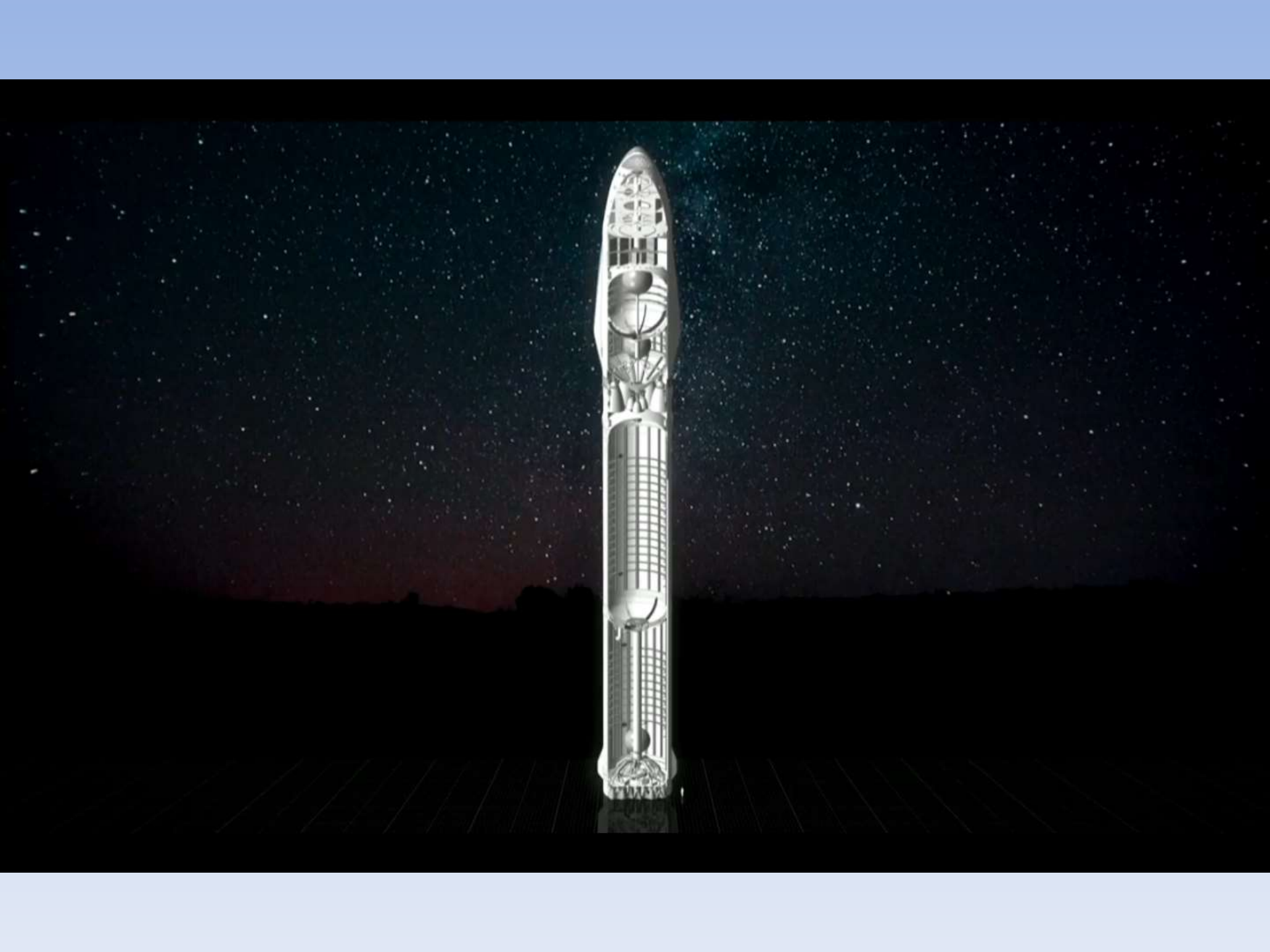
1,000 uses per booster

100 per tanker

12 uses per ship

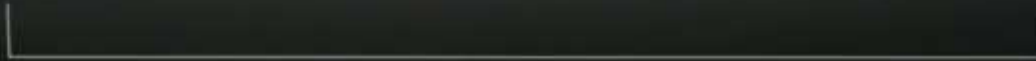












**BFR**

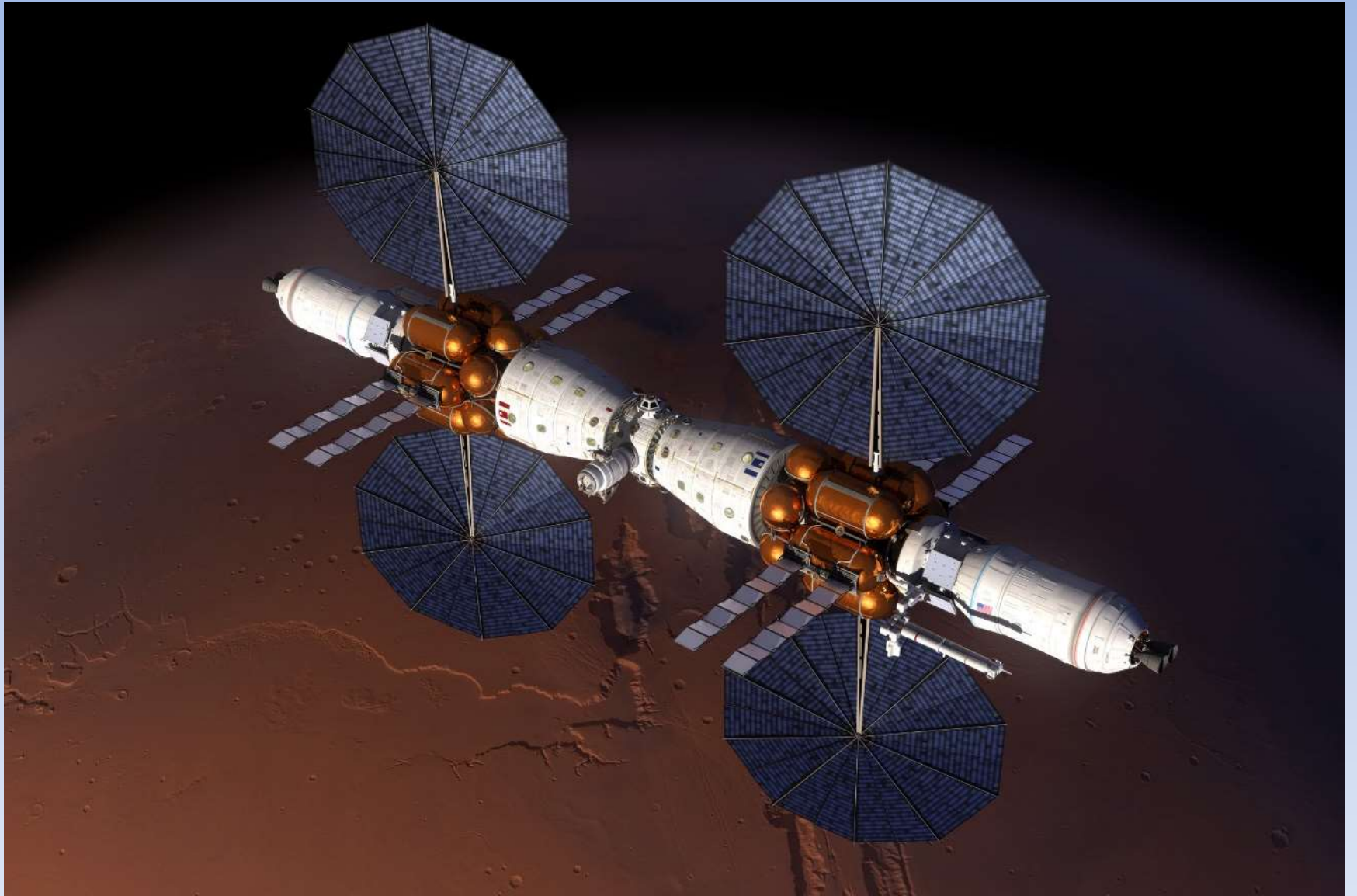
118 m Tall

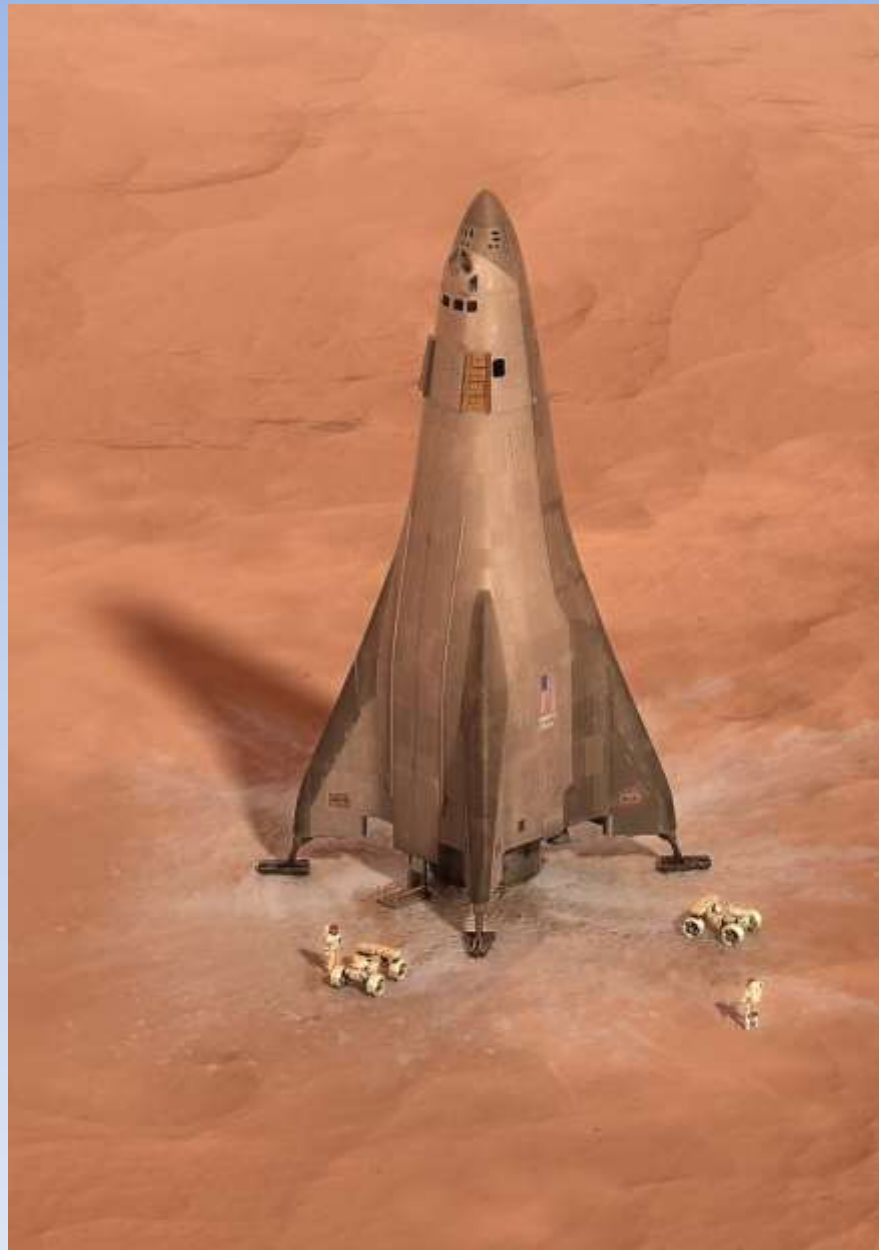
Over 100 t Payload to LEO with Full Reuse



**“Our vision is millions of people living and working in space, and New Glenn is a very important step. It won’t be the last, of course.”**

**Jeff Bezos, Blue Origin**

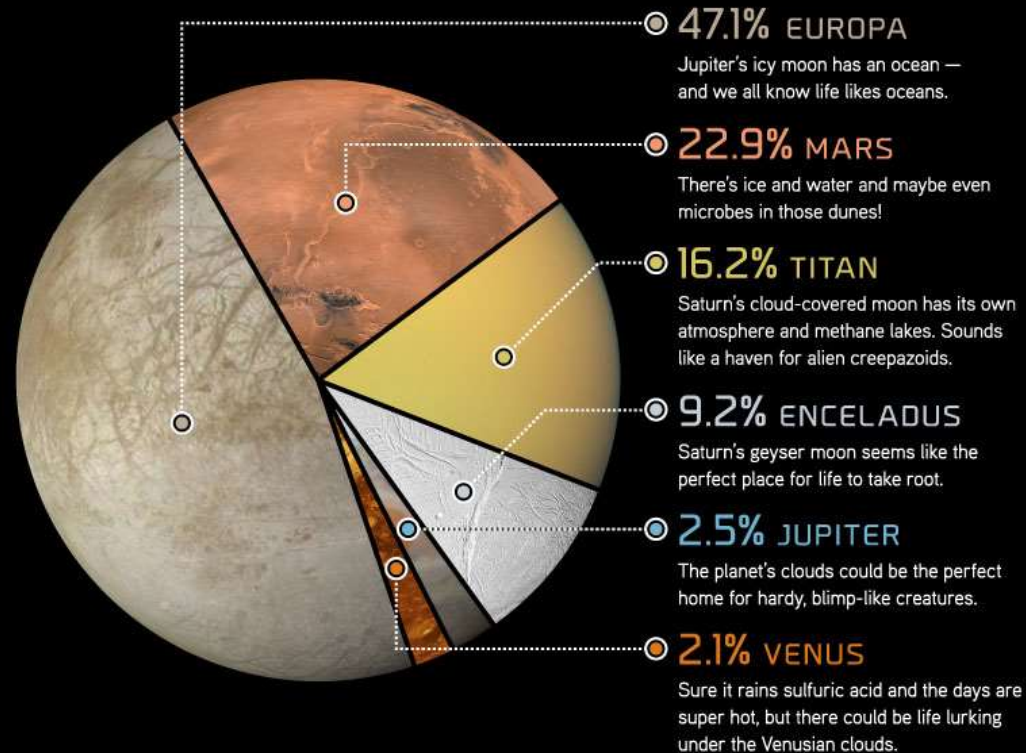






# Where will we find life next?

If there's some place in our solar system that's secretly harboring life, you told us where you thought it might be hiding. That icy shell didn't stop Europa from taking top honors, although you said you're probably not ready to move there just yet. But once there's a Starbucks, most of us would be game.



## How willing would you be to live on a planet other than Earth?



I'll wait until a colony has been established somewhere.



As soon as there's a ship with a seat for me, I'm game.



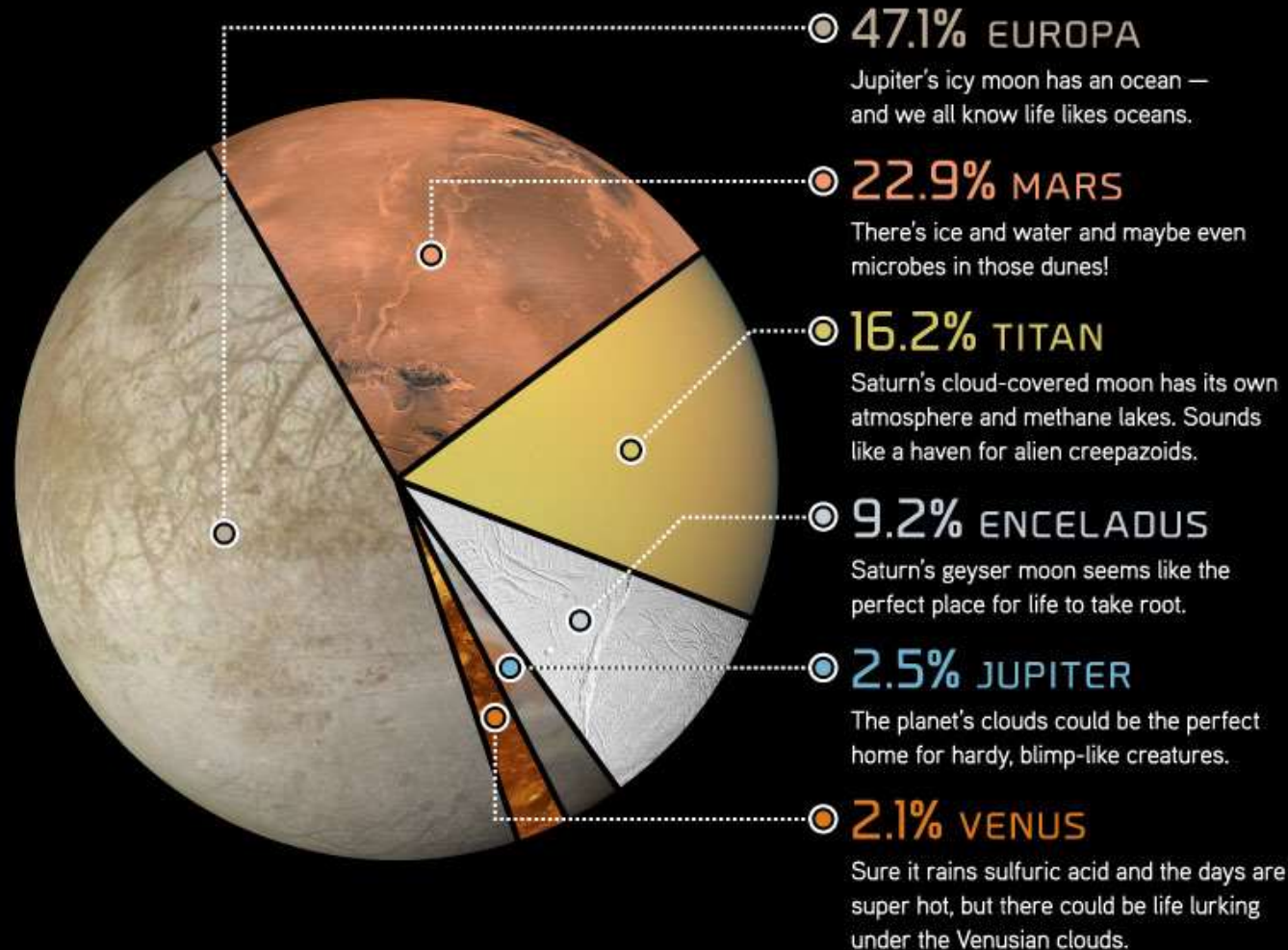
I'd go, but only if I could return to Earth eventually.



Planet Earth is the only one for me.

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SOURCE: THINKGEEK.COM

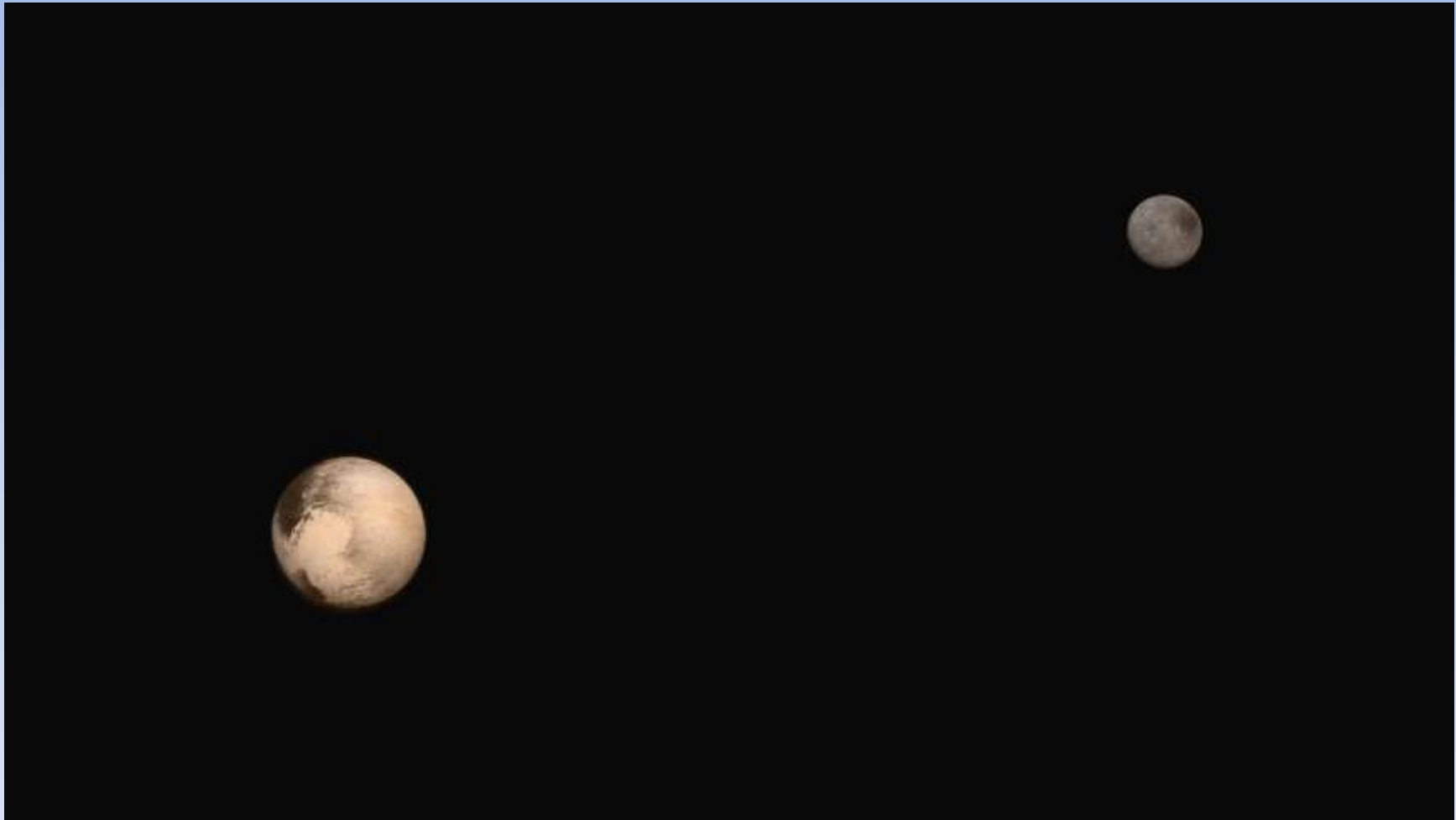
PHOTOS: NASA

# **New Horizons Team Finds Haze, Flowing Ice on Pluto**

**Press Conference, July 24, 2015**

Flowing ice and a surprising extended haze are among the newest discoveries from NASA's New Horizons mission, which reveal distant Pluto to be an icy world of wonders.









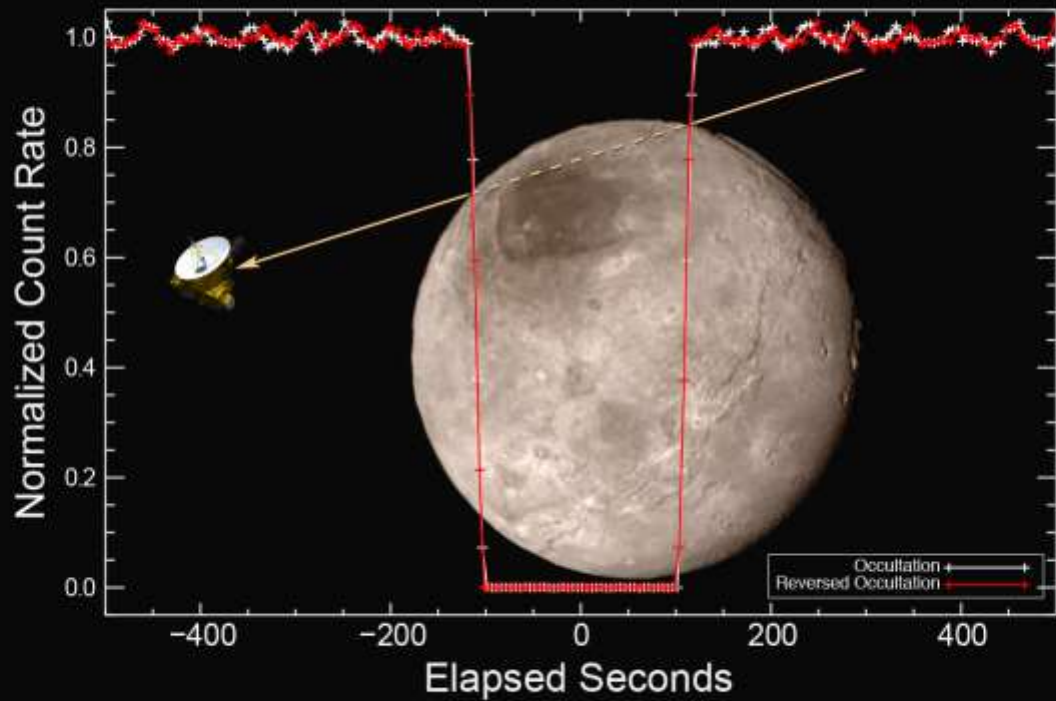




False Color



# Alice Solar Occultation of Charon

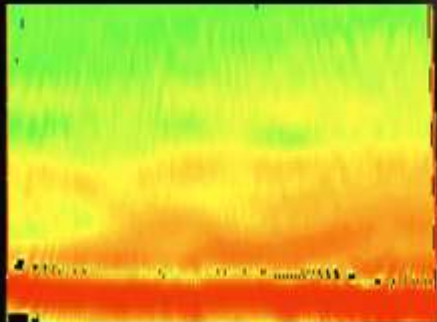




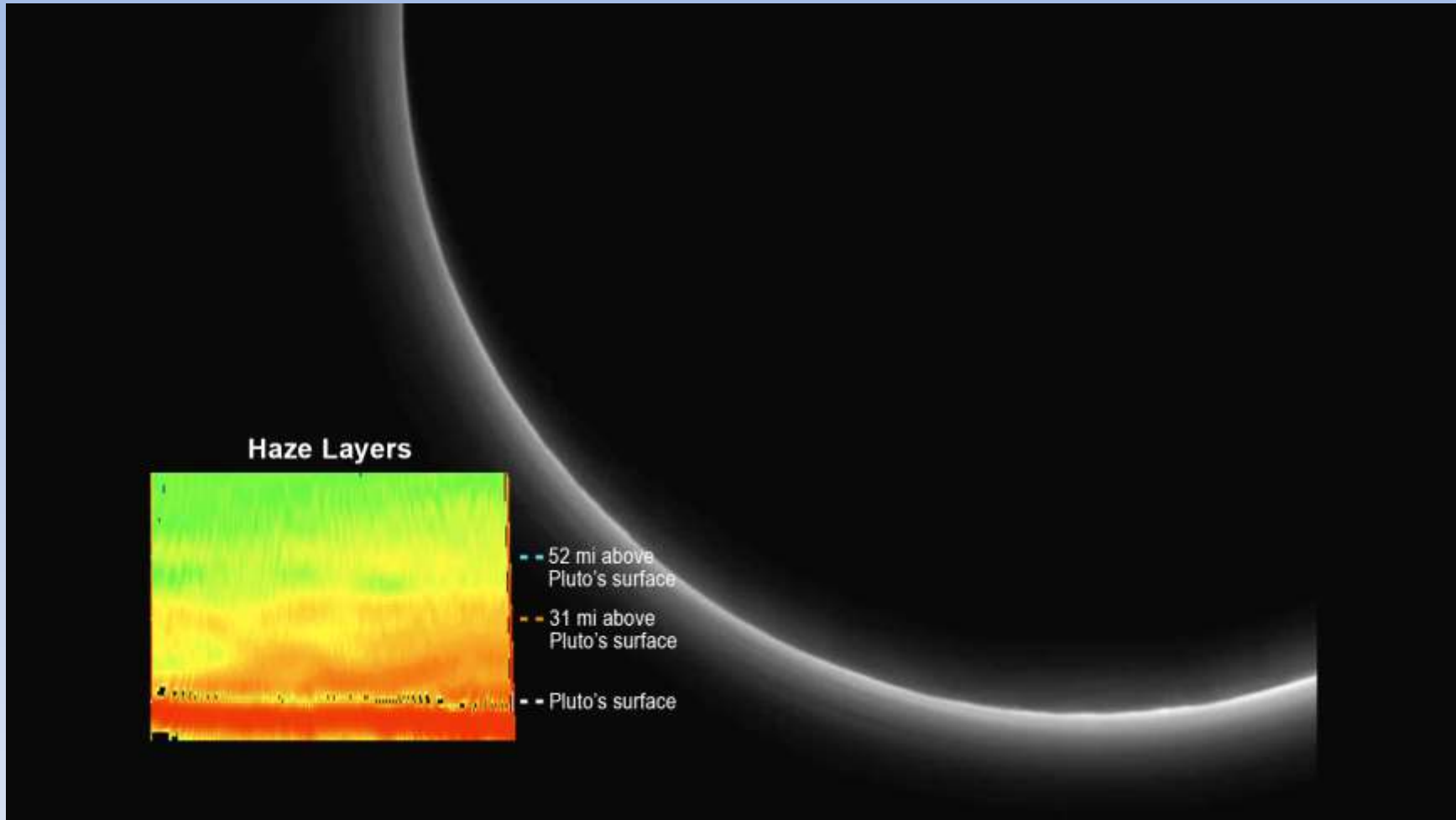




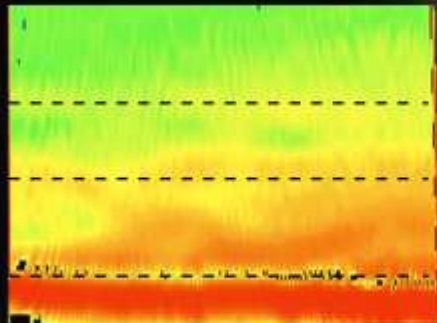
## Haze Layers



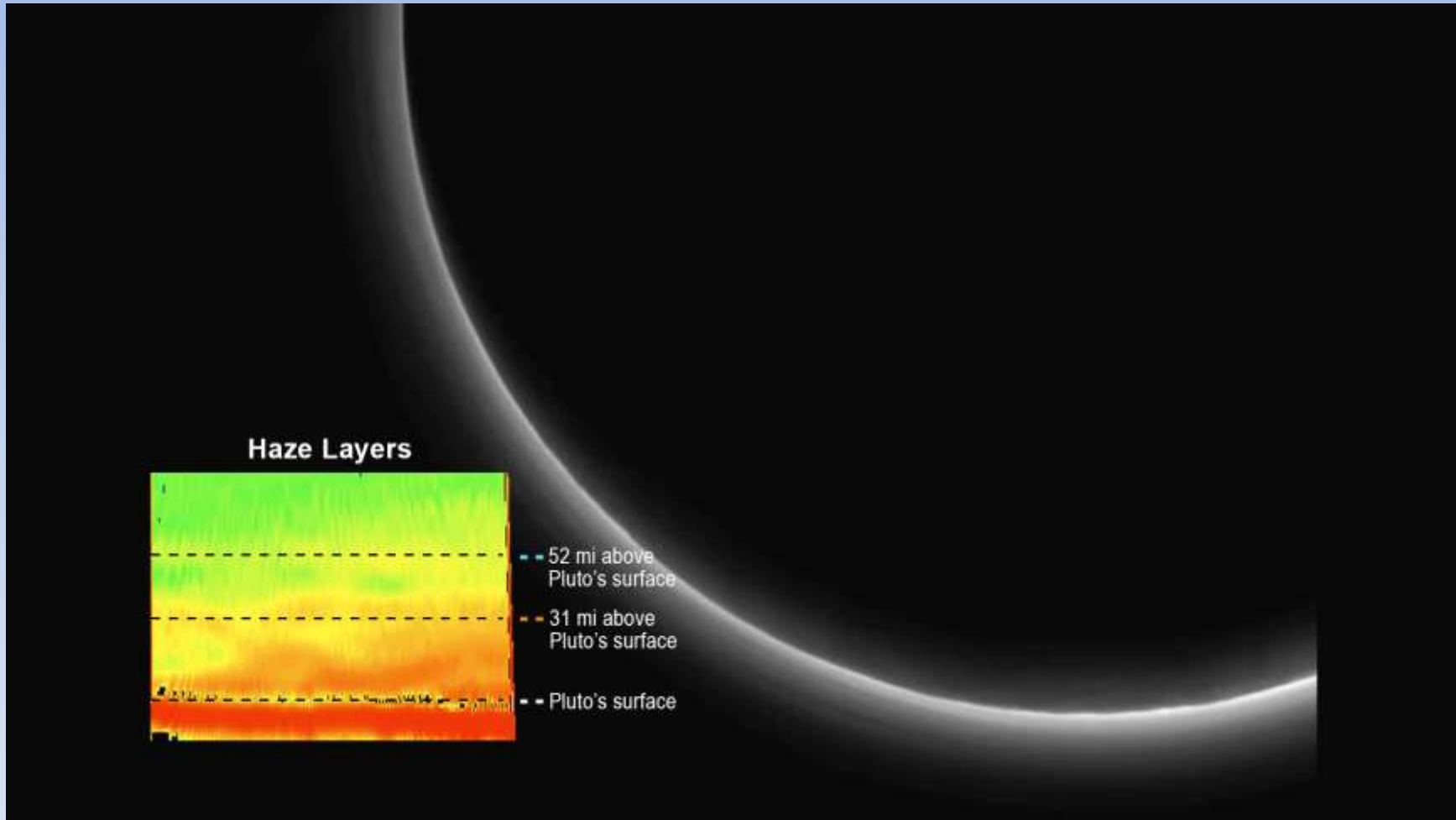
- - 52 mi above Pluto's surface
- - 31 mi above Pluto's surface
- - Pluto's surface

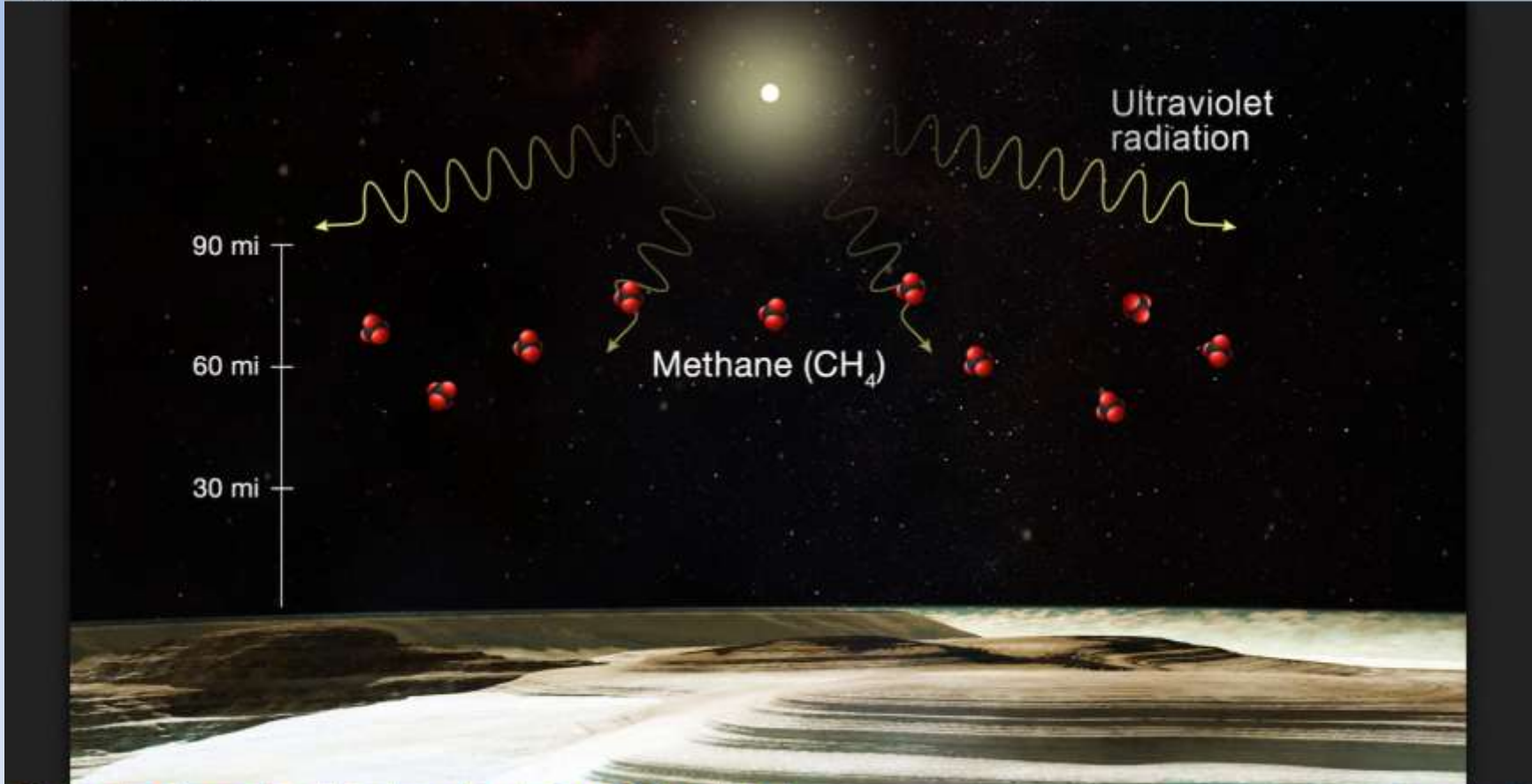


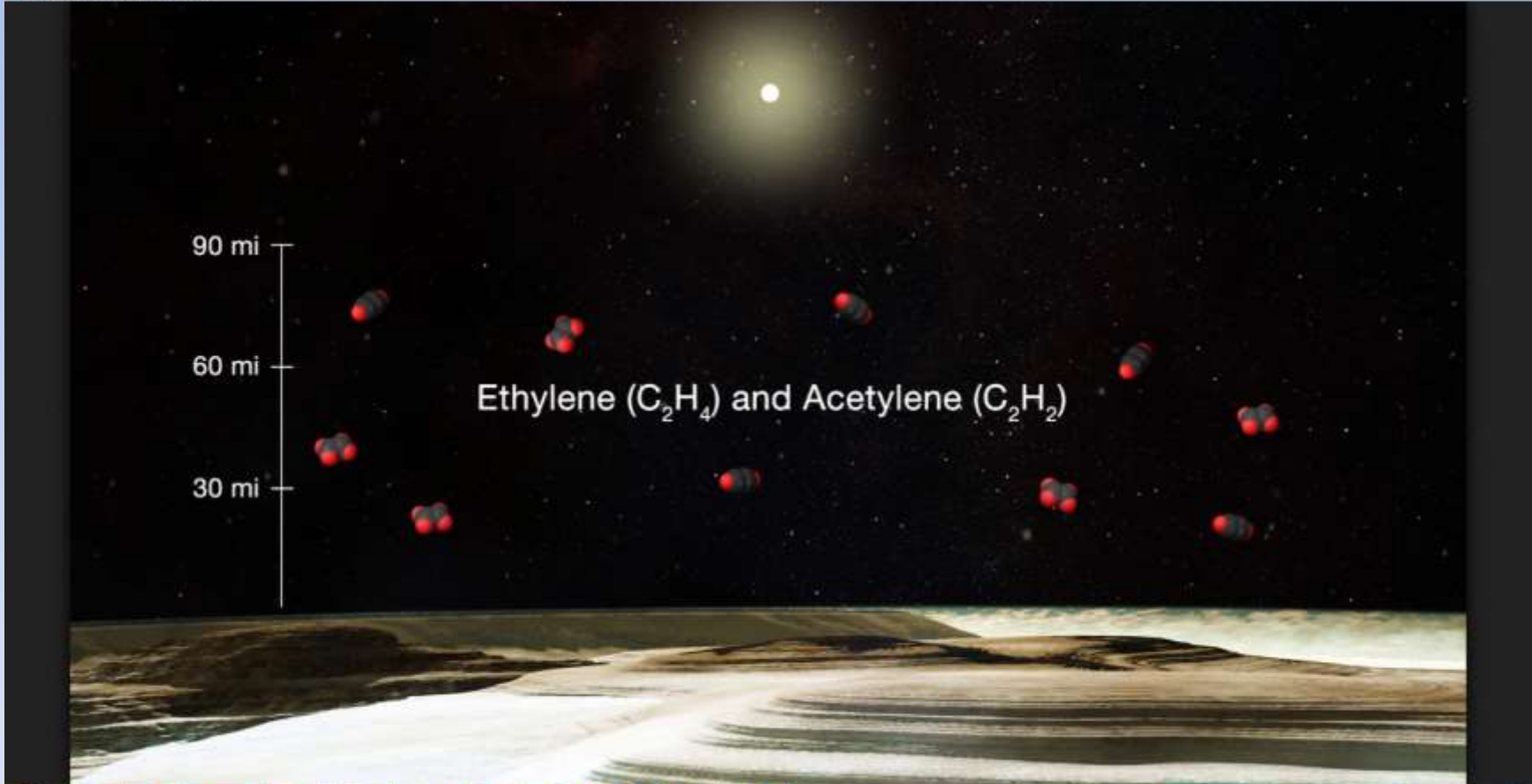
### Haze Layers



- - 52 mi above Pluto's surface
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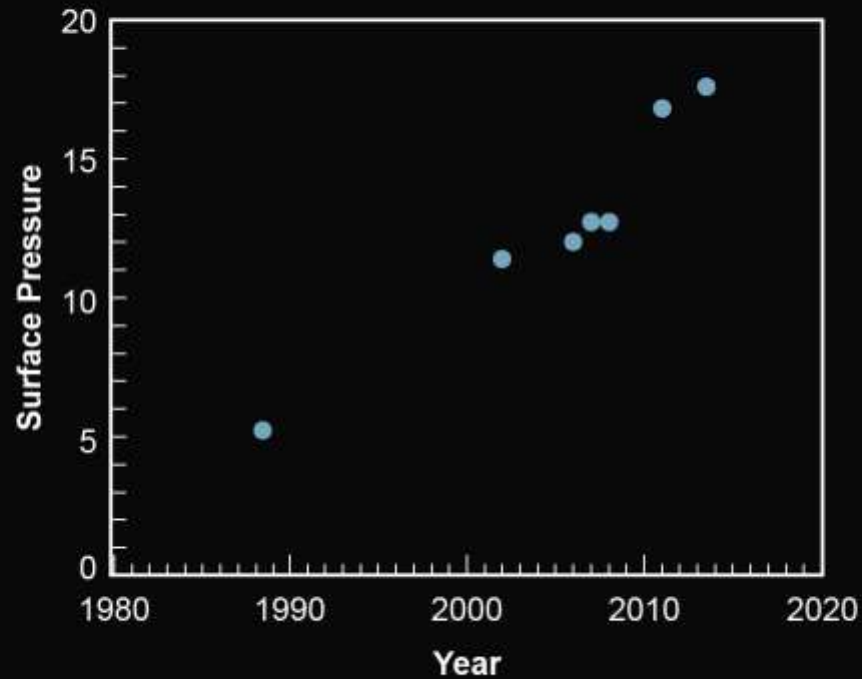




Ethylene ( $C_2H_4$ ) and Acetylene ( $C_2H_2$ )

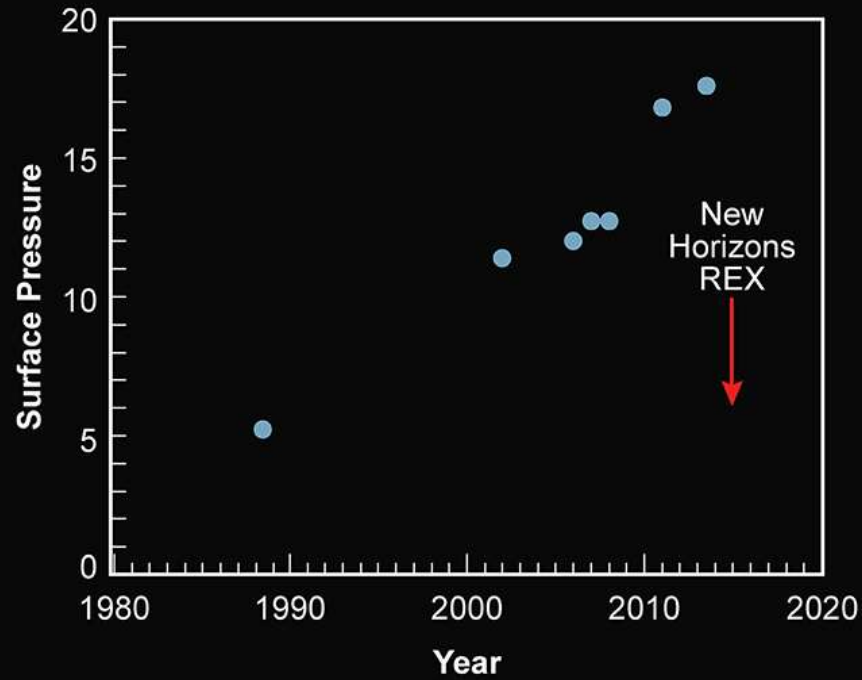


## Changes in Pluto's Surface Pressure



Pluto's atmospheric pressure in micro bars (millionths of a bar; 1 bar = 14.5 p

## Changes in Pluto's Surface Pressure

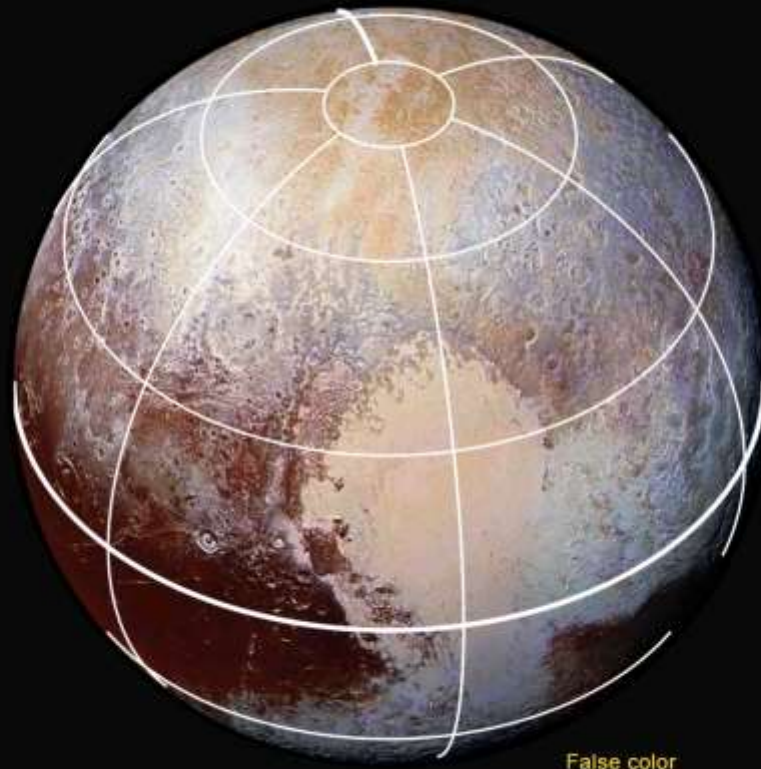


Pluto's atmospheric pressure in micro bars (millionths of a bar; 1 bar = 14.5 psi).  
New Horizons REX measured 10 microbars

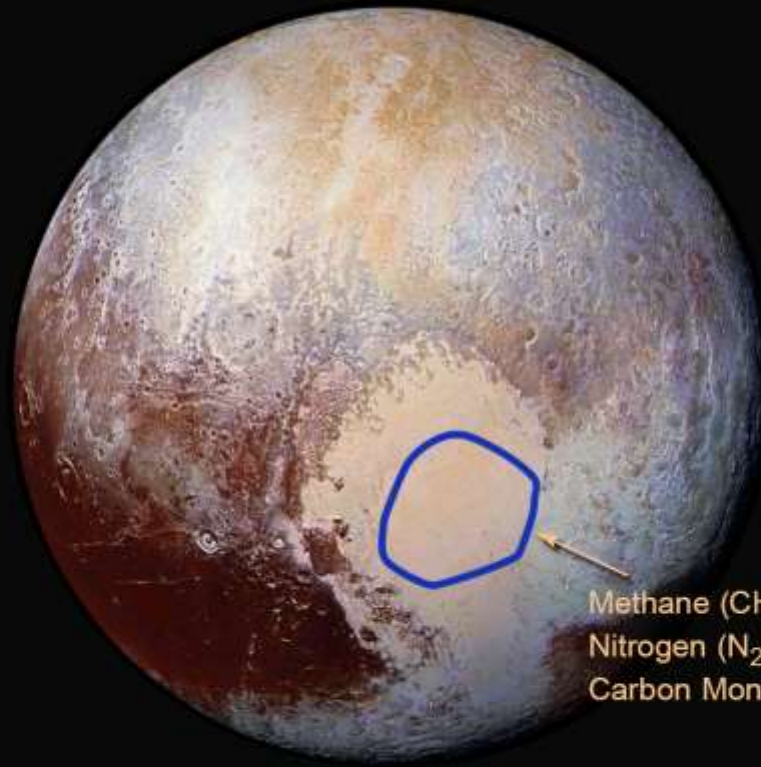




False color



False color



Methane ( $\text{CH}_4$ ) ice  
Nitrogen ( $\text{N}_2$ ) ice  
Carbon Monoxide ( $\text{CO}$ ) ice

File Edit View History Bookmarks Tools Help

New Horizons x New Horizons x 04\_McKinnon\_01\_1080.mp4 x +

photo.jhuapl.edu/News-Center/Press-Conferences/2015-07-24/resources/04\_McKinnon\_01\_1080.mp4

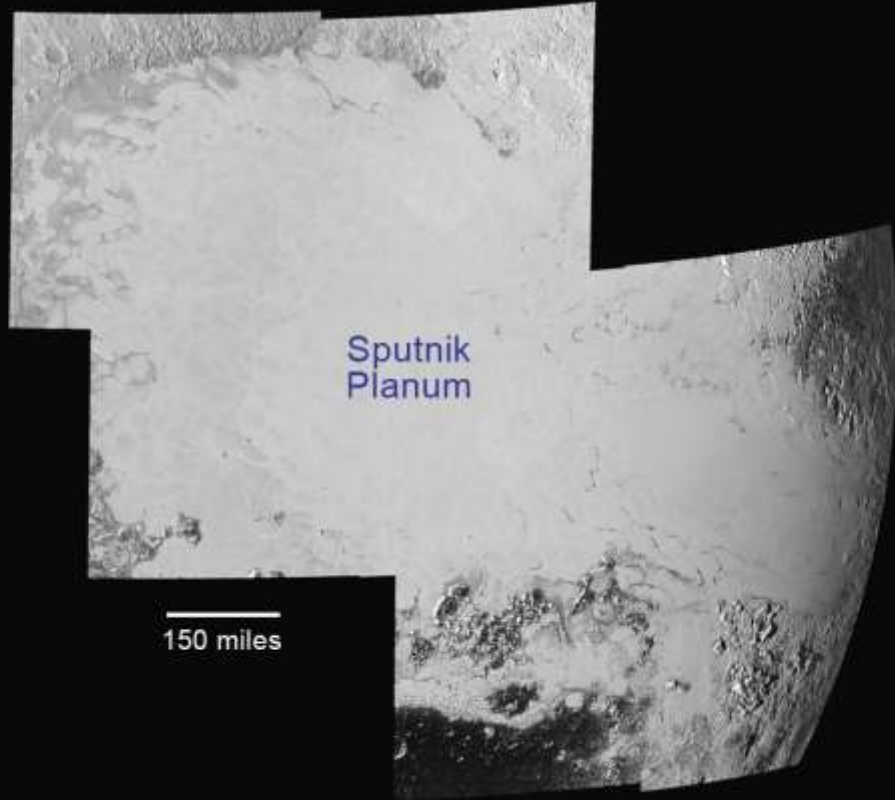
pluto press conference july 2015

Most Visited Getting Started



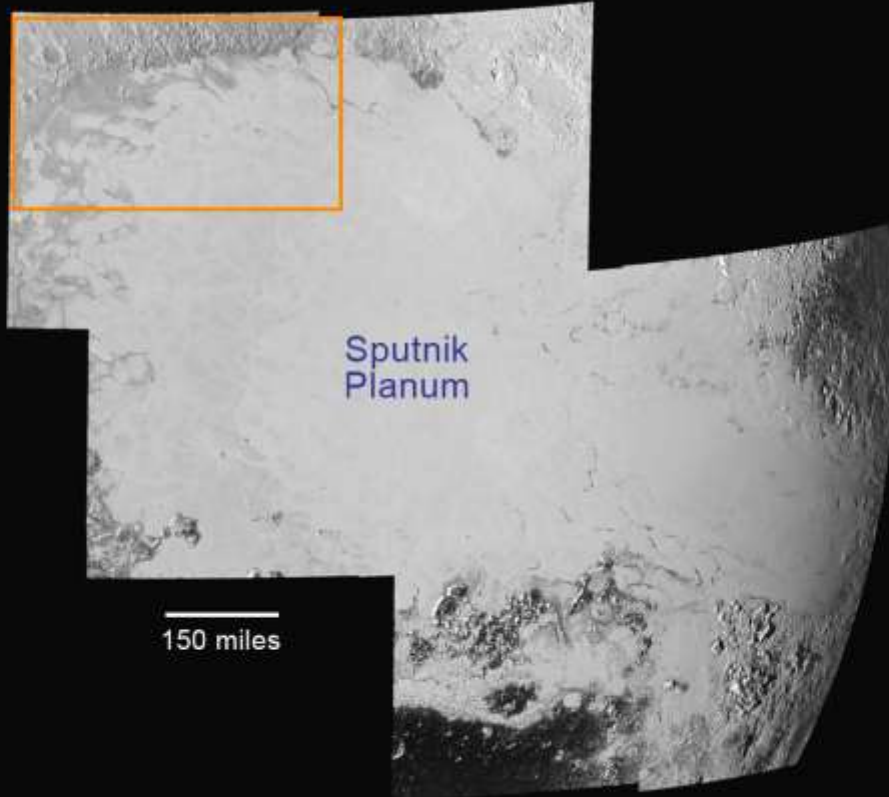
10:08 AM 8/4/2015

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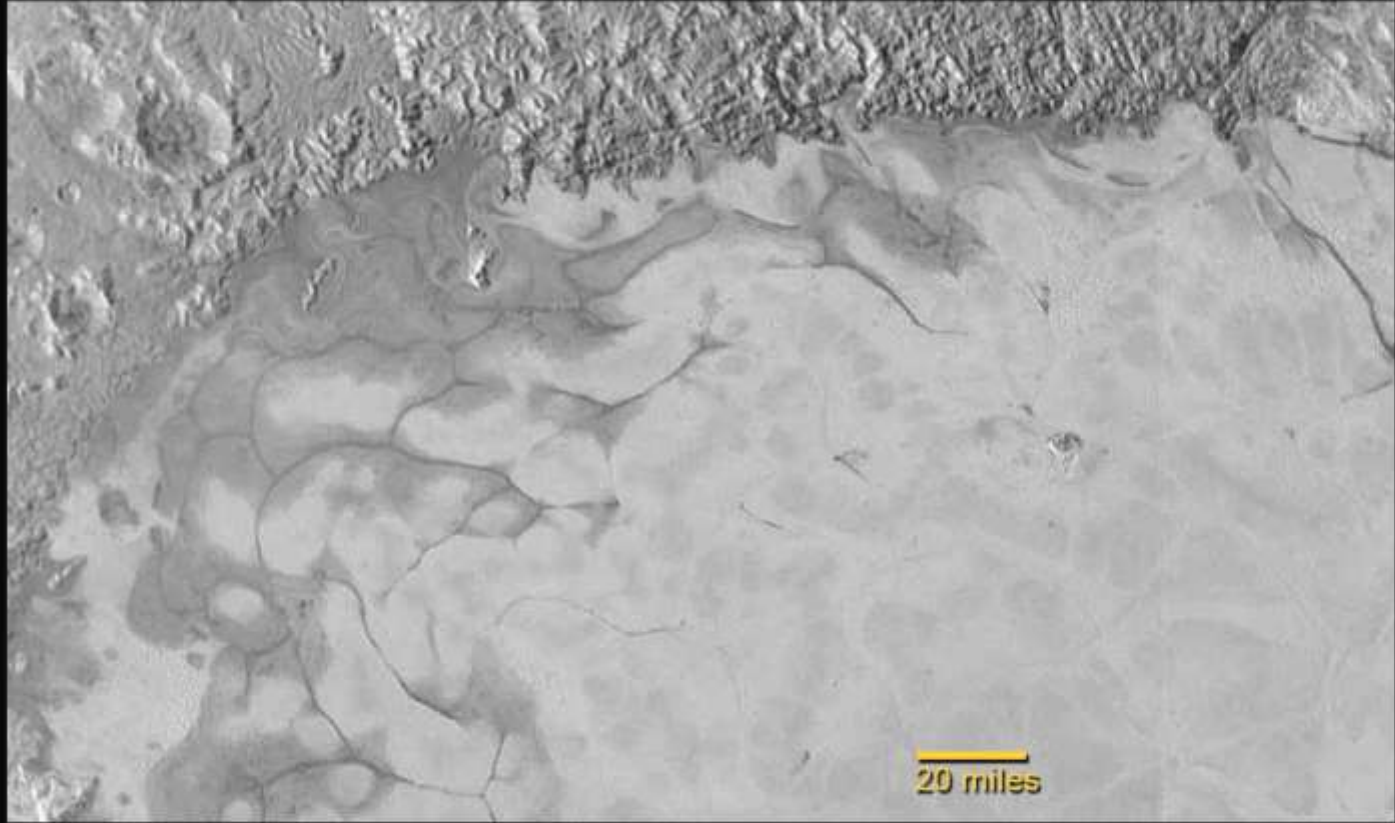
Sputnik  
Planum

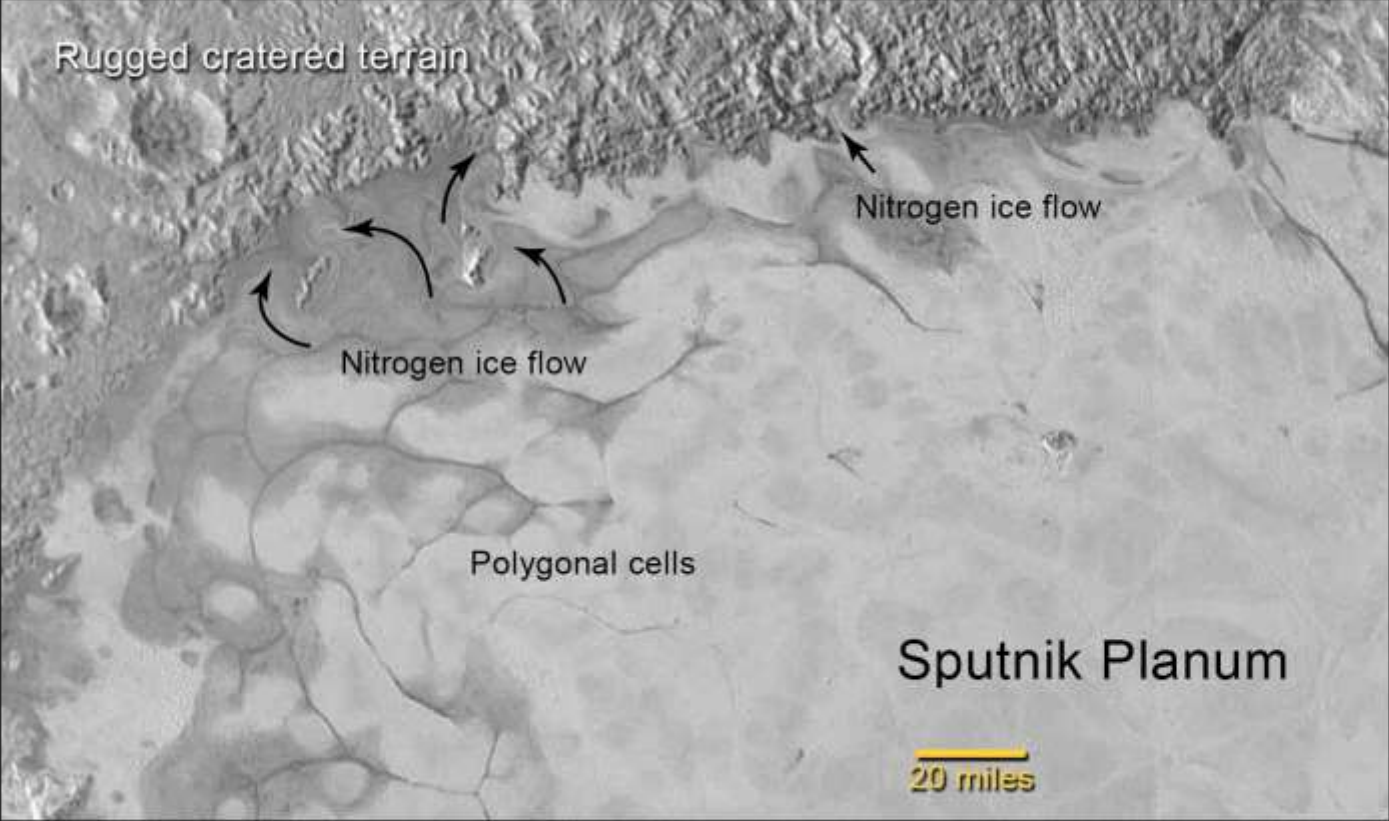
150 miles



Sputnik  
Planum

150 miles





Rugged cratered terrain

Nitrogen ice flow

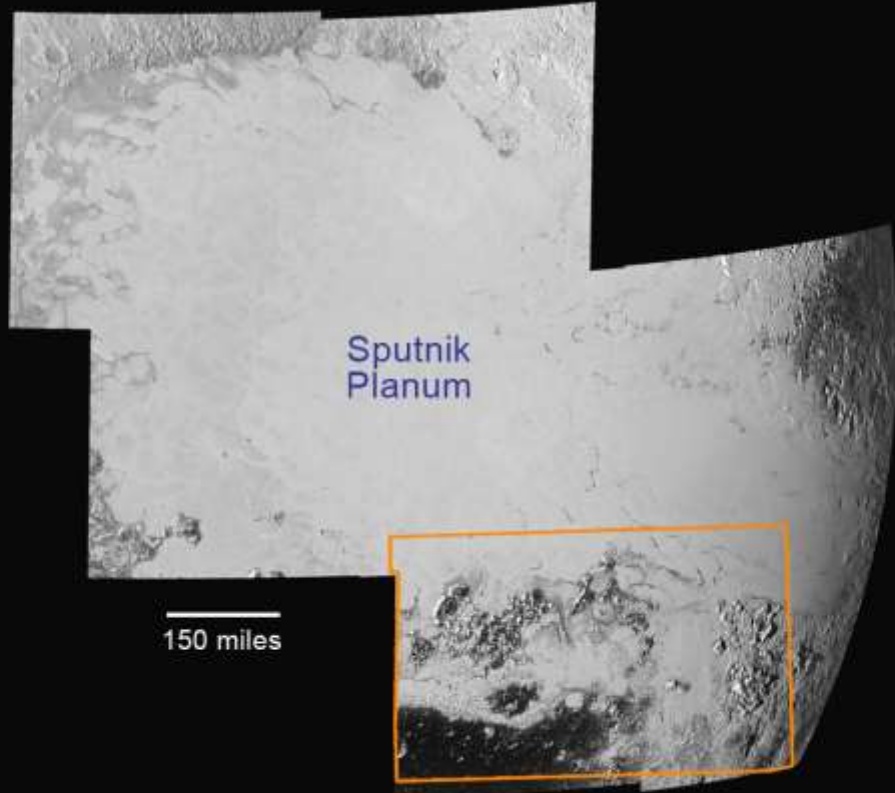
Nitrogen ice flow

Polygonal cells

Sputnik Planum

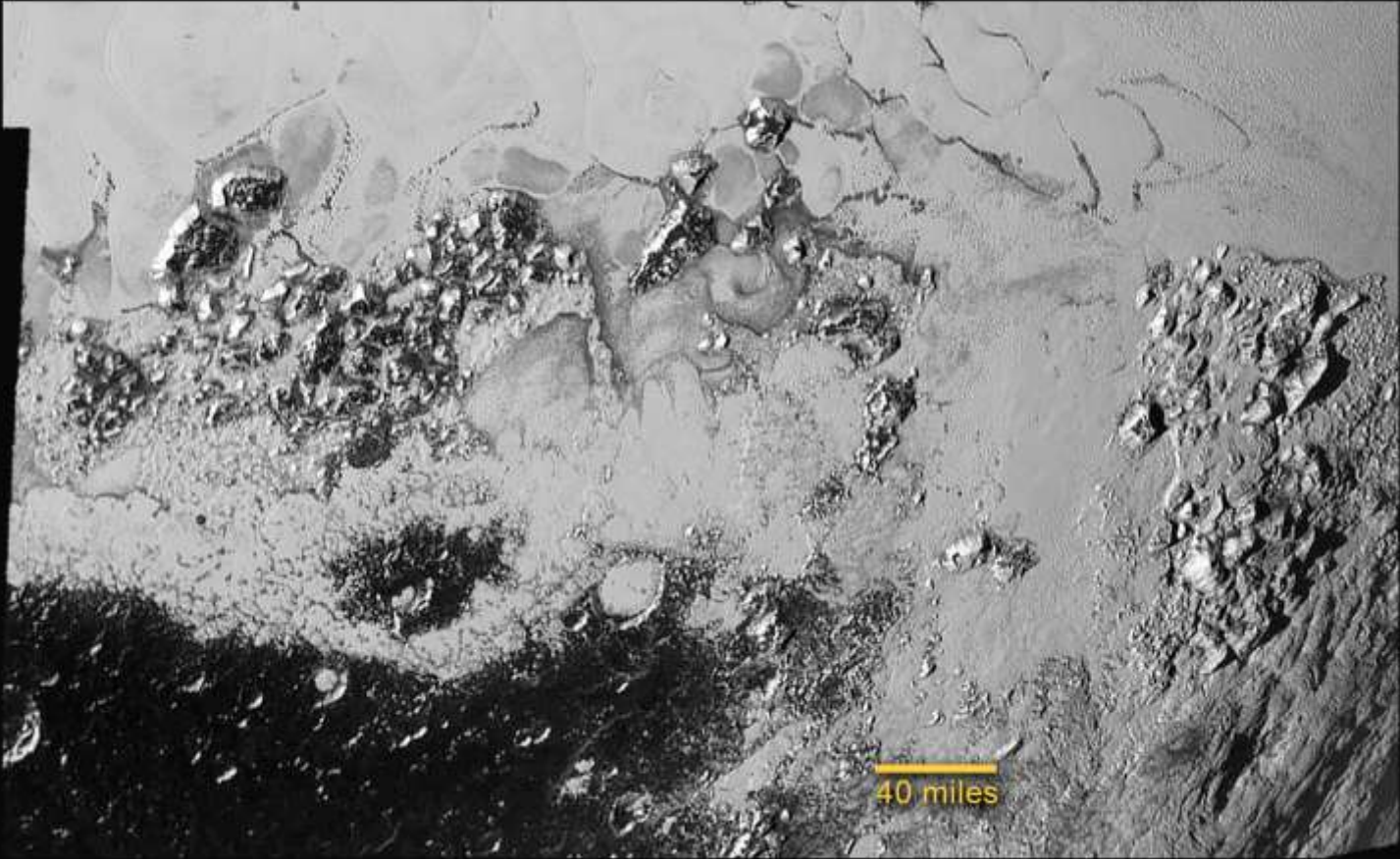
20 miles



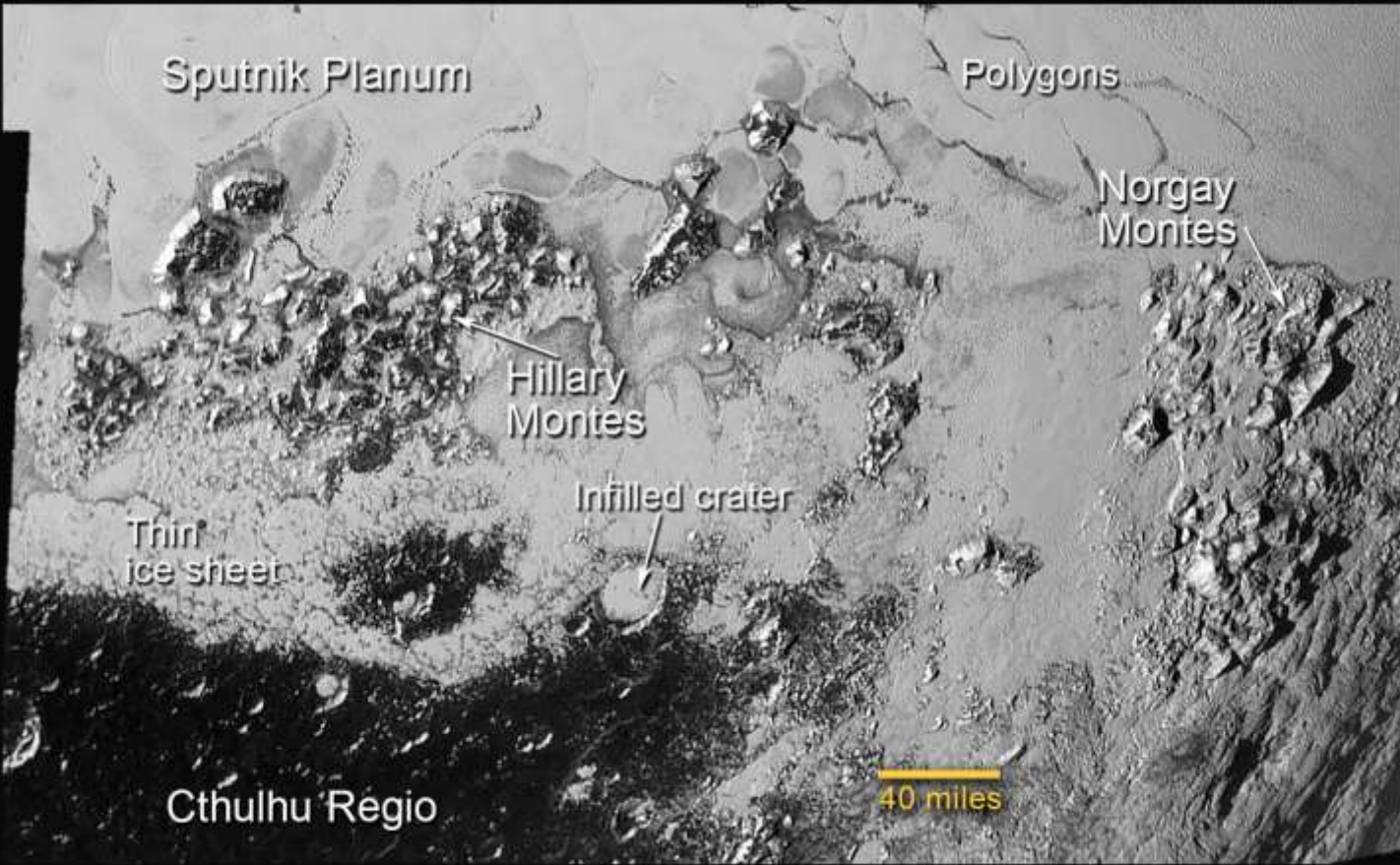


Sputnik  
Planum

150 miles



40 miles



Sputnik Planum

Polygons

Norgay Montes

Hillary Montes

Infilled crater

Thin ice sheet

Cthulhu Regio

40 miles

# PLUTO

## ICY WORLD OF WONDER



#PlutoFlyby #askNASA



PLUTO  
ICY WORLD OF WONDER



On Phone  
Question From Media





**With advanced propulsion,  
one must always look to the past  
and look to the future.**

