Explore
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EXOMARS: NEXT STEPS

TEACHING RESOURCE

INSPIRE THE NEXT GENERATION **of scientists and engineers**

STEM DISCOVERY CENTRE

In partnership with
NORTH HERTFORDSHIRE COLLEGE

In the summer of 2022 ESA (European Space Agency) launch their ExoMars Mission. This mission is part of a wider project, looking for evidence of life within the Solar System. For this mission a rover, Rosalind Franklin, will be sent to the Mars surface to undertake a series of science investigations.

This mission is ground breaking for several reasons. This is the first time that ESA have developed a rover to send to Mars and this rover was developed and built, predominantly, in the UK (Stevenage). This will be the first rover to drill more than a few millimetres into the surface of Mars. This rover will also be the first to use AI (Artificial Intelligence).

This is an amazing opportunity for us to celebrate the achievements of STEM careers in the UK and use that to inspire the next generation to engage with Science, Technology, Engineering and Maths.

In these resources we will be providing an explanation of the process and science involved in the Mars surface analysis, using terms and curriculum links suitable for a KS2 audience.

WHY MARS?

Student Question:
Why do you think Mars is the first planet in the solar system that we are exploring for evidence of life?

Answers:

- Mars is one of the closest planets to Earth
- Mars has the most suitable temperatures for life.
- Mars has water (though mostly in the form of ice)

Mars, like Earth, is in an area of the solar system that we refer to as the "Habitable Zone", or the "Goldilocks Zone", because as with the porridge in the story, it's not too hot, it's not too cold, it's just right... for life to potentially thrive.

Mercury and Venus are too close to the sun. The temperatures on those planets are too high, over 400 degrees Celsius.

Student Question:
What temperature does water boil at?

- Answer: 100 degrees (Celsius)

All forms of known life require a combination of Water and Heat to exist and evolve. Within the Solar System, Earth and Mars have the best conditions for life as we know it to exist.

Activity:
Mapping the Solar System – see Appendix

Though we are looking for evidence of life on Mars, we are not looking for donkey's or rabbits, or even insects. We are looking for tiny, microscopic forms of life, called micro-organisms. We don't even mind if they are not actually alive. If we find fossilised remains of micro-organisms, we will still learn a lot about the potential for life on Mars, though obviously living organisms would be incredibly exciting!

THE CHALLENGES OF EXPLORING MARS

Although Mars is the closest suitable planet to explore for evidence of life, the conditions on the surface still provide many challenges when planning a mission.

The main difficulty in searching for evidence of life is the effect of radiation on the surface of the planet. Due to the thin atmosphere around mars (only 1% of what we enjoy on earth), and the minimal magnetic field, the first 1.5m depth of the crust has been subjected to constant radiation. This means that we will not find any evidence of life within this area, as it will have been decomposed by the exposure to radiation.

Our atmosphere on Earth helps to protect us from radiation. The atmosphere is made from layers of gasses that are wrapped around the planet. On Earth we have a layer that we call the Ozone Layer. It is this layer of the atmosphere that helps to protect us from harmful radiation from the Sun, as the layer of ozone absorbs harmful ultraviolet radiation. Ultraviolet radiation can penetrate the bodies of animals and plants, causing disease and illness, such as skin cancer – which is why we need to protect ourselves with sun cream. Mars does not have the same level of protection, due to its very thin atmosphere, so the ultraviolet rays have been penetrating the surface of the planet, causing damage, for millions of years.

Activity:
Blacklight and sun cream pictures

Even though we are fortunate enough to have a nice dense atmosphere, this on its own would not be enough to protect Earth. Without the protection of our magnetic field solar winds, which buffet the Earth on a daily basis, could strip away the ozone layer, leaving us without protection from the UV rays.

Our magnetic field acts like a shield, deflecting most of the solar wind, though we can sometimes witness the effects on our magnetic field at the extreme North and South of the globe, through the phenomena known as Aurora Borealis (the Northern Lights) in the north or the Aurora Australis (the Southern Lights) in the south. This happens when charged particles from a solar wind come into contact with gases in our atmosphere.

Those gases become "excited" much like the gases in a neon light, and that is when we can see the Aurora. Many scientists believe that it is the decline of the magnetic field around Mars that has stripped away it's atmosphere, allowing radiation to affect the first 1.5m of the crust.

To overcome this the Rosalind Franklin Rover will have a drill, capable of drilling 2m under the surface. The drill will extract samples to be analysed by an onboard lab, which will then send data from the results back to earth.

Activity:
Archimedes Screw

Additional challenges for the ExoMars Mission include the wide variation of temperature within a Sol (Martian equivalent to a day, approx. 24hrs 39min 35sec). Like Earth, Mars can experience a variety of temperatures from day to day. An average day time temperature on Mars is about 5 degrees Celsius, though at the equator it can reach up to 20 degrees during summer months. At night the average temperature drops down to approx. -120degrees Celsius, though at the poles this can fall to -195 degrees during winter months. This means that on a daily basis the surface of the planets sees a wide range of temperatures (approx. 125 degrees difference). Even for a rover, this is not good. If we repeatedly heat up materials and cool them down, they become brittle over time, breaking easily. It is especially important for the controls and electronical equipment to maintain a fairly even temperature, or the wires inside the rover could break, bringing a premature end to the mission. To help overcome this problem the rover will have a little onboard heater, to help keep it warm at night. Additionally, it has been designed to use certain materials to help insulate it. For example the body of the Rosalind Franklin Rover has been sprayed with actual gold, due to its thermal properties.

Activity:
Thermal Conduction Experiment

Another major challenge for the Rosalind Franklin Rover is the terrain and this is where the all important AI will be used to greatest effect. Previously all robotic missions to Mars have been controlled from Earth, with scientists observing via camera and programming the rover accordingly. The problem with that approach is that it can take up to 20minutes for information to travel from Mars to Earth. This means that any video footage that is being used to control the rover, happened up to 20 minutes beforehand. So if you are controlling the rover and it reaches the edge of a cliff, that happened 20 minutes ago. By the time you have sent the commands back for the rover to STOP! Another 20 minutes have passed, and it is most likely already too late! The Rosalind Franklin Rover has been designed to use special cameras for navigation. It has a pair of cameras, which will act like a pair of eyes, allowing it to judge how far away things are, how big rocks are and how steep slopes might be. Not only this, but it is also programmed to make decisions based on that information. Due to all the tests that have been carried out using the prototype rovers in Stevenage, the Rosalind Franklin rover will know if a rock is too big, or a slope too steep and will plan its path according to the information that it is able to gather. This being the case, this rover will be able to move much faster than previous rovers. Due to the time delay in receiving information, previous rovers moved at a speed of 1-2cm per minute. The Rosalind Franklin Rover will be able to move at a speed of 1-2cm per second.

Activity:
(Battleships/grid map activity) Maths activity – how long (slowest and fastest based on info) will it take the rover to travel various distances? How far will it travel in a set amount of time?

Although the majority of the work on this Mars rover has taken place in the UK, it will not be launched into space from here. Most major rocket launches take place on or near the equator. This is due to the shape and motion of the Earth and the fact that the equator is the widest part. If we view the northern hemisphere, for example, as a series of concentric circles, with the smallest being at the top (the arctic circle) and the largest being at the bottom (the equator), we can use the lines of latitude as a rough guide. Although those circles have different circumferences, and so are different sizes, they all move at the same time, but this does not mean that they all move at the same speed. If fact it means that they are all moving at different speeds, to keep up with each other; the arctic circle, which is a small circle, takes 24 hours to rotate once and the equator, a big circle also rotates once in the same time. It is easier if we think of it like this; lets imagine that the circumference of the arctic circle is 25miles and that it rotates once every hour, that means that it is travelling at 25mph. It takes the same amount of time for the equator to rotate once, in this example, 1hr, but the circumference of the equator is, say 50miles, in which case the equator is travelling at 50mph, even though they are both turning at the same time. So essentially, the equator is "moving faster" than any other part of Earth, which produces a kind of sling-shot effect. If you have a ball tied to the end of a piece of rope and swing it around in circles before you let go, it will travel further than if you just swung it once. The faster you swing the ball, the more momentum you will generate, allowing it to travel further. The same physics can be applied to launching rockets. When they are launched from the equator, more momentum is generated, which makes it easier to overcome Earth's gravitational pull.

Activity:
Concentric Circle activity

GETTING TO MARS

Mars, at its closest position to Earth, is 30 million miles away.

Student Question:
If it takes five days to travel to the moon, how long do you think it will take to get to Mars?

Answers:
Approximately nine months

We only have an opportunity once every 2yrs to launch a rocket to travel to Mars. All planets orbit around the sun, but the further away they are from the sun, the bigger the "circle" of their orbital path, which means that planets are not always close to each other. Sometimes they are on opposite sides of the sun. As the sun is a big flaming ball of gas (approx. 15,000 degrees on the surface and 5million degrees at its core) trying to fly a rocket straight through it is not advisable. Due to this, we have to wait until Mars and Earth are as close together as possible before we can launch our rocket.

Engineers have to design space craft very carefully as space can be extremely cold or hot depending on where the rocket is travelling. In direct sunlight, metal can heat up to approx. 260 degrees in space, but in the shade, for example if a space craft is behind or in the shadow of a planet, that same piece of metal will cool to temperatures of approx. -100 degrees. These extremes of temperature can easily damage the materials and equipment (payload) on board the space craft.

Activity:
Make Your Own Space Blanket

Once it arrives the rocket will release the landing shuttle, which will take the rover down to the surface of Mars. The lander being used for this mission is similar in shape to a dodecahedron. When it first enters the atmosphere, it will have an almost cone shaped heat shield on the underside. Even though the atmosphere is very thin, the action of the lander falling through it will create friction, from the air resistance, which will make the shell of the lander extremely hot. Extreme temperatures can be very damaging to the Mars rover and so the heat shield will help to protect from this. At a certain point in its descent the lander will deploy a parachute, which though not as effective as it would be on Earth, will still have the effect of slowing down the motion of the lander (and allowing it to cool a little). Once this has occurred the lander will release the heat shield, revealing sensors in the underside of the unit, which will be able to sense the distance to the surface of the planet. When it has reached a specific distance the lander will then start firing in-built thrusters (like little rocket packs), to slow the unit down even more and allow, for a controlled landing. Once it has landed the top and sides will open up, much like the petals of a flower and the rover will be able to use them as a ramp and trundle off on its mission.

Activity:
Egg drop – what is the best shape to use to protect our lander/egg? Can we use methods to slow down descent other than a parachute?

Once on the surface of Mars the rover will be looking for areas that look like they may have been riverbeds at some point. In particular, it will look for areas that may have had two or more rivers converging. This is because it is likely that life, or evidence of it would have been swept along by the moving water. At an area where two or more rivers converged there is the potential for evidence from two, or more, origins, increasing the chance that evidence will be present.

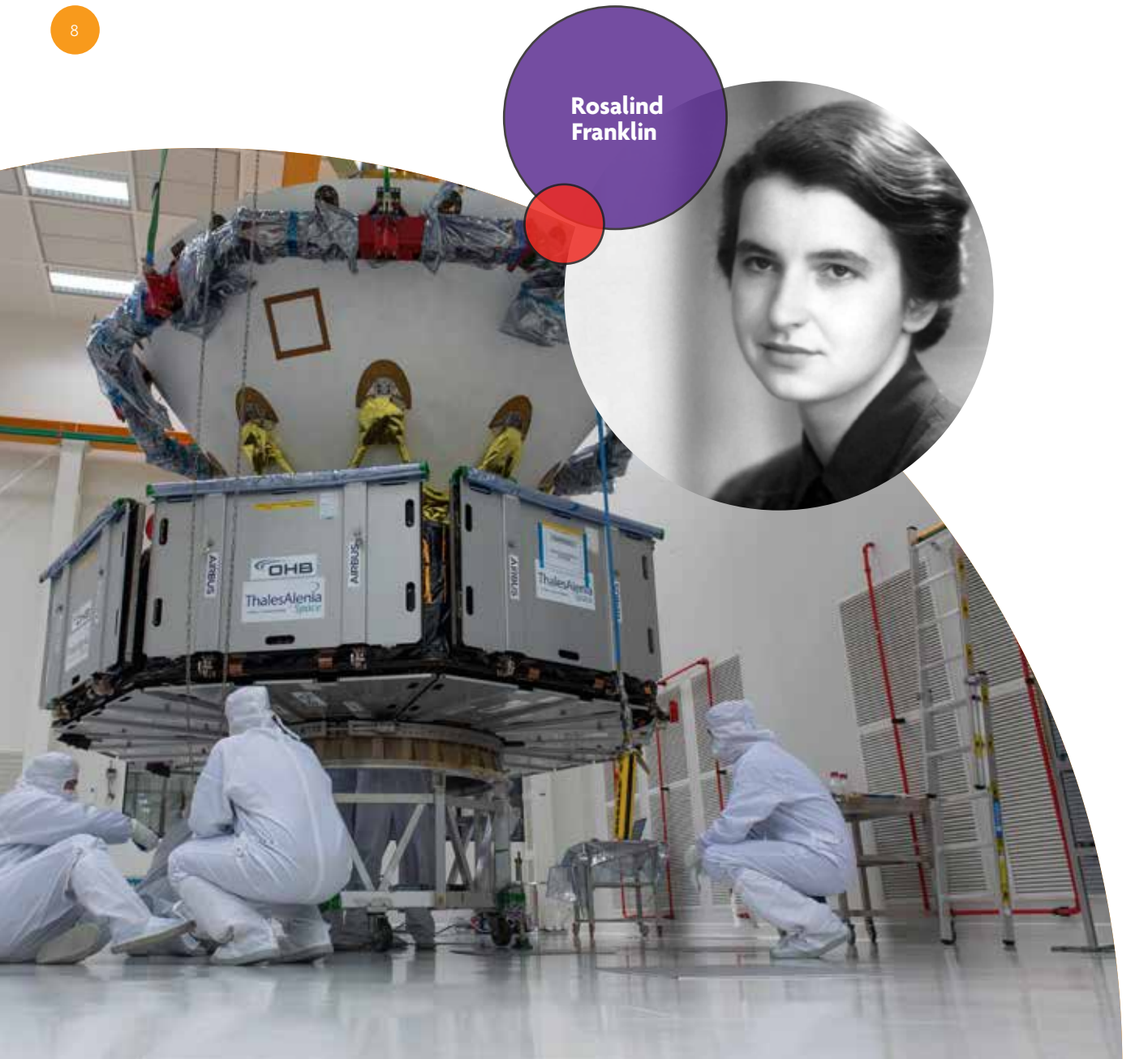
NEXT STEPS:
the mission on Mars

ROSALIND FRANKLIN ROVER

Student Question:
Do you know why the rover has been named Rosalind Franklin? Do you know who Rosalind Franklin was?

Activity:
Research Rosalind Franklin

Answer:
Rosalind Franklin was a British Scientist who is most famous for her work contributing to the discovery of the double helix structure of DNA. She was not acknowledged in the award of the Nobel Prize, though this occurred after her death. The ExoMars Rover has been named after Franklin in acknowledgement of her vital contributions to our understanding of the building blocks of life.



ONBOARD INSTRUMENTS

Once it has reached Mars, the Rosalind Franklin Rover will be on its own. At the moment, we cannot easily retrieve things from the surface of another planet, which is one of the reasons that we send robots instead of people. Due to this, it is essential that the rover can observe, sample and analyse materials on the surface of Mars. To do so the rover has been designed with a series of external and internal instruments, to help it navigate, identify opportunities for taking samples, collecting those samples and then analysing them, before sending the results back to Earth.

INSTRUMENTS USED FOR SELECTING SAMPLING SITES

The ExoMars rover can only take a limited number (18) samples during the 9 months of its mission. Taking and analysing drill samples uses precious time, energy and expense so using several instruments as a preliminary screen to choose the best drilling site is essential. ExoMars will choose sample sites exactly as a field geologist does – by observation and experience, using a combination of the following instruments;

PAN CAM (PANORAMIC CAMERA)

The digital "eyes" of the rover, the PanCam uses digital terrain mapping to build up images of the Martian surface. This means that the rover takes lots of photos of the land around it, these photos can be laid on top of each other to build up a 3D image. This allows the rover to safely navigate across rocky, sandy surfaces, over or around potential obstacles. The camera also has a colour filter wheel, meaning that it can look at the ground through different colour filters. This allows for colour images as well as, for example, picking up fluorescent molecules by looking through a UV light filter.

Activity:
Karnovsky Images and Make UV torch

WISDOM (WATER ICE SUBSURFACE DEPOSIT OBSERVATION ON MARS)

A ground-penetrating radar that has been designed to provide information about the nature of the ground below the Martian surface over depths ranging from 3 to 10 metres. After driving for 2 metres, the rover stops, takes photos using PanCam and fires the WISDOM radar into the ground. The strength and nature of the reflection from the radar can be compared to reflections from known materials (for example, the reflection of light from a piece of glass is different to that from a mirror or water or even a painted wall). WISDOM will help decide on the best places to use the drill as well as the safety and success of drilling operations by identifying potential hazards that could interfere with retrieval of drill samples.

SPECTROMETERS

Spectrometers are instruments that are used to gather measurable data from certain spectrums, for example light or (molecular) Mass. Spectrometers are used to identify and measure chemical components and composition.

How does a mass spectrometer work?

"Everything around us consists of very small building blocks "atoms" and clusters of building blocks "molecules". Atoms and molecules are so small that we cannot see them. The different building blocks of different materials have a different mass."

A mass spectrometer separates samples depending on their mass to charge ratio. It is used to find out the mass of particles, and to find the basic chemical elements in a sample or molecule. It can also make clear the chemical structures of molecules, such as peptides and other chemical compounds. It works by ionizing the particles in the sample, which means an electron is removed from each particle, producing positively charged ions. This is done by using an electron gun - a high energy beam of electrons is passed through the sample to make electrically charged particles or ions. The ions are accelerated through a short tunnel, by use of negatively charged plates to which the positively charged ions are attracted. On passing through the tunnel, the ions are exposed to a magnetic field which causes them to travel in a curved path, depending on how heavy they are. Heavier ions are bent less than lighter ions. This results in heavier ions hitting a detection plate, at the end of the tunnel, at a different position to lighter ions. From this information, the mass-to-charge ratio of the particles, and the relative abundance (how much was in the sample) of each type of particle can be worked out. For each sample a 'spectra' is produced which shows a peak each time an ion hits the detection plate. This can be compared to the peaks produced by 'known' particles and used to distinguish what particles are being detected.

Activity:
Spectroscope

ISEM (INFRARED SPECTROMETER FOR EXOMARS)

Working with PanCam, ISEM will help select suitable samples for further analysis. It will be attached to the ExoMars rover's mast to measure reflected solar radiation (light) in the infrared light range. When infrared light is absorbed by chemical structures they vibrate differently, and this can be measured by ISEM.

MA_MISS (MARS MULTISPECTRAL IMAGER FOR SUBSURFACE STUDIES)

This is a tiny spectrometer that is located inside the drill head. This will be used to analyse samples while they are still in situ (in the place that they originated) before they are taken onboard the rover for further analysis.

CLUPI (CLOSE-UP IMAGER)

A high-performance colour close-up imager – the equivalent to a hand lens. CLUPI can work at very low temperatures at a working distance from 10cm to infinite, providing outstanding quality pictures.

CLUPI is the essential final step in the choice of drill site for the ExoMars Rover. The images taken by CLUPI are also important for observation of the drill head placement, the fines that come out of the drill hole and the surface of the core drilled materials when they are in the sample drawer.

Activity: Water Drop Magnifier

Instruments used for analysing samples

There are multiple instruments on board the Rosalind Franklin Mars Rover

SPDS (SAMPLE PREPARATION AND DISTRIBUTION SYSTEM, ALSO KNOWN AS THE CRUSHER)

Each sample taken by the drill needs to be prepared for analysis, this will first involve crushing the sample into a powder. This powder will then be distributed into 20 equal sample pots for further analysis. For some spectrometry analysis samples need to be in gas form for analysis, this is either done by heating the sample, or zapping it with Ultraviolet (UV) Light pulses.

Activity: Design and Make Your Own Soil/Rock Crushing Device

RLS (RAMAN SPECTROMETER)

Raman spectrometer is used to understand more about the make-up of materials. A sample is illuminated using a single colour of light and the way the light interacts with the sample tells us information about it. We can identify unknown materials from their unique Raman spectral fingerprints, typically using databases of known spectral fingerprints and comparing the two.

MOMA (MARS ORGANIC MOLECULE ANALYSER)

The MOMA instrument on board the ExoMars rover will analyse a wide range of organic compounds that may be found in the drill. The overarching goal of MOMA is to seek the signs of past or present life on Mars through analysis of these samples.

What are they looking for in the analysis?

1. 1Molecular bio-signatures – A pattern or distribution of molecules that results from biological processes
   e.g. cell wall lipids.
2. Evidence of active processes – carbon cycle, oxidation, reduction etc.

THE PROCESS FOR SCIENTIFIC ANALYSIS ON MARS

Once the rover has landed on Mars it will be autonomous, which means that it will be able to drive and make decisions for itself. To allow it to navigate the surface of Mars the rover will have an instrument called Nav Cam. In conjunction with these it will use Pan Cam. This is a pair of panoramic camera's, which means that it can take a wide view of the landscape. As there are two camera's they will act like eyes providing stereoscopic vision (3 dimensional, providing depth of vision). It will use the information from these camera's to analyse the surface through different filters.

While the rover is driving over the landscape it will use several different methods to scan the terrain and select the best places to take samples from. The 2 main instruments used for this are WISDOM (Water and Ice Subsurface Deposit Observation on Mars) and CLUPI (CLose UP Imager). WISDOM uses infra-red to scan the surface to find potential areas for further investigation. CLUPI is the final decision maker, using close up images (basically a microscope) to decide if the scanned area has the key indicators to suggest that it is worth stopping and taking a sample to analyse.

Once CLUPI has given the go ahead, the rover will deploy its drill. The drill pushes out like a telescope and contains Ma_MISS (Mars Multispectral Imager for SubSurface) fibre optic cameras to make observations, as well as being able to take samples.

Once a sample has been taken, it must be prepared for analysis. This happens in the SPDS (Sample Preparation and Distribution System) also known as The Crusher. This instrument prepares the sample by first of all crushing it (as the name suggests) to break it into smaller pieces to provide a greater surface area to be distributed between the instruments for analysis.

In the diagram below the process is illustrated in the Blue boxes and the instruments used for that part of the process are illustrated using the Green boxes.

APPENDICES

APPENDIX 1.

Additional Links: Solar System Planets Print Out, Comparative Planetary Size images

APPENDIX 2

- Appendix 1: Mapping the Solar System Activity
- Appendix 2: UV Light vs Ozone Layer Activity
- Appendix 3: MYO UV Torch Activity
- Appendix 4: Archimedes Screw Activity
- Appendix 5: Thermal Conduction and Insulation Experiment
- Appendix 6: Rover Navigation Activity
- Appendix 7: Concentric Circle Activity
- Appendix 8: Space Blanket Experiment
- Appendix 9: Egg drop Activity
- Appendix 10: Rosalind Franklin Research (pop-up book)
- Appendix 11: Carnovsky Filters Activity
- Appendix 12: Spectroscope Activity
- Appendix 13: Water Drop Magnifier Activity
- Appendix 14: Design and Make Your Own Soil/Rock Crushing Device

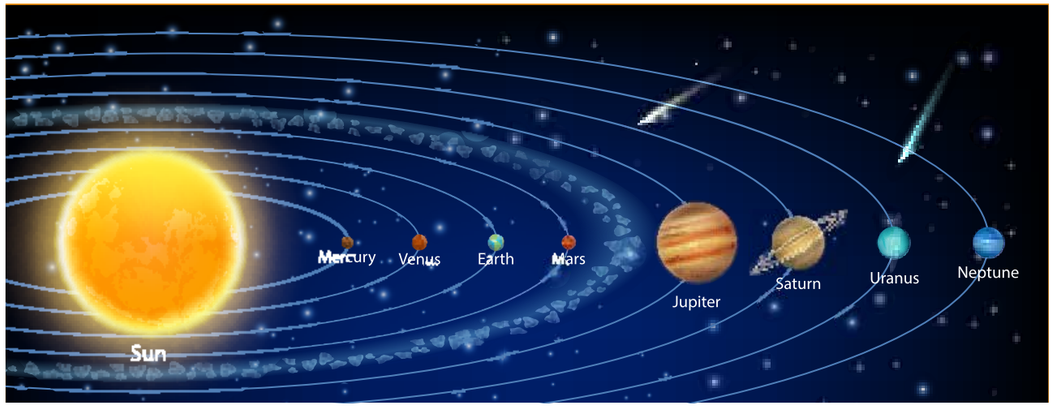
STEM DISCOVERY CENTRE

APPENDIX 2.1

Mapping the Solar System

KS2: Yr5

Subject:	Science: Earth and Space, Maths
Duration:	45 - 60min
Type:	Make and Measure investigation



MATERIALS:

- 2M Length of display border role per student
- Pencils
- Crayons/Felt Pens

Extension task

- Paper/solar system planets printouts
- String
- Scissors
- Tape
- Ruler

Aims:
Create a map of the solar system, with specific reference to the distance between each planet, measured in fractions of the whole.

SCHEMES OF WORK:

Describe the movement of the Earth and other planets relative to the sun in the solar system

Inquiry:
Comparing different distances between planets and the sun; using known measurements to assist with mathematically finding unknown quantities, using research to provide diagrams/illustrations and additional information.

Critical Thinking:
How can a known measurement assist with finding unknown measurements? How can this be recorded?

Objectives:
To learn the order and relative distance between planets in the solar system

INSTRUCTIONS:

Step 1: At one end of strip of paper write "SUN" in small, neat letters. At the other end write "Pluto" or "Kuiper Belt". The Kuiper Belt is the asteroid belt that Pluto is part of.

Step 2: Fold the paper carefully in half, Pluto/Kuiper Belt to the Sun. Write "Uranus" on the fold.

Step 3: Fold the paper again, the end labelled "Pluto" to the fold labelled "Uranus". Write "Neptune" on the new fold.

Step 4: Fold the paper again, the end labelled "Sun" to the fold labelled "Uranus". Write "Saturn" on the new fold.

Step 7: Fold the paper again, the end labelled "Sun" to the fold labelled "Saturn". Write "Jupiter" on the new fold.

Step 8: Fold the paper again, the end labelled "Sun" to the fold labelled "Jupiter". Write "Asteroid Belt" on the new fold.

Step 9: Fold the paper again, the end labelled "Sun" to the fold labelled "Asteroid Belt". Write "Mars" on the new fold.

Step 10: Fold the paper again, the end labelled "Sun" to the fold labelled "Mars". Write "Venus" on the new fold.

Step 11: Fold the paper again, the end labelled "Sun" to the fold labelled "Venus". Write "Mercury" on the new fold.

Step 12: This final fold is tricky, so take your time to get it right. Fold the crease labelled "Venus" to the fold labelled "Mars". Write "Earth" on the new fold.

EXTENSION TASKS:

1. Can you identify and mark, in some way, the "Goldilocks Zone" on your map?
2. We know that the distance between the Earth and the Sun is 93 million miles (we refer to this distance as an astronomical unit). Measure the distance between the Earth and the Sun on your Solar System Map. Using that information can you a) work out the distance between the Sun and each of the planets? b) work out the distance between each of the planets (when they are aligned) and c) an estimated size for the "Goldilocks Zone".
3. Using paper/planetary printouts and bits of string, can you produce realistic pictures to stick into the correct positions on your map? Can you also produce a way of displaying key bits of information for each planet?

THE SCIENCE

Mars, like Earth, is in an area of the solar system that we refer to as the "Habitable Zone", or the "Goldilocks Zone", because as with the porridge in the story, it's not too hot, it's not too cold, it's just right... for life to potentially thrive.

Mercury and Venus are too close to the sun. The temperatures on those planets are too high, over 400 degrees Celsius.

There are now currently eight planets in the Solar System;

- Mercury
- Venus
- Earth
- Mars
- Jupiter
- Saturn
- Uranus
- Neptune

The first four of these planets are terrestrial – solid and not terribly large compared to the rest of the features of the solar system.

The second four are gas giants, being composed of layers of gases (though technically, in scientific terms, Uranus and Neptune have been more recently classed as Ice Giants).

We used to include Pluto in this list, but Pluto has been relegated to the category of "dwarf planet" as it is smaller than many of the moons in the solar system. In fact some people believe that Pluto is in fact just a very large and spherical asteroid that forms part of the Kuiper Belt (the asteroid belt that encircles the outer edges of the solar system.

THE CONTEXT

All forms of known life require a combination of Water and Heat to exist and evolve. Within the Solar System, Earth and Mars have the best conditions for life as we know it to exist. We call the area where these planets are to be found, the Goldilocks Zone.

APPENDIX 2.2

UV light vs Ozone layer activity

KS2: Yr6

Subject:	Science: Extension of Earth and Space, Light
Duration:	30 - 45min
Type:	STEAM Investigation

MATERIALS:

- UV torches or Light
- Variety of paper (white or fluorescent is best)
- Sun Cream
- Saucer/shallow dish (small pie tin)
- Paint brush (optional)

Extension Materials

- UV reactive beads (extension only)
- Thread/elastic (extension only)
- Cyanotype or Photoreactive Paper

Aims:
To create a self portrait using sun cream to help understand how certain materials can block UV light, much like the Ozone Layer

SCHEMES OF WORK:

- Working Scientifically
- Plants; explore the requirements for life and growth...
- Light; recognise that they need light in order to see things and that dark is the absence of light
- notice that light is reflected from surfaces
- recognise that light from the sun can be dangerous and that there are ways to protect their eyes
- recognise that light appears to travel in straight lines
- use the idea that light travels in straight lines to explain that objects are seen because they give out or reflect light into the eye
- explain that we see things because light travels from light sources to our eyes or from light sources to objects and then to our eyes

Objectives:

- For students to learn that Ultra Violet (UV) rays can be harmful. Make the link between sun cream protecting us from UV rays in the same way that the ozone layer protects us from UV radiation.
- To observe pictures drawn with sun cream, when UV light is shining on them and discuss the difference to when white light is shining on them.
- To learn that light (radiation) can be reflected or absorbed.
- To introduce the Electro-magnetic Spectrum and extend knowledge of the nature of light and Earth Sciences

INSTRUCTIONS

1. Give each child a piece of paper (white or fluorescent is best)
2. Distribute shallow dishes with sun cream around the tables/group
3. Get each child to use their fingers (or paint brush if preferred) and sun cream to create a picture of themselves
4. Stick/pin the finished pictures on the wall, turn the lights off and shine your UV torch/light over the pictures – what do the children notice?
5. The paper should seem to "glow", while the sun cream will appear black.

EXTENSION INSTRUCTIONS/ SUGGESTIONS

Inquiry:
Does the thickness of the sun cream make a difference?
Does the type of paper effect the way we view the results?

Critical Thinking:
How can we create an experiment with measurable results to support our hypothesis? How can this be recorded?

3. Science experiment – does the sun cream still work the same after a period of time? Test is every so often (every couple of hours, this could go on for several days). How would you measure whether it has changed? What might cause any changes? Does sun cream last forever on humans? Why would this be?
4. What happens if you use the same method on Photoreactive paper?
5. Make bracelets out of UV reactive beads – test with sun cream and uv light – explain how these can be used during the summer, to let you know when you might need to use sun cream.
6. Further experiments with UV beads – place in strategic places around the classroom; windowsill, shelf, cupboard etc. In each place set up several beads, but in different condition; one plain, one covered in sun cream, one in glass on water, one in clear plastic bag, one in baby oil?, may be even one with a little cocktail umbrella over it. At certain times of the day make observations of each set of beads. Try over several days, or even months, to compare the different exposure to UV light throughout the year. Discuss how you will be fair in making your observations. How will you make sure that conditions remain the same throughout the test?
7. You could place a plant or seedling in the same places to demonstrate the impact of sunlight on plants
8. Try shining the UV light on different colours and types of paper – what happens? Are there any surprises? (Could also try this with different materials – Washing powder, toothpaste and tonic water should all clearly fluoresce).

THE SCIENCE

The sun cream blocks the UV rays from reaching the paper so the pictures will appear black, where as most of the papers will fluoresce. The Ozone layer works in a similar way, blocking damaging UV rays from reaching Earth.

We see because there is light! Light is reflected or absorbed by the things around us. We can only see objects if light hits them and is reflected to our eyes. If there isn't any light then we can't see. If light is absorbed, we can't see anything, because it is not reflecting. With the pictures you have made, the UV light has reflected from the paper to your eyes, so you can see the back ground of the image. The job of the sun cream is to absorb UV light, so the lines will appear black as the light is not bouncing off it (reflecting) but is sinking into it.

The Ozone layer of our atmosphere works in a similar way. It is more of a sieve allowing less harmful rays to travels through, but blocking most of the UV radiation.

Some radiation does still come through, which is why it is important for us to protect ourselves with sun cream on hot, sunny days. We do need some UV light. Plants use energy from UV light to help make their food. Without plants, we would have nothing to eat, so a little UV light is a good thing, but a lot is dangerous.

Certain colours or materials appear to glow or "Fluoresce" under UV light. The Pam-Cam instrument on the Rosalind Franklin Rover will have a special UV filter available to use. This will allow it to block out all types of light, except UV light, so it can observe the surface of Mars to see if any of the minerals have fluorescent properties.

THE CONTEXT

The main difficulty in searching for evidence of life is the effect of radiation on the surface of the planet. Due to the thin atmosphere around mars (only 1% of what we enjoy on earth), and the minimal magnetic field, the first 1.5m depth of the crust has been subjected to constant radiation. This means that we will not find any evidence of life within this area, as it will have been decomposed by the exposure to radiation.

Our atmosphere on Earth helps to protect us from radiation. The atmosphere is made from layers of gasses that are wrapped around the planet. On Earth we have a layer that we call the Ozone Layer. It is this layer of the atmosphere that helps to protect us from harmful radiation from the Sun, as the layer of ozone absorbs harmful ultraviolet radiation. Ultraviolet radiation can penetrate the bodies of animals and plants, causing disease and illness, such as skin cancer – which is why we need to protect ourselves with sun cream. Mars does not have the same level of protection, due to its very thin atmosphere, so the ultraviolet rays have been penetrating the surface of the planet, causing damage, for millions of years.

APPENDIX 2.3

DIY UV Torch

KS2: Yr3 and Yr6

Subject:	Science: Working Scientifically, Light
Duration:	30 - 45 min
Type:	Experiment

MATERIALS:

- Small bright light, or smartphone torch
- Clear tape
- Cellophane (clear) or Acetate (optional, depending on size of light source)
- Selection of Blue, Purple (also pink and red) Sharpie/ Permanent Markers (we have found that the pigmentation of sharpies provides the most reliable results, but other markers do work – you may wish to use this as an opportunity to experiment to see which markers/colours/ratio combination is most effective).
- Selection of objects/materials in variety of colours. Recommend to include items (but not limited to) such as; washing powder, toothpaste, tonic water, bananas, oranges, slices of kiwi/cucumber/lemon/banana, fluorescent pens/paint, white paper, variety of stamps, variety of monetary notes, spinach (partially crushed).
- Darkened/blacked out room or area (large box on its side with a thick blanket over the opening would work for an observation area if you cannot blackout a whole room.

Extension task
Can be used in conjunction with UV Light vs Ozone activity and materials.

Or you can look at the fluorescence of chlorophyll – this does involve alcohol, so you may wish to use this as a demo, of prepare in advance as one of your items for investigation.

- Spinach
- Alcohol (isopropyl or even vodka)
- Mortar and pestle or bowl and rolling pin/large spoon
- Coffee filter paper
- Couple of beakers/containers to collect and dispose of excess liquid.

See also list in The Science section.

Aims:
To experiment to see if you can make a UV filter for a torch or light and use it to observe the unseen properties of materials.

SCHEMES OF WORK:

Science

Working Scientifically

Light; recognise that they need light in order to see things and that dark is the absence of light

- notice that light is reflected from surfaces
- recognise that light from the sun can be dangerous and that there are ways to protect their eyes
- recognise that light appears to travel in straight lines
- use the idea that light travels in straight lines to explain that objects are seen because they give out or reflect light into the eye
- explain that we see things because light travels from light sources to our eyes or from light sources to objects and then to our eyes

Objectives:
- For students to learn that Ultra Violet (UV) rays though included in natural, white light (from the sun), is not part of the visible spectrum and will reflect from materials differently to white light.
- To observe a selection of materials and identify which ones fluoresce under UV light.
- To introduce the Electro-magnetic Spectrum and extend knowledge of the nature of light and Earth Sciences

INSTRUCTIONS:

1. Get your torch or smart phone light and cut 3 pieces of tape (or cellophane/acetate) of the same size.
2. Colour two of these using the blue marker and stick them one on top of the other, over the light source (covering it completely).
3. Take your final piece of tape/cellophane/acetate and colour it using the purple marker, then add this to the previous two layers.
4. Have a selection of items and materials on a tray and make observations about their colour, under white light.
5. Make predictions as to how the colours might be affected when viewed under your light with the blue/purple filter.
6. Place the items in a darkened area or room and observe again using your blue/purple light filter as your light source – what happens? Were your predictions correct? Make notes in results table.
7. Repeat instructions 1-6 using different combinations of colour on layers of tape.

Suggestion for simple table of results

Test No.	No. Layers	Colour combinations (in order)	Predictions	Observations
1				
2				
3				
4				
5				

EXTENSION TASKS:

See UV Light vs Ozone Activity

Or

- Grind some spinach in a small amount of alcohol – isopropyl (pc screen cleaner or even a little vodka should be fine. Obviously, if you use vodka, it is probably appropriate to decant some into an empty water bottle and label “Lab Alcohol” or something similar in advance of the lesson).
- Pour mixture through coffee filter paper.
- Get rid of the liquid and examine the matter left on the filter paper under a UV light – it should “glow” red.

Finally, you could experiment to see how fluorescent the household items are that we have listed and whether your students can make a comparative self portrait using them, to go with their sun cream image.

THE SCIENCE

Light travels in straight lines, but in a wave formation, very much like if you have two people holding a skipping rope or slinky between stretched them and one of them makes it ripple up and down. We call those ripples "waves".

White light, like the light emitted by the sun, is made of a combination of all colours (see our resources page for Newton's Colour Spinner). Each of those colours travels in a very similar way, but the size of the waves (the wavelength) is slightly different for each one. For example the wavelength for violet light is shorter than the wavelength of red light. When they all travel together, they combine to make white light.

There are is a whole range of waves, a spectrum, all with different lengths, which identify them, moving at different frequencies (number of waves in a set period). We call this range the Electro-magnetic Spectrum (EMS). Sound waves, radio waves, X-rays, microwaves, infra-red waves and ultra violet waves are all part of the same spectrum, but the waves that form white light are the only ones that we can see with the naked eye.

The sort of UV light created in this activity is not the same as the dangerous UV light emitted by the sun, as this light has been produced using a filter to create the colour, it's wavelength is longer than the "UVB" and "UVC" light which can burn and cause cancer.

This kind of UV light is often referred to as black light, because UV light is not visible to the naked eye and although the light source may seem bright, objects actually absorb UV light, rather than reflect it so it does not light up a space (just certain objects). Light is present, but is not visible and does not illuminate, hence "black light".

You will have noticed through your experiments that some objects can be seen using UV/black light. The reason for this, is that those objects contain chemicals or materials which fluoresce.

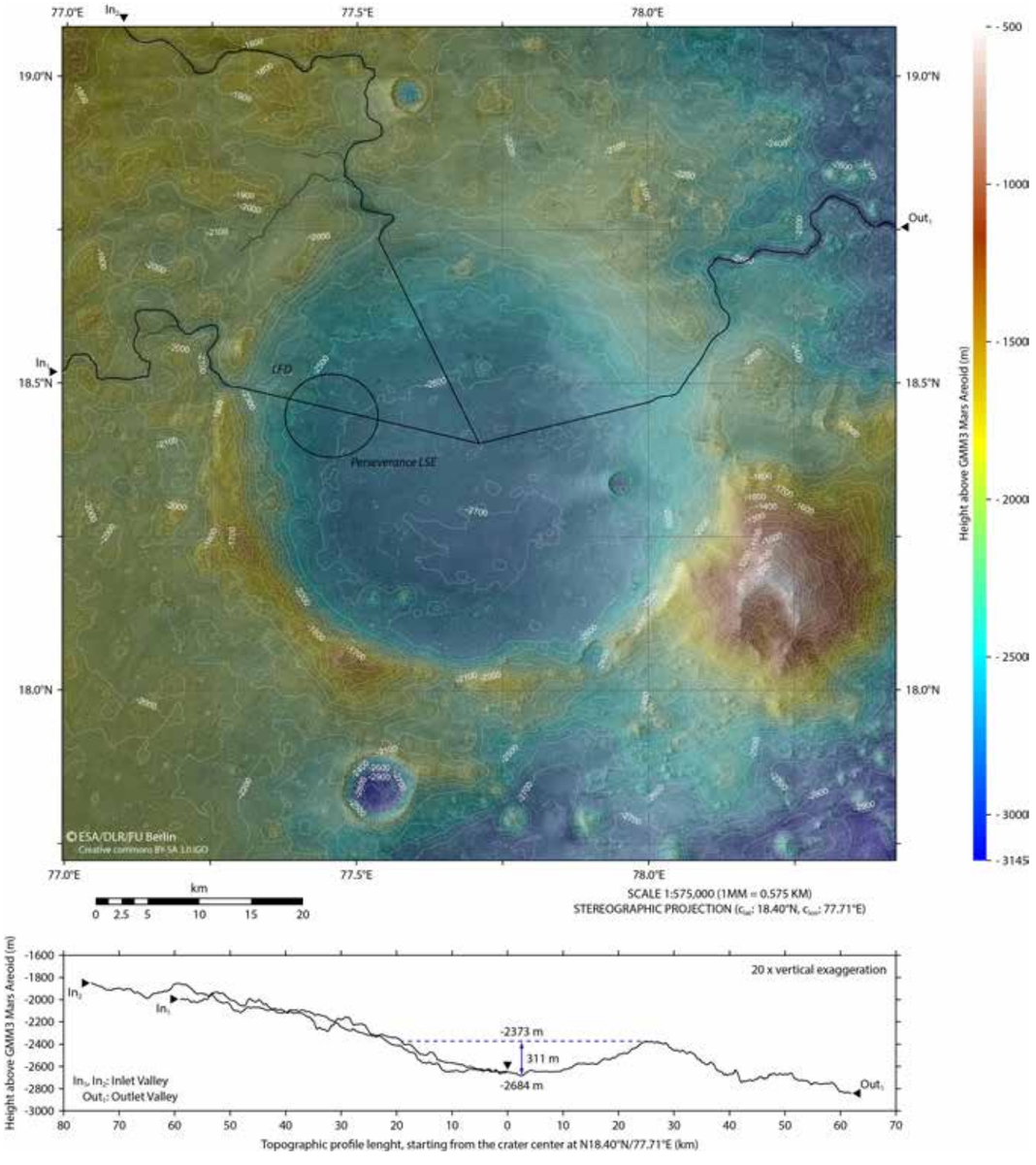
Fluorescent materials absorb and then immediately re-emit UV light. This process absorbs some of the energy from the waves, effecting their wavelength (making it longer). This change to the wavelength changes the nature of the light, making it visible and making the material affecting the change appear to glow.

Lots of things contain substances which fluoresce, such as;

- Flowers – some scientists believe that this helps attract insects and direct them to the pollen
- Washing Powders – its how they make whites look so white
- Toothpaste – as Washing powders
- Tonic – the quinine in tonic fluoresces, some brands fluoresce more than others, you might need to try a few out!
- Bodily fluids, particularly urine, but we are not going to encourage you to go there with your class!
- Chlorophyll – is usually green, but under UV light it can fluoresce a deep red colour.
- Antifreeze has a fluorescent additive mixed in to help accident investigators reconstruct crash scenes. It is so strong it can fluoresce in sunlight.
- Many Rocks fluoresce, which is one of the things the Mars Rover will be looking for. Examples of these types of rocks are; fluorite, calcite, gypsum, ruby, talc, opal, agate, quartz, and amber.
- Bank notes often glow under ultraviolet light as inbuilt parts of the design to help prevent forgeries.
- Bananas – overripe bananas, with spots, glow under UV light. The black spots show where the chlorophyll in the skin is breaking down, which causes them to fluoresce blue under UV light.
- Oranges - areas of/approaching decay fluoresce under UV light.
- White paper made since 1950's contains fluorescent chemicals, which is why UV light is often used when testing for forgeries.
- Some Make-up – to brighten complexion and as part of the reflective substances used in nail varnishes
- Petroleum jelly, such as Vaseline, glows a bright blue colour under a fluorescent light.
- Rock salt
- Turmeric (a spice)
- Olive oil
- Canola oil
- Some postage stamps – UK 2nd Class in particular
- Highlighter pens
- Honey
- Pipe cleaners (chenille craft sticks)

THE CONTEXT

The digital "eyes" of the rover, the PanCam uses digital terrain mapping to build up images of the Martian surface. This means that the rover takes lots of photos of the land around it, these photos can be laid on top of each other to build up a 3D image. This allows the rover to safely navigate across rocky, sandy surfaces, over or around potential obstacles. The camera also has a colour filter wheel, meaning that it can look at the ground through different colour filters. This allows for colour images as well as, for example, picking up fluorescent molecules by looking through a UV light filter.



APPENDIX 2.1

The Archimedes Screw

Kst2: Yr5 and Yr6

Subject:	Science: Working Scientifically, Forces; Maths: Measurement, Geometry
Duration:	60 - 90 mins+
Type:	Make and Measure investigation

MATERIALS:

- Plastic bottle 500ml recommended – needs to be circular and straight sided (same width all the way down)
- Ruler
- Mathematical Compass
- Pencil
- Scissors
- Card (thin)
- Drinking straw (slightly wider than dowel/paper stick)
- Dowel/Rolled Paper Stick (approx. 30cm – slightly longer that the bottle)
- Drawing Pin
- Tape
- Rice/popcorn/cereal (optional)

Extension task

- Pipe cleaners
- Lollipop sticks
- Glue Gun
- Polymorph
- Set of (digital) scales
- Sand
- Gravel

Aims:
To demonstrate how the drill on the Rosalind Franklin Mars Rover will work to collect samples..

SCHEMES OF WORK:

Science: Forces - recognise that some mechanisms including levers, pulleys and gears allow a smaller force to have a greater effect,

Maths: Measurement measure, compare, add and subtract: lengths (m/cm/mm); mass (kg/g); volume/ capacity (l/ml)

Geometry: draw 2-D shapes and make 3-D shapes using modelling materials; recognise 3-D shapes in different orientations and describe them

Geometry: recognise angles as a property of shape or a description of a turn

Geometry: identify right angles, recognise that two right angles make a half-turn, three make three quarters of a turn and four a complete turn; identify whether angles are greater than or less than a right angle

Geometry: properties of shapes identify lines of symmetry in 2-D shapes presented in different orientations

Geometry: properties of shapes complete a simple symmetric figure with respect to a specific line of symmetry.

Geometry: Properties of Shape draw 2-D shapes using given dimensions and angles 0 Geometry - Properties of Shape recognise, describe and build simple 3-D shapes, including making nets

Geometry: Properties of Shape compare and classify geometric shapes based on their properties and sizes and find unknown angles in any triangles, quadrilaterals, and regular polygons

Geometry: Properties of Shape illustrate and name parts of circles, including radius, diameter and circumference and know that the diameter is twice the radius 1 Maths Y6 **Geometry:** Properties of Shape recognise angles where they meet at a point, are on a straight line, or are vertically opposite, and find missing angles.

Design Technology: Design - use research and develop design criteria to inform the design of innovative, functional, appealing products that are fit for purpose, aimed at particular individuals or groups

Design Technology: Design - generate, develop, model and communicate their ideas through discussion, annotated sketches, cross-sectional and exploded diagrams, prototypes, pattern pieces and computer-aided design

Design Technology: Make - select from and use a wider range of tools and equipment to perform practical tasks [for example, cutting, shaping, joining and finishing], accurately

Design Technology: Make - select from and use a wider range of materials and components, including construction materials, textiles and ingredients, according to their functional properties and aesthetic qualities

Design Technology: Evaluate - evaluate their ideas and products against their own design criteria and consider the views of others to improve their work

Design Technology: Evaluate - understand how key events and individuals in design and technology have helped shape the world

Design Technology: Technical knowledge - apply their understanding of how to strengthen, stiffen and reinforce more complex structures

Design Technology: Technical knowledge - understand and use mechanical systems in their products [for example, gears, pulleys, cams, levers and linkages]

Objectives:
Students will be able to identify and label the radius of a circle.

Students will be able to understand and use an Archimedes Screw, learning some of its applications in the real world.

Students will gain experience with forces, learning that mechanisms can allow a small force to have greater effect.

INSTRUCTIONS:

1. Make sure the inside of the bottle is clean and dry and turn upside-down
2. Keep the lid on your bottle, but cut out an equilateral triangle(pointing downwards) just above the next of the bottle, with the sides to be a measurement of 5cm each.
3. Cut off the bottom of the bottle.
4. Measure the inside diameter of the bottle then, using mathematical compass, draw and cut out 6 circles of card of the same size.
5. Using a pencil, slightly enlarge the whole in the middle of each circle that was made by the compass. Enlarge further to the right size by pushing dowel through the centre of each circle
6. Cut one slit from the edge of each circle of card to the hole in the middle (the radius). Place the circles so that the slit in each of them is pointing away from you. On each circle write an "A" to the left of the slit and a "B" to the right of it.
7. This bit is tricky and will likely require working in pairs. Place the first circle in front of you. Get a piece of tape (couple of cm) stick it half way on the underneath of the side labelled "A" so that the other half of the tape sticks out of the slit, sticky side up, with its back resting on the side labelled "B".
8. Place a second circle on top, in exactly the same position. The back of "B" on the second circle should stick to the tape already in place. Now get another bit of tape and place it half way over the front of part "A" of the first circle and the "B" of the second circle.
9. Now get a piece of tape (couple of cm) stick it half way on the underneath of the side labelled "A" of the second circle as before (so that the other half of the tape sticks out of the slit, sticky side up, with its back resting on the side labelled "B"). Place the third circle on top as before, sticking the back of its part "B" to the tape, then taping over the top of "A" on the second circle and "B" of the third circle.
10. Repeat instructions 7&8 until all the circles are connected together, with one side of each circle attached to the opposite side of the next circle. If you gentle pull the loose side at either end you will see that you have along spiral shape.
11. Lay the circles flat again and push the dowel through the holes in the middle. Gently stretch out the card along its length until you can see the spiral again. This bit will require working in pairs again – one person will need to hold the spiral in place, while the other tapes the ends of the spiral to the dowel (can try taping all of it, depending on time allowances and ability/disposition of children – not essential), leaving approx. 5cm clear at the top.
12. Cut straw into 1cm lengths, then make one cut (top to bottom) in each piece. Place one piece of straw in between each layer of card. Push the cut up against the central dowel/paper stick, so that the two edges go to either side and stay in place.
13. 13. Push the drawing pin through the middle of the lid of the bottle, then slide the spiral into the bottle, ensuring that the bottom of the dowel pushes onto the drawing pin. This will help it stay central.
14. 14. Using the 5cm at the top of the dowel, turn the spiral to make sure it fits and works (the spiral should move but the bottle stays still). This is your Archimedes screw.
15. 15. Place the bottom end of your screw into a bowl or container of rice, popcorn, cereal (until the triangle bit is submerged) and turn the top. You may need to keep scooping your rice etc over the triangular opening to ensure that it remains submerged.
16. 16. You may need to experiment with which way to turn the spiral, and what angle to lean it, but when it is turning the correct way it will move the rice/ popcorn/cereal from the bottom of the spiral to the top

EXTENSION TASKS:

17. 1Can you design and make a handle to fit onto the top of your spiral to make it easier to turn? Draw a design of how this would work.
18. 2Does the weight or size of the items you are trying to lift affect the way the Archimedes screw works? What would you need to do to your design to adapt it to be used to move other items? Could it move water, sand or rocks for example?
19. Can you make a bigger Archimedes Screw? What would be the benefits of this? Do the same materials work for building this, or do you need to consider using other materials?
20. Can you devise a way to connect all your Archimedes Screws (from the class/group) together, so that each one supplies the next one in line?
21. Evaluate your design – what works well, what could you improve and how?
22. Can you devise a way to power your design with electricity?
23. Can you design a computer programme to control your design? Why might this be necessary?

THE STORY OF THE SCREW

The Archimedes Screw is named after the scientist believe to have invented it. Archimedes of Syracuse was first known to introduce this machine for the purpose of moving water in the 3 Century BC. Though Archimedes was Greek, he first used this device in Egypt to help irrigate crops.

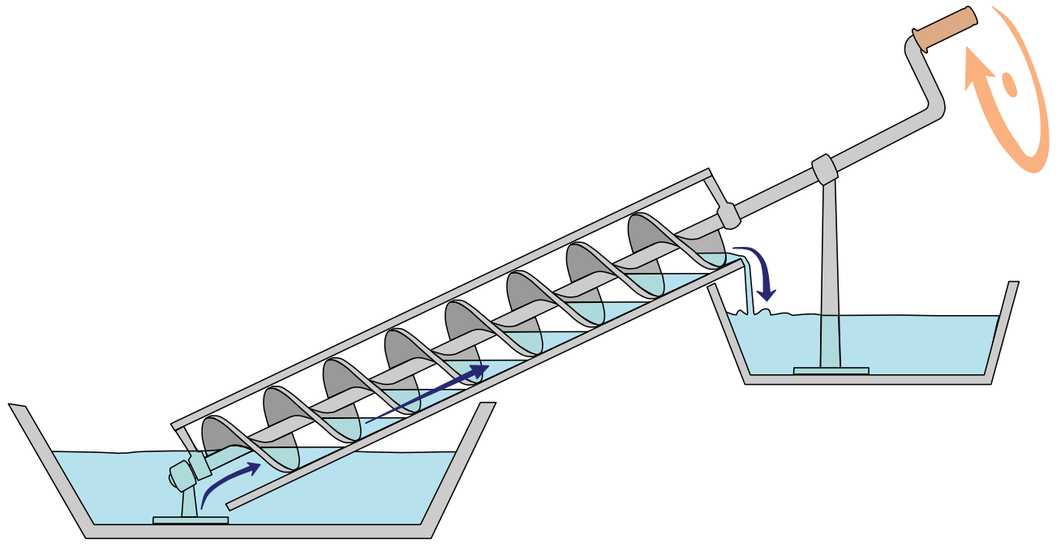
The Archimedes screw is still used today, in almost exactly the same design, because it is so energy efficient, there is very little to be done to improve on the machine invented over 2,000 years ago. The design means that large amounts and weights of materials can be moved with relatively little force or energy being applied. It is still used in many places to move water, either to remove water from underground (Netherlands and the stabilisation of the tower of Pisa) and also to move grain, fisheries use it to remove fish for transportation to other waterways, it is even used in chocolate fountains.

The drill on the Rosalind Franklin ExoMars Rover works in a similar way, though not exactly the same. The spiral or screw shape around the core of the drill will help to bring samples up from under the ground for analysis.

THE CONTEXT

Many scientists believe that it is the decline of the magnetic field around Mars that has stripped away it's atmosphere, allowing radiation to affect the first 1.5m of the crust.

To overcome this the Rosalind Franklin Rover will have a drill, capable of drilling 2m under the surface. The drill will extract samples to be analysed by an onboard lab, which will then send data from the results back to earth.



APPENDIX 2.5

Thermal Conduction

KS2/Yr5

Subject:	Science: Working Scientifically, Properties and Changes of Materials.
	Design and Technology: Design, Make, Evaluate
Duration:	40-60 min
Type:	Experiment

MATERIALS:

- 4-5 identical waterproof containers (per group)
- Different coloured paper including black and metallic paper
- Tape
- Scissors
- Hot water
- Thermometers (preferably min 1 per group)
- Timer (or use clock)
- Kitchen roll/paper towels

Tray, 1 per group (optional)

EXTENSION MATERIALS

- Drawing pins
- Different materials (newspaper, bubble wrap, bin bags, tin foil, sock, polystyrene cup etc)
- Plastic bottles/disposable cups in a range of sizes
- Sand, polystyrene balls, marbles, Lego bricks, Wool, Fabric, leaves, twigs, matchsticks, pipe cleaners etc

Aims

To investigate whether the colour of a material effects the temperature.

SCHEMES OF WORK:

Science: Materials

Maths: Measurement Recording

Objectives

Learn how to use a thermometer correctly

Use a table to record results

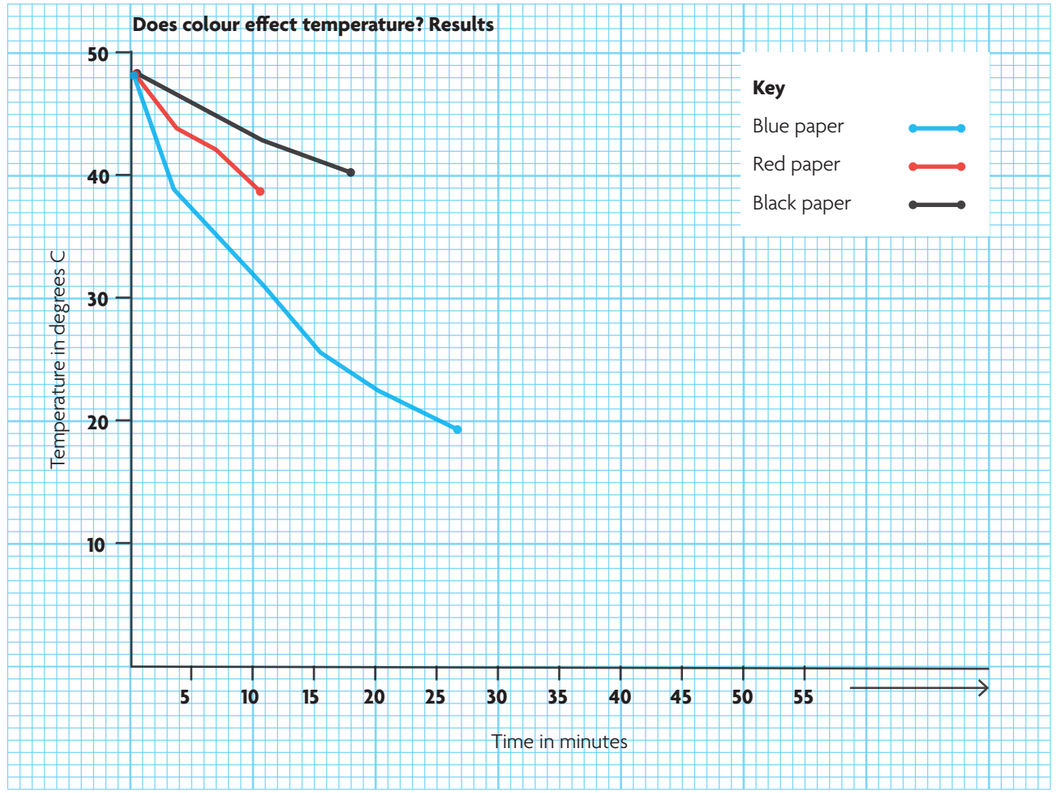
Identify whether using different colours of the same material can affect the temperature of water.

INSTRUCTIONS

1. Children to work in groups, each group to be given 4-5 identical containers (as long as containers within a group are identical, does not matter if all containers within the class are identical at this stage).
2. Each child/group to draw a simple table to record results, as below (Provide times of 5min intervals up to 1hr/60min).

Colour of paper	Start temp.	Temp after 5min	Temp after 10min	Temp after 15min	Temp after 20min	Temp after 25min	Temp after 30min	Temp after 35min
.e. Black								
Blue								
White								
Yellow								
Silver								

3. Each group to chose 4-5 different colours of paper (1 per container). Each container needs to be carefully wrapped in a different coloured paper, using tape to hold in place and ensuring that the top is left open so that water can easily be poured into the container.
4. Each group to select an area within the room for their containers to be placed for the duration of the experiment (recommend kept away from electrical equipment. Suggested areas would be; window sill, cupboard, near door, in direct sunlight etc) and make note of placement at the top of their results table.
5. Carefully pour hot water into each container and take start temperature for each container – record in results table. Make note of time or set timer.
6. Every 5min measure and record temperature for each container. During this time, students can draw a simple line graph to show comparison of their results, as per below.



7. Use results to compare colours within groups, then same colours used by different groups. Discuss similarities and differences in results. Does black paper consistently show the same pattern (for example taking the longest time to cool)? Are there any other similar patterns?
8. Are the cooling times for each different colour of paper the same? Why do you think this is – discuss.
9. Can you create a giant line graph to share the results from all of the experiments? Maybe use a display board and pins/wool to plot the lines.
10. From these results, can you suggest which colour might be best to use to keep the inside of the Mars Rover warm?

EXTENSION INSTRUCTIONS/ SUGGESTIONS

If you were building a Mars rover that needed to be able to stay warm on Mars, what experiments and tests might you run to find out the best way to do this? In groups discuss your results and what you need to consider for your next experiment. You will need to decide what information you want to find and design a fair test in order to do so.

- Does the same experiment as above work with ice cold water? How do the results differ, if at all?
- Does it matter which way round the paper is facing (for example if it is white on one side, does it matter if the white is facing in or out?)
- Does it matter what materials are used for this experiment – would it work differently with something other than paper? What other variables might affect the temperature? How can you make a fair test to prove your hypotheses?
- Using plastic bottles/disposable cups, can you create a container to maintain the same temperature inside for as long as possible? How would you test this? (could create double walled containers and test different materials in the gap between for insulative properties).

THE SCIENCE

Light and heat work in a very similar way. White light is made from a combination of all of the colours in the spectrum (like a rainbow). If we shine white light onto a white piece of paper, all of the colours in the spectrum are reflected back, which is how we can see the piece of paper. If we shine white light onto a black piece of paper, much of the light is absorbed, hence we see the paper as being black, reflecting no "colour" back at us. Heat works in the same way. White materials will reflect heat, which is why white and lighter colours are more popular for clothes in hot countries, whereas black materials will absorb the heat.

If you have extended your activity to include different materials, you will have seen that some materials absorb heat better than others. When we look at the thermal properties of materials we generally use the terms "conduction" and "insulation". These terms help describe how quickly heat moves through a material. If heat moves quickly through a material, (for example, if we put a metal spoon in a cup of boiling water it will soon be hot to the touch) we consider that material to be a conductor. If, however, heat moves slowly through a material (for example, if we put boiling water into a Styrofoam cup, we can easily hold the cup without burning our hand), we consider that material to be an insulator.

Heat moves or transfers from hot places to cold places. The purpose of insulation is to slow that movement, so that it takes longer for things to cool down, (they stay warm for longer).

THE CONTEXT

Additional challenges for the ExoMars Mission include the wide variation of temperature within a Sol (Martian equivalent to a day, approx. 24hrs 39min 35sec). Like Earth, Mars can experience a variety of temperatures from day to day. An average day time temperature on Mars is about 5 degrees Celsius, though at the equator it can reach up to 20 degrees during summer months. At night the average temperature drops down to approx. -120degrees Celsius, though at the poles this can fall to -195 degrees during winter months. This means that on a daily basis the surface of the planets sees a wide range of temperatures (approx. 125 degrees difference). Even for a rover, this is not good. If we repeatedly heat up materials and cool them down, they become brittle over time, breaking easily. It is especially important for the controls and electronical equipment to maintain a fairly even temperature, or the wires inside the rover could break, bringing a premature end to the mission. To help overcome this problem the rover will have a little onboard heater, to help keep it warm at night. Additionally, it has been designed to use certain materials to help insulate it. For example the body of the Rosalind Franklin Rover has been sprayed with actual gold, due to its thermal properties.

STEM DISCOVERY CENTRE

APPENDIX 2.6

Rover navigation/offline coding activity

KS2

Subject:	Maths, Geography, Computing
Duration:	90 min or longer as required
Type:	Challenge

MATERIALS

- River Grid (provided)
- Contour Grid (provided)
- Key Sample Sheet (provided – could be used as a wall poster)
- Log Sheet (provided, but could be copied by children to save printing)
- Pencils
- Rulers
- Paper (Squared and blank or lined)
- String
- Straws
- Tape (and/or Masking Tape)
- Drawing pins
- Balloons

EXTENSION MATERIALS

- Team Briefing Sheet (provided)
- Protractors
- CLUPI Waterdrop Magnifier (if completed) or Magnifying Glass
- PamCam Coloured Filter Lenses (if completed) or Coloured Filters/Cellophane
- Pavement Chalks (optional)
- Meter Ruler(optional)
- Trundle Wheel(optional)
- Magnetic Compass
- Protractor
- Small Bells

Aims

Work in small groups to manoeuvre a mars rover across a grid map representing the surface of mars, with restricted communication methods, to replicate the sort of limitations faced by Mars Rover missions prior to the use of AI.

SCHEMES OF WORK:

Maths:

Number – Place Value, Addition, Subtraction, Multiplication and Division, Fractions, Ratio and Proportion, Geometry – Position and Direction, Statistics

Design

Technology: Design, Make, Evaluate, Technical Knowledge

Computing

Some reference to Geographical knowledge, specifically the use of contours on maps.

Objectives

- To use the grid maps provided and become familiar with the concept of axis and co-ordinates
- To use simple coded instructions to guide a teammate through unseen terrain.
- To learn some value for the concept and application of coding, without using computers.
- To learn soft skills and develop strategy in areas such as communications, patience and problem solving.

INSTRUCTIONS

This activity offers a more immersive approach to understanding the ExoMars mission, particularly the challenges associated with the remote navigation of a vehicle across a landscape and an introduction to the concept of coding.

There are various ways that you can use the materials to suit the needs of your class. At the most basic level you can create a map grid then use the coding grid provided with these resources, for your students to create a treasure hunt for each other, written in code.

For a more in-depth activity, relating specifically to the ExoMars mission, we have provided a recommended approach, which covers multiple curriculum areas, but may need a couple of lessons to complete. For each segment we will explain why we have proposed the approach, so that you may assess the relevancy and impact for your students.

Establishing Mission and Command Structure

As the class teacher, you will hold the position of "Mission Control", you have the inside information and final say in any disputes, teams will be acting on information provided by you.

The class will need to be split into teams, ideally of 4-5 children per team (to ensure that all children may be involved in the mission), each team then needs to be split into 2 groups; "Command" and "Mars Rover". Success depends on the ability of the children to work well within their teams. They will need to use their listening skills, they will need to use critical thinking and they will need to communicate well.

The purpose of the Command group will be to receive instructions from Mission Control, then to plot a route and send a coded message to the Mars Rover to complete the mission.

The purpose of the Mars Rover will be to de-code the message and assess whether the instructions can be carried out, according to the terrain. They must either complete the instructions, or let the Command group know that the instructions cannot be completed.

This "Mission Command Structure" provides a communication framework and encourages development of the soft skills necessary within a working team. By splitting the team into separate groups we are emphasising the need for clear and concise communication and encouraging students to consider what they need to communicate in advance. Using small groups still allows for discussion, sharing of ideas and peer learning, whilst reducing opportunity for large scale disagreements.

Establishing Communications

In order for the coding aspect of this activity to work and be relevant, we would recommend that there be no talking allowed, during the mission, between the Command Group and the Mars Rover. The rover itself cannot actually understand spoken instructions and only communicates using code.

Messages sent from Earth to the Rover can take up to 20minutes to be received.

There are various ways to replicate this and support non-verbal communication between the groups, but to embed some Design Technology curriculum into the activity, we would recommend taking some time to allow each team to design and set up a communication system, to allow them to send coded messages between the Command group and the Mars Rover group, without coming into direct contact with each other.

For this to work with multiple groups, it may be that all "Command" groups are set up one side of the classroom, with the corresponding "Mars Rover" groups working from the other side of the classroom.

This session could allow for discussion of mechanisms, such as pulleys, cogs and cams, and could allow for research as to how large institutes (post office, office blocks, department stores) managed to communicate quickly between different floors and departments without the use of email or phones (pneumatic tubes for example), depending on how much time you with to spend on it – it could of course also be a crazy, timed 15-20 minute exercise where you just provide them with a load of junk/scrap materials and string and see what they come up with.

A quick and simple solution would be for each team to have a line set up across the room, with a balloon rocket attached.

OR a long piece of string that crosses the room and back, looping around the back of a chair at either side, with the ends tied together (effectively a big loop!). Attached to this piece of string, using a bit of tape, should be a 5cm length of drinking straw, which would be the message cylinder.

THE MISSION

Once the teams have been set and a method for non-verbal communication has been established, the Command and Mars Rover groups will need to set up their working areas, (one at either end of the communication line).

From this point on groups will not be allowed to speak to each other (even within their own teams).

The Mission Brief is simple: Each team must work together to navigate a course over the surface of Mars to collect and test samples in their search for life.

Their mission has a time limit (set by you, we would recommend minimum of 30min, an hour may be more appropriate), during which they must collect as many samples as possible.

Three test sites have been identified. The Command group will be given a map with the test sites marked on it, but very little other information. The Mars Rover group will have a much better map of the Martian terrain (as they are there) with contours marked, but they will not be able to see where the test areas are (because the destinations had not been finalised before the rover launched). For each test area there are co-ordinate associated samples (provided) for the teams to analyse. Both the Mars Rover and Command team must analyse the samples and get the same result, before they can move on to do another test.

THE SIMPLE WAY TO "PLAY"

Both groups within a team will be provided with a Coding grid, Log sheet and Sample Key, as well as paper, pencil, scissors and possibly a matchstick (to help role the message small enough to fit into a straw), as well as the map relevant to their team (needs to be printed A3).

The Log sheet is to be used to write down each decoded message (both sent and received). This is to help them should they need to debug something (work out and correct an error).

Teams will use the code grid to write messages, which will be sent between the teams using the communications line.

Explain the basic roles or each group; Control Team to give directions, Mars Rover to mark progress on their map – if they can complete instructions respond with affirmative, if they cannot, respond negative and co-ordinates.

Explain that messages need to be sent across the room in a straw (no longer than 5cm, attached to a loop of string (the string needs to loop through the back of a chair on either side of the room).

While Command Team are planning and writing out first instruction, Mars Rover Team need to be establishing the communication system.

Start Mars Rover at -10x, -10y coordinates on the map

On retrieving data from a sample, both the Mars Rover and Command groups will work separately on the analysis, comparing final results. If the results of both groups match (and are correct for the specific grid co-ordinate, as verified by Mission Control), they can move on to take another sample, if not they must re-analyse until both groups have the same, correct, answer.

SUGGESTIONS TO STRETCH AND CHALLENGE

We have provided Command and Mars Rover Team briefing sheets, with more comprehensive rules and restrictions; for example if contours are too close together, the mars rover will not be able to travel through that square on the grid and another route will need to be selected.

To start each team must draw 2 numbers out of the Mission Control bag/box. These numbers are your (xy) co-ordinates for your landing site, which will be the starting point for your mission. If contours are too steep, Rover group must track them down hill, to the closest flat area, again to be verified by Mission Control.

If the CLUPI or Coloured Lens activities have been completed, the Mars Rover teams may use these to analyse the test sites to retrieve information about the samples (using magnifiers or coloured lenses will also allow them to see the sample number that they need to present to Mission Control to retrieve the data) – or the command group can just inform mission control of their grid reference when they reach a test site and mission control can provide them with the sample data to analyse.

The sample analysis consists of a string of elements. The teams will have a Sample Key for comparison, which identifies required chemical molecules. They will have to see how many of each type of molecule they can make from the chemicals found in each sample and report to Mission Control which chemical is predominant. Carbon Dioxide and Iron Oxide confirm results from previous missions. Water and Methane provide positive results, in the search for life. There are 2 levels of analysis; Level 1 is just working out how many molecules of any of the given chemicals can be made, Level 2 is looking for a specific percentage of the results, for example. if the water or methane molecules use up more than 60% of the elements present in the sample, it is a successful result.

Extension Instructions/Suggestions

- Extend the mission time scale
- Offer the students the opportunity to create their own maps for a second mission.
- Reduce or extend the vocabulary available for coding (by increasing the grid, or blocking out certain squares).
- Challenge students to use the coding grid to create and "automated" programme or instruction. Can they send one set of instructions to the rover and leave it to find its own way to a destination?
- Can the children create their own code grid? If not for the map, then maybe for moving around the classroom or school?
- If you put a scale to the map (ie 1cm/sq = 1km) can the teams work out how far the rover has travelled to reach certain destinations. Can you add in similar measurements for contours to stretch and challenge?
- Students to do a combined analysis of all (their) samples – what elements are present? What percentage/fraction/ratio of each? What is the best way to display this information? Based on the information gained from the samples, what would be their recommendations for a future mission?
- Students to write a report on their mission, to include; good and bad, what worked well, what needed improving, how well did the communications system work, what did they find, overall was it a successful mission, what would improvements would they recommend for future missions?
- Extend the size of the "Mars Map" - The Rover Grid Map could be drawn out on larger scale (for example 50cm:1square) Either on huge sheets of paper or floor/playground. The class would need to work together to measure out and draw the grid accurately. The Rover \groups would then need to draw in the contours. This would allow for multiple groups to guide their rover simultaneously on the same grid, with a student representing the rover in each case. Should you wish, a compass and compass directions could be added into proceedings at this point, maybe replacing left/right/forward/backward directives. The compass would only be available to the rover groups and their first task on receiving landing co-ordinates would be to inform Command of their attitude (direction they are facing). Equally you could consider inserting the requirement of including degrees of rotation in the instructions, rather than moving left of right, the rover must turn that way before it can consider moving forward again.

THE CONTEXT

Another major challenge for the Rosalind Franklin Rover is the terrain and this is where the all-important AI will be used to greatest effect. Previously all robotic missions to Mars have been controlled from Earth, with scientists observing via camera and programming the rover accordingly. The problem with that approach is that it can take up to 20minutes for information to travel from Mars to Earth. This means that any video footage that is being used to control the rover, happened up to 20 minutes beforehand. So, if you are controlling the rover and it reaches the edge of a cliff, that happened 20 minutes ago. By the time you have sent the commands back for the rover to STOP! Another 20 minutes have passed, and it is most likely already too late! The Rosalind Franklin Rover has been designed to use special cameras for navigation. It has a pair of cameras, which will act like a pair of eyes, allowing it to judge how far away things are, how big rocks are and how steep slopes might be. Not only this, but it is also programmed to make decisions based on that information. Due to all the tests that have been carried out using the prototype rovers in Stevenage, the Rosalind Franklin rover will know if a rock is too big, or a slope too steep and will plan its path according to the information that it is able to gather. This being the case, this rover will be able to move much faster than previous rovers. Due to the time delay in receiving information, previous rovers moved at a speed of 1-2cm per minute. The Rosalind Franklin Rover will be able to move at a speed of 1-2cm per second.

Coding helps us to send a lot of information in a small (data) package, which makes communicating with robots on another planet much easier.

COMMAND GROUP BRIEF AND RULES

Brief

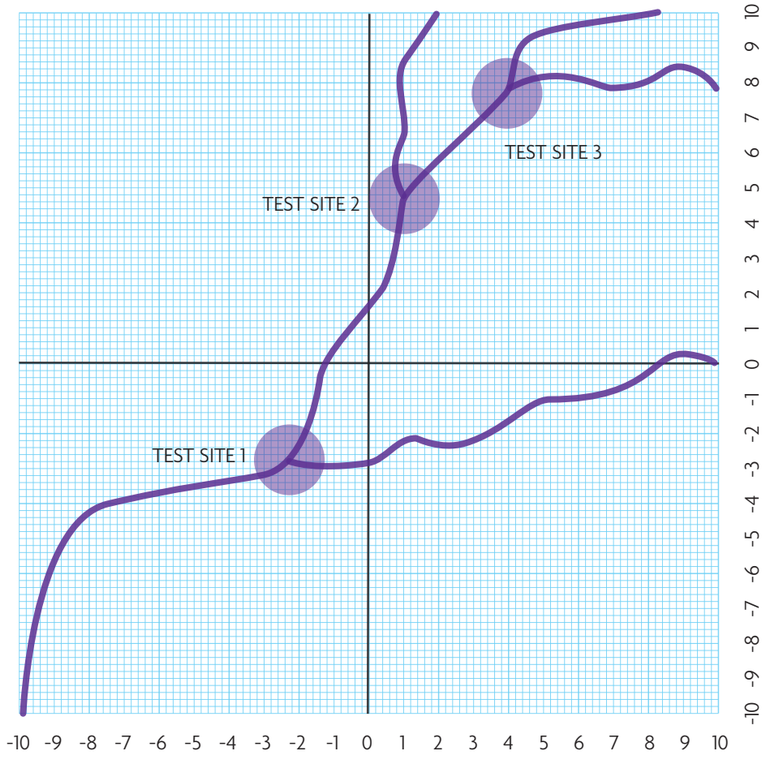
Your mission is to guide the Mars Rover to the test sites identified on your map.

You must collect and identify as many samples as possible within the timeframe given by mission control.

Rules

1. You can only communicate with the Mars Rover by sending a message written in code.
2. You must use the code grid provided to write your code. Every message written and received must be recorded and de-coded on your log sheet. This is to help with de-bugging.
3. You must use the code to send the rover directions, tell it when to test and which method of testing to use (CLUPI or Lens Filters).
4. If the Rover sends a "Negative" response to your instructions, it means that it cannot complete them. Check your coding before doing anything else.
5. Using a pencil, you must record on your Riverbed Test Areas (Command Map) the route the rover is taking.
6. Using a pencil, you must mark areas where the rover is unable to travel (based on the responses received from the rover).
7. Once the test has taken place the findings must reported to the Mission Control, along with the grid reference co-ordinates. Mission Control will provide information as appropriate.
8. Sample information received from Mission Control MUST be shared with the Mars Rover team for on board analysis.
9. You must use the Sample Key to analyse your sample and discover which chemical is most dominant. You are particularly looking for water and methane, though other chemicals will be present. Finding the listed chemicals will give you a positive result. If one chemical makes up over 60% of your sample, that test is considered to be successful.
10. In order to move forward with your mission, both the Command Team and the Mars Rover team must get the same result from their sample and this must be verified by Mission Control. At that point you may take another sample from within the test area or move to a new test area as you choose.

GRID MAP A – RIVERBED TEST AREAS (COMMAND MAP)



MARS ROVER GROUP BRIEF AND RULES

Brief

Your mission is to follow the instructions sent by the Command group, who will direct you to the test sites.

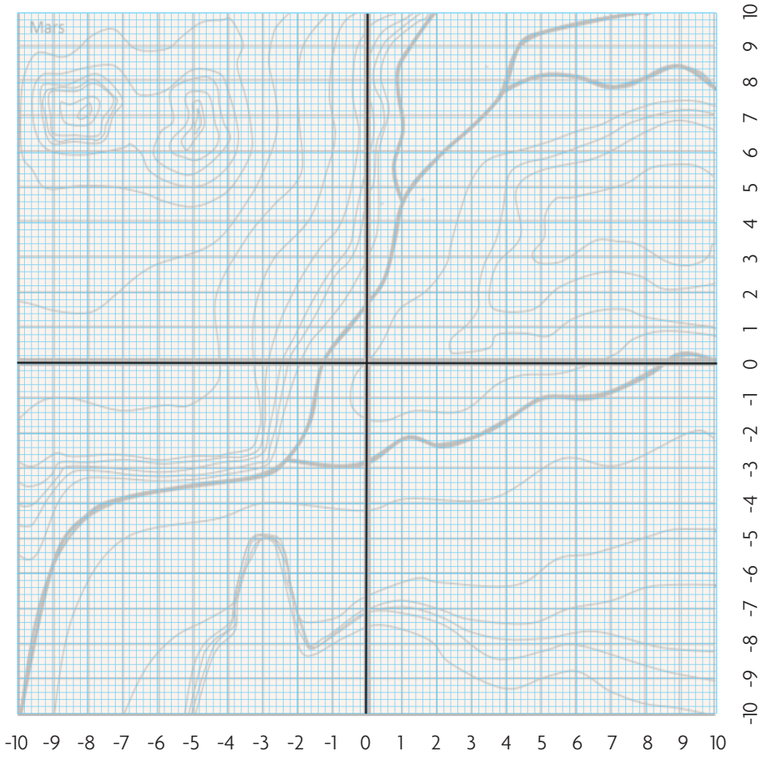
You must collect and identify as many samples as possible within the timeframe given by mission control.

Rules

1. You can only communicate with the Command Group by sending a message written in code.
2. You must use the code grid provided to write your code. Every message written and received must be recorded and de-coded on your log sheet. This is to help with de-bugging.
3. You must respond to each message sent with either "Affirmative" code (if the instructions can be completed) or "Negative" code (if the instructions cannot be completed).
4. You cannot travel through squares containing more than 3 contour lines, or lines that are closer than 2mm together – these areas are too steep for the rover to manage.
5. Using a pencil, you must record on your Contours (Mars Rover Map) the route the rover is taking.
6. The Command Group will tell you when to test and which on-board instrument you must use to identify if a valid sample is present (CLUPI or Lens Filters).
7. Once the test has taken place the findings must reported to the Command Group to verify with Mission Control.
8. Sample information received from Mission Control MUST be shared with both the Command Group and Mars Rover team for analysis.
9. You must use the Sample Key to analyse your sample and discover which chemical is most dominant. You are particularly looking for water and methane, though other chemicals will be present. Finding the listed chemicals will give you a positive result. If one chemical makes up over 60% of your sample, that test is considered to be successful.
10. In order to move forward with your mission, both the Command Team and the Mars Rover team must get the same result from their sample and this must be verified by Mission Control.

GRID MAP B – CONTOURS (MARS ROVER MAP)

Coding Grid



	1	2	3	4	5	6	7
A	Forward	-	6	Yes	Stop	A	i
B	Backward	0	7	No	Square	a	k
C	Left	1	8	IF	Test	C	l
D	Right	2	9	THEN	CLUPI	e	M
E	X	3	45°	OR	Filter	F	O
F	Y	4	90°	FOREVER	Affirmative	g	P
G	+	5	180°	%	Negative	H	S

Example: A1, E2, B5 = Forward 3 Square

Log Sheet

Message Received	Coded Message	(tape received message here)
	De-coded Message	
Message Sent	Message	
	Code	
Message Received	Coded Message	(tape received message here)
	De-coded Message	
Message Sent	Message	
	Code	
Message Received	Coded Message	(tape received message here)
	De-coded Message	
Message Sent	Message	
	Code	
Message Received	Coded Message	(tape received message here)
	De-coded Message	
Message Sent	Message	
	Code	
Message Received	Coded Message	(tape received message here)
	De-coded Message	
Message Sent	Message	
	Code	
Message Received	Coded Message	(tape received message here)
	De-coded Message	

MISSION BRIEF AND RULES OF ENGAGEMENT

Aim

Work as a team to direct your Mars Rover over the surface of Mars, collecting evidence in the search for life. You must achieve as many objectives as possible. You must follow the mission rules at all times. You must achieve all of this within the time limit given for the project.

Objectives

- To retrieve and analyse as many samples as possible from the 3 identified test sites, within the time limit provided.
- To use the code grid provided to communicate between Command and Mars Rover
- For all team members to analyse data from the samples.

Rules

1. The Command group must direct the rover to identified test sites.
2. The Command group and Mars Rover group can only communicate using written instructions, delivered by the communications line your team have set up.
3. Both groups within a team must have permanent access to the communications line.
4. Communications may not be thrown.
5. Communications lines must be set up taking into account the safety of other space agencies (no trip hazards or choke hazards. All teams must be able to evacuate the area safely, should they need to).
6. You may speak to other members of your group, but not to the other group within your team.
7. If an instruction is successfully completed, the Mars Rover may stay in its new position to await further instruction. If an instruction is not possible, the rover must stay in its original position until it is able to complete an instruction successfully.
8. The distance travelled must be measured in squares.

MISSION CONTROL (TEACHER): SAMPLES

Most common elements found on Mars

- Silicon = Si
- Oxygen = O
- Carbon = C
- Iron = Fe
- Magnesium = Mg
- Aluminium = Al
- Calcium = Ca
- Potassium = K
- Sulphur = S
- Phosphorus = P
- Chlorine = Cl

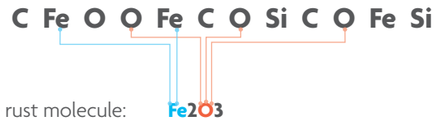
Hydrogen (= H) is also present, but it accounts for less than 0.001% of the chemicals that compose the surface of Mars.

- **Fe2O3 = Rust**
- **CH4 = Methane**
- **H20 = Water**
- **CO2 = Carbon Dioxide**

Analysing the samples, discover which of the above elements are most prevalent in each sample?

If it accounts for more than 60% of the sample, it is a positive result

For example the test sample below is made from a combination of 12 (Elements/) Chemicals.



From this sample we can make one rust molecule:

Although there are more Iron (Fe) and Oxygen (O) molecules, there are not enough to create another full rust/iron oxide molecule.

C Fe O O Fe C O Si C O Fe Si

From this same sample we can make 2 carbon dioxide molecules: **CO2 CO2**

As there are 12 letters, if we look at the Iron Oxide(rust), it uses 5 of them, 5/12 or (100 ÷ 12 x 5 =) 41.67 (round up to 42)%.

If we look at the number of those letters/elements used to make the Carbon Dioxide, we can see for two molecules it takes 6 letters/elements, 6/12, ½ or 50%. With relation to the class mission, this would confirm results from previous missions. Though if this was either Methane or Water, it would be considered a positive result, but as it has not met the 60% necessary to be successful.

Both the Command Team and the ExoMars Rover team, must achieve the same correct results, to be confirmed by Mission Control, before they can move on.

The team must now decide whether to take another sample at this site or move on to another site.

Test Site Samples

Test Site 1

S1. Coordinate: x-3, y-3

Si	Ca	C	S	Si	Al	Si	C	C	O
Si	Fe	Fe	O	O	K	Si	Ca	C	Si
H	Fe	Si	Si	Mg	Fe	C	Cl	K	O
P	Si	Fe	O	O	O	Si	P	O	Fe

S2. Coordinate: x-2, y-3

C	Ca	K	H	Mg	Al	Fe	O	C	P
O	Si	S	O	Fe	Si	O	C	C	Ca
Fe	Al	P	Si	Fe	C	O	Mg	Fe	Al
H	Mg	Cl	Fe	Si	O	Fe	Si	Si	H

Test Site 2

S3. Coordinate: x2, y5

C	O	Fe	H	Si	Si	Fe	C	Al	Ca
Si	Fe	P	Cl	K	S	Si	C	P	Fe
Fe	C	C	Si	Mg	Si	C	Fe	S	Ca
Mg	S	Si	C	Fe	Cl	Fe	Si	Fe	S

S4. Coordinate: x1, y5

H	Si	O	H	C	H	Si	Si	O	H
O	Ca	H	Si	H	O	Si	H	H	C
C	C	Al	Fe	O	Si	Fe	P	Fe	H
O	Fe	H	O	H	Fe	H	K	H	O

S5. Coordinate: x2, y6

K	Ca	Si	Mg	Si	O	Fe	H	Si	Fe
Si	Fe	Si	S	Fe	Si	C	O	K	Si
P	C	Si	Al	C	O	K	Fe	C	H
Fe	C	Fe	O	Mg	C	S	O	Fe	Mg

Test Site 3

S6. Coordinate: x4, y9

Si	Fe	O	Al	H	K	Ca	S	Fe	H
Fe	H	Si	Fe	Si	O	Mg	H	Si	Al
Ca	O	K	H	C	Al	Fe	O	H	Mg
Si	Al	Si	P	O	Si	H	H	Cl	O

S7. Coordinate: x4, y8

H	Fe	Fe	Si	Mg	H	S	C	H	Mg
C	Si	C	H	H	C	H	Si	H	Si
H	H	O	S	H	S	Al	H	H	H
S	H	Si	H	C	Fe	H	Fe	C	H

S8. Coordinate: x5, y8

Cl	K	Si	Fe	C	O	C	Si	Fe	Fe
S	P	Mg	Si	Ca	Cl	Si	P	Si	H
Ca	O	Fe	Cl	Cl	Fe	P	K	H	C
Al	H	C	Fe	S	Si	Si	Fe	O	Cl

Mission Sample Analysis Key

Chemical Name	Chemical Symbol
Silicon	Si
Oxygen	O
Carbon	C
Iron	Fe
Magnesium	Mg
Aluminium	Al
Calcium	Ca
Potassium	K
Sulphur	S
Phosphorus	P
Chlorine	Cl
Hydrogen	H

In your sample analysis you need to look for the following molecules

- **Fe2O3 = Rust**
- **CH4 = Methane**
- **H20 = Water**
- **CO2 = Carbon Dioxide**

The letters tell you which element you need and the numbers tell you how many, so water or H2O requires 2 Hydrogen and 1 Oxygen (we only need to use numbers if it is for more than one of that chemical element. The letter itself indicates the presence of one)

Finding either Methane or Water will be considered a positive result.

Level 1 Analysis: How many of each type can you find in each sample?

Level 2 Analysis: If it composes more that 60% of the overall sample, it has been a successful analysis.

Finding Rust and Carbon Dioxide will confirm the results of previous missions.

LANDING SITE SELECTION

Cut out the numbered squares. Fold each into quarters and place inside a bag or container.

Each team takes it in turns to pull out 2 numbers, the first is the x co-ordinate, the second is the y. This is their landing site.

If the landing site is not compatible with the Mars Rovers rules of travel, then Mission Control must assess which of the nearest co-ordinates best meets the rules of travel.

1	2	3	4
5	6	7	8
9	10	-1	-2
-3	-4	-5	-6
-7	-8	-9	-10

STEM DISCOVERY CENTRE

APPENDIX 2.7

Concentric Circles

KS2: Yr5

Subject:	Science – Earth and Space; Maths - Geometry
Duration:	(Demo 5/10min) 30 – 45min
Type:	Demo/Investigation

MATERIALS

- Floor Space
- Chalk
- Meter Ruler
- String
- Scissors
- Cane
- (Beach) Ball
- Marker Pen

Extension Materials

- Tennis Ball
- Piece of string/rope
- Strong glue

Aims

To gain understanding of why rockets are launched from the equator.

SCHEMES OF WORK;

- Science: Earth and Space
- Maths: Measurement, Geometry - Properties of Shape
- Geography: Location Knowledge

Objectives

- Learn terms diameter, radius and concentric
- Learn term Latitude and Longitude
- Learn that the Earth is roughly spherical
- Learn that not all parts of a sphere travel at the same speed

INSTRUCTIONS

This can be used either as an activity or a demonstration.

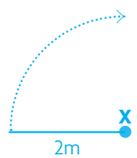
In advance get a ball and draw a circle, using a marker pen, around the middle/its widest point. Measure up 5cm from that line and draw another circle. Repeat until there is no more room to draw circles. These circles/ lines are the lines of Latitude, moving Northwards from the equator. If you look at the ball from the top, you will see that these are concentric circles – all fit inside each other, with the same central point.

This helps us understand why rockets are launched from the equator. As you look down on the ball, the "equator" line is the biggest circle and the smallest circle is equivalent to the "Arctic Circle". If you spin the ball on it's axis, the whole ball moves at the same speed, but the equator circle is bigger than the Arctic Circle, so it is actually moving faster.

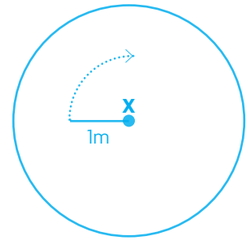
An easier way to understand this is by drawing the circles on the floor or the playground.

Get the children to work in groups of 2-4.

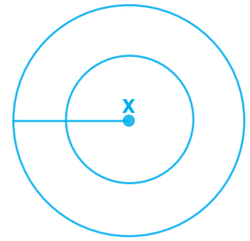
1. Each group will require a cane (or pole or broom handle) a meter ruler, piece of chalk and length of string (approx. 2M).
2. One end of the string needs to be tied around the cane/pole. The other end of the string needs to be tied to the chalk.
3. Each group need to find a big space and draw a little cross with the chalk – this is where the cane/pole must go. Hold the cane/pole in place and pull the string out straight, along the ground.
4. Keeping the cane/pole in place, and pulling the string tight, draw a circle around the pole using the chalk tied to the end.



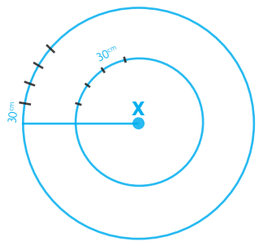
5. Once you have drawn your circle, remove the chalk and measure 1M out from the cane/pole and tie the chalk to that point (you may wish to cut the string to make this easier – keep the spare bits of string).
6. Keep the cane/pole in the middle, and pull the string tight to draw a smaller circle around the pole. This circle should have a 1M radius (measurement from centre to edge of circle).



7. Using the meter ruler and chalk, draw a line from the cross at the middle point of your circles to the outer edge of the large circle.



8. Cut 2 x 30cm pieces of string. Starting from the line you have just drawn, measure and mark 30cm sections all the way around each of your circles



9. In pairs start at the line, one standing on the outside circle and one standing on the inner circle. Either using music or clapping the beat, both children must move around the circle 30cm per second. Soon the one moving around the outside circle will be left behind.
10. Try the exercise again, but this time make the pairs hold the meter ruler between them. The objective this time is for the child following the inner circle to move 30cm per second. The child following the larger circle must just keep up. Get the other team mates to count how many 30cm marks the child following the outer circle has to move each second to keep up with the child in the middle.

Extension Instructions/Suggestions

- Can you write the difference in speeds as a ratio?
- How many cm per second were each of the children travelling? How Many rotations would they make in a minute?
- Use a (tennis) ball attached to a piece of rope/string, spin it around once and let it go – what happens?
- Get children to predict what will happen if you spin it round more before you release it.
- Is there any correlation between the amount of times spun and the distance achieved?

The Science

The Earth is spherical, just like a ball, and just like a ball, if we draw lines straight across it, some areas will be bigger or wider than others.

When we look at a globe, we do use these lines. The ones that go across, like the Equator, are called lines of Latitude. The lines that go from pole to pole (top to bottom) are called Longitude.

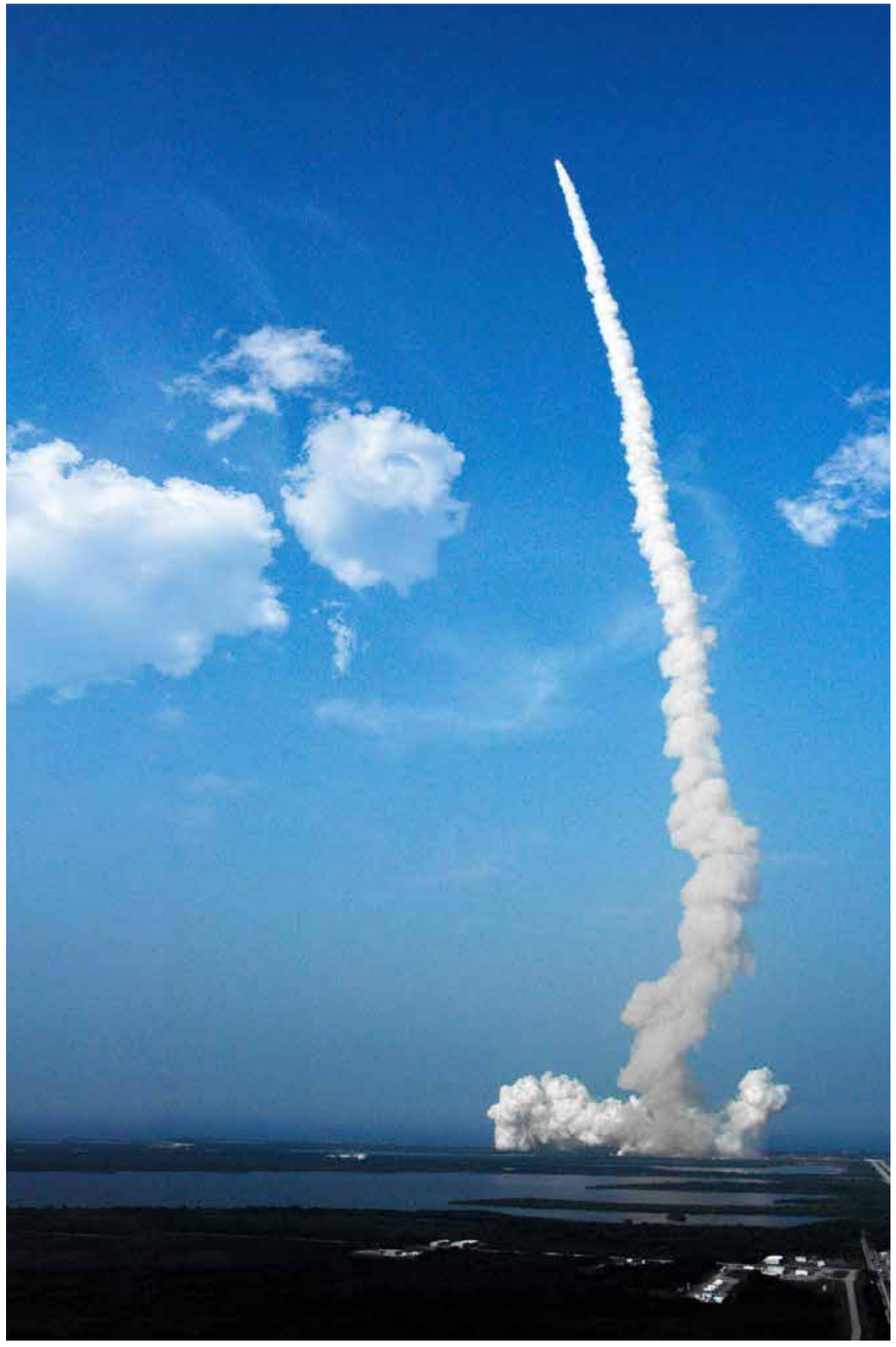
When we look at the lines of latitude, we can see that the Equator is the widest part of the Earth, it makes a big circle, but it takes that big circle exactly the same amount of time to turn once as it does the little circle (we can use the Arctic Circle as an example); it takes each of these circles 24hrs to rotate once, even though one is much bigger and covers a greater distance in that time.

The circumference of the Earth at the Equator is 24,902 miles (or 40,075km) and at the Arctic Circle it is approx. 9,932miles (or15,984km), which means at the Equator it is moving almost 25,000mile per day, whereas at the Arctic Circle it is only moving at approx. 10,000mile per day.

Because it is moving faster at the equator, the earth creates a kind of sling shot effect when we launch our rockets. Very much like if you have a tennis ball attached to a piece of rope. If you swing it once and let go, it will travel well, but if you spin it around several times before you let go, it will build up momentum, which will allow it to travel further and faster.

The Context

Although the majority of the work on this Mars rover has taken place in the UK, it will not be launched into space from here. Most major rocket launches take place on or near the equator. This is due to the shape and motion of the Earth and the fact that the equator is the widest part. If we view the northern hemisphere, for example, as a series of concentric circles, with the smallest being at the top (the Arctic Circle) and the largest being at the bottom (the equator), we can use the lines of latitude as a rough guide. Although those circles have different circumferences, and so are different sizes, they all move at the same time, but this does not mean that they all move at the same speed. If fact it means that they are all moving at different speeds, to keep up with each other; the Arctic Circle, which is a small circle, takes 24 hours to rotate once and the equator, a big circle also rotates once in the same time. It is easier if we think of it like this; lets imagine that the circumference of the Arctic Circle is 25miles and that it rotates once every hour, that means that it is travelling at 25mph. It takes the same amount of time for the equator to rotate once, in this example, 1hr, but the circumference of the equator is, say 50miles, in which case the equator is travelling at 50mph, even though they are both turning at the same time. So essentially, the equator is "moving faster" than any other part of Earth, which produces a kind of sling-shot effect. If you have a ball tied to the end of a piece of rope and swing it around in circles before you let go, it will travel further than if you just swung it once. The faster you swing the ball, the more momentum you will generate, allowing it to travel further. The same physics can be applied to launching rockets. When they are launched from the equator, more momentum is generated, which makes it easier to overcome Earth's gravitational pull.



STEM DISCOVERY CENTRE

APPENDIX 2.8

Space Blanket

KS2: Yr5

Subject:	Science – Properties and Changes of Materials; Maths - Measurement
Duration:	30 – 45min
Type:	Experiment

MATERIALS:

- Kitchen Foil
- Fruit Mesh (ie used to contain supermarket bought oranges or lemons)
- Scissors
- Ice Cubes (4 per group)
- Plate/ Tray, per group
- 1 sheet of coloured A5 paper per group
- Lamp or sunny windowsill
- Timer
- 3 Identical clear containers (large jam jars for example)
- Hot water, Room temperature water, Iced water (enough of each to fill one of your clear containers
- Food colouring

Extension Materials

- Thermometer (and retort stand or similar if possible)
- Digital scales
- Additional Ice
- Crisp packets, Cellophane, White bin bags, Metallic paper (of various colours), Sandwich bags (other materials as available)

Aims

To carry out an experiment to appreciate the purpose and establish the effectiveness of Multi Layered Insulation.

SCHEMES OF WORK:

Science:

- Working Scientifically
- States of Matter
- Properties and Changes of Materials

Maths:

- Number
- Measurement
- Potential Geometry and Statistics

Objectives

- Undertake an experiment, as instructed, to investigate the effectiveness of MLI for the use of space craft.
- Design an extension experiment, asking relevant questions and using comparative and fair tests to make systematic and careful observations.
- Take accurate measurements using thermometers and/or data loggers
- Record findings using simple scientific language, drawings, labelled diagrams, keys, bar charts, and tables
- Reporting on findings from enquiries, including oral and written explanations, displays or presentations of results and conclusions
- Use initial test results to make predictions to set up further comparative and fair tests.
- Explore the concepts of conduction and insulation with reference to materials, especially changes of state.

INTRODUCTION DEMONSTRATION

Purpose: To demonstrate the effect of temperature on the behaviour of (water) molecules.

Prep: Fill one of your clear containers with tap water and leave at room temperature (preferably over night). Fill another container with cold water and add a couple of ice cubes or place in the freezer for 10- 15min. Fill final container with hot water – as hot as you feel safe handling in a classroom of children – same temp as a cup of tea is ideal. If possible place jars in front of a white background, so that the results are clearer to see.

- Set up your 3 clear containers in a row.
- Explain that one has hot water, one has room temperature water and one has iced water.
- Squeeze 3-4 drops of food colouring into each container (to keep the demonstration fair, use the same colour in each) – get the children to observe what happens to the colour.

The drops of colour squeezed into the hot water will spread out much more quickly than the drops squeezed into the cold water. The molecules in the hot water have more energy, and so are able to move around more. The molecules in the cold water have less energy, so do not move as quickly. The experiment you are about to do is to see if you can control the temperature of ice cubes and therefore control the behaviour of molecules.

Instructions

1. Cut your A5 paper into 4 equally sized pieces and leave to one side.
2. Cut 10 squares of Kitchen Foil (approx. 15 x 15cm)
3. Cut 7 squares of Fruit Mesh (approx. 15 x 15cm)
4. 4Place on square of Kitchen Foil to the side
5. Take 3 squares of kitchen foil and 2 squares of fruit mesh and layer alternatively (foil, mesh, foil), and place to the side.
6. Take the remaining 6 squares of foil and 5 squares of mesh and layer as before (foil, mesh, foil etc).
7. Get plate/tray and spread your 4 pieces of coloured paper over it.
8. Get 4 ice cubes.
9. Place one ice cube on one of the pieced of paper, just as it is.
10. Wrap a second ice cube in one single square of kitchen foil and place on a second piece of paper.
11. Wrap the third ice cube in your pile of 3 squares of foil and 2 squares of mesh and place on the 3rd piece of paper.
12. Wrap the fourth ice cube in the pile of remaining foil and mesh squares and place on the final piece of paper.
13. Place plate on windowsill or under lamp and set timer for 5 minutes
14. After 5 minutes return to plate and observe differences between the 4 ice cubes. Observe the shape, size and how much water has soaked into the paper. Which one has melted the most?
15. Keep checking every minute up to 10 minutes, recording observations.
16. After 10 min, unwrap ice cubes to observe which have melted the most.

Extension Instructions/Suggestions

- If you have thermometers, you may wish to take the temperature of the surface of the plate, when placed under the lamp (but before the ice cubes have been placed on it). You could then repeat aspects of the experiment but increase/decrease the distance between the lamp and the place to see if that effects the temperature and also whether if effects the reaction of the ice cubes.
- If you have digital scales, you could weight ice cubes before and after experiment. If only one set of scales, could maybe record an average weight for ice cubes before and after.
- You could maintain observations beyond the initial 5 minutes to see how long it takes each of the ice cubes to melt.
- You could allow groups to perform a further experiment, to see who can make their ice cube last the longest before it melts. How many layers do they think they will need? Is the size of the layers important? What do they need to consider to make this a fair test for everyone? What are the variables (things that can be changed)? Which ones should they change and which should they keep constant?
- You could add a theoretical budget to the exercise to include maths and impose limits, for example each group has £100 budget, foil costs £1 per 5x5cm square, mesh costs £1 per 10x10cm square – that does not mean that they have to "purchase" or use materials in those measurements, only that they have to be more considerate with their planning.
- You could see if the size/number of the ice cube impacts the rate at which it melts.
- Do the children notice any patterns? What measurements can they take to back up their observations? What is the best way to display their results?
- Get the children to observe that one side of the kitchen foil is shinier than the other – could you do an experiment to see if it makes a difference as to which way around they use it? Shiny facing side in/ shiny side facing out?
- Could extend the experiment by testing other materials to see if it is necessary to have foil. The main purpose of the foil is to reflect heat, so could other shiny materials work just as well? Or different coloured materials, white for example?

- Consider how can the temperature of the lamp or heat source be measured consistently? If the thermometer is simply laid on the plate with the temperature of the place or the melting water effect the reading? If it is held by hand will the temperature of the hand effect the reading? Will it consistently be held at the same distance from the lamp/heat source? Would the distance from the heat source effect the temperature reading?

THE SCIENCE

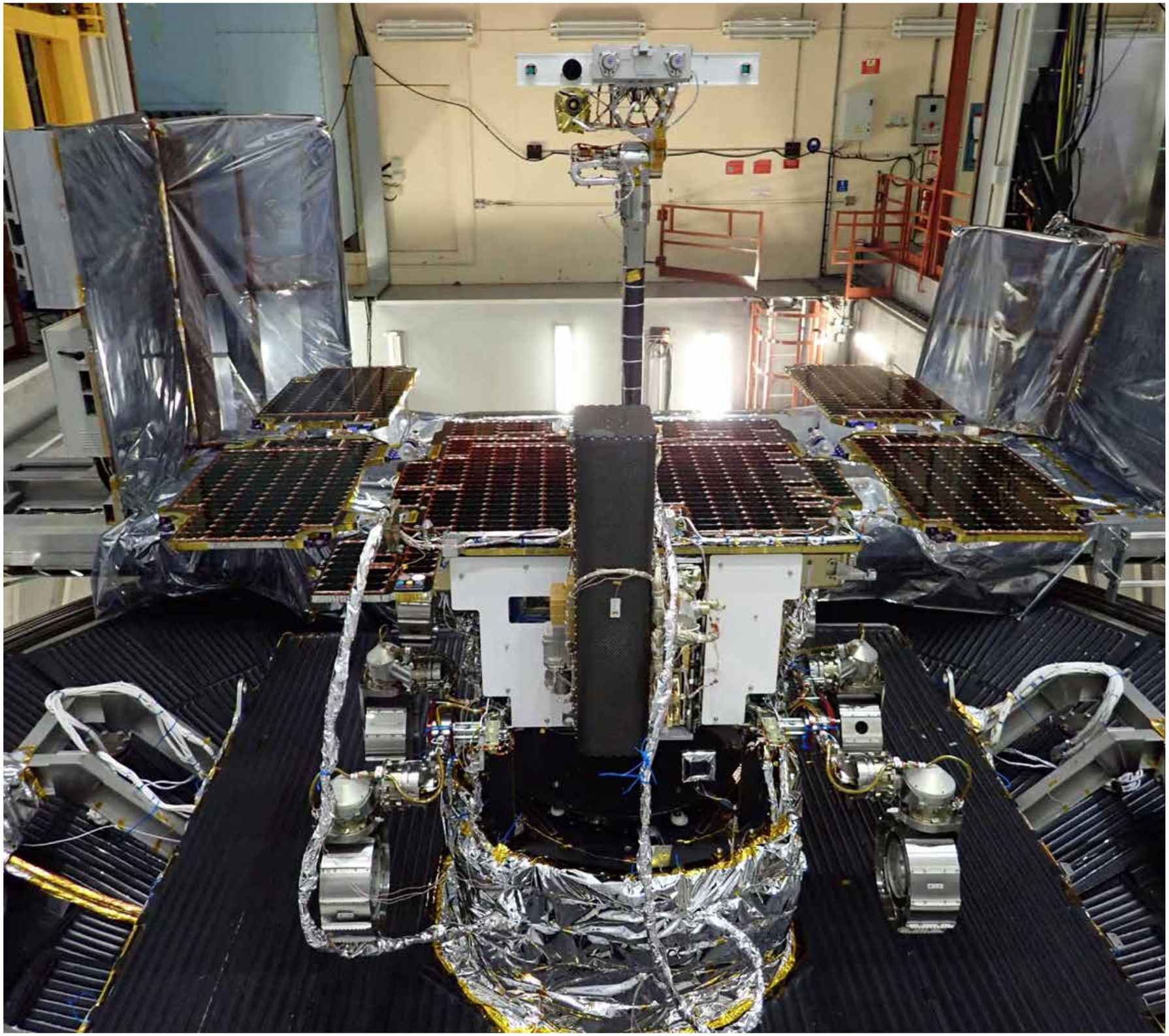
In space solar radiation can be extremely hot and damage the instruments onboard space craft and satellites. Equally, if the sun is not shining directly onto a space craft, it can become extremely cold (as space is a vacuum there are no air molecules to hold the heat). This being the case, it is very important for engineers in the space industry to find ways to protect the things that they send into space, like the ExoMars Rover.

One of the ways they do this is by using something called MLI (Multi Layer Insulation). MLI uses a material that is very similar (though much stronger) to kitchen/aluminium foil, with layers of net in-between. One layer of the shiny "foil" layer, reflects approx. 85% of the energy from the sun, which is great, but 15% can still get through. If we were talking about the kind of temperatures that we have on the surface of Earth, this would not seem so bad, but in space, metal can reach temperatures of approx. 260 degrees Celsius when exposed to the sun. As we do not want all our very expensive and sensitive science equipment to break, it is important that we reduce the impact of the heat from the sun as much as possible.

Even the 15% of heat that is absorbed by the space craft is considered to be too hot, so more than one layer of the "foil" is required. Each additional layer reduces the amount of energy being absorbed by a further 85%. The problem is, that the foil is metallic and metal conducts heat/energy, so if all the layers of foil are touching each other they all become the same temperature and effectively act as a single layer of protection. To overcome this problem, layers of netting or mesh are placed in-between the layers of foil, to keep them separate from each other and prevent conduction. MLI can use up to 20 layers to reduce the heat from external sources and maintain a constant temperature within the space craft.

THE CONTEXT

Engineers have to design space craft very carefully as space can be extremely cold or hot depending on where the rocket is travelling. In direct sunlight, metal can heat up to approx. 260 degrees in space, but in the shade, for example if a space craft is behind or in the shadow of a planet, that same piece of metal will cool to temperatures of approx. -100 degrees. These extremes of temperature can easily damage the materials and equipment (payload) onboard space craft.



STEM DISCOVERY CENTRE

APPENDIX 2.9

Egg drop

KS2

Subject:	Science – Forces; Maths; Design and Technology – Design, Make, Evaluate
Duration:	90min+
Type:	Make and Measure Investigation

MATERIALS

- Eggs
- Straws
- Pipe cleaners
- Elastic bands
- Polystyrene cups
- Paper
- Card
- Carrier bags
- Bamboo BBQ Skewers
- String
- Scissors
- Rulers
- Mathematical Compass
- Pencils and paper (for design)
- (digital) Scales
- Step ladder/Table/Platform, from which to drop the landers (recommended height of drop 3M)
- Extension Materials

List of materials above is recommendation only. Use any plentiful materials available, get children to bring in items from their recycling at home maybe. The smaller the variety of materials available, the more opportunity for innovative design.

Aims

To create a "MARS LANDER" to protect our Egg-ceptional Mars Explorer when it is released to the surface of Mars. Students must work to a budget and can only use the materials provided.

Recommended: When engineers create Mars Landers, they do not just do one test. If the first one does not work, they evaluate their design, consider what can be improved, make adjustments and then retest. If time allows, it would be worth following this process in groups, then as a class, to share ideas and learn from disappointing results.

SCHEMES OF WORK:

Science

Working Scientifcally, Properties and changes of materials, Forces

Maths

Number - Addition and Subtraction, Number - Multiplication and division, Measurement,

Geometry - Properties of shape

Design Technology

Design, Make, Evaluate, Technical Knowledge

Objectives

- Identify ways to stop the egg from smashing against the floor.
- Consider the properties of the materials available and of (geometric) shapes to design and "egg protection device".
- Justify choices made in design.
- Apply prior knowledge of forces (laws of motion and air resistance).
- Construct landing device.
- Evaluate design, compare with others in the class and from real life, suggest improvements.

INSTRUCTIONS

You may wish to provide time and opportunity for groups to research "Egg Drop" designs.

This might be appropriate after the first test, as part of the evaluation and improvement process.

Once the landers have been built, you may want to discuss, as a class, what needs to be taken into consideration to make the testing fair for each group.

Design Brief

Children to work in groups to design and build a Mars Lander model, to be tested using an egg as the payload (mars rover).

Each group must design a device which is as light as possible, using only the materials offered on the budget sheet.

Each group must stick to the budget and materials on offer and may only purchase materials once the design has been explained and approved.

Total Budget available is £200,000. The design must cost no more than £200,000, though you do not have to spend the full amount.

Each group will be provided with paper and pencils on which to plan and present their designs and must be ready to justify their choices and decisions. These may not be used as materials for the build of the lander.

Each group will be provided with Scissors, Rulers and Mathematical Compasses as tools to be used in the construction of their landing device. These are TOOLS and may not be used as materials for the build of the lander.

Once build is complete lander must be weighed, both with and without the egg.

Once all landers have been weighed in, a suitable official (teacher) will undertake the testing for each group (unless of course you are able to safely allow groups to drop their device from a suitable height themselves).

Each group must briefly show their design to the rest of the class and explain its features. At this point you could allow the class to make predictions on the performance, based on their prior knowledge of shapes and materials.

Each group must use the score sheet provided to evaluate the performance of their design and generate ideas for suggested improvements.

Extension Instructions/Suggestions

You may wish to devise a formal presentation sheet, for the designs, to allow for wall display.

It may be that as a class, you can come up with a better way to record results. This might be worth discussion after the first test.

It could be that a second test is run as a family event.

Design Presentation and Budget Sheet

Total Budget available is £200,000

Your design must be explained and approved before you can purchase your materials.

DESIGN PRESENTATION

Materials	Cost Each	Number Required	Total Cost
Straws	£10,000		
Pipe cleaners	£15,000		
Elastic bands	£ 5,000		
Polystyrene cups	£65,000		
Paper	£30,000		
Card	£35,000		
Carrier bags	£20,000		
Bamboo BBQ Skewers	£25,000		
String (per 30cm)	£ 7,000		
TOTAL			

SCORE SHEET

Use this sheet to score your design after testing.

Put a tick in the appropriate column to indicate the state of the lander (and payload) after test. Tot up the ticks in each column.

Make notes in the final column about how materials were used or damaged to help evaluate design and improve for the next test.

Materials used	Intact	Damaged	Broken	Notes
Straws				
Pipe cleaners				
Elastic bands				
Polystyrene cups				
Paper				
Card				
Carrier bags				
Bamboo BBQ Skewers				
String (per 30cm)				
Egg				
TOTAL				

THE SCIENCE

The egg drop activity is most closely related to the first two of Sir Isaac Newton's laws of motion (inertia and velocity). The first law being, that an object, whether in rest or in motion, will stay in that state, unless a force is applied to change it. The second law looks at how those external forces can affect or control an object in motion; F=am (Force = acceleration x mass). The purpose of the egg drop is to see if the students can increase air resistance or devise a way to absorb some of the force of the impact. They need to either apply a force to stop/slow the downward motion or find a way to control that movement, especially at impact.

As with the Mars Rover, an egg can be both strong and brittle. If you pinch an egg, top and bottom, between your fingers, it will not break. In fact, if you have 6 eggs, in egg cups (of the same height) and place a book on top, they can easily hold the weight of 6 bags of flour – try it. Their shape is strong, but the material they are made from is brittle and therefore easy to break.

THE CONTEXT

Once it arrives the rocket will release the landing shuttle, which will take the rover down to the surface of Mars. The lander being used for this mission is similar in shape to a dodecahedron. When it first enters the atmosphere, it will have an almost cone shaped heat shield on the underside. Even though the atmosphere is very thin, the action of the lander falling through it will create friction, from the air resistance, which will make the shell of the lander extremely hot. Extreme temperatures can be very damaging to the Mars rover and so the heat shield will help to protect from this. At a certain point in its descent the lander will deploy a parachute, which though not as effective as it would be on Earth, will still have the effect of slowing down the motion of the lander (and allowing it to cool a little). Once this has occurred the lander will release the heat shield, revealing sensors in the underside of the unit, which will be able to sense the distance to the surface of the planet. When it has reached a specific distance the lander will then start firing in-built thrusters (like little rocket packs), to slow the unit down even more and allow, for a controlled landing. Once it has landed the top and sides will open up, much like the petals of a flower and the rover will be able to use them as a ramp and trundle off on its mission.

The lander is the part of the mission that the Mars Rover engineers are most concerned about. It is essential that the rover lands safely and in one piece, but there are very few opportunities to test in Martian conditions. Due to this, it is very important that the engineers building the rover consider very carefully the materials and shapes that they use. The lander must be very light, so as not to waste fuel on the journey, but still strong enough to withstand a landing. It must also have some sort of suspension built in, so that the instruments on board are not damaged or destroyed on impact.

APPENDIX 2.10

Rosalind Franklin research

pop-up book/crystals

KS2

Subject:	Science ; Computing; Design and Technology; English; History
Duration:	Ongoing
Type:	Research Project

MATERIALS

- Access to computers
- Paper
- Pens/pencils
- Scissors
- Glue

Extension Materials

Additional craft materials as required

Aims

To learn about Rosalind Franklin and why the ExoMars Rover (2022) has been named after her.

To promote female figures in STEM

SCHEMES OF WORK:

- Computing
- Design and Technology

Objectives

Research Rosalind Franklin

Produce a piece of work or presentation to explain who Rosalind Franklin was, what she did and why the ExoMars Rover has been named after her.

INSTRUCTIONS

There are many ways to present the information found during research. We are providing basic instructions for making a short pop-up book, though you may want to offer your class a wider choice to fit with your English requirements. They could for example design a poster, write a persuasive letter to the Nobel Prize Commission, produce a PowerPoint presentation, write a short play, create an animation, this list is endless.

We have opted for a pop-up book to allow us to embed elements of STEM in the production.

To produce this pop-up book, students will need to create a series of double page spreads, which will be stuck back to back to compile the final book.

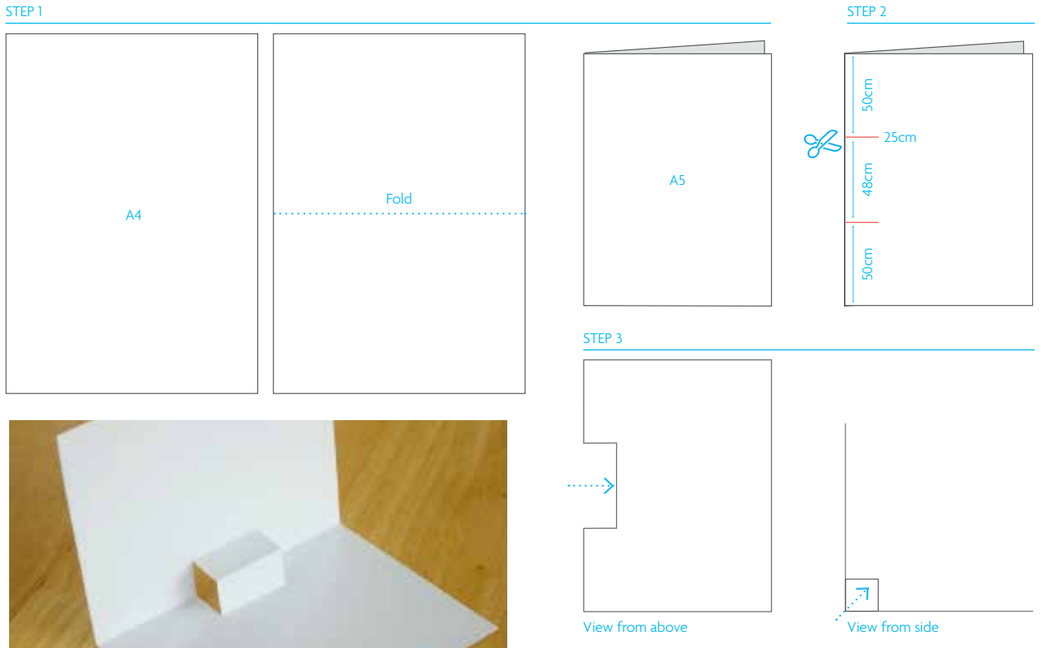
Once students had completed their research they will need to plan the information that they will include on each double page, for example they might want to plan the subjects to be covered; Childhood, Education, Career, Reason for Fame, What happened to her?

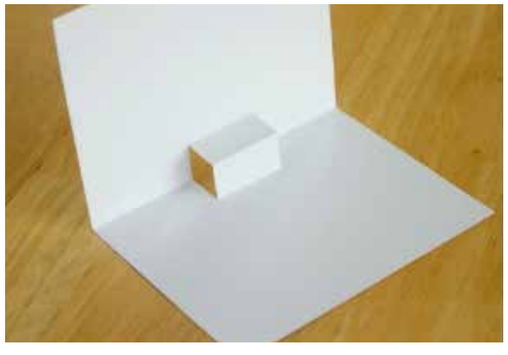
We would recommend no more than 2 pop-ups per page. More than that can crowd the page and effect the strength/structure.

They will also need to plan whether to produce their booklet in portrait of landscape – we find that it works better if they choose one or the other, though it is not essential to do so.

We would recommend leaving the sticking together and addition of front cover until everything else has been completed.

1. For each double page take a piece of heavy duty paper or light-weight card and fold in half
2. Work out where you want to place pop-up and measure two parallel lines of same size (approx. 2-3cm), making sure that they are no further apart than the image you want to make pop-up, then cut along those lines.
3. Unfold paper and push forward the area between the two lines you have just cut.
4. Stick picture or keyword on pop-up tab and decorate the rest of the page.
5. Repeat above steps for each page, then stick back to back.
6. Use piece of A4 paper as cover. Fold in half, decorate, then stick in place.





Extension Instructions/Suggestions

You could use other pop-up techniques, such as flaps and fold-outs to combine images and information.

Maybe this could be an additional research task.

THE SCIENCE

Rosalind Franklin was born in 1920 and became a Chemist and X-ray Crystalographer. After school she went on to study Natural Sciences and Newham College, Cambridge. From there she went on to do a fellowship in Chemistry at the University of Cambridge, which she gave up when approached to do research, vital for the War efforts, by the British Coal Utilisation Research Association. She was able to use the work she did there towards getting her doctorate in 1945.

Due to this and other work she did during the war Franklin was later (1947-50) given the opportunity to work at the State Chemical laboratory in France, studying X-ray diffraction technology and researching crystallography and the structural changes in heated graphite.

In 1951 she joined King's College, London, as a research fellow in the Biophysical Laboratory, where she applied her experience with X-ray diffraction to the study of DNA. It was this work that led to the discovery of the double helix structure for DNA for which James Watson, Francis Crick and Maurice Wilkins are credited. It is said that Franklin create an X-ray photograph that provided evidence of the double helix, which Maurice Wilkins shared with Watson and Crick. There is some suggestion that she was not initially aware that her work had been shared, though many official documents state otherwise. What is true is the fact that Franklin was not officially recognised in the publication of findings by Watson and Crick in 1953, or awarded the Nobel Prize alongside them and Maurice Wilkins in 1962. It is true that no more than three people are able to be awarded the Nobel Prize at one time, and Franklin had sadly lost her battle against ovarian cancer in 1958, prior to the award of the Nobel prize, but it is also true that the breakthrough discovery of the double helix could not have been accomplished without Franklin's work.

Franklin is also known for her work with viruses, especially those effecting plants.

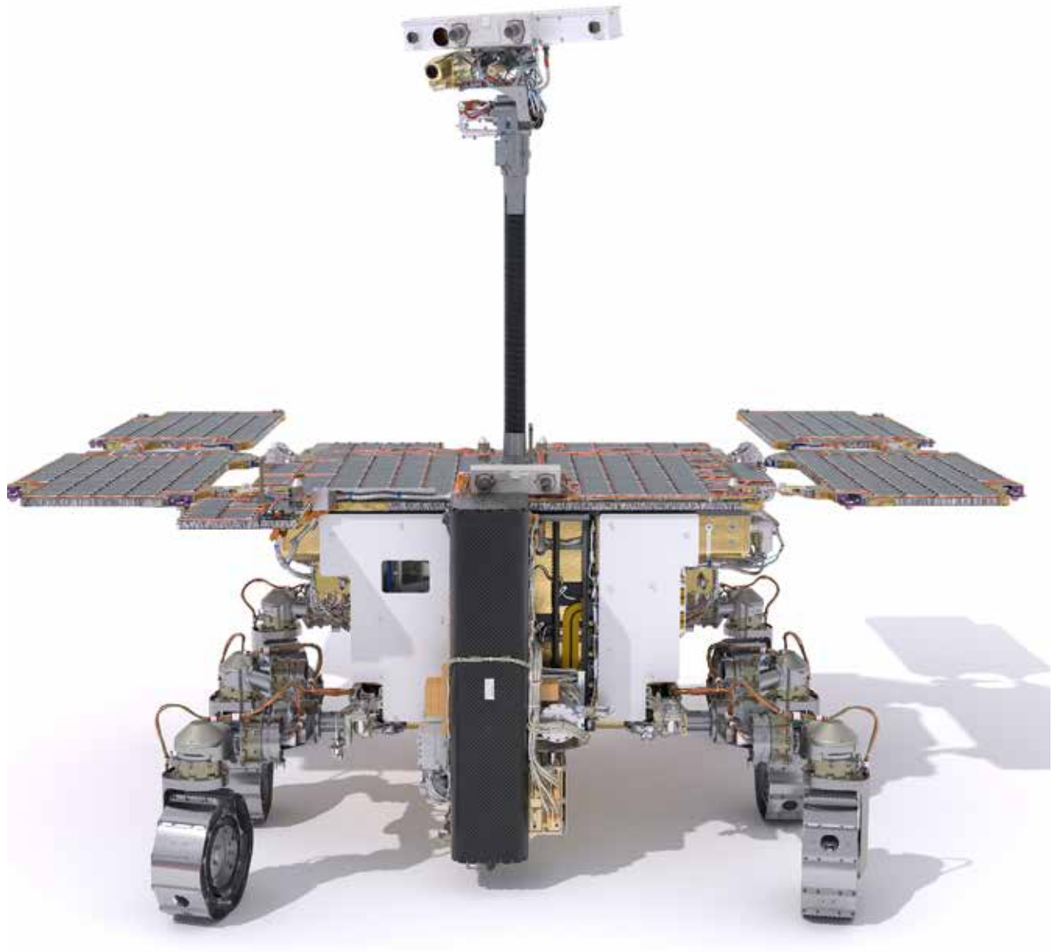
Franklin was just 37yrs old when she passed away.

The Context

Although there is no rule against posthumous awards of the Nobel Prize, the Nobel Committee does not generally select posthumous nominations.

The naming of the Mars Rover after Rosalind Franklin gives a nod to her contributions to our better understanding of life, through our improved knowledge of DNA, which was felt to be appropriate for this mission, specifically looking for evidence of life on another planet.

Rosalind Franklin was a British Scientist who is most famous for her work contributing to the discovery of the double helix structure of DNA. She was not acknowledged in the award of the Nobel Prize, though this occurred after her death. The British built ExoMars Rover has been named after Franklin in acknowledgement of her vital contributions to our understanding of the building blocks of life.



STEM DISCOVERY CENTRE

APPENDIX 2.11

Carnovsky Filters

KS2: Yr3, Yr6

Subject:	Science – Working Scientifically, Light; Art
Duration:	45 – 60min
Type:	Make and Investigate

MATERIALS

- Red, Yellow/Green, Blue Cellophane (cut into approx. 10cm squares)
- A4 (cut in half lengthways) Card
- Rulers
- Pencils
- Scissors
- Tape
- Screen showing http://www.carnovsky.com/RGB.htm

Extension Materials

- Torches (at least 3)
- Larger demo version of Tri-colour viewer
- Red, Yellow, Blue pencils, crayons, felt pens
- White Paper
- PC/laptop/tablet

Aims

To use and create Carnovsky type images to better understand the purpose of the colour filters used with the Pam-Cam instrument on the Rosalind Franklin Mars Rover.

SCHEMES OF WORK:

Science

Light

Objectives

- Make tri-coloured viewing lens
- Create red, yellow, blue multi-layered images
- Investigate multiple interactions and applications of the use of light with the tri-coloured lens and a variety of images.

INSTRUCTIONS

Part 1:- Make the tri-colour lens viewer

1. Take piece of card (A4 cut in half lengthways) and fold into 3 equal parts
2. Keep the card folded and on one side, draw a shape that leaves at least 1.5cm around each of the edges. Cut shape out of all 3 layers of card.
3. Tape a piece of cellophane behind the each of the shapes that have just been cut out, a different colour behind each shape (Red, Yellow, Blue). Make sure it is taped flat.
4. Show class images from http://www.carnovsky.com/RGB.htm and get them to view them through their new tri-colour lens viewer.

http://cargocollective.com/JSCinteriors/Carnovsky

Extension Activity Suggestions

What happens when you look at the Carnovsky images using more than one cellophane panel at a time?

Either using the larger demo model or one of the childrens' tri-coloured viewers, fold flat, so that all pieces of cellophane are lined up and shine a torch through the cellophane – what happens to the light?

What about if you unfold it to shine it through 2 layers at once? Does it matter which two layers you use?

Now stand the tri-coloured viewer upright, placing the 3 sides in a triangular formation. Shine a torch through first one of the cellophane panels, then two simultaneously, then all three at once – what happens to the light?

Can you create your own Carnovsky images? Either freehand or using a PC? Does the exact shade of colour matter? Do different colour combinations work more effectively? For example, Red, Yellow Blue (primary colours)? Red, Green, Blue (colours seen by eye)? Or Magenta, Yellow, Cyan (as used in printing)? Can you design an experiment to find the answer?

Can you use this technique to hide information in a picture or send a secret message?

THE SCIENCE

The cellophane acts like a sieve, filtering out all colours except the colour of the cellophane itself. So when all 3 colours are combined before the torch light is shone through it, all colours are filtered out. As white light is made from a combination of all the colours in the spectrum and those colours have all been blocked out, you see shadow rather than a colour of light. Colour mixing involving just one source of light, like this, is referred to as Subtractive colour mixing.

When the torch light is shone through the different coloured panels simultaneously, although the light is still filtered, it is a different colour being filtered out of each panel, so all of the colours of the spectrum are still present and combine to recreate white light. When coloured light from multiple sources are combined, it is referred to as Additive colour mixing.

There is also a difference between coloured light and coloured objects.

With coloured light, in this instance we are talking about white light that has been filtered through a lens or a gel. As white light is composed of a combination of all of the colours in the spectrum, what happens is that all the colours are filtered out, except the colour of the filter. That light is able to pass through it.

With coloured objects, it is almost the opposite. All the colours of the spectrum are absorbed, except the colour we can see, which is reflected back to us.

The Carnovsky images that we have recommended have been created by a Milan based partnership of artists/designers, Francesco Rugi and Silvia Quintanilla, and is an ongoing project experimenting with the interaction of light and printed colours, specifically Red, Green and Blue.

THE CONTEXT

The digital "eyes" of the rover, the PanCam uses digital terrain mapping to build up images of the martian surface. This means that the rover takes lots of photos of the land around it, these photos can be laid on top of each other to build up a 3D image. This allows the rover to safely navigate across rocky, sandy surfaces, over or around potential obstacles. The camera also has a colour filter wheel, meaning that it can look at the ground through different colour filters. This allows for colour images as well as, for example, picking up fluorescent molecules by looking through a UV light filter.

STEM DISCOVERY CENTRE

APPENDIX 2.12

Spectroscope

KS2: Yr3, Yr6

Subject:	Science – Light; Maths – Measurement, Geometry
Duration:	60min
Type:	Make and Investigate

MATERIALS

- Old CD's
- Card or cardboard tubes (middle of kitchen rolls/ wrapping paper)
- Black craft paper(thick)/thin card (approx. 10cm squares, couple per child)
- Pencil
- Scissors
- Tape
- Ruler
- Protractor

Extension Materials

- Variety of light sources
- Variety of lengths of cardboard tube

Aims

To build a spectroscope that can be used to replicate part of the process for analysing chemicals on Mars.

SCHEMES OF WORK

Science:

Light

- recognise that light appears to travel in straight lines
- use the idea that light travels in straight lines to explain that objects are seen because they give out or reflect light into the eye
- explain that we see things because light travels from light sources to our eyes or from light sources to objects and then to our eyes

Maths:

Geometry

- draw 2-D shapes and make 3-D shapes using modelling materials; recognise 3-D shapes in different orientations and describe them
- recognise angles as a property of shape or a description of a turn
- identify right angles, recognise that two right angles make a half-turn, three make three quarters of a turn and four a complete turn; identify whether angles are greater than or less than a right angle
- identify horizontal and vertical lines and pairs of perpendicular and parallel lines.
- identify acute and obtuse angles and compare and order angles up to two right angles by size
- identify lines of symmetry in 2-D shapes presented in different orientations
- know angles are measured in degrees: estimate and compare acute, obtuse and reflex angles
- draw given angles, and measure them in degrees (o)
- recognise, describe and build simple 3-D shapes, including making nets
- illustrate and name parts of circles, including radius, diameter and circumference and know that the diameter is twice the radius

Objectives

Students will each make and use their own spectroscope.

Students will identify the term scope in association with viewing items and the term meter in association with measuring items.

Students will become aware of the word Diffraction and understand that this indicates white light separating to show the colours of the spectrum.

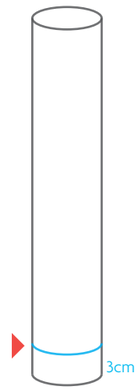
Students will be given the opportunity to use protractors to measure and place degrees in relation to their build.

Students will reinforce their maths skills, with particular reference to measurement and geometry, by completing the build of their spectroscope.

Students will be able to link the use of their spectroscope, with the purpose of the Spectrometer to be used by the Mars Rover.

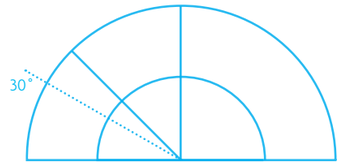
INSTRUCTIONS

1. 1Either use a cardboard tube (kitchen roll or from the middle of wrapping paper) or make one (approx. 30cm long, 3-5cm diameter).
2. (Temporarily) Flatten along one side. Measure 3cm up from the bottom of the tube and draw a line straight across.



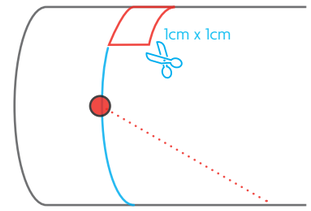
3. Turn the tube sideways so that the flattened side is going from left to right. Using a ruler, find the midpoint of the line you have just drawn and make a small mark there.

4. Using a protractor, draw a line, at an angle of 30 degrees, from the flattened edge to the midpoint. Then, keeping the tube folded, cut along that line (so that the card is cut both sides of the fold). This is where the CD will slot in later. You may wish to label it now.
5. Flatten a small section of the tube, opposite to the

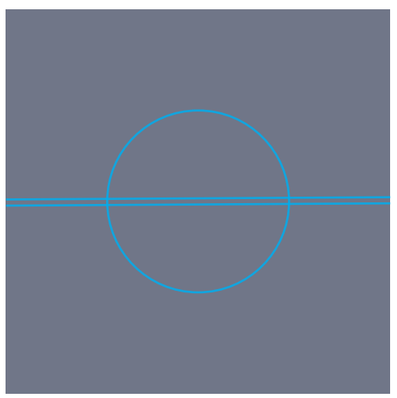


cut you have just made, and draw a small square, 1cm x 1cm, then cut it out (cutting both sides of the fold you have just made). This will be your viewer, you may wish to label it now.

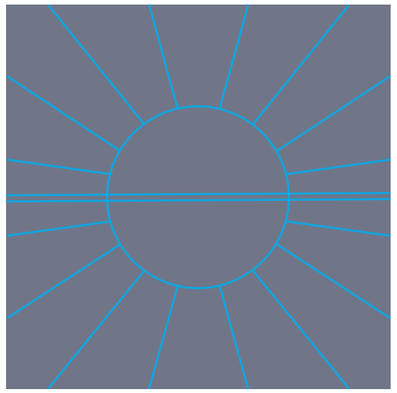
6. Unfold/reshape the tube by gently squeezing back to original shape.



7. Get a piece of thick black paper, or thin black card (approx. 10cm square). Place end of tube in middle of card and draw around it.
8. Using a ruler, measure and draw two parallel lines going straight across the middle of the circle you have just drawn. The must be no more than 1mm apart.
9. Then draw lines every 0.5cm from around the edge (circumference) of the circle, to the edge of the paper/card.

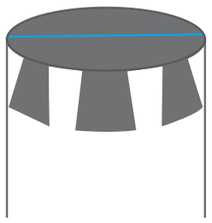


10. Carefully cut along the two lines that you have drawn across the middle of your circle.
11. Carefully cut along the lines from the edge of the



paper to the circumference of the circle, then fold each of the sections upwards, so that you are left with two semi circles, with tabs around them pointing up.

12. You may need to work in pairs to achieve the next step. Take one of your semicircles and place it over the end of your tube (the opposite end to your CD holder and Viewer) with the tabs facing down, along the sides of the tube. Using tape, stick the tabs in place, making sure that the semicircle across the end of the tube remains flat and lays flush with the end of the tube. Then repeat with the other semicircle, covering the other half of that end of the tube. You should end up with the end of the tube being covered, but with a very thin slit across the middle.
13. Take a second piece of black paper/card, place the (other) end of the tube in the middle and draw around it, then draw lines from the circumference of this circle to the edge of the card. Cut along those



lines and fit the circle over the bottom end (same end as CD holder and Viewer) of your tube, using tape to stick the tabs in place. You may need to trim some of the tabs so that they do not cover the viewer or CD holder.

14. We need to control the amount of light getting into the tube. It should only be able to get in through the viewer hole and the slit in the top of the tube. If there are any chinks or gaps in the black paper at either end (other than the intentional slit in the top), take a few moments to cover these with any scrap pieces of black paper. You may also wish to take this opportunity to ensure that your name is written on the tube somewhere and, time allowing, personalise it with some decoration.
15. Slot the CD into the CD slot, with the underneath of the CD facing upwards.
16. Put your eye to the viewer and aim the slit in the top of the tube at a light source. Look at the CD and you will see the colours of the rainbow, the "spectrum". Adjust the angle of your spectroscope until you are able to see the spectrum in a solid line of colours.

Extension Instructions/Suggestions

- Try different sources of light – fluorescent, incandescent, LED, sunlight*, neon, street lights etc
- What happens when you look at coloured lights?
- Does the length of the tube affect the results?
- Does the angle of the CD affect the results?
- How can you test these questions fairly?
- Record and compare your observations.
- How can you measure the results? Is it possible?

***Be careful not to look directly at the sun using your spectroscope, as this could damage your eyes. Try aiming the spectroscope at a white wall or piece of paper that is reflecting the sunlight.**

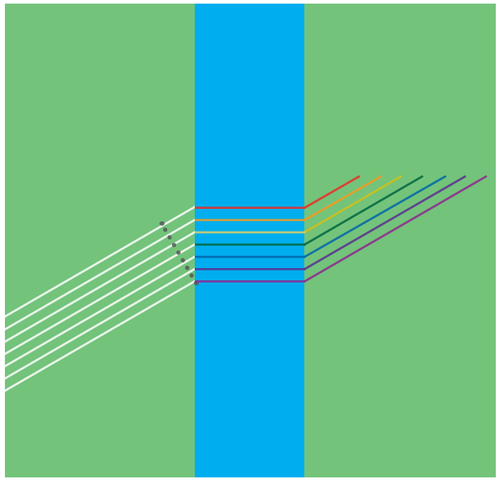
Did you know that we were able to identify the chemicals that the sun is composed from using spectroscopes and spectrometers? By using these apparatuses that we discovered helium in the sun, before we discovered it on Earth! In the late 1800's William Huggins was able to identify what the stars, including our sun, were made out of, by viewing them through a spectroscope.

THE SCIENCE

Words that contain "scope" in them are generally used to describe items that observe things (microscope, telescope, stethoscope etc). Words that contain "meter" are generally used to describe items that measure things (millimetre, centimetre, diameter, perimeter, thermometer, speedometer, pedometer).

The spectroscope you have made, allows you to observe the spectrum of colours produced by different sources of light. The coating on the CD causes refraction, which slows down the movement of light. White light contains all of the colours of the rainbow moving together, but when it passes through materials such as glass, plastic or crystal, the speed of the light slows. We call this refraction.

Sometimes we can create something called a "prism" with these materials. Different colours travel at different speeds, and when light travels through a prism it slows down so much that the different colours separate out and we are able to see the whole spectrum/rainbow.



The classic way of explaining this is by imagining a troop of soldiers, 7 columns, marching in formation. They are marching diagonally across a field. A river is flowing straight down the centre across the path of the troop of soldiers. We all know that it is much easier to walk through air, than it is to walk through water. The soldiers want to get to the other side of the field as quickly as possible. If they walk diagonally across the river it will take them longer. So as the first person of the first column reaches the river, they change direction to walk straight across it. The first person of each column does this as they reach the river, which means that the columns come out of the other side slightly staggered.

Different types of light use different chemicals, and these chemicals all reflect light differently. When you look at different sources of light, they might appear to be the same colour, but when viewed through the spectroscope we can see that the spectra displayed are totally different. For example, when you view fluorescent light, you will see that the spectra is displayed in bright lines of colour. These lines present the spectrum as reflected by the mercury gas that is contained inside the fluorescent tube. However, when you view an incandescent light source, you will see that rather than displaying as lines, the spectrum is continuous. Can you find similar types of differences between other light sources?

THE CONTEXT

Spectrometers are instruments that are used to gather measurable data from certain spectrums, for example light or (molecular) Mass. Spectrometers are used to identify and measure chemical components and composition. A Spectroscope, however, is an instrument used to observe spectra of different light sources, but it is unable to gather measurable data.

How does a mass spectrometer work?

"Everything around us consists of very small building blocks "atoms" and clusters of building blocks "molecules". Atoms and molecules are so small that we cannot see them. The different building blocks of different materials have a different mass."

A mass spectrometer separates samples depending on their mass to charge ratio. It is used to find out the mass of particles, and to find the basic chemical elements in a sample or molecule. It can also make clear the chemical structures of molecules, such as peptides and other chemical compounds. It works by ionizing the particles in the sample, which means an electron is removed from each particle, producing positively charged ions. This is done by using an electron gun - a high energy beam of electrons is passed through the sample to make electrically charged particles or ions. The ions are accelerated through a short tunnel, by use of negatively charged plates to which the positively charged ions are attracted. On passing through the tunnel, the ions are exposed to a magnetic field which causes them to travel in a curved path, depending on how heavy they are. Heavier ions are bent less than lighter ions. This results in heavier ions hitting a detection plate, at the end of the tunnel, at a different position to lighter ions. From this information, the mass-to-charge ratio of the particles, and the relative abundance (how much was in the sample) of each type of particle can be worked out. For each sample a 'spectra' is produced which shows a peak each time an ion hits the detection plate. This can be compared to the peaks produced by 'known' particles and used to distinguish what particles are being detected.

STEM DISCOVERY CENTRE

APPENDIX 2.13

Waterdrop Magnifier

KS2: Yr3, Yr6

Subject:	Science –Light; Design and Technology – Design, Make, Evaluate
Duration:	30 – 45min
Type:	Make and Investigate

MATERIALS

- Plastic bottle (clear, recommend 2ltr, with curved top)
- Marker pen/sharpie
- Scissors
- Water
- Kitchen Towel
- Pipettes (or straws)
- Circular template or item to draw around (approx. 5/6cm dia)
- Small printed text (recommend food packaging or photocopy – something that it won't matter if it gets wet)

Extension Materials

- Pipe Cleaners
- Straws
- Tape
- Cellophane
- Lollipop Sticks
- Matchsticks
- Acetate

Aims

To make and use your own magnifying glass to view items close up.

SCHEMES OF WORK:

Science

Light: recognise that light appears to travel in straight lines

- use the idea that light travels in straight lines to explain that objects are seen because they give out or reflect light into the eye

Design Technology

Make: select from and use a wider range of materials and components, including construction materials, textiles and ingredients, according to their functional properties and aesthetic qualities

- Evaluate: evaluate their ideas and products against their own design criteria and consider the views of others to improve their work
- Technical knowledge: apply their understanding of how to strengthen, stiffen and reinforce more complex structures

Objectives

- Students will learn about the use of lenses
- Students will learn that although light travels in straight lines, some materials can affect the behaviour/movement of light
- Students will consider the practical aspects of using water as a magnifying device

INSTRUCTIONS

1. Using the marker and template, draw a circle on the bottle, on the curved shoulder, just below the neck (it is important that you have a curved circle), then cut it out.
2. Once you have cut it out, you will see that your disc of plastic is like a very shallow bowl. Using the pipette or straw, put a little water into your disc/bowl until it is approx. half full.
3. Carefully place the disc of water over the small printed text. The text directly underneath the water will be magnified.
4. Compare your magnifier with other peoples, is there any difference in the magnification?

Extension Instructions/Suggestions

- Does the type of bottle make a difference to the magnification? Can you create an experiment to test this?
- Does the amount of water used make a difference to the magnification? Can you create an experiment to test this?
- Can you create a device to contain the water so that you may carry it around without spilling it?
- What items can you look at, other than writing? How does your magnifier effect the way these things look?

THE SCIENCE

A magnifying glass is a lens. Lenses change the behaviour of light so that we can see things differently. Magnifying glasses use a convex lens, which helps make images larger. One light has travelled through the lens, it reflects back, off the object, and into our eyes.

As light passes through a lens, it refracts. Refraction occurs when light travels through different materials, like glass, plastic or water. Light changes speed as it passes through these materials and as it changes speed it also changes direction. This can affect the way that light behaves. For example, if you have a glass of water and place a straw in it, from a certain angle, it will look as if the straw bends at the surface of the water. Equally, if you shine white light through a prism, the light will refract and separate into a rainbow.

The best way to think of it is as if you are on a skateboard or a go-cart. If you are travelling along a smooth surface, you will be able to move quickly, but if you reach a rough surface, such as gravel, the first wheels to hit that surface will be slowed down. This can affect the way/direction your skateboard or go-cart moves.

Because the section of bottle you have used curves outwards, the middle of it becomes thicker than the edges when it is filled with water, making it convex.

A concave lens is thinner in the middle that around the edges, which would make an image smaller.

THE CONTEXT

CLUPI (Close-Up Imager)

A high-performance colour close-up imager – the equivalent to a hand lens. CLUPI can work at very low temperatures at a working distance from 10cm to infinite, providing outstanding quality pictures.

CLUPI is the essential final step in the choice of drill site for the ExoMars Rover. The images taken by CLUPI are also important for observation of the drill head placement, the fines that come out of the drill hole and the surface of the core drilled materials when they are in the sample drawer.

STEM DISCOVERY CENTRE

APPENDIX 2.14

The Crusher

KS2

Subject:	Science – Working Scientifically, Forces, Materials, Rocks; Design and Technology – Design, Make, Evaluate
Duration:	May require several lessons and/or homework
Type:	Make and Measure Investigation

MATERIALS

Largely dependent on your budget and the scope of materials available to you. You may wish to set the finding of suitable materials as homework – could be a great opportunity to "recycle" materials and equipment that family and guardians have stashed away in cupboards/sheds garages etc.

Design Brief (provided)

Suggestions;

- Paper
- Pencils
- String
- Elastic Bands
- Tubes (variety of sizes)
- Weights
- Bottle/jar lids
- Bottles
- Blocks of wood
- Card
- Dowel
- Lollipop Sticks
- Plant pots
- Cans
- Gravel
- Foil
- Plastic Pots/Jars/Punnets
- Sand
- Glue (Multipurpose or glue guns)
- Tape
- Polymorph

Tools

- Hack Saw
- Screwdriver
- Sand paper
- G clamps
- Hammer
- (Hand) Drill
- Screws
- Nails

Extension Materials

Segmented Chocolate Bars

Aims

To design, make, test and evaluate a device to (try to) crush stones and rocks (and other organic debris found around the playground/playing field.

SCHEMES OF WORK

Science:

Rocks - compare and group together different kinds of rocks on the basis of their appearance and simple physical properties; recognise that soils are made from rocks and organic matter

Design Technology:

Design - use research and develop design criteria to inform the design of innovative, functional, appealing products that are fit for purpose, aimed at particular individuals or groups; generate, develop, model and communicate their ideas through discussion, annotated sketches, cross-sectional and exploded diagrams, prototypes, pattern pieces and computer-aided design

Make - select from and use a wider range of tools and equipment to perform practical tasks [for example, cutting, shaping, joining and finishing], accurately; select from and use a wider range of materials and components, including construction materials, textiles and ingredients, according to their functional properties and aesthetic qualities

Evaluate - investigate and analyse a range of existing products; evaluate their ideas and products against their own design criteria and consider the views of others to improve their work

Technical Knowledge - apply their understanding of how to strengthen, stiffen and reinforce more complex structures; understand and use mechanical systems in their products [for example, gears, pulleys, cams, levers and linkages]; understand and use electrical systems in their products [for example, series circuits incorporating switches, bulbs, buzzers and motors]; knowledge apply their understanding of computing to program, monitor and control their products.

Objectives

For children/groups to consider the problems faced by the ExoMars rover, when collecting and analysing samples

To consider the properties of a variety of rocks and other organic based deposits and sort them into comparative groups

To design, build, test and evaluate a device to be used to "crush" rocks for analysis

INSTRUCTIONS

This resource can run as a classroom activity or provide a great opportunity to include parents in a family event.

For this activity groups, be they classroom or family based, are set the task of designing and building their own rock "Crusher". You will need to give them time to consider the purpose of this device, consider the materials available and to review their ideas before finalising a design and moving on to the build stage. This activity could be given an immersive, competitive element should you choose to suggest that fair tests will need to be considered as they are competing to create an instrument for the Mars Rover. If you wished to push this idea further you could create a budget and put costs to each of the materials, so that financial aspects are also included in the final decision as to the winner – this would also be more reflective of the process within industry.

NB. It is unlikely that groups will be able to actually make a device with the power to crush stones – this need not be shared with the group at the outset. The value of considering the problem, understanding the properties of materials and learning that not fully succeeding, does not mean failure (evaluation is vital to improving on designs) will be much higher if the group do not feel that the task is impossible before they have begun.

We would recommend the following structure for classroom activity;

Session 1. Discuss the brief, research ideas and mechanisms, start thinking about what mechanisms and devices might be appropriate and what materials will be required. Look at materials available in the classroom. Consider the testing process – how would they ensure that all tests are fair? What would be a good way to record the results? Can they come up with a fair way to "score" each device? What aspects of the brief need to be considered for this? Who should do the scoring? HWK: Ask Parents/Family/Guardians for any scrap materials and equipment that can be used (and potentially destroyed or pulled apart.

Session 2. Take into account any materials that have been brought in and create a design of the device that the group intends to build. Review that design; do we have the materials? do we have the tools? what can we adapt/go with out should we need to? how would this impact out design?

Collect materials and start build process

Session 3. May need more than one session on build, depending on time and equipment. Complete build, then test. Everyone to watch each test.

Session 4. Review – discussion, followed by write up/ presentation. How did the testing go? What was good about their design? What areas do they think required improvement? What would they do to improve those areas, if given the chance? What did they think of the

devices created by other groups? Did it give them any ideas for their own design? Did they learn anything from doing this? Anything that surprised them or confirmed things they already had an idea about? Which bits did they find easy/difficult? What advice would they offer to someone else who was going to attempt this challenge?

Extension Instructions/Suggestions

You could add an extra item to your list of analysis objects (Egg, Can, Rock). Something like a bar of chocolate (segmented, like Dairy Milk etc) might be a good object to crush. It should break into multiple pieces, allowing the opportunity for teams to gauge the success of their design, by measuring and comparing the surface area before and after crushing. Maybe the class can make predictions as to the outcome/number of pieces/type of crush (broken into pieces, evenly sized pieces, lots of pieces or outright annihilation!) for each device based on it's previous performance. Predictions can then be compared to actual results and discussed. Where were the predictions correct? Where did the prediction vary? Why did the device perform better/not so well as expected?

THE SCIENCE

The reason that the sample must first be crushed, is to increase its surface area.

When we talk about the area of something, we are usually referring to the amount of space that is taken up by a (2-dimensional) shape.

When we are talking about "surface area", we are talking about the amount of space that is taken up by the outside or surface of a 3-dimensional (height, width, depth) shape.

In science, we can often increase the speed or effectiveness of an experiment or chemical reaction by increasing the surface area of something. Instead of adding more of that thing, we can break that thing into smaller pieces, each of which will be smaller 3D shapes with it's own surface area. Some of these shapes would have been hidden on the inside of the original shape.

For example, if you use Lego to build a 10cm, 3D Cube, the surface area will be 60cm2. But if you break that cube down into all the individual components, measure the surface area of each of those components, then add them all together, you will get a much higher number.

You could try this as an experiment, launching an alka-seltzer rocket. Try launching rockets, but for each one crumble the tablet up into slightly smaller pieces. Time how long it takes them to launch. There will always be anomalies, so is best to run each test several times to get an average result.

THE CONTEXT

SPDS (Sample Preparation and Distribution System, also known as The Crusher)

Each sample taken by the drill needs to be prepared for analysis, this will first involve crushing the sample into a powder. This powder will then be distributed into 20 equal sample pots for further analysis. For some spectrometry analysis samples need to be in gas form for analysis, this is either done by heating the sample, or zapping it with Ultraviolet (UV) Light pulses.

DESIGN BRIEF

1. Must design, build and test a device to be used to "crush" things (ultimately stones/rocks).
2. Must be made from readily available materials, scrap materials and recycled household items.
3. Must be able to use it within the classroom.
4. Must be big enough to hold; an egg, a drinks can, a rock and a chocolate bar (though not all at the same time)
5. The design must include some way to contain the "test sample", in such a way that it does not contaminate following samples.
6. The safety measures need to be embedded in the design.
7. It must complete at least 3 stages of testing;
   - Can it crush an egg?
   - Can it crush a drinks can?
   - Can it crush stone/rocks?
   - Can it crush Chocolate?

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