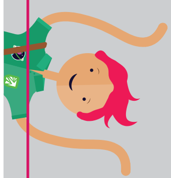
DESTINATION SPACE!

Satellite applications

Satellite applications

www.destinationspace.uk



Satellite applications

Satellites are our orbital life-improvers beyond the skies

Over the last 60 years, our utilisation of space has gone from zero to something we rely on daily. Whatever we do, wherever we go, satellites are in the background, supporting us in our everyday activities.

Why space?

Being in orbit gives satellites unprecedented coverage of the planet. Beyond the drag effects of the atmosphere, they are free to circle the globe, taking data and transmitting information without taking up any space down here on planet Earth.

Seeing the bigger picture

Before satellites, our observations of the Earth were limited to looking at a few tens of kilometres at a time from aeroplanes. Satellites can view an entire hemisphere at the same time, allowing instant, real time analysis of weather patterns, disasters, and monitoring of things like air quality, surface temperature and crop health. All the time, this data is being used to improve our models and predictions of future climate-based behaviour.

Improving communications

Satellites also enable much easier communication. A satellite can relay a signal from one point on a hemisphere to any other point on it. With just a few satellites, global communications are possible.

This was partially possible before satellites, but required much greater levels of infrastructure. This revolution has allowed not only global near-instant communications but live television broadcasts, global radio services, and the ability to communicate with satellites and probes sent to the edges of our solar system. In fact, if all the satellites were to suddenly stop working, global communications would shut down instantly with potentially terrible consequences.

Networks of satellites have revolutionised our ability to move around the planet. In the past, we would rely on maps, compasses and the position of the Sun to navigate. By placing atomic clocks on satellites, we can use them to accurately place us on the globe down to centimetre accuracy. This is used every day by people commuting to work, trucks and trains delivering parcels and even aeroplanes taking us on holiday.

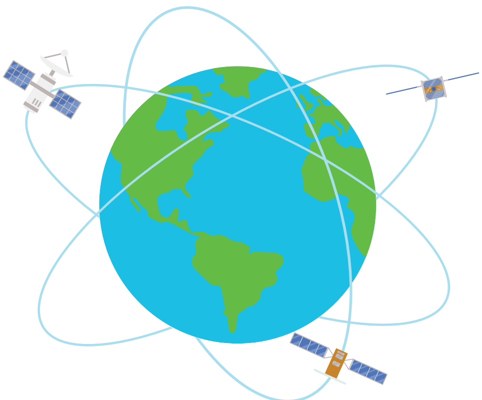
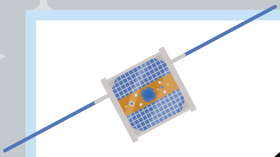
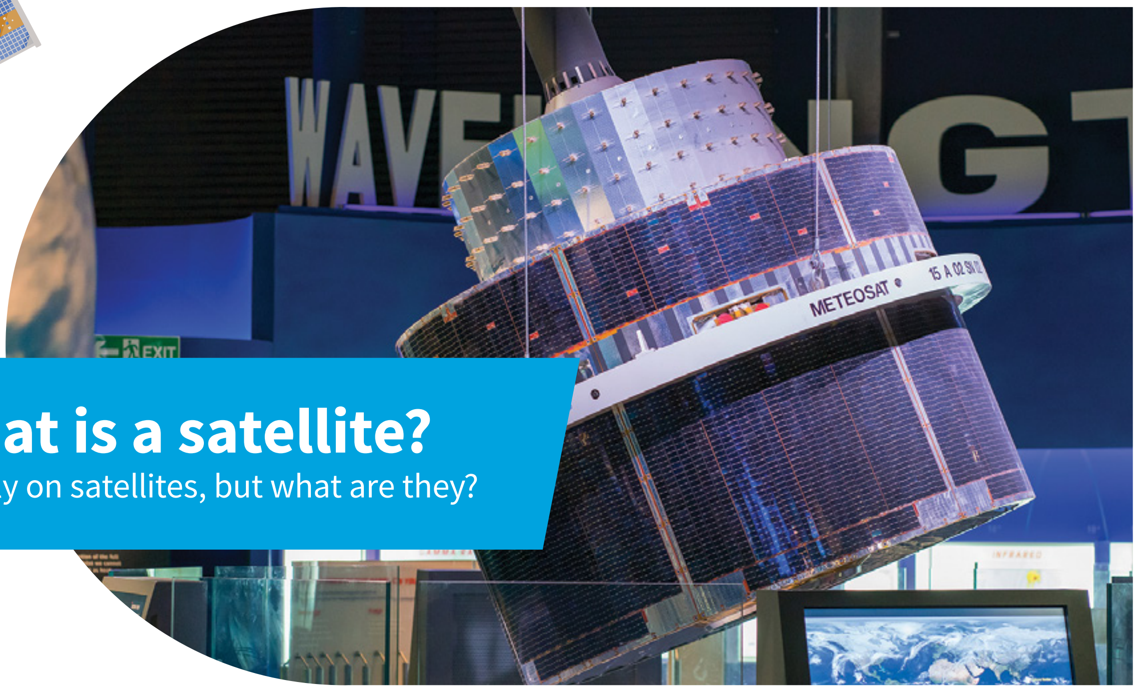


Image: Space satellite orbiting Earth. Credit: NASA





What is a satellite?

We rely on satellites, but what are they?

A satellite is an object that orbits around another object. They can be naturally occuring, like planets or moons, or built by humans, like satellites. Our Moon is a satellite of the Earth. The Earth, and the other planets in our solar system, are satellites of the Sun.

How do objects stay in orbit?

An orbit is a curved path, like a circle or an oval

A moving object will continue moving unless something pushes or pulls on it (Newton's first law of motion). Without gravity, a satellite would fly off into space. With gravity, a satellite is constantly pulled back toward Earth. It's this tug-of war that keeps the satellite in orbit.

Why build satellites?

After developing technology to leave Earth's atmosphere, we wanted things to stay in space for longer to increase their usefulness. Placing objects into the orbit of Earth, creating an artificial satellite, is a good way to do this.

Did you know?

The world's first satellite was Sputnik 1, launched by the Soviet Union. It spent 3 months and 1400 orbits in space measuring temperature and pressure.

Power in space

If satellites stop working while they are in space, it is difficult to get up to fix them, so they are built to last and to be as self-sufficient as possible.

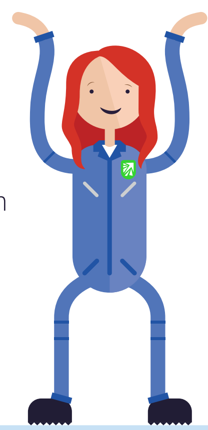
Power is one resource that every satellite needs. While they could carry this in batteries, these are heavy and have a limited capacity.

If a satellite can generate its own power while in space, it can function for longer. The most common way of doing this is with solar panels.

Some satellites have been sent to the outer solar system, where the energy received from the Sun is less. In cases like these, miniature nuclear reactors have been used as an alternative energy source.

The UK's satellite speciality

Space is one of the harshest environments we have built equipment for. There is a high level of technical expertise needed to make sure that satellites can function properly in these conditions. The UK has a lot of this expertise and has developed a thriving industry around building satellites. The UK's satellite industry has grown every year throughout the last decade and now employs 42,000 people.



Satellites come in all shapes and sizes as Meteosat on display at National Space Centre shows, Credit: NSC

Build-your-own-satellite

Taking charge of your own mini-mission

Most satellites look very similar, though the tasks they perform are extremely varied. Getting things into space is tricky, so it makes sense to maximise the science you can do with a satellite by including different instruments.

How it works

When you picture a satellite, you probably imagine a metallic box with solar panels and maybe a communications dish.

Satellites look similar because it would cost too much to completely redesign a satellite each time you launch one. Using the same base structure, you can easily add or alter modules to produce a reliable satellite that meets the needs of the customer.

Satellites have a central frame that houses the must-have electronics: computer processor, temperature controls and batteries, for example. On the outside of this you can mount extra devices such as scientific packages, communications dishes and cameras. If you have something you want to launch into space, you can probably fix it to the side of a satellite.

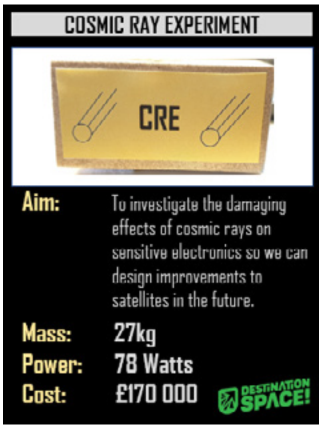
Your satellite and modules need to remain small enough to fit inside a rocket. Sometimes this means that devices will be deployed or unfolded only after the satellite reaches space.

How to run this activity

Visitors are given a kit that contains a central control unit (the main central frame) with several ports where additional components can be added.

As a simple busk, you can gather a family around and ask them what a satellite is for. Discuss examples of satellites and point out the relevant extra components: a weather satellite will need a visible camera, or an Earth observation satellite might need a near-infrared camera. Of course, since your satellite is going up to orbit anyway, it would be a great idea to send up some extra science packages. Ask how the satellite is powered and get your visitors to assemble their complete satellite.

This activity can be extended with the use of the component cards. These give more detailed information allowing visitors to consider the implications of increasing mass, providing enough power and having a large enough solar array to power everything.



How far away/close are satellites?

Getting to grips with the scale of things

Distances in space can range from hundreds to millions of kilometres and more. This makes it very difficult to get an idea of just how big it is. This activity is aimed at getting visitors to begin to get to grips with the distances involved in satellite orbits, both natural and artificial.

Sense of scale

It is incredibly easy to underestimate how big space is. A useful tool to aid our understanding of large distances can be a scale model. While this doesn't accurately depict the enormous distances being dealt with, it can give us an insight into the relative positioning of things. This activity will help you set up a model that can be assembled beforehand, or you could give it to volunteers and guide them in the construction. A set of picture arrows depicting objects at each orbital distance is available as an additional digital resource.

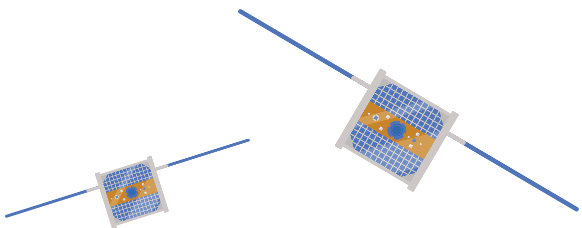
Satellites at different distances

For this activity we first must start by scaling down our Earth. This reduction can be tailored to your presentation space. We suggest using a model of Earth that is 35cm in diameter, and have based the measurements on that.

With the Earth set at this scale, each centimetre of distance is roughly equivalent to 350km.

- 1cm above Earth's surface – International Space Station – 350km
- 2cm above Earth's surface – Iridium satellite phone constellation – 770km
- 6cm above Earth's surface – highest altitude considered 'low Earth orbit' – 2,000km
- 47cm above Earth's surface – average altitude considered 'medium Earth orbit' – 16,500km
- 66cm above Earth's surface – Galileo satellite navigation constellation – 23 000km
- 102cm above Earth's surface – geostationary orbit – 35,800km
- 102cm above Earth's surface – Meteosat weather satellite – 35,800km
- 1000cm above Earth's surface – the Moon – 384,400km
- 4290cm above Earth's surface – James Webb Space Telescope – 1,500,000km

The next page talks about how these different heights are more or less suitable for different satellite applications.



Choosing an orbit

Why are there different types of satellite orbit?

From observing the Earth to transmitting communications, different satellites are designed with different tasks in mind and each task requires a different type of orbit.

What is an orbit?

An orbit is the curved path an object in space takes around another object, like the Earth. Satellite orbits must be far enough from the surface of the Earth to avoid atmospheric drag, but the further out you go, the less detail you can see on the Earth and the longer it takes to complete a full orbit. Which orbit you choose depends on your mission.

What's the best orbit?

Need high resolution images of the Earth? Then you want a low Earth orbit (LEO).

Have a constellation of satellites for GPS? Then a medium Earth orbit (MEO) places you close enough for easy and quick communication, but far enough to get global coverage.

Want to provide satellite communications for polar regions? A highly elliptical orbit (HEO) speeds through its closest approach, slowing down over high latitudes.

Need constant communication with a point on the Earth? Then a geostationary orbit (GEO) with an orbital period of one day will stay above the same spot on the equator.

Looking to map or study the entire planet? Then a polar orbit will pass from pole to pole while the Earth spins below, viewing the entire surface.

Need constant power and lighting conditions for weather observation or reconnaissance? A Sun synchronous orbit (SSO) is perfect.

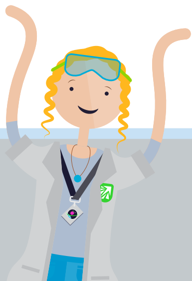
How to run this activity

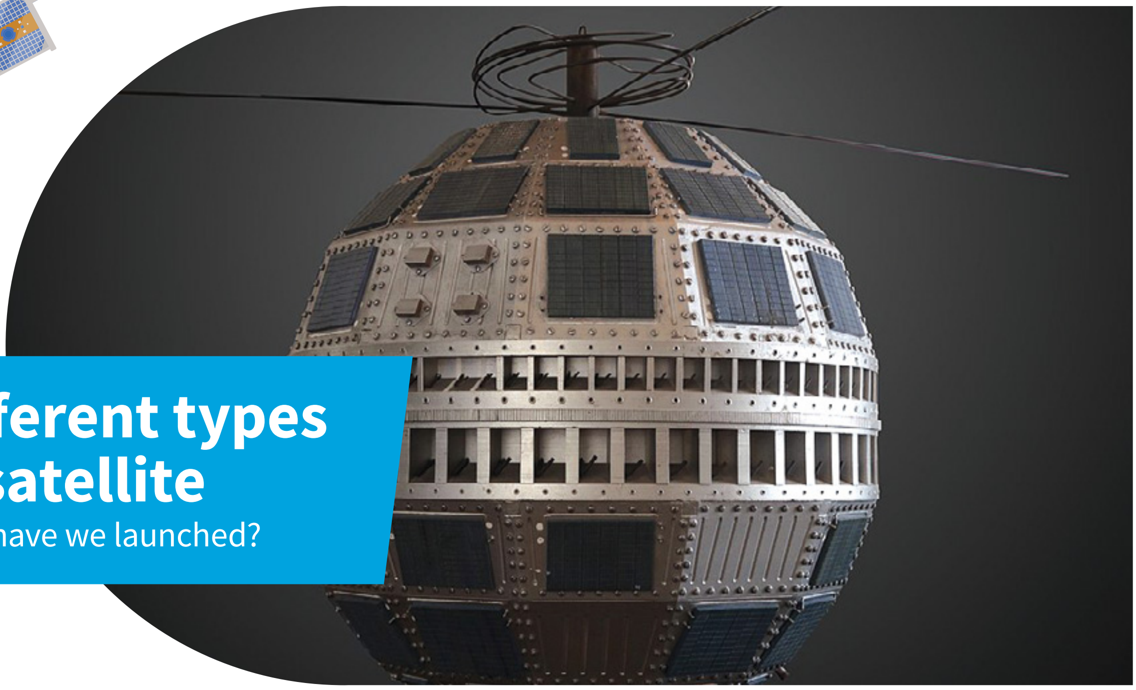
You will need:

- Earth globe attached to a hat
- Powerful torch

For this demonstration, the satellite (specifically the line of sight from the satellite to Earth) is represented by a torch shining on the planet. You could even add a picture of a satellite to it.

Select a volunteer to wear the globe and get them to start to slowly rotate on the spot. Dim the lights and aim the torch at the Earth, keeping it pointed there all through the orbits. For LEO and polar orbits you should be a at distance of 0.5-1m. For GEO you should be at a distance of 2-4m. Don't forget that for GEO, you need to match your orbital speed and be slow enough that your torch continues to point at the same spot on the equator.





Different types of satellite

What have we launched?

Satellites cover a wide range of functions from enabling communications to monitoring disasters. We have launched many of them into space over the last 60 years.

Using satellites to communicate

Communication satellites were one of the first types of satellite built. Further from the surface of Earth than communication towers, these satellites could send signals much further, connecting remote and distant locations more easily. Most communications satellites are in geostationary orbit above the Earth at around 36000km.

One of the first communication satellites to launch was Telstar 1 (see image above). This satellite was a joint project between the USA, France and the UK, designed to relay signals across the Atlantic Ocean.

Navigation satellites

Radio waves have been used for navigation since before World War I. Using this technique with a network of transmitters in orbit around the Earth meant unprecedented levels of accuracy for global navigation.

Most satellite navigation has been handled by two networks, Russian GLONASS and the US GPS. In 2020, a new network will be completed by the European Union called Galileo. This network will be able to track objects down to an astonishing 1cm accuracy.

Later in this section, there is more information about navigation using satellites and a practical triangulation demonstration.

Remote sensing satellites

Remote sensing satellites are used to gather information about an object while orbiting around it. Around the Earth, they are used for a variety of purposes, including weather forecasts, land surveying and humanitarian applications. The second half of this section expands a bit on these.

Remote sensing satellites are also one of the most common types of satellites sent to orbit objects other than the Earth. These satellites are used by the scientific community to carry experiments to planets, moons and other celestial objects, so that we can investigate them without having to physically transport people there.

Top: Telstar 1 Model Satellite. Credit (CC): RAMA

Middle: Gallileo Constellation. Credit: ESA

Pocket satellite

Build and use your own mini-satellite

Space travel can be expensive so smaller payloads are essential to make it affordable. The pocket-sized satellite is the perfect example of tech that may be launched from UK soil.

Why are satellites getting smaller?

The smaller and more efficient we can make satellites, the more satellites we can launch with the same fuel and costs. Developments in electrical engineering and construction methods mean that we can shrink components down and miniaturise satellites. This has helped to expand the availability of space-based projects to more organisations and people.

What's in your mini-satellite?

One of the components you may recognise are the solar panels. This mini-satellite is powered using energy from the Sun. The panels on this satellite keep it in operation in space, allowing it to take roughly one picture per orbit. The satellite has a battery to store charge and it takes the solar panels roughly six hours to fully charge the battery.

Our miniature satellite has a small Arduino computer to run its operations. This computer is as powerful as desktop computers were in the mid 1990s.

This satellite is not designed to return to Earth, so all data it gathers must be transmitted home. This is achieved by the radio component on board. It's a small green chip which is powerful enough to transmit a signal from space to Earth.

To gather information, our satellite is equipped with a temperature sensor, a gyroscope, a light sensor and a small camera.

How do I demonstrate this?

The base station should be plugged into a computer running the Arduino software. When the mini-satellite is switched on, it can wirelessly beam data back to the base station. Once connected, you can tilt the satellite by a small amount to get it to take a photo.

The captured image will be sent to the base station as a stream of data which you can see in the computer's monitoring window. You can convert this code into an image after the data transfer is complete.

If you have a bit of knowledge of Arduino programming, the satellite can be programmed to respond to other inputs (such as temperature or light changes) or to function differently (e.g. measuring the temperature when tilted slightly). The satellite user manual will guide you through programming the satellite.

This is a good opportunity to get your participants thinking about what kind of data they might use. satellites to collect.

Testing for space

Equipment must be sturdy to survive in space

Space is a harsh environment and equipment is often sent on a one-way trip. To ensure it survives (it's tricky to repair anything once it's up there), everything going into space is rigorously tested beforehand.

Shaken to destruction

Any object destined for space must get there on board a rocket. These enormous machines harness incredible energy, relying on one long controlled explosion to power them into space. One very notable feature of a launch are the vibrations of the engines passing through the rocket. These vibrations can have devastating effects on the rocket's payload. All payloads must be subjected to extreme vibration testing before they go into space. This is to ensure that the payload survives, but is also not a risk to the entire rocket.

Vibration testing is one of the most feared processes in preparing for space. One of the biggest concerns is that your equipment could be shaken to the point of damage. If you look online, you can find videos of vibration tests on parts of the James Webb Space Telescope.

Acoustic testing

The noise level generated at launch can potentially damage the payload. Rocket launches can reach a volume about 20 times louder than a jackhammer, so engineers need to expose components of the launch vehicle and equipment to high-intensity noise before sending it into space.

Baked by the Sun

Generally, we consider space to be very cold. However, in direct sunlight, without an atmosphere to dissipate the heat, things can get very warm. Satellites around the Earth can reach temperatures of over 120oC when in direct sunlight.

To prepare satellites for these extreme conditions, any equipment destined for space is baked inside giant ovens. With components held at high temperatures for long periods of time, engineers can check how the pieces will perform and ensure no dangerous gases are given off.

Blasted by Radiation

On Earth, our atmosphere absorbs most of the harmful radiation from space. Any object heading out into space will be exposed to this radiation, which can have some troublesome effects on electronics. As the radiation interacts with the circuits, it can alter data, create inaccurate signal readings and destroy memory. Electrical components have to be protected against this radiation by 'hardening' prior to launch. There are several ways to harden electronics, often including some sort of insulation or shielding against the radiation.

Image: Columbia launch. Credit: NASA

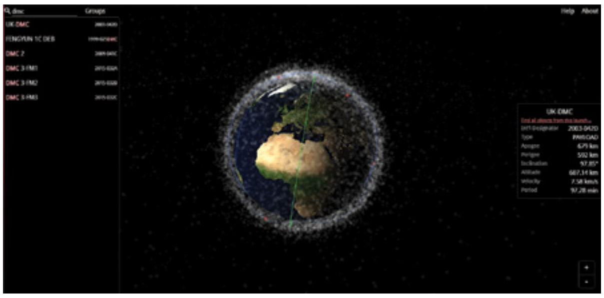
Are there satellites above us now?

And how can we spot them?

There are so many satellites being sent into space that there is a swarm of them around the Earth. Though you might not be able to see them, at any point in time there are lots of satellites above you in the sky.

Can I see the satellites above me?

It is possible to see some larger satellites like the Iridium communications satellites with the naked eye. Often mistaken for a meteorite, they present as a bright spot moving across the night sky, that disappears almost as quickly as it appeared. They can be seen against the dark night sky because, if their solar panels are large enough and the angle between the Sun, satellite and Earth are just right, light will reflect off the solar panels down towards Earth. However, as soon as the satellite has moved sufficiently in its orbit, the angles are no longer right, and the satellite disappears from view. The picture above shows one of these 'Iridium flares'.



Top image: Iridium flare over the Colorado River. Credit: Sean M Sabatini
Bottom left: Stuffin.space website. Credit: StuffinSpace

While most satellites cannot be directly observed by us, we can still locate satellites by tracking their position. This is something that is not only important to ensure they don't collide, but it gives us an insight into just how much we use satellites these days.

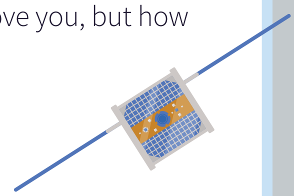
How do I spot a satellite?

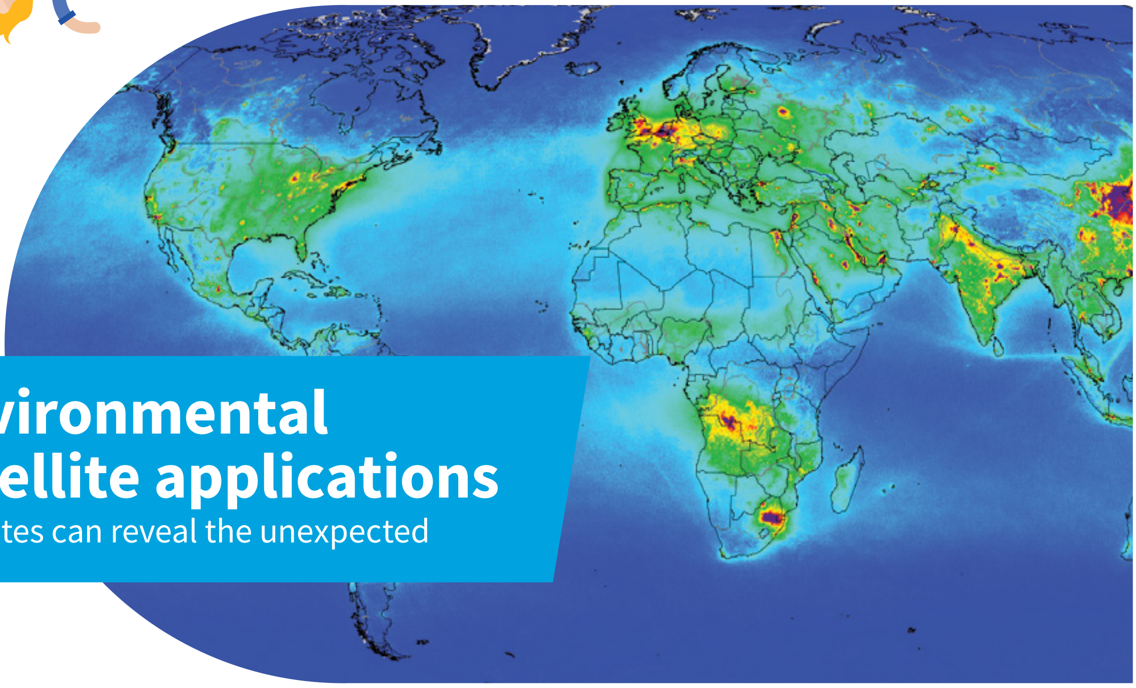
There are several different ways to track satellites in orbit. Some satellite providers have dedicated resources to do this.

The European Space Agency maintains a live International Space Station tracker so you can see, and even be notified, when the space station is passing overhead. To sign up and see its current position, head to: isstracker.spaceflight.esa.int.

Another tool by the European Space Agency allows you to track their Galileo navigation satellites. The GalileoPVT app is available on the Google Play store for compatible android devices. It uses the satellite signals to show exactly where the satellites are using the phone's camera.

While the above services just track a few satellites, the website: stuffin.space tracks almost every satellite in orbit. It gives a really good picture of not just which satellites are above you, but how many there are in total.





Environmental satellite applications

Satellites can reveal the unexpected

Many satellites launched into space are placed there to look at the Earth. Access to this unique viewpoint has influenced many areas of our lives. This large-scale view has benefitted weather forecasting, disaster management and our understanding of the planet.

Humanitarian crises

With an array of satellites looking back at the Earth, we have an indispensable tool when it comes to emergencies. In large-scale humanitarian crises Earth observation satellites can be used to inform emergency services of the developing situation. From the ground, the scale of events like floods or forest fires can be obscured in the panic. However, the birds-eye view provided by satellites can track where, for instance the flames are moving and what may lie in their path.

Bird watching

Tracking animals can be very tricky, but a team of scientists from the British Antarctic Survey used satellites to aid them.

While studying the breeding patterns of penguins the scientists were able to locate and understand their behaviour. Using Landsat satellite images, the team spotted stains in the snow from the penguins' poo. Using the changing colour of these stains the team could make accurate estimates of not just the breed of penguin but also the ratio of baby to adult penguins.

Pirates ahoy!

A team of environmental scientists from the University of Leicester noticed something odd when studying shipping lanes from space. Initially they were tracking the pollutants from boats' smokestacks. They noticed that the shipping lanes would sometimes change, meaning that the boats would sometimes deviate from the usual course. Further investigation revealed that these detours coincided with reports of naval piracy. This discovery has given authorities a wider picture of this issue and they now have a new tool for discovering similar activities around the world.

Climate monitoring

Satellites have allowed us to compile longitudinal, large-scale studies of our environment. The melting of glaciers and sea ice is something that can be easily monitored from space, as the whole picture can be seen rather than only localised results.

Top image: Studying shipping lane pollution from space. Credit: ESA. Bottom left: Penguin poo seen from space. Credit: GoogleEarth

Near Infrared webcam

Checking plant health from space

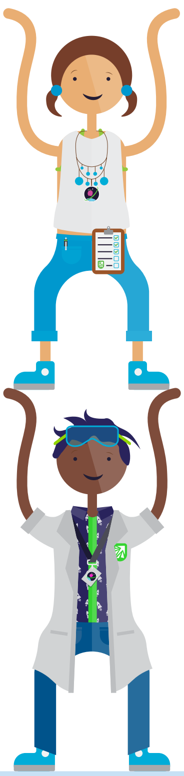
Agriculture is hugely important to sustaining the population of the planet. However, as plantation and crop sizes get bigger, monitoring the health of the crops we grow becomes harder. Luckily, we can use near infrared light to give us information on the health of crops, from the skies and even from satellites.

Healthy plants reflect near infrared light

The chlorophyll in plant leaves absorbs visible light from sunlight to produce energy through photosynthesis. Visible light has a wavelength between 0.4µm and 0.7µm.

Near infrared light (just a little longer in wavelength than visible light) is not useful for photosynthesis and is reflected by the cell structure of the leaves.

Consequently the healthier a plant is, the more near infrared it reflects and the less visible light it reflects (because it is using this for energy).



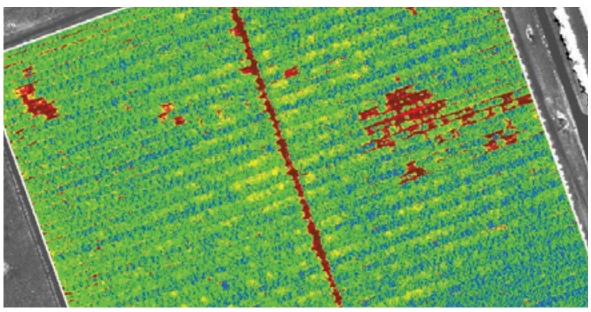
Measuring plant health

The NDVI (Normalised Difference Vegetation Index) is a measure of the ratio of near infrared reflected to visible light reflected. The lower the NDVI, the less near infrared and more visible light is reflected, indicating a less healthy plant. Colour can then be attributed to each NDVI level to give a visual representation of the health of vegetation.

The equation used to calculate the NDVI is:

$$\text{NDVI} = \frac{\text{Reflected Near IR} - \text{Reflected Visible}}{\text{Reflected Near IR} + \text{Reflected Visible}}$$

The reflected light is given as a fraction of the incident light. The image below shows a region of low NDVI in red, indicating poor health in the crops in this area of the field.



The European Space Agency's Sentinel-2 mission is conducting one of the biggest NDVI studies of our planet.

Near infrared webcam

It is not necessary to spend a huge amount of money to obtain a near-infrared webcam. In fact, a cheap visible light webcam can be easily converted into one. The camera in your kit has had its infrared filter removed. If you plug it in and view the image without the use of polarising filters, you will see that the image is washed out in white due to the saturation on the camera chip of near infrared.

How to demonstrate this

1 Demonstrating plant health

You will need:

- A live healthy plant
- An artificial plant
- A computer with VLC media player installed (or other webcam viewing software)

Ask the audience which of the plants they think looks healthier. Explain that you will then view them using this special webcam, which will detect not just visible light, but near infrared light too. By looking at the amount of near infrared light the plants are reflecting, we will be able to tell remotely which plant is healthiest, just as satellites do with crops from space.

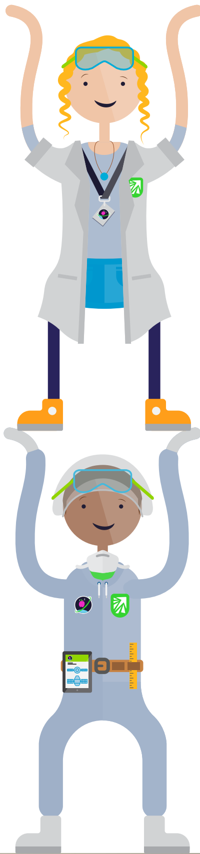
Place the camera about 40cm away from the plants and make sure it is plugged in to the USB port so that the image is being streamed. You may need to rotate the focus ring slightly to make sure that the two plants are in focus.

The live plant will be immediately obvious as it will glow in the image – because it is reflecting a far greater amount of near infrared light.

2 Other demonstrations

You can point a remote control at the near infrared webcam and press any button. A flash will be observed from the infrared diode which is not observable using visible light.

Bank notes are treated with a near infrared reflective ink. This ink is missing on the central section of a £5 note and so, when viewed with this camera, half the note disappears!



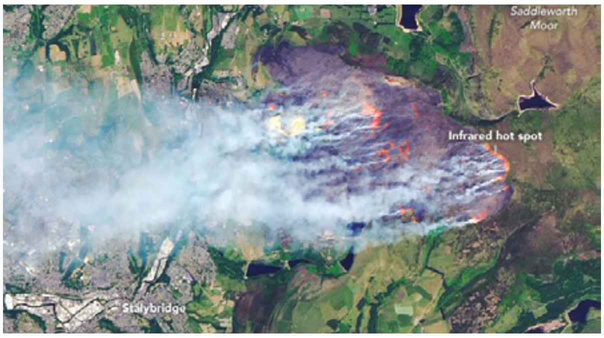
Earth observation

Satellite imagery insights

Travelling into space fundamentally alters our view of Earth. Satellites give us an insight into what we can see when we look back at our planet.

Looking back at Earth

A large proportion of satellites launched into space are placed there to look back at the Earth. From orbit, we gain a unique perspective of our planet that it is impossible to get from the ground.



Before and after

Using satellites, we can get a real understanding of how impactful large-scale events can be. The 'Spot the Difference' set of satellite images show how environments can change following large-scale disasters or events. In this set of images, we can see the effects of extreme weather in the form of flooding and droughts. We can also see the impact humans can have on the world around us. Not only do we see the presence of cities but also the effects that things like dams can have. This activity gives people a chance to explore and understand how satellites help us consider effects over a larger scale. Satellites have enabled this view to be obtained much more readily.

Bottom image: Saddleworth More fire, UK.,Credit: Wikipedia

How to run this activity

Use the set of satellite images to discuss the advantages to having this view. Each of the images showcases unusual terrain, human activity or extreme events, and has a small description to accompany it. These can be used as conversation-starters and you might ask your participants to match descriptions with images, which can be surprisingly tricky.

A bit closer to home

As part of your Destination Space Phase 2 kit you recieved a satellite mat of the locality around your centre. Use these to talk about the kinds of things you can see from above, and which local features are particularly noticeable.

Can participants immediately recognise their town? Can they locate the Science Centre and maybe even spot the roof of their school or home?

Did you know?

Most of these images are from Landsat. Check out their website for new images.

Triangulation and navigation

How do satellites get us from A to B?

Using networks of satellites, we can determine our position on the planet down to 20cm accuracy.

Why is this important?

Satellite navigation has become an integral part of our lives and is probably the space-based activity that people interact with most often on a day-to-day basis. Many of us use satellites to drive to somewhere exciting and new, or to avoid traffic jams. Emergency services can track stolen goods or locate a ship in danger. We even use the atomic clocks in satellites to synchronise financial transactions.

How does it work?

Satellite positioning systems use networks of satellites to ensure full coverage. There are several global networks including Europe's GALILEO, Russia's GLONASS, the United States' GPS and China's BeiDou. These networks all use the same principle to provide you with a location.

To get a position from these satellites, your device connects to three of the many satellites in the network and calculates the distance from you to each of the satellites. Once these distances are known, a SatNav can triangulate where you are.

How do I demonstrate this?

You can demonstrate how a satellite positioning network works with three pieces of ribbon. The ribbon can be of differing lengths but should be long enough to overlap in your demonstration space. You will need three people to represent satellites and one person to be the receiver. The satellite and receiver calculate their separation distance: this is represented by holding the ribbon.

With just one distance, the receiver can be anywhere within a circle around the satellite. Two satellites gives two possible locations, and a third should limit it to just one. For added effect, volunteers can wear GPS and Satellite hats while doing this!

The relationship between distance and time

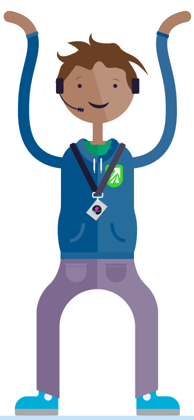
Atomic clocks

From early human navigation by stars to modern exploration of space, our ability to accurately know where we are has always been inherently linked to knowing what time it is.

Navigating by stars

Before humans built satellites, navigation was done by looking at fixed stars in the night sky. Maritime navigators used nautical charts to determine their position in the sea. A tool called a sextant was the most essential instrument for celestial navigation. You can still use tools like this to determine your position anywhere on the Earth's surface to within a hundred metres or so, as long as you have an accurate clock.

This navigational need for an accurate clock (with the stars alone you can measure latitude but not longitude), drove the development of accurate mechanical clocks in the mid-18th century. At that time most clocks were based on a swinging pendulum or a hairspring, which were not always reliable at sea. John Harrison is credited with the creation of the first highly accurate marine chronometer, based on a pair of counter-oscillating weighted beams connected by springs.



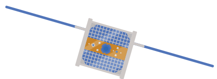
Satellite navigation and atomic clocks

Satellite navigation systems such as GPS require unprecedented accurate knowledge of the time. GPS receivers work by measuring the relative time delays of signals from at least four satellites. Electric and quartz clocks had followed on from the marine chronometer with increasing accuracy, but neither of these was well-suited to the extremities of space or the particular accuracies required to measure this time delay.

Atomic clocks are the most accurate time and frequency standards known. Based on atomic physics, atomic clocks measure the electromagnetic signal that electrons in atoms emit when they change energy levels. First suggested by Lord Kelvin in 1879, the magnetic resonance necessary for this wasn't developed until the 1930s by Isidor Rabi.

GPS satellites have at least two onboard caesium and as many as two rubidium atomic clocks. The relative times of these clocks are combined into one absolute time coordinate. The European Galileo Global Navigation Satellite System operates in a similar way, with a control centre in Fucino, Italy, generating Galileo System Time.

Once you know the absolute time coordinates for a satellite, you can determine the time delay it took a signal to reach you from it, and from this you can deduce how far away it is.



GOES-16 takes image of Hurricane Irma, Credit: NOAA

Weather Forecasting

Satellite data helps us create accurate models for predicting weather

Weather forecasts are made by collecting data on our atmosphere's current behaviour (particularly the temperature, humidity and wind) and predicting how it will evolve in the future.

Weather satellites

Weather satellites are used to monitor the weather and climate on Earth. They can be polar orbiting, cover the entire Earth asynchronously (at different times) or be geostationary (hovering over the same spot on the equator).

How do they work?

Weather satellites carry radiometers which scan the Earth to form images. These usually have a small telescope or antenna, a scanning mechanism, and detectors which record visible, infrared or microwave radiation. They monitor weather around the world: for example, the European Space Agency's Meteosat satellite covers Europe and Africa.

Polar satellites

As polar orbiting satellites are closer to the Earth than geostationary satellites, it is easier for them to take sharper photographs. Their orbits are also nearly Sun-synchronous which means that their position relative to the Sun remains the same, as the Earth itself orbits the Sun. Some Sun-synchronous orbits are set up so that a satellite can remain in sunlight with its solar panels operational at all times. This type of orbit also means that the light conditions (the surface illumination angle from the Sun) will be the same every time they pass over the same part of the Earth, so that images can be more easily compared for changes. View this video www.esa.int/spaceinvideos/Videos/2018/08/Aeolus_orbit for a visualisation of the orbit of ESA's wind monitoring satellite, Aelus, in a Sun-synchronous orbit. It travels over sites on Earth at nightfall every time.

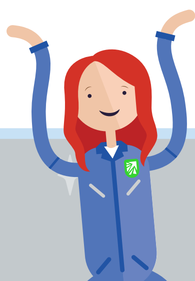
Geostationary satellites

Geostationary satellites have a very high altitude, around 35,880 km. That's nearly 88 times higher than the International Space Station. It is more difficult for geostationary satellites to take high-resolution images than polar satellites, because they require elaborate telescopes and precise scanning mechanisms to compensate for being further away. However, they can view the same region of Earth throughout the course of a day. This is useful for real-time weather emergencies and helping to create weather models based on location.

Is this how they predict weather on TV?

The Met Office provides UK weather updates. It uses satellite data to build computer-based models which predict what the weather will do next.

Sometimes weather forecasters on TV get it wrong. This happens when weather changes rapidly, especially in the UK. For example, rain during the summer is difficult to predict as it develops quickly and over small areas, with forecasters getting it wrong almost 40% of the time.



Communications

Satellites help us to share information around the world

One of the first ever uses for satellites continues to be important to this day, communication. Satellite communications technology has supported military and civilian communications for over 50 years.

Communication satellites

All satellites share information by sending electromagnetic signals to satellite receivers, and many also receive instructions in the same way. For communications satellites sending and receiving information is their primary purpose. Satellite signals allow faster communication between two points on the Earth's surface by reflecting and redirecting signals in straight lines. They also allow people to send or receive information in remote areas where there is no wired infrastructure. Satellite telephone communication is an obvious example, but they can also send television signals, encrypted information, military instructions, and even financial transactions.

Global connections

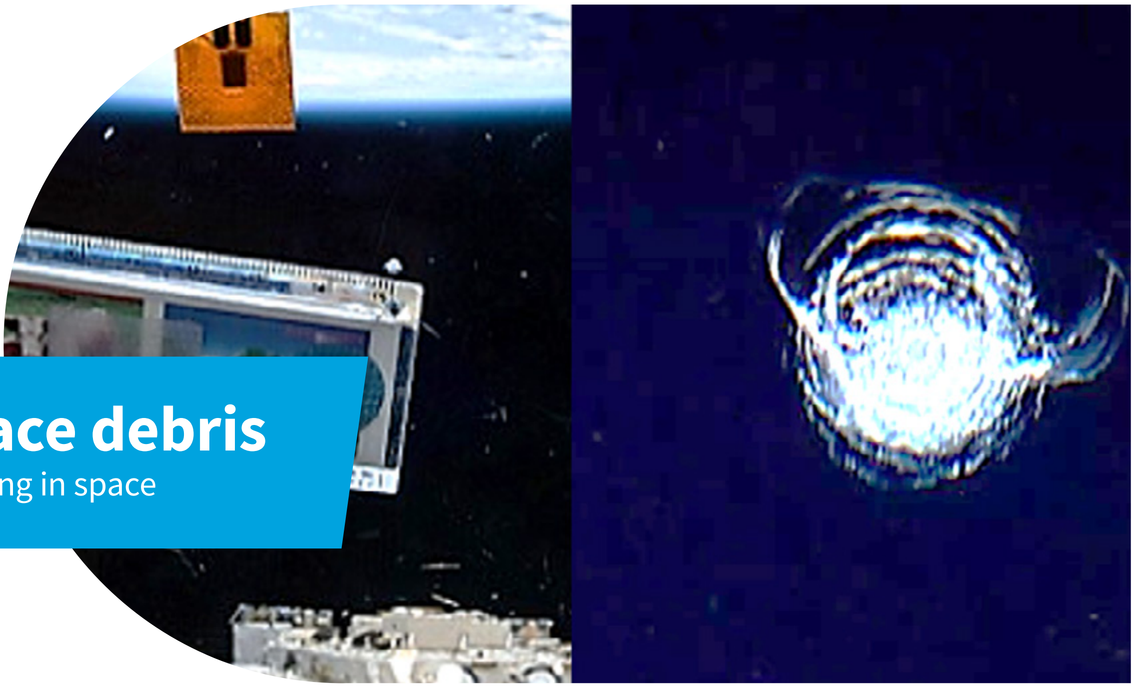
Thanks to multiple networks of communications satellites, information can spread around the world nearly instantaneously. Before they existed, this wasn't possible. Physical recordings of events had to be sent via courier in order to be shared on national television or in cinemas. Communications satellites have changed how connected people in different countries feel to one another. Seeing iconic moments happen in near real-time on live television, such as the fall of the Berlin wall in the second half of the 20th century, changed people's expectations of how international news could be shared.

It is estimated that over 50% of the Earth's population does not currently have reliable access to the internet. Many government and private companies are launching satellite constellations specifically to enable these people to access reliable satellite broadband wherever they are.

Working together in emergencies

There are times when the need for communication is more urgent. Natural disasters like floods, earthquakes, wildfires and landslides create rapidly changing and dangerous situations on the ground, cutting off communities and leaving people in need of rescue. Satellites can swiftly gather up-to-the-minute information in the aftermath or even during disasters, helping governments to limit the risks to rescuers and arrange relief efforts. There are even special networks of satellites called 'clusters' that are operated from different countries, which can switch over into working together in the case of a disaster. The Disaster Monitoring Clusters are a fantastic example of international co-operation in space.

Image: Communications satellite. Credit: Which?



Space debris

Littering in space

Tiny pieces of space junk seem harmless. However, at orbital speeds they can become deadly. The compressed air rocket launcher is an explosive way to showcase this.

Is space junk a problem?

Decades of space exploration has left millions of pieces of debris orbiting our Earth, from defunct spacecraft down to tiny dust-sized particles. Even tiny particles pose a threat, as they travel at enormous speeds. This means that they have a huge amount of energy and could cause damage to working spacecraft if they collide.

How does it work?

Orbiting objects travel at tens of thousands of kilometres per hour. Since kinetic (movement) energy is proportional to the velocity squared (KE = ½ mv2) this huge velocity yields an even higher kinetic energy. The launcher can launch a card rocket at around 70 miles per hour. This can give a paper or card rocket enough energy to easily pierce a cardboard box, often traveling in one side and out the other, proving that in orbit, seemingly innocuous tiny objects at high velocity pose extreme danger.

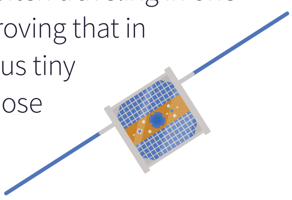


Image: Space junk leaves dents in the cupola of the International Space Station. Credit: NASA

How do I demonstrate this?

Roll 160gsm card around the launch pipe to make your rocket tube the same size as the rocket launcher, which will ensure the best launch speed.

Make a nose cone by cutting a circle out of card and cutting a quarter out of it, rolling it into a cone shape and adding some Blu-Tack or playdough for stability. Make sure that your rocket tube and cone are airtight.

Slide the rocket onto the launcher. Place a cardboard box in the firing line, ensuring that nothing is behind the box in case the rocket penetrates both sides. Pump the launcher to a pressure of no more than 60psi.

Twist the handle to open the valve. The quicker the valve is opened, the faster the rocket will travel. The rocket should leave the end of the launcher and penetrate at least one side of the box.

Did you know?

Micrometeoroid and orbital debris (MMOD) impacts occur all the time on the ISS and other spacecraft. In 2014, the ISS's altitude was raised by half a mile to avoid an impact from an old part of a European rocket. Just 1cm of space debris could cause critical damage, while anything larger than 10cm can shatter a satellite or spacecraft into pieces.