STEM ACTIVITY 2
TEACHER NOTES

RADAR

RAF 100

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EQUIPMENT REQUIRED PER PAIR OF STUDENTS:

- A target board (see Technician notes)
- A copy of the STEM student instructions
- Ruler and pen/pencil
- Two ping-pong balls
- Two sheets of A4 paper
- Sticky tape
- Metre rule
- Stopwatch or timer function on a phone
- Two copies of the STEM extension sheet (optional)
- Two copies of the Radar Plotting Sheet (optional)

PREPARATION REQUIRED

Before carrying out the activity you may need to download the accompanying video: The Battle of Britain. You will also need to make target boards for each pair of students (see Technician notes). The target boards need to be placed on a hard surface (eg a lab bench) and you should note the range and bearing data for each board before setting them up.

PHYSICS CURRICULUM LINKS: SPEED; REFLECTION OF WAVES

STEM ACTIVITY: TARGET DETECTION

In this activity students build a ping pong ball model of a radar station and use it to find the range and bearing of targets they cannot see.

Introduce the activity by playing the accompanying video: *The Battle of Britain*. If students are not familiar with how radar works, explain the basic principle: a transmitter is used to send out a signal and a receiver is used to detect the echo from the object (target).

Students should follow the STEM activity instructions to construct a ping pong ball transmitter out of two sheets of A4 paper. When they insert a ball it will launch along the surface of bench. They should find its average speed by taking repeat measurements of the time it takes for the ball to travel one metre.

Explain the scenario: their radar station is on the south coast of England and can detect incoming enemy aircraft over the English Channel. To determine the **bearing** (the angle from due north) for targets hidden under their board they should start with their transmitter aligned to the 140° mark and launch a ping-pong ball at their board. It will either roll straight through or bounce back off a hidden target. If the ball is reflected they should note the bearing before increasing the angle by five degrees and repeating until they reach to 220°.

Once they have made an estimate of the number of targets and their bearings they should devise their own method of determining the **range** (the distance from the transmitter). Encourage them to take repeat measurements in order to estimate an average of the range of each target. If they struggle, remind them of the relationship distance = speed x time, and that range is half the distance that the ping-pong ball travels. After collecting all their range and bearing data they can check if they were good target spotters by asking you for details of the positions of the targets for their board.

FIGURE 1:
SETTING UP PING-PONG BALL RADAR

A ping-pong ball transmitter set-up to investigate hidden targets.

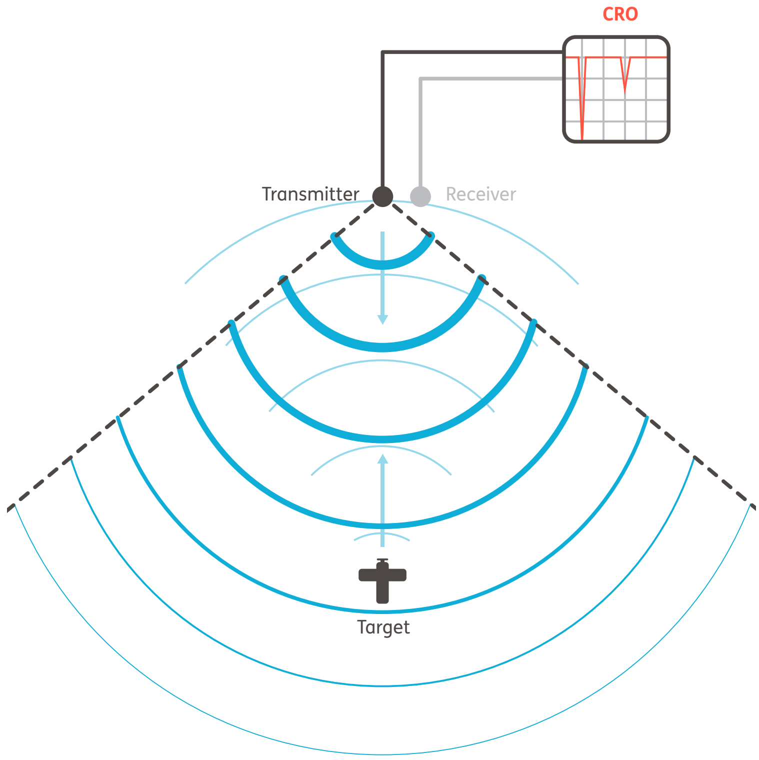
RADAR

ABOUT EARLY RADAR

Depending on the students' age and aptitude, you may want to include more discussion about the operation and limitations of the type of radar stations used in the Battle of Britain.

FIGURE 2:
AN EARLY RADAR STATION

The radar stations used by the RAF during the Battle of Britain had cathode ray oscilloscope (CRO) displays, and static transmitters and receivers.



A simplified diagram of an early radar station is shown above (figure 2). The transmitter was used to send radio waves to illuminate the region in front of it and any return signal was picked up using a receiver next to the transmitter.

Unlike the targets in the STEM activity, real targets scatter radiation over a wide range of angles (see figure 3). And, unlike ping pong balls, real radar signals spread out as they travel. Diffraction and scattering reduces the intensity of the signal as it travels to and back from the target.

Detecting the reflected signal was a particular challenge in early radar systems because unlike modern radar, the transmitters could not rotate. They were large static structures that resembled the towers used for commercial radio broadcasts. Radar coverage was provided by sending out the radio waves in a broad beam to 'floodlight' a large area in front of the transmitter and so the signal intensity dropped rapidly with distance (you could use an analogy of a torch: the decrease in brightness with distance is greater for a torch with a wide beam than a torch with a narrow beam). By the time the radar signal returned to the receiver, it was much weaker than the transmitted one. To allow its detection transmitters that sent out a pulsed, rather than a continuous signal were used so that the reflected signal could be detected in the interval between transmission pulses (you could ask students to think about clapping in the hope of hearing an echo: they wouldn't hear the faint echo if they clapped continuously).

For analysis, the reflected signal was amplified and displayed on a cathode ray oscilloscope (CRO). Target range was worked out by determining the time between the transmitted and reflected pulses and the bearing was found by comparing the strength of the signal received by different parts of the receiver.

Detection of aircraft by each station was limited to about 50 degrees either side of the transmitter's line of sight. Once an aircraft flew over the station it became invisible to radar and tracking had to be done visually using binoculars.

The RAF constructed a network of such radar stations along the UK coastline in the build-up and during the Second World War. It became known as Chain Home, and by the time of the Battle of Britain it provided almost complete radar coverage of the south and east coasts of the UK out to about 300 km.

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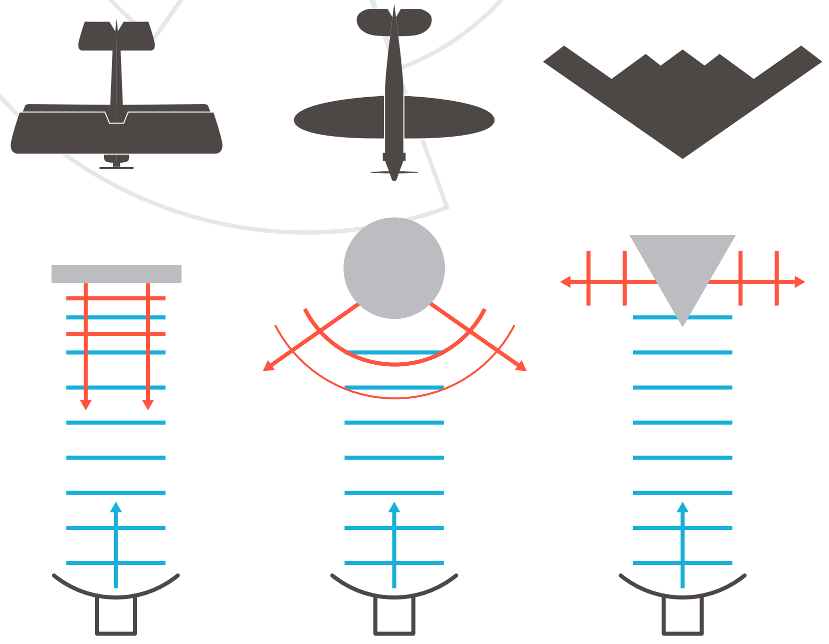

FIGURE 3: TARGET SHAPES

The visibility of an aircraft to radar depends on its shape.

Left: Flat targets with their surfaces perpendicular to the transmitter's line of sight (like the ones used in the STEM activity) are easy to detect because they reflect most of the signal back towards the receiver.

Middle: Real targets scatter radiation over a wide range of angles. Only a small fraction of the signal is reflected back towards the receiver (they could investigate this for themselves by aiming their ping pong ball transmitter at a small lab beaker).

Right: Modern stealth aircraft have sharp angled edges that reflect the radar away from the receiver. They are difficult to detect.

EXTENSION (OPTIONAL): RADAR DATA

As an extension students can follow some of the steps that radar operators took in order to process data during the Battle of Britain.

Each student will need a copy of the STEM extension sheet and the Radar Plotting Sheet. They should start by using the CRO trace provided to find that range of the target F1. Remind them that radio waves travel at the speed of light and that one millisecond is a thousandth of a second. They should conclude that the range of the target F1 is 60 km (see figure 4).

They should add the range of target F1 to the data table for Station F and then to plot the position of the targets from both stations F and BH on the Radar Plotting Sheet to decide which pairs of plots could represent the same target and which are likely to be two separate targets.

The expected results are shown over the page (figure 5). For guidance, explain that they can assume that plots in the same square such as F2 and BH1 are the same target. They will have to reach their own conclusions for the other points from the limited data available. For example, they may decide that BH2 is an erroneous result as if a real aircraft was in that square, it should probably have been picked up by station F. Target F1 could be a separate target, or an erroneous result, depending on whether they think this square is outside the detection area of station BH or not. Emphasise that for the other targets there are no right or wrong answers.

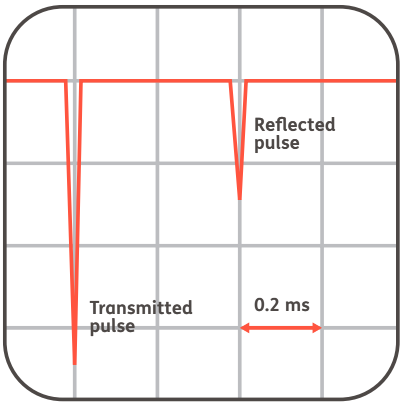

FIGURE 4: ANALYSING A CRO TRACE

For the trace shown on the extension sheet the target range can determine by using the time between the two pulses (0.0004 s) to work out the distance the signal has travelled (300,000 km/s X 0.0004 s = 120 km) and then the distance to target (½ X 120 km = **60 km**).

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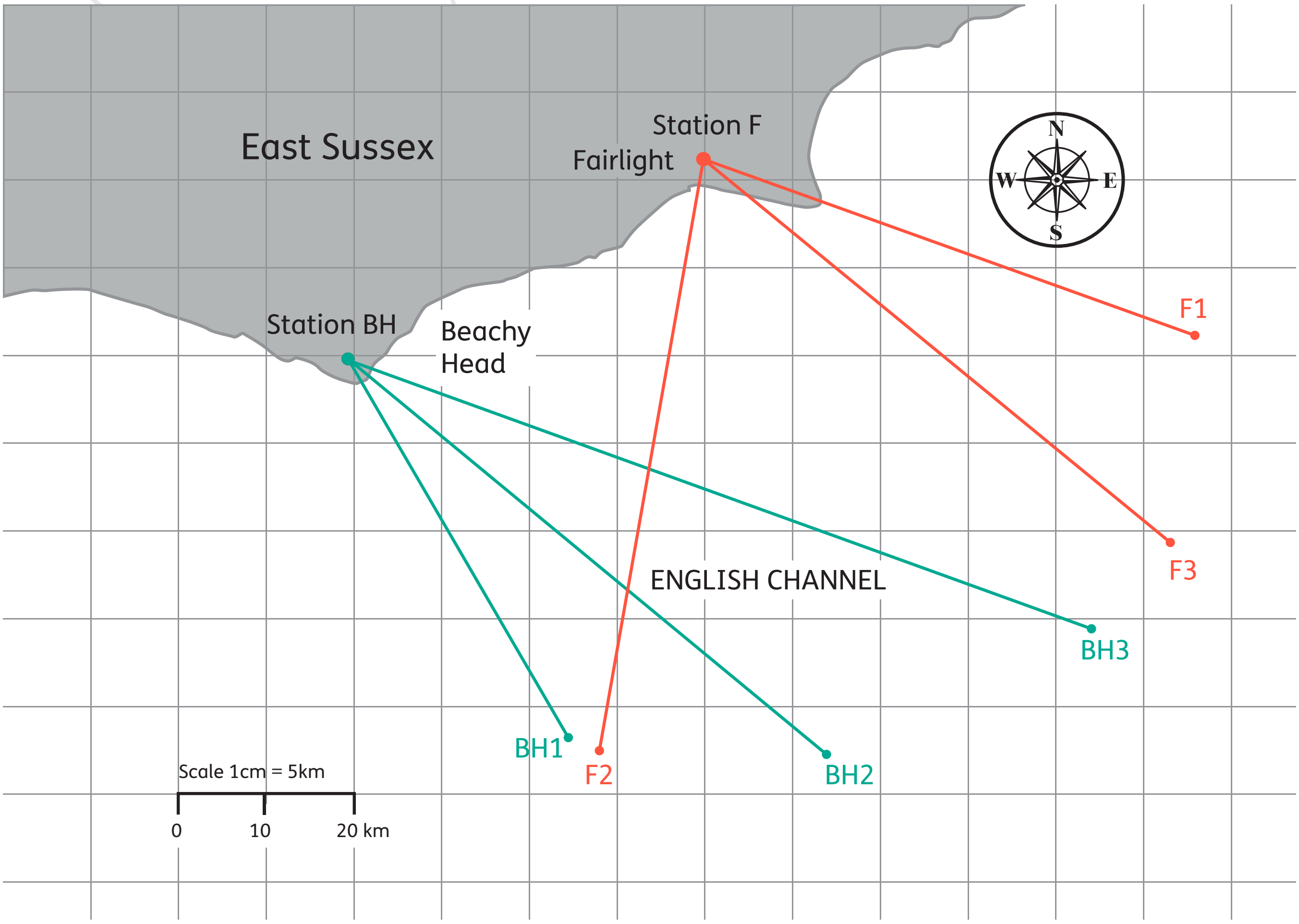
FIGURE 5:
TARGET PLOTTING

As the final part of the extension activity students should plot target data for stations F and BH. Expected results are shown below.



MAKING THE HISTORY CONNECTION

The linked history activity is designed to show how technology was used in the past. The history activity here is about the Battle of Britain. Team up with a history teacher to help students explore and role of radar in Britain's defence strategy during the Second World War.

FURTHER INFORMATION

For more information about radar, see **bit.ly/RAF-Radar.**
For more information about teaching waves see Supporting Physics Teaching (14-16): **bit.ly/RAF-Waves**.