MISSION TO MARS

HOW WILL ENGINEERS MAKE IT POSSIBLE TO LIVE ON OTHER PLANETS?

TEACHER GUIDE

ROYAL ACADEMY OF ENGINEERING

THIS IS ENGINEERING

This resource aims to give students the opportunity to investigate the science, technology, engineering and mathematics (STEM) of space exploration.


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MARS
HOW WILL ENGINEERS MAKE IT POSSIBLE
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INTRODUCTION

The aim of this resource is to give students the opportunity to investigate the science technology, engineering and mathematics (STEM) on the aerospace industry.

THE SPACE INDUSTRY HAS LED TO MANY INNOVATIONS THAT HAVE HAD A POSITIVE IMPACT ON LIFE ON EARTH.

In medicine, there have been many technological advancements that have origins in space, from CAT scans and robotic surgery, to more functional prosthetic limbs. Foam material developed by NASA to be used as a shock absorber has been adapted to create natural looking flesh for prosthetics as well as to help reduce friction between the prosthesis and the skin of the user. This foam has also been used in memory foam mattresses.

Another NASA invention is used every day in mobile phones. While at NASA, Eric Fossum wanted to miniaturise cameras for an interplanetary mission, so he invented the complementary metal-oxide-semiconductor (CMOS) active pixel image sensor and the so-called 'camera-on-a-chip' CMOS image sensor.

This image sensor technology, along with the charge-coupled device (CCD) and the pinned photodiode (PPD), has transformed medical treatments, science, personal communication and entertainment. It saves lives, by using non-surgical pill cameras and endoscopes inside our bodies to diagnose medical problems, as well as helping to reduce X-ray doses to patients and improving dental care.

For this advancement in image sensor technology, Eric Fossum, George Smith, Nobukazu Teranishi and Michael Tompsett won the Queen Elizabeth Prize for Engineering (QEPrize) in 2017. Awarded every two years, the QEPrize celebrates the greatest achievements of modern engineering. The Create the Trophy competition to design the next trophy for the QEPrize is open to 14 to 24 year olds.

For more information about the QEPrize, and the Create the Trophy competition visit **http://qeprize.org/**

INFORMATION

FOR STEM ACTIVITY LEADERS

This resource will be cover three aspects of travel to Mars, and each can be completed on its own or form a narrative for a whole day session. The three sections are *Launch, Landing* and *Life on Mars*.

CURRICULUM LINKS

Activity	Key Stage	Subject	National Curriculum
Launch Crew	KS3	Mathematics	Solving problems Ratio, proportion and rates of change Geometry and measure
Launch Aerodynamics	KS3	Science	Experimental skills and investigation Forces and motion
Landing Gravity	KS3	Mathematics Science	Algebra Space physics
Landing Heat shield	KS3	Science Design and technology	Experimental skills and investigation Energy changes and transfers Energy in matter Evaluate
Life on Mars Taste in Space	KS3	Science	Experimental skills and investigation
Life on Mars Food on Mars	KS3	Science	Experimental skills and investigation Photosynthesis Relationships in an ecosystem

PREPARATION

- Ensure all materials and equipment needed is available well in advance of the session. See the resource list below for essential materials and components.
- A full risk assessment should be conducted prior to the session.

RESOURCE LIST

Name	Product code	Quantity	Where to buy
Colour clay modelling material	06-8603	2	www.rapidonline.com
Modelling balloons	562149	1	www.ypo.co.uk
String	34-5730	1	www.rapidonline.com
Cress seeds	161450	1	www.suttons.co.uk

LAUNCH

CREW

Boeing's new CST-100 module has been designed to fit up to seven crew members comfortably, or any number of crew less than seven plus cargo. To reduce the fuel that is needed for launch, the crew and cargo need to be configured in a way that balances the forces.

TIME TO THINK

How many people could you accommodate in different space modules and does that leave enough space for cargo?

METHOD 1

Calculate the areas of the floor space for each space modules to estimate the maximum number of seats you can fit in the following space craft:

Apollo

The diameter of the Apollo module 3.90 m

CST-100

The diameter of the CST-100 module 4.56 m

Soyuz

The diameter of the Soyuz module 2.72 m

A seat needs a space with a height of 1.18 m and a width 0.52 m

? Why is the real maximum number of seats lower than this?

NOTES FOR STEM LEADER

Students should calculate the areas of the floor space for each of the space modules using the equation

$$A = \pi r^2$$

The area of Apollo is $\pi \times 1.95^2 = 11.95\ m^2$

The area of the CST-100 is $\pi \times 2.28^2 = 16.33\ m^2$

The area of the Soyuz is $\pi \times 1.36^2 = 5.81\ m^2$

The area each seat takes up in $0.61\ m^2$.

Students could work out the number of times the seat area goes into the module areas to calculate the maximum number of seats. Students should identify the issue with this model being that the calculations do not take into account the fixed shape of the seats.

METHOD 2

1. Draw a scale plan of the spacecraft on A3 sheets of paper.
2. Create an outline shape for the seat on paper and card. These outlines are your basic repeat units. Use them to work out the maximum number of seats that can fit in each craft.

NOTES FOR STEM LEADER

Resources required:

- A3 paper
- Pencils
- Compass drawing tool
- Scissors

Support can be provided to students by offering a scale of 1:20 would mean that all three modules fit on an A3 sheet of paper.

AERODYNAMICS

All moving objects experience a drag force, which slows the moving objects down. It occurs because objects moving through gas or liquids push their way through particles.

Launch vehicles are designed to be aerodynamic, making it easier to push past the particles and therefor reducing the drag forces on launch. This means less thrust is needed to launch a rocket into space.

TIME TO INVESTIGATE

Part 1

Investigate how different shapes move through fluids.

- Shape the same mass of plasticine into the following shapes: sphere, cube, disc, cone.
- Ensure each shape has string attached, so that you can easily remove the shapes from the oil.
- Pour 450ml of oil into a 500ml measuring cylinder
- Drop the shapes, one at a time, into the measuring cylinder of oil. Time how long it takes each one to fall through the measuring cylinder.

Shape	Time taken to drop to bottom of cylinder(s)

The most aerodynamic shape is

1. What has been done to ensure the experiment is reproducible?
2. Identify the independent, dependent and control variables.

NOTES FOR STEM LEADER

Resources required:

- Plasticine or modelling clay
- String
- Oil
- Measuring cylinder

Students should find that the cone drops fastest. This activity could get messy, covering desks with newspaper could make cleaning up easier.

Conduct a full risk assessment before carrying out this activity.

Part 2

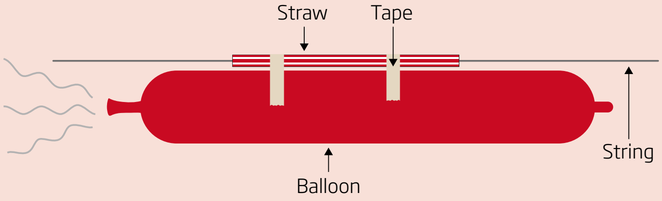
Use what you have learnt to design the nose cone for a balloon rocket.

NOTES FOR STEM LEADER

Resources required:

- Modelling balloons
- String
- Scissors
- Tape
- Straws
- Paper

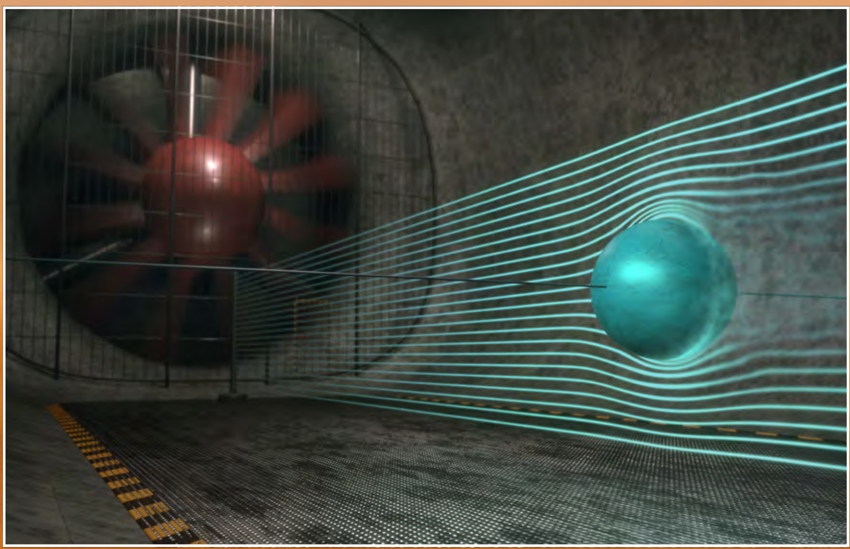
Students should use what they learnt about aerodynamic shapes to design and make a paper nose cone for a balloon rocket. To set up a race track for the balloons, tie one end of string to a stand and slide a straw onto the string so that it can move freely across the string. Then attach the free end of the string to another stand to create a track for the balloon rocket.



Blow up the balloon and pinch the end, attach the nose cone and stick the balloon to the straw. Let go of the balloon and measure the distance and time the balloon moves. Students could then calculate the speed of their balloon.

You could use data loggers to capture this information in real time.

Conduct a full risk assessment before carrying out this activity.



LANDING

GRAVITY

Gravity is a force that attracts objects towards each other. The gravitational force felt by an object depends on the mass of the objects and the distance between the objects.

The gravitational force felt by objects is different on different planets.

Weight is a force measured in Newtons, caused by gravity. Therefore, objects have different weights on different planets or moons. This can be observed when watching astronauts walking on the Moon.

HEAT SHIELD

When spacecraft enter an atmosphere of a planet at high speed, it must be able to withstand high temperatures. For example, the outside of the Soyuz capsule can reach temperatures of 3000°C upon re-entry to the Earth's atmosphere.

The melting point of steel, a commonly used material in transport and infrastructure, is between 1425°C and 1540°C. Engineers must make sure that the spacecraft they design can withstand high temperatures without melting or burning the people inside.

TIME TO CALCULATE

Weight can be calculated using the equation:

$W = m \times g$

Where

W = weight, m = mass and g = gravity.

The gravitational force on the Earth is 9.81m/s2

The gravitational force on the Moon is 1.62m/s2

1. Calculate the weight of a 15kg object on Earth
2. Calculate the weight of a 15kg object on the Moon
3. What is the gravity on Mars if an object with a mass of 15kg weighs 55.65N?

NOTES FOR STEM LEADER

1. $W = m \times g_E = 15 \times 9.81 = 147.15N$
2. $W = m \times g_M = 15 \times 1.62 = 24.3N$
3. $g_{moon} = W \div m = 55.65 \div 15 = 3.71 m/s^2$

DESIGN CHALLENGE

Part 1

Investigation into the temperature change of water in a beaker when heat is applied to a beaker covered in different insulating materials.

Pour water into a beaker and cover the outside of the beaker with insulating materials. Use a thermometer to find the temperature of the water before and after heating the beaker. Heat the beaker with a hairdryer for 5 minutes.

Part 2

Use your observations to design a heatshield for a spacecraft.

Make a container for a small square of chocolate to protect the chocolate from heat.

To test the heat shield, place the covered box a warm oven set at 45°C for two minutes to see if it protects the chocolate. Chocolate melts at body temperature so the oven does not need to be too hot.

- How would layers effect the heat shield?
- How would adding a gap between layers effect the heat shield?

NOTES FOR STEM LEADER

Resources required:

- Hair dryer
- Oven
- Thermometer
- Chocolate
- Scissors
- Adhesive
- Stopwatch
- A variety of materials

To ensure the experiment is reliable, make sure that the students have the same amount of chocolate, and the same heating method is used for the same amount of time.

Provide students with a variety of materials, including ceramics, insulator and reflective foils. Students should think about the properties of the different materials and how they can combine these properties to create the ultimate heat shield.

Conduct a full risk assessment, including food allergies, before carrying out this activity and ensure that none of the materials used are flammable, or will melt in the oven.

Insulating material	Temperature of water before heating (°C)	Temperature of water after 5 minutes (°C)	Temperature change (°C)

LIFE ON MARS

TASTE IN SPACE

Astronauts have found that food tastes different in space. On Earth, fluids in the body are pulled down due to gravity. In the first few days' astronauts spend in space the fluids are distributed equally around the body due to the reduced gravity, which is called fluid shift.

This causes astronauts to have a puffy face and the fluid blocks the nasal passages. The puffy face feels like a heavy cold and can reduce their ability to smell.

TIME TO INVESTIGATE

Investigate how food tastes different in space.

Taste each of the foods, first with your nose covered, then with your nose uncovered.

Write your observations in the table.

NOTES FOR STEM LEADER

Resources required:

- Variety of different foods, for example chocolate and fruit

For this activity, any variety of food can be tested. Always check for food allergies before this activity and conduct a full risk assessment.

FOOD ON MARS

The journey to Mars will take approximately six months, so it is essential to be able to grow food on Mars to be able to sustain human life. For plants to grow on the surface of Mars the conditions of the atmosphere and soil need to be right.

The atmosphere on Mars is almost 95% carbon dioxide. Plants use carbon dioxide to produce energy in a process called photosynthesis. Photosynthesis is a chemical process used by plants and algae to make glucose and oxygen from carbon dioxide and water, using light energy.

carbon dioxide + water → glucose + oxygen

Almost all life on Earth depends upon this process. Plants provide energy for animals when they are eaten, and photosynthesis also maintains the levels of oxygen and carbon dioxide in the atmosphere.

Theoretically Mars would be a great environment to grow crops for food, however plants also need oxygen for respiration.

Soil on Mars contains all the nutrients need to grow plants; such as potassium, phosphorus and nitrogen. Nitrogen is an essential constituent of chlorophyll, the green chemical in chloroplast that enables photosynthesis to take place.

Food	Taste with no smell	Taste with smell

TIME TO INVESTIGATE

Investigate the effects of acids and alkalis on plant growth.

- Set up three petri dishes, one labelled "acid", one labelled "alkali" and the final labelled "neutral"
- Insert cotton around the edges and bottom of Petri dish.
- Add 10 ml of diluted sulphuric acid to the petri dish labelled "acid".
- Add 10 ml of tap water to the "neutral" petri dish.
- Add 10 ml of limewater to the "alkali" petri dish.
- Test and record the pH of each of the petri dishes in the table below.
- Place 5 cress seeds in each of the petri dishes and observe the growth over 5 days.

NOTES FOR STEM LEADER

Resources required:

- Petri dishes
- Cress seeds
- Tissue or paper
- Acid for example sulphuric acid
- Alkali for example limewater
- Pen to label petri dish

Conduct a full risk assessment before carrying out this activity.

	Observations		
Day	Acid pH___	Neutral pH___	Alkali pH___
1			
2			
3			
4			
5			

PRESENTATION ACTIVITY

HOW WILL ENGINEERS MAKE IT POSSIBLE TO LIVE ON OTHER PLANETS?

Use the information and ideas that you have gathered from these activities to present your answer to the big question: How will engineers make it possible to live on other planets?

PRESENTATION SPECIFICATION

The presentation must:

- include a supported answer to the 'big question', 'How will engineers make it possible to live on other planets?'
- include examples of problems faced during the launch and landing of a mission as well as living in space and on other planets.

The presentation could:

- refer to previous space missions, including the missions to the moon.
- include relevant information about life on the International Space Station
- include relevant information from internet-based research, identifying the source of the information
- identify specific examples of the contributions made by one or more types of engineer
- explain the relevant science, technology or mathematics knowledge you used for a problem-solving activity.

The presentation could take a number of forms and could include:

- text
- photographs
- diagrams
- charts
- data

NOTES FOR STEM LEADER

The presentation is an opportunity for students to draw on all the information and insights they have gathered and for members of each group to work cooperatively to produce the presentation.

It is important for each group of students to have the opportunity to present their work to other groups. There should also be an opportunity for all students to contribute to this process.

The presentation produced by a single group might be a poster, or a talk supported by images and data. Where time and resources allow, it might be a short video presentation, a PowerPoint presentation or a Prezi presentation (see **www.prezi.com**).

The content of individual presentations will very much depend on which challenges the students have taken part in but the overall message that students should take away is that:

- Engineers are involved in all aspects of space exploration.
- Engineers draw on scientific, technological and mathematical knowledge and skills to solve problems.
- They need to understand people as well as technology.
- They also need to be observant, creative, resourceful and able to work in teams.
- Engineers review what they have learned to produce a better solution in future.

Thank you

This STEM teaching and learning resource has been developed by the Royal Academy of Engineering as part of its national **Connecting STEM Teachers** (CST) programme.

CST is a support network for teachers across all STEM subjects ensuring they have the knowledge and confidence to engage a greater number and wider spectrum of school students with STEM. The programme operates across all regions of England, and in Scotland, Wales and Northern Ireland.

The programme, founded by the Royal Academy of Engineering, would not be possible without the generous support of its funders:

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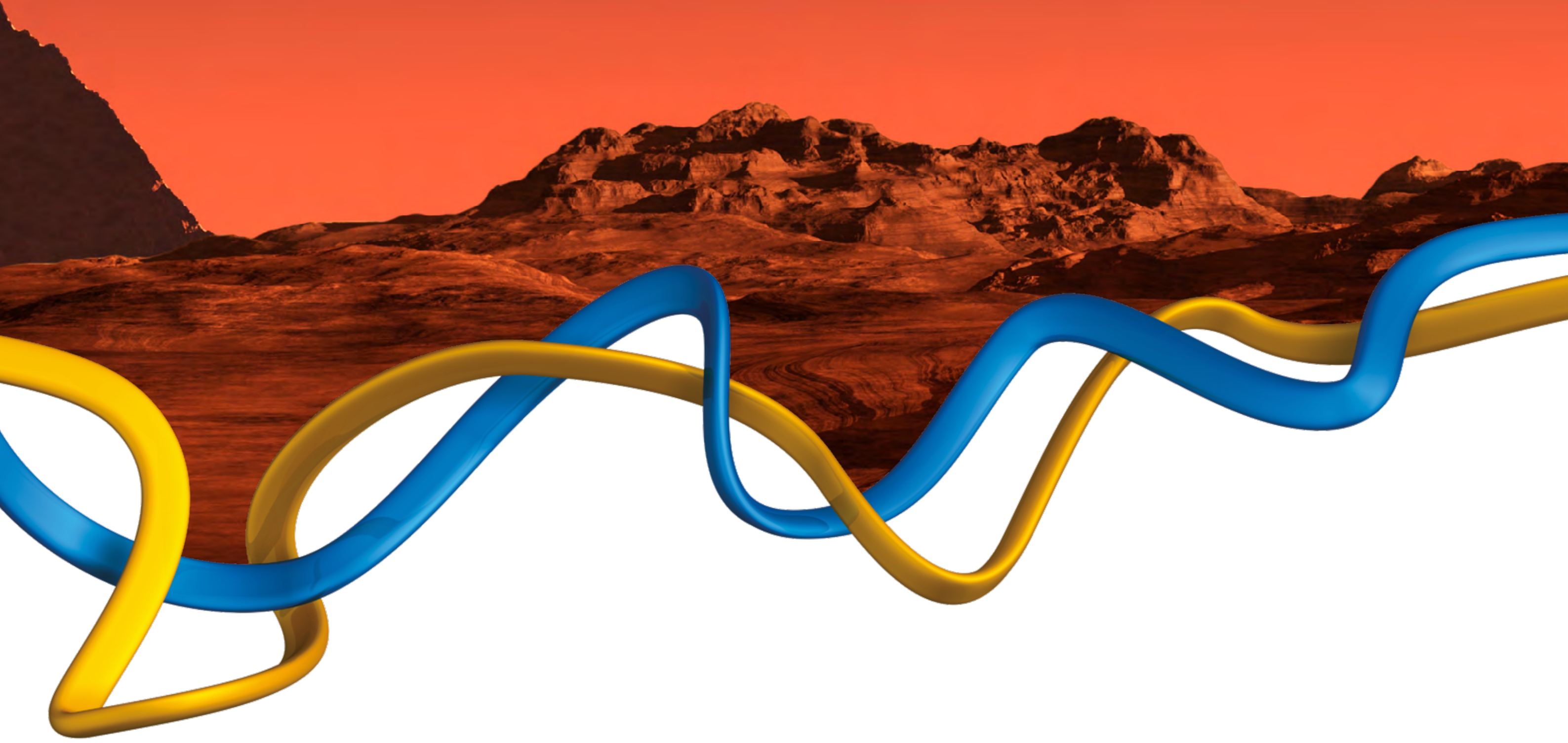

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