Science and Technology Facilities Council

STEM Careers Challenge

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Introduction

Welcome to the Science and Engineering Careers challenge!

The challenge has been created by members of the graduate scheme from the Science and Technology Facilities Council (STFC) at the Rutherford Appleton Laboratory in Harwell. The challenge is designed to introduce different science and engineering careers found at STFC. The challenge is split into three sections.

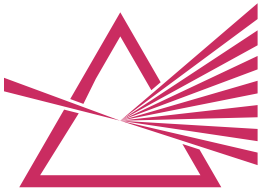
To complete the challenge, we recommend the unit completes one activity from each section, please adapt the activities to suit your needs. We have included activities for all age groups and there are a lot of choices, so do not think you have to do everything!

The recommended age groups for each activity are for guidance. Feel free to do whichever activities you think your groups will be comfortable with. We have also included case studies of people working in all the three sections.

Once you've finished the challenge, complete the badge order form via the link here, along with the feedback form.

www.smartsurvey.co.uk/s/STFC-CareerChallenge

Section 1
Fluid Engineer



Section 2
Optical Engineer

Section 3
Project Manager

Disclaimer

Please note: Adult supervision is required for all activities. The challenge team takes no responsibility for any accidents occurring while completing the challenge. Units are encouraged to complete an additional risk assessment before undertaking the activities.

About STFC

The Science and Technology Facilities Council (STFC) is a world-leading multi-disciplinary science organisation, one of nine Research Councils within the United Kingdom Research and Innovation (UKRI). STFC's goal is to deliver economic, societal, scientific and international benefits to the UK and its people.

STFC has large-scale scientific facilities in the UK and Europe that are used by more than 3,500 people each year, carrying out more than 2,000 experiments! The facilities provide a range of research techniques using neutrons, muons, lasers and x-rays, as well as high performance computing and complex analysis of large data sets.

STFC is based at various sites around the UK, including:

- Boulby Underground Science Facility
- Chilbolton Observatory
- Daresbury Lab
- Rutherford Appleton Laboratory (RAL) in South Oxfordshire
- UK Astronomy Technology Centre (UK ATC) and Royal Observatory in Edinburgh

Boulby

Boulby Underground Laboratory is the UK's deep underground science facility, located 1.1km below ground in Boulby mine, a working potash, polyhalite and salt mine in the Northeast of England. Boulby is a special place for science because it enables experiments that can only be performed in a deep underground environment, where there is very little background radiation. For over two decades, UK and international scientists have developed and tested world-leading dark matter detector technologies.

Chilbolton

The Chilbolton Observatory is a research facility primarily for studying the Earth's atmosphere. It is home to a wide range of science facilities for research in atmospheric science, radio communications, astronomy, space science and technology. The site has fully steerable 25m antenna, which can host advanced powerful radars and sophisticated sensitive receivers for satellite and astronomy work.

Daresbury

From the day it opened in 1962, Daresbury Laboratory has pushed the boundaries of modern science. I is internationally recognised for world-leading scientific excellence in many fields, from nuclear physics to supercomputing. The facilities are used by over 300 staff including scientists and engineers, from both the university research community and industrial organisations. Staff work in a range of departments and facilities at Daresbury such as Accelerator Science, Hartree Centre, Scientific Computing, Technology, Nuclear Physics, Business and Innovations, and Public Engagement.

Rutherford Appleton Laboratory in Harwell. One of the sites owned by STFC.

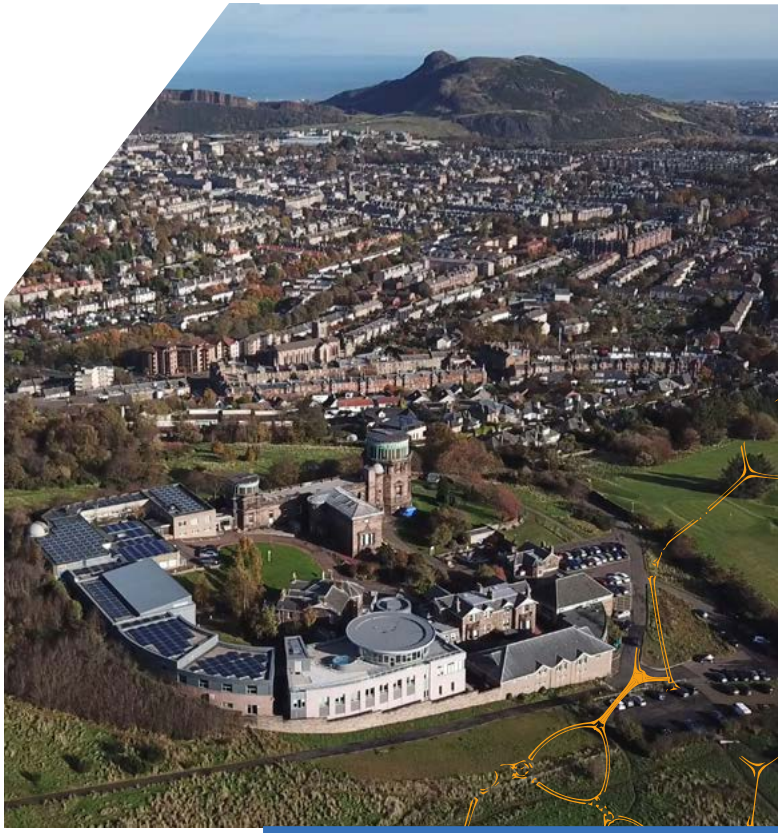
RAL

Rutherford Appleton Laboratory (RAL) is a laboratory that has existed on the Harwell site since 1957. Some of the scientific facilities include:

- RAL Space- RAL Space carries out world-class science research and technology development with involvement in more than 210 spacecraft to date.
- ISIS neutron and muon source-The ISIS neutron and muon source is a world-leading accelerator for research in the physical and life sciences.
- The Scientific Computing Department manages high performance computing facilities, services and infrastructure, supporting some of the UK's most advanced scientific facilities.
- The Central Laser Facility is one of the world's leading laser facilities; its high-power lasers can recreate the conditions inside stars while its small, compact lasers have medical, security and environmental applications.
- Technology underpins some of the world's leading science experiments. Our technology ranges from the very small - micro/nano-engineering, to the very large – major engineering structures.

Edinburgh

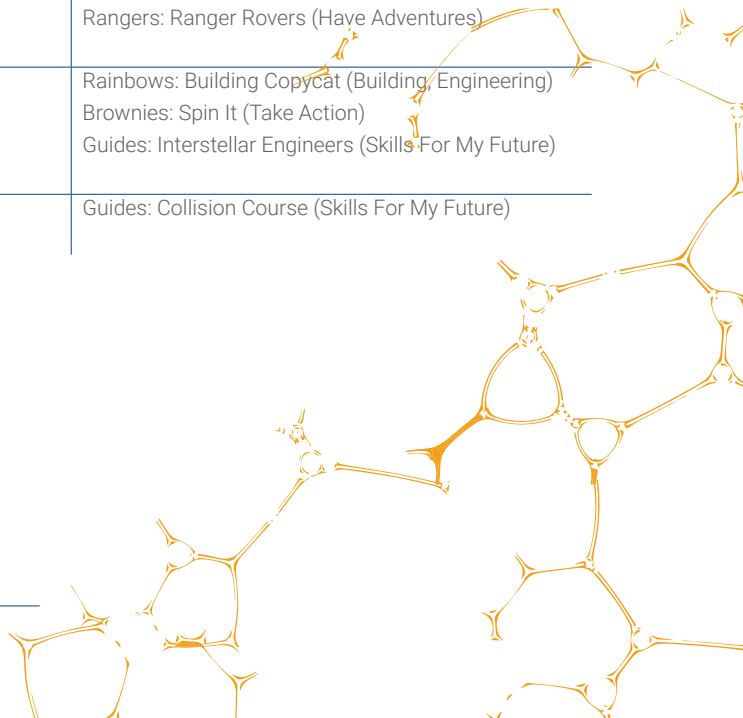
The Royal Observatory Edinburgh (ROE) is a historic site which combines three organisations: UK Astronomy Technology Centre (UK ATC), Institute for Astronomy which is part of the University of Edinburgh and ROE Visitor Centre for outreach activities. The ROE is unique in combining astronomical research, forefront technology, teaching, public outreach, and a rich historical heritage on a single site. The ROE Trust is a registered charity which acts to protect and showcase the heritage of the ROE, and to develop projects connected with public interest in Astronomy.



UK Astronomy Technology Centre, another site owned by STFC

Table of activities

Section	Activity Name	Target Audience	Related skill builder/ UMA/interest/activity badges
Fluid Engineer Page 6	Cabbage pH Indicator	All ages	Brownies: Magical Mixtures (Skills For My Future)
	Lava Lamp	All ages	Brownies: Magical Mixtures (Skills For My Future) Rangers: Fuels of the Future (Take Action)
	Fun with Oobleck!	All ages	Rainbows: What is That? Brownies: Slime Time (Skills For My Future) Guides: Clay Makers (Express Myself)
Optical Engineer Page 11	Communicating in Morse Code	All ages	Brownies: Crack The Code (Express Myself) Guides: Information Overload (Skills For My Future) Rangers: Cipher Decipher (Skills For My Future)
	Light Filters	All ages	Rainbows: Everyday Inventors Brownies: Camera Obscura (Skills For My Future)
	Optical Fibres and Light Paths	All ages	Brownies: On the Radar (Skills For My Future)
Project manager Page 17	Lost in Communication	All ages	Guides: Information Overload (Skills For My Future) Rangers: Ranger Rovers (Have Adventures)
	Problem Solving	All ages	Rainbows: Building Copycat (Building, Engineering) Brownies: Spin It (Take Action) Guides: Interstellar Engineers (Skills For My Future)
	Shepherd the Sheep	All ages	Guides: Collision Course (Skills For My Future)



Fluid engineering

Section 1

A fluid engineer is interested in the properties and behaviour of fluid. Understanding properties of fluids and how fluids interact is key for scientists and engineers working with them.

Fluid Engineers may be part of the design, maintenance, test and analysis of fluid-based mechanical systems and their dynamics.

Cabbage pH indicator

One of the properties of fluids is the pH.

pH is a measure of how acidic or alkaline a solution is, on a scale of 0-14. Water has a neutral pH of 7, acidic substances have lower pH values, and alkaline substances have pH values higher than 7. It can be measured using an indicator which changes colour in the presence of solutions with different pH values.

A natural indicator is red cabbage water! Red cabbage contains an ingredient called anthocyanin which reacts to solutions with different pH values.

What you will need:

- Water and kettle to boil
- Red Cabbage
- An acidic substance – vinegar or lemon juice
- An alkaline substance – baking soda or soap
- Knife
- Bowl or container
- Strainer

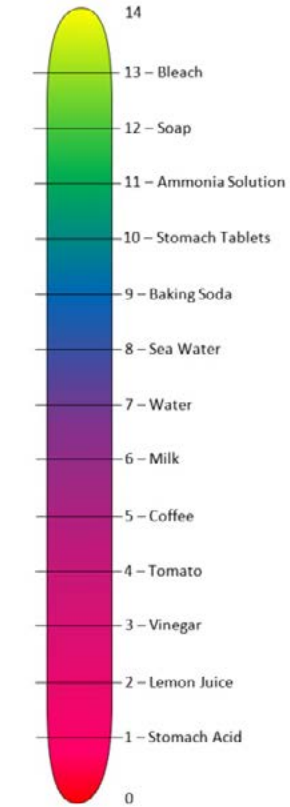
Prep work

1. Chop up the cabbage into small pieces.
2. Put the cabbage into a large glass container and cover with boiling water.
3. Wait around 10 minutes for the colour to leak out of the cabbage.
4. Strain the liquid, which should now be purple-coloured, into a separate container.
5. Separate the liquid into 3 different glasses.

What to do:

6. Provide 3 glasses of cabbage water per group. (Groups can be of any size to suit the unit).
7. Leave one of the glasses untouched so the colour remains the original purple.
8. Add either the acidic or alkaline substance to one of the glasses.
9. What colour does the water change to? Use the colour chart below to figure out if the substance was the acid or the alkali.
10. Add the other substance to another one of the glasses.
11. What colour does this water change to?

As an extension, alkali can be added to the acidic glass, and vice versa. This should change the colour again!



pH scale

Cabbage water pH indicator colorings

Lava lamp

In this activity, participants will make their own Lava Lamp which allows them to see fluid properties and how they can change.

Across STFC there are many experiments and systems where understanding fluid properties are important, such as space-based coolers and renewable fuel research.

Each lava lamp needs:

- 1x plastic bottle (or jar)
- 300ml Oil (For example, vegetable or sunflower oil)
- Water
- Food colouring
- Effervescence/fizzing tablet e.g. vitamin C tablets

Instructions:

1. Ensure the bottle is clean and label removed.
2. Fill about one third of the bottle with water.
3. Add a few drops of food colouring.
4. Fill the remainder of the bottle with oil.
5. Drop the tablet into the bottle.

DO NOT PUT THE LID ON THE BOTTLE WHILE THE REACTION IS OCCURING

Tips:

- Have a variety of food colourings, see what looks best!
- Before adding the tablet, you can shake the bottle to make bubbles of water in the oil.
- Break up the tablet before if you want the reaction to go quicker.
- Turn off the lights and put a torch under your lava lamp and see how it looks.

How it works:

There are many different scientific effects occurring in this experiment. Firstly, when we add the oil to the water, we see the oil floats on top of the water and does not mix. This is because oil has a lower density than water, meaning if you had the same amount of oil and water, the oil would be lighter.

When we shake the bottle we force the oil and water to mix and form coloured bubbles of water, this is because the oil is 'hydrophobic.' Due to their chemical structure, oil and water do not like to mix and they form bubbles so the water molecules can be close to other water molecules and away from oil molecules.

When the tablet is added it dissolves and makes carbon dioxide gas. This gas has a lower density (is lighter) than both oil and water so it rises, and we see this as small bubbles of gas. This gas carries bubbles of water with it and it rises through the oil. Eventually the gas escapes the water bubble and the bubble sinks back down through the oil as it is denser (heavier) than the oil again.

Water and Oil do not mix and will quickly separate if you try.

Gas bubbles carry water bubbles up through the oil. When the gas bubble pops, the water bubble falls back down.

Fun with Oobleck!

In STFC, fluid engineers look at the interaction of fluids and the thermal or mechanical systems they are a part of in order to verify their design. An example would be the investigation into the Beagle 2 Mars lander to understand how heat is transferred between the materials and structure it was made from. Engineers use thermal space test chambers at RAL to simulate how spacecraft would react in extreme temperatures, down to -100°C and make sure they will survive and achieve the mission goals.

In this challenge, the objective is for the group to create Oobleck, which is a non-Newtonian fluid. Its viscosity or thickness will depend on the force exerted on it. If you handle it gently, it will act more as a liquid and be runnier. The more forcefully you handle it, the more solid it will be.

What you will need:

- Water x 1 cup
- Corn flour x 2 cups
- Food colouring (optional)
- Glitter (optional)
- Surface protection e.g. newspaper
- Bowl
- Spoon
- Gloves (optional)

NOTE: Do not dispose of Oobleck down the drain. It can be easily washed off your hands with water and it should be disposed of in a bag in the bin.

To create the Oobleck, the ratio of water to corn flour is important. In a container, begin with the cup of water and 1 cup of corn flour, then add more corn flour to reach a more solid consistency. You will need to mix these for well over 10 minutes. Mixing and stirring gently will ensure an even consistency.

It will be ready when the faster you stir it, the harder it feels and gives more resistance but if you try to scoop it up, it will feel like a runny liquid.

For a bit of flare, add in food colouring and/ or glitter to make different coloured Oobleck!

Once the Oobleck is ready, you can try some tricks in the container before emptying it onto the table. It can get quite messy as it has a slimy consistency so make sure you have it on non-staining and well-protected surfaces to prevent any damage.

What to do:

The objective:

1. Create your Oobleck, adjusting the amounts of water corn flour to achieve the desired consistency.
2. Play with your Oobleck!

Some things to try:

1. Slapping it
2. Dropping it onto a table
3. Throwing it from one hand to the other
4. Holding it gently in your hands
5. Gently lower your finger into the Oobleck container and then try quickly pulling it out
6. Squeezing it

Write down what the results are from each of these actions. Discuss with the group whether they would describe Oobleck as a solid or a liquid and why, or whether it could have a combination of properties (I.e., it's a non-Newtonian fluid).

The science explained:

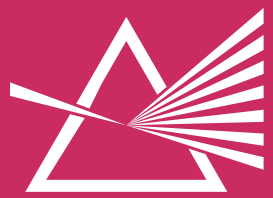
As mentioned above, Oobleck is a non-Newtonian fluid.

This is because the relationship between the water molecules and starch particles in the corn flour does not follow the observations made by scientist Isaac Newton on how liquids should behave.

When you apply a lot of force to the Oobleck, the starch particles group together to act as a solid surface, when this force is taken away, the water molecules give it a more liquid quality!

Oobleck acting as a liquid when dripped from a height into a bowl

Food colouring spirals in the Oobleck as it behaves like a liquid



Optical engineering

Section 2

Optical engineers are involved in controlling light for different purposes, by generating, transmitting, and detecting light. It can be used in communications, space observation, microscopes, and to understand properties of materials. Optical engineers work with LEDs, lasers, sensors, lenses and filters to manipulate the light.

Communicating in Morse code

An optical communications engineer uses light to send information and messages at very high speeds around the globe. There is nothing faster than light in the universe (that we know of!) and sending light is currently the fastest available method of communication.

Across STFC, optical engineers work in laboratories to design and test models which may be used to align telescopes for both ground-based and space-based missions.

Morse code uses combinations of dots and dashes to represent letters and numbers. It is a simple and reliable method to send messages when you cannot use modern communication such as emails and phone calls.

What you will need:

- Torch
- A clock that displays seconds
- A Morse code chart each (see the table)

This can be done in pairs, small or large groups.

What to do:

1. One person picks a letter from the Morse code chart.
2. Using the torch, switch it on and off to 'send' this letter to their group:
3. A long pulse of light is a dash, and a short pulse of light is a dot.
4. Agree beforehand how long the pulses and breaks should be. For example, 1 second for a short pulse (dot), 3 seconds for a long pulse (dash), and also long and short break times to mark breaks between letters or whole words.
5. The other people in the group note down the order of long and slow pulses.
6. Using a Morse code chart, translate the pulses into the letter or number.

Possible extensions:

- Decrease the times of the pulses and breaks to increase the speed of data transfer.
    - The faster data is sent, the faster you can receive messages, upload photos, load a webpage...we enjoy being able to do things quickly without have to wait for loading times. Exploring ways to increase speeds further is a constant area of research.
    - However, if data is sent too quickly that the receiver cannot understand the message, this can lead to miscommunication and confusion. The receiver may translate the code into the incorrect message. This may be demonstrated if team members struggle to keep up with the person using the torch.
- Try sending a word or even phrase via the torches – see if a pair can successfully send a question and an answer.

Morse Code charts

A	• —	S	• • •
B	— • • •	T	—
C	— • — •	U	• • —
D	— • •	V	• • • —
E	•	W	• — —
F	• • — •	X	— • • —
G	— — •	Y	— • — —
H	• • • •	Z	— — • •
I	• •	1	• — — — —
J	• — — —	2	• • — — —
K	— • —	3	• • • — —
L	• — • •	4	• • • • —
M	— —	5	• • • • •
N	— •	6	— • • • •
O	— — —	7	— — • • •
P	• — — •	8	— — — • •
Q	— — • —	9	— — — — •
R	• — •	0	— — — — —

Light filters

Optical Engineers can be involved in designing telescopes. For example, a team at the UK Astronomy Technology Centre in Edinburgh designed all the optics for the recently launched James Webb Space Telescope. This included lenses, reflectors and filters.

Here is an animated video demonstrating how light travels inside the telescope:

https://youtu.be/l_5OrKs7N8I

Filters are included in the optics of a telescope to help detect objects in more detail by increasing the contrast. Planetary filters are colour filters; they filter out all the colour from a scene except for the colour of the filter itself. If you use a red filter whilst observing Mars, a red planet, it increases the detail of the planet's markings.

In this exercise, different objects are going to be observed through different coloured filters to see how they are perceived to change colours.

What you will need:

- Objects of various colours, for example:
  - Red tomatoes
  - An orange
  - A green broccoli
- White paper
- Various coloured pens or paints
- Red, green, and blue colour filters –
  - This can be the see-through coloured wrappers from chocolates, or any type of coloured plastic that allows light through.
  - Primary Science Colour Paddles - Set of 18 (in 6 Colours) - by Learning Resources LER0352 | Primary ICT, £6.95 for a pack of 18 coloured paddles
  - Acetate Sheets A4 OHP Sheet Colour Acetate Clear Film Plastic Light Filter Gel Reading Aid Red, Yellow, Blue, Pink, Green, Clear Thick 100 Micron Reading Aid (A4 Size - Assorted Colour - 6 Sheets) : Amazon.co.uk , £3.99 for a pack of 10 colours

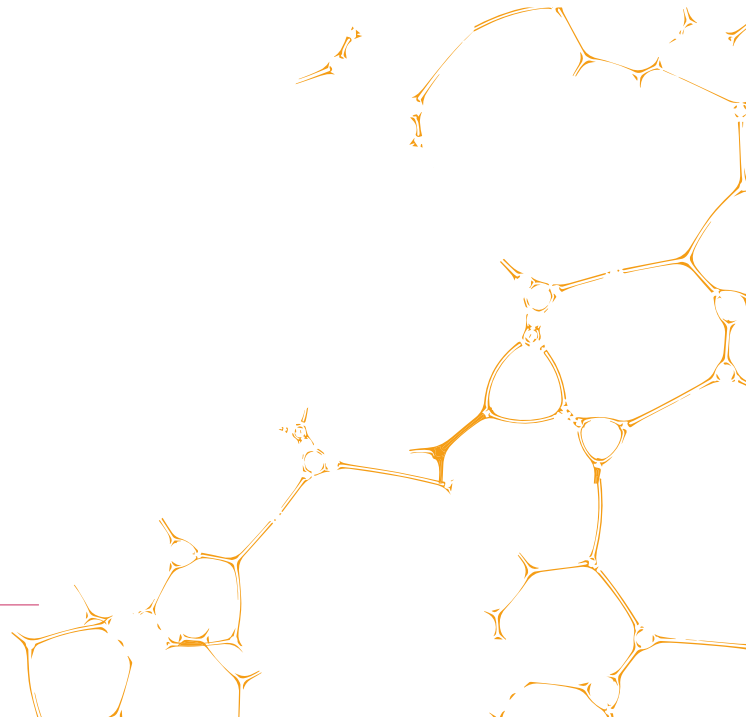
What to do:

1. Observe the objects through different filters.
2. Discuss what you can see and how the colours change with different coloured filters. Is it different from what you expected?
3. Draw your own pictures and observe them through the filters, and allow time for experimenting with different colours and combinations. The most effective colours will be the primary light colours of red, green, and blue.

Possible Extensions

As an extension, try looking through 2 or 3 filters at a time.

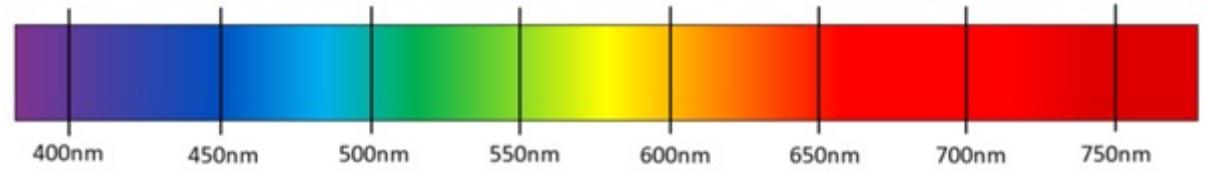
Look at a light through the filters, observe how combining filters allows different colours of light through.



What's going on?

Light is electromagnetic energy which travels as waves. White light is a combination of many colours, which can be seen in rainbows or soap bubbles! Each colour is a different wavelength and has a different energy. Here is a diagram that shows the different wavelengths in nanometres, a unit for measuring very small distances (there are a billion nanometres in 1 metre).

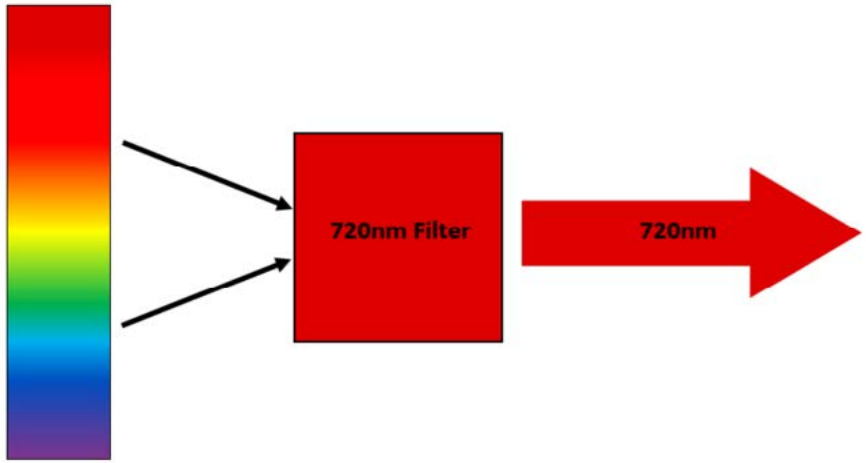
An optical filter works by blocking certain wavelengths and allowing only one, or a particular range, to pass through.



Spectrum of light, each colour comes from a wave with a certain wavelength.

Items appear to be different colours due to which wavelengths they reflect and absorb. Under white light a tomato appears red, as it reflects the red wavelengths in the white light and absorbs all the other wavelengths. If you look at the tomato through a green filter, it should appear black as there is no red light in the green for the tomato to reflect.

Applying the same principle to all objects: the colour they appear depends on the parts of the colour spectrum which are present.



A red filter with a certain wavelength lets through light with the same property.

Optical fibres and light paths

An optical communications engineer uses light to send information around the globe. To transport these light signals, specialist tubes called optical fibres are used. An optical fibre is a very small tube, with a diameter of less than half a millimetre, made of either glass or plastic. The fibre uses different materials to reflect the light inside the tube. The tube acts as a path for the light to travel in.

Referring to the diagrams below:

- The light ray travels inside the core.
- The cladding reflects the ray, so that it stays in the core and does not leave the fibre.
- The plastic coating protects the delicate fibre from being damaged.

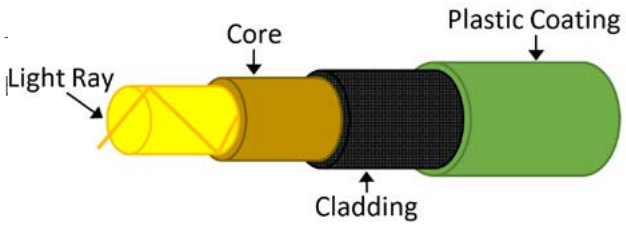
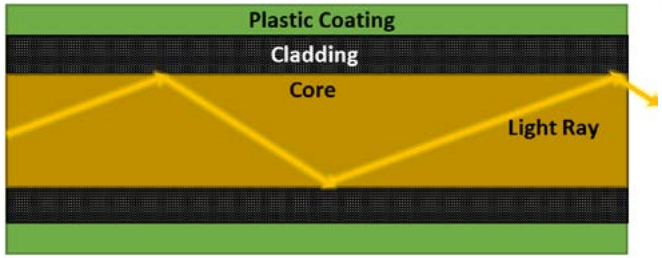


Diagram of material make-up of an optical fibre



Light ray carried along a tube by repeated reflections off the tube cladding

What you will need:

- Torch
- White paper with a target drawn on
- Mirrors or foil on cardboard
- Cardboard tubes to use as paths e.g. pringle tubes, kitchen rolls, loo rolls
- Thick tape e.g. parcel or masking tape
- A room which can become reasonably dark

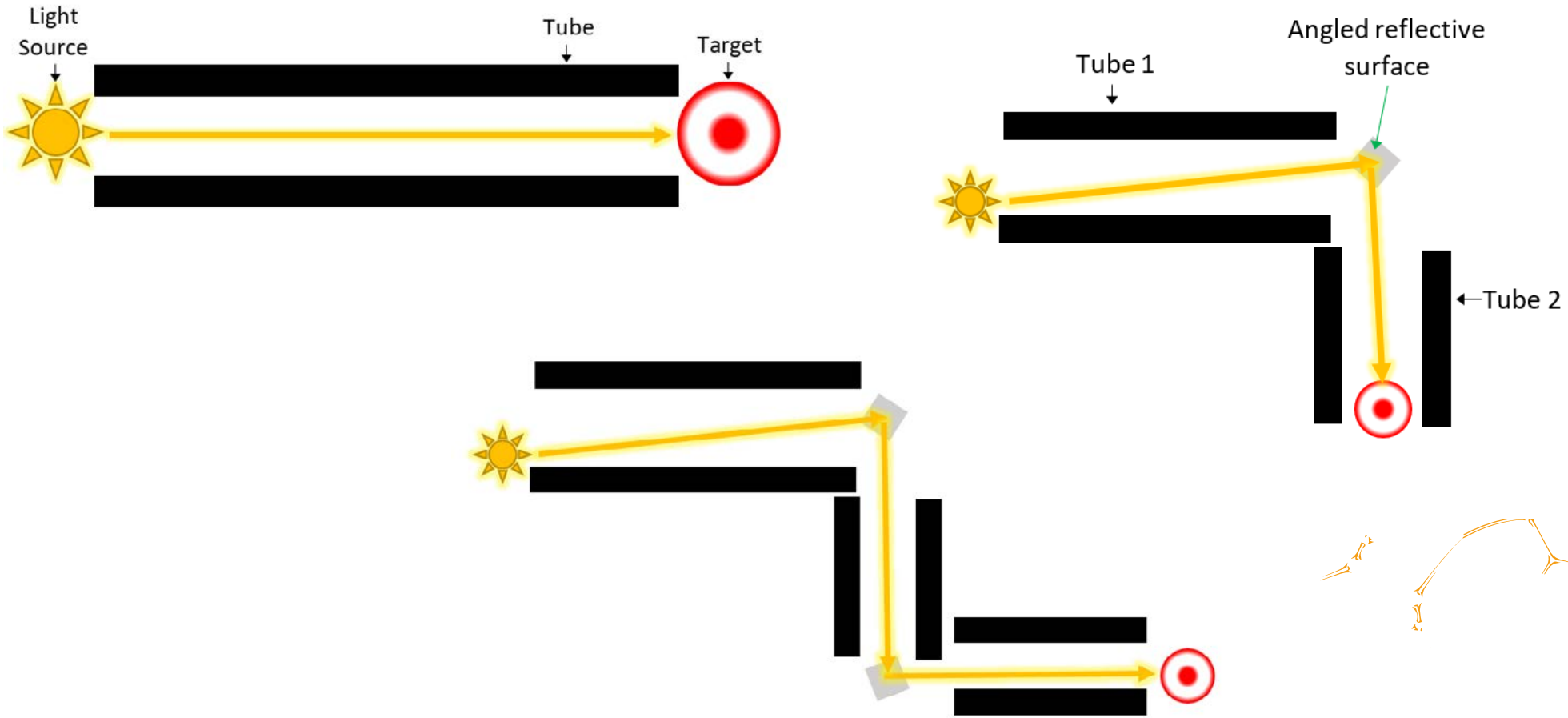
This can be done in pairs, small or large groups.

What to do:

- Set up a straight path with no turns. Use the tube as the path. Place the target at one end and shine the torch through the other end, aiming to hit the target.
- Create a path with one corner.
  - Use two tubes for the two sections of the path.
  - Between the tubes place the mirror or foil on cardboard.
  - Adjust this mirror so it reflects the light coming from the first tube down the second tube.
  - Aim to hit the target again.
- Once happy with one corner, add more tubes and corners to create a more complicated path.

Consider creating paths with one corner in pairs/ small groups, and then as an extension make a larger, more complicated path as a big group.

When making a complicated path, adjust the reflectors one at a time starting with the one closest to the entrance.



Light rays passing through a tube; directly to a target (Upper left), reflecting off an angled surface (Upper right), and performing multiple reflections (Lower).

Project manager

Section 3

Within a project there will always be important support roles, including a project manager and support engineers.

A project manager oversees a full project and guides the team members to ensure the project is completed smoothly within budget and on time.

A support engineer is usually a specialist in their field and will support multiple projects and people at once. If someone is struggling with an issue, they can ask for help from a support engineer. The supporter often works through the problem with them, showing them the process of how to solve their issue instead of simply presenting them with a solution.

Lost in communication

Communication between people and teams is an essential tool in achieving your objectives. It is necessary at all levels to ensure any risks and issues are dealt with promptly, to ensure team members all know what they are doing and that tasks are completed on time and to the right specifications.

It is important to note that not all projects always go to plan, there will be times where things go wrong, and effective communication is needed to overcome any obstacles.

A spacecraft could crash on another planet due to poor communication!

In this challenge, the group have crashed and are stranded on Mars. One member of the group is given a list of objects which may help them get off the planet and back to civilisation. In a team of 3 people, they have 15 minutes to compile a list of the 15 objects and order them from most useful to least useful.

What you will need:

- 3 people per team
- Pen and paper
- A list of 15 objects:

1. "How to build a rocket" book
2. Spacesuit
3. Torch
4. Mirror
5. Water
6. Rations for 2 days
7. Suncream
8. Rope
9. Sundial
10. First aid kit
11. Tool kit
12. Tent
13. Oxygen tank
14. Knife
15. Seeds

What to do:

1. Out of your team of 3 people, one person is not able to speak and the team should decide who this is. This person will then be given the list of 15 objects (in a randomised order) and they will have to convey – through actions – what that object is. The remaining 2 people are not able to see the list.
2. The responsibility of the other 2 within the team is to determine what the objects are from the first person's actions, and write them down.
3. Once you have conveyed all the objects, and they have been written down, you then need to re-order them from most useful to least useful.

Adapting for different ages:

Easy (<10 y/o): Guide with hints of why the objects could be useful, allowed to skip steps 1 and 2 and go straight to step 3.

Medium (10-15 y/o): Teams of 4 people, 2 can view the list, 2 cannot. Steps 2 and 3 as normal.

Hard (15-18 y/o): Steps 1-3 as stated above.

Possible solutions:

There is no right or wrong answer to this challenge, but the challengers need to be able to justify their order choices.

1. "How to build a rocket" book – In order to leave the planet, you would need to have the fuel and launch pad (currently not on Mars), so this would not be of much use.
2. Spacesuit – Essential for moving around on Mars, to save yourself from exposure to the harsh climate.
3. Torch – Light is the fastest mode of communication so using this to signal others via Morse code could be essential, although you would need a strong torch.
4. Mirror - Light is the fastest mode of communication so using this to signal others via Morse code could be essential, and you can use this to reflect the Sun's rays back to Earth.
5. Water – Water is essential for survival. A person can only survive without water for 3 days, and you will find it difficult to get liquid water on Mars.
6. Rations for 2 days – It is believed that the human body can survive 1 to 2 months without food, as it can convert fat stores into energy.
7. Suncream – As Mars' atmosphere is much thinner than that of Earth's, more of the Sun's rays will hit the surface. This means you have a higher chance of getting sunburnt on Mars than on Earth.
8. Rope – This would be useful for tying around large, heavy objects so that they can be moved around (for example, when trying to build a permanent shelter).
9. Sundial – Useful for telling time on Earth – but you would have to have one that is specifically adjusted to the Mars Day or a 'Sol' which is roughly 40 minutes longer than a day on Earth.
10. First Aid Kit – Considering you have just crash landed on Mars, a first aid kit will more than likely come in handy.
11. Tool kit – This will be essential in helping to create a long-term shelter (should it be needed) from parts of the rocket ship.
12. Tent – Great for short-term shelter and protection from the Sun, although you would need one big enough to fit you all and your spacesuits.
13. Oxygen tank – Martian air has too little oxygen and too much carbon dioxide, making it toxic to humans, therefore an oxygen tank will be essential for short-term, but you will need a longer-term solution after the tanks run out…
14. Knife – Could have numerous uses: cutting food, cutting out softer materials in the spaceship to be used for other purposes.
15. Seeds – You will need a long-term food source in case you are stranded for a while, seeds could be a great way to grow your own fruit and vegetables (although how successful that would be is up for debate).

STFC public engagement event

Puzzle solving

Within STFC, there are Project Support roles which are responsible for supporting or managing projects. It is vital that excellent communication is maintained between the support engineers and team members so problems can be solved as efficiently as possible.

In this challenge, the objective is to solve one of the puzzles from Appendix as a pair.

Stepan's Quintet © NASA, ESA, CSA and STScI

Cosmic Cliffs in Carina © NASA, ESA, CSA and STScI

What you will need:

- 2 people
- 1 puzzle*
- 1 person acts as the 'Guide'
- 1 person puts the puzzle pieces into place, the 'Placer'
- 1 blindfold

* The pictures for the puzzles can be found in Appendix of this activity pack. Please print out the pictures and cut them according to the difficulty suitable for the age group of the challengers.

Our recommendation is as follows:

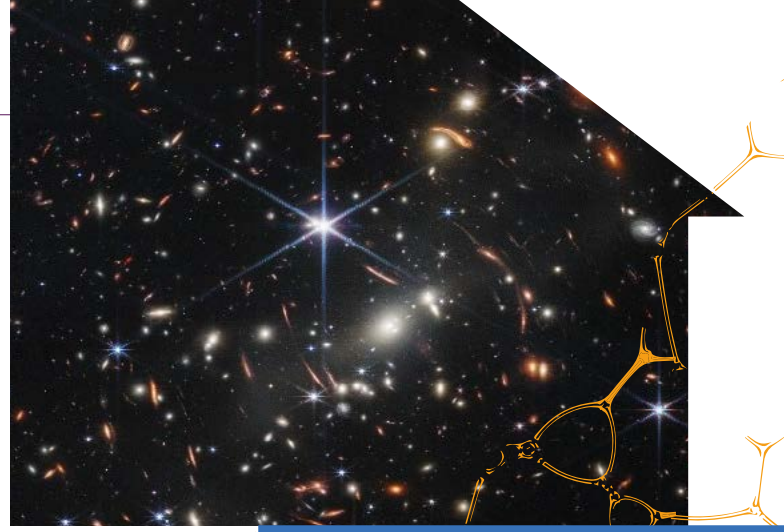
- 5-7 y/o: 4 pieces
- 7-11 y/o: 10 pieces
- 11-15 y/o: 15 pieces
- 15-18 y/o: 25 pieces

NOTE: Some pictures are more difficult than others and it may be better to have these images as smaller piece puzzles for younger challengers.

What to do:

The rules are as follows:

1. The person appointed as the Guide is not able to touch the puzzle pieces.
2. The person appointed as the 'Placer' needs to be blindfolded.
3. To start, the Placer sits in front of the puzzle to be solved. They are not able to see the puzzle pieces in front of them and are therefore reliant on the Guide to help them complete the puzzle.



James Webb first deep field image © NASA, ESA, CSA and STScI

4. The Guide is allowed to give any instructions they like in order to help the Placer solve the puzzle, without touching any of the pieces or guiding the Placer's hands. They are only allowed to communicate instructions verbally to the Placer .

The objective:

- Complete the puzzle.
- Set a timer to see how many puzzles each pair of challengers can complete in that time, or have a race to see who can get to a pre-determined number of puzzles first.

Helpful tips:

1. Start with corner pieces.
2. Use exact instructions such as: Rotate clockwise 90 degrees.
3. Give clear and concise instructions.

Shepherd the sheep

In STFC there are many members of staff working across different projects. Effective communication is essential in carrying out tasks to a high standard, to achieve the world-class science, technology and innovation.

In this challenge, the objective is for the group to establish a method in which one shepherd can direct all the sheep into the pen.

What you will need:

- One person to act as the 'Shepherd'
- A group to act as the 'Sheep' (the number does not matter, the more people, the longer it will take)
- Rope
- As many blindfolds as there are people

What to do:

The rules are as follows:

1. The person appointed as the Shepherd is not able to speak or move.
2. The people appointed as the sheep are not able to see and are only able to make sheep noises such as 'bah'. They can move as freely as they wish.

The objective:

1. You will need to set up the rope in a circle, leaving a metre gap between the ends to act as the 'entrance' to the coop.
2. The group, collectively, have 10 minutes in total to establish:
3. Firstly, who will be the 'Shepherd', the rest will be the 'Sheep'.
4. Secondly, a method in which the Shepherd can successfully direct all the sheep into the coop, in line with the rules above.
5. After the 10 minutes, the Shepherd will stand in one corner of the room. The 'sheep' will all need to be blindfolded and placed randomly in the room. You will then need to carefully spin them round a couple of times to disorient them.
6. When you have placed all the sheep, you can signal to the Shepherd that they can begin their herding. There is no time limit for this section, the group can take as long as they need but if any of the rules are broken, the 'shuffling' at the start of the game need to be repeated and the game starts over again.

Helpful tips:

There are numerous ways in which you can make this work, but here are two possible solutions:

- Coming up with a role call for which number each of the sheep corresponds to.
- Having one sheep yell 'bah' to direct all other sheep towards them so that they can be directed as a group.
- Establishing signals in which the Shepherd can communicate if a sheep is moving in the right or wrong direction.

Adapting for different ages:

- Easy (<10 y/o): Give them the helpful tips at the start. Give the solution after 1 or 2 attempts of their own. No need to worry about having a set plan to begin with, they can troubleshoot as they're going.
- Medium (10-15 y/o): Give the solution after 1 or 2 attempts of their own. No need to worry about having a set plan to begin with, they can troubleshoot as they're going.
- Hard (15-18 y/o): Follow 'The objective' as stated above.

A solution:

1. Establish a role call for all the sheep.
2. Once they sheep have been shuffled, the Shepherd claps once to make their sheep hold up their numbers.
3. The Shepherd claps as many times as the number of the sheep closest to the pen.
4. This sheep, now identified as the lead 'sheep' makes 'bah' noises to attract the remainder of the sheep to them, forming a line of sheep behind them.
5. Once all the sheep have been collected, only the Shepherd will know and the Shepherd can then direct the lead sheep into the pen. The signal for this being complete can be 3 claps in quick succession.
6. Now that all sheep have been collected, 1 clap from the Shepherd signifies that the sheep outstretches their arm and sweeps it slowly across the room to determine the route to the pen, 2 claps indicate the right direction from the Shepherd and to start walking. 3 claps indicate to stop walking as the lead sheep is now in the pen. 5 claps indicate all sheep have been directed successfully into the pen.

Careers

If your group has enjoyed these activities, maybe they would like to consider their next steps. We offer many opportunities for real-life experiences:

Work experience

We offer one- or two-week work experience placements to over 100 year 10, 11, 12, and 13 students each year, applications usually open at the start of the year. **https://stfc-workexperience.co.uk/**

Apprenticeships

STFC has over 20 years' experience in providing engineering apprenticeships and provides an excellent training ground to equip individuals with the relevant skills and experience for their chosen career. There are competitive salaries that increase annually, 4 years of supervised training, additional core skills development and the opportunity for overseas placements.

Summer placements

We offer a variety of summer placements, usually lasting 8-12 weeks that can be completed during a degree, or whilst still at school.

Industrial placements

There are a variety of industrial placements up to a yearlong which can be completed during a university degree.

Graduates

There is a graduate programme for people who have completed their degrees. The programme helps with building necessary workplace skills, bridge the gap between full time education and employment. All the information and opportunities at STFC can be found on the careers website: **www.stfccareers.co.uk/careers/**

Early careers people working across RAL Space labs, offices, clean rooms, space test facilities and in the field at observatories.
Credit: STFC RAL Space, Phil Perillat/Arecibo Observatory

Acknowledgements

This pack was created by Aristea Seitis, Ocean Bach, Rowan Read, and Sukhvinder Singh who are graduates at STFC RAL, with support from Vicky Hall.

We would like to give thanks to our funders; the STFC graduate scheme and the STFC SPARK awards, as well as advice received from Vicky Hall, and Girlguiding Oxfordshire and Oxfordshire Scouting.

About the team

Téa Seitis

Téa is a Project Manager within the Imaging Systems Division of RAL Space, having joined as part of the 2020 Graduate cohort. Since starting at RAL, she has managed medium- to large-sized electro-optics engineering projects, such as PUNCH, HARMONI and ProSPA, in collaboration with partners such as NASA Goddard and the European Space Agency. Téa joined STFC following an MGeol in Geological Sciences from the University of Leeds.

Ocean Bach

Ocean is a Scientific Engineer in Cryogenics and Magnetics and RAL. Ocean's team design and build cryocoolers for satellites, cryocoolers are fridges which get very cold and are used to cool telescopes and other components in space.

Rowan Read

Rowan is a Microelectronic Support Engineer within the Microelectronics Support Centre at RAL, she is responsible for providing training to and supporting academic researchers across Europe with the use of analogue integrated circuit design tools. Rowan joined STFC as a graduate in 2020 after completing a MEng in Electrical & Electronic Engineering from the University of Sheffield.

Sukhvinder Singh

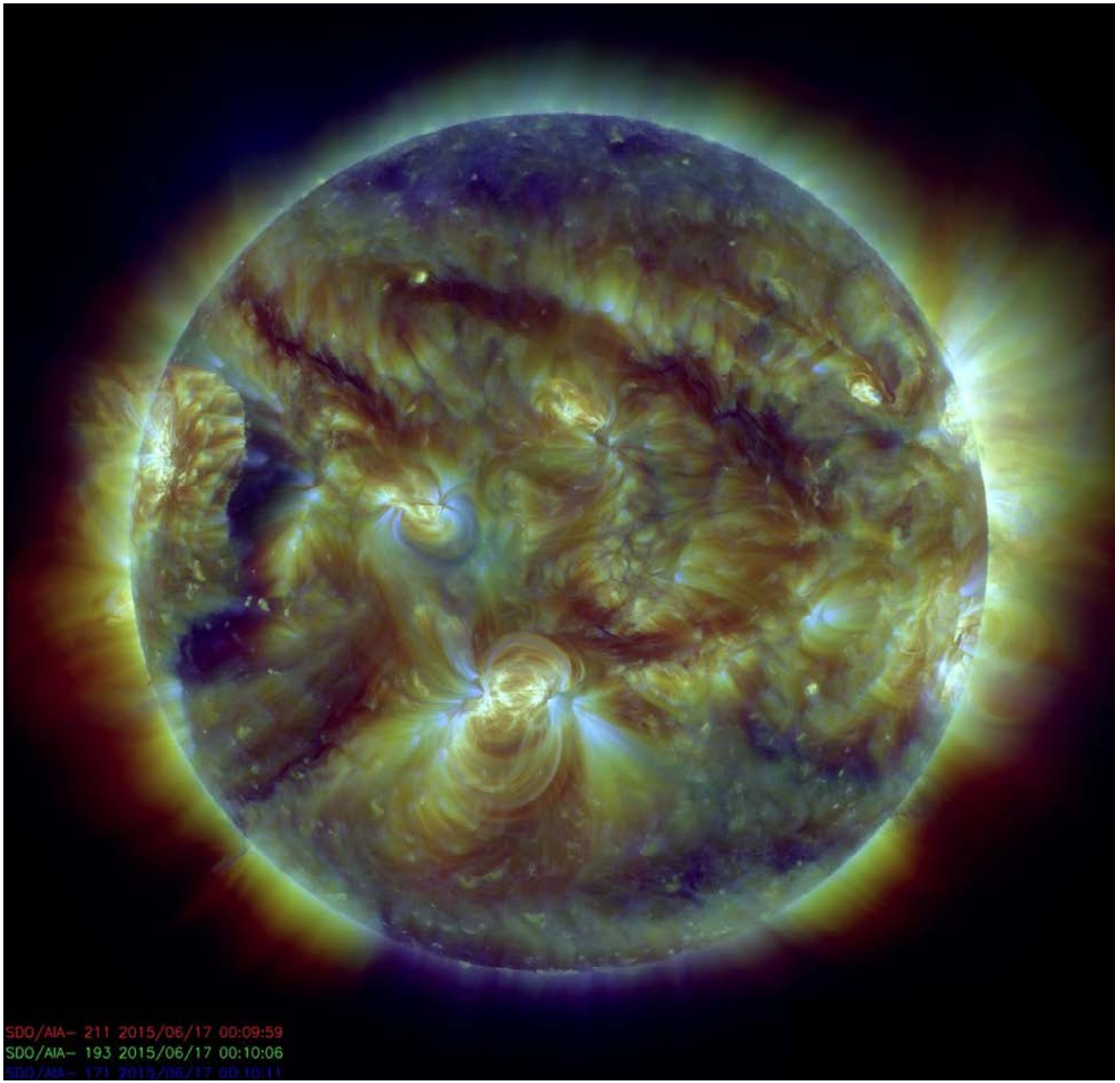
Sukh is a Project Manager within ISIS Computing Division based at RAL. He was a placement student during 2019/20 period and then re-joined as part of the Graduate cohort 2021 after completing a BSc in Computing from University of Gloucestershire. He manages IT projects which help facilitate some of the science that happens at RAL such as new proposal submission software upgrade, New User Dashboard, upgrade of older hardware infrastructure.

Vicky Hall

Vicky is the Engagement and Communications Officer for RAL Space. After graduating with an MPhys in Physics and Astronomy from Durham University, she gained teaching experience and combined her expertise in science and languages to pursue science communication. She runs outreach and engagement activities for the public, schools, universities and stakeholders across industry and government. She manages and trains the department's STEM Ambassadors to deliver inspirational space activities.

Appendix

Tip of Cornwall	Taken on 25/03/2020 by the Sentinel-2B satellite. Copernicus data processed by RAL Space.
Cosmic cliffs in the Carina Nebula, where stars are being born	Taken by NIRCam and MIRI on board the James Webb Space Telescope (JWST). Credit: NASA, ESA, CSA, STScI.
Southern Ring Nebula, leftover from a dying star	Taken by MIRI on board JWST. Credit: NASA, ESA, CSA, STScI.
The Sun's solar filaments	Taken by NASA's Solar Dynamics Observatory.
The Sun ejecting a solar flare	Taken by NASA's Solar Dynamics Observatory.
Stepan's Quintet, a group of five galaxies	Taken by MIRI on board JWST. Credit: NASA, ESA, CSA, STScI.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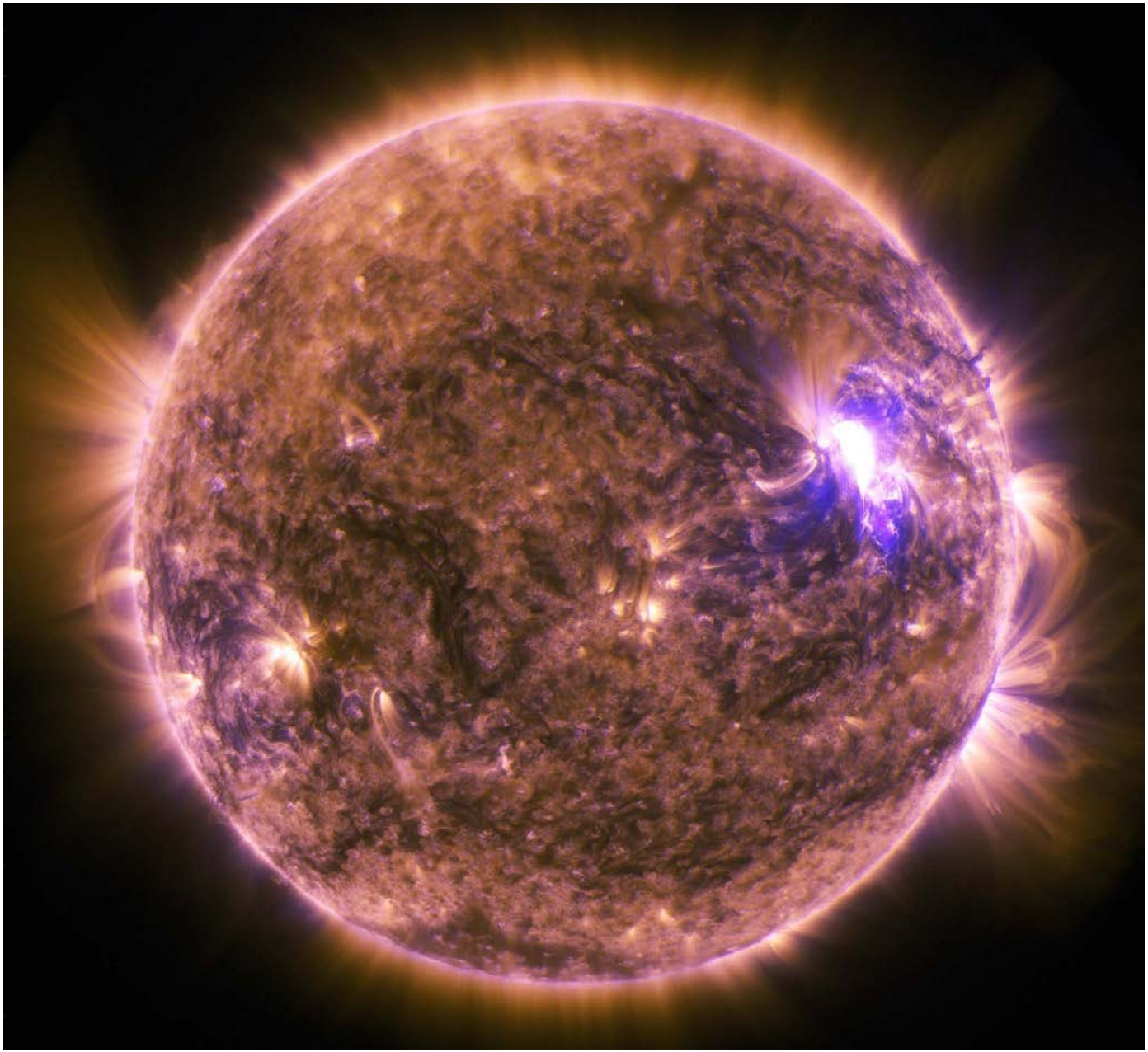
SDO/AIA- 193 2015/06/17 00:10:06



Ocean Bach

Cryogenics Engineer
Technology, RAL

Describe yourself in 3 words.

Enthusiastic, Ambitious, Analytical

What is your typical day like?

My day is a mixture of design work and calculations for various components. My designs will be used on satellites such as ARIEL which will be used to discover new exoplanets.

I work with low temperature fluids such as liquid helium (-270°C); properties of fluids change with temperature and knowing about this is key.

Why is the work you do important?

My work contributes to multi-national projects which make scientific discoveries. Our group did key work on the Planck satellite which calculated the age of the universe!

Why did you choose to work at STFC?

STFC has a great working atmosphere and allows you to work on many world-class science projects.

What are the top 3 skills you need to work at STFC?

Critical thinking, Passion for science, Problem solving

Richard Cowan

Sustainable energy engineer
Technology, RAL

Describe yourself in 3 words.

Curious, Enthusiastic, Friendly

What is your typical day like?

I will come into work, and after chatting with colleagues, I will work at my computer on producing heat flow simulations, fluid flow simulations or otherwise to inform the design work we do. I might also have some meetings to discuss projects or build some of the experiments we are making.

How do you work with fluids?

I simulate the flow of fluids, either gasses or liquids or both, to work out how they expert forces around them, and how best to use them. Usually this is done on computer simulations but often it also involves real models to test and designing pieces which can be put into production.

Why is the work you do important?

I get to work on projects that make a real difference to the world, such as exploring new ways of making green fuels for ships. My work protects people, by ensuring environments are safe to work in and leaks and failures are minimised.

Why did you choose to work at STFC?

STFC is a very broad, academic-focused organisation, with a lot of scientists, engineers and technicians working from a lot of different backgrounds, and I get to work on innovative and cutting-edge projects, so I learn something new every day working here.

What are you most proud of?

When I design a part and then hold it in my hands, and then see it working, that's when I feel most proud.

How did you get here?

I studied Aerospace Engineering at Bristol because I liked physics and maths but wanted to do something practical. I applied to STFC and I liked the interview and it seemed like a fun place to work, with the right mix of interesting problems and friendly people.

What are the top 3 skills you need to work at STFC?

I think you need to be curious about the world, be excited about discovering new things and solving problems, and a certain amount of attention to detail.

Bea Fischer Harrison

Optics Engineer
RAL Space, RAL

Describe yourself in 3 words.

Positive, Confident, Open-minded

What is your typical day like?

My typical day involves modelling optical systems in a software called Zemax. I am currently working on a project called ARIEL which is a satellite due to launch in 2029 to image exoplanets using infrared cameras to observe their atmospheres and chemical compositions. This will answer fundamental questions about the formation and evolution of planetary systems. I also do lab work aligning optics and modelling the common components on the satellite.

Why did you pick to be an Optics Engineer?

I studied Astrophysics at university and had a placement year working with high power lasers. During that year, I would work in optics labs to align the laser beam and have since enjoyed laboratory work involving optical systems.

Why is the work you do important?

STFC is a facility striving for innovation and knowledge. By undertaking these important projects, RAL Space is carrying out world-class research and technology development in the quest of advancing the understanding of space and our environment. Every single employee at STFC partakes in this vision and works towards an increased knowledge of our universe.

Why did you choose to work at STFC?

I chose the graduate scheme at STFC after taking my placement year there. I found that I made significant advancements in my professional career and working in laboratory environments. I thoroughly enjoyed the practical work and projects that I partook in and felt that the natural step after university was to continue with my personal and professional development at STFC.

What are you most proud of?

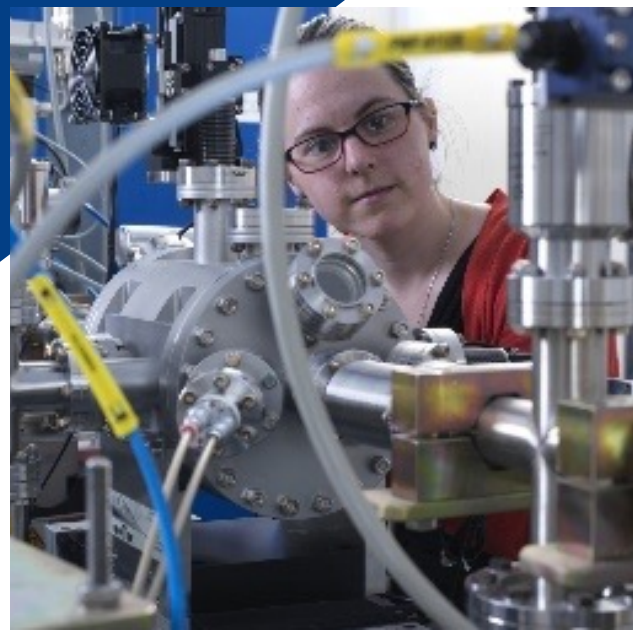
I am most proud of the personal development I have had through my placement year and the time spent on the graduate scheme. I grew up very reserved and shy but taking a placement year forced me out of my shell and to interact with large teams working on a variety of projects. I now consider myself a very confident and extroverted person. This is down to the people I met working at STFC and the incredible work environment it has. I was able to present my project work in a safe and educational space, to gain confidence in public speaking which I had previously struggled with.

How did you get here?

I studied Astrophysics at Loughborough University where I had a placement year at STFC as a Vulcan Laser Sandwich Student. I then undertook an MSc at the University of Edinburgh in Mathematical Physics before applying to the graduate scheme in RAL Space as an Optics Engineer.

What are the top 3 skills you need to work at STFC?

Communication, Problem Solving, Teamwork



Ann Fitzpatrick

Optics Engineer
RAL Space, RAL

Describe yourself in 3 words.

Friendly, Curious, Hardworking

Why did you pick to be an Optics Engineer?

I chose to be an optical systems engineer as it allows me to continually learn new skills and be part of huge projects doing amazing things no one could do on their own the work I do is important because it makes large projects like the James Webb Space Telescope possible. The science done by these instruments adds to human knowledge, so this is my way of contributing to forwarding our understanding of the universe.

Why did you choose to work at STFC?

I have worked for different parts of STFC for 8 years and I love the wide variety of research it enables.

What are you most proud of?

I am proud of all the projects I have been involved in, but I am probably most proud of the ultrafast laser spectroscopy instrument I built while living in America.

How did you get here?

I did my undergraduate in Physics and then my PhD was in Biomolecular Sciences. After that I have always looked for new jobs which are challenging and collaborative where I can learn new skills.

What are the top 3 skills you need to work at STFC?

Communication, Proactive, Innovative

Tristan Cakebread

Microelectronics Support Engineer
Technology, RAL

Describe yourself in 3 words.

Determined, Versatile, Curious

What is your typical day like?

Most of my day is spent investigating a wide variety of different problems being experienced by customers with microelectronics design software, and identifying the correct solution to resolve them.

I also regularly deliver training courses to teach customers the best design methodologies and use of design tools to design microelectronics circuits.

Why did you pick to be a microelectronics support engineer?

I am fascinated by microelectronics and enjoy learning more and more about them. I enjoy helping people and resolving their issues, and this role allows me to do this whilst also working with a technical area I find incredibly interesting.

Why is the work you do important?

Microelectronics are vital in the modern world to keep progressing and help resolve some of the key challenges humanity faces. Supporting people with the design process is crucial to enable them to focus on their high-performance specialised designs.

What do you enjoy most about your role?

I support a wide range of different electronics design tools and technical areas, and I find this variety to be very enjoyable.

What are you most proud of?

I have worked hard to develop my knowledge in a wide array of technical areas, and I am proud the versatility I have developed because of this.

How did you get here?

I have been an electric guitar player from a young age, which gave me a big interest in electronics and eventually lead to me choosing to study electronic engineering at university, and STFC after graduating.

What are the top 3 skills you need to work at STFC?

Problem solving, Keenness to learn, Communication

Sukhvinder Singh

Project Manager
ISIS, RAL

Describe yourself in 3 words.

Ambitious, Passionate, Sociable

What is your typical day like?

As a Project Manager/Product owner, I manage multiple projects which includes monitoring tasks, project boards, software issue board, and issues priority. In a typical day I would liaise with the technical lead and software developers via regular online meetings and via email. I often liaise with the high-level stakeholders to provide update on project progress, new functionality requirements, and software releases.

Why did you pick to be a Project Manager?

I enjoyed working with various teams and I liked working with technology and as a project manager in the computing area I get to do just that. I like being the person that bridges the gap between the technical side to the customer side.

Why is the work you do important?

I manage the delivery of new software, new functionality, new hardware and bug fixes to support our end users such as the instrument scientists. Without my role there wouldn't be anyone to ensure the software or hardware is delivered on time in line with the deadline of the organisation such as ISIS operating cycles. My role is necessary to ensure that tasks within the project are assigned to the team members and are completed in line with the project schedule and budget.

Why did you choose to work at STFC?

I've always enjoyed making a difference and being at STFC allows me to do just that, for example the work that I do in my role, facilities part of the science that goes on at STFC which enables the scientists to carry out the work they need to.

What are you most proud of?

I did a sandwich year (placement year) whilst I was at university, and I am proud of the work that did during that period and as a result of that I was offered my role that I am doing today. Whilst being on the graduate scheme at STFC I've had the opportunity to be involved in many graduate activities, public engagement activities.

How did you get here?

I undertook a BSc in Computing at the University of Gloucestershire, and as part of that I did a sandwich year at STFC and at the end of the year I was offered a graduate role.

What are the top 3 skills you need to work at STFC?

Passion, Dedication, Friendliness

Téa Seitis

Project Manager
RAL Space, RAL

Describe yourself in 3 words.

Enthusiastic, Driven, Outgoing

What is your typical day like?

As a Project Manager, I monitor my projects to ensure that the tasks are being done on time and to a pre-determined budget. In a typical day this would consist of liaising with the Project Engineers and Customers via Email or Zoom, updating schedules and monitoring risk and finance pages.

Why did you pick to be a Project Manager?

I have always been well-organised and quite an outgoing person. Project Management allows me to develop these skills.

Why is the work you do important?

Without Project Managers, there would be no one to ensure that a project is delivered to specification and to budget. We are necessary to provide a structure, ensuring that each individual task is completed so that projects can succeed.

Why did you choose to work at STFC?

I have always been passionate about the space industry; RAL Space has enabled me to be involved directly in the innovative technology we are producing for Space companies around the world.

What are you most proud of?

Working at STFC has enabled me to take part in numerous Public Engagement opportunities. For example, most recently, running a booth at the UK in Space Festival at the National Space Centre in Leicester, where attendees could build and test their own spacecraft using our shaker table!

How did you get here?

I undertook an Integrated Masters of Geological Sciences at the University of Leeds, where I was able to study abroad at Western University. This consisted primarily of Planetary Science and Astronomy modules and allowed me to explore my interests in space further.

What are the top 3 skills you need to work at STFC?

Determination, Eagerness to learn, Innovation

The badge design has been expressly approved by Oxfordshire Scouting, Girlguiding and STFC.