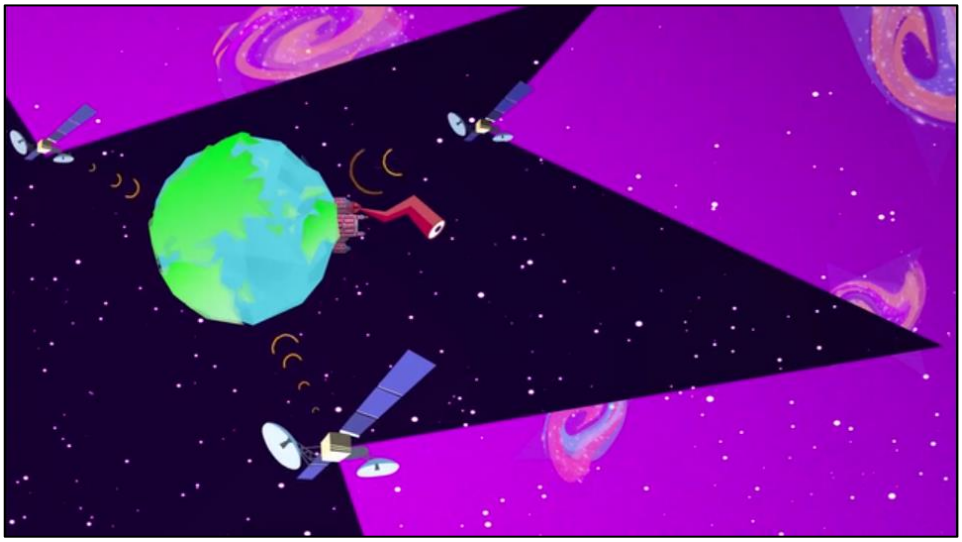
Satellites in Space

Key Stage 4

Topics covered: orbital speed and time, types of orbit, wavelength and frequency of light

Watch the video "What makes the Universe Colourful?"
https://vimeo.com/213990458



NASA's Tracking and Data Relay Satellites (TDRS) are a collection of satellites orbiting around the Earth used to communicate with and send data to space instruments like the Hubble Space telescope and the Earth.

Boeing has been making the third generation of satellites and the final spacecraft of this group of 12 will be launched in August 2017.

Teacher note: this worksheet consists of curriculum-linked questions (GCSE Science, GCSE Astronomy) that extend around the content mentioned in the video.

1. The Earth has a radius of 6371.4 km. The satellite system is made of 3 satellites orbiting at a speed of 3.08 km/s at a height of 35866 km above the Earth's surface at the equator.

$$T = \frac{2\pi(r + h)}{v}$$

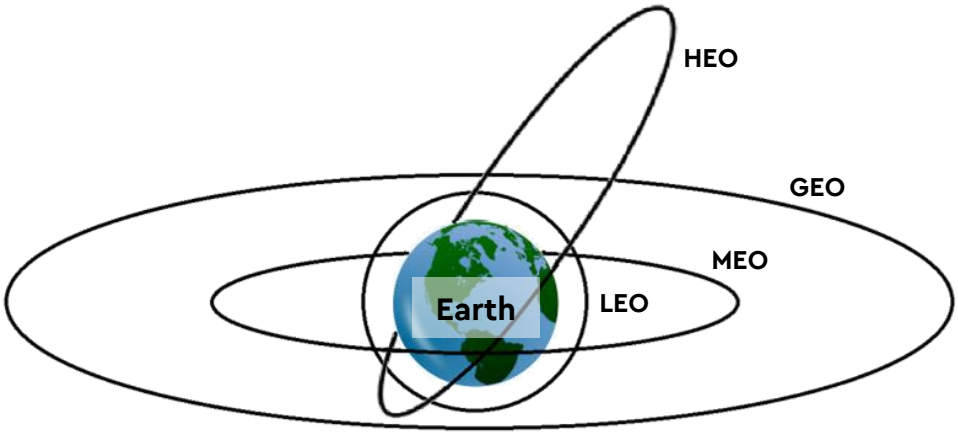
T – orbital period	(s - seconds)
r – radius of Earth	(km - kilometres)
h – height above Earth	(km - kilometres)
v – speed	(km/s - kilometres per second)

a) Assuming a circular orbit, work out the orbital period of the satellite in seconds.

b) How many hours, minutes and seconds is this?

c) What is this amount of time roughly equivalent to?

d) Look at the diagram below; what type of orbit do you think these satellites are in?



(LEO) Low Earth orbit
Satellites at a height of 160 – 2000 km.

(MEO) Medium Earth orbit
Satellites at a height of 2000 km and just over 35000 km

(GEO) Geostationary orbit
Satellites above the Earth's equator taking 23.93 hours to complete an orbit.

(HEO) Highly Elliptical orbit
Satellites in a highly elliptical shaped orbit – these elongated orbits mean that the satellites speed up when closer to the Earth and slow down when further away.

2. Each of the 3 satellites is placed along the equator. Each satellite is at a different position (longitude) to provide almost full coverage of the Earth's surface.

   One is placed at 41°W longitude,
   The second is placed at 171°W longitude.
   The third is placed at 62°W longitude.
   Each satellite can cover 90° east and 90° west from its position.

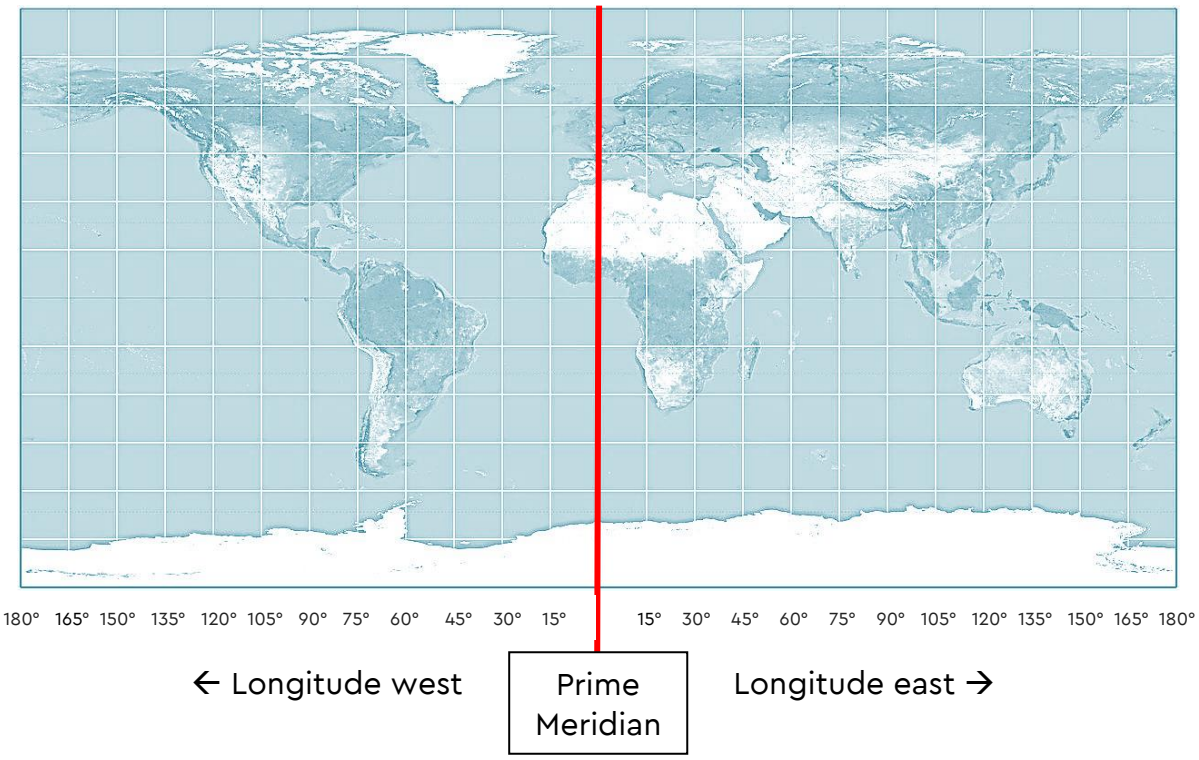
   a) Mark on the map (using vertical lines) the positions of the 3 satellites.

   b) Shade on the map the area 90° east and 90° west of <u>each</u> satellite.

   c) Out of the 360° of the Earth's surface, calculate how many degrees of the Earth's surface the satellites cover altogether.

   d) Work out the percentage of the Earth's surface that these 3 satellites can cover in total by inserting your answer to part c in the formula below.

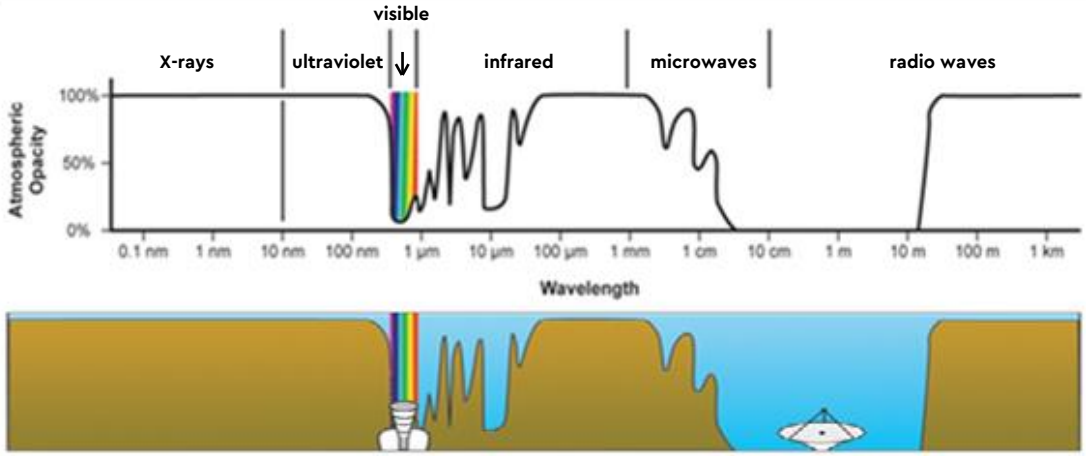
$$\%\ coverage = \frac{[\ \ ]}{360} \times 100$$



3. The satellites use different frequencies to send signals or messages. The uplink frequency is used to send information from Earth stations up to the satellites and the downlink frequency is used to send information from the satellites down to Earth.

   One particular range of frequencies is known at the S band.
   - uplink frequency 2,287.5 MHz
   - downlink frequency 2,106.4 MHz

   1 MHz is equal to:
   1×10^6 Hz or 1000000 Hz)



A graph to show how impenetrable (atmospheric opacity) different parts of the electromagnetic spectrum (wavelengths) are to the atmosphere.
100% - completely absorbed by the atmosphere.
0% - completely penetrates / gets through the atmosphere.

a) Convert each of the frequencies into wavelength in metres.

$$\lambda = \frac{c}{f}$$

λ – wavelength	(m - metres)
f – frequency	(Hz – Hertz)
c – speed of light (3 x 10^8 m/s)	(m/s – metres per second)

b) Look at the diagram above, which part of the electromagnetic spectrum do these wavelengths belong to?

c) Use the image above to explain why these wavelengths are used.

d) '***The higher the frequency, the greater the signal loss and more power is needed for reliable transmission.***'
Using this statement, can you explain why the uplink frequency is higher than the downlink frequency?

Satellites in Space: ANSWERS

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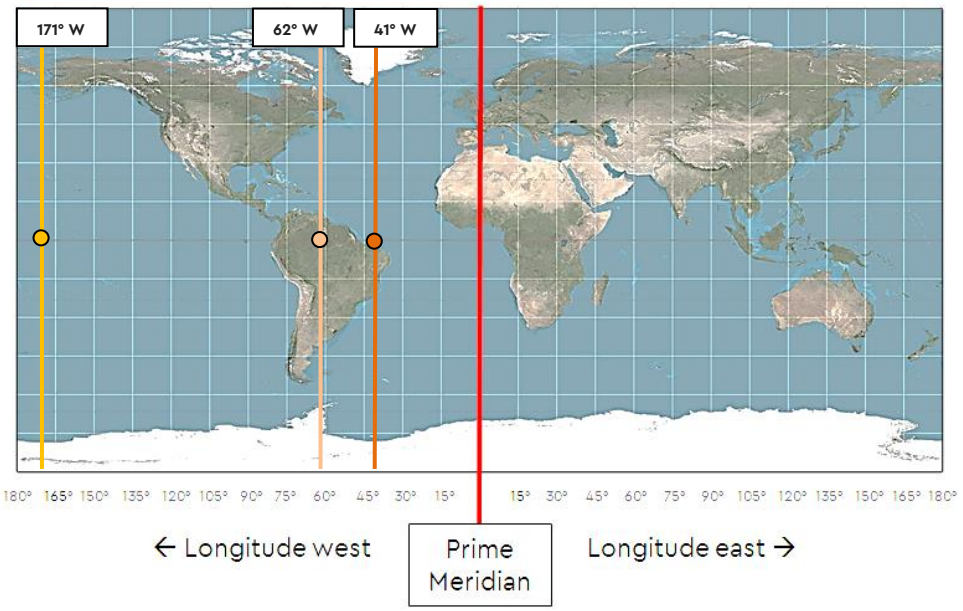
1. a) 86164 seconds

   b) 23 hours, 56 minutes, 4 seconds. (Length of a sidereal day).

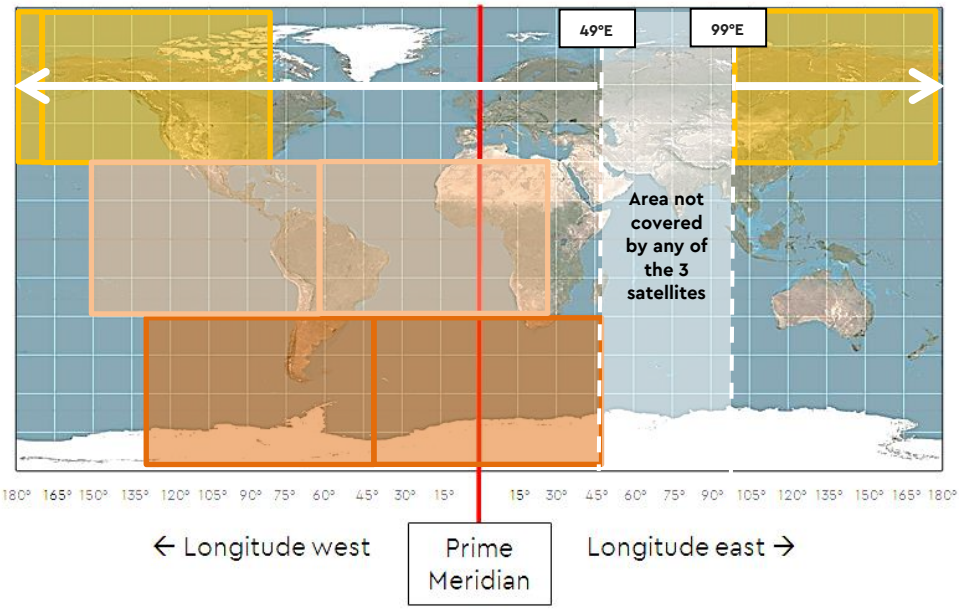
   c) Approximately 1 day

   d) Geostationary orbit (or geosynchronous orbit because these satellites are above the equator) – a satellite in this orbit will be in the same place in the sky at the same time of day, every day.

2. a)



b) Example only – each satellite would cover from north to south pole. Shading here has been split into 3 sections for clarity.



2. c) The satellites together can cover 310° of the Earth's surface.

   d) 86%
   $\frac{310°}{360°} = 0.86\dot{1}$

3. a) S band uplink wavelength 0.13m (13cm)
   S band downlink wavelength 0.14m (14cm)

   b) Microwaves / radio waves.

   c) The Earth's atmosphere can absorb particular wavelengths of light. The S band wavelengths are used because they are absorbed very little by the atmosphere. This means information can be sent up to satellites and detected from them without the signals being absorbed, weakened or undetectable.

   d) Stations on Earth are able to use more power compared to light-weight satellites. To avoid a satellite detecting its own signal, uplink and downlink frequencies must be different. Because Earth stations can draw on more power – it's the uplink frequency that's always higher.