DRONES: FRIEND OR FOE?

Missing drones

ROYAL ACADEMY OF ENGINEERING

THIS IS ENGINEERING

This resource is designed as an introduction to the mathematics involved in GPS location.

Missing drones

Kotdanda, Lalitpur, Nepal - 2 May 2015: A DJI Phantom 2 with a GoPro Hero3+ is used to assess the damages in the village. How else could GPS and drones help a search and rescue mission?

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GPS

The Global Positioning System, or GPS, is a network of about 30 satellites orbiting the Earth twice a day at approximately 20,200 km. Wherever you are on Earth, you are visible to at least four of these satellites. To work out your location on Earth, a GPS device calculates how far you are from three or more satellites and finds the position where all the circles intersect.

GPS Network

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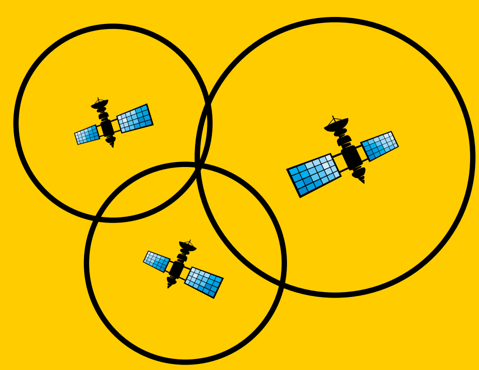
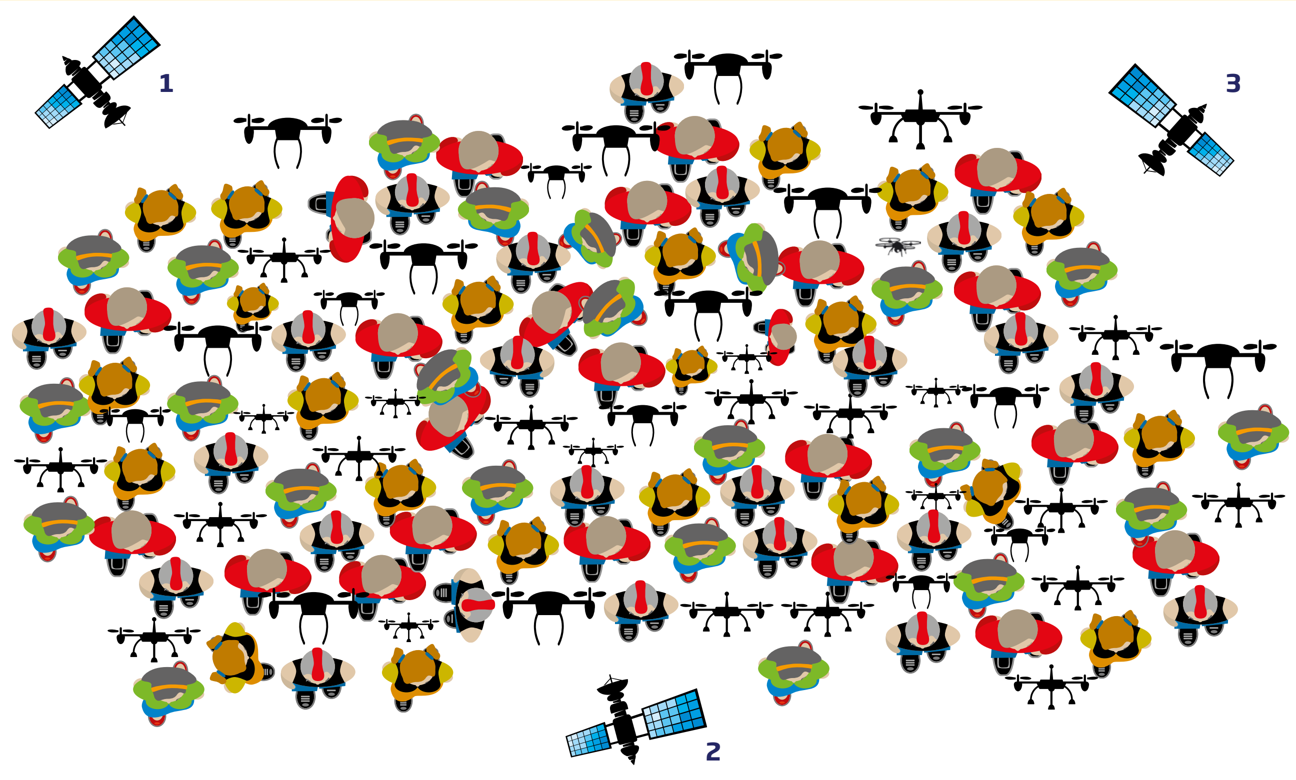


Activity 1 – Locating a drone

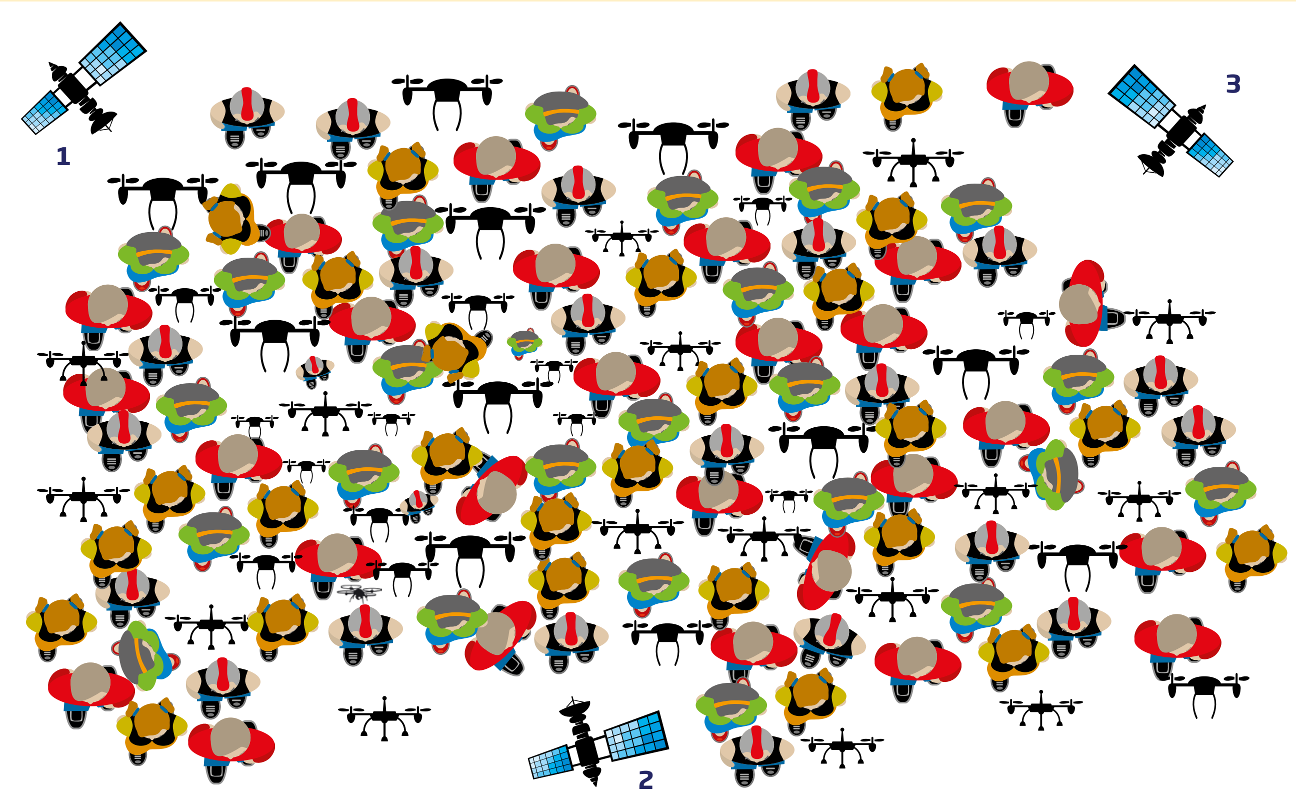
Find the missing quadcopter in the pictures on the next page.

Use the information to construct circles. The quadcopter is positioned where the circles intersect.

The quadcopter below is 10.4cm away from satellite 1, 6.9cm away from satellite 2 and 3.4cm away from satellite 3.



The quadcopter below is 7cm away from satellite 1, 3.1cm away from satellite 2 and 11.8cm away from satellite 3.



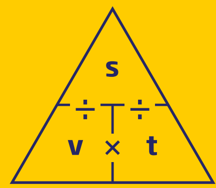
Stretch and challenge 1 – Calculating distance

GPS satellites constantly broadcast a microwave signal with their current time and location. The GPS receiver uses this data to work out how long it took for the signal to travel from the satellite to the receiver, and therefore the distance between the two.

Your Quadcopter received the following messages at 14:36:45.0000 from the three satellites:

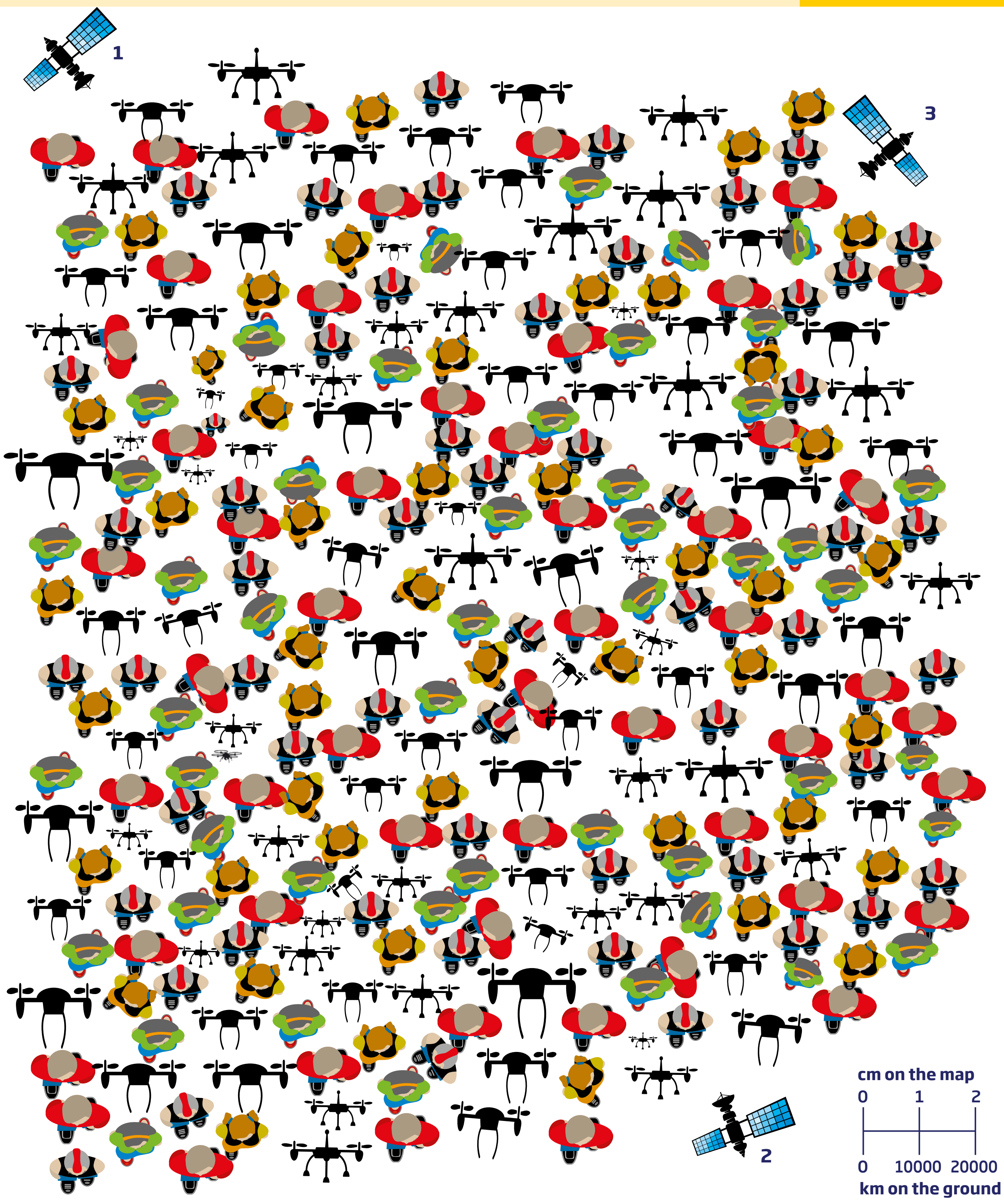
Satellite 1: The time is 14:36:44.5931
Satellite 2: The time is 14:36:44.6431
Satellite 3: The time is 14:36:44.4863

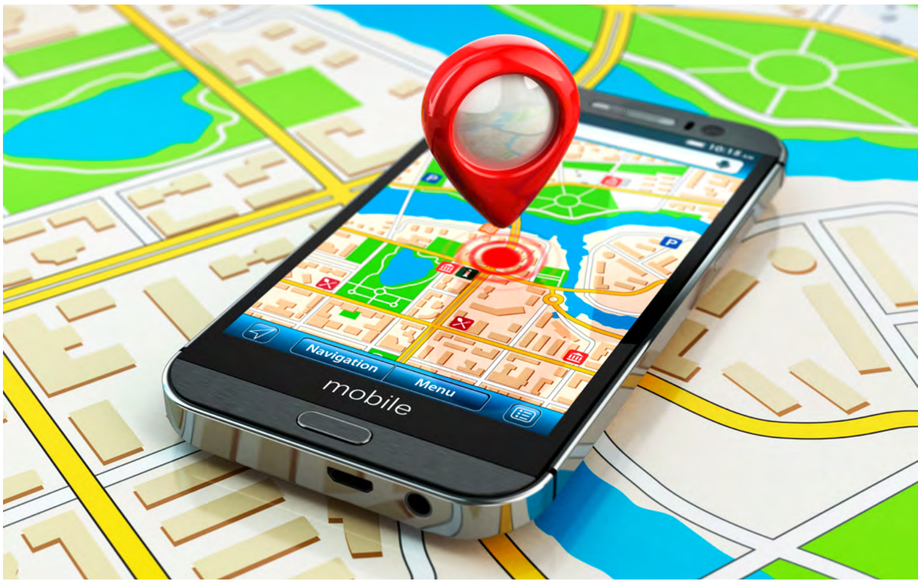
Use this information and the equation to the right to find the quadcopter. Once you have worked out the distance in metres don't forget to use the scale to work out the distance on the map.



s = distance
v = speed
t = time

Hint: The speed of microwaves is 299,792,458 m/s





Mobile phone with GPS app

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Activity 2 – GPS tracking

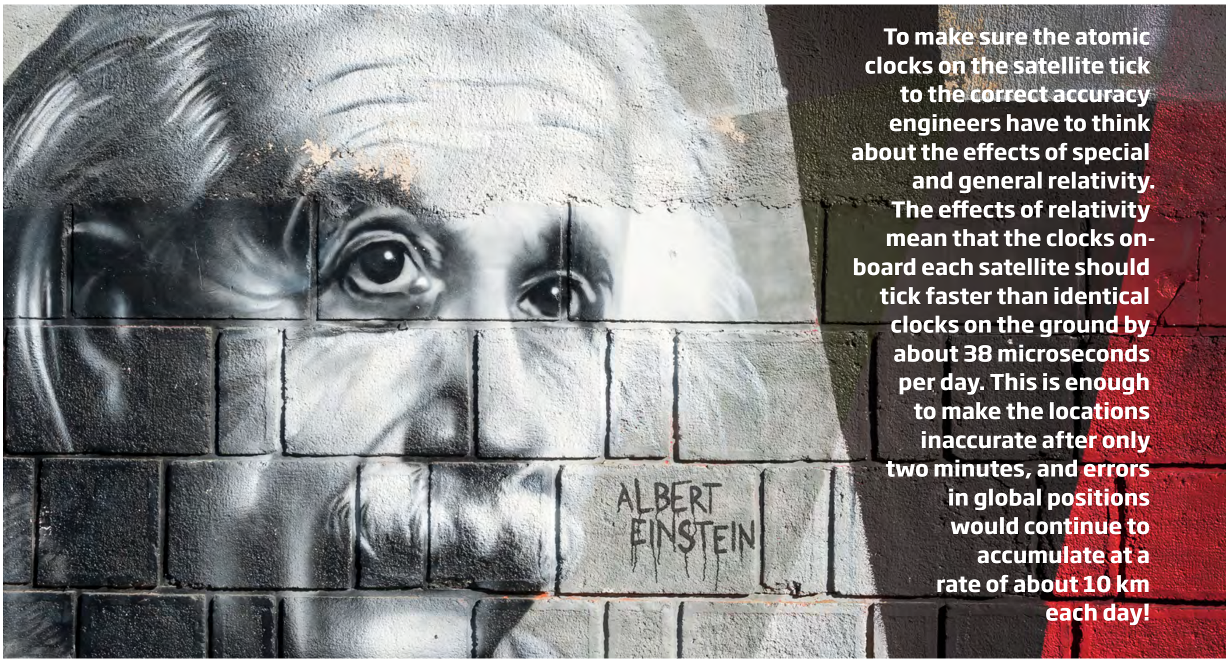
In activity 1 we have looked at trilateration on a 2D plane. In practice, GPS calculates your location in three dimensions; latitude, longitude and altitude.

This can be done with three satellites, however, the results are often less accurate than when there are more satellites.

Create or draw a 3D model of trilateration with three satellites. Instead of circles around the satellites, there will be spheres.

- How many times do the three spheres intersect?
- Why is it still possible to locate a GPS receiver on Earth with three satellites?

To get a really accurate location, the clocks on board a GPS satellite have to be accurate to 20–30 nanoseconds, that is 0.00000002 seconds! To be able to do this, GPS satellites have expensive but highly accurate atomic clocks on board. By using data from four satellites instead of three, the accuracy is increased. The fourth satellite is used to synchronise the clock on the GPS receiver with the far more accurate atomic clocks on the GPS satellites.



To make sure the atomic clocks on the satellite tick to the correct accuracy engineers have to think about the effects of special and general relativity. The effects of relativity mean that the clocks on-board each satellite should tick faster than identical clocks on the ground by about 38 microseconds per day. This is enough to make the locations inaccurate after only two minutes, and errors in global positions would continue to accumulate at a rate of about 10 km each day!

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Notes for teachers

Activity 1

Students should draw circles around the satellites using a pair of compasses. The radii of each circle should be the distance provided. Where the three circles intersect, the students should find a small image of a quadcopter.

Stretch and challenge 1

For this activity, students are required to calculate the radius of each circle they need to construct.

1. The time difference is 0.4069s.

$$s = v \text{ x } t = 0.4069 \text{ x } 299,792,458$$
$$= 121985551m$$

The scale is 1cm = 10,000km or 10,000,000m

So the distance on the map is 12.2cm

2. The time difference is 0.3569s.

$$s = v \text{ x } t = 0.3569 \text{ x } 299,792,458$$
$$= 106995928m$$

The scale is 1cm = 10,000km or 10,000,000m

So the distance on the map is 10.7cm

3. The time difference is 0.5137s.

$$s = v \text{ x } t = 0.5137 \text{ x } 299,792,458$$
$$= 154003386m$$

The scale is 1m = 10,000,000m

So the distance on the map is 15.4cm

Activity 2

The three spheres will intersect at two points: one will be on Earth, the other will be somewhere in space. We can discard the location in space, leaving the position the spheres intersect on Earth as the location of the GPS receiver.

A fourth satellite is needed for accurate results as it allows you to solve for a fourth variable, time. The atomic clocks on board the GPS satellites are far more precise and accurate than the clocks on a GPS receiver.

The GPS receiver uses the signal from a fourth satellite to solve an equation that lets it determine the exact time, without needing an atomic clock, allowing for a more precise calculation of the distance for each satellite and therefore a more precise location of the receiver.

Ideas for extension

You could extend this session by investigating different GPS apps available to smartphones.

Download a GPS tracker such as *Family Locator* created by Life 360, which is free to download, onto a school mobile and hide it in the school somewhere.

The students could track the phone using the website (**www.life360.com**). You could then discuss the accuracy of the app and the moral and ethical implications of tracking friends and family.

Or you could download a fitness app created to track running or cycling and students could draw a distance-time graph from the map. You could use this as an opportunity to discuss cyber safety and the implications of sharing this information on social media.

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