How GPS Works

Over the years, people have used a variety of techniques to navigate across the globe. Traditionally, people relied on stars and landmarks to travel between various locations, while maps and compasses helped to prevent people from getting lost. The advent of the Global Positioning System, or 'GPS' for short, means people no longer have to rely on these traditional (and often complex) positioning techniques to find their way around.

The GPS project first began in 1973 and became fully operational in 1994. The system is run by the United States Department of Defence and was originally intended for military applications only, but was made available for public use on completion.

The GPS system consists of a network of 24 active satellites (and 8 spares) located nearly 20,000 km above the earth's surface - that's the same as driving from Melbourne to Perth six times! Each satellite broadcasts different signals which can be tracked by a GPS receiver on earth, which are then analyzed by the GPS receiver to determine its precise location. The signals operate in all weather conditions but can't penetrate through solid objects, so GPS receivers perform best when they have a clear view of the sky.

FAST FACTS

1. **The GPS system became fully operational in 1994.**
2. **On average, it costs the US Government $2 million every day to run, but it is free for public use.**
3. **A typical GPS satellite travels through the sky at nearly 14,000 km per hour!**
4. **GPS receivers can determine your position anywhere on earth – even in the outback, the ocean or in Antarctica.**
5. **GPS works 24 hours a day in all weather conditions – rain, fog, hail or shine.**
6. **Satellite signals can travel through most plastics and glass, but not wood, rock or concrete.**

GPS receivers come in all different shapes and sizes, are widespread and are affordable. Today, GPS receivers can be found in watches, phones, tablets, computers, cars and a wide variety of other devices.

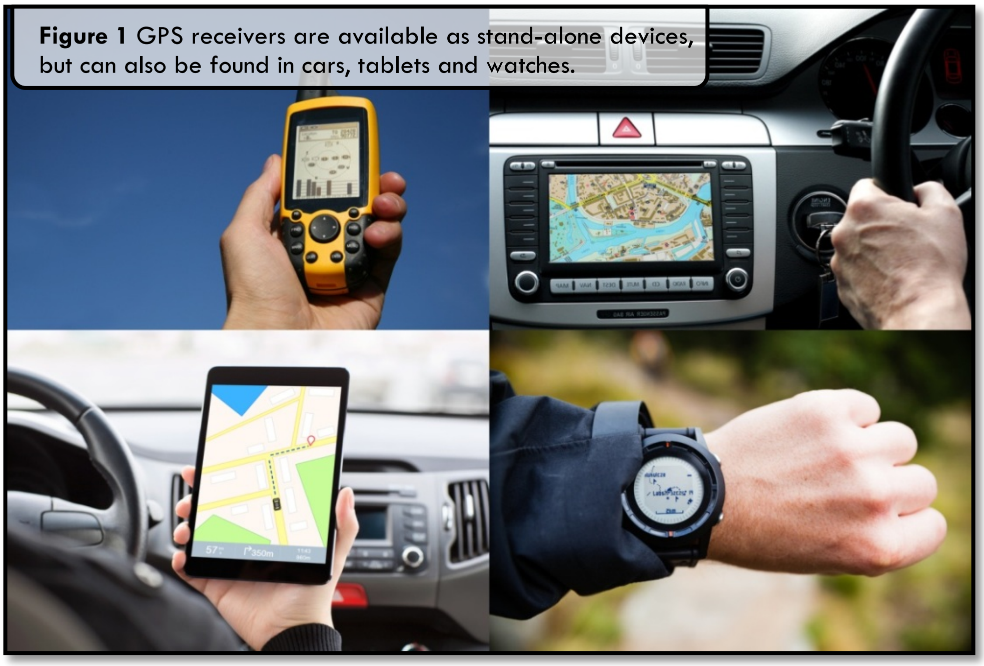

Figure 1 GPS receivers are available as stand-alone devices, but can also be found in cars, tablets and watches.

Produced by the University of Tasmania in conjunction with Geoscience Australia as part of the AuScope GPS in Schools Project – 2014.

Determining Your Position

So if a GPS receiver is tracking signals from multiple satellites, how does it convert these into a position that can be used for navigation? GPS receivers use a mathematical process called *trilateration*. This process can be a little tricky to comprehend in three-dimensional space, so let's begin with an example in two-dimensions…

You are travelling through outback Australia and find yourself at a lookout near an unfamiliar lake. At the lookout, there is a signpost with distances to three Australian towns.

The first sign tells you that you are 740 km from Adelaide. This fact alone isn't particularly useful, as you could be anywhere on a circle around Adelaide that has a radius of 740 km.

The second sign informs you that you are also 1,500 km from Cairns. If you combine these two facts, you can limit your location to one of two possibilities (A or B, shown by the intersection of the two circles in Figure 2).

The third sign also tells you that you're 1,430 km from Sydney. Using this final bit of information, you can eliminate Location B from Figure 2 and quickly determine that you're at Location A - Lake Eyre in South Australia (see Figure 3).

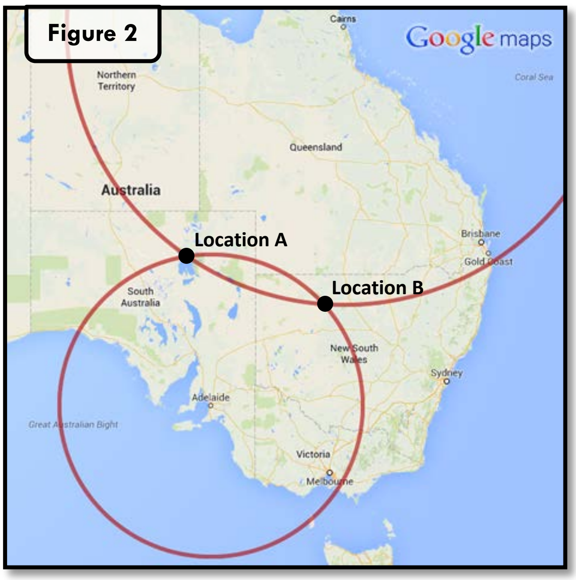

Figure 2

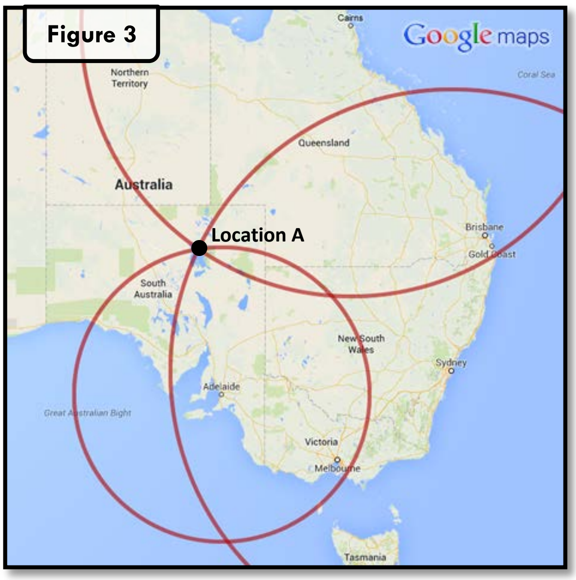

Figure 3

Trilateration also works in three-dimensions as well, but involves using spheres instead of circles and requires *four* distances to form a unique solution instead of three. GPS receivers use three-dimensional trilateration to tell you A) where you are on the earth and B) your current height.

In order to make this calculation, every GPS receiver must know the following things:

1. The location of at least four GPS satellites above it and;
2. The distance between the receiver and each of those GPS satellites.

The GPS receiver figures both of these things out by analysing radio signals transmitted from the GPS satellites and timing how long it takes for the signal to travel from the satellite to the receiver. If a GPS receiver cannot do this for at least four satellites, it will not be able to figure out where it is. If more than four satellites are detected, the accuracy of the trilateration increases.

Further Information

Are you wondering how exactly a GPS receiver can measure the distance between itself and multiple satellites? Are you curious about how each GPS satellite knows exactly where it is in space at any given time? Perhaps you'd like to know how a GPS satellite actually gets launched into space? Answers to all these questions and more can be found using the following resources:

Recommended Books

- 'GPS for Dummies' by Joel McNamara (2008). ISBN: 0470156236
- 'How does GPS work?' by Leon Gray (2014). ISBN: 1482403943

Recommended URL's

- Official GPS Homepage - http://www.gps.gov/
- 'What is GPS?' A more detailed explanation - http://www8.garmin.com/aboutGPS/

Recommended YouTube Videos

- NASA Launchpad: 'How GPS Works' - http://youtu.be/DsmvTzw3GP4
- Discovery News: 'How GPS Works' - http://youtu.be/loRQiNFzT0k

Australian Curriculum Content Descriptors: ACMNA178, ACSIS124, ACHGS049, ACHGS050, ACHGS052, ACSHE227, ACSIS145, ACSIS146, ACHGS057, ACHGS058, ACHGS060

Worksheet 1

Instructions: Use the information provided to answer the following questions.

1. What does the acronym 'GPS' stand for?

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2. Why was the GPS network originally developed?

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3. How many satellites are used in the network? How many are actually active at any one time? Why are this many satellites required?

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4. What mathematical technique does a GPS receiver use to determine its position? What is the minimum number of satellites required to achieve this? Can you think why this many satellites are required?

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5. Using the same mathematical positioning technique as a GPS receiver, determine your 2D position on the map of Moonah, Tasmania (see next page) given the information below. Draw on your map to show your working.

- You are 950 m from Hazelwood School.
- You are 1200 m from Moonah Bowl.

A) How many possibilities are there for your current location? What are they?

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B) Someone is then kind enough to tell you that you are also 850 m from the New Town Bay Golf Club. Which of the two possible positions from 5A) was correct?

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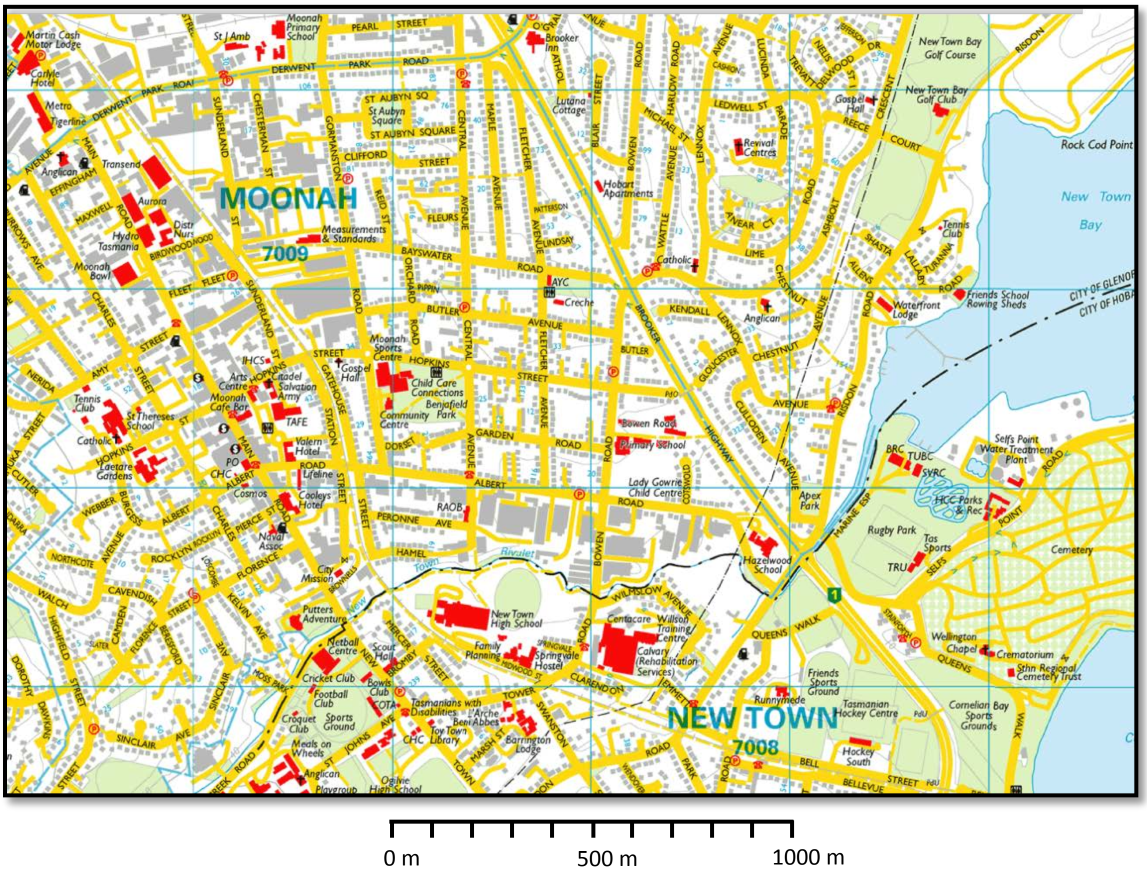

6. A GPS receiver needs to know two things in order to determine where it is on the earth. What are these two bits of information? If the signal containing this information is travelling at 300,000 km per second (i.e. the speed of light) and the GPS satellite is 20,000 km above the earth, how long does it take for the signal to reach the GPS receiver? Be sure to show your working.

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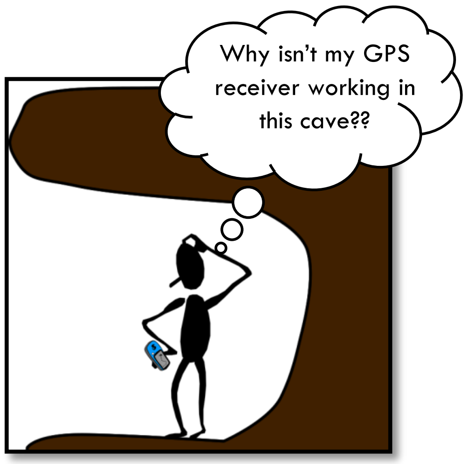
7. GPS receivers rely on the transmission of radio waves from the GPS satellite network, but sometimes these signals can get blocked. How and why does this occur? What can you do to fix the issue?



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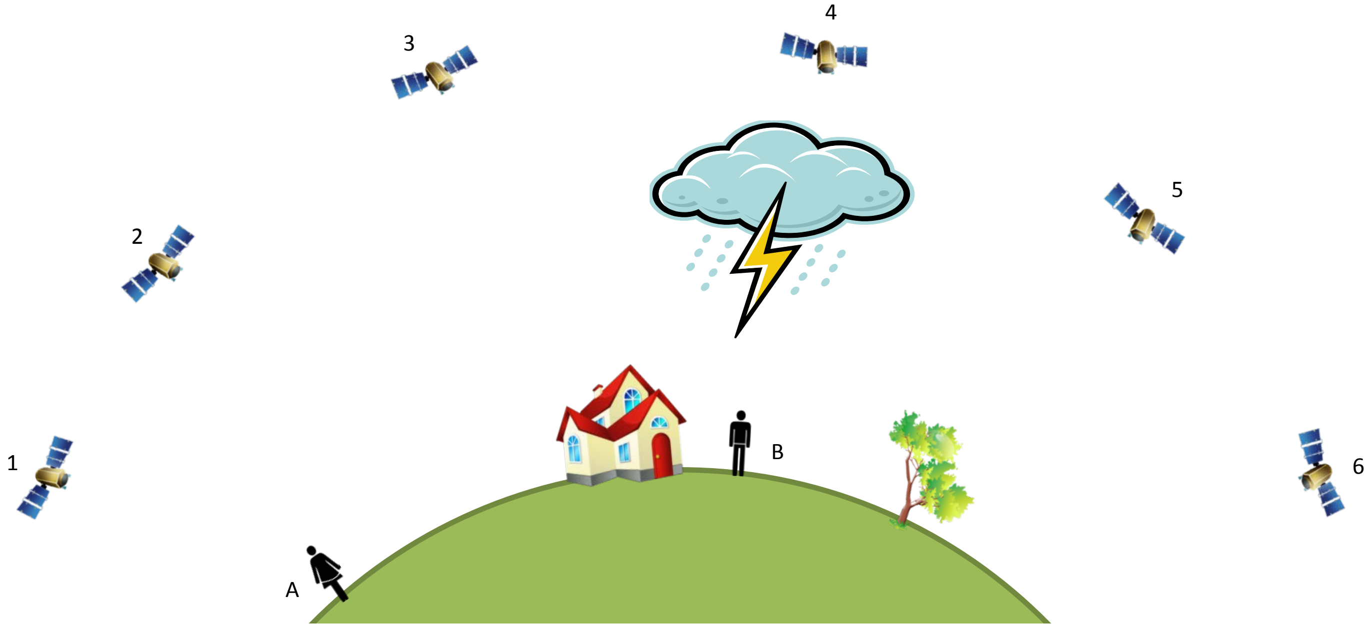
8. GPS satellites move around the earth to provide constant and global coverage. The figure below shows GPS satellite locations for two observers at a particular time. Using your knowledge of GPS, refer to the diagram and answer the questions below.



A) If both Observer A and B have GPS receivers, which satellites are each of them able to track?

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B) Can Observer A track enough satellites to get a position fix? Why/why not? What about Observer B?

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C) If the tree and the house were removed, could Observer A track all the satellites? Why/why not? What about Observer B?

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D) If each GPS satellite travels 166,000 km every time they do one lap around the earth, and if each satellite is travelling at 13,900 km/hour, how long does it take each satellite to do one complete rotation? How many rotations does each satellite do in a single day (24 hours)? Be sure to show your working.

9. Describe what you believe are some of the advantages of the GPS system. Can you think of any limitations?