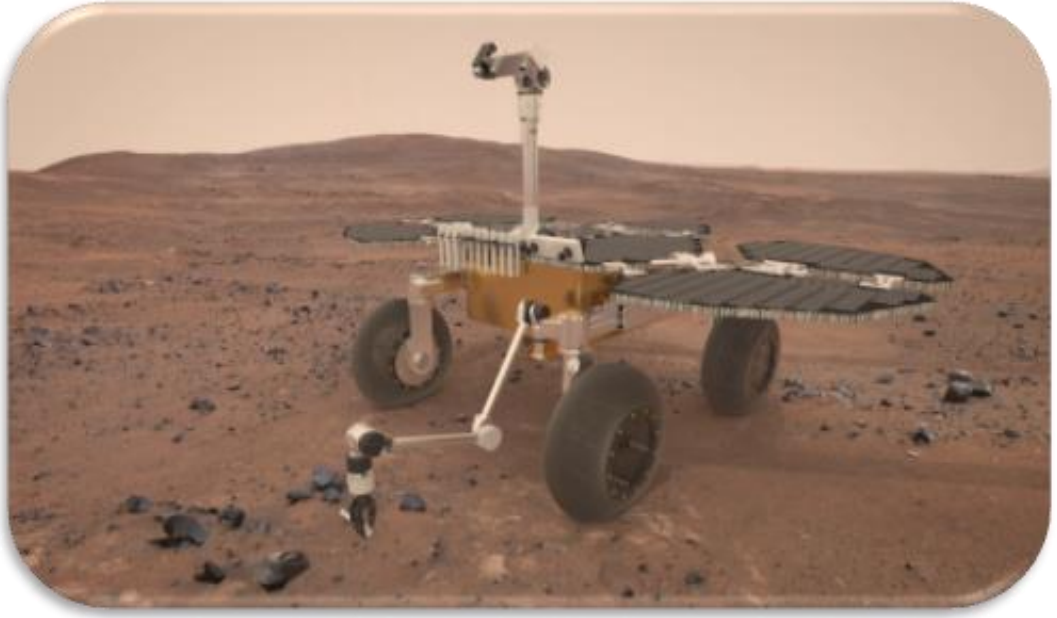
Landing on Mars

CESAR Scientific Challenge

Exploring Mars with *Mars Express* and *ExoMars*



Beatriz González García on behalf of the CESAR Science Cases Team

Looking for the lost Martian

A Greek philosopher, Anaxagoras in the century VI BC, raised a theory (not yet demonstrated), it was called **panspermia** (“pan”, all and “sperma” seed). It is the hypothesis that life could have originated somewhere in the Universe and reached Earth, embedded in the remains of comets and meteorites.

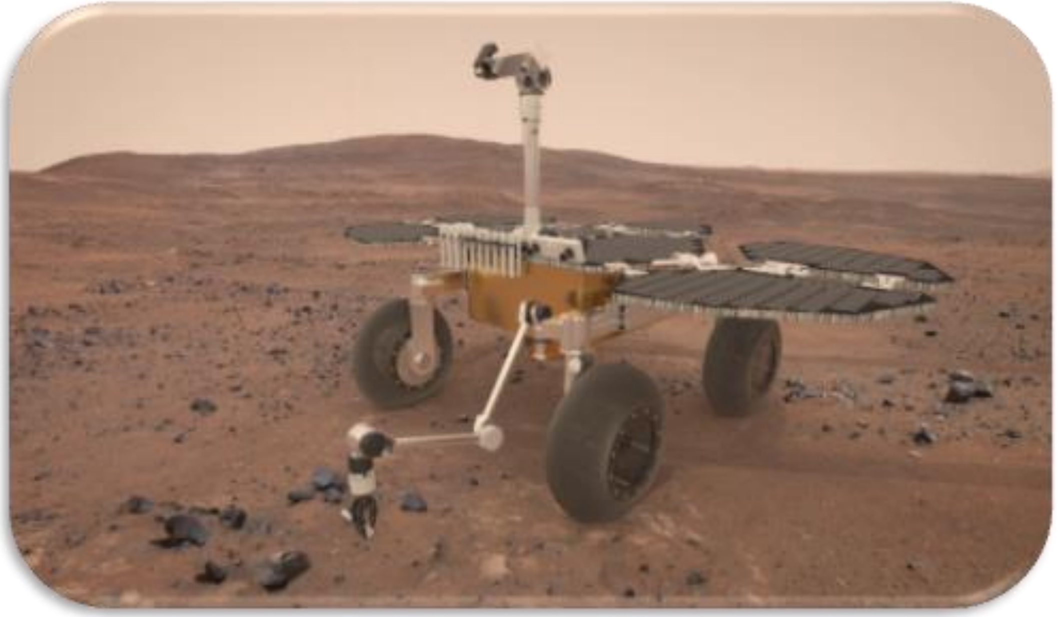


Figure I Martin rover motors ahead (Credits: ESA)

Would you like to travel with us to Mars in search of life traits

Do you dare to try it?

Didactics

Figure I: *The considered top 10 skills in the 2020. (Credits: Rethinking).*

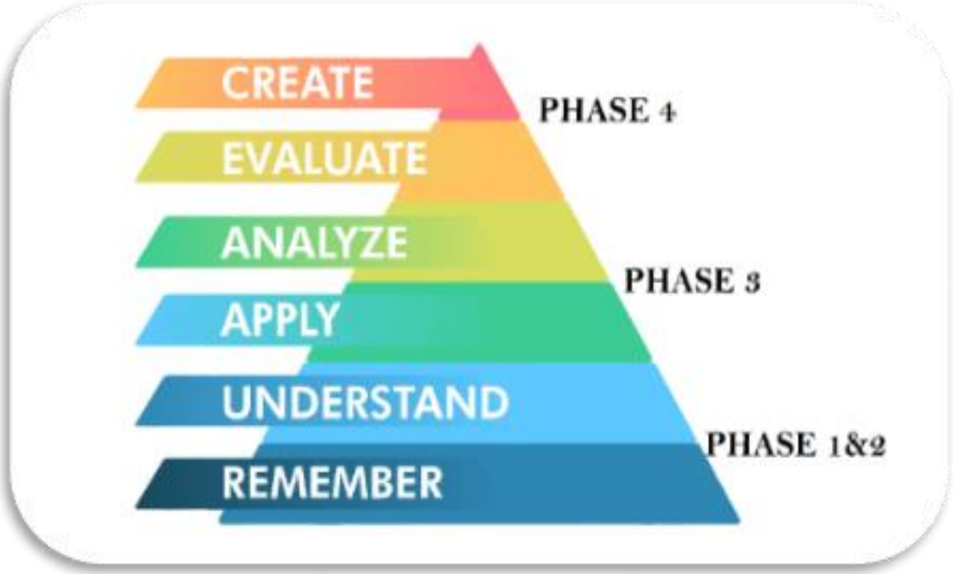
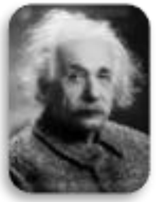


Figure II: *Bloom's Taxonomy diagram. (Credits: https://medium.com/@ryan.ubc.edtech/)*

Names				
Profession	Mathematician/ Software engineer	Astrophysics	Engineer	Biologist
Roles	She/he is in charge of leading the correct execution of calculations	She/he is in charge of planning the observations of the ESA/Mars space missions	She/he is in charge of finding the best strategy agreed between the members of the Team and its correct execution.	She/he is in charge of leading more detailed investigations on energy processes and composition of celestial objects
Reference (female)	Katherine Johnson 	Vera Rubin 	Samantha Cristoforetti 	Marie Curie 
(male)	Steve Wozniak 	Matt Taylor 	Pedro Duque 	Albert Einstein 

Fast Facts

Age range: 14 - 17 yr

Type: Practice

Complexity: Medium

Preparation time: 2 to 4 hours depending on the chosen experience

Required time: Between two hours and a term depending on the chosen format

Location: Indoor

Includes the use of: Computers or tablets, internet, Google Earth Pro

Currículum relevance

- **Physics and chemistry:** The scientific method, laboratory work. Thermal energy: Heat and its temperature.
- **Mathematics:** use of technological means in the learning process (orderly collection of data, representation of graphs).
- **Geography and History**: The physical environment: the movements of the Earth and their consequences.
- **Biology and Geology:** Planet Earth. Movements and characteristics of those movements.

The students should already know…

- Use physical maps.
- Distinguish latitude and longitude on globes.
- Basic concepts of biology. What is life?
- Identify and explain characteristics of the main forms of energy: light, thermal, electrical, etc.
- Understand the graphical representation of a table of values.
- Basic concepts of geometry: parallel and perpendicular lines, angles and their relationships

Students will learn …

- What are the most important factors for life to be viable on a planet.
- The importance of working with a multidisciplinary team to obtain better conclusions.
- Analyze the importance of studying all these data and its usefulness in science and society

Students will improve …

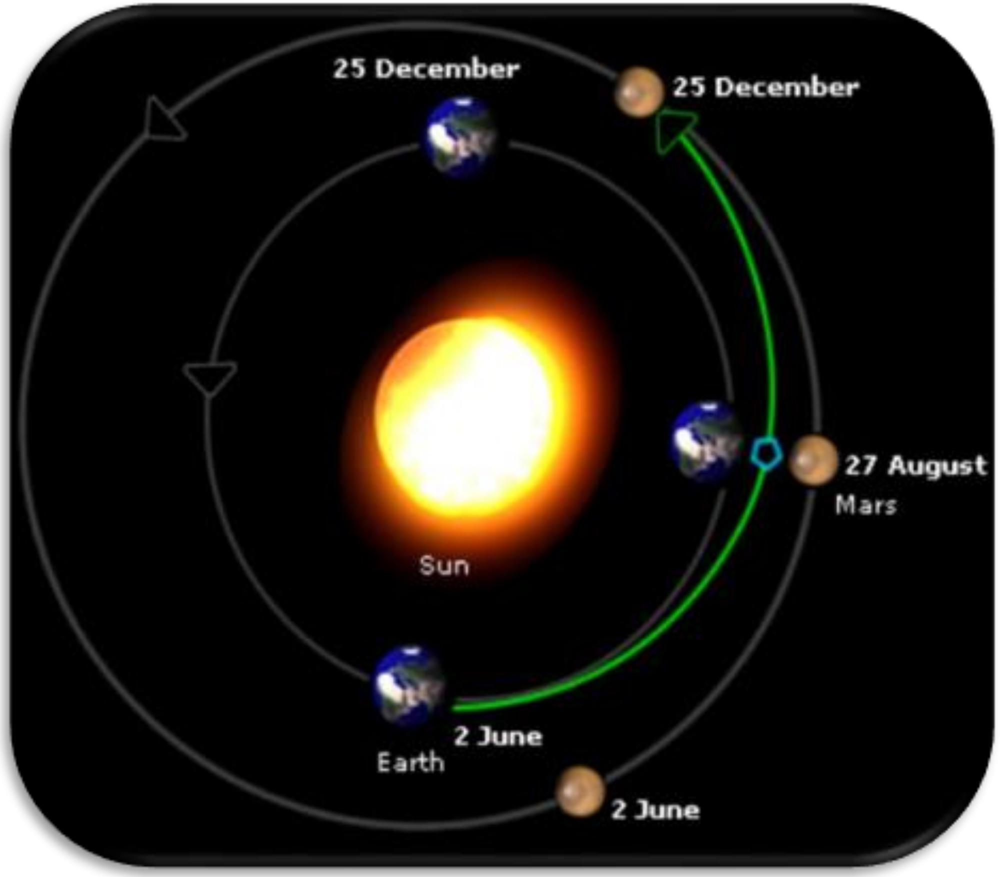
- Their understanding of scientific thinking.
- The strategies of the scientific method.
- Teamwork and communication.
- Skills of evaluation and analysis of results.
- The application of theoretical knowledge to real situations.

What did you know?

Menti.com – what do you know about Mars?

Mentimeter   Features   Solutions   Pricing   Blog

Code 71 49 90 1



SPRING	SUMMER	FALL	WINTER

Let's start the Challenge

SCIENCE OPERATIONS CENTRE (SOC) • Where the scientific operations of the missions to Mars are carried out (they define the observations) by scientists and engineers. • In continuous contact with the MOC	**European Space Astronomy Centrel, ESAC, Madrid**
CENTER FOR DESIGN, INTEGRATION AND TESTING OF SATELLITE COMPONENTS • Where the design, integration and testing of the satellite and the mission support systems (such as the rover) are performed mainly by engineers	**European Space Research and Technology Centre, ESTEC, The Netherlands**
MISSION OPERATIONS CENTRE (MOC) • Where the orbit of the spacecraft is designed and safety requirements are ensured tracking the satellites by engineers and operators	**European Space Operations Centre, ESOC, Germany**

Menti.com – Role Models

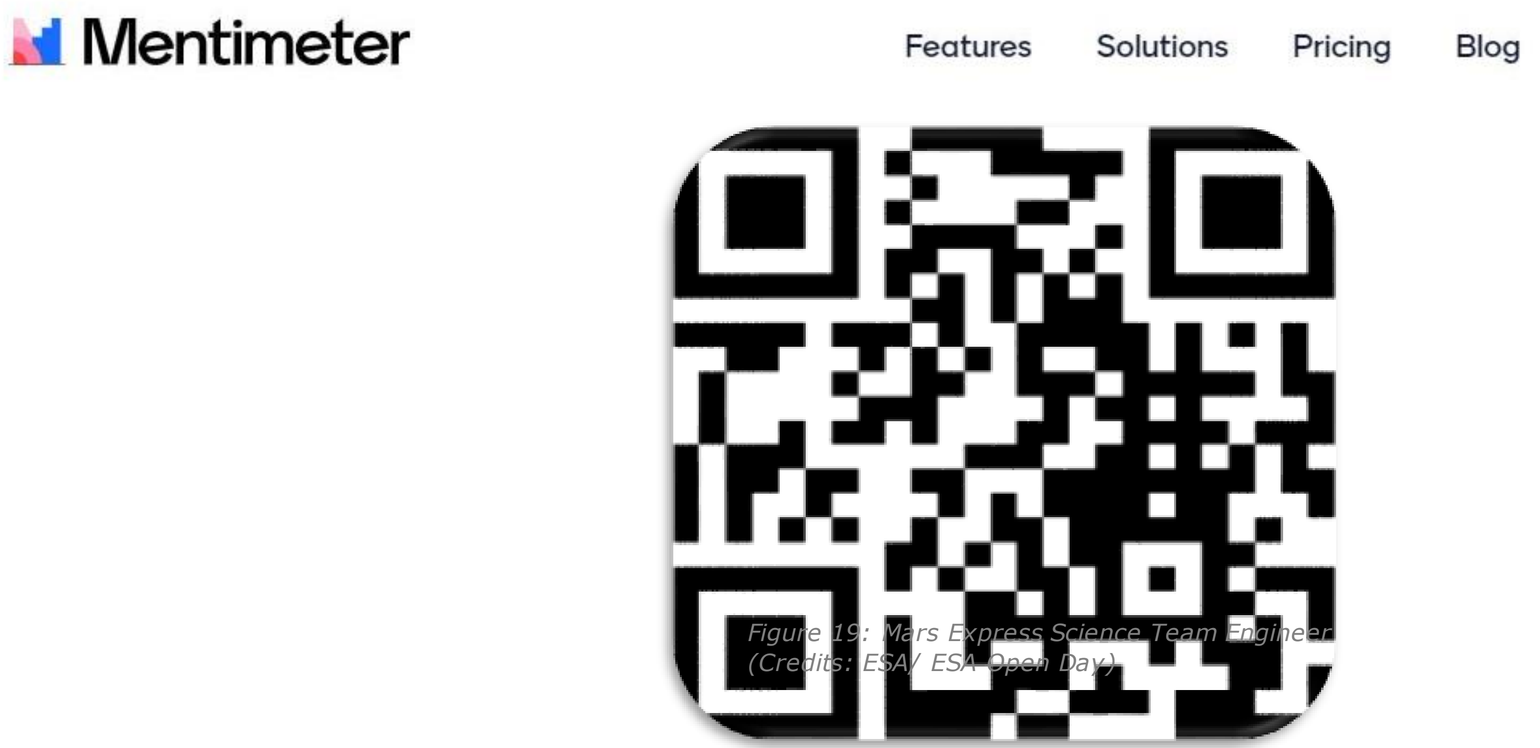


Figure 19: Mars Express Science Team Engineer (Credits: ESA/ ESA Open Day)

Code 51 31 90 7

SCIENCE OPERATIONS CENTRE (SOC) • Where the scientific operations and the planning of the scientific instruments on board the missions to Mars are defined and checked by scientists and engineers (Scientific Operations). • In continuous contact with the MOC	**European Space Astronomy Centrel, ESAC, Madrid**
CENTER FOR DESIGN, INTEGRATION AND TESTING OF SATELLITE COMPONENTS • Where the design, integration and testing of the satellite and the mission support systems (such as the rover) before the launch, performed mainly by engineers	**European Space Research and Technology Centre, ESTEC, The Netherlands**
MISSION OPERATIONS CENTRE (MOC) • Where the orbit and maneuvers of the spacecraft (Flight dynamics Team) are designed and the safety requirements are ensured by tracking the satellites by engineers and operators (Spacecraft controllers – SPACON) • In continuous contact with SOC	**European Space Operations Centre, ESOC, Germany**

Step 1

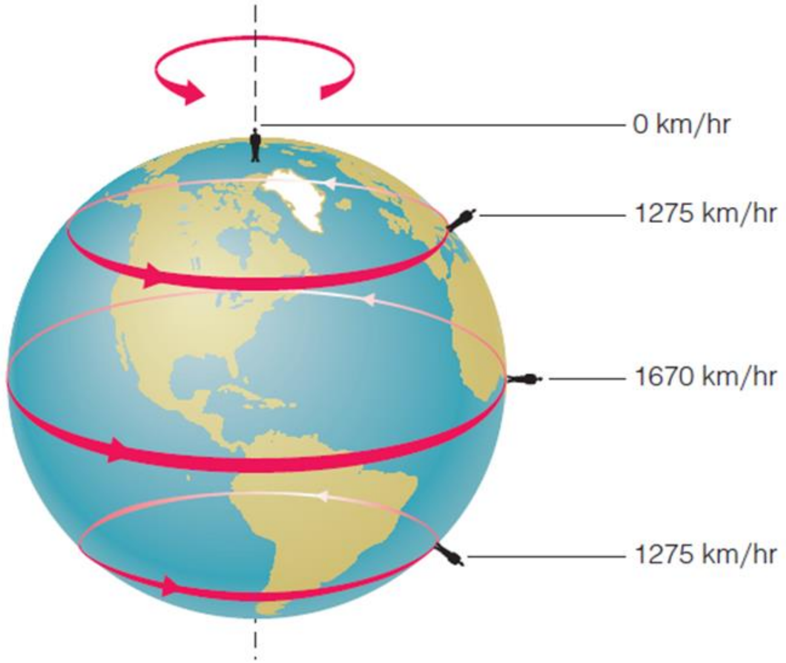
To take care for
the ExoMars launch

Flight Dynamics Team

From where on Earth to launch the satellite?

Flight Dynamics Team

From where on Earth to launch the satellite?



Flight Dynamics Team

Getting to Mars in the shortest time possible is an important consideration in setting a launch date.

Therefore, we want to be sure that we would launch ExoMars 2022 at the right time.

- Watch this VIDEO

Flight Dynamics Team

Getting to Mars in the shortest time possible is an important consideration in setting a launch date.

Therefore, we want to be sure that we would launch ExoMars 2022 at the right time.

- Watch this **VIDEO** and try this simulator

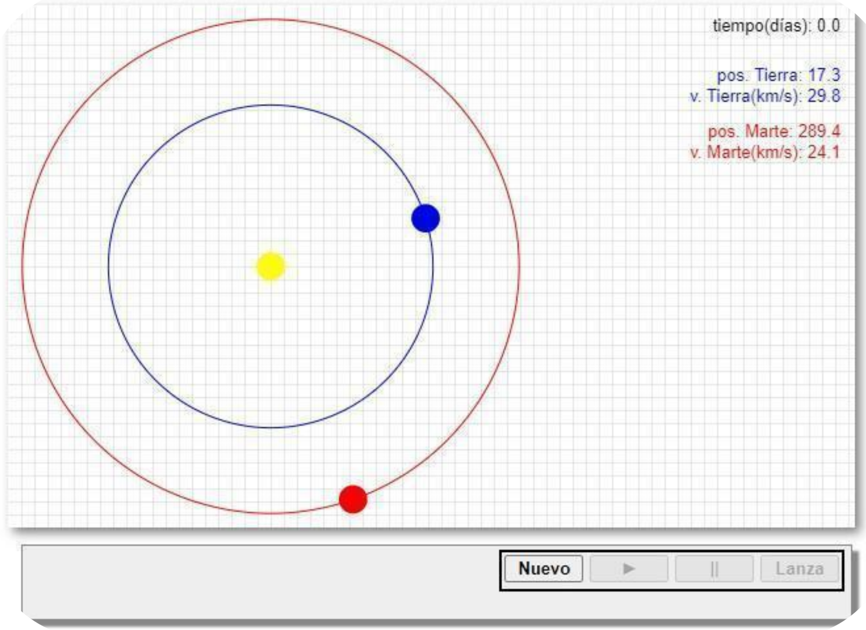


***Figure 37**: Interplanetary travel simulator. (Credits: Universidad del país Vasco*

Flight Dynamics Team

- Try this simulator1 (launch) and simulator2 (Kepler laws)

- Mars and Earth orbit at **different speeds** (sometimes they are far apart and sometimes they come closer together).
- Approximately every two Earth years, the two planets are in the perfect position to reach Mars in the shortest time.
- But that's not all! In order to get to Mars we have to make sure that we point our spacecraft well.

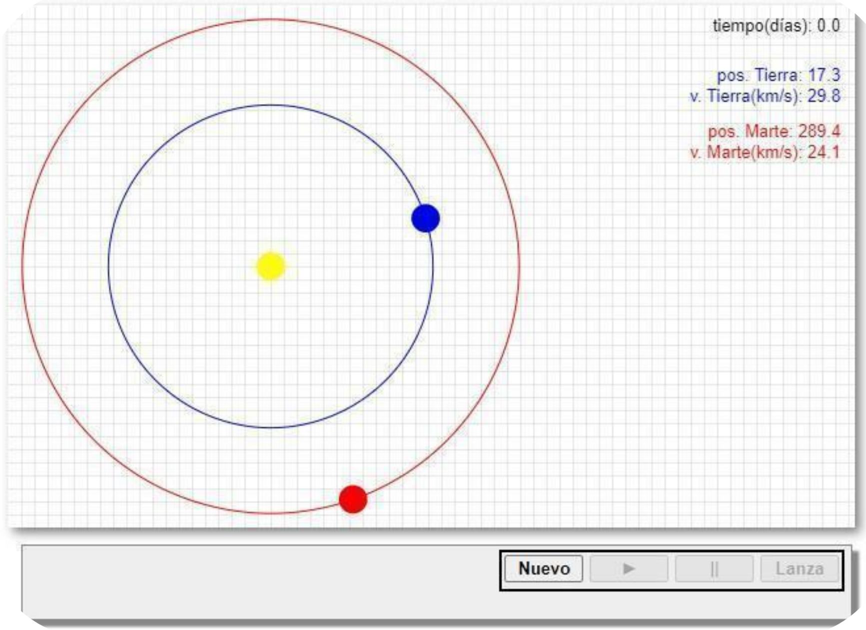
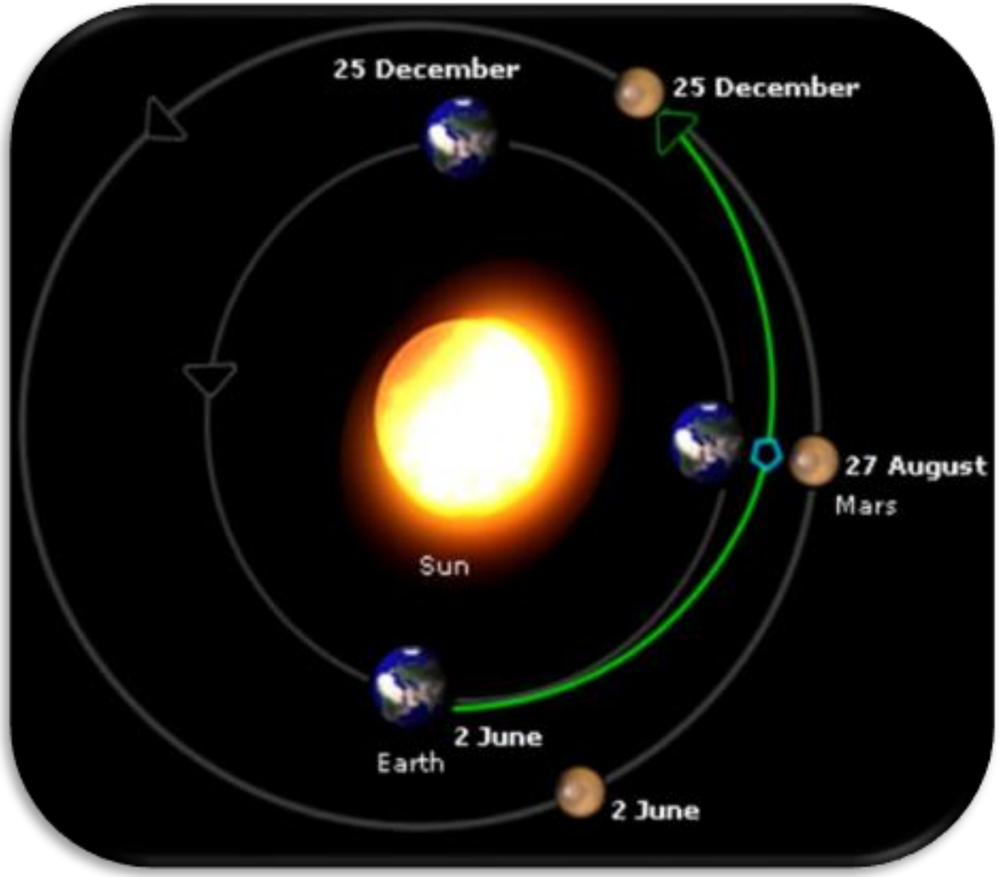
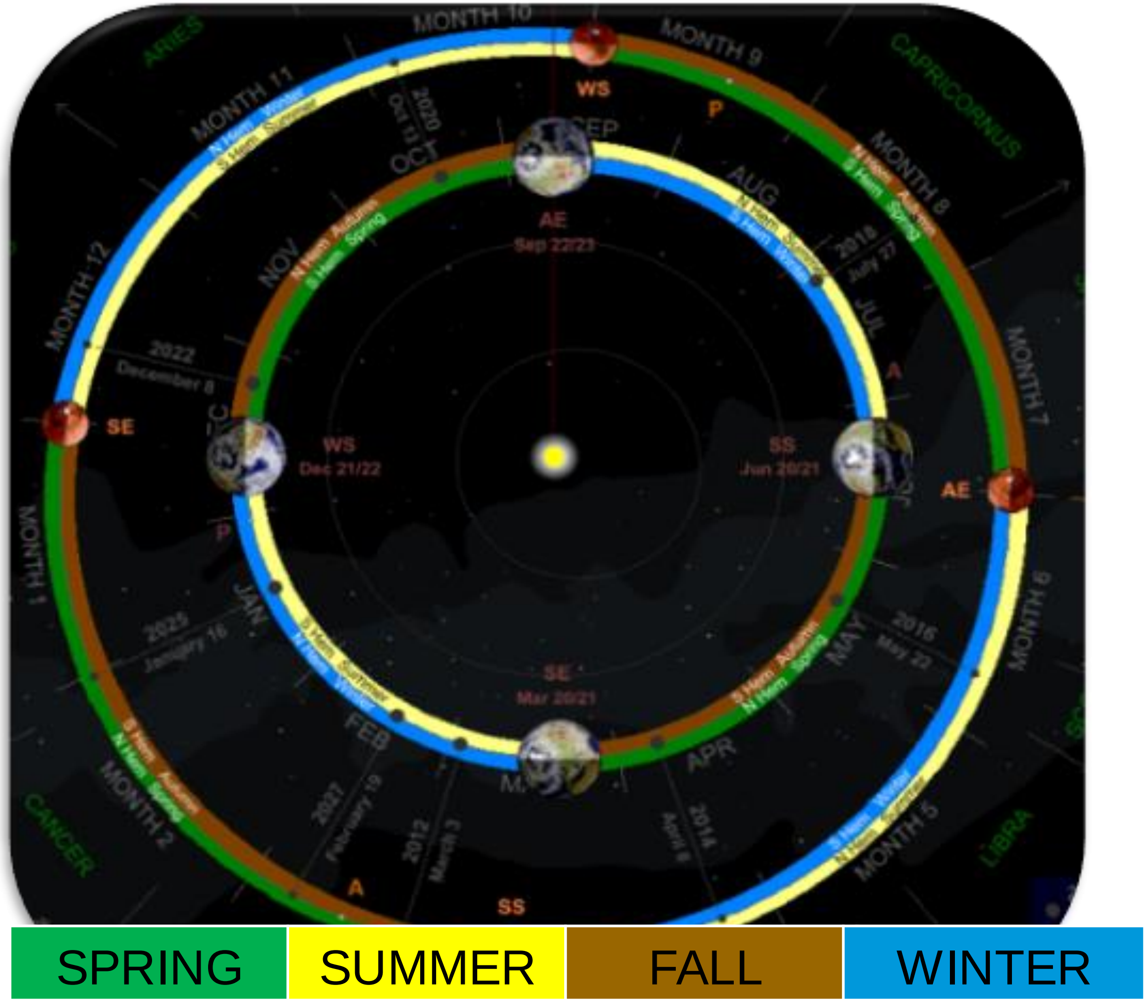


***Figure 37**: Interplanetary travel simulator. (Credits: Universidad del país Vasco)*

Flight Dynamics Team



From Mars Express experience



Step 2

Where to land on Mars

Flight Dynamics Team

Team 1	Mission

Expert team in charged of the flight of the ship.	**From the ship's point of view, in what position (latitude, longitude, altitude) would you land? Why?**
	• Where do you think that the difference in velocity between the satellite and the planet would be lower? (therefore safer to approach the planet)
	• Do you see any difference between the two hemispheres of Mars? If so, which one (s)?
	• Is the Martian atmosphere as thick as the one from Earth?
	  • Will it be enough to stop a lander with a parachute?
	  • Where do you think the parachute can be more effective, in the highest or lowest areas of Mars?

Flight Dynamics Team

Team 2	Mission
Expert team in charged of the Martian Rover/ Car efficiency/ Safety	**From the point of view of landing on a drivable or walkable area, on what terrain would you land (latitude, longitude, altitude)? Why?** • We have to land on steep slopes? Rocky areas? With many craters? • It is safer to land on the northern or southern part of the planet? Would you look for wider or narrowrer areas to land?

Flight Dynamics Team

Science Operation Team

Team 3	Mission

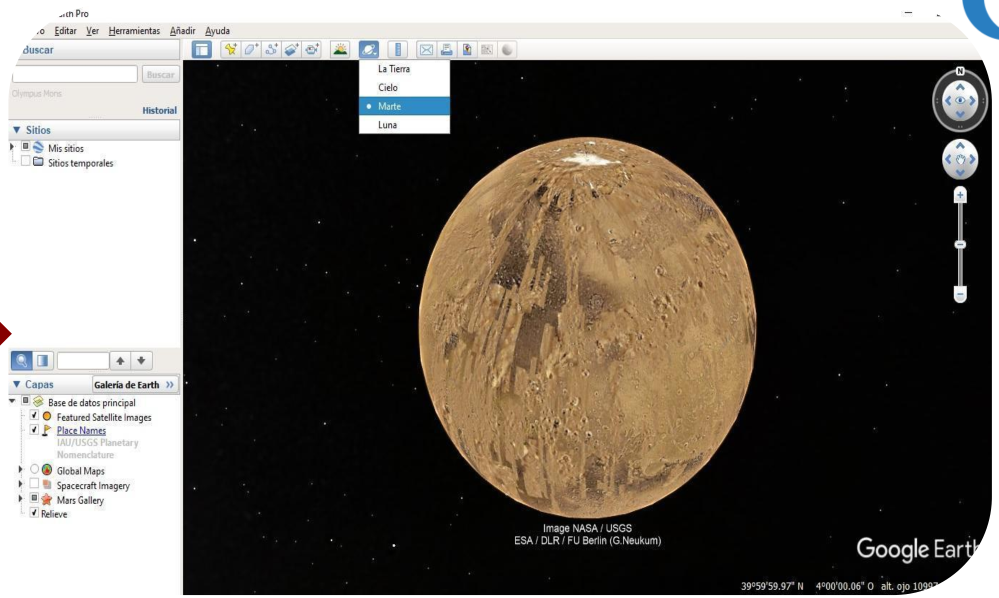
Expert team in charged of the Mars Science Data return	**From a scientific point of view, where would it be more interesting to land? Why?**
	
	Taking into account that there may be past life on Mars
	
	• We could look for areas where **liquid water existed**
	    • Could you see a dry riverbed somewhere? Where exactly?
	
	• The geological history is distinguished by specific climate conditions, which have left their print on Mars surface.
	    • We can roughly know the age of a surface **by counting the craters** (impacts) it has. Knowing this, could you order geological ages in a timeline?

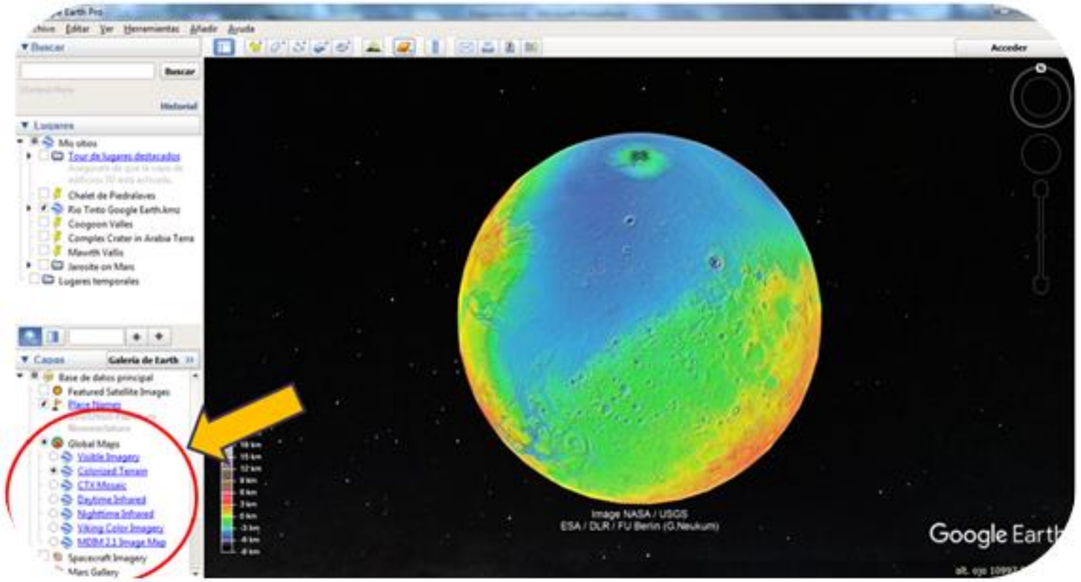
Flight Dynamics Team

Science Operation Team

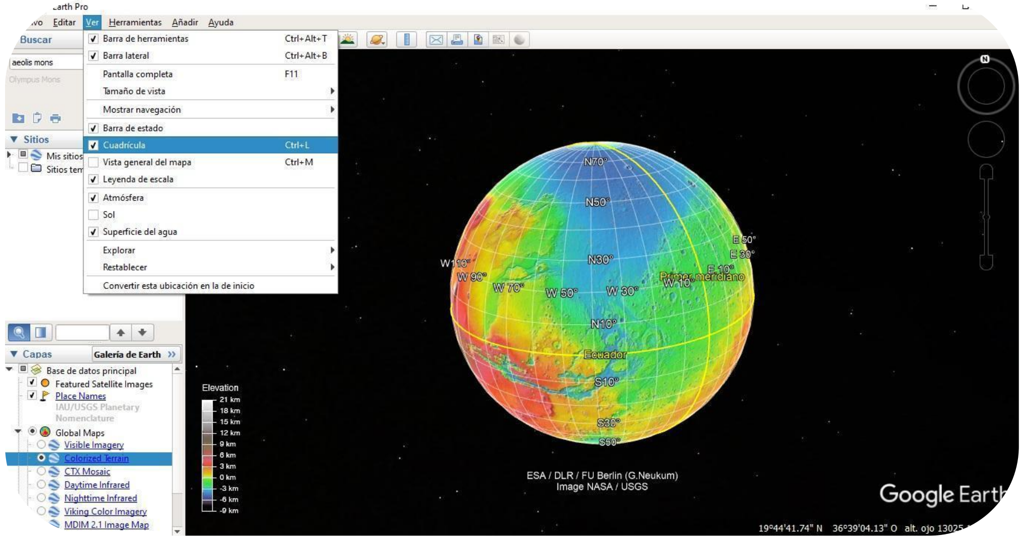
Team 4	Mission
Expert team in charge of the requirements for a robotic/ uncrewed mission	If we plan to take a robotic, non-tripulated mission to Mars (Rover), what extra requirements would our landing zone need?

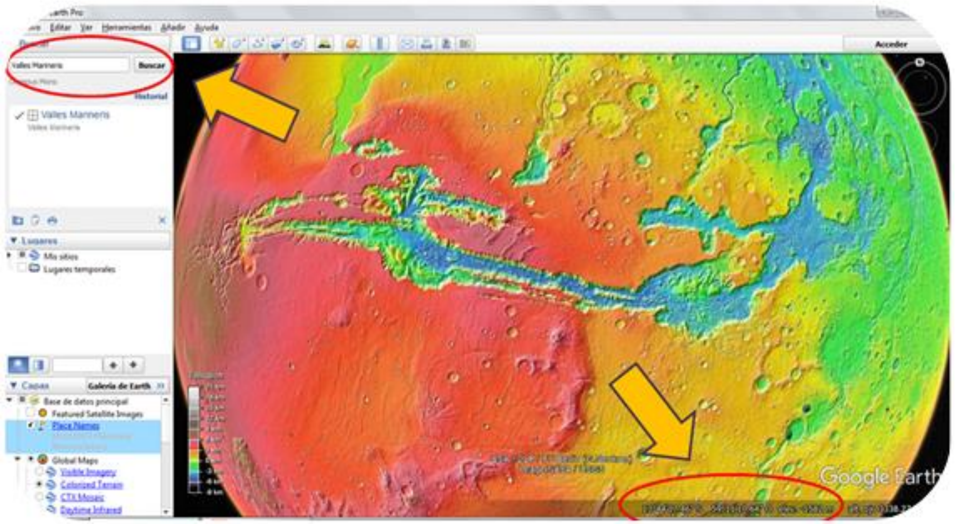
Team 5	Mission
Expert team in charge of the requirements for a mission crewed by astronauts	If we plan to take a crewed mission to Mars (colonized Mars) what extra requirements would our landing zone need?

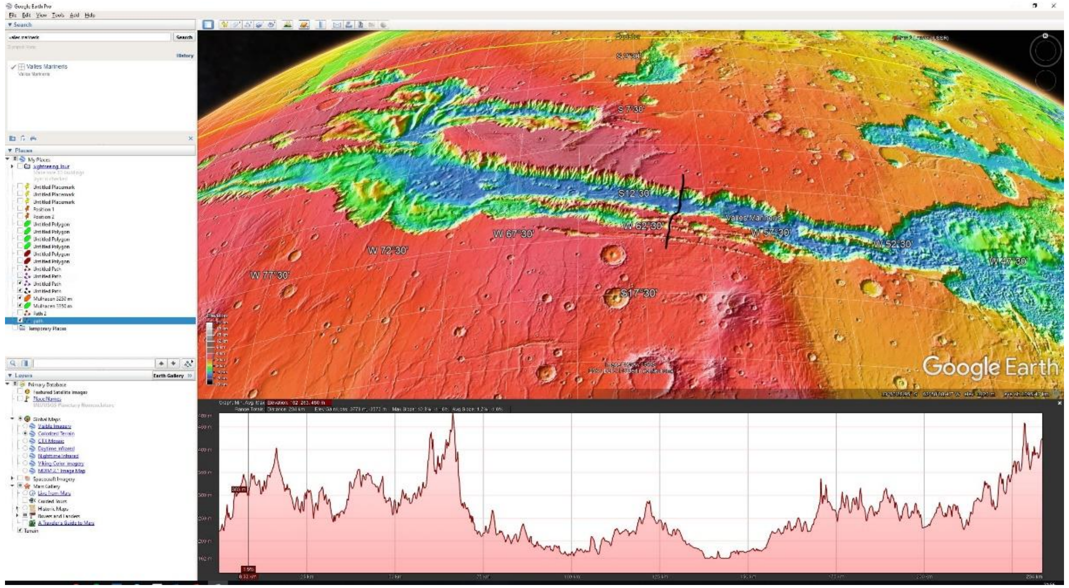




Mars in Google Earth Pro

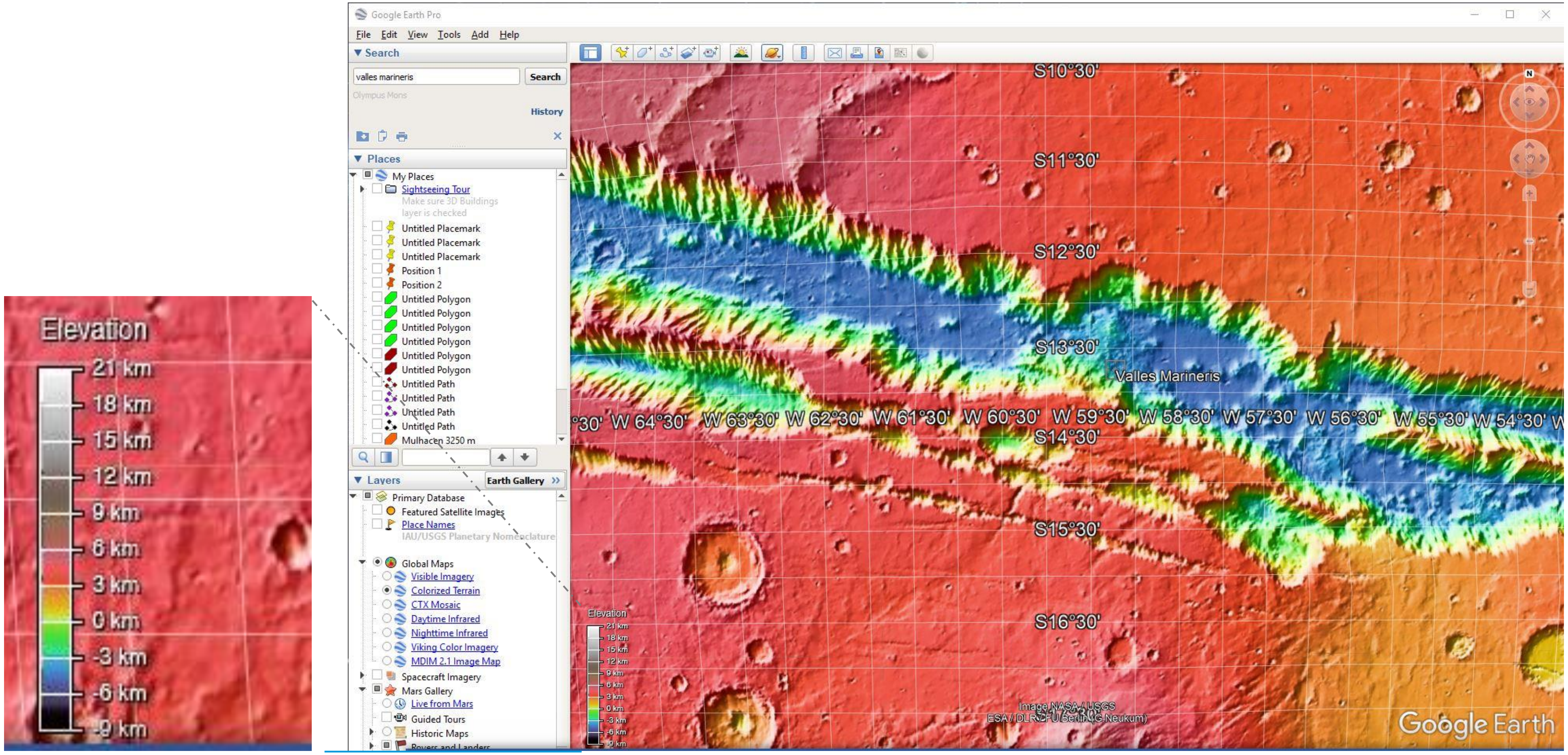






Mars in Google Earth Pro

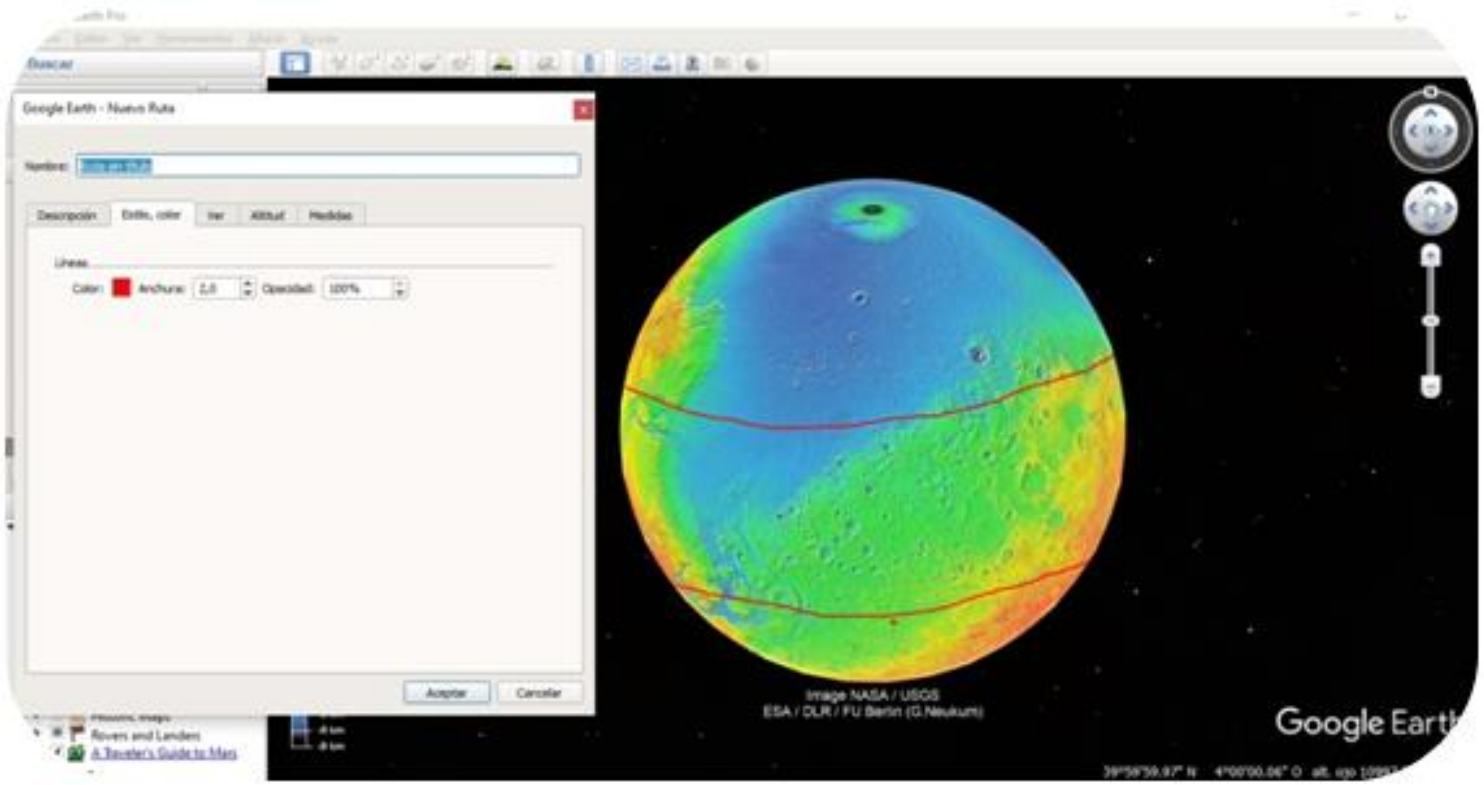
Place	Latitude	Longitude	Altitude
Marineris Valleys	13º 44' 59.97" S	59º 11' 59.97" O	-4 182 m
Eos Chasma	11º 58' 11.97" S	39º 42' 00.03" O	-3 723 m
Aeolis Mensae	2º 52' 11.97" S	140º 23' 59.97" E	-889 m



Team 1	SOLUTION TO THEIR MISSION

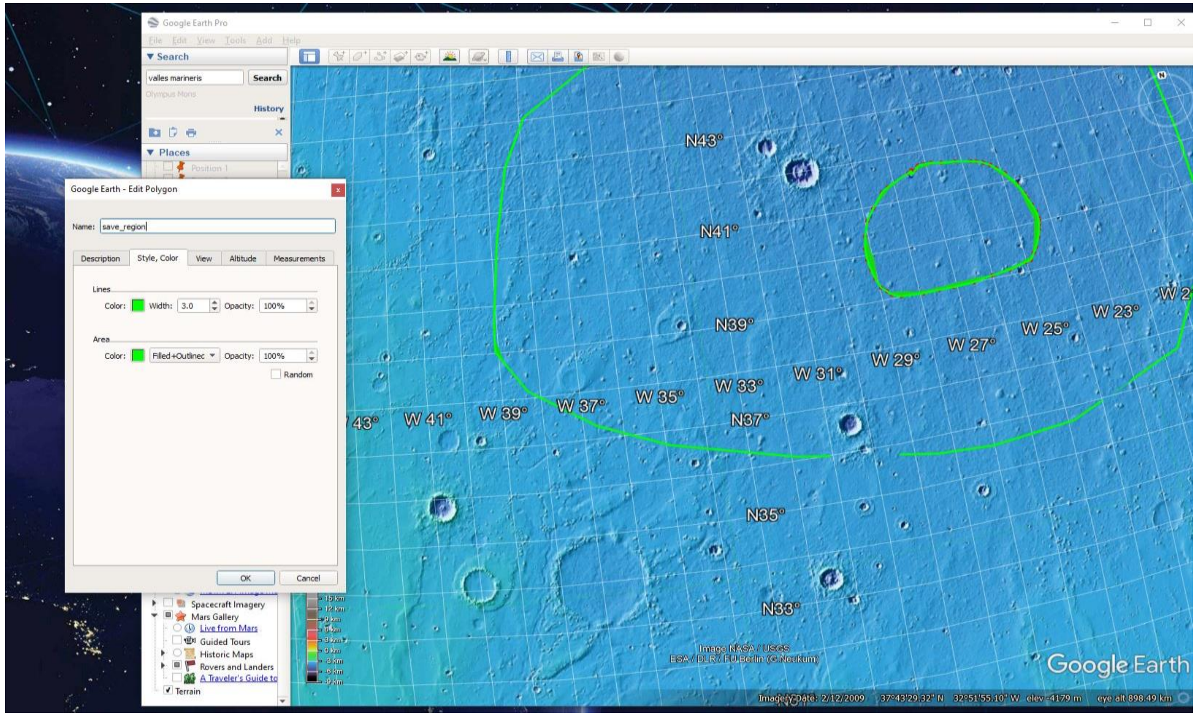
Expert team in charged of the flight of the ship	From the ship's point of view, in what position (**latitude, longitude, altitude**) would you land? Why?
	• Similar to Earth, **close to the Equator**, the velocity of the planet is higher than at the poles. Therefore a satellite approaching a planet would suffer less if the landing is close to its Equator.
	• The difference that you see between the two hemispheres is called the "**global dichotomy" of Mars**.
	• The Martian atmosphere is 100 thinner than the one on Earth
	  • The lander will need thrusters, airbags, parachutes ...
	  • The parachute can be more effective, in the lowest areas of Mars, to get advantage of the atmosphere braking the entrance of the probe.
	SOLUTION:
	It may be safer to land **close to the Equator** & in the **Northern Hemisphere** (1) because it is a lower area **(better for the parachute),** (2) it **hardly has any geographical features (no craters/mountains to skip)**

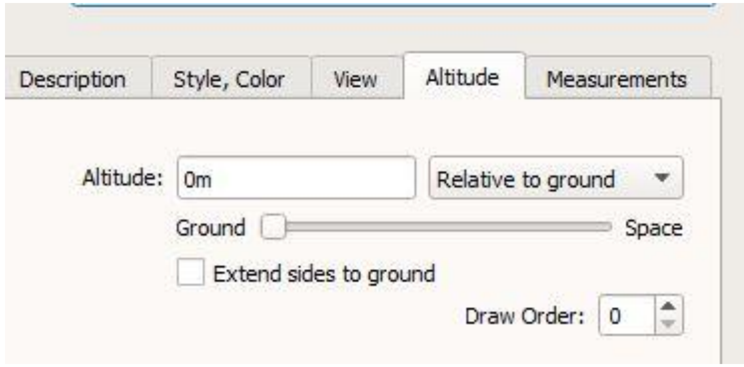
SOLUTIONS:



New path (bounders)

Team 2	Mission
Expert team in charged of the Martian Rover/ Car efficiency/ Safety	**From the point of view of landing on a drivable or walkable area, on what terrain would you land (latitude, longitude, altitude)? Why?** • **Avoid areas with craters, rocks**, uneven terrain, steep slopes • The northern hemisphere seems much flatter & wider than the southern (with higher areas and with many craters, very irregular)



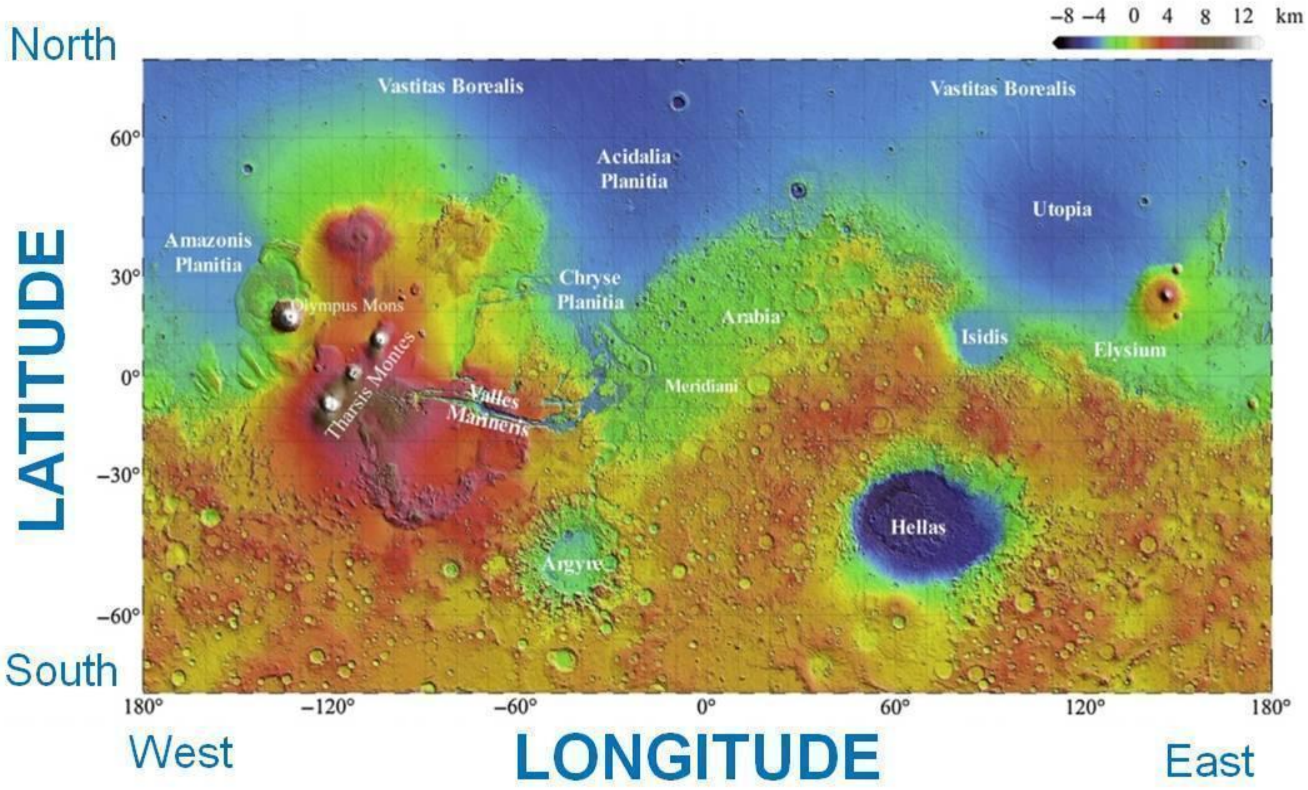


Mark with <u>green</u> circles the safest areas to land.

Mark with <u>red</u> circles the areas that you would avoid to land.

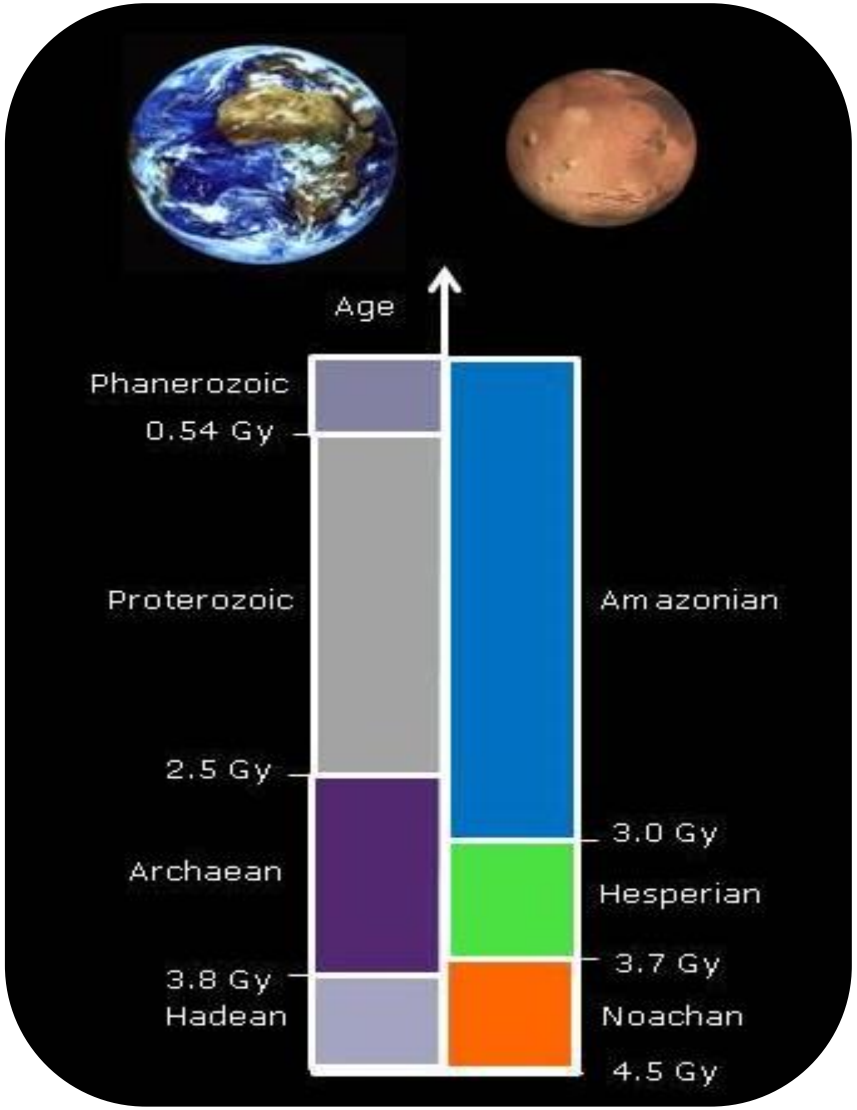
SOLUTIONS:

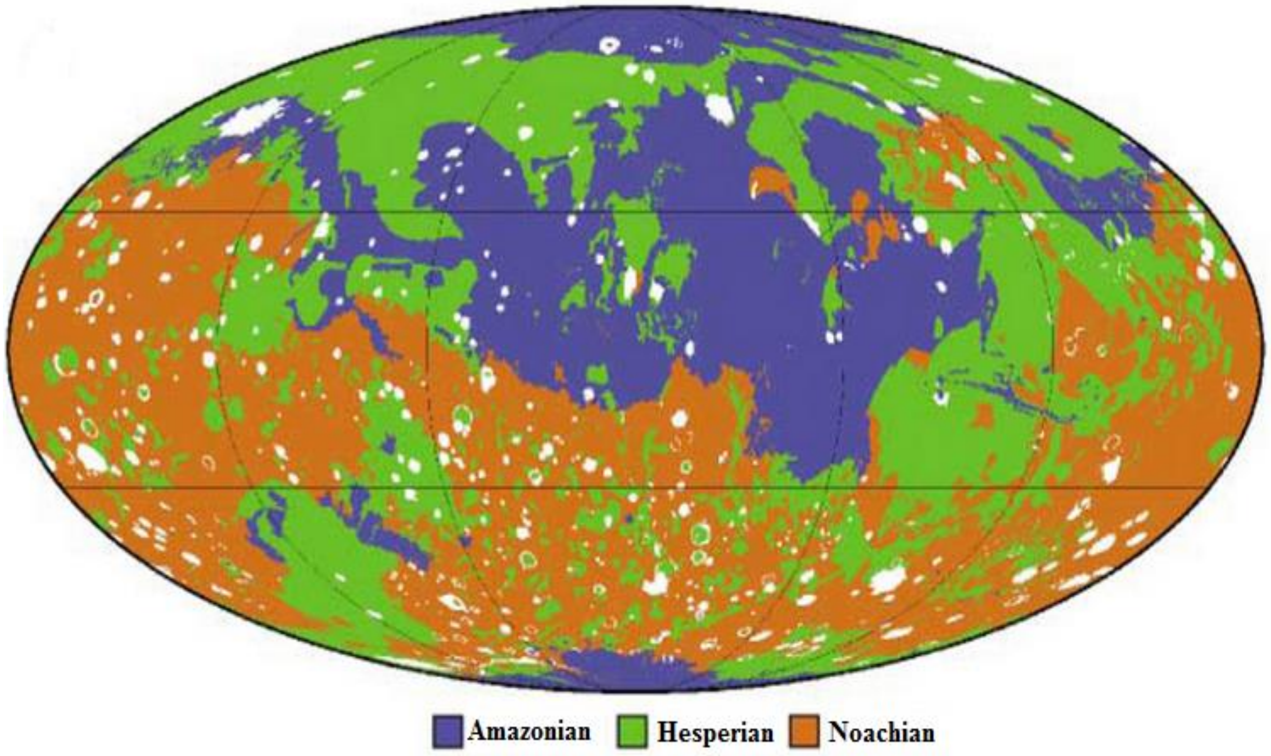
Name	Coordinates
Amazonis Planitia	24º 40’ 00,41”N 164º 00’ 00,10”O
Acidalia Planitia	46º 40’ 47,78”N 22º 00º 00,05”O
Utopia Planitia	49º 40’ 47,91”N 118º 00’ 00,05” E



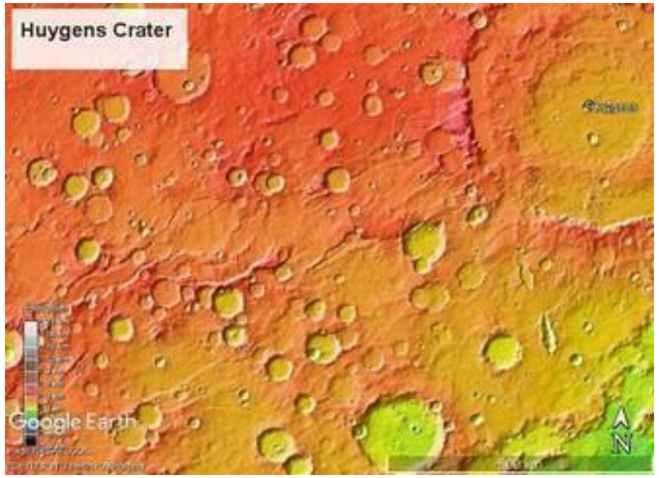
Team 3	Mission

Expert team in charged of the Mars Science Data return	**From a scientific point of view, where would it be more interesting to land? Why?**
	
	Taking into account that there may be past life on Mars
	
	• We could look for areas where **liquid water existed**
	    • Could you see a dry riverbed somewhere? Where exactly?
	• The geological history is distinguished by specific climate conditions, which have left their print on Mars surface.
	    • We can roughly know the age of a surface **by counting the craters** (impacts) it has. Knowing this, could you order geological ages in a timeline?

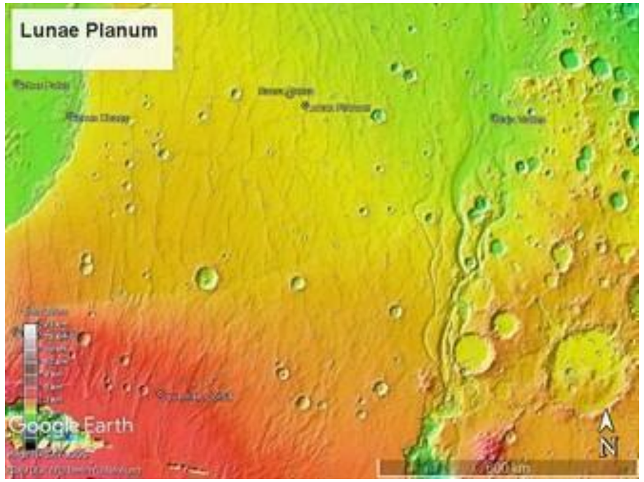

Age
Phanerozoic
0.54 Gy
Proterozoic
2.5 Gy
Archaean
3.8 Gy
Hadean
Amazonian
3.0 Gy
Hesperian
3.7 Gy
Noachan
4.5 Gy


Amazonian
Hesperian
Noachian

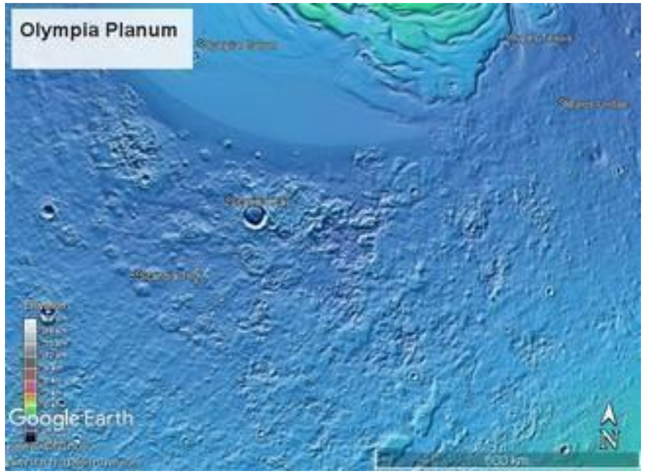
Name of the Period	Time	Climate	Main Minerals	Volcanism	Magnetic Field
Noachian	4.5 -3.7 Gy	Hotter and wetter	Clays, carbonates and phyllosilicates	Yes	Yes
Hesperian	3.7 -3.0 Gy	Acid rain	Sulfates	Yes and a lot	No
Amazonian	3.0 Gy to - present	Colder and drier	Iron oxides	Mostly none	No



Noachian period

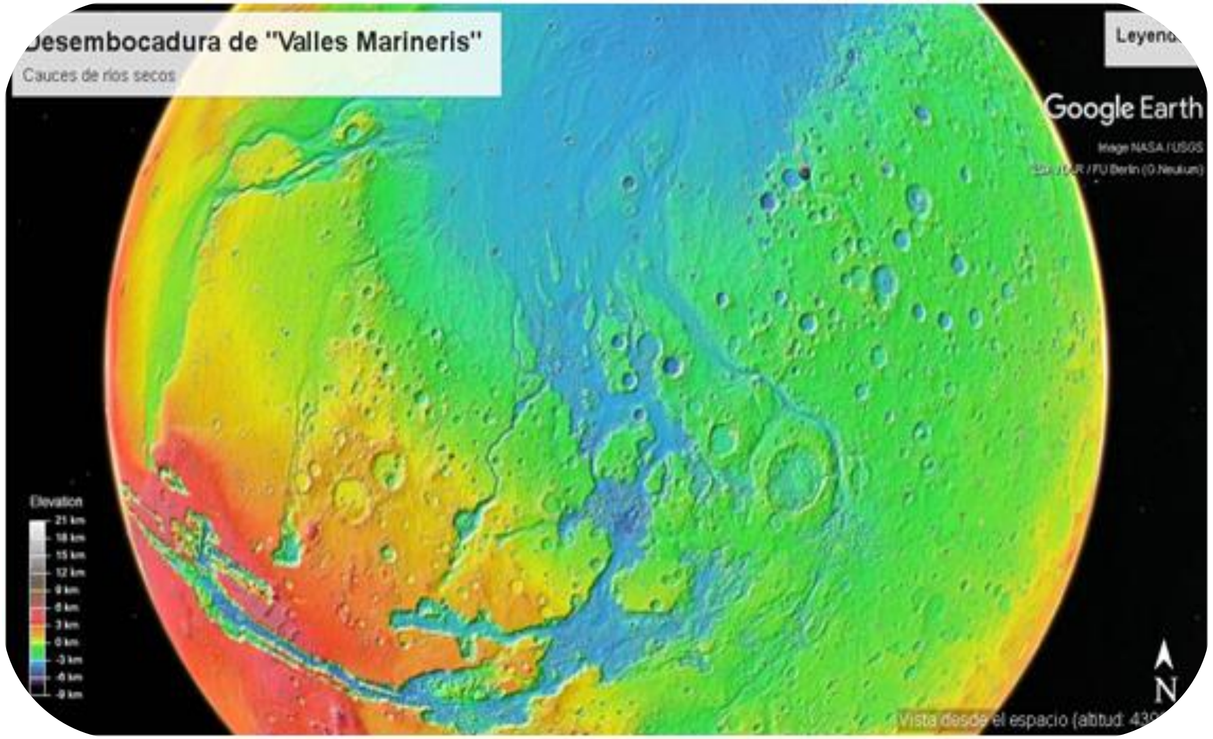


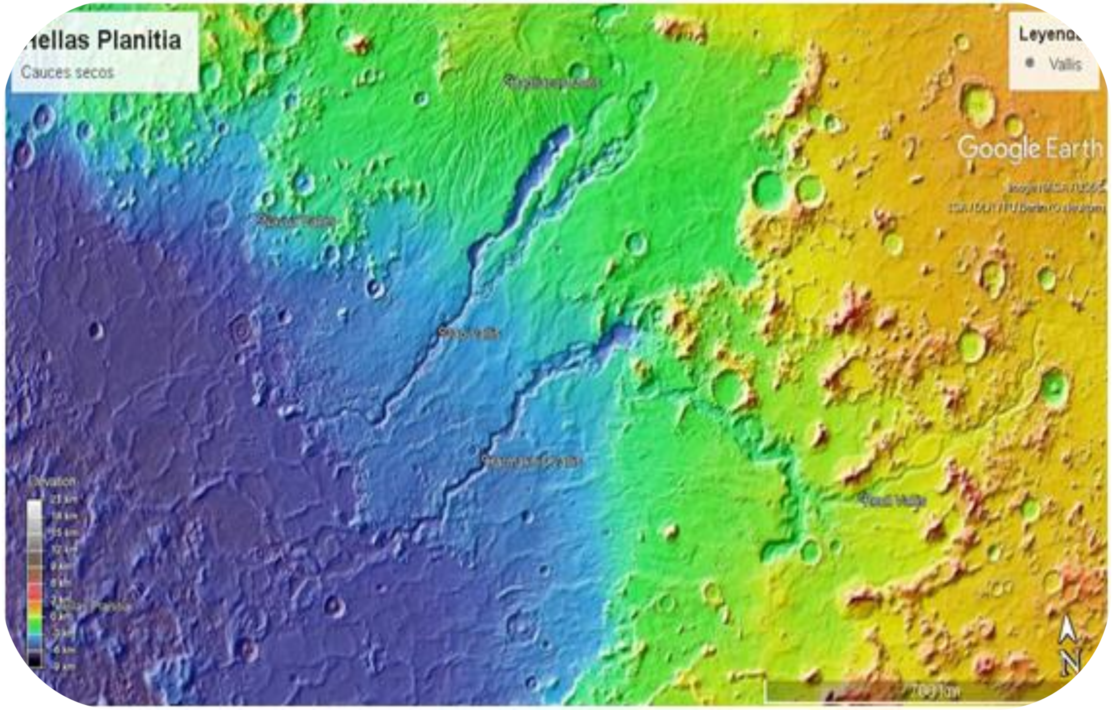
Hesperian period



Amazonian period

SOLUTIONS:

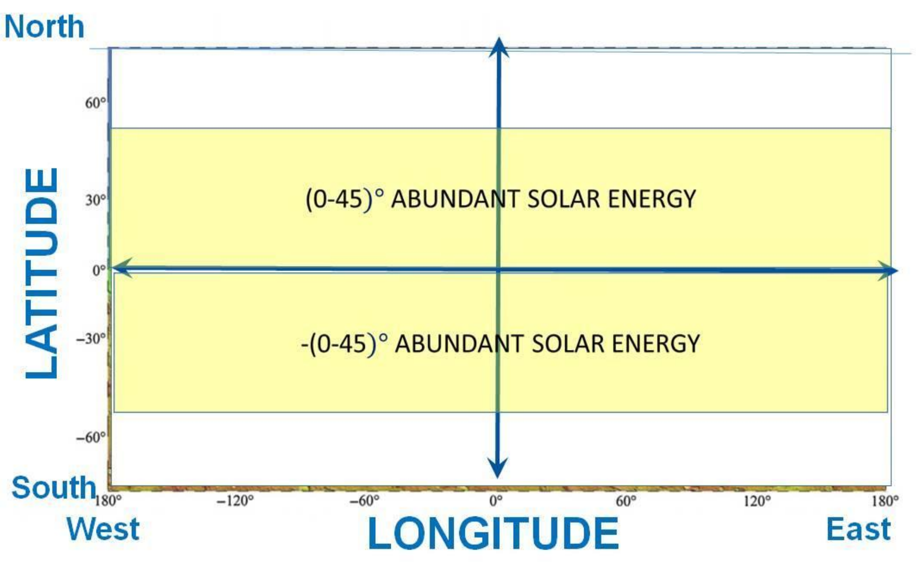

esembocadura de "Valles Marineris"
Cauces de ríos secos
Google Earth
Elevation

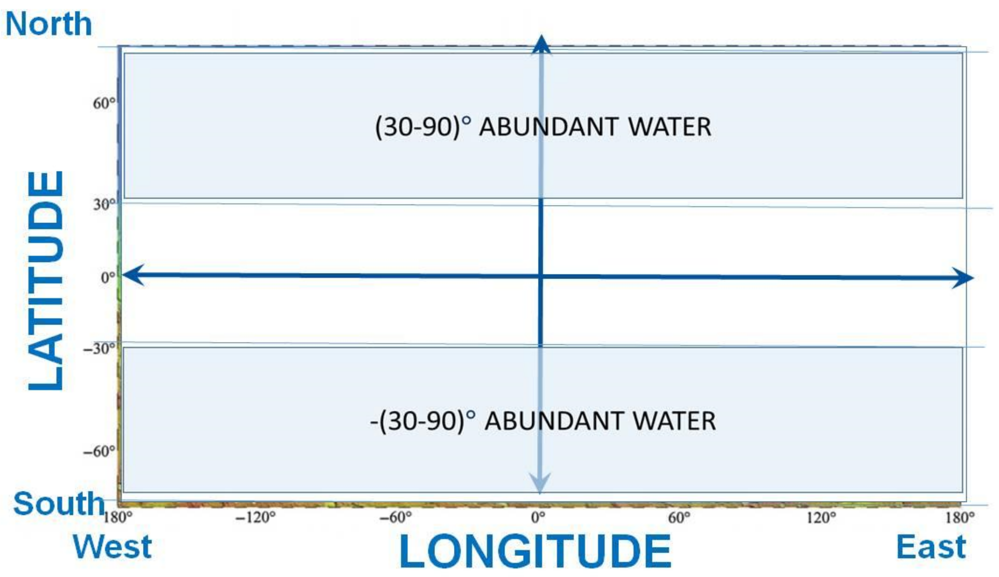

ellas Planitia
Cauces secos
Google Earth
Vallis

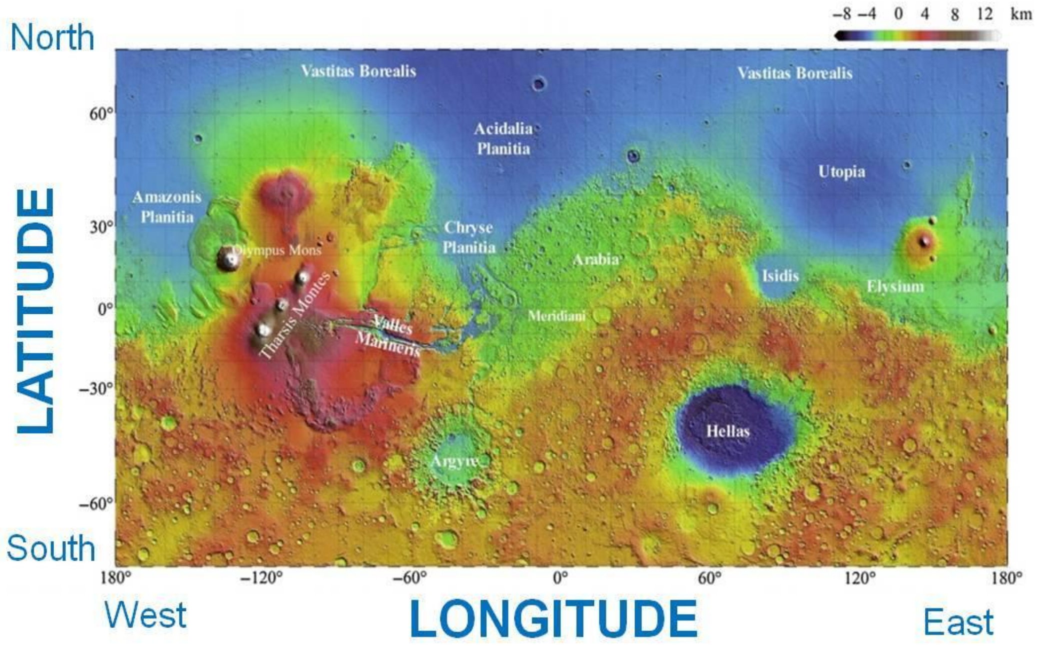
Team 3	Mission
Expert team in charged of the Mars Science Data return	**From a scientific point of view, where would it be more interesting to land? Why?** • the **Noachian period** is the oldest period and there are **more craters and** those craters are **bigger**;

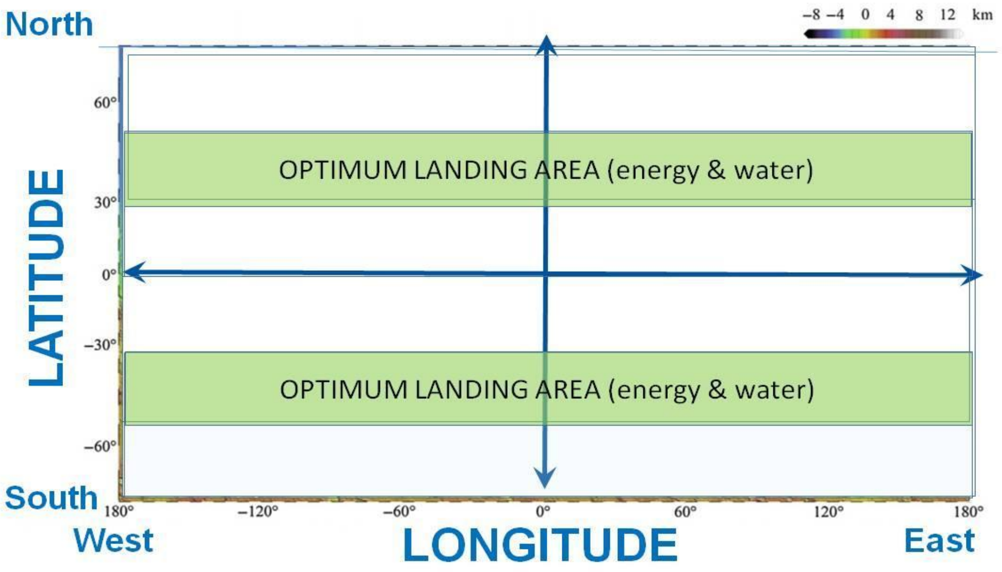
Team 4	Mission
Expert team in charge of the requirements for a robotic/ uncrewed mission	If we plan to take a robotic, uncrewed mission to Mars (Rover), what extra requirements would our landing zone need? Taking into account that we are taking a robotic mission to Mars, we have to plan what kind of requirements our rover would need, such as energy, what kind of samples we could analyze ...

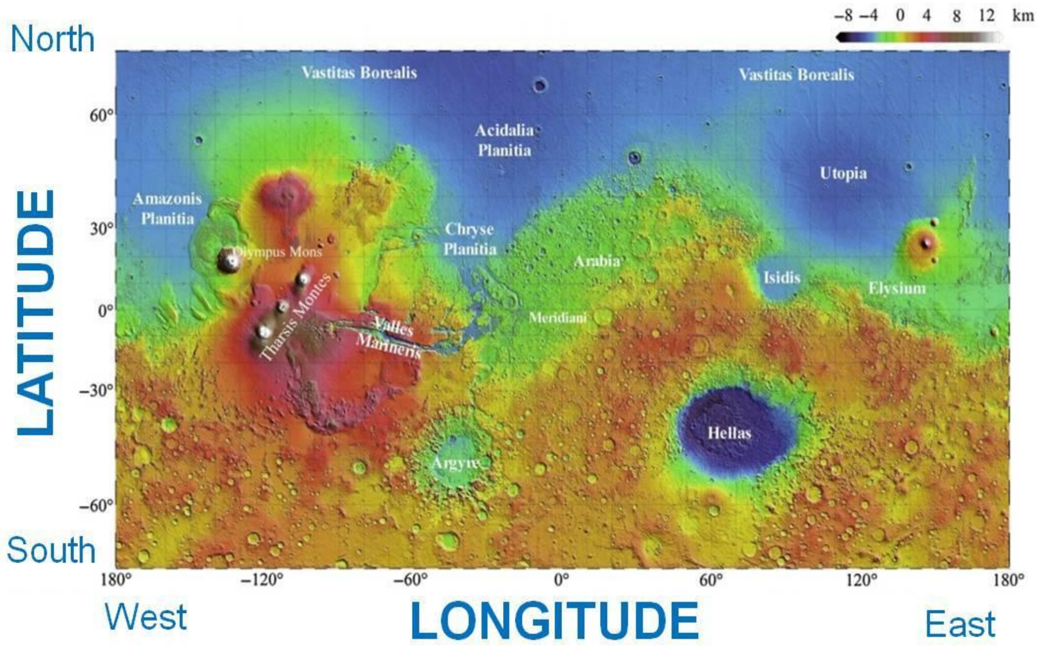
Team 5	Mission
Expert team in charge of the requirements for a mission crewed by astronauts	Taking into account that Mars is much further away than the Moon and its gravity is considerably greater than that of the Moon, we cannot simply consider spending a few hours on Mars. It would be necessary to consider making a more or less permanent colony on Mars, and for this, we need minimum conditions so that the astronauts and first colonizers of Mars can survive there for a while. What water and light requirements would they need to be there for a while?

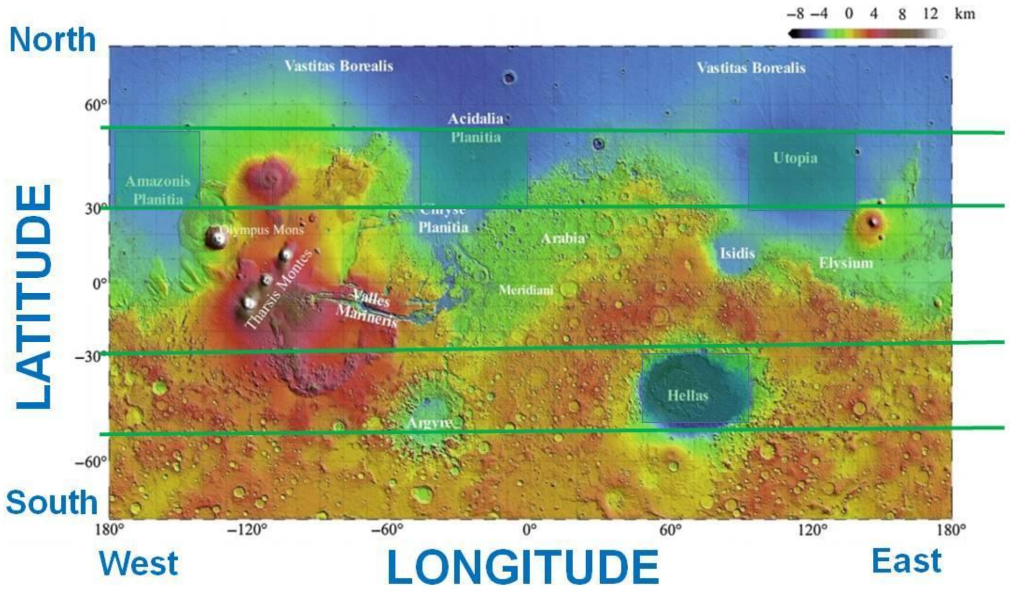

North
LATITUDE
60°
30°
0°
−30°
−60°
(0-45)° ABUNDANT SOLAR ENERGY
-(0-45)° ABUNDANT SOLAR ENERGY
South
180°
−120°
−60°
0°
60°
120°
180°
West
LONGITUDE
East


North
LATITUDE
60°
30°
0°
−30°
−60°
(30-90)° ABUNDANT WATER
-(30-90)° ABUNDANT WATER
South
180°
−120°
−60°
0°
60°
120°
180°
West
LONGITUDE
East

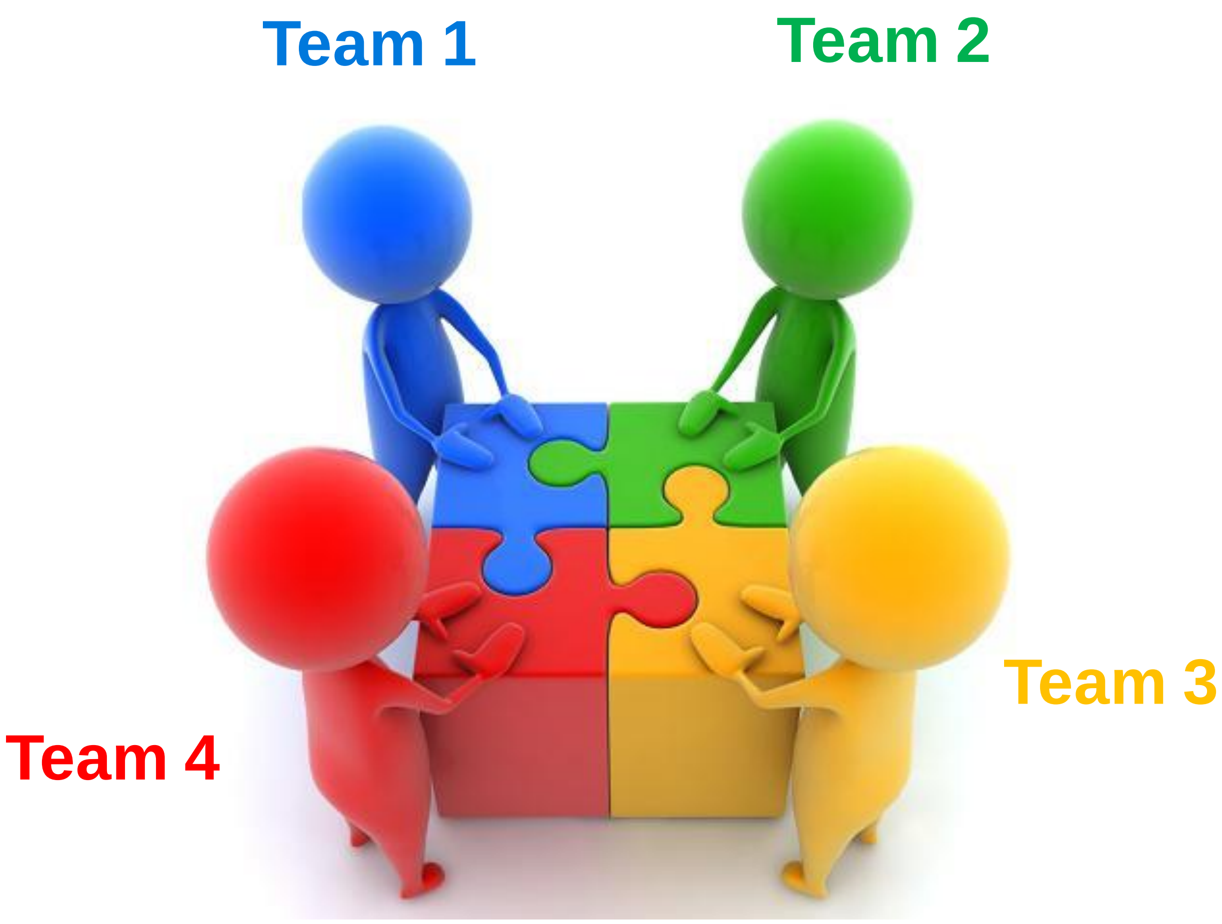

−8 −4 0 4 8 12 km
North
LATITUDE
60°
30°
0°
−30°
−60°
Vastitas Borealis
Vastitas Borealis
Acidalia Planitia
Utopia
Amazonis Planitia
Olympus Mons
Chryse Planitia
Arabia
Isidis
Elysium
Tharsis Montes
Valles Marineris
Meridiani
Hellas
Argyre
South
180°
−120°
−60°
0°
60°
120°
180°
West
LONGITUDE
East


North
South
LATITUDE
OPTIMUM LANDING AREA (energy & water)
OPTIMUM LANDING AREA (energy & water)
60°
30°
0°
–30°
–60°
180°
–120°
–60°
0°
60°
120°
180°
West
LONGITUDE
East
–8 –4 0 4 8 12 km


North
South
LATITUDE
Vastitas Borealis
Vastitas Borealis
Acidalia Planitia
Utopia
Amazonis Planitia
Olympus Mons
Chryse Planitia
Arabia
Isidis
Elysium
Meridiani
Tharsis Montes
Valles Marineris
Hellas
Argyre
60°
30°
0°
–30°
–60°
180°
–120°
–60°
0°
60°
120°
180°
West
LONGITUDE
East
–8 –4 0 4 8 12 km

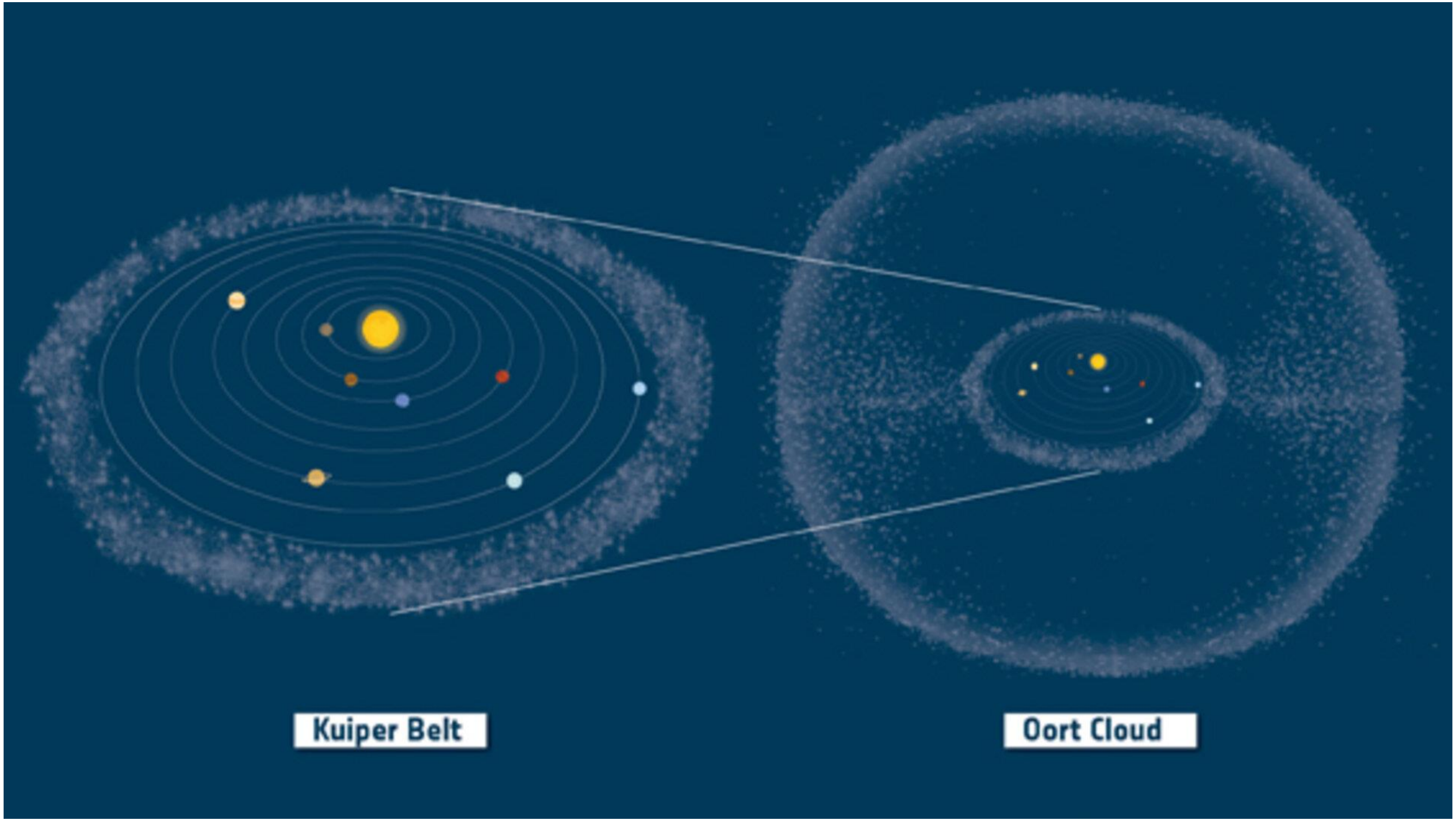

North
South
LATITUDE
Vastitas Borealis
Vastitas Borealis
Acidalia Planitia
Utopia
Amazonis Planitia
Olympus Mons
Chryse Planitia
Arabia
Isidis
Elysium
Meridiani
Tharsis Montes
Valles Marineris
Hellas
Argyre
60°
30°
0°
–30
–60°
180°
–120°
–60°
0°
60°
120°
180°
West
LONGITUDE
East
–8 –4 0 4 8 12 km

Team member	Important landing site requirements
Expert in ship efficiency / safety (Team 1)	-Close to the equator -Low area
Rover efficiency / safety expert (Team 2)	-Wide area -Safe area, without craters, steep slopes -Flat area -Without arenas
Mars Scientific Expert (Team 3)	-Old area, with Noáicos deposits -With signs that water has passed through there in the past, such as dry channels or ILD (inner layer deposits)
Robotic / Unmanned Mission Requirement Expert (Team 4)	-Enough solar energy to operate if the rover has solar panels (45ºN to 45ºS)
Manned Mission Requirement Expert (Team 5)	-Enough water and light resources (from 30 to 45ºN and from 30 to 45ºS)



Type of Mission	Landing sites
Robotic mission	
Manned mission	
Mixed mission	

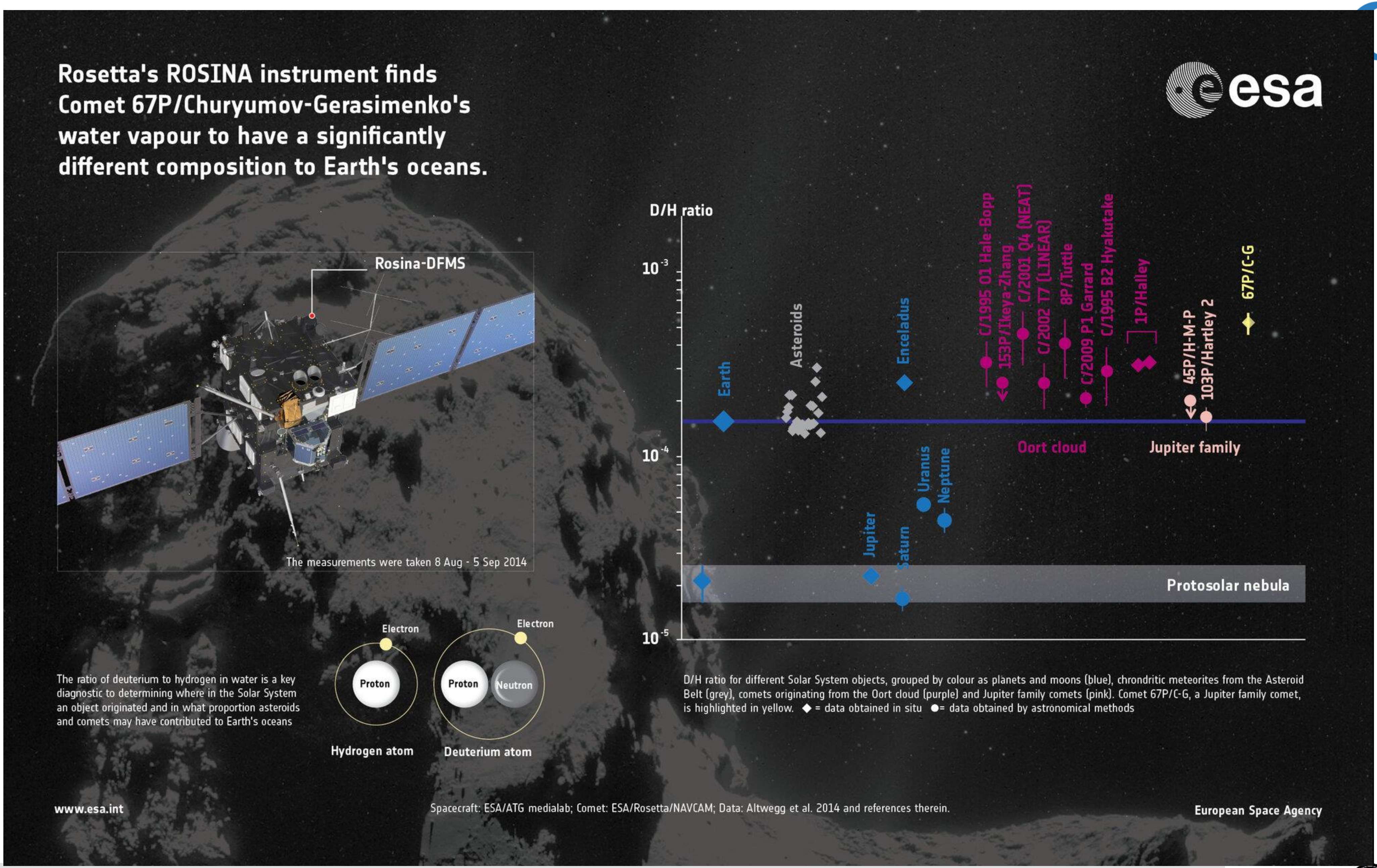
Looking for live


Kuiper Belt
Oort Cloud

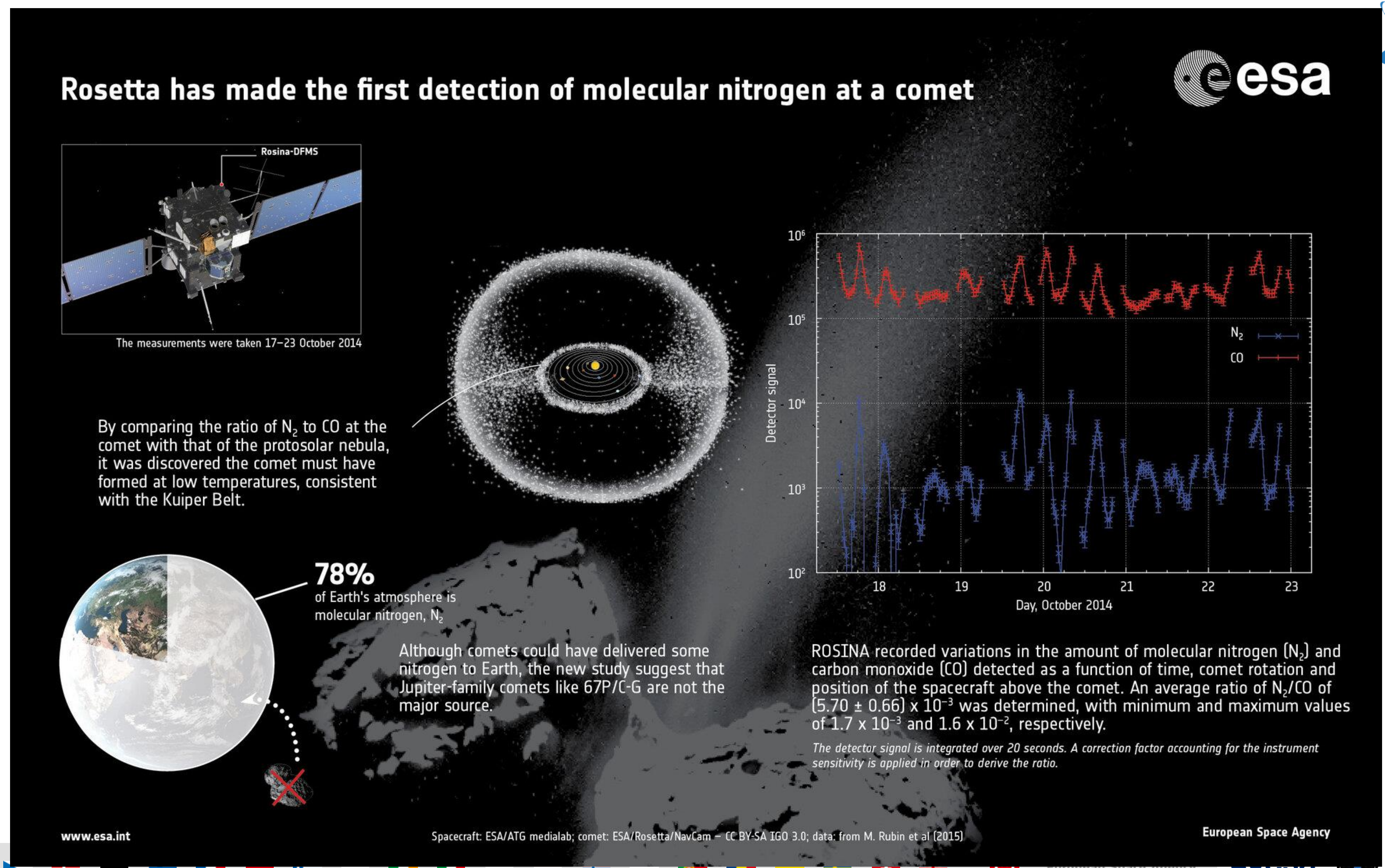
[Rosetta trip]

[Rosetta trip kids]


DLR
LANDER CONTROL CENTER



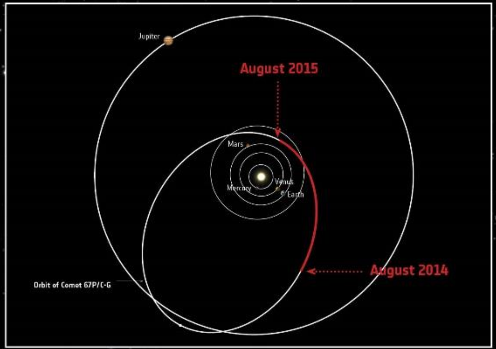
Rosetta's ROSINA instrument finds Comet 67P/Churyumov-Gerasimenko's water vapour to have a significantly different composition to Earth's oceans.
esa
Rosina-DFMS
The measurements were taken 8 Aug - 5 Sep 2014
D/H ratio
10-3
10-4
10-5
Earth
Asteroids
Enceladus
C/1995 O1 Hale-Bopp
153P/Ikeya-Zhang
C/2001 Q4 (NEAT)
C/2002 T7 (LINEAR)
8P/Tuttle
C/2009 P1 Garrard
C/1995 B2 Hyakutake
1P/Halley
45P/H-M-P
103P/Hartley 2
67P/C-G
Oort cloud
Jupiter family
Uranus
Neptune
Jupiter
Saturn
Protosolar nebula
Electron
Proton
Neutron
Hydrogen atom
Deuterium atom
The ratio of deuterium to hydrogen in water is a key diagnostic to determining where in the Solar System an object originated and in what proportion asteroids and comets may have contributed to Earth's oceans
D/H ratio for different Solar System objects, grouped by colour as planets and moons (blue), chrondritic meteorites from the Asteroid Belt (grey), comets originating from the Oort cloud (purple) and Jupiter family comets (pink). Comet 67P/C-G, a Jupiter family comet, is highlighted in yellow. ◆ = data obtained in situ ● = data obtained by astronomical methods
www.esa.int
Spacecraft: ESA/ATG medialab; Comet: ESA/Rosetta/NAVCAM; Data: Altwegg et al. 2014 and references therein.
European Space Agency


Rosetta has made the first detection of molecular nitrogen at a comet
esa
Rosina-DFMS
The measurements were taken 17–23 October 2014
By comparing the ratio of N2 to CO at the comet with that of the protosolar nebula, it was discovered the comet must have formed at low temperatures, consistent with the Kuiper Belt.
78%
of Earth's atmosphere is molecular nitrogen, N2
Although comets could have delivered some nitrogen to Earth, the new study suggest that Jupiter-family comets like 67P/C-G are not the major source.
Detector signal
10^6
10^5
10^4
10^3
10^2
N2
CO
18
19
20
21
22
23
Day, October 2014
ROSINA recorded variations in the amount of molecular nitrogen (N2) and carbon monoxide (CO) detected as a function of time, comet rotation and position of the spacecraft above the comet. An average ratio of N2/CO of (5.70 ± 0.66) x 10^-3 was determined, with minimum and maximum values of 1.7 x 10^-3 and 1.6 x 10^-2, respectively.
The detector signal is integrated over 20 seconds. A correction factor accounting for the instrument sensitivity is applied in order to derive the ratio.
www.esa.int
Spacecraft: ESA/ATG medialab; comet: ESA/Rosetta/NavCam – CC BY-SA IGO 3.0; data: from M. Rubin et al (2015)
European Space Agency

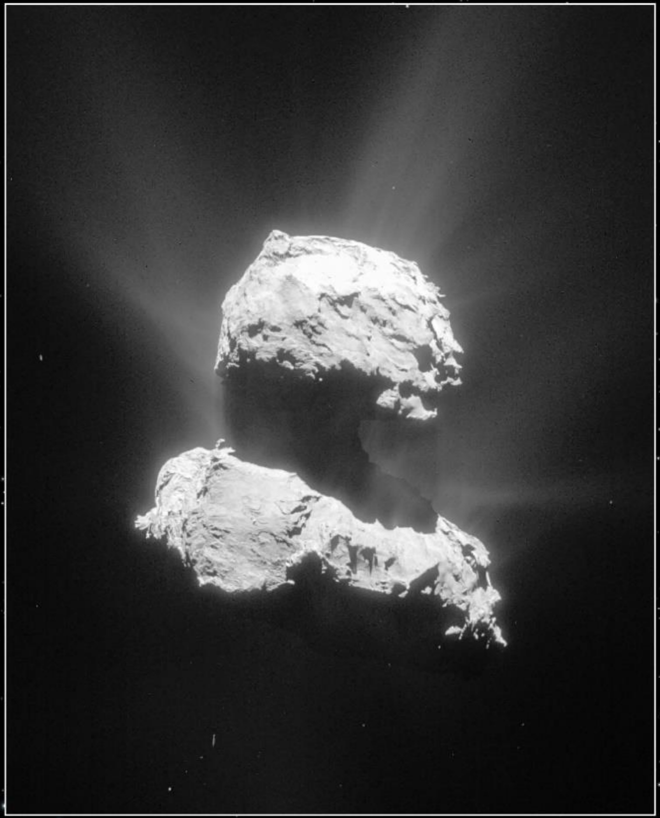
→ ROSETTA'S COMET CONTAINS INGREDIENTS FOR LIFE

esa

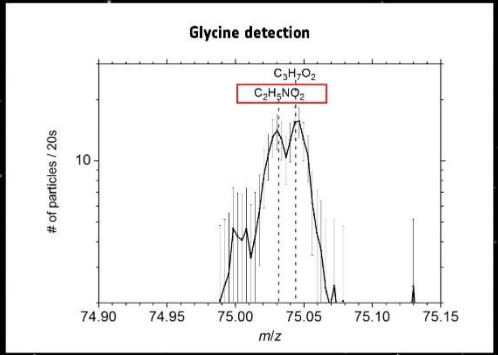
The measurements were made with the Rosetta Orbiter Spectrometer for Ion and Neutral Analysis Double-Focusing Mass Spectrometer (ROSINA-DFMS).



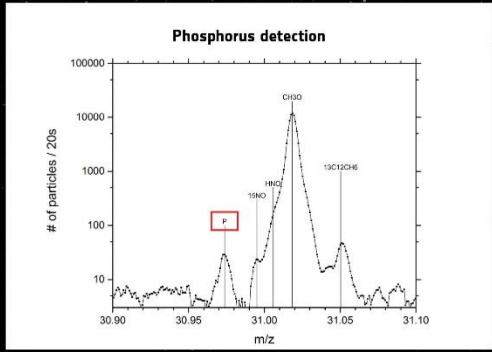
The data were collected between August 2014 and August 2015.



The measurements were made when Rosetta was between 10 and 200 km from the comet.



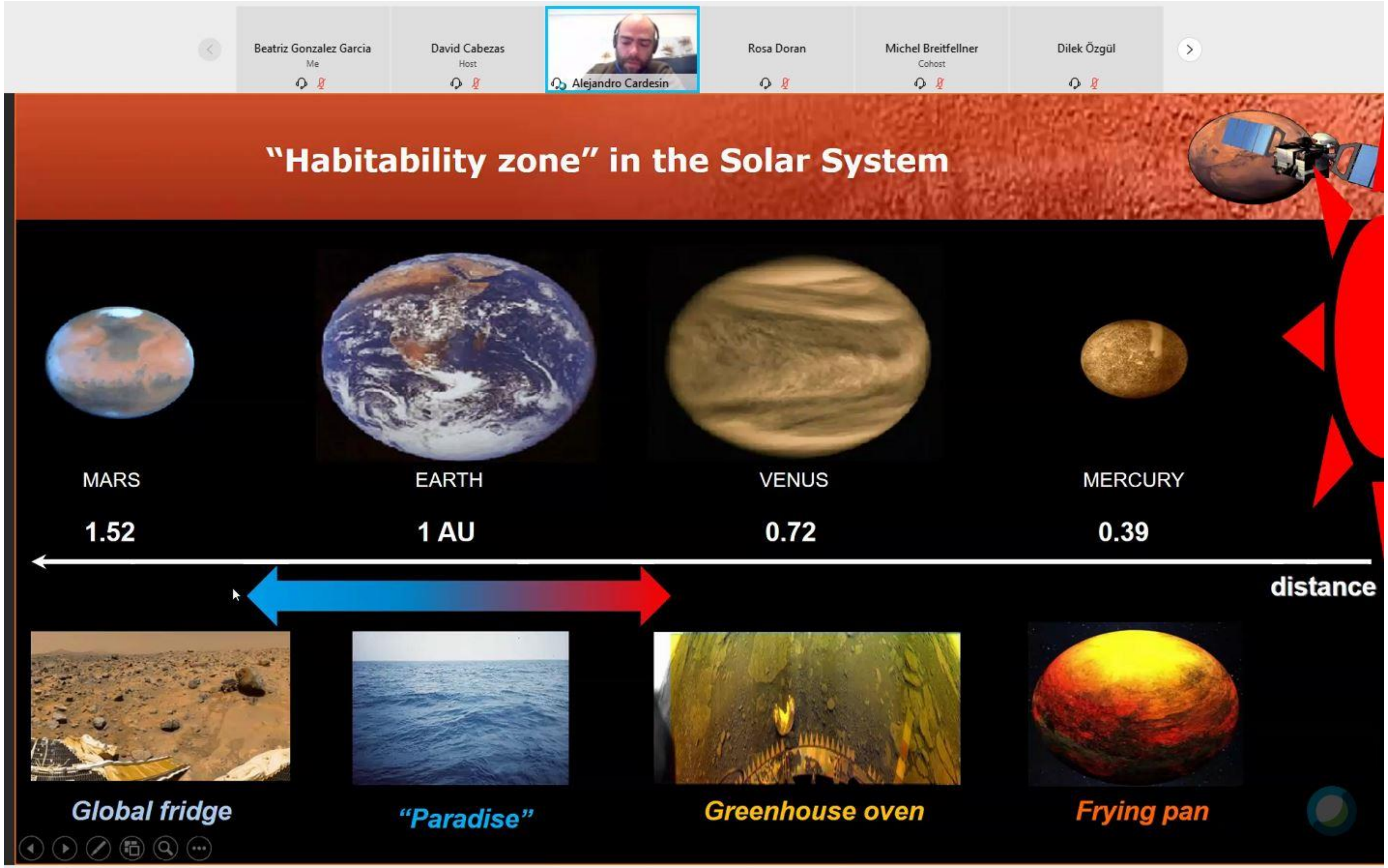
Spectrum indicating glycine ($C_2H_5NO_2$) detection on 9 July 2015. The simple amino acid glycine is a biologically important organic compound commonly found in proteins.



Spectrum indicating phosphorus (P) detection, along with other gases, on 26 October 2014. Phosphorus is a key element in all living organisms. It is found in DNA, RNA and in cell membranes, and it is used in transporting chemical energy within cells for metabolism.

www.esa.int

European Space Agency



European Space Agency