

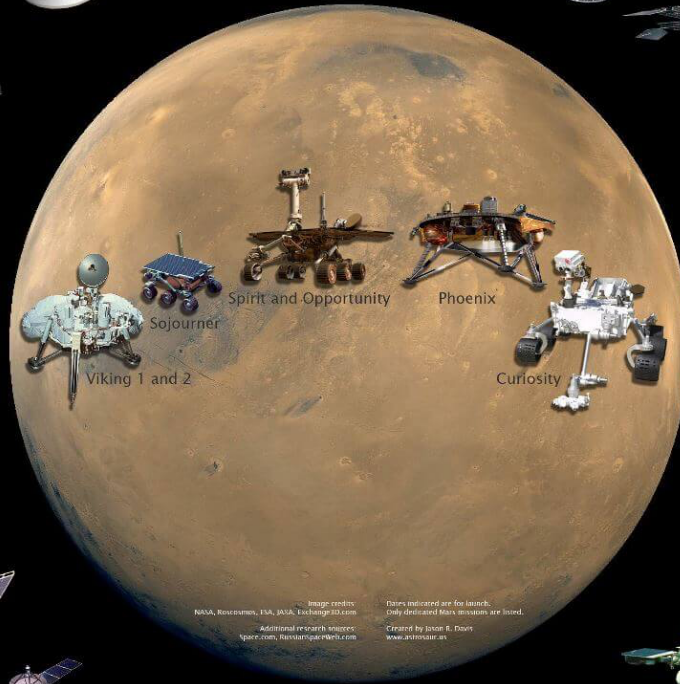
Mars Exploration and the search for the Holy Grail!

Enrico Flamini

IRSPS- Università D'Annunzio



Mars Missions family Portrait today



40: Mars Science Laboratory Curiosity
November 26, 2011
Mission to Gale Crater

1, 2: MARS 1M No. 1 / MARS 1M No. 2
October 10 / October 14, 1960
Both destroyed during launch

39: Phobos-Grunt
November 8, 2011
Stranded in Earth orbit

38: Phoenix
August 4, 2007
Landed, dug for water

3, 4, 5, 8: MARS 2MV-4 No. 1 / Mars 1 / Mars 2MV-3 No. 1 / Zond 2
October 24 / November 1 / November 4, 1962 / November 30, 1964
Broke up in Earth orbit / Radio failure en route / Stranded in Earth orbit / Radio failure en route

37: Mars Reconnaissance Orbiter
August 12, 2005
Orbiting Mars

6, 7: Mariner 3 / Mariner 4
November 5 / November 28, 1964
Payload fairing failed to open / First flyby and picture return

35, 36: Mars Exploration Rovers Spirit and Opportunity
June 10 / July 7, 2003
Both landed on surface, Opportunity still in operation

9, 10: Mariner 6 / Mariner 7
February 25 / March 27, 1969
Both flew by, returned pictures

34: Mars Express / Beagle 2 lander
June 2, 2003
Orbiting Mars, Beagle lost after separation

11, 12: Mars 1969 A / Mars 1969 B
March 27 / April 2, 1969
Both destroyed during launch

33: Mars Odyssey
March 7, 2001
Orbiting Mars

13, 17: Mariner 8 / Mariner 9
May 8 / May 30, 1971
Destroyed during launch / First probe to orbit Mars

32: Mars Polar Lander
January 3, 1999
Crashed on surface

14, 15, 16: Cosmos 419 / Mars 2 / Mars 3
May 10 / May 19 / May 28, 1971
Failed in Earth orbit / Lander crashed / Lander failed

31: Mars Climate Orbiter
December 11, 1998
Crashed due to imperial/metric unit mixup

18, 19, 20, 21: Mars 4 / Mars 5 / Mars 6 / Mars 7
July 21 / July 25 / August 5 / August 9, 1973
Missed planet / Orbed planet / Lander failed (6 and 7)

30: Nozomi
July 4, 1998
Missed planet

22, 23: Viking 1 / Viking 2
August 20 / September 9, 1975
Both landed on surface, returned data

29: Mars Pathfinder
December 4, 1996
Landed on surface, deployed Sojourner rover

24, 25: Phobos 1 / Phobos 2
July 7 / July 12, 1988
Lost communication en route / Lost communication near Phobos

28: Mars 96
November 16, 1996
Destroyed during launch

26: Mars Observer
September 25, 1992
Lost communication near Mars

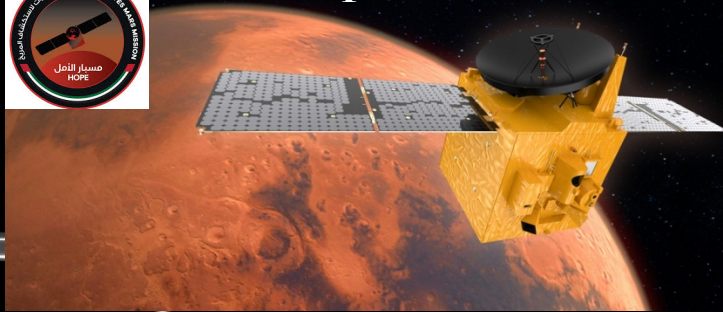
27: Mars Global Surveyor
November 7, 1996
Orbited and returned data

Image credits:
NASA, Roscosmos, ESA, JAXA, Eschlagner/ESA.com
Additional research sources:
Space.com, Ransar/gaer/retu.com
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www.actionstar.us

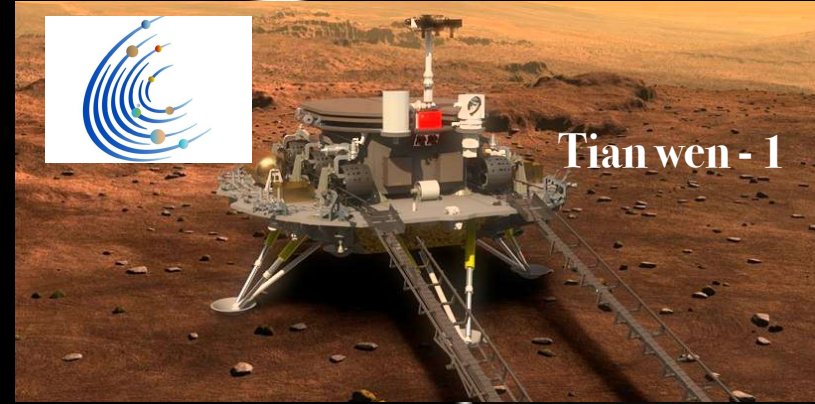
The New members of the Family



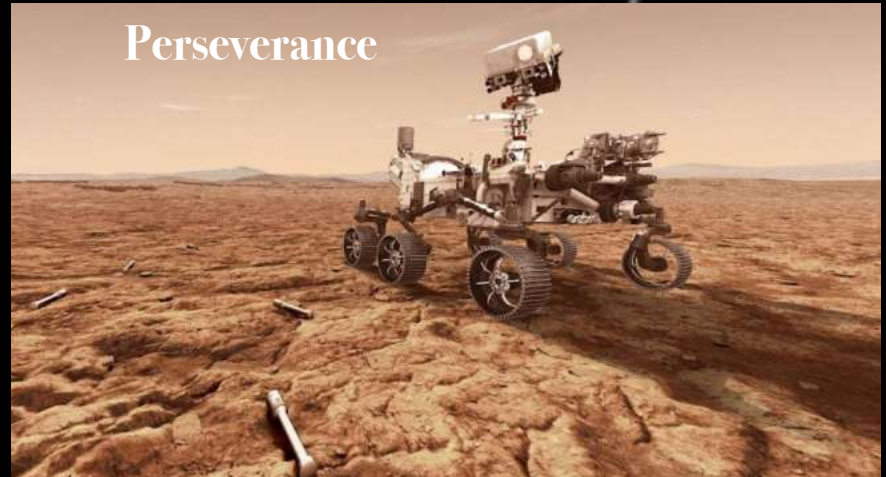
Hope



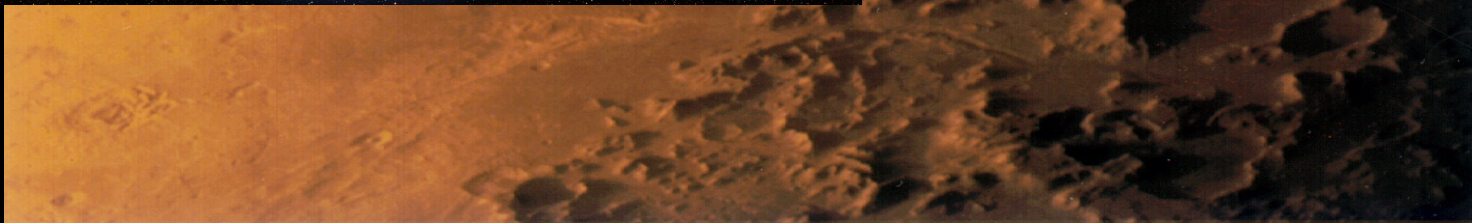
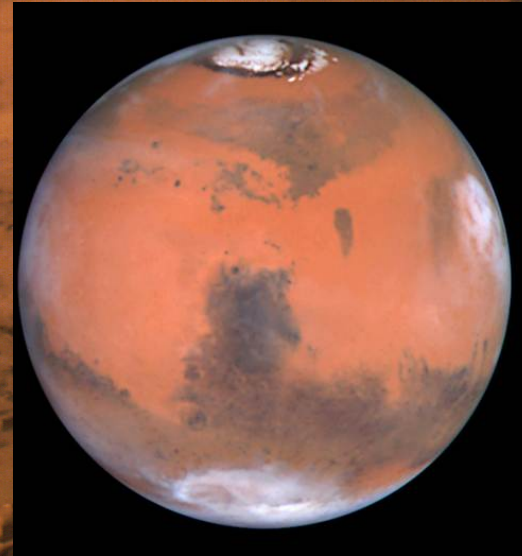
Tian wen - 1



Perseverance



Mars: Why?

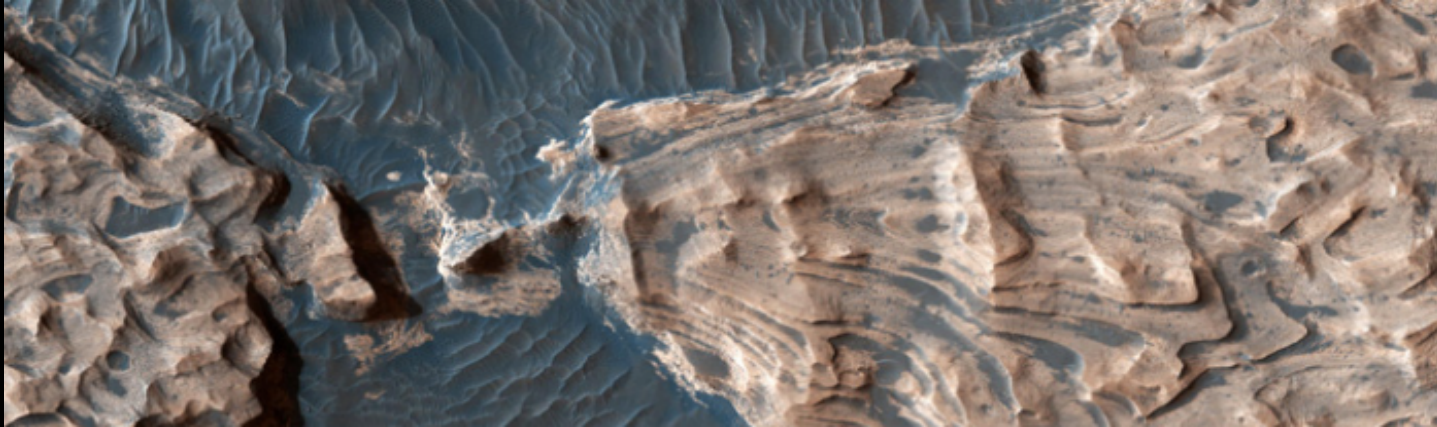


Mars Missions and Findings



A brief history of the search for water on Mars

Planet Boundary Conditions



Aram Chaos NASA/JPL/CalTech/Univ. Arizona

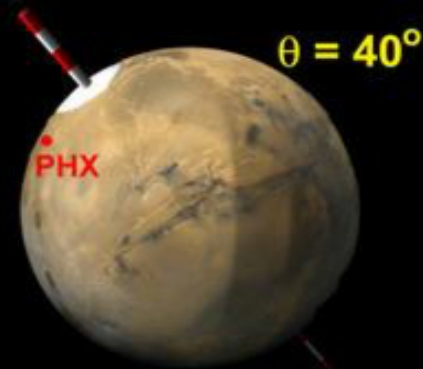
Setting the boundary conditions:

- Obliquity Variations
- Inner Structure and Heat Flow
- Permafrost Behavior and Effects
- Morphological and Mineralogical Evidences

Obliquity Variations

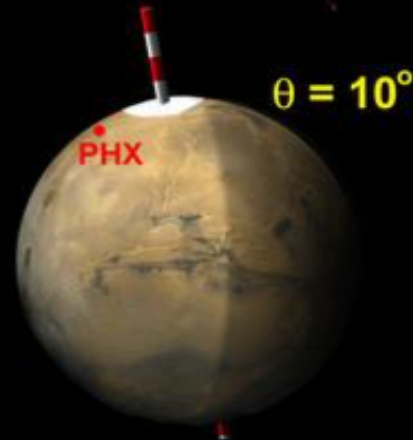
High Sun
Warm Summer
High Humidity

High Obliquity

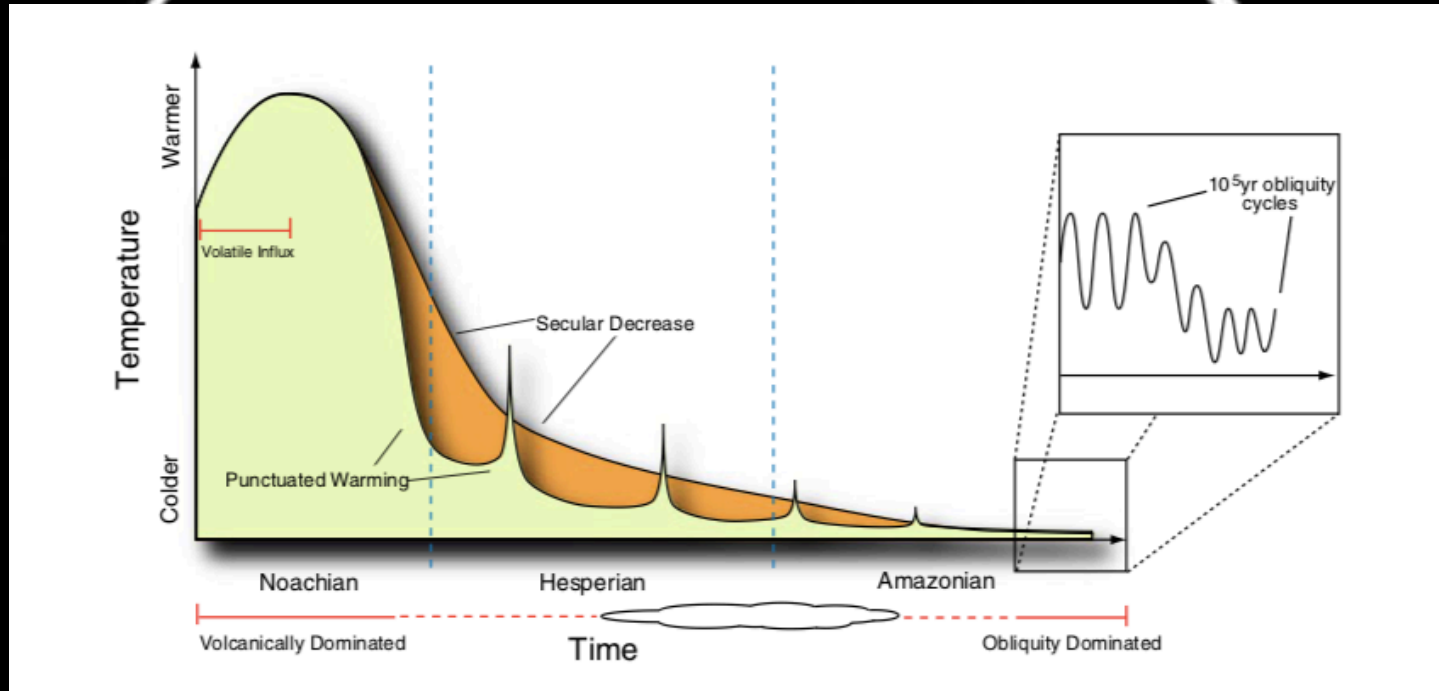


Low Sun
Cool Summer
Low Humidity

Low Obliquity



Obliquity Variations



MISCHNA ET AL.: OBLIQUITY/TRACE GAS GREENHOUSES ON MARS, JGR 2013

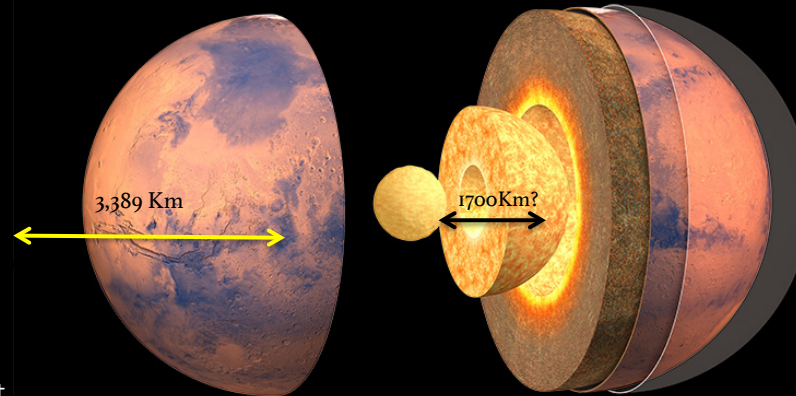
Martian obliquity has a periodic cycle of ~124,000 years and oscillates regularly, with swings of as much as 30–40 per cycle. Numerical integrations have calculated Martian obliquity back as far as 20 Myr [Laskar et al., 2004] and have provided probability functions of Martian obliquity (which is chaotic on longer timescales) throughout its history.

Inner Structure

Mars Geophysics

Waiting for InSight results...we only know mass, diameter and moment of inertia.

Satellites orbit perturbations point towards a layered internal structure

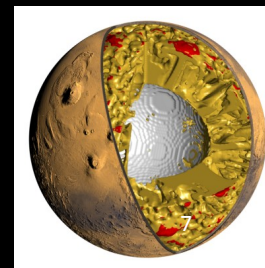


The Martian crust is thought to be between **30 and 100 Km** thick depending on the hemisphere, with a mean thickness of **65 Km**, a value that is closer to that of the Earth's continental crust.

Theoretical simulations show that the Martian mantle should still be subject to convective motions, the planet having a sufficient amount of heat to fuel such motions. However, unlike the Earth, this convection has perhaps not been able to correctly homogenize the mantle's material

Is the hemispherical dichotomy an indication of ancient plate tectonics?

Ana Plesa/DLR



Heat Flow

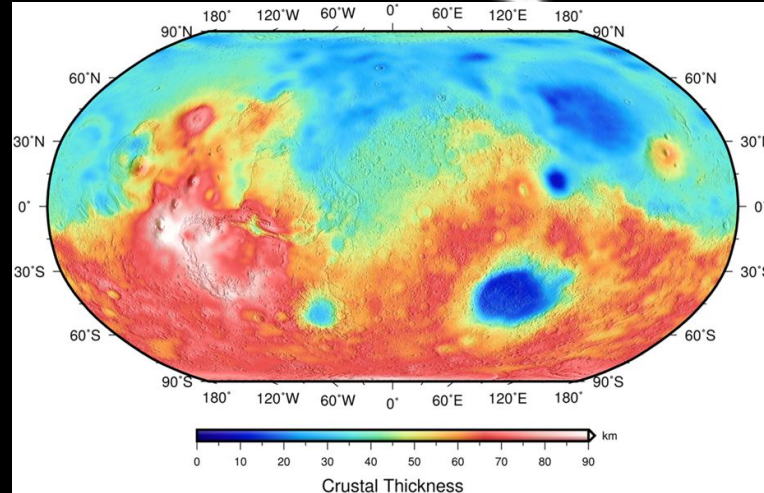
Mars has a **Heat Flow** (heat flows varying between **14 and 25 mW m⁻²**, with an average value of **19 mW m⁻²** that increases in intensity where the crust is thicker (sum of the heat generated in the crust and the heat flow from the mantle)

The bulk Urey ratio U_r describes the contribution of internal heat production to planetary-scale energy balance.

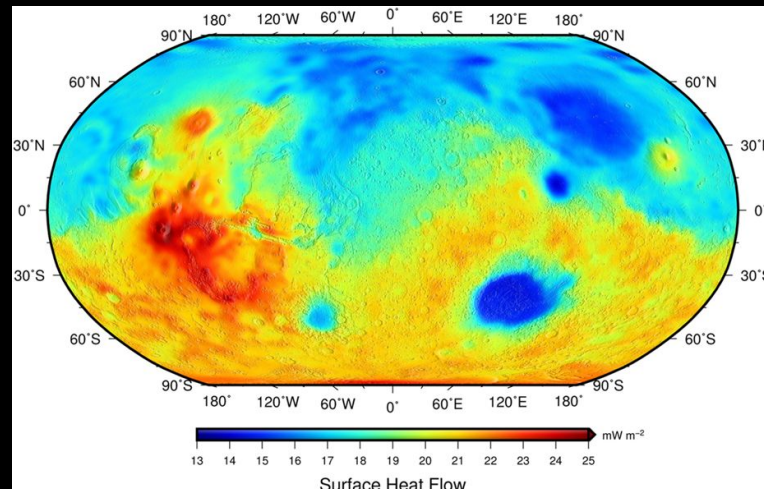
U_r is the ratio between total internal heat production and total heat loss through the surface

On Earth U_r is 0.35

On Mars is (presumably) 0.70-0.75



Parro et al Nature Scientific Reports, 2017



Permafrost

Permafrost: why is it important?

Permafrost is a major characteristic of the Mars surface

On the basis of IR observations permafrost ice extends down to 13° latitude in the Southern Hemisphere but is restricted to latitudes higher than 32° in the north (Vincendon, Forget & Mustard *J. Geophys. Res.*, 115, 2010).

Coradini & Flamini solved the equation of the heat propagation under Martian conditions and demonstrated the existence of a secular 'layer' of about 100-m depth (1979).

30 years later Mitrofanov et al (Geophysical Research Letters, vol. 34, 2007) confirmed the existence of an equilibrium top layer (ETL), in the North hemisphere, and a non-equilibrium DTL in the South Hemisphere (due to presence of dust)

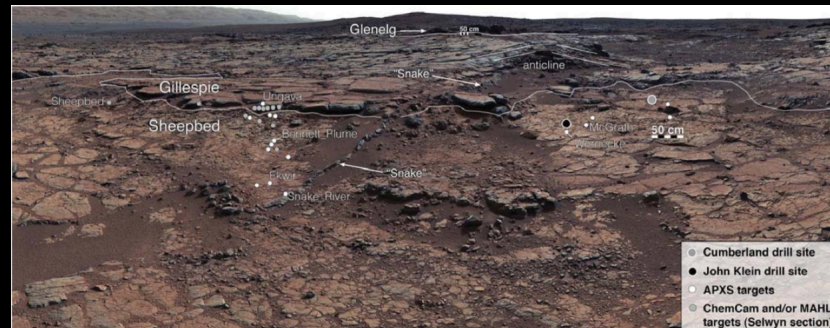


Both ETL and DTL act as “insulator” screening deep layer from heat/cold waves propagation

Ground Evidences

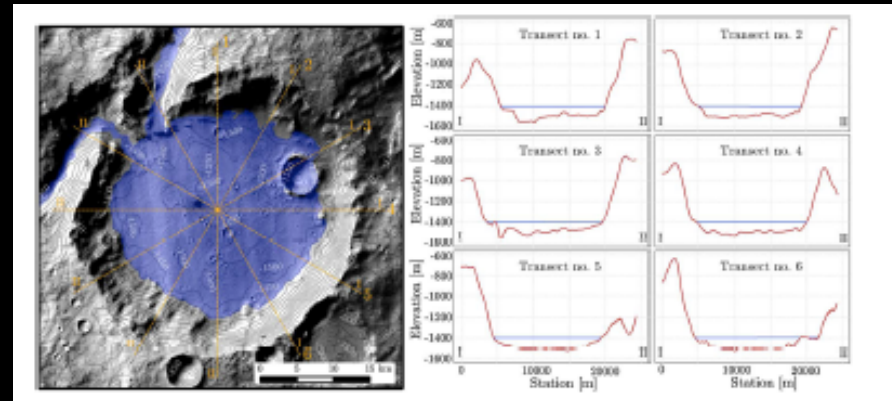
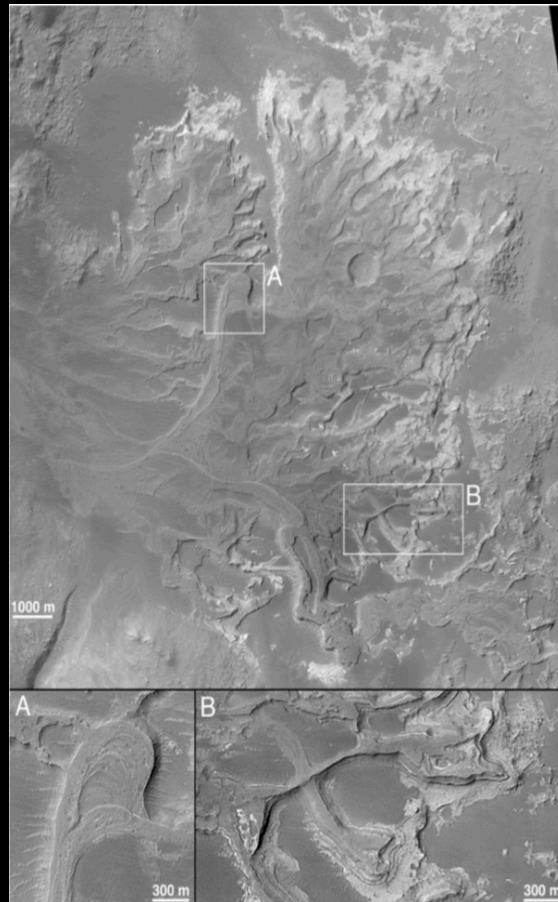


Mineralogy of an ancient lacustrine succession from the Murray formation, Gale crater, Mars: Rampe et al., Earth & Planet. Sci. Letters 471, 2017.



A Habitable Fluvio-Lacustrine Environment at Yellowknife Bay, Gale Crater, Mars
Grotzinger et al. SCIENCE, 343, 2014

Evidences from Orbit

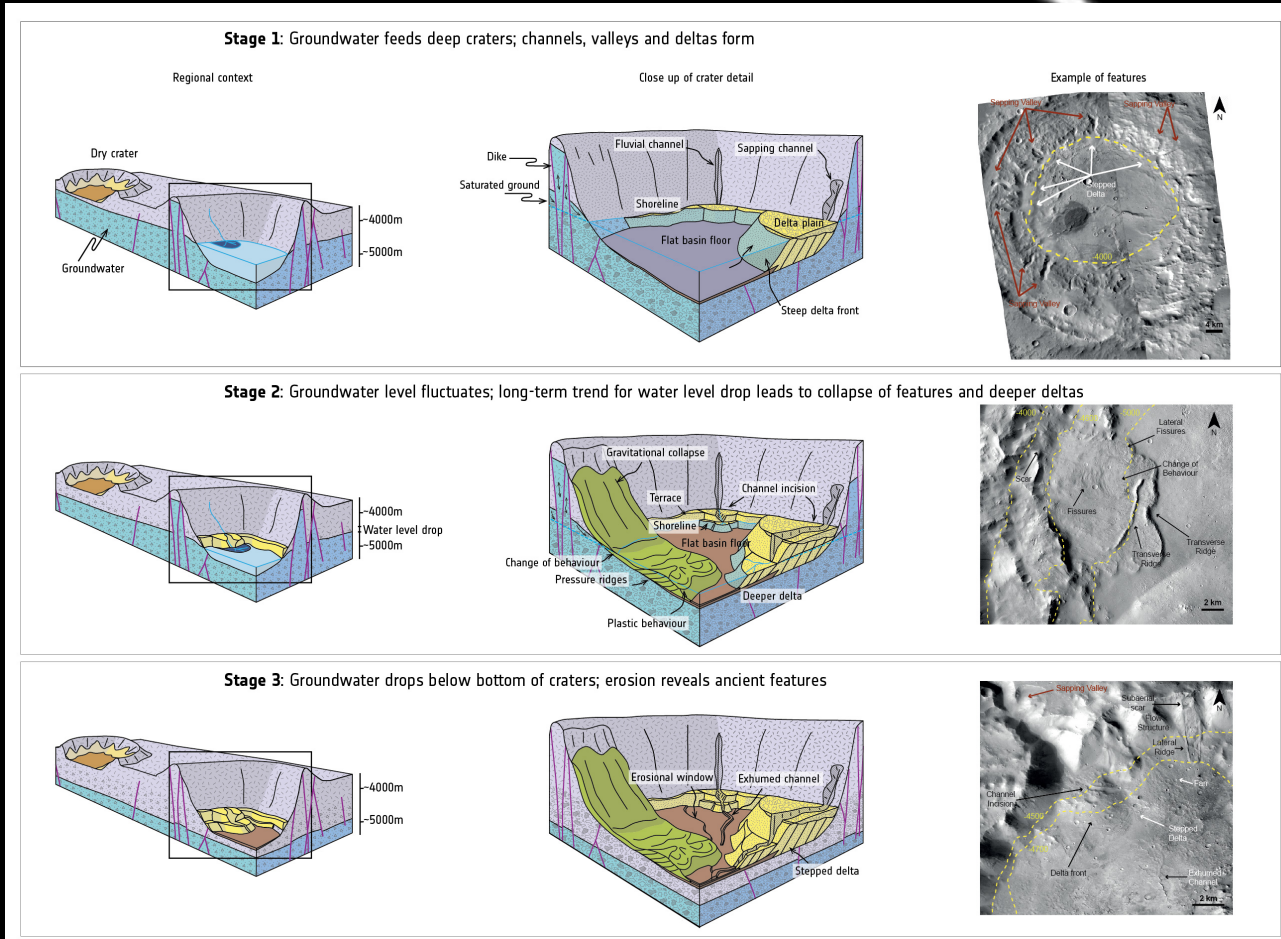


Hydraulic modeling of the tributary and the outlet of a Martian paleolake located in the Memnonia Quadrangle (Baratti et al., *J. Geophys. Res. Planets*, 120, 2015)

Evolution and depositional environments of the Eberswalde fan delta, Mars (M Pondrelli, et al. - *Icarus*, 2008)

Evidence for Persistent Flow and Aqueous Sedimentation on Early Mars (Malin and Edgett, *SCIENCE* 302, 2003)

Groundwater planet-wide system



Geological evidence of planet-wide groundwater system on Mars: Salese et al., JGR 2018

Surface Evidences

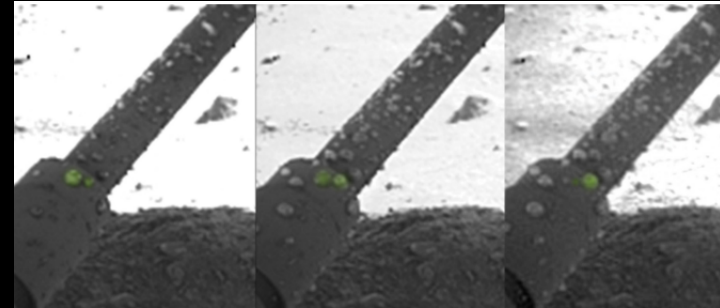


Mars Location This false-color image taken by Mars Rover Spirit's panoramic camera (Pancam) shows salt deposits on the basin floor of Gusev Crater. These salts may record the past presence of water on Mars, as they are most easily mobilized and concentrated in a liquid solution. (Image credit: NASA/JPL/Cornell)

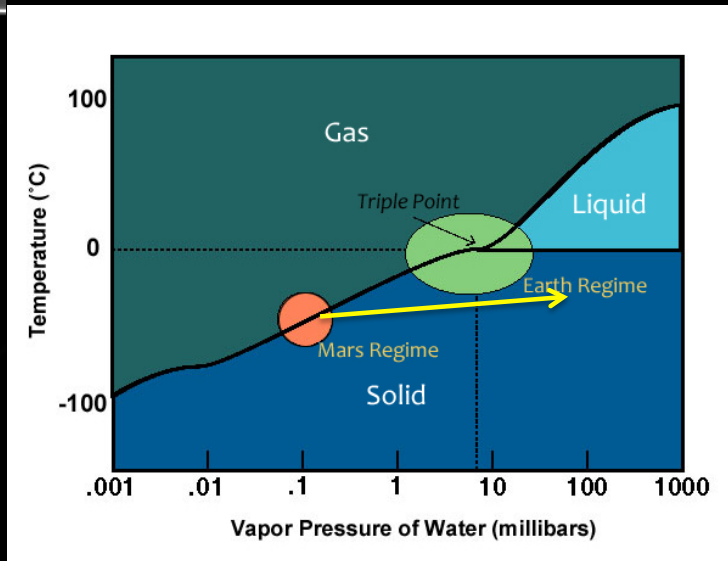


Earth Analog This image shows evaporite deposits near springs in the region of Cuatrociénegas, Mexico. Evaporites are sediments that form from the evaporation of saline water. (Image credit: John W. Holt, Institute for Geophysics, University of Texas)

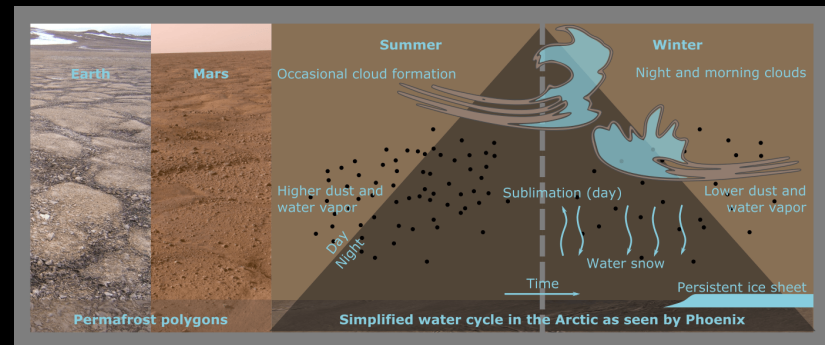
the Water Cycle on Mars



Existed —————→ Still exists

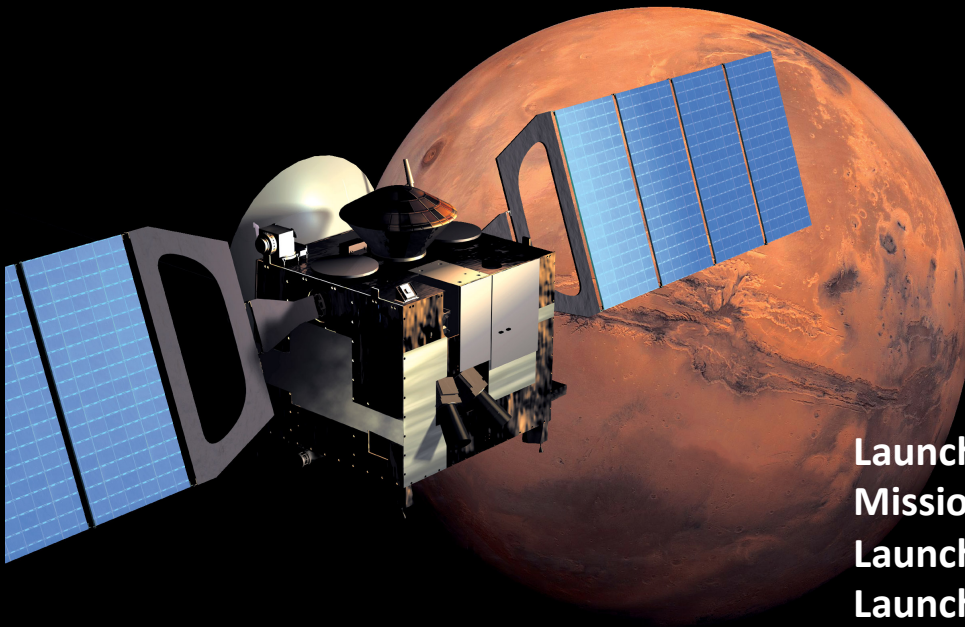


this site would have a night-time relative humidity that's sufficient for perchlorate salts to latch on to water molecules. As the temperature warms during the day, the salts would give up the water to the atmosphere again, creating a water cycle.



It is reasonable to assume that a good percentage of water percolated underground mixing with surficial and underground salts

Mars Express (MEX for his friends), the Martian water diviner

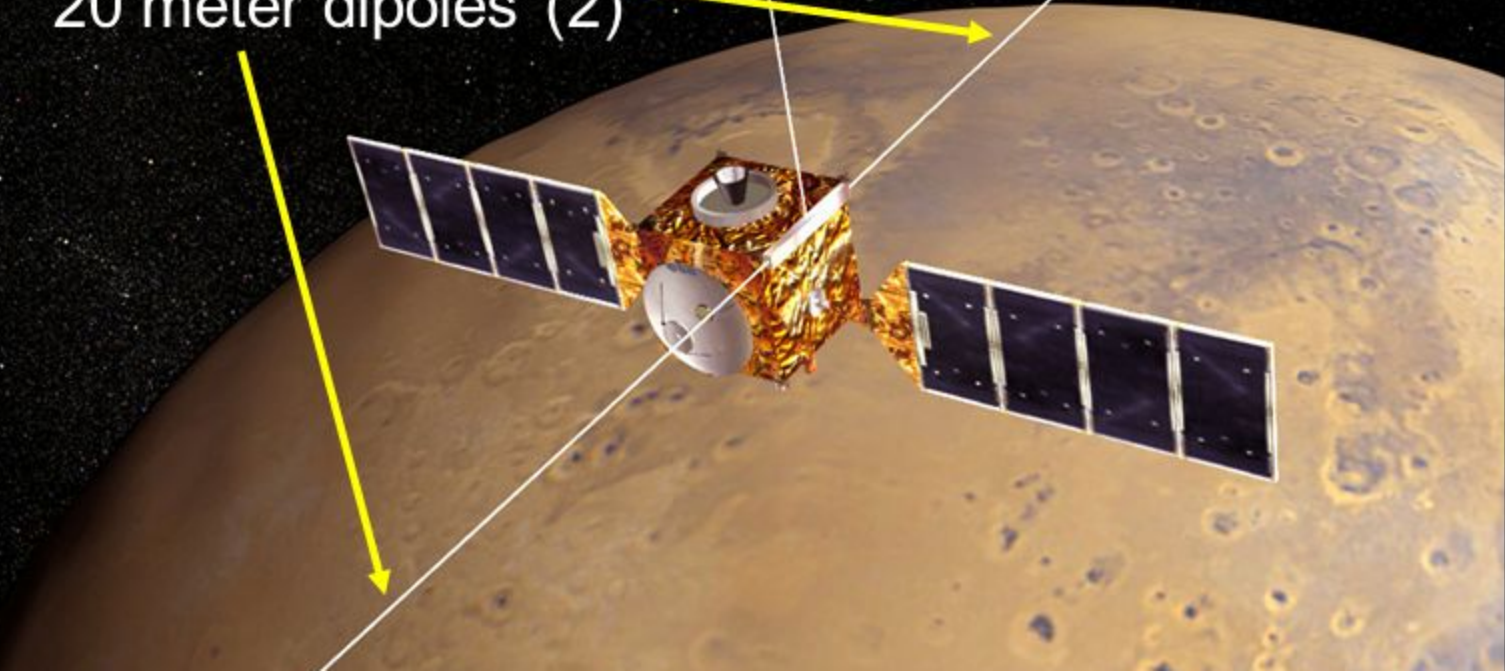


Launch date:	02-Jun-2003 17:45 UT
Mission end:	31 December 2022
Launch vehicle:	Soyuz-Fregat
Launch mass:	1223 kg
Mission phase:	Operational
Orbit:	Orbital Inclination: 86.9°
	Pericentre: 330 km
	Apocentre: 10 530 km
	Period: 7 h 00 m

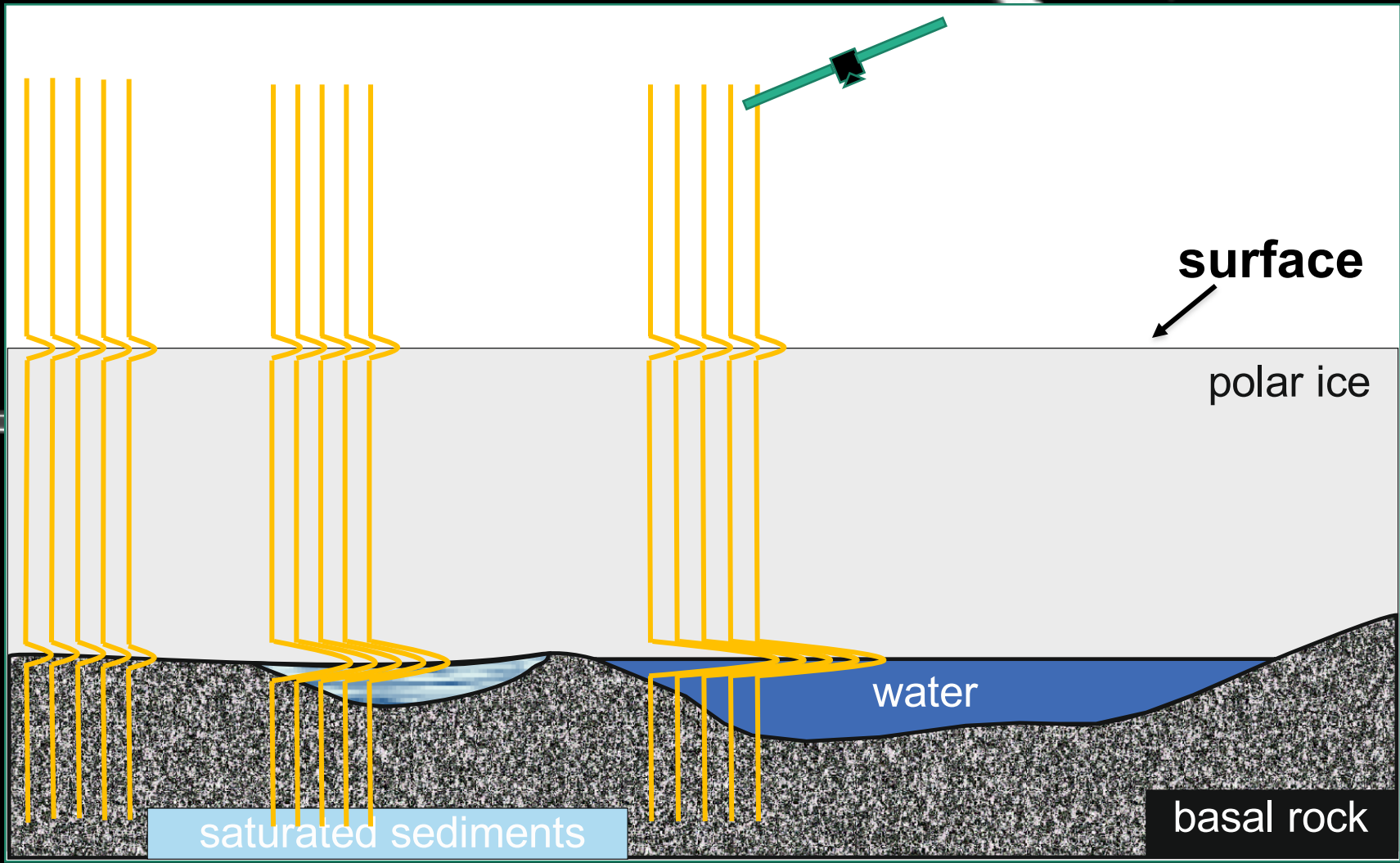
MARSIS Antennas

7 meter monopole

20 meter dipoles (2)



Subglacial liquid water on Mars



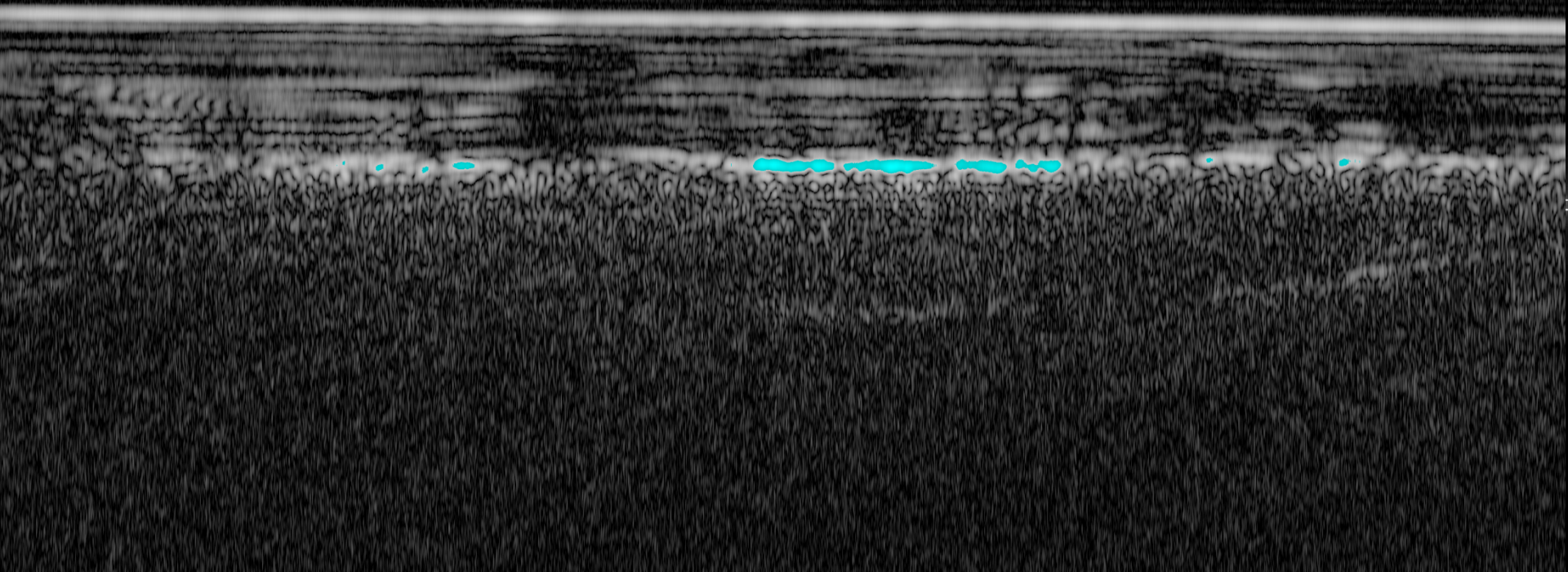
Subglacial liquid water on Mars

On-board processed data

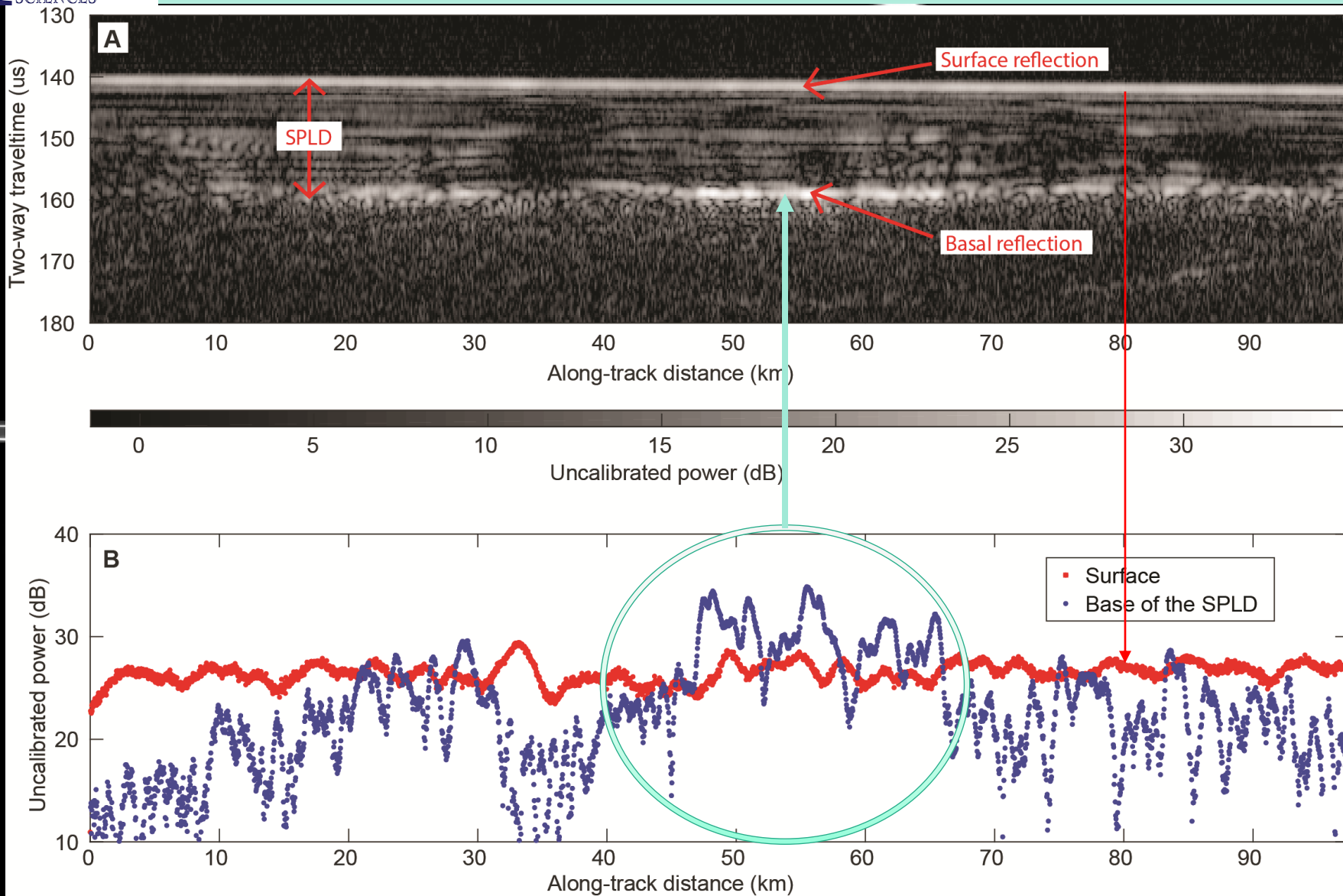
The image shows a dark, blurry scene with a prominent, bright, curved horizon line. The background is mostly black with some horizontal streaks and a few small white specks, suggesting a low-resolution or motion-blurred image of a celestial body's surface or atmosphere.

Subglacial liquid water on Mars

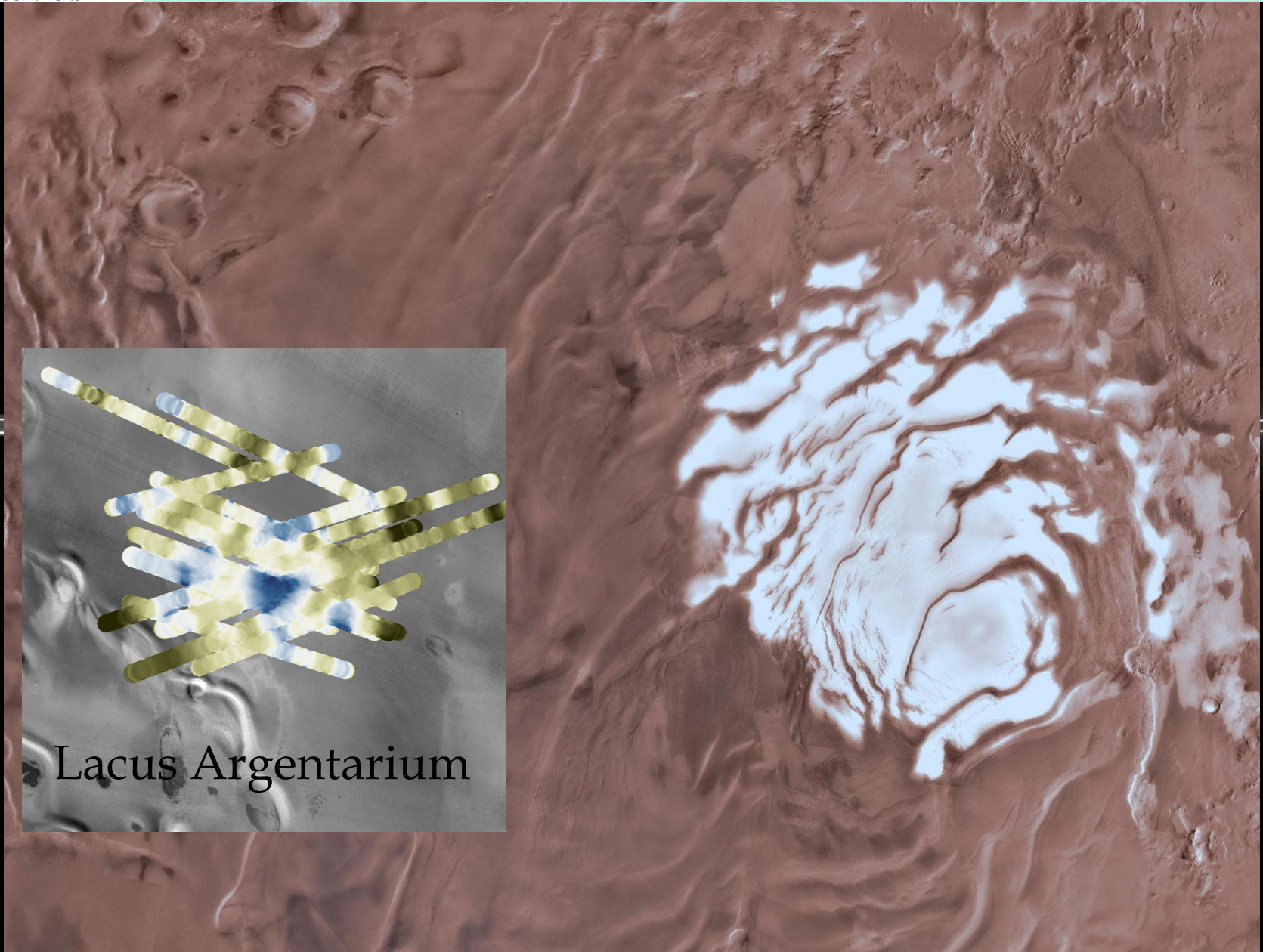
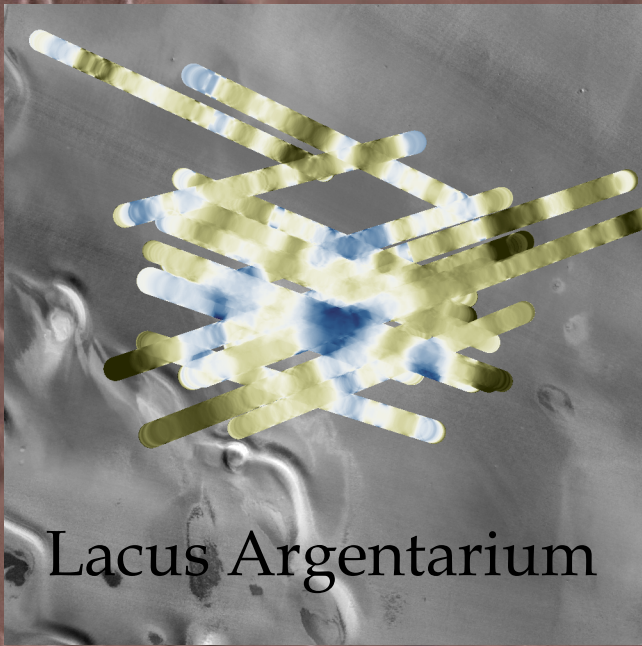
Raw uncompressed data stored in Flash memories



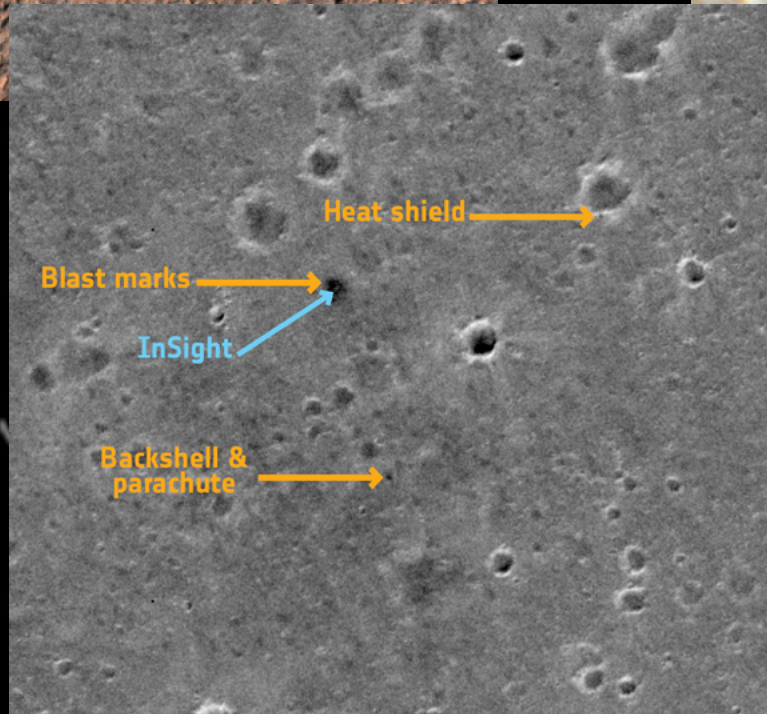
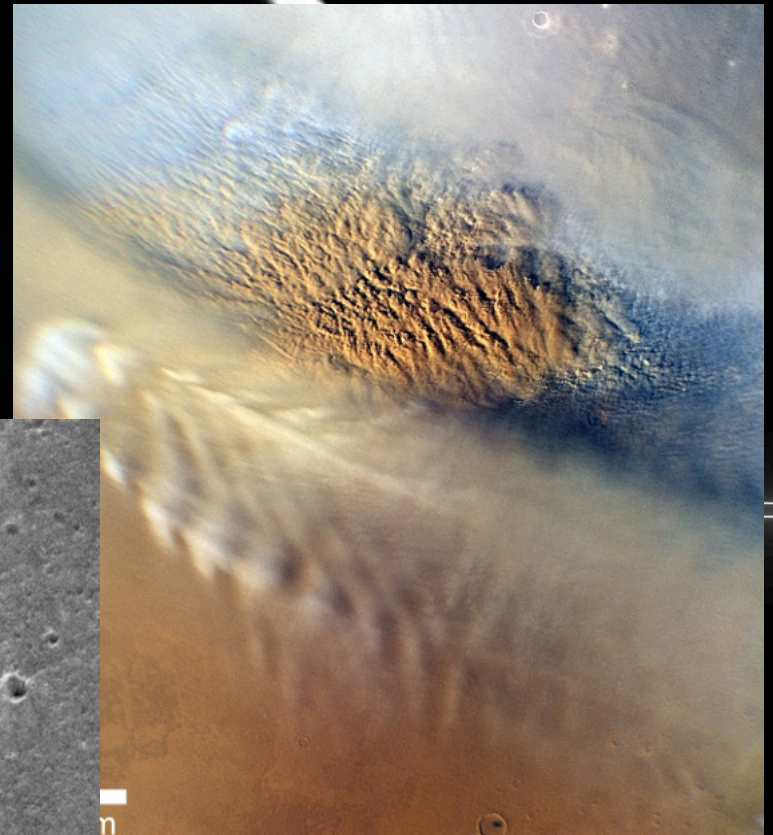
Subglacial liquid water on Mars



Subglacial liquid water on Mars



Today around Mars: TGO



The last 10 days : Hope

Launch 19, July 2020

OBJECTIVES

The First Complete Picture of the Martian Atmosphere.

01

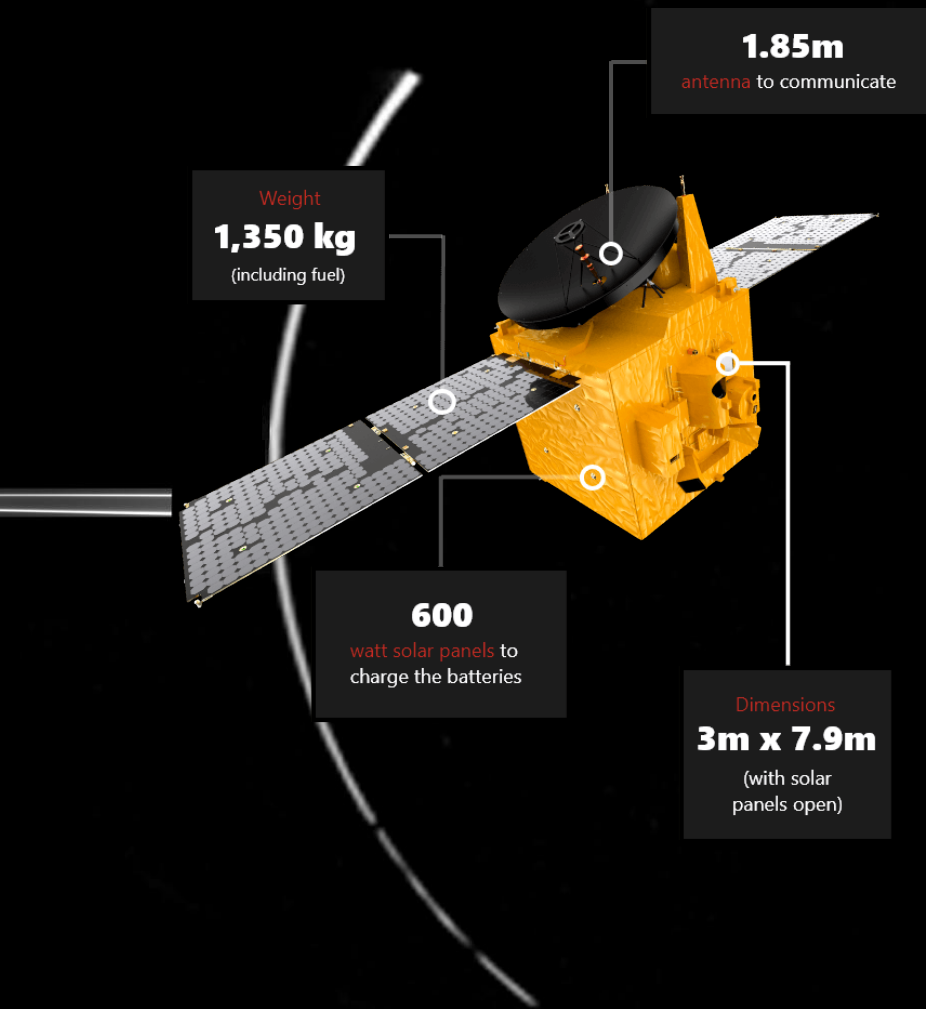
Understand climate dynamics and the global weather map through characterizing the lower atmosphere of Mars.

02

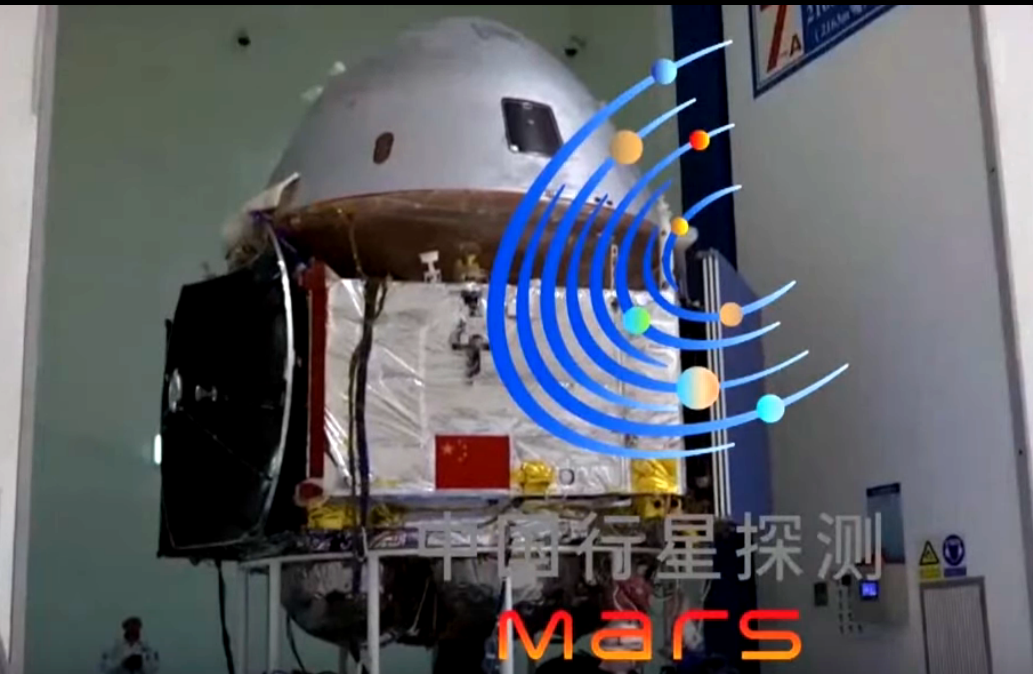
Explain how the weather changes the escape of Hydrogen and Oxygen through correlating the lower atmosphere conditions with the upper atmosphere.

03

Understand the structure and variability of Hydrogen and Oxygen in the upper atmosphere, as well as identifying why Mars is losing them into space.



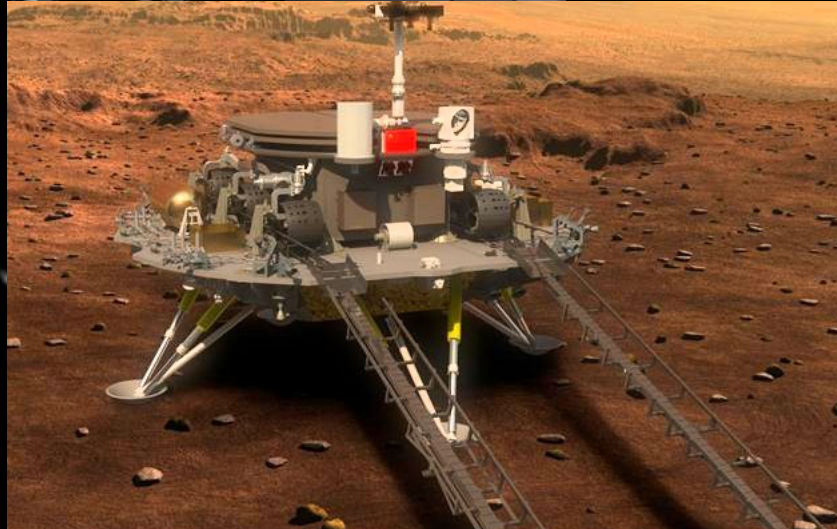
The last 10 days : Tianwen-1



Launch 23 July 2020

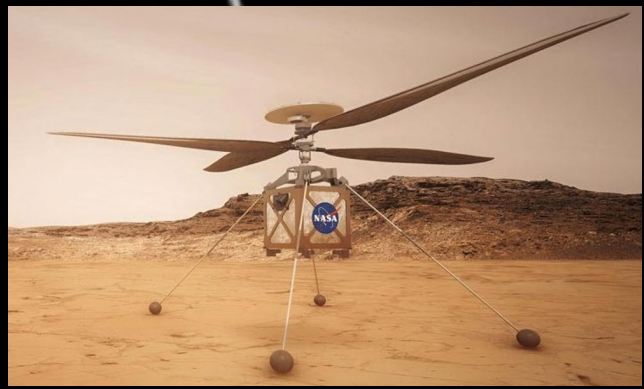
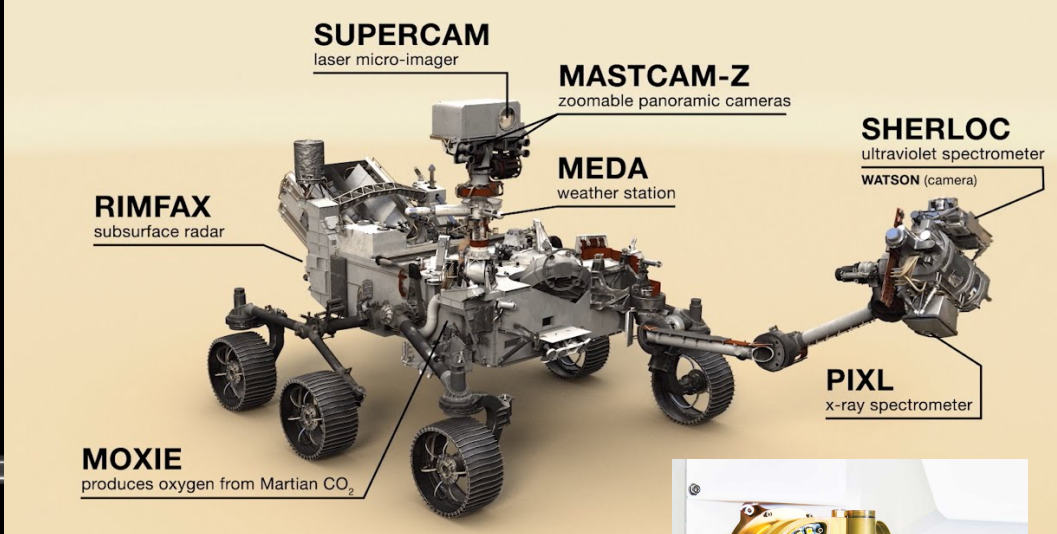
Objectives

- Find evidence for current and past life,
- produce Martian surface maps,
- characterize Martian soil composition and water ice distribution,
- examine the Martian atmosphere, and ionosphere



The last 10 days : Perseverance

Launch 30 July 2020



Habitability

Identify past environments capable of supporting microbial life

Biosignatures

Seek signs of possible past microbial life in those habitable environments, particularly in special rocks known to preserve signs of life over time

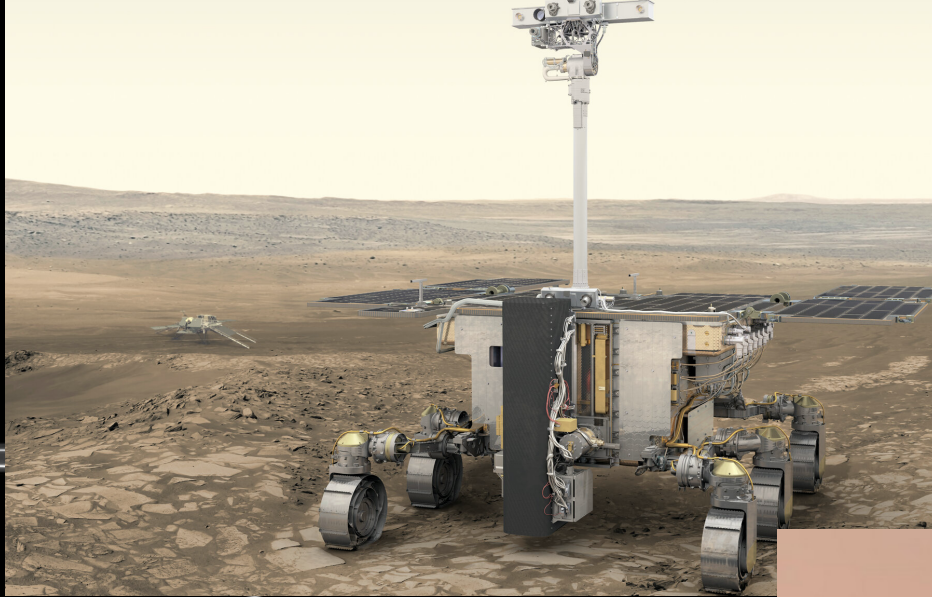
Caching Samples

Collect core rock and "soil" samples and store them on the Martian surface

Preparing for Humans

Test oxygen production from the Martian atmosphere

What next?



ExoMars 2022

Mars Sample Return



Being Prepared for the Mars Exploration Future



Universita' d'Annunzio
Campus di Pescara

Indirizzo in Planetary Sciences

Laurea Magistrale in Scienze e Tecnologie
Geologiche della Terra e dei Pianeti

2 anni: 3 Semestri di Lezioni, 1 semestre per tesi e tirocinio

Escursioni in analoghi marziani e planetari: Marocco, Spagna, Grecia e Dolomiti

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