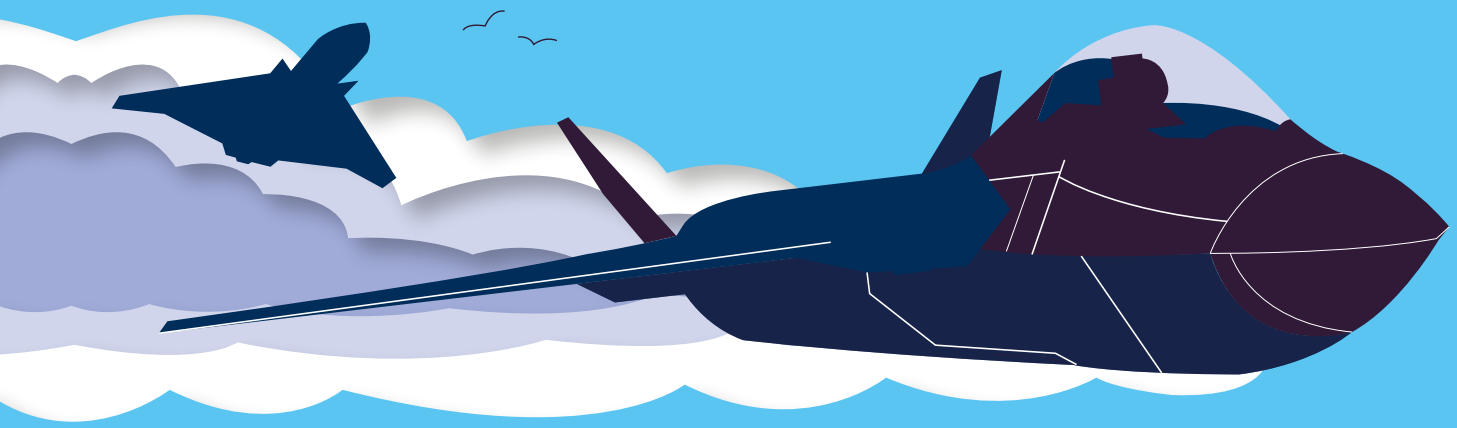
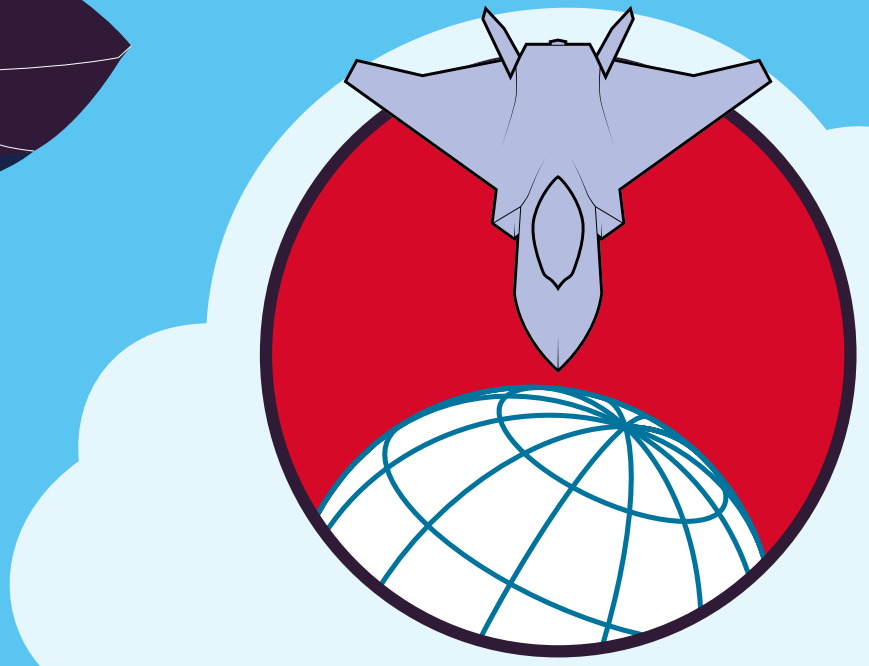
Future of flight:

Communication





Royal Academy of Engineering

THIS IS ENGINEERING

TEAM TEMPEST

Introduction

Communication is a fundamental part of engineering. We have been constantly developing and evolving the different technologies and systems in place to send and receive information.

The Tempest aircraft will be designed to be at the centre of a wider communications system, from human interaction to communicating with computers as well as computers communicating with other computers. The aircraft will have the capability to send and receive this information clearly and securely.

Case studies

Sarah

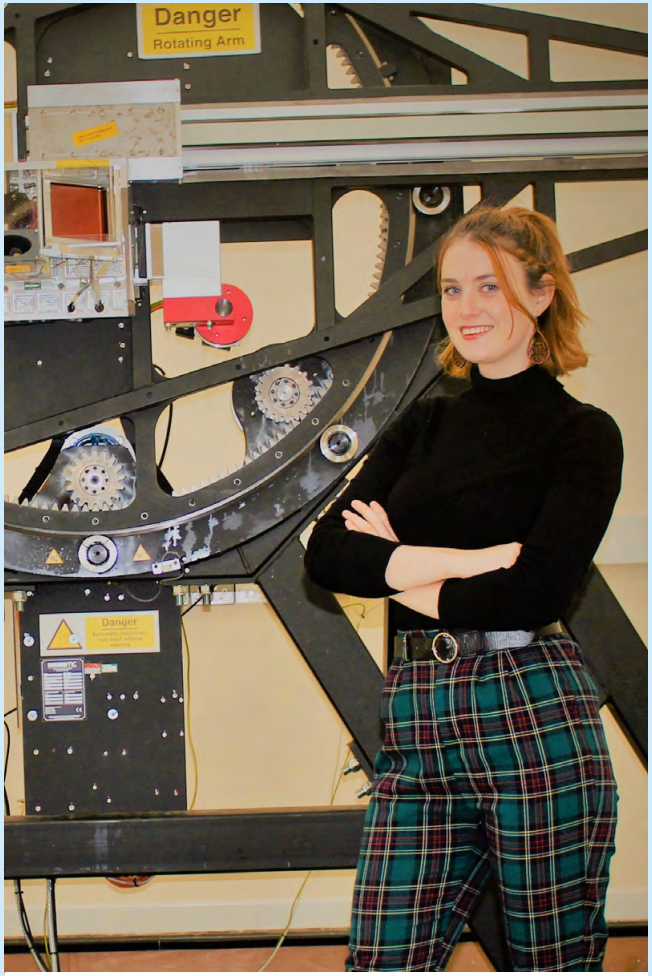
Senior hardware engineer at Leonardo

I was lucky enough to grow up in a family of Scientists, Engineers and Mathematicians. Curiosity about the world around me was engrained into me, and I was encouraged to always ask the What, Why, How questions – no matter how silly they seemed. What makes flowers grow? Why is the sky blue? How do cars go?

Now, I have a job designing the electronics for future generation aircraft systems. These systems give the pilot what is called 'situational awareness' which means that they give the pilot the ability to 'see' objects in the sky that they might not be able to see with their own eyes because they are very far away, moving very fast or obscured by clouds.

My job, along with lots of other types of engineers, is to make sure that the sensors on the outside of the plane communicate with all the different parts of the system, so that they will always alert the pilot to exactly what is going on around them and ultimately, keep them safe.

The thing I love the most about this job is the collaboration – I am constantly working together with other people to solve problems and come up with new ideas. My day can be anything from conceptualising and simulating new designs on my laptop, to trying out prototypes in the lab, to overseeing the installation of the final system on an aircraft – and there's not a messy overall in sight!



"The best part of my job is working on the forefront of technology, everything we do is looking towards the future and it is exciting to be working with innovative equipment."

Sean

Aerospace Systems Engineer at BAE Systems

Through my younger years, I was always interested in machines, technology and engineering. After attending air shows and other events, I knew I wanted to work around aircraft.

I joined BAE Systems through the engineering apprenticeship route. At college, I studied maths, physics, geography and photography. After college, I felt the apprenticeship scheme was right for me, as I like to apply what I am learning to real life scenarios.

A typical day will usually involve working in a team to come up with ideas that will be applied to the aircraft of the future. This involves creative thinking on a wide scale, and team working is essential to make sure we consider everything and everyone's point of view.

We will come up with different ideas together that we think will work in the future, and then use maths and technology to investigate them further.

We are always thinking around how sustainable and eco-friendly our solutions are, and ensuring we come up with the best solution possible in terms of the environmental impact.

"Innovation happens when different people with different ideas and different skills come together to create, and I wanted to show the next generation of scientists and engineers how they could be a part of that."

Where do we communicate?

Time to reflect

We often associate communication with words and conversation. But this is certainly not the only form of communication we use.

- What do we mean by communication?
- Why is it important?
- How do we communicate?
- Who do we communicate with?

Fibre optic communication

We use fibre optics to send and receive data.

Data from one computer is converted into super-fast pulses of light, which can be sent down optical fibres to others all around the world.

In order to increase security, our online activity is encrypted. This means that all our online data has been converted into a code or a cipher.

Data can be **encrypted** to make it difficult for anyone else to access unless they have the secret key to unlock the information.

Time to reflect

Why do you think it is important that we can send messages securely?

Time to encrypt

Using the circuit boards and fibre optics, send encrypted messages to your classmates.

Materials

- 2m optical fibre
- Croc leads
- Resistor
- Battery box
- LED
- 2 x 3D printed adapters
- Switch

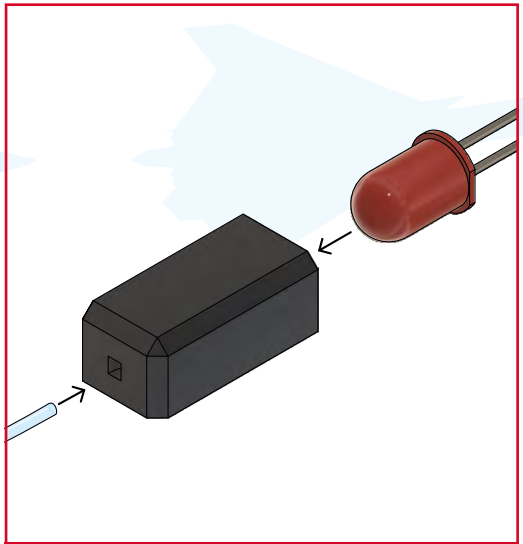
Challenge

Create a system where you can send a message to another person/group just using the fibre optics messaging system.

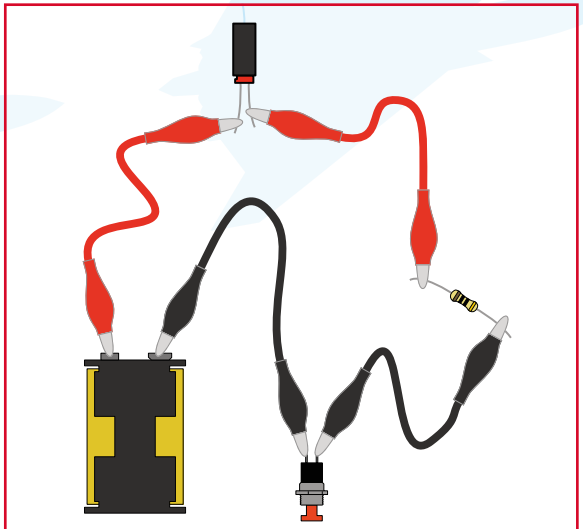
You will be sending messages using the LED light that you will see through the fibre optics cable.

One person/people from within your group will be sending the message.

One person/people from your group will be receiving the message.



1. Insert the LED into the black connector block
2. Insert the fibre optic cable into the other end of the connector block



3. Make a circuit. Connect the LED, switch, resistor, and battery box as per the diagram. **Note:** The long leg of the LED must be connected to the positive end of the battery terminal.

Example code:

A	
B	
C	
D	

Use this system to send one word to the receiving group.

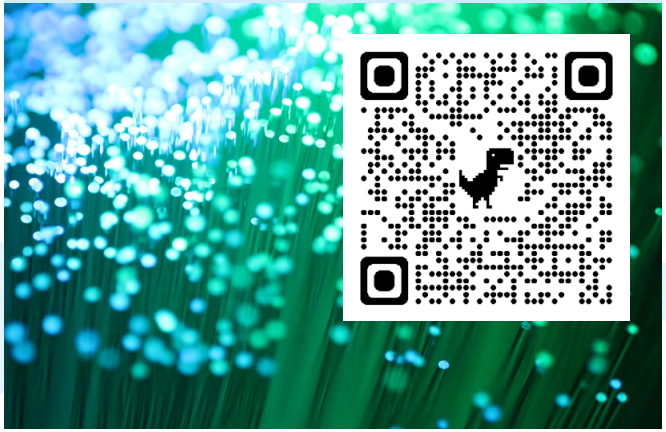
- What happens if you make a mistake?
- Can you make your system more efficient?

Hint: could you use a grid system to help organise your letters?

	A	B	C	D	E	F
	G	H	I	J	K	L
	M	N	O	P	Q	R
	S	T	U	V	W	X
	Y	Z				

Do we use some letters or words more than others? Could this information help you create a different encryption code?

Watch this video of a message being sent using the fibre optics messaging. Can you decipher the code?



Time to program – Crumble activity

Use the fibre optic kit to send a message to the Crumble.

Additional materials

- Crumble board
- Grey adapter
- LDR (Light Dependent Resistor)

The LDR will change resistance depending on how much light falls on it.

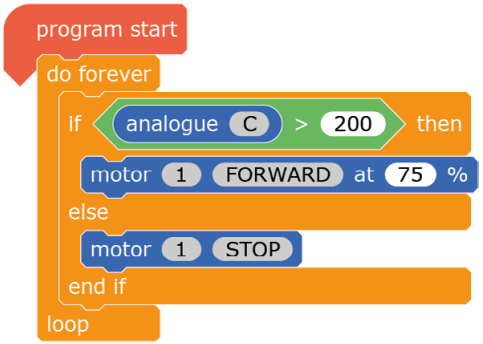
We can connect the LDR to the Crumble to detect whether the LED is on/off at the other end of the cable. Can you use this instead of the switch in other activities in the resource pack?

Go to the variables tab. What do you notice when you press the switch?

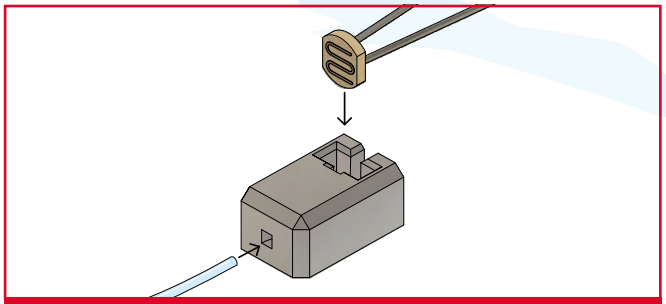
How can this be used as a communication tool?

Use the fibre optics messaging system to control a motor. Can you change direction?

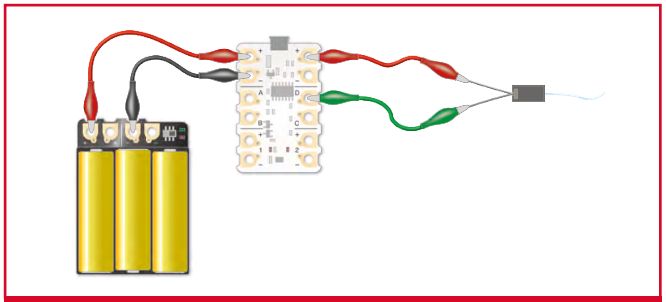
Use this program to get you started:



Can you write a program that will control a sparkle baton?



1. Insert the LDR into the grey connector
2. Insert the other end of the grey connector to the fibre optic cable



3. Connect the Crumble to the circuit
4. Connect the Crumble to the computer using a USB

Communicating with computers

Computer programming is another form of communication and will be fundamental to Tempest operations.

Computers use binary – the digits 0 and 1 – to store data. A binary digit, or bit, is the smallest unit of data in computing.

Computer programs are sets of instructions (algorithms). Each instruction is translated into machine code – simple binary codes that activate the **processor**. Programmers write computer code and this is converted by a translator into binary instructions that the processor can execute.

All the music, streaming and social media that you do on your computer, smart phone or tablet is processed by a computer, so is also stored using binary.

How do we write numbers?

Binary is a base two number system, which means there are only two digits, one or zero. Our normal number system is a base 10 number system, which means we use 10 number digits, zero to nine.

Using Table 1:

- What is the value of each number in the top row?
- Fill in the gaps.

Stretch and challenge

- What happens on the place value grid before 10^0?

Using Table 2, what is the value of each number in the top row?

What is the largest number you can make using the base 2 grid below?

What is the smallest number you can make?

Stretch and challenge

What happens on the place value grid before 2^0?

Table 1 – Base 10

10^4	10^3	10^2	10^1	10^0	
10^4 =	10^3 =	10^2 =	$10^1 = 10$	$10^0 = 1$	
		2×10^2 =	3×10^1 =	7×10^0 =	200 + 30 + 7 = 237
		5		4	500 + +4 = 574
	3	0	3	6	3000 + 0 + 30 + 6 =
?					= 72401

Table 2 – Binary numbers (base 2)

2^4	2^3	2^2	2^1	2^0	Base 2	Base 10
2^4 =	2^3 =	2^2 =	$2^1 = 2$	$2^0 = 1$		
				1×2^0 =	1	1
			1×2^1 =	0×2^0 =	10	2
			1×2^1 =	1×2^0 =		3
						4
					111	
						22
						29

Communicating with computers

Binary sequences

Working in groups of four, can you count to 15 in binary – this is not as easy as it might seem at first!

1. Get into groups of four.
2. Assign each person to a column from the binary grid (2^0, 2^1, 2^2, 2^3).
3. Start all sitting down. Stand up when your number is needed. Sit down when it is not.

What patterns do you notice?

Decode these facts

- Ada Lovelace was born on the **1010** December, 1815. She was a British mathematician and computer engineer whose work is considered to be the first written algorithm.
- Mary Jackson became NASA's first female black engineer in 1958. She analysed data from wind tunnels experiments. The **10000** square foot, **111100** thousand horsepower wind tunnel is used to study forces on model by generating winds twice the speed of sound.
- By 2025, it is predicted that global aircraft passenger traffic will increase by **100**%
- The temperature outside an aircraft is **–11011**°C
- The average cruising speed for an aircraft is **1110000100** km/h.

"There are 10 kinds of people in the world. Those that understand binary and those that don't."

Can you explain this joke?

Sorting machine – parallel algorithms

Robots and computers are programmed using algorithms, which are a set of instructions that tell them how to solve a problem or complete a task.

A parallel algorithm is an algorithm that will carry out several instructions at the same time.

The computers and robotics involved in Team Tempest will be processing large amounts of data and writing programs that will enable them to carry out tasks efficiently and accurately, which will save time and money but could also save people's lives.

Create a number sorting machine using parallel algorithms that will order any numbers from smallest to largest.

1. Working in pairs, select any two number counters.
2. Starting from the input, follow the lines until you meet in a box. The person with the lowest number should follow the line out to the left and the person with the higher number follows the line leaving right. Stop once you have both reached the next box.
3. Repeat this process with the remaining counters.
4. Repeat this process until all numbers have reached the output.

Are your numbers in the order of smallest to largest?

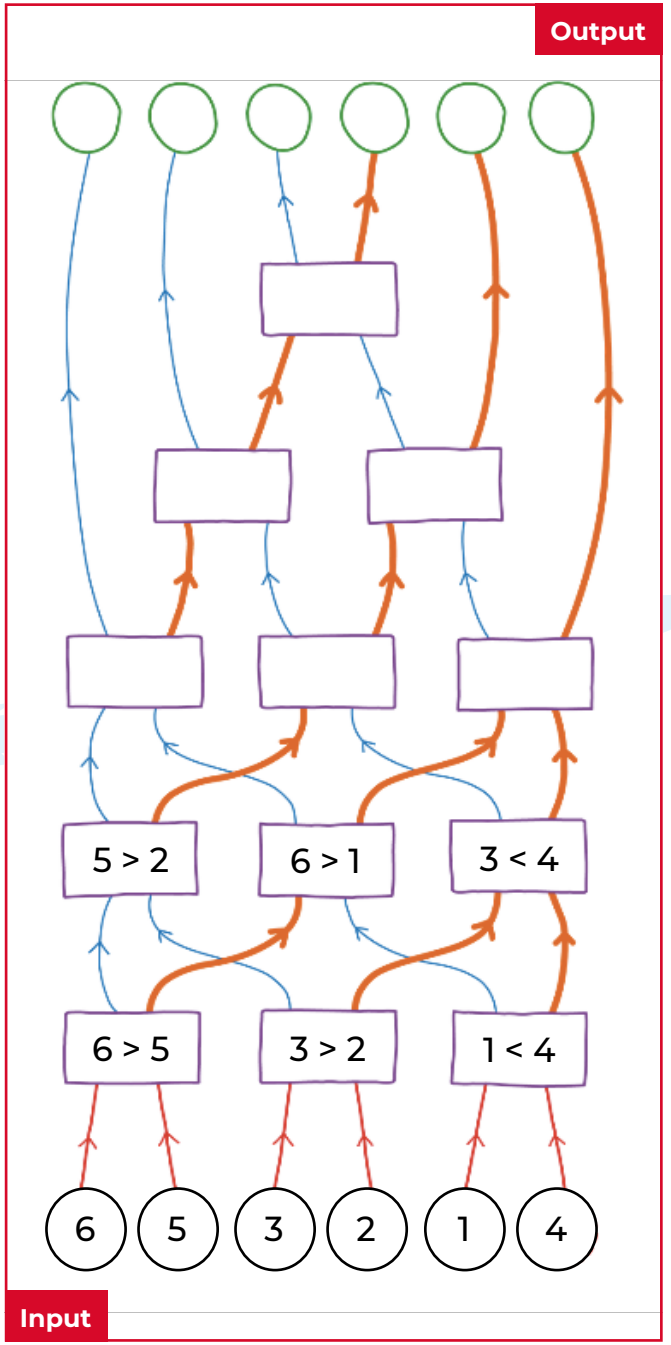
- What happens if you change the order of the counters at the input?
- What happens when you use different counters?
- Can you trace the path for the lowest number?
- Can you trace the path for the largest number?

Write an algorithm to show what is happening in each of the boxes.

Will your algorithm always work? Can you prove this?

Stretch and challenge

- What happens if you increase the number of rows of boxes?
- What happens if you decrease the number of rows of boxes?
- Is there a minimum amount of rows that is needed to sort the numbers in size order?



Counters – set 1

-7 −4 −1 3 1 0

Counters – set 2

14 21 36 47 66 91

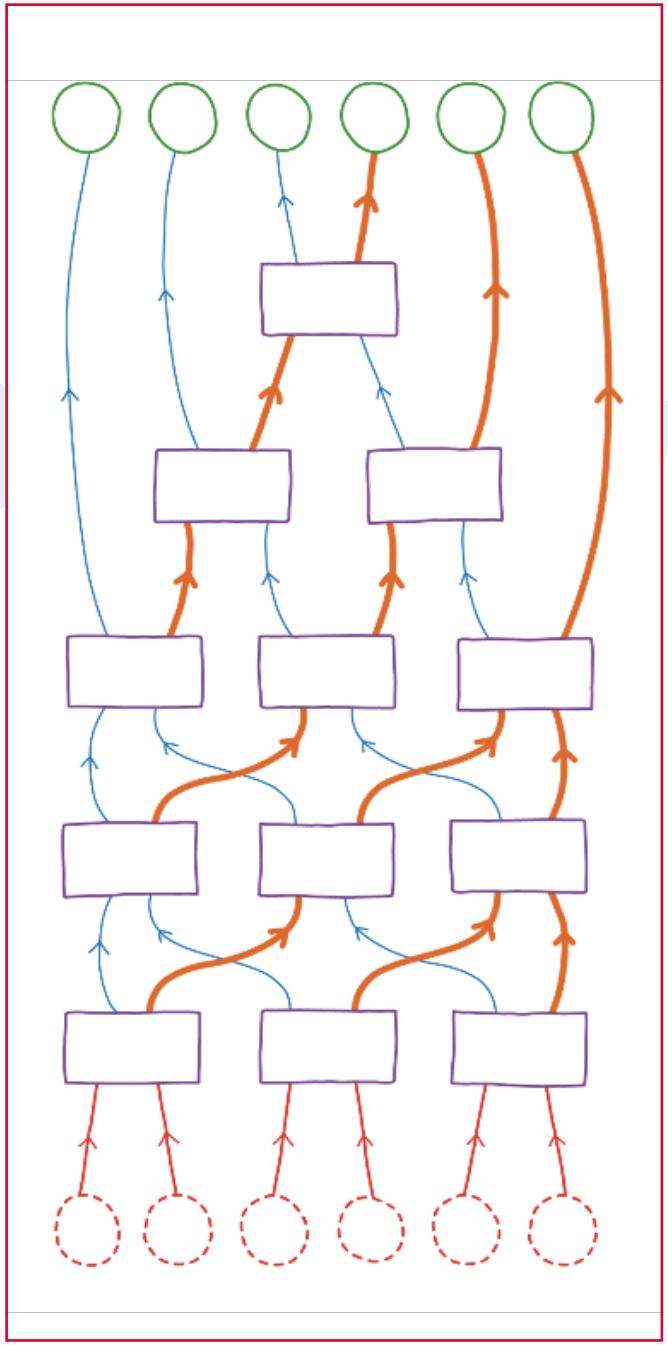
Counters – set 3

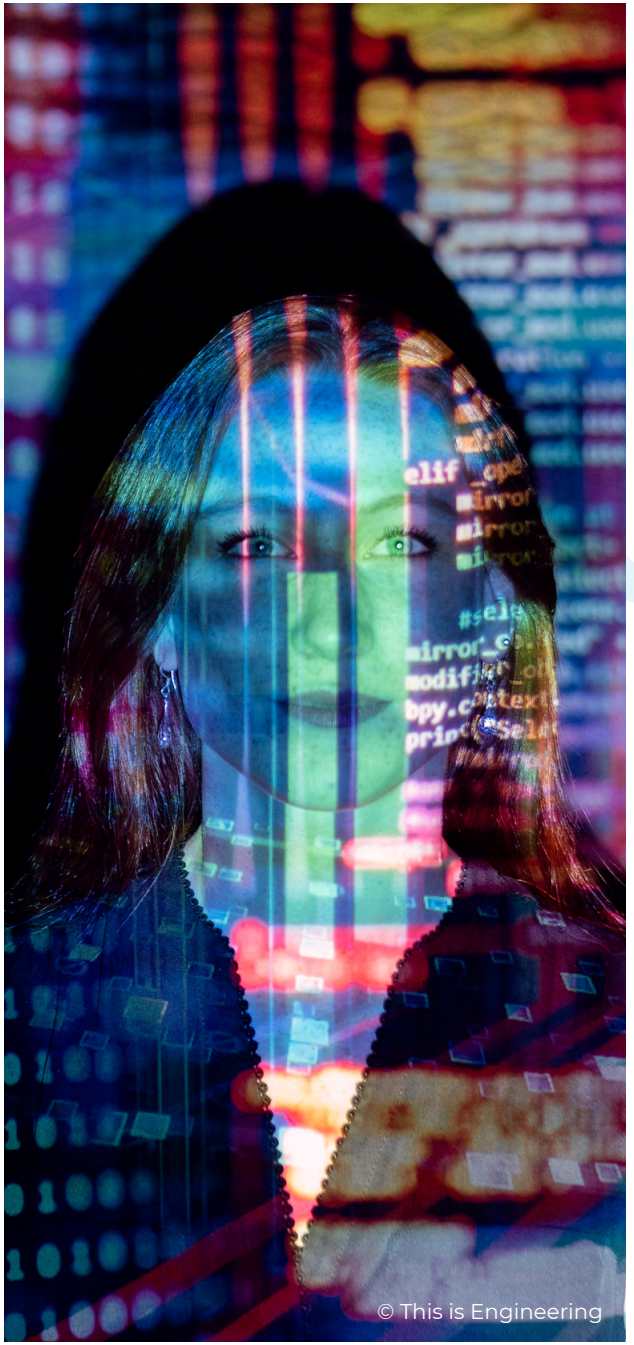
$\frac{1}{8}$ $\frac{1}{4}$ $\frac{1}{3}$ $\frac{1}{2}$ $\frac{5}{8}$ $\frac{5}{6}$

Counters – blank

Teacher note: change the difficulty of this challenge by using different numbers to order such as fractions, decimals or algebraic terms.

Activity adapted from Sorting Networks, CS Unplugged





Ground control communication

Being able to communicate when there might be no visual common ground is an important part of the work the Team Tempest partners do.

The following challenge is inspired by the Colourblind activity, originally developed as part of Air Traffic Control Cadet training.

Aim

In teams, recreate the images and shapes on the 'Ground control' cards using the hexagonal puzzle pieces provided. One person from each team will have a 'Ground control' card. They will act as the 'Controller' and will give instructions to the rest of the team on how to recreate the image. The rest will have the puzzle pieces. The 'Controller' cannot see what the rest of the team are doing until they have completed the puzzle following the instructions given.

How to play

- Get into groups of three to five
- One person from each group becomes the 'Controller'. They take a 'Ground control' card.
- The rest of the team take the puzzle pieces.
- The 'Controller' gives instructions to the rest of the team on how to build the puzzle.
- After the 'Controller' has finished giving their instructions, they reveal to the team what the image is on their ground control card.

Do they look the same?

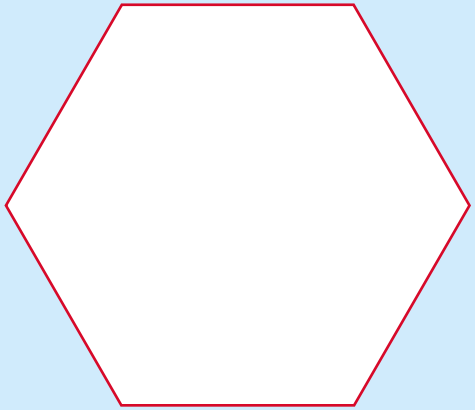
If they do not, can you as a team identify where the miscommunication happened?

Time to reflect

- What skills do you think you need to carry out this activity?
- What challenges did you face? How did you overcome these?
- How might you change your strategy when you do this again, removing two different pieces?

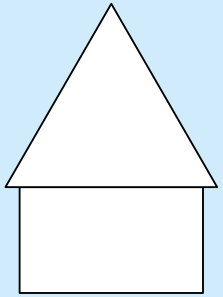
At times, as a team, you might not have anyone who can guide you.

As a team, can you fit all the puzzle pieces into the hexagonal frame?

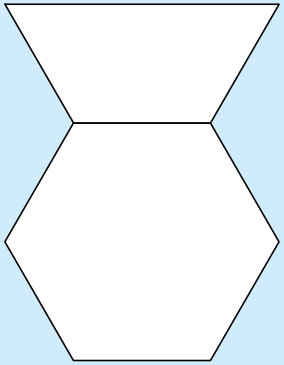


Ground control cards

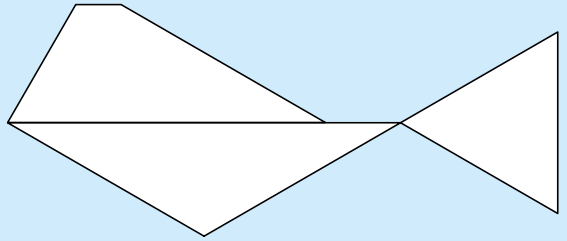
House



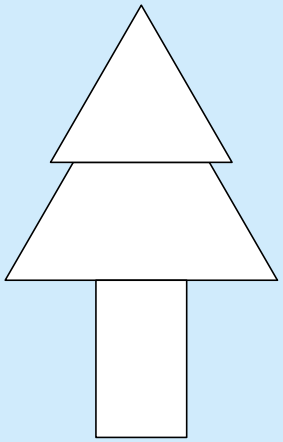
Medal



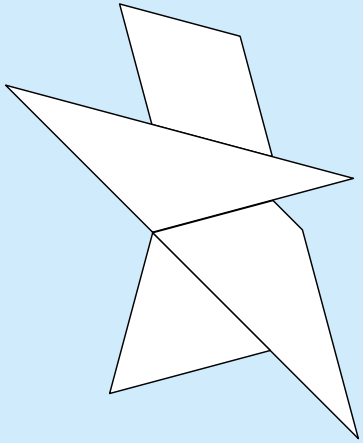
Fish



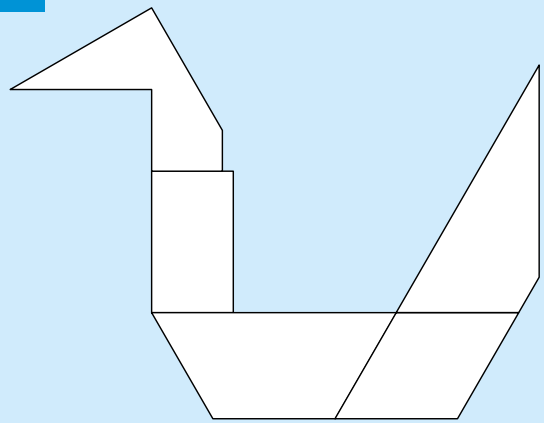
Tree



Dancer



Swan



Cut out the cards. One person from each team acts as 'Ground control' and explains to the other team members how to create the shape using the puzzle pieces.

Create new ground control cards for your classmates to try and recreate.

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