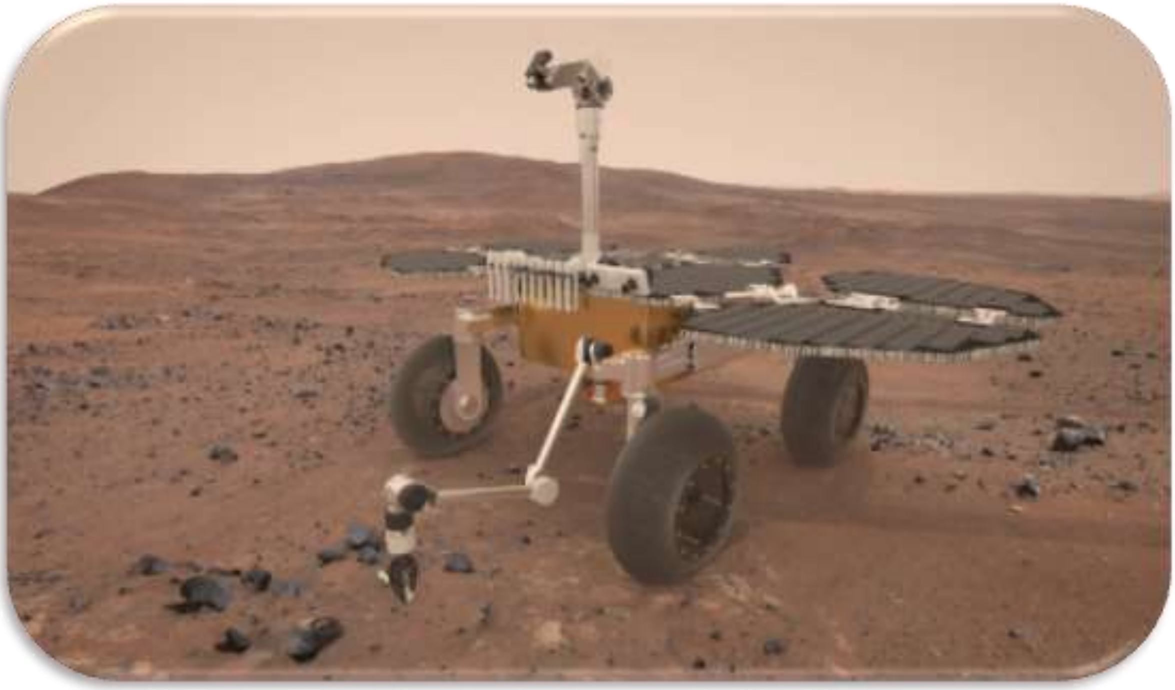
CESAR Scientific Challenge

Are we Martians?

Looking for indicators of past life on Mars with the missions of the European Space Agency

Teacher's Guide



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Didactics

Learning objectives

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

The CESAR Team generates activities for students to develop the considered top 10 skills in the 2020, where problem solving requires critical thinking and creativity. Our proposal is to execute these activities in teams. Students will find the environment where to develop their communication skills, managing different opinions and approaches, and making use of their emotional intelligence.

The CESAR scientific challenges aim to follow the thinking skills order established by the Bloom's taxonomy diagram, from a low order thinking skills (remembering, understanding) to a high order thinking skills (evaluating, creating), passing through mid-order thinking skills (applying methods and concepts for analyzing events).

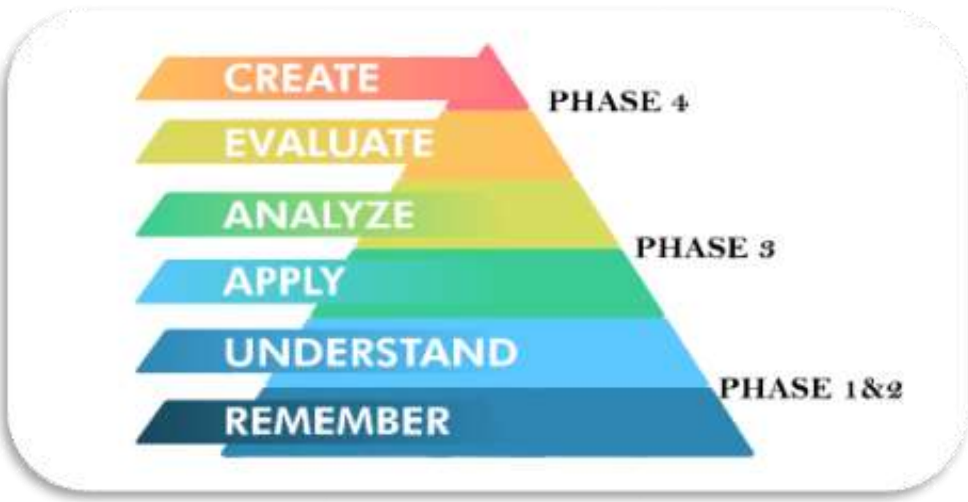


Figure II: *Bloom's Taxonomy diagram. (Credits:* https://medium.com/@ryan.ubc.edtech/*)*

Teaching Techniques:

In order to achieve the previously mentioned Learning Objectives, the CESAR Team recommends the use of some techniques like, ***flipped-classroom, solution of daily life problems (using the scientific method) and collaborative work.***

In this activity students will make use of the *flipped classroom* for Phases 0 and 1 to get ready for the problems solution of their Challenge during Phase 3. Phase 2 is optional and consist on a video call with us. In Phase 4, each team will evaluate their Experience and share it with the Scientific Community (their class/center and us, the CESAR Team). All phases are recommended to be executed as collaborative work (using **forum and blogs)**. Here we detail the process:

- **Your Scientific Challenge:** We introduce the Challenge to students and ask for their support
- **Phase 0: Putting things into context**
    - The role of the **European Space Agency** their center in Spain (European Space and Astronomy Centre, ESAC) as well as the CESAR Team. (in videos)
    - **Nowadays role models** for students to build the **Teams for their Challenge**. We recommend that Teams are formed by 4-6 people, each one of them with well-defined tasks. When possible, try to balance them in gender and diversity of capabilities.
- **Phase 1 and Phase 2:** ***remembering and understanding*** using different sources:
    - **Phase 1**: scholar cv material & new concepts (videos, documents, games)
    - **Phase 2 (optional)**: learn from an expert
        - For the teachers: talks provided by experts on the topic in previous CESAR teacher workshops.
        - For the classroom: A video call with the CESAR Team to solve doubts that may have appeared until the moment in what students have just learnt. At this stage, students had already become "experts" on the topic of the Challenge .
- **Phase 3:** ***applying*** the already known concepts following a methodology (procedures) for ***analyzing*** *data* and *solving daily life problems* (their Scientific Challenge).
- **Phase 4:**
    - ***evaluating*** their learning process during the Challenge (self and co-evaluation)
    - ***creating*** a final product to show to the Community (class/school/us) their learning process. With this you could participate in the CESAR Scientific Challenge contest.

As Figure III shows, the CESAR Scientific Challenges should execute all mentioned Phases. Phase 0 and 1, are the roots for all the Scientific Experiences, always to be done in the classroom/home. Phase 2 (video call executed from the classroom to us) is optional.

Depending on the type of Phase 3, there are various CESAR Experience Types:

- **Type I: Space Science Experience(s) @ESAC**: At ESAC, (as always in the past), completely run by the CESAR Team. Total duration 1.5 hours, with 45 minutes for the Activity and another 45 minutes the tour around the ESA spacecraft models.
- **Type II : On-line Space Science Experience(s)**: In the classroom/home, (Type I but completely guided by the teacher). Total duration 1h (MIXED when combined with Type I/III)
- **Type III: On-line Research Project**: In the classroom/home, completely guided by the teacher. Total duration several days. (Type II but executing more or all the Activities of the Guide).

Phase 4 is always executed in the classroom/home to evaluate the learning process per Team as a whole.

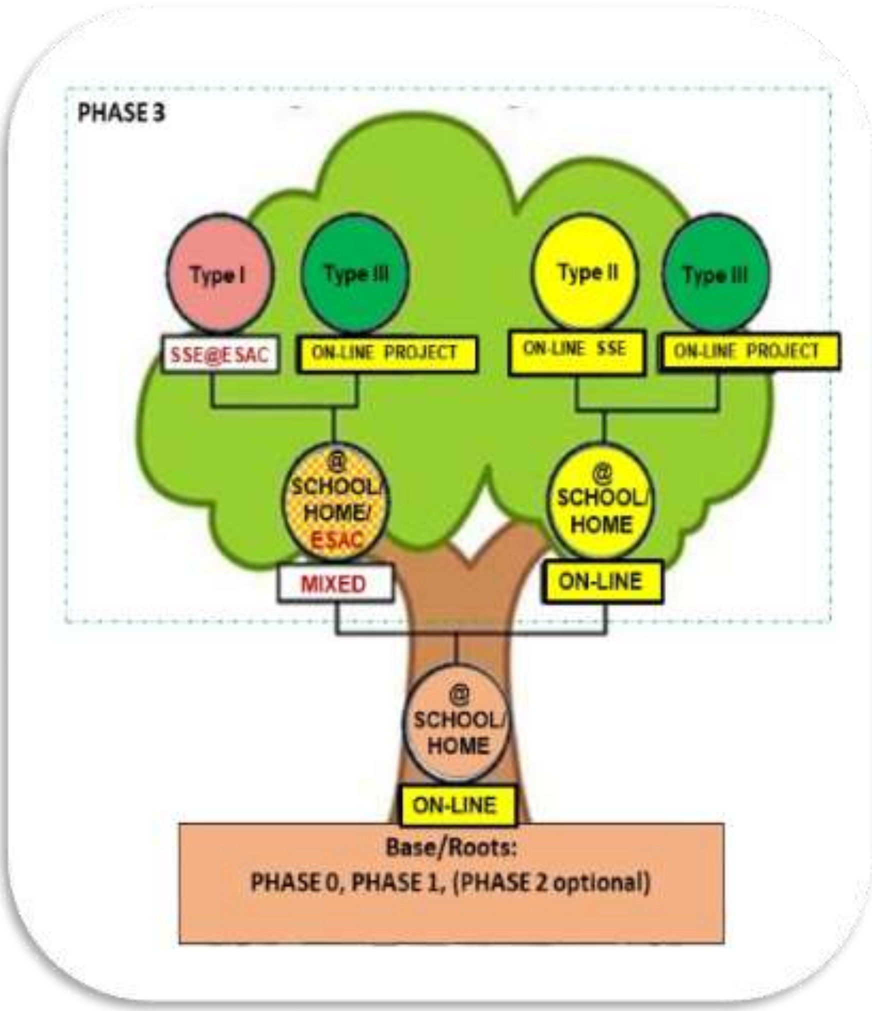


Figure III: Decision tree of the CESAR Experiences according to Phase 3 (Tipo I @ESAC, Tipo II y III, on-line) .In yellow are indicated those paths that can be run completely on-line.(Credits:teacherspayteachers.com)

Teachers are the best ones in assessing the Type of Experience (Challenge) for their classroom and school year conditions. Per each Type of Experience we propose you different Adventures. The teacher decides if each Team in the class execute an Adventure and once finish they put them in common or whether all the Teams execute the same Adventure(s) at the time (see Tables I, II and III). Teachers can also decide whether they want to execute some Activities on-line, and when it became feasible, to ask for the already well known an SSE @ESAC (Type I), for the same Challenge but different Adventure or another Challenge (see Figure III).

The CESAR Team recommends you to follow the phases in order (for an optimum learning process) and do not start one before closing the previous one. The Table Summary of Activities" will mention when the execution of a previous Activity is required. The CESAR Team can be contacted once in phase 2 (with the class) and in phase 3 (only for the teacher). For that, dedicated slots of 30 minutes are scheduled.

- For the Scientific Challenge, the Fast Facts section provides the information regarding the school curriculum and the contents of each of the Activities (by Phase) can be found in the Table "Summary of Activities". The flavors of Adventures, per each Type of Scientific Experience are in Tables I, III and III.
- **Table I: Space Science Experience @ESAC (SSE @ESAC):**

PHASES	0	1	2	3 (@ESAC)	3 (@class/home)	4	Minimum duration
ACTIVITIES (Adventure 1)	3 videos	1,2,3,4,6,7	9*	10.1, 10.2	11	12,13	2,55h
ACTIVITIES (Adventure 2)	3 videos	1,2,3,4,6,7	9*	10.1, 10.3	11	12,13	2,55h
ACTIVITIES (Adventure 3)	3 videos	1,2,3,4,6,7	9*	10.1, 10.4	11	12,13	2,55h
ACTIVITIES (Adventure 4)	3 videos	1,2,3,4,6,7	9*	10.1, 10.5	11	12,13	2,55h
ACTIVITIES (Adventure 5)	3 videos	1,2,3,4,6,7	9*	10.1, 10.6	11	12,13	2,55h

- **Table II: On-line Space Science Experience (On-line SSE):**

PHASES	0	1	2	3 (@class/home)	4	Minimum duration
ACTIVITIES (Adventure 1)	3 videos	1,2,3,4,6,7	9*	10.1, 10.2,11	12,13	2,55h
ACTIVITIES (Adventure 2)	3 videos	1,2,3,4,6,7	9*	10.1, 10.3,11	12,13	2,55h
ACTIVITIES (Adventure 3)	3 videos	1,2,3,4,6,7	9*	10.1, 10.4,11	12,13	2,55h
ACTIVITIES (Adventure 4)	3 videos	1,2,3,4,6,7	9*	10.1, 10.5,11	12,13	2,55h
ACTIVITIES (Adventure 5)	3 videos	1,2,3,4,6,7	9*	10.1, 10.6,11	12,13	2,55h

- **Table III: Research Project:** All Activities

PHASES	0	1	2	3 (@class/home)	4	Minimum duration
ACTIVITIES	videos	1,2,3,4,5,6,7,8	9*	10,11	12,13	4,05h

(*)The video call is optional, we recommend running the questionnaire to take a decission

REALLY IMPORTANT

- ✓ As a teacher, **register as part of the CESAR Community** **here** (If you approach us for the first time, it may take some time – a non-automatic process -, but you will not regret ;o))
- ✓ **Once you have been confirmed as part of the CESAR Community** ask for the CESAR Scientific Experiences to live with your class **and you will be guided in the process:**
  - Click here to request an on-line experience – Type II & III
  - Click here to request a combined experience - Type I (Only for schools in the Comunidad de Madrid and close cities)
- ✓ **Guides are very long (many possible tools) to build your Experience but also very flexible**

It is your time! Choose your Adventure!

Fast Facts

Basic Data	Students should know…
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	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.
Currículum	**Students will learn…**
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.	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
You will need…	**Students will improve…**
Installation of the free programme Google Earth Pro in case of doing Challenge 3. Porexpan spheres (optional).	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.

Summary of Activities

Phase	Activity	Material	Results	Requirements	Time
Phase 0	Putting things in context	VIDEOS: a) This is ESA b) ESAC: ESAS's window to the universe c) Presentation a ESA/ESAC/CESAR by Dr. Javier Ventura (in spanish) d) Other videos	Students get used to: • ESA • ESAC • CESAR team	None	10 - 20 min
Phase 1	1. Refresh concepts		Students will remember definitions given in their academic courses and related to the scientific case.	None	3 min
Phase 1	2. Getting used to coordinates 2.1. Identifying coordinates on an earthly map 2.2. Martian zero meridian 2.3. Identification of coordinates on the Martian map 2.4. Mars model	Required material: • Google Earth Pro • Porexpan spheres Web resource: Spherical model of Mars	Students will improve:: • Their spatial vision. • Understanding parallels and meridians • Extrapolation of measurements on Earth to other planets	None	30 min
Phase 1	3. The life origin 3.1 What is life? 3.2 Trace of extraterrestrial life 3.3 DNA extraction	ESA KIDS: Rosetta Web resources: Article about Rosetta Article about Rosalind Franklin DNA experiment	Students will improve: • The extraction of useful information from reliable sources. • Their abilities to communicate results and work as a team.	None	15 min – 1 hour

Phase 1	4. Habitable zones 4.1. Habitable zone of our star 4.2. Study the habitable zones of different stars 4.3. Past, present and future of water in Mars 4.4. Extremophiles	Worksheets Web resources: • Twitter 1 (spanish) • Twitter 2 • Press 1 • Press 2 • Wikipedia • Habitable zone • Video:Life Beyond Circumstellar Habitable Zone Simulator ESA education - Extremophiles	Students will improve: • Their knowledge about why there is life on Earth • Understanding the key factors for life • Your teamwork and communication skills.	None	1 hour
Phase 1	5. What do you know about Mars?	Worksheets Web resource: *Mars CESAR Booklet*	Students will improve: • Their knowledge about Mars	None	10 min
Phase 1	6. Scientific knowledge from Mars surface 6.1. Geology of Mars 6.2. Atmosphere of Mars	Worksheets	Students will understand: • Basic concepts about Mars's features	It is advisable to have seen the materials from activity 5	10 min
Phase 1	7. Mars exploration by European Space Agency 7.1. Major milestones of the European Space Agency on Mars	Worksheets Web: Missions to Mars Mars Express Mission Highlights Videos: Mars Express ExoMars	Students will improve: • The ability to extrapolate situations on Earth to other planets. • The relationship of concepts between different learning areas, (Geology, Biology, Physics or Chemistry)	It is necessary to have completed activity 6 and advisable activities 3, 4 and 5	40 - 50 min

		Mars missions 2020-2030 3D Models: ESA's Scientific Satellite Fleet Mars ExoMars More web resources: Water at Martian south pole Mars Express and the story of water on Mars Mars Express detects liquid water			
Phase 1	8. Check what you have learnt so far	questionnaire	Students will improve en: ● Their ability to self evaluation		30 - 40 min
Phase 2	9. Ask for a videocall with the CESAR Team if needed	http://cesar.esa.int/index.php?Section=Scientific_Cases&Id=24&ChangeLang=en	Students can have first hand information from European Space Agency experts	Advisable to have done Activities 1 to 6.	30 - 40 min
Phase 3	10. Prepare Mars landing 10.1. Get used to Google Mars 10.2. Flight engineer's team (Team 1) 10.3. Martian rover/ car efficiency/ safety expert team (Team 2) 10.4. Mars science data expert team (Team 3) 10.5. Expert team in requirements of a robotic/	Worksheets Google Earth Pro Web resources: Simula tu lanzamiento ExoMars 2022 ExoMars rover instruments ExoMars Raman Laser Spectrometer ExoMars MOMA Instrument Survey. What do we take to Mars?	Students will be able to do: ● Observe and interpret map images that do not represent the visible spectrum. ● Analyze the data and draw logical conclusions. ● Improve teamwork and result presentation ● Understand the importance of a multidisciplinary team	Advisable to have done, at least, activities 4, 5 and 6	25 min

	uncrewed mission (rover) (Team 4) 10.6. Expert team on a mission crewed by astronauts to colonize Mars (Team 5)				
Phase 3	11. Expert committee 11.1. Multidisciplinary teams 11.2. Choose whether to do a crewed / uncrewed or mixed mission 11.3. Chose a place to land 11.4. Vote for the best mission! 11.5. Conclusions	It is advisable to have a projector.	Students will improve en: ● Discussion and defense of results. ● Debate skills	It is essential to have done activity 10	15 min
Phase 4	12. Evaluate	questionnaire	Students will check if they have internalized the concepts. Students will improve: ● Their understanding of the scientific method and critical thinking. ● Their strategies for working as scientists. ● Their evaluative ability. ● Their ability to apply theoretical knowledge to real life situations.	It is necessary to have completed at least the entire Phase 3	10 min
Phase 4	13. Present your results	Free format chosen by the students	Students will improve: ● Their teamwork and communication skills. ● Their knowledge about topography.		30min – 2h

Your Scientific Challenge

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.

Is it possible that life on Earth is of Martian origin? Can you imagine being a Martian?

Scientifically we have not yet found traces of life on Mars, but we continue planning missions to help us discover if it exists.

Would you like to travel with us to Mars in search of life traits and trying to confirm/deny this theory? You would go down in history!

Do you dare to try it?

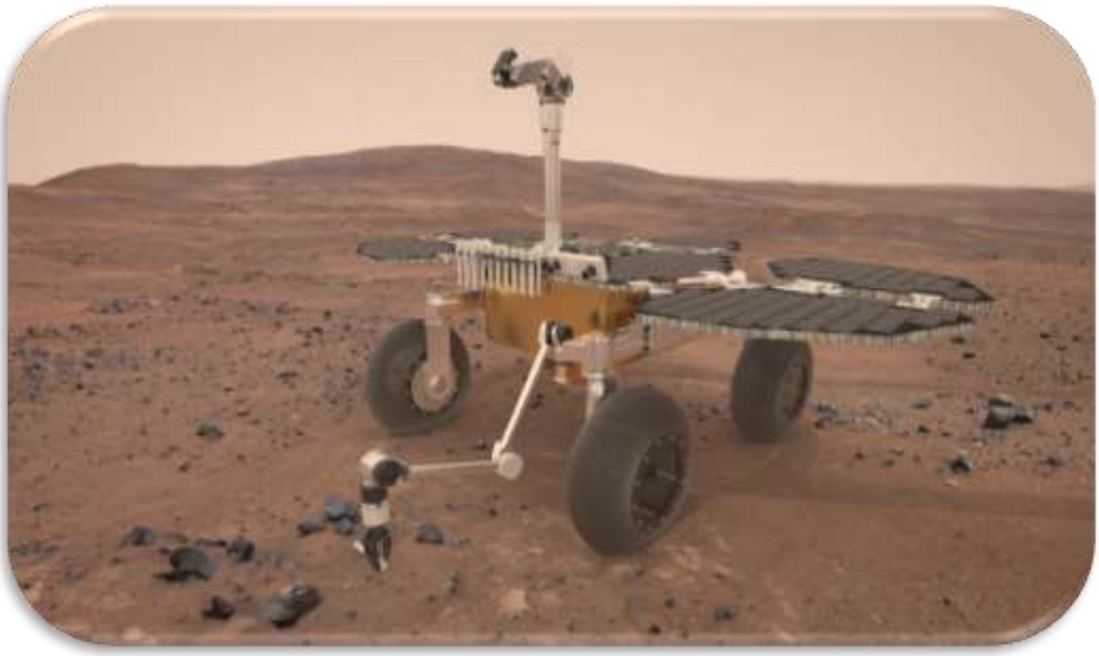


Figure I Martin rover motors ahead (Credits: ESA)

Phase 0

To put ourselves in context, we recommend you watch these videos**:**

- This is ESA
- ESAC: ESA's Window on the Universe
- Presentation ESA/ESAC/CESAR by Dr. Javier Ventura

You will work in **teams** (4-6 people), having each one a specific role. Fill in Table 0 with the name of the team and the team members associated with various professions related to space.

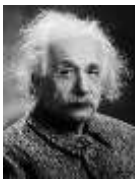
Challenge Identificator ID		Team Number (1-6):		
Team members				
Professions	Mathematician/ Software engineer	Astrophysicist	Engineer	Chemist/Physicist
Roles	She/he is in charge of leading the correct execution of calculations	She/he is in charge of planning the observations of the ESA/Mars space missions	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
References (feminine)	Katherine Johnson 	Vera Rubin 	Samantha Cristoforetti 	Marie Curie 
(masculine)	Steve Wozniak 	Matt Taylor 	Pedro Duque 	Albert Einstein 

Table 0: *Define the identifier of your challenge (a unique number), your Team Number (1-6) and the name of the Team members, each of them with defined tasks within the Team.*

Note: The documentation makes use of the International System of Units.

Phase 1

Activity 1: Refresh concepts

Our challenge involves finding an optimal place (location) and precise coordinates to land. The roughly spherical shape of Mars allows us to use a geographic coordinate system to be able to locate places and easily locate ourselves on its surface. These coordinates are **latitude** and **longitude**.

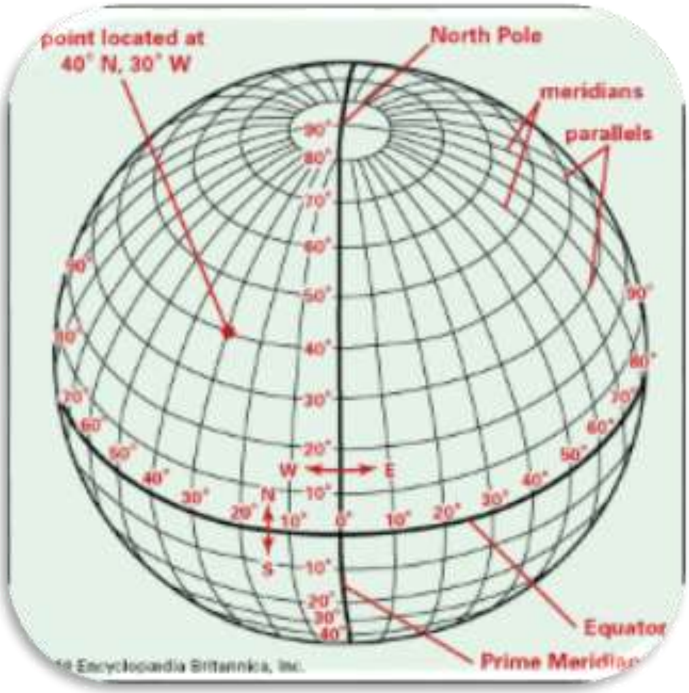


Figure 1. *Geographical coordinates (Credits: Britannica)*

Longitude is the distance (measured in angular units) between the meridian of a place and the meridian zero (in the case of Earth, Greenwich meridian). Its units are degrees, minutes and seconds of arc and it is measured from 0 to 180º towards the East or towards the West from the zero meridian. It can also be measured as 360º to the East

Latitude is the angular distance between the parallel of a place and the Equator, it is expressed in the same units as longitude and it is measured from 0 to 90º towards the North or South. It can also be measured from 0 to 90º or 0 to -90º North. (If you use negative numbers, the reference is always the geographic North).

Activity 2: Getting familiar with coordinates

Activity 2.1: Identify coordinates on an Earth map

In this activity you will have to learn to use geographic coordinates. For this, you will use the Google Earth Pro program.

1. Open de Google Earth Pro program. You will see Figure 2:

***Figure 2**. Earth map. (Credits: Google Earth)*

2. In the menu bar above you have to select the option "View" and there select the option "Grid" as indicated in the image in Figure 3:

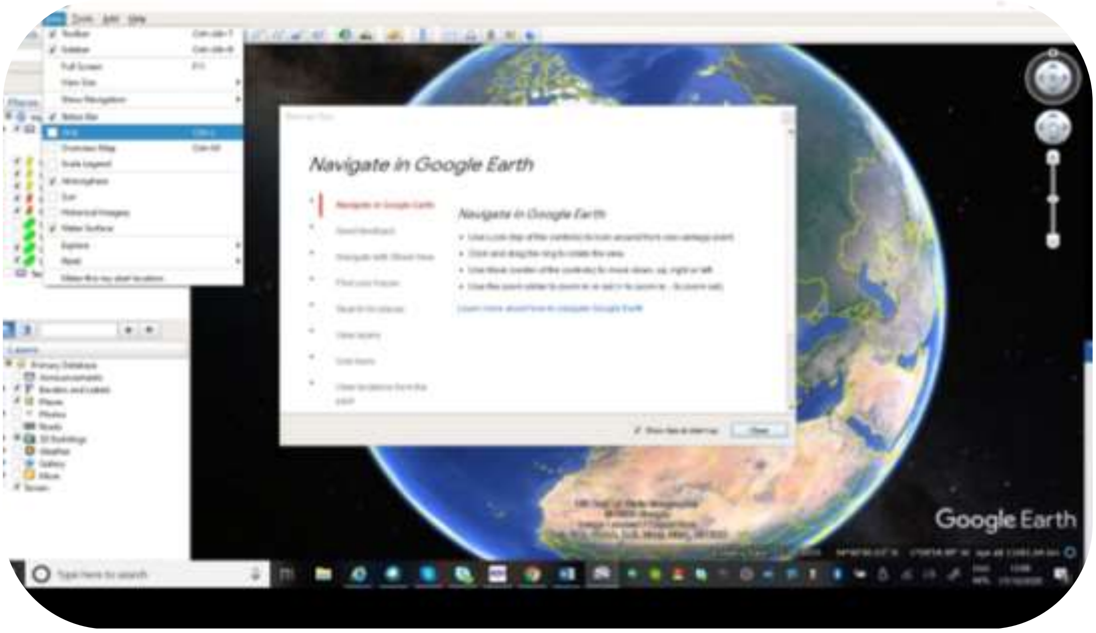


***Figure 3**. Earth map. (Credits: Google Earth)*

3. The parallels and meridians will appear on the globe, as shown in Figure 4:

***Figure 4**. Map of the Earth's sphere with coordinates (Credits: Google Earth)*

In Table 1, relate each of the given coordinates (latitude, longitude) with one of the following places:

Coordinates	Place
Latitude	ESAC (Madrid)
Longitude	
Latitude	Baikonur
Longitude	
Latitude	French Guiana
Longitude	
Latitude	Cape Canaveral
Longitude	
Latitude	Royal Observatory of Greenwich
Longitude	
Latitude	South Pole
Longitude (all)	

***Table 1.** Table with coordinates of different places*

Activity 2.2: The Martian zero meridian

Once we are clear about how to locate a point on Earth, we will try to do the same on Mars. For this we are going to use a topographic map of the Martian surface, that is, Google Mars.

The first thing we will do is understand a little better the altitude of Mars, since the highest mountains in the Solar system are found on this planet. To do this, click on the following Google Mars link and look at the color scale that is at the bottom left (*Figure 5*)

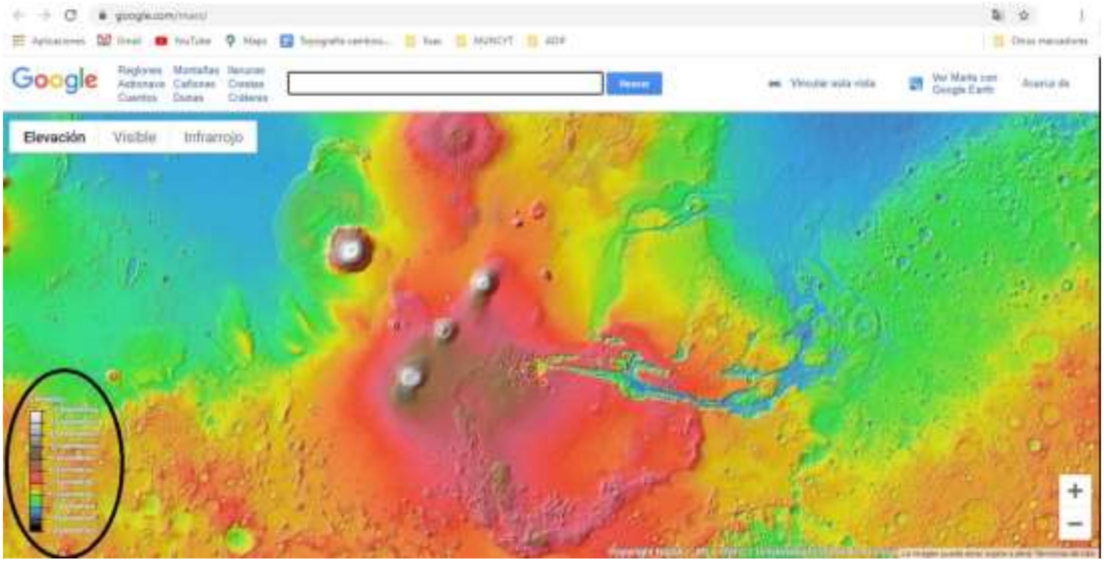


***Figure 5**. Images from the martian surface. (Credits: Google Mars)*

As can be seen, the same color code is used as on Earth, but this does not mean that there are oceans of liquid water on Mars or that the tops of the mountains are covered in snow. It is simply a color code.

On Mars the position of the zero meridian is in the **Airy-0 crater**. To locate it, the following steps are followed:

1. Select in the upper left menu the option "Craters" and look for the name of Airy-0 (you can also put the name directly in the browser above).
2. How deep is the crater, taking into account the color scale? Compare that depth to some very deep landform on Earth.

On Earth we have different quite deep landforms such as:

- The Challenger Abyss in the Mariana Trench (- 11 034 m) is the deepest place on our planet.
- Denman Canyon (- 3 500 m) is the deepest place on Earth not covered by water. It is located in Antarctica under the glacier of the same name.

Activity 2.3: Identify coordinates on a Martian map

Now the coordinates of a place on the surface of Mars will be searched and placed on a sphere simulating the Martian globe, that is, Mars

1. Click the link: Google Mars

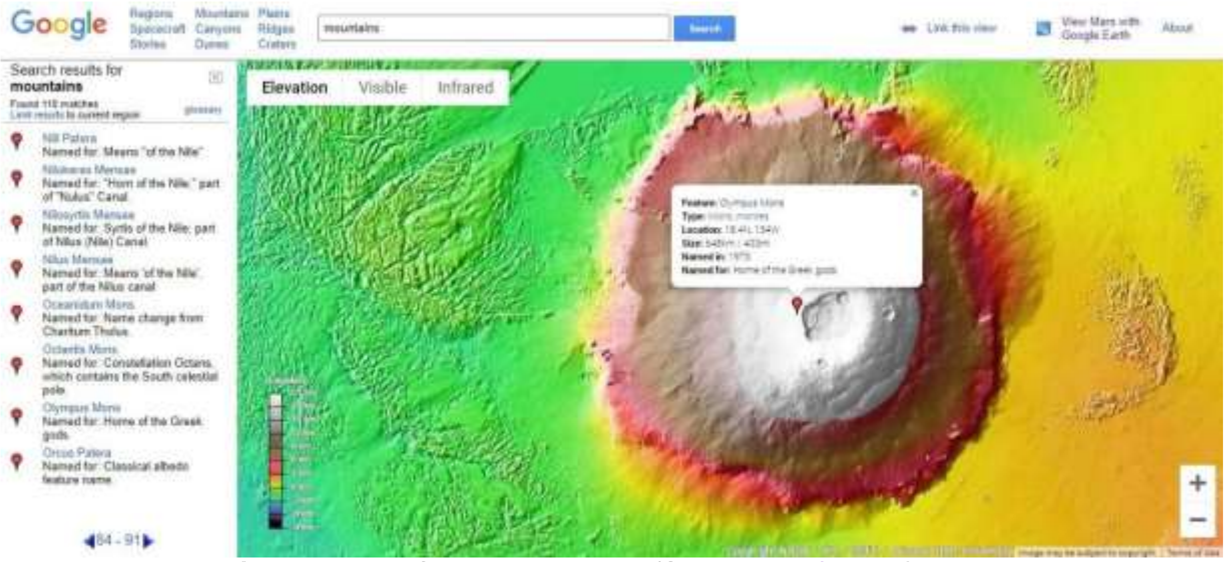


***Figure 6**. Map of Mars's mountains (Credits: Google Mars)*

2. Select in the menu, on the top left, the option "Mountains" and a menu with the different mountains of Mars will be displayed on the left as shown in Figure 6. Write some of them.

Each group will be able to choose different mountains. Three different types of them are mentioned here:

- Olympus Mons (Mons refers to a large isolated mountain. Its plural is Montes)
- Albor Tholus (Tholus refers to a small mountain-shaped dome. Its plural is Tholi)
- Alba Patera (Patera to refer to an irregular crater or a complex one with scalloped edges. Its plural is Plateae)

3. Look for the mountain seen in *Figure 6* (Olympus Mons) and click on its highest point. Write the information that Google Mars gives you on this point.

Olympus Mons

Localization: 18,4º N and 134º W

Size: 648 km

Above all they have to look at the coordinates, which are the ones they will have to use later: 18,4º N y 134º W (N North y W West).

4. Look at the coordinates of Olympus Mons and mark on *Figure 7* the position it has. (Choose and mark as the zero meridian the one you consider most appropriate. Hint: to remember how the latitude and longitude coordinates are indicated, you can review the previous activities).

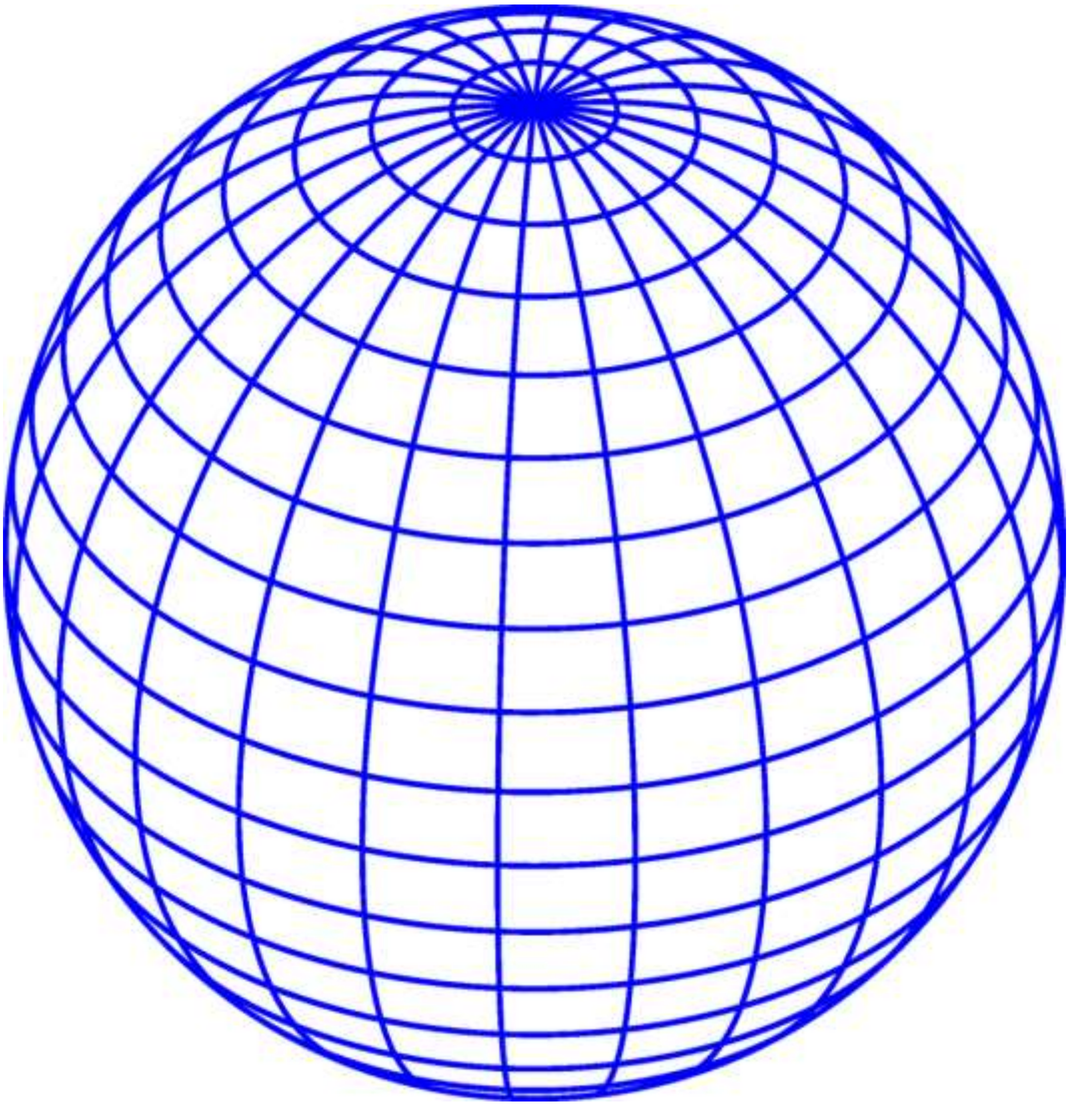


Figure 7. *Meridians and parallels (Credits: https://www.pngegg.com/es/png-tauhu)*

Groups can mark any meridian as zero. They will simply have to realize (counting the number of meridians there are) that the separation between them is 15º.

Activity 2.4: A model of Mars

On the following link you can download the *Figure 8* image, cut it out and stick it to a spherical surface made of polystyrene or other material. For your planet Mars to look good you must bear in mind that the width of *Figure 8* has to be equal to the maximum circle of your sphere.

The **maximum circle** is the line that divides the sphere into two equal hemispheres (on Earth it would be the Equator). You can calculate its **length** in the following way:

$$L = \pi \cdot D$$

where D is the **diameter** of your sphere.

If you look at the **height** of Figure 8 it is half this length:

$$l = (\pi \cdot D)/2$$

Where D, again, is the **diameter** of your sphere.

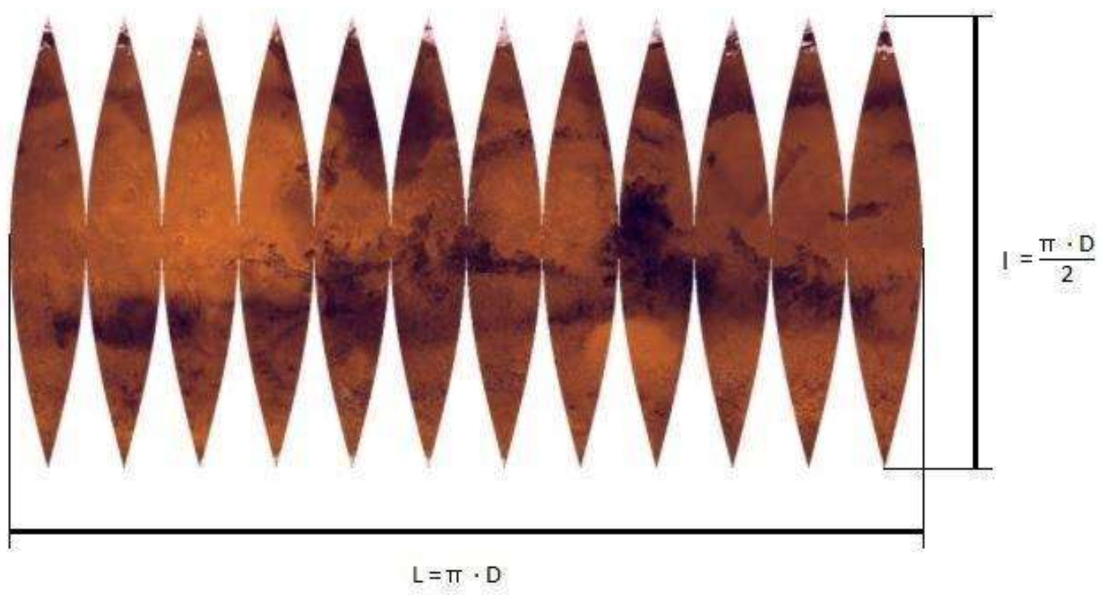


***Figure 8**. Martian globe. (Credits: Making globes of the planets)*

Activity 3: The origin of life

Activity 3.1: What is life?

1. What do we call life? Justify your answer.

The term life from biology, refers to what distinguishes animals, plants, fungi, protists, archaea and bacteria from the rest of natural realities. It implies the capacities of organization, growth, metabolize, respond to external stimuli, reproduction (in some definitions) and death.

2. What hypotheses do you think have been given throughout history that explain the origin of life?

One of the most famous is the one based on Miller-Urley, in 1953. It took the primordial atmosphere of the Earth (rich in methane and hydrogen), water, mineral salts and an electric current (resembling electrical rays). And the first organic molecules appeared.

But today, it has been seen that this atmosphere rich in methane and hydrogen is common on Jupiter and Saturn (also on one of Saturn's moons, Titan), but not in the Earth's atmosphere.

In order for the breeding ground to form, for life, on Earth, we have to go to hydrothermal vents or layers of clay. But it's difficult. This greatly supports the theory of panspermia.

After having organic molecules, comes the theory of the RNA world, where an RNA molecule (also has catalytic capacity, so it can replicate (reproduce), grow, metabolize by itself. From this RNA molecule it would be created a RNA-protein interaction, and from there, it would pass to the RNA-DNA step. It is wrapped in a lipid bilayer and we have the first cell.

3. What experiments can you think of to detect it?

Mainly looking for complex organic molecules, which can only originate from life. Finding DNA or RNA would be great. One more living cell.

It could also be studied using the same techniques to detect diseases or different microorganisms (pathogens or not) to simply find life, such as the famous PCR, or antigen-antibody reactions.

4. Do you think that when searching for evidences of past life of extraterrestrial it is done in a similar way to the search for these on Earth? Justify your answer.

First of all, organic matter and water are very common in our Solar System and in our Universe. It is a combination that we know it works and would be the first thing to look for. Something similar to what we have on Earth.

But you have to keep our eyes open in case what we find is not so similar. A silicon base, instead of carbon, is a recurring hypothesis. The problem is that silicon doesn't have as much variability as carbon (for example, it can't make double and triple bonds).

Using solvents other than water (passing, for example from water, to ammonia and from there to methane-ethane), are very popular, to try to predict life on Titan, at -180º C

All the evidences we have place the origin of life around 4 000 million years ago. The general idea is that life originated from lifeless (inert) matter when the ideal conditions were met, but there are also other hypotheses such as a possible extraterrestrial origin.

We call the **origin of life** the moment where the common molecules of the universe (and our planet) came together to form the first compounds before life, but it is not so clear how or where it appeared.

The search for life in the celestial bodies is carried out by following the traces that it may have left in them.

As a hunter follows the clues that his prey leaves on the ground, astrobiologists interpret the molecular traces of what may have been biological activity long ago on Earth, Mars, the Moon, or any meteorite fallen on Earth.

Activity 3.2: Traces of extraterrestrial life

Different missions have been and are being carried out by the European Space Agency to try to find **biological traces** in other celestial bodies and thus understand a little better our own life. These biological tracers can be, for example, indicative molecules of biological processes.

One of the most important missions in this endeavor was **the Rosetta mission**, which traveled to a comet for 10 years to study its composition. More specifically, to study whether the comet's water was equal to that of Earth or not. Despite the fact that the mission ended a few years ago, much of the data that was obtained is still being analyzed.

Activity 3.2.1: Read the following article

You must read the following article that explains the mission's discoveries, and watch the following video, then answer these questions:

What compounds essential for life did Rosetta discover?

Glycine, an amino acid essential to make proteins, and phosphorus, a basic ingredient for life.

Where are these two substances (found in the comet) in the organism of living beings?

Glycine in proteins, and phosphorus mainly in DNA (deoxyribonucleic acid) and RNA (ribonucleic acid). Phosphorus is also essential as the energy currency of the cell's metabolism, since it forms ATP (adenosine triphosphate)

Would you know how to explain the meaning of DNA?

Deoxyribonucleic acid. DNA is a nucleic acid that is responsible for hereditary transmission and also contains the genetic instructions used in the development and function of all living organisms and some viruses.

Activity 3.2.2: Read about Rosalind Franklin and ExoMars 2022

Another of the great missions of the European Space Agency in search of life is ExoMars. This mission has already yielded many fruits as it has been underway for years, but in 2022 the launch of a rover (a vehicle designed to explore some celestial bodies) is scheduled to land on the red planet.

Read the following article and find out why is known the scientific Rosalind Franklin and her relation with the next mission of European Space Agency.

Rosalind Franklin was a British scientist with a degree in chemistry and an expert in X-ray crystallography (a technique that uses light to study the structure of small materials that we cannot examine with the naked eye). He helped us to know that DNA is in the shape of a double helix with his famous photograph 51. ESA maintains the tradition of naming its missions after great scientists such as Newton, Planck or Euclid, so the name is very well chosen because the Rosalind Franklin rover will search Mars for the elements that originate life

Activity 3.3: Experiment for DNA extraction

We propose the following experiment to conclude the activity.

Have you managed to extract DNA? Was it easy? Tell us about your experience.

> Here, the students have to write their impressions while doing the experiment. If it has been easy, difficult, interesting or if they have learned things they did not know.

Activity 4: Habitable zones

Initial hypothesis.

Have you read in the news that potentially habitable planets have been discovered? What do you think they refer to?

> This is an hypothesis. We must emphasize that all the hypotheses are equally correct, the students shouldn't feel ashamed if they don´t know the right answer.
>
> It's just an initial idea from which we start working and draw some conclusions.
>
> Each group will have different ideas and it would be interesting if they could share them.

Activity 4.1: Habitable zone of our star

Make five teams to perform the following exercise.

Each team will learn about life on other planets and about the "habitable zone" in different media. In addition to the links that we leave you, you can expand the information with other articles.

- Team 1: search on twitter
  - https://twitter.com/search?q=zona%20de%20habitabilidad&src=typed_query
  - https://twitter.com/OuterWorlds/status/1278775110199959552
- Team 2: search on press
  - https://newatlas.com/space/two-dozen-exoplanets-superhabitable-identified/
  - https://www.sciencetimes.com/articles/26581/20200723/scientists-find-previously-lost-planet-search-habitable-worlds.htm
- Team 3: search on Wikipedia
  - https://en.wikipedia.org/wiki/Circumstellar_habitable_zone

- Team 4: search on the European Southern Observatory
    - https://https://www.eso.org/public/www.eso.org/public/
- Team 5:Have a look at this documentary film
    - Youtube (Life Beyond)

Once you have been informed, we will try to draw some conclusions. To do this, try to answer the following questions.

Write the name of your team and the medium used (Twitter, press, wikipedia, specialized pages or documentaries).

> Each team writes in what type of medium they have been informed. They can search for more information but always in the same type of medium.

What do we call the habitable zone?

> In astrophysics, the region around a star in which the incident radiation flux would allow the presence of water in a liquid state on the surface of any rocky planet (or satellite) found in it and that with a mass between 0.5 and 10 Earth masses and an atmospheric pressure greater than 6.1 mbar, corresponding to the triple point of water at a temperature of 273.16 K.
>
> Each team will give a different definition because in the links they have to see / read, what they find may vary.

Does Mars meet the necessary conditions to find life? Justify your answer.

> Yes. According to the latest scientific data, especially from Curiosity in Gale crater, along with experiments in planetary chambers (laboratories on Earth that resemble conditions on other planets and satellites in the Solar System) life on Earth (Extremophilic microorganisms) could live in Martian conditions, especially buried in the Martian subsoil.

What do you think of the information medium used? Is this information enough or do you think it would be necessary to contrast this news?

> In this part of the activity, it would be interesting for the different groups to comment on their opinions as well as the answers they found.
>
> They will realize that finding truthful information costs more in some media than in others and that the news is often very sensational (even in the scientific field), leaving aside rigor.
>
> In all media you can find good information but you have to choose well the articles, the people you follow or the documentaries you see.

The habitable zone depends mainly on two factors: the **mass** of the star and its **age**. As a star evolves, its temperature and luminosity change.

Figure 9 compares the habitable zone of our solar system, showing the innermost planets for reference, with the extrasolar planetary system Gliese 581 and its six planets discovered to date.

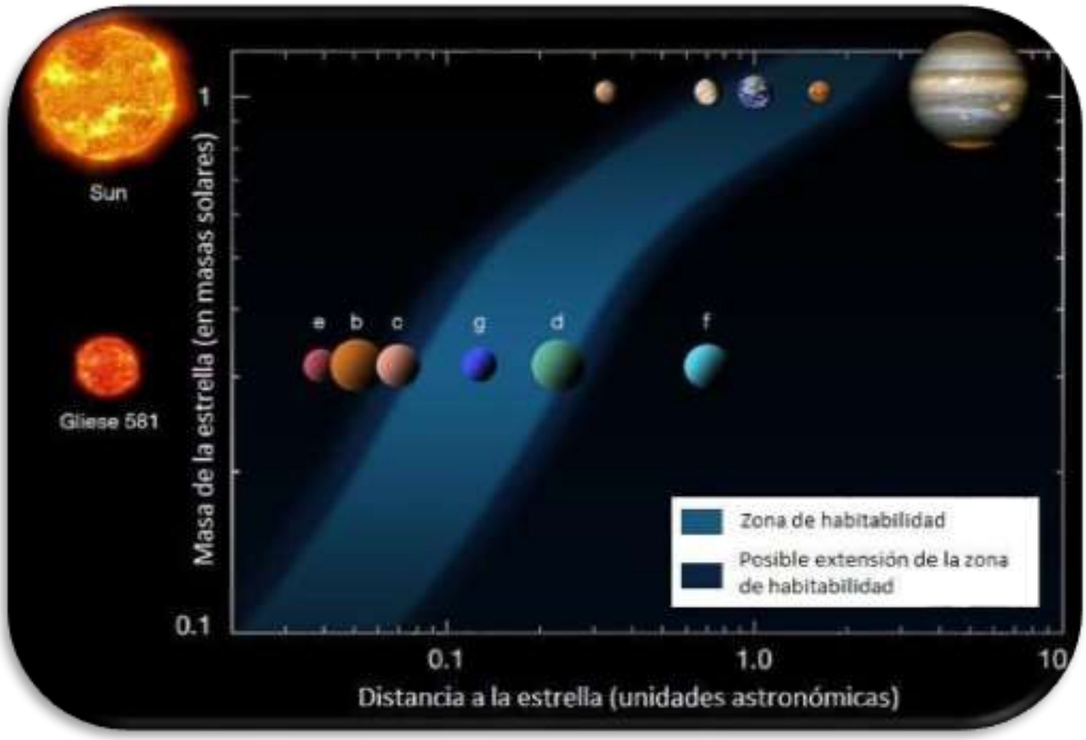


Figure 9*. Graph of the habitability zone (Credits: OpenMind-BBVA)*

Our planet is neither far nor close to the Sun, this means that the planet's average temperature is 15º C, thus allowing us to find water in a liquid state on its surface.

If the Earth were smaller, its mass would not be able to attract by gravity to its protective atmosphere and it would also be so thick and dense that it would not allow sunlight to pass through. The Earth's atmosphere lets visible light pass through, with which plants carry out vital processes, and yet it traps high-energy radiation due to its oxygen-rich composition (of biological origin). This composition allows the formation of ozone, a molecule made up of three oxygen atoms.

After all that we have been seeing, we could conclude that the **habitability** zone can be defined as the region around a star in which the incident radiation flux would allow the presence of water in a liquid state, on the surface of any planet (or satellite) rocky that was in it. This rocky body must have a mass between 0.5 and 10 Earth masses and an atmospheric pressure greater than 6.1 mbar. These conditions correspond to the triple point of water (point at which water is stable both in solid, liquid and gaseous form) at a temperature of 273.16 K.

The reason for looking for this habitable zone is that we consider that liquid water is essential for life, which does not have to be strictly true.

Activity 4.2: Study the habitable zones of different stars

To carry out this activity we are going to use a simulator that will help us and greatly simplify everything we will have to do.

We have seen in the *Activity 4.1* what was the habitable zone, and this simulator will recreate it perfectly for different stars.

1. Click on the simulator link and you'll see the next figure (*Figure 10*).

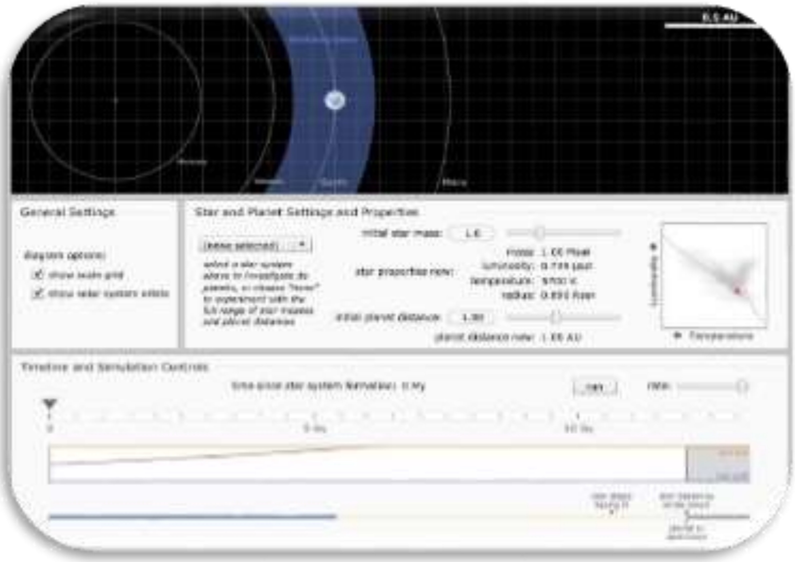


***Figure 10**. Home page simulator (Credits: University of Nebraska-Lincoln)*

Note: If this page cannot be seen, it will be necessary to give permission in the browser bar to run "Flash".

2. Look at the options menu to see the different parameters:

- Input parameters (can be modified):
    - Name of the star
    - Mass of the star
    - Distance from the planet in its orbit around the star
    - Star age (how the star evolves over time)
- Output parameters (result of input ones)
    - Brightness
    - Temperature
    - Hertzsprung-Russell diagram (luminosity-temperature graph)
    - Star life phase
    - Impact on the planet

Now you can choose between this two options:

a. You can choose one of the predetermined stars and vary the proximity of the planet to it. (Figure 11a)
b. Choose none, modify the mass and vary the proximity of the planet to it. (Fig. 11 b)

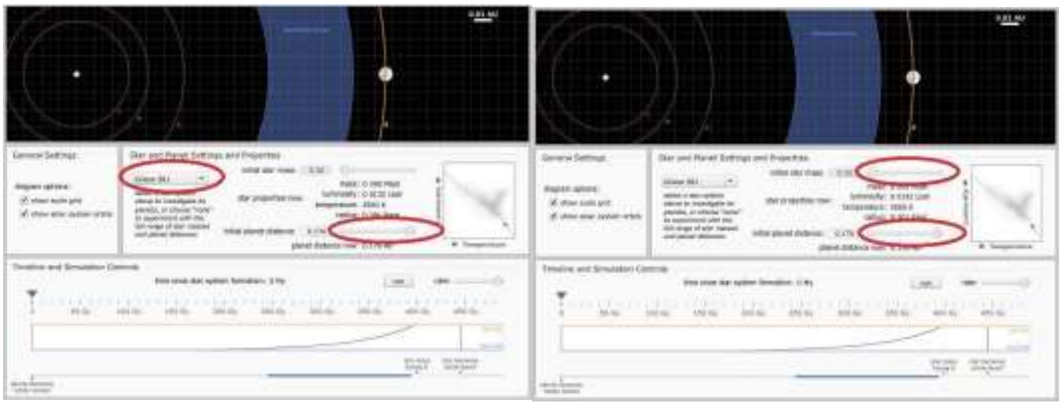


***Figure 11**. a. star variation b. variation of the mass. (Credits: University of Nebraska-Lincoln)*

3 Choose option a or b and take a star for your study in order to see how the habitability zone simulator works. Press "run" to see how it evolves over time.

What do you see when you run the simulator?

> On the timeline you can see when our planet will be in the habitable zone.
>
> You will also be able to see the graph of brightness versus temperature, also known as an H-R (Hertzsprung-Rusell) diagram.

Note: The simulator draws the range of the habitable zone (CHZ, Circumstellar Habitable Zone) for different stars based on their mass. The mass will be given in solar masses (Msun) to be able to compare the habitable zones with the distances in our Solar System. Remember also that 1 AU = 150,000,000 km (distance from the Earth to the Sun).

Once you have experimented with the simulator you can already make different teams to investigate different stars. It can also be done individually where everyone will choose a predetermined star.

You will have to fill in the *Table 2*:

Name of the star:		Mass : (Msun)		Lifetime (Gyr)	

Age (My o Gy)	Stellar luminosity (Lsun)	Inside distance CHZ (ua)	CHZ outer distance (ua)	CHZ width (ua)
0				
4.6 (today)				
12				

***Table 2.** Habitability range table*

The example is shown for the Sun in the *Table 2a*:

Sun: 1 Msun , Lifetime: (0-12) Gyr				
Age (Gyr)	Stellar luminosity (Lsun)	Inside distance CHZ (ua)	CHZ outer distance (ua)	CHZ width (ua)
0	0.739	0.820	1.18	0.36
4.6 (today)	1.03	0.96	1.39	0.43
12	212	13.6	19.4	5.8

Extra table *Habitability range table with data from the Sun*

How do the luminosity and width of the habitable zone vary for the different star's ages?

The luminosity increases slowly until the star becomes a white dwarf, which decreases rapidly.

The width of the habitable zone increases, little by little, over time as the luminosity of our star increases until it becomes a white dwarf and decreases rapidly. Furthermore, the more the luminosity increases, the further away the habitable zone of the star is.

Discuss with the rest of the teams your results, what general conclusion can be obtained about the dimension and distance to the CHZ star for the different types of stars? Fig *12*.

For all planetary systems, the habitable zone starts out narrower and, little by little, it gets wider as its star evolves. It also happens, for all cases, that when the luminosity increases, the habitable zone moves away from the star.

The moment the star evolves, whether it is a white dwarf, a neutron star or a black hole, the zone of habitability shrinks rapidly.

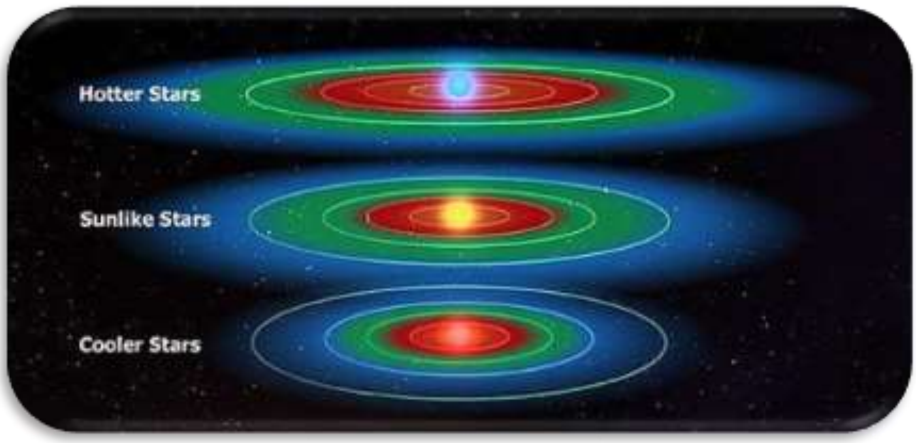


Figure 12*. Comparison of habitability zones for different types of stars (Credits: Circumstellar Habitable Zones - Habitable Zones - NAAP)*

Activity 4.3: Past, present and future of water on Mars

In *Activity 4.2* we have talked about the habitability zone around other stars that were not ours. Now we are going to focus on the Sun and the planet Mars to understand a little better the existence, or not, of liquid water on the surface of the red planet.

If it has not been done, go to *Activity 4.2* to know how to better handle the simulator that we are going to use.

1. Click on the simulador link and the initial screen will appear as shown in *Figure 13*.

2. Make sure the initial star mass is 1 solar mass (Msun).

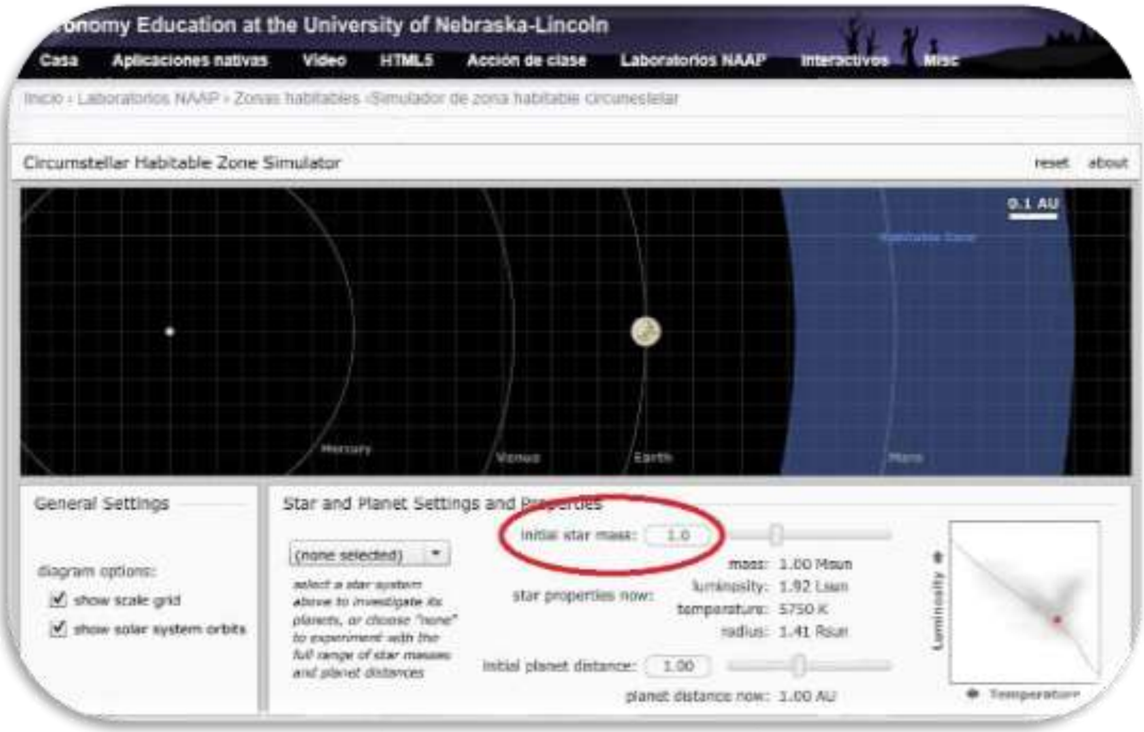


Figure 13. *Simulator with initial mass 1 Msun (Credits: University of Nebraska-Lincoln)*

3. Look at the window of the timeline, which indicates the star age, and slow down the simulation (*Figure 14*).

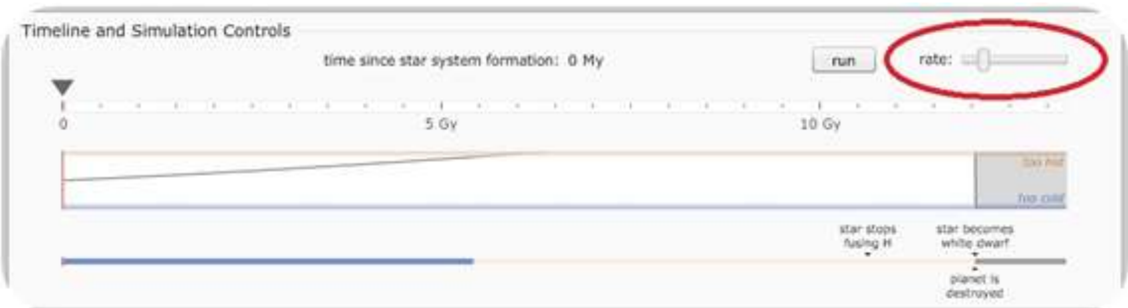


Figure 14. *Simulator timeline (Credits: University of Nebraska-Lincoln)*

4. Press "run" and observe in the upper window (image of the planets and the star) in which periods Mars is in the habitable zone to be able to fill in Table 3. (Note: the habitability zone can also be observed in the blue line that is generated at the bottom of the timeline) (*Figure 15*).

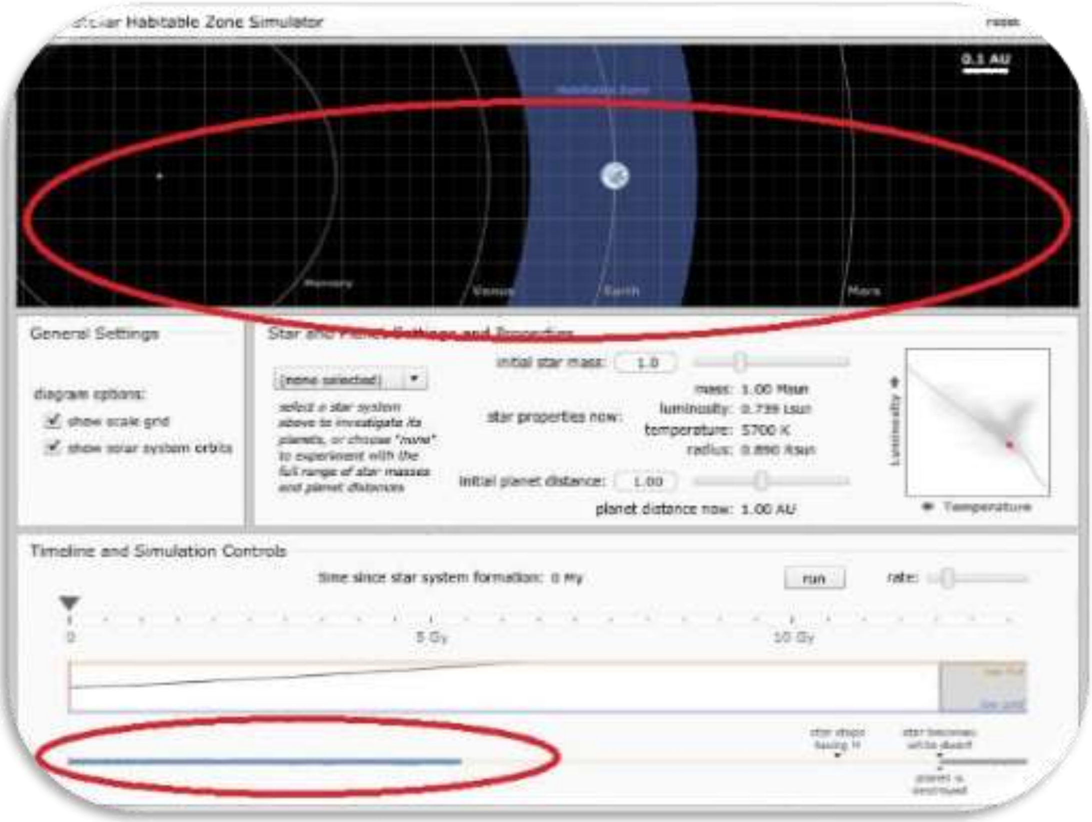


Figure 15. *Simulator timeline (Credits: University of Nebraska-Lincoln)*

Sun age range	Mars in habitable zone
(0 – 6.9) Gyr	
(6.9 – 11.1) Gyr	
(11.1– 13.2) Gyr	

Table 3. *Habitable zone in Mars*

Activity 4.4: Extremophiles

In the previous activities, life has been related to environments in which liquid water must exist on the surface of the planet or a rocky body, since when we talk about organisms or living beings we usually think of our pets, a whale, a ladybug or the plants in our house, but in reality this concept encompasses a much larger group. Among them are organisms called **extremophiles** and their main characteristic is that they live in environments that at first glance would seem tremendously hostile.

Some live in extreme temperatures both hot and cold, others are capable of living in places where not even a ray of sunlight reaches, where there is extreme radiation or where the acidity of the environment makes it an inhospitable place.

Figure 16: *Image of an Extremophile. (Credits: BBC)*

Try to find out which is the organism that appears in Figure 16, knowing that it is one of the most famous **extremophiles**, and choose what most catches your attention about it (you can choose several characteristics).

It is a Tardigrade. It has many interesting features such as:

- They survive in a vacuum.
- Withstand ionizing radiation
- They withstand very high pressures (almost 6000 atmospheres)
- They survive in a very wide range of temperatures, from -200 ºC to 150 ºC
- They can go up to 10 years without water.

It is recommended to carry out this educational activity for Extremophiles designed by ESA Education. Can you think of an Extremophile that could live on Mars?

Yes, especially microorganisms from the earth's subsoil. For example, chemolithotrophic microorganisms (bacteria and archaea), which are microorganisms that can create organic matter by obtaining energy from redox reactions of chemical compounds found in rocks or in solution in volcanic hydrothermal zones. For example, Extremophilic microorganisms from Río Tinto, a river in Huelva that is completely red due to having large amounts of dissolved iron in extremely acidic waters, could live in the subsoil of Mars, without problems. Moreover, the minerals of Río Tinto are also found on Mars (as iron sulfates of the jarosite family) also appear on Mars, and those minerals, which need these extreme conditions of acidity, iron and sulfates, at least in on Earth and in Rio Tinto, these conditions are produced by these microorganisms. They are conditions of biological origin on Earth.

Activity 5: What do you know about Mars?

In the next activity you are going to know everything you will need to know about Mars to design your challenge.

Check the next infographic (Figure 16) about Mars and fill in *Table 4*:

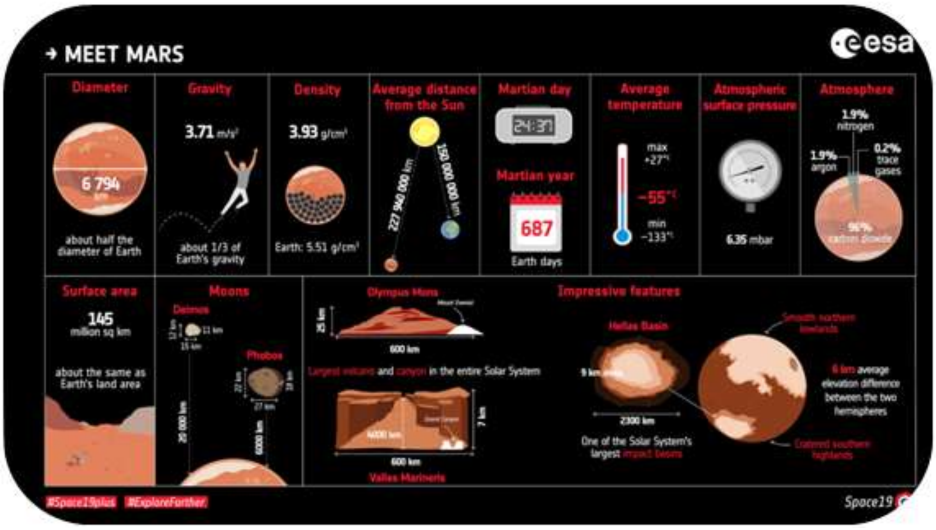


***Figure 17**: Important information about Mars in comparison with the Earth. (Credits: ESA)*

	Earth	Mars
Radius	6 371 km	3 389 km
Colour	Mainly blue	Reddish brown
Rotation axis inclination	23.26º	25.19º Very variable
Atmospheric pressure	1 013.25 mbar	6,35 mbar
Atmospheric Composition	78% N_2, 21% O_2, 0.93% Ar 0.04% traces of other gasses	96% CO2, 1.9% Ar, 0.2% traces of other gasses
Gravity	9.78 m/s^2	3.71 m/s2
Polar ice caps	Yes, at the north pole and the south pole	Yes, north (H2O ice) and south (H2O and CO2 ice)
Medium temperature	14.05ºC	-55ºC

***Table 4.** Comparison between the Earth and Mars*

For more information about Mars, read Mars CESAR booklet if necessary.

Activity 6: Scientific knowledge from Mars' surface

Activity 6.1: Geology of Mars

Hypothesis.

Would you think that Mars' geologic history is similar or different from Earth's one? Tell us your version of its history

The Mars' geologic history seems to be frozen in time. Younger deposits can be up to 3.0 Gy. We can find outcrops really old on Mars comparing to the ones we can find on Earth. This is giving us the possibility to study samples from nearly the beginning of the Solar System formation.

Note:

- Giga years = 10^9 years (Gyr) = Billion years in English = Thousand of millions years in Spanish
- Mega years = million years = 10^6 years (Myr) both in English and Spanish
- Trillion years in English = 10^{12} years = Billion years in Spanish

The geological history of Mars can be divided into the Noachian, Hesperian and Amazonian. These geological eras are distinguished by specific climate conditions, which leave their mark on the surface to the present day.

During the **Noachian,** which is the most ancient period of Mars from approximately 4.1 to 3.7 billion years ago, the planet was warmer and wetter than it is now. Vast amounts of liquid water ran across the surface, carving out huge channels, and there was a magnetic field that protected the surface from solar wind.

The **Hesperian** period, which ranged from roughly 3.7 to 3.0 billion years ago, was characterised by widespread volcanism and huge flooding. During this time, huge lava plains were deposited, and liquid water became less widespread and more acidic where it existed.

During the **Amazonian**, which spans from 3.0 billion years ago to today, the magnetic field disappeared. This allowed the solar wind to divide water in the atmosphere into its constituent molecules, hydrogen and oxygen. The Martian atmosphere could not retain the hydrogen and the hydrogen was dragged off by the solar wind into space. On the other hand, the oxygen oxidized (rusted) the planet: the reddish colour of Mars is due to the iron oxide that results from this.

Which period/s do you think had the highest probability of having life on Mars: the Noachian, Hesperian or Amazonian? Why?

Noachian (and maybe Hesperian). There was liquid water on the surface (which is important for life) and the planet was protected by a magnetic field, which protects from radiation, but also helped it to maintain an atmosphere.

Something curious is that when the best period for life on Mars is finished, the Noachian, it is the same period that first traces of life appear on Earth. Is it just a coincidence? Or the cause? Could life on Earth come from Mars at that time? Write your theory.

In the panspermia theory, life on Earth (endolitic extremophiles microorganism which live inside rocks) can survive to the meteorite entry through the atmosphere. The outside area of the meteorite melts, but inside part does not melt, keeping optimum temperatures for life to resist. This panspermia theory says martians exist and they are us. Life on Earth might come from Mars inside a meteorite.

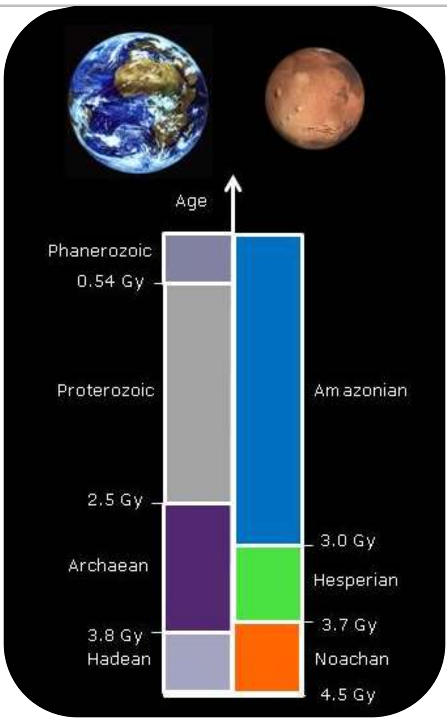


Figure 18a: Comparative of geological ages from Mars and Earth

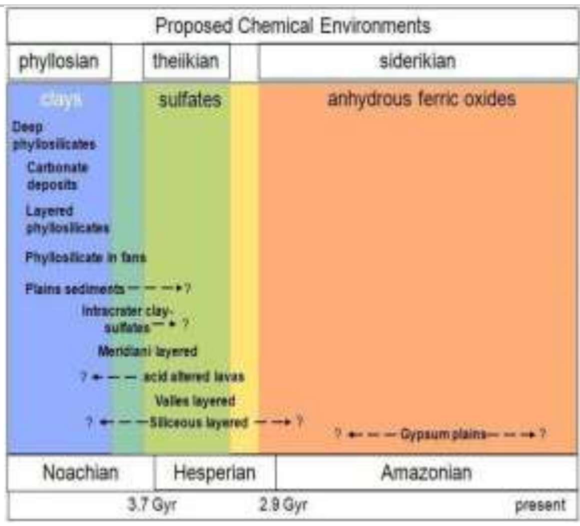


***Figure 18b**: Chart from Murchie et al., 2009, showing different chemical environments on Mars. That means global climatic changes produced different global mineralogy on the martian surface.*

Choose the best option for the Table 5 with the information given about different periods/ages of Mars. You can take a look into the text about geological periods of Mars (Noachian, Hesperian and Amazonian) and figures 18 a and b.

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

***Table 5**: Periods of Mars*

Geological ages are coincident when we compare crater counting ages (Noachan, Hesperian and Amazonian with geochemical environment ages (Phillosian, Theiikian, Siderikian)?

It can be seen in the figure 18b that Phyllosian, Theiikian and Siderikian ages coincide in a big part with the Noachian, Hesperian and Amazonian ages. But not in one hundred percent.

With the arrival of Mars Express ESA's mission and the OMEGA instrument (visible and infrared spectrometer that can be used to do mineralogical maps on Mars), we could see that in different Martian ages, there were different minerals (figure 18b)

What do you think that happened on Mars, such as global climate changes, to change martian mineralogy in that way? What event could cause the global acidification of a Theiikian age? and the global oxidation in the Siderikian age? These changes were not local, but global. They changed all the martian surface. Could it happen on Earth?

It seems that during the Theiikian age, big volcanoes (Olympus mons is the biggest of all the Solar System, for example), arised. This extreme volcanism seems to produce an important acid rain around all Mars, due to the liberation of a huge cuantity of SO_2 gas.

Afterwards, during the starting of the Siderikian age, it seems that the martian magnetic field that protects the martian atmosphere, disappeared. Then, the solar wind hit directly all the atmosphere and surface of Mars, producing the photolysis of water. The water vapor was disintegrated into oxygen and hydrogen. Then, the hydrogen le ave the planet with the solar wind (it is a very light molecule, and martian gravity is low enough to do not be able to keep hydrogen molecules on its atmosphere), and the oxygen,..., it rusted or oxidized completely a planet. Due to that, Mars is red nowadays.

Activity 6.2: Atmosphere of Mars

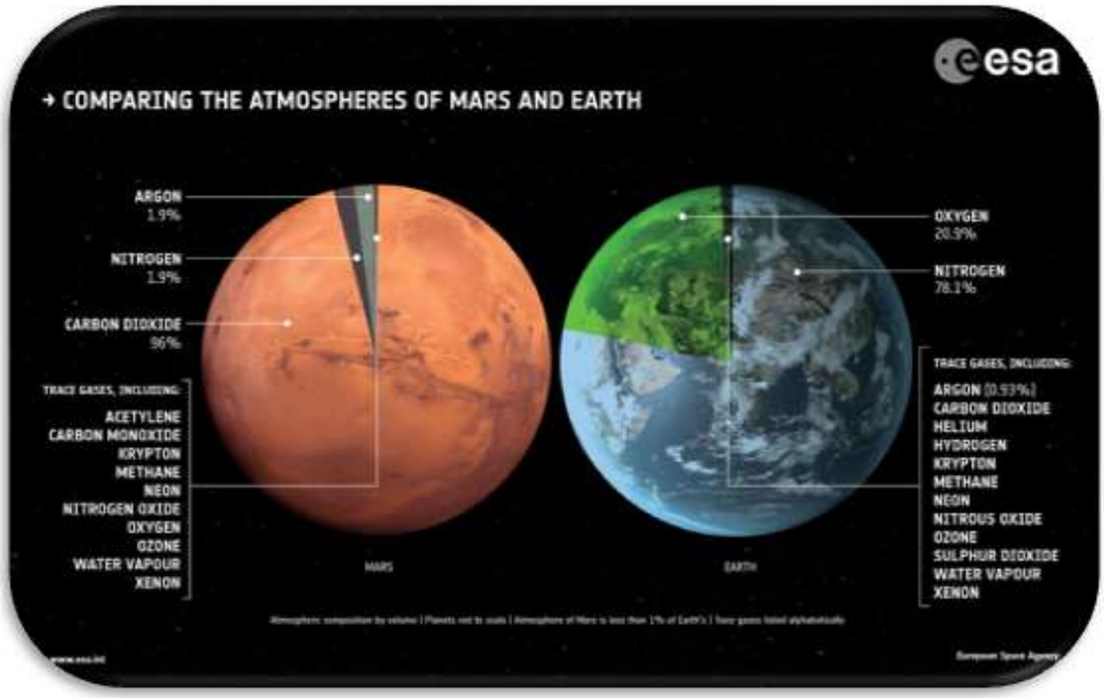


***Figure 19**: Comparison between Mars' and Earth´s atmosphere. (Credits: ESA)*

Martian atmosphere is quite thinner than Earth's one. Its surface pressure is 100 times lower than Earth's one. Moreover, Mars is losing more and more atmosphere due to it does not have a magnetic field protection at present, and solar wind is sweeping away the atmosphere into the space.

As we are seeing in the *Figure 19, martian atmosphere is composed mostly by* , carbon dioxide (CO_2) (96%), followed by nitrogen (N_2) and argon (Ar), (nearly 2% each). All the rest of its composition are trace gases, finding between them oxygen (O_2), water vapour or methane (CH_4).

The problem of Mars, is that together with its continuously atmosphere loss, volcanism seems to be extinguished for billions of years and if there was plate tectonics on Mars, is a fact with a very disagreement between the scientific community. Due to that, martian carbon dioxide is not renewed. Considering that the carbon oxyde is the main green house warming gas of Mars, it is a very important fact (careful!, even though carbon dioxide is the 96% of the martian atmosphere composition, martian atmosphere is very very thin comparing with Earth's one. Without its renewal, greenhouse on Mars is nearly nonexistent.

Write the chemical formulation of different molecules and atoms that you can find on Mars' atmosphere.

CO_2, N_2, Ar, O_2, CO, H_2O, N_2O, Ne, Kr, $H_2C{=}O$, Xe, O_3, H_2O_2, CH_4

Activity 7: Mars exploration by European Space Agency

Mars is the planet that more missions have been sent there, after planet Earth. Since the beginning of the space race and space exploration programs, in the 60's, around 40 planetary missions have been sent to Mars. And more than a half of them have partially or totally failed, as we can see in the *Figure 20*. Scientists used to say that there was a mystery force that sabotages missions sended to Mars, and it was called "the Mars devil". This mystery force seems to sabotage planetary missions to Mars, making them to get lost into space or crash them into the red planet.

The first successful mission arriving the red planet was Mariner 4 (NASA) in 1964. It took 22 pictures of Mars' surface, as it was planned. Mars 2 (Russia, 1971) was the first mission orbiting Mars and Mars 3 could land a landing module that was active for 20 seconds.

It was in the middle of 70's when the Viking mission (NASA) arrived to Mars, they took pictures from nearly all the planet and they were able to land, making first metabolic tests, to look for martian life. These tests were one negative and two of them positive, but the positive ones could be explained by abiotic processes. Joined to the fact they could not find organic matter on Mars (they would have had the same problem looking for life on Atacama desert, for example, and there is life there), the scientific conclusion was "we could not find a clear evidence of life on Mars". The press and political translation of that sentence was "there is not life on Mars", and due to that, planetary missions to Mars were cancelled for almost 15 years.

***Figure 20**: Missions to Mars. Credits: ESA.*

The European Space Agency has been involved in two big missions to Mars, Mars Express (*Figure 21*) and ExoMars. ExoMars was splitted up into ExoMars 2016 and Exomars 2022) (*Figure 23*).

Figure 21*: Mars Express orbiter on Mars. Credits: ESA*

Mars Express arrived on Mars in 2003 and it is still working nowadays. Its name is originally referred to the speed and efficiency with which the spacecraft was designed and built. Mars Express and Venus Express made use of a big part of the Rosetta mission's technology, but adapted to its planet conditions. This mission was composed by to modules, the Mars Express orbiter and the Beagle 2 lander. Beagle 2 wanted to make geochemical and exobiological experiments on the Mars surface. This landing failed but Mars Express orbiter is still working and could reach important milestones, as we can see in *Figure 22*.

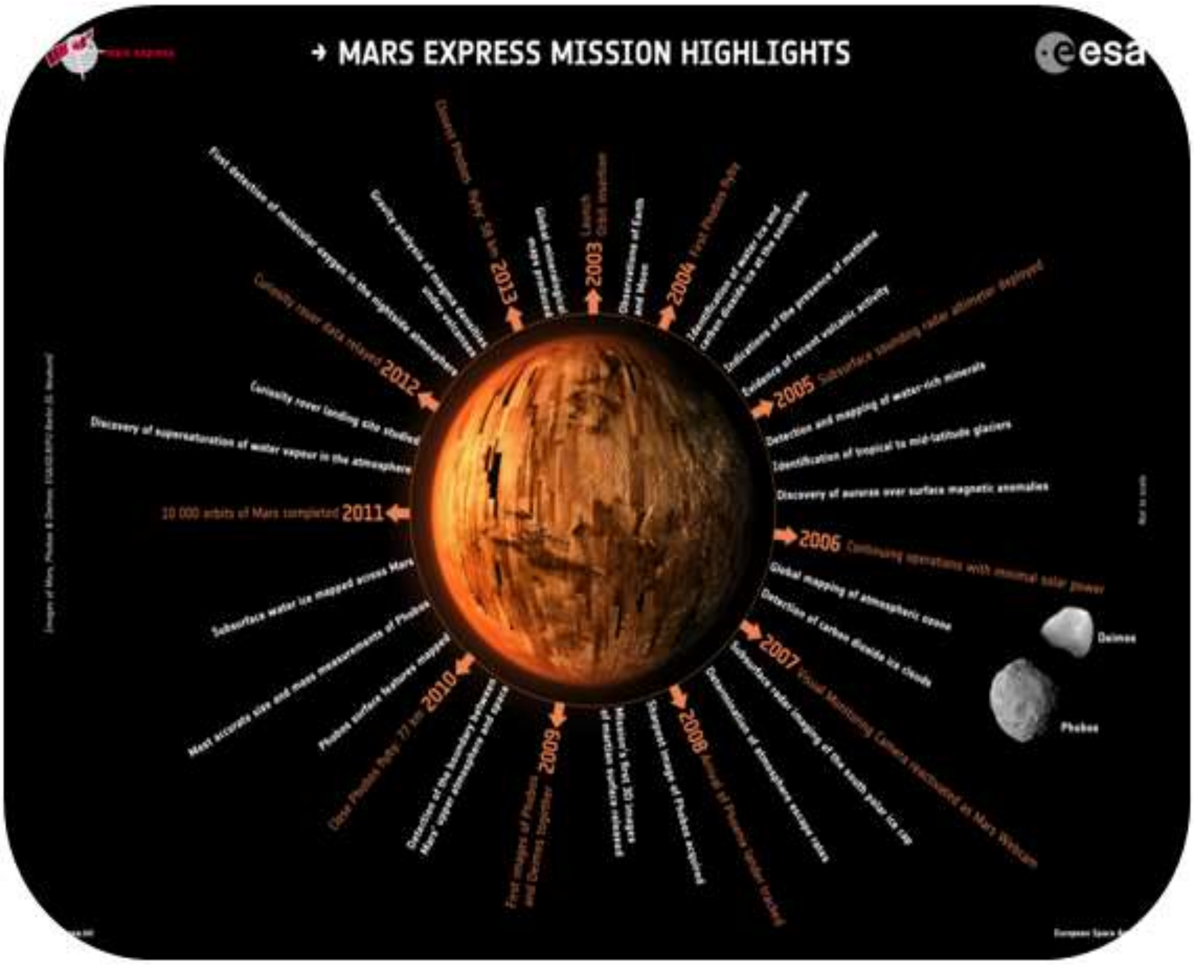


Figure 22: *Mars Express mission highlights. Credits: ESA*

Thanks to the Mars Express mission, it was possible mapping nearly all the martian surface, including its moons Fobos and Deimos. It was confirmed there were water and CO_2 ice on Mars, and there are extensive mineralogical maps of Mars surface. Thanks to this mission, the famous hydrated minerals were found, and they are telling us that Mars was quite hotter and wetter than now. Mars Express has even found a liquid water lake below the southern polar cup. This mission has analyzed in detail the martian atmosphere, detecting methane and other interesting gases.

ExoMars is the other big mission from the European Space Agency on Mars. It is in collaboration with Roscosmos, the Russian space agency. This mission is focussed in finding life on Mars, and it was splitted on 2 missions, ExoMars 2016 and ExoMars 2022. Its name comes from “Exobiology on Mars” and its main goal is to find traces of past or present life on Mars, joined to study the water and the atmosphere of Mars, and getting prepared for a possible new return sample mission from Mars back to Earth. .

***Figure 23**: Artistic representation of ExoMars mission. Credits: ESA*

ExoMars was splitted up in two missions to try to fight against this "martian devil" that provokes this "accidents" when we try to land on Mars safely. Landing safely is a pending question from both the European Space Agency and Roscosmos. This is one of the reasons of the first mission of ExoMars 2016, where a landing module called Schiaparelli EMD (*Entry, Descent and Landing Demonstrator Module)*. It seems that the "Mars Devil" make its effect with Schiaparelli EMD, but we can learn from our mistakes. Anyway Exomars TGO (*Trace Gas Orbiter*) is making a really good job, giving us high value scientific data to get ready for ExoMars 2020 and next mission such as "Mars Sample Return mission" (mission to go to Mars, taking samples, and bringing them back to Earth)

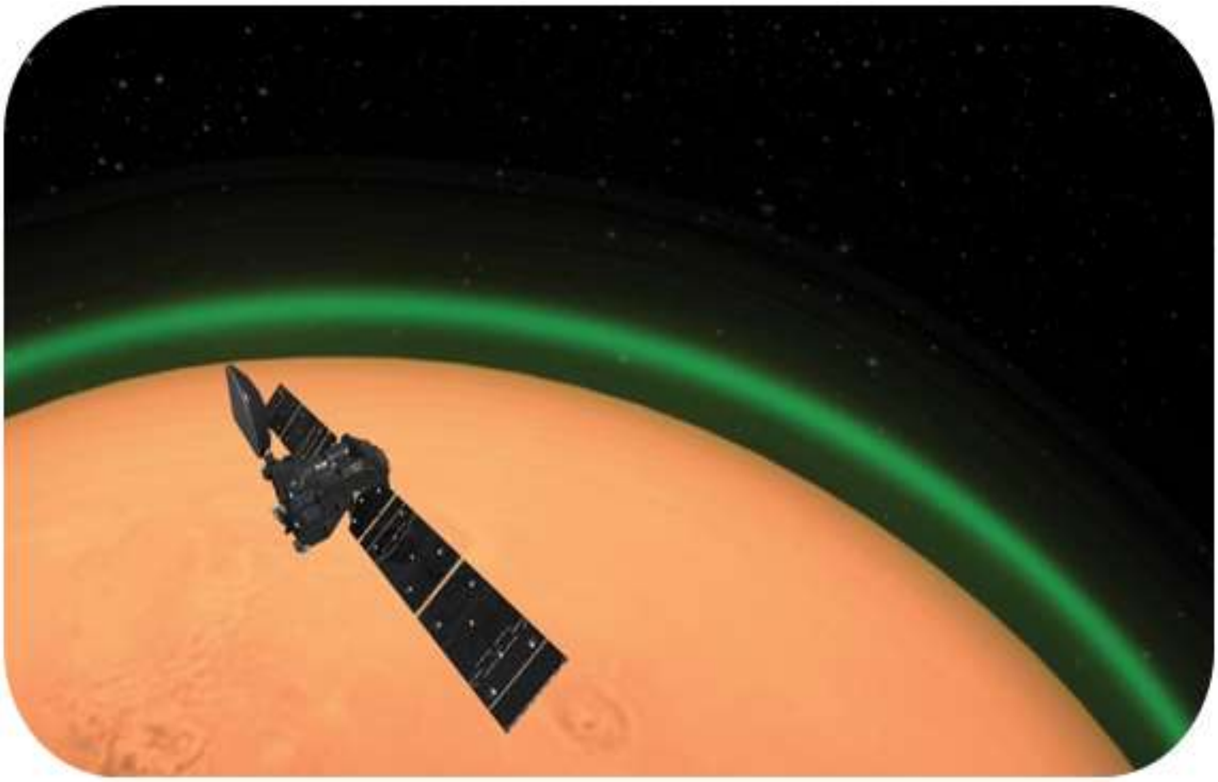


***Figure 24**: TGO Looking for the "green oxygen" in the martian atmosphere. Credits: ESA*

For more information, you can take a look to these links:

WEB:

- Missions to Mars
- Mars Express Mission Highlights

VIDEOS:

- Mars Express
- ExoMars
- Mars missions 2020-2030

3D MODELS:

- ESA's Science Satellite Fleet
- Mars
- ExoMars

Read carefully these two important researches coming from Mars exploration. They will help you to optimize your challenge: Find traces of Life on Mars.

Water detection on Mars

First discoveries:

One of the first things we try to find on Mars was water. We consider this molecule, so far, primordial to find Life outside Earth planet. Mars has two polar caps, northern and southern, which are easily observed from Earth.

These two polar caps were presumably composed of water ice, but we need to demonstrate it.

In 2004 it was demonstrated thanks to **Mars Express** and its **OMEGA** (Visible and Infrared Mineralogical Mapping Spectrometer) instrument, which analyzed the southern polar cap, where temperatures can reach up to -120ºC, and there is an equilibrium with water and carbon dioxide ices.

One of the major milestones of Mars Express is to be able to find water, both ice and liquid form. Detection of molecules and biomarkers, that on Earth usually are related to microbial activity, are keys to find traces of past and present life on the red planet.

Figure 25: *Joke about if there is (Water on Mars. Credits: [reddit]*

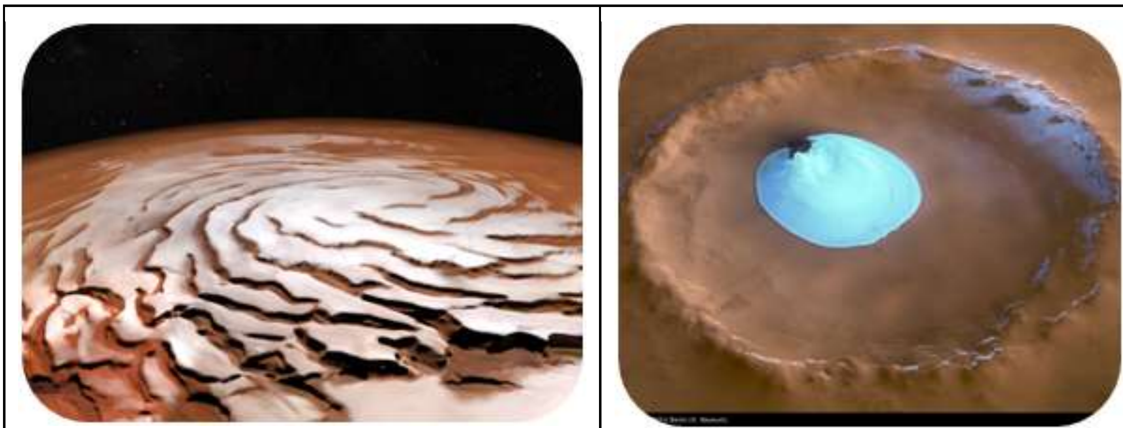


Figure 26: *Water ice on the northern polar cap (left) and inside craters (right). Credits: ESA.*

Subsequent discoveries:

The big avance in this field arrives during the summer of 2018, when the **MARSIS** (Sub-surface Sounding Radar Altimeter) from Mars Express detected what it seems a salty liquid water lake beneath the southern polar cap (*Figure 27*).

This lake is around 20 km wide and has of at least 1 m deep.

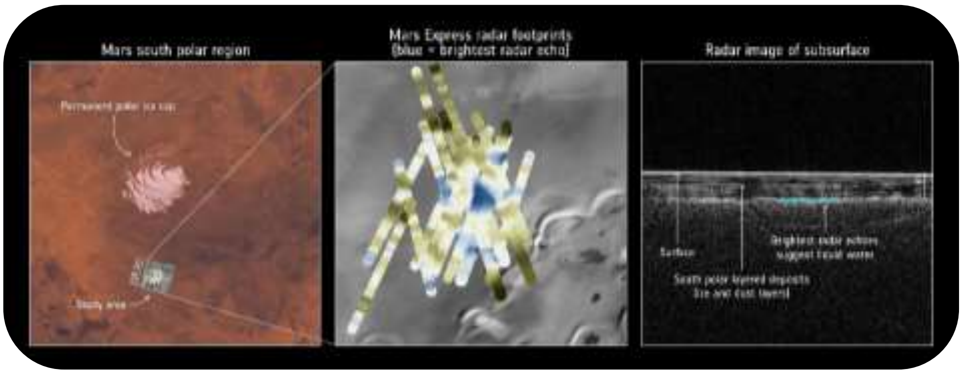


Figure 27*:subglacial lake beneath the southern polar cap. Credits: ESA.*

This shiny layer that was found analyzing radar images at the southern polar cap of Mars is in an area of 200 km^2 and with 1,5 km deep below ice layers and martian red dust. This shiny radar layer is extremely flat, without imperfections. It can be explained only with a 20 km wide ice layer without any crack or imperfection (something quite improbable) or with a liquid water lake, extremely salty to be allowed to be liquid at -70 ºC.

Methane detection on Mars:

Another key point to find traces of Life on Mars is the big mystery of methane emissions.

Methane on Earth is mainly a subproduct associated to Life, very common in subsoil microorganisms. Lately it is in a focus both ESA and worldwide scientists, for the importance of methane as a greenhouse gas on Earth. But in astrobiology, it is a very interesting gas, because it records a really potent chemistry fingerprint associated to Life. When there is microbial metabolism producing methane, the isotope fractionation C^{13}/C^{14} changes drastically, making methane a powerful indicator to microbial life in our Solar System.

But **methane is not stable under the atmospheric conditions on Mars surface**, making it very difficult to study. Moreover, when a scientific instrument detects methane on Mars, other instrument, few days or hours later are not able to detect any of it. This happened, for example, when Curiosity rover from NASA detected a methane peak during the nighttime of June 21st 2019, in crater Gale. 5 hours later, ExoMars TGO (Trace Gas Orbiter) was unable to detect any trace of methane in the same area.

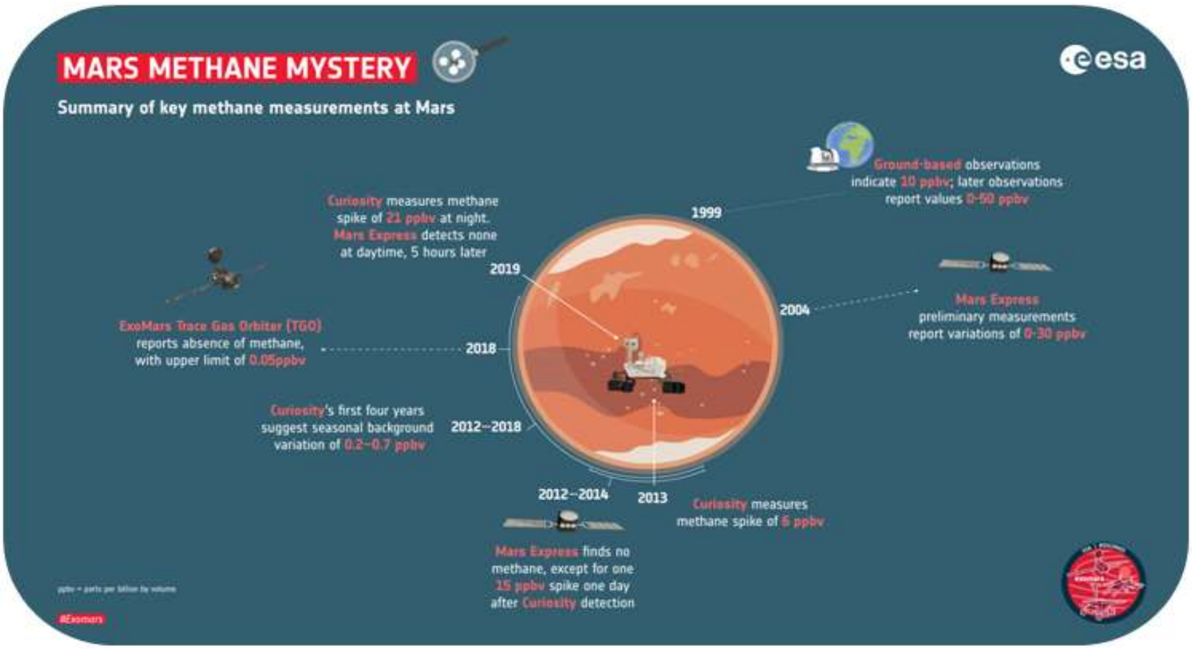


Figure 28: *Mars methane mystery. Credits: ESA.*

Activity 8: Check what you have learnt so far

Check what you have learnt so far with this [questionnaire]

Phase 2

How to proceed in this Phase depends on the results obtained in the latest Activity of Phase 1 (questionnaire)

- **Case 1:** Your students replied quite well to the questionnaire
  ➔ **Go to PHASE 3**

- **Case 2:** Your students did not reply very well to questionnaire or they have many questions related to the topic of the Scientific Challenge
  ➔ **Review PHASE 1** (see below) with this complementary material:

http://cesar.esa.int/index.php?Section=Scientific_Cases&Id=24&ChangeLang=en	
• Expert talks given at CESAR Teacher workshops (pdf and/or videos) • ESA dedicated videos • CESAR Monographics (booklets) • Simulators/websites	

➔ **Go to PHASE 3**

- **Case 3:** You can not make it alone and you need interaction with the CESAR Team – Ask for a 30 min video call with your class in Phase 2

Activity 9: Ask for a videocall with the CESAR Team if needed

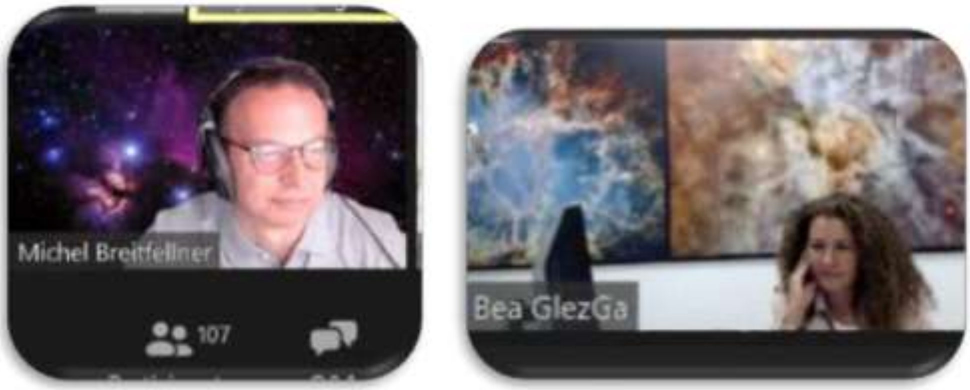


Figure 22: *Image of the CESAR Team making a video call (Credits: ESA)*

Note: Per scientific challenge you could request

- A 30 minute call with your class (in Phase 2) to clarify concepts
- A 30 minutes video call, just with the teacher (in Phase 3) to review issues with the software/results

Phase 3

Activity 10: Prepare the Mars landing

The mission begins! We need expert teams in: (each team chooses only one mission)

Team	Mission	Activity
Team 1	Expert team in the flight of the ship.	From the ship's point of view, in what position (latitude, longitude, altitude) would you land? Why? Take into account the area in which the planet rotates the fastest and where the satellite would cross the most atmosphere (for this you will use Google Mars). Explain your answer. Carry out Activity 10.2
Team 2	Martian Rover/ Car efficiency/ Safety expert team	From the point of view of the explorer robot (rover) or the Martian car (crewed), on what terrain would you land? Why? Taking into account the orography and the type of terrain of Mars (for this use Google Mars) identify the type of place with the range of coordinates (latitude, longitude and altitude) where you would land. Explain your answer. Carry out Activity 10.3
Team 3	Mars Science Data Expert Team	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 has existed, and therefore could contain life as we know it on Earth. Carry out Activity 10.4
Team 4	Expert team in requirements of 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 ... Carry out Activity 10.5
Team 5	Expert team on 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? Carry out Activity 10.6

***Table 6**: Specialized team*

Activity 10.1: Get used to Google Mars.

This is an activity that all research teams must do.

Preparation material:

- Computer or device with touch screen
- ***Google Earth Pro*** software installed

Let's get acquainted with the use of Google Earth software, particularly on Mars.

Process:

1. Open the Google Earth Pro program. *Figure 29* will appear on your monitor.

Figure 29*: Image from Google Earth Pro Software (Credits: Google Earth)*

2. In the upper menu, click on the symbol of a planet with a ring. In the drop-down select Mars and *Figure 30* will appear.

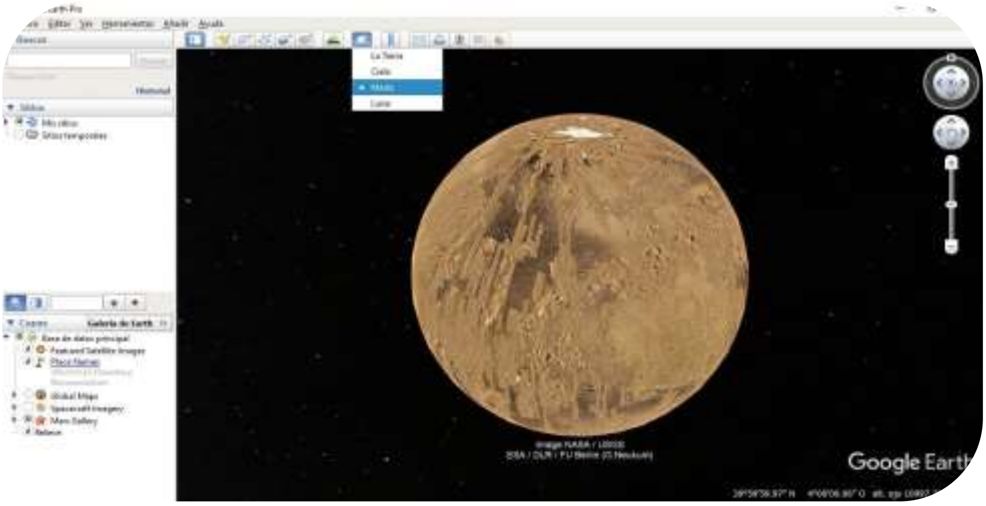


Figure 30*: Image from Google Earth Pro Software (Credits: Google Earth)*

3. The cursor appears as a hand with which you can move around the planet.
4. Follow the sequence below in the drop-down on the bottom left to get to *Figure 31*

Layers → Main Database → Global Maps → Colorized Terrain.

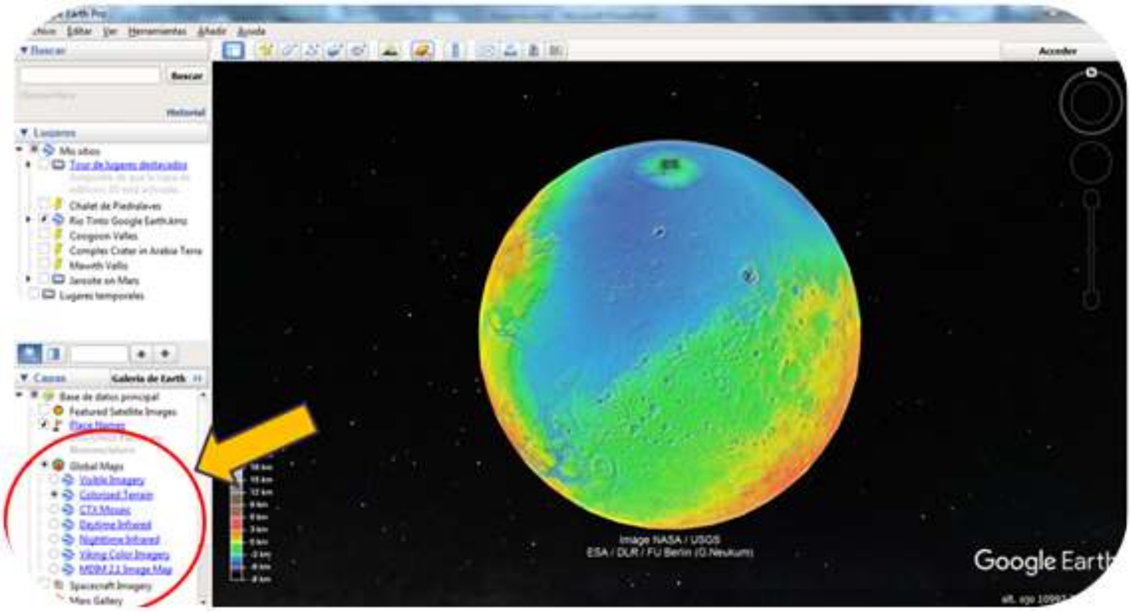


***Figure 31**: Image from Google Earth Pro Software (Credits: Google Earth)*

5. On the top right you can see the compass in which the north (N) is marked, a hand to move and a zoom (*Figure 32*).

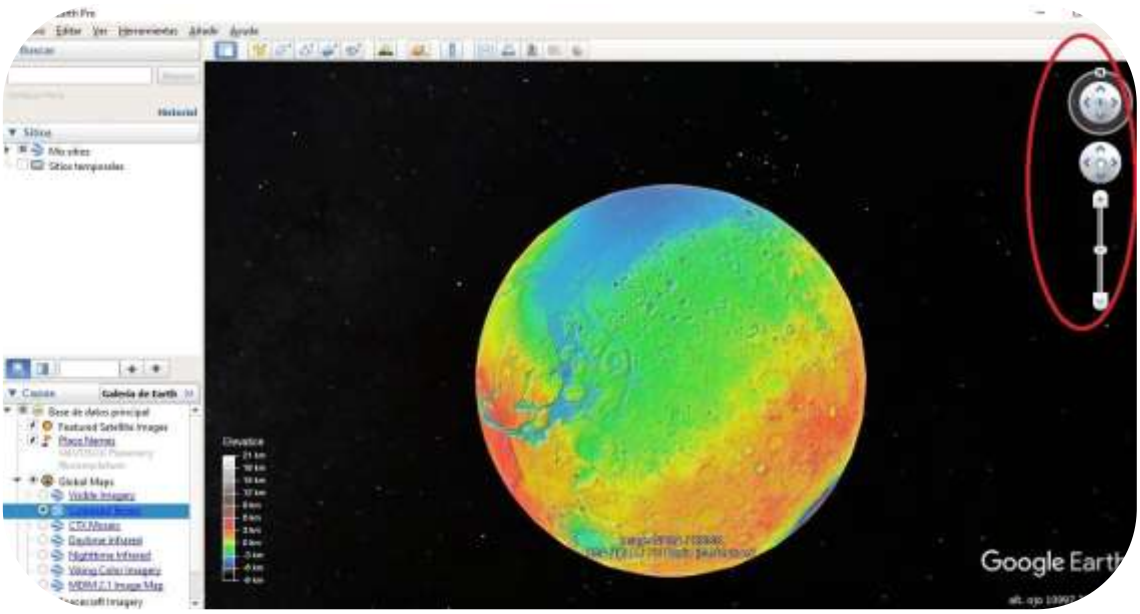


***Figure 32**: Image from Google Earth Pro Software (Credits: Google Earth)*

6. Experiment a few minutes with the program to gain fluency.

What do the different colors on the map mean?

The different heights. The deepest areas being black and bluish, the middle areas, yellow, green and orange, and the highest areas reddish and white. The color scale and the different heights can be seen at the bottom left.

What difference do you see between different areas of the Martian globe? Is there a clear difference between the northern and southern hemispheres of Mars?

Yes, there are differences to the naked eye. The northern hemisphere appears to have a smoother orography than the southern hemisphere. The northern hemisphere appears much flatter and there does not seem to have been much volcanic activity in it, while in the southern hemisphere there are many highlands with a large number of volcanoes.

In order to identify the coordinates of the following regions in Google Mars we will follow the following steps:

1. We will put the meridians and parallels*: top menu → View → Grid* (*Figure 33*).

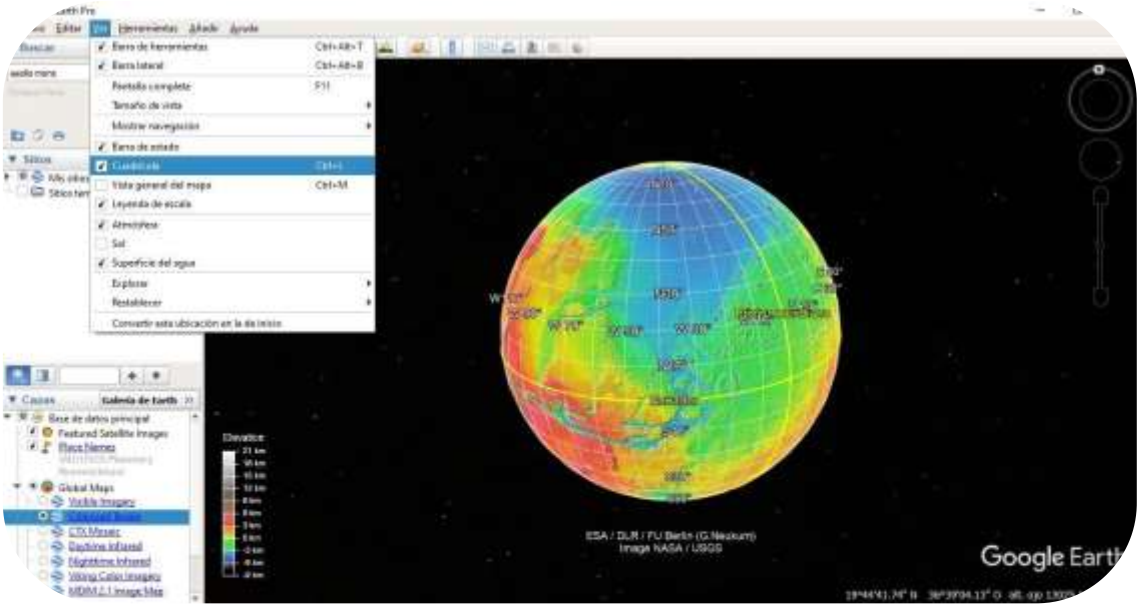


***Figure 33**: Image from Google Earth Pro Software (Credits: Google Earth)*

2. The coordinates are indicated at the bottom right (*Figure 34*).

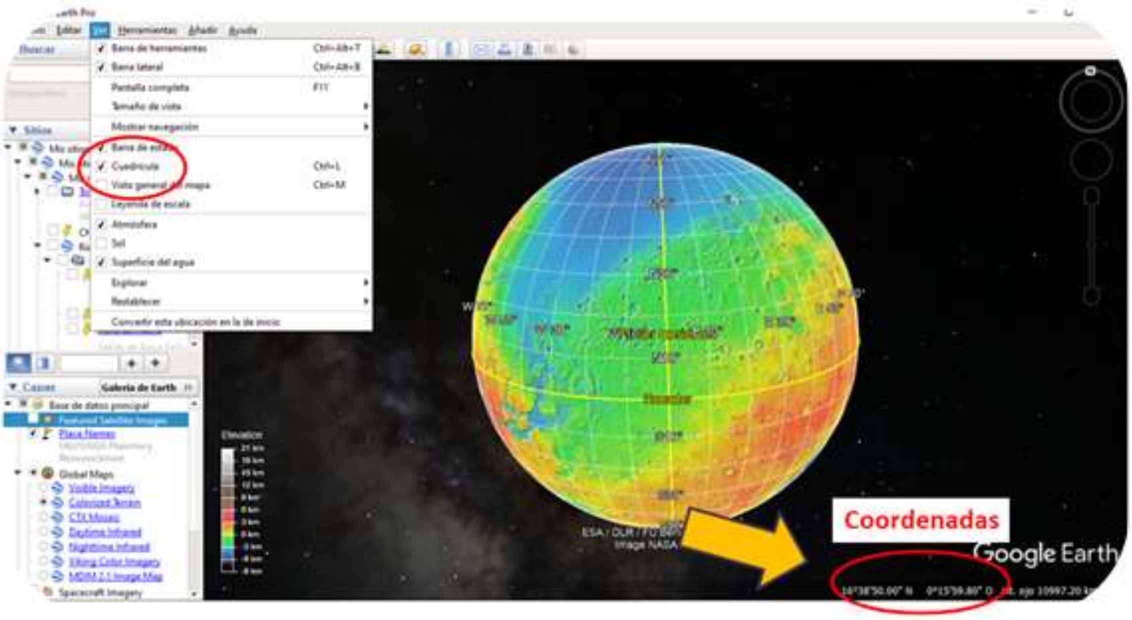


Figure 34*: Image from Google Earth Pro Software (Credits: Google Earth)*

3. You can search for different places by entering their name at the top left (*Figure 35*).

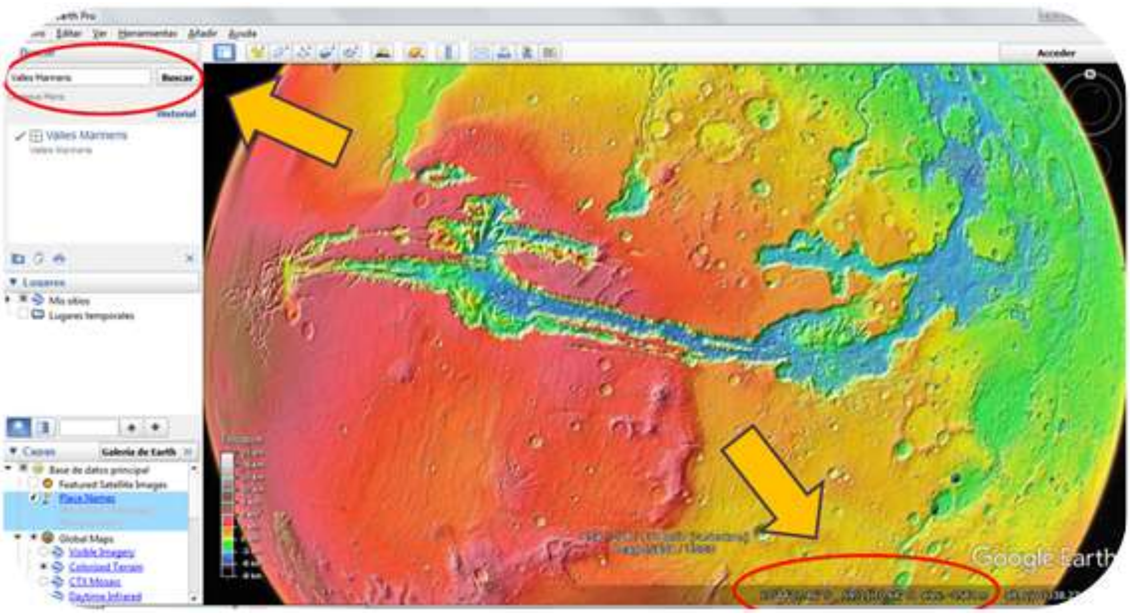


Figure 35*: Image from Google Earth Pro Software (Credits: Google Earth)*

Write down the coordinates of the different places on *Table 7*.

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

***Table 7**: Specialized teams*

Activity 10.2: Flight engineer's team (Team 1)

Launching

Activity 10.2.1: Orbit design

As you see in *Activity 4* the Martian year lasts about two Earth years, that is, it takes Mars about twice as long to go one revolution around the Sun than Earth. This leads us to the fact that the distance between Earth and Mars varies periodically, with the shortest distance being approximately every two years.

Taking into account that the probe we send to Mars is going to be subjected to the gravitational force generated by the Sun, its trajectory is going to curve, approaching an ellipse (*Figure 36*). Therefore, although at first glance it seems to us that what implies less fuel consumption is a straighter launch, in reality the orbits chosen for minimum fuel consumption are elliptical.

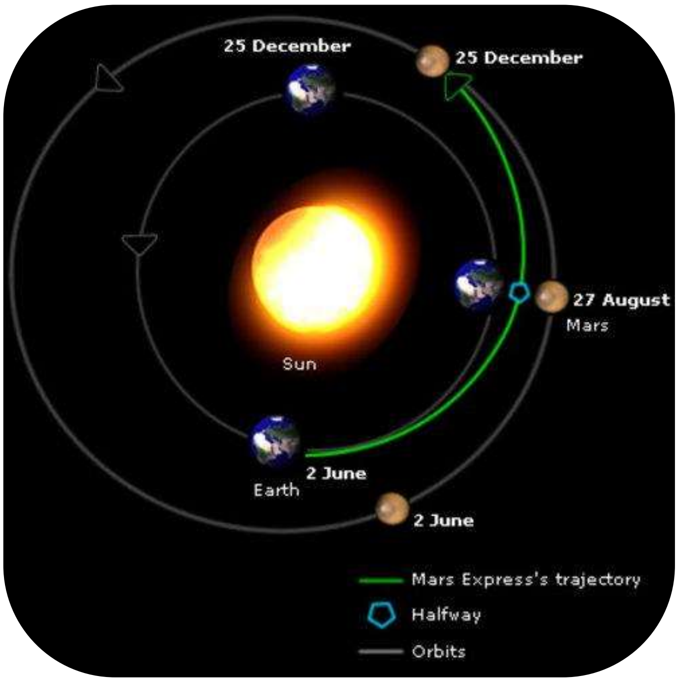


***Figure 36**: Mars Express trajectory. (Credits: ESA)*

In the following link you could use a simulator to launch your own rocket and try to reach Mars. To do this you will have to look on the page for the graphic that appears in the *Figure 37*, press "new", then the symbol "➢" and launch, with the Launch button when you consider appropriate. Good luck with your trip!

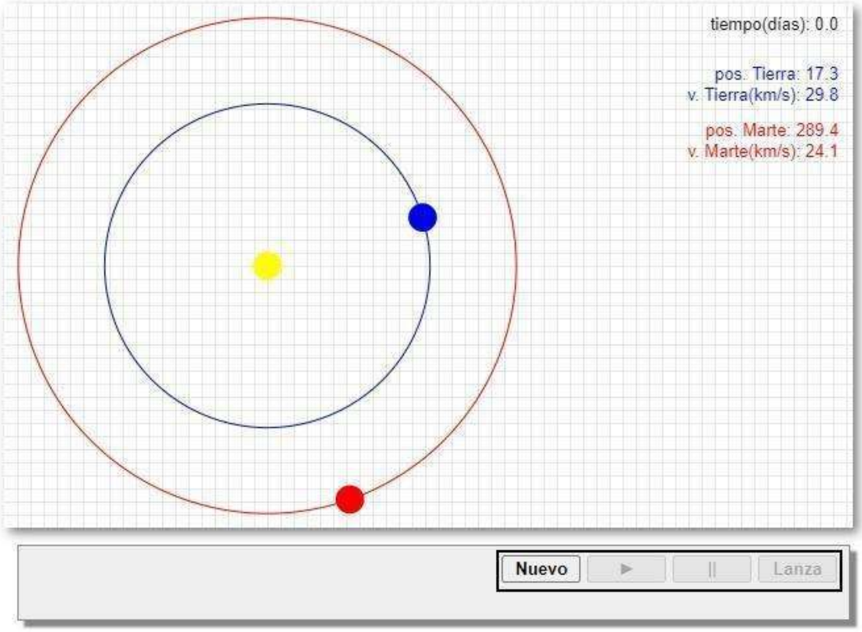


***Figure 37**: Interplanetary travel simulator. (Credits: Universidad del país Vasco)*

Mars landing

Activity 10.2.2: Select the coordinates (latitude, longitude) and altitude.

Latitude and longitude:

It can be useful to have a globe to better visualize the speed at which a person is moving on the surface of the Earth depending on the latitude at which they are.

Think of a point on the surface of a planet. As the planet rotates, this point traces a circumference. This point describes the great circle at the equator, a smaller and smaller circle as we get closer to the poles and a fixed point is observed if we are exactly at the poles.

Knowing that. Where do you think an object moves faster, at the equator or at the poles?

If we are talking about a solid object such as our Earth, it will have to rotate faster at the equator than at the poles, since these points are further away from the axis of rotation.

On Earth, the rockets are launched from areas closest to the equator, since in this way they manage to gain an extra speed due to the rotation of the planet itself and thus save fuel.

Below, there is an image (*Figure 38*) in which the concept explained above is illustrated.

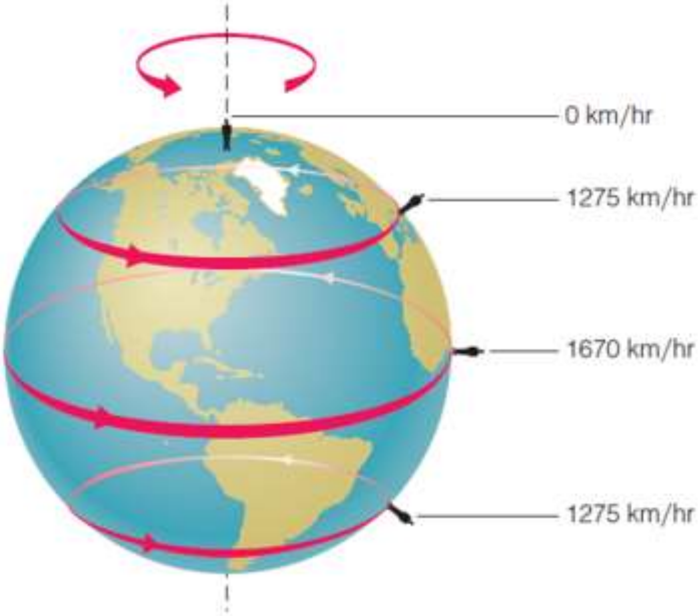


***Figure 38**. Speed of the Earth's surface depending on latitude (linear velocity). (Credits: Planetario de Madrid)*

Since we usually work together with different teams of researchers of different nationalities, it is important to work with the International System of Units (SI), since if this were not the case it could lead to an error as serious as our mission crashing or to get lost in the vastness of space.

In the Google Earth app, change again the chosen planet to Mars. From now on we will refer to this option as Google Mars.

Think of a satellite traveling from Earth to Mars at high speed. In what part of the planet do you think the spacecraft has to slow the least to reach the speed of the rotating planet, near the equator or the poles? Explain your answer.

At the equator because that way it has to brake less. This occurs because the equator rotates much faster than the poles

After this you already know the latitude at which it is easier to land on Mars, but you have to take into account other factors such as the altitude of the terrain, the landing systems that our probe carries and the date chosen for the landing.

Altitude and landing systems:

Choose on Google Mars the option *"Colorized Terrain"* inside the section "Global Maps" and you will see a colored image of Mars as shown in *Figure 39*. If you doubt how to reach this image, go back to Activity 10.1.

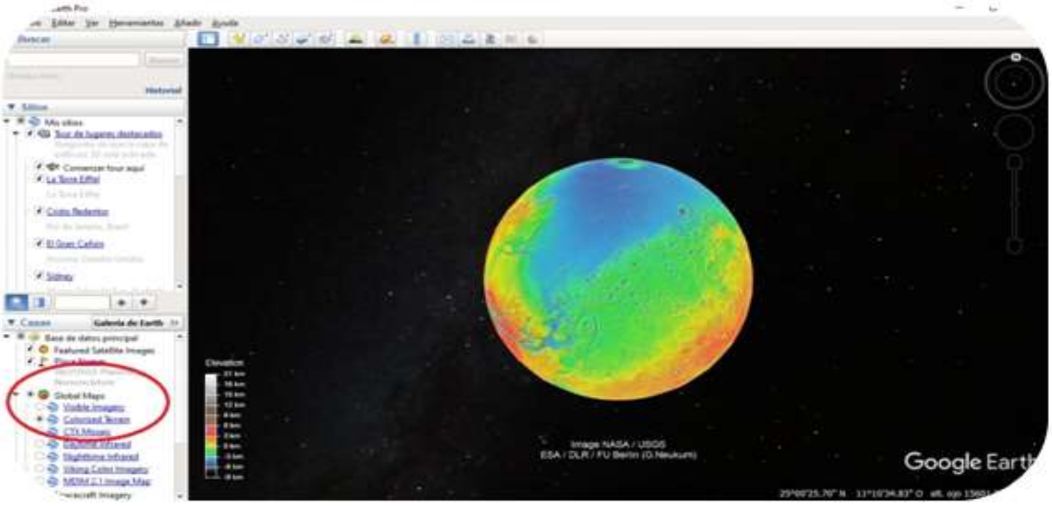


***Figure 39**: Image from Google Earth Pro Software (Credits: Google Earth*

In these images, the highest areas are colored white, the middle areas are orange / brown, and the lowest areas are bluish. This type of images will allow you to better see the orography (relief) of the Martian terrain. Below left you can see the color scale as shown below (*Figure 40*):

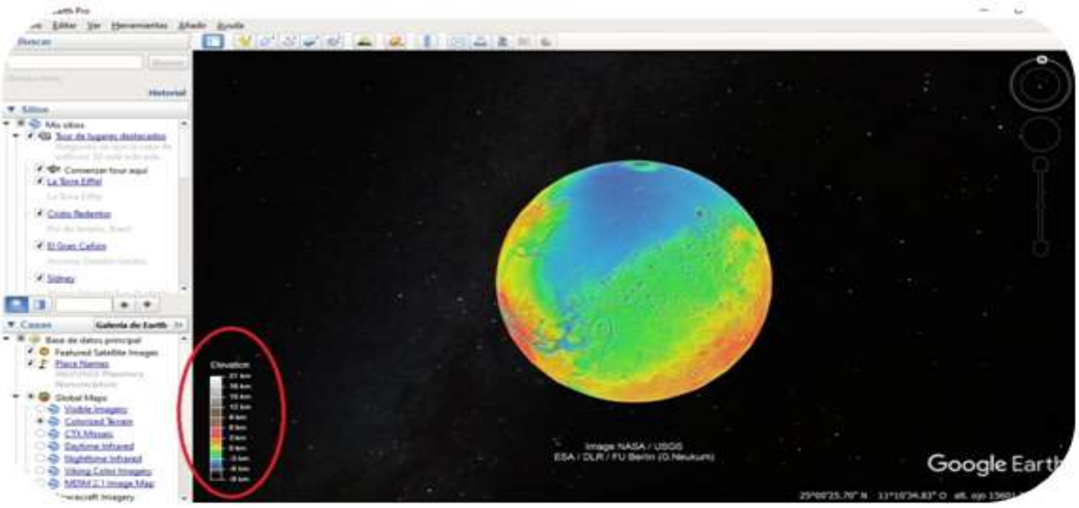


***Figure 40**: Image from Google Earth Pro Software (Credits: Google Earth)*

Observe the planet from the distance and then zoom in little by little to see the topography of Mars.

Do you see any difference between the two hemispheres of Mars? If so, which one (s)?

Yes, there are differences to the naked eye.

The northern hemisphere appears to have a smoother orography than the southern hemisphere. They are called the southern highlands on Mars. The northern hemisphere appears to be much flatter and there does not seem to have been much volcanic activity in it, and they are called the northern lowlands, while in the southern hemisphere there are many highlands with a large number of volcanoes.

In general, where are the highest areas? And the less elevated areas?

The highest areas are in the southern hemisphere (highlands) and the lowest in the north (lowlands). A large bluish area (color that indicates low height) is quickly appreciated that occupies a large part of the northern hemisphere.

The difference that you see between the two hemispheres is called the "**global dichotomy" of Mars**.

Using Google Mars as explained above, identify:

- The coordinates of the highest areas of Mars (*Table 8*).

Name	Altitude	Coordinates
Olympus Mons	20 270 m	18º 24' 00.09" N 134º 00' 00.03" O
Ascraesus Mons	17 364 m	11º 46' 12.03" N 104º 30' 00.10" O
Elysium Mons	13 213 m	24º 53' 00.03" N 146º 53' 59.97" N

Table 8: *Coordinates of the highest areas of Mars.*

- The coordinates of the most depressed (least elevated) areas of Mars (*Table 9*).

Name	Altitude	Coordinates
Badwater (Peneus Palus, Hellas Planitia)	-8 413m	32º 46' 17,96'' S 62º 08' 04,12'' E
Hellas Planitia	- 6 674 m	42º 40' 47,97'' S 69º 59' 59,96'' E
Lomonsov (Acidalia Planitia)	- 6 506 m	65º 27' 42,16'' N 10º 10' 34,84'' O

Table 9: *: Coordinates of the lowest areas of Mars.*

As we already saw in previous activities, Mars is about half the size of Earth in diameter and has a much thinner atmosphere, about 100 times less dense than on our planet. For this reason, most landing teams usually implement some type of parachute to help slow the fall of the satellite.

Where do you think the parachute can be more effective, in the highest or lowest areas of Mars? Why?

In the lower areas to have a greater distance to brake from the entrance of the probe into the atmosphere. This is all the more important because the atmosphere of Mars is very thin.

Although the atmosphere of Mars is thinner than ours, it does, and that means that we also have to carry a heat shield in our ship if we do not want it to burn when entering the red planet.

All this and the own size of the probe make our mission very heavy. Using just a parachute would lead us to land on the Martian surface at about twice the speed of sound, which would imply a failed mission by crashing so violently to the ground. To prevent this to happen, more and more original systems are being devised to implement in the probes and that have the softest possible landing.

Let your imagination fly and propose different systems that can be implemented in the probes for a good landing:

Retropropellers, airbags, parachutes ...

Extra activity: Do we learn from mistakes? Schiaparelli

As you may have already observed after what you have thought and calculated, making an interplanetary journey has many difficulties. That is why on some occasions, despite having very large investigation teams, fatal errors occur that lead to the completion of a mission earlier than expected. This is the case, for example, of the Schiaparelli mission, which crashed onto the surface of Mars due to a small failure of the on-board computer, which caused the descent sequence to end prematurely.

Below is an excerpt from the press release that ESA offered after the accident.

“An independent external investigation, led by ESA's Inspector General, has now just concluded.

It identifies the circumstances and causes of the hard landing, and provides general recommendations to avoid such defects and weaknesses in the future.

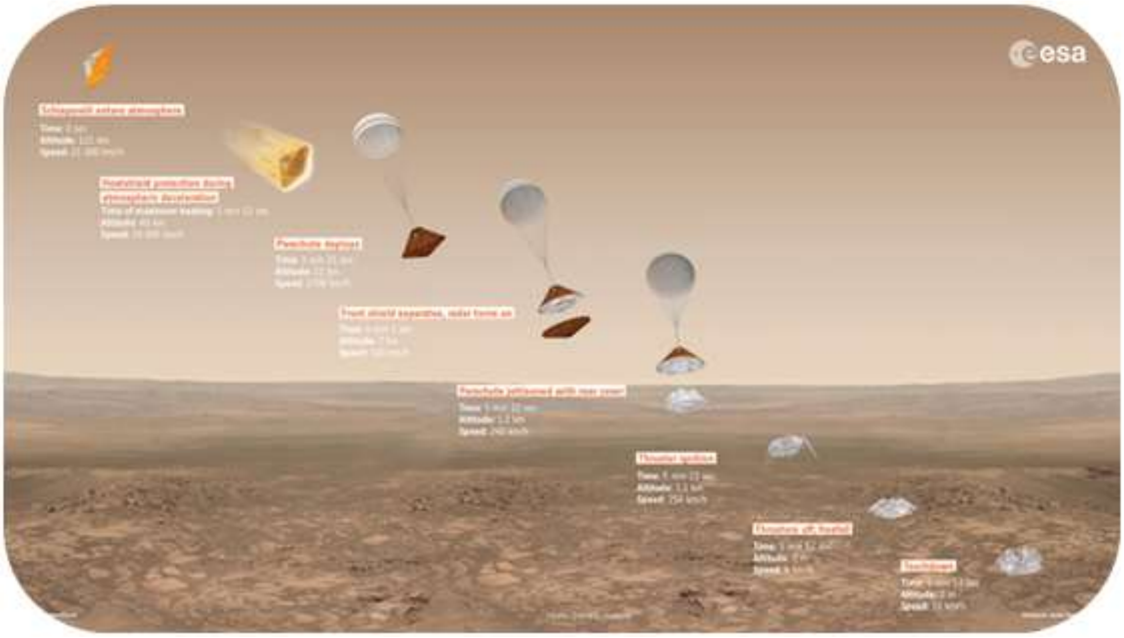
About three minutes after entering the atmosphere, the parachute deployed, but the module experienced unexpectedly high rotational speeds. This caused a brief 'saturation' - that is, the expected measurement range was exceeded - in the Inertial Measurement Unit, which measured the rotational speed of the module.

This saturation caused a serious error in the orientation calculation by the software of the guidance, navigation and control system. The combination of this incorrect orientation calculation with subsequent radar measurements caused the computer to estimate that the module was below ground level.

This triggered the premature deployment of the parachute and rear shield, firing of the thrusters for just 3 seconds instead of 30, and the activation of the system on the ground, as if Schiaparelli had already landed. The surface science packet sent a maintenance data packet before the signal was lost.

In reality, the module remained in free fall from an altitude of about 3.7 km, resulting in an impact speed of about 540 km / h.

The report of the Schiaparelli Commission of Inquiry indicates that the module was close to landing successfully at the planned location and that a very important part of the *demonstration objectives was achieved. "*

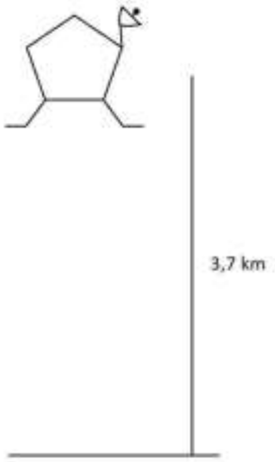


Despite the fact that the mission ended abruptly, it was possible to collect data from both those that were sought in the mission and those that caused the accident, thus being able to improve the following launches so that these errors are not repeated.

Considering what happened to Schiaparelli, what would you change for future missions?

Improve software, improve gyroscopes. Modify the propellants so that instead of turning them off using software, they stop working when they use a certain amount of fuel. Install airbags on the outside of the probe obtaining additional and mechanical protection that does not depend on the proper functioning of a computer.

We can try to calculate how fast Schiaparelli fell against the Martian soil if we know that he was 3.7 km high when he began to fall in free fall (in reality he did not start from an initial velocity equal to zero).



Gravity on Mars is about a third of that on Earth:

$g_M = 3{,}7\ m/s^2$

We will take its initial speed as zero:

$v_0 = 0\ m/s$

We know that the final velocity is given by:

$v_f = v_0 + g_M t$

So we only have to know how long it took to fall. Since we know that the height is:

$h = v_0 t + (g_M t^2)/2$ and that the initial speed was $v_0 = 0\ m/s \rightarrow h = (g_M t^2)/2$

We are left that the time it took for the probe to fall was:

$$t = \sqrt{\frac{2h}{g}}$$

Substituting $h = 3{,}7\ km = 3\ 700\ m$ y $g_M = 3{,}7\ m/s^2 \rightarrow t = 44{,}72\ s$

Plugging this time into our equation for velocity:

$v_f = v_0 + g_M t \rightarrow v_f = g_M t \rightarrow v_f = g_M t \rightarrow v_f = 165\ m/s$

As we can see, the speed with which an object hits the ground varies a lot, whether it starts from a zero initial speed or not.

Activity 10.2.4: Team 1 conclusions.

Taking into account all the findings made in the sections of Activity 10.2, draw your conclusions and finally decide the best landing areas.

What do you think is safer, to land in the northern or southern hemisphere of Mars? Why?

It will be safer to land in the Northern Hemisphere because it is a lower area and there are hardly any geographical features. In addition, there is a sea that covers a large part of the hemisphere. It is a much safer and more comfortable area to land.

Finally, draw the landing region or regions using Google Mars. For this you will have to do the following:

1. Go to the option 'adding a route' found in the upper menu the fourth icon (*Fig41*).

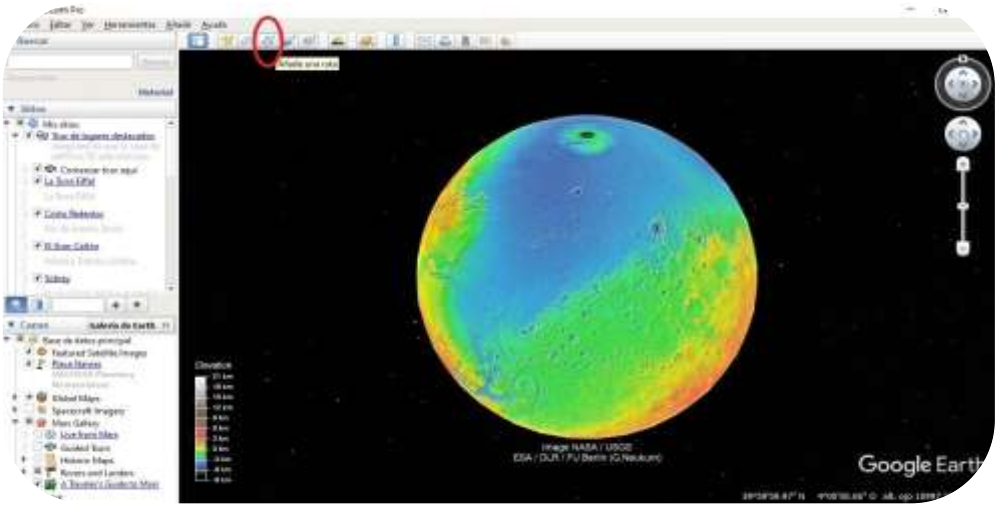


Figure 41: *Image from Google Earth Pro Software (Credits: Google Earth))*

2. Once you have clicked on the icon, the following box will appear where in the Style tab, you can choose the color with which you want to mark your regions as well as the thickness of the line (*Figure 42*).

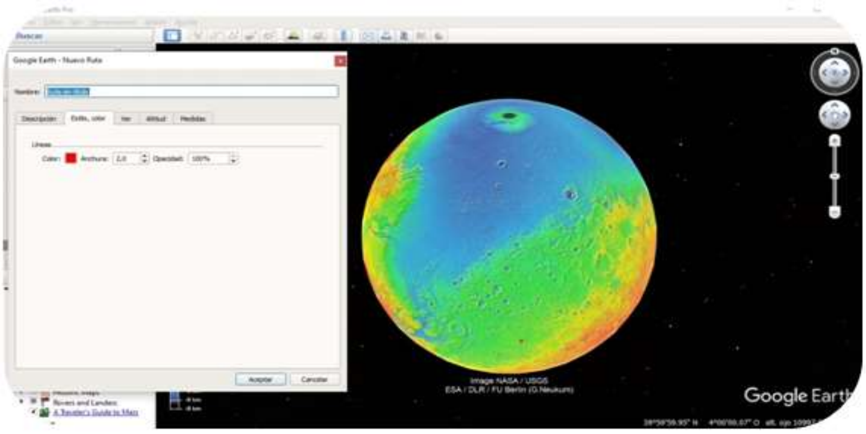


Figure 42 *Image from Google Earth Pro Software (Credits: Google Earth)*

3. Finally, by clicking on Mars and dragging the mouse you can mark the area that you like for your mission to land (*Figure 43*). When you are making the mark instead of appearing a line, dots will appear, but at the end if you click on *OK* it will remain as a line.

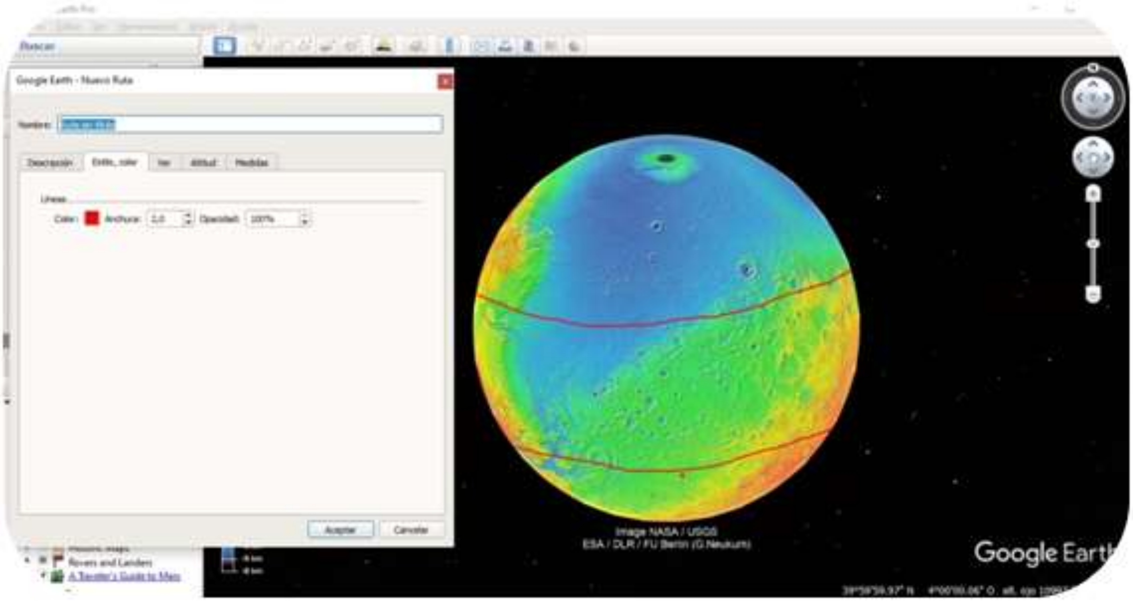


***Figure 43**: Image from Google Earth Pro Software (Credits: Google Earth)*

Now it only remains for you to paste in the box the screenshot of the area or areas that seem most suitable for your mission to land.

The group will be able to put one or more images of the areas that they liked the most to land, after studying them well.

They will have to take into account several things such as:

- If it is an area full of craters, you will land very badly.
- If they move away from the equator they slow down less
- If it is a very high area, it will not give time for the parachute to perform its function.

Activity 10.3: Martian rover/ Car efficiency/ Safety expert team (Team 2)

Our mission is important, we need to look at a more specific area where the satellite can land safely.

If the satellite does not survive the landing, the mission would be a failure. This is why it is very important to find a place where it is less likely to get damaged the satellite during landing.

Activity 10.3.1: Which surface of Mars we should avoid on landing?

We have to land on steep slopes? Rocky areas? With many craters?

> We must avoid areas with many craters, rocks, very uneven terrain or steep slopes. They are areas where our landing module could end up damaged or destroyed

Looking at the colored images ("Colorized terrain") of Google Mars (go to Activity 10.1 if you don't know how to get here) Is it safer to land in the north of the planet or the south of the planet? Why?

> The northern hemisphere of the planet seems much flatter and wider than the southern hemisphere, which are higher areas with many craters and very irregular

When observing Mars on the topographic map, we see that Mars presents an important dichotomy or two very different areas:

- The lowlands in the northern hemisphere of the planet, where the altitude is much lower and the ground is much flatter, with few craters.
- The highlands in the southern hemisphere of the planet, where the altitude is much higher and a terrain much more dotted with craters.

¿Where do you think it will be safer to land? Why?

> The lowlands of the northern hemisphere. It seems to be much safer because it is flatter and wider.

When we are going to dock, we can propose very precise coordinates, but the truth is that it is actually different where you want to land and where exactly is where you do it. There is always a certain error in the calculations, since small changes can not be predicted 100%, such as winds that pass through the Martian atmosphere, slight changes in speed, ... That is why we are going to look for large safe areas, without large slopes, craters, rocks on the surface.

Also, if we end up in a confined site, such as inside a crater, we can only study what happens in that crater, since we will have trouble climbing the walls and seeing what is outside. This applies to us whether in a rover or motorized vehicle, or if we go with a crewed mission and Martian vehicles. The flatter and wider these areas are, the more distance we can safely travel with the rover.

Activity 10.3.2: Look for large areas

When we travel to Mars, usually they look for wide areas to land. Why do you think it is so important?

Because if there are errors in the landing or we deviate a little, it is still a safe zone to land.

Can you tell us where those areas would be by looking for them in *Figure 44* and Google Mars? Fill in the *Table 10.*

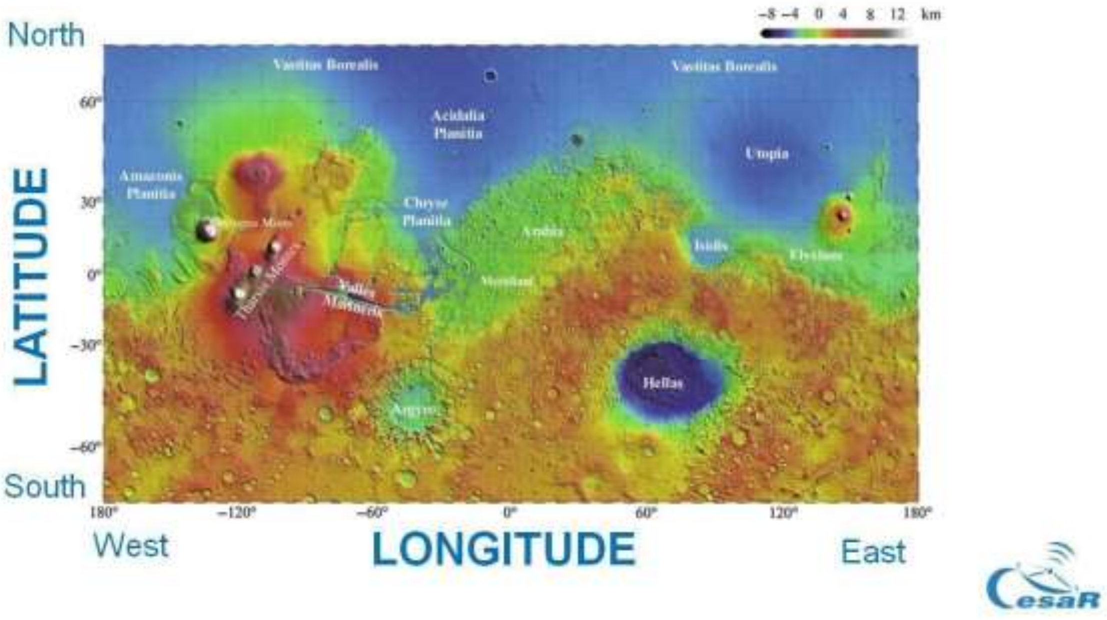


Figure 44: Topographical map of Mars. Origin: CESAR

Name	Coordinates	Observations
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	

***Table 10**: Mars's places and their location.*

Activity 10.3.3: Draw on Google Mars

Busca en la superficie de Marte, ejemplos seguros para moverte con el rover y otros no tan seguros.

Para dibujar con Google Mars, ve al botón de “añade una ruta” como aparece en la *Figure 45* y te aparecerá una ventana donde podrás cambiar los parámetros de la ruta, como el nombre, color,..., como aparece en en la *Figure 46*. Look on the surface of Mars, safe examples to move with the rover.

To draw with Google Mars, go to the button "add a route" as it appears in *Figure 45* and a window will appear where you can change the parameters of the route, such as the name, color, as it appears in *Figure 46.*

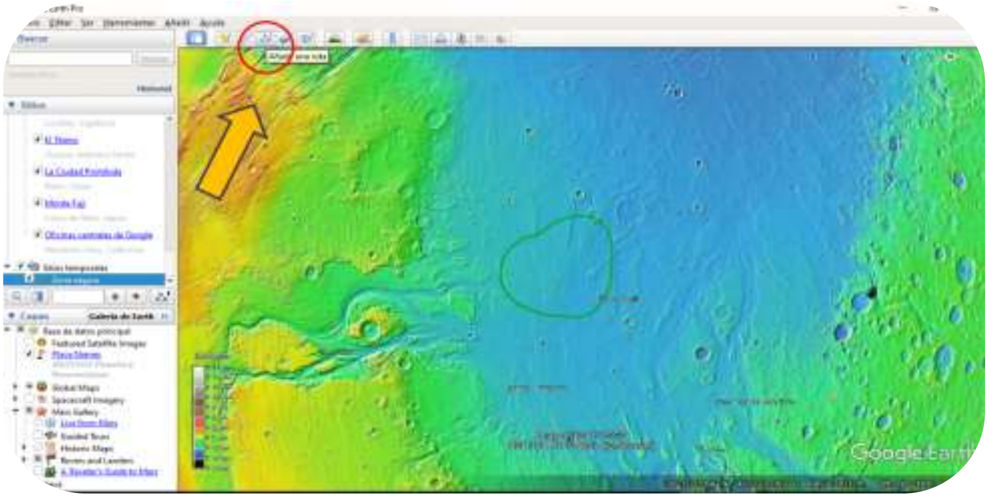


***Figure 45**: Image from Google Earth Pro Software (Credits: Google Earth)*

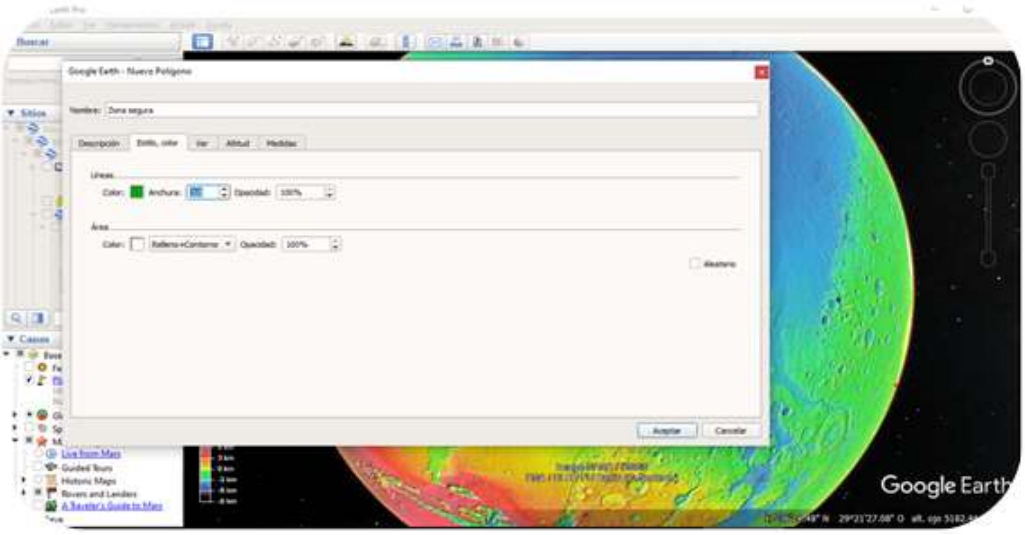


***Figure 46**: Image from Google Earth Pro Software (Credits: Google Earth)*

- Mark with <u>green</u> circles the safest areas you can find to land.
- Mark with <u>red</u> circles the areas that you would avoid to land.

Why have you chosen these areas?

The green circle areas should be flat, without large slopes, smooth, ... The areas marked by red circles are usually with many craters, slopes, very irregular

Activity 10.3.4: Select an optimal area

We propose the following places to study: Valles Marineris, Eos Chasma and Aeolis Mensae. Would any of them be a good option? Compare them with your chosen areas in Activity 10.3.3, inspect them in detail and give your answer.

Valles Marineris Rough terrain, large cliffs on the sides. Eos Chasma Very irregular area, with a very bulky terrain (with many mounds) Aeolis Mensae It looks like a fairly flat area, safe to land, a bit higher than Valles Marineris, but low enough to be able to land safely. Aeolis Mons is in Gale Crater, where Curiosity landed.

Activity 10.3.5: Infrared image analysis to reject sandy areas

Another point to consider in terms of safety is that the terrain is neither too hard nor too soft. To do this, look at infrared images of rocks / sediments on the ground. Infrared images measure the temperature of the ground. The brighter, the hotter; and less bright, colder. There are infrared images during the day and at night, with which you can determine if the same surface is very hot during the day and the same surface is very cold at night. This way we can avoid sandy terrain, which makes it a very unstable terrain for landing rovers and other landing modules.

Example: Gale crater (5º 14' 45,72''S; 137º 01' 02,04'' E)

To do this, select in "Global maps", in the menu on the left marked in *Figure 47*, the maps of "daytime infrared" (daytime infrared) and "nighttime infrared" (nighttime infrared).

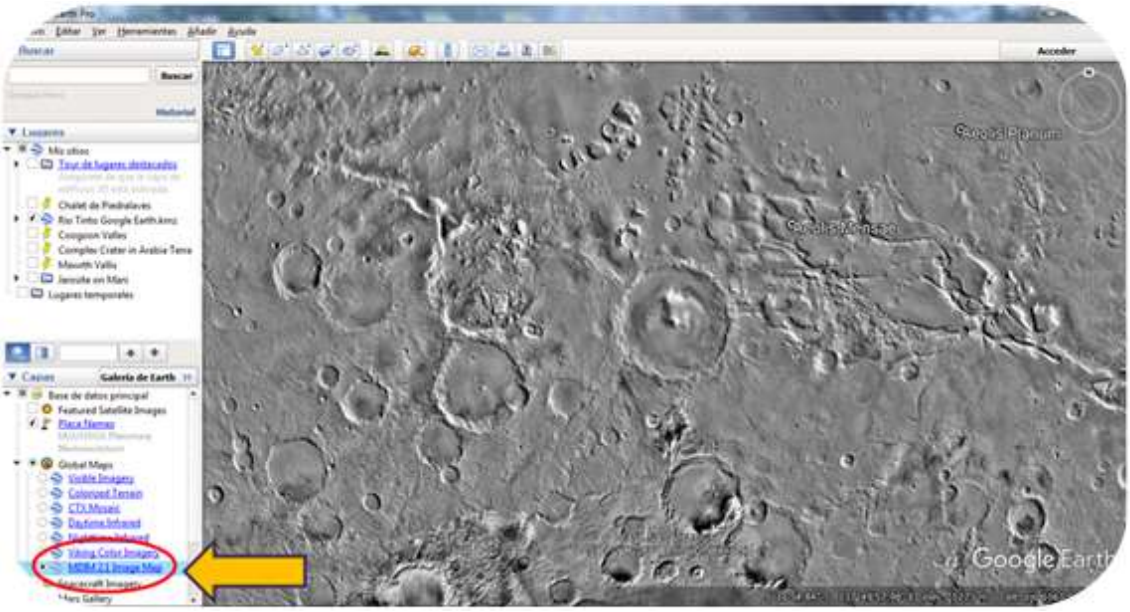


***Figure 47**: Image from Google Earth Pro Software (Credits: Google Earth)*

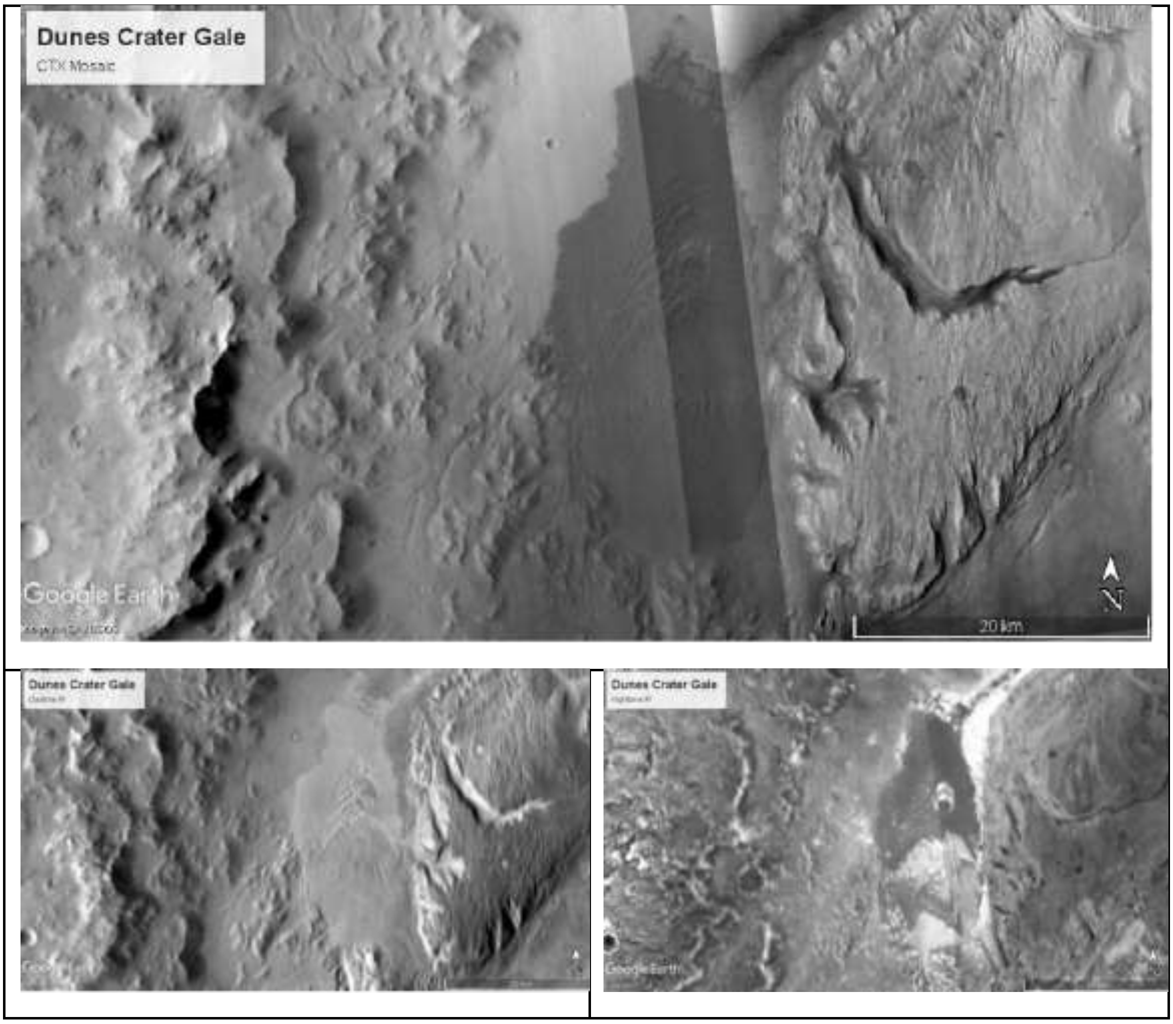


Figure 48: *Image from Google Earth Pro Software (Credits: Google Earth). 48a (arriba), Gale crater dunes seen with the CXT Mosaic map. 48b (bottom left, the same area seen with daytime infrared images). 48c (bottom right), the same area seen with nighttime infrared images*

Look in the safe areas that you have marked before, if there may be an area that changes a lot in color during the day and at night (go from very bright to very dark).

Are there sandy areas in your safe areas? Where? If there are, mark them with a yellow polygon on Google Mars.

In the Gale crater images (image 48) you can see that there is a light gray area in image 48a that turns a very dark gray in image 48b. They are warm areas (light colors in infrared) during the day, which become very cold at night (very dark in infrared).

This is characteristic of dunes. We also see the opposite effect around the dark area of the dune dunes in the night image (48b). They are terrains with great thermal amplitude that is better to avoid.

Activity 10.3.6: Team 2 conclusions

What large open areas do you see on Mars so that the Martian rover moves freely over large open areas?

Choose 3 areas that you would propose as ideal for the safety of the rover. What characteristics must these areas have to be suitable?

Name	Coordinates	Observations
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	

***Table 11**: Mars's places and their location*

Activity 10.4: Mars science data expert team (Team 3)

When choosing a region to land in, it is important to consider that the area is of the greatest possible scientific interest. To do this, we need to think about the geological characteristics and the age of the terrain in which to land.

Activity 10.4.1: Impacts that make history

The geological history is distinguished by specific climate conditions, which have left their print on Mars surface.

What do you see in *Figure 49*?
Clue: look at Activity 6.1, and answer here.

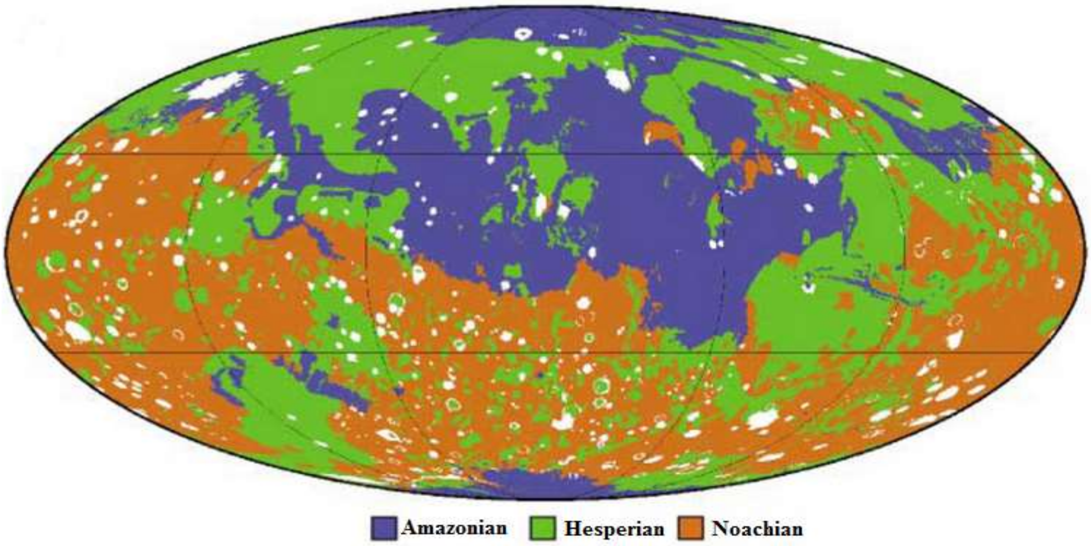


Figure 49: Distribution on the surface of Mars of the Martian geological ages. In blue, Amazonian, Hesperian in green and Noachian in orange. (Credits: Greeley and Guest, 1987; Scott and Tanaka, 1986)

In which Martian era were there more impacts?

In the Noachian

In **planetary geology,** 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?

Noachian > Hesperian > Amazonian

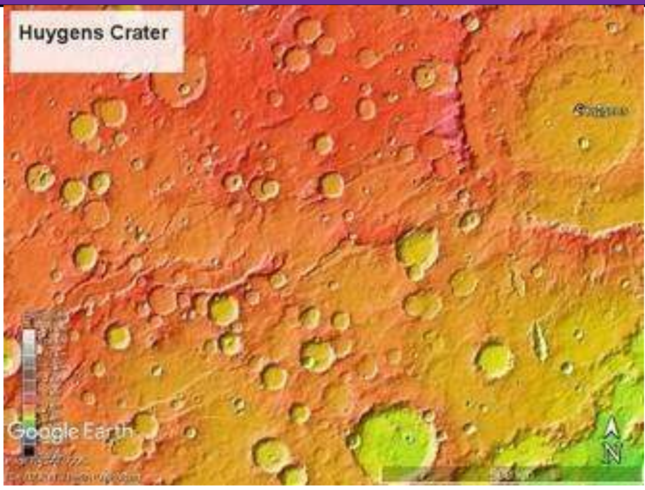
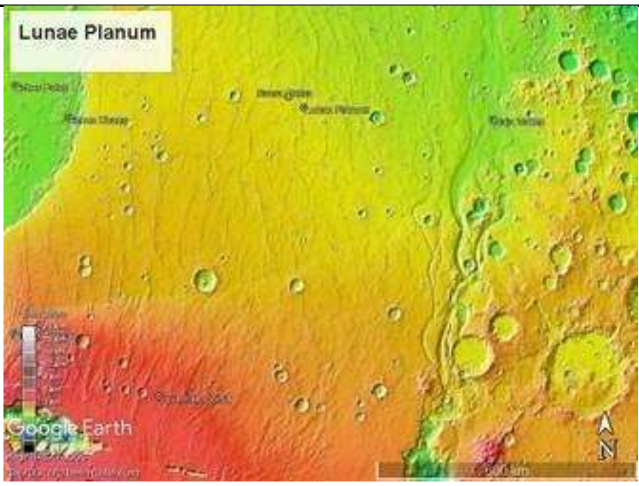
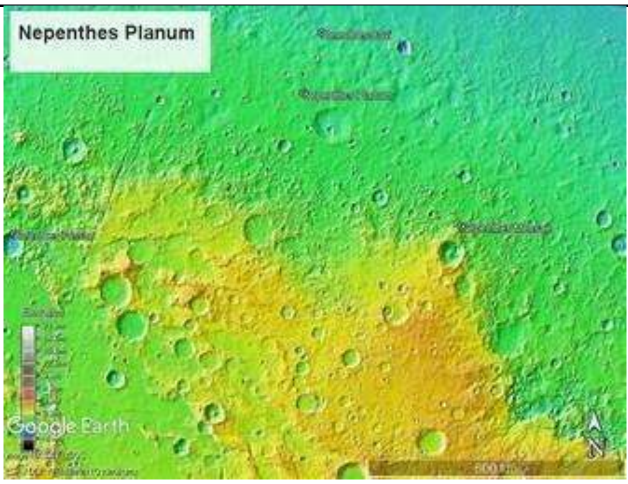
Check Activity 6.1 to see if you got it right.

In planetary geology, we can know the approximate age of a surface by looking at how many crater impacts it has.

We are now going to look at different Martian surfaces to try and determine their approximate age.

Remember: the Noachian is the oldest period and there are more craters and those craters are bigger; the Hesperian period is intermediate; the Amazonian period has the youngest surfaces, with smaller craters and there are less of them.

Which geological period do you think these Martian pictures belong to?

Imagen	Martian period
	It does have an abundant number of craters and they are quite big craters, compared with the other images. It corresponds to the **Noachian** period.
	Intermediate area. Not too may craters and not too less. It corresponds to the **Hesperian** period
	Intermediate area. Not too may craters and not too less. It corresponds to the **Hesperian** period

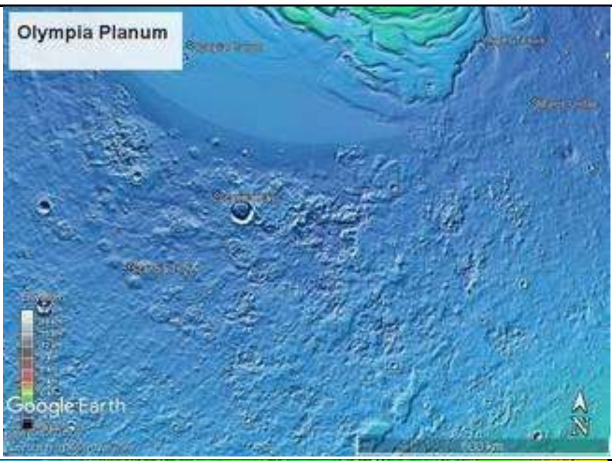
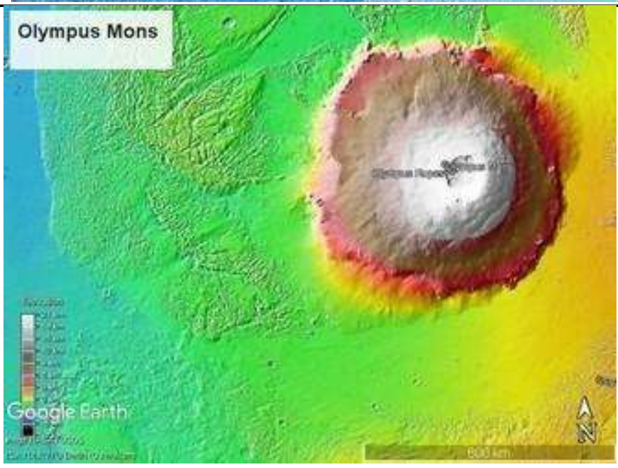
	This area has a few craters and they are quite small ones, compared with other images. It corresponds to the **Amazonian** period.
	This area has a few craters and they are quite small ones, compared with other images. It corresponds to the **Amazonian** period.
	It does have an abundant number of craters and they are quite big craters, compared with the other images. It corresponds to the Noachian period.

***Table 12**: Lugares de Marte y su localización.*

Activity 10.4.2: Looking for water signs.

In the *Figure 50* you can see a topographic map of Mars, but instead blue, green and orange colours, to express different altitudes, white color is used for higher areas and black colours for the lower areas. Intermediate areas are colored by different tones of grey.

In this map are represented different hydrated mineral outcrops, such as phyllosilicates or sulphates, detected by OMEGA's Mars Express instrument. These outcrops are quite huge, big enough to be seen from a Mars orbiter, and that means that in the past of Mars, there was a big quantity of liquid water to these outcrops to be formed.

We can see that these outcrops are distributed by all the surface of Mars, and that means it is not an isolated incident, but something that happened globally around all Mars' surface.

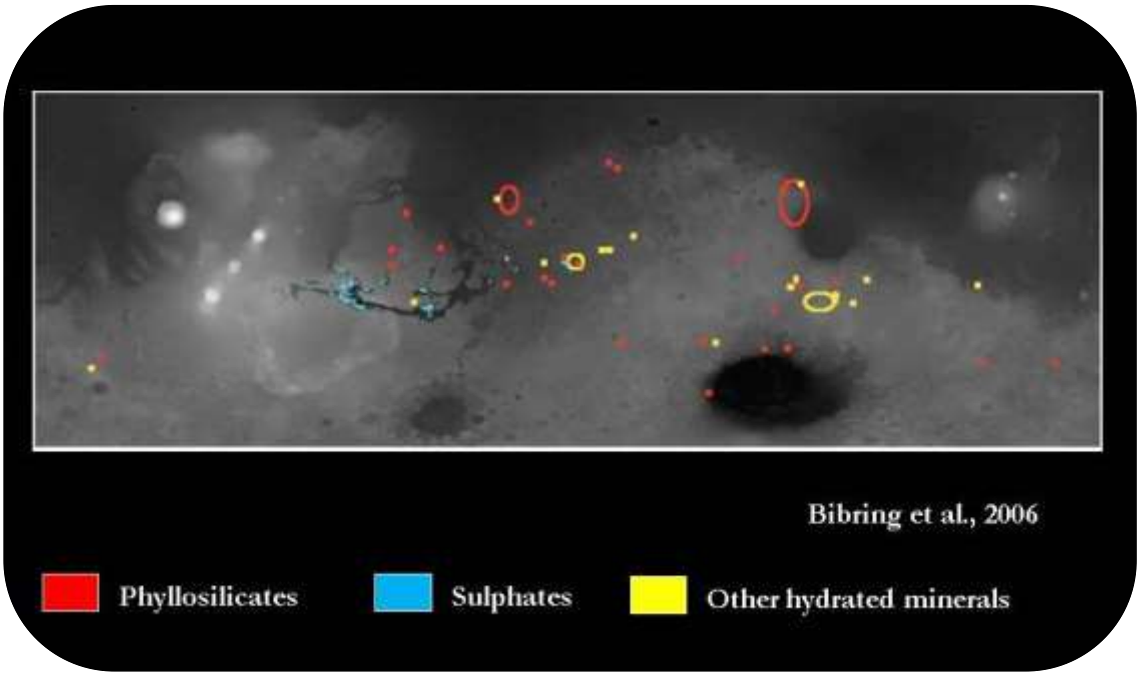


***Figure 50**. Figure obtained from the publication of Bibring et al. 2006.*

These areas are very interesting to research on, when it is decided to send a scientific exploration mission. They are areas where outcrops are exposed to the surface with minerals that needed a lot of water to be formed. These areas are crucial to keep a possible trace of past Life on Mars.

To seek for traces of past Life on Mars, we have to look for past liquid water signals in Mars history. Nowadays, there are only water ice. The low atmospheric pressure and low temperature make water to sublimate (it goes from solid to gas without passing the liquid state)
But the past of Mars was different. We can see some signals that there were a quite important quantity of liquid water on the martian surface.
Open the Google Mars program and follow the steps from Activity 10.1 until we see the colorized terrain of the topographic map of Mars.

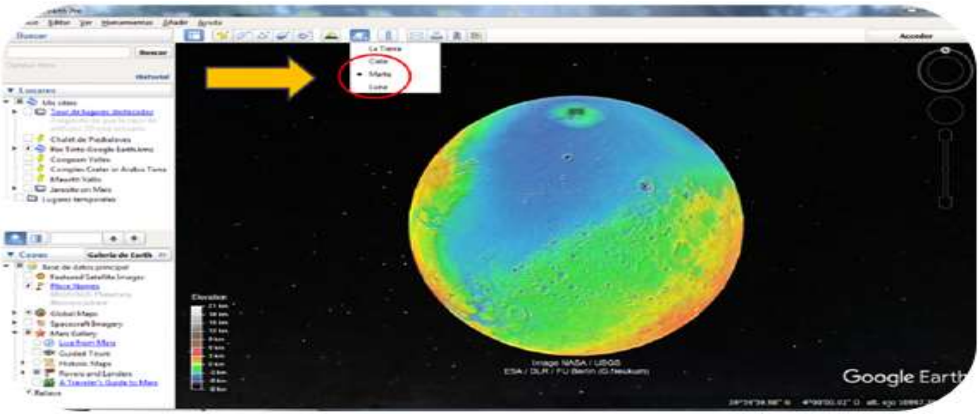


Figure 51*:* *Image from Google Earth Pro Software (Credits: Google Earth)*

You must be watching the colorized image from Mars such as the one at *Figure 51*, where higher areas has brown/orange colors, and lower areas has blue colors. If you are not watching a colourful map of Mars, you must go to “Gobal Maps” and choose the “Colorized Terrain”. You can also choose the “CTX Mosaic” option, which is unisng images from the NASA “Mars Recoinnaissance Orbiter” with a quite good high resolution. Both “Colorized Terrain” and “CTX Mosaic” options are in the “Global maps” menu, signed in *Figure 52*.

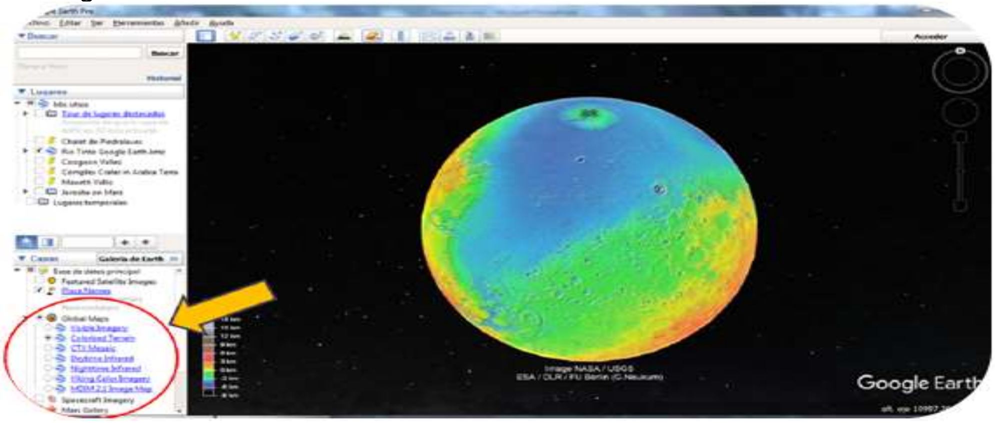
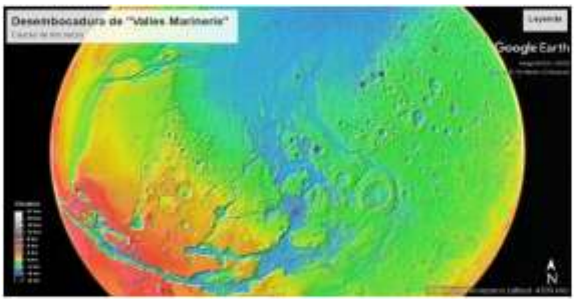


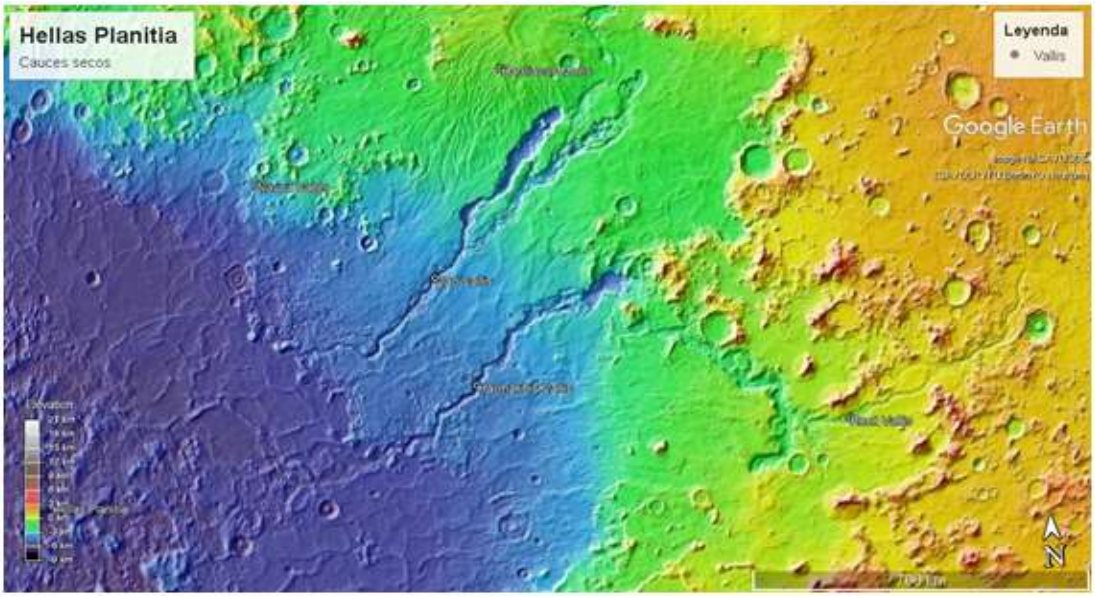
Figure 52*:* *Image from Google Earth Pro Software (Credits: Google Earth))*

Could you see a dry riverbed somewhere? Where exactly?

There are a lot of dry riverbed examples in the dichotomy area between southern highlands, and northern lowlands. Inside craters, you can find them too. You can see them in the big estuary of “Valles Marineris”. Inside craters you can look for “Hellas Planitia” or Jezero crater.



Extra figure: *Image from the Software Google Earth Pro, showing, in blue colours, the estuary area from the big delta coming from "Valles Marineris" (Credits: Google Earth)*



Extra figure: *Image from the Software Google Earth Pro, showing dry riverbeds in " Hellas Planitia" (Credits: Google Earth)*

Extra figure: *Image from the Software Google Earth Pro, showing the alluvial fan or delta from Jezero crater (Note: it is the landing site for the Mars rover Perseverance 2020 (NASA)). Credits: Google Earth*

Activity 10.4.3: ILD (Interior Layered Deposits)

Finally, we need to look for specific features which might be of interest to study when the spacecraft successfully lands on Mars. When scientists look for traces of life, they often look for signs of water.

ILD (*Interior Layered Deposits)* are just one of the many interesting geological formations we know of on Mars that indicate there was water in the past. These deposits, which are in layers or sheets, have been analysed and are known to have hydrated minerals (which means they needed to be in contact with vast amounts of liquid water to be formed).

Since there are many layers, one on top of the other, there is a good chance that **some traces of past life could be preserved in these deposits.** This is due to they are formed with hydrated minerals.

The *Figure 53* shows the layered deposits in Juventae Chasma, taken by the CASSIS instrument on board ESA's Trace Gas Orbiter. You can find it at the coordinates 3º 21' 14.72''S, 61º 24' 59.96''W, at the south of "Maja Valles".

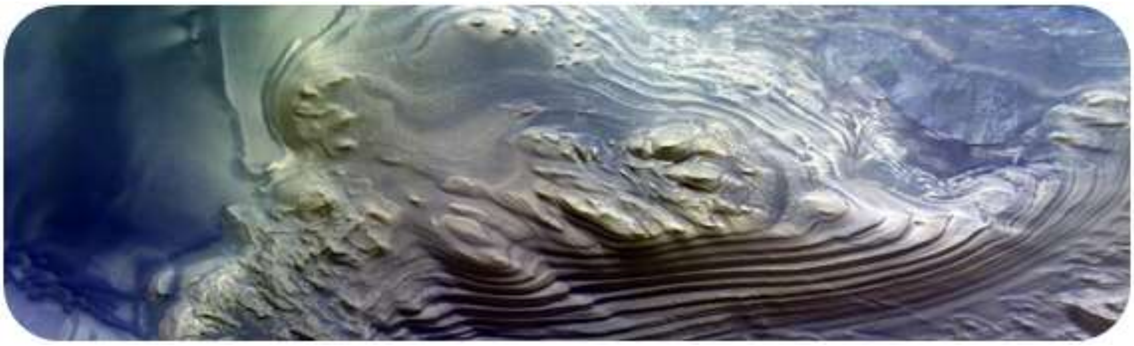


***Figure 53**: Interior Layered Deposits in Juventae Chasma, captured by ESA's Trace Gas Orbiter. The image covers an area 25 x 7 km wide. Copyright: ESA/Roscosmos/CaSSIS, CC BY-SA 3.0 IGO*

These deposits can be found inside craters or dry riverbeds, can you find some of them using Google Mars? You can see the figure 50 for some clues.

These Interior Layered Deposits can be found inside Valles Marineris, (such as inside Melas Chasma or in the big delta such as e Aureum Chaos, Mawrth Vallis,). You can find them in Juventae Chasma, in Gale crater, Gusev crater,...

Activity 10.5: Expert team in requirements of a robotic / unmanned mission (rover) (Team 4)

Activity 10.5.1: Advantages / Disadvantages of a robotic mission

***Figure 54**: Elements of the ExoMars 2016-2022 program. (Credits: ESA)*

Until now, the missions that have been taken to Mars, as to other planets in the Solar System, have been robotic. The manned missions, the farthest they have gone has been to the Moon. Why do you think this is so? What advantages / disadvantages do you think a manned mission has to robotic ones?

The robotic mission is much cheaper, the energy expenditure of a rover is much smaller, and it can hibernate all the way to Mars with no extra energy expenditure. Also there are no costs in human lives if something goes wrong.
In addition, the risk of contaminating Mars with terrestrial life (we carry many bacteria and microorganisms with us and we cannot sterilize ourselves) is much higher, creating doubts as to whether we find life outside of Mars or whether we brought it ourselves.
The manned mission is much more expensive, but the ability to bring trained astronauts to Mars would make the mission much more productive. It is much easier to catalog and discriminate samples *in situ* than from Earth remotely. Also, we can build equipment right there by sending engineers, something that a rover, no matter how much artificial intelligence it has, can't do. It is also the next frontier for humans, being able to colonize and survive on another planet.

Remember that sending a robotic mission to Mars involves the work of many people, for about 20 years in the largest ESA missions, with a very important personal and financial cost, so if something fails, it is a lot of work and money invested that has not been of much use, although one can learn from mistakes.

That's why you have to plan it well.

Activity 10.5.2: Energy requirements

The rover needs energy to function. What kind of energy would you use? What are the pros and cons of using this type of energy?

Power type for the rover	Advantage	Disadvantage
Solar panels	Unlimited energy as long as the sun shines Quite inexpensive and widely used in space missions. Being unlimited, as long as the solar panels work and there are no major failures, we can continue with the mission for many years.	You need enough power to move the rover. At the poles it is not enough, and it will have more energy the closer it is to the equator. Solar panels can break, deteriorate (after sandstorms, for example). If the rover falls into a crevasse where the Sun does not shine, it does not work.
Wind power	Unlimited, cheap	The atmosphere of Mars is too thin. Even if sandstorms appear from time to time, it is not enough to get enough power to move a rover.
Fossil fuels	It can work without sunlight limitations, such as near the poles or during the Martian night	It is limited, once the fuel is finished, there is no more. It weighs a lot and takes up a lot of space, it is difficult to get out of the earth's gravity and it is necessary to optimize weight and volume to send into space.
Nuclear energy	It is very effective, with little weight and volume you have a lot of energy. It allows you to go to areas where sunlight does not reach well (poles, caves, crevices,)	It is limited. Once finished, the mission cannot continue.

***Table 13**: Which energies are better on Mars.*

One resource that we can find on Mars, which is unlimited, is Solar Energy, which is the main source of energy for current Martian missions, both in rovers and satellites. But to be able to use solar energy, we have to be in low latitudes, close to the equator. For there to be enough solar energy to use solar panels, the limitations of solar light mean that the Martian station must be between 45ºN and 45ºS, as seen in *Figure 55*.

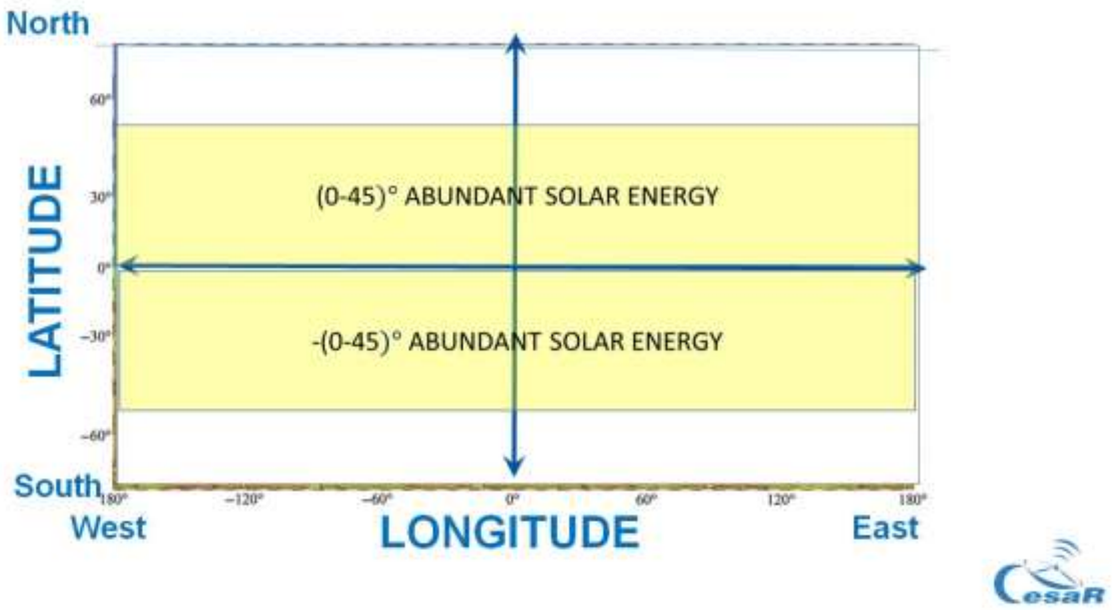
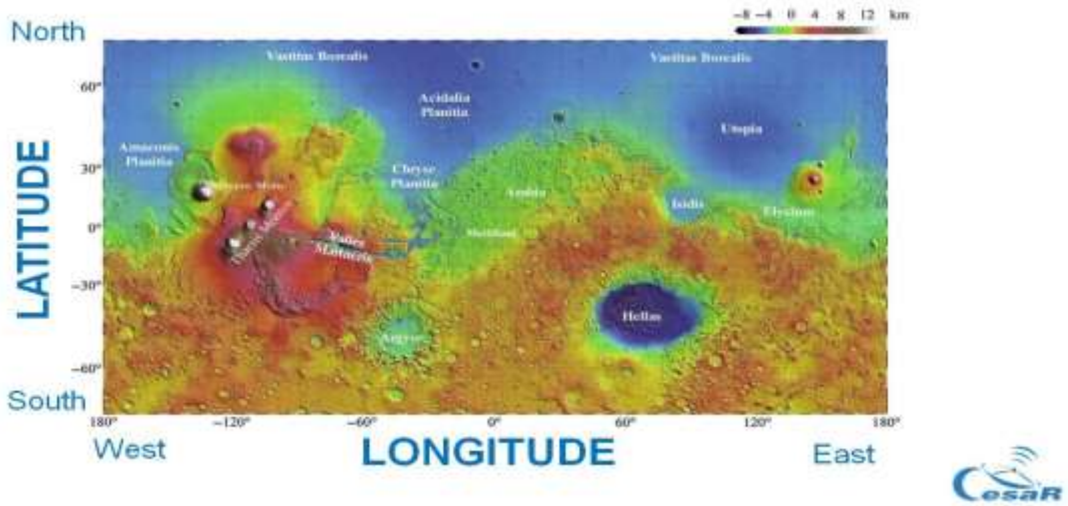


Figure 55: *Sunlight requirements. (Credits: CESAR)*

What areas do you see as ideal for landing a rover, which are low and have enough solar energy?

Blue zones more or less close to the equator:
Amazonis Planitia, Chryse Planitia, Isidis and southern Utopia planitia, Valles Marineris.
Green areas near the equator:
Meridiani Planum, Arabia Terra, Elysium Planitia



Extra Figure: *Topographic map of Mars. (Credits: CESAR)*

Activity 10.5.3: We seek life. How?

Now comes the fun. What do we have to look for? What tests do we have to do to find life on Mars?

How do you think life could be or can be on Mars? Microbial? More complex? What do we hope to find?

We do not expect to see green Martians or large forests. What we are going to look for are microorganisms, such as bacteria or terrestrial archaea. Those microorganisms can be alive now in the Martian subsoil (at least, we know that terrestrial Extremophilic microorganisms could survive in those conditions without problems) or they could be alive in the past. We will have to look for current microorganisms or remains that those microorganisms left in the past on Mars.

This part of the challenge needs one more step for the development of the mission, because we cannot take large laboratories to Mars. We have very limited weight and volume that we can send into space. In addition, if we find a proof that can indicate that there is life on Mars, that has to be irrefutable. That is, that test has to tells us completely sure that there is or there was life on Mars, without any doubt. We can already find that there are indications of microbial life on Mars (methane, mineral deposits and mineral structures that in terrestrial soils are indicative of microbial activity in the soil), but these indications could be formed abiotic or with chemical processes that do not involve living beings. So for the scientific community to accept that there is life on Mars, we need definitive proof. What kinds of experiments would you do to find that definitive evidence of traces of life on Mars, both in the present and in the past?

Search for live microorganisms: cultures, microscopes, ...
Search for biomarkers or molecules that only life can create, DNA, RNA, Proteins, complex, chiral molecules.
Look for remains or chemical signals that life leaves in its wake: isotopic fractionation, mineral structures associated with life (such as stromatolites)

Very similar methods are used when studying the Archaic period of the Earth. When we come across a very ancient rock on Earth, for example 3.8 billion years ago, was there life on Earth then? When did life appear on Earth? Those same techniques can be used with other planets, like Mars.

The ExoMars mission is ESA's mission to search for life on Mars. The Rosalind Franklin rover, a rover that will be named in memory of one of the great scientists who, thanks to her work, was able to discover and understand the DNA molecule and the genetic code.

We are going to investigate a little about the ESA mission, for that we are going to enter the ESA page and we are going to investigate a little:

https://exploration.esa.int/web/mars/-/48088-mission-overview

In the menu on the left of the web we have the links to ExoMars 2022, where they comment on how the rover is, the instruments it carries, ... We investigate what they have planned:

What scientific tests will they carry out?

Instruments are reviewed and explained here:
https://exploration.esa.int/web/mars/-/45103-rover-instruments

Special emphasis can be placed on **RLS** instruments (the Raman laser spectrometer), which detect minerals and complex organic molecules. In addition, it is an instrument developed mainly in Spain, by the Center for Astrobiology.
https://exploration.esa.int/web/mars/-/45103-rover-instruments?section=rls---raman-laser-spectrometer

The other instrument on which special emphasis can be placed is the **MOMA** (the Martian Organic Molecules Analyzer), consisting of a gas chromatography mass spectrometer (GC-MS) and a laser desorption mass spectrometer (LD-MS). also to detect complex organic molecules, even at very low concentrations, and a possible

What kind of samples are you going to take? Why are they going to drill under the surface of Mars?

The surface of the planet is not very friendly to life. There is no protection against the solar wind, there are extremely arid and oxidizing conditions due to perchlorate. This makes not only that the conditions for life are limiting, but they can destroy or modify any biomarker that might exist in the beginning. But the conditions of the subsoil change drastically, becoming much more habitable. Shielded from the solar wind and with layers of ice and water in the depths of Mars, we could find life even today and biomarkers can be better preserved.

Would you do the same? Do you have other ideas?

For example, you can consider detecting DNA or proteins with the same techniques that we use for clinical diagnosis. Just as you can detect coronavirus DNA with PCR or immunochromatography, you can consider simply detecting DNA or RNA.

Activity 10.6: Expert team on a mission manned by astronauts to colonize Mars. (Team 5)

Figure 56: Artistic image of a colony on Mars. Credits: [National Geographic]

So far, we have sent robotic missions or rovers to analyze the Martian surface. The problem is that the technology that we can send to Mars, especially in terms of precise scientific instruments, is very deficient compared to the technology we have in scientific laboratories on Earth. For example, a mass spectrometer in a laboratory on Earth can occupy 2-3 meters and weigh several tons. That makes it infeasible when it comes to bringing this technology to Mars, due to the weight and volume limitations of space shuttles.

On Mars, the rovers are equipped with much smaller and lighter instruments. By this we mean that by taking human beings to Mars, a very important discrimination can be achieved when looking for "interesting samples", much more than a machine , with which it could greatly influence, when it comes to finding remains of Martian life in the present or in the past of Mars.

Unlike the Moon, the trip to Mars is much longer (to the Moon it took 3 to 5 days, while to Mars it takes about 6 months, when the orbits of both planets are closer). In addition, Mars has more gravity than the Moon, so returning from Mars is more difficult. This makes going back and forth more complicated and expensive. Therefore, if a manned mission to Mars is carried out, suitable conditions should be sought for the creation of a more or less permanent colony, on Mars, where astronauts and future colonizers of Mars can survive.

To live a season on Mars, new requirements appear when it comes to landing. Astronauts will need extra requirements in order to find a safe landing zone, along with an area where they can find the resources necessary to maintain a human bubble city under Martian conditions.

Activity 10.6.1: What would you take to Mars?

First, you will have to decide what you are going to wear and what not and why. Remember that they are things both for the trip (without gravity) that will last about 6 months one way and another 6 back, and the relatively long time that you will be on the surface of the planet.

Then we have to see that it is a low enough zone so that there is an atmosphere that allows to have sufficient atmospheric requirements for the colony (for example, they can use Moxie to extract oxygen from the CO2 of the Martian atmosphere.

The lower areas are represented by blue colors in *Figure 57*.

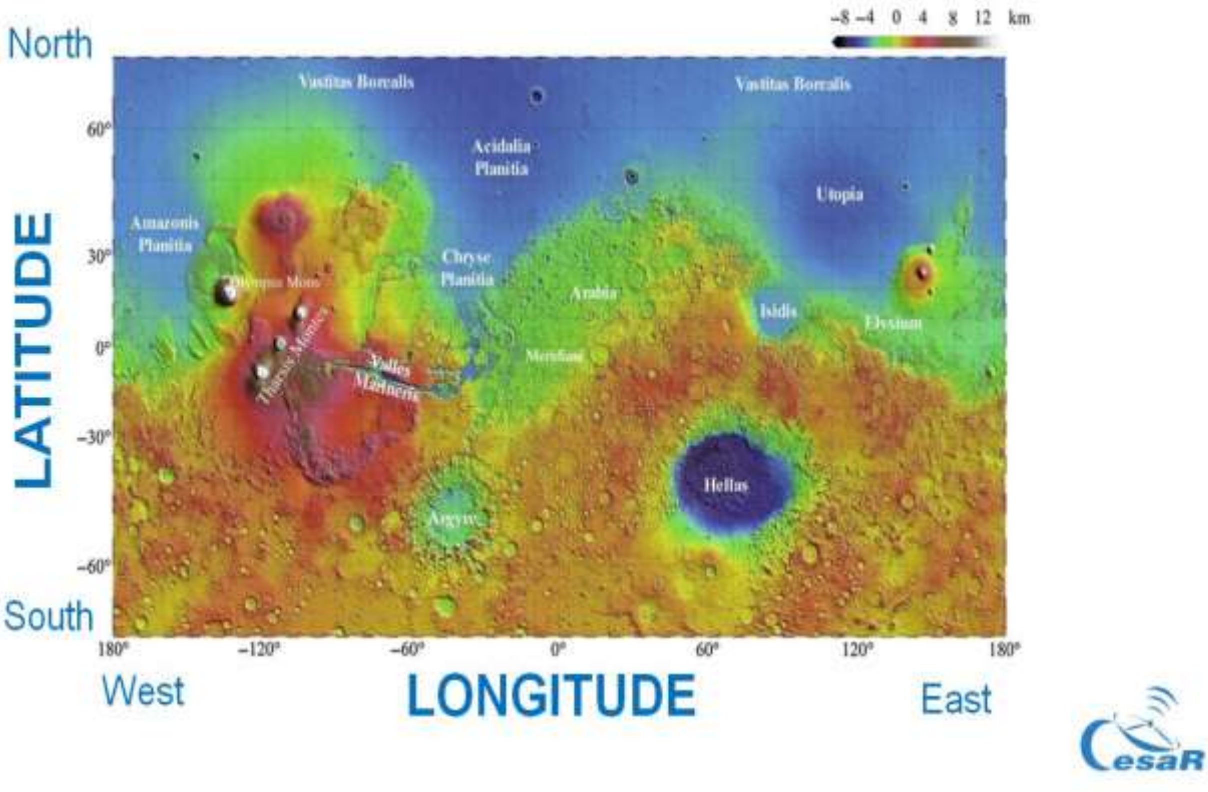


Figure 57: Topographic map of Mars (Credits: CESAR)

Activity 10.6.2: Light requirements

The energy requirements of that colony are important, for this, a resource that we can find on Mars is Solar Energy, which is the main source of energy for current Martian missions, both in rovers and satellites. But to be able to use solar energy, we have to be in low latitudes, close to the equator. For there to be enough solar energy to use solar panels, the limitations of sunlight mean that the Martian station must be between 45ºN and 45ºS.

Draw in Figure 57 the areas with sufficient sunlight for the astronauts.

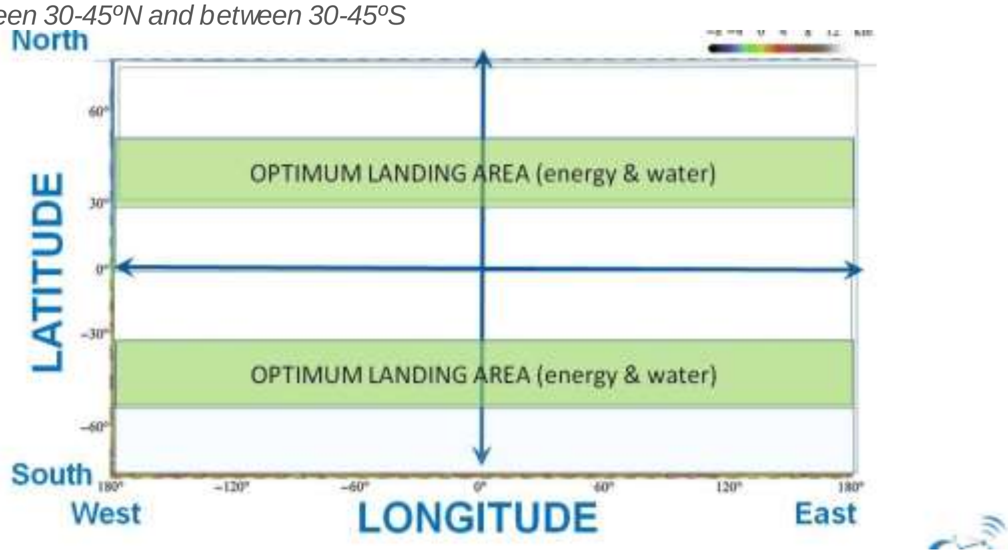
Activity 10.6.3: Water requirements

Unlike a robotic mission, if they go astronauts need a primary resource, water. With water they can drink, irrigate hydroponic crops and water or H2O can be dissociated, separating oxygen from hydrogen, being able to use oxygen to breathe and hydrogen as a source of energy. This is a resource that is abundant, in the form of ice, on Mars, but the problem is that it is accessible at high latitudes, the closer we are to the Martian poles. To have a water ice resource available near the surface for the Martian station, we have to land at 30º to 90ºN or -30º to -90º in the southern hemisphere.

Draw in *Figure 57* the area with enough water for the astronauts.

At what latitude can we have both sunlight and water ice resources? Draw the optimal landing zone on *Figure 57*.

Between 30-45ºN and between 30-45ºS

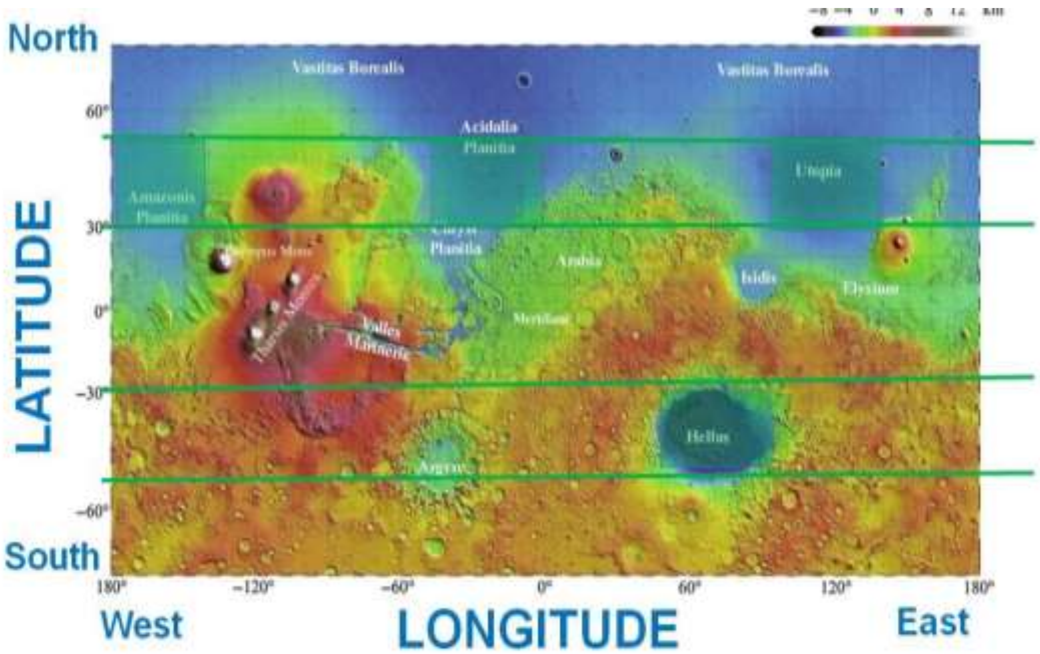


NOTE: If one requirement has to be prioritized, water should be prioritized over sunlight. Without water, astronauts cannot survive. They need it to drink, irrigate crops, obtain oxygen from water, and even to have another source of energy, which is the hydrogen obtained from water. Still it is better to have both requirements.

Activity 10.6.4: Wide flat areas

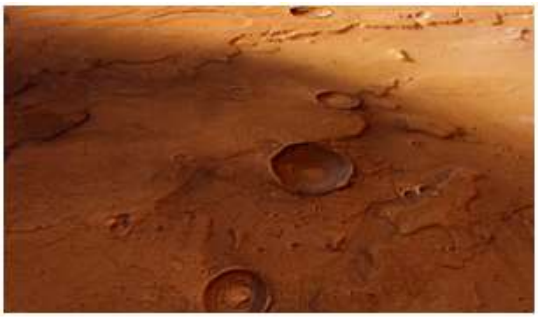
The success of the mission resides in the fact that the landing itself is safe, which means that the landing module is safely positioned on the Martian surface and can move over a wide area safely. For that, it must be landed in flat areas large enough to be able to move safely.

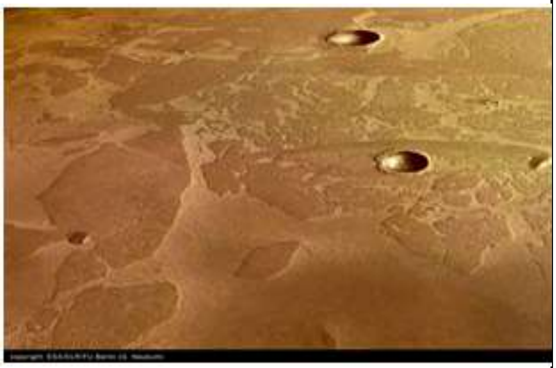
So what large areas can you see that have all the requirements? Low areas, between 30º and 45ºN or 30º and 45ºS, so that they have both light and water, and also that they are flat enough to move with the Martian vehicle? Describe them by looking at Figure 57.

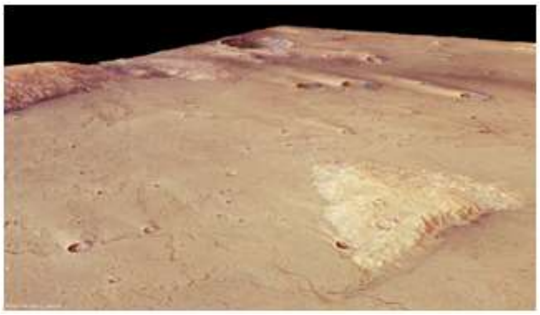
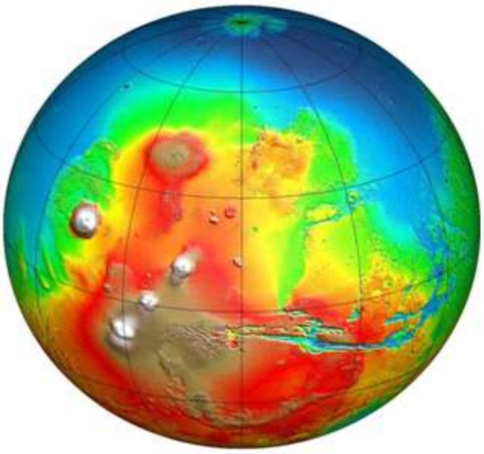


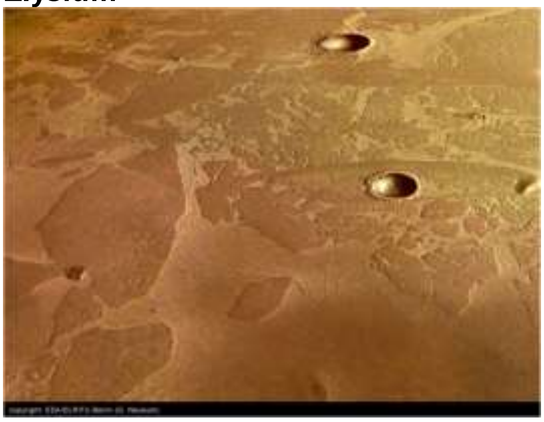
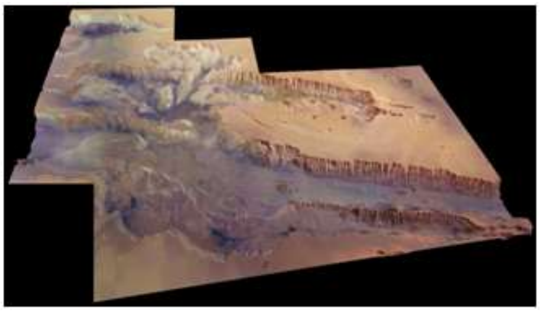
Extra figure: Optimal landing areas, with requirements for both light, water and low and wide areas. (Credits: CESAR)

Here we propose some that may or may not coincide with yours. Do they meet the requirements?

Place	Observations
Acidalia Planitia (South)  Mars Express images (HRSC camera) Berlin (G. Neukum), CC BY-SA 3.0 IGO	It has water and energy (especially in the southern area). It is very flat and extensive. But it is a long way from the equator and has little scientific value. On the positive side, it would have good access to the North Pole Ice Cap, although it would be a long journey.

Chryse Planitia  Mars Express images (HRSC camera) ESA/DLR/FU Berlin	It has access to water, has a lot of light energy and is flat. It has a high scientific value as it is located at the entrance of Valles Marineri.
Utopia Planitia  Mars Express images (HRSC camera) ESA/DLR/FU Berlin	It has a lot of water, a lot of light energy and is very flat, but it has little scientific value. Still, it has access to the Elysium volcanic zone and the Isidis zone, although at very long distances. The border between Isidis and Utopia Planitia (western area) is very interesting due to the proximity of Nilli Fossae, an area of very high scientific interest.
Amazonis Planitia  Mars Express images (HRSC camera) ESA/DLR/FU Berlin	There is a lot of water, light energy and it is very flat, but scientifically uninteresting.

Isidis Planitia  Mars Express images (HRSC camera) ESA/DLR/FU Berlin	It has little access to water for a manned mission, although it is fairly energetic and flat (though confined to a crater). Scientifically it is very interesting because here is Nilli Fossae, with some very interesting rocky outcrops
Tharsis North  NASA/MGS/MOLA Science Team, FU Berlin	It has water (only the north of Tharsis), light energy, but it is not an extremely flat area and it is also higher than the areas of bluish colors. It is scientifically uninteresting, unless you want to study the volcanism of Mars.
Hellas Planitia  Mars Express images (HRSC camera) ESA/DLR/FU Berlin	It has water, light energy and flat areas. But the southern hemisphere is higher than the northern, cratered, and highly irregular, so exploration outside of this area would be much more difficult. Still, it is very interesting scientifically. There are important remains of dry riverbeds and deposits of phyllosilicates. We also have access to areas of the Martian Noáic and Hesperic, having access to a large part of the geological history of Mars.

Clouds Vastitas Borealis & Northern Polar Cap  Mars Express images (HRSC camera) ESA/DLR/FU Berlin	It is an area with a lot of water and very flat, but it has very little light energy. Scientifically it is not very interesting, except for the possible access to the ice of the Martian North Pole, although it would be quite far from the base. It is very difficult to land there because it is far from the equator.
Elysium  Mars Express images (HRSC camera) ESA/DLR/FU Berlin	It has a lot of light energy, but little water and it is a green terrain, a little higher. It is very interesting scientifically, for example it is close to the Gale crater (where the Curiosity rover is), although reaching the area of the craters is difficult to access from outside.
Valles Marineris  Mars Express images (HRSC camera) ESA/DLR/FU Berlin (G. Neukum), CC BY-SA 3.0 IGO	It has a lot of light energy but very little water. The terrain is highly variable, not very flat and with 8 km high walls around it (dangerous for landing). But it is very interesting scientifically, with remains of having had large amounts of liquid water and large deposits of phyllosilicates and sulfates.

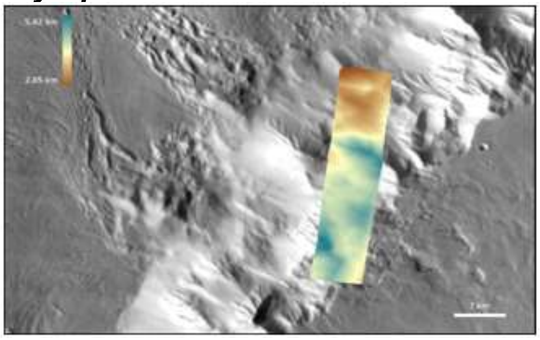
Argyre Planitia  Mars Express images (HRSC camera) ESA/DLR/FU Berlin CC BY-SA 3.0 IGO	It is an area with water and light energy, but it is not very flat and the terrain is somewhat elevated (green area). But it is a very interesting area scientifically, with a complex geological history and access to the Noachian and Hesperian of Mars.
Olympus Mons  ESA/Roscosmos/CaSSIS (footprint)	It is an area with a lot of light energy but very little water and a very high terrain. Still, it's flat. It has little scientific value unless you want to study volcanism on Mars.

***Table 14**: Different places on Mars where to land or not.*

Activity 11: Expert Committee

Evaluate the different landing zones and choose the optimal one. Explanine to the other teams about the reasons for your decisions.

Activity 11.1: Multidisciplinary teams

We make new teams! Each team of experts has seen an important part for the mission to be successful, but now we all have to work together to carry out the mission. We make new teams with at least one expert from team 1, another from team 2, another from team 3 and another from team 4.

Taking into account all that we have learned and discussed, it is time to choose a place to land on Mars or to dock!

To do this, a balance must be found between the results obtained in each of the investigations carried out by the different expert teams. Remember, teamwork requires listening to everyone and agreeing together on the best place to land.

Team members

Remember that the new multidisciplinary team must have at least one member of the previous expert teams 1, 2, 3, 4 and 5. There may be a team with more than one member of the expert teams

The first thing when coming to a new team is to introduce yourself and explain what has been learned in Activity 10. What requirements are important?

Team member	Important landing site requirements
Expert in ship efficiency / safety	-Close to the equator -Llow area
Rover efficiency / safety expert (Team 2)	-Wide area -Safe area, without craters, steep slopes -Flat area
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	-Enough solar energy to operate if the rover has solar panels (45ºN to 45ºS)
Manned Mission Requirement Expert	-Enough water and light resources (from 30 to 45ºN and from 30 to 45ºS)

***Table 15**: Requirements land according to each team.*

Activity 11.2: Choose whether to do a manned / unmanned or mixed mission

The experts from team 4 and 5 explain to the rest of the team why it is better to do a manned or robotic mission.

	Advantages	**Disadvantages**
Robotic mission	Cheaper -There is no loss of human life if there is a failure. -Needs fewer requirements to be carried out	-You cannot carry large laboratories .The analysis on Mars are limited. -Very difficult to discriminate "in situ" samples in real time
Manned mission	-A well-trained human can select more interesting samples. -Engineers can build necessary tools directly on Mars -It would be the next great step for humanity since the arrival on the Moon.	-It is much more expensive -The risk is much higher, since if something fails, human lives are at stake

Table 16: *Advantages and disadvantages of the different missions (manned and unmanned).*

Choose your option:

Robotic mission	
Manned mission	
Mixed mission	

Table 17: *Choice of the type of mission (robotic, manned or mixed).*

Activity 11.3: Choosing a landing site

Now we all have to choose a landing site that meets all (or most) of the requirements. Our landing site has... (fill in the Table putting yes or no)

Correct latitud	
Suitabler terrain	
Information from an interesting period in the history of Mars	
Traces of existence of water in the near past	
Enough light	
Enough water (only if you are carrying out a manned mission)	

***Table 18**: Characteristics of our landing site.*

Write down this information about the place chosen to dock thanks to Google Mars:

Name of the zone	Latitude	Longitude	Observations

***Table 19**: Places to land.*

You can choose the place that you see most interesting, but here are some proposals that you can use or not. Remember that you only have to choose one:

Activity 11.4: Vote for the best mission!

Now it is time for each team to expose its proposed landing site and defend it before the others. Because you have to choose only one among everything.

What is your landing place?

Name of the zone	Latitude	Longitude	Observations

***Table 20**: Final place to land.*

¿Why do you think is the best place to land?

Here they must write a summary with the key points of the place they have chosen to land and why.

Good luck!

Activity 11.5: Conclusions

What difficulties have you found in choosing an ideal landing place, where all the characteristics of a safe place to land are met, and which is an area of scientific interest and with the requirements to carry out a robotic or manned mission?

The main difficulty is finding an area with all the requirements. In general, the safest areas to dock are the most "boring", scientifically speaking, and the most scientifically interesting areas are often unsafe. You have to find a middle ground.

If a manned mission is carried out, it is even more difficult, since for a future colony on Mars where human beings can survive, in addition to sunlight, access to water (ice) is needed as a priority resource.

Has it been easy or difficult to work in multidisciplinary teams? Was it easy or difficult to understand each other? Why?

It is usually complicated. The priorities of one expert team tend to run contrary to those of the other team on many occasions. Among different branches of scientists or engineers we usually have different ways of thinking and expressing ourselves, because our training has enhanced some characteristics or others. Communication and respect are essential.

Do you think it is important to be a specialist in science? Why?

Yes, it is important because scientific knowledge is so extensive nowadays that it is not possible for one person to cover everything. Either you know a lot of a little, or a little of a lot.

Do you think it would be easier to have someone who knows a little of everything to help specialized scientists understand each other? What ideas do you have to improve collaboration between multidisciplinary teams?

The fact that there is someone more generalist, who knows a little about everything, and above all, who understands the different language or way of thinking of each scientific / engineering branch, makes it possible for experts to communicate and make themselves understood by that generalist person, who will take that concept to the rest of the group, using a common “language”.

What are the advantages and disadvantages of taking a robotic mission to Mars compared to a manned mission?

They are described in Activity 11.2

Would you volunteer for a manned mission to Mars? Why?

This is an open answer, where students should write their opinion. For example: As an advantage, you would be making history and would become part of the history books forever, but you have to consider that it may be a one-way trip, with a high probability of not being able to return, because something may fail, or because you can't go back to Earth for a long time. It may be to survive there or not to survive.

Phase 4

Congratulations!

You have completed your Science Challenge!

Tell us your story!

Stop to think about the Experience with your Team and teacher and complete these Activities.

Activity 12: Evaluation

- **Teams:** Fill in this questionnaire so that you can check what you have learned in the Challenge.
- **With your teacher:** Give us your feedback

IMPORTANT NOTES

- Teachers will make sure that each Team performs the evaluations (quizzes)

Activity 13: Present your results

Students will have to create a final product (an A0 poster in pdf format, using power point, for example) showing what they have learned in the different phases of the Scientific Challenge.

This poster is the ticket to participate in the CESAR international adventure competition.

IMPORTANT NOTES:

- It would be very interesting if you could present it to your schoolmates on a certain date, simulating a congress of scientists.
- Any document involving photos of your students can be published on the CESAR website or social networks. Therefore, please only attach those images for which you have explicit permission for publication, intellectual property and image. The CESAR Team is not responsible for their intellectual property and image.

Congratulations teacher!

Thanks to your dedication your class will receive a

CESAR Team Super Diploma

Links

Links to

Phase 0

- This is ESA
- ESAC: ESA's Window on the Universe
- Presentation ESA/ESAC/CESAR by Dr. Javier Ventura

Phase 1

- Making globes of Mars
- ESA KIDS: Rosetta
- Article about Rosetta
- Article about Rosalind Franklin
- DNA experiment
- Twitter 1 (spanish)
- Twitter 2
- Press 1
- Press 2
- Wikipedia
- Habitable zone
- Video:Life Beyond
- Circumstellar Habitable Zone Simulator
- Mars CESAR Booklet
- Missions to Mars
- Mars Express Mission Highlights
- Mars Express
- ExoMars
- Mars missions 2020-2030
- ESA's Scientific Satellite Fleet
- Mars

- ExoMars
- Water at Martian south pole
- Mars Express and the story of water on Mars
- Mars Express detects liquid wáter
-

Phase 2

Phase 3

- Launch simulation (Simula tu lanzamiento) (Spanish)
- ExoMars 2022
- ExoMars rover instruments
- ExoMars Raman Laser Spectrometer
- ExoMars MOMA Instrument
- Survey. What do we take to Mars? link

Phase 4

Credits

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- Previous guide: http://cesar.esa.int/index.php?Section=SSE_Mission_to_Mars_II&ChangeLang=es
- https://www.esa.int/
- http://cesar.esa.int/
- http://planetaciencias.es/