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

Funcube-1 (AO73)

Launch from Yasny, Russia, 21 Nov. 2013

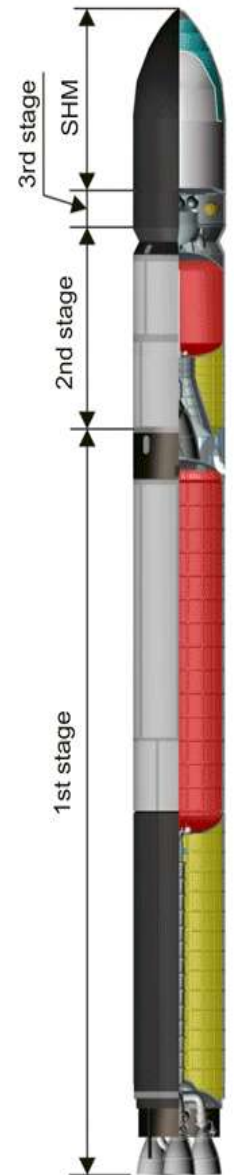SS-18 Intercontinental ballistic missile (Dnepr)

Primary payload DubaiSat-2

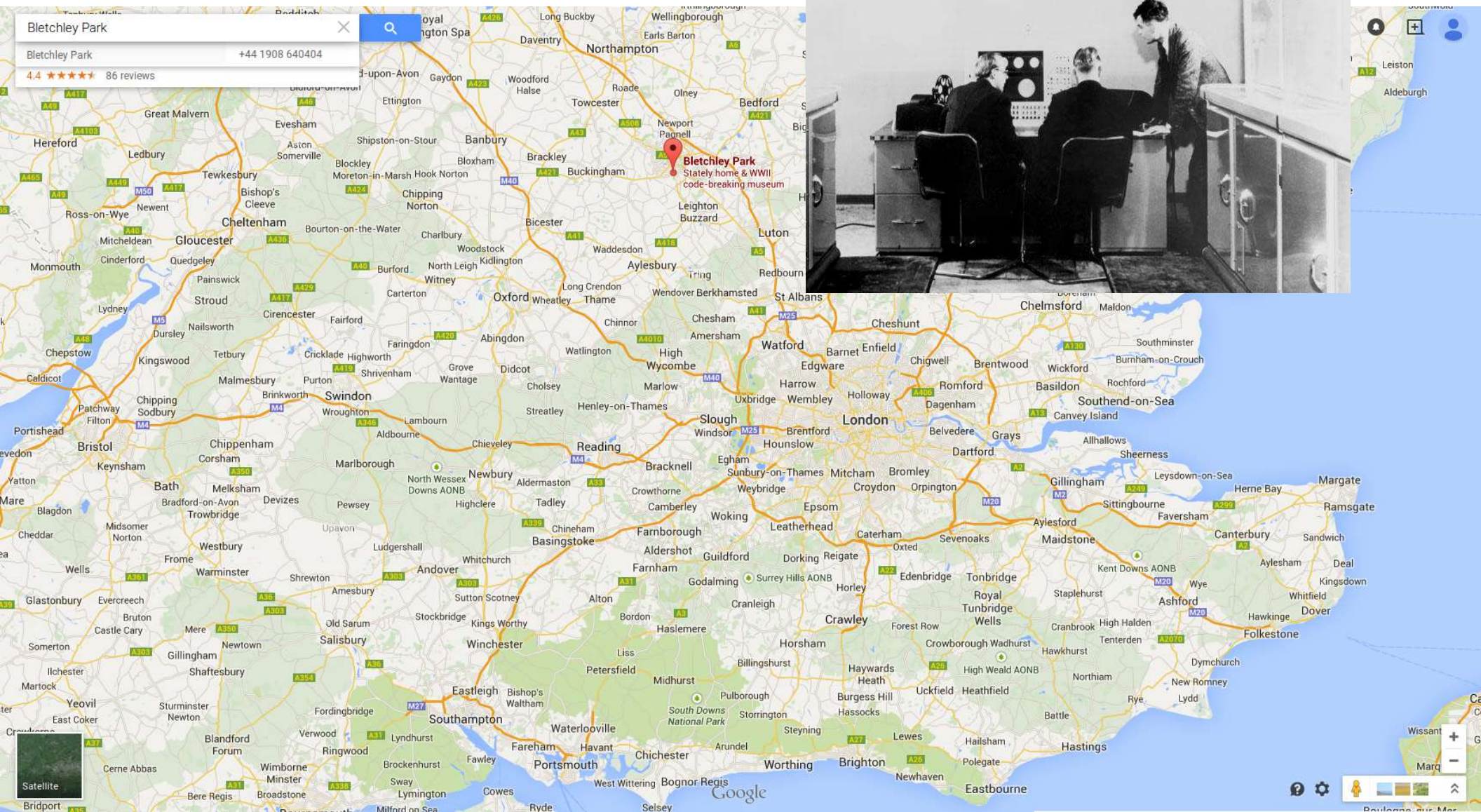19 secondary micro and nanosat payloads

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)
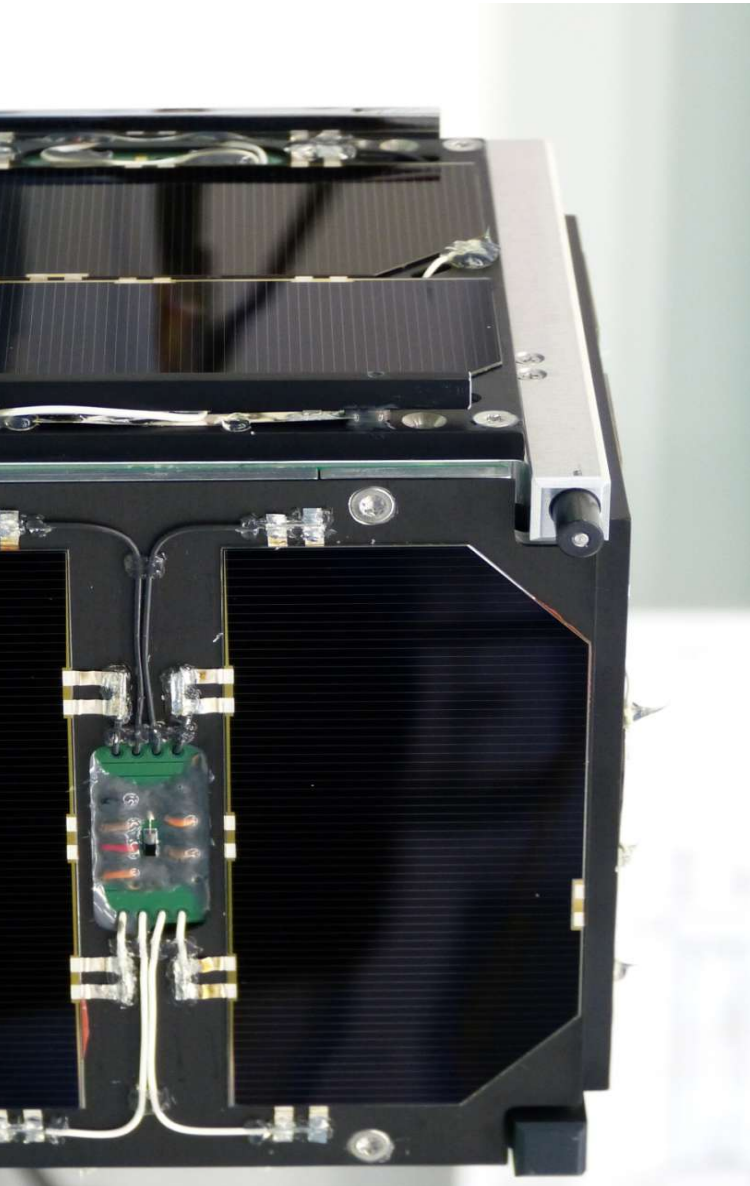
- Six surfaces
  - all with solar panels
  - one with black and chrome metal strips

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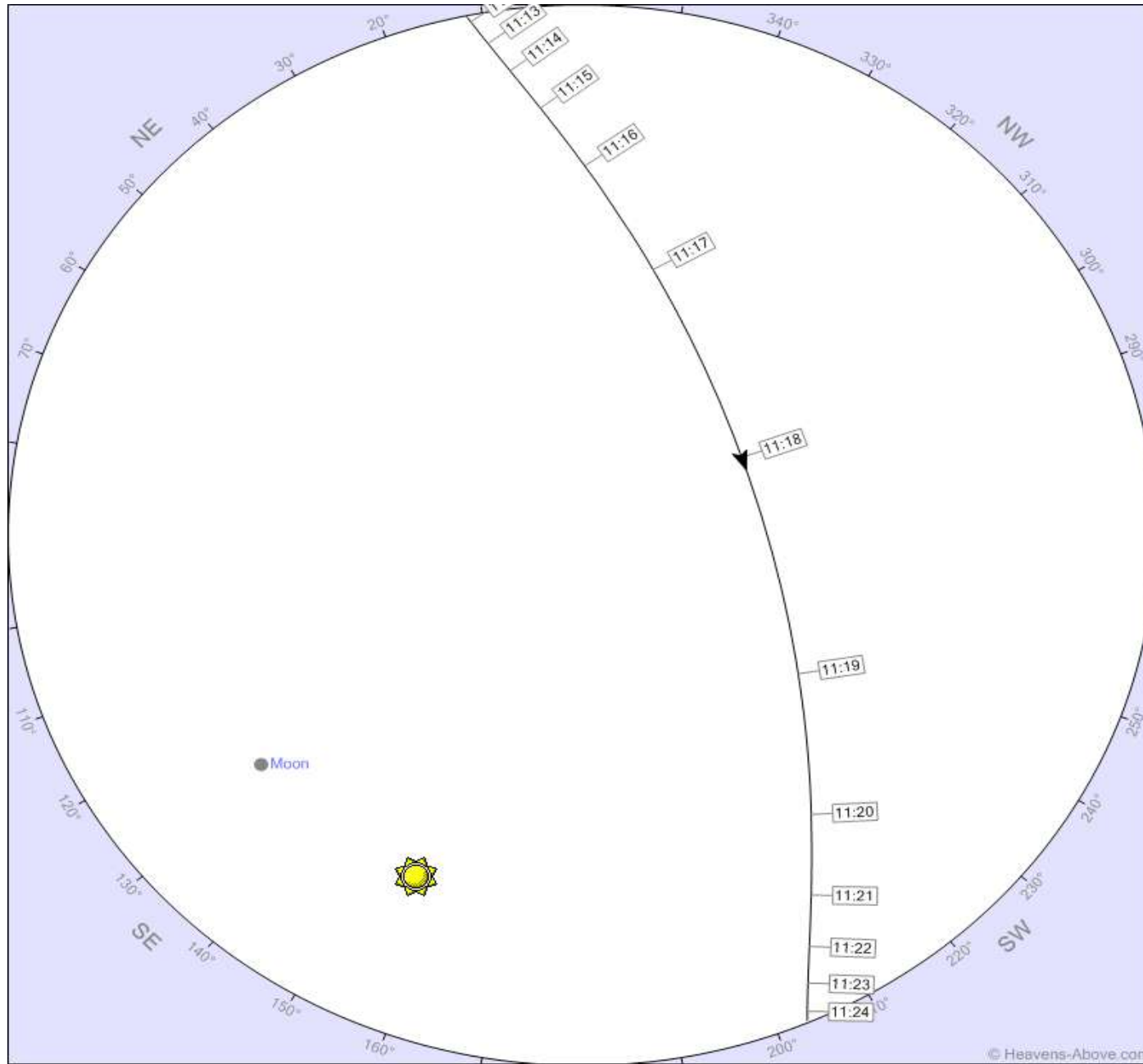
Demo (11:13 - 11:24, Feb 20 2015)

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)
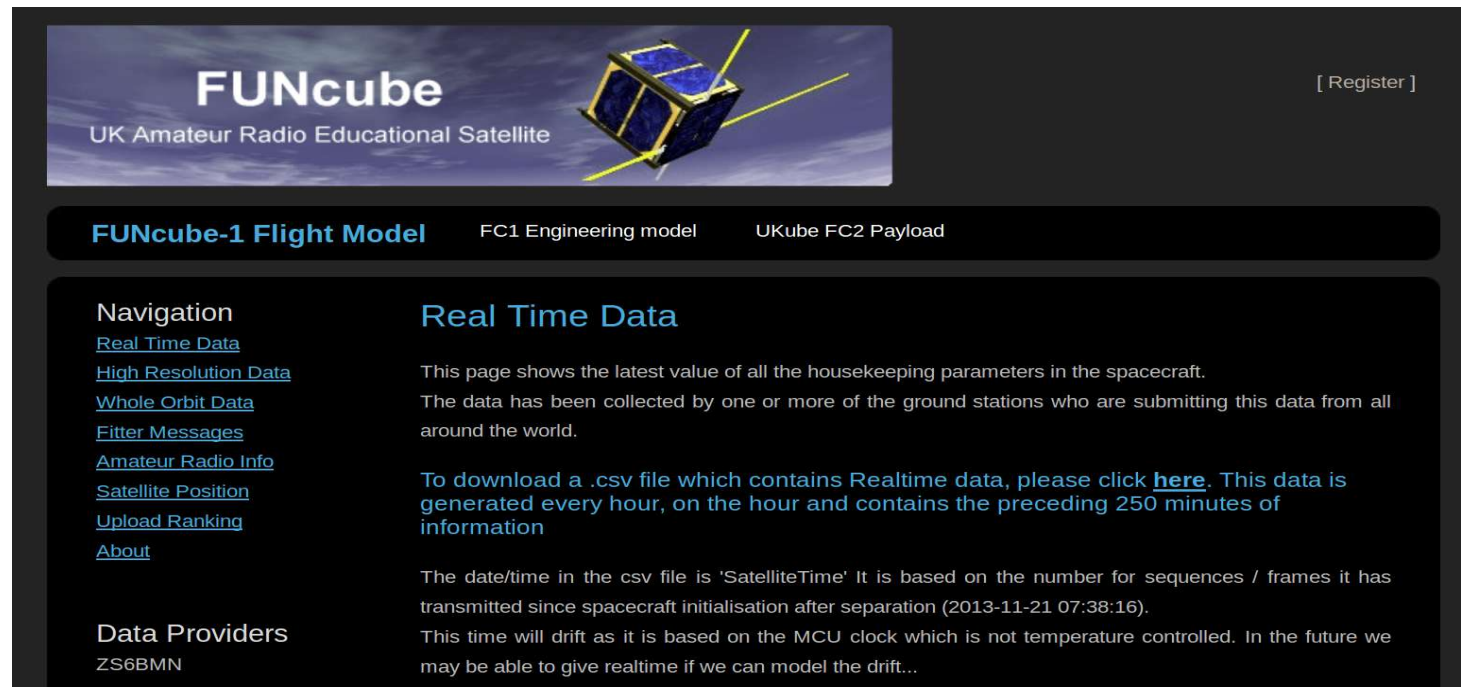
Setting up the ground-station

- 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/

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/

Preparing the reception

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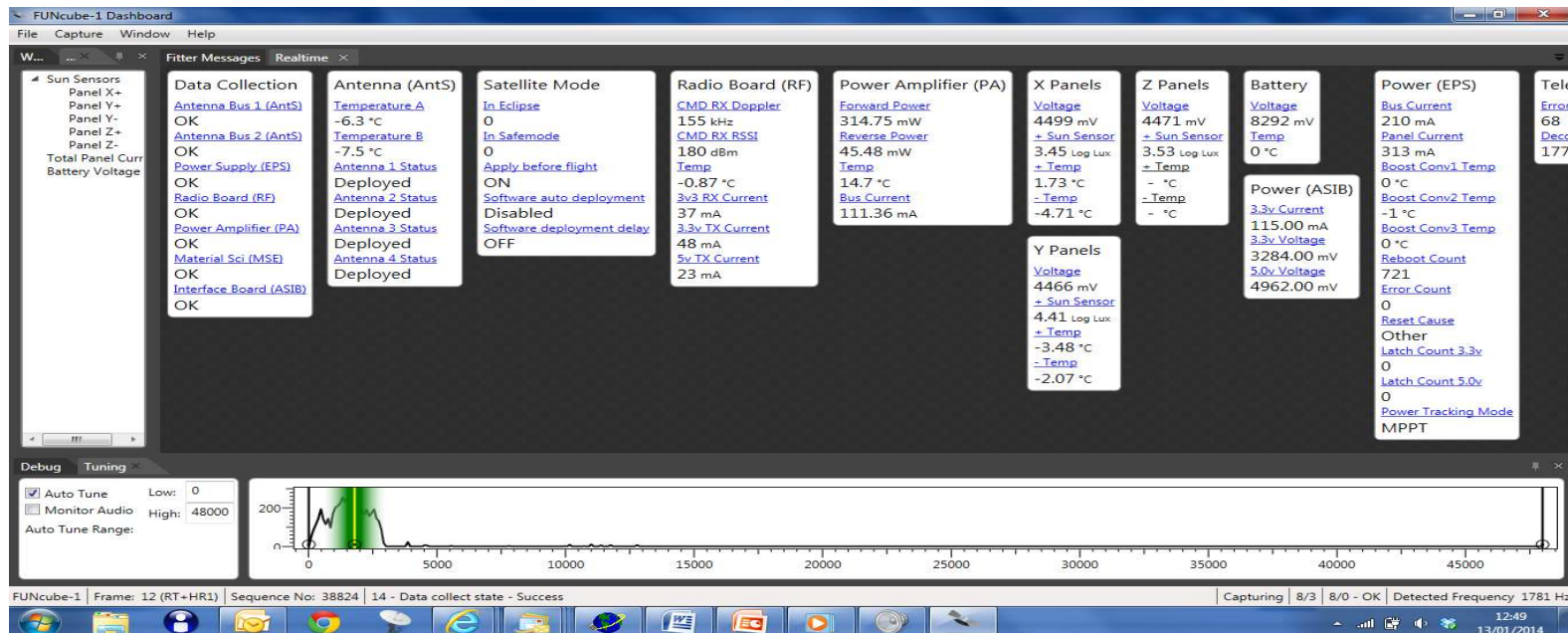
Understanding the satellite

- 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 activites

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
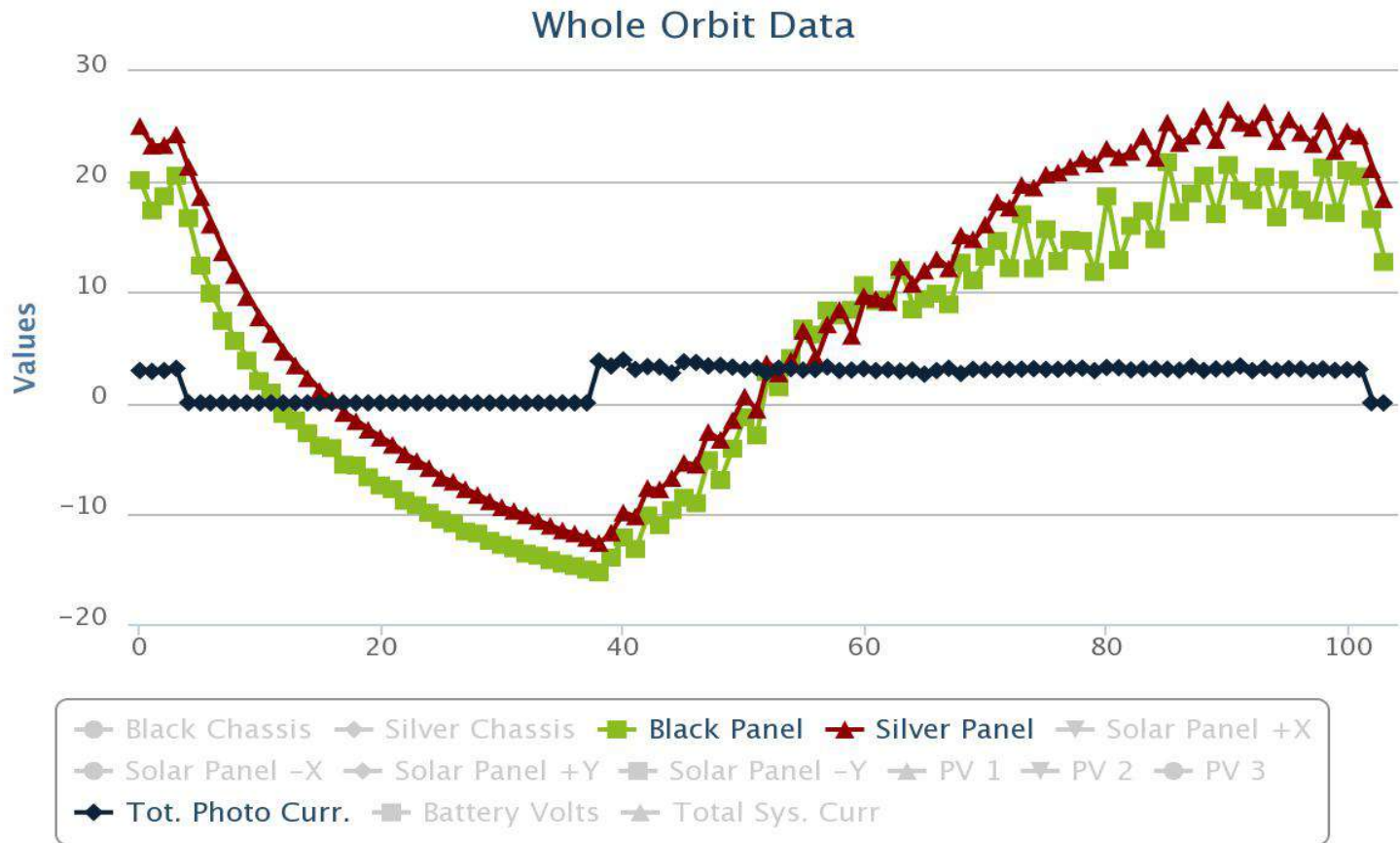
Examples

- Velocity (eclipse time, orbital period, altitude)
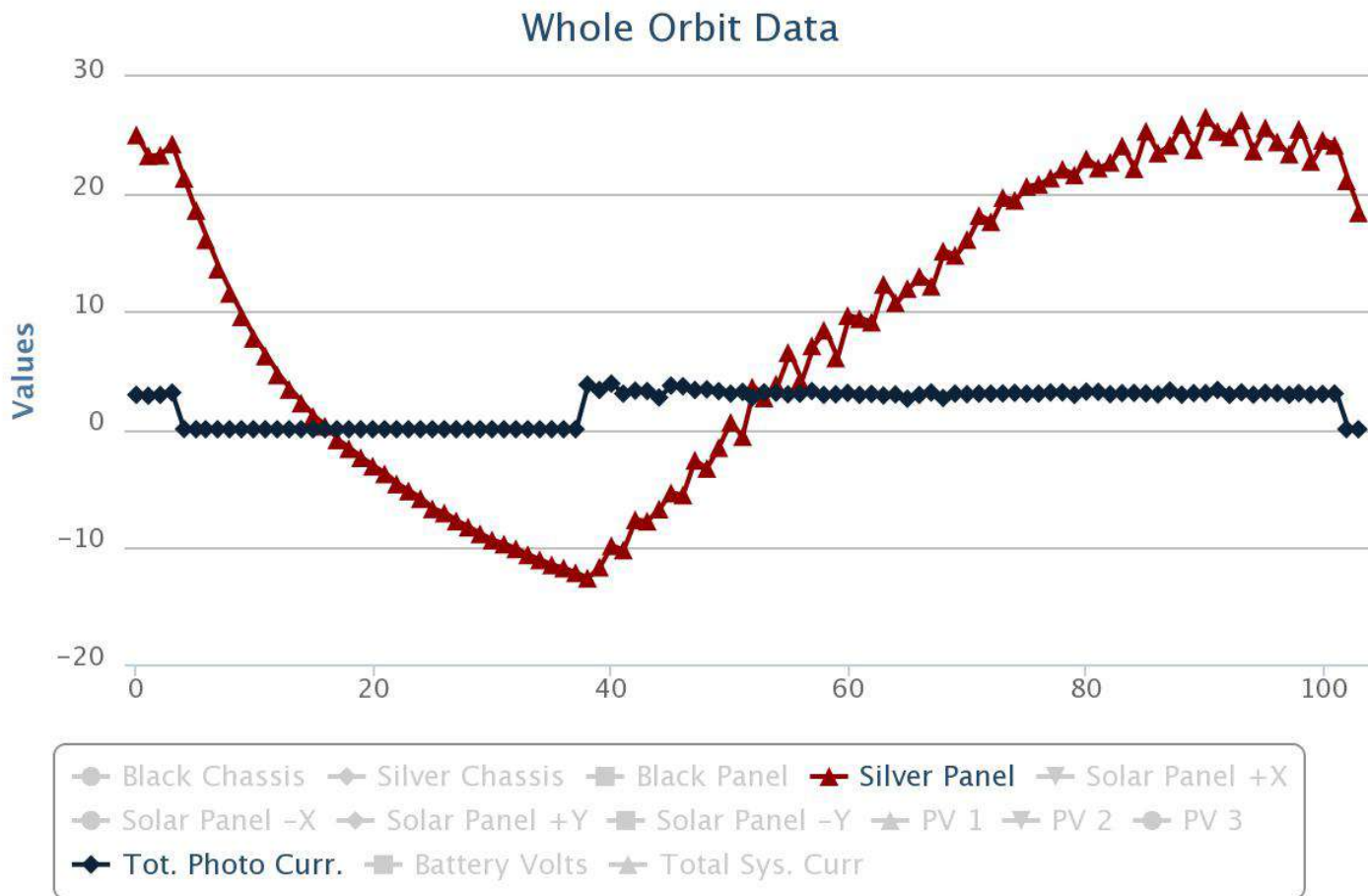
Examples

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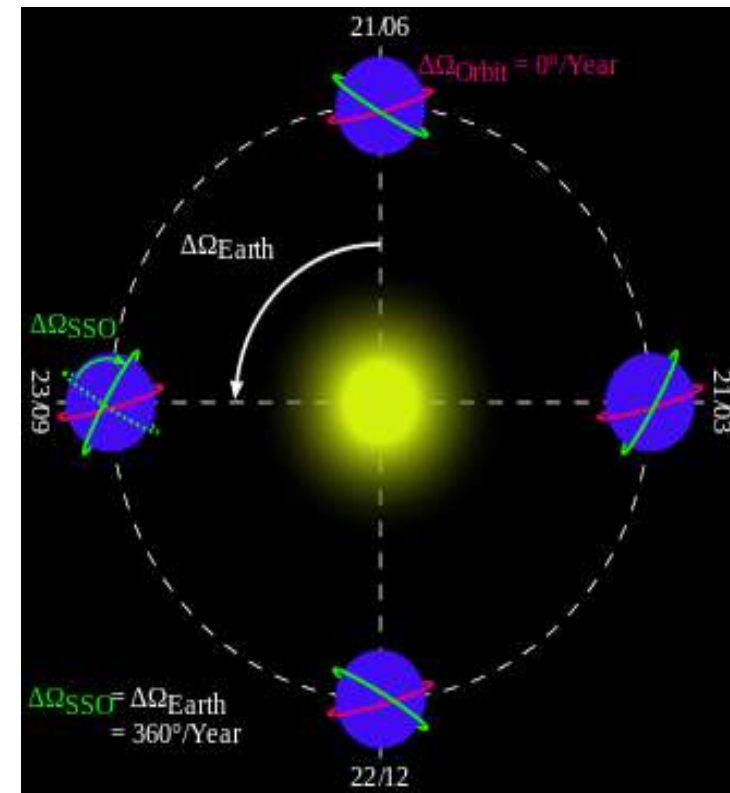
Examples

- 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 an 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
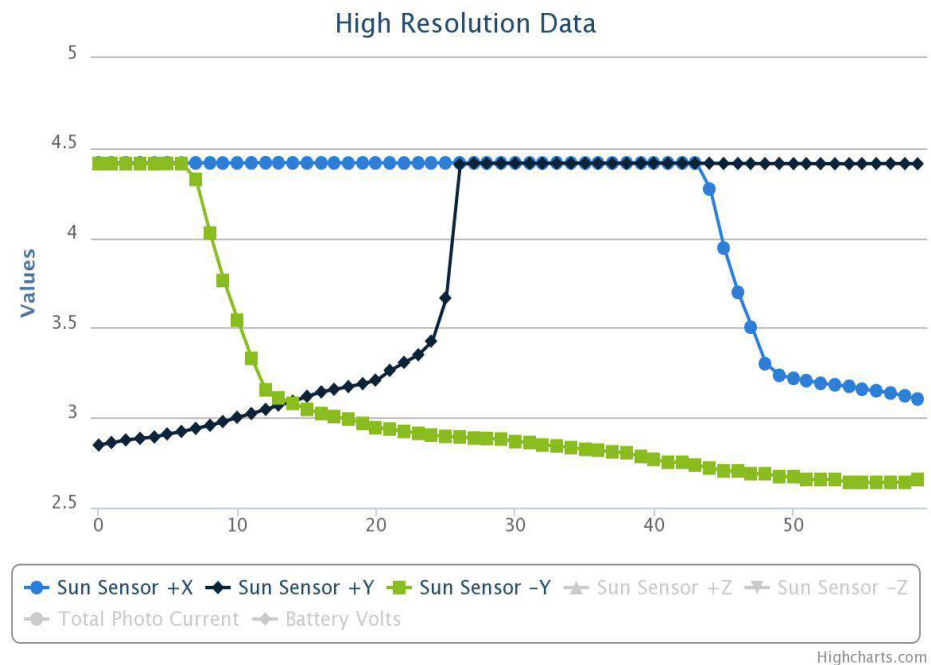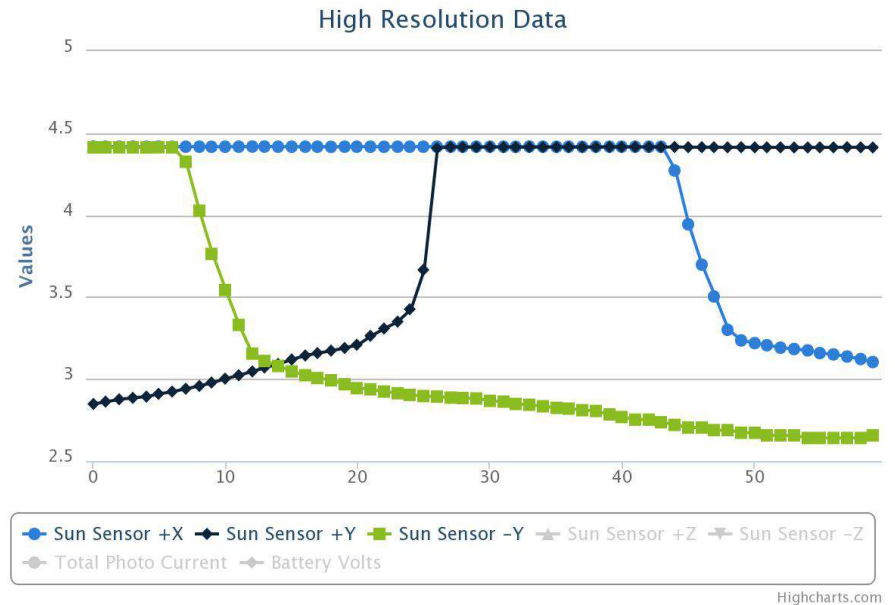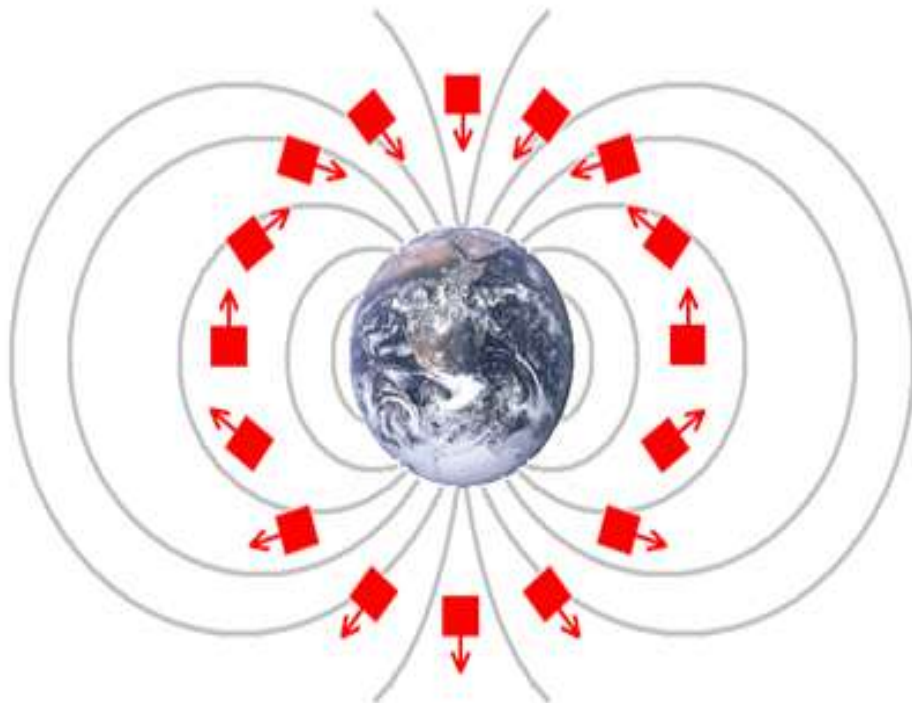
Other ideas

- 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 (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