

# GPS

## GLOBAL POSITIONING SYSTEM

- British scientists are currently involved in the development of the next generation of GPS
- Essen and Parry did the groundwork for GPS at the government-funded National Physical Laboratory in the UK
  - Modern armaments carried by the Royal Navy carry sophisticated GPS technology

### What is it?

Where am I? This is a simple question but sometimes one that is not easy to answer. Until recently, in the absence of a map, the best way to calculate your exact position would be to use the stars. The launch of the first man-made satellite, *Sputnik*, in 1957 changed this. Scientists tracking the satellite saw that the radio signal that it was transmitting could be used as a means of navigation – if the satellite's position is known, the position of the observer can be calculated. Ivan Gettling, working for the US Air Force, proposed a new system involving many satellites orbiting the Earth to provide an accurate and reliable positioning system. Gettling's idea was put into practice immediately, and by the early 1990s there were more than 20 global positioning system (GPS) satellites in orbit providing global coverage, allowing anyone, at any time, anywhere on the planet to know exactly where they are.

Developed by the US defence services, GPS is widely used by the military forces of many nations, including Great Britain, on battlefields all over the world. It is also a standard feature of all modern military planes, along with being the system behind “smart” bombs. The first civilian users were aircraft pilots and sailors, and the system also rapidly became popular with hikers and mountaineers.

Today GPS technology is extremely important to mobile communications and is behind the satellite navigation systems found in many cars. With its foundations in the theories of Albert Einstein and the development of atomic clocks, GPS is now so commonplace that it is an almost invisible part of everyday life, though few drivers suspect that they owe their speedy and efficient journey to Einstein's theory of relativity.

British scientists are currently involved in the development of the next generation of GPS, the European project GALILEO, which will provide wider coverage and more accurate information to an increased number of users. Able to operate for 24 hours a day in all weather conditions and free of charge, Ivan Gettling's dream of “lighthouses in the sky serving all mankind” now looks to be becoming real.



### The science

When somebody asks the GPS where they are, the receiver they carry measures how far away it is from three or more satellites orbiting the Earth. Once it knows this, and the satellites' locations, it can calculate its position on the globe. As such, the operation of the system is dependent on the numerous GPS satellites that are constantly orbiting the Earth. To find the distance to each satellite, the time taken for a signal sent by the satellite to reach the user is measured. This time is proportional to how far away it is. The signal contains

the time when the satellite sent the signal, which can be compared with the time when the GPS computer received the signal and its position in space.

The time taken for a signal travelling at the speed of light to go from the satellite to the Earth is so short that the clocks used must be accurate to billionths of a second. The satellites are each carrying their own atomic clock, which can be accurate to 1 s in 3 million years. Louis Essen and J V L Parry built the first reliable atomic clock at the government-funded National Physical Laboratory in the UK in 1955, and the clocks used in the GPS satellites follow the principles of their design. Atomic clocks keep such good time by constantly checking themselves against a caesium atom. Atoms can only absorb certain exact frequencies of light. Caesium atoms happen to absorb light in the microwave range. By tuning a microwave generator through a range of frequencies and monitoring how many caesium atoms absorb the light, the generator can match itself to the exact frequency of the atoms. Calibrating its microwave generator in this way, the clocks can keep time extremely accurately. Atomic clocks are now used as the gold standard for time – even Big Ben is checked against one.

A further complication is that the Earth's gravity has the effect of making a clock on the ground run slightly slower than a clock in space, an effect predicted and explained by Albert Einstein in his theory of relativity. The theory also allows for corrections to be made. These are essential. If they were not made the system would rapidly become too inaccurate to be used.

## GPS timeline

<b>1955</b>	The first reliable atomic clock is built at the National Physical Laboratory in the UK
<b>1957</b>	<i>Sputnik</i> is launched and people understand that this “artificial star” could be used for navigation
<b>1960</b>	The first navigation satellite is launched for the use of the US Navy
<b>1960</b>	Ivan Getting proposes the idea of a space-based multisatellite positioning system for land forces
<b>1967</b>	The second is redefined in terms of atomic clocks
<b>1978</b>	The first GPS satellite is launched, equipped with an atomic clock
<b>1990</b>	The first GPS car navigation system is launched by the Pioneer Corporation
<b>1993</b>	The GPS is fully operational, giving worldwide coverage
<b>2004</b>	A GPS navigation systems costs less than £100
<b>Today</b>	British scientists are contributing to the GALILEO European satellite positioning system

Since its creation the GPS has been used to track and guide missiles and smart bombs. The first missile with the ability to guide itself using a GPS-based targeting system was developed in 1993 and was first used in 1995 in Bosnia.

Einstein’s theory of relativity predicts that a clock orbiting the Earth on a satellite will be seen to run faster than an equivalent clock held by an observer on the ground. The effect is due to the Earth’s gravity, which is so strong that it slows down time, with gravity being stronger on the surface of the Earth and decreasing in strength as the distance from the surface increases – the gravity that the satellites experience is one-fourth the strength of the gravity felt on Earth.

The clocks on the satellites are manufactured to run slightly slower when on the Earth so that they will keep the correct time once in orbit. The users’ GPS equipment is able to do further corrective calculations as they calculate their position. Such is the precision required of the system that without these corrections, positioning errors would increase at the rate of around 10 km per day, rendering the system useless.

To be able to handle the ever-increasing volume of traffic, modern communication systems must use single cables to transmit many different phone calls at once. This is achieved using computers at each end of the cables to switch between calls thousands of times every second – a process known as multiplexing. For this process to work, these computers, located miles apart, must know which conversation is being sent when so that they are able to join the sections back together again without jumbling all of the calls up. To achieve the precise timing required to do this the computers each check their internal clocks against atomic clocks. A similar procedure is used for mobile phone networks and digital television. Increasingly, communication companies are using the GPS clocks as their standard; such is their accuracy and availability.

## Military accuracy

Modern armaments carried by the Royal Navy, such as the Stormshadow missile manufactured by BAE Systems, carry sophisticated GPS technology used to locate the target and to navigate. The co-ordinates of the desired target are programmed into the missile prior to its launch, and as the missiles travel towards their target it constantly checks its position against an optimum flight plan. The GPS navigation allows the missile to be launched from planes more than 150 miles away from the target, so putting the aircraft and crew in less danger of being shot down. The GPS navigation combined with digital terrain mapping enables the missile to steer around mountains, and infrared cameras allow the missile to confirm the target. These two systems make these some of the smartest missiles around.



Hand-held global positioning system receiver.

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