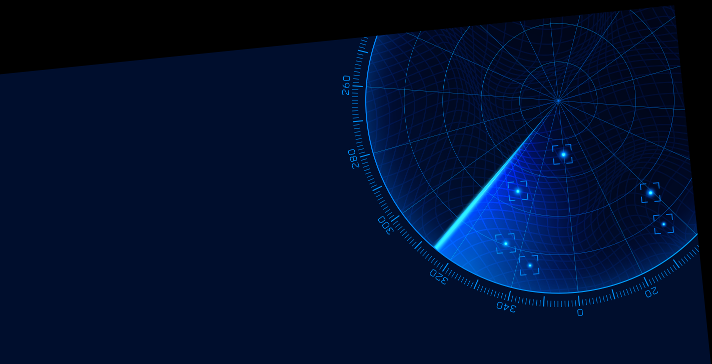
Royal Academy of Engineering

THIS IS ENGINEERING



CODE AND RESCUE

Teacher Guide

This resource teaches students how to code through a series of physical computing and practical activities which explore the essential role engineers have in search, save and rescue missions.

ABOUT THIS RESOURCE

Code and rescue! teaches students how to code through a series of physical computing and practical activities that explore the essential role engineers have in supporting emergency services and search and rescue missions.

This resource places computer programming at the centre of STEM (science, technology, engineering and maths) learning, providing hands-on thematic educational opportunities that support the National Curriculum.

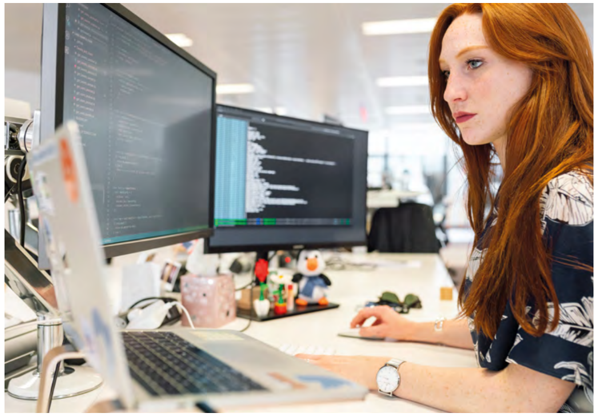
Through a series of creative and collaborative challenges, students will develop enquiring minds and team-working skills, understanding the role STEM-based learning plays in real world engineering scenarios.

Code and rescue! allows young learners to express and share their thoughts and ideas, while developing computational thinking and creativity to understand, change and make a difference in the world around them.

Computer programming, generally referred to as 'coding', is a basic literacy for the digital age. It is important for young learners to understand and be able to work with the technology around them. Pupils learning code at a young age prepares them for the future. It fosters their creativity, allows them to apply maths in real world situations and helps them to become confident problem solvers.

TEACHER NOTES

This resource is designed to provide practical and contextualised applications where people can see the role that STEM-based learning plays in real-world engineering scenarios.



Although the focus of the box is computer science, it still has deep links with mathematics, science and design and technology. It provides opportunities for students to use computational thinking and creativity to understand, change and make a difference in the world.

DON'T WORRY! Experience or prior training on computer programming is not necessary to deliver this resource with your students. The resource has been designed to allow students to learn independently and at their own pace with your support as a facilitator and not a coding legend. As students work through the activities, they build their skill level and expertise and can move onto more complex programming challenges themselves.

Saying that, students can jump in and work on any activity or challenge in the resource. As long as they have a base level of understanding about how the Crumble software works, they can set their own level of difficulty with most activities, providing plenty of scope to stretch, challenge and invite further investigation.

Working in small groups, the activities are designed to run simultaneously so students can take turns using the practical components included.

We suggest you have a look at the 'Talk like a programmer' section to familiarise yourself and the students with key vocabulary that will be used throughout the resource.

We want to make the resource as inclusive and accessible as possible. All the Crumble software is available for free to download. Even if the students are not using the Crumble board, they can still be working in their groups testing, investigating and considering different scripts.

We are not suggesting Crumble is to be used in replacement of any other programming boards you may already use, but to be used in addition to or to compliment any existing school resources.

This hardware is available to purchase from redfernelectronics.co.uk. Included in this resource box is a voucher that will give you 10% off your next order.

For more resources around how engineers save lives, check out the Save lives as an engineer poster from Neon and the accompanying teacher's notes (which can be found at – https://neonfutures.org.uk/resource/poster-save-lives-as-an-engineer/).

We have two types of activities

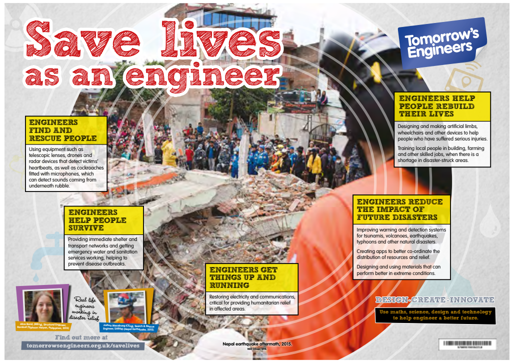
Plugged in

Where you see this symbol, pupils will need to use the Crumble board and some of the hardware that's included in the box.

Unplugged

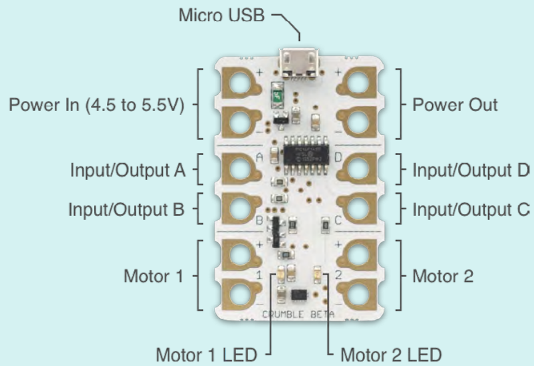
Where you see this symbol, pupils will not need to use the Crumble board or any hardware, however they might still need access to a computer.

We suggest that all pupils have had a go at the 'Emergency lighting' activity on page 8 before doing any of the 'unplugged' activities that use the Crumble coding blocks (activities from page 10 to page 13).



THE CRUMBLE CONTROLLER BY REDFERN ELECTRONICS

The Crumble is a programmable controller that can be coded to drive outputs such as motors and lights known as sparkles. It uses crocodile leads for simple connections and once programmed it can be easily embedded into a design or product. A useful output component is the sparkle baton consisting of eight LEDs that can be programmed to display interesting light sequences.

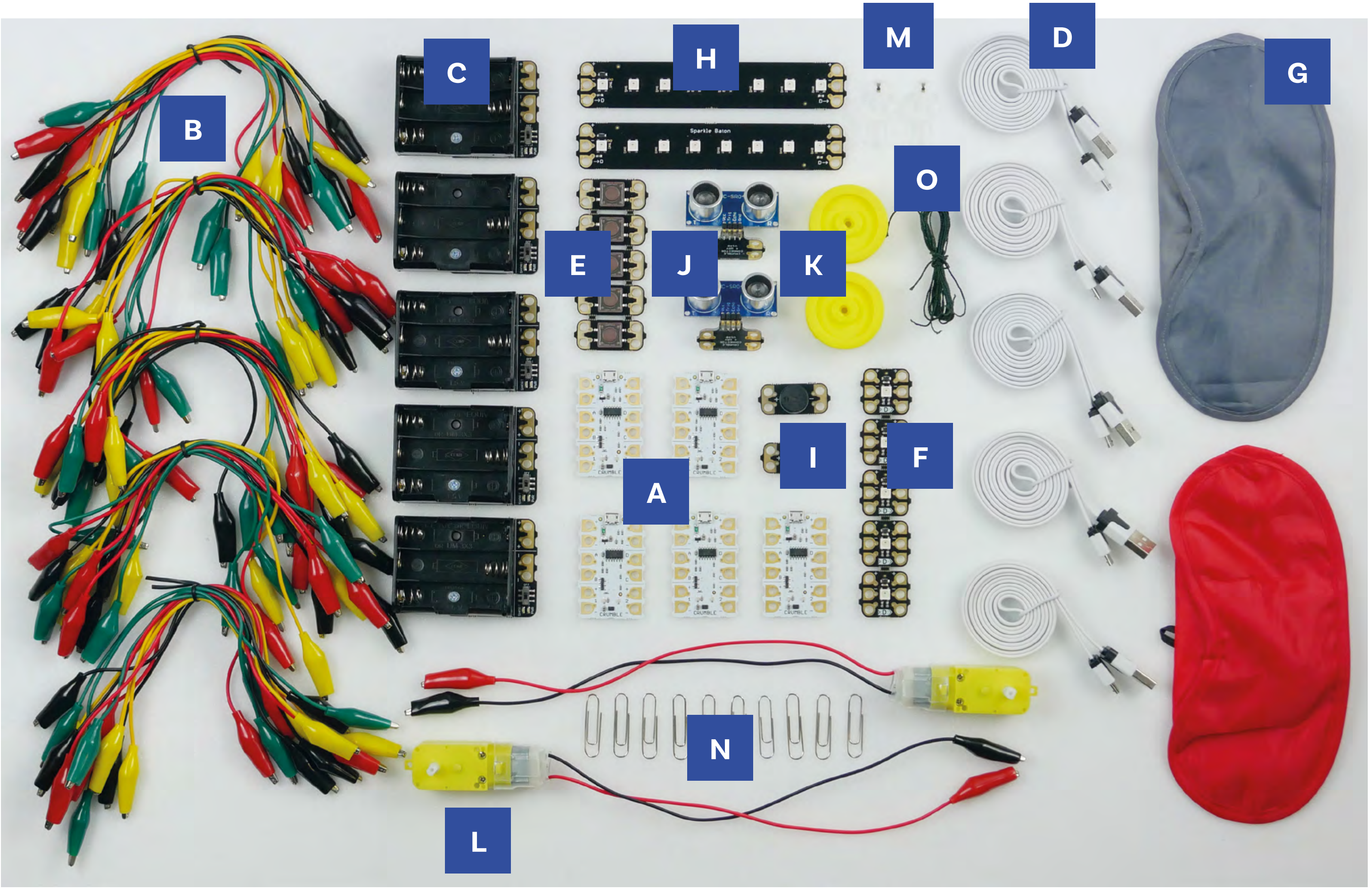


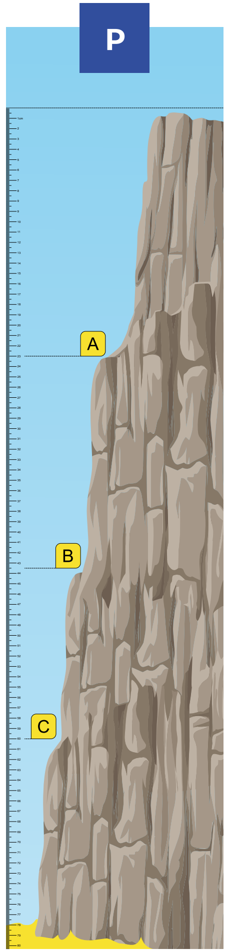
https://redfernelectronics.co.uk/crumble/

The 'getting started guide' available from the Redfern website is an excellent starting point for those that haven't used Crumble before or need a refresher!

WHAT'S IN THE BOX

A. Crumble board x 5
B. Croc leads x 5 bundles of 12
C. Battery box x 5
D. USB x 5
E. Push switch x 5
F. Sparkles x 5
G. Blindfold x 2
H. Sparkle baton x 2
I. Buzzer x 2
J. Ultrasonic x 2
K. Pulley x 2
L. Geared motor x 2
M. Magnetic person x 2
N. Paper clips x 10
O. Metre of twine
P. Cliff face
Q. A4 cardboard crumble cutout





CURRICULUM LINKS

Although the focus of this resource is computer science, the activities and challenges bridge several subjects across the curriculum. Age group is also given as a guide and activities can be extended or broken down depending on the group.

Subject	Age group	Skills
Computer science	*Age 7–11*	■ Design, write and debug programs that accomplish specific goals, including controlling or simulating physical systems. ■ Use sequence, selection, and repetition in programs. ■ Work with variables and various forms of input and output. ■ Use logical reasoning to explain how some simple algorithms work and to detect and correct errors in algorithms and programs. ■ Create, develop and evaluate computing solutions in response to a design challenge.
	Age 11–14	■ Select appropriate development tools to design, build, evaluate and refine computing solutions based on requirements.
Maths	*Age 7–11*	■ Convert between different units of measure (seconds, milliseconds, hours).
	Age 11–14	■ Apply knowledge of compound units (speed) to different contexts.
Design technology	*Age 7–11*	■ Understanding and using electrical systems in products.
	Age 11–14	■ Apply computing and use electronics to embed intelligence in products that respond to inputs and control outputs using programmable components.
Science	*Age 11–14*	■ Demonstrates through practical investigations that (ultrasonic) sound waves travel in straight lines and are reflected off a flat surface.

More information about the national curriculum in England **can be found here**.

More information about the Scottish Curriculum for Excellence **can be found here**.

More information about the Northern Irish school curriculum **can be found here**.

More information about the curriculum for Wales **can be found here**.

ENGINEERING HABITS OF MIND

The activities presented in this resource are designed to be interactive, open-ended, encourage discussion and promote the engineering habits of mind (EHoM).

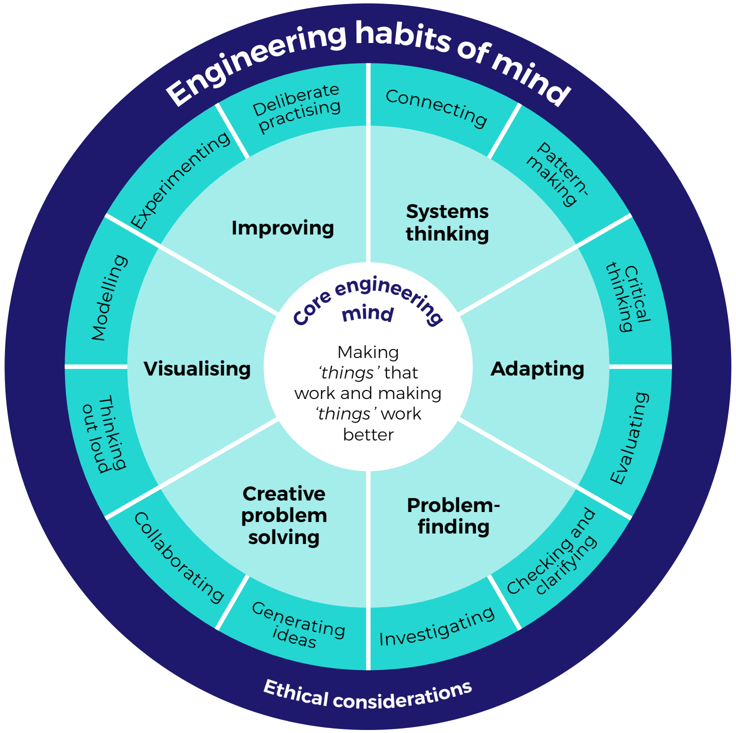
EHoM encourages the use of a pedagogical approach that cultivates problem-solving skills, creativity, making mistakes, reviewing and planning.

However, as this resource focuses largely around computing, we refer instead to 'computational thinking' instead as per the Scottish, English and Northern Irish curriculum (the Welsh curriculum is still in development).

Computational thinking skills have a significant cross-over with the 'engineering habits of mind', which we have highlighted in the table below.

We have sign-posted points in the resource where we ask young learners to identify what computational thinking skills they are demonstrating. However we suggest you introduce them (and the EHoM) at different stages of your teaching as you see fit.

Read **Engineering the future: training today's teachers to develop tomorrow's engineers** to find out more about using EHoM and the Crumble board in the classroom.



EHoM	Description	Design and technology and computing
Systems thinking	*Seeing connections between things, seeking out patterns*	■ Looking for patterns in coding
Adapting	*Making something designed for one purpose suitable for another purpose*	■ Making things function as intended – using the iterative approach
Problem finding	*Deciding what the actual question is, finding out if solutions already exist by clarifying needs*	■ Debugging ■ Assessing within the project
Creative problem solving	*Generating ideas and solutions as creative problem solvers*	■ Developing computational thinking and solving design issues
Visualising	*Seeing the end product, being able to move from abstract ideas to concrete*	■ Having a rough visual image in mind to designing products
Improving	*Making things better by experimenting and adapting*	■ Evaluating products during and after the making process

DISCOVERY AWARDS

Young learners can achieve a CREST Discovery award by working on this project.

CREST is a nationally recognised scheme for pupil-led project work in STEM subjects. It enables five to 19-year-olds to build skills and demonstrate personal achievement in creative STEM project work that supports their curriculum-based learning.

Discovery Awards offer an introduction to real project work and give pupils the freedom to run their own investigations. They can be completed over the course of a day, or for one hour a week over the course of a school term with pupils working together in self-managed groups.

How to get your CREST Discovery Award

1. Sign-up for a free account at https://my.crestawards.org
2. Download the teacher guide and Discovery Passport
3. Create a project. For example – **Code and rescue**
4. Pupils provide details of the project in their passports
5. Upload pupils' names and two or three passports and any accompanying work
6. Assess pupils. Have they:
    a. completed around five hours of work on the project?
    b. participated fully in the project?
    c. reflected on their learning?

For more information on assessing a CREST Discovery award visit: http://bsa.sc/assess-discovery

CREST AWARDS

BRITISH SCIENCE ASSOCIATION

SOLUTIONS

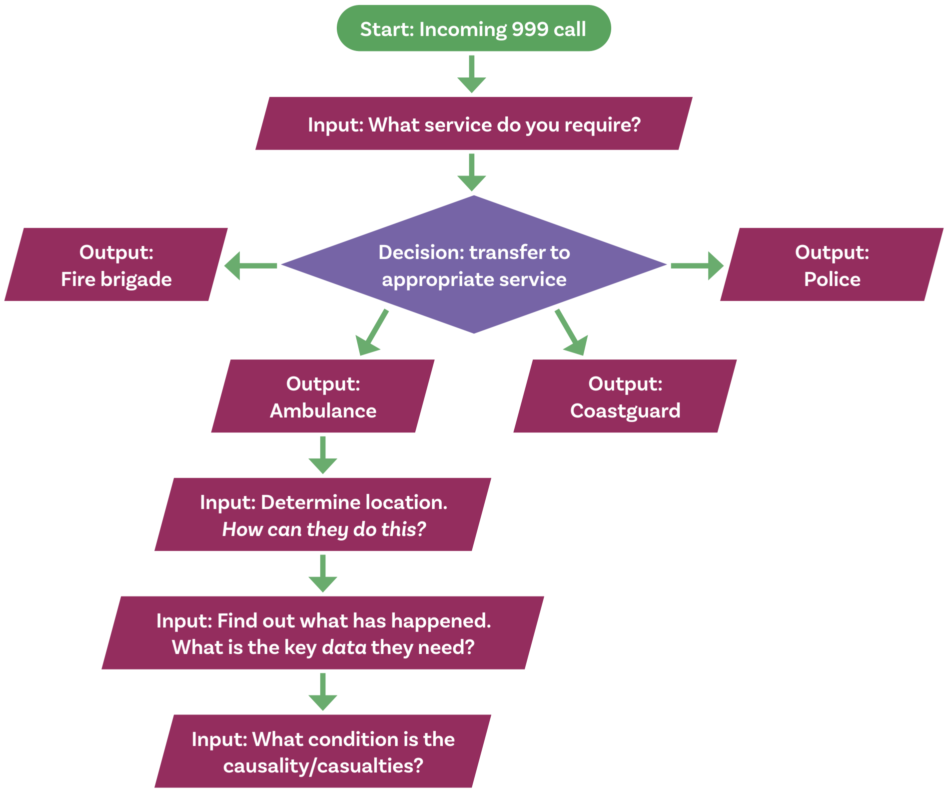
TALK LIKE A PROGRAMMER

- **Algorithm**
  - A set of instructions to achieve a specific goal.
  - Check out our resource ***Are we connected?*** Available on our STEM Resource Hub for more ideas on activities around algorithms
- **Variables**
  - Data values that change depending on the input
- **Bug**
  - A mistake in a program.
- **Debug**
  - To investigate and fix mistakes in a program.
- **Loop**
  - A piece of code that runs itself repeatedly.
- **Nested**
  - Contained within something else.
- **Program**
  - A full piece of software that is ready to be run.
- **Run**
  - To perform the instructions written in code.

999 – WHAT'S YOUR EMERGENCY

For more ideas on 'unplugged algorithm' activities, check out our other resource ***Are we connected?***.

"999, what's your emergency?"



Example of part of a flow chart to get pupils started on this activity.

If you have access to computers/laptops/tablets pupils can do this activity on Word, PowerPoint or online flowchart tools such as draw.io.

THE SEARCH IS ON...

Locate the casualty

The casualty is located in M8.

Ask pupils to create different challenges for each other using the map.

Use a map of your school to turn this activity into a 'treasure hunt' type challenge.

What 3 Words

entitles.merit.spirits is the location of a HM Coastguard station in Lyme Regis.

grafted.games.varieties is in Lands End, Cornwall.

They are approximately 250km apart.

It would take the helicopter just under an hour to reach the casualties.

$60 \div 260 \times 250 \approx 58$ minutes

Calculate the time it takes the helicopter to travel 1km and multiply this by the distance it needs to travel.

MISSION PLANNING

There is no set way to complete this task, however we have given some suggestions and ideas to get your group started.

Equipment needed:

- Copies of the map on page 7
- Scrap A4 paper
- Rulers
- A3 paper (to present final plan)
- Protractor (for stretch and challenge)

Getting started

Give pupils scrap paper to write their plan and each group a copy of the map on page 7.

Set the class a time limit in which to have their plan ready by.

Highlight the importance of communication in this activity.

Encourage pupils to first decide on what information they need and how they will collect that information.

The map shown here shows one waythat pupils can calculate how long it will take each rescue vehicle to arrive at each of the boats that are in distress.

Example calculations (but pupils might have different way to approach this task).

Helicopter to blue: 10.5cm = 105km
$60 \div 260 \times 105 \approx 24$ minutes
Calculate the time it takes the helicopter to travel 1 km and multiplied by the distance it needs to travel.

Rescue boat B to orange boat: 6cm = 60km
$60 \div 65 \times 60 \approx 55$ minutes
Calculate the time it takes the boat to travel 1km multiplied by the distance it needs to travel.

Stretch and challenge

We provide a few suggestions for how to extend this task, however this is of course open for you to add different factors or possible obstacles that learners will need to consider for their mission plan (for example, there are less crew available on one of the lifeboats).

TEACHERS NOTE

There is no right or wrong answer to the rescue plan challenge. This activity is designed to encourage pupils to work in groups, communicate and collaborate, discuss the challenges they might face, putting together a rescue plan whereby they explain and justify their decisions.

Find more resources around the STEM involved in Coastguard operations at the **London Grid for Learning** website.

More information about the S-92 helicopter – **https://www.homelandsecurity-technology.com/projects/s-92-sar-helicopter/**

More information about the **Atlantic 85 B-Class** to share with your class can be found on the RNLI website.

EMERGENCY LIGHTING

Materials needed

- Crumble board
- Battery pack
- Sparkle x 1
- Croc leads x 5

Encourage pupils to investigate different flashing light colours and patterns for different vehicles.

Orange / amber

Vehicles with flashing amber beacons are slow moving vehicles or assistance / recovery / maintenance vehicles that include:

- road maintenance
- highway maintenance
- road clearance
- breakdown recovery

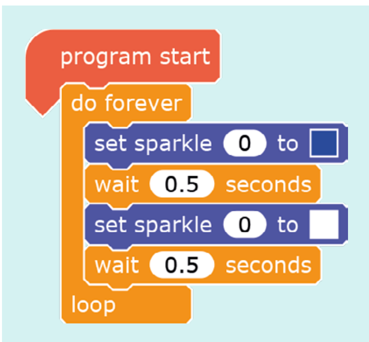
Green

The only vehicle that will display a green flashing beacon is a doctor’s car that is responding to an emergency.

Blue

All other emergency vehicles will display a blue flashing beacon. Vehicles that will display this light include:

- police
- fire service
- ambulance
- cave rescue
- coastguard



Example program

LIGHT THE WAY

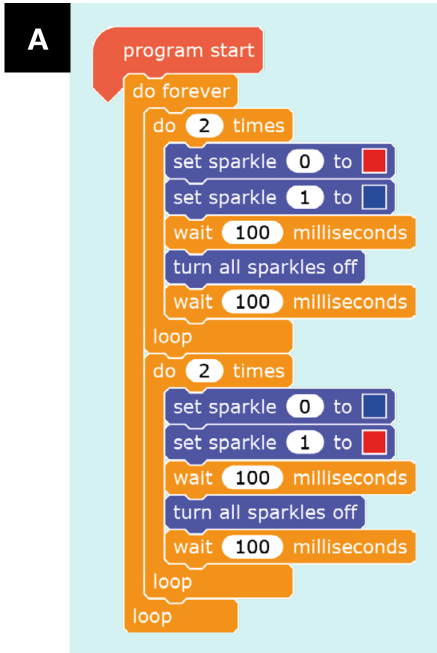
Lighthouse	Sequence	Algorithm
Lizard Point	**Flashing** sequence in a three second loop	A (written program)
Whitby	**Flashing** white and red in a five second loop	G
Donaghadee Harbour	**Isophase** white and red in a four second loop	B (flow chart) and E
Portland Bill	**Flashing** four times white in a 20 second loop	H
Rattray Head	**Flashing** three times in a 30 second loop	D
Point Lynas	**Occulting** white sequence in a 10 second loop	C (graph) and F

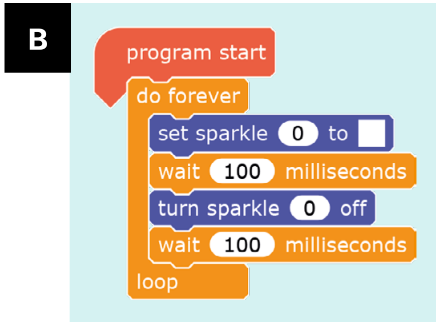
If you have enough Crumble boards, give young learners the opportunity to test their lighthouse programmes using the hardware.

CODE EFFICIENCY

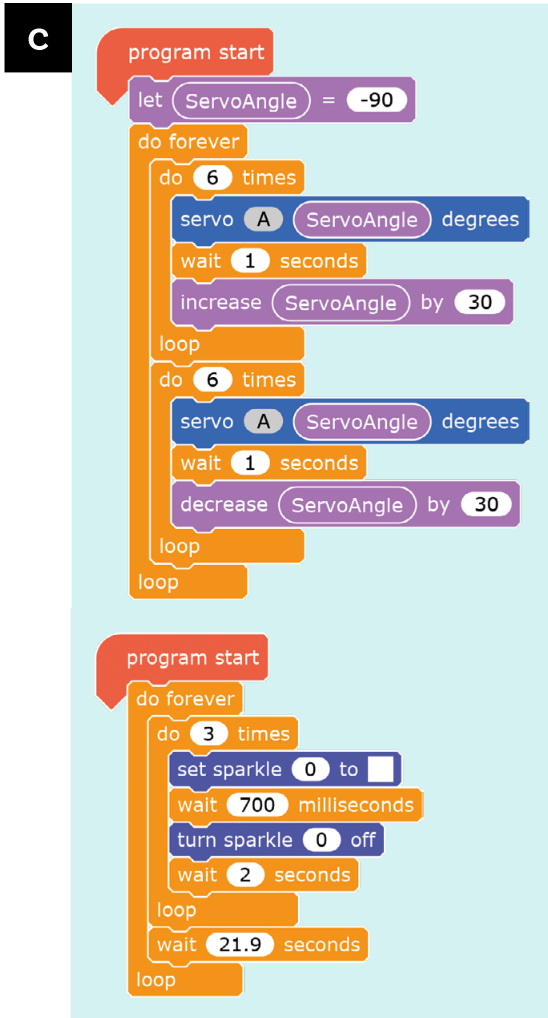
The solutions given below are just possible answers. Pupils might write different code that gives the same output.

If you have enough Crumble boards, give young learners the opportunity to test their programs using the hardware. Do their more efficient codes give the same output as the original lengthy code?





Stretch and challenge



Code efficiency is linked to the algorithmic efficiency and the speed of program runtime and one way to improve the efficiency of a code is to remove unnecessary code.

HOW MUCH POWER?

Program	Time the battery will last
A	2 hours
B	3 hours
C	6 hours
D	4 hours
E	10 hours

One example of working out for program B:

$$\frac{1\ (time\ LED\ is\ on)}{3\ (total\ loop\ time)}$$

This means the LED light is on for $\frac{1}{3}$ of the total loop time.

In one hour the LED light would be on for 20 minutes.

It would take three hours for the program to run the LED light on for one hour (and the battery would run out).

This is just one way that pupils could work this out, however there are other ways that pupils might approach this challenge.

Stretch and challenge

$$100 \times 154 = 15400$$

$$1900 \times 4 = 7600$$

$$15400 + 7600 = 23000$$

$$\frac{23000}{2000\ (total\ time)} = 11.5$$

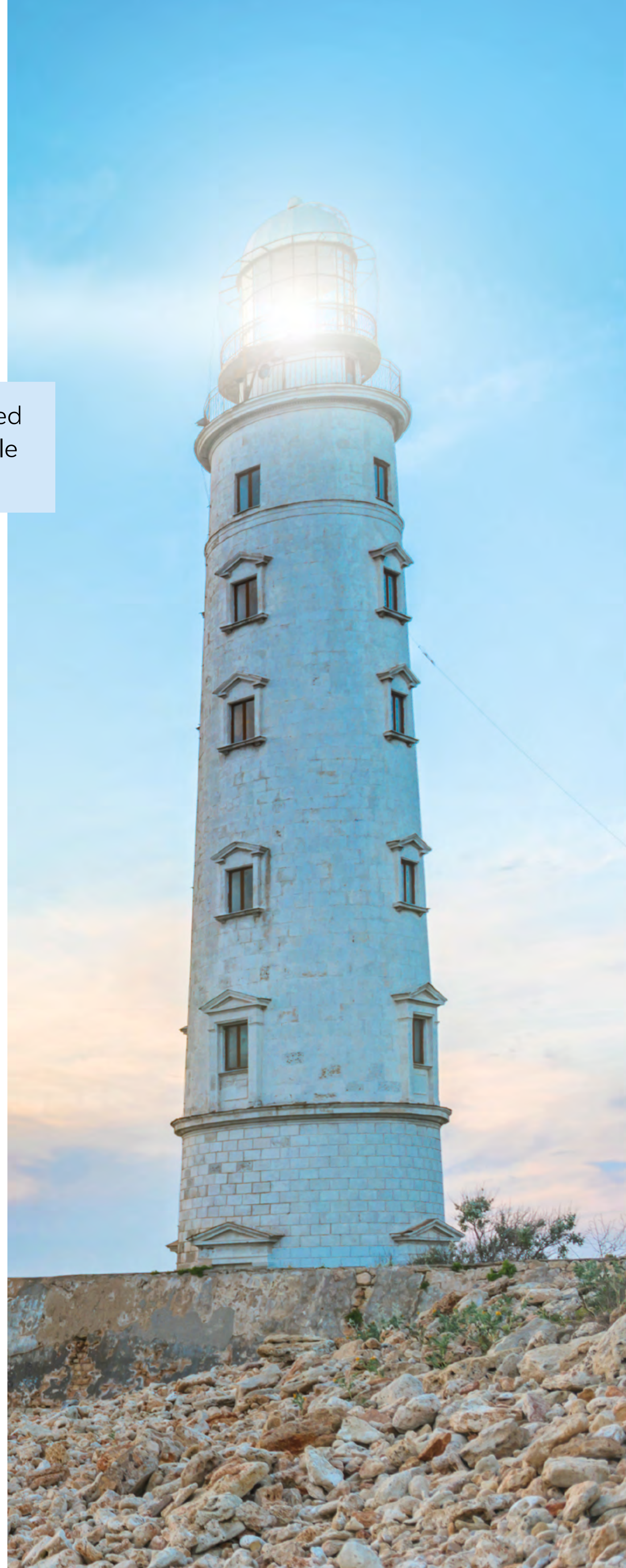
Average mA used across the whole program.

$$\frac{1000mAh}{11.5} \approx 87\ hours$$

Under every ‘plugged in’ activity, we have given examples of full or part programs in this guide to support pupils in case you feel they need extra guidance to get started. We have not put these in the pupil guide to give young learners the opportunity to tinker with the coding blocks and the Crumble hardware and see what they can come up with!

These are just examples, and pupils may well and should be encouraged to have different solutions.

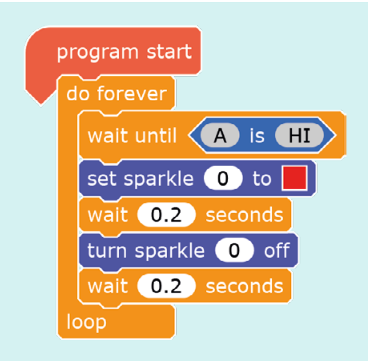
A good discussion point would be to look at why different programs carry out the same output and if one program is more efficient to use than the other.

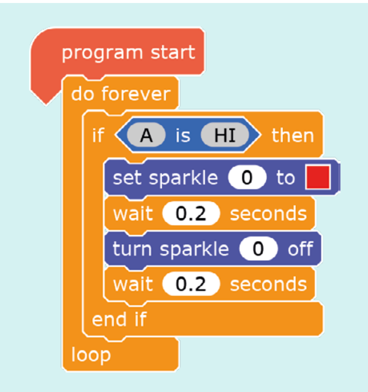


LED LIFEJACKET

Materials needed

- Crumble board
- Battery pack
- Sparkle x 1
- Croc leads x 7
- Paper clips
- Bowl for water



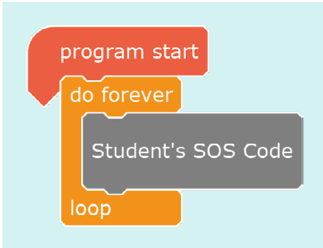


Example programs

SENDING OUT AN SOS

Materials needed

- Crumble board
- Battery pack
- Sparkle baton x 1
- Croc leads x 5
- A stick the baton could be attached to (such as a metre ruler)
- Elastic bands to secure the baton at the stick



Example program

TEACHERS NOTE

Learners will need to plan their message before they write their program. They will need to pay careful attention when translating their plan to code as their plan is written vertically and the code horizontally.

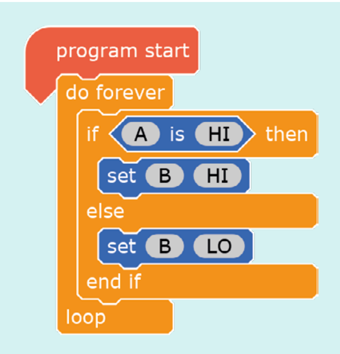
SOUND MORSE CODE

Materials needed

- Crumble board
- Battery pack
- Buzzer x 1
- Croc leads x 4
- Push switch

Push-to-make Morse code message

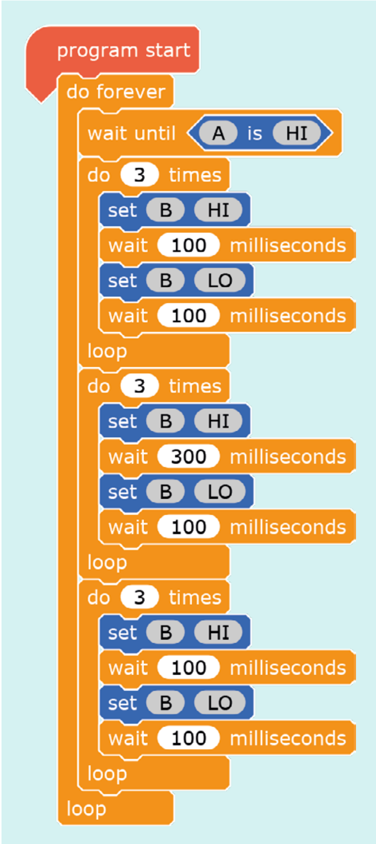
The first task in this section requires no programming, just for pupils to build a circuit with a buzzer and switch.



Example program for switch and buzzer

Pre-program Morse code messages – SOS

Pupils will need to write programs that run to make Morse code messages with just one push of the switch. Example code shown for SOS message.

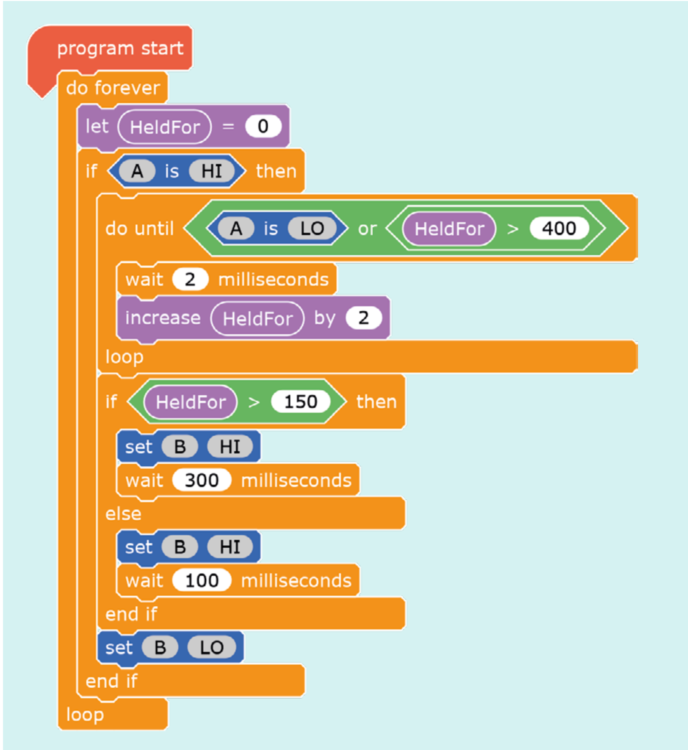


Example program

Stretch and challenge

Extend this task by asking pupils to experiment with setting limits to the amount of time the buzzer sounds for. We have given one example of how this could be done below, but there will certainly be many other options so give young learners the opportunity to experiment with different code.

A discussion would be whether this makes it easier or more difficult to send Morse code messages.



One example program to set time limits for buzzer

ULTRASONIC OBJECT FINDER

Materials needed

- Crumble board
- Battery pack
- Croc leads x 8
- Buzzer
- Ultrasonic sensor

Find out more about microwaves and the electromagnetic spectrum in our previous resource ***Are we connected?***


```
program start
do forever
    let Distance = distance (cm) T: D E: C
    if Distance < 10 then
        set A HI
        wait 25 milliseconds
        set A LO
        wait 25 milliseconds
    else
        if Distance < 20 then
            set A HI
            wait 50 milliseconds
            set A LO
            wait 50 milliseconds
        else
            if Distance < 30 then
                set A HI
                wait 100 milliseconds
                set A LO
                wait 100 milliseconds
            else
                set A LO
            end if
        end if
    end if
loop
```

Example program

WINCH RESCUE PLAN

We have provided links to a couple of real-life stories where the winch was used for search and rescue operations, which you might want to share with your class.

Search on the BBC for a news item about a **'Winch rescue after Cairngorms climber falls'** for a story about winch time and distance travelled.

Search on the BBC for a news item about a **'Stranded dog rescued from a mountain'**.

TEACHERS NOTE

There is no right or wrong answer to the rescue plan challenge. This activity is designed to encourage pupils to work in groups, communicate and collaborate, discuss the challenges they might face, putting together a rescue plan whereby they explain and justify their decisions.

WINCH TO SAFETY

Materials needed

- Crumble board
- Battery pack
- Motor
- Cardboard
- Aluminium foil
- Pulley
- Croc leads x 4
- Twine
- Metal paper-clips
- Magnetic person
- Cliff face
- Cellotape

The first challenge in this section asks learners to program the winch system so that they can operate it using a switch.

```
program start
do forever
    wait until A is HI
    wait until A is LO
    motor 1 FORWARD at 75 %
    wait until A is HI
    wait until A is LO
    motor 1 STOP
    wait until A is HI
    wait until A is LO
    motor 1 REVERSE at 75 %
    wait until A is HI
    wait until A is LO
    motor 1 STOP
loop
```

Example program

Pupils will need to set up their winch mechanism on the edge of table or shelves so they can lower it off the edge.

Use the cliff face provided for context and to measure distance.

The second challenge asks learners to pre-program the winch so that it travels to and from different levels of the cliff face with one push of the switch.

Example program

```
program start
  do forever
    wait until < A is HI >
    motor 1 FORWARD at 75 %
    wait 3500 milliseconds
    motor 1 REVERSE at 75 %
    wait 3500 milliseconds
    motor 1 FORWARD at 75 %
    wait 6000 milliseconds
    motor 1 REVERSE at 75 %
    wait 6000 milliseconds
    motor 1 STOP
  loop
```

*The timings will vary depending on how fast the pupils winch travels.

The third challenge asks learners to write a program whereby the winch will automatically stop once it reaches the motor. There are a number of ways that pupils can do this so encourage them to be creative with their design process but getting them to think about how they can complete the circuit to act like a switch.

Example program – motor stopping with a switch

```
motor 1 REVERSE at 75 %
wait until < A is HI >
motor 1 STOP
```

Pupils will need to move the motor away from the switch otherwise it will be permanently triggered.

Give them the opportunity to figure this out first.

The final challenge asks pupils to write a program that will collect and a return a ‘casualty’ (the magnetic person) from the ground with one push of the switch.

This will use similar code to the second challenge (pre-program winch) but it requires pupils to be precise with their timings.

Stretch and challenge

Possible ideas for winch design:

- Buzzer to alert crew that they are close to the casualty or that they are near the motor.
- LED lights to be used for visibility.
- Ultrasonic distance sensor to measure how close/far away they are from the casualty.

Depending on your group size and if you have access to additional croc leads, pupils could possibly look to design, build and program a system that uses all three additional components.


RESCUE
RNLI

Royal Academy of Engineering

The Royal Academy of Engineering is harnessing the power of engineering to build a sustainable society and an inclusive economy that works for everyone.

In collaboration with our Fellows and partners, we're growing talent and developing skills for the future, driving innovation and building global partnerships, and influencing policy and engaging the public.

Together we're working to tackle the greatest challenges of our age.

What we do

Talent & diversity

We're growing talent by training, supporting, mentoring and funding the most talented and creative researchers, innovators and leaders from across the engineering profession.

We're developing skills for the future by identifying the challenges of an ever-changing world and developing the skills and approaches we need to build a resilient and diverse engineering profession.

Innovation

We're driving innovation by investing in some of the country's most creative and exciting engineering ideas and businesses.

We're building global partnerships that bring the world's best engineers from industry, entrepreneurship and academia together to collaborate on creative innovations that address the greatest global challenges of our age.

Policy & engagement

We're influencing policy through the National Engineering Policy Centre – providing independent expert support to policymakers on issues of importance.

We're engaging the public by opening their eyes to the wonders of engineering and inspiring young people to become the next generation of engineers.

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