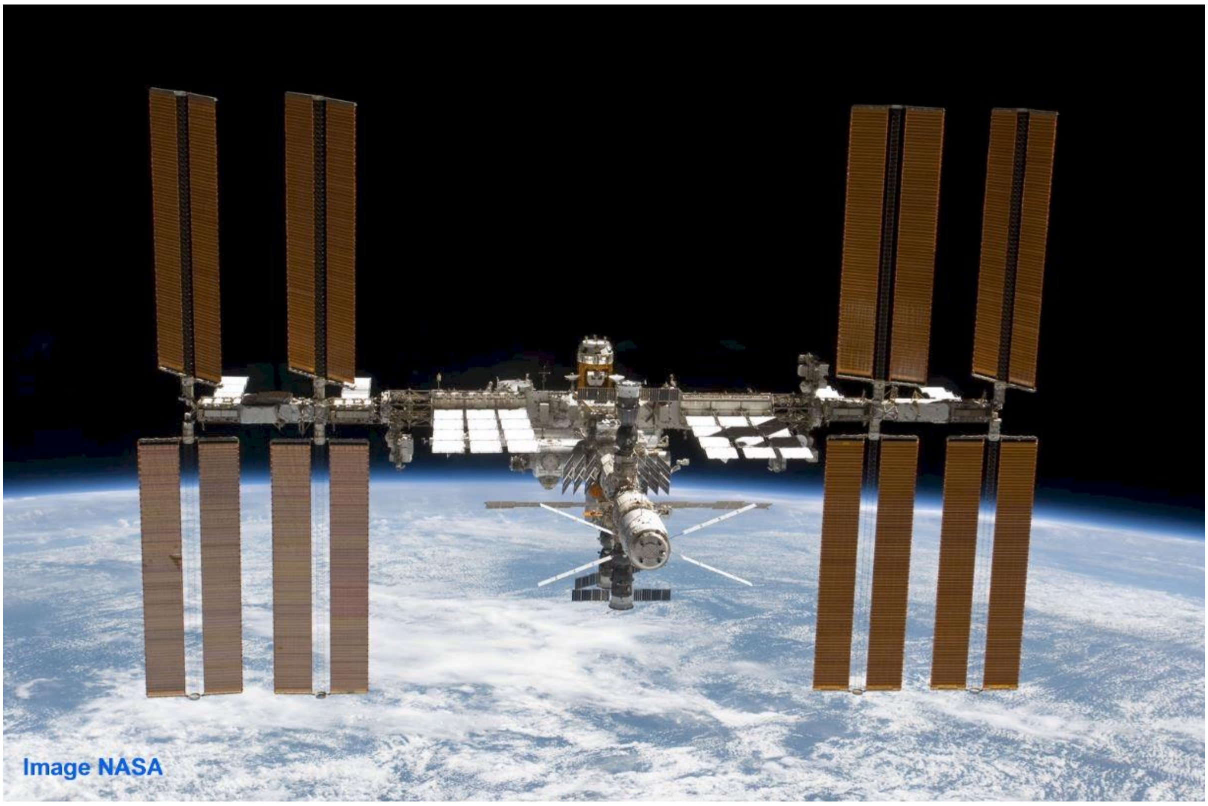
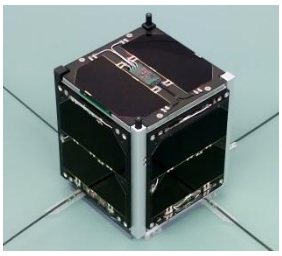
Satellite communications and the environment of space



The first artificial satellite was launched in 1957.
Now, satellites explore the solar system, search for planets orbiting distant stars and chase comets. But they also bring us services like Sky TV, satellite navigation for our cars and pictures to help forecast the weather.

Data from satellites is sent back to Earth by electromagnetic waves. – Radio waves, microwaves or even lasers.

These three exercises use data from the FUNcube satellite to investigate how satellites work and the environmental conditions experienced by a satellite in orbit.



Exercise 1

Your task is to use the data sent by FUNcube to calculate the velocity of the satellite in orbit.

Background

As the FUNcube satellite orbits the Earth, it travels over the poles passing from sunlight into darkness (Eclipse).

While the satellite is in illuminated by the Sun, it produces energy from its solar panels, but in eclipse the power drops to zero and the satellite uses power from its batteries.

Method

The graphs contain data taken once a minute for 104 minutes. Use the data to find:

1) The number of minutes in sunlight

2) The number of minutes in eclipse

3) The number of minutes it takes to complete one orbit

Calculating velocity

Velocity is expressed as distance per unit time. e.g. Miles per hour or metres per second.

You now know the time in minutes to complete one orbit. If you can find the distance travelled in that time you can calculate velocity.

The satellite's orbit is circular 630km above the surface of the Earth.

The radius of our planet is 6371km.

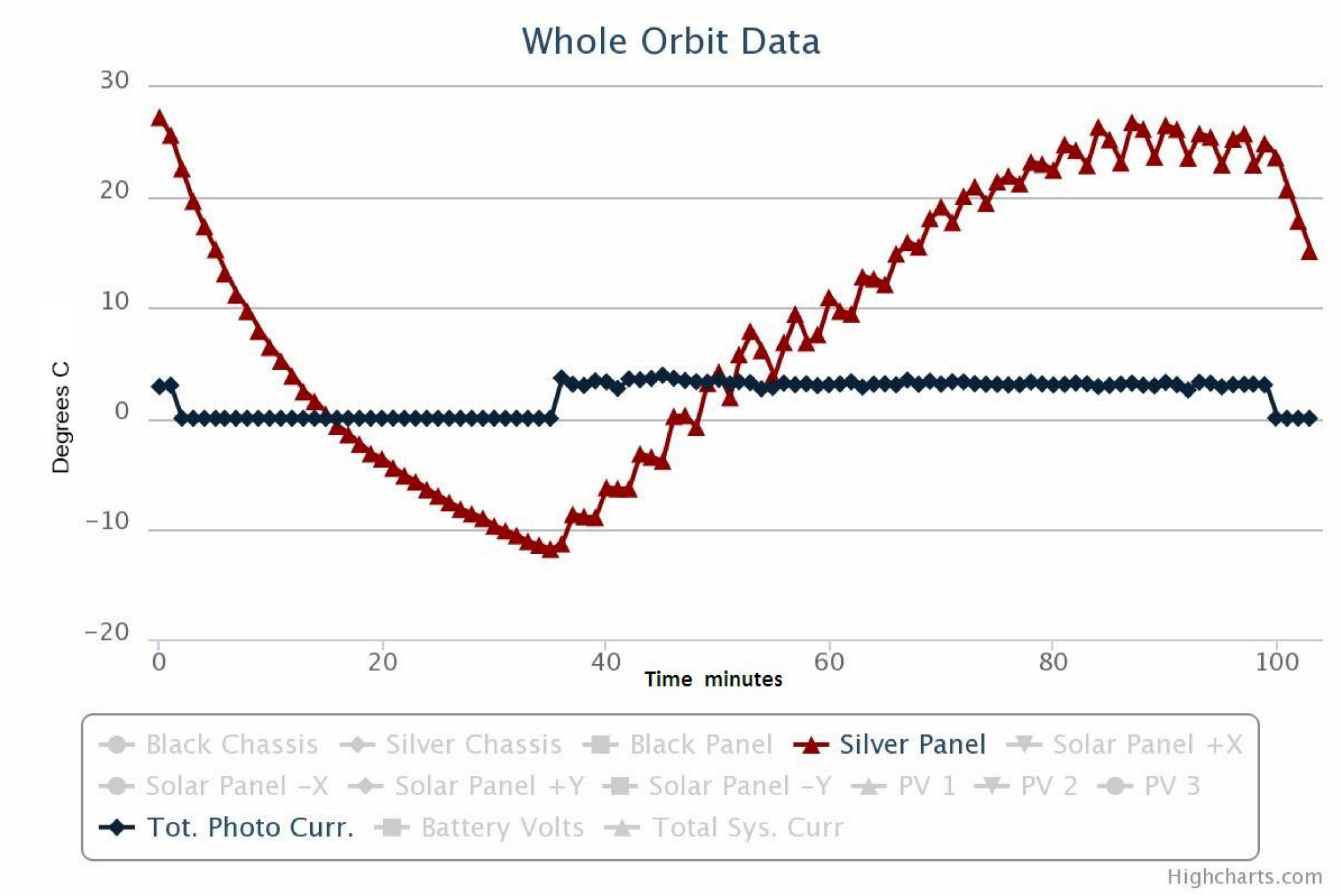
What is the formula used to find the circumference of a circle? Use the formula to find:

4) The circumference of the orbit in km.

= km

5) The velocity of FUNcube in orbit.

= (units?)


Whole Orbit Data
30
20
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Degrees C
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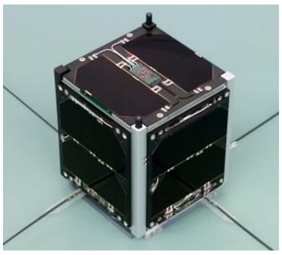
20
40
60
80
100
Time minutes
Black Chassis
Silver Chassis
Black Panel
Silver Panel
Solar Panel +X
Solar Panel −X
Solar Panel +Y
Solar Panel −Y
PV 1
PV 2
PV 3
Tot. Photo Curr.
Battery Volts
Total Sys. Curr
Highcharts.com



Exercise 2

Your task is to use the data sent by the FUNcube satellite to examine the environment of space and compare it to conditions on Earth.

Background
The FUNcube satellite orbits the Earth at an average altitude of 630km. At this height it is above the atmosphere, in the vacuum of space. With no air around it, heat energy cannot be transferred by conduction and convection; instead heat energy is gained and lost by radiation.

Data provided
The graphs contain data sampled once a minute for 104 minutes.

Graph A was recorded on 1st January and shows the temperature of a chrome plated bar of aluminium mounted on the outside of the satellite. (Silver panel)
Graph B was recorded on 22nd January – 3 weeks later and again shows the temperature of the silver panel.
Graph C was also recorded on 22nd January and shows the temperatures of the chrome plated metal bar and one that is an identical size and mass but is coloured matt black.

Questions

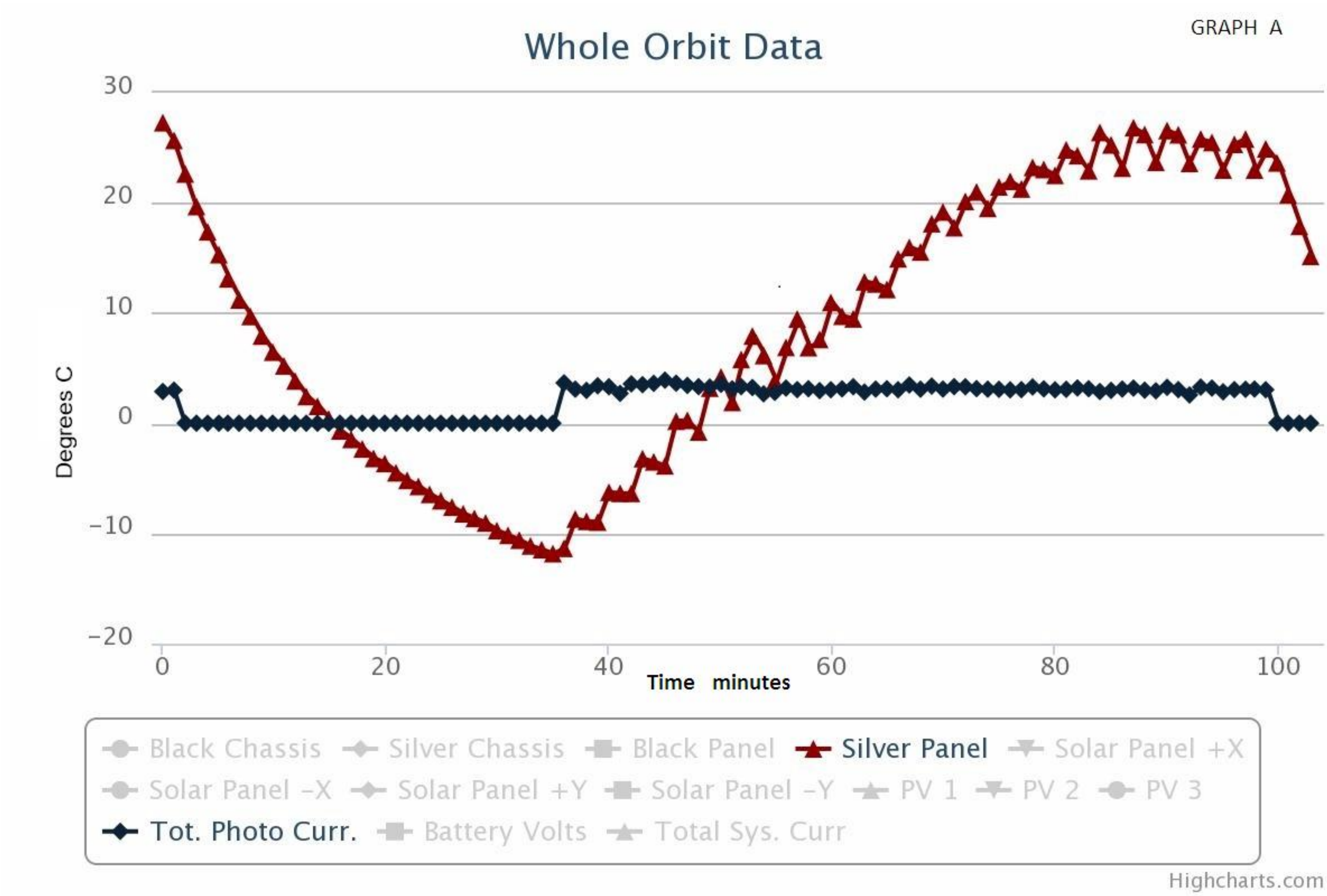
1) From graph A, find the maximum and minimum temperatures of the chrome plated aluminium bar.

2) What is the temperature range? (max-min)

3) How does this range compare to temperatures during a 24hr period here on Earth? e.g. What was the temperature midday yesterday and at midnight?

4) Using Graph B, recorded 3 weeks later. Look at the temperature of the chrome plated metal bar while in sunlight. The shape of the graph is very different. Can you suggest what has happened to the FUNcube satellite to cause this?

5) Using Graph C, what differences can you see in the temperatures of the silver and black metal bars when in sunlight? What does this suggest about materials with silver and black surface finishes?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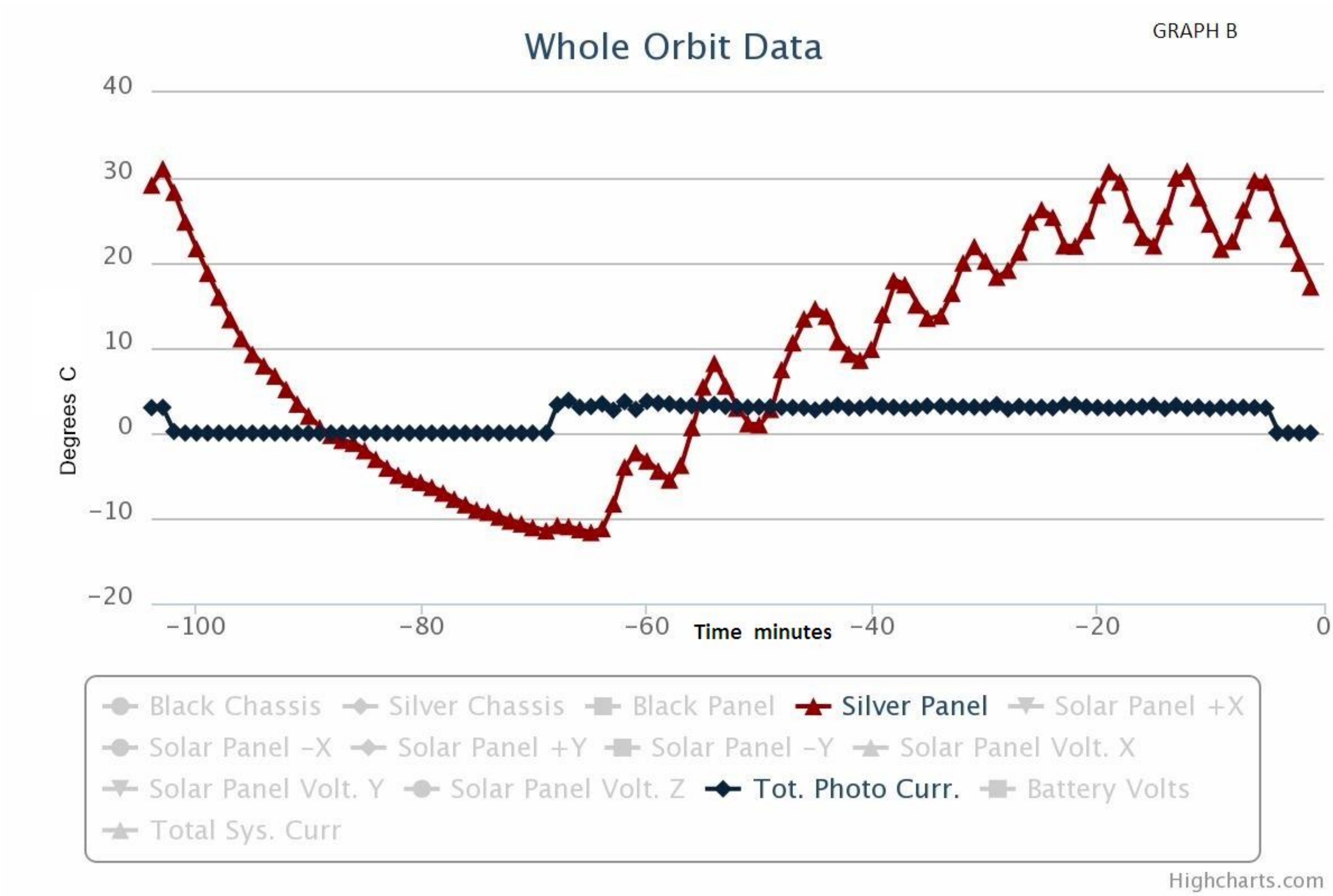
GRAPH B
Whole Orbit Data
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0
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Degrees C
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−60
Time minutes
−40
−20
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Black Chassis
Silver Chassis
Black Panel
Silver Panel
Solar Panel +X
Solar Panel −X
Solar Panel +Y
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Solar Panel Volt. Y
Solar Panel Volt. Z
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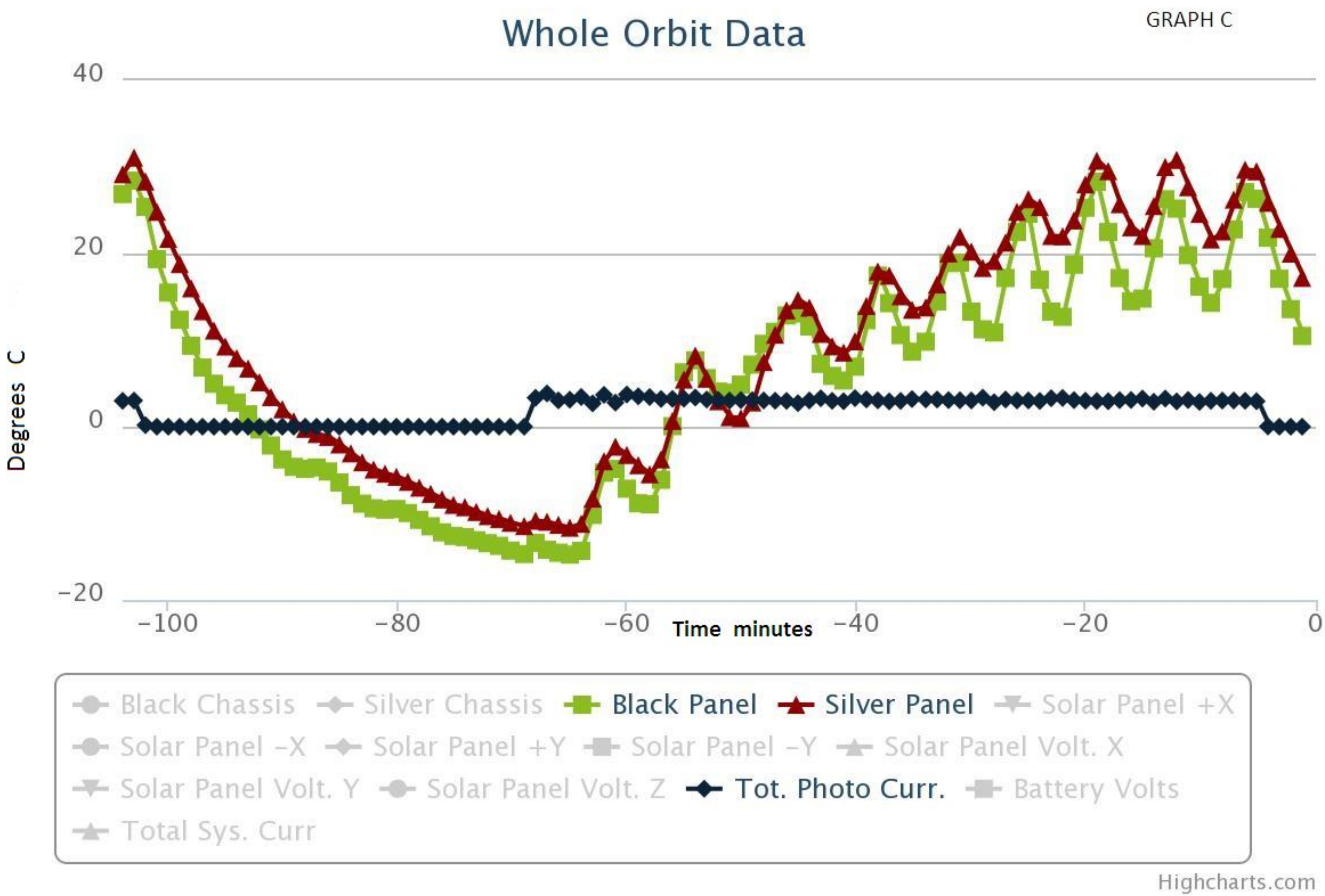

Whole Orbit Data
GRAPH C
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Degrees C
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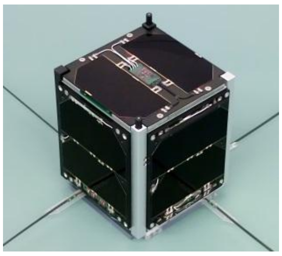


Exercise 3

Investigating FUNcube's Electrical Power System.

Great care is taken with the way the satellite generates and uses power. Like many laptop computers, FUNcube uses a Lithium ion battery to store energy. This battery must be carefully managed to ensure it has maximum life. Unlike a laptop, you can't replace a battery in space, so when the battery fails, the satellite fails too.

Your task is to investigate how much power the satellite generates from the solar panels and how it uses that energy to operate its computer, transmitter, other electrical systems and how it manages the health of the battery. Finally, you are going to estimate the lifespan of FUNcube by predicting when its battery will fail.

Remember, when FUNcube is orbiting the Earth in sunlight, it uses energy from solar panels. However, when in eclipse, it can only use the energy stored in its Lithium ion battery.

Method

The two graphs D and E contain whole orbit data received from the satellite's telemetry.
The graphs show detail of :

Battery voltage. – shown in mV
Total current produced by the solar panels and the total current used by the satellite. (mA)

Using the formula *Power (Watts) = Current x Voltage*

Find:

1) The average power **generated** by the solar panels when the satellite is in sunlight.

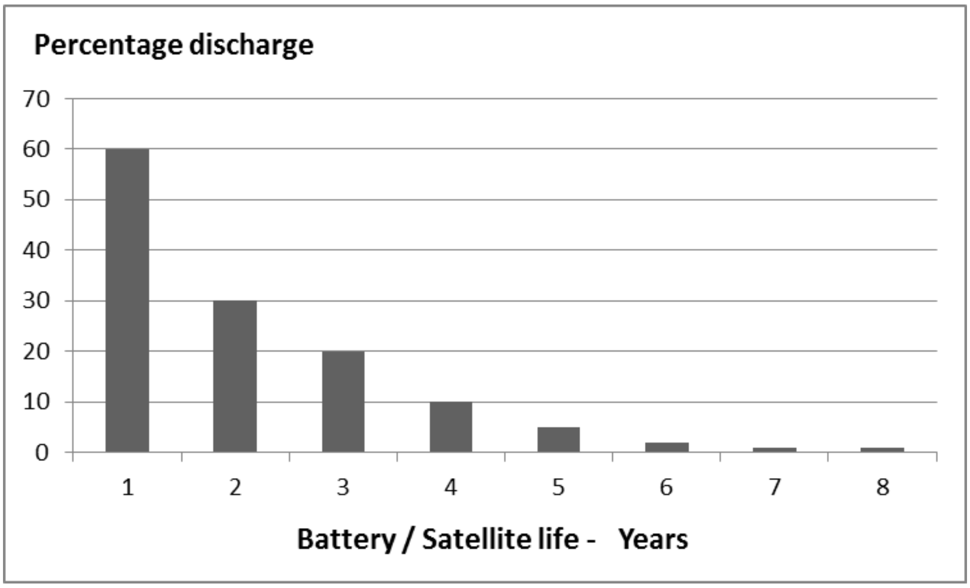
2) The average power **used** by the satellite in sunlight.

3) What is the difference between these two figures and can you suggest what that excess power is used for?

4) When the satellite is in eclipse, the power from the solar panels is zero. But what happens to the power used by the satellite during eclipse. Why do you think it does this?

5) Looking at graph E, how long does it take to recharge the battery after eclipse?

Extension: The life of the battery and the satellite can be estimated by calculating the percentage of the total energy used from the battery in each eclipse. The higher the percentage used, the shorter the lifespan of the battery.



The battery has a typical voltage of 7.8 Volts and a capacity of 1800mA/hr.

This means the battery can supply 7.8 Volts at 1.8 amps for 1 hour.

Energy (Joules) = voltage x current x time.

6) Using the formula, with current in amps and time in seconds, calculate the energy stored in a fully charged battery.

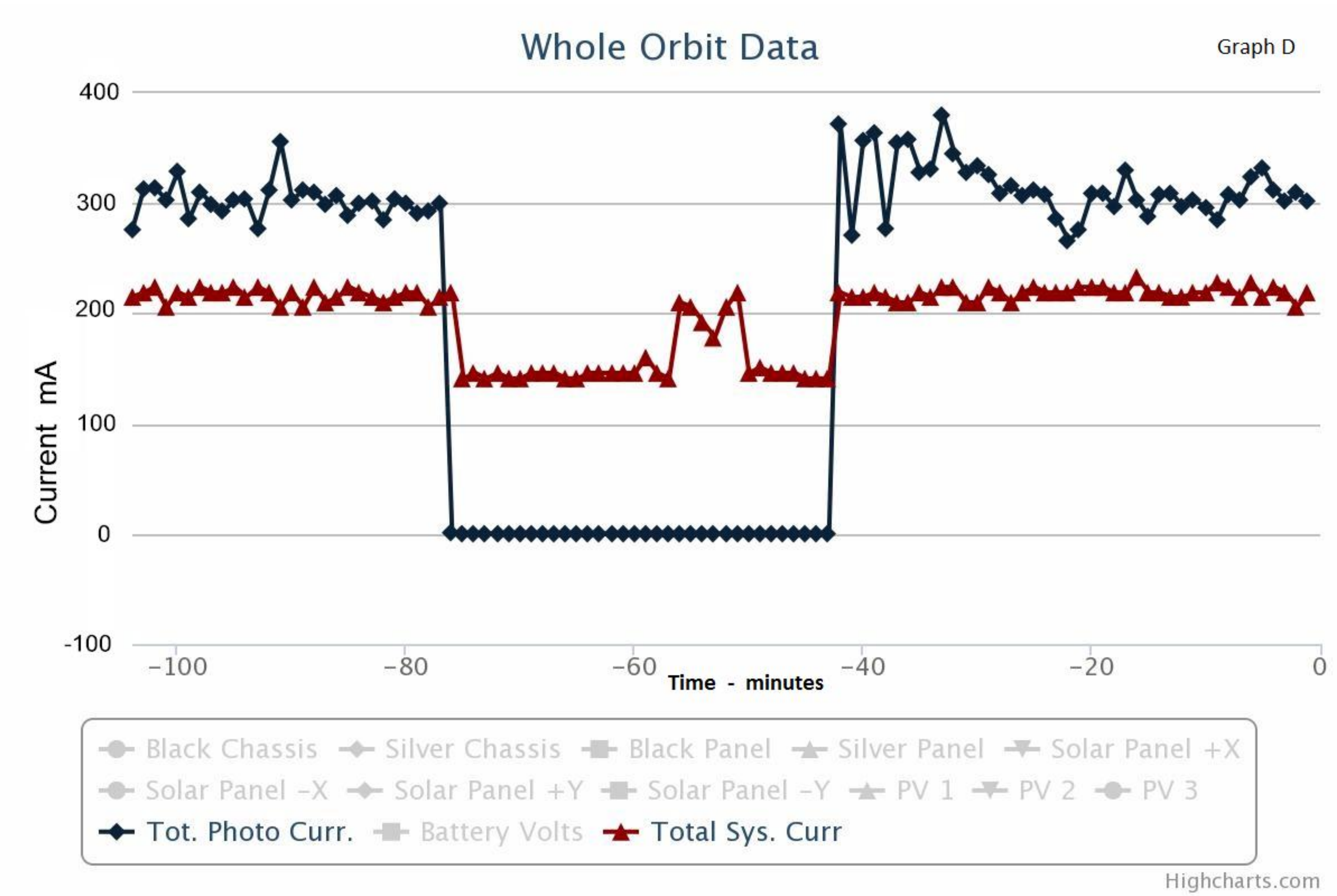
_____ Volts x _____ Amps x _______ seconds = ________ Joules

7) From the graphs find out how much energy is used in the 33 minutes of eclipse

_____ Volts x _____ Amps x _______ seconds = ________ Joules

Finally, calculate the percentage of the total battery energy used in eclipse and use the graph above to estimate the lifespan of the FUNcube satellite.

Percentage discharge = _______ % Estimated lifespan ___________ Years


Whole Orbit Data
Graph D
400
300
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-100
Current mA
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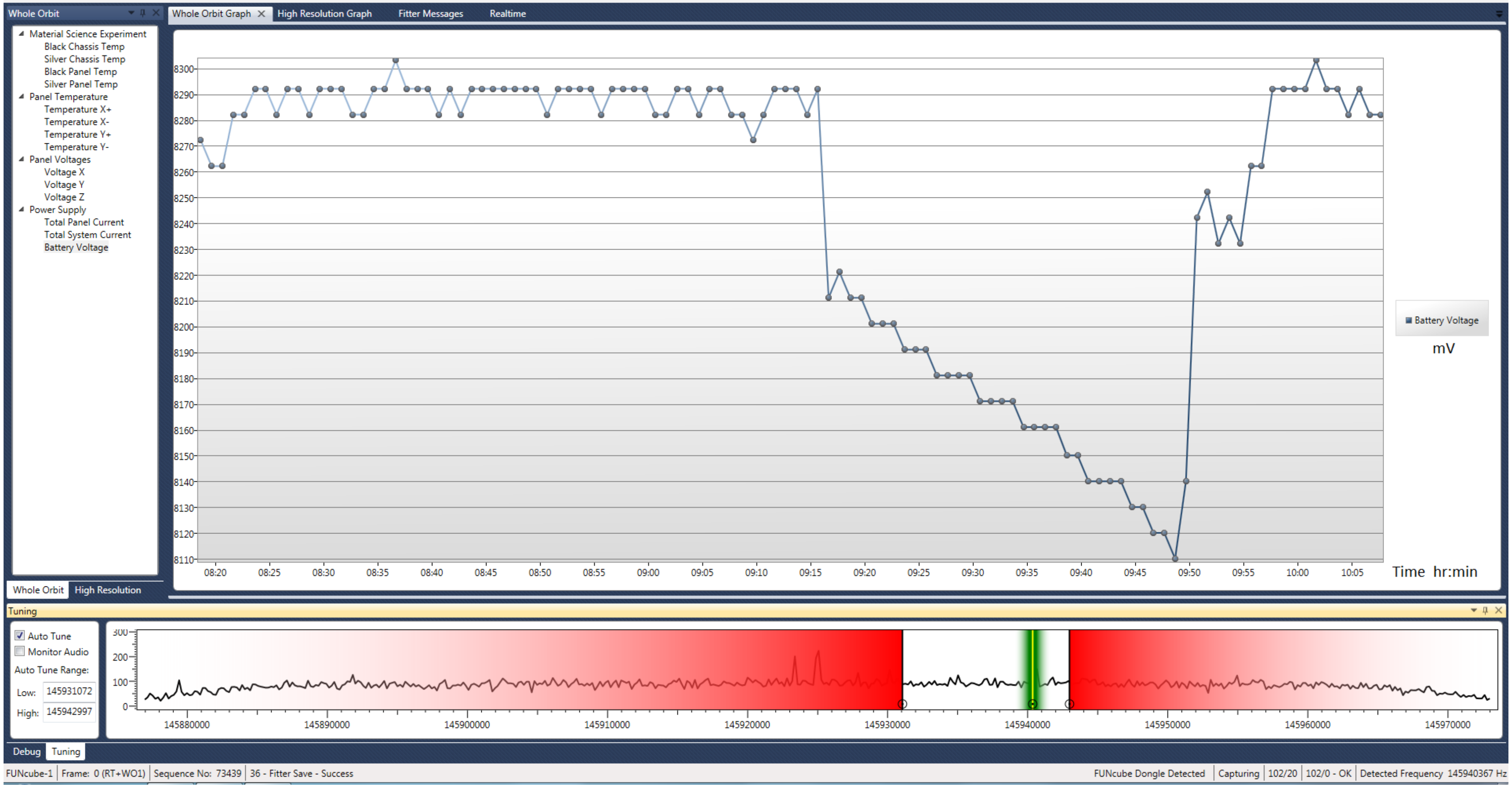
A screenshot from a computer receiving data from space. Graph E.



Range of communication

This map shows the position of the satellite over the Mediterranean Sea on 10th March at 9.15pm.
The circle is the "satellite footprint". – This shows the area visible from orbit. It also defines the maximum distance the satellite can send its data signals. The direction of travel is shown by the line heading North over Germany and then Norway.

The total distance across the footprint is over 5000km.
The electromagnetic waves (EM waves) from FUNcube's transmitter are low power, very similar to the power of a small torch. However, communication by EM waves is so effective, that the signals travel to all of the countries in the footprint within in a fraction of a second.

For more information, or to see live data from space, visit:

www.warehouse.funcube.org.uk www.funcube.org.uk