Summary: Satellite communications and the environment of space.

Uses of satellites: Since the launch of the first man made satellite in 1957 satellites have played an increasingly important part in our everyday lives. Telecommunications satellites have played a major part in the global communications revolution where we can call someone on the other side of the world using a mobile phone or watch events around the world, as they happen.
Some satellites look down on our planet from orbit, monitoring the environment for deforestation in the tropics, melting of the polar ice caps and changing sea temperatures as evidence of global warming, to searching for water in arid regions and studying the health of crops. Other satellites look away from our planet imaging stars and galaxies while others are used to in preference to manned missions to explore planets moons and comets in our solar system.

Space is a very harsh environment and satellites need to operate reliably.
Radiation. Operating in a vacuum and exposed to radiation and temperature extremes while also travelling around the Earth many times in 24hrs.

The exercises use data from the FUNcube satellite. Most secondary students will plot graphs at school. These exercises require the students to interpret the graphs given and use that to visualise the behaviour and environment of FUNcube and other satellites in low Earth orbit.

Possible introduction / Background and other topics in national curriculum:

Satellite definition. Object orbiting a much larger object.

Mass / Gravity / concept of orbit predicted by Isacc Newton in 1623. Newton's drawing of cannon on mountain top.

Describe the forces acting on a projectile during flight
Differentiate between artificial and natural satellites.

History: Sputnik 1957 / Cold war – FUNcube was launched on an Intercontinental ballistic missile.

Satellite health: via telemetry / radio communication using radio waves (electromagnetic waves)

Environment of space: Vacuum / Energy transfer by radiation. Temperature is an effect of energy transfer.

Orbit types: low polar orbit satellites. (Earth observation). GEO - Broadcasting and telecommunications.
Personal futures:

Satellites / space as a career.
University courses in space engineering and careers in the space industry

Satellite telecommunications. Class exercise teaching notes.

Ex 1.

1) From graph: Time in eclipse = **33 minutes**
2) From graph. Time in Sunlight = **64 minutes**
3) Time to complete 1 orbit is 64+33 minutes = **97 minutes**
4) To calculate satellite velocity or speed (distance per unit time)

Find the distance travelled in one orbit by calculating the circumference. 2 x pi xradius.

radius of the satellites orbit. Radius of Earth + satellite altitude.
Radius = 6371 + 630 = **7001km**

Circumference = 2 x 3.142 x 7001 = **43,988km** travelled each orbit

Or 43,988km in 97 minutes

To convert to common units m/s km/hr or km/sec

43988 / 97 x 60 = 27,209 km/hr

Or 43988 / 97 / 60 = **7.56 km/ sec**

To put into perspective. The London Eye is about 16km from the school. – You can see it on a clear day from the 3rd floor. It takes about 30minutes to drive there…on a good day.
But, a satellite in orbit can cover the same distance in just 2 seconds.

Ex 2.

1) **Max temp 26 C Min temp -13C**
2) Graph A shows a range +26 – (-13) **= 39 degrees**
3) Typically (Feb) min +1C overnight to +9C Range 8 degrees
4) There are 9 peaks and troughs in the sunlit portion of the graph. When the side of the satellite with the metal bar faces the sun it gets hot. As it faces away from the sun it cools down. What is shown in the graph is the satellite slowly rotating. If you count the 1 minute samples **you can see it is rotating once every 8 minutes.**
   In the 3 weeks between graph A and B **its rotational rate has slowed down**.
5) Looking at the section of the graph around 18 minutes on the X axis. - The silver panel shows variations every 8 minutes of apx 8 degrees C. However the black panel has higher temperature changes in the same 8 min period – Typ 12 – 13 degrees.
   This shows that the black metal sample is absorbing and radiating more energy from the sun than the silver sample. – The colour black absorbs all wavelengths of light whereas the silver panel reflects some wavelengths absorbing less energy.
   Finally, the graph shows the red and green waveforms have the peaks at the same time. This shows the two metal samples are mounted onto the same side panel of the satellite.

Ex 3.

1) Power generated sunlight. P = V x I
   From graph E. V= 8.28 From graph D Current = 320mA **P = 2.65 Watts**

2) Power used in sunlight P = V x I
   From graph E. V = 8.28 From graph D Current = 220mA **P = 1.82 Watts**

3) Excess power generated is 2.65 – 1.82 = **0.83 Watts**
   This excess power is used to recharge the battery ready for the next eclipse.

4) Find the eclipse period on graph D – solar panel current = 0.
   During eclipse, the total system current drops from 220mA to 140mA.
   The satellite senses when it is in eclipse and reduces the output power from its transmitter. This uses less energy from the battery giving a longer life.

5) Graph E shows the battery voltage dropping from 8.28V down to 8.11V during eclipse. When FUNcube re-enters sunlight at 09:48 the battery recharges. Each point on the graph is one minute. Count the minutes on the graph. **Time to recharge = 9 minutes**

Extension task:

6) Total energy stored in battery (Joules) = Volts x Amps x Time in seconds
   = 8.2 x 1.8 x (60 x 60) **= 53,136 Joules**

7) Energy used in eclipse (Joules) = Volts x current x time in seconds
   = 8.2V x 0.14A x 33 x 60 = **2,273 Joules**

8) 2273 J / 53136 J x 100 % **Percentage discharge = 4.7 %**
   and from the graph. **Estimated Lifespan = 5 years**