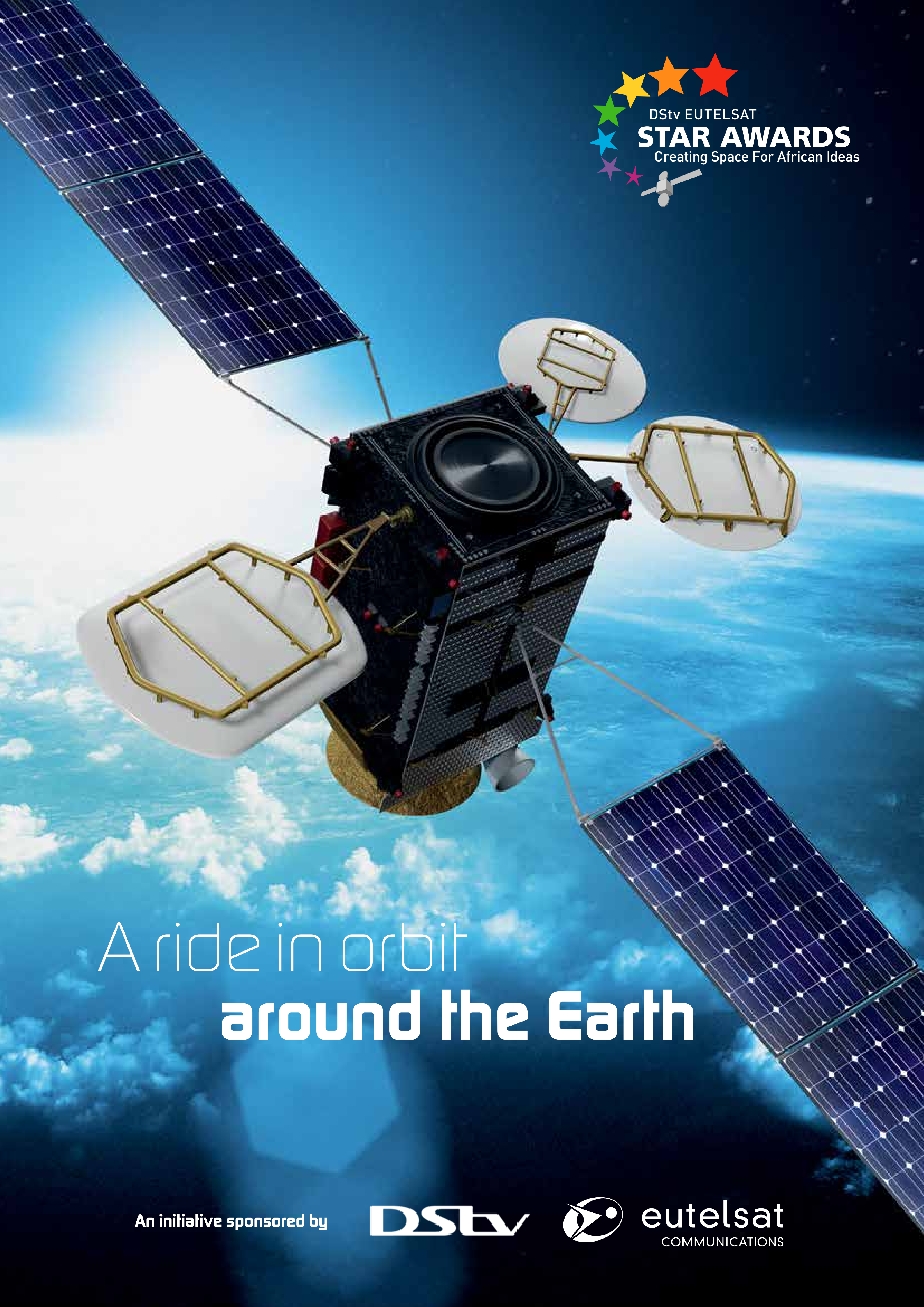

DStv EUTELSAT
STAR AWARDS
Creating Space For African Ideas

A ride in orbit around the Earth

An initiative sponsored by DStv eutelsat COMMUNICATIONS

THIS GUIDE IS PART OF THE RESOURCES MADE AVAILABLE FOR EDUCATORS AND STUDENTS PARTICIPATING TO THE DSTV EUTELSAT STAR AWARDS.

> The DStv Eutelsat Star Awards, which are a product of a partnership between Eutelsat and MultiChoice Africa, aim to stimulate interest in science and technology and to inspire innovative thinking among secondary and high school students across Africa.

The awards take the form of a competition open to 14-19 year-old students in 42 countries. Students are invited to write an essay or design a poster depicting how innovative use of satellite technology in the fields of communication, Earth observation or navigation can propel Africa into the future.

Top entrants at the national level win prizes such as computers or tablets, and go forward to compete in the overall awards for the winning and runner up essay and poster prizes. The winning essay entrant wins a trip with a parent or guardian to Eutelsat in Paris and onwards to witness a live rocket launch. The best poster winner and their parent or guardian also win a trip to Eutelsat, including a visit to a satellite manufacturing facility. The runners-up in the overall awards win a trip for two to visit the MultiChoice Africa broadcast facilities and the South African Space Agency near Johannesburg, South Africa.

The schools attended by the overall award winners and runners-up are rewarded with a DStv installation, including dish, television, state-of-the-art PVR decoder and free access to the DStv Education Bouquet.

More information on : www.dstvstarawards.com

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A ride in orbit **around the Earth**

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Summary

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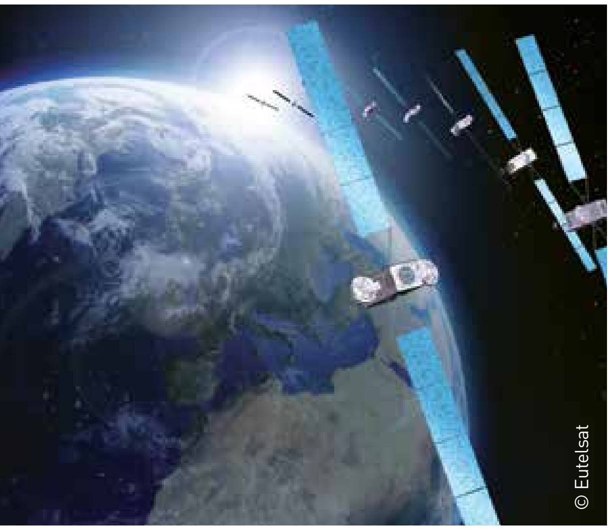

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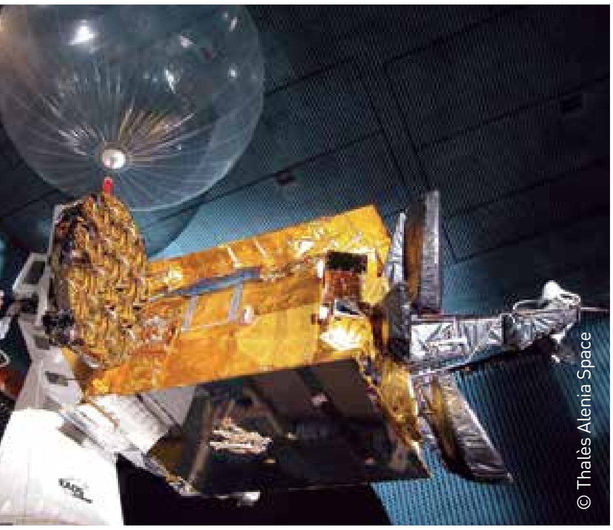

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Introduction

Gazing up into the starry sky at night, you will be familiar with the Moon - the Earth's natural satellite which revolves in its orbit around the Earth. Some of the shining "stars" in the night sky aren't really stars, but are different kinds of satellites, also orbiting the Earth and actually doing amazing things for us here on our planet.

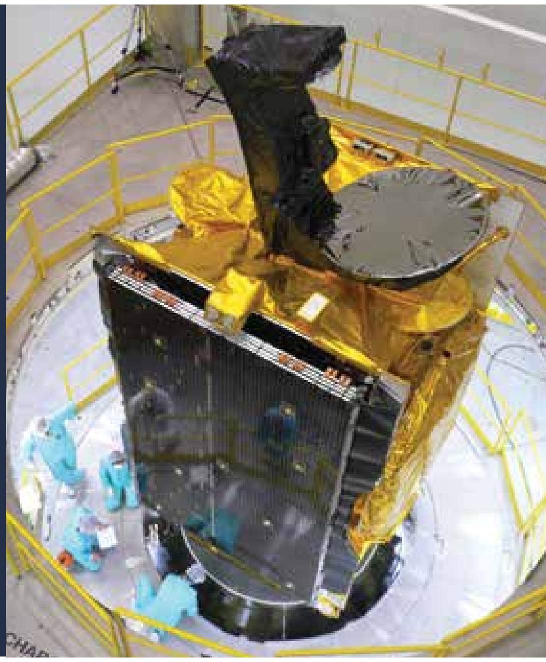
\> Can you believe that there are thousands of satellites orbiting the Earth? Many of these aren't operating anymore, but **over 900 are operational** and providing us with a lot of valuable information and tools. You won't be able to see most of these satellites in the night sky, but the largest ones circling the Earth in low orbits can be seen as sunlight reflects off them, just like it does when we see the Moon in the night sky.

\> **You may wonder why there are so many out there, how they got there and what they are actually doing there.**
Satellites can make our lives safer, improve our understanding of our environment, enable us to communicate and provide us with entertainment. Some take pictures of the planet that help meteorologists predict the weather and track hurricanes. Some take pictures of other planets, the sun, black holes, or faraway galaxies to help scientists better understand the solar system and the universe. Other satellites are used for communicating, such as TV signals, phone calls and internet access around the world. Some satellites are used to help us navigate.

\> We invite you through this book to take a trip into orbit to explore the world of satellites, the vast range of services they render and to think about what amazing things satellites may be able to do for us in the future.

01 What is a satellite and how does it work?

Put simply, satellites are smaller objects that revolve or orbit around another much larger object, such as the Moon that orbits around planet Earth.



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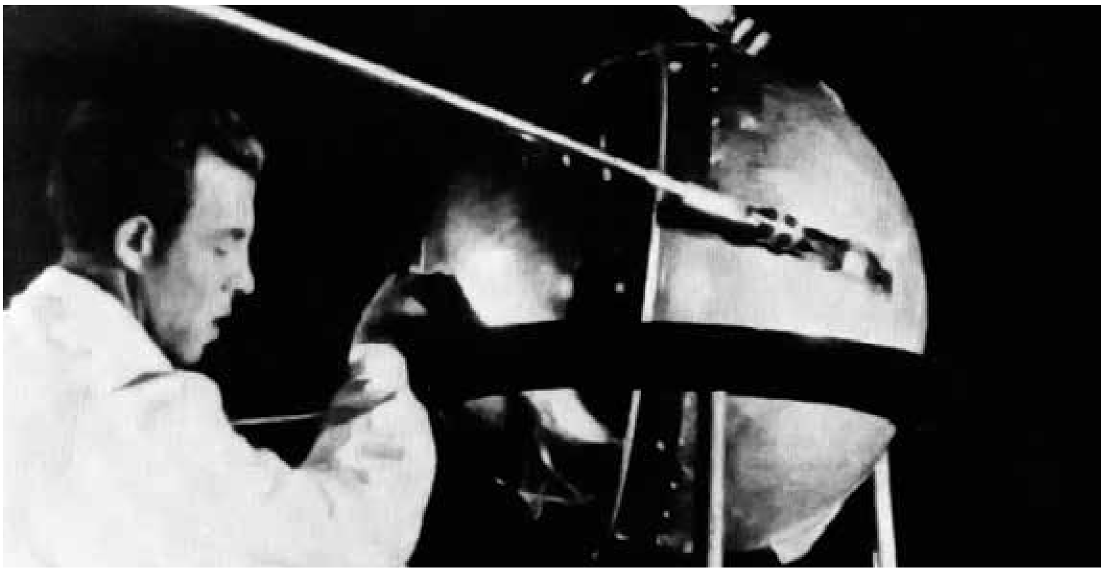
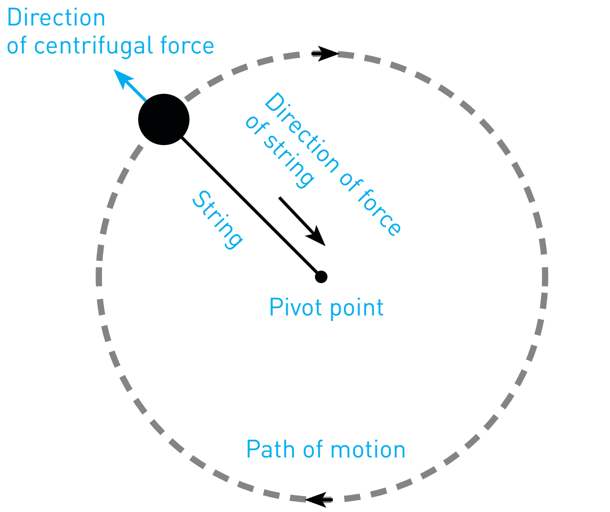
The satellites we are going to discuss in this guide are called artificial or man-made satellites; they are different to natural satellites such as the Moon.

Basically, artificial satellites are designed to receive and send back to Earth messages and information for exploration, observation and communication. They are customised for specific missions depending on what type of information you want to receive and/or send. For example, communications satellites, navigation satellites and Earth observation satellites all have different designs and ways of working.

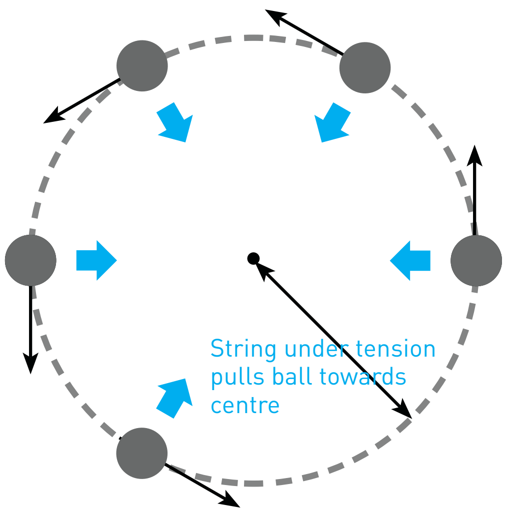
The first satellite was launched by the Soviet Union on 4 October 1957. It was called Sputnik 1. It lasted 92 days in orbit before gravity pulled it back into the Earth's atmosphere where it burned up. SCORE (Signal Communications by Orbiting Relay Equipment) was the world's first communications satellite. Launched on 18 December 1958, SCORE provided the first test of a communications relay system in space. It captured world attention by broadcasting a Christmas message from U.S. President Dwight D. Eisenhower through an on-board tape recorder.





Force ( ) towards centre pulls ball around in a circle

If the force is removed, the ball carries on in straight line



How does a satellite get into orbit and stay there ?

Because of the gravitational pull of the Earth, a satellite stays in orbit and doesn't disappear off into deep space. The Earth's gravity doesn't pull it back down into our atmosphere because it is moving at a very high speed. So it stays moving in orbit because of a balance between the two forces of its speed (or tendency to keep going) and the Earth's gravity. This speed is called orbital velocity. If it goes too fast, it will fly off into space. Its velocity needs to be above a certain threshold, called the escape velocity, in order for the satellite to "escape" the gravity of the Earth and fly off into space. On the other hand, if the satellite goes too slow, it will fall back to Earth under the pull of gravity. Because the gravitational pull is stronger closer to Earth, a satellite at a lower altitude (or height above the Earth) will need a faster orbital velocity to stay in orbit.

Imagine a ball on the end of a string or a yo-yo. If you swing it around, the string acts like gravity and keeps it spinning around, but if you let go of the string, the ball will fly off. Also, if it doesn't spin fast enough, the ball will fall out of orbit and fall to the ground. So, the balance of the pull from the string and the centrifugal force and the speed at which it is going keeps the ball swinging around its pivot point. The same basic principle applies to a satellite orbiting the Earth.

This example shows us how important it is to understand physics in order to imagine what satellites can do for us.

If you remember, it was Sir Isaac Newton who discovered the law of gravity. Did you know he also had a theory on how artificial satellites could be launched from Earth? It was more than 200 years after his death that the first satellite was launched and his ideas were put into practice, but it's amazing to think that he had this idea way back then.

You may be wondering how fast a satellite would need to go to stay in orbit. At an altitude of about 240 kilometres, a satellite would need a speed of about 27,000 kilometres per hour to keep in orbit. That's incredibly fast, more than 200 times the speed limit on our highways! To get a satellite moving fast enough in space to stay in orbit, you need something very powerful to launch it. This is where rockets come in. A rocket must accelerate fast enough to overcome the pull of gravity and get into space. It must accelerate to at least 40,320 km/h.

Rockets have a flight plan. Their path is carefully calculated and precisely controlled. Each rocket has a control system which constantly monitors positions and speed, and makes the necessary adjustments to the rocket. The rocket releases the satellite when it has reached the correct altitude and speed for the satellite to be positioned on its targeted orbit.

Then, depending on the altitude, the rocket falls back into the ocean or burns up as it re-enters Earth's atmosphere. Larger satellites will have small on-board thrusters which allow corrections of the orbit from a ground control station when necessary. Very small satellites of less than 10 kg are too small to carry thrusters, so it's not yet possible to control their orbit, although scientists are working on different types of thrusters that may serve this purpose.

MORE ABOUT +

THE SCIENCE BEHIND THE SATELLITE LAUNCH

Gravity is the key concept in understanding how a satellite is launched and can stay in orbit. Isaac Newton observed the movement of the moon and also watched an apple fall from a tree.

After thinking about why the Moon orbits in a regular way and why the apple fell, he came up with the idea of gravity. To explain his observations, he suggested that there must be a force of attraction between all objects in the Universe that have mass. It is this same force of attraction that makes the apple fall and keeps the Moon in a fixed orbit around the Earth. We say that there is a gravitational field around any object that has mass. When another object that has mass enters this field, it experiences a force of attraction.

Here are some questions for you to think about and discuss:

> QUESTION 1

Just before it is launched, the rocket and satellites on board have a large mass, more than 7×10^5 kg. What is the minimum force required to lift this mass off the surface of the Earth?

// DISCUSSION

Gravitational force is strongest close to the surface of the Earth as the force of attraction between two objects depends on their masses and the distance between their centres of gravity.

We also know that when any object with mass falls towards the Earth, it experiences a constant acceleration (g). Although there are slight variations in the value of g at different places on Earth, at school we accept the value of 9.8 m/s^2 downwards to make calculations.

The minimum force required to lift an object off the surface of the Earth is equal to the force the Earth exerts on the object. The force the Earth exerts on any object (weight) is equal to the product of the mass and the acceleration due to gravity (g).

So the minimum upward force (thrust) you need just to lift a rocket and satellites, is equal to mass x g = 7×10^5kg x 9.8 m/s^2 = 6.86×10^6N.

Note that this minimum force is however not enough to accelerate the rocket upwards.

> QUESTION 2

How do rocket engines work?

// DISCUSSION

There are two important scientific concepts you need to think about when answering this frequently asked question, Energy and Newton's Third Law of motion (Action/reaction pair).

> ENERGY

Rocket engines produce thrust by expelling high-speed fluid exhaust. This fluid is nearly always a gas which is created by high pressure (100-200 bar) combustion of solid or liquid propellants, consisting of fuel and oxidiser components (which are stored in separate tanks), within a combustion chamber.

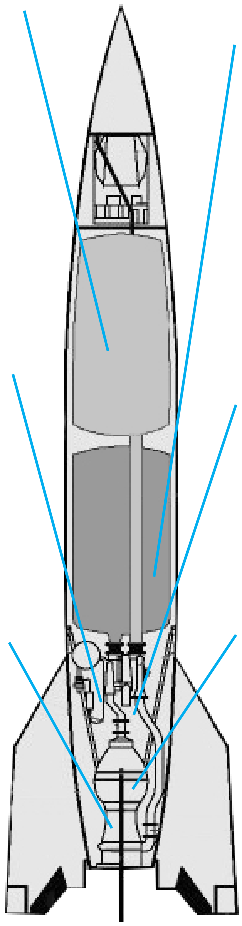
The fluid exhaust is then passed through a nozzle to accelerate the exhaust to very high speed. The resulting reaction pushes the engine in the opposite direction. As a result, the rocket starts to accelerate upwards. The rocket gains kinetic energy due to its motion but also gains potential energy due to its changing position above the

Earth.

> ACTION/REACTION PAIR

On ignition, gases are pushed downwards through the rocket engine. The force of the rocket on these gases is equal to the force of the gases on the rocket. This pair of forces act on different objects and are in the opposite direction to each other. We call this pair of forces an action-reaction pair.

> LIQUID ROCKET ENGINE



Fuel Tank
It stores fuel. Examples of fuel are alcohol, Liquid Hydrogen, RP-1 Kerosene, Aniline and Hydrazine (mixture of fuel and Oxidiser)

Oxidiser Tank
It stores oxidiser. Examples of oxidisers are liquid Oxygen, Nitric Acid, Nitrogen Tetroxide and Hydrazine

Pomp
It pomps the fuel and the oxidiser into the combustion chamber. It generates extremely high pressures

Igniter
Starts the burning process

Nozzle
It accelerates hot gases further and produces thrust

Combustion Chamber
Pumped fuel and oxidiser are mixed, ignite and burned in here to create a high pressure and high velocity of hot gases

> QUESTION 3

After launching, the rocket seems to tilt over and doesn't go straight up.
Do you know why?

// DISCUSSION

If the rocket moved straight up, the thrust would remain vertical and only vertical motion would occur. To place the satellite into orbit, it must also have a horizontal speed. That is why the rocket is inclined in order to combine vertical and horizontal thrust. The vertical thrust makes the rocket go higher while the horizontal thrust gives the rocket horizontal velocity. The horizontal velocity increases until the rocket and satellite separate and the satellite begins its orbit around the Earth.

> QUESTION 4

When a rocket is launched, it seems to move slowly at first and then speeds up. Can you explain what is happening?

// DISCUSSION

The motion of the rocket as it lifts off is very interesting. Let's apply Newton's Laws of motion to explain what is happening. Remember, Newton's 1^{st} Law states that if an object is not attracted by a new force, it will remain at rest or continue to move at constant velocity in a straight line. But we see the rocket speeding up, which means that the upward thrust must be greater than the downward force of the Earth on the rocket.
Newton's 2^{nd} Law explains what happens when there is a resultant force exerted on any object. We can summarise this law in the equation: $FR = m.a$, where FR is the resultant force, m is the mass and a is the acceleration of the object. We can conclude that a resultant force causes an object to accelerate. But notice the acceleration and force are linked to mass too.
Let's think about what changes as a rocket is launched. There are two changes that are important : distance above the Earth, mass of the rocket.

Can you predict what effect these factors will have on the acceleration of the rocket?

> DISTANCE FROM EARTH

The further the rocket moves away from the Earth, the weaker the downward force of the Earth on the rocket. This means that less thrust is required to keep the rocket accelerating away from Earth.

> MASS OF ROCKET

During the launch, the rocket uses up fuel in its fuel tanks. You may also see the booster tanks falling off a rocket a few minutes into the launch. So the mass of the launcher carrying the satellites into space decreases quite rapidly. This also decreases the downward force of the Earth on the rocket.

When these two effects are combined, the force required to accelerate a rocket decreases. Mission controllers can vary the thrust of the rocket engines to ensure that the final speed of the rocket is correct to get the satellite into the targeted orbit.

02 Which satellite for which orbit?

Satellites obey the physical laws of universal gravity. They move along trajectories (orbits) calculated for their mission around the centre of the Earth and their speed depends on their altitude.

> DIFFERENT TYPES OF ORBITS

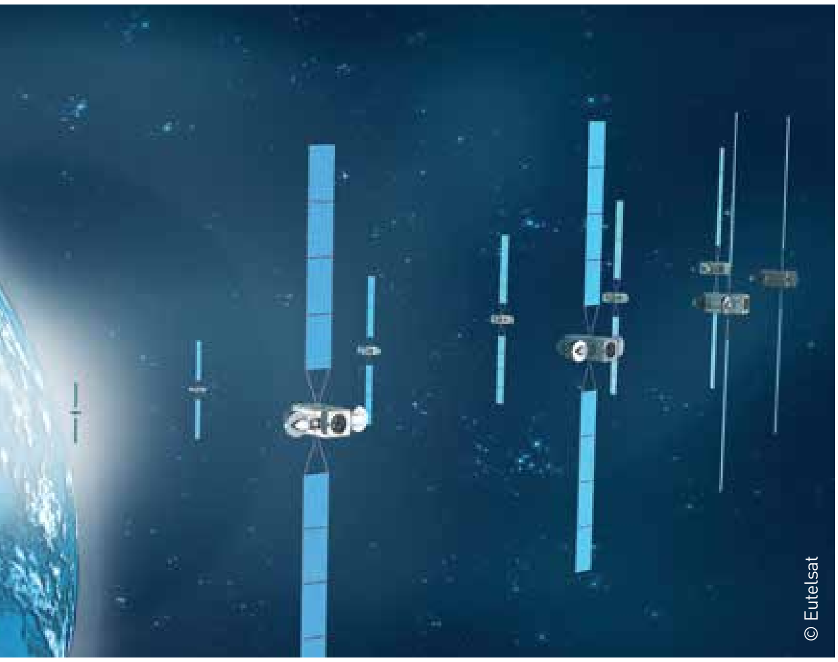
A satellite orbiting in a Low Earth Orbit is at an altitude of 100 to 1,200 km above the Earth's surface; at Medium Earth Orbit it is at an altitude of 1,200 to 25,000 km and at High Earth Orbit it is at an altitude of 35,790 km or higher. Each orbit is adapted for specific missions.

A satellite in polar orbit will pass over, or nearly over, the Earth's poles. A satellite in this type of orbit is not fixed on one point relative to the Earth. As the Earth spins below it, the satellite can study the entire planet, strip by strip, over a period ranging from one to a few days, making it useful for surveillance and collecting data.

Geostationary orbit matches the Earth's period of rotation. In other words, it takes the satellite the same time to orbit the Earth as the Earth takes to spin once. The satellite has to be at a very specific altitude of about 35,786 km, directly over the equator. To someone on Earth, the satellite will appear to be stationary in the sky.

The positioning of a geostationary satellite requires extreme precision and a gradual approach. This orbit offers significant benefits for telecommunications satellites as we will see later. A satellite in geostationary orbit appears to be at a fixed a point above Earth, which means we don't need to adjust our TV dishes in order to find the signal every time we want to watch TV!

Name of orbit	Range of altitude	Main fields of application
Low Earth Orbit	100 – 1,200 km	Earth observation, remote sensing, weather satellites, mobile telephony, scientific research, International Space Station
Medium Earth Orbit	1,200 – 25,000 km	Navigation
Geostationary Orbit	35,786 km	Telecommunications, TV broadcasting, weather satellites
High Earth Orbit	35,790 and above	Scientific research

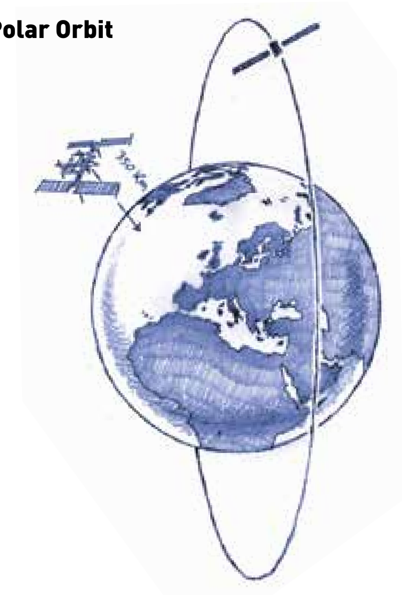


Launching a satellite into geostationary orbit

Some satellites have quite a long way to go to reach the orbit where they will start service. This is particularly so for geostationary satellites which need to reach the geostationary belt at almost 36,000 km above the equator. Following launch, it takes on average three to four weeks for a geostationary satellite to reach its position.
(Illustration page 13).

The rocket will first place the geostationary satellite into a transfer orbit. The satellite's solar panels, which were folded at launch, are then partially deployed. This partial deployment is sufficient to supply energy to the electrical equipment as the satellite progresses towards its designated orbital position. At first, the satellite will follow an elliptical orbit. Then, through a series of firings of an on-board apogee motor, the satellite's trajectory (or path) is adjusted and it is brought into a circular orbit. Once in geostationary orbit, the solar panels are fully opened to deliver a span of approximately 40 metres (about the length of four buses). The on-board antennas are deployed and the satellite begins its drift to its allotted location in geostationary orbit for a series of tests. These are followed by its entry into commercial service.

Polar Orbit



Synchronized Constellation

Geostationary Orbit

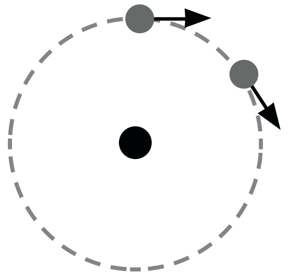
MORE ABOUT +

THE SCIENCE BEHIND ORBITS

The simplest orbits to explain are circular orbits. A satellite moves around a fixed position (the centre of the Earth) at constant speed. Let's apply Newton's Laws of motion to explain this behaviour.

Newton's 1st Law of Motion

We know that an object will remain at rest or continue moving at constant speed in a straight line, unless a new force acts on it. The satellite in our example is moving at constant speed. We can show this by using a simple diagram, where the arrow represents the speed of the satellite. Notice the two arrows are the same size but they have changed direction.



What caused this change of direction?

According to Newton's 1st Law, there must be an external force which prevents the satellite from moving in a straight line forever.

In which direction is this force acting? It may be helpful to draw a similar diagram and place arrows at different positions along the circular path (orbit). Note that the change of direction of the arrows is always turned towards the centre of the Earth at a constant angle as the satellite progresses. So there must be a force that pulls the satellite towards the centre of the Earth at every point of its orbit. This is the force of attraction between the Earth and the satellite. Even in geostationary orbit, where the satellite is almost 36,000 km above the Earth's surface, it is still in the Earth's gravitational field. There is a constant downward force that keeps the satellite falling back to Earth, just like an apple falls from a tree. That's why we say a satellite is in free fall as it orbits the Earth.

Note that this downward force does not change the magnitude of the velocity. The satellite was given its horizontal speed when it was launched by the rocket. As there is no force acting in this direction, it continues with a constant speed. In this way, a satellite's motion follows Newton's 1st Law.

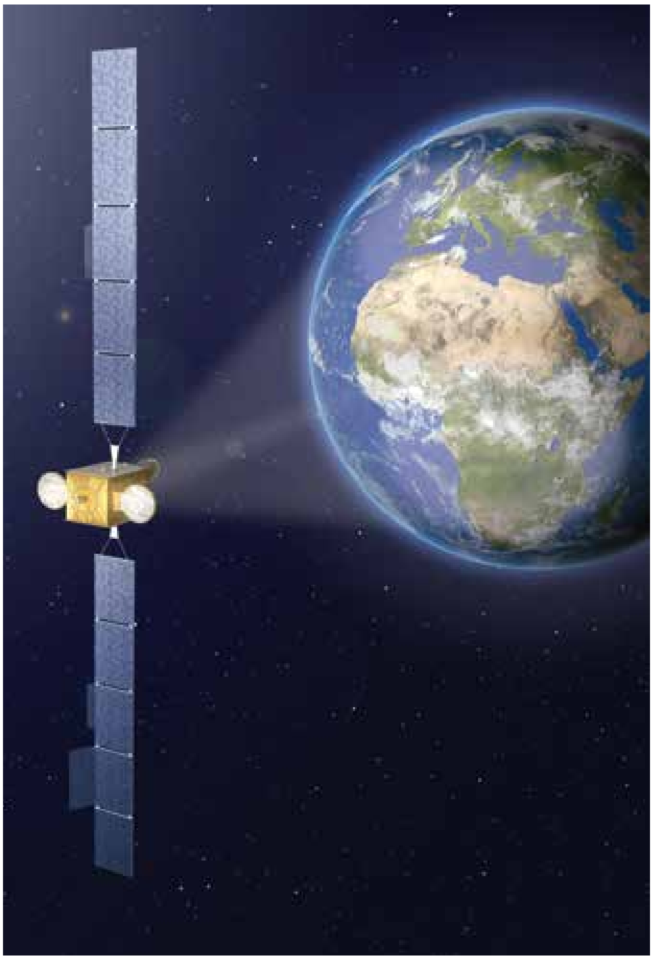
Here are some other questions about orbits you could think about:

> QUESTION 1

What does geostationary position mean?

// DISCUSSION

If you are standing still and a friend moves towards you in a train travelling at 5 m/s, you can observe their change in position each second. However, if you were on the train seated next to your friend, you would say that she did not change position even if the train was moving faster or slower. Relative to you, her position did not change because you were on the same train moving at the same speed. So if a satellite positioned above the Equator circles the Earth with exactly the same rotation as the rotation of the Earth, the position of the satellite will remain fixed. Geostationary means that relative to the Earth, the satellite does not change position. This is why communication satellites in geostationary orbit can relay information to fixed antennas on the ground. But remember, if we were at some other position in space, we would see that the Earth and satellites in geostationary orbit are all moving together at the same speed.



> **QUESTION 2**
> What is special about the distance of 35,786 kilometres above the Earth?

// DISCUSSION

There is a direct relationship between distance from the centre of the Earth and the period it takes for a satellite to complete a rotation around the Earth. The different types of orbits help us to confirm the relationship first suggested by Kepler. The period for satellites at 35,786 kilometres above the equator (or 42,160 kilometres from the centre of the Earth) is one day, the same as the Earth. A satellite cannot be geostationary if it is positioned at a different distance above the Earth and/or at a different inclination to the equatorial plane.

> **QUESTION 3**
> Does zero gravity exist on satellites?

// DISCUSSION

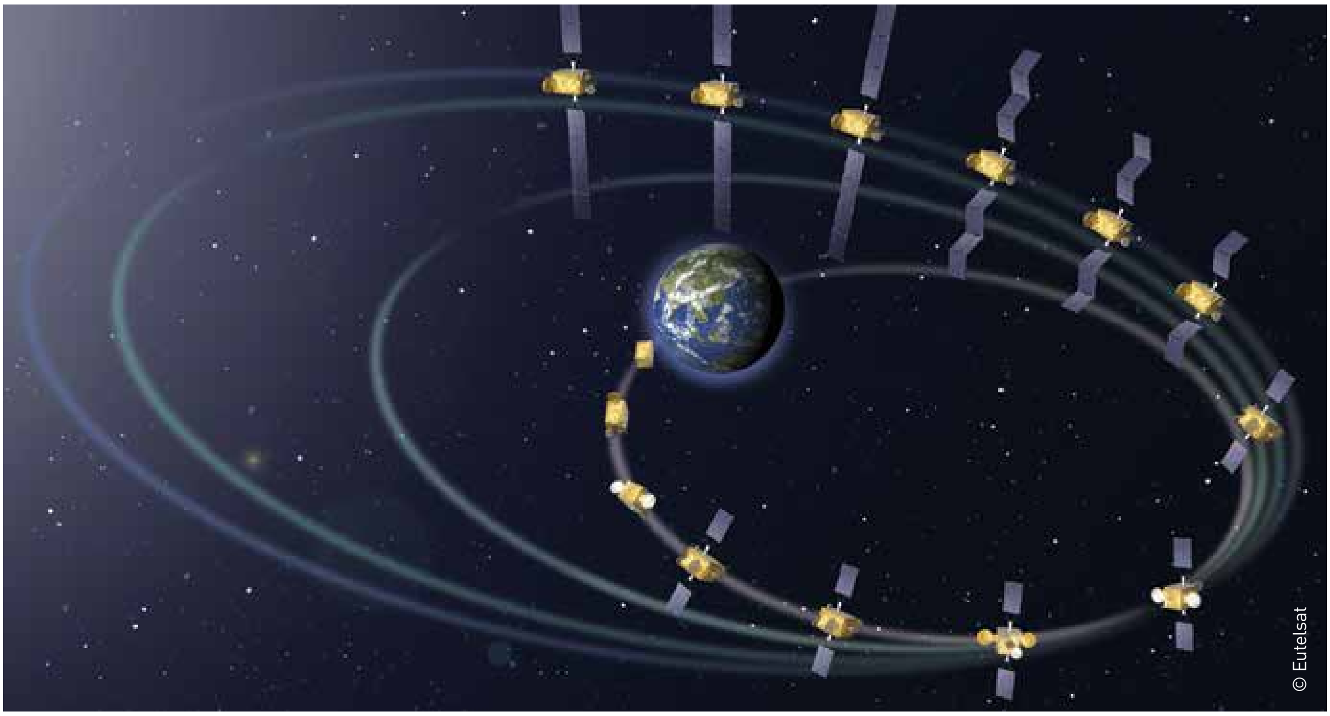
This is a common misconception. The Earth's gravitational field does not end where the atmosphere ends. Even the moon, asteroids, other planets and the sun experience the force of the Earth's gravitational field. All satellites still experience a force of gravity. This keeps them in a circular orbit. They are constantly falling towards the Earth with a downward acceleration equal to the acceleration of gravity at that position. So, astronauts on the International Space Station who are still in the Earth's gravitational field, experience weightlessness because they are also in free fall.

Why did satellites like Sputnik 1 and SCORE fall back into the Earth's atmosphere?

Even though most of the Earth's atmosphere is concentrated very close to Earth, there are still traces of atmospheric gases at very high altitudes. An altitude of 100 km (called the Kàrmàn line) is often regarded as the divide between atmosphere and space, but in reality the atmosphere gradually thins out the higher up we go.

Depending on the altitude of a satellite and its orbit above the Earth, a satellite may run into traces of the Earth's atmosphere, creating "drag" and slowing it down in orbit. Eventually, it will be pulled back down to Earth. When it re-enters the Earth's atmosphere, it will burn up before it reaches the ground.

The higher the orbit, the longer the satellite can stay in orbit, because at higher altitudes there is almost no drag. Satellites can stay in orbit for centuries, even long after they have stopped working.



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03 What is a satellite made of and how does it work?

Satellites are designed to operate in a hostile environment, in the vacuum of space which is subject to radiation and extreme thermal conditions.

© Arianespace

Regardless of their function, all satellites are made in very similar ways because they all require a similar structural design to be able to survive in space and perform their function. They all have a frame and body made of metal or composite materials (often much stronger than metal). This is usually called the structure. This has to be incredibly strong and durable to ensure rigidity in space and resist intense vibration during launch. It should be as light in weight as possible. It must protect the satellite from the Sun's radiation and keep it at a temperature at which its instruments can function. External thermal protectors insulate and protect the satellite from its hostile environment with temperatures ranging from -150° C to +150° C. Aluminium panels with radiative surfaces release heat generated by the satellite's equipment.

Satellites all need a source of power, such as solar cells. The amount of power a satellite will need will depend on the equipment it has on board and its mission. Using solar cells is very common because they can use the Sun's energy that is available in space (without worrying about clouds in the sky) and convert it into electrical energy. Batteries on board will store excess energy to provide back-up power when the solar panels can't provide enough power, such as when the Sun is eclipsed by the Earth (i.e. if the Earth is between the Sun and the satellite).

All satellites have an on-board computer to monitor and control different systems. They also all have a radio system and antenna to send and receive signals and instructions. These allow them to be controlled from the ground so that adjustments can be made to their orbits, or their computer system can be reprogrammed. Most satellites also have an attitude control system to keep the satellite pointing in the right direction.
Another very important part of the satellite is the propulsion system. This system enables mission controllers on Earth to make small changes to the satellite's orbit. These changes are necessary because there are small irregularities in the gravitational field, caused by the changing positions of the Sun, the Moon and other planets. When a satellite is no longer able to function, the propulsion system is used to move the satellite into a higher orbit so that new satellites can take its place.

In addition to these general parts, satellites will also have specific parts depending on their function. The satellite's "payload" hosts all the other things that it requires to do its job and achieve the objective of the mission. A communications satellite will have radio transponders and antennas to receive signal, amplify and relay it back to Earth. A weather satellite and an Earth Observation satellite will have cameras. Scientific satellites will carry a range of instruments or sensors to collect very specific information.

In order to fulfil its function, a satellite doesn't work alone. A ground control system is very important to its functioning. It collects and processes information from the satellite and also transmits commands to the satellite if it needs to perform a task, adjust position or change orbit. The ground station will have power transmitters, sensitive receivers and large dish antennas.

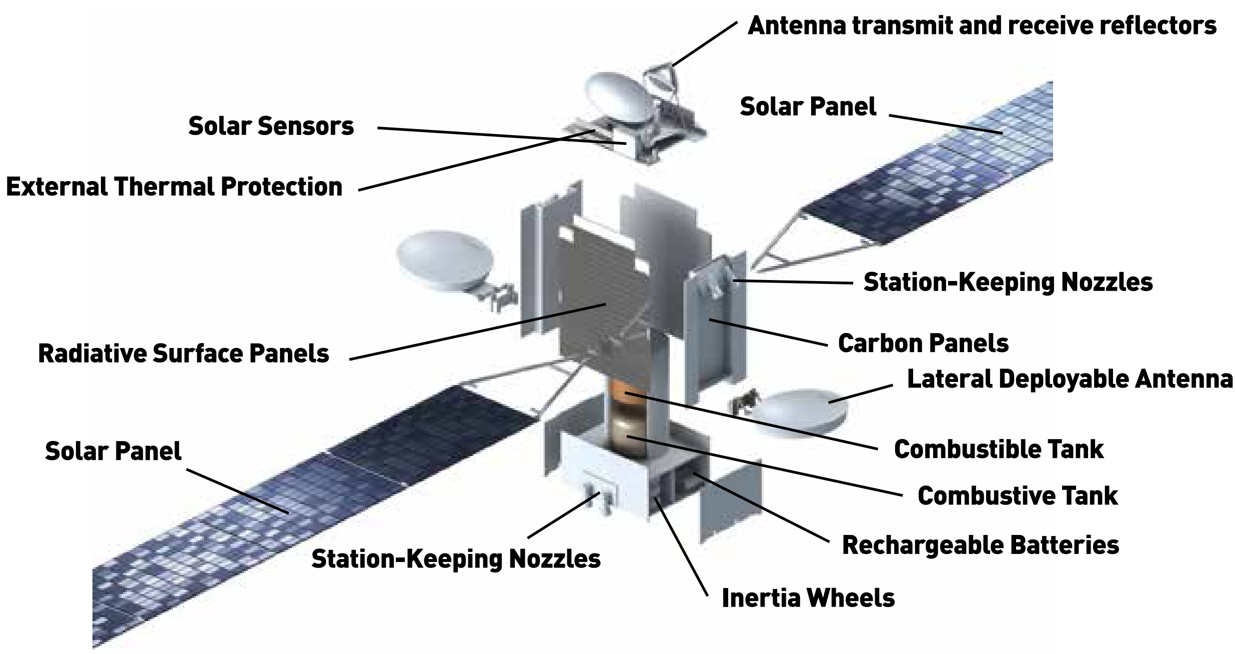
How does a satellite communicate with Earth?

Satellites are made to send and receive messages and information by using electromagnetic waves. Light is an example of an electromagnetic wave which has wavelengths visible to the naked eye, but there are many other wavelengths or frequencies that we can't see. Radiowaves have a low frequency, below that of visible light. Infrared is another example that also has frequencies lower than visible light but higher than radiowaves. Different satellites will receive and transmit signals at different wavelengths of the electromagnetic spectrum. With all signals there has to be a transmitter which sends the signal and a receiver which receives the signal and translates it into information we can make sense of.

In order to receive signals transmitted by a satellite, receivers on the ground are equipped with antennas whose size and shape depends on a number of factors: the frequency band used, the strength of the incoming signal and the need to differentiate signals transmitted by other satellites in nearby slots using the same frequency bands for the same coverage zone.

DID YOU KNOW?

In 1945, British science fiction writer Arthur C. Clarke (also known for *2001: A Space Odyssey*) was the first to propose the practical use of telecommunication satellites in orbit, theorised that three satellites in geostationary orbit would be sufficient to cover the whole planet with the exception of polar regions.



04 What can satellites do for us?

Nowadays satellites are an important part of our everyday lives. Some of us have satellite TV dishes in our homes, or we use "GPS" to help us find our way. There are many more uses even beyond these more familiar ones.


Turtle with Argos beacon

© CNES

> NAVIGATION SATELLITES (GPS)

Navigation satellites, for example Global Positioning System (GPS) satellites, allow you to determine where you are anywhere in the world at any time, and give you directions to where you want to go. GPS was originally intended for military use by the United States Department of Defence, but it has since been made available for public use. It has become an important part of navigation in aviation, making flights safer and more efficient. It is crucial in natural disaster and emergency situations where other navigation tools may not exist. It's also very convenient in day-to-day life.

GPS is made up of a network of 24 satellites. The satellites orbit the Earth twice a day (every 12 hours) in very precise orbits, and transmit signal information to the Earth. They are about 20,000 km above us and travel at about 14,000 km/hour.

Radio signals transmitted by GPS satellites are picked up by GPS receivers which can be located in your car or cell phone, for example. The information in the signal from the satellite is decoded to tell you which satellite the signal is from, what the time and date are and the position of the satellite in its orbit. All this information is important to calculate your position.

The receiver needs to receive a signal from at least three GPS satellites in order to know your latitude and longitude position and to track your movements. If a fourth satellite is added, the receiver can also determine your altitude. The receiver will calculate your distance from a satellite by interpreting the time it took the signal to travel from the satellite to the receiver. Then, if it receives this information from a few satellites, it can calculate exactly where you are. This involves geometry! If you only received information from one satellite, your receiver couldn't tell you much about your position except how far away you are from that satellite, which doesn't help you. Knowing your distance from two different satellites narrows down your position a bit more, but there would still be many possible locations. By adding a third satellite to the equation, you can know exactly where you are. Once a GPS receiver has calculated where you are it can tell you what your speed is, how far away your destination is and how long it will take you to get there.

Imagine all the purposes that this could have! GPS is already being used for security purposes, tracking of stolen vehicles and more.

Let's go through some more uses of GPS:

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Agriculture:
Farmers can use GPS information in combination with other sensors to tell them which parts of their fields need different amounts of nutrients and water. This is called precision farming and means that not all fields are treated with the same fertilisers, chemicals and irrigation, but are given what they need more specifically. This is making farming a lot smarter!

Environment:
GPS is used to help analyse environmental problems and to improve conservation projects. For example, GPS receivers attached to buoys in the ocean can help track oil spills and monitor the spread of oil. GPS receivers can track the migratory patterns of endangered species. The gorillas of Rwanda are tracked by GPS to help preserve their population.

Marine, Rail and Air Travel:
Ships use GPS to navigate in open waters and into and out of busy ports. GPS is used within a system called Automatic Identification System (AIS) which identifies and tracks vessels. This relays information about a ship's identity, where it is and what cargo it is carrying. This improves security in ports. Trains are also tracked by GPS to reduce the chances of accidents and collisions, and improve safety on the railways. In aviation, GPS helps not only the pilots to fly and navigate the planes, but also with the air traffic control on the ground to improve safety.

Rescue and Relief Efforts:
GPS plays an important role in rescue and relief operations when natural disasters hit, such as tsunamis, earthquakes and hurricanes. Along with other data, GPS can be used to map the area to improve aid to the affected area, as well as to map the damage in the area. In the case of forest fires, aeroplanes combine GPS with infrared sensors to map the fire hotspots. This helps the fire fighters battle the fires more effectively.

Surveying and mapping:
GPS is used with other geographic information systems (GIS) tools, such as Earth Observation satellites, to accurately map areas. Along the coast, GPS is used with sonar technology to measure ocean depth and to alert ships to possible hazards along the coast.

Sport and recreation:
GPS has made hiking and outdoor adventure safer, compared to relying on paper maps. GPS is used in sports such as cross-country racing or sailing and has even been incorporated in the game of golf. With GPS, you can know exactly how far away you are from the hole !

Time:
In addition to location, GPS also gives accurate time. This provides a useful tool for financial institutions, which can synchronise a network of computers across the world with GPS and keep an accurate record of transactions and the timing of transactions.

Can you think of any other ways navigation satellites could be useful to us? New applications are being thought of all the time.

> COMMUNICATION SATELLITES

Communication satellites can be used to link all regions and people of the world. Satellites have made long-distance communication easier, have given us the entertainment of satellite TV and made images from around the world available in real-time.

Communication satellites operate like terrestrial relays except that they are in space. Signals sent up from one point on the Earth (uplinked) are sent back down to Earth to another point or multiple points (downlinked). Communications satellites carry transponders that receive signals through antennas in one frequency, amplify them and retransmit them back to Earth in another frequency to prevent interference with the uplink signal. The transmission has to respect what is called the "link budget" i.e. the larger the uplink antenna is, the smaller the receiving satellite dish can be. For example, in TV broadcasting, programs are uplinked from large antennas (about 5 to 10 metres in diameter) to be received by small satellite dishes (< 1 metre in diameter) on homes.

Communications satellites give us four main types of communication services: telephony, TV broadcasting, professional data exchanges for businesses, and internet access in remote areas. Telephony services reinforce and back-up terrestrial networks for long-distance calls and allow people in remote areas to communicate with the rest of the world. They also allow for phone communication on aeroplanes. Iridium Communications Inc. is a satellite phone communication company with 66 satellites in Low Earth Orbit, providing coverage over the whole Earth, including Africa. Eutelsat's fleet of geostationary satellites located over Europe and Africa are used to provide mobile telephony and internet access across Africa in areas non-served or underserved by terrestrial networks.

The most popular use of geostationary satellites is TV and radio broadcasting. Satellites are used to feed terrestrial transmitters as well as deliver signals direct to home to a satellite dish. The dish has to be carefully pointed to the satellite position from where the programmes are broadcast, for example, to the EUTELSAT 36A satellite located at 36° East to receive channels from the DStv platform. The signals from broadcasting satellites are sometimes scrambled. This means you need a decoder to unscramble the signal to be able to view the TV programmes. The scrambled signal also means that, in the case of paid channels, only authorised subscribers to a satellite TV company can receive the unscrambled signal.

Broadcasting satellites, such as those for satellite television, are all in geostationary orbit at 35,786 km above the equator. In this specific orbit, they appear as "fixed points in the sky". They can serve large audiences across a wide area that can encompass a whole continent such as Africa. They are placed at precise positions on the geostationary belt, and because they all have their own place and are all moving at the same speed in sync with the Earth, they don't crash into each other even though they are in the same orbit. The positions of satellites in their orbit are controlled by international agreements.

More science in communication satellites:

> QUESTION 1

Can you calculate the time it takes for a television signal from a live event at a stadium in Nairobi to get to the broadcast centre via the EUTELSAT 36A satellite located at 36° East (same longitude as Nairobi)? The distance between the stadium and the broadcast centre is 10 kilometres, so it can be ignored.

// DISCUSSION

There are two important facts that you can use to solve this problem.

Fact 1: The television signal moves from the outside broadcast unit to the satellite and down to the broadcast centre at the speed of light, 3×10^8 m.s^{-1}.

Fact 2: The vertical height to the communications satellite from both venues is approximately 36,000 kilometres.

SOLUTION:

The distance from the outside broadcast unit to the satellite is 36,000 km = 3.6×10^7m

The distance from the satellite to the broadcast centre is 36,000 km = 3.6×10^7m

Total distance = $2 \times 3.6 \times 10^7$m = 7.2×10^7m

Time = Distance ÷ speed = 7.2×10^7m ÷ 3×10^8m.s^{-1}

= 0.24s

> QUESTION 2

Why does a satellite television dish (antenna) have a curved shape?

// DISCUSSION

The shape of a satellite dish is actually a parabola. When parallel signals coming from the satellite strike the dish, the waves are reflected according to the laws of reflection. All the incoming waves are focused at a single point or focus, because of the parabolic shape. If you look carefully at the dish, you will see that there is a receiver device (LNB) that is positioned exactly at this focus point. If you visit a broadcast centre, you will find that the transmitters have the same shape too.

Data communications involve the transfer of data from one point to another. Many corporations use satellites to transfer financial information, for inventory management and for credit card authorisations. Satellites are also used in business communications for video conferencing, to reduce the need for travel. They are often the only way to connect oil and gas rigs located in deserts or at sea to company headquarters. Satellites are also used for distance-learning and virtual universities. A significant amount of internet traffic also goes through satellites.

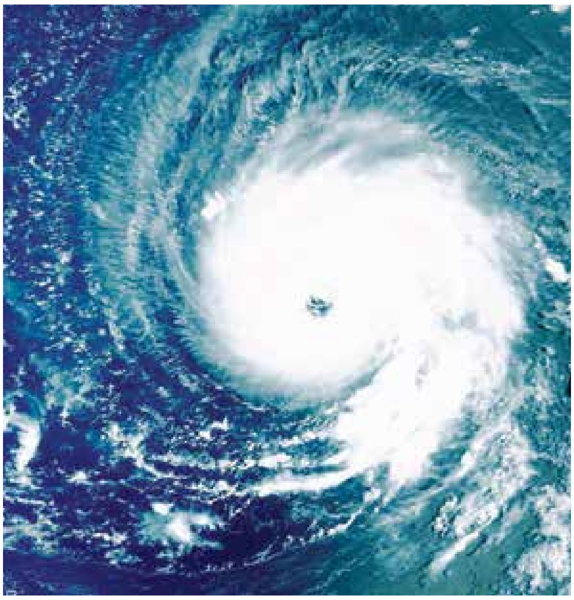
Communications satellites use a frequency range of one to 50 gigahertz to transmit and receive signals. Different frequency ranges (or bands) are distinguished by different letters: V-, Ka-, Ku-, X-, C-, S-, L-bands (from highest to lowest frequency). Signals in a higher frequency need smaller antennas to receive signals, as is the case for small antennas used for satellite TV. Higher frequency signals lose more energy over a given link distance. This loss is compensated for through a concentration of power over smaller coverage areas.

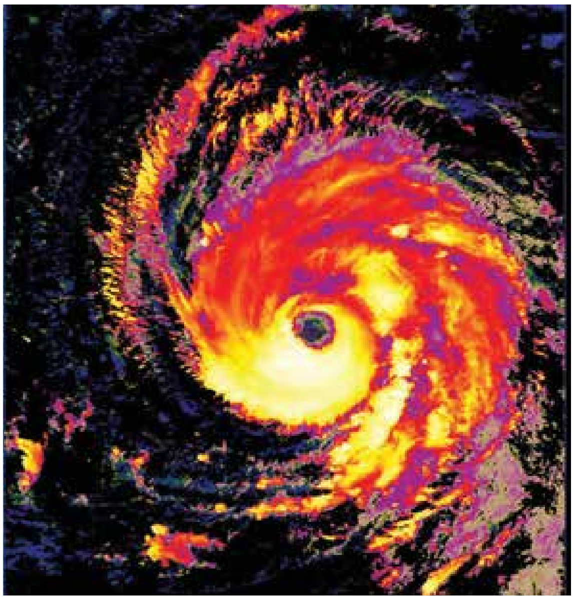
> WEATHER SATELLITES

Weather satellites help meteorologists predict the weather. They usually contain cameras and sensors that send back images and details about the Earth's weather. The images of these satellites tell us about storm systems, fronts, upper-level wind direction and speeds. They help meteorologists predict hurricanes and tornadoes with much greater accuracy. Storms can be easily seen and traced by visible-light images and infrared images. The visible-light images can show things like clouds and cloud systems, fires and pollution. Infrared images show how much heat is reflected off the clouds and Earth. This can tell us about the temperature of the Earth and water. It can also tell us about storms, as cold cloud tops often indicate a more intense storm.

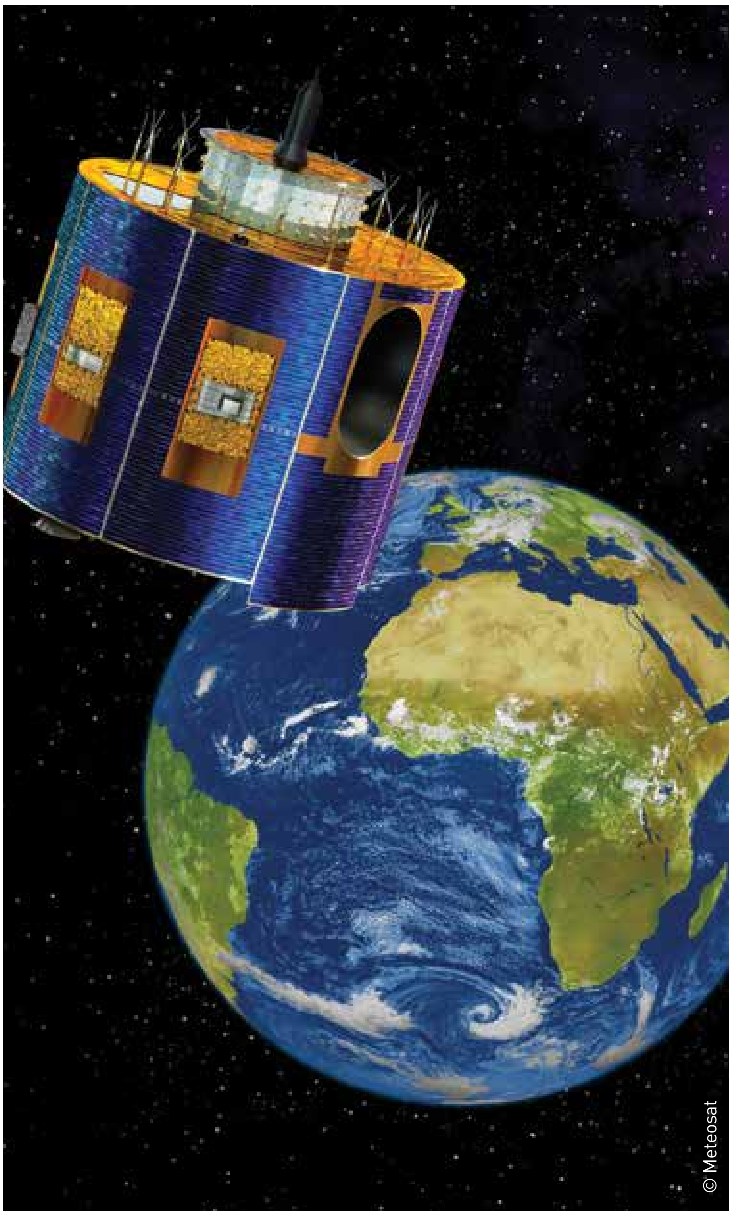
Some weather satellites are geostationary. They show images of the whole hemisphere below them. Others are launched into polar orbit which scan the whole Earth every 12 hours strip by strip to monitor temperature, moisture and cloud positions.

Satellites can also give us information for climate change research, because they can give us information about ocean temperatures and currents, and about the size of glaciers in Polar regions. They can give us information about long-term rainfall patterns and emission of greenhouse gases, as well as show long-term warming or cooling of the Earth.





Isabel hurricane (MERIS image)



© Meteosat

Horsehead nebula (HUBBLE telescope)

> SCIENTIFIC SATELLITES

Scientific satellites perform a variety of scientific missions. Research satellites gather data including those about the Earth's atmosphere, stars, sun and space. For example, satellites can monitor ozone in the atmosphere which protects the Earth from solar radiation and they can measure different levels of radiation. Scientific satellites can also tell us about what's happening in outer space. Astronomy satellites are like big telescopes without the problems we have with the atmosphere obstructing the view of telescopes on Earth. They can send us images at different wavelengths. For example, the Hubble telescope has been taking wonderful photographs of stars, galaxies, nebulae, supernova and much more since 1990. Space weather involves the forecasting and prediction of conditions in the space environment, which can have an effect on technology on Earth. Data used for space weather and for the continuous monitoring of the Sun is collected from scientific space weather satellites.

Andromeda Galaxy (observatoire spatial HERSCHEL)

> SEARCH AND RESCUE SATELLITES

Satellites can save lives. These satellites can detect emergency signals from ships, aeroplanes, etc. in dangerous or remote places. If a satellite picks up an emergency signal and relays it to Earth, scientists can use mathematical calculations to figure out its coordinates.

> SURVEILLANCE SATELLITES OR SPY SATELLITES

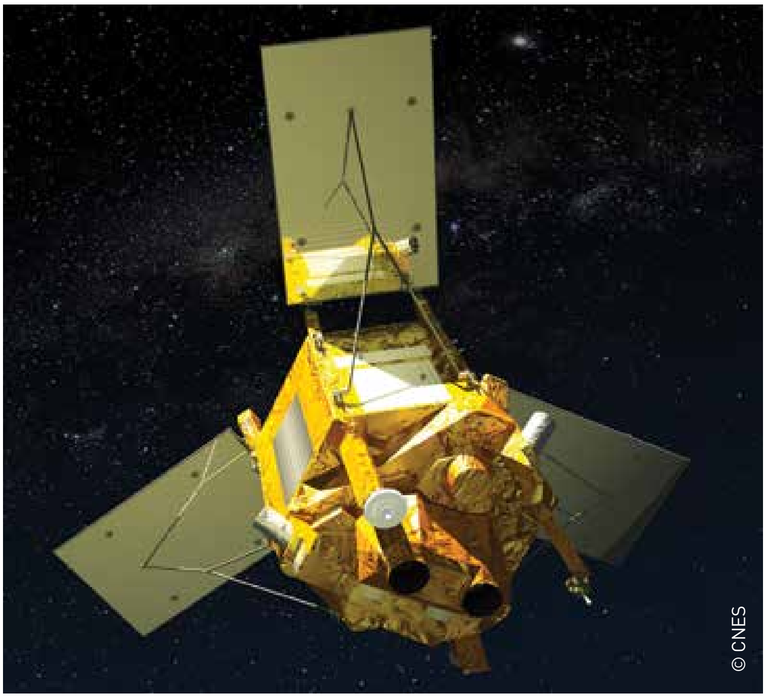
These use cameras to take photographs of places, have infrared detectors to detect elements in the dark, and pick up radio transmissions. Military satellites gather intelligence and are essential for reconnaissance, but their activities are top-secret.

> EARTH OBSERVATION SATELLITES

Earth Observation (EO) satellites help us to observe many features of the Earth's surface. Images can be taken at different wavelengths to give different types of information. The type of data gathered by EO satellites needs processing by computer systems into information that is useful to us.

EO satellites gather information about the Earth's systems and help us to monitor the natural environment as well as built environment, and changes over time. This kind of information helps us, for example, spot environmental disasters and manage our natural resources, which is important for our sustainable future. This information is valuable to a wide variety of decision-makers, including those in areas such as agriculture, food security, water management, disaster management, infrastructure planning, housing development, mining safety and national safety and security.

Two examples of EO satellites are the SPOT satellites and the Landsat satellites. The SPOT satellites are in polar orbits at about 800 km high. Landsat satellites follow a near polar, sun-synchronous orbit at an altitude of 705 km above the Earth. Sun-synchronous means the satellite takes pictures of the same latitude at the same time every day, so that scientists can compare data of the same place under roughly the same lighting conditions. Polar-orbiting satellites like SPOT and Landsat take images of the Earth with better resolution than geostationary satellites which are at a much higher altitude above the Earth. Here are some of the uses of Earth observation:



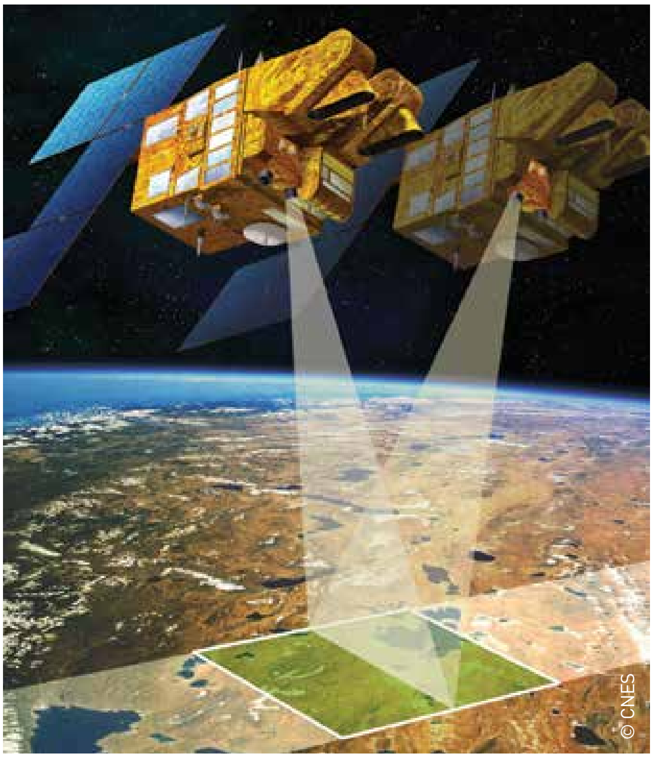
© CNES

Resource and water management:
EO satellites can detect mineral resources. Satellite pictures can show us faults in rocks that are not visible from the ground, so that geologists can see where mineral or oil deposits may be. Water is such a precious resource and EO satellites can help map surface water distribution, measure water quality and measure groundwater content.

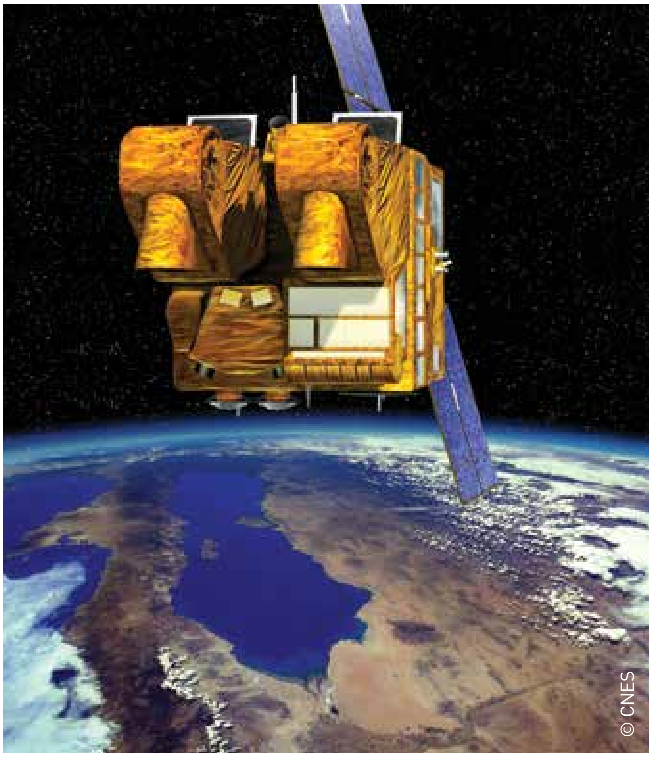
Environmental monitoring, conservation and impact assessment:
Information from EO satellites can be used for environmental mapping and monitoring. They can be used to determine land cover and vegetation patterns, water distribution, soil contamination, soil erosion, wildlife habitats and migration, as well as desertification patterns. Nature conservation strategies can be developed around this type of information about the surface of land and vegetation. EO satellites can help to manage environmental disasters by detecting and monitoring the extent of oil spills, airborne pollution and forest fires, and by monitoring ocean and wind currents.

Agriculture and forestry:
EO satellites can give us information about where and what type of crops are growing in a region, and also predict the yield of crops. They can tell us about the health of crops and detect spread of disease in crops and forests. Infrared photographs can show us how dry a region is, as the amount of water in a plant will determine the amount of infrared it reflects. This helps farmers predict drought. Farmers can also receive reports about river flooding and forest fires from satellite information. All this information can help governments anticipate food shortages, so that backup plans can be made.

Information from EO satellites can be used for forest mapping and management, and can be an important tool in combating illegal logging in many countries.



How the HRS instument works (Spot 5)



Law enforcement:
EO satellites can pick up the cultivation of illegal drugs. They can provide evidence when ocean vessels pollute waters or can show whether illegal fishing is taking place.

Urbanisation:
Urbanisation is one of the major global environmental changes, and will continue to be so in the future. Urbanisation is driving changes in landscape; changing land surface, vegetation, the water cycle and heat patterns. EO satellites give us information about structures, objects and patterns on the land surface. The data can be processed by computer models to show the impact of urbanised land on energy and water. They can show how buildings and other concrete structures create impermeable surfaces, meaning rainfall cannot penetrate the soil and therefore runs into streams, concentrating pollution and causing soil erosion. Buildings and other urban structures also affect heat patterns which can be detected by infrared images. Heat patterns then also affect rainfall patterns. All this information becomes important in managing the effects of urbanisation.

Global Earth Observation System of Systems (GEOSS), of which a number of African countries are members, aims to be a global public infrastructure that generates environmental data available for a wide range of users, with the aim of enhancing the relevance of Earth observations to global issues of importance to people and society. Nine areas being addressed are: protection against natural and human-induced disasters, understanding the environmental sources of health hazards, managing energy resources, responding to climate change and its impacts, safeguarding water resources, improving weather forecasts, managing ecosystems, promoting sustainable agriculture and conserving biodiversity.

Satellite Laser Ranging:
Satellite Laser Ranging (SLR) measures the precise distance to specific satellites by laser pulses. The time it takes the laser pulse to reach the satellite, reflect and return to the SLR station gives the measure of the precise distance of the satellite. This not only gives information about the precise orbit of the satellite, but it also gives very important scientific information about the Earth and its centre of mass, field of gravity, and other important geodetic information.

That's a lot of important things that satellites can help us with. Can you think of any more?

Typhoon hits Amani in Japan

05 Can anyone launch a satellite anywhere in orbit?

Coordination between satellite operators is managed within the framework of regulation drawn up by the International Telecommunication Union, a United Nations Agency.

To answer that, we need to go back and look at the different types of orbits that satellites can use. Satellites that have low or medium Earth orbits can generally be launched anywhere in orbit, because there are so many possible altitudes and positions they can occupy. However, calculations need to be made to ensure that they don't collide in orbit with another satellite.

Geostationary satellites are all orbiting at the same altitude at 35,786 km above the equator, and therefore there is limited place available for new satellites. An agency of the United Nations has a very important role to play in coordinating and allocating geostationary orbits and radio frequencies for communication satellites so that they do not interfere with each other. This agency is called the International Telecommunication Union (ITU).

© Eutelsat

The ITU has 193 member countries and over 700 private sector entities and academic institutions across the world. The ITU holds the World Radiocommunication Conference every two to four years, where radio frequencies for various applications are assigned to various regions of the world.

Once a satellite is launched, the data and information from the satellite is either kept confidential (for example, in the case of military satellites), commercialised through licensing from commercial companies (TV platform, telecom operator, Internet service provider, etc.), shared between countries through agreements, or is made available for public use (for example, satellite images produced by NASA are published by the Earth Observatory and are freely available to the public).

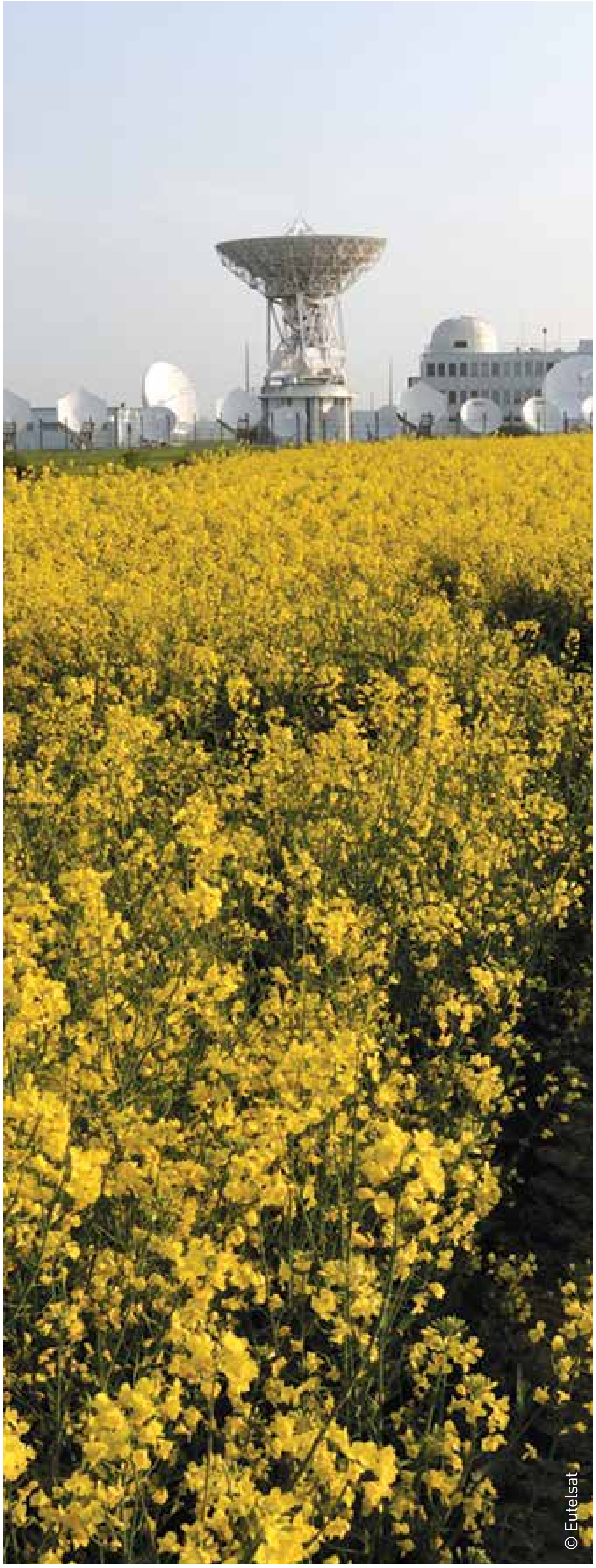
> COOPERATION BETWEEN COUNTRIES

International cooperative groups have come together to maximise the use of satellite data. This is important as satellite technology is an expensive technology and maximum benefit should be gained from the resources invested. The Committee on Earth Observation Satellites (CEOS) was established in 1984. It aims to enhance international cooperation and coordinate public Earth Observation data so that it is of benefit to all. Two African countries are Members of CEOS: Nigeria, through its National Space Research and Development

© SEA LAUNCH

Agency (NASRDA), and South Africa, through the South African National Space Agency (SANSA). SANSA's Space Operations Directorate and Kenya's United Nations Environment Program are Associates of CEOS. The Group on Earth Observations (GEO) has similar objectives. GEO has 88 members in total, including a number of African countries: Algeria, Burkina Faso, Cameroon, Central African Republic, Republic of Congo, Cote d'Ivoire, Egypt, Ethiopia, Gabon, Ghana, Guinea-Bissau, Republic of Guinea, Madagascar, Mali, Mauritius, Morocco, Niger, Nigeria, South Africa, Sudan, Tunisia, and Uganda. The GEOSS is an initiative of GEO, aiming to use Earth Observation information to benefit society.

More specific to Africa, the African Resource Management (ARM) Constellation was agreed upon in December 2009, through a Memorandum of Understanding signed by the governments of South Africa, Kenya, Algeria and Nigeria. The planned constellation will consist of satellites from each of these countries, and will provide shared information for disaster management, food security, public health, infrastructure, land use and water resource management.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DStv Eutelsat Star Awards: Guidelines for educators and students


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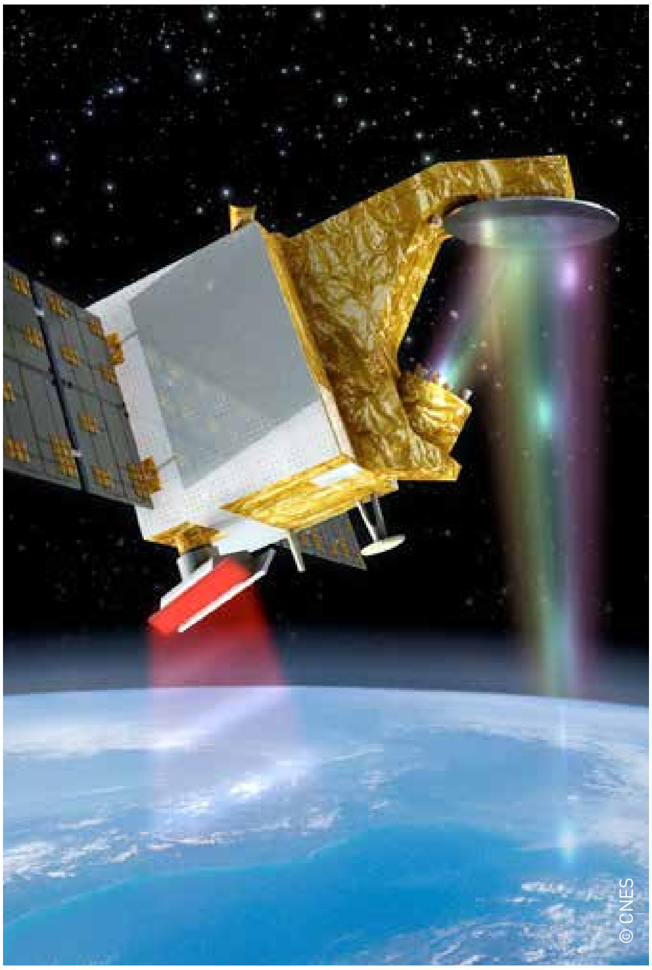
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TOPIC 2013

Imagine you were allowed to use all the satellites in space. What would you do with them to benefit your community, your country or your continent?

Elaborate on three priorities.

> CHOOSE YOUR FOCUS AREA(S)

Think about the capabilities of satellites and the application of satellite technology that you read about in this guide. Now think about particular priorities in your community, country or the continent. You need to consider how the capabilities of satellites can address these priorities and make the community, country or continent a better place. Research the priorities you have identified properly so that you are able to tell the judges about the extent of the problems/issues you have identified as priorities. Here are some examples to inspire you:

. If satellites can be "eyes in the sky", are there any needs in your community , country or in Africa as whole that satellites can provide for?

. What are the challenges and problems in your community, country or Africa that you think satellite services are best suited to tackle?

. For what purposes do you think navigation satellites like GPS can be used to improve the way things are done currently in your country? What about communication and Earth observation satellites?

. Africa is a resource-rich continent. Can satellites help with the management and detection of these resources?

. There are some very remote places in Africa. Can satellites help connect communities and make even the most remote villages part of the global village?

. What would be the knock-on effects of satellite technology? Would this have an effect on the economy, education systems, food situation, medical care, etc.?

. Could satellites help to make your community a safer place?

. Can satellite technology help solve environmental problems such as rhino poaching or pollution?

. How can satellite technology help improve Africa's management of transport and air traffic?

Remember you have to focus on three priority areas, so give each area equal consideration in the way you structure your essay.

> DO YOUR RESEARCH

Think about all the types of satellites that would be best suited to address the priorities you have identified. Then think about how you are going to use these satellites to bring about improvements. You may consult sources such as books, journals, news papers or the internet if you have access. Remember to check the credibility or your sources when using the internet. Consult your teacher for recommendations on your bibliography.

> LAY DOWN YOUR IDEAS CLEARLY AND LOGICALLY

Think about these questions:

. What are the social, economic and/or environmental priorities you have identified and why are they important?

. What types of satellites do you need to address these priorities and what specific capabilities do the satellites have that make them relevant to your chosen priorities?

. How will your ideas benefit your community, country or the continent?

. Where will the satellite be in orbit? How will the position of the satellite make it possible to do its function?

. Who will manage the information from the satellite?

. Who will benefit from the information from the satellite?

. How will the information from the satellite get to the people who need it?

Poster:

- Visually appealing – if a poster is dull it will not draw anyone's attention!
- Do you own illustrations and drawings and do not use photos or magazine clippings.
- If you use text on the poster – the size of the text should be big enough that people can read it from a distance.
- Your poster needs to address the topic.
- Your poster must be accompanied by a creative summary. The summary need to inform the judges of the topic, a summary of the concept of your poster (what priorities did you select and how are satellites able to assist?) and all references you consulted in coming up with the concept.

Essay:

If you have chosen an essay, you will need to paint the picture with your words. Choose your words carefully.

All essays have the following components:

1. Introduction : This is where you introduce your focus area(s). It is the first thing that the reader will go through so it needs to capture the reader's imagination. It needs to make the reader excited about what is to come and to make him/her want to read more!

2. Body : The body of an essay can be made up of a number of paragraphs. This is where you unpack the topic/focus area(s) that you have chosen and answer some of the questions listed above. Remember to do this is a logical manner to make your writing flow. Sentences should average between 15-25 words.

3. Conclusion : This is a summary of your main points. It is also the part of your essay that the reader is likely to remember the most. And, it is your last chance to make an impact on your reader.

Stick to the criteria!

Criteria for essay:

- Language: English, French or Portuguese.
- Length: 1,200 – 1,400 words.
- Must be typed in Arial 12, 1.5 spacing and pages to be numbered or it must be handwritten, but clearly legible.
- Only hardcopy entries will be accepted.
- Entries may include illustrations, graphics, or diagrams.
- List your references (all sources consulted during the preparation of the entry).

Criteria for poster:

Design a creative poster by illustrating an idea on the competition topic. The poster must be accompanied by a creative explanation/ summary in the following format:

. Title

. Summary idea/concept

. Explanation of idea

. References (all sources consulted during the preparation of the entry)

- Language: English, French or Portuguese.
- Entries may not be bigger than A3 Size (42 X 29.7 cm only).
- Only hardcopy entries will be accepted.

No electronic submissions will be accepted.

Good luck!

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