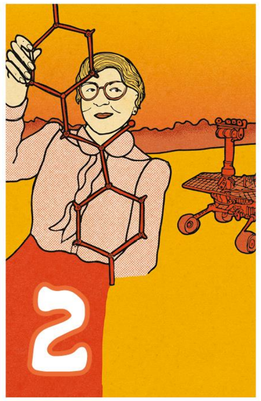
DISCOVER
MATERIALS

UK SPACE AGENCY

CHALLENGE BOOKLET



INTRODUCTION

Dear adventurers,

Congratulations on being selected for **"Let's Move to the Moon"**!

Inside this booklet, you will find eight missions that you must complete before we can launch our mission to the Moon. Each mission is colour-coded. You'll need to find the items in your Moving to the Moon box that have the matching colour-coded stickers on them in order to complete it.

For example, Mission 1 is colour-coded **red**. Find the items with **red** stickers on them and follow the instructions in the booklet to learn about the density of different materials.

The stickers look like this:

Each mission has an instructional YouTube video, which you can use while you're completing the assigned tasks. You can access the videos using the QR codes in this booklet.

We've also asked you to record your results for each mission in a Google Form. This helps us to see what you've learned, so we can bring your rewards when you complete all of the missions. The Google Forms also have a QR code in this booklet.

When you reach Mission 7, you will need to contact us so we can help you with your final goal: launching a 3D-printed rocket to the Moon! Ask your teacher to tell us you've finished.

You are the future engineers, artists, scientists, astronauts, explorers, and architects who will make our dream of moving to the Moon come true. We can't wait to see your Moon base designs!

See you on the other side!

MEET THE TEAM

Dr Leah-Nani Alconcel
Spacecraft Engineer and Mission Commander

Chris Hamlett
"Discover Materials" Captain and Mission Operator

Emma Falconer
Artist, Educator and Mission Designer

Amy Newell
Materials Technician and Mission Manager

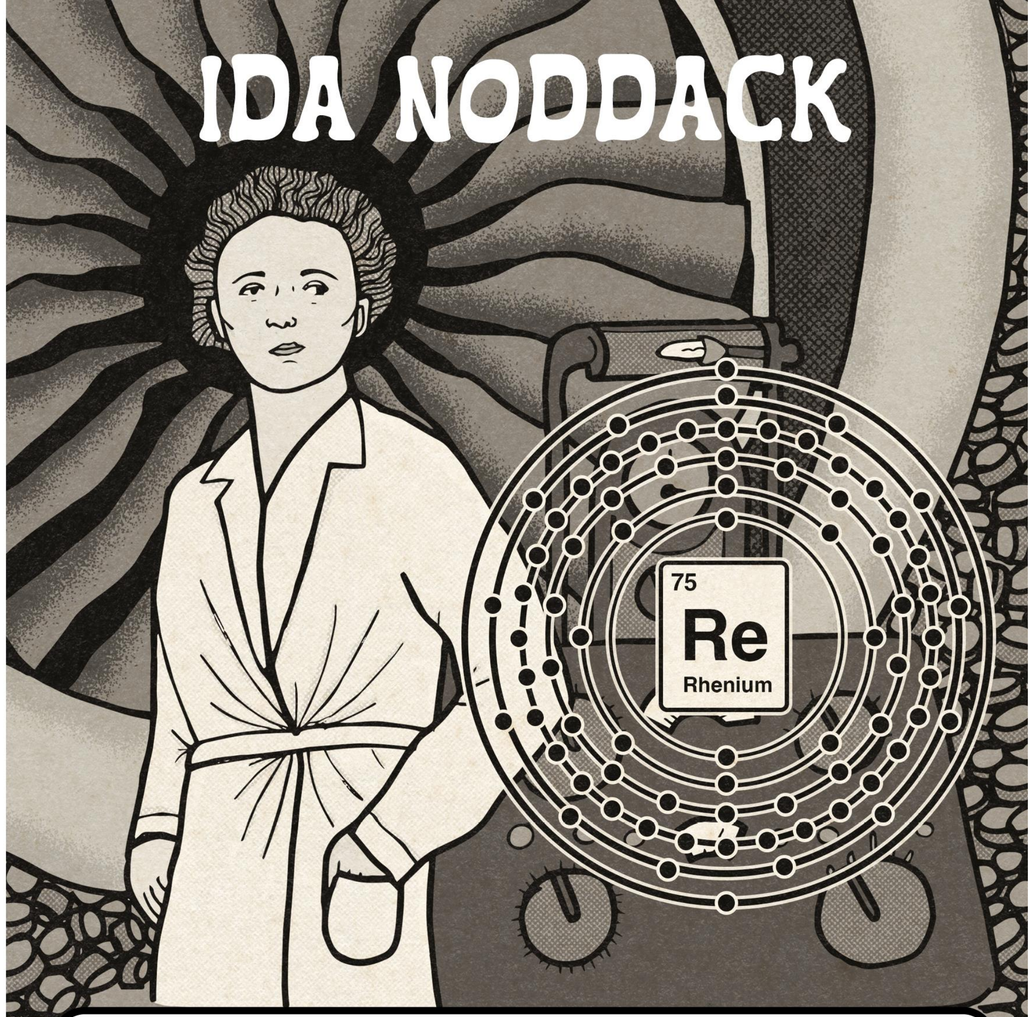
Jon Wood
Video Wizard

Anastassia Milleret
Materials Scientist and Rocket Designer

Additional contributors: Han Zhang, Idris Mohammed, Dorina Kis, Richard Turner, Tess Knowles, Dan Scotson, Henry Hoddinott, Zoe Powell-Best, Chris Gell, Wakib Said

BEHIND THE SCENES!

Scan the QR code to watch our behind the scenes video with the student ambassadors.
If the video doesn't work try tinyurl.com/movetothemoon



Dr Ida Noddack co-discovered the element rhenium (atomic number 75) with her husband, Walter Noddack and another German chemist, Otto Berg. She is known to be one of the earliest people to unlock the secrets of nuclear fission. Rhenium and technetium, which Dr Noddack also co-discovered, form salts with chlorine (atomic number 17).

Rhenium is rare, but very useful. It can be applied in many ways, from photography to the production of high-octane petrol for race cars. With other metals, it forms strong alloys that won't melt at high temperatures. These are needed for jet engines, which get very hot. Would you use rhenium in your Moon base?

CHALLENGE 0

Your first mission is to unlock your suitcase so you can access the contents! Use the clues in the bio and the video to figure out the combination.

YOUR CHALLENGE

We need to get to the Moon to build a base, but our Associate Professor of Space Engineering can't get into the case to retrieve the equipment needed to help work out what we need to take!

Help her by cracking the code to unlock the suitcase so we can start planning what we need to go the Moon and how we will get there.

Scan the QR code to watch a video from Dr Aloncel.
If the code doesn't work, try tinyurl.com/noddackvideo

EQUIPMENT

- Case (with combination lock attached)

SAFETY INFO

- **Case**
  Don't pinch your fingers in the lock!

THINK ABOUT

What clues does Dr Aloncel give you in the video?
What sorts of things might you need for going into space?

INSTRUCTIONS

1) Read the biography of Ida Noddack
2) Watch the introductory video with Dr Alconcel
3) What important information did you learn about Ida's discoveries? How could this be turned into a security number?
4) Enter the four-digit combination on the suitcase lock
5) Talk to the other students– what kinds of challenges could people face trying to set up a moon base?
6) Fill in the survey using the QR code below, tell us what the combination was and what challenges you think face us when planning a moon base!

OUR IDEAS

What could be difficult about setting up a moon base? Why?

LOG YOUR RESULTS

Scan the code to enter your results into the form.
If the QR code doesn't work go to tinyurl.com/noddack

Cecilia Payne-Gaposchkin was the first scientist to discover what stars are made of. She found that they were mainly composed of the lightest elements, hydrogen and helium, which are even lighter than air. Imagine if we could build a moon base that was lighter than air!

Since we can't build our Moon base out of hydrogen, we'll use Cecilia's scientific method to find out the density of our materials, which will help us figure out the best ones to bring with us, and where to use them. Be sure to make your measurements as carefully as Cecilia did.

CHALLENGE 1

Now you'll start to learn how much you can carry with you to the Moon. Learn about density by weighing the sets of bars.

When packing your space shuttle up for your journey to the Moon you need to think carefully about what to take with you. This is especially important when thinking about how much the cargo weighs, as the heavier your load the more fuel you will need. This is important both as a cost and safety concern!

YOUR CHALLENGE

Measure the mass and volume of each bar.
Calculate the density and note how they look and feel.
Scan the QR code to watch a video to help you.
If the code doesn't work, try tinyurl.com/gaposchkinvideo

EQUIPMENT

- Mass balance
- Callipers and ruler
- Iron bar
- Aluminium bar
- Wooden bar
- Acrylic bar
- Polypropylene bar
- PTFE bar
- Copper tube
- Reinforced carbon composite bar

SAFETY INFO

Bars
Be careful to make sure the bars of material do not roll off a surface and drop on your foot! It could hurt (especially the iron!) and do damage to your foot or any other body part it strikes.

THINK ABOUT

What could you use each material for when you settle on the Moon?

INSTRUCTIONS

1) Place the first material on the mass balance and record its mass in grams (g).
2) Use the callipers to measure the length and diameter of the rod in millimetres (mm). For tubes, also measure the outer diameter and inner diameter in millimetres.
3) Note down any additional observations that might help decide on what to use it for. Is the material see through? How does it feel?
4) Repeat steps 1–3 for each material.
5) Leave the density column until last

LET'S FIND THE DENSITY

Use these equations to help you fill out the density column

FOR THE SOLID BARS

Equations you will need in the order you should use them

- **RADIUS** = Diameter ÷ 2
- **VOLUME in mm³** = π x Length x (Radius)²
- **VOLUME in cm³** = Volume in mm³ ÷ 1000
- **DENSITY in g/cm³** = Mass ÷ Volume in cm³

FOR THE TUBES

Equations you will need in the order you should use them

- **VOLUME in mm³** = π x Length x (Outer Diameter² – Inner Diameter²) ÷ 4
- **VOLUME in cm³** = Volume in mm³ ÷ 1000
- **DENSITY in g/cm³** = Mass ÷ Volume in cm³

LOG YOUR RESULTS

Scan the code to enter your results into the form.
If the QR code doesn't work go to tinyurl.com/paynegaposchkin

Material	Mass (g)	Length (mm)	Diameter (mm)	Outer diameter (mm) Tubes only!	Inner diameter (mm) Tubes only!	Description	Density (g/cm3) (Use the equations to help you!)
Iron							
Aluminium							
Wood							
Acrylic							
Polypropylene							
PTFE							
Copper							
Carbon composite							

STEPHANIE KWOLEK

Stephanie Kwolek is most famous for creating a material known as Kevlar. Stephanie was a very successful materials scientist at DuPont and worked in researching new materials for 40 years. Stephanie was determined that her research would be useful and benefit the world. She also has a book written about her by Edwin Brit Wyckoff – The Woman Who Invented the Thread That Stops the Bullets: The Genius of Stephanie Kwolek.

Kevlar is a very strong and stiff material, but is also lightweight, and has several applications including protective equipment. Kevlar has even made it to space and the planet Mars! Would you take it to your Moon base?

CHALLENGE 2

Mechanical properties describe how an object behaves when force is applied (how does a nail behave when hit by a hammer?). An important consideration when choosing which materials to use for a moon base are their mechanical properties – this will ensure that the moon base doesn't crack and collapse.

YOUR CHALLENGE

The strength of a material under a bending force depends both on its properties **and** on the shape of the object it's used in. Use this to help chose which materials to take to the Moon.

Scan the QR code to watch a video to help you.

If the code doesn't work, try tinyurl.com/kwolekvideo

SAFETY INFO

- **Rulers**
  Be careful when bending the rulers – if they snap they can result in sharp edges or splinters
- **Bars of materials**
  Be careful when handling the bars of materials. Take care to ensure they do not roll off table tops as they could cause impact injuries.

EQUIPMENT

- Metal ruler
- Plastic ruler
- Some of the bars of different materials from Challenge 1 (you decide which ones!)

THINK ABOUT

What mechanical properties (e.g. stiffness) are important for a moonbase?

INSTRUCTIONS

1) Take metal ruler and bend it – what happens?
2) Take the plastic ruler and bend it – what happens?
3) Take the aluminium and polypropylene rods that were used in Mission 1 and try bending those.
4) Discuss the difference of how the different rulers bent – this will concern the mechanical properties due to the material
5) Discuss the differences of how the plastic bar and plastic rod bent – any changes in mechanical behaviour will be due to engineering.

WHAT HAPPENED?

Write your answers below

In the video, what happened to the wooden ruler?

What happened to the metal and plastic rulers when you tried to bend them?

Which metal and plastic rods did you try to bend? What happened when you tried to bend them?

LOG YOUR RESULTS

Scan the code to enter your results into the form.
If the QR code doesn't work go to tinyurl.com/kwolekresults

OUR MOONBASE

Now that you have learned something about the materials you might take to the Moon, sketch a design for a room in your Moon base here.
What will you make the walls out of? What about the furniture?

JOCELYN BELL BURNELL

Professor Dame Jocelyn Bell Burnell knows all about exploring space after discovering a type of star. Neutron stars are over a million degrees hotter than our Sun. Jocelyn's work contributed to a Nobel Prize, although she didn't receive it herself. She believes everyone should be able to study science and has donated lots of money to help students from a wide range of backgrounds study Physics.

Jocelyn is a Professor at the University of Oxford and loves space. She even edited a poetry book about space (Dark Matter; Poems of Space)! Poetry won't build our Moon base, but we do need know to if our materials can stay hot – or cold – in space.

CHALLENGE 3

The Moon's surface temperature can range from –130°C and 120°C so choosing the correct materials is essential to keep the correct temperature in our moonbase. We will do this by learning about thermal conductivity of different materials– this describes how well heat travels through them.

YOUR CHALLENGE

Study the thermal conductivity of different materials by using hot and cold packs, an infrared thermometer and a simple calculation to find out which materials are the best thermal conductors and which are the best insulators.

Scan the QR code to watch a video to help you.
If the code doesn't work, try tinyurl.com/bellburnellvideo

EQUIPMENT

- Infrared (IR) thermometer
- Cubes of different materials
- Instant heat packs
- Instant cool packs
- A timer such as a stopwatch, smart phone / tablet device – not included in the box

SAFETY INFO

- **Heat /cool packs**
  Prolonged contact may cause discomfort and, possibly, burns (especially with the heat pack).
- **Liquid inside heat/cool packs**
  If a cool / heat pack splits, liquid will spill out presenting a slip hazard so best to carry out the experiment in a shallow container or on an absorbent surface (e.g. tissue paper).
- **Infrared thermometer**
  Do not shine the red laser from the IR thermometer into eyes

THINK ABOUT

Before testing them, which of the materials do you think would be best for making the walls of a moon base? Why?

INSTRUCTIONS

1) Activate a cool pack by squeezing the little capsule inside the bag until it pops and place on the desktop.
2) The cool pack feels cold because the chemical reaction between the water and the solid in the bag is **endothermic** (takes in energy) so it feels cold.
3) Place the cube onto the cool pack and record the temperature of the top face of the cube immediately in the "Initial temperature" column. Now start your timer!
4) After 1 minute record the temperature of the top face of the cube in the "Temperature after 1 min" column.
5) Calculate the temperature difference of the top face of the cube over the course of 1 minute and record this in the "Temperature difference" column. This will indicate how good a thermal conductor the material is.
6) Repeat steps 3 and 4 with the other cubes of different materials.
7) Using a heat pack instead of a cool pack, repeat step 3–5 and use the second table tor record your data.
8) The heat pack feels warm because the chemical reaction between the water and the solid in the bag is **exothermic** (gives out energy) so it feels warm.
9) Compare the calculated temperature difference values for all of the materials. Which ones would you use to keep your Moon base from getting too hot? Which ones would use to keep your Moon base from getting too cold?

Did the materials behave how you expected? Which ones were surprising? Do you still have the same ideas about which ones are good for a base?

LOG YOUR RESULTS

Scan the code to enter your results into the form.
If the QR code doesn't work go to tinyurl.com/bellburnellresults

WITH COLD PACK

Material	Initial temperature (°C)	Temperature after 1 min (°C)	Temperature difference (°C)
Nylon			
Pine			
PVC			
Poplar			
Copper			
Aluminium			
Brass			
Maple			
Iron			
Acrylic			

WITH HEAT PACK

Material	Initial temperature (°C)	Temperature after 1 min (°C)	Temperature difference (°C)
Nylon			
Pine			
PVC			
Poplar			
Copper			
Aluminium			
Brass			
Maple			
Iron			
Acrylic			

MARIE CURIE

Marie Curie was a physicist and a chemist who discovered the radioactive elements radium and polonium. She was the first woman to win a Nobel Prize, the first person and the only woman to win the Nobel twice, and the only person to win it in both chemistry and physics. And finally, she was the first woman professor at the University of Paris.

Marie Curie discovered the hazards of radiation first-hand and without protective equipment. Thanks to her, we know we need to protect our Moon base inhabitants from dangerous radiation. Which of our materials can we use in their space suits? For example, would you make a visor out of aluminium foil?

CHALLENGE 4

Ultraviolet (UV) rays make some materials fluoresce, such as invisible inks, BUT they can cause sunburn! On Earth, the ozone layer protects us from the most damaging UV rays but the moon has no ozone layer, so the materials we take need to protect our moon settlers from the Sun's harmful UV rays.

YOUR CHALLENGE

Work out which materials our moon settlers could use as a space suit and visor to protect themselves from UV rays. Use a UV torch and colour changing beads to find out which of the sheet materials give the best protection.

Scan the QR code to watch a video to help you.
If the code doesn't work, try tinyurl.com/curiechallengevideo

EQUIPMENT

- UV colour changing beads
- Petri dishes
- UV torch
- Sheet materials such as different coloured cellophane (transparent) or samples of cloth (opaque)
- UV sun index chart (printed on the next page)

SAFETY INFO

- **UV torch**
  Can cause eye damage – DO NOT look directly at the light and DO NOT shine into people's eyes
- **UV colour changing beads**
  if spilled these can cause a slip and choking hazard so clear up any spilled beads immediately

THINK ABOUT

What do you usually use to protect yourself from UV light from the sun?

INSTRUCTIONS

1) Fill in the "Materials" column with which material you will test.
2) You may want to mix different number of layers of material. If you do, note down the material(s) used and how many layers of each.
3) If using cellophane, remember to note down which colour of cellophane you used.
4) In the "Predicted UV index" column predict how well you think the material will block out UV light using a scale of 1–10 where:
   1 = a very good UV blocker
   5 = blocks out about half of the UV light
   10 = a very poor UV blocker
5) Fill a Petri dish with UV beads. Place a sheet of material on top of the beads and shine the UV torch onto the materials for 10 seconds.
6) Remove the sheet material. Match the colour of the beads with the UV Sun Index chart (see next page) and record the value in the "Actual UV index" column.
7) The depth of the colour will give you a numerical value for the UV Sun Index.
8) The beads can turn different colours (blues, purples, pinks). It doesn't matter what colour they turn. The boldness of the colour determines the UV Sun Index. Wait for the beads to fade to clear before repeating steps 2–6 with a different material

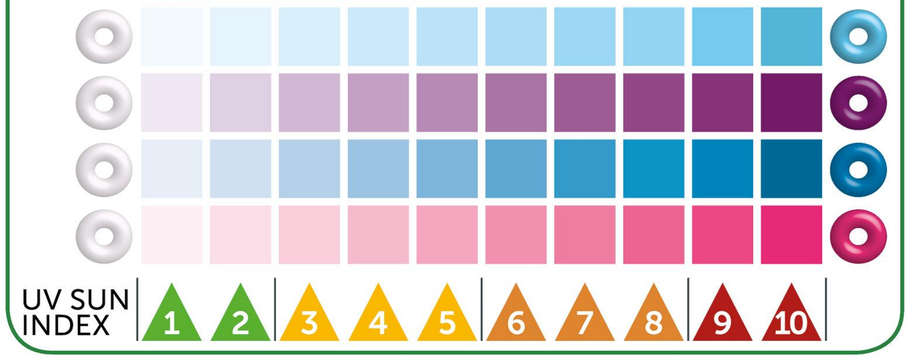
TALK ABOUT

Were you surprised by any of the materials? Which ones do you think would be good to use on the spacesuits and helmets and why?

LOG YOUR RESULTS

Scan the code to enter your results into the form.
If the QR code doesn't work go to tinyurl.com/curieresults

COLOUR CHANGE GUIDE & UV SUN INDEX



Material	Predicted UV index (1= best 10 worst)	Actual UV index	Good for spacesuit or visor?

Helen Sharman is best known as the first British astronaut to go to space in 1991. Before going to space, Helen had to train for the challenges of living in space in Moscow, Russia for 18 months, including weightlessness training for the vacuum of space. Helen spent eight days in space, showing the dedication required to become an astronaut!

After space, Helen continued working as an engineer, and then as a scientist for Mars Wrigley, who make sweets and chocolate! Helen now works at Imperial College London, sharing science with the public. Helen hosts a podcast (*Zero Pressure*) and has written two books: *Seize the Moment* and *The Space Place*.

CHALLENGE 5

Some materials are **rigid** and can support large loads without changing shape or breaking and some are **elastic** and can change shape when they are pulled or pushed, without breaking. These two types of materials respond very differently when put in a vacuum, such as outer space. Let's find out why!

YOUR CHALLENGE

To conduct some experiments on a marshmallow to help understand what makes a material rigid or elastic, and what happens when we put these materials inside a vacuum.
Scan the QR code to watch a video to help you.
If the code doesn't work, try tinyurl.com/sharmanvideo

EQUIPMENT

- A wide-mouth glass mason jar, to be the vacuum chamber
- A lid with a one-way valve, to hold the vacuum
- A pump, and our hands to operate it, to create the vacuum
- And of course, a marshmallow to experiment on!

SAFETY INFO

- **Vacuum jar**
  May leave red marks if the vacuum touches skin
- **Pump**
  Don't pump too hard and strain yourself
- **Marshmellow**
  Keep the equipment clean if you want to eat it afterwards

THINK ABOUT

Why do marshmallows expand in a vacuum? Think about the material structure.

INSTRUCTIONS

1) First, try gently squeezing a marshmallow and watch how it returns to the same shape when you let go with one hand.
2) What happens if you squeeze it harder?
3) Do you think a marshmallow is rigid or elastic? Next, do you have any hard sweets such as chocolate?
4) Repeat what you tried above; does it respond in the same way? Do you think it is rigid or elastic?

Now we will put a marshmallow inside a vacuum chamber to demonstrate what happens to it under these conditions.

5) Place the marshmallow in the jar and screw on the lid to seal it shut
6) Connect the hand pump to the valve on the lid
7) Use our hands to pump out the air from the jar – this is harder than it looks!
8) Watch the marshmallow as we pump out the air and record any observations
9) Stop pumping and record any observations
10) Release the vacuum by opening the valve and record any observations
11) Repeat steps 5–10 with the balloon and table tennis ball, and record your results

TALK ABOUT

Do you think marshmallows are a good snack to bring to space?
Why or why not? What did you discover in the experiment?

LOG YOUR RESULTS

Scan the code to enter your results into the form.
If the QR code doesn't work go to tinyurl.com/sharmanresults

Object	How did it behave when the jar was evacuated?	Is this material elastic or rigid?
Marshmallow		
Balloon		
Table tennis ball		

ZAHA HADID

Dame Zaha Hadid received many awards and prizes for designing some of the most iconic buildings in the world. In many cases, she was the first woman ever to win those prizes. Her work is instantly recognisable for its futuristic look and stunning curves. Her designs in the UK include the Aquatics Centre for the London Olympics in 2012 and the Riverside Museum in Glasgow. She also designed a school, the Evelyn Grace Academy in Brixton.

Zaha believed in the power of architecture and design to inspire people and to influence wellbeing. How would you design your rocket and your Moon base to make your travellers feel good?

CHALLENGE 6

Now you've looked at the different considerations for materials to take into space, it is time to look at leaving planet Earth. In this mission you will investigate how thrust is generated to launch a rocket and experiment with different fuel formulations to see how this changes how high it flies.

YOUR CHALLENGE

Using a fuel made from a solid (effervescent vitamin C tablet) and liquid (water) launch a mini rocket and then experiment with the fuel formulation to see how high it can fly.
Scan the QR code to watch a video to help you.
If it doesnt work try tinyurl.com/hadidvideo

EQUIPMENT

- Fizzy vitamin C tablets
- 35mm film cannister (ask your parents about them!)
- Pipettes
- Water
- A suitable launchpad (this could be on a table outside or in room with a high ceiling)
- Decorations for the rocket (optional)
- Tissue / absorbent cloth (not included in the space case)

SAFETY INFO

- Eye injury from flying rocket (wear eye protection). If the rocket takes a long time to launch then approach it and do not look directly down on it.
- If the rocket is launched inside ensure that it is launched in a room with a high ceiling (such as a sports hall) and not aimed at any light fittings or anything else which may be damaged and cause further hazards (such as cuts from broken glass).

THINK ABOUT

Which ingredients make the tablets fizz?
Why do the rockets fly?

INSTRUCTIONS

1) Find a suitable launch zone. The rockets can fly high so make sure that this is either done outside or in a room with a very high ceiling with no low hanging lighting.
2) Make sure that the launch zone is clear.
3) Take a film cannister (decorate it if you want – we would love to see your pictures!) and put on safety goggles.
4) Fill the cannister to about 1/3 full of water
5) Put a effervescent vitamin C tablet in the cannister (start with ¼ of a tablet for your first launch)
6) Quickly close the lid (tightly), invert the rocket and place it lid down onto the launch pad
7) Watch to see if the rocket launches
8) IF the rocket doesn't launch you may need to return to it and give it a little shake or it may leak a bit.
9) If you return to it make sure you do not look directly down on the film cannister and wear goggles.
10) Try experimenting with launching the rocket again but change the tablet/water ratio or try thinking about different ways that you can set off the reaction between the effervescent tablet and water.

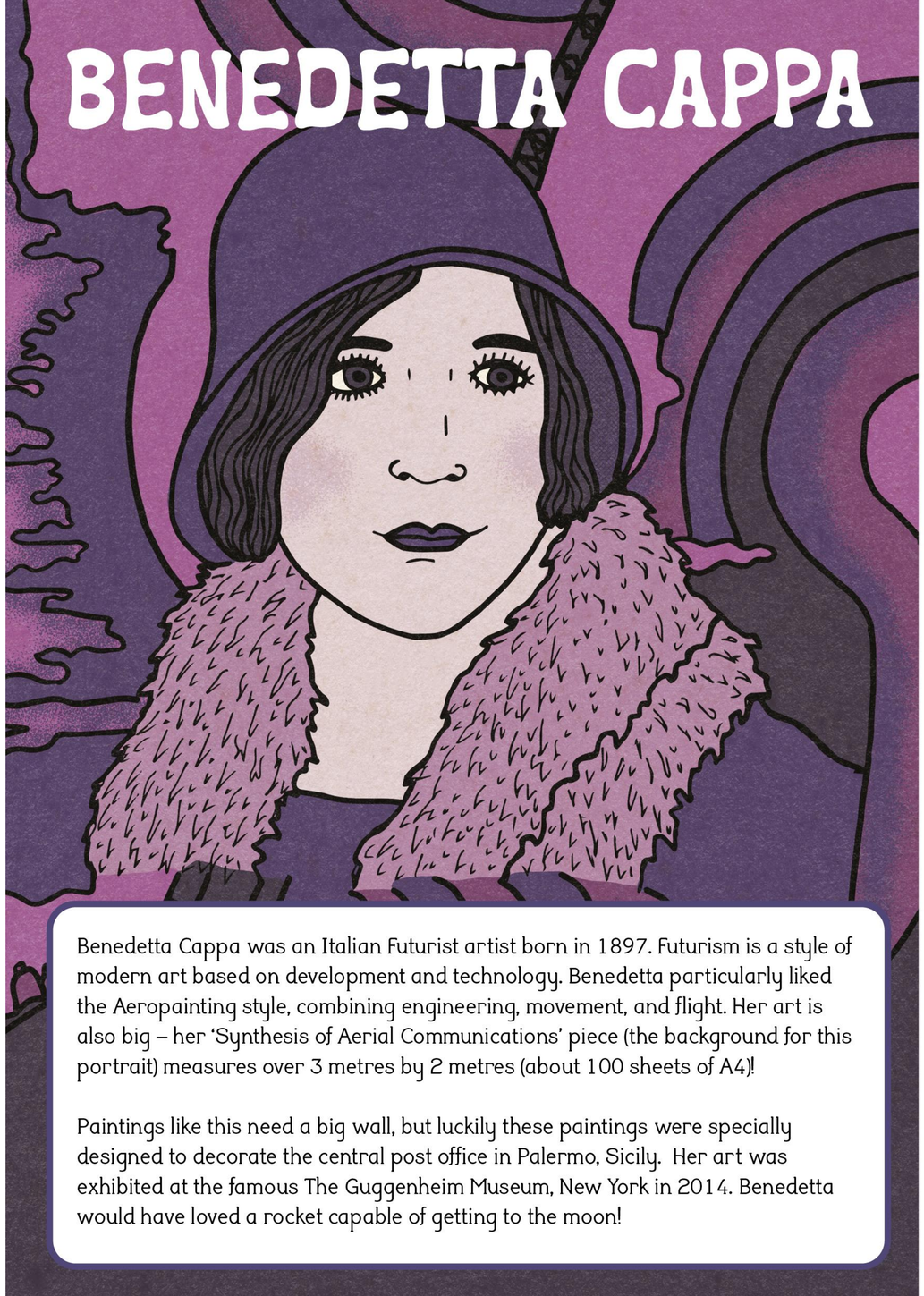
TALK ABOUT

What was the best rocket fuel formulation?
How does your fuel make the rocket take off?

LOG YOUR RESULTS

Scan the code to enter your results into the form.
If the QR code doesn't work go to tinyurl.com/hadidresults

Volume of water (ml) Use the pipette to get a rough volume	Vitamin C tablets (tablet)	How high did the rocket go
15ml	**1/4**	



Benedetta Cappa was an Italian Futurist artist born in 1897. Futurism is a style of modern art based on development and technology. Benedetta particularly liked the Aeropainting style, combining engineering, movement, and flight. Her art is also big – her 'Synthesis of Aerial Communications' piece (the background for this portrait) measures over 3 metres by 2 metres (about 100 sheets of A4)!

Paintings like this need a big wall, but luckily these paintings were specially designed to decorate the central post office in Palermo, Sicily. Her art was exhibited at the famous The Guggenheim Museum, New York in 2014. Benedetta would have loved a rocket capable of getting to the moon!

CHALLENGE 7

You have one more mission to go before the big blast off.
In this mission you will work in teams to bring all of your big ideas together and to design your moonbase and what it will be made from. You will then show these to an Ambassador who will then help you blast off into space

YOUR CHALLENGE

From what you have learned about materials, their properties and the conditions they have to withstand in space your challenge is to design a poster to show what your moon base will look like and what it will be made from.

Scan the QR code to watch a video to help you.
If it doesn't work try tinyurl.com/cappavideo

EQUIPMENT

- Paper
- Pens
- Your imagination and knowledge
- An ambassador (equipped with a 3D printed rocket and a bike pump!)

SAFETY INFO

- **Rocket**
  Listen to the Ambassador's safety briefing well and pay attention whilst they launch the 3D printed rocket as it can cause impact injuries.

THINK ABOUT

How does the 3D printed rocket launch? Does this differ from Mission 6?

INSTRUCTIONS

1) Work in groups to design a moonbase and what materials you will take to the moon with you and why
2) Try out different ideas in the boxes opposite, and discuss which you think are the best ideas and why
3) When you have your best idea, create a big poster in your group to with a diagram and explanations about your moonbase. Make sure it's nice and colourful.
4) Show your poster to our Ambassador
5) Follow the Ambassador to launch the 3D printed rocket here.

WHAT DOES OUR MOONBASE NEED?

What problems will your settlers have? How could you solve these using materials or clever design? Jot down some ideas here.

LOG YOUR RESULTS

Scan the code to enter your results into the form.
If the QR code doesn't work go to tinyurl.com/capparesults

DESIGN IDEA 1

DESIGN IDEA 2

DESIGN IDEA 3