teach with space

→ ASTROGEOLOGY ON MARS

Navigate the Mars landscape and use spectroscopy to identify its rocks

Teacher guide

teach with space – astrogeology on mars | T12
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An ESA Education production collaboration with ESERO UK

→ ASTROGEOLOGY ON MARS

Navigate the Mars landscape and use spectroscopy to identify its rocks

FAST FACTS

Subject: Planetary Science, Maths, Physics, Chemistry, Biology, Geology
Age range: 10 -17 years old
Type: Student activity
Complexity: Easy-medium
Lesson time required: 2 to 4 hours
Cost: medium (10-30 euros)
Location: Indoors
Includes use of: Gridded map of Mars/ Checkerboard Mat/ Large Grid- any large surface with squares large enough to step in.
Timing device
Optionally: Lego Educational robotics set and/ or remotely controlled vehicle
Keywords: Physics, Chemistry, Planetary science, Mars, Sample analysis, Chemistry, Biology, Space science

Brief description

In this set of activities students will learn how operate a planetary exploration mission. They will organise themselves into groups to form 'mission control'. With the help of a 'Mars rover' they will explore a map of Mars and search for regions of interest on the surface to collect. Mission control and the rover have a limited time to find these regions of interest and can only communicate using a limited number of commands each time. This will teach students about the limited data transfer during mission and the importance of mission control planning. Students will then receive the samples that they collected at the regions of interest and will be guided to analyse them, identifying what they have found on the surface. Students can then present their findings to the rest of the class.

This resource was developed in the framework of a collaboration between ESERO UK and ESA.

Learning objectives

- Find the best way to navigate the map to maximise sample collection within the time limits of the exercise.
- Understand the rover operations, given the limited communication between the 'rover' and 'mission control'
- Gain experience in sample analysis
- Learn to identify spectral signatures and interpret geological information
- Improve communication and presentation skills, by presenting findings to the other teams

→ Summary of activities

Depending on the time and equipment available activity 1, 2 or 3 can be completed. Activity 4 follows on each one of these activities.

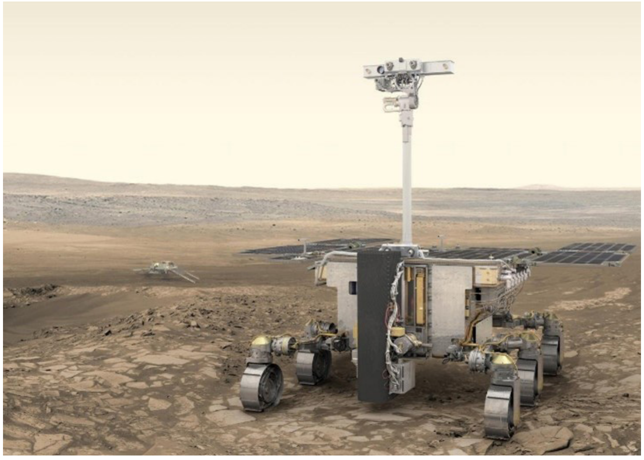
Summary of activities					
	Title	Description	Outcome	Requirements	Time
1	Human analogue missions	Navigate a map of Mars and find samples of interest.	Understand how an algorithm works and apply it in the real world	None	60 minutes
2	Lego Rover analogue mission	Navigate a map of Mars and find samples of interest.	Use coding skills to navigate the Mars surface and to arrive to targets	Robotics educational set (examples: Lego Mindstorms or Lego Spike)	60-90 minutes
3	Sample Analysis	Analyse samples found on Mars	Students will analyse the samples using the spectra and images provided to figure out what samples they have found on Mars.	Activities 1 and 2.	60 minutes

→ Introduction

Planetary exploration robotic vehicles, or rovers, have been helping us explore Mars for over 20 years. It was 1997 when the Sojourner drove for the first time on the surface of Mars and sent us an amazing set of pictures. Since then, 5 more robotic vehicles have been successfully sent to Mars.

ExoMars is a future ESA rover mission designed to search for past or present life on Mars. This mission incorporates atmospheric science, sample analysis and geology to help us understand the surface of Mars, its history and whether it could have ever hosted life or not.

Figure 1



↑ ExoMars Rover

The ExoMars rover was named Rosalind Franklin after a British scientist who contributed on the discovery of our DNA structure. Roving with Rosalind is a series of ExoMars-based classroom activities for pupils to do real Mars mission-based activities connected to what they learn in the classroom or laboratory. Pupils will investigate a map of Mars, learn about mission control, and analyse and identify samples that the real rover will look for on Mars.

In this classroom resource, students will learn how to navigate a mars surface and collect geological samples that later they'll receive information on. Afterwards, they'll need to compare their samples with actual spectra datasheets (reference data) to make their own conclusions. Activities 1 and 2 are the same activity – done with 2 different platforms. Activity 1 can be done without any educational robotics tool – it's an human analog mission. However, Activity 2 needs the use of an educational robotics platform such as Lego Mindstorms or Lego Spike. Educators may choose either to choose activities 1 or 2 to start with, and then progress to activity 3.

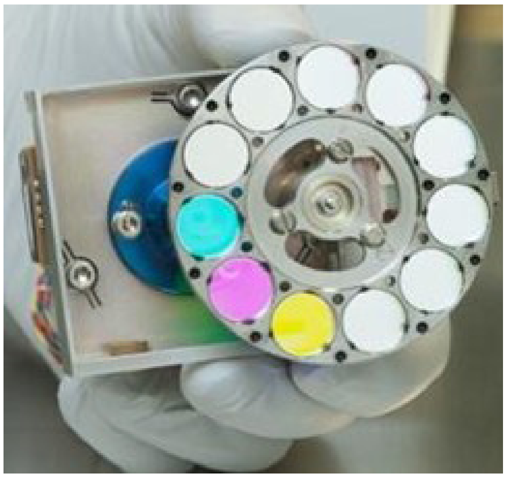
→ Background

The ExoMars mission will search for evidence of past or present life on Mars, but this is a very difficult challenge. We believe Mars was once much more like the early Earth. If life did evolve on Mars, it is likely to be from this early period of time, known as the Noachian. So today, to search for life we are looking for evidence of life (either living or fossilised evidence of microbial communities), organic molecules (they are based on Carbon, Hydrogen, Nitrogen, Oxygen, Phosphorous, etc.) having properties that indicate a biological origin; most likely they will be preserved in minerals formed in the presence of liquid water (like clays or hydrothermal deposits).

The ExoMars Rover - called Rosalind Franklin, has specifically been designed to do this, even featuring a 2-metres subsurface drill to make sure we can access the Martian subsurface where the sun's radiation cannot penetrate and destroy signs of life. There are several instruments onboard the Rosalind Franklin rover that will contribute to the first step of understanding the Martian surface. These instruments include PanCam (Wide angle Cameras and High-resolution camera – HRC) supported by the Infrared spectrometer for ExoMars (ISEM). These instruments all study the way light interacts with different materials. PanCam's wide angle cameras take pictures like normal cameras but through multiple circular filters in the visible and near infrared (NIR) spectrum. This is also referred to as 'multispectral imaging'.

Figure 2

Figure 3

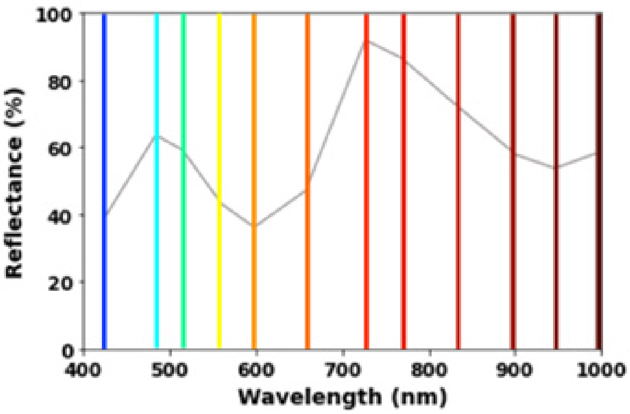


↑ PanCam instrument and filter wheel, M. de la Nougerede, UCL/MSSL

The principle behind multispectral imaging is that each filter of the PanCam only lets through a specific range of wavelengths of sunlight that is reflected on the Martian surface. Grey images are retrieved from each filter which are added together to get colour and spectra. This means that the PanCam gives us multispectral data at each of the wavelengths that correspond to the filters (Figure a, below). However, spectra can also look like smooth lines; this is hyperspectral data - where information is obtained at every wavelength (Figure b, below). Hyperspectral images can be seen as regular camera images where spectroscopic data is also obtained.

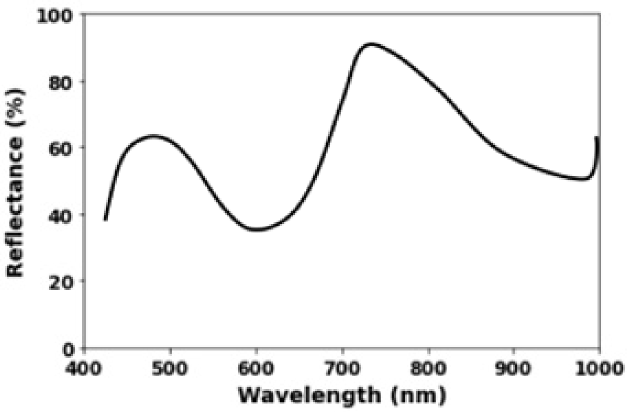
Multispectral data looks like this:

Figure 4



Hyperspectral data looks like this:

Figure 5



↑ a) PanCam wavelengths compared to multispectral data, b) Hyperspectral data example

Spectral imaging is a very useful technology to map details of the surface of Mars, but also other distant objects in space. Depending on the materials present on the Martian surface, specific wavelengths of sunlight are absorbed whereas other are reflected. Each type of material has thus its own unique spectrum that can be recognized. Therefore, the spectrum of a material can also be seen as a specific fingerprint.

→ Activity 1: Human rover analogue mission

In this activity, students are split up in 'mission control' teams where each team navigates a rover across a large map of Mars (or grid) to identify points of interest (POI's). One student of each team will play the role of the Mars rover to whom the plan will be communicated. The team must collect as many regions of interest as possible in the time allowed while avoiding the hazards, which cause time deductions. Once the team has found these points of interest, they receive 'mission' data to analyse. Students must analyse the samples using the spectra and images provided to figure out what samples they have found on Mars.

Equipment

- Gridded map of Mars/ Checkerboard Mat/ Large Grid- any large surface with quadrants large enough to step in.
- Timing device

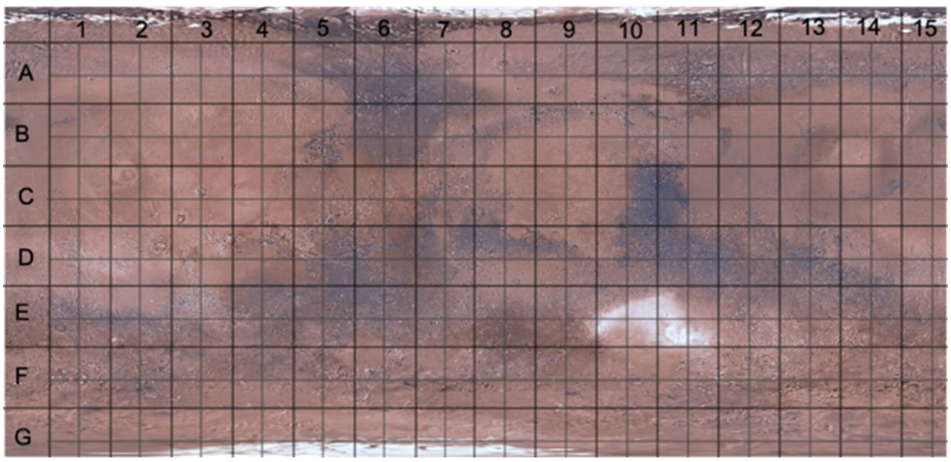
Exercise

1. Set up Mars Map to explore

An example of a Mars background can be found here: https://www.esa.int/ESA_Multimedia/Images/2019/02/Dried_out_river_valley_network_on_Mars#.YIGJoa1zbaM.link

You can print this background by dividing sections of it and printing them in A1 size. You can divide sections in a grid, using tape on the classroom floor.

Figure 6

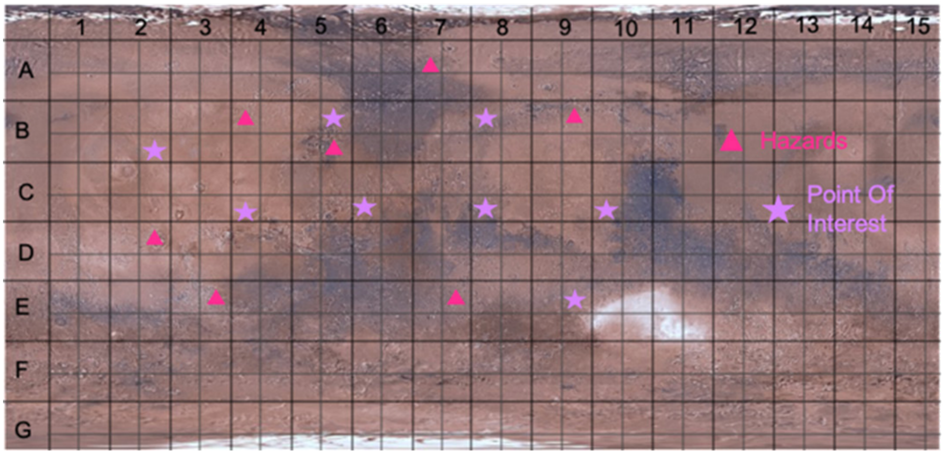


↑ Mars Map Example

2. Set out points of interest (POI) in some squares and hazards in others without showing the class

We suggest using two different coloured types of paper and cutting them into two different shapes to represent the POIs and the hazards.

Figure 7



↑ Mars map example with POIs and Hazards

3. Split students into teams of 4-6, let the students decide who will be their rover.

4. The rover student can start anywhere they want on the edge of the map. Once they start the team have 10 minutes to collect as many POI's as possible while avoiding the hazards. Every hazard encountered incurs a 30 second time penalty.

5. The rover students must describe what they can see in 5 words or less (per turn)

6. Mission control then must decide what instructions to give the rover, up to a maximum of 3 actions. (e.g 1. Step forward, 2. Turn 90 degrees right, 3. Step forward).

7. At the end of their time, students should be given a downlink file (annex 2) for every POI they collected.

→ Activity 2 (optional): Lego rover analogue mission

This activity is a variation of activity 1 but using an actual rover. In this activity, students act as a 'mission control' team and navigate a Lego made rover across a large map of Mars (or grid) to identify points of interest (POI's). Students are given 10 minutes to plan out their routes before the timer starts. The team must collect as many points of interest as possible in the time allowed while avoiding the hazards, which cause time deductions.

Equipment

- Gridded map of Mars/ Checkerboard Mat/ Large Grid- any large surface with quadrants large enough to step in.
- Timing device
- Lego WeDo 2.0 kit/Lego Spike (1 or 2 depending on the rover to be built) or other Lego Education robotic set.
- Laptop or tablet to build the instructions.

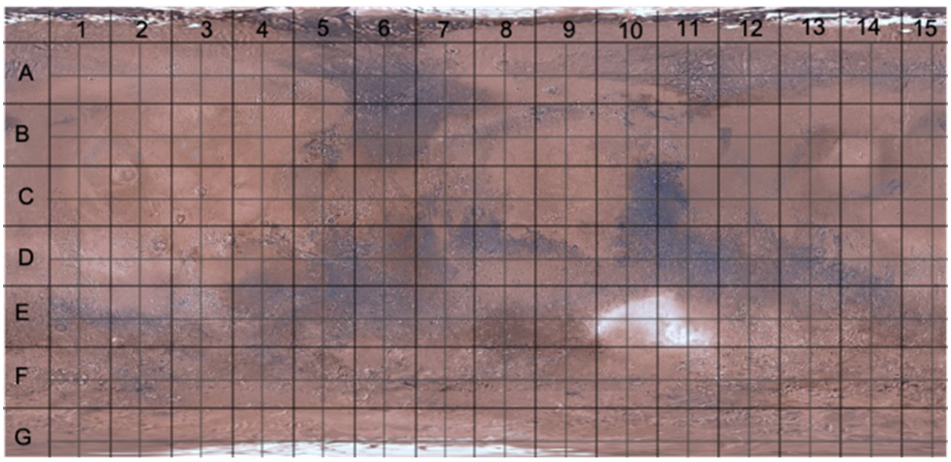
Exercise

1. Build the rovers. You can find instructions to do this here:

a. Lego WeDo: https://education.lego.com/v3/assets/blt293eea581807678a/blt93026f2eecb58ffa/5fe32e74520daf30e5a2f117/en-gb_365e16c6-a026-44e9-a296-e7dc623d6362.pdf or https://education.lego.com/en-us/product-resources/wedo-2/downloads/building-instructions, MILO Twins

b. Lego Spike: https://education.lego.com/v3/assets/blt293eea581807678a/blt990212b2cd50c4d3/5f88025fbc43790f5c4389ee/going-the-distance-bi-pdf-book1of2.pdf

Figure 8

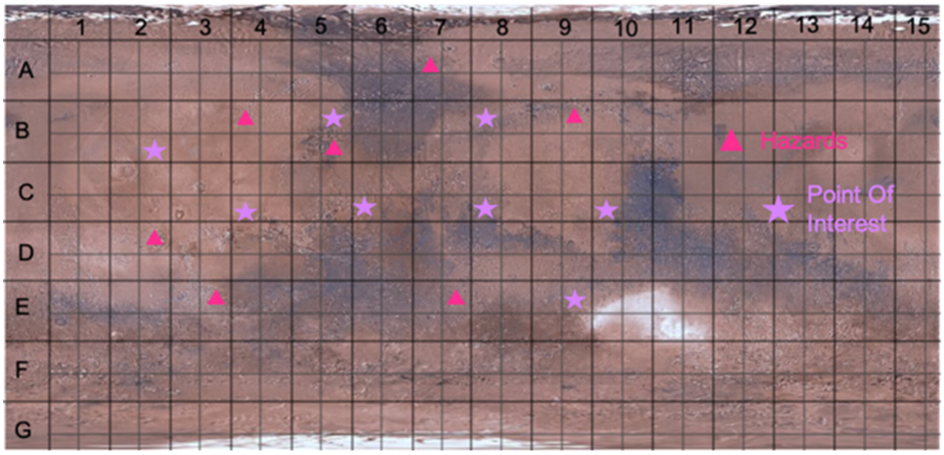


↑ Mars Map Example

2. Set out points of interest (POI) in some squares and hazards in others without showing the class

We suggest using two different coloured types of paper and cutting them into two different shapes to represent the POIs and the hazards.

Figure 9



↑ Mars map example with POIs and Hazards

3. Split students into teams of 4-6. All the students are responsible for mission control.

4. Place the rover build anywhere in a square on the edge of the map.

5. Show all the teams the map and give them 10 minutes to plan out their routes. Students can draw their own map and write instructions, to help their plans.

6. Once they have started, the teams have 10 minutes to navigate around the map and collect as many POI's as possible (by driving over them) while avoiding the hazards. Every hazard encountered incurs a 30 second time penalty.

7. At the end of their time students should be given a downlink file (annex 1) for every POI they collected.

→ Activity 3: Sample Analysis

By the end of activity 2, teams must have collected several multispectral samples (downlink or target data, found in the annexes 1 and 2) for each point of interest they visited with their rover. The entire team must work together to figure out what they have found. To do this, they must compare the 'Downlink data' (in annex 1) collected from the points of interest to the 'Reference data' (in annex 2) provided by the teacher or educator.

Exercise

There are 8 reference samples included in the Reference data (annex 1). These reference samples consist of "visible and near-infrared hyperspectral data" or "VNIR hyperspectral data" that is used to compare the Downlink data (annex 2) to that they found during their mission.

Students should match the reference data they have with the downlink data that their rover has collected. Matches can be found when the multispectral image of their collected sample corresponds to one of the hyperspectral reference images.

The aim of this exercise is to help students understand how we use different types of data returned from Mars to help us create a full picture of the surface. Students should debate their findings with their peers and reach conclusions.

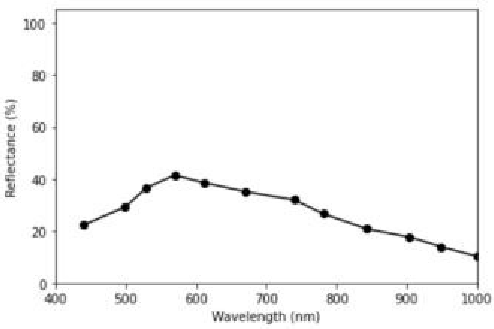
Disclaimer: The downlink datasheet is populated with simulated graphs. We will hopefully obtain the real data after the ExoMars mission is deployed!

Downlink data will look like this:

PanCam Image: **HRC Image:**

Credit: Nasa

PanCam Multispectral Data



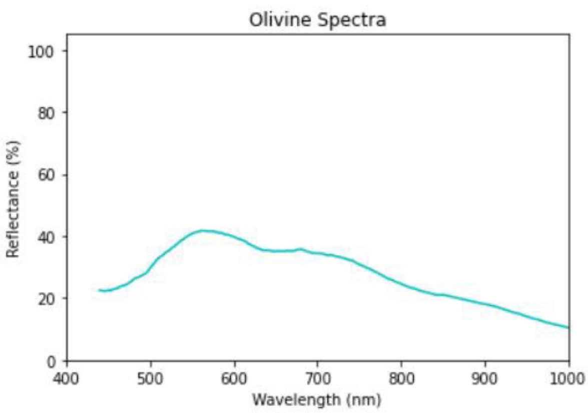
Reference data will look like this:

Olivine

Target Summary

Olivine is found in igneous (volcanic) rocks. If we find it at the surface of Mars there must be large amounts or volcanism or tectonic activity in the area.

VNIR Hyperspectral Data



Solution

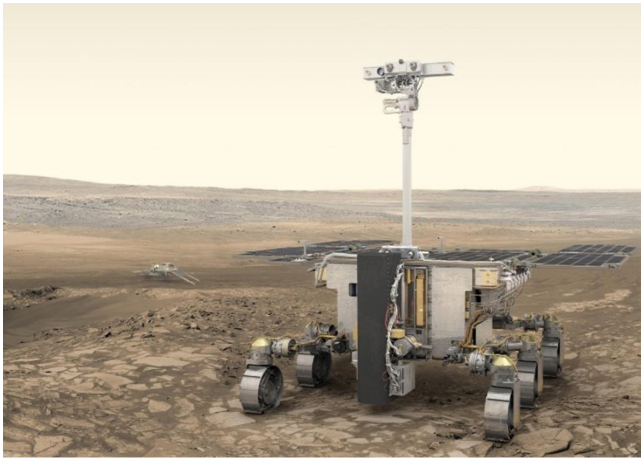
Reference Data	Downlink Data
Olivine	Target 007
Kaolinite	Target 005/001/003
Gypsum	Target 005/001/003
Augite	Target 008/009
Smectite	Target 004
Opal	Target 006
Goethite	Target 008/009
Hermatite	Target 002

→ ASTROGEOLOGY ON MARS

Navigate the Mars landscape and use spectroscopy to identify its rocks

Have you ever wondered how a planetary exploration mission is operated? How engineers send commands to a rover on planet Mars and how they get its feedback? Rovers sent to planet Mars, are operated by the "Mission Control" operators on Earth, but they are also integrated with various hardware and software technologies to be semi-autonomous. The payload instruments carried onboard, can collect samples, and perform some experiments. Data from those experiment are sent back to Earth to be analysed by the scientists.

Figure 1



↑ ExoMars Rover

ExoMars is a future rover mission lead by ESA and designed to search for past or present life on Mars. The pan-European mission incorporates atmospheric science, sample analysis and geology to help us understand the surface of Mars, its history and whether it could have ever hosted life.

At the top of the rover are several instruments that will be the first step to understanding the surface of Mars. These instruments include PanCam (Wide angle Cameras and High-resolution camera – HRC) and the Infrared spectrometer for ExoMars (ISEM). These instruments all **study the way light interacts** with different materials.

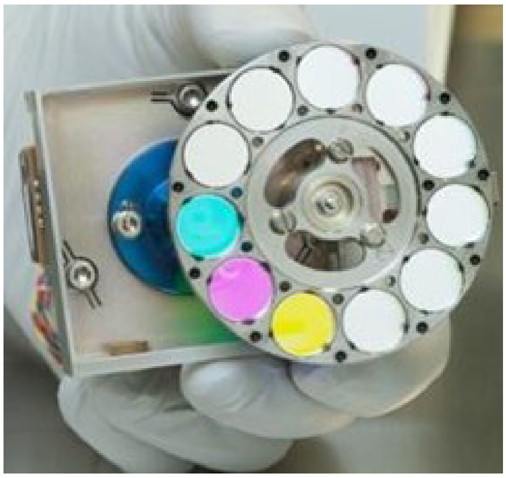
→ Background

The ExoMars mission will search for evidence of past or present life on Mars, but this is a very difficult challenge. We believe Mars was once much more like the early Earth. If life did evolve on Mars, it is likely to be from this early period of time, known as the Noachian. So today, to search for life we are looking for evidence of life (either living or fossilised evidence of microbial communities), the ingredients for life (Carbon, Hydrogen, Nitrogen, Oxygen, Phosphorous etc) and we are looking for conditions that can preserve these signs of life (like clays).

The ExoMars Rover - called Rosalind Franklin, has specifically been designed to do this, even featuring a 2-metres subsurface drill to make sure we can access the Martian subsurface where the sun's radiation cannot penetrate and destroy signs of life. There are several instruments onboard the Rosalind Franklin rover that will contribute to the first step of understanding the Martian surface. These instruments include PanCam (Wide angle Cameras and High-resolution camera – HRC) supported by the Infrared spectrometer for ExoMars (ISEM). These instruments all **study the way light interacts** with different materials. PanCam's wide angle cameras take pictures like normal cameras but through multiple circular **filters** in the visible and near infrared (NIR) spectrum. This is also referred to as 'multispectral imaging'.

Figure 2

Figure 3

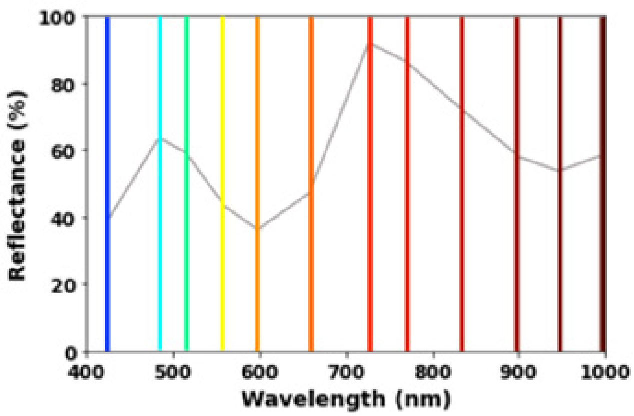


↑ PanCam instrument and filter wheel, M. de la Nougerede, UCL/MSSL

The principle behind multispectral imaging is that each filter of the PanCam only lets through a specific range of wavelengths of sunlight that is reflected on the Martian surface. Grey images are retrieved from each filter which are added together to get colour and spectra. This means that the PanCam gives us **multispectral** data at each of the wavelengths that correspond to the filters (Figure a, below). However, spectra can also look like smooth lines; this is **hyperspectral** data - where information is obtained at every wavelength (Figure b, below). Hyperspectral images can be seen as regular camera images where spectroscopic data is also obtained.

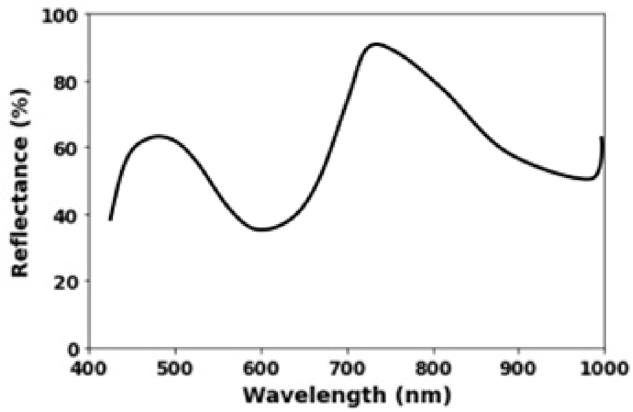
Multispectral data looks like this:

Figure 4



Hyperspectral data looks like this:

Figure 5



↑ a) PanCam wavelengths compared to multispectral data, b) Hyperspectral data example

Spectral imaging is a very useful technology to map details of the surface of Mars, but also other distant objects in space. Depending on the materials present on the Martian surface, specific wavelengths of sunlight are absorbed whereas other are reflected. Each type of material has thus its own unique spectrum that can be recognized. Therefore, the spectrum of a material can also be seen as a specific fingerprint.

Did you know?

- The ExoMars Rover was named Rosalind Franklin after a scientist who contributed on the discovery of our DNA structure
- The ExoMars rover has two 'eyes' in the PanCam instrument so it can see in 3D like us!
- PanCam has 12 filters in each eye, meaning it can see in over 15 colours
- The ExoMars rover will look further into the subsurface of Mars than any other rover!

→ Activity 1: Human rover analogue mission

Exercise

1. Once split into teams, you must decide who will be the rover, the rest form the mission control team.

2. The rover student can start on any square you want on the edge of the map. Keep in mind that mission control can't see the map!

3. You have 10 minutes to collect as many Points of Interest (POI's) as possible while avoiding the hazards. Every hazard encountered incurs a 30 second time penalty.

4. The rover student will describe what it sees to mission control using 5 words or less (per turn).

5. Mission control then must discuss and decide what instructions to give the rover, up to a maximum of 3 actions to find the POI's and avoid hazards. (e.g 1. step forward, 2. turn 90 degrees right, 3. step forward).

6. Steps 4 and 5 are repeated until the time runs out.

7. For every POI you have found you will be given a downlink file from Mars (in annex 1). Downlink files contain PanCam images, spectra and HRC images.

8. The entire team must work together to figure out what you have found by comparing their downlink files to the reference files (annexes 1 and 2).

→ Activity 2: Lego rover analogue mission

Exercise

1. You will be all split into mission control teams.

2. Once the Lego rover is on place at the edge of the map you will have 10 minutes to look at the map and plan a route to collect the points of interest (POI's). You can draw your own mini map, write instructions etc to plan.

3. Once you start you have 10 minutes to collect as many POI's as possible (by driving over them) while avoiding the hazards. Every hazard encountered incurs a 30 second time penalty removed from your 10-minute total.

4. At the end of your time, you will be given a downlink file for every POI collected. Downlink files contain PanCam images, spectra and HCR images.

5. Your entire team must work together to figure out what you have found by comparing the downlink files to the reference files.

→ Activity 3: Sample Analysis

To help us understand what rover instruments find on Mars, we use matching instruments to investigate lots of different substances, like those we might find on Mars, that are here on Earth. We use these results to compare them to our Martian data. These materials are called analogues, or reference samples.

Typically, the instruments we have here are much better than what we can send on the rover because we have no temperature, mass, size, or data limits.

Exercise

By the end of each mission, your team must have collected several samples for each point of interest you visited with your rover. Now, the entire team must work together to figure out what you have found.

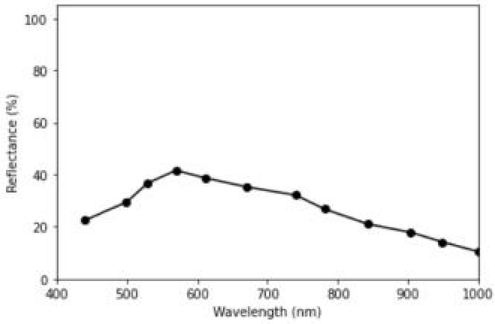
Compare your mission data (downlink samples) to the following analogue/reference targets to work out what they are. You can compare shape, colour, layers, and the spectra of the samples to work out what you have found during your mission.

Downlink data will look like this:

PanCam Image: **HRC Image:**

Credit: Nasa

PanCam Multispectral Data



Reference data will look like this:

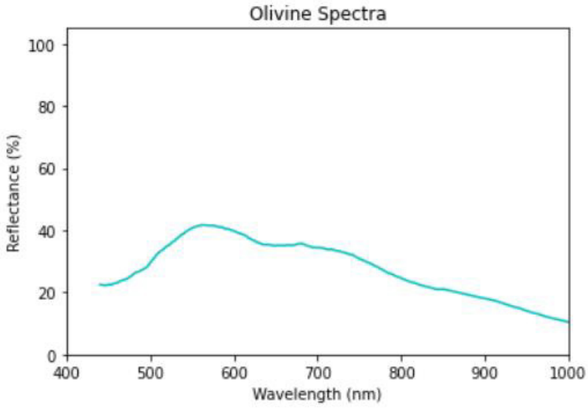
Olivine

Target Summary

Olivine is found in igneous (volcanic) rocks. If we find it at the surface of Mars there must be large amounts or volcanism or tectonic activity in the area.

Tumbled Olivine Crystals from Earth (several mm in diameter)

VNIR Hyperspectral Data



The way you will be identifying the Martian samples is the same way we would identify different types of rocks on Mars. By looking at layers, colours, shapes, and textures, alongside spectra, we can work out what substances are on the red planet!

Debate your finding with your peers. Discuss what do you think would be the most likely rocks to find in Mars.

→ Links

ESA resources

ESA classroom resources:
esa.int/Education/Classroom_resources

ESA Kids homepage:
esa.int/kids

ESA's Paxi videos:
esa.int/ESA_Multimedia/Sets/Paxi_animations

The Solar System and its Planets:
esa.int/kids/en/learn/Our_Universe/Planets_and_moons/The_Solar_System_and_its_planets

ESA space projects

The ESA ExoMars mission:
esa.int/Science_Exploration/Human_and_Robotic_Exploration/Exploration/ExoMars

Extra information

More "Roving with Rosalind" resources:
stem.org.uk/cxgt4x

Find your role in a mission to Mars (personality quiz):
spacecareers.uk/?p=mars_quiz

Why the ExoMars rover is named after Rosalind Franklin:
gov.uk/government/news/name-of-british-built-mars-rover-revealed