

A science class experience that is out of this world

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Summary

- Optimization Research Group
- Funcube project and reception of data (demo)
- Class activity ideas

Optimization Research Group

- 3 Computer Science faculty
- 9 Masters students
- 2 PhD students
- We involve several undergraduate students in research yearly
- (Junior) high school student visits?

Optimization Research Group

Research (resource management):

- Scientific computation (eg: weather prediction)
- Transportation, logistics (eg: courier industry)
- Facility location (eg: job shop scheduling)
- **Telecommunication** (eg: cellphone tower placement)

Objectives

- **You will know to set up a “ground station” to receive the Funcube-1 satellite transmission**
- You will see some examples of class activities

Funcube Project

(see BBC short video)

Funcube-1 (AO73)

- 1U cube sat (one unit): 10cm x 10cm x 10cm dimensions; 988 g mass
- built and financed by volunteers from AMSAT-UK and AMSAT-NL

The image shows a collage of three web pages related to the Funcube-1 satellite project. On the left is the AMSAT-UK website, featuring a navigation menu with items like 'About', 'Beginners', 'Colloquium', 'FAQ', 'FUNcube', 'Links', 'Membership', 'Satellites', 'Shop', 'Projects', and 'Media'. Below the menu is a section titled 'More ISS Slow Scan TV Activity' with a thumbnail for 'RS0ISS серия 1' (4/12) showing a space station and a man in a space helmet. In the center is the AMSAT-NL website, which has a header with the logo and text 'AMSAT-NL Radio Amateur Satellites'. The main content area states: 'FUNcube-1 was launched on November 21st, 07:10:11 UTC.' Below this is a link for 'Mission status page (new tab / window)'. A 'Placeholder for AMSAT-NL' section follows, explaining that the page is still in setup and directing users to 'funcube.org.uk'. At the bottom is a 'Welkom op de website van AMSAT-NL' section in Dutch, detailing the organization's goals and the satellite project. On the right is a 'Funcube-1 / AO-73' dashboard snippet showing technical details: 'Radio Communications Subsystem', '145.935 MHz BPSK Telemetry 30 or 300 mW', and 'Inverting SSB/CW transceiver'. It also includes social media icons for Facebook and Twitter.

Funcube-1 (AO73)

Launch from Yasny,
Russia, 21 Nov. 2013

SS-18 Intercontinental
ballistic missile (Dnepr)

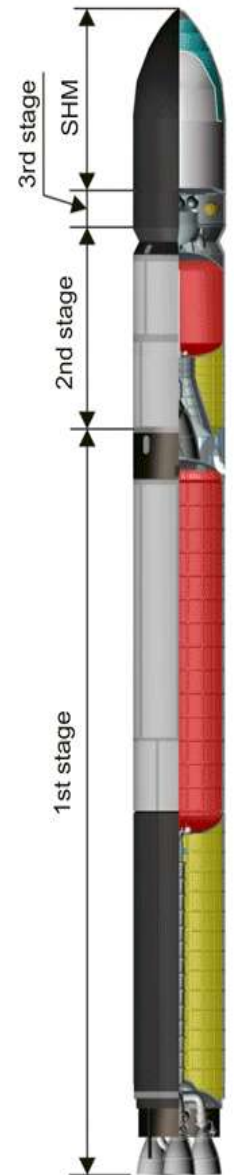
Primary payload DubaiSat-2

19 secondary micro and
nanosat payloads

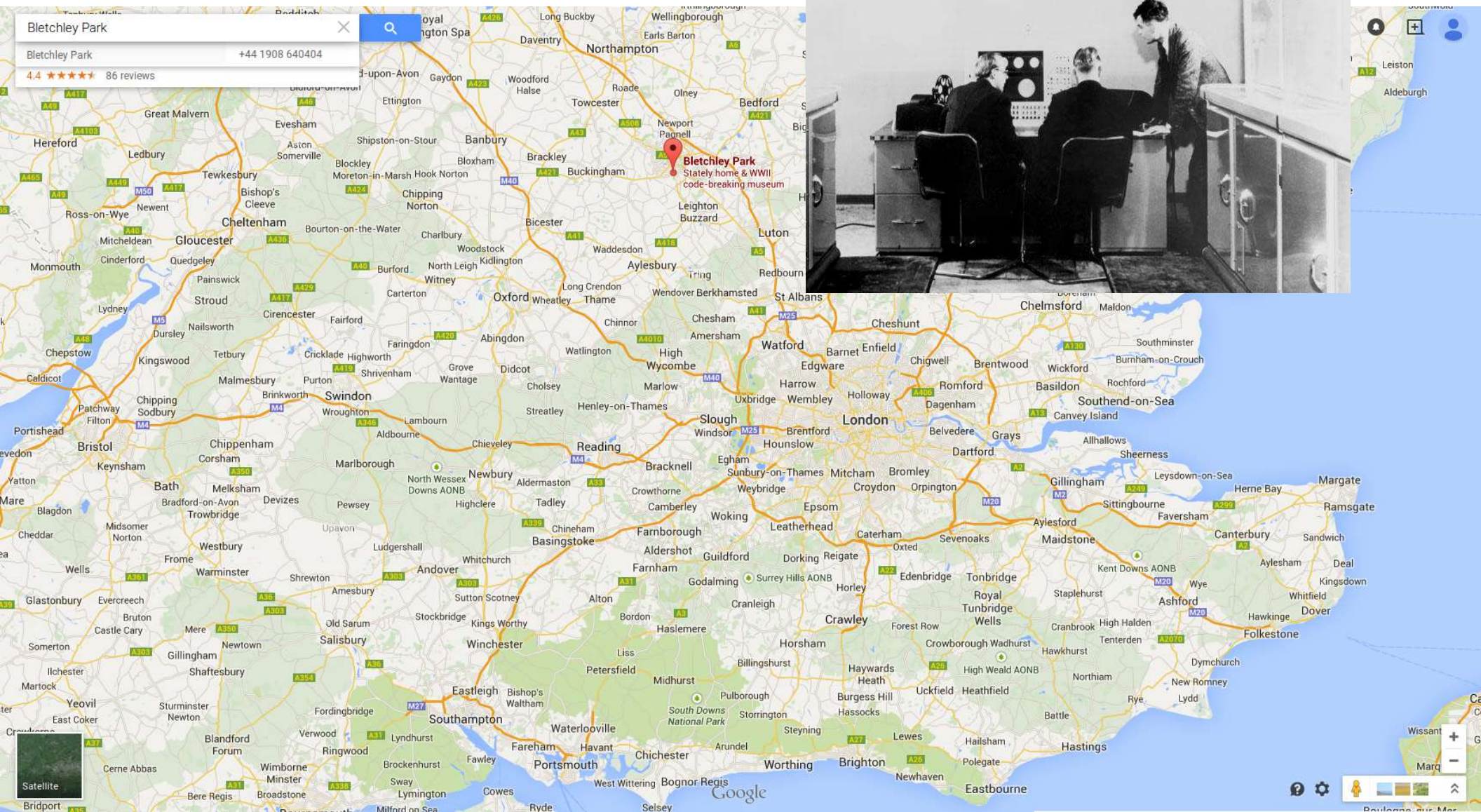
Launches from underground
silo.

Inclination 98.2 deg, 'near
circular' Sun synchronous
orbit

Approx altitude 600x685 km



Funcube-1 (AO73) monitoring station (Bletchley Park, UK)



Funcube-1 (AO73) monitoring station (Bletchley Park, UK)



Launch day



Funcube-1



PRIMARY MISSION

During the sunlit part of its orbit (65 mins), FUNcube-1 operates in EDUCATIONAL mode

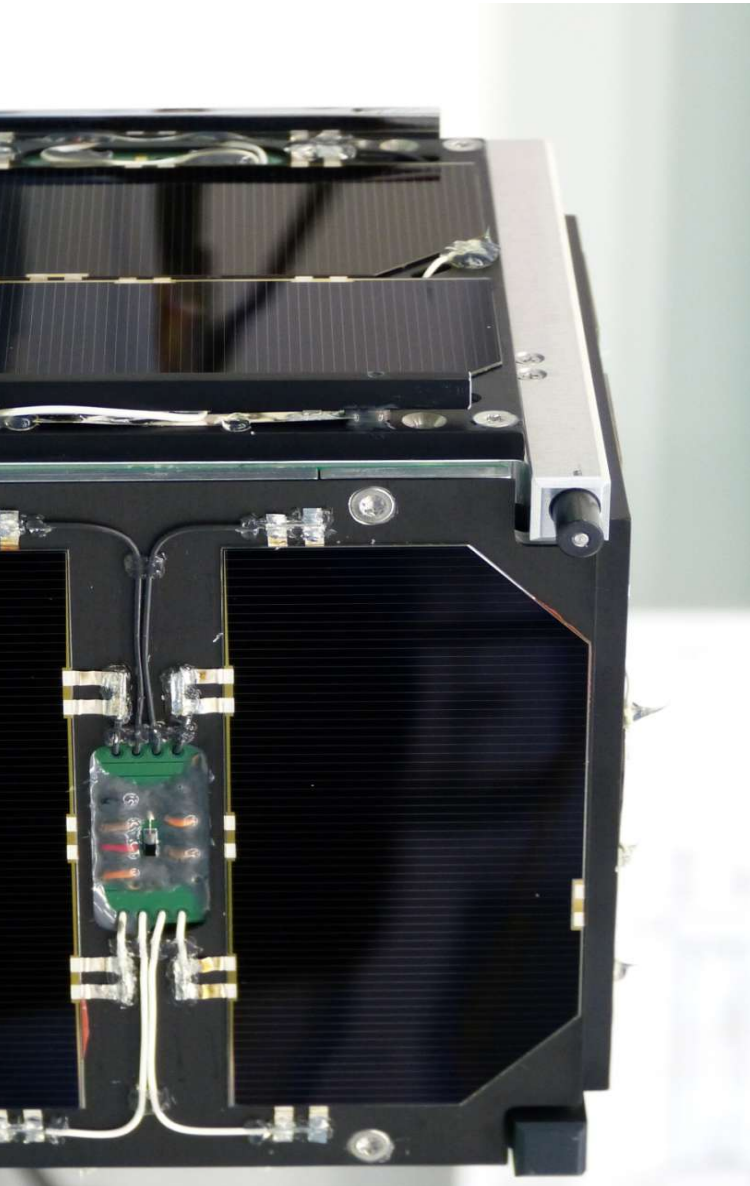
- High power (300mW) telemetry
- Generally 2/3 passes every morning wherever you are on earth

SECONDARY MISSION

During eclipse (32mins), FUNcube-1 operates in TRANSPONDER mode.

- Used by radio amateurs to communicate over long distances via the satellite.
- Telemetry still transmitted but at low power (30mW)
- Generally 2/3 passes every evening wherever you are on earth

Funcube-1 (AO73)

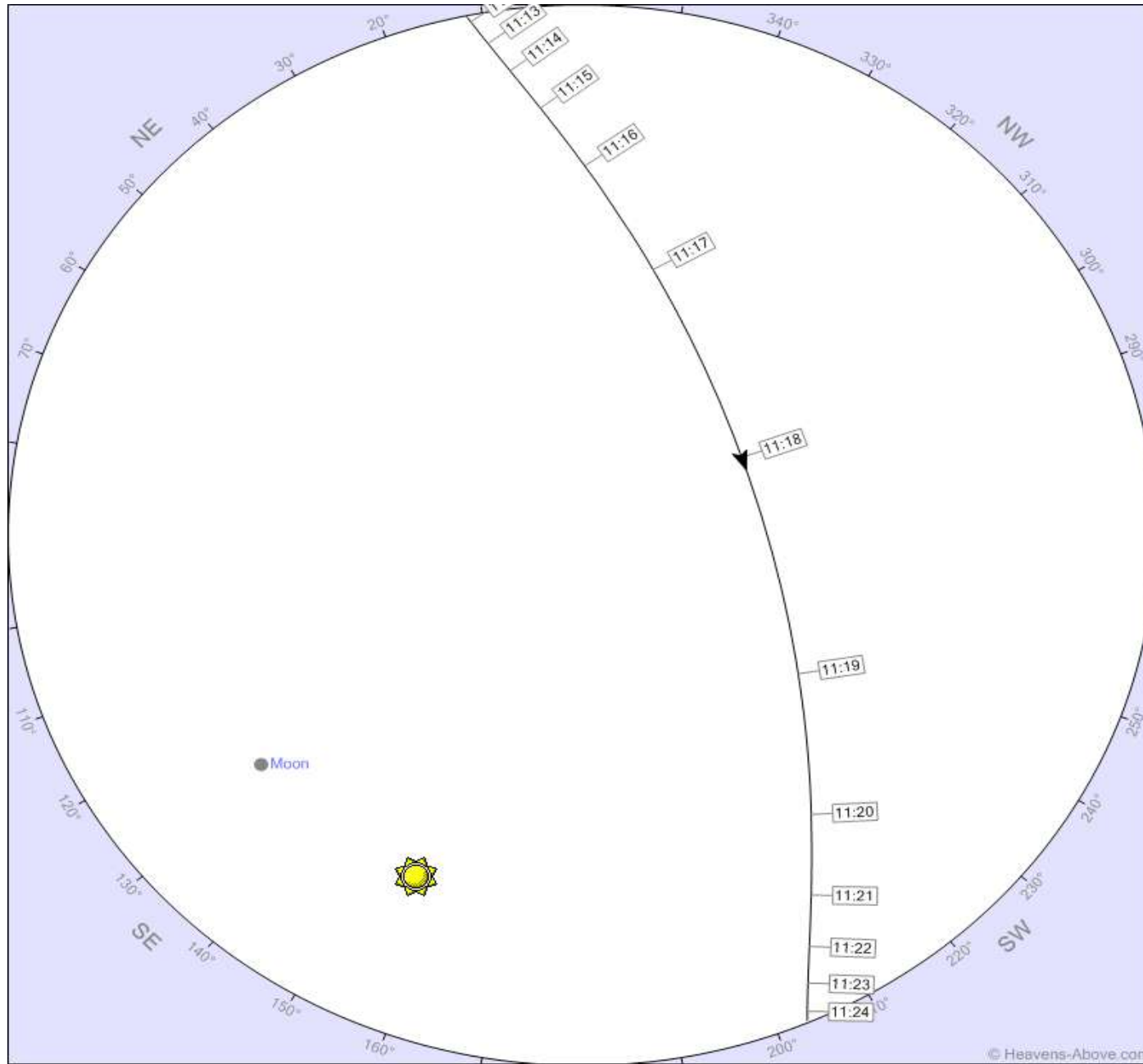


- Six surfaces
 - all with solar panels
 - one with black and chrome metal strips
- Data transmitted
 - voltages from solar panels
 - temperatures from metal strips and four metal bars (satellite body)
 - Battery voltage
 - Amperages

Receiving Funcube-1 signals (demo)

- laptop + free software (Funcube Dashboard)
- receiver (Funcube Dongle Pro)
- home made yagi antenna
- line transformer (optional) + long cable + SMA male/coax female adaptor
- satellite schedule

Satellite schedule



Demo (11:13 - 11:24, Feb 20 2015)

Setting up the ground-station

- All documentation I used for setup + these slides + classroom activities available at

http://www.cs.uleth.ca/~benkoczi/wordpress?page_id=474

Setting up the ground-station

- Antenna:
 - Yagi-Uda type (in the demo). Other antennas to consider: turnstile, quadrifilar helix



Setting up the ground-station

- Yagi Uda antenna:
 - very simple and cheap (< 10 CAD): wooden boom, some gauge 10 copper wire, drill, glue, measuring tape; time approx 30-40 min.
 - schematics by Kent Britain, *Cheap Yagi antennas for VHF/UHF*.
 - satellite frequency: 145.935 MHz
 - antenna peak frequency: 144.2 MHz (but still works!)

Setting up the ground-station

- Antenna construction:



Setting up the ground-station

- Coaxial cable:
 - impedance 50 ohm: tuned for amateur radio equipment; best but expensive and rare
 - impedance 75 ohm: found everywhere, but tuned for cable TV equipment. It works as long as the cable is not too long
 - I use a transformer from another antenna (long cable)

Setting up the ground-station

- Dongle:
 - Available at <http://www.funcubedongle.com/>
 - Cost approx 124 GBP + shipping + import tax (5%)



Setting up the ground-station

- Dongle:
 - requires SMA female for antenna
 - I use a cheap SMA-male to coaxial (F) female adaptor (2.99 + 4.99 shipping from amazon.ca)



Setting up the ground-station

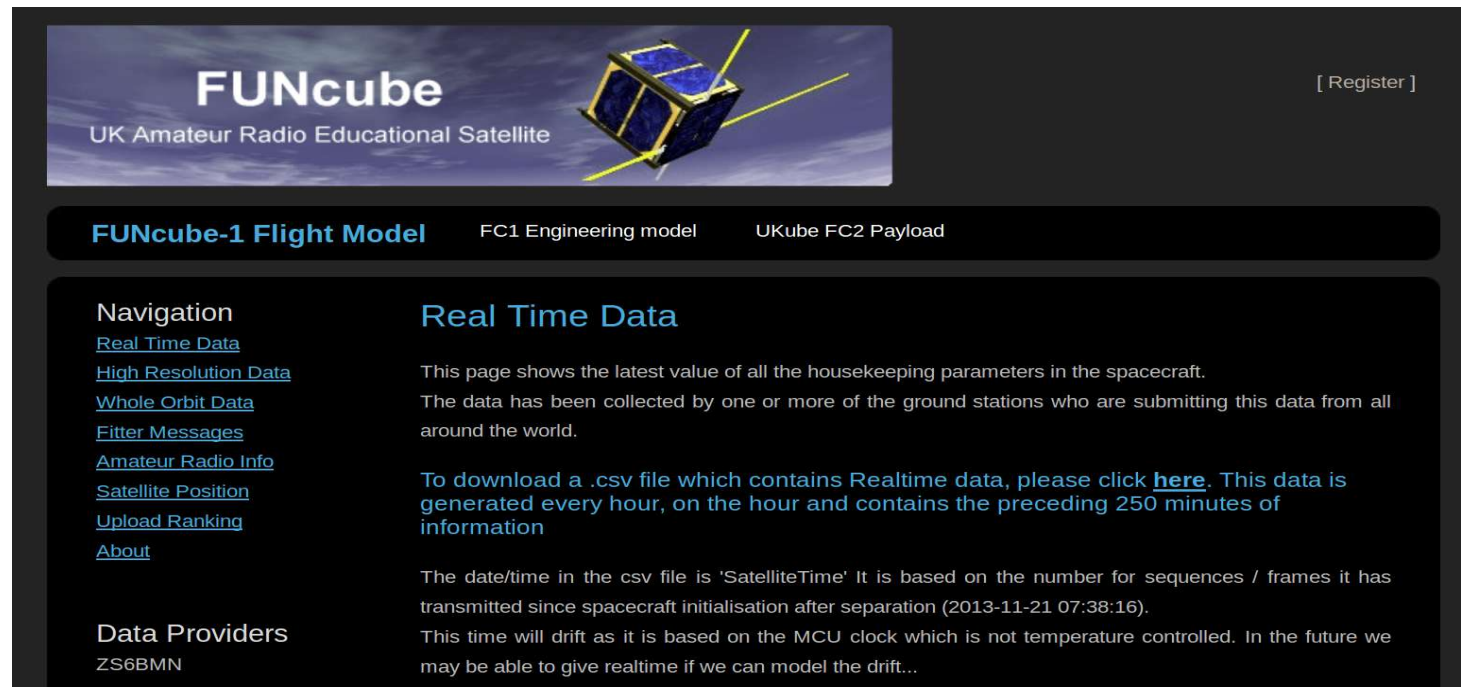
- Software

- Funcube dashboard, Windows, free.
- download from

<http://funcube.org.uk/working-documents/funcube-telemetry-dashboard/>

Setting up the ground-station

- Database:
 - the dashboard has the option to upload the captured data to a central repository.
 - registration required (free) at <http://warehouse.funcube.org.uk/>



The screenshot shows the FUNcube website dashboard. At the top, there is a header with the FUNcube logo and the text "UK Amateur Radio Educational Satellite" next to an image of a satellite. A "[Register]" link is visible in the top right corner. Below the header, there are navigation links for "FUNcube-1 Flight Model", "FC1 Engineering model", and "UKube FC2 Payload". The main content area is divided into two columns. The left column contains a "Navigation" section with links for "Real Time Data", "High Resolution Data", "Whole Orbit Data", "Fitter Messages", "Amateur Radio Info", "Satellite Position", "Upload Ranking", and "About". The right column contains a "Real Time Data" section with a paragraph explaining that the page shows the latest values of housekeeping parameters and that data is collected from ground stations. It includes a link to download a .csv file and a note that the data is generated every hour. Below this, there is a paragraph explaining that the date/time in the csv file is 'SatelliteTime' based on the number of sequences/frames transmitted since spacecraft initialisation after separation (2013-11-21 07:38:16). At the bottom of the right column, there is a "Data Providers" section with the name "ZS6BMN".

Setting up the ground-station

- Database (c'ed):
 - registration provides an authorization code to be entered in the Dashboard
 - csv data files are available for download; students can use this data for various calculations (see classroom activities).

Preparing the reception


- Satellite schedule:
 - www.heavens-above.com (demo)
 - Orbitron (Windows program), free:
<http://www.stoff.pl/>

Satellite tracking • HAM radio • ISS • Visual observing • Tracking software • Iridium flares • Satellite tracking at home

Orbitron - Satellite Tracking System

sebastian stoff
h·o·m·e·p·a·g·e

home downloads cardware forum guestbook chat links about me my apps email



version **3.71** - 2005.09.08 - Win 9x/Me/2k/XP/2k3/Vista
(C) 2001-2005 by Sebastian Stoff

Orbitron is Cardware!
Click here to see postcards list.
What is satellite tracking?



[More languages]
[For translators]


News **RSS**

2007.11.07: New Orbitron forum

2007.07.17: Dear Users...

2005.11.05: Web chat starts!

[More news]



NO SPYWARE
NO ADWARE
NO VIRUSES

SOFTPEDIA
certified by www.softpedia.com

Downloads

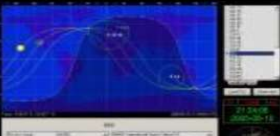
Orbitron 3.71, size: 2 MB
Site 1 - USA - Read me
Site 2 - Germany
Site 3 - Poland

[More downloads - TLE, Maps...]

LATEST POSTCARDS

Roland, F6HGD from Dole (France) • Leonardo, PY2GLO from Sao Paulo (Brazil) • Robert, KI4BKE from Holly Springs (NC, USA) • Rene, WA6MJE from Westlake Village (CA, USA) • [More]

Screenshots



Details

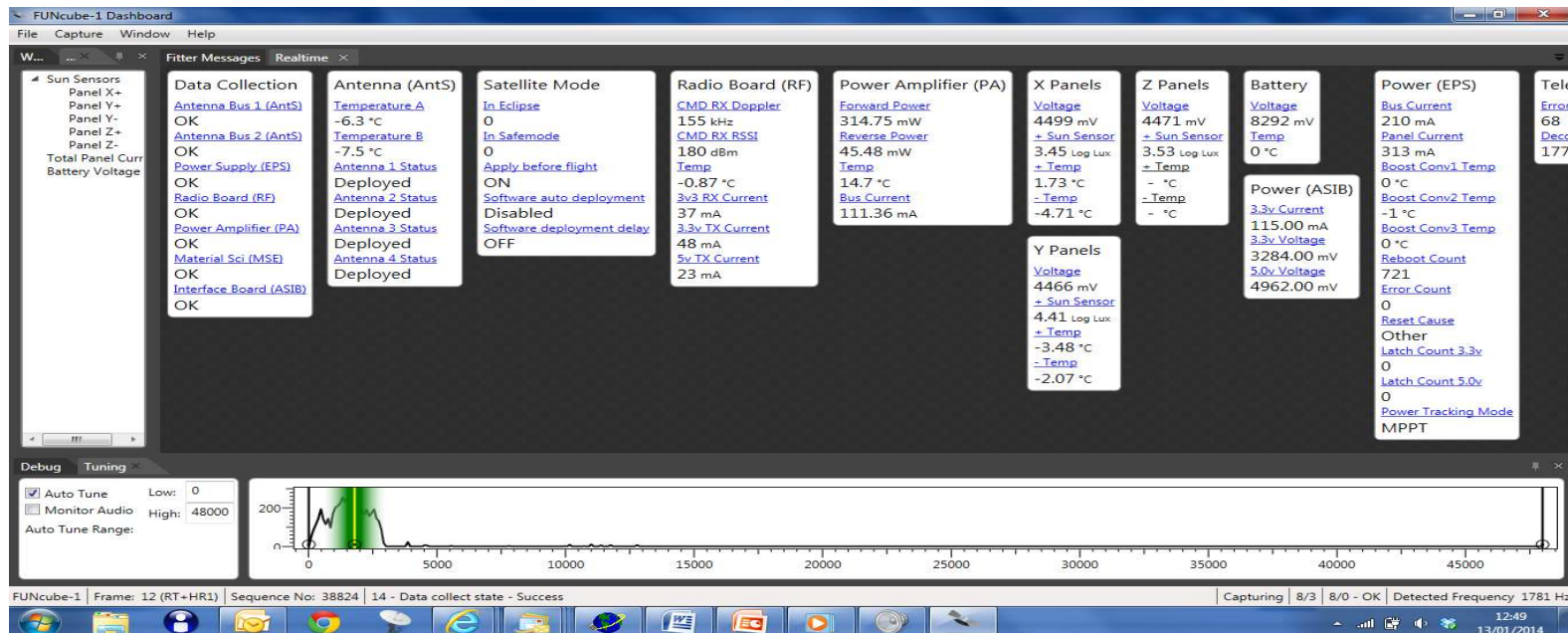
Orbitron is a satellite tracking system for radio amateur and observing purposes. It's also used by weather professionals, satellite communication users, astronomers, UFO hobbyist and even astrologers. Application shows the positions of satellites at any given moment (in real or simulated time). It's FREE (Cardware) and it's probably one of the easiest and most powerful satellite trackers, according to opinions of thousands of users from all over the world.

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Preparing the reception

- Dashboard:
 - “capture from dongle” (demoed)
 - configure database info
 - request custom fitter messages by sending a message to operations@funcube.org.uk



Understanding the satellite

- Telemetry:
 - 1200 BPS BPSK with forward error correction with 54 Telemetry channels
 - Telemetry is sent in 24 x 5 second frames over 2 minute period
 - “Real time” every 5 secs, “Whole orbit” data sampled every 60 secs stored for 104 minutes and “High Res” data sampled at 1 second intervals for 60 seconds
 - Text messages- 9 x 200 character greetings messages & 27 additional messages stored in memory
 - Very distinctive sound to enable easy identification
 - 4.3 seconds of data + 0.7 seconds of BPSK mark tone

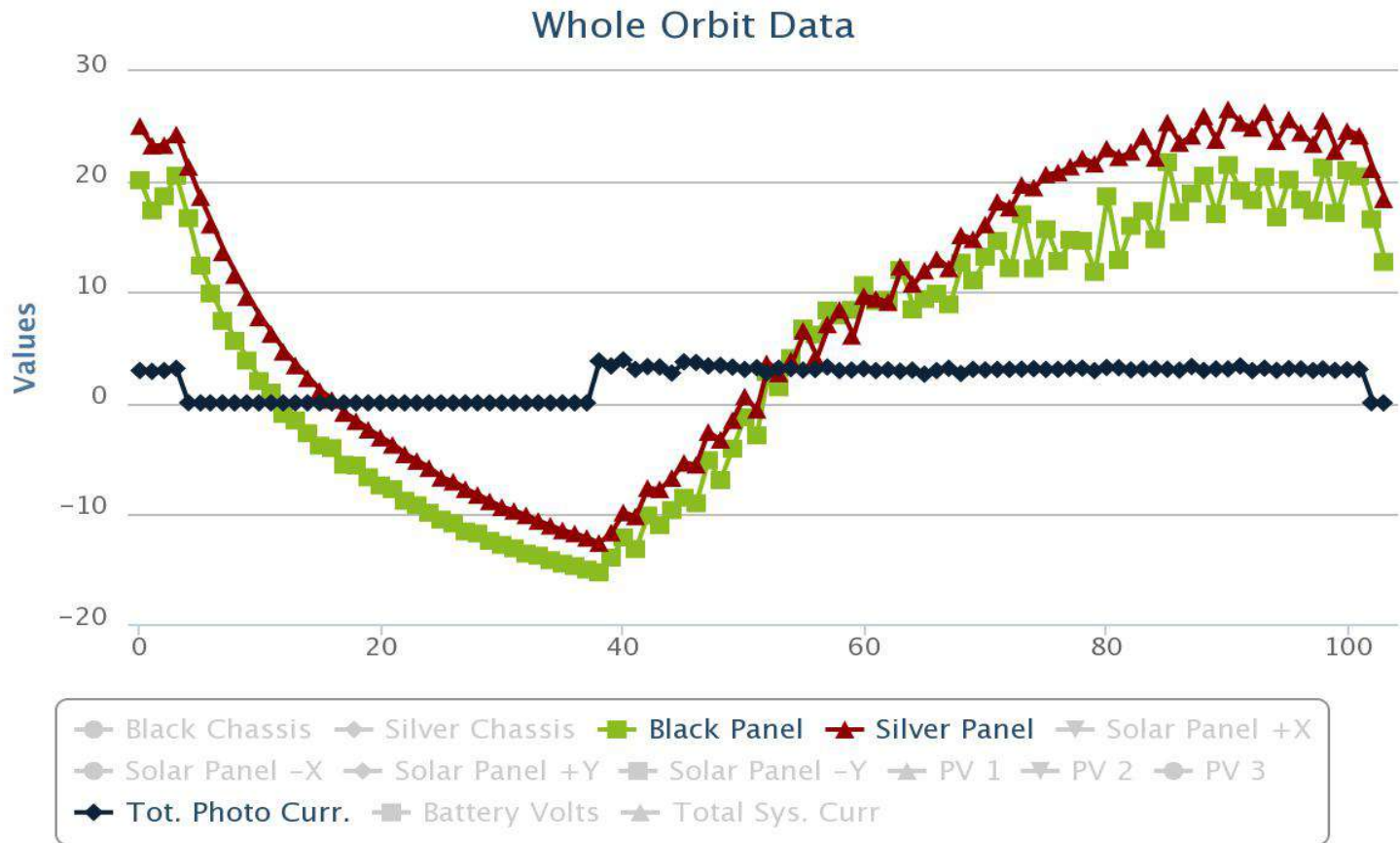
Classroom activities

Alberta program of studies

- Units:
 - gr. 7 C: heat and temperature (energy exchange by radiation)
 - gr. 8 C: light and optical systems (solar panels)
 - gr. 8 D: mechanical systems (antenna deployment, velocity)
 - gr. 9 D: electrical principles and technology (solar panels, satellite battery)
 - gr. 9 E: space exploration (orbits, telecommunication)

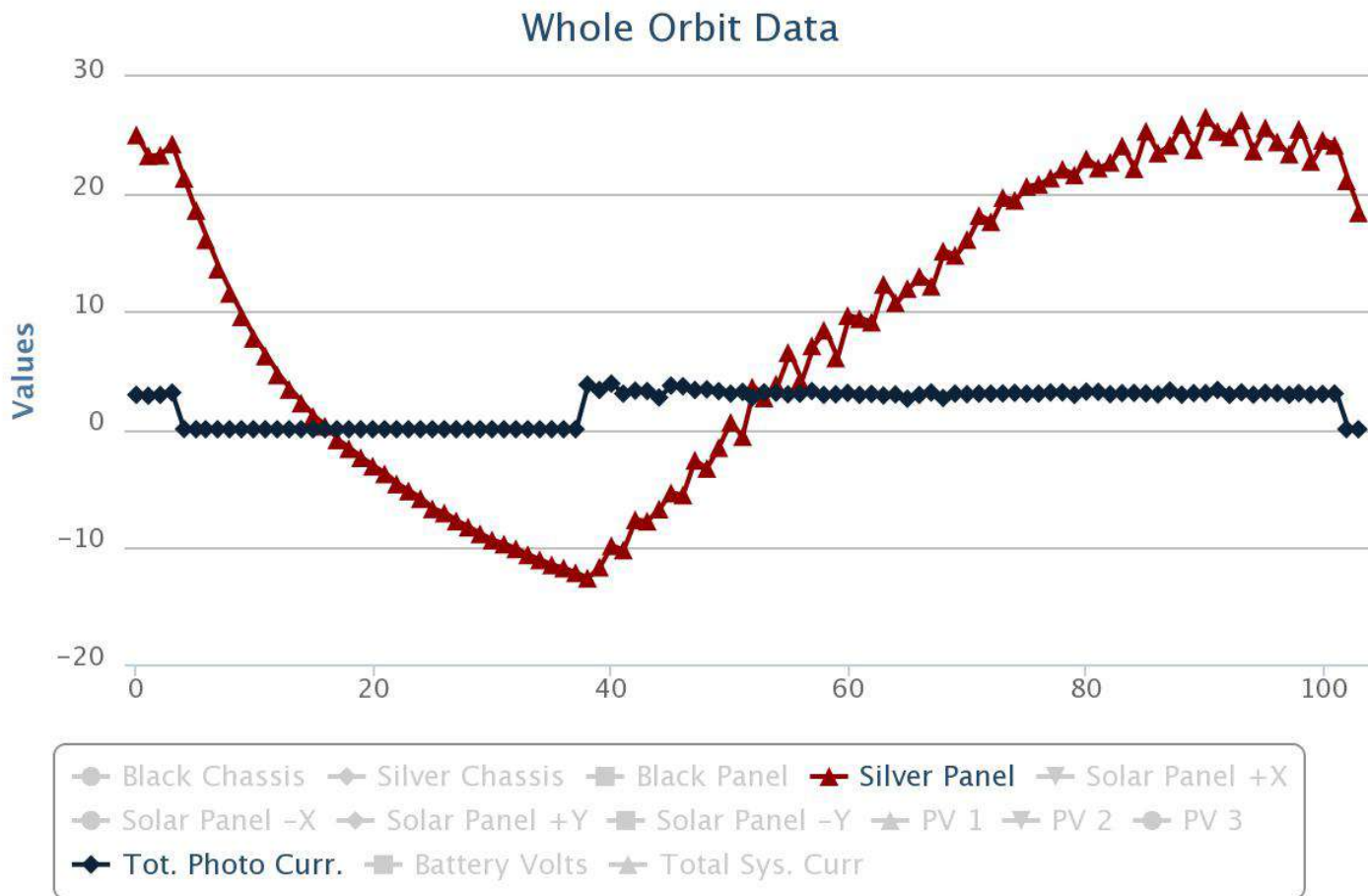
Examples

- Conduction, radiation, heat capacity



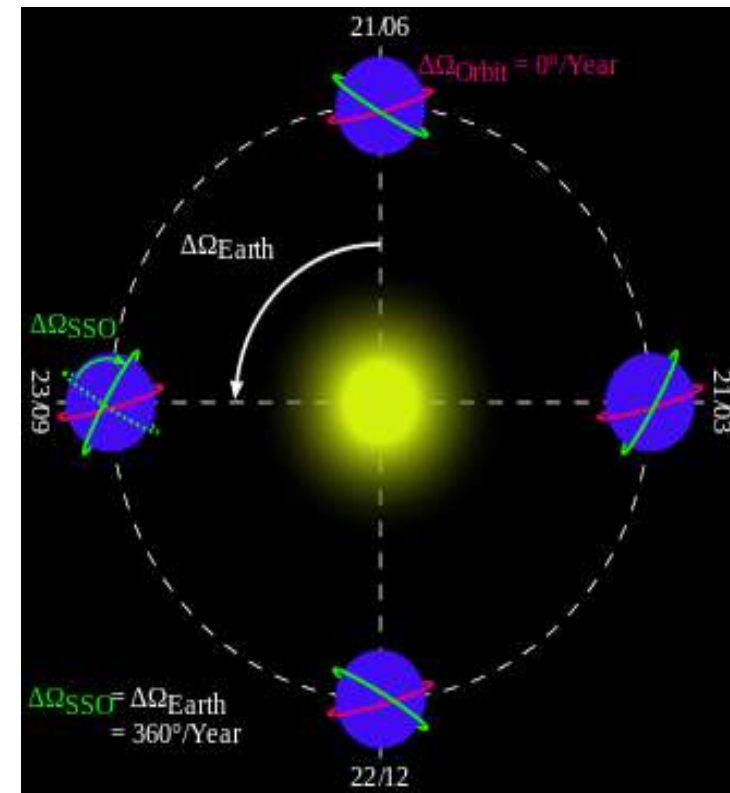
Examples

- Velocity (eclipse time, orbital period, altitude)



Examples

- Orbits
 - What are orbits?
 - Kinds: geosynchronous, sun synchronous, low earth orbit; why do communication satellites use low earth orbits?



Examples

- Light, electro-magnetic radiation (EMR)
 - How is light related to EMR?
 - What are the different uses (communication, medicine, astronomy, etc)?
 - What is analog/digital communication method?

Examples

- Alternative energy sources
 - Where does a satellite get its energy from?
 - How do you recharge batteries in space?
 - How do you monitor the energy produced by a solar cell in space?

Sample activity

- Investigate the environment in space and how it is different from that on Earth
 - Find max/min temperature of chrome plated AL bar
 - What is the range during a 2h period?
 - What is the typical temperature range on Earth during 2h period?

Sample activity

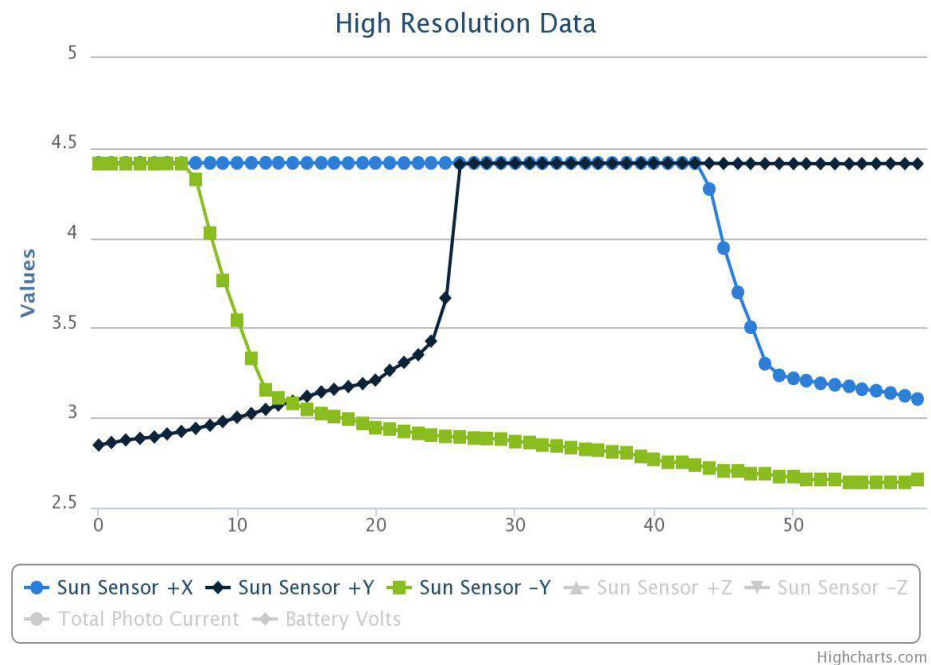
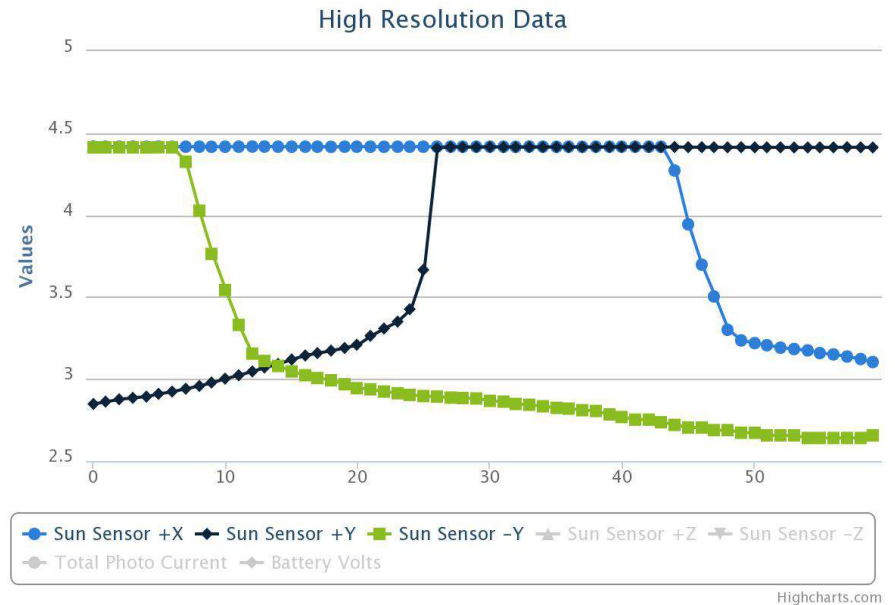
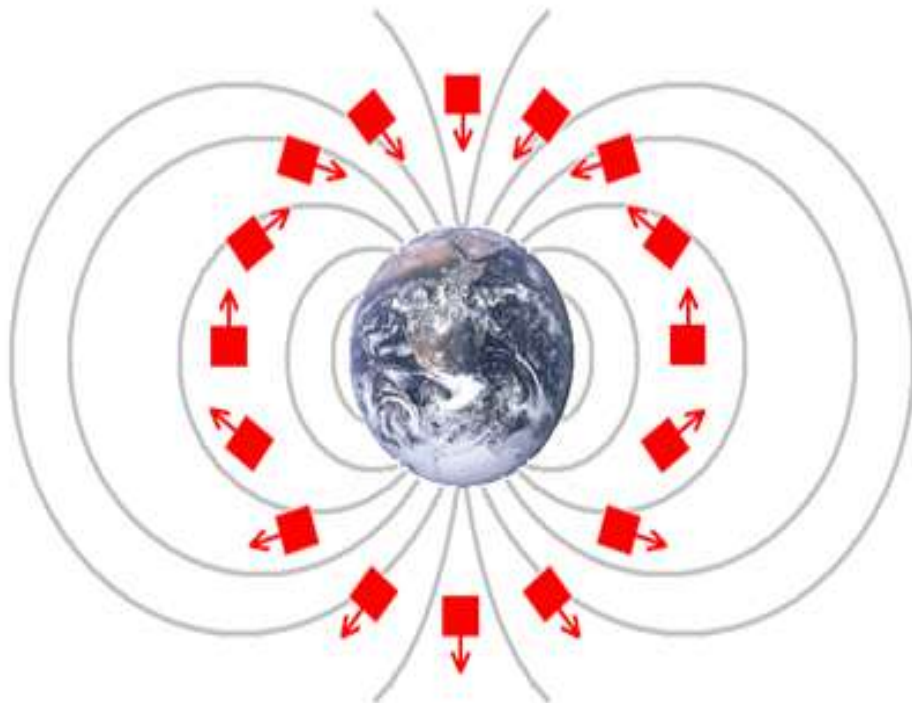
- Investigate the power generated from solar panels and how it is used to operate the equipment and maintain the battery
 - Input: battery voltage, total current produced by solar panels and total current used by equipment
 - Find: average power generated by panels, average power used in sunlight, percentage discharge of battery during eclipse -> estimate battery lifetime

Sample activity

- Find the communication range of the satellite
 - Heavens-above.com
 - Orbitron software

Sample activity

- Learn about magnetic fields; Funcube has a permanent magnet to try to keep its z-axis aligned
 - estimate Z-axis wobble



Other ideas

- Long time studies
 - Monitor change in emissivity of the bars (material degradation)
 - Monitor changes in solar panel operating temperatures
 - Monitor changes in battery performance
 - Monitor changes in z-axis wobble
 - Maximum panel bar temperature vs rotation rate

Other ideas

- Short time studies
 - Determine direction of rotation
 - Compare heat loss/gain in space vs Earth
 - Determine the temperature of the Sun's surface
 - Determine frame decode success vs transmitter power output
 - Determine solar panel temperature as function of current draw from the panel

Classroom resources

- Available from the link provided on slide no 16
 - Funcube satellite telemetry exercises, Heathland School / AMSAT-UK, March 2014
 - Pragmatic guide for using the Funcube (AO-73) materials science experiment in the classroom, Mark Spencer, ARRL Education and Technology Program, [mspencer@arrl.org](mailto:m Spencer@arrl.org) (Feb 2014)

Good luck!

- Have fun
- Feel free to contact me for questions or any assistance in can offer:
 - <http://www.cs.uleth.ca/~benkoczi>