CESAR Scientific Challenge

Does Mars have seasons?

Explore Mars with *Mars Express* and *ExoMars*

Teacher Guide

Contenido

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

Activity 2.1: Compare Mars and Earth properties.

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

	Earth	Mars
Ratio		3389 km
Mass	~ 6 x 10^{24} kg	
Axis Tilt	23.5 degrees	25 degrees
Atmosphere	Yes, very dense	
Polar caps		
Average temperature		-63^{o}C

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?

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?

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

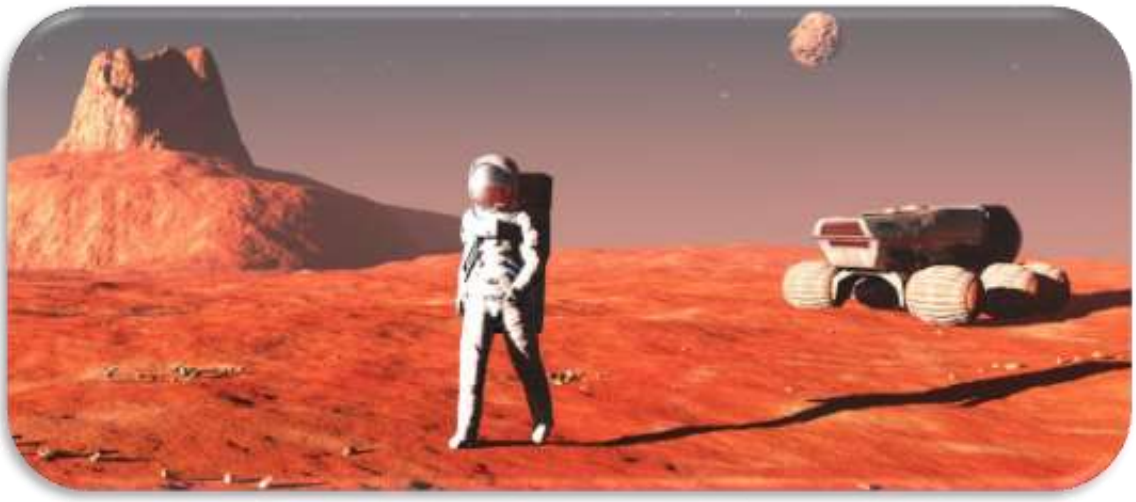


Figure 2: Mars mission astronaut representation (Credits:blastingnews.com)

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)

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

Activity 3: 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

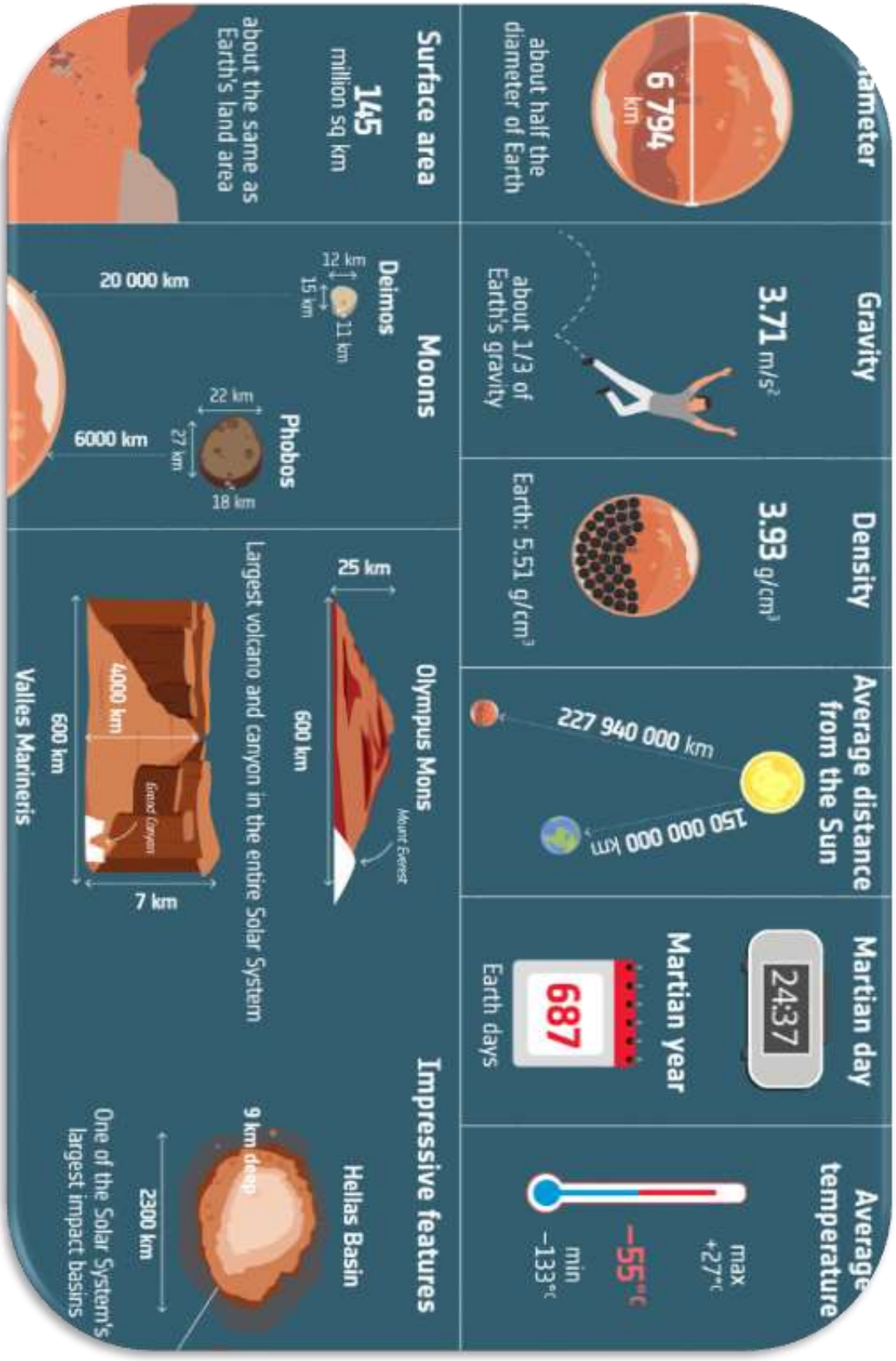


Figure 4: Meet Mars. (Credits: ESA)
https://www.esa.int/Science_Exploration/Human_and_Robotic_Exploration/Exploration/ExoMars/Meet_Mars

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?

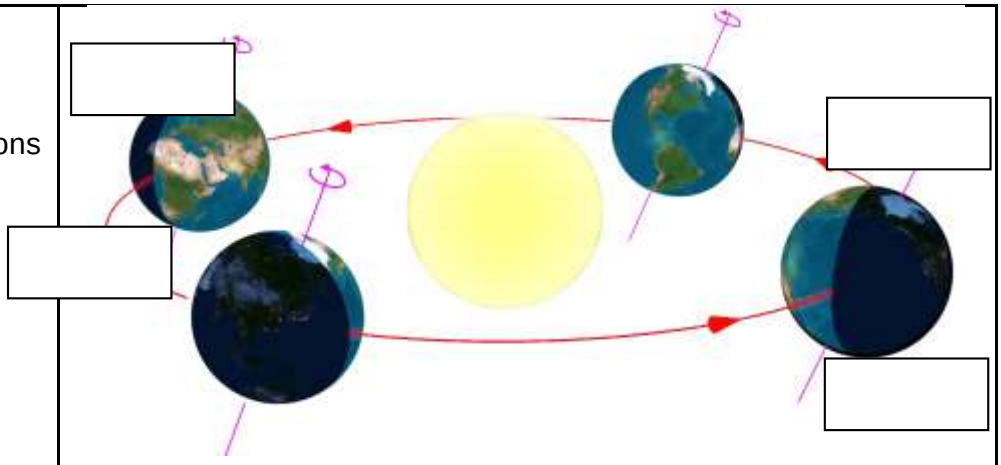
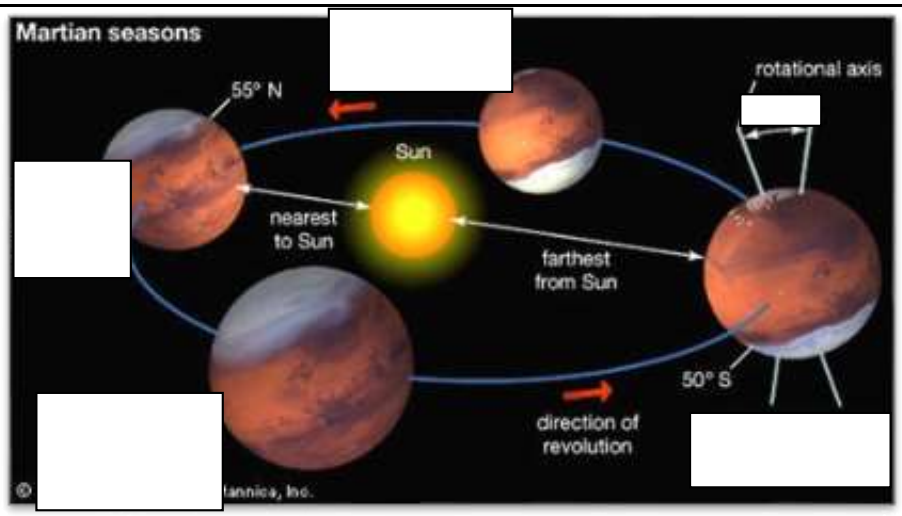
Figure 5: Seasons on Earth (Credits: https://www.freepik.es)

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

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?

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 seasons on the Earth and on Mars might be?

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

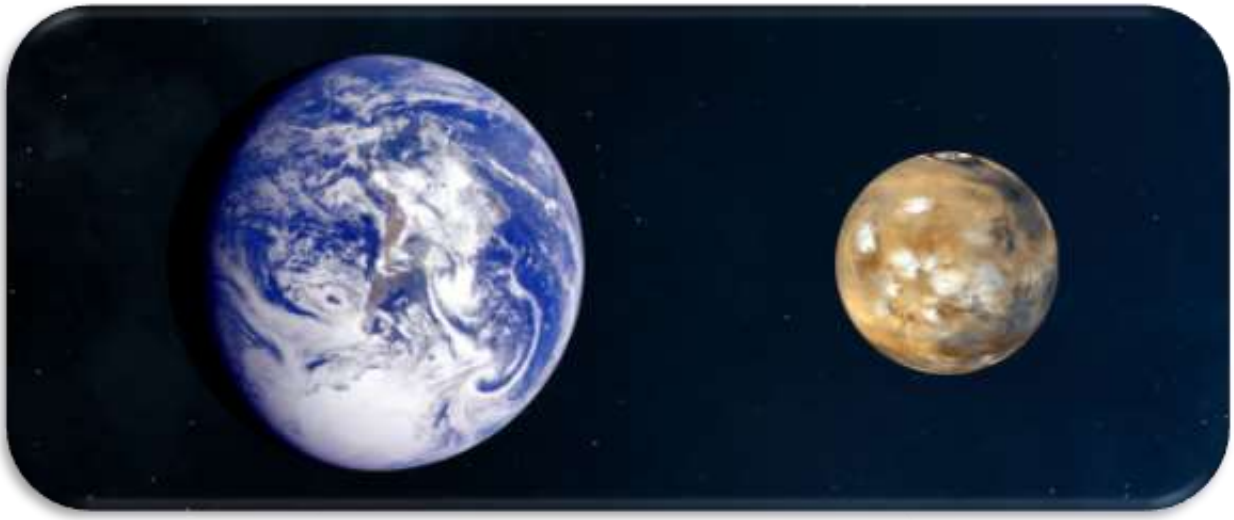


Figure 8: Mars and Earth (Credits: www.livescience.com)

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

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?

.

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

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

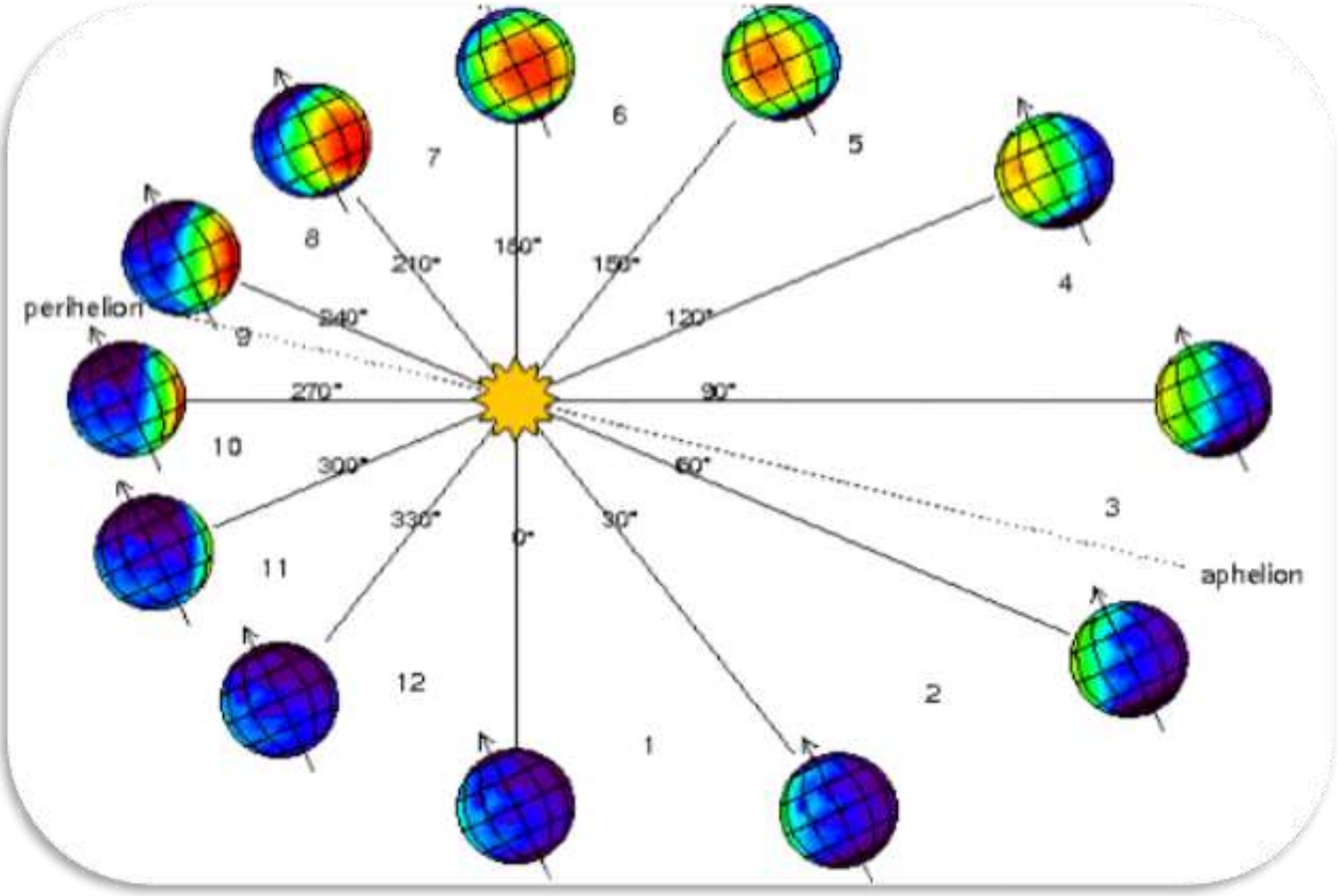


Figure 10: The climate of Mars (Credits: ESA)

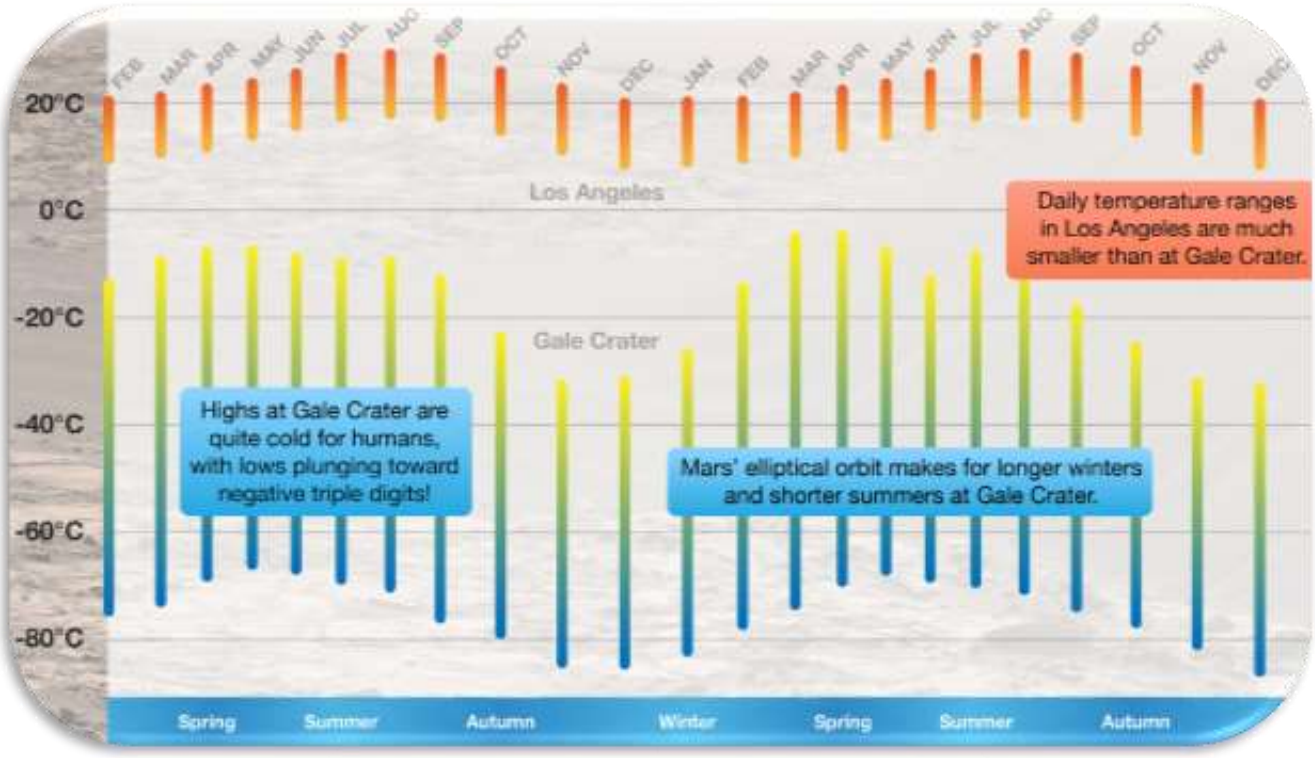


*Figure 11: Mars and Los Angeles weather comparison, CA (Credits: **astronomynotes**)*

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?

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?

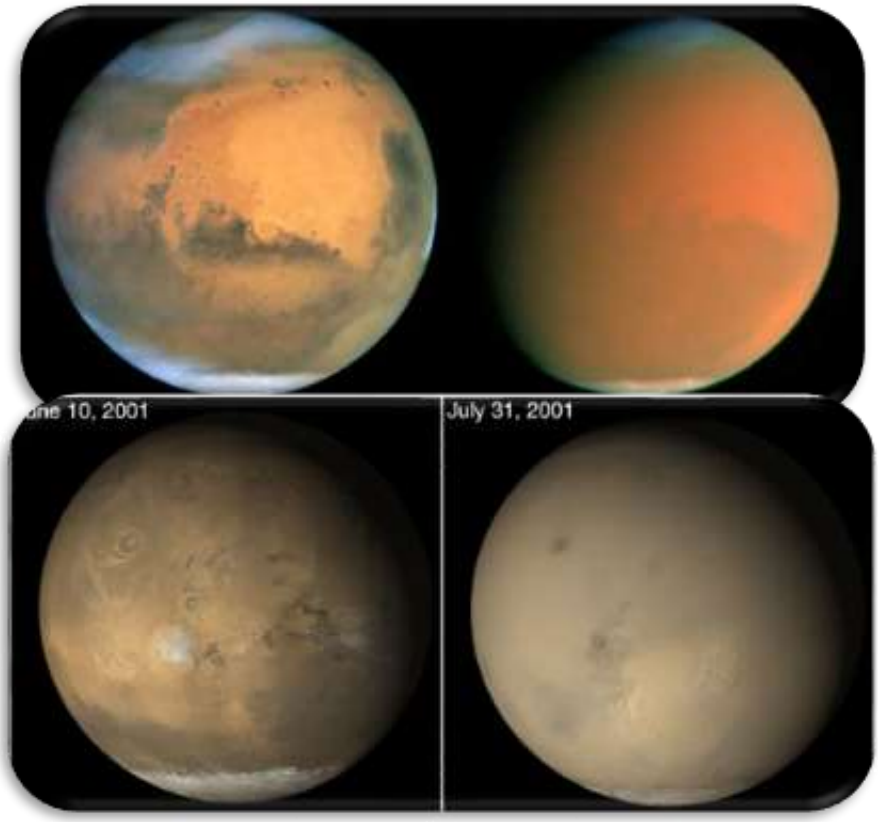


Figure 12: Mars dust storms (Credits: www.alpo-astronomy.org)

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?

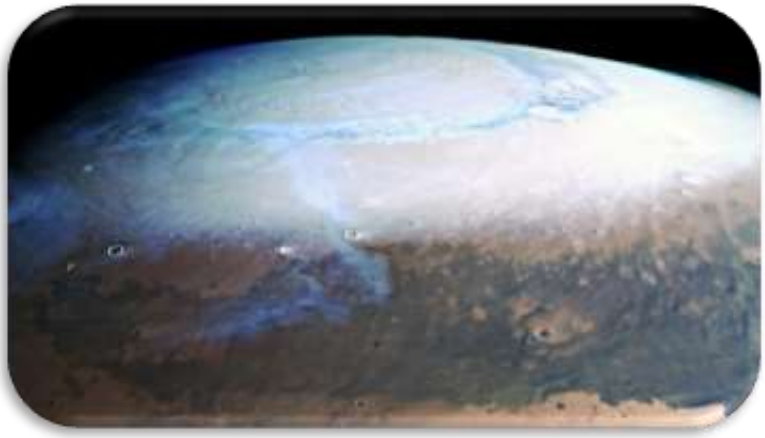


Figure 14 North Pole Mars (Credits: ESA)

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.

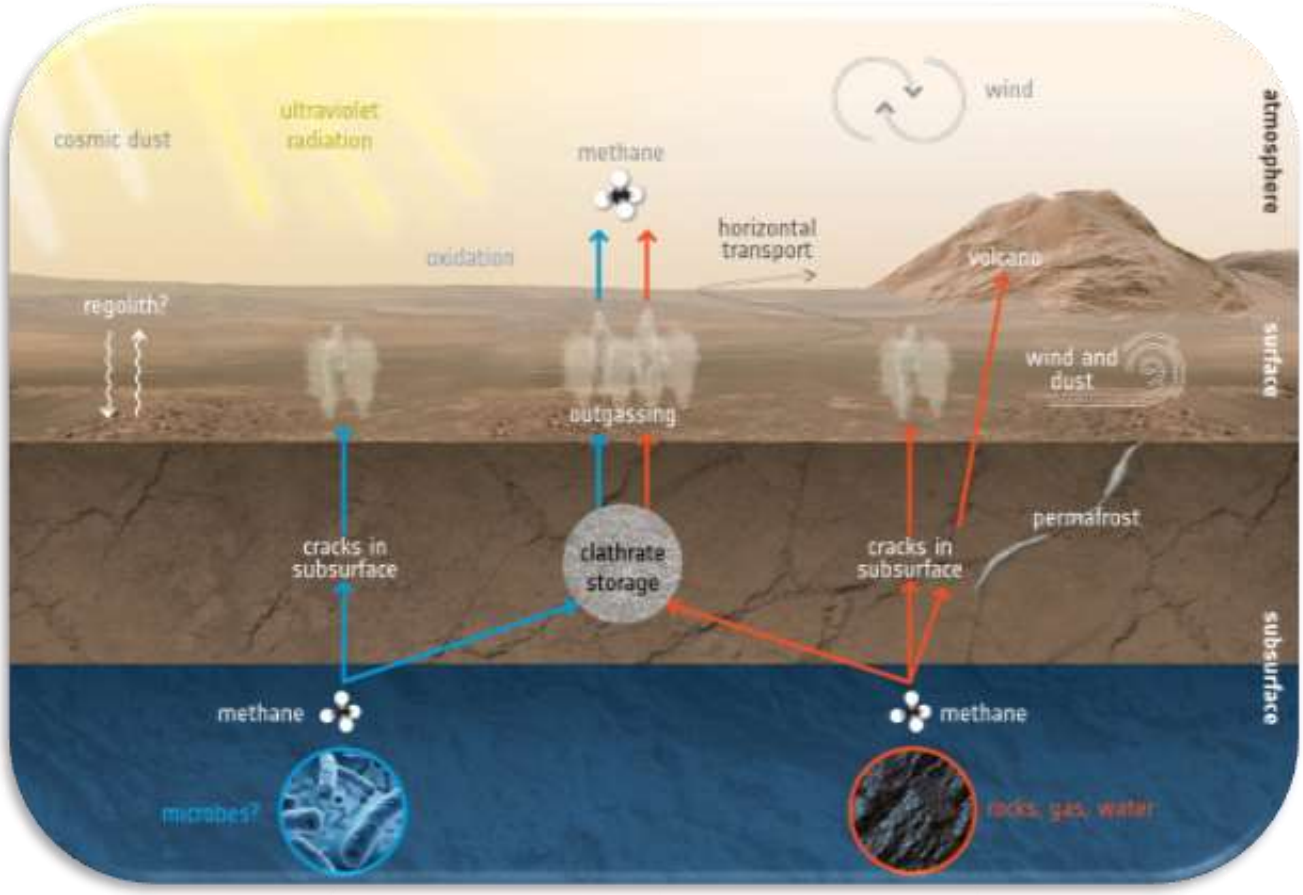


Figure 15: Processes of methane appearance on Mars (Credits: exploration.esa.int.)

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

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.

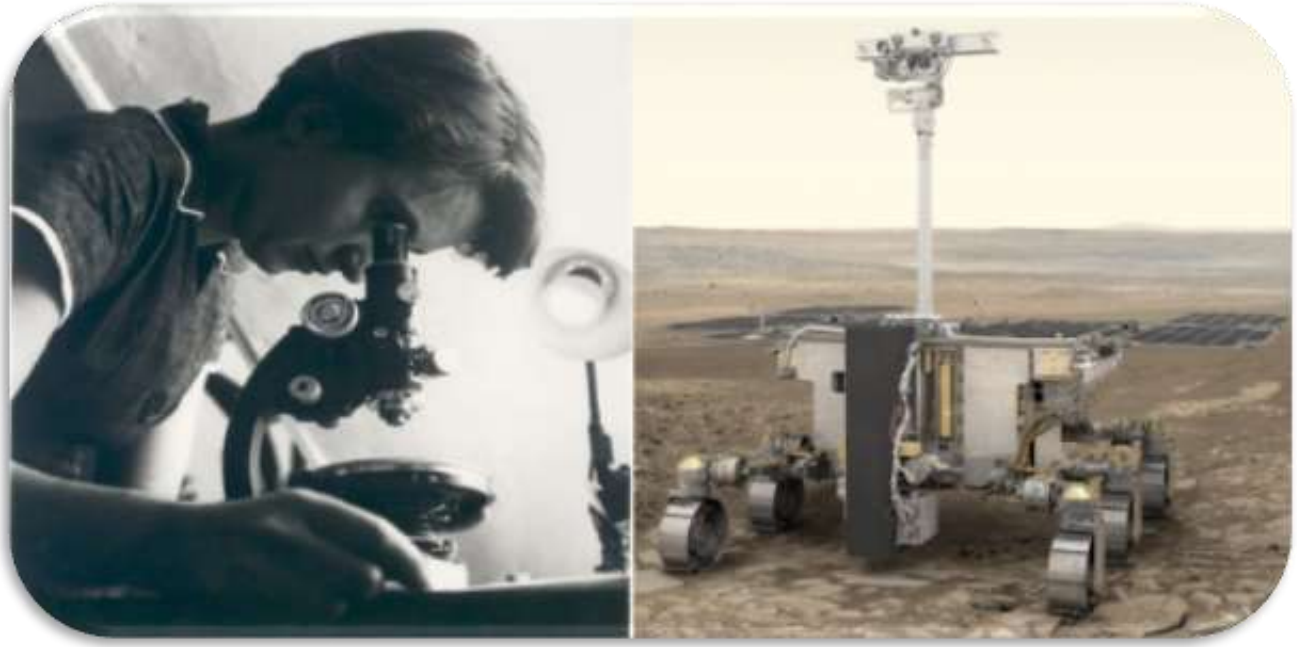


Figure 18: rover Rosalind Franklin. *(Credits: ESA/INTA)*

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)

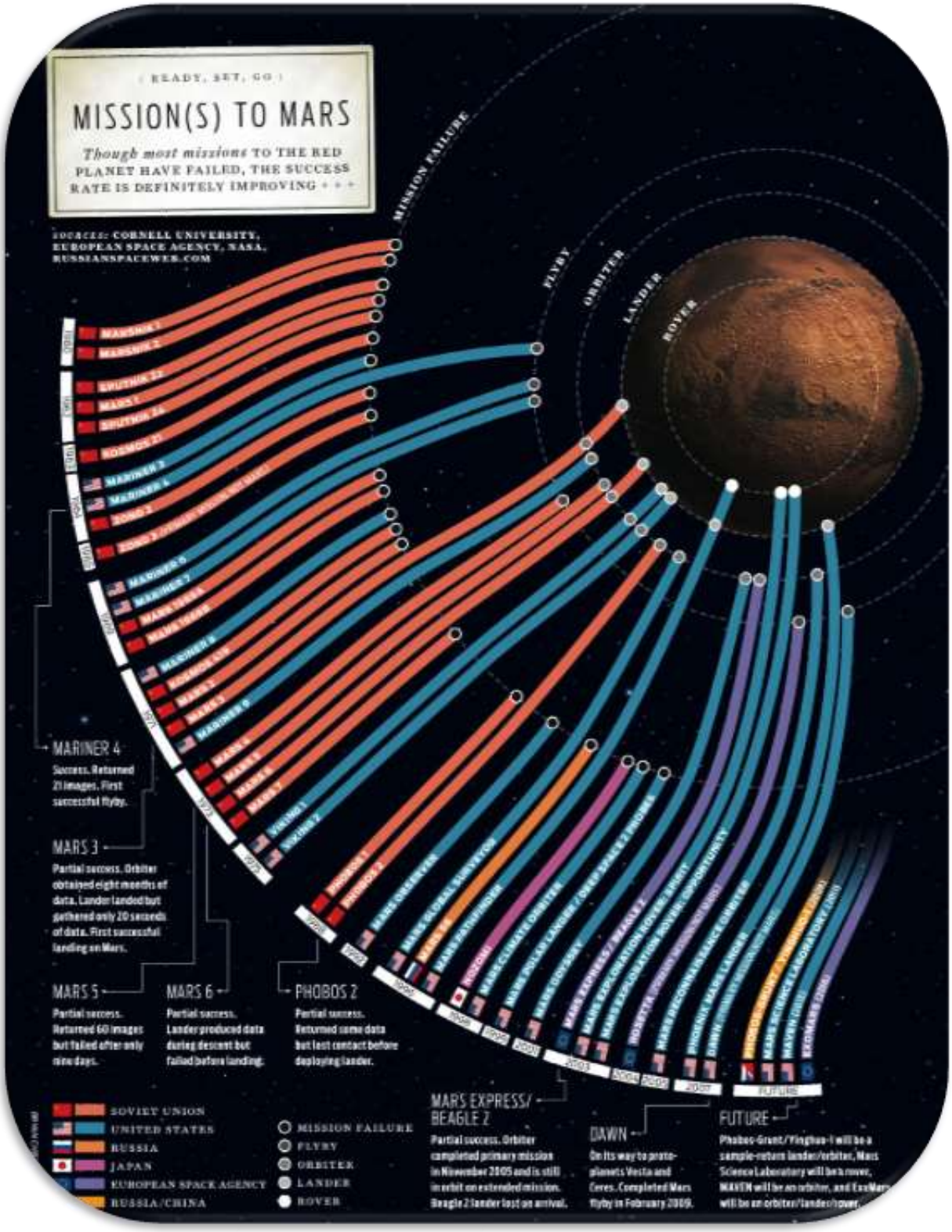


Figure 22: Missions to Mars. (Credits: Cornell University).

Activity 7: What have you learnt so far?

Answer this questionnaire to check what have you learnt so far

Phase 2

Figure 23: Mission ExoMars 2016. (Credits: ESA).
https://twitter.com/ESA_History/status/1318101830774128641

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?

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.

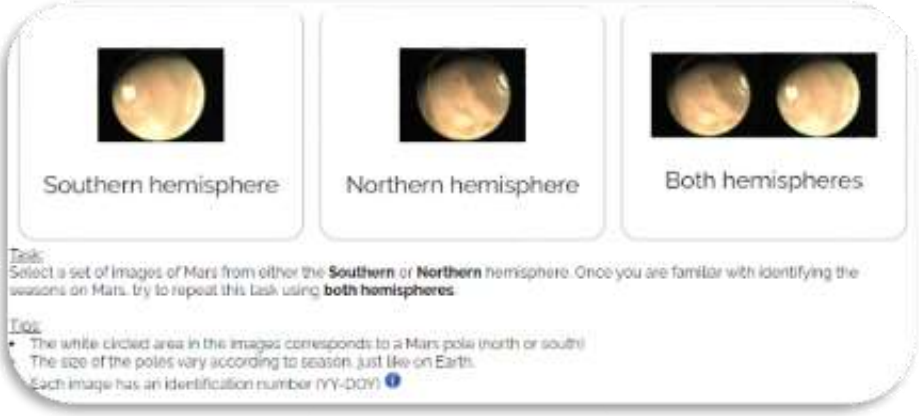


Figure 24: The home page to the "seasons on Mars" web tool and Step 1. (Credits: CESAR)

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 seasons.

Summer	*Spring/Autumn*	*Winter*

Table 4: Explain why you chose each of the seasons 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?

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

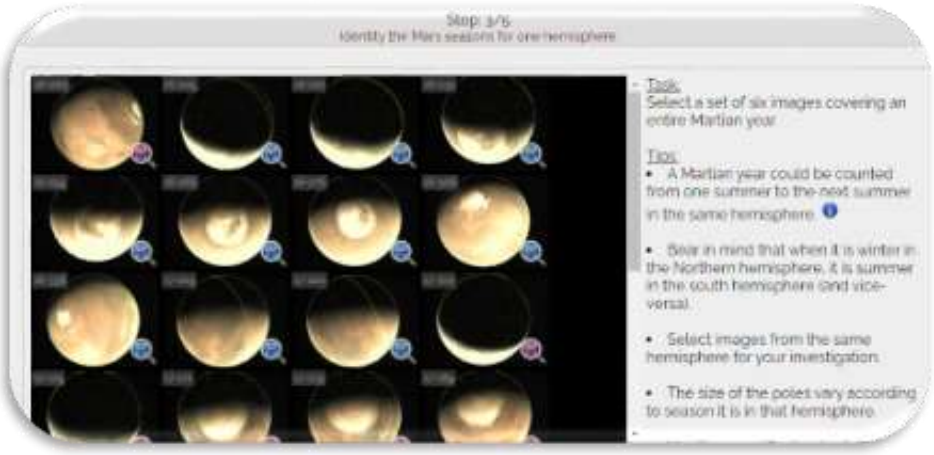


Figure 26: Step 3 of the CESAR tool. Pink magnifying glass identifies the northern hemisphere images of Mars and blue magnifying glass the southern hemisphere images (Credits: ESA /Mars Express/VMC – CC BY-SA IGO 3.0)

(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

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?

How old would you be in Martian years?

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 Rosalind Franklin in 2022

GOAL:

- 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 environmental 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:

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**

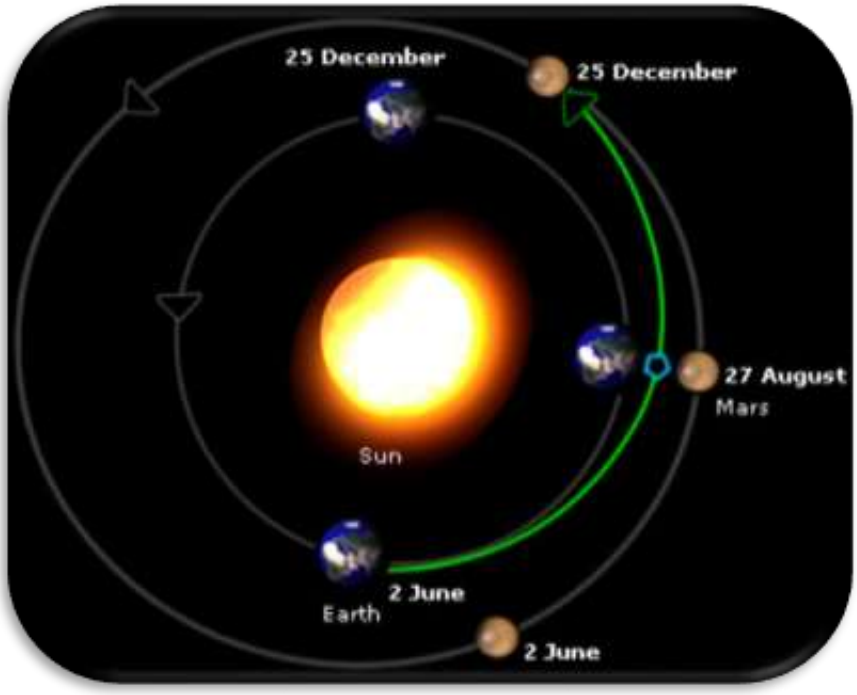


Figure 28: Trajectory followed by the Mars Express mission at launch (Credits: ESA)

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**?**

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:

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)

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**.

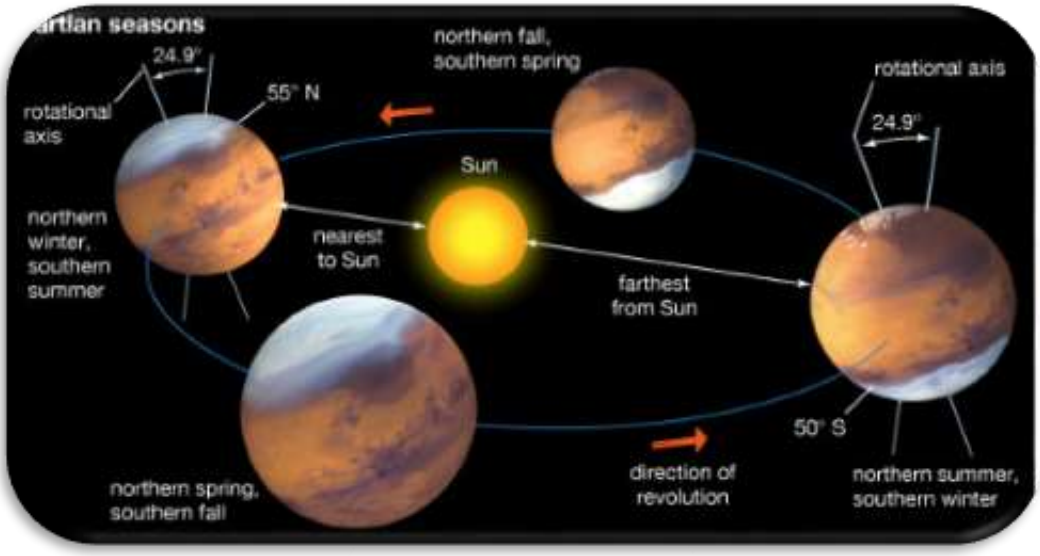


Figure 29: seasons on Mars (Credits: ESA)

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		
Dust storms		
Variations in polar caps		

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?)	
Search for possible trails of past life on Mars, studying the water of Mars (Ice caps)	
To study the main phenomena seasons depend in the clima, atmosphere pressure and geological processes of Mars.... (and dust storms)	

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.

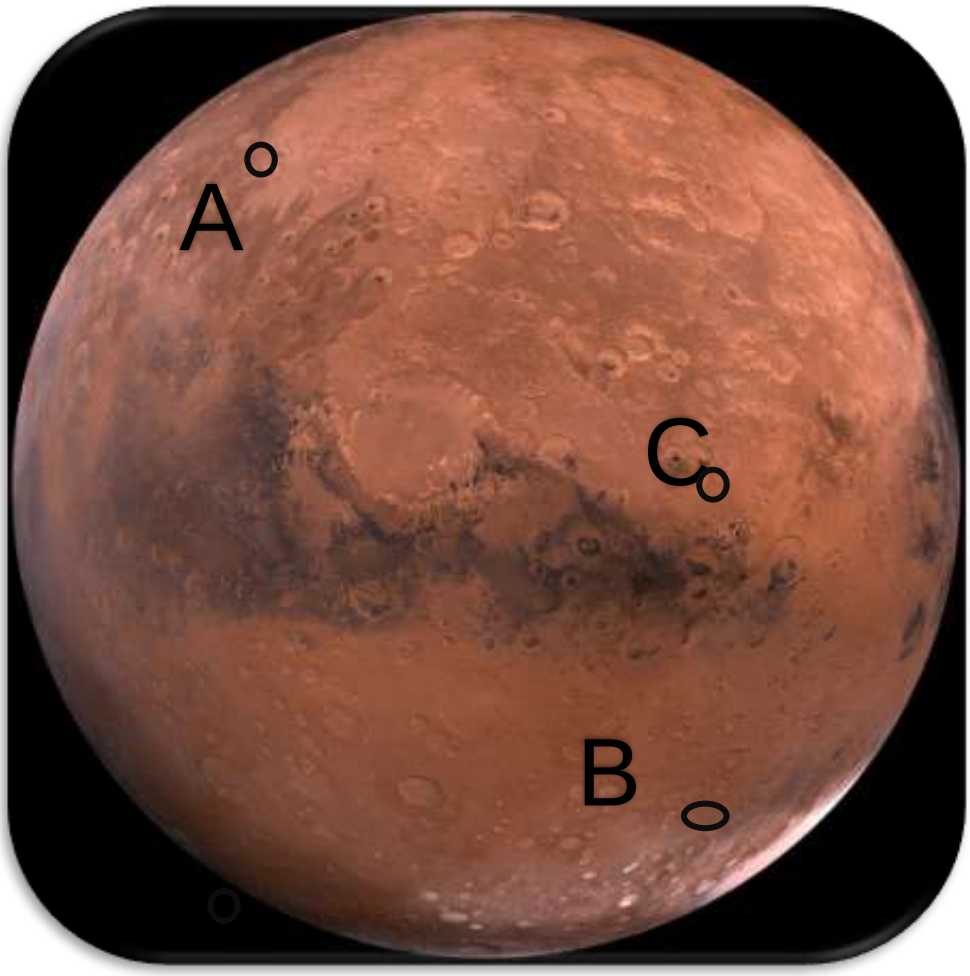


Figure 30: Photographic composition of Mars. (Wikipedia)

5. **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?**

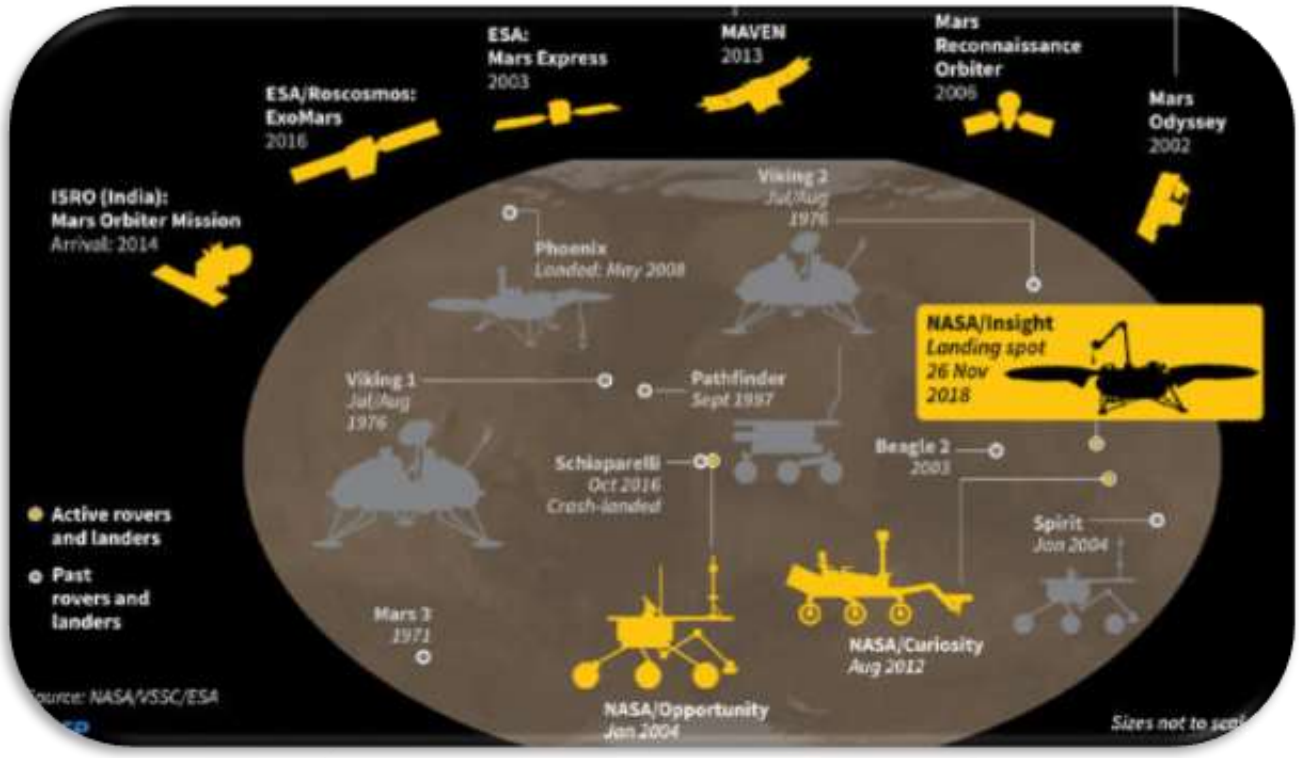


Figure 31: History of missions to Mars. (Wikipedia)

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: Self-Assessment and Co-Assessment

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

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.

Links

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

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
- http://cesar.esa.int/form.php?Id=3&k=&ChangeLang=en

FASE 2

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)

FASE 4:

APP/JUEGO/CUESTIONARIO:

- http://cesar.esa.int/form.php?Id=3&k=&ChangeLang=en

EXTRA MATERIAL (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.**

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

The CESAR Team has been supported by Young Graduate Trainee (YGT) Programme.