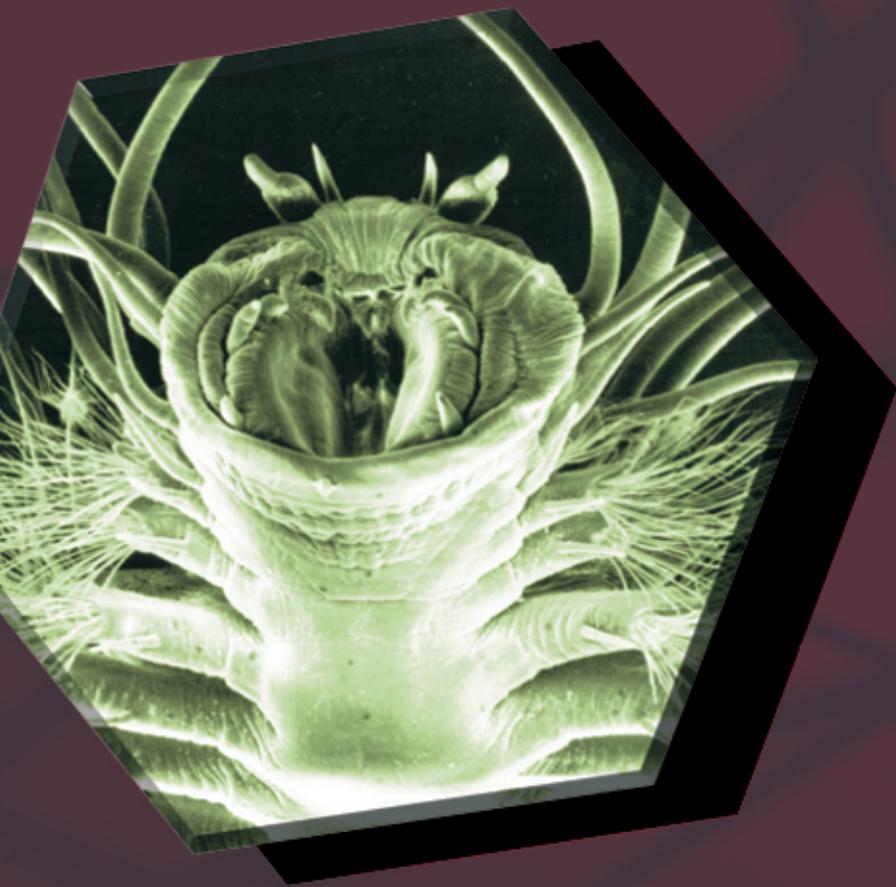
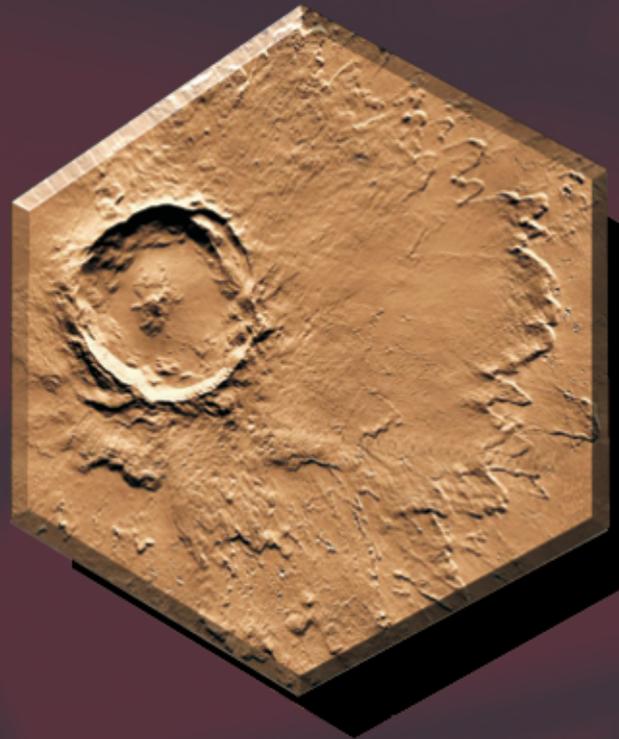


Is There Anyone Out There?

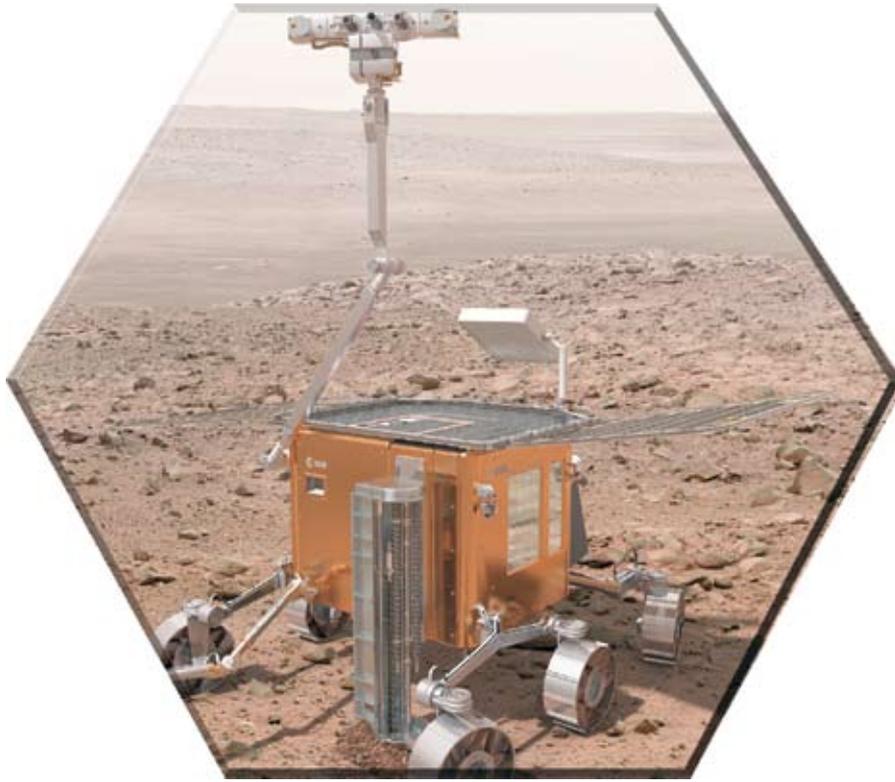
A science investigation pack
for teachers of 9-12 year olds



UK SPACE
AGENCY



Promoting science



Is There Anyone Out There?

**A science investigation pack
for teachers of 9-12 year olds**

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Introduction

This resource is based upon the quest to discover more about our solar system through space projects such as the European Space Agency's Aurora programme, and NASA's Curiosity mission seeking to gather evidence of life on the planet Mars. The children take on the role of space scientists or space engineers to discover more about Mars.

Age range

The activities in this resource are designed for children aged 9-12 years. Activities in the Life and Landscape themes are suitable for children in Years 5-6. Activities in the Landing theme are intended for children in Year 7 or to challenge Gifted and Talented primary children.

Approximate duration

The activities vary in duration from approximately 1 to 3 hours, depending on the circumstances in each school and class.

Activities

The activities are organised into three themes: Life, Landscape and Landing. They are designed to appeal to the imagination of children. See the table overleaf for a summary of the activities in each theme. Themes can be taught independently, and teachers can select the ideas in a particular section according to the interests of their pupils.

The investigative activities and images in each theme provide a sequence that helps the children to explore features of the planet Mars in practical ways involving the use of key skills. They introduce the children to a range of challenges each requiring the use of enquiry skills, discussion and problem solving consistent with UK curricula requirements.

It is intended that children develop their own ideas, and methods of recording and presenting their results and conclusions. To support this approach, hints and facts, and ideas for investigation and recording are provided, to be adapted by teachers to suit the needs of their children.

Resource website

The following websites can be used to download the images and .pdf of the written resource.

www.stem.org.uk/rx7kt

www.cciproject.org/topicBank/space.htm

Glossary

The glossary contains definitions of words that appear throughout the teachers' notes as highlighted text.

Summary of activities

Life	<p>Children consider the criteria essential for life and discuss what form life might take. They go on to:</p> <ul style="list-style-type: none">• compare and test samples of 'soil' identifying properties that indicate characteristics of Martian 'soil'.• test for the possible presence of microorganisms.• investigate conditions affecting their growth.
Landscape	<p>The children study images from Mars to note significant features and make hypotheses about their formation.</p> <p>They carry out and evaluate practical tasks to mimic crater formation, lava flow, and the creation of channels and deltas.</p>
Landing	<p>Children consider data from the viewpoint of scientists or engineers to identify the best landing site for the rover.</p> <p>They estimate the age of landing sites, identify landscape features such as craters, rocks, deltas, canyons, elevations and interpret scales, data and images.</p> <p>The class debates to decide the most appropriate location.</p>



Image of Mars surface from a lander

England

At the time of publication, the National Curriculum and assessment processes were undergoing review. For updates and information related to the 2013 curriculum and assessment, please visit www.ciec.org.uk or the DfE website www.education.gov.uk/schools/teachingandlearning/curriculum/nationalcurriculum.

Science: The Life and Landscape themes cover substantial areas of Scientific Enquiry (Sc1) and Materials and their properties (Sc3) as well as Forces from Physical Processes (Sc4) in the current National Curriculum for Science. Aspects of Life and Living Processes (Sc2) are included in the Life theme. The activities can also be used to support work in Earth and Beyond (Sc4) and levels 3-5 of each assessment focus for Assessing Pupils' Progress.

Maths and Geography: The Landscape and Landing themes cover Using and applying number (Ma2), Understanding measures (Ma3) and Using, applying and handling data (Ma4). There are opportunities to measure and record, use scales and produce and interpret graphs and other data. They also include geographical enquiry and skills and understanding of places, patterns and processes. The children identify, compare and contrast key geographical features.

Literacy and ICT: There are ample opportunities for 'speaking and listening' due to the high levels of discussion promoted throughout the resource. The Landscape and Landing themes cover ICT via internet-based research and preparation of presentations respectively. The children develop ideas, exchange and share information and describe and talk about the effectiveness of their work.

KS3: The Landing theme covers key processes in science of critical understanding of evidence and use of ICT to communicate, to work creatively and collaboratively. In Maths the theme offers opportunities to apply competence and creativity (Key concepts) and to represent, analyse, interpret and evaluate in number and measures (Key processes). In Geography the children consider physical characteristics of places using geographical enquiry and visual literacy. The theme offers a creative context in English for speaking and listening, particularly in formal debate and presentation.

Scotland

Science: The Life theme covers aspects of biodiversity, body systems and cells, properties and uses of substances, and planet Earth. The Landscape theme focuses on forces, materials and properties and uses of substances. Topical science is covered in the Landing theme.

Maths: The themes interweave skills of using and manipulating number throughout the practical tasks. They allow the children to communicate and reason mathematically (Number, money and measurement). They analyse and interpret data and draw conclusions. (Information handling)

Literacy: All themes encourage children to share, explain and clarify their ideas, (Listening and Talking), to find and use information (Reading) and to select and convey information. (Writing-Organising and using information and Creating texts)

Geography: The Landscape theme allows children to investigate factors affecting formation and shaping of landscapes. (People, place and environment)

ICT: All themes provide opportunities for using ICT to access information and to create and capture text and images to communicate in creative ways. (ICT to enhance learning)

Curriculum coverage

Third Level: The Landing theme allows pupils to use mathematical skills in applying number and measures, interpret maps and apply scale and to analyse a variety of data. In science they consider the possibility of life elsewhere in the universe (Planet Earth-Space). They can investigate the physical features of a natural environment and interpret images and geographical information. (Social studies). There are numerous opportunities for discussion, debate, persuasion and communication of ideas (Listening and Talking and Writing) and extracting and analysing information (Reading).

Wales

Science and Maths: The Life and Landscape themes provide ample opportunities to carry out different kinds of enquiry, and to compare the properties and features of materials. The Landscape theme also covers the environment and living organisms. The Landing theme offers numerical opportunities for P7 children to use quantitative measurement, and use tables, charts and graphs to record their work.

Literacy, Geography and ICT: The themes offer contexts for developing skills of communicating confidently, reading a range of texts and writing for a purpose. The Landscape and Landing themes cover geographical skills of identifying and describing natural features and ICT via internet-based research and preparation of presentations. All themes encourage children to use creative ways of recording and communicating information.

KS3:Science:The Landing theme offers opportunity to search for information (Communication). In Maths, pupils use a range of mental and written computational strategies, read tables and graphs (Solving mathematical problems), and interpret mathematical information (Reason mathematically). They also use place value, calculate and use measures (Number) and interpret real data (Handling data). In Geography, the theme includes describing physical features, using maps and imagery to interpret locational information, communicating and answering questions.

Northern Ireland

Science and Geography: The Life and Landscape activities include the variety of living things, conditions for life, forces, materials and landscape features, covering four strands of the World about Us.

Maths: Children have a variety of opportunities for using number and applying mathematical skills in context, particularly in measuring and analysing and presenting data. The Landing theme covers place value, area, scale and data handling.

Literacy: All themes encourage discussion, recording and presentation of ideas in a variety of ways, incorporating ICT skills

KS3: In Science the Landing theme allows pupils to learn about the solar system and universe and in Maths to develop knowledge and understanding of number, measures and data handling, and apply skills to real life situations. There are opportunities to work collaboratively and justify logical argument, communicate effectively using mathematical and ICT formats, showing an awareness of audience. In Geography, pupils can develop geographical skills and manage information effectively to investigate geographical issues.

Activity 1: Martian soil



Objectives

- To identify key criteria for life and recognise that life can adapt to, and exist in, extreme environments
- To compare mixtures of solids and use investigative skills to identify key characteristics
- To describe rocks and soils on the basis of their characteristics, including appearance, texture and permeability

Resources

per group of four children

Activity sheets 1-3

Images A-J from www.cciproject.org/topicBank/space.htm

Role badges (optional)

Soil samples A, B, C

Magnifying lens

2 teaspoons

3 petri dishes/shallow bowls

Blue and red litmus paper (supplied by TTS or other suppliers)

or vinegar and bicarbonate of soda (1/4 cup)

3 filter funnels and filter paper.

3 plastic cups

3 measuring cylinders

Tea light and stand

Foil evaporating dish

Sand tray

4 pairs of safety glasses

Advance preparation

Activity sheets 1-2 made into a set of cards

Soil samples A, B, C (Appendix 1)

Role badges (Appendix 1)

Advance preparation

All the classroom sessions involve children working together in groups of four. A set of role badges for each group should be prepared before the lesson should the teacher wish to use them. (See page 56).

Introduction

The teacher uses the images A-D (see page 15 or website) to begin a discussion about the possibility of life on Mars and asks the children *Can we see evidence of life on the surface? Where else could we look?* 'Rovers' are being designed to search for signs of life on and below the Martian surface. Each pair in the group is asked to discuss how we know if something is alive. Pairs share their initial ideas with their group. Images of living/non living things (Activity sheet 1) can be used as a revision aid in a sorting activity to support discussions. The 'Snowball technique' (Appendix 2) could be used to share ideas between groups, before the class produces a consensus of key criteria for life.

The teacher describes conditions on Mars, using information in Appendix 3 and asks the children if they can suggest extreme places on Earth; they should consider examples of adaptations of living things in such environments. Images E-J of **extremophiles** and extreme habitats are shown. Considering this information about extremophiles, *Is it possible that there has ever been life on Mars? What might that life look like?* We need to find out as much as we can about conditions on Mars to answer these questions. They next consider the kinds of life (possibly microbial) and evidence that **astrobiologists** may be searching for on Mars.

Activity

The teacher explains that one day, space scientists hope that real samples of Martian soil will be brought back to Earth but in this activity, they will simulate the work of space scientists investigating 'mock samples'. The Space Agency has given each group three different samples of 'soil' and through observations and tests they must decide which might be most like Martian soil. Each child in the group is given a card from Activity sheet 2. The children should take turns at sharing their information with the rest of the group; the key facts will help them in their investigation. This activity is intended to be child-led and therefore they decide what evidence they need to collect and how they might record their observations, measurements and conclusions.

The children should be encouraged to observe each sample of soil closely, to feel the soil texture and note its characteristics. They use small quantities of each sample to carry out further tests. Activity sheet 3, if required, is provided for children to summarise their observations, results and conclusions.

Safety notes, practical tips and guidance

- Children should wear safety glasses to protect their eyes when evaporating water from salt solution, due to potential spitting.
- Tea light stands should be placed in a tray of sand for safety. Consult ASE's Be Safe! for further guidance.

- Teachers should ensure that each soil recipe is mixed thoroughly. It is recommended that teachers test the mixtures before the lessons.
- Litmus paper¹ can be used to show whether a liquid is acidic or not. Just add a teaspoon of soil to a cup, add water to cover the soil and mix. Then dip the paper into the liquid.

Plenary

The communications manager from each group reports their observations, measurements, results and conclusions to the class. The results may be collated on the whiteboard for display and discussion by the class. Unusual or unexpected results or observations may be noticed. The teacher can ask some of the following questions:

Did all groups identify the same sample as most like Martian soil?

Were there any disagreements?

How did you decide which sample was the most like Martian soil?

Did you recover any salt crystals?

What methods did you use and what evidence did you have?



Hot springs in Yellowstone Park: a suitable extremophiles' environment

¹ If you do not have litmus paper, put a teaspoon of soil into each of two containers. Then, add vinegar to one. If the soil bubbles or fizzes, it's not acidic. If there's no reaction, add water to the second sample and mix. Then, add two teaspoons of bicarbonate of soda. If the soil bubbles or fizzes the soil is very acidic.

Activity 2: Looking for evidence of microorganisms



Learning objectives

- To know that microorganisms are living organisms too small to be seen.
- To know that some microorganisms produce carbon dioxide if suitable nutrients are provided.
- To use observations, measurements or other data to draw conclusions.

Resources

per group of four children

Activity sheets 4-5
2 tsp soil samples A-C
¼ cup sugar
Thermometer
Teaspoon
Warm water (45-50°C)
Plastic cup or beaker

Advance preparation

Soil samples (Appendix 1)
Add a packet of dried instant yeast to sample C, ensuring it remains completely salt-free.

Introduction

The teacher explains that the children will look for evidence of the presence of life (microorganisms) in the soils and record their observations. If life is present, adding warm water and sugar to each sample may result in the production of gas (carbon dioxide). Groups are provided with helpful hints and facts cards (Activity sheets 4-5).

Activity

The children:

1. Dissolve 2 teaspoons of sugar in 30ml of warm water (45-50°C) and quickly add this to the sample.
2. Press the bag to remove air excess air and seal.
3. Mix the contents together by gently pressing the contents with their fingers, ensuring that the bag is completely sealed to prevent escape of carbon dioxide should microorganisms be present.

The children may record the gradual inflation of the samples using drawings, video or photographs.



Photograph showing the inflated bag of Sample C after 20 minutes

Plenary

The children share their observations with the class.

Did the groups all have similar results?

Were there any unexpected results?

Can they explain what happened?

The teacher should explain that scientists take great care when they draw conclusions from tests such as these. The production of gas does not necessarily mean that life is definitely present.

Safety notes, practical tips and guidance

Teachers check that the water is no hotter than 50°C to avoid killing the yeast. If yeast is present, the children should see the formation of bubbles of carbon dioxide very quickly. The bag should begin to swell after about 20 minutes and after an hour should be well-inflated.

Extension

The children could be encouraged to suggest further investigations to discover how different conditions may affect the growth of microorganisms. They may wish to try investigating the effect of light, temperature or different nutrients upon the growth of the yeast.

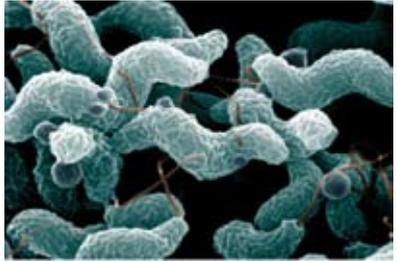
Background information

When scientists study very small samples or fossilised material, the characteristics of present or past life are very difficult to determine. The tests used by previous missions to Mars were based around the belief that life would cause changes in the air or soil, in a similar way to life on Earth. The missions did not detect the presence of life. It is intended that the children will not find evidence of life in the sample most like Martian soil.

One of several signs of life scientists search for is the exchange of gases in respiration or fermentation, as modelled in this activity. Here, the microorganism yeast is using sugar as a source of energy and is producing carbon dioxide. Most living things on Earth need oxygen to survive, but some organisms have adapted to extreme conditions where oxygen is absent, as on Mars. Sensitive techniques are used by scientists to detect minute quantities of gases that might indicate evidence (but not prove) that some form of life once existed on Mars.

Living/non-living discussion cards

Images can be downloaded from the website (see page 1).

Soil Challenge Card 1

You have 3 samples of soil; A, B, C. As space scientists you are to decide which one you think is most like soil from Mars.

Helpful Hints

Salt dissolves in water. Sand does not.

Fabulous Facts

Soil from Mars is mostly dust that falls out of the air from big dust storms.

Soil Challenge Card 2

You should feel and observe each sample.

Helpful Hints

You can use special paper called indicator paper to show whether a liquid is acid or not.

Fabulous Facts

Mars soil is made from very fine dust like talc, bits of sand, tiny rocks and larger lumps from meteorites. Some samples of Mars soil are acid but most are not.

Soil Challenge Card 3

You should carry out some investigations and use the Mars facts to help you.

Helpful Hints

Filtering can be used to separate materials that do not dissolve in water.

Fabulous Facts

Mars soil is rusty. It looks reddish brown. Under the surface are tiny bits of rock that let water pass quickly through them.

Soil Challenge Card 4

You need to collect evidence, decide how to record it and present your findings.

Helpful Hints

Evaporation can be used to get back materials that have dissolved in water.

Fabulous Facts

Almost every Mars lander or rover has found some salt or salt crystals in the soil.

Space scientists Martian soil studies

✓ Yes or X No	Samples		
	A	B	C
Red-brown colour			
Feels like talc or flour			
Range of particle sizes			
Contains salt			
Lets water pass through quickly			
Acidic			

We think sample is most like Martian soil because

.....

.....

.....

.....

.....

Life Helpful Hints

You can make some food for the microorganisms by dissolving 2 teaspoons of sugar in 30 ml of warm water (between 45°C and 50°C).

Life Helpful Hints

If microorganisms are present, you may see bubbles of gas (carbon dioxide) and the bag may begin to swell up.

Life Helpful Hints

Make sure you press the bags flat before sealing them!

Life Helpful Hints

When the bag is sealed, mix the food with the soil by pressing it with your fingers.

Life Fabulous Facts

Living things need water and food and the right conditions to survive.

Mars is very cold, dry, dusty and windy. It has hardly any oxygen and has a third of Earth's gravity.

Life Fabulous Facts

Scientists believe that water existed on Mars 1 million years ago. Water may be present under the surface of Mars.

Life Fabulous Facts

Microorganisms can live in very extreme places on Earth. They may once have lived on Mars!

Most living things need oxygen but not all microorganisms do.

Life Fabulous Facts

Microorganisms may produce gas when given water and food.

Space scientists test soil samples for materials that have come from living things in the past.

Images of the Martian surface

Images can be downloaded from the website (see page 1).

<p>Image A</p>  <p>Image of Mars taken from a Viking Orbiter showing the 'canals'.</p>	<p>Image B</p>  <p>Surface of Mars taken from orbiting satellite</p>
<p>Image C</p>  <p>Mars rover</p>	<p>Image D</p>  <p>Surface of Mars taken from a lander</p>

Extremophile habitats

Images can be downloaded from website (see page 1).

Image E



Antarctica

Image F



Volcanic lava

Image G



Volcanic ash

Image H



Methane worm



Deinococcus radiodurans

Image I



Ocean depths

Image J



Yellowstone hot springs

Activity 3: Landscape discussion



Learning objectives

- To know that science is about thinking creatively to try to explain how living and non-living things work, and to establish links between causes and effects.
- To know that comparing Mars' key landscape features with similar features on Earth can help us to understand their formation.

Resources

per group of four children

Activity sheets 6-7 and 12
 Images K-U (Q for teacher use only (see page 36))

Advance preparation

Activity sheets made into cards

Introduction

The teacher explains that the new Mars rover, searching for evidence of past or present life, will look in particular for the presence of water. Where water is or has been there is a chance of discovering evidence of life. On Earth, where volcanic heat and water interact, scientists have found life. The groups study images K-P. The task is to identify what each might be and how each might have been formed by comparing images of similar features from Earth to aid identification (Images R-U).

Groups may choose one of the key features and perform one of three practical tasks. The three practical tasks use models to simulate how the key Martian features may have been formed. Children use Activity sheets 6-7 to help them decide which feature to investigate. The whole class could try all three activities (3-4 hours) or a third of the class could each investigate one feature and report back to the others (1- 1½ hours). Later, they will compare their ideas with those of the 'experts' (Activity sheet 12). Finally, they share their ideas and evidence and suggest suitable locations for the rover landing and sampling sites.

Practical tasks, described in detail later in this section, include:

1. Exploring how the mass, size, shape, velocity, and angle of impact of falling bodies (**meteorites**) and the surface might affect the size and shape of the crater produced.
2. Investigating **lava** flow and layering patterns by making a '**volcano**'.
3. Studying patterns produced by flowing water across a surface.

Landscape Helpful Hints

Comparing images taken on Earth may help you to identify important features on Mars.

Landscape Helpful Hints

Doing practical tests and investigations may help you to find out how these features were made. Scientists call this 'modelling'.

Landscape Helpful Hints

After your experiments, read the expert's information about the important feature you have been investigating. You could find out more from books or the internet.

Landscape Helpful Hints

Talk about your observations and measurements. How do you think the feature was made? Do your conclusions agree with the experts?

Landscape Fabulous Facts

A crater is a hole, usually circular in shape, made when a piece of rock (meteorite) or an ice/rock mixture (comet) from outer space crashes into a rocky planet such as Mars.

Landscape Fabulous Facts

Mars is very cold and temperatures average -55°C but it may not always have been so cold. There could be ice on or under the surface. Scientists believe that where water is, or has been, there may be a chance of finding evidence of life.

Landscape Fabulous Facts

Volcanoes and/or lava flows can be found on all large rocky planets. Lava can make channels similar to those made by water.

Landscape Fabulous Facts

Where heat from volcanoes and water are close together on Earth, scientists are finding life. In hot springs they have found different kinds of living things.

Activity 4: Investigating craters



Learning objectives

- To use simple equipment and materials to make observations and measurements
- To use observations and measurements to draw conclusions
- To know that the size of a crater is dependent upon the size, weight or velocity of the object dropped

Resources

per group of four children

Activity sheet 8 cut into cards

Tray $\frac{1}{2}$ filled with sand

A variety of 'meteorites' (e.g. marbles, rubber balls, stones)

Tube for safely directing dropping/rolling 'meteorites'

Measuring device (see diagram on Activity sheet 8)

Ruler

Metre stick

Activity

The children begin by investigating the effects of dropping various masses, such as marbles, into a tray of sand. The children should be alerted to the safety issues when dropping objects. Using a tube through which to drop the objects would direct them safely to the tray.

Trays could be placed on the floor to allow the height of drop to be increased safely. Encourage discussion about fair testing, how the speed, density, size of the projectile is important, and how and why this affects the size of the crater produced.

Plenary

The communication manager from each group shares their results with the class. The results can be collated and displayed on the whiteboard for comparison. Interesting patterns or unusual figures could be highlighted. The importance of replication of results is emphasised. This is also an opportunity for graphs to be constructed and suitable graphing software to be employed. The children compare their craters with the images from Mars:

Are they similar or not? Why?

What are the limitations of the model?

How would they improve their tests? Were they fair?

Were the results reliable? Were they repeated?

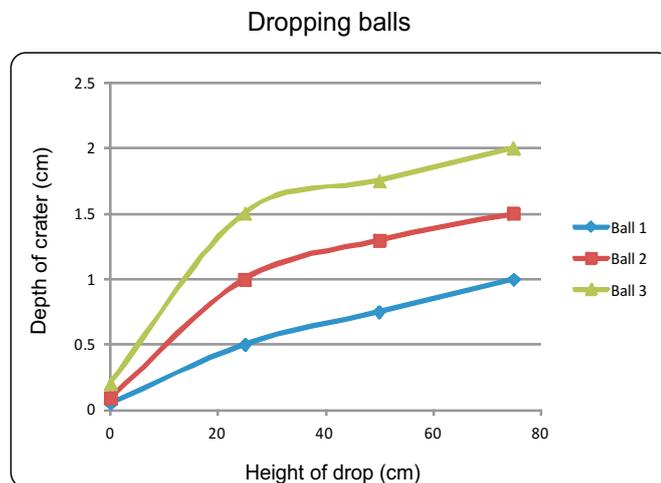
What have they learned about real crater formation?

The only fair comparison is to change only one variable at a time; different sizes or mass of ball should be dropped from the same height, or the same mass from different heights and craters compared. In reality, meteorites would break up into pieces and possibly produce secondary craters, but in this case, the masses dropped stay in the craters produced.

The table below shows the depth of crater produced when dropping balls with identical volume but increasing mass.

Height of drop (cm)	Crater depth (cm)		
	25	50	75
Ball 1	0.5	0.75	1.0
Ball 2	1.0	1.3	1.5
Ball 3	1.5	1.75	2.0

The graph below shows the depth of crater produced when dropping balls with identical volume but increasing mass into damp sand.



Extension

The children may suggest investigating dropping the masses at different angles rather than straight down or dropping rocks of similar mass but different size or shape. They could make meteorites from a material that will break on impact, such as damp sand.

Safety notes, practical tips and guidance

An example of an easily-made device for measuring crater depth is shown on Activity sheet 8. Ensure that the bottom of the straw, on which has been placed a blob of Blu-Tack, is resting lightly on the bottom of the crater. The card circle can be moved up or down the straw to gently rest on the edge of the crater, whilst the depth is marked on the straw. The straw can then be placed next to a ruler and the depth measured. A possible way to achieve same size/different masses is to use plasticine wrapped around objects of varying weight. Alternatively, various weights could be placed inside hollow spheres.

Activity 5: Investigating powdery surfaces



Learning objectives

- To understand that the greater the size, mass or velocity of an object dropped, the greater the impact crater produced
- To know that layers under a surface may be exposed or material ejected upon impact of a falling object

Resources

per group of four children

As in Activity 3 plus:

A tray $\frac{1}{2}$ filled with layers of sand, flour and thin top layer of chocolate powder (to represent layers of Martian 'soil')

Basalt rock samples (optional)

4 pairs of safety glasses

Introduction

In order to simulate what may happen to the surface and underlying layers of Mars when a **meteorite** impacts, a second tray can be prepared to represent the Martian surface. The teacher points out that the cocoa/chocolate powder could be the iron oxide (rust) covering and the layer below represent the rocks of Mars, then explains what types they might be, e.g. Basalt (rocks from volcanoes). If rock samples are available in school, they could be shown to the children.

Activity

The children choose suitable 'meteorites' and drop them on to the surface. After one or two drops, the children are encouraged to look at the pattern produced e.g. **ejecta blanket** (ejected matter that surrounds a crater) of white flour, and may notice that the material which was once low down is now on top. Explain that this can help scientists, allowing them access to look at the rocks under the surface of Mars. The children continue to investigate dropping meteorites of various sizes and from different heights. They can smooth the surface and add a fresh layer of flour and chocolate powder when necessary.

Plenary

The children look again at the images and compare the patterns produced by their investigations with those on the images from Mars. *Can they find similarities? What conclusions can they make?*

Safety notes, practical tips and guidance

Since there is a danger of fine particles being dispersed into the air, it is advised that the children wear safety glasses during this investigation to prevent fine powder entering the eyes and care should be taken to prevent powder inhalation.

Activity 6: Investigating muddy surfaces



Learning objectives

- To investigate links between the size, weight or velocity of an object dropped onto a surface and the distance travelled by the material ejected
- To use observations and measurements to draw conclusions

Resources

per group of four children

Activity sheet 8 cut into cards
 A variety of 'meteorites' (eg marbles/rubber balls/stones)
 Tube for safely directing dropping/rolling 'meteorites'
 Mud
 Large sheet of paper/card
 Ruler
 Metre stick

Activity

The children are challenged to predict what patterns might be produced if meteorites had landed onto a wet Martian surface. They can prepare a mix of soil and water. The mud should be sufficiently sloppy to eject mud splats when the mass is dropped! The mud is placed into the middle of a large sheet of paper or card. The children drop a variety of 'meteorites' into the mud from different heights and observe the patterns produced. They measure the distance travelled by the mud ejected on impact.

Plenary

The teacher shows the children the information about Tooting Crater provided by the experts (Activity sheet 12). The children look again at the images L and M of Tooting Crater and look for similarities between the images and the patterns they produced in their investigations. Teachers can ask the following questions:

Did they find a link between the heights of drop and distance the mud travelled or size/weight of body dropped and the area covered by the splats?

What do they think produced the patterns in the images?

Do their conclusions agree with those of the experts?

Extension

The children could be encouraged to discover more about the key landscape features of Mars and reinforce their understanding by further reading or through internet-based research.

Safety notes, practical tips and guidance

It is advisable to use soil rather than compost and to conduct this investigation outdoors. Dropping masses onto mud and observing ejecta would simulate meteorites landing in wet terrain. Allowing the splattered surface to dry would enable further observations and comparisons to be made between the images of Martian channels and the patterns produced. Children should wash their hands thoroughly after handling soil or wear protective gloves during the activity. For further information, see ASE's Be Safe!¹

Background information for teachers

An object's weight depends upon gravity. Since this investigation is taking place under the same gravitational conditions, we can use either weight or mass, depending upon the level of understanding of the children. The higher the drop, the greater the speed on impact. The greater the speed, the larger the impact crater. When dropped from a given height, the greater the mass (weight) the larger the crater. When dropped from a given height, the greater the size (volume), the larger the crater.

Impact craters are caused when a body (**bolide**) collides with a planet. The body may be composed from rock (**meteorite**) or ice or a mixture of the two (**comet**). A crater's size and features depend on the nature of the surface and the speed, size and mass of the body. The speed of the balls dropped in this case is low. In real impacts, compression shock waves run through the bolide and the surface; the body or meteorite would vaporise or be broken into small pieces. The target material is melted or fractured. Rebounds of the bolide cause further excavation of the surface and possible collapse caused by gravity. Secondary craters can be formed and material can be ejected on impact.

Mars is densely cratered. Some Martian craters have central peaks; some are surrounded by material that has been ejected, called the **ejecta blanket**. Impact craters are interesting to study and provide insights into the age and geology of a planet's surface. They can give a view of the types of subsurface rock. Scientists hypothesise that large craters may create a **transient atmosphere** that may have induced rainfall in the past. Images from Mars suggest that there may have been water on or under the surface at some time in the past. Certainly, some patterns are just like those made when rocks are thrown into mud! Impact craters on Earth older than about 200,000 years are worn by weathering, **erosion**, and **plate tectonics**. Lack of these events on Mars leaves craters in their original form.



Tooting Crater image taken from orbiting spacecraft

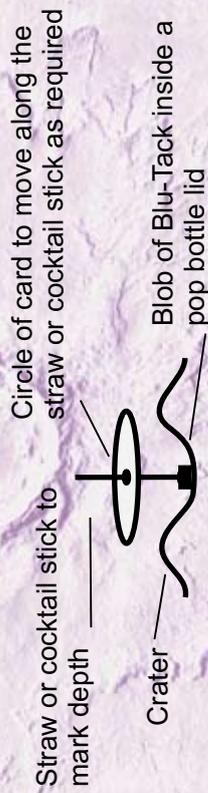
¹ For further information regarding safety in the classroom see *Be Safe – Health and Safety in School Science and Technology*, available from the Association for Science Education.

Crater Challenge Card 1

Look carefully at the image of Tooting Crater on Mars. Can you make craters?

Helpful Hints

You could try using marbles or balls as meteorites!



You could make one of these to measure how deep the craters are.

Crater Challenge Card 2

The Space Agency would like you to find out whether different kinds of meteorite make different kinds of craters.

Helpful Hints

Try dropping the 'meteorites' into sand.

Questions

If the 'meteorite' lands on damp sand instead of dry sand, is the crater different?

What happens to the crater when the 'meteorite' is dropped from a great height?

Crater Challenge Card 3

The Space Agency would like you to test dropping meteorites on different surfaces.

Helpful Hints

You could try dry flour with a thin coating of chocolate powder on top, like Mars' dry, rusty surface!

Questions

What happens to the surface and the layer below when the 'meteorite' lands?

Is any flour flung out from the hole when the 'meteorite' lands? What happens when the 'meteorite' lands on mud?

Crater Challenge Card 4

The Space Agency would like you to find out whether the size or weight of a meteorite can affect the crater made.

Helpful Hints

Try 3 same-sized balls of different weight.

Questions

Is there a link between the size of the 'meteorite' and how wide and deep the crater is?

Is there a link between the weight of the 'meteorite' and the diameter and depth of the hole made?

Activity 7: Volcanoes and lava



Learning objectives

- To describe changes that occur when materials are mixed or heated
- To use models to mimic the eruption of a **volcano** and **lava** flow

Resources

per group of four children

Two methods are described for this activity. Option A mimics volcanic eruption and lava flow by using vinegar and sodium bicarbonate. Option B models lava flow by using melted chocolate. The teacher may choose either one. If choosing option A, teachers might want to point out to children that it is not a chemical change like this one that causes volcanoes to erupt but melting of the rock and pressure from within the Earth.

Option A: Vinegar and Sodium bicarbonate volcano	Option B: Chocolate volcano
Activity sheets 9-10 A3 sheet of card Small egg cup or tea-light container ½ cup bicarbonate of soda ½ cup clear vinegar Teaspoon 2 plastic cups or containers 4 colours play dough* or plasticine Small rolling pin or wooden cylinder 2 waterproof markers Paper towels (5-10ml) Measuring cylinder or syringe Pipette Large straw or transparent biro case Cocktail stick or match stick * (There are many play dough recipes on the internet)	Activity sheets 9-10 Large card or plate Filter funnel or cardboard cone 3 x 100g baking chocolate (white, milk and dark) 3 small jugs or beakers Apple corer Plastic straw Microwave and 3 microwavable bowls or hob, pan and glass bowl NB. For suggestions for suitable varieties of chocolate to use see Appendix 1.

Option A: Vinegar and sodium bicarbonate volcano

Advance preparation

A die made or covered with the numbers 3, 4, 4, 5, 5, 6.

Introduction

The teacher explains that the children are going use vinegar and sodium bicarbonate to mimic the eruption of a **volcano** and flow of lava. A set of volcano facts cards (Activity sheet 10) is provided. A throw of a die will decide the number of 'eruptions' that the children will model.

Activity

Each group throws the die to determine how many eruptions there will be. The children then follow the first set of instructions on Activity sheet 9 to produce the 'foam' lava and record the flow with layers of coloured play dough. The teacher should encourage the groups to make a drawing of the distance, pattern and shape of each lava flow. Finally, a plastic drinking straw may be used to remove samples from the play dough layers.

Safety notes, practical tips and guidance

Ideally, more than one group will choose to try the volcano activity, and then on completion, the volcanoes and their lava layers may be swapped between groups. Each group can map and take samples from a volcano whose pattern of lava flow is different from their own. This will simulate more closely how geologists study the geologic history of an area or feature. The children are encouraged to look carefully at the model volcano and suggest how they could discover what is below the surface without lifting the play dough layers. They should decide where to drill for samples and how many they would need in order to obtain most information. Straws or transparent biro cases can be used to simulate the drill taking the samples. They should be pushed gently and deeply through all the layers of play dough at each sampling point. Extracting the sample requires care.

Option B: Chocolate volcano

Advance preparation

For the 'volcano' either block the tip of a filter funnel or make a small cone from card.

Introduction

The children follow the second set of instructions on Activity sheet 9 to produce layers of chocolate lava flow. A roll of the die determines the number of lava flows. The children could take photographs or draw the shape of the lava flow whilst waiting for the chocolate to begin to solidify. They can try putting obstacles,

Teachers Notes: Landscape

such as small stones in the lava path and observing the effect. When all the layers have been added, the children may then take samples of the chocolate lava layers, using an apple corer.

Safety notes, practical tips and guidance

The tables can be covered with newspapers or plastic sheeting. The children should wear aprons, old shirts or lab coats to protect clothes. Melt the chocolate in either a microwave oven or on the hob in a bowl over a pan of hot water. Stirring a little warm water into the melted chocolate improves its runniness, and reduces the amount of chocolate needed. Have 3 small beakers or jugs available for the children to collect the chocolate. As a guide, a minute in the microwave oven on full power should be sufficient to melt 100g chocolate.

Plenary

The children look again at the images N and S (see page 36) and read the information about Volcano Ceraunius Tholus provided by the experts (Activity sheet 12). They report upon the success of their models and sampling and consider:

What have they learned about lava flow patterns and layering?

Did the lava always flow in the same direction or as far?

Did they observe any lava flow patterns similar to the image on Mars?

Do they agree with the experts' opinions on how Ceraunius Tholus was formed?

Do they believe that the rover should take samples from this area?

They should realise that the oldest flows are the deepest layers on the model and the newest are on the surface. They could reflect upon whether the process was similar to real life.

Background information

Photo geologists use images taken by planes and satellites to interpret the history of a planet's surface. If they can get to the surface, they take samples and draw maps.

Not all lava flows are buried by the next. Sometimes older flows can be visible. The direction of the lava flow can be affected by previous flows, by old lava or channels on the surface, and also by the speed of the eruption. The energy of an eruption can determine how far the lava can flow and how easily it passes obstructions. In real field studies, geologists would, of course, be unable to take such deep samples through all the lava layers. On Mars, scientists hope that a new rover will drill below the surface in order for samples to be collected and analysed.

Make a volcano

1. Put an egg cup in the centre of a big piece of card
2. Put a teaspoon of bicarbonate of soda into the egg cup. Slowly pour 5-10 ml of vinegar to the cup. Your volcano should fizz!
3. When the lava has stopped flowing, quickly draw a line all around the lava and then mop it up with a paper towel.
4. Take a ball of play dough and roll it flat. Completely cover the shape left by the lava with the play dough - but not the egg cup!
5. Soak up the mixture from the egg cup with a paper towel. Leave the egg cup in the centre of the flow and repeat the eruption. Use a different colour of play dough each time, and don't worry if the last layer of play dough is covered.
6. When you have finished, try taking a sample of the lava layers by using a large straw. Push the straw vertically down into the play dough, twist and pull out the straw. Cut the straw just above the top of the play dough sample. Push out the sample with a cocktail stick or matchstick.

Make a chocolate volcano

1. Put a cone or an upside down filter funnel in the middle of a plate or card.
2. Pour melted chocolate over the cone or funnel letting it run down the sides.
3. Leave the chocolate to cool and harden a little on the cone or funnel.
4. Choose a different colour of melted chocolate and pour it over the cone or funnel.
5. Repeat each time using a different colour of chocolate.
6. When the chocolate has cooled and hardened, push the apple corer right down into the chocolate layers, twist and pull out a sample.



Chocolate volcano

Volcano Fabulous Facts

Volcanoes or evidence of volcano activity are found on Mars.

On Mars, the north is covered by lava rock from lots of very big volcanoes. One of these is called Olympus Mons.

Volcano Fabulous Facts

Olympus Mons is about 24 km tall; that's more than twice as tall as Mount Everest and its area is almost the size of Spain! About a hundred of the biggest volcanoes on Earth could fit inside it.

It is the largest volcano in the Solar System.

Volcano Fabulous Facts

On Mars, the volcanoes grew bigger as the lava layers built up on top of one another. As the volcanoes are so big, this means that there must have been heat under each volcano for a very long time.

Volcano Fabulous Facts

Missions to Mars have not found any active volcanoes. As well as volcanoes, there are dark flat layers of lava rock on Mars. Scientists take samples of rock by drilling and pulling out a column of rock layers.

Activity 8: Investigating water channels



Learning objectives

- To think about what might happen or try things out when deciding what to do, what kind of evidence to collect and what equipment and materials to use
- To know that it is important to test ideas using evidence from observation and measurement
- To know that flowing water can wash away or make patterns in a surface

Resources

per group of four children

Activity sheet 11

Images O-P, T-U (see page 36)

Trough (wallpaper or planting) or deep tray

3cm layer of sand/gravel mixed, covering $\frac{3}{4}$ of tray's length

$\frac{1}{2}$ cup of fine grit

$\frac{1}{2}$ cup small stones

$\frac{1}{2}$ cup larger stones

Jug

Filter funnel

Bucket

Advance preparation

Drill a drainage hole at one end of the tray or trough

Activity sheet 11 made in to cards

Introduction

The teacher asks the children to look carefully at the two images O-P, showing some interesting patterns on the surface of Mars, and explains that scientists believe that they could possibly have been made by water flowing across and washing away its surface a long time ago. Their task is to carry out investigations to discover whether water can change a surface such as sand. Their measurements and other observations could help scientists to understand more about the fascinating landscape of Mars.

Activity

The children prepare their trough with sand, grit and gravel, to a depth of 2-3cm. They smooth the surface of the sand and press out a short channel at one end. Pouring water through a funnel directs the water flow to the channel. The pupil cards (Activity sheet 11) provide challenges, hints and facts to support the activity.

Teachers Notes: Landscape

The children are encouraged to:

- make predictions about the effects of altering the angle of the trough
- change the volume or speed of the water they pour
- make careful observations and measurements of shapes and patterns formed on the surface or channels carved into the sand
- test whether water flows faster on the inside or outside of a bend
- discover how obstacles such as pebbles placed along the channel might produce a **delta**
- put tiny particles, such as grit, at the head of their 'stream' measuring how far and how quickly they are carried
- investigate adding a mixture of different sized particles

Images T-U showing channels from Earth or **deltas**, such as the Nile delta could be compared to the patterns they have made. They should discover that tiny particles are carried further along their 'stream' than larger particles. This would represent sediment in a natural situation.

The children can record their observations in a variety of ways, including video, photographs or drawings.

Plenary

When discussing their observations, the children should look again at the image of channels on Mars and draw conclusions based on patterns they noted. They read the information about Eberswalde provided by the experts (Activity sheet 12), and consider the following:

Do their ideas match those of the experts?

How do they think the channels were made?

Do they think water once flowed on Mars?

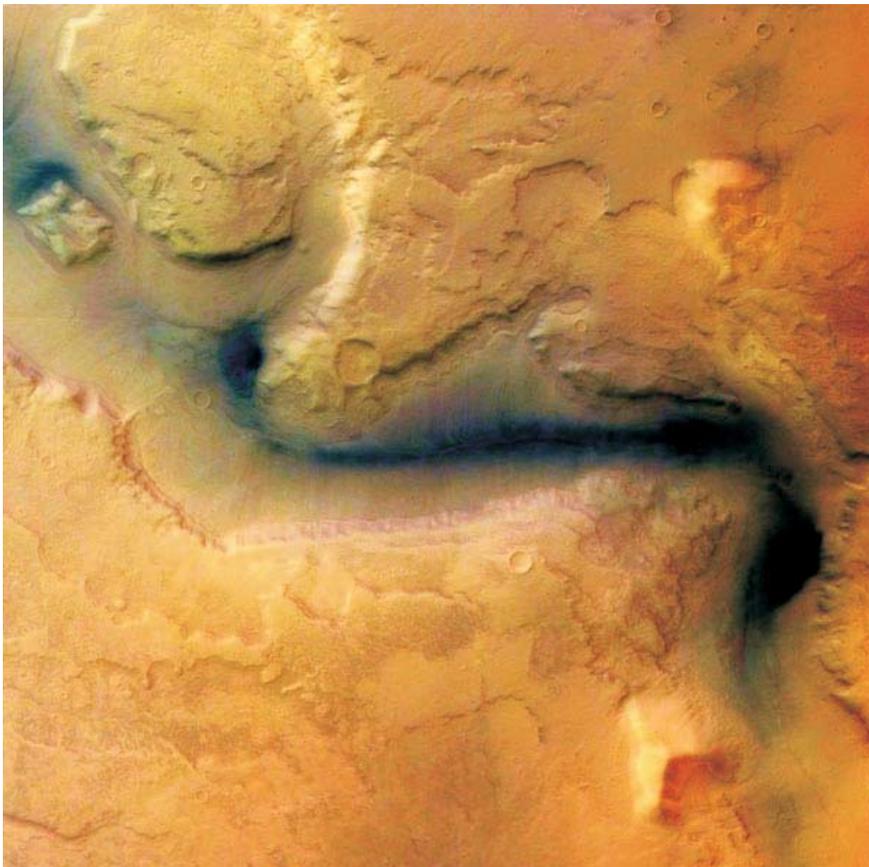
The children could prepare a report for the UK Space Agency. The children should be encouraged to include any measurements or other evidence to support conclusions. Communications managers from each group could act as 'envoys' (Appendix 2), moving on to a new group in order to summarise and explain their group's ideas to others.

Safety notes, practical tips and guidance

Teachers should ensure that excess water is drained or scooped out of the trough and into a bucket. A fresh layer of sand and gravel may be added each time if required. The children will soon discover that the sand is washed along the trough if they pour too much water too quickly or if the trough is supported at too steep an angle. If a small volume of water is poured slowly then the pattern of flow can be seen. The best results are obtained by positioning the tray at a very slight inclination.

Background information

Water makes distinct patterns when it erodes a landscape and deposits sediment. Most river beds have a very slight incline, less than 5 degrees. Gently flowing rivers carry sediment and distribute the particles. Small, light particles are carried further and more easily than large heavy ones. Martian images seem to support the hypothesis that water once flowed on its surface. Mars would have to have had a different climate in the past, warmer with greater pressure, to have allowed water to flow.



European Space Agency image showing possible evidence of erosion by water

Investigating Water Channels 1

Your task is to investigate whether flowing water can change the shape of a surface or channel.

Helpful hints

Pour water very gently through a funnel into the channel. Let the water run along the sand.

Fabulous facts

Today, nearly all liquid water would either freeze or evaporate on Mars.

Investigating Water Channels 2

Can you discover whether the steepness of a river can affect the patterns made by the water?

Helpful hints

Lift one end of the tray a little and see what happens.

Fabulous Facts

Some scientists believe that there may have been huge floods on Mars in the past.

Investigating Water Channels 3

Are tiny stones carried along by the water? If so, how far do they move? What difference does the size of the stone make?

Helpful hints

Try putting tiny stones or grit at the top of the channel.

Fabulous facts

On Earth, rivers can carry sand and other particles and drop them onto their banks or into lakes or seas.

Investigating Water Channels 4

If the water flows faster, do stones travel further?

Helpful hints

You can scoop out the water each time into a bucket and repeat.

Fabulous facts

Rivers can wash away the land. This is called erosion.

Tooting Crater

The photographs (Images L and M) were taken by a special camera on a spacecraft.

The crater is west of a big volcano called Olympus Mons (see Mars map, Image Q).

Crater age:

Scientists think that the crater is very young, less than 2 million years old! The crater is very deep. It seems that there has not been time for its edge to be worn away.

Main features:

The crater is 29 km in diameter and 2200 m deep. It is a very large crater.

The photograph shows the inside of the crater.

We can see the crater's raised edge, the lower level crater floor and the crater's peak in the centre. We can see shapes that look a bit like those that would be made by 'splatting' an object into a wet muddy surface! This tells us that water was in the rocks hit by the meteorite to form Tooting Crater.

Volcano Ceraunius Tholus

It is north east of a very big volcano called Olympus Mons.

Volcano age:

The volcano is thought to be roughly 3 billion years old! It has not been active since this time.

Main features:

This is a medium sized volcano. It is 6 km high. It has a big, deep hole in the centre that has a smooth floor inside. This is where lava burst out onto the volcano's surface.

Main features:

Ceraunius Tholus is thought to be a shield volcano. This means that it was built by lots of eruptions of runny lava so its sides are not steep.

You may notice that the volcano has dark coloured 'lines' which run from the top to the bottom, all around its edges. These are thought to be ditches made by water!

What is the Eberswalde feature?

It is made from small rock particles carried and dropped, usually by wind or flowing water.

In Eberswalde, scientists think that most of the rock has been carried by water, as you can see big channels in the photograph.

Scientists think that the feature is similar to the deltas on Earth. When a river flows into a lake or a sea, a delta can be made. In Eberswalde, they think there used to be a lake in the crater floor.

Delta age:

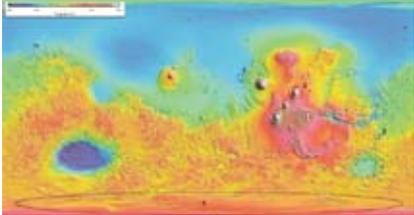
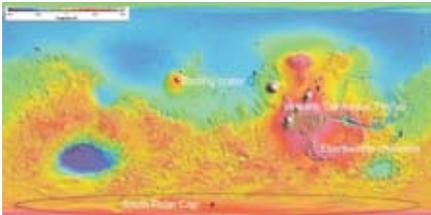
Scientists think it is 1.5-2 billion years old because there are lots of small craters on the surface.

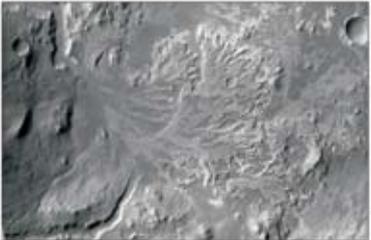
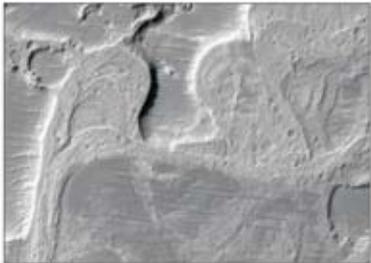
You can see wide channels or ditches in image P. They are up to 150 metres wide. Just like rivers on Earth you can see bends in the channels.

Water flows fastest around the outside of river bends.

Landscape

Images can be downloaded from the website (see page 1).

<p>Image K</p>  <p>Image of Mars with landscape features for pupils <i>N.B. topographic map, the colour denotes elevation</i></p>	<p>Image Q</p>  <p>Image of Mars with landscape features marked and named for teachers and pupils</p>
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<p>Image L</p>  <p>Tooting Crater</p>	<p>Image M</p>  <p>Tooting Crater close up</p>	<p>Image N</p>  <p>Volcano Ceraunius Tholus</p>
<p>Image O</p>  <p>Eberswalde Channels</p>	<p>Image P</p>  <p>Eberswalde Channels close up</p>	<p>Image R</p>  <p>Crater on Earth viewed from space</p>
<p>Image S</p>  <p>Volcano on Earth</p>	<p>Image T</p>  <p>Water channels on Earth</p>	<p>Image U</p>  <p>River delta on Earth viewed from space</p>

Activity 9: Identifying the best landing site for a Mars rover



This section of the resource is suitable for children in Year 7 of Key Stage 3 or to challenge Gifted and Talented children in Year 6.

Learning objectives

- To obtain, record and analyse data from a range of secondary sources and use their findings to provide evidence for scientific explanations
- To use appropriate methods including ICT to communicate scientific information and contribute to presentation and discussion
- To be able to calculate the age of landing sites, identify landscape features such as craters, rocks, deltas, canyons, elevations and interpret data, scale and images
- To use the data to identify the best landing site for a Mars rover

Resources

per group of four children

Activity sheets 13-19
Image V (see page 50)
Calculator
Activity sheets 13-14 made into two sets of cards

Advance preparation

Laminate images W-Z (see page 51-54)
Half the class in groups of 4 scientists
Half the class in groups of 4 engineers

Introduction

To help the children to understand and identify craters and channels on Mars, Introduction Landing images 1-5 from the website should be displayed on the whiteboard and discussed. The table, on page 55, provides details of each of these images.

The teacher explains that the children have been asked by the Space Agency to identify the best landing site for a Martian rover. They are to study photographs from four different locations on Mars. The four photographs are real images, taken from space, of the surface of Mars. They are so detailed that if a car was parked on the surface of Mars, it could easily be seen! Image V is a **topography** map showing high and low areas on Mars and the positions of the four landing sites. The children are to analyse and interpret data from Mars. They are to consider the information from the viewpoint of either space scientists or space engineers when identifying the best landing site. The scientists are interested in finding evidence of life. Their main mission is to identify landing sites close to where water and/or heat may once have been. The engineers' main concern is to identify sites that are stable, without obstacles and are low enough for the parachute on the lander to have enough time to slow down the rover's descent so that it makes a safe landing.

Activity

Small groups of children study the images provided to identify the best landing site for the next Mars mission. Children in turn share the information on their challenge cards within their group. Engineers and scientists have different aims and concerns about the mission. Scientists and engineers identify landscape features such as craters, rocks and elevation, interpret scale and calculate the age of the landing sites using crater concentration data (Activity sheet 15). The scientists must decide where the rover should take samples and why (Activity sheet 16). In addition, the engineers consider the safety of each site by extracting rock concentration data and calculating crater concentrations. (Activity sheets 17-19).

We suggest that the teacher runs through the task with the scientists and engineers in two separate groups. Each group uses different criteria to select a suitable landing site. Later, in class debate, each must provide evidence to justify this choice. It is important that the children pick out the key information contained in the challenge cards. They are looking for old sites; the older the site, the higher the number of craters. They use the scale and look for circular craters larger than 200m. Engineers need to use the table and rock safety chart provided, to determine the safety of the site. They should also look at the **topography** map of Mars to determine the elevations of each landing site. Answers are provided for teachers on Activity sheet 20 together with detailed information about each landing site (see page 47-49).

Plenary

Each group clarifies its reasons for its chosen landing site and begins to prepare a presentation to justify the choice. Groups should then have a whole class debate to decide the best landing site from both the scientists' and engineers' perspectives. This models current practice within the Space Agency, with one person then responsible for making the final decision.



Mars showing the polar cap

Landing Challenge Card 1 Scientist

Your main mission is to find a landing site where evidence of life on Mars is more likely to be found.

Helpful hints

Evidence of life might be fossils in rocks, so you need to look for an old site. Old sites usually have lots of craters. Use the crater calculations on Activity sheet 15 to help you.

Fabulous facts

The rover can collect samples on and under the surface. The rover can take very detailed photographs. The new rover is expected to work on Mars for seven months.

Landing Challenge Card 2 Scientist

Living things need water. Can you find a landing site close to where water might once have been?

Helpful hints

Mars may have had water a long time ago. So, scientists think we should look for the oldest surfaces and rocks.

Fabulous facts

The new rover is the size of a mini cooper or a long go-cart. The rover can find sources of water, past and present.

Landing Challenge Card 3 Scientist

As space scientists you have been asked to find a landing site close to interesting features. A new Mars rover has to take samples and photographs to find out what Mars used to be like long ago.

Helpful hints

It might be good to land close to rocks to take samples. You will need to find rocks that have been there for a long time.

Fabulous facts

The rover's toolkit has nine science instruments to examine rocks, soil and the atmosphere. The rover's laser can turn rock into gas from a distance!

Landing Challenge Card 4 Scientist

Your team of scientists must choose from the four photos a landing site that is safe for the rover to drive around to take samples.

Helpful hints

The rover could land anywhere shown on the photo but it has to save energy and can only travel 2 km in total.

Fabulous facts

The rover has 6 wheels that can ride over obstacles. Its maximum speed is 5 metres per hour.

Landing Challenge Card 1 Engineer

Your team of engineers will need to look for a low, clear site to enable the parachute to gently land the rover on the surface of Mars.

Helpful hints

Mars has lots of places for a safe landing. Remember, the rover could land anywhere on the landing site photograph.

Fabulous facts

The rover must land at a level that is lower than -1000 m so that it goes through enough of the Martian air to slow down without crashing.

Landing Challenge Card 2 Engineer

You will need to look for an old site as this is more stable and safer to land on.

Helpful hints

A high number of craters mean a site is old.

Fabulous Facts

The rover can only travel at 5 m per hour. (An Olympic athlete sprints 100 m in less than 10 seconds).

Landing Challenge Card 3 Engineer

You will need to look for a site with enough light to let the solar panels work well.

Helpful hints

The safe areas to land this rover on Mars are the landing sites between 30°N and 30°S on the coloured map.

Fabulous facts

The rover can only travel short distances to save energy. The Mars rover can take the energy from the sun using solar panels.

Landing Challenge Card 4 Engineer

You will need to look for a smooth surface with no obstacles like rocks or craters to allow the rover to move easily.

Helpful hints

Use the rock and crater charts to decide whether your landing site is safe enough for the rover.

Fabulous facts

The rover can roll over obstacles up to 75 cm high.

Age of landing site

	Landing site 1	Landing site 2	Landing site 3	Landing site 4
Total area of landing site (km ²)	19	29	29	28
Number of craters with diameter bigger than 200 m (your counts)				
Number of craters bigger than 200 m per km ² (divide your count by total area)				
Age (from below, in years)				

Results of crater concentration calculation	Age (years)	
	< 0.02	100 million
0.02 - 0.2	1 billion	1,000,000,000
0.2 - 0.4	2 billion	2,000,000,000
0.4 - 0.6	3 billion	3,000,000,000
0.6 - 1	4 billion	4,000,000,000

Concentration definition: The quantity of something (number of craters for example) over a specific area. Example: there are 10 children per 100 m² area of the classroom

Sample locations work sheet (Scientists)

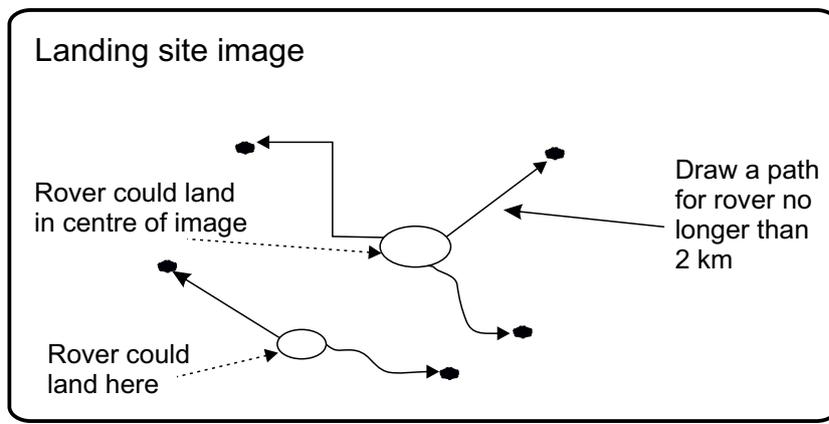
The rover can land anywhere on the image.

The rover can only drive 2km before it runs out of energy.

Use the scale under the image to help you draw the path you want your rover to take.

The rover can take five samples from anywhere along this path.

Draw a dot to show where you will take each sample.



The diagram shows examples of alternative pathways.

	Taken from	Why
Sample 1		
Sample 2		
Sample 3		
Sample 4		
Sample 5		

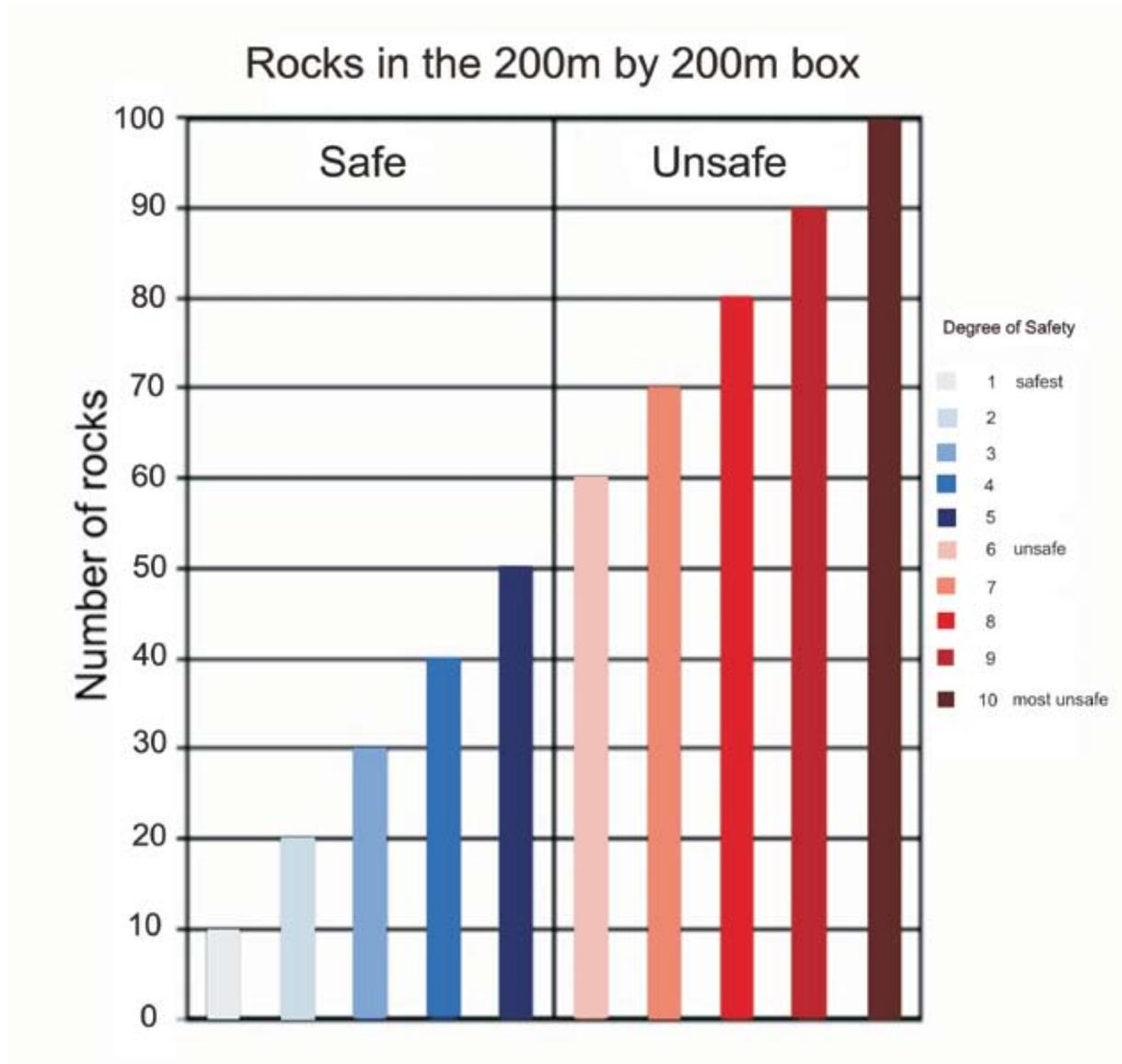
Rock safety work sheet (Engineers)

Any big rock on the photograph is a danger to the rover. If you can see a rock that is about the size of your pencil head, it is the size of a table or car and could damage the rover when it lands.

Rocks look like small dark blobs on the image and they are casting small shadows. Look at the table to find out how many rocks there are and then use the rock safety chart to decide whether each landing site is safe enough to land.

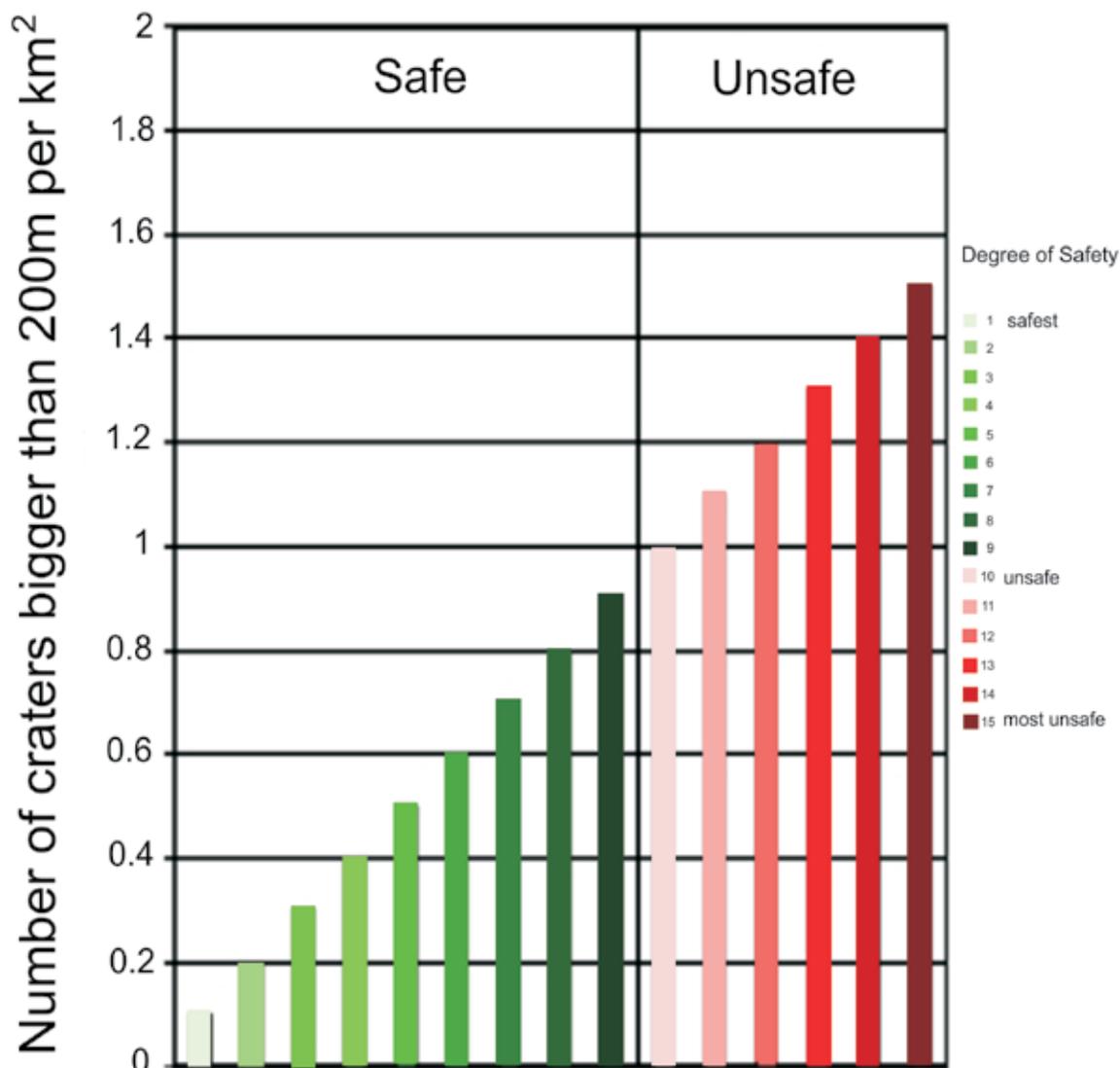
	Landing site 1	Landing site 2	Landing site 3	Landing site 4
Number of rocks in the 200 m by 200 m box	More than 50	Fewer than 50	10-20	More than 50
Safe? Yes or No				

Rock safety chart (Engineers)



Crater concentration chart

Concentration of craters bigger than 200m in diameter



Answers for teachers

	Landing site 1	Landing site 2	Landing site 3	Landing site 4
Number of rocks in a 200 m by 200 m box	More than 50	Fewer than 50	10-20	More than 50
Safe? Yes or No	no	yes	yes	no

	Landing site 1	Landing site 2	Landing site 3	Landing site 4
Total area of landing site (km ²)	19	29	29	28
Number of craters with diameter bigger than 200 m (your counts)	0 or 1	9	4	13
Number of craters bigger than 200 m per km ² (crater concentration calculation)	0.05	0.31	0.14	0.46
Safe? Yes or No	yes	yes	yes	yes
Age (from below, in years)	about 100 million	1 - 2 billion	almost 1 billion	2 -3 billion

Results of crater concentration calculation	Age (years)	
< 0.02	100 million	100,000,000
0.02 - 0.2	1 billion	1,000,000,000
0.2 - 0.4	2 billion	2,000,000,000
0.4 - 0.6	3 billion	3,000,000,000
0.6 - 1	4 billion	4,000,000,000

NOTE: We are here using the US definition of a billion as one thousand million

Landing site 1, Lat. Long. 47.5 S, 5.3 E

Engineering Constraints

Sunlight: too far south

Elevation: too high

Rock Concentration: parts are too rocky, category 10 on the chart in places

Crater Concentration: very safe, category 0 on the chart

Science Constraints

Life: Has very small gullies that were carved by water, possibly melted snow or groundwater coming from cliffs. If the source is groundwater, there is more potential here for life. Limited access to a lot of sediments deposited by water is a problem here

Age: About 100 million years, very young surface for Mars (essentially modern). But, if the water came from underground, the water may carry with it evidence of much older things!

Secondary Science Objectives: Very interesting cliff of rocks here that will allow you to access millions of years of Mars history. This is the best landing site for secondary objectives.

Path Length: No matter where you land here, you can get to the gullies.

Landing site 2, Lat. Long. 13.2 S, 42 W

Engineering Constraints

Sunlight: OK

Elevation: OK

Rock Concentration: Safe, category 1-2

Crater Concentration: Safe, category 3

Science Constraints

Life: Landing site is centered on an amazing channel system that is cut into a large fan of sediment. Any place on this image is a spot where water has deposited sediment. Similar to landing site 1, the channel itself may not have had water in it for long but the sediments carried by the channel might have a variety of rock types carried from far away and therefore deposits that might contain fossilized evidence for life.

Age: About 1 to 2 billion years, this is not the time of the ancient 'Earth-like' Mars but it is much older than landing site 1 and a better candidate for being a time when Mars had a thicker atmosphere.

Landing site details for teachers

Secondary Science Objectives: Sediment fans like this are excellent for accessing a variety of rock types. The channel carried with it materials that were eroded from distant mountains. These rock types can tell us something about the geologic history of the planet but without layers we don't know the exact origin of the rocks.

Path Length: If you land at the north part of the image, you will not be able to access the southern-most fan. If you land to the south, you might not be able to access the northern most fans. But, there are other things that can be sampled here, such as the sediment in and surrounding the channel.

Landing site 3, Lat. Long. 23.8 S, 33.6 W

Engineering Constraints

Sunlight: OK

Elevation: OK

Rock Concentration: Not very rocky, highest between 10 – 20, category 1 - 2

Crater Concentration: very safe, category 0-1

Science Constraints

Life: This landing site contains a large fan of layered materials that can be sampled by the rover. Space scientists believe that the meandering features are the remnants of channels. The pattern is most similar to a river **delta** where channels enter a lake or sea. The obvious bonus of this landing site is that it not only contains channel sediments, but because it is a delta, there must have been a standing body of water here. The rover can now access river and lake sediments to look for life. Life enjoys calm water environments, so the lake is an ideal setting.

Age: Almost 1 billion years. This is a fairly young surface so it might not capture the early "Earth-like" period. Also, it's a fairly unique feature on Mars. However, we know there was a river here and a lake. These are ideal ingredients for life.

Secondary Science Objectives: The delta contains river sediments that were carried from far away. This might be a good way to access multiple rock types.

Path Length: No matter where you land here, you can access the delta.

This is Eberswalde delta. It was a finalist landing site for NASA's Mars Science Laboratory mission which will land in August 2012, (www.marsprogram.jpl.nasa.gov/msl/). All the issues raised above are the reasons why the site was not chosen in the end. It was considered too young, and did not capture the period of warm-wet Mars.

Landing site 4, Lat. Long. 29.9 S, 81.8 E

Engineering Constraints

Sunlight: OK

Elevation: OK

Rock Density: parts are too rocky, category 10 on the chart in places to the south of the image

Crater Concentration: safe, category 4-5 on the chart

Science Constraints

Life: This is a fairly ancient surface of the crust of Mars, almost 3 billion years old (or older as the craters are not well preserved here). The image contains a series of very poorly-preserved intersecting streams. This is an indication of ancient surface water flow, possibly by rainfall. The sediments in these streams may have been carried from far away sources, but it's unclear in the image where these sediments are or if water was here long enough for life to have arisen or survived. The channels here are very hard to see; they are very poorly preserved. This means they were present at the surface of Mars for a very long time and were subject to wind and water **erosion**. Compare these channels to the channel in landing site 2 for example.

Age: 2-3 billion years, the oldest of the landing sites.

Secondary Science Objectives: Little or no evidence of sediment deposited by the channels. Also, there are no obvious exposures of bedrock apart from the small boulder pile to the south of the image.

Path Length: Access to all the channels.

Map of Mars

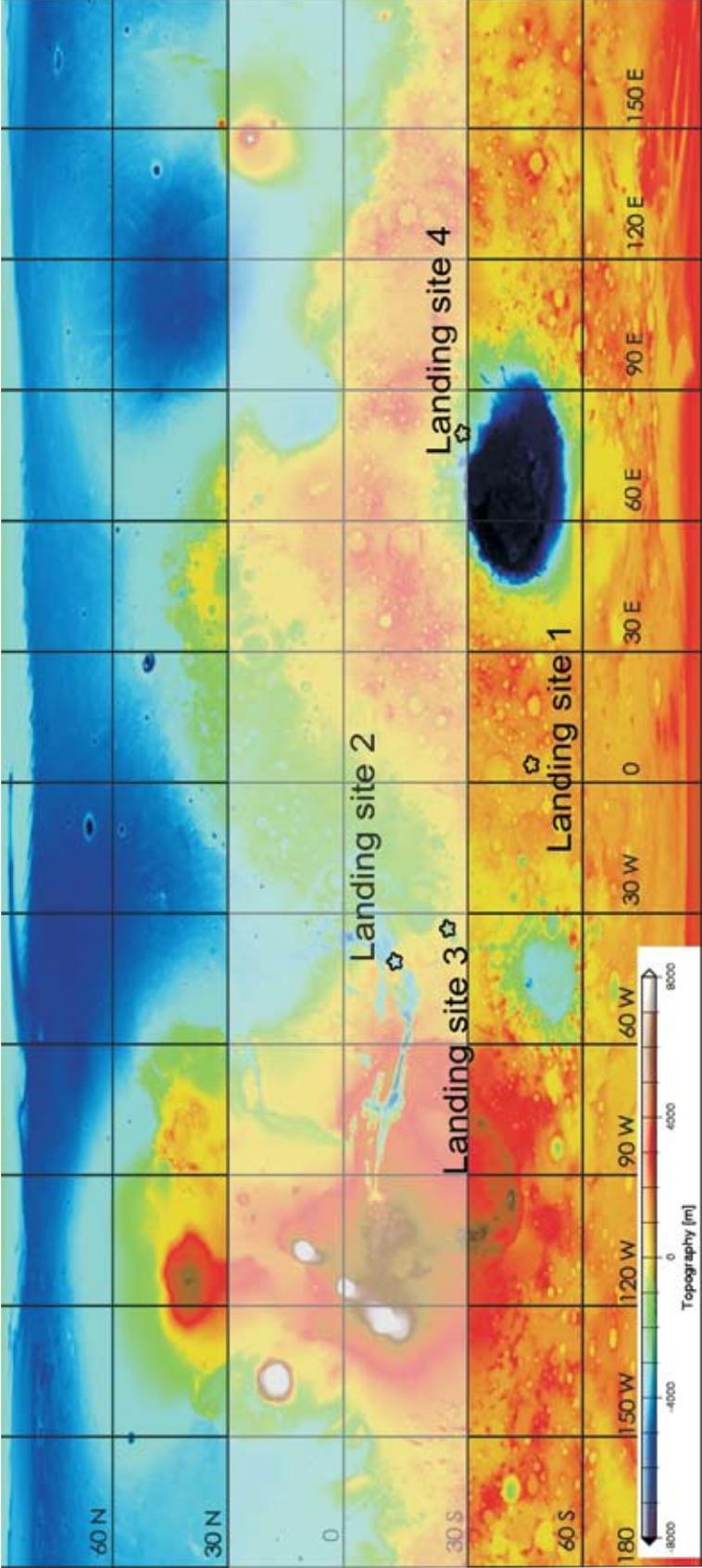


Image V

Landing site 1



Image W

Landing site images

Landing site 2



0 1 2 kilometres

Image X

Landing site 3



Image Y

Landing site images

Landing site 4



0 1 2 kilometres

Image Z

Activities 1 and 2* Soil Testing

3 samples of 'Martian soil' in sealable sandwich bags, labelled A, B, C.

Sample A	Sample B (Martian)	Sample C
2 tbs building sand	2 tbs building sand	2 tbs building sand
2 tbs rock salt	2 tbs rock salt	1 tbs fine grit
1 tbs table salt	1 tbs table salt	1 tbs gravel
1 tbs fine grit	1 tbs fine grit	1 tbs flour or talc
1 tbs gravel	1 tbs gravel	
	1 tbs flour or talc	

* For the microorganism test, Activity 2, yeast should be added to sample C and it should remain salt free

Activity 7 Chocolate Volcano

Milk chocolate	White chocolate	Dark Chocolate
Any supermarket own Belgian chocolate	Any supermarket own brand	Any supermarket own brand
Green & Black, 34% Cocoa solids	Green & Black	Green & Black cooking chocolate 72% Cocoa solids
Ryelands	Ryelands	Ryelands

Additional Images for Landings section

Image number	Name of feature	Description of feature
Introduction Landing 1	Depositional fan of sediment.	Fan of material in unnamed crater.
Introduction Landing 2	Impact crater.	Well preserved 'simple' structure. 4 km impact crater.
Introduction Landing 3	Fissure formed by tectonic faulting with boulder-covered scree slopes coming down the fissure edges.	Boulder slopes in Cerberus Fossae. The Cerberus Fossae are a series of semi-parallel fissures on Mars formed by faults which pulled the crust apart. Ripples seen at the bottom of the fault are sand blown by the wind. The faults pass through pre-existing features such as hills, indicating that it is a younger feature. The formation of the fossae is suspected to have released pressurised underground water.
Introduction Landing 4	Impact crater superimposed on a ridge formed by folding of lava.	Impact crater of top of wrinkle ridge close to the Viking 1 landing site.
Introduction Landing 5	Fresh impact crater with prominent rays.	Fresh impact crater formed February-July 2005.

Role Badges

All the classroom sessions involve children working together in groups of four.

Each child is responsible for a different job or role within the group and wears a badge to identify this. The images below may be photocopied onto card and made into badges, by slipping them in to plastic badge sleeves. Keep sets of badges in 'group' wallets, to be used on a regular basis in all science lessons.

Children should be encouraged to swap badges in subsequent lessons; this will enable every child to experience the responsibilities of each role.

Administrator keeps a written and pictorial record for the group.

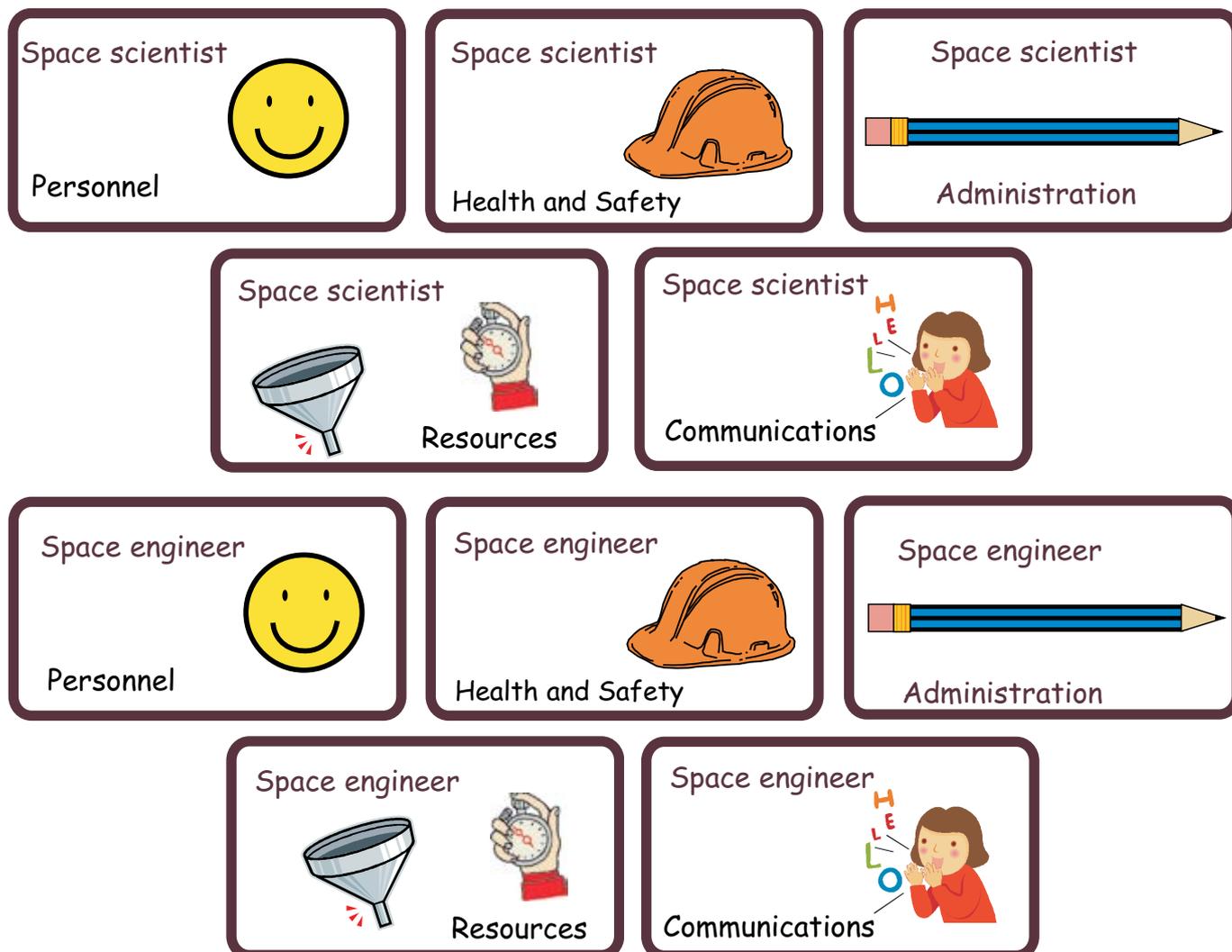
Resource Manager collects, sets up and returns all equipment used by the group.

Communications Officer collects the group's ideas and reports back to the rest of the class.

Health and Safety Manager takes responsibility for the safety of the group, making sure everyone is working sensibly with the equipment.

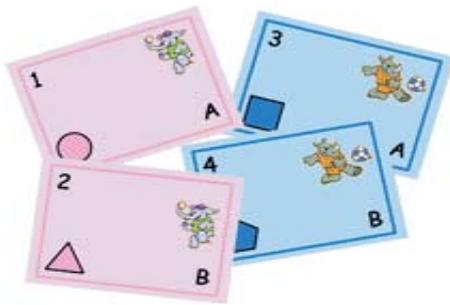
Where groups of 5 are necessary, the following role can be used:

Personnel Manager – takes responsibility for resolving disputes within the group and ensuring the team works cooperatively.



Discussion strategies

The following strategies are used extensively as part of the Discussions in Primary Science (DiPS)¹ project, and have been proven to be successful when developing children's independent thinking and discussion skills.



Talk cards

Talk cards support the teacher in facilitating these discussions, with the letters, numbers, pictures and shapes enabling the teacher to group children in a variety of ways.

The example provided here shows one set for use with four children. The set is copied onto a different colour of card and talk groups are formed by children joining with others who have the same coloured card.

Children can then pair up by finding a partner with the same animal or a different letter e.g. elephant, rhino or a + b pair. Each TALK pair would then have a card with a different number or shape.

The numbers or shapes may then similarly be used to form alternative groupings and pairings.

Note: The example talk cards are provided in MS Word format so you may make changes if you wish.

ITT (Individual Think Time)



Each child is given time to think about the task individually before moving into paired or group work.

Talk Partners



Each child has a partner with whom she/he can share ideas and express opinions or plan. This increases confidence and is particularly useful where children have had little experience of talk in groups.

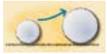
¹ For more information go to www.azteachscience.co.uk

A > B Talk



Children take turns to speak in their pair in a more structured way, e.g. A speaks while B listens B then responds. B then speaks to A while A listens and then A responds to B.

Snowballing



Pupils first talk in pairs to develop initial ideas. Pairs double up to fours to build on ideas. Fours double up to tell another group about their group's ideas.

Envoying



Once the group have completed the task, individuals from each group are elected as 'envoys', moving on to a new group in order to summarise and explain their group's ideas.

Jigsawing



Assign different numbers, signs or symbols to each child in a group. Reform groups with similar signs, symbols or numbers, e.g. all reds, all 3s, all rabbits and so on. Assign each group with a different task or investigation. Reassemble (jigsaw) the original groups so that each one contains someone who has knowledge from one of the tasks. Discuss to share and collate outcomes.

Information for teachers

Mars is the fourth planet from the sun and the seventh largest. It has two tiny satellites Phobos and Deimos. Mars' orbit is 227,940,000km, its diameter 6,794km and mass 1/10th of Earth's. Early in its history, Mars was much more like Earth. Most of its carbon dioxide was used to form carbonate rocks but as it cannot recycle any of this back into the atmosphere, it is much colder than the Earth would be at that same distance from the sun. Mars' orbit is elliptical. Its average temperature is approx -55°C but surface temperatures range widely from as low as -133°C at the winter pole to almost 27°C on the day side during summer. Mars is much smaller than Earth but its surface area is similar to Earth's land surface. Mars has a very thin atmosphere composed of a tiny amount of carbon dioxide, nitrogen, argon and traces of oxygen and water. The average pressure is 1% of Earth's but it is thick enough to support very strong winds and huge dust storms that cover the planet for months. Early telescopic observations revealed that Mars has permanent ice caps at both poles. We know they are composed of water ice and solid carbon dioxide (dry ice). Mars has some of the most highly varied and interesting terrain of any of the terrestrial planets, including;

Olympus Mons - the largest mountain in the solar system rising 24km above the surrounding plains

Tharsis - a huge bulge on the surface 4000km across and 10km high

Valles Marineris - a system of canyons 4000km long and 2-7km deep

Hellas Planitia - an impact crater in its southern hemisphere over 6km deep and 2000km in diameter

Much of the Martian surface is very old and cratered but there are younger rift valleys, ridges, hills and plains. None of this can be seen in detail with a telescope, not even the Hubble telescope but can be seen from spacecraft.

There does not appear to be any current volcanic activity but it is likely to have **tectonic** activity in the past. There is evidence of **erosion** in many places including large floods and small river systems. At some point in the past there was clearly some kind of fluid on the surface. Liquid water is a likely fluid but other possibilities exist. There may have been large lakes or oceans. Scientists believe that there were wet episodes that occurred briefly but very long ago.

Canals of Mars are apparent systems of long straight markings on the surface of Mars that we now know are caused by the chance alignment of craters and other natural surface features, observed through telescopes when the telescopes are nearly at the limit of their resolution. The Italian astronomer Giovanni Virginio Schiaparelli reported observing about 100 of these markings in 1877 and described them as canali (Italian for channels) but did not imply anything about their origin. Around the turn of the 20th century, American astronomer Percival Lowell described canal networks covering most of the planet. Many believed them to be bands of vegetation bordering irrigation ditches dug by intelligent beings to carry water from the polar caps. The controversy was finally resolved only when close-up images of the Martian surface were taken from spacecraft beginning with Mariner 4 (1965), 6 and 7 (1969). These images showed many craters and other features but nothing resembling networks of long linear channels.

Since 1960, the Russians and American Space Agencies have sent many spacecraft to Mars; some have been very successful. Mariner 4 was the first mission to make it successfully to Mars. Mariner 4, 6, 7 and 9 missions took many photographs of Mars and its moons. Then, the Russians sent Mars 2- 6, bringing back data about the Martian surface, atmosphere, temperature and gravity. The Viking missions were very successful in the 1970s, providing in excess of 50,000 images. After a quiet decade, Martian exploration took off again in the 1990s. In April 2001, the Mars Odyssey was launched. It has been successfully collecting data about the minerals and chemicals that make up the Martian surface. In December 2003 the European Space Agency's Mars Express Mission, including Beagle 2 Lander, arrived at Mars. NASA's Mars Exploration Rovers, landed in 2004 and have been sending back information ever since!

The UK Space Agency is providing 165M Euro contribution to the European ExoMars programme, in addition to 25M for the development of instruments to search for signs of past or present life on Mars. The instruments are part of the scientific payload on a new rover currently being developed. Rovers have to be designed and built from materials that will not contaminate the planet in any way. The new rover is a robotic scientist which will search for evidence of past and present life and study the local Martian environment to understand when and where conditions that could have supported the development of life may have prevailed.

Glossary

Active volcano	Volcano that is currently erupting lava.
Astrobiologist	Scientists seeking to understand the origin of the building blocks of life, how these compounds combine to create life, how life affects - and is affected by the environment from which it arose, and finally, whether and how life expands beyond its planet of origin.
Basalt	Hard, dull, black igneous volcanic rock, the most common in the solar system and common on the Martian surface.
Bolide	Astronomers tend to use “bolide” to identify an exceptionally bright fireball, particularly one that explodes.
Comet	Small icy solar system body that, when close enough to the sun, displays a visible fuzzy atmosphere and sometimes also a tail. They are composed of loose collections of ice, dust, and small rocky particles.
Delta	A landform that is formed at the mouth of a river where that river flows into an ocean, sea, estuary, lake.
Ejecta blanket	Generally symmetrical apron of ejected matter that surrounds a crater; it is layered thickly at the crater’s rim and thin to discontinuous at the blanket’s outer edge.
Erosion	The process by which material is removed from a region of a planet’s surface. It can occur by weathering and transport of solids (sediment, soil, rock and other particles) in the natural environment, and leads to the deposition of these materials elsewhere. It usually occurs due to transport by wind, water, or ice, by down-slope creep of soil and other material under the force of gravity or by living organisms, such as burrowing animals, in the case of bio erosion. Erosion is distinguished from weathering which is the process of chemical or physical breakdown of the minerals in the rocks. The two processes may occur concurrently, however.
Extremophile	Organism that thrives in physically or geochemically extreme conditions that are detrimental to most life on Earth.
Lava	Molten rock that has been released from a volcano across the surface of a planet.
Magma	Molten rock within a planet, building up beneath a volcano before it erupts.
Meteoroid	Sand to boulder sized particle of debris in the solar system.
Meteor	The visible path of a meteoroid that has entered the Earth’s or another body’s atmosphere.
Meteorite	Derived from small astronomical objects called meteoroids, but they are also sometimes produced by impacts of asteroids.
Photo geologist	Geologist using images taken by plane or satellite to interpret the history of a planet’s surface.

<i>Plate tectonics</i>	Scientific theory that describes the large scale motions of plates making up the Earth's crust, which move in relation to one another to create continental drift.
<i>Shield volcano</i>	Types of volcano common on Mars, with very broad and shallow slopes formed as flow after flow gradually build up on top of one another.
<i>Tectonic</i>	Relating to, causing, or resulting from structural deformation of the Earth's crust.
<i>Topography</i>	Relating to the surface shape, features and elevation of Earth or planets. Elevations are usually marked in colour.
<i>Transient atmosphere</i>	Localised weather conditions caused by the trapping of moisture in a sheltered area.
<i>Volcano</i>	Mountain formed from the build up of <i>magma</i> beneath a planet's crust.

Useful websites

CIEC <i>Promoting Science</i>	www.ciec.org.uk www.cciproject.org/topicBank/space.htm
European Space Agency (ESA)	www.esa.int/SPECIALS/Aurora/ESA9LZPV16D_0.html
Information on everything from rockets to planets, the site offers regular news plus puzzles and other activities.	www.esa.int/esaKIDSen/
ESA's Education section. Information for teachers on current space news and links to children's activities.	www.esa.int/education
UK space agency	www.bis.gov.uk/ukspaceagency
Website of ESERO-UK, the UK Space Education Office, a project funded by ESA and the Department for Education.	www.esero.org.uk/
National STEM centre's treasure chest of resources for teachers of Science Technology, Engineering & Maths.	www.nationalstemcentre.org.uk/elibrary/
International Space Station (ISS) education kit :ESA's resource pack with ideas for primary schools with ISS as the theme.	www.nationalstemcentre.org.uk/elibrary/resource/826/international-space-station-iss-education-kit-primary
NASA's home site providing links to missions and activities for schools.	www.nasa.gov/
All about the Mars rover missions on NASA website.	http://marsrover.nasa.gov/home/index.html
Discovery.com: excellent site with information on the international space station, with interactive space walk.	www.discovery.com/stories/science/iss/interactives.html
Hubble telescope site: excellent images of stars, and galaxies.	www.hubblesite.org/the_telescope/
Arizona State University Mars Education Programme	http://tes.asu.edu/
Primary Projects. Useful for children's research. Hands-on section on Earth and other planets.	www.learning-connections.co.uk/curric/cur_pri/space/frames.html
ExoMars rover prototypes conceived by Astrium	http://event.astrium.eads.net/en-wsw/more-space/the-exomars-rover-will-be-able-to-go-where-no-rover-has-gone-before.html
Astronomy and space for children	www.kidsastronomy.com
Coxhoe Primary School website filled with lesson plans, information and interactive games.	www.schooljotter.com/showpage.php?id=35519

Appendix 5: Useful websites

Lunar and Planetary Institute Host of images and information for teachers.	www.lpi.usra.edu/
Lesson ideas based on Mars rovers	http://marsrovers.jpl.nasa.gov/classroom/roverquest/
Earth Science Teachers' Association website	www.esta-uk.net
'Astronomy for kids'. Simple information for children on the solar system	www.frontiernet.net/~kidpower/astronomy.html
Information and images from Mars	http://ircamera.as.arizona.edu/NatSci102/NatSci102/lectures/mars.htm
Fear of Physics: animations of the movement of planets.	www.fearofphysics.com/SunMoon/sunmoon.html
Sea and Sky: some excellent images in the sky gallery	www.seasky.org/space-exploration.html
Liverpool telescope: free use of the telescope for teachers.	www.schoolsobservatory.org.uk/teach
Faulkes telescope: free use of global telescopes	www.faulkes-telescope.com/aboutus
Bradford telescope: free interactive learning resource for schools.	www.telescope.org/schools.telescope
Free lessons and ideas	www.teachingideas.co.uk/science
Animated demonstrations	www.bbc.co.uk/schools/scienceclips
Sets of lesson plans for KS1 & 2	www.hamiltoneducation.org.uk
Science & Technology Facilities Research Council supports astronomy, space science, particle and nuclear physics	www.stfc.ac.uk/teachers
Network of providers of space-related experiences across Yorks and Humber	www.YES-net.net
Journal aims to promote inspiring science teaching	www.scienceinschool.org/online

It is a cold, dry, inhospitable place, with an atmosphere comprising almost entirely carbon dioxide. Even the Grand Canyon would be dwarfed by one of its valleys and the solar system's largest volcano can be found here. Dust storms darken its skies. Despite this, Mars is the planet most like Earth and where scientists believe there may be a possibility of finding evidence of primitive life. After news of tantalising new evidence of frozen water lurking beneath its rusty surface, the UK Space Agency released funding for the development of instruments to search for signs of past or present life on Mars.

For more information on the programmes and publications available from CIEC *Promoting Science*, visit our web site at:

www.ciec.org.uk

or contact

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