



DSstv EUTELSAT

# STAR AWARDS

Creating Space For African Ideas

## A Ride on the Magic Circle



## Introduction

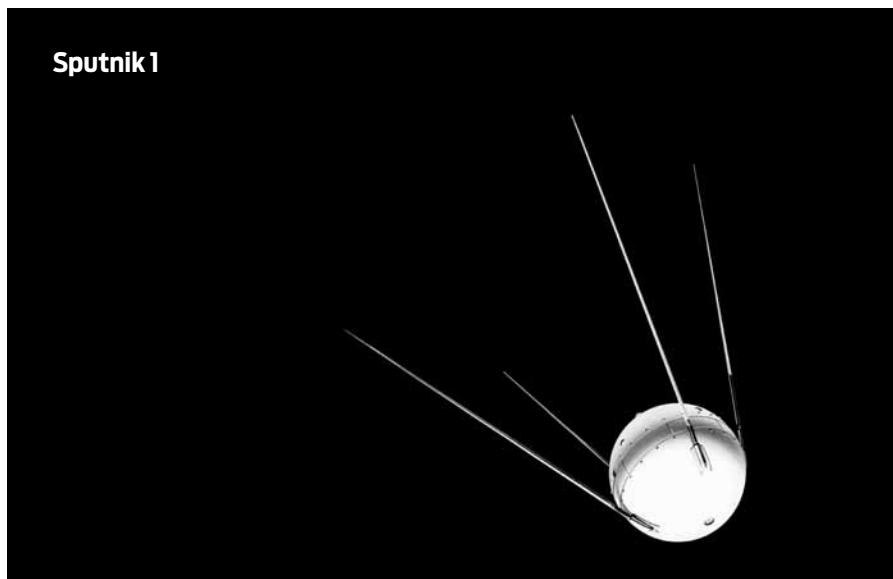
This guide will take you on an amazing ride into the fascinating world of satellites. You will be introduced to exciting scientific ideas and the connection of science and your immediate world will suddenly jump to life.

In this booklet, we have called the orbit of a satellite around the Earth, the Magic Circle. As you read through this booklet it will be like going on a ride on which you discover that the theory you learn about in your science classroom is applied to different aspects of a satellite's life.

On this ride, you will learn about satellites, how they work and how they impact our lives every day. The objective of this resource is to bring the science of satellite technology closer to you and help you to understand how satellites have made a huge difference in all our lives in ways that we do not even realise.

### So let the Magic begin.

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## 1 Blast Off

The first ride on the Magic Circle around the Earth took place on October 4<sup>th</sup> 1957. A Soviet rocket launched the first man made satellite called Sputnik 1 into orbit around the Earth. Sputnik 1 was not much more than an aluminium box that was only 58 cm wide and weighed about 84 kg. The satellite travelled almost three months, taking about 100 minutes to circle the Earth. Sputnik 1 burned up on 4 January 1958, as it fell from orbit upon re-entering Earth's atmosphere. Despite the fact that Sputnik 1 was not much of a satellite, it signalled the beginning of an age in which the dreams of many would become reality.



Today's modern satellites follow Sputnik 1 into orbit around the Earth. The difference is that the launch mass of today's satellites can exceed six tons while their wing span can extend to over 40 metres. They are launched into space from space ports in French Guiana, Kazakhstan, Florida (USA), China or India, aboard rockets such as the Ariane 5 ECA which stands approximately 50 metres high and weighs over 700 tons at lift-off. To get this huge load into space requires a tremendous force. The rocket engines fire and lift the precious cargo up into the atmosphere. Once in space, the rocket and satellite separate and the satellite begins its orbit around the Earth at a speed of about 10 kilometres per second.

Watching a rocket launch a satellite into space is one of the most thrilling adventures you could ever dream of. The excitement and tension builds as the rocket engines fire and the sound levels rise until it seems like the whole world is shaking. Then slowly the rocket lifts off and rises into the atmosphere, beginning the ride on the Magic Circle.



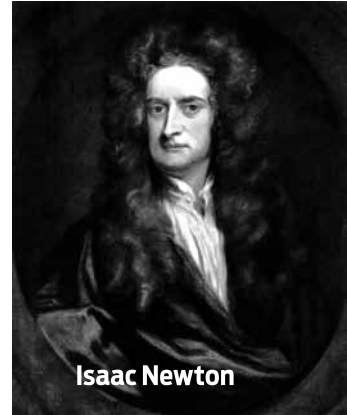
**8K71PS of 1957, the type of rocket that took Sputnik 1 in orbit**

## The science linked to Blast Off

Science is based on two key processes – observation and questioning. From the time people first lived on Earth, they have taken note of the world around them and asked questions. They came up with ideas to answer these questions too. So now think about the launch of a satellite again. What questions spring to your mind? Can you explain what is happening?

The key idea is gravity. People have wondered about what keeps the stars and moon in regular positions at different times of the year. They also wondered what keeps us stuck to Earth. At first people thought there were different forces that controlled the stars to what happens on Earth.

But then along came Isaac Newton. He 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 around any object that has mass there is a gravitational field. When another object that has mass enters this field, it experiences a force of attraction.



### Teaching Tips

Instead of only referring to apples falling and throwing up balls when introducing the topic of gravity, you could study gravity in the context of launching a satellite. The questions and discussion below are given as a framework to establish the important concepts. You will see how the topic helps you to introduce all of Newton's Laws of motion too.

Let's apply the idea of gravity to the launching of a rocket carrying a satellite. Here are some questions for you to think about and discuss.

### Focus Question 1

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

### Discussion: Focus Question 1

Close to the surface of the Earth the gravitational force is strongest, since the force of attraction between two objects depends on their masses and the distance between their centres. 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 place on Earth, at school we accept the value of  $9,8\text{m}\cdot\text{s}^{-2}$  downwards to do 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  $\text{mass} \times g = 7 \times 10^5 \text{kg} \times 9,8 \text{m}\cdot\text{s}^{-2} = 6,86 \times 10^6 \text{N}$ . Note that this minimum force is not enough to accelerate the rocket upwards.

## Focus Question 2

The rocket seems to move slowly at first and then speeds up. Can you explain what is happening?

### Discussion: Focus Question 2

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<sup>st</sup> Law states that if there is no resultant or net force an object will remain at rest or continue to move at constant velocity in a straight line. But we see the rocket speeding up so there must be a resultant force. The thrust must be greater than the downward force of the Earth on the rocket.

Newton's 2<sup>nd</sup> Law explains what happens when there is a resultant force exerted on any object. We can summarise this law in the equation:

$F_R = m \cdot a$  where  $F_R$  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 the 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 the Earth.

### **Mass of the Rocket**

During the launch the rocket uses up fuel in its fuel tanks. You may 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 we combine these effects you should recognize that the force required to accelerate a rocket decreases. The 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.

### **Focus Question 3**

After launching, the rocket seems to tilt over and doesn't go straight up. Why?

### **Discussion: Focus Question 3**

If the rocket moved straight up, the thrust would remain vertical and only vertical motion would occur. In order to put the satellite into a Magic Circle, the rocket tilts to give a thrust which combines vertical and horizontal components. The vertical thrust makes the rocket go higher and the horizontal component of thrust gives the rocket a horizontal velocity. The horizontal velocity increases until the rocket and satellite separate and the satellite begins its ride on the Magic Circle around the Earth.

### **Focus Question 4**

How do rocket engines work?

### **Focus Question 4: Discussion**

There are two important science ideas you need to think about when answering this

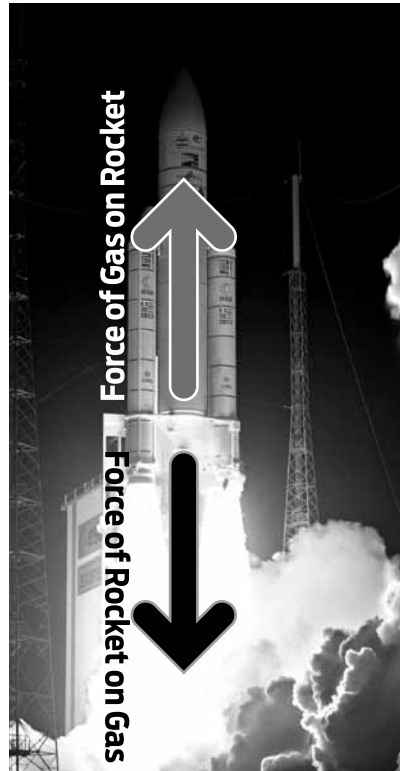
frequently asked question, Energy and Newton's Third Law of motion.

**Energy:** The rocket fuel contains chemical potential energy. On ignition there is a chemical reaction. We can think of this as an explosion that releases huge amounts of energy.

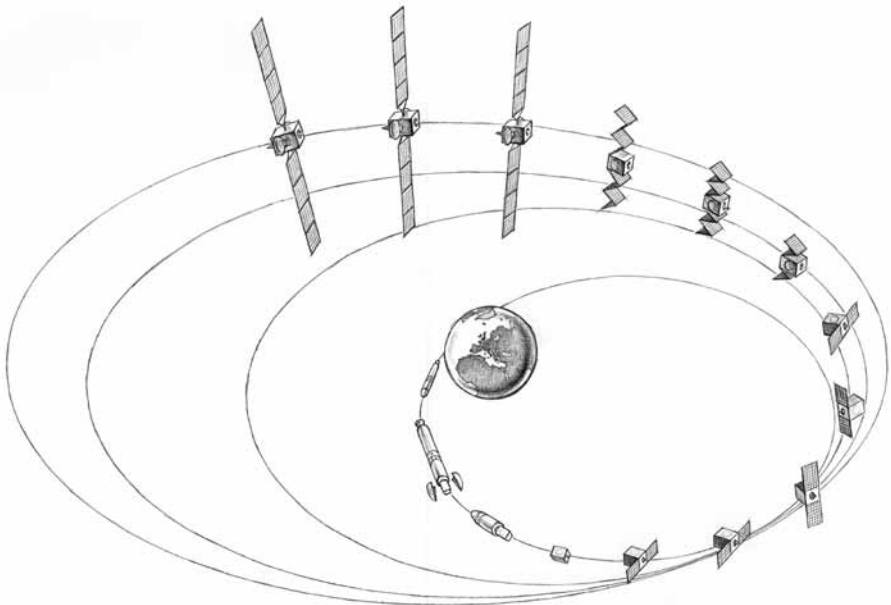
### Can you identify the different forms of energy?

You could include the following heat, light and sound (vibration). But the most important effect of the rocket firing is that the rocket starts to accelerate upwards. We say the rocket gains kinetic energy due to its motion but it gains gravitational potential energy due to its changing position above the Earth.

Newton's 3<sup>rd</sup> Law of Motion: 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. Notice that this pair of forces act on different objects and are in the opposite in direction to each other. We call this pair of forces, an action- reaction pair.



## 2 The Magic Circle Ride



Large, powerful rockets carry satellite through the Earth's atmosphere into space. On this journey through the atmosphere, different parts of the rocket detach while the satellite remains safely carried inside the launcher fairing. The satellite is specially packed into the smallest size possible. Once in space, beyond the Earth's atmosphere, the satellite leaves the launcher and its giant solar panels begin to unfold as the Magic Circle ride around the Earth begins.

At first a satellite will follow an elliptical orbit. During this initial phase of the ride, all the onboard system are checked and tested by engineers at mission control. The onboard propulsion system is used to adjust the orbit and exact positioning of the satellite. You'll be surprised to know that every satellite is designed to function in a very specific orbit and position above the Earth. The orbits of man-made satellites are not all the same. These are defined by characteristics such as the height above the planet's surface, the inclination to the planet's equator and the shape of the orbit.

**The table below summarises the three main families of orbit**

Name of Orbit	Range of Altitudes	Shape of Orbit	Inclination to Equator
Low Earth Orbit (LEO)	400 – 2 000 km	Circular and Elliptical	Various
Middle Earth Orbit (MEO)	2 000 – 25 000 km	Circular and Elliptical	Various
Geostationary Earth Orbit (GEO)	35 784 km	Unique and Circular	0°

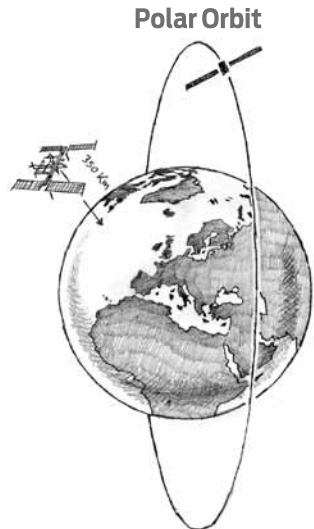
Satellites experience different Magic Circle rides because of the job they do. Here are some examples to think about and discuss:

**• Earth Observation Satellites**

These satellites are usually placed in circular low orbit (400 – 1 200 km). This allows them to travel around the Earth once every few hours, and to obtain detailed views of the planet's surface. The best path for these satellites is a "polar" orbit, which carries them over the north and south poles. As the Earth spins beneath them the satellites can look directly down and study the entire planet – strip by strip - over a period ranging from one to a few days.

**• Weather and Communication Satellites**

Most of them "hover" above the same point on Earth 24 hours a day. This is made possible by placing them on the Geostationary orbit. At this altitude, they keep pace with the Earth's spin, so they



are always looking down on the same regions. This means to an observer on Earth, the satellite remains in a fixed position. In reality these satellites are moving at a speed of about 11,000 kph (3 kps) to complete their orbit in 24 hours. The geostationary orbit forms a 265,000 kilometres long belt, along which communication satellites are placed at precise positions, separated by approximately 1,500 kilometres. All communications satellites work in the same way: they receive a signal from the Earth through their on-board antennas, amplify the signal and relay it back to Earth to a designated coverage area. In this way, they are able to connect two points on Earth thousands of kilometres apart, even in the most isolated areas, and broadcast television to million of fixed antennas.

### Geostationary Orbit



#### • Navigation Satellites

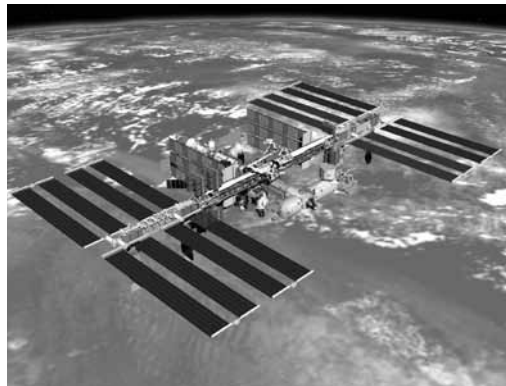
Spread over six circular orbits at approximately 20,000 kilometres above the Earth and at an inclination of 55o relative to the Earth's equator, the satellites of the positioning system GPS move in a synchronized way so that they periodically pass over the same geographical point after a certain number of revolutions. Consisting of 24 satellites in operation, the GPS system is arranged so that six satellites are always within line of sight from almost everywhere on ground, at sea and in the air. (Four satellites are enough to obtain accurate information about the position and speed of an object).

### Synchronized constellation



#### • The International Space Station (ISS).

This important satellite was designed to develop and test technologies for exploring space travel. One of the key area of research is to monitor the health of the crews. The ISS is kept in an orbit between 280 and 460 kilometres above the Earth. It travels at an average speed of 28 000 kph completing 15,7 orbits per day.



## • Scientific Satellites

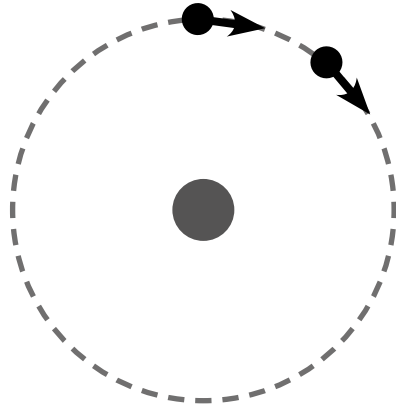
A number of scientific satellites, such as ESA's Cluster and XMM-Newton, follow very elliptical (egg-shaped) orbits that bring them close to Earth and then carry them far away.

### The science linked to the Magic Circle ride.

The simplest orbits to explain are the circular orbits. The satellite is moving 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 1<sup>st</sup> Law of Motion

We know that an object will remain at rest or continue moving at constant speed in a straight line, unless an unbalanced force acts on it. The satellite in our example is moving at constant speed. We can show this 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 1<sup>st</sup> Law there must be an unbalanced force which prevents the satellite from moving in a straight line forever.

In which direction is this unbalanced force acting? It may be helpful to draw a similar diagram and place arrows at different positions along the circular path (orbit). Note that when a force acts on an object, the direction of force will be the same as the change in the direction the object is moving in. Here we can see the direction of the speed is always changing, moving downwards towards to the centre of the Earth.

So there must be a force that pulls the satellite towards the centre of the Earth at every point of its Magic Circle ride. This is the force of attraction between the Earth and the satellite. Even though the satellite is 36 000 kilometres 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.

Notice this downward force does not change the horizontal speed of the satellite. There is also no rocket pushing the satellite forward. The satellite was given its horizontal speed when it was launched by the rocket. There is no force acting in this direction so the satellite will continue with a constant speed. In this way, a satellite's motion confirms Newton's 1st Law.

### **Teaching Tips**

When teaching circular motion you can use a ball on a string to illustrate the main idea. But satellites provide an interesting and relevant context for studying this important topic of Physics.

Here are some additional questions about the Magic Circle ride you could discuss.

### **Focus Question 1**

What does geostationary position mean?

### **Discussion**

If you are standing still and a friend moves towards you in a train travelling at  $5\text{m}\cdot\text{s}^{-1}$ , 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 is not changing 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 the satellites on the Magic Circle ride are all moving together at the same speed.

### **Focus Question 2**

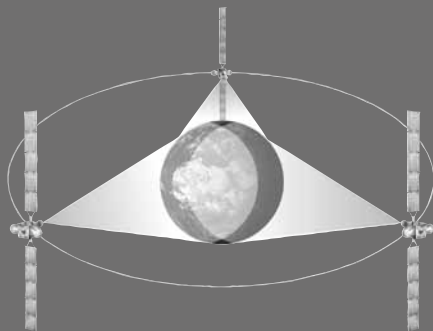
What is special about the distance of 36 000 kilometres above the Earth?

### **Discussion**

There is a direct relationship between distance from the centre of the Earth and the time it takes for rotation (period). The different types of orbits help us to confirm the relationship first suggested by Kepler. The period of satellites at 35 784 kilometres above the equator (or 42 160 kilometres from the centre of the Earth) is one day, the same as that of the Earth. Satellites are not geostationary if they are positioned at different distances above the Earth and/or at a different inclination to the equatorial plane

### Did you know?

In 1945 British science fiction writer Arthur C. Clarke (also known for 2001 Space Odyssey), published his ideas about having a collection of satellites in geostationary orbit, in *Wireless World* magazine.



### Focus Question 3

Does zero gravity exist on satellites?

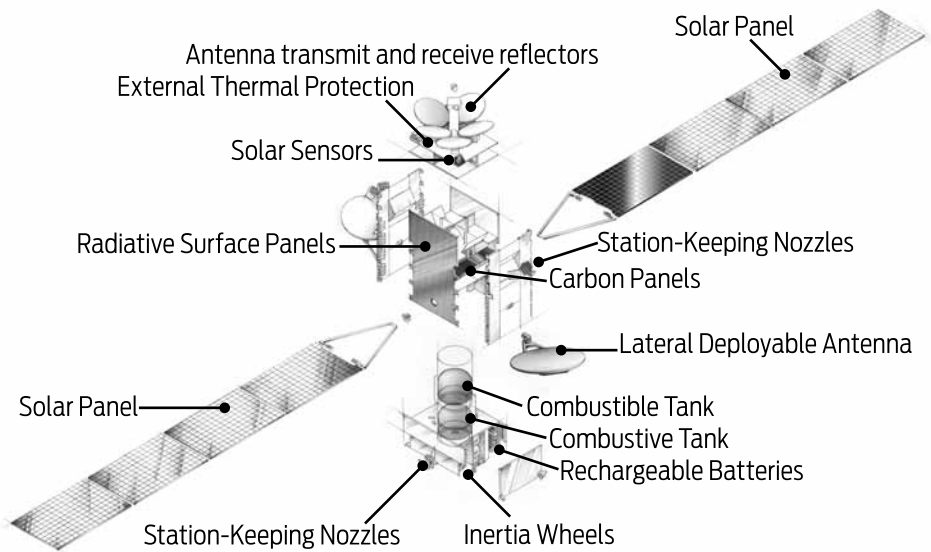
### Discussion

This is a common misconception. The Earth's gravitational field does not end where the atmosphere ends. Even the moon, the asteroids, the 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 in free fall.

### 3 Space Survivor

Before leaving on the Magic Circle ride a satellite needs to be properly prepared to be a Space Survivor. Space is a hostile environment where temperatures range from  $-150^{\circ}\text{C}$  to  $+150^{\circ}\text{C}$ . In addition, there are streams of high energy particles carried by the solar wind and high frequency electromagnetic radiation.





All satellites are designed to function in these very harsh conditions. The sensitive reception and transmission equipment needs to be protected and is housed in a central case. External thermal protectors insulate and protect the satellite equipment from the harsh environment of space, especially the extreme temperatures. In addition, aluminium panels with radiative surface evacuate the heat generated by the receiver, amplifier and transmitter.

Like all survivors, satellites in space need a source of energy to keep the satellite equipment functioning. Fortunately, there is lots of electromagnetic radiation available in space. The large solar panels attached to the body of the satellite convert solar energy to electrical energy. The electrical energy is used to supply electric energy to all the equipment onboard and it also charges the batteries. The rechargeable batteries are used to keep all the systems onboard the satellite working when the satellite passes into the Earth's shadow.

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, 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 on the Magic Circle ride.

### **The science of Space Survivor**

There are many different science ideas that you can explore when thinking about how a satellite is the ultimate Space Survivor. The engineers who design satellites need to use the right materials to ensure survival. One of the most important ideas they

need to understand is the topic of heat. Some materials are thermal insulators. These do not allow a rapid transfer of heat. Other materials are thermal conductors which allow for the rapid transfer of heat. In satellites both these types of materials are used to ensure space survival. Here are some questions for you to think about and discuss while exploring the theme of Space Survivor.

### **Teaching Tips**

You could use the theme of Space Survivor to explore Properties of Materials (thermal properties, electrical properties, density and strength); Thermodynamics, Energy (Photovoltaic cells) and Newton's Laws. Alternatively, when you teach any of these topics, refer to the context of a satellite in orbit to create interest amongst your learners.

### **Focus Question 1**

Why does a satellite experience extreme thermal conditions during its Magic Circle ride?

### **Discussion**

All man-made satellites orbit the Earth above the atmosphere. This means that there is a vacuum around these satellites. You should realise that heat is not transferred in a vacuum. So the temperature in the vacuum of space is extremely low. However, there is lots of solar radiation. When parts of a satellite are exposed to the sun's radiation these parts can become very hot. At the same time other parts of the satellite may fall in the sun's shadow and these parts will be extremely cold.

When you think about these extreme differences in temperature that a Space Survivor has to cope with, you should recognise that we don't have to survive these because of the Earth's atmosphere. The Earth's atmosphere is a very thin band of gases that protects all life on Earth. The temperature on Earth is kept constant by the process of convection, which also contributes to our weather systems.

### **Teaching Tips**

For more advanced learners consider linking the concept of temperature to the average kinetic energy of particles present.

### **Focus Question 2**

Why is carbon a good thermal insulator and why are metals good thermal conductors?

### **Discussion**

You could test this experimentally using graphite and metals. Carbon panels in satellites are made from the Buckyball allotrope, which is extremely strong and a good

thermal insulator. In a thermal insulator, the electrons are not free to move. Even when placed near a source of thermal energy, the electrons in these materials do not easily change their behaviour.

However, in good thermal conductor, such as aluminium and gold, there are many delocalised electrons that are free to move. When a thermal conductor is placed near a source of thermal energy, the electrons inside the material move around much faster. They collide with other electrons and these start moving faster too. In this way heat is transferred through a conductor.

### **Focus Question 3**

Can you identify energy changes that allow a satellite to function?

#### **Discussion**

The energy from the sun, in the form of electromagnetic radiation, is converted to electrical energy by the solar cells fitted on the large solar panels. The electrical energy is primarily used to supply power to the electronic systems onboard the satellite. The electrical energy is also used to charge the batteries which will take over the electric supply when the satellite moves into the Earth's shadow.

During the charging process, electrical energy from the solar panel is sufficient to cause a chemical reaction inside the battery which increases the chemical potential energy. When the batteries are used during the "shadow" periods, they discharge. During the discharging process, chemical potential energy in the battery cells is converted into electrical energy.

When electric energy is used to power the electronic systems and the batteries, heat is generated too.

#### **Teaching Tip**

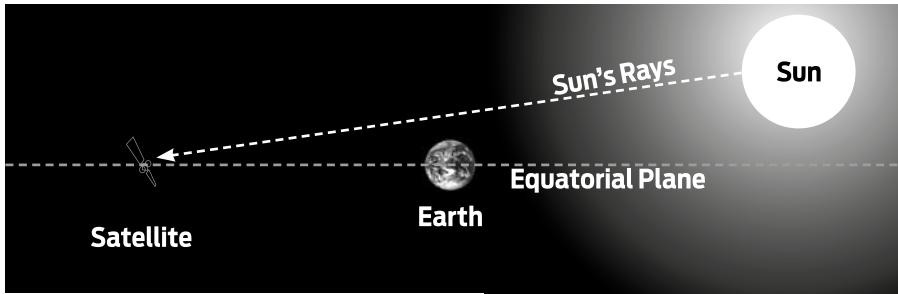
As an extension to this topic you could investigate how a photovoltaic cell works.

### **Focus Question 4**

How often does a geostationary satellite have to rely on its batteries?

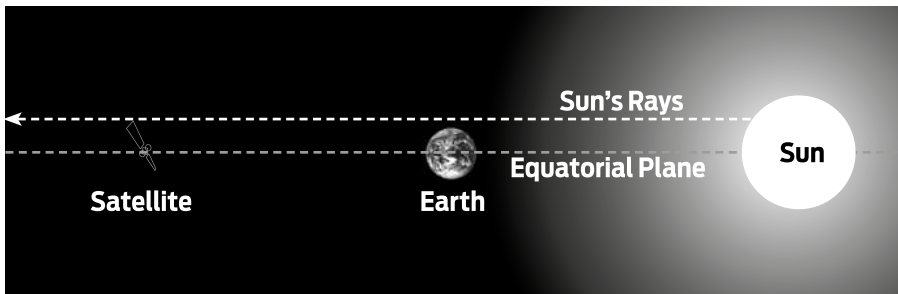
#### **Discussion**

For most of the time a geostationary satellite does not use its batteries even when it is the night for us. This is because most of the time the sun is not in the same plane as the satellite's orbit and sun rays can reach the large solar panels without being obscured by the Earth.



The panels can rotate and are constantly positioned to collect the maximum amount of energy. But as the seasons change, the position of the sun changes too.

At the equinox, which occurs in March and September every year, the sun passes across the plane of the equator, which means that it is in the same plane as the geostationary orbit.



At these times of the year, the satellite moves into the Earth's shadow for several minutes of eclipse every 24 hours. The duration of the satellite eclipse gradually changes as the equinox approaches, building up to a maximum of 70 minutes on the day itself. During these periods, the energy stored in the batteries takes over from the solar panel to supply electric power.

**Key Question 5: How does the propulsion system on a satellite work?**

**Discussion**

This is an application of Newton's Laws and works similarly to that of a rocket. Here the fuel is made up of two different gasses in liquid form which are pressurised by an inert gas like helium. Releasing the two propellant gasses through jets creates a spontaneous combustion and delivers thrust. Thrusters point in different directions enabling commands from Earth to change the position of a satellite.

**4 Staying Connected**

Going on the Magic Circle ride is not only about having fun and surviving. There is work

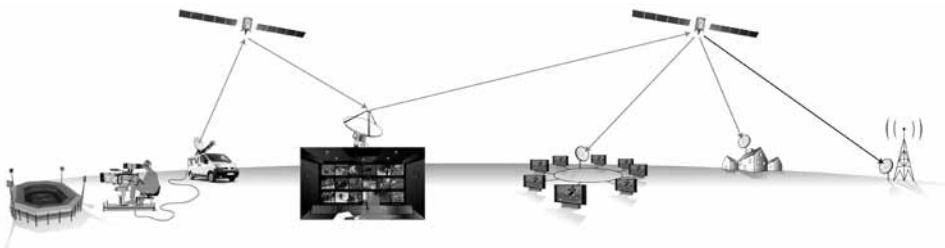
to be done too and one of the most important roles modern communications satellites play is to keep people everywhere on Earth connected. Advances in communication satellite technology have changed the way people live on Earth.

All communications satellites have the same way of working: they receive a signal from the Earth through their on-board antenna, amplify the signal and relay it back to Earth to a designated coverage area. Theoretically, three equidistant satellites would be enough to cover the planet, with the exception of the Polar Regions.

But this works only in theory. The fact is that nowadays over 350 satellites share the geostationary orbit, ensuring precise coverage on demand. Each satellite operates with a specific frequency. Frequency coordination between satellite operators is managed by a United Nations agency based in Geneva called the International Telecommunication Union.

The signals transmitted from Earth to satellite cover a broad range of frequencies from 235 MHz to 30GHz. This allows for the broadcast of television, radio and data. The satellite receives these signals and transmits them back to station on Earth after changing their frequency and/or polarisation and amplifying them. The receivers on Earth can be at sea, in the air, in towns or in the desert. In some cases, specific regions can be targeted with specific frequencies. The signals can also be encrypted and requiring a decoder for the end user to receive the original signal.

Satellite technology has made it possible for everyone on Earth to share experience in real time. An outside television broadcast delivers signals to a satellite; the satellite transmits that signal back to a central broadcast station which can send the signal to other broadcasters in different parts of the world using another satellite channel. The central broadcast unit can also send the signal back to the satellite for transmission to homes, cable networks or any other terrestrial television network.



## The Science of Staying Connected

Satellites function because of the very interesting properties of electromagnetic waves. This collection of waves form the electromagnetic spectrum which includes

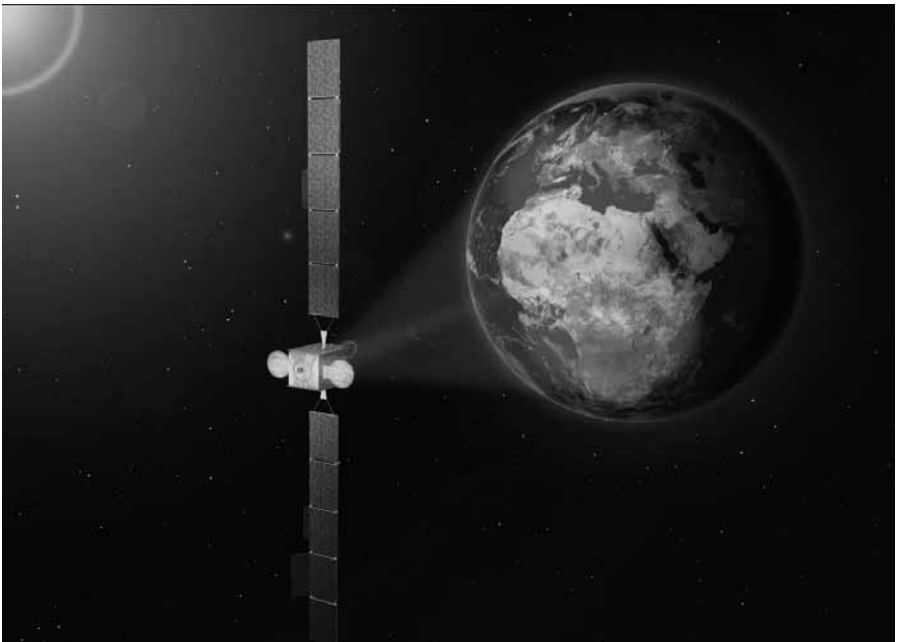
radio waves, microwaves, infra red, white light, ultra violet, x-rays and cosmic rays. They all travel at the speed of light in a vacuum, have an electric component and a perpendicular magnetic component, and are self propagating. These waves do not need a medium to travel. They also display the properties of waves such as reflection, refraction, interference and polarisation.

Satellites give us an interesting context to explore the electromagnetic spectrum. They are exposed to the full range of the spectrum in space, from cosmic rays to microwaves. Observational satellites are designed to operate in different bands of the electromagnetic spectrum. For example, the can collect infra-red radiation to form images of Earth or ultraviolet radiation to form images of distant galaxies.

Communications satellites are not tuned in to the natural electromagnetic radiation but are designed to pick up specific man-made signals and transmit these. They operate where the frequencies range from 1,5 GHz (L-band) to 30 GHz (Ka-band). This has impacted on society and made it possible for information to be distributed across the globe in real time.

**Teaching Tip**

When you teach the topic of communication, make sure you include the role of communication satellites.



Discuss the focus questions to learn more about the science of communication.

### Focus 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 Eutelsat' satellite W7 located at 36° East (same longitude as Nairobi)? The distance between the stadium and broadcast centre is 10 kilometres, so can be ignored.

### Discussion

There are two important facts that you can use key 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,  $3 \times 10^8 \text{ m.s}^{-1}$

**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 =  $3,6 \times 10^7 \text{ m}$

The distance from the satellite to the broadcast centre is 36 000 km =  $3,6 \times 10^7 \text{ m}$

Total distance =  $2 \times 3,6 \times 10^7 \text{ m} = 7,2 \times 10^7 \text{ m}$

$$\begin{aligned}\text{Time} &= \text{Distance} \div \text{speed} \\ &= 7,2 \times 10^7 \text{ m} \div 3 \times 10^8 \text{ m.s}^{-1} \\ &= 0,24 \text{ s}\end{aligned}$$

### Teaching Tip

As an extension, you could also use a different satellite for this same problem. For example you could use the Eutelsat's **Atlantic Bird™ 3** which is located at 5° West.

You could also ask learners to do the same calculation from different points on Earth. For example you could compare the time it takes for the signal to travel when two points on the same latitude are 1 000 km apart. Your learners can solve this problem using trigonometry. More complex problem would include points that are at two very different positions on Earth. See if they can solve the problem if you give them only the position using latitude and longitude.

### Focus 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.



## Focus Question 2

Why do different satellites operate using different frequencies? What prevents us from receiving mixed up signals?

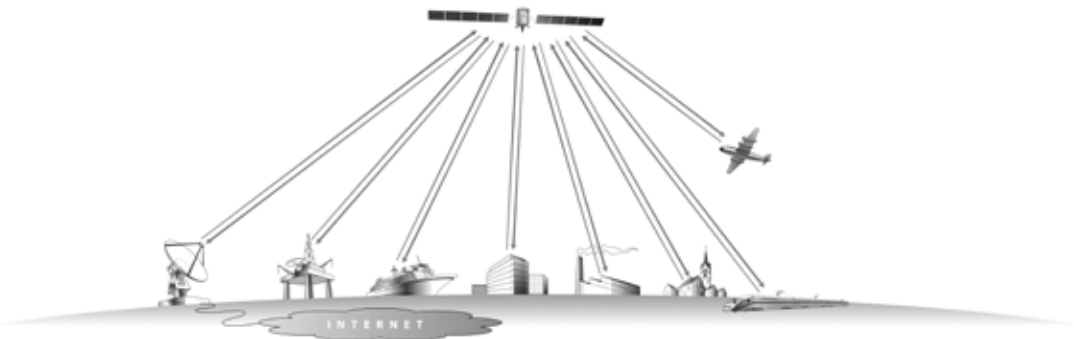
## Discussion

Different frequencies are used to prevent or minimise interference. The signals can also be polarised to target specific receivers.

## 5 What Have You Done With Your Satellite Today?

In this part of the Magic Circle ride, we'd like to introduce you to Joe. His story should help you think about how satellites help you every day without you even recognising that they are there.

My name is Joe and I am twenty two years old. I home is in a rural village about 250 km from the largest town. We are farmers and keep cattle and grow crops.



I was the first in my family to go to school. At times it was hard because I had to walk more than 10 km to school and 10 km home again and I still had to help work on the farm. At this school, they have many interesting things that I had never seen before. We watched science programmes on television and I decided that I wanted to learn more about science. I think if I understand more, I can use it to help my family.

I am now studying Agricultural Science in the city and working part time to earn some extra money. I am learning so many new things. I have learnt about weather patterns and we check the satellite photographs on the weather channel every day. While I'm in the city, I need to keep in touch with my family. I can call them via a phonebox installed in their village and connected by satellite. I can tell my father when the rain is coming and when to get the fields ready. We learnt the other day that in some places, farmers can get photos and information from satellites that tell them what fertilisers to add to the soil.

When I first came to the city I was always getting lost. Now it is not so bad. I have made friends and we travel together all over the city. One of my friends has maps on his mobile phone and this application can even give us directions. We are never lost anymore. I really enjoy the weekends in the city. There are many things happening and even though I don't have much money, I can watch soccer matches, concerts and important news events on the satellite television on the campus. I am also learning more about computers and have started to meet new friends online, using Facebook. I can spend many hours online finding out more information about things that interest me. I found out the other day that there is a banking satellite linkup to the shop in our village. So now I can send money home to my family safely.

### **Can you identify how satellites have helped Joe?**

#### **Additional Notes**

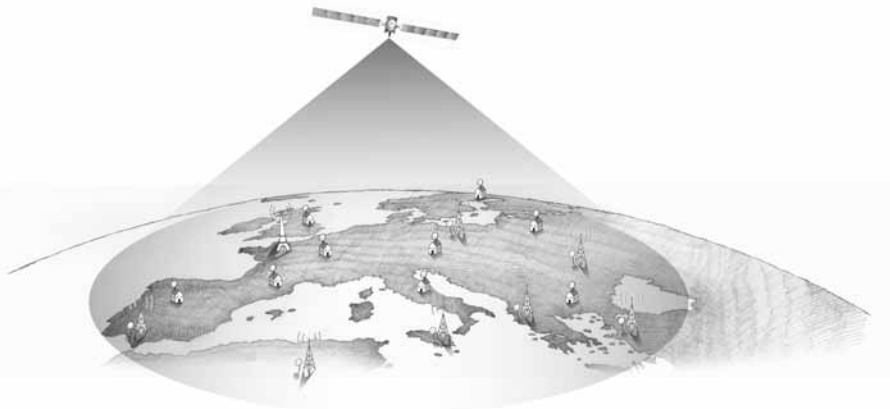
Communication satellites do not only carry television signals designed for entertainment. There are many important applications of television that are impacting on society in a positive way.

Education is the key to breaking the cycle of poverty. Satellite television provides a way to give people in rural communities, access to knowledge that can change their lives.

Another ground-breaking use of satellite is in the field of health. This is called Tele-medicine. Patients in remote areas can be diagnosed and helped by experts that could be thousands of kilometres away. Images and information about the patient are transmitted from rural centres to a specialist facility. Here doctors and nursing staff analyse the information given to them and communicate the diagnosis and treatment to the staff at the rural clinic via satellite.

In times of natural disaster, communication is a key to save lives. Satellites can be used to direct emergency operations especially where normal communication systems are no longer work. Rescue workers and relief aid can be directed using satellite phones. Satellite images can also assist aid workers in assessing the damage caused and finding routes to get to stranded people.

Navigation satellites are also important sources of information that have changed our life styles. The use of the GPS technology means that people can always know where they are and can navigate even in remote areas.



Satellite can give us lots of very useful information. For example, weather forecasting is not a guessing game because satellite images can give a very accurate, up to date picture of the cloud patterns. In addition, by monitoring images of the Earth using infrared and ultraviolet cameras, scientists are able to model the effects of pollution and global warming.

### **Teaching Tips**

The focus of this section is to show the impact of satellites on society and to help learners explore ways in which satellites could be used to solve problems in their community. One way of highlighting the importance of satellites is to arrange a series of class debates. This will help learners think about the positive and negative impacts.

You may also want to debate the following statements

### **Debate Statement 1:**

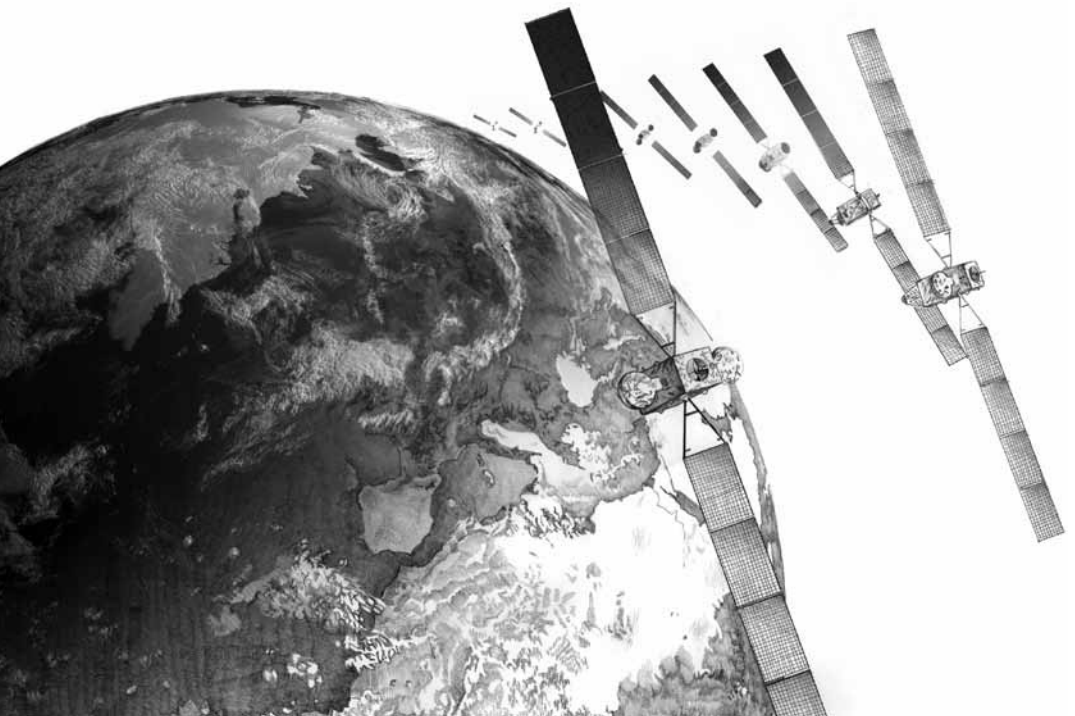
Satellite technology has made a huge difference to ordinary people's lives.

### **Debate Statement 2:**

Satellite technology has given humankind a warning system that should prevent environmental disasters in the future.

### **Teaching Resources**

Please visit the website [www.dstvstarawards.com](http://www.dstvstarawards.com). You will find additional resources including two videos that you can use when teaching any of the topics covered in this booklet.





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