CESAR Scientific Challenge

Does Mars have seasons?

(Exploring Mars with *Mars Express* and *ExoMars*)

Teacher Guide

Table of Contents

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).

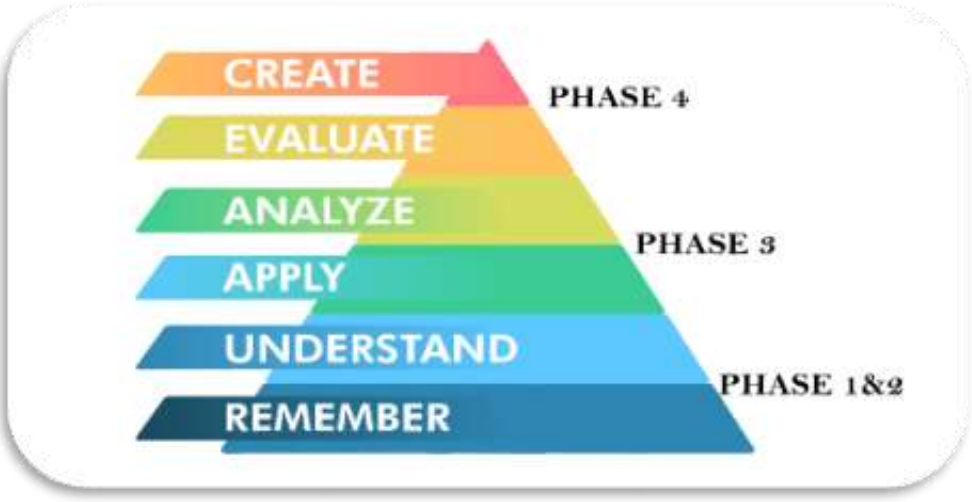


Figure II: *Bloom's Taxonomy diagram. (Credits:* https://medium.com/@ryan.ubc.edtech/*)*

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.

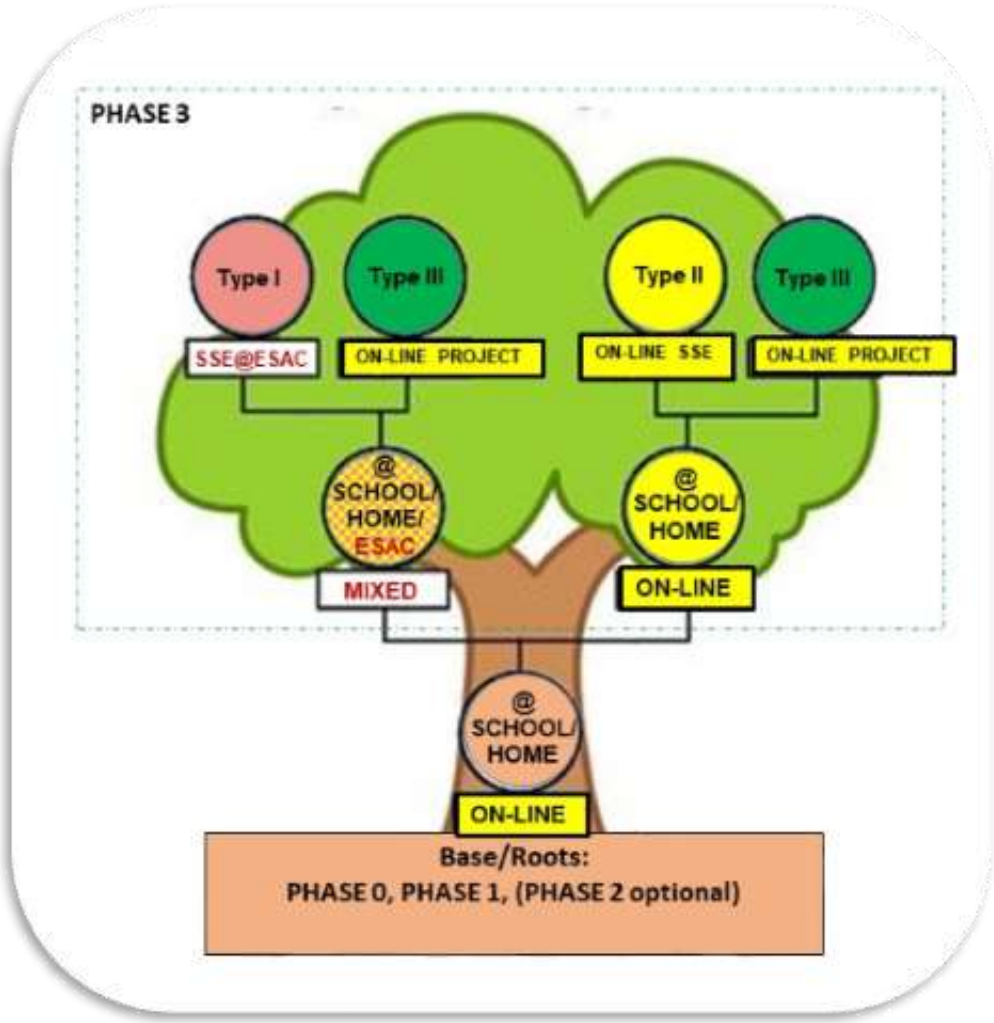


Figure III: Decision tree of the CESAR Experiences according to Phase 3 (Tipo I @ESAC, Tipo II y III, on-line) .In yellow are indicated those paths that can be run completely on-line.(Credits:teacherspayteachers.com)

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	1,3,4,5,6	8*	9	10	13	3h, 20min
ACTIVITIES (Adventure 2)	3 videos	1,3,4,5,6	8*	9	11.1	13	3h, 20min
ACTIVITIES (Adventure 3)	3 videos	1,3,4,5,6	8*	9	11.2	13	3h, 20min
ACTIVITIES (Adventure 4)	3 videos	1,3,4,5,6	8*	9	11.3	12	3h, 20min

- **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	1,3,4,5,6	8*	9,10	12,13	3h, 45min
ACTIVITIES (Adventure 2)	3 videos	1,3,4,5,6	8*	9,11.1	12,13	3h, 45min
ACTIVITIES (Adventure 3)	3 videos	1,3,4,5,6	8*	9,11.2	12,13	3h, 45min
ACTIVITIES (Adventure 4)	3 videos	1,3,4,5,6	8*	9,11.3	12,13	3h, 45min

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

PHASES	0	1	2	3 (@class/home)	4	Minimum duration
ACTIVITIES	3 videos	1,2,3,4,5,6,7	8*	9,10,11	12,13	4h 30 min

(*)The video call is optional, we recommend running the mentimeter if this is not done .

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:

Age range: 12-16

Type: Scientific challenge for students

Complexity: Medium

Preparation time: 1-4h

Time required: 3h - days

Location: Indoor

Includes the use of: Computers, internet

Currículum

General

- The method of science. The use of ICT

Physics

- Rotation of the planets.

Space/Astronomy

- Research and exploration of the Solar System.
- The stations.

You will need...

- web CESAR: http://cesar.esa.int/tools/18.martian_year/

More info...

CESAR booklets:

- "Mars"
- "The Solar System"

Abstract

In these activities, students will learn about Mars and its movements around the Sun.

Using real images taken by the VMC camera on board the Mars Express mission, we can observe the different stations on Mars.

The size of the polar ice caps will give students a clue about the station on Mars. With this information students will be able to estimate the duration of a Martian year.

They will also learn about the process of creating real missions to Mars, being part of one of ESA's teams to make the mission possible

Students should know...

1. The basics of how the seasons work on Earth.
2. How to identify features in images (e.g., polar ice caps)
3. The connection between the size of the poles and the polar caps and the stations
4. Mathematical elements.

Students will learn...

- The basic properties of Mars compared to those of the Earth.
- How to handle astronomical images?
- How the information, extracted from astronomical images, allows researchers to perform their scientific studies.
- The length of the Martian year.
- Process of a space mission

Students will improve...

- Their understanding of scientific thought.
- The strategies of the scientific method.
- Teamwork and communication skills.
- Evaluation skills.
- Your ability to apply theoretical knowledge to real situations.
- Your skills in the use of ICT.

Summary of Activities:

Phase	Activity	Material	Results	Requeriments	Time
Phase 0		Videos: • ESA • ESAC: The Window to the Universe • Dr. Javier Ventura	Students will improve: • Their ability to work in teams Students will learn: • What is ESA	None	25 min
Phase 1	1. *Refresh concepts*	• Latitude & Longitude • Eccentricity • Seasons simulation	Students will review concepts: • Coordinate systems. • Stations	None	10 min
Phase 1	2. *What do you know about Mars?* *2.1 Compare Mars and Earth proerties.* *2.2: The structure of Mars and Earth* *2.3: Atmospheric composition of Mars and Earth* *2.4: How much do you weigh on Mars and Earth?*	Fill Table 1	Students will improve: • Knowledge of Mars. • Their understanding of the scientific method. • Their strategies about scientific work. • The similarities/ differences between the Mars and Earth stations	None	15-30min
Phase 1	3. *Mars* *3.1.1.1.*		Students will improve: • The differences between the seasons of Mars and Earth	You must have done Activity 1 and we recommend Activity 2.	10 min
Phase 1	4. *The seasons.* *4.1. The seasons on Earth. Why are there winter and summer?* *4.2. Do you think that Mars has seasons? Would they be like those on Earth?*		Students will improve: • Their knowledge of the Mars stations. • Their understanding of the scientific method. Students will compare their hypotheses (Activities 2 and 3) with known data about Mars.	It is necessary to have done Activity 1 and we recommend Activities 2 and 3.	30 min

Phase	Activity	Material	Results	Requeriments	Time
Phase 1	5. *What impact do the seasons have on Mars?*		Students will learn: • The practical importance of studying a planet's stations for mission and research • Seasonally variable factors and their impact on the planet	It is recommended to have done Activity 4.	20 min
Phase 1	6. *Space exploration of Mars by the European Space Agency*	Depending of the time available, WEB: • Rosetta mission • Venus Express blogs / • Mars Express • News about Mars Express mission • The camera VMC • Roscosmos, • pictures from the movie "the Martian" • MarsExpress Team • ExoMars Team VIDEOS: • Mars Express • ExoMars • Missions 2020-2030	Students will learn: • How to work in the European Space Agency. • Space exploration. • How to recognize terrains on Mars. • How scientists obtain information. • Mars exploration missions • Scientific imaging and observation instruments • Equipment that forms a space exploration mission.	It is recommended to have done Activity 4 and 5	30-45 min
Phase 1	7. *What have you learned so far?*	questionnaire	Students will review the concepts learned so far through a Mentimeter game	It is recommended to have done activities 2,3,4,5,6	10 min
Phase 2	8. *Ask for a videocall with the CESAR team if needed*	http://cesar.esa.int/index.php?Section=Scientific_Cases&Id=15&ChangeLang=en	Students will have first-hand information from experts • CESAR teachers' course on-line talk • video call with an expert.	You should have done Activities 1 to 7	30 min -1 h

Phase	Activity	Material	Results	Requeriments	Time
Phase 3	9. *The seasons on Mars*	Web tool designing by CESAR Team	Students will learn: • What astronomical images look like. • How to identify patterns in real images (polar caps) • How to analyze variations in actual image patterns (size of polar caps) Students will improve: • Their abilities to use ICTs. • Their knowledge about the stations. • Their scientific and critical thinking.	It is recommended that you have executed Activities 1,2.1 and 4	20 min
Phase 3	*10. How long does a year last on Mars?*	Web tool designing by CESAR Team	Students will learn: • How scientists extrapolate information. • The length of a Martian year. Students will improve: • Their understanding of the scientific method and critical thinking. • Their strategies to work as scientists. • Their evaluation skills. • Their ability to apply theoretical knowledge to real life situations.	It is necessary to complete Activity 9 and it is advisable to have completed the previous ones.	20 min
Phase 3	*11. Join ExoMars* *11.1 Flight Dynamics Team.* *11.2 ExoMars Science Operations Planning Team* *11.3. Expert Team*	• video: orbital trajectory in order to get to Mars	Students will learn: • The importance of the study of stations for a mission • How ESA works. • To study possible terrains of Mars. • Mars exploration missions • Equipment that forms a space exploration mission.	It is recommended that you have executed Activities 4,5 and 6	30 min

Phase	Activity	Material	Results	Requeriments	Time
Phase 4	*12. Evaluate*	questionnaire	Students will check to see 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 evaluation skills. • Their ability to apply theoretical knowledge to real life situations.	Needed to have performed at least Activities 1,3,4,5, 6 ,9,10	10 min
Phase 4	*13. Present your results*	Free format for students (ppt, youtube, Word)	Students will improve: • Their teamwork and communication skills. • Their knowledge of Mars and its stations.	It is necessary to have performed at least Activities 1,3,4,5, 7,8 and 9	30 min – 2h

Your Scientific Challenge

Does Mars have seasons?

The VMC camera, located on the scientific satellite of the European Space Agency (ESA), Mars Express, is sending us images of the surface of Mars.

ESA scientists and engineers want to program the Mars Express observations to obtain information needed for the preparation of the future ExoMars 2020 mission, to be launched in 2022.

Can we count on you?

Figure 1: Mars (Credits: https://video.nationalgeographic.com)

If you help us, you will first identify variations in the images of Mars from the VMC camera, on board the Mars Express spacecraft, particularly in the area of the polar caps.

You will analyze whether these changes in the size of the poles are related to the seasons on Mars, as is the case with the seasons on Earth. If so, you could deduce the length of a Martian year.

Finally, you will calculate what date ExoMars could arrive on Mars, if the launch took place in September 2022 and what would be found at its arrival in different areas of the Mars surface, depending on the seasons.

We need help preparing the ExoMars mission, ***Are you joining ESA's Mars experts?***

Phase 0

In order to put into context, we recommend students to watch these **videos:**

- This is ESA (10 min)
- ESAC: ESA's A window on the Universe (3 min)
- Presentation to ESA/ESAC/CESAR by Dr. Javier Ventura (15 min)

We recommend to **work in teams**, of (4-6) people, with a clear role in their team, assigned per profession. Students will fill Table 0 for the coming Challenge with a name for their Team and the name of the team members after having agreed among themselves on their role in the team.

Challenge ID			**Team number (1-6):**	
Names				
Profession	**Mathematician/ Software engineer**	**Astrophysics**	**Engineer**	**Biologist**
Roles	Lead the correctness of the calculations	Lead the use of the telescope and the understanding of space missions.	In charge of finding the optimum strategy agreed among the team members and its correct execution.	Lead the more detailed research about the scientific understanding of the energetic processes and composition of the celestial objects.
Reference **(female)**	Katherine Johnson 	Vera Rubin 	Samantha Cristoforetti 	Marie Curie 
(male)	Steve Wozniak 	Matt Taylor 	Pedro Duque 	Albert Einstein 

Table 0: *Define the working groups for solving this Challenge.*

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

Phase 1

Activity 1: Refresh concepts.

Latitude & Longitude	Eccentricity Solar system movements	season simulator
Celsius to fahrenheit	How Earth Moves	Heat and Temperature.

Table 1: *Concepts that need to be refreshed before facing this scientific challenge.*

Activity 2: What do you know about Mars?

Write here what you know about Mars and if you think it has seasons

Mars, also known as "the Red Planet", because of its red-orange appearance, mainly because of the iron oxide on its surface. It is the fourth planet from the Sun and the second smallest planet in the Solar System after Mercury.

The first observations of Mars, with telescopes, were made by Galileo Galilei in 1610. Today we know that Mars is a rocky planet with a thin atmosphere and a very varied surface (craters, deserts, valleys, volcanoes). Mars is the largest volcano in the Solar System, Mount Olympus, with 27 km of height.

Mars also has polar caps, which vary with the seasons. Mars has a cold and thin atmosphere, which means that liquid water cannot exist in most places on its surface.

Activity 2.1: Compare Mars and Earth properties.

Complete the table and compare some properties of Mars with the Earth.

	Earth	Mars
Radius	6 371 km	3 389 km
Mass	~ 6 x 10^{24} kg	~ 6 x 10^{23} kg
Axis Tilt	23.5 degrees	25 degrees
Atmosphere	Yes, very dense	Yes, very thin
Polar caps	yes	yes
Average temperature	14ºC	-63ºC

Table 2*: Comparison of some properties of Mars and Earth*

Activity 2.2: Structure of Mars and Earth.

What differences do you think there are in the structure of Mars compared to Earth?

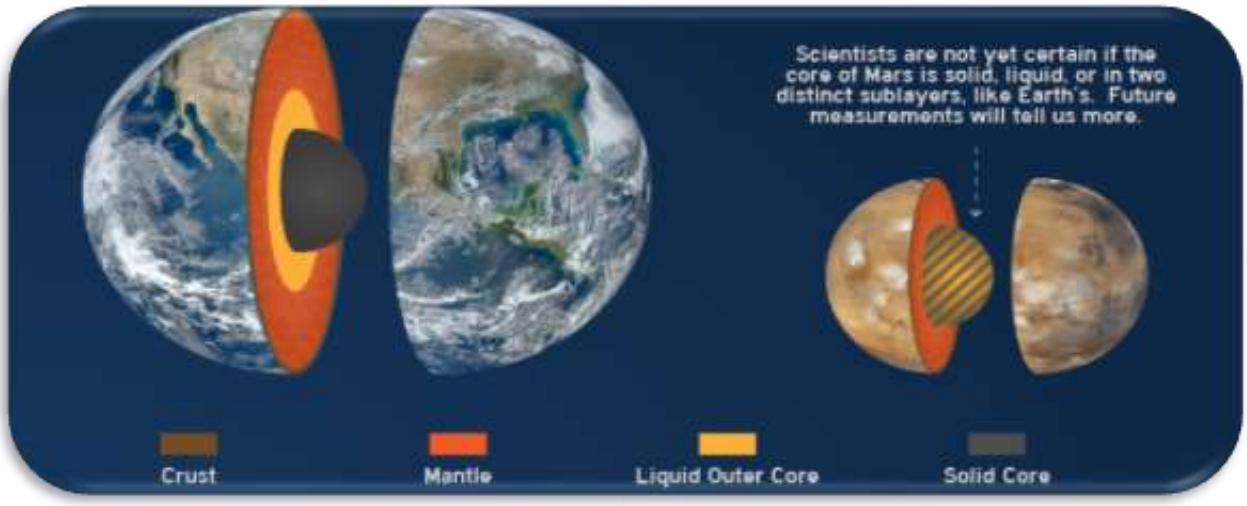


Figure S.1: It structures the Earth (left) and Mars (right). (Credits: NASA)

Activity 2.3: Atmospheric composition of Mars and Earth

What differences do you think exist between the composition of Mars' atmosphere and that of Earth?

Figure S.2: (Credits: ESA)

Mars has a cold and fine atmosphere. Its composition consists of 96% carbon dioxide, 1.93% argon and 1.89% nitrogen with certain traces of oxygen and water.

Activity 2.4: How much is your weight on Mars and Earth?

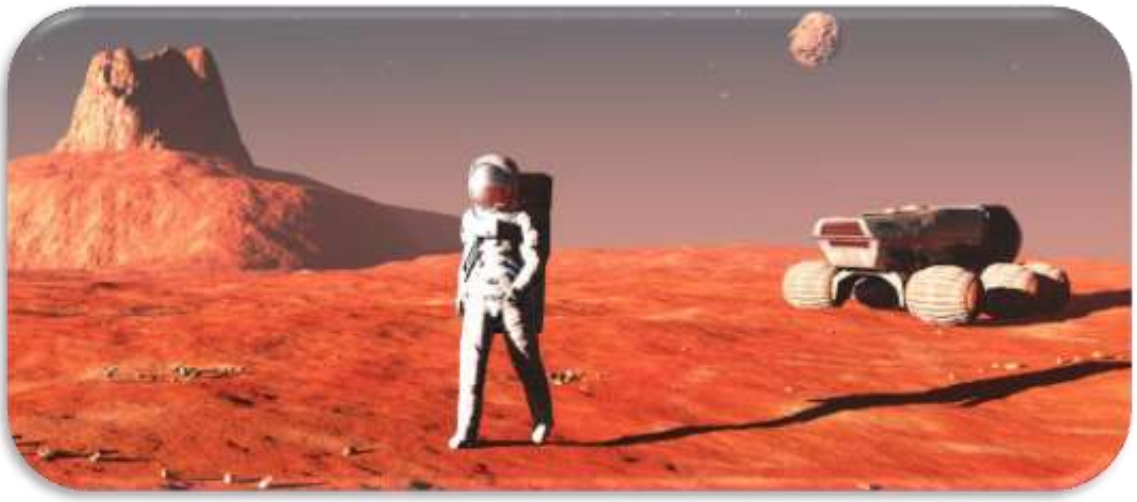


Figure 2: Mars mission astronaut representation (Credits:blastingnews.com)

Do you know how much you would weight on the surface of Mars? Calculate it!

To do this, keep in mind that gravity on Mars is one third of the gravity we experience on the Earth's surface (9.8 m/s^2)

Figure S.3: Weighing Earth vs. Mars (Credits: NASA)

P=m x g If a person has a mass of 50kg:

- On Earth it will weigh: P=mxg= 50 x 9,8= 490 Newtons
- On Mars with a gravity of 3,711 m/s^2 P=mxg= 50 x 3,71= 185,5 Newtons
- http://www.traducimos.cl/planet/ in this link you can calculate your weight in other planets

What consequences do you think the difference in gravity between Mars and Earth will have when defining a mission?

The attraction that the ship will suffer when approaching the planet has an impact on the design of the orbit (flight dynamics in general)

Activity3: Mars

Mars is one of the planets in our Solar System that can be seen with the naked eye. And since its discovery, astronomers have made multiple findings, such as dark patches on its surface and the presence of polar ice caps.

Thanks to numerous space missions, the surface and atmosphere of Mars have been tracked and today its composition is better known. Thus, gases similar to those in the Earth's atmosphere have been found in the Martian atmosphere, such as carbon dioxide, nitrogen, water vapor and some others.

It is also believed that in the past Mars may have been covered by seas of water, but the reasons why Mars evolved from a world with water to a dry world are not fully understood today.

Figure 3: Mars Express VMC camera images. (Credits: ESA)

Look at Figure 4 and tell us your hypothesis about what could have happened to Mars to lose its water on the surface

It is believed that Mars' atmosphere was much thicker when Mars was formed. Mars is believed to have lost its magnetosphere about 4 billion years ago, and because of this the interactions of the solar wind with the Mars ionosphere have been reducing the thickness of its atmosphere.

Mars has a thin, cold atmosphere, which means that liquid water cannot **exist for long on its surface but it pass from ice to water vapor**.

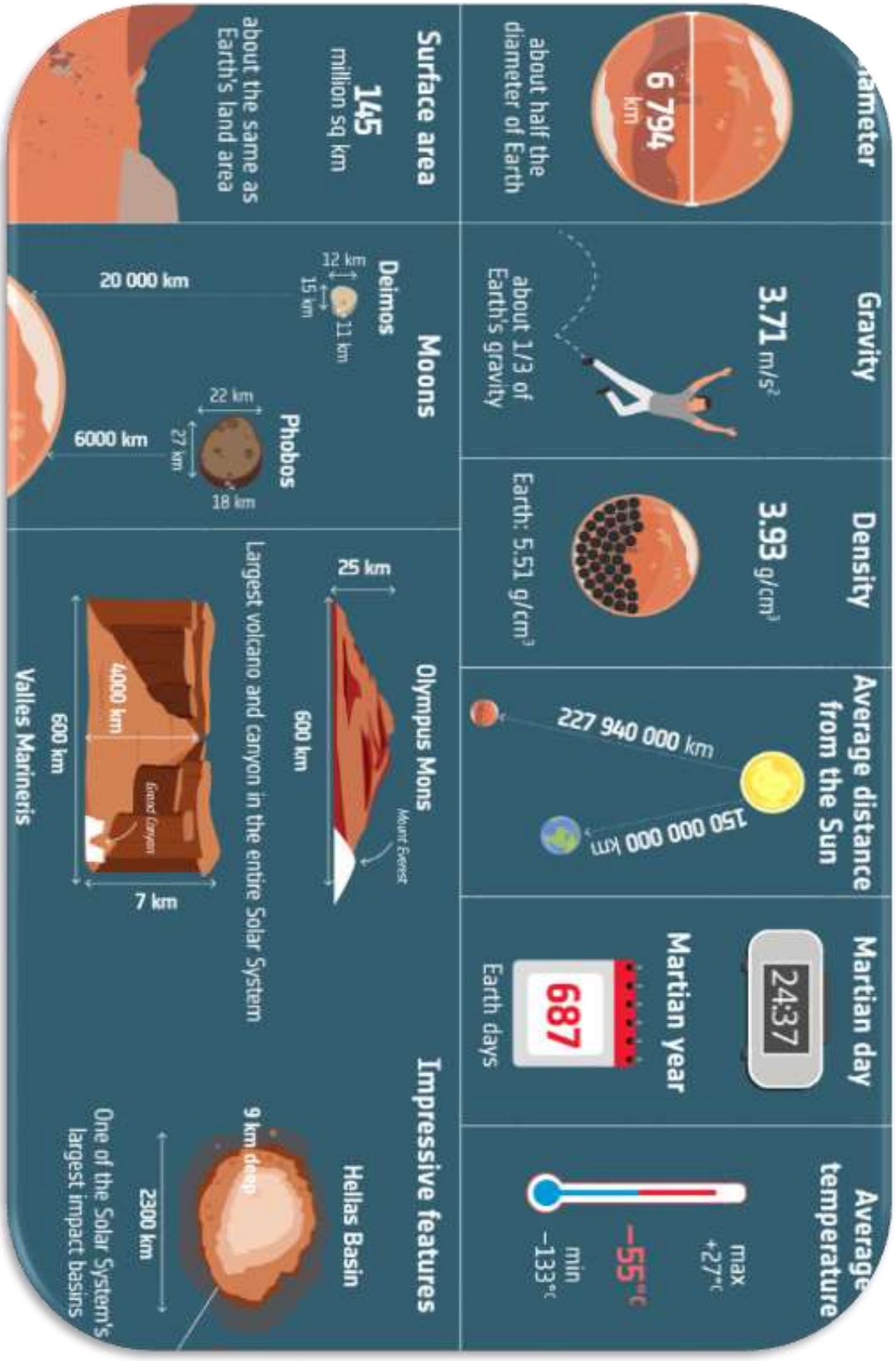


Figure 4: Meet Mars. (Credits: ESA)
https://www.esa.int/Science_Exploration/Human_and_Robotic_Exploration/Exploration/ExoMars/Meet_Mars

Activity 4: The seasons.

Activity 4.1: The seasons on Earth: Why are there winter and summer?

If you live in Europe, it's cold in January and hot in July. Do you think this happens the same in all parts of the Earth?

Figure 5: Seasons on Earth (Credits: https://www.freepik.es)

Explain why the seasons and how you think they vary in different parts of the Earth.

The Earth rotates around the Sun and is tilted 23º, that is, the Earth's axis is not perpendicular to the plane of the solar system and that this is the reason for the seasons on Earth

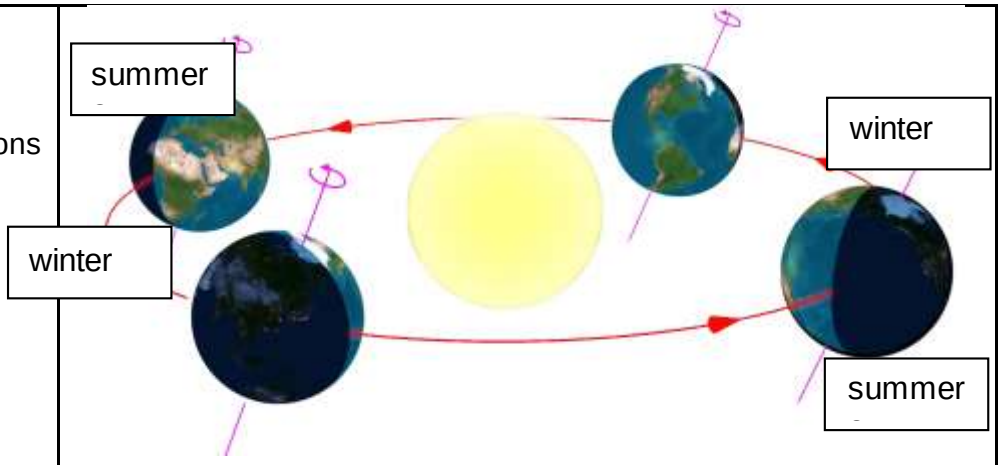
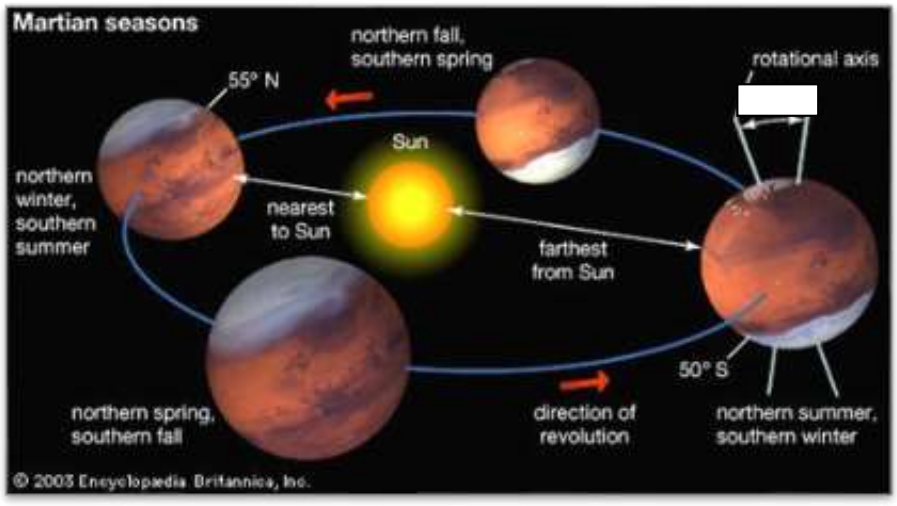
Figure S.4: Earth axis tilt - seasons (Credits: ESA)

Activity 4.2: Do you think that Mars has seasons? Would they be like those on Earth?

1. **Do you believe that Mars has seasons?** If so, what do you think is the cause?

Similar inclinations of its axis mean that Mars has seasons just like the Earth. Mars' axis of inclination is 25 degrees.

2. Look at the information in Figures 6 and 7, which explains why there are seasons on Earth and Mars. Identify the different seasons for the northern and southern hemispheres and write them down in these Figures

Diagram of the seasons on Earth	 ***Figure 6:*** *Orbit Earth around the Sun (Credits: www.astromia.com)*
Diagram of the seasons on Mars	 ***Figure 7:*** *Orbit of Mars around the Sun. (Credits www.britannica.com)*

3. What do you think the similarities between the seasons on the Earth and on Mars might be?

Mars has seasons that are very similar to those on Earth. The seasons are produced by the tilt of Mars' axis of rotation.

4. What do you think the differences between the seasons on the Earth and on Mars might be?

However, because Mars is at a greater distance than the Earth from the Sun, the length of the seasons on Mars are longer. Due to the high eccentricity of Mars' orbit, summer temperatures in Mars' southern hemisphere are higher than in its northern hemisphere.

Mars has the largest dust storms in the Solar System. These storms occur on Mars on a regular basis during the southern hemisphere's summer season, when the planet is closest to the Sun.

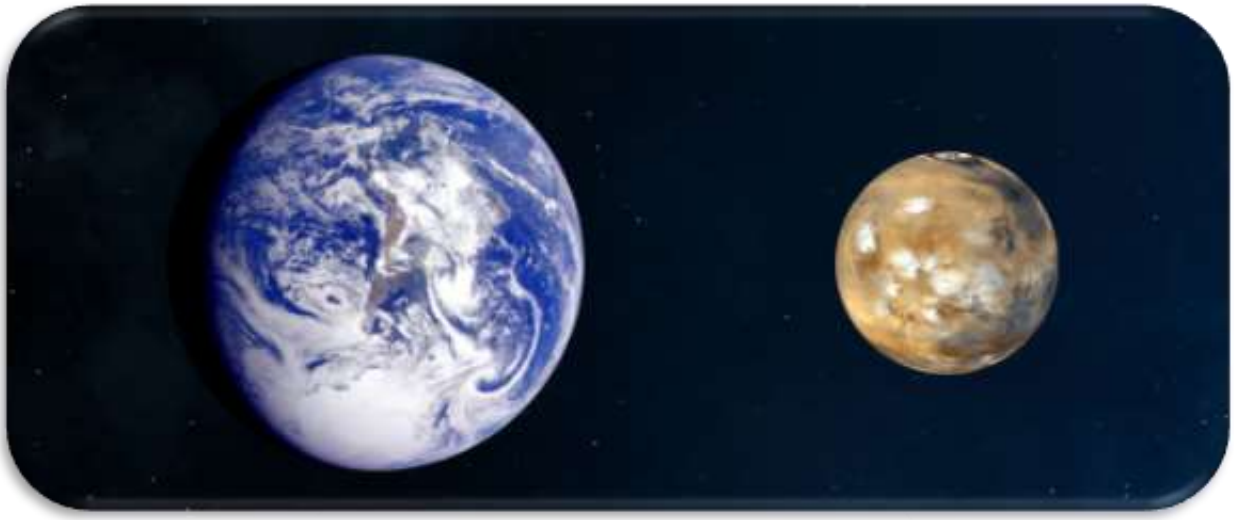


Figure 8: Mars and Earth (Credits: www.livescience.com)

5. How important can seasons be when planning a mission to Mars?

Take into account the investigations that are carried out in each seasons (explained in Activity 5) and the conditions to which the mission may be subjected due to seasonal changes

In Figure 9 we can see the Earth (inner circle) and Mars (outer circle) rotating around the Sun. The different colors painted on the circumference represent the different seasons, **being** *green* for the spring, *brown* for the fall, *blue* for the winter and *yellow* for the summer.

Figure 9: Mars and Earth orbiting around the Sun. (Credits: www.nakedeyeplanets.com) image link: http://www.nakedeyeplanets.com/mars-orbit-&-seasons.png

6. Look at Figure 9 and reply to the following questions:

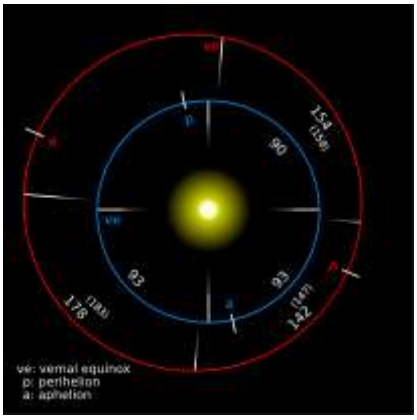
Do you think that seasons on the Earth and on Mars happen at the same time or is it any time delay?

The seasons on Mars and on the Earth are shifted by one season. When the Earth and Mars are in the same quadrant of their orbits, Mars is about one season ahead of the Earth

.

Why do you think that seasons do not match in time for both planets?

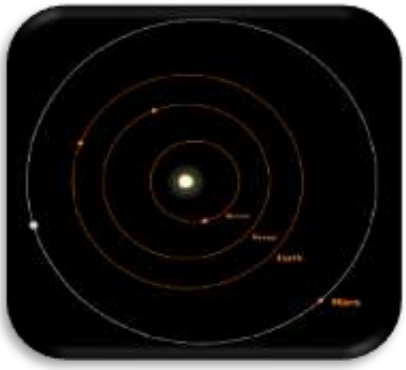
The rotation axes of Mars and the one on Earth are tilted at very similar angles respect to the planes of their orbits. These angles are ~ 25° for Mars and ~23° for the Earth. However, the axes of the two planets do not point in the same direction in space; there is a difference of approximately 95° in longitude for the perigees of their orbits.



https://en.wikipedia.org/wiki/Timekeeping_on_Mars

Activity 4.3: Duration of seasons on Mars

Kepler's Laws were a great revolution in the 17th century. With them scientists were able to make very precise predictions of the movement of the planets. Kepler's laws can be summarized and tested with the Kepler's laws simulator:

Kepler's law	**Simulator**
First Law: The orbit of each planet is an ellipse, with the Sun in one of the two focuses.	
Second Law: A line connecting a planet and the Sun sweeps out equal areas for equal intervals of time	

Activity 5: What impact do seasons have on Mars?

In this Activity we will analyze the impact that seasons have on Mars. Look at the following Figures and try to answer the questions. Try to keep in mind all this information (in Activity 11) to identify later in your Challenge (Activity 11) the impact of these factors at your landing.

The climate

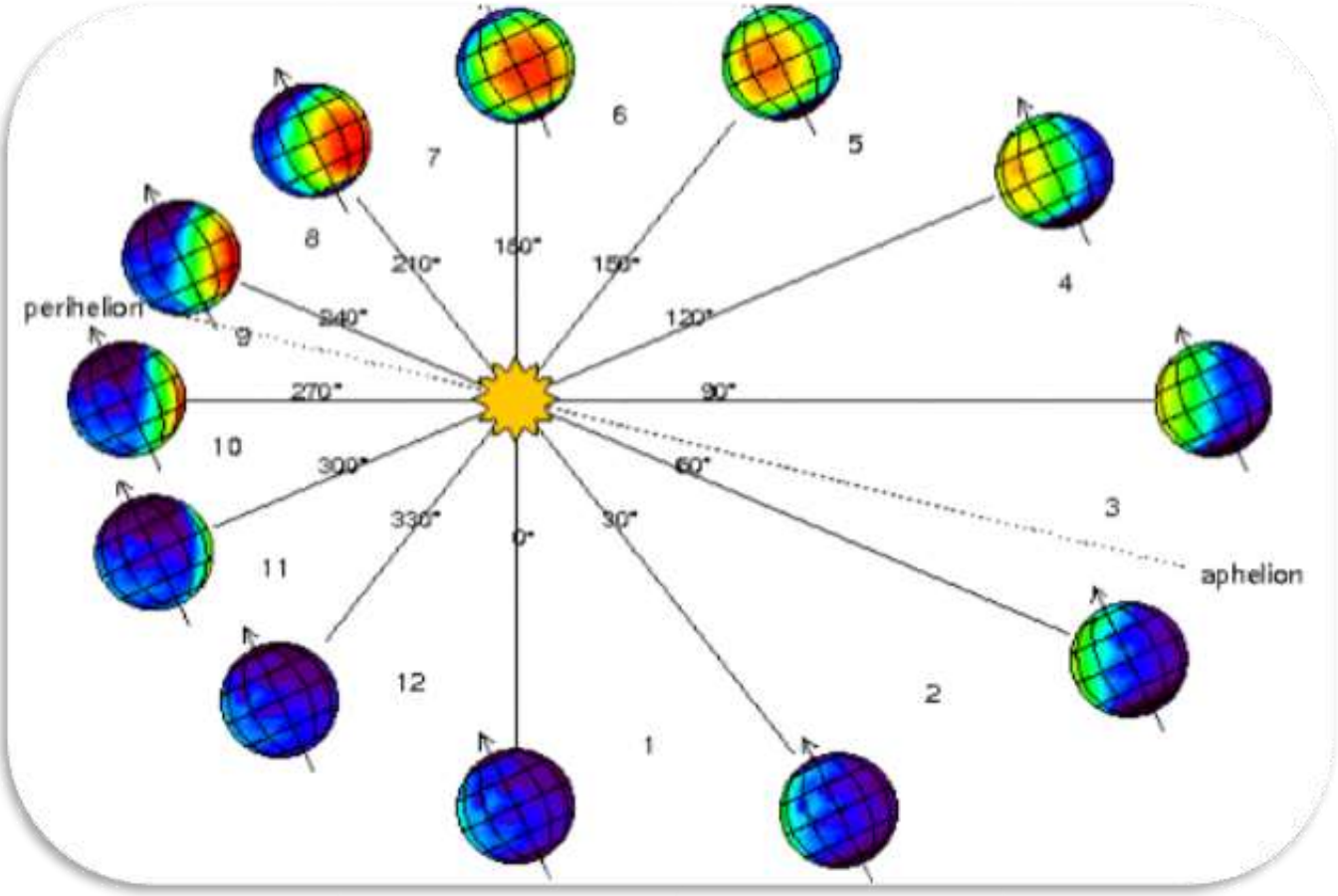


Figure 10: The climate of Mars (Credits: ESA)

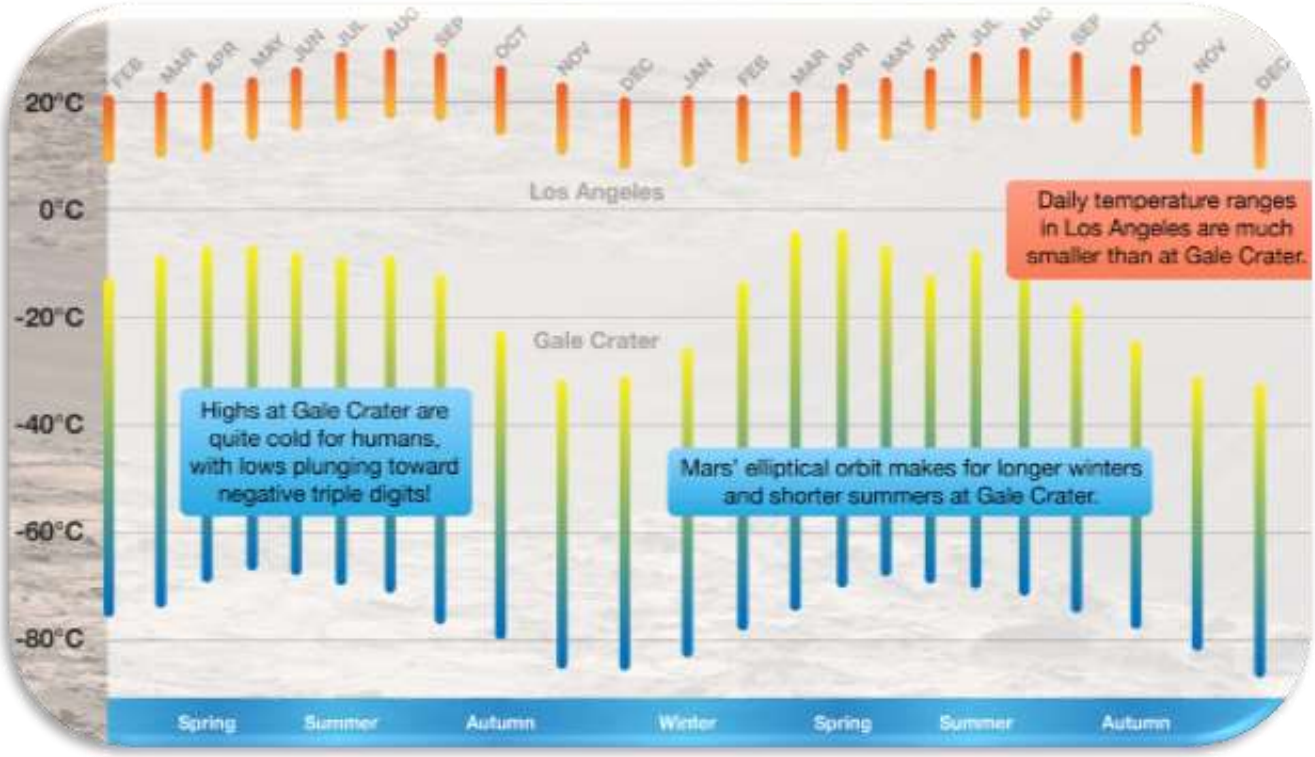


*Figure 11: Mars and Los Angeles weather comparison, CA (Credits: **astronomynotes**)*

According to Figures 10 and 11, how do you think the climate changes with the seasons on Mars and on Earth? What implications can it have for our mission to take into account?

The thin atmosphere of Mars does not trap much heat even though it is 95% carbon dioxide (CO 2). Because the atmosphere is so thin, the greenhouse effect is negligible and Mars has a rapid cooling. During winter, the temperature drops to -130°C. During the summer, they are warmer in the southern hemisphere, where summer occurs near the perihelion. The surface temperature can approach +25C near the equator, strong winds are produced by large daytime temperature fluctuations.

It is worth noting that while the wind speed can be very high, even the strongest winds on Mars would feel like a gentle breeze on Earth, due to the thin Martian atmosphere. However, the Martian winds are sufficient to produce impressive dust whirls and seasonal dust storms that can be global in scope. The biggest dust storms are in the summer of the southern hemisphere. **http://www.astronomynotes.com/solarsys/s10.htm**

Dust storms

In Figure 12 you can see the seasonal changes that Mars experiences due to the giant dust storms that take place on its surface. What do you think these storms are due to?

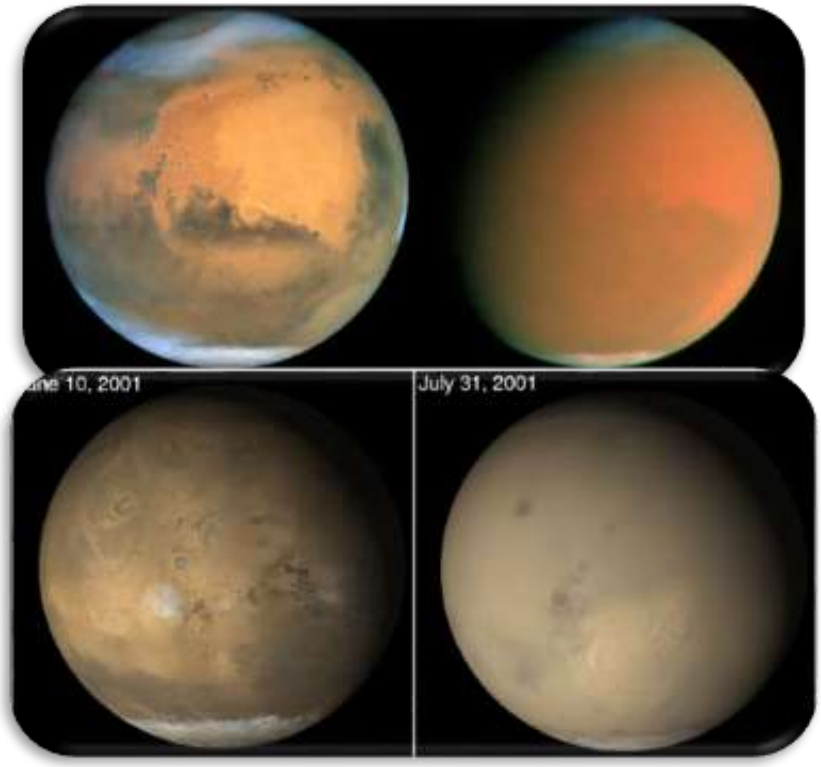
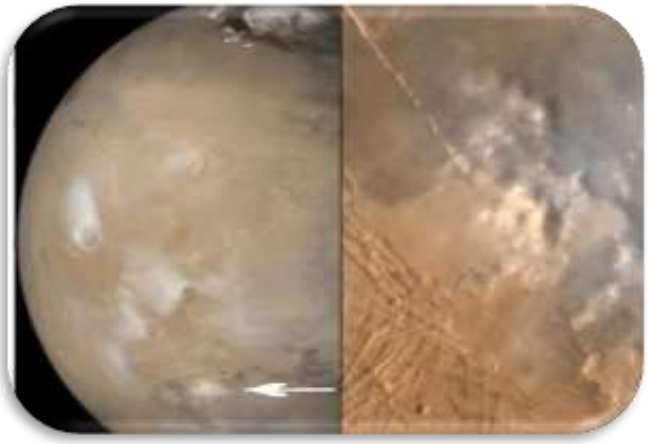


Figure 12: Mars dust storms (Credits: www.alpo-astronomy.org)

The temperature on Mars changes caused among seasons. This produces strong winds, which raise dust and in a few weeks can produce dust storms that cover the entire planet for a few months.



Dust storms start most often in the desert regions near Serpentis: Noachis (0°, 45° S), Solis Lacus (80° W, 20° S), Chryse (25° W, 10° N) or Hellas (292° W, 50° S). That is, during the summer period of the southern hemisphere.

There is a "peak" of secondary dust storm in the early summer of the northern hemisphere.

It is worth noting that while the wind speed can be very high, even the strongest winds on Mars would feel like a gentle breeze on Earth, due to the thin Martian atmosphere. However, the Martian winds are sufficient to produce impressive dust whirls and seasonal dust storms that can be global in scope. The biggest dust storms are in the summer of the southern hemisphere.

http://www.astronomynotes.com/solarsys/s10.htm

http://www.astronomynotes.com/solarsys/s10.htm

Variations in the size of the polar caps

During the winter the light does not reach the Mars pole (for that hemisphere) while during the summer that pole is continuously illuminated.

Figure 13: Images taken by VMC camera of Mars in a Martian year (Credits: ESA)

Look at Figure 13 and answer the question: Do you think that polar caps change a lot between winter and summer?

Mars has two permanent polar caps. The caps of both poles consist mainly of water ice. Frozen carbon dioxide accumulates as a comparatively thin layer about one meter thick on the northern ice cap in the northern winter, while the southern ice cap has a permanent dry ice cover about 8 m thick.
In fact, MEX's discovery of lakes in the southern polar ice cap is several kilometers thick.
Like the Earth's polar caps, the Martian polar caps are greatly affected by the tilt of the planet's axis in space. They are seen to contract and expand

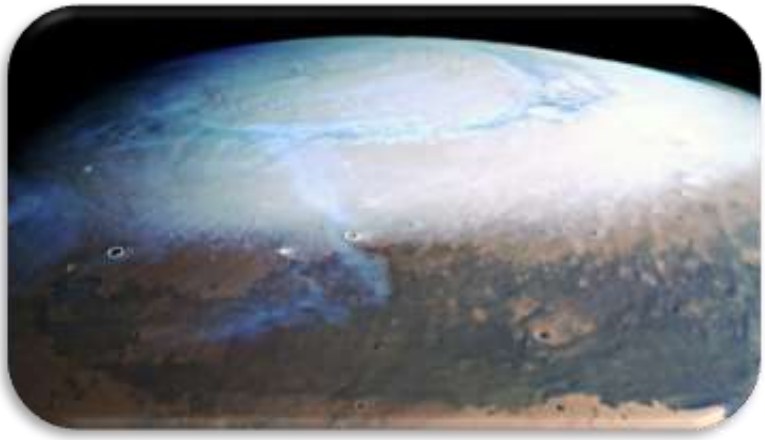


Figure 14 North Pole Mars (Credits: ESA)

The mystery of the Methane

On Mars, like oxygen, methane is constantly in the air in very small amounts (0.00000004%). While **methane increases and decreases seasonally**, it increases in abundance by approximately 60% in the summer months for unexplained reasons.

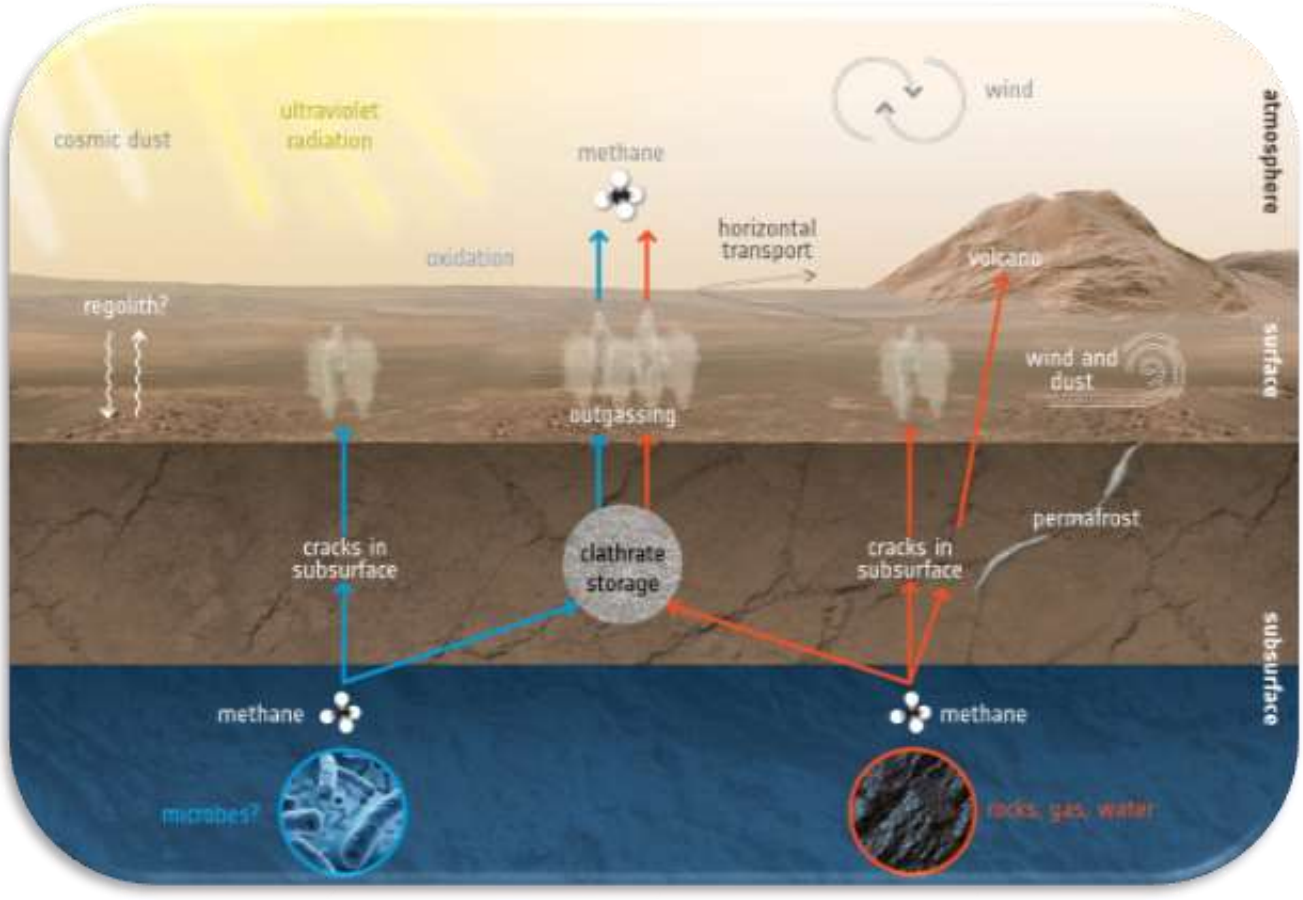


Figure 15: Processes of methane appearance on Mars (Credits: exploration.esa.int.)

By looking at Figure 15 try to guess why do you think it is important to discover methane on Mars?

Oxygen and methane can be produced both biologically (from microbes, for example) and abiotically (from water and rock chemistry). Scientists are considering all options, although they do not have any convincing evidence of biological activity on Mars. There are no instruments that can say definitively whether the source of methane or oxygen on Mars is biological or geological. Unfortunately, the ExoMars Trace Gas Orbiter has been unable to detect methane on Mars. Previously unknown spectral features of ozone are known to occur at the wavelength of the suspected methane feature and are postulated as an alternative explanation for the spectral features that have been labeled as methane.

https://exploration.esa.int/web/mars/-/46038-methane-on-mars.

Activity 6: Exploration of Mars by the European Space Agency

Since the beginning of the space age, satellites from different world agencies have been sent to explore Mars. This has provided scientists with a lot of data, broadening our knowledge of the Red Planet, but it has also opened up many new questions to investigate in the future exploration of Mars, such as, **has there ever been life on Mars? Was Mars ever covered with seas that have disappeared over time?**

Mars Express

It was the first mission of the European Interplanetary Space Agency in charge of the exploration of Mars. It is named after the speed of the construction of the spacecraft, based on the design of the Rosetta mission and Venus Express. The Mars Express orbiter is successfully taking scientific data from Mars since 2003, carrying on board the satellite different instruments capable of measuring the composition of the planet and its thin atmosphere.

Figure 16: Artist's impression of the Mars Express mission to Mars (Credits: ESA)

VMC camera

Mars Express carries on board a unique instrument, similar in resolution and color to the webcams we have at home in our computers. It was placed on board the satellite to monitor instrument health and scientific operations, as well as the descent of the Beagle 2.

Figure 17: Images from the Mars Express VMC camera on Mars. (Credits: ESA)

The VMC camera, named after Visual Monitor Camera, is like an ordinary camera placed in an extraordinary location, allowing us a global view of Mars. Its more than thousands of images of Mars in which we can see the entire disk of the planet, allow us to study the evolution of clouds, dust storms and variations in the polar caps. Your data will be used in our Scientific Challenge.

- VMC: https://blogs.esa.int/mex/2015/03/17/what-is-vmc/
- Mars's Webcam: https://blogs.esa.int/vmc/
- Data Archive VMC: https://blogs.esa.int/vmc/vmc-data-archive/
- VMC images: https://www.flickr.com/search/?text=VMC%20Mars%20Express
- Blog: https://blogs.esa.int/mex/2016/08/05/vmc-grows-up/

ExoMars

ExoMars (Exobiology on Mars) is a joint project of the European Space Agency (ESA) and Roscosmos. ExoMars searches for signs of life on Mars in the past and present, studies the composition of its atmosphere, investigates water and its sources of origin, while testing the technology for future manned missions**. ExoMars** consists of two missions**, the ExoMars 2016 Trace Gas Orbiter (TGO),** which observes the atmosphere and surface of Mars (from 2016), and the ExoMars 2022 rover and surface platform, which will enter the atmosphere of Mars and explore Mars from its surface, thanks to the **Rosalind Franklin rover.**

ExoMars searches for signs of life on Mars in the past and present, studies the composition of its atmosphere, investigates water and its sources of origin, while testing the technology for future manned missions.

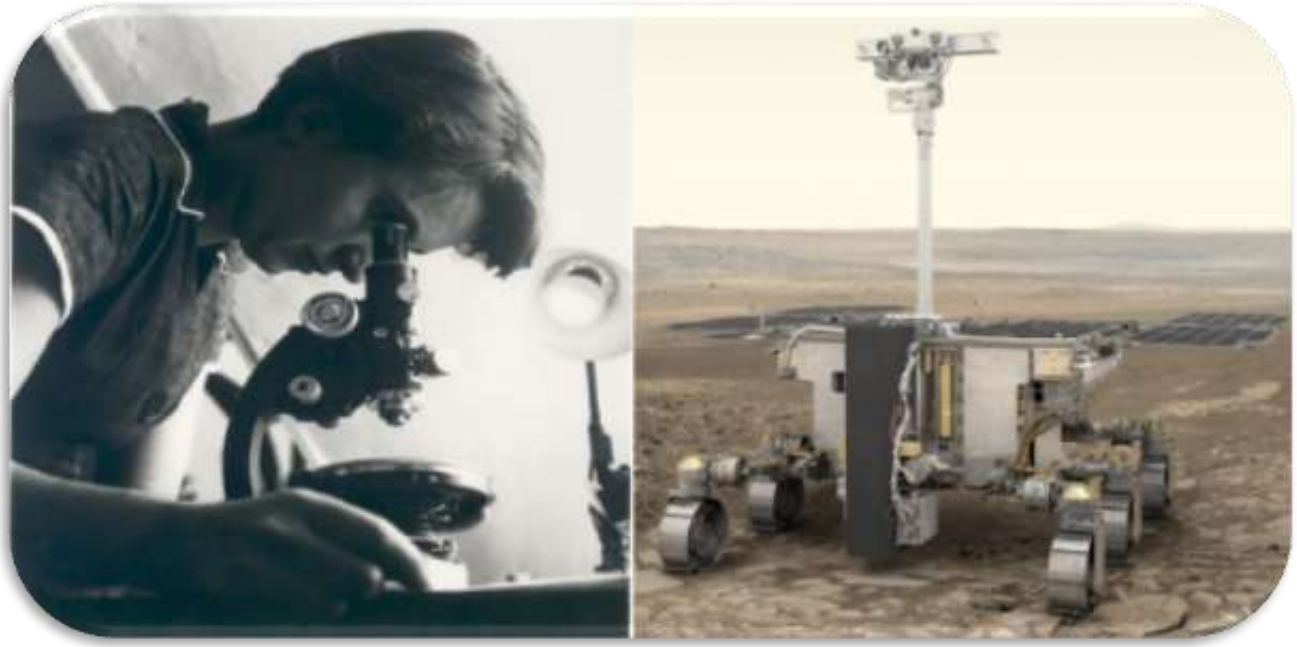


Figure 18: rover Rosalind Franklin. *(Credits: ESA/INTA)*

European Space Agency Teams dedicated to the Mars Exploration

Getting to Mars is a challenge! That's why a great team of professionals specialized in different fields is needed to make the mission possible (MarsExpress Team and ExoMars Team). For simplicity, Table 3 shows three representative locations on European Space Agency missions with professionals working on Mars missions.
We recommend that you cut out the squares and look for the pairs. Solution given here.

SCIENCE OPERATIONS CENTRE SOC • Where the scientific operations of the missions to Mars are carried out (they define the observations) • The team consists of engineers and scientists in contact with the experts of the instruments (in the dedicated institutes). • In continuous contact with the MOC In ESAC there are also archives of the missions to Mars (PSA), in charge of the data for scientific publications. *Figure 19: Mars Express Science Team Engineer (Credits: ESA/ ESA Open Day)*	European Space Astronomy Centrel, **ESAC,** Madrid 
CENTER FOR DESIGN, INTEGRATION AND TESTING OF SATELLITE COMPONENTS • Where the design, integration and testing of the satellite and the mission support systems (such as the rover) are performed. • The team is formed by engineers and scientists in charge of the integration of the different instruments in the satellite platform to later carry out the tests that simulate take-off and flight conditions (vibration, extreme temperature changes) *Figure 20: Rover testing team. Credits: ESA*	European Space Research and Technology Centre, **ESTEC**, The Netherlands 
MISSION OPERATIONS CENTRE. MOC • Where the orbit of the spacecraft is designed and safety requirements are ensured. • The Team consists of engineers and operators who control the data traffic between the scientific satellites and the ground segment through antennas and ensure the correct execution of the commands (for data acquisition and orbit/landing) as well as the health of the instruments on board. • In continuous contact with the SOC. *Figure 21: MOC's flight dynamics team; in particular the successful landing of Rosetta*	European Space Operations Centre, **ESOC**, Germany 

Table 3: *European Space Agency missions with professionals working on Mars missions*

Figure 22 shows the space missions that have gone to Mars of all the Space Agencies of the World. (Recommendation: click the link)

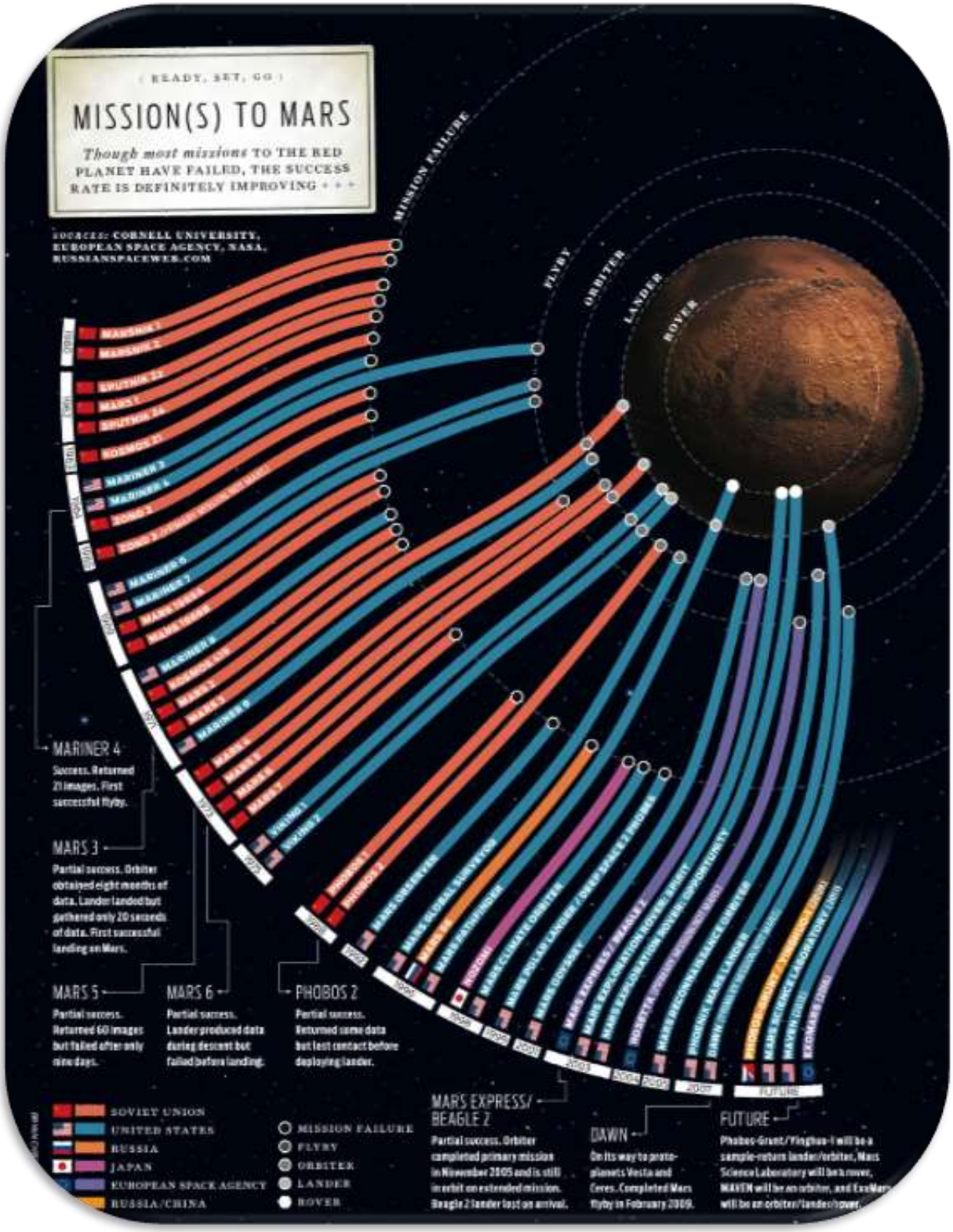


Figure 22: Missions to Mars. (Credits: Cornell University).

Activity 7: What have you learnt so far?

Check what have you 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 (quizz)

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

- **Case 2:** Your students did not reply very well to the quizz 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=15&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

Activity 8: Ask for a videocall with the CESAR Team if needed

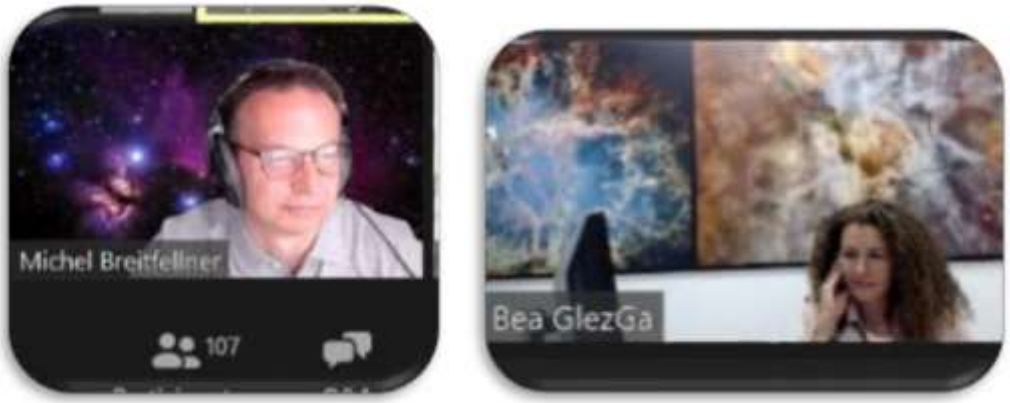


Figure 23: *Image of the CESAR Team making a video call (Credits: ESA)*

Note: Per scientific challenge you have the opportunity to ask for 30 min video calls

- with your class (in PHASE 2) to clarify concepts
- with the teacher (in PHASE 3) in case you are stuck with software/answers

Phase 3

Phase 3 is going to be executed following **the scientific method** were students make hypothesis, do some experiments with real data and finally check their results/conclusions with their hypothesis.

The data used for their experiments are images collected by the VMC camera, on board the Mars Express mission during more than two years (2016-2018), where we see Mars at different seasons and therefore we can calculate the duration of a Martian year.

In the webtool developed by the CESAR Team, Activity 10 is executed after Activity 9 and for that to work **we should not close the web tool between Activities 9 and 10.**

Activity 9: The seasons on Mars

Hypothesis

What information in scientific images of Mars could give you clues about the season?

The location of the polar caps, which are larger in winter than in summer. The appearance of dust storms that cover the surface of Mars, especially in summer.

Experiment

1. Access images from the Mars Express VMC camera and identify Mars seasons by clicking on the web tool: http://cesar.esa.int/tools/18.martian_year/index.php?ChangeLang=en

Do not close the tool between Activities 9 and 10!!

2. Execute the following steps:

- **Step 1/5:** Select from which hemisphere you will analyze the Mars images
  - From the northern hemisphere
  - From the Southern Hemisphere
  - From both hemispheres

- **Step 2/5:** Once you have chosen a hemisphere, identify which season each image corresponds to Hint: the size of the polar cap will help you in this identification.

Figure 24: The home page to the "seasons on Mars" web tool and Step 1. (Credits: CESAR)

Figure 25: Step 2 of the Mars seasons web tool for Southern Hemisphere images. (Credits: CESAR)

- **Check your results by clicking on the "Check" button!!**

- **Note 1**: In this activity you will not have enough information to differentiate, by the size of the polar cap, if you are in spring or autumn. We could only identify this if we see the temporal evolution of the images to get the picture whether we come from summer or winter.
- **Note 2**: On Mars, just as on Earth, neither the North nor the South Pole receives light during the winter. In the cold winter the carbon dioxide (CO2) in the atmosphere freezes from gas to ice - forming part of the polar caps. When winter ends and sunlight begins to heat the poles, the CO2 in the polar caps does not melt into a liquid like water, but changes from a solid state to a gaseous state (a process called sublimation), passing these gases into the atmosphere while reducing the size of the polar caps.

Conclusion

Explain in Table 4 why you have considered that image 1, 2 and 3 (see Figure 25) belong to one or another season.

Summer	*Spring/Autumn*	*Winter*
Image 3, very small polar cap	Image 1 and 2, intermediate size of the polar cap	We do not see images of this type in Figure 25, it almost does not give light to the planet in that area

Table 4: Explain why you chose each of the season in the selected images.

Activity 10: How long does a year last on Mars?

Hypothesis

How long do you think a Martian year lasts? How many Martian years would you have?

More or less two earth years.

If I am 24 years old on Earth, I would be about 12.7 years old on Mars.

Now that you have learned to identify the passage of time (seasons) on Mars by looking at the evolution of the size of the polar caps, try to identify the length of a year on Mars.

Experiment

Execute steps 3 to 5 of the web tool you are working with. http://cesar.esa.int/tools/18.martian

- **Step 3/5:** Select a set of 6 images from the VMC camera that you consider to cover the same Martian year.

  - **Note 1:** All the images selected for the estimation of a Martian year must belong to the same hemisphere (in the tool, those belonging to the northern hemisphere are identified with a pink magnifying glass and those belonging to the southern hemisphere with a blue magnifying glass).
  - **Note 2:** Each image is associated with an identifier. The numbering of the identifier **YY-XXX** corresponds to:
    - **YY:** earth year in which the image was taken. For example, 16 refers to the year 2016.
    - **XXX:** or DOY (Day Of The Year), which ranges from 1 to 365 (or 366 days in the case of leap years). For example, DOY 32 corresponds to February 2.
  - **Note 3**: Some images displayed in the tool appear almost dark. These correspond to the winter of Mars, but since they are overexposed we will not use them

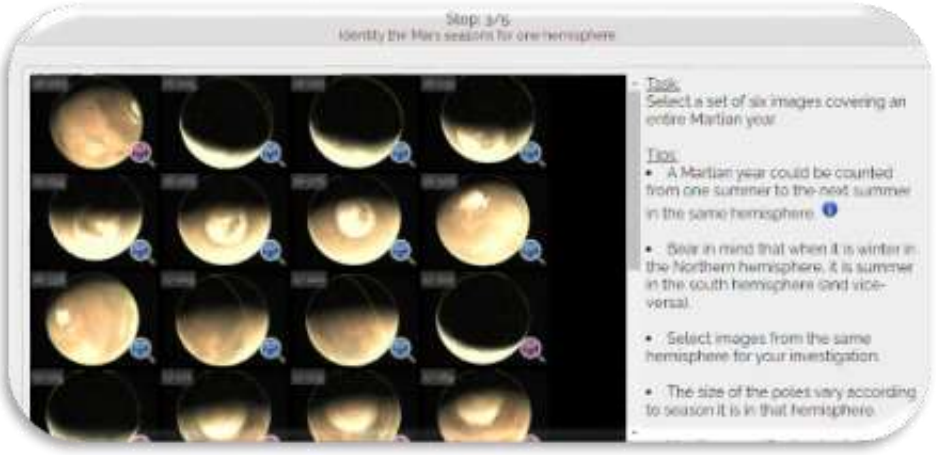


Figure 26: Step 3 of the CESAR tool. Pink magnifying glass identifies the northern hemisphere images of Mars and blue magnifying glass the southern hemisphere images (Credits: ESA /Mars Express/VMC – CC BY-SA IGO 3.0)

(Optional): If you want you can write in Table 5 the year and day of the selected images, otherwise the information is stored in the webtool for your experiment.

Image Identifier	Year	DOY
17-189	2017	189
17-288	2017	288
17-264	2017	264
16-060	2016	60
17-171	2017	171
17-171	2017	227

Table 5: Year and day of the images you have chosen to calculate a Martian year.

- **Step 4/5:** Enter the time between the first and last image chosen. This will be your estimate of the duration of a Martian year. Tip: You need to do the calculation mentally or in a paper outside, the webtool will not make it from the selection of the images)

Figure 27: Step 3 of the web tool - image gallery. Credits: CESAR)

- **Step 5/5: Check your results by clicking on the "Check" button!**

Conclusions:

Based on your calculations, how long does a Martian year last?

(do the calculation here)

Date of Image 1: (Year 2016, DOY: x)

Date of Image 2: (Year 2018. DOY: y)

Result = 593 days

Dates are measured referenced to Earth time.

Note: the exact martian year duration is 687 days, therefore with the optimum selection of images provided in this experiment there is an error in the measurement of 13 %.

[(687-598)/ 687] * 100 = 13 % error

The webtool provides percentages of error in our calculation being almost 40% of it considered acceptable and worst results requires repetition of the Activity (so it was coded the webtool).

How old would you be in Martian years?

If I'm 24, I'll be 12.7 on Mars

Activity 11: Join ExoMars

As we have seen in Activity 6, a space mission is formed by several Teams, all of them necessary and working in collaboration for the good result of the mission.

We will work in Teams, as if we were part of the ExoMars 2020 mission. We are going to see the different tasks performed by the different specialized Teams to better understand their functions. We recommend that all Teams perform all the Activities.

1. Flight Dynamics Design and Implementation Team - Activity 11.1
2. Mission Planning Team - Activity 11.2
3. Expert Support Team - Activity 11.3

The common goal is to identify where to land the ExoMars Rover 2020, Rosalind Franklin

- Considering that you will land on Mars (with ExoMars) on the same hemisphere as the hemisphere where you live on Earth (for simplicity), obtain the arrival date and the season at your arrival to Mars as well as the enviromental conditions that you will find on that hemisphere.
- This Excel worksheet could be used to solve Activities 11.1 y 11.2 .Please make a copy of it and use this copy if desired.
  https://docs.google.com/spreadsheets/d/1VwPQVc5cmVAV7xJLIeJTXXWR34XoHW3b9KoPosn0x10/edit?usp=sharing

Activity 11.1: Flight Dynamics Team.

Now you are part of the Flight Dynamic Team to ExoMars

Figure 21: MOC's flight dynamics team; in particular the successful landing of Rosetta. (Credits: ESA)

Check the Activity 6 and write in which European Space Agency center you would work most safely with this profile:

At the European Space Operations Centre, ESOC, Germany

It is the mission's center in charge of controlling the ESA satellites:
There the orbit of the spacecraft is designed and the safety requirements are ensured.

- The Team consists of engineers and operators who control the data traffic between the scientific satellites and the ground segment through antennas and ensure the correct execution of the commands **(for data acquisition and orbit/landing) as well as for the health of the instruments on board**.

Getting to Mars in the shortest time possible is an important consideration in setting a launch date. Therefore, we want to be sure that we would launch ExoMars 2020 at the right time. Other factors that determine the launch date are:

- fuel consumption for the transfer orbit
- the time and orientation of the spacecraft's arrival
- Considerations about the landing site and the objectives of the scientific community.

The shortest transfer time may not offer the best mission profile and ExoMars has a number of quite different transfer scenarios with very different transfer times. Determining the optimal transfer is, of course, the task of ESOC Flight Dynamics

Mars and Earth orbit at different speeds (the two planets do not revolve around the sun at the same time, but sometimes they are far apart and sometimes they come closer together). Approximately every two Earth years (which we know from Activity 10 is about a Martian year), the two planets are in the perfect position to reach Mars in the shortest time possible.
But that's not all! In order to get to Mars we have to make sure that we point our ship well. **We have to arrive to where Mars will be when the ship gets there!**

- To understand it better look at this **VIDEO**

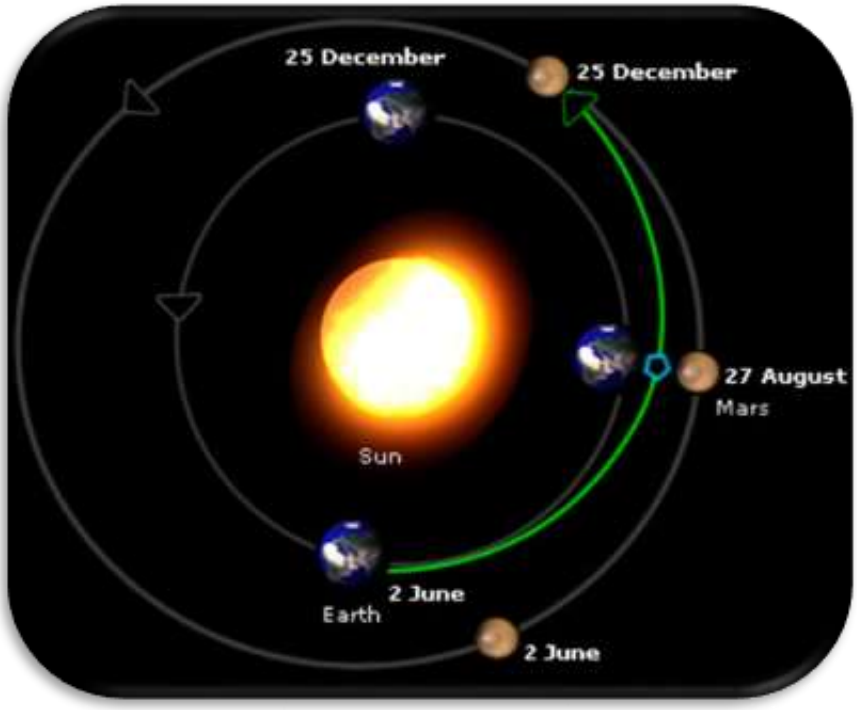


Figure 28: Trajectory followed by the Mars Express mission at launch (Credits: ESA)

Remember, you are part of the 'Flight Operations' team of ExoMars 2022, that prepares the mission before it is launched. The new launch schedule is set between August and October 2022.

1. If ExoMars launches in September 2022, what will be the date when it reaches Mars?

Taking as a reference the Figure 28, in which it is shown the Mars Express transfer orbit, where the trip to Mars lasts 6 months (following its shorter orbit), ExoMars will arrive approximately in March 2023.

Now, to start planning the ExoMars 2022 "Science Operations" (Activity 11.2), we need to inform the Team Science Operations Team for the possible seasons of the year (depending on the Mars hemisphere) when ExoMars could land on Mars.

2. To do this, remember what you learned in the Activity 4.3 and identifies:

o Earth seasons at the exit (from Earth) of ExoMars (September 2022):
o Season on Earth at the arrival (to Mars) of ExoMars 2022 (March 2023: spring/fall)

o Mars seasons at the exit (from Earth) of ExoMars 2022 (September 2023)
o Mars seasons at the arrival (to Mars) of ExoMars 2022 (March 2023: summer/winter)

If they had miscalculated the date of ExoMars but this part was consistent it would also be valid.

Activity 11.2: ExoMars Science Operations Planning Team

Now it is time to change our role in the ExoMars 2022 missions (if we had executed Activity 11.1 we were part of the Flight Dynamics Team) and became part of the ExoMars "Scientific Operations Team".

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

.

Check the Activity 6 and write in down in what centre of the European Space Agency r would you most probably be working with this profile (Science Operations Team)

At the European Space Astronomy Center, ESAC, Madrid
It is the center of scientific operations, where the scientific operations where the activities to be executed by each of the scientific instruments on board the ESA missions to Mars are carried out

As experts in the scientific instruments on board ExoMars, we must be clear about what scientific operations we would program, depending on the season and landing zone (landing on Mars). In March 2023**, Mars will be far from the sun: it will be summer in the northern hemisphere and winter in the south hemisphere**.

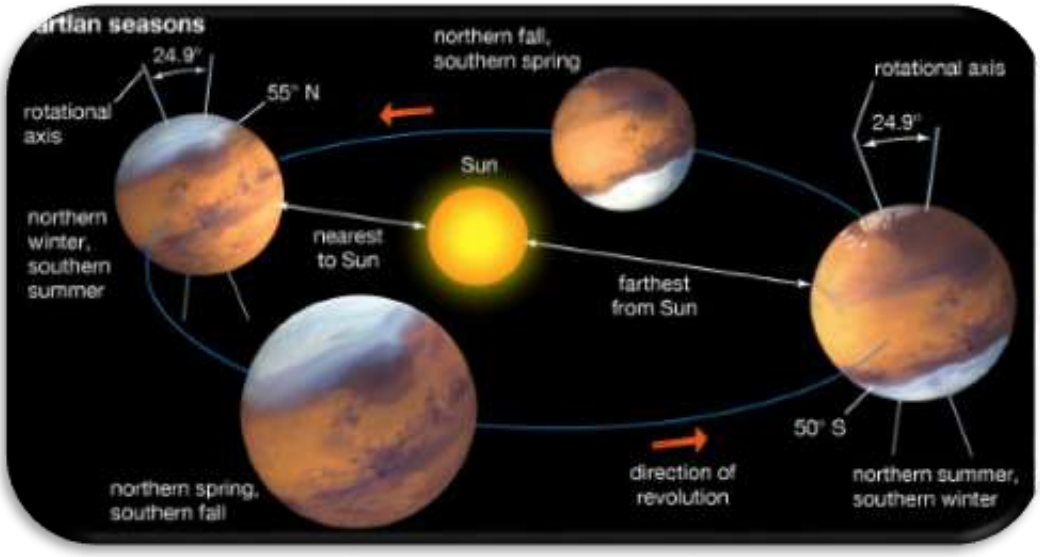


Figure 29: seasons on Mars (Credits: ESA)

Taking into account what we want to investigate, we must land in one hemisphere or another, because the seasonal circumstances will be different in each hemisphere.

1. Now decide in which hemisphere to land (in March 2023), taking into account the factors that change with the seasons. Review Activity 5 and fill in Table 6:

DATE : MARCH 2023		
FACTORS	**SUMMER @Northern Hemisphere**	**WINTER @Southern Hemisphere**
The climate	Mile temperatures. Winds. Atmospheric pressure higher because of CO_2 in the atmosphere	Temperatures up to -130 ° C and carbon dioxide (CO_2) in the atmosphere is frozen, which reduces air pressure significantly
Dust storms	Dust storms	Less wind than in summer and therefore less dust storms.
Variations in polar caps	A reduced size of the polar cap made out of water ice, because the 1-m thin layer of dry ice (CO_2) was sublimated to the atmosphere.	They size of the polar caps increase considerably in size considerably (a permanent 8-m thick layer of dry ice).

Table 6: Factors that change with the Martian.

2. Now you have to decide what you want to investigate on Mars with the solution calculated for ExoMars in Activity 11.1.:

Search for possible trails of past life on Mars, by studying possible biological processes (Methane?, Ozone? Oxygen?)	Summer at the Northern Hemisphere
Search for possible trails of past life on Mars, studying the water of Mars (Ice caps)	Winter @ the Souther Hemisphere
To study the main phenomena seasons depend in the clima, atmosphere pressure and geological processes of Mars.... (and dust storms)	Summer Northern Hemisphere

3. Assuming that Exomars will be launched on the estimated date and that it lands on Mars in the same hemisphere as you are on Earth. Write in this Excel what date, season and properties of that season you will find. **link**

4. The map in Figure 30 provides four possible landing options. Fill in table 7 with what you think you will find in those areas.

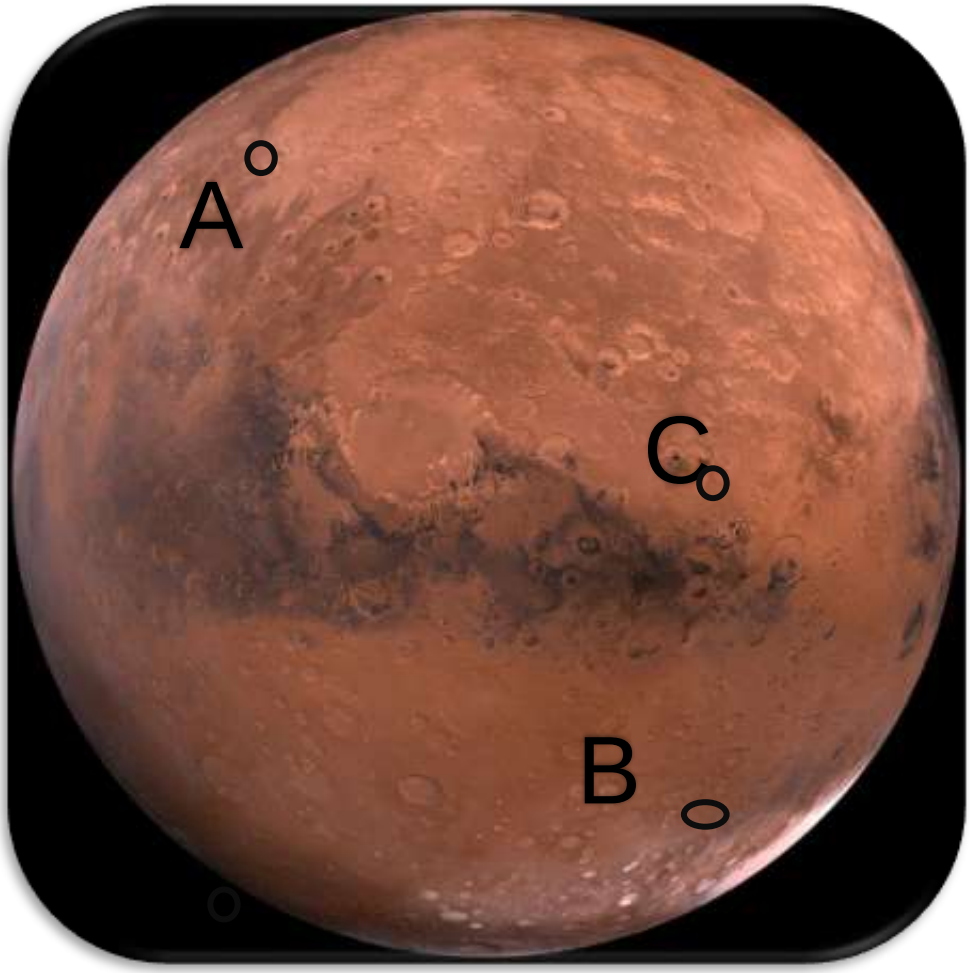


Figure 30: Photographic composition of Mars. (Wikipedia)

4. **Do you want to know which is the best landing option? c**ompete with the other teams! Choose one of these zones, write down the pros and cons and defend your choice to your classmates.

Zone: A Northern Hemisphere / B Equator / C Southern Hemisphere **Season: Winter / Summer** **Why:**

Activity 11.3. Expert Team

Look at this image with the areas where they landed previous missions. **What do you think they went there to do?**

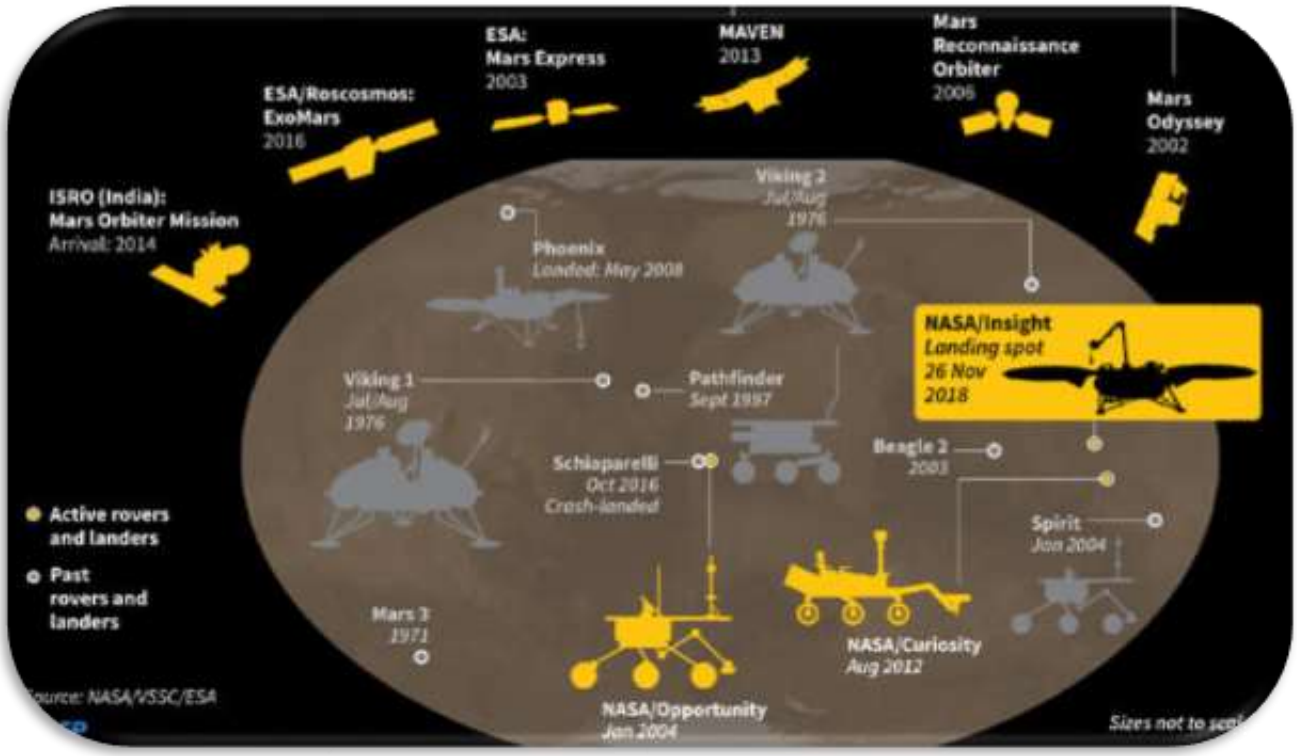


Figure 31: History of missions to Mars. (Wikipedia)

Mission	Landing site	Landing date (season)	Scientific Objective
Viking 2		July/August 1976	
Pathfinder		September 1997	
Spirit		January 2004	
Phoenix		May 2008	
Curiosity		August 2012	
Insight		November 2018	
Rosalind Franklin		….	

Note: To the date, ESA missions have not landed on Mars as desired (Beagle 2, Schiaparelli). We are very interested in the splashdown of ExoMars 2022, as it will be the first European rover to do so, so stay tuned!

Phase 4

Congratulations!
You have completed your Science Challenge!
Tell us your story!

Activity 12: Evaluation

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

IMPORTANT NOTES

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

Activity13: Tell us your Adventure

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

ENLACES DE LA FASE 0:

VIDEOS

- https://www.youtube.com/watch?v=9wdbNU7Pu8U&feature=youtu.be
- http://www.esa.int/ESA_Multimedia/Videos/2015/01/ESAC_ESA_s_Window_on_the_Universe
- http://cesar.esa.int/index.php?Section=Multimedia&Id=63

ENLACES DE LA FASE 1:

VIDEOS

- https://youtu.be/P5xYp-mCEN0
- https://www.youtube.com/watch?v=b_NwWJttruE
- https://www.youtube.com/watch?v=IJhgZBn-LHg
- https://www.youtube.com/watch?v=LL54E5CzQ-A

APP/JUEGO/CUESTIONARIO

- http://astro.unl.edu/classaction/animations/coordsmotion/eclipticsimulator.html
- http://www.traducimos.cl/planet/
- http://astro.unl.edu/classaction/animations/renaissance/kepler.html
- https://www.menti.com/t49k12g3m6

WEBS:

- https://journeynorth.org/tm/LongitudeIntro.html
- https://en.wikipedia.org/wiki/Eccentricity_(mathematics)
- https://www.rapidtables.com/convert/temperature/celsius-to-fahrenheit.html
- https://www.esa.int/Science_Exploration/Human_and_Robotic_Exploration/
- https://mx.blastingnews.com/ciencia/2018/02/cinco-cosas-que-necesitariamos-para-que-la-gente-vaya-a-marte-002366993.html
- https://www.esa.int/Science_Exploration/Human_and_Robotic_Exploration/Exploration/ExoMars/Meet_Mars
- https://www.freepik.es/vector-premium/globo-terraqueo-ilustracion-circulo-cuatro-estaciones_7977447.htm
- https://www.astromia.com/solar/estatierra.htm
- https://www.britannica.com/place/Mars-planet/Basic-astronomical-data
- *http://www.nakedeyeplanets.com/mars-orbit-&-seasons.png*
- http://www.astronomynotes.com/solarsys/s10.htm
- http://www.alpo-astronomy.org/jbeish/Observing_Mars_6.html
- https://exploration.esa.int/web/mars/-/46038-methane-on-mars.
- https://www.esa.int/Space_in_Member_States/Spain/Rosetta_-_Resumen_
- http://www.esa.int/Space_in_Member_States/Spain/La_nave_Venus_Express_de_la_ESA_llega_a_su_destino
- Qué es VMC: https://blogs.esa.int/mex/2015/03/17/what-is-vmc/
- Webcam de Marte: https://blogs.esa.int/vmc/
- Archivo de datos VMC: https://blogs.esa.int/vmc/vmc-data-archive/
- Imágenes VMC: https://www.flickr.com/search/?text=VMC%20Mars%20Express
- Blog: https://blogs.esa.int/mex/2016/08/05/vmc-grows-up/
- https://es.wikipedia.org/wiki/Agencia_Espacial_Europea
- https://es.wikipedia.org/wiki/Roscosmos
- https://inta.es/ExoMarsRaman/es/mision-exomars/rover-rosalind-franklin/
- http://www.esa.int/Science_Exploration/Space_Science/Mars_Express_mission_team
- https://exploration.esa.int/web/mars/-/56623-exomars-mission-team
- http://www.esa.int/Our_Activities/Space_Science/Mars_Express

- http://blogs.esa.int/mex/files/2013/06/Mars-Express-10-year-highlights.png
- http://exploration.esa.int/mars/44997-the-red-planet/
- http://cesar.esa.int/upload/202004/bookletmars_v6_spanish.pdf
- http://exploration.esa.int/mars/43608-life-on-mars/
- http://www.esa.int/Our_Activities/Human_and_Robotic_Exploration/Exploration/ExoMars/Highlights/Ten_things_about_Mars
- https://www.esa.int/Our_Activities/Space_Science/Mars_Express/Olympus_Mons_-_the_caldera_in_close-up
- http://www.esa.int/Our_Activities/Space_Science/Fly_through_a_canyon_on_Mars

ENLACES DE LA FASE 2

VIDEOS

- http://cesar.esa.int/index.php?Section=Teacher_Training&ChangeLang=es
- https://www.youtube.com/watch?v=00lewuf_j1M
- https://youtu.be/upIUpkpymoE
- https://youtu.be/TOb2G6MDfYQ
- https://youtu.be/zAwQNAkVaOg

ENLACES DE LA FASE 3:

VIDEO

- https://www.youtube.com/watch?list=PL9TFrgFq7557nWqmfuVngU22OhTpUE9qg&time_continue=1&v=gYJsMBabjVY&feature=emb_title

APP/JUEGO/CUESTIONARIO:

- **http://cesar.esa.int/tools/18.martian_year/**

WEBS

- https://es.wikipedia.org/wiki/Marte_(planeta)

ENLACES DE LA FASE 4:

APP/JUEGO/CUESTIONARIO:

- http://cesar.esa.int/index.php?Section=Admin&Admin=Quiz&Id=3&BlockQuiz=1
- https://www.menti.com/m8846mzj2b
- https://cft.vanderbilt.edu/guides-sub-pages/blooms-taxonomy/

EXTRA (ESA Educación):

- https://www.esa.int/Education/Teachers_Corner/Could_life_survive_in_alien_environments_-_Defining_environments_suitable_for_life_Teach_with_space_B09
- www.esa.int/Education/Teachers_Corner/Astrofarmer_-_Learning_about_conditions_for_plant_growth_Teach_with_space_PR42
- https://www.esa.int/Education/Teachers_Corner/Astrofood_-_Learning_about_edible_plants_in_Space_Teach_with_space_PR41
- https://www.esa.int/Education/Teachers_Corner/Plants_on_Mars_-_Build_an_automatic_plant_watering_system_Teach_with_space_T09

Credits:

Material prepared to be executed on-line, from an initial version of material **by the CESAR Team and Planeta Ciencia in collaboration with the Mars Express Scientific Team and the University of Bilbao**, under the initiative and coordination of the **European Space Agency** in the framework of the **CESAR program.** The CESAR Team has been supported by Young Graduate Trainee (YGT) Programme.

Special thanks to Alejandro Cardesín, Elenis Ravanis and Jorge Hernández, engineers and scientists of Mars Express, experts in the scientific data of VMC, for their supervision in the development of the material.

First version:
http://cesar.esa.int/index.php?Section=Las_Estaciones_en_Marte_I&ChangeLang=es