



FUN in Space

The story of FUNcube-1 (AO-73)

Wouter Weggelaar, PA3WEG

FUNcube Team



AMSAT-NL
Radio Amateur Satellites



Contents

History of amateur radio satellites (skipped, Henk PA3GUO will cover this)

Introduction to FUNcube (also check the 2013 presentation)

FUNcube mission

Building FUNcube

Launch and early operations

What is next?



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Wouter Weggelaar

Worked on Delfi-C3 – The first dutch Nanosatellite

Now RF engineer at Delfi-spinoff ISIS

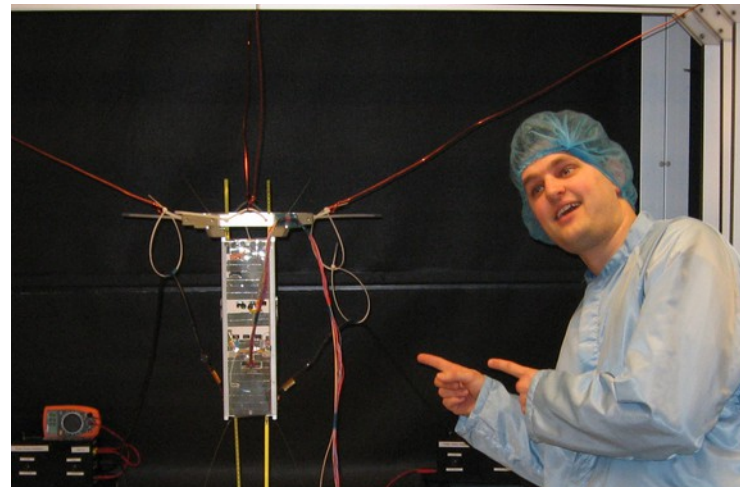
Radio Amateur – PA3WEG

AMSAT-UK member

co-founder of AMSAT-NL

FUNcube design team

member



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The FUNcube Project – primary objective

Educational outreach

STEM subjects

Radio – practical understanding of communication

Electronics – how radios work

Physics – Data from 50+ telemetry channels

Orbital mechanics - Doppler

Materials science payload - Demonstrate loss of heat energy by radiation from two materials with differing surface finishes

“Fitter Message” - Short greetings messages



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STEM experiment – CubeSat structure cont.



This is what the Flight Model looked like after assembly.

You can see the corners in different colours and the panels which are actually coloured too (hidden by solar cells)

The blue tape on the edges protected the surfaces during assembly.

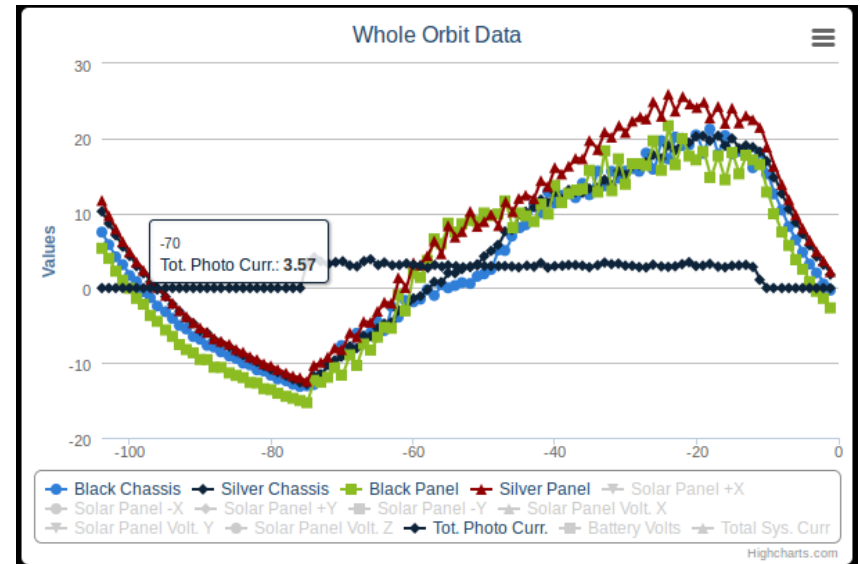




STEM experiment – Data available

Each frame and panel has a thermocouple attached to it and the data from these is sent as part of the telemetry.

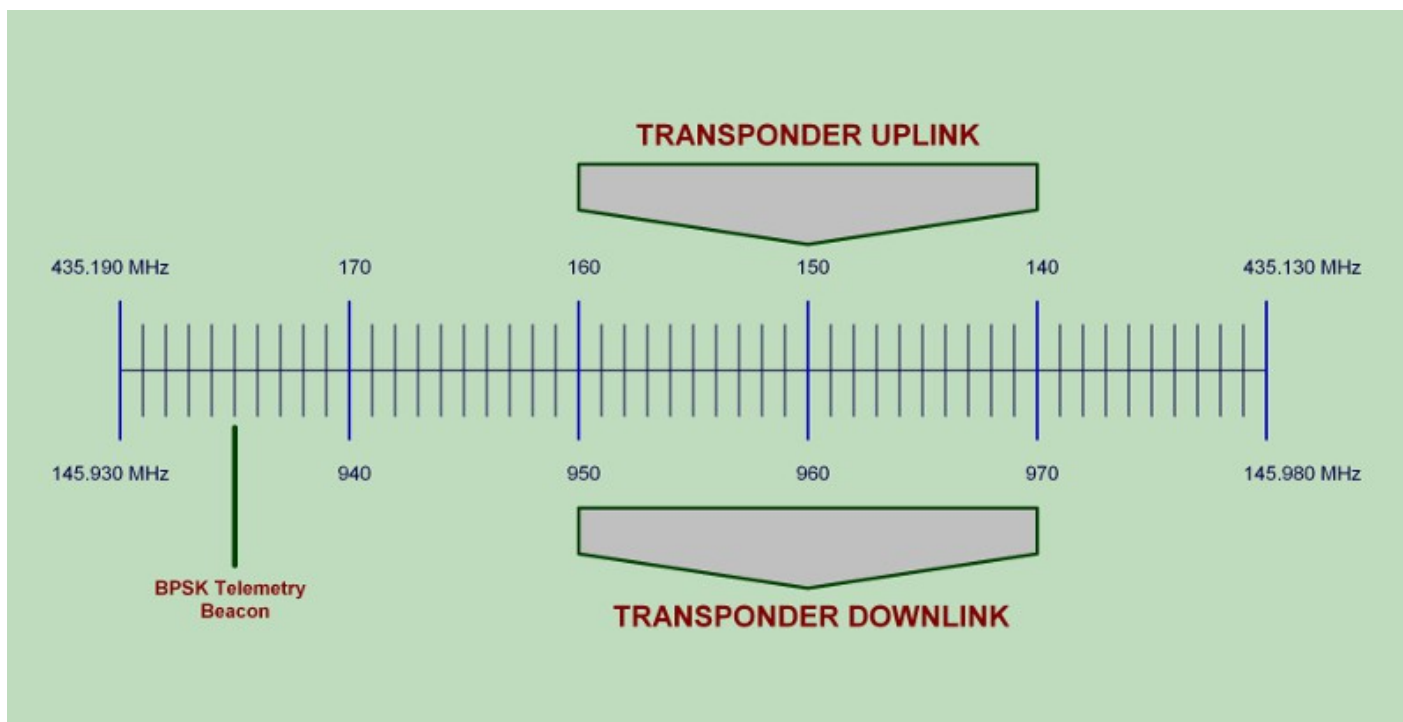
As the satellite is spinning in three axes and going in and out of eclipse, we can generate some interesting graphs for students to interpret.





FUNcube Amateur Radio Payload

The radio frequencies on which the satellite transmits data, relays audio traffic and receives command uplinks are within the Amateur Satellite Service of the Amateur Radio spectrum as specified by the International Telecommunications Union (ITU)





Radio Hardware – MCU

Xilinx CPLD command decoder

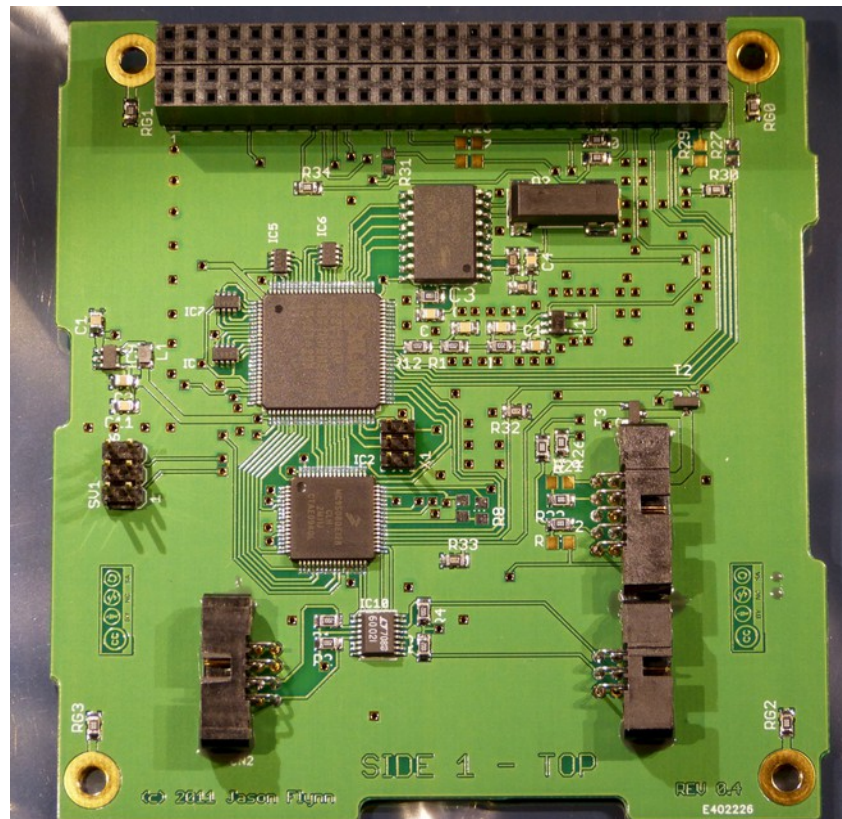
Freescale CPU for telemetry generation

2 x I2C Bus

3.3V supply

Average power consumption 15mW

Peak power 33mW



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Radio Hardware – RF Board

Designed by PA3WEG

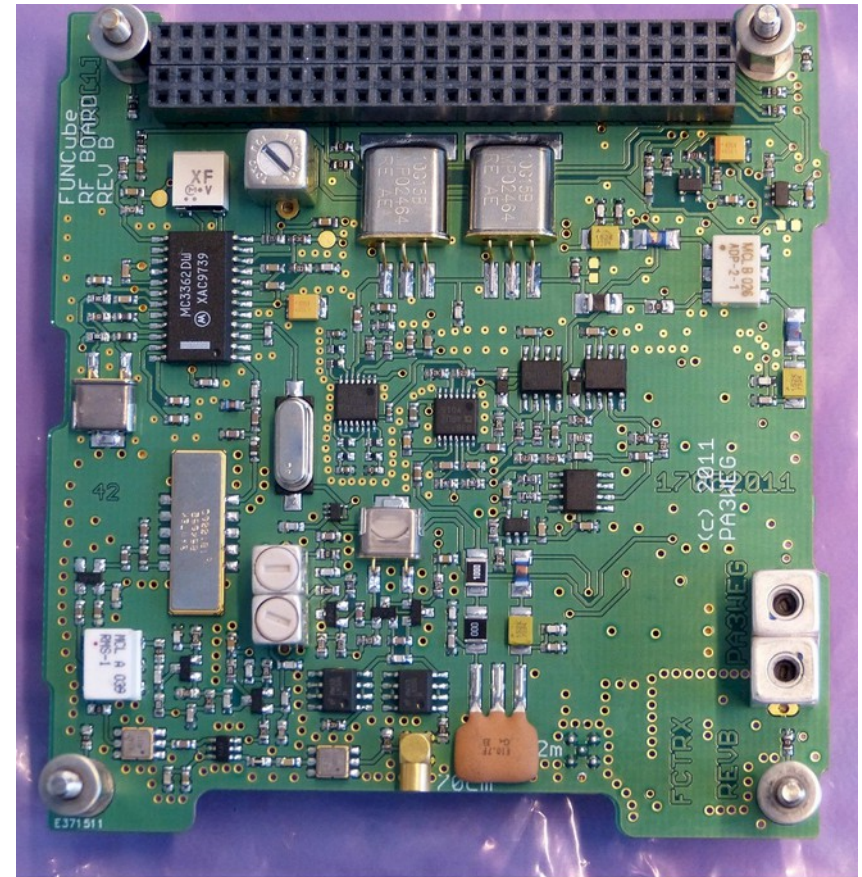
Contains:

Command receiver

19kHz UHF-VHF

transponder

6 telemetry channels



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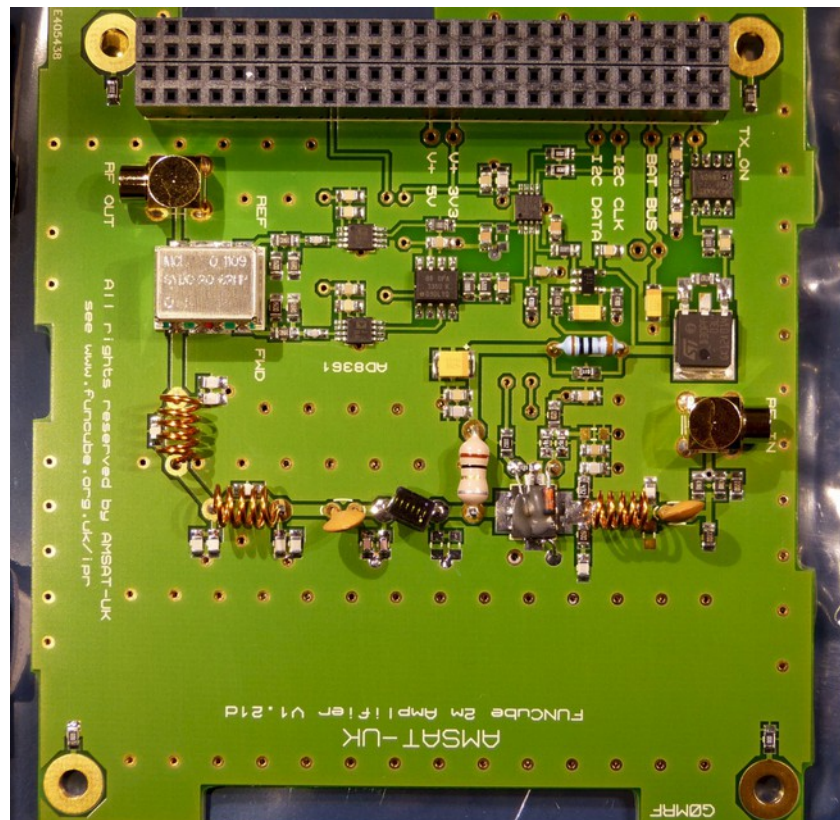
Radio Hardware – PA Board

Designed by G0MRF

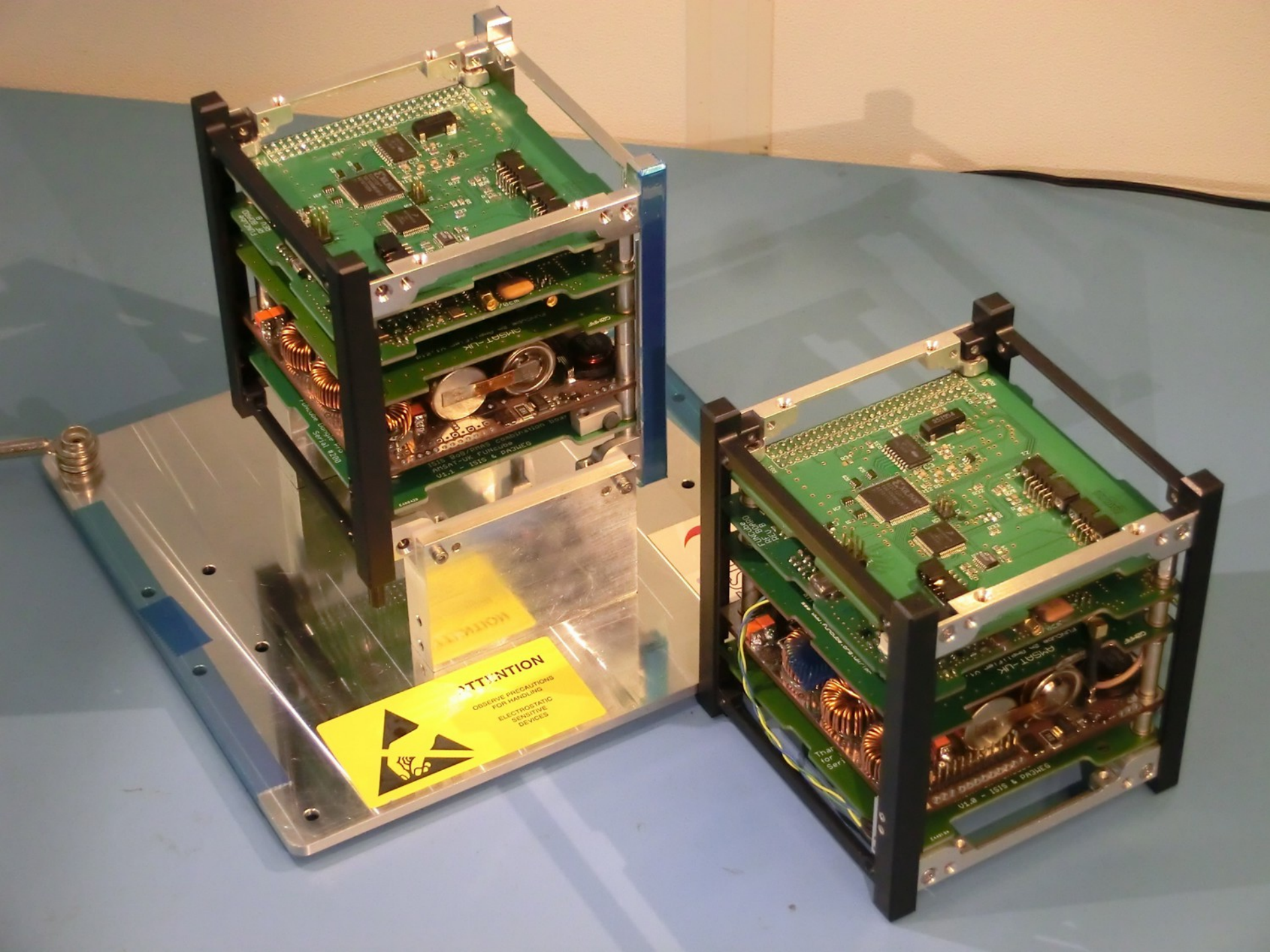
Contains:

RD02MUS1 FET

4 channels of
telemetry



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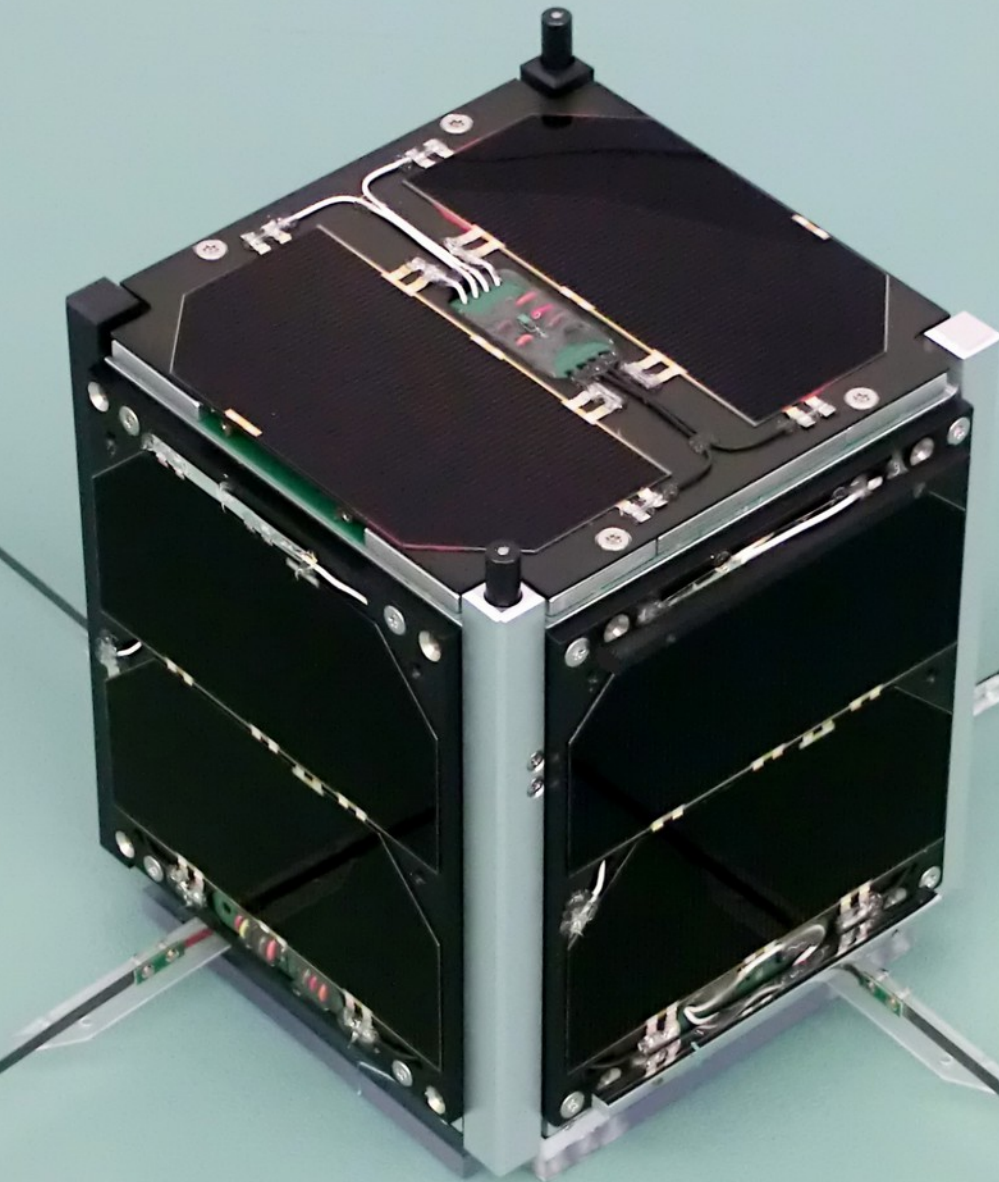
ATTENTION
OBSERVE PRECAUTIONS
FOR HANDLING
ELECTROSTATIC
SENSITIVE
DEVICES

NOTICE

CHSQT-11K
V1.0 - 1S15 & PRODES

CHSQT-11K
V1.0 - 1S15 & PRODES

THAT FOR SERVO





Amateur radio operations

During the local night (eclipse) the sub-system switches into amateur radio mode

The amateur radio transponder can be used to demonstrate radio communications to schoolchildren and students of all ages

Students are able to hear amateur voice signals when the satellite passes overhead





The “Ground Segment”- the FUNcube dongle



USB receiver dongle

Works with all freeware SDR software & any OS

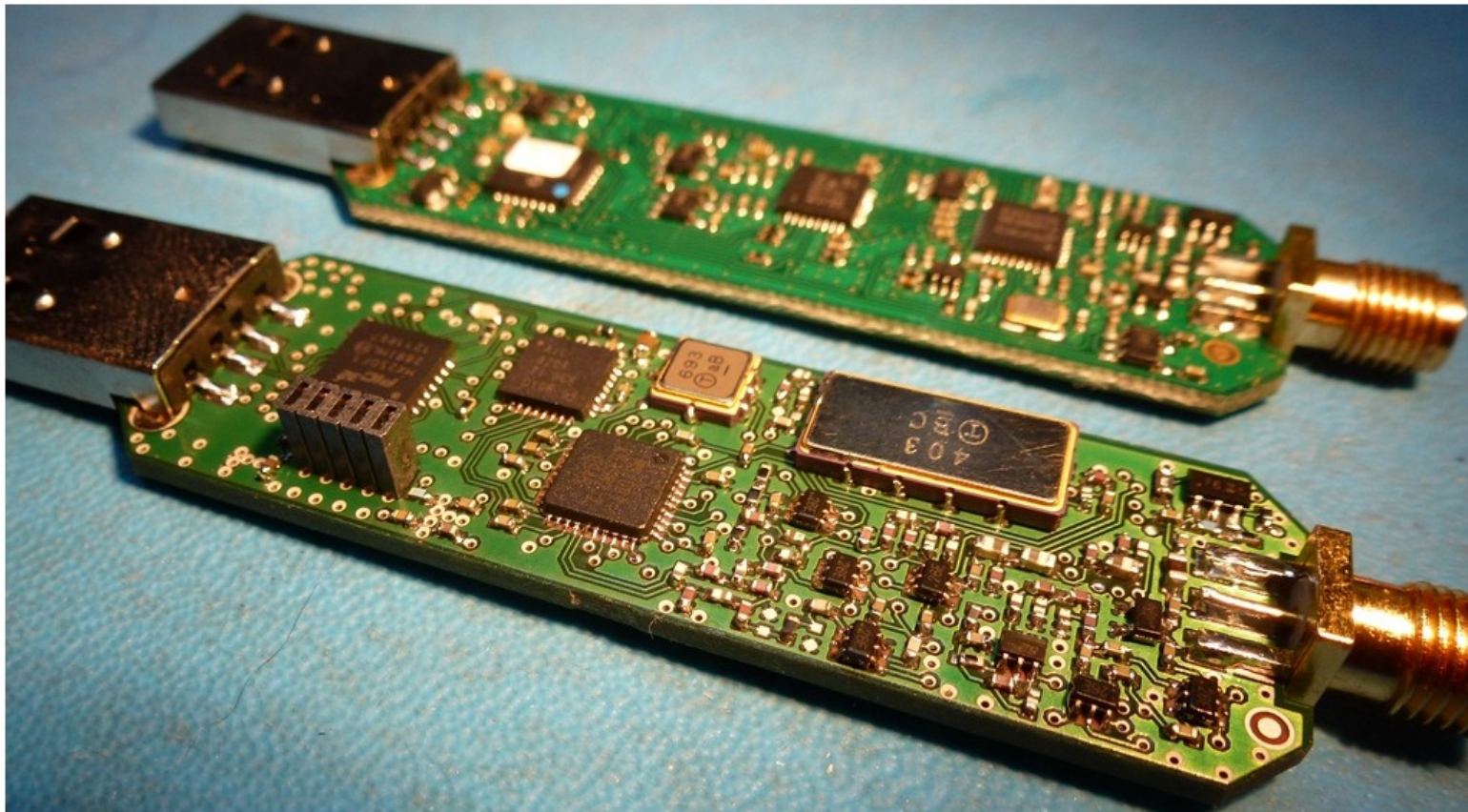
Works in combination with the FUNcube Dashboard



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The “Ground Segment”- the FUNcube dongle



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The project team

AMSAT-UK is a club with a membership of approx' 380 members. To plan, design and build FUNcube we put out a request for people with the skills to see it through to completion. We ended up with this motley crew with a huge breadth of experience in RF, structures, software and project management. You can see that great FUN is being had, more of that later... (Photo Copyright 2013 RSGB)



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FUNcube-1 in its POD

(it's the one in the middle!)



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FUNcube – telemetry reception

FUNcube Dashboard

File Capture Window Debug Help

Whole... High Res... Fitter Messages Realtime

- Material Science Experiment
 - Black Chassis Temp
 - Silver Chassis Temp
 - Black Panel Temp
 - Silver Panel Temp
- Panel Temperature
 - Temperature X+
 - Temperature X-
 - Temperature Y+
 - Temperature Y-
- Panel Voltages
 - Voltage 1
 - Voltage 2
 - Voltage 3
- Power Supply
 - Total Panel Current
 - Total System Current
 - Battery Voltage

Data Collection

[Antenna Bus 1 \(AntS\)](#)
OK

[Antenna Bus 2 \(AntS\)](#)
OK

[Power Supply \(EPS\)](#)
OK

[Radio Board \(RF\)](#)
OK

[Power Amplifier \(PA\)](#)
OK

[Material Sci \(MSE\)](#)
OK

[Interface Board \(ASIB\)](#)
OK

Antenna (AntS)

[Bottom Temp](#)
22.5 °C

[Top Temp](#)
22.5 °C

[Status A](#)
Deployed

[Status B](#)
Deployed

[Status C](#)
Deployed

[Status D](#)
Deployed

Satellite Mode

[In Eclipse](#)
0

[In Safemode](#)
1

[Apply before flight](#)
ON

[Software auto deployment](#)
Disabled

[Software deployment delay](#)
OFF

Radio Board (RF)

[CMD RX Doppler](#)
165 kHz

[CMD RX RSSI](#)
182 dBm

[Temp](#)
23.99 °C

[3v3 RX Current](#)
41 mA

[3.3v TX Current](#)
56 mA

[5v TX Current](#)
28 mA

Power Amplifier (PA)

[Forward Power](#)
15.99 mW

[Reverse Power](#)
11.71 mW

[Temp](#)
34.1 °C

[Bus Current](#)
34.42 mA

X Panels

[Voltage](#)
1609 mV

[+ Sun Sensor](#)
38

[- Temp](#)
22.04 °C

[- Temp](#)
22.37 °C

Y Panels

[Voltage](#)
1894 mV

[+ Sun Sensor](#)
5

[- Temp](#)
22.68 °C

[- Temp](#)
22.14 °C

Z Panels

[Voltage](#)
1671 mV

[+ Sun Sensor](#)
4

[- Temp](#)
N/A °C

[- Temp](#)
N/A °C

Battery

[Voltage](#)
7856 mV

[Temp](#)
22 °C

Power (ASIB)

[3.3v Current](#)
130.00 mA

[3.3v Voltage](#)
3280.00 mV

[5.0v Voltage](#)
4956.00 mV

Power (EPS)

[Bus Current](#)
146 mA

[Panel Current](#)
0 mA

[Boost Conv1 Temp](#)
22 °C

[Boost Conv2 Temp](#)
22 °C

[Boost Conv3 Temp](#)
22 °C

[Reboot Count](#)
92

[Error Count](#)
0

[Reset Cause](#)
5

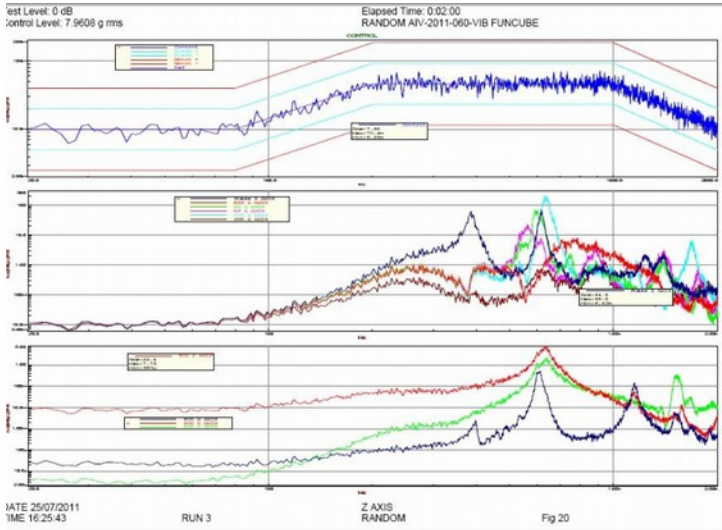
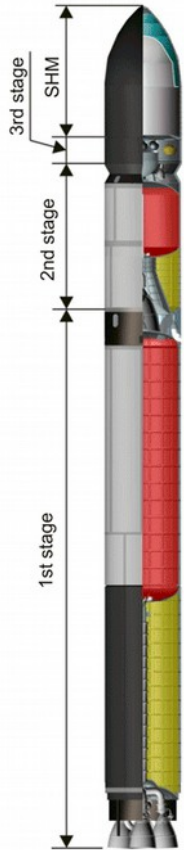
[Latch Count 3.3v](#)
0

[Latch Count 5.0v](#)
0

[Power Tracking Mode](#)
1



DNEPR: converted SS-18 Intercontinental ballistic missile



- Primary payload: DubaiSat-2
- 19 secondary micro and nanosat payloads
- Launches from an underground silo
- Approx altitude 600x685 km





Assembly

The assembly time lapse video was shown to the audience. It is available for viewing at:

[Http://youtu.be/sEMoLOcGOOw](http://youtu.be/sEMoLOcGOOw)



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Antenna deployment test

The antenna deployment test video was shown to the audience. It is available for viewing at:

<http://youtu.be/ddR-IIZHNbw>

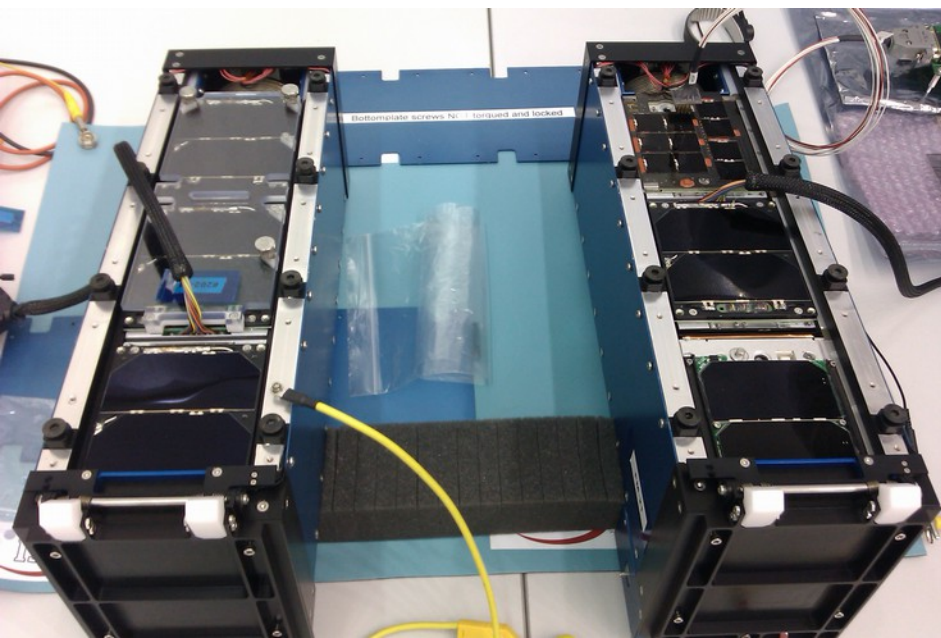


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To the launch site!

Fly Antonov
Charge FUNcube
Wave goodbye



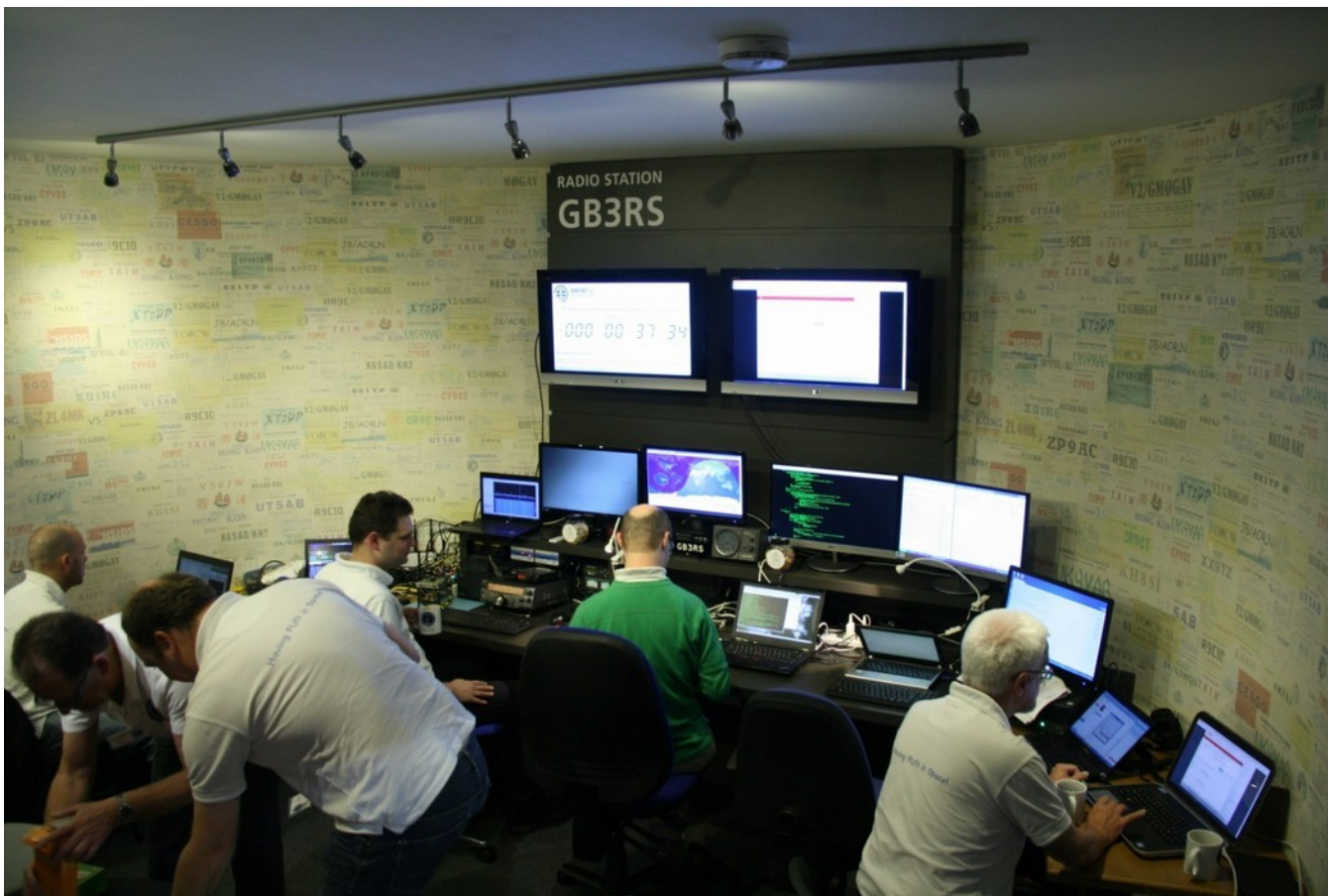


Launch day monitoring station RSGB NRC – Bletchley Park





Launch day monitoring station RSGB NRC – Bletchley Park



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Launch video

The launch video was shown to the audience. It is available for viewing at:

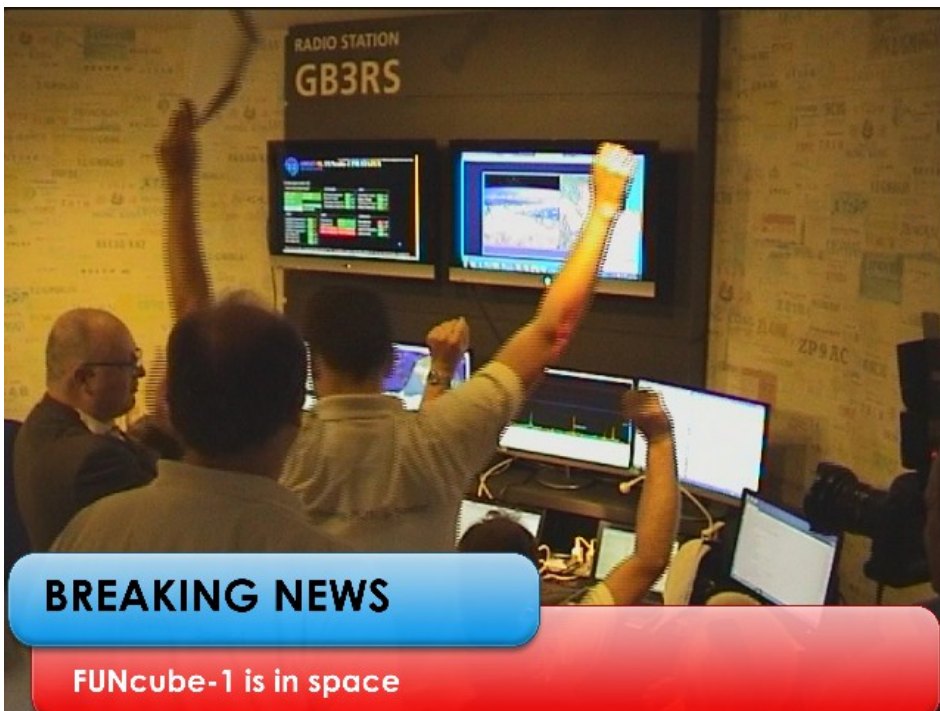
<https://youtu.be/0W6hIXXAFcE>



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Nov. 21st 07:10 UTC Deployment!



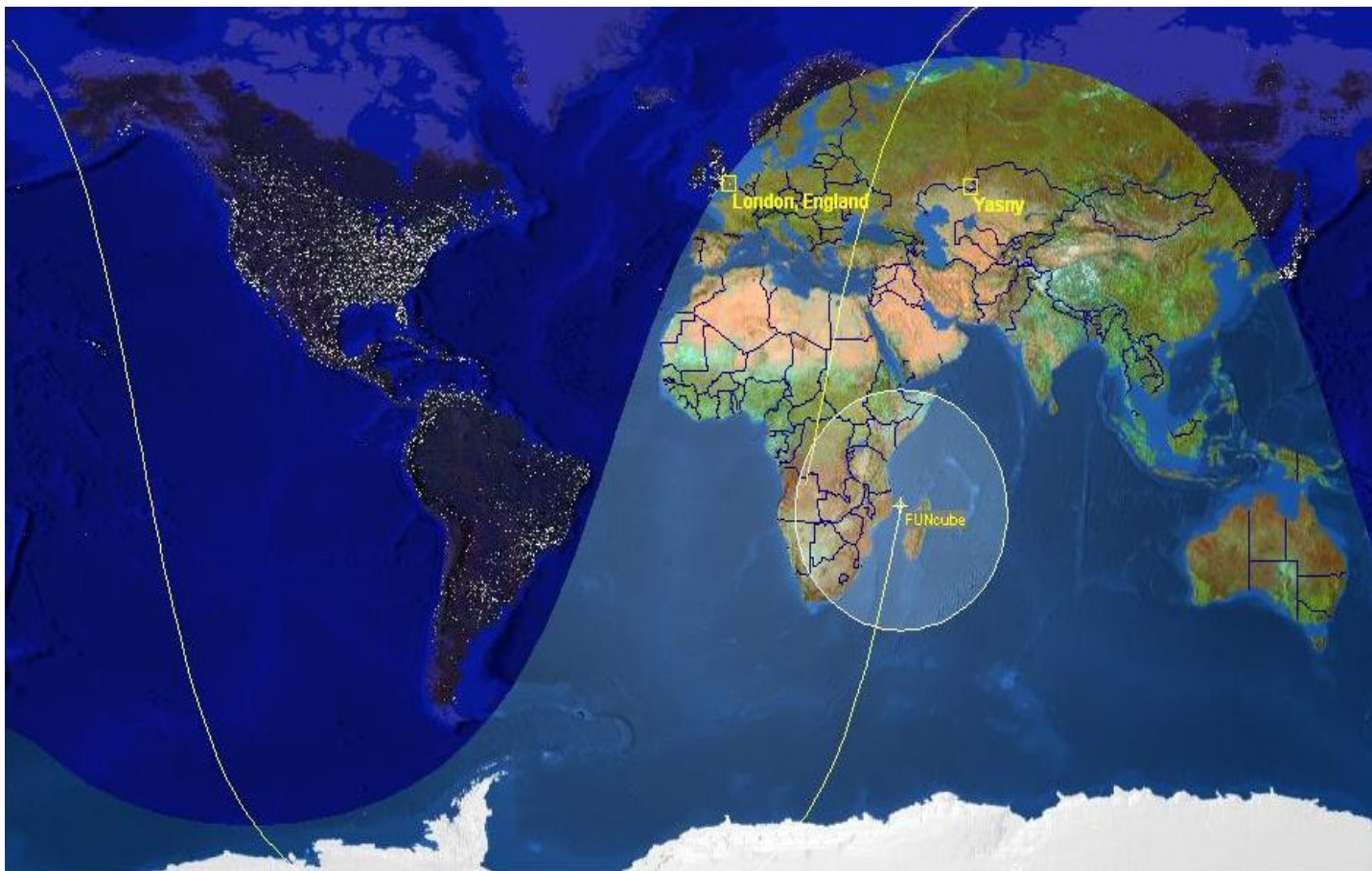
- 19 satellites deployed from the DNEPR launch vehicle.
- You can see how happy we were!
- Now the real work of the next few hours starts...



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FUNcube-1 LEOP



Antenna deployment at T+27 minutes. First telemetry approx 1 min later
Safe mode 30mW BPSK beacon

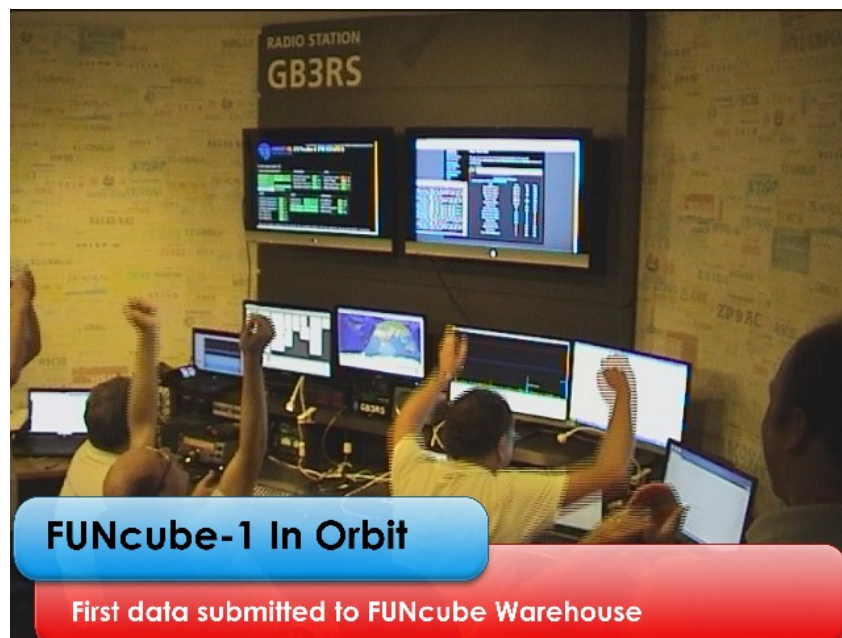


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We've got data!

One of a network of amateur radio operators (ZS1LS, in South Africa) received signals at **07:36**, decoded them and uploaded the packets to the data warehouse in real-time over the internet.



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AMSAT-NL FUNcube-1 FM STATUS

Radio Amateur Satellites

Last updated on: Thu Nov 21 2013 07:59:03 GMT+0100

Last data sequence number: 470

DATA COLLECTION STATE

| | |
|------------------|------------------|
| ASIB VALID | EPS VALID |
| PA VALID | RF VALID |
| MSE VALID | |
| ANTS BUS A VALID | ANTS BUS B VALID |
| IN SUNLIGHT | SAFE MODE |

RF BOARD

| | |
|-------------------------|---------|
| RF Board Temperature | 14.6 °C |
| Receiver Current | 40 mA |
| Transmitter Current 3V3 | 33 mA |
| Transmitter Current 5V0 | 22 mA |

EPS

| | |
|----------------------|---------|
| Total Photo Current | 431 mA |
| Battery Voltage | 7866 mV |
| Total System Current | 123 mA |
| Battery Temperature | 13 °C |

ASIB

| | |
|---------------------------|---------|
| solarPanel Temperature X+ | 17.7 °C |
| solarPanel Temperature X- | 18.0 °C |
| solarPanel Temperature Y+ | 18.5 °C |
| solarPanel Temperature Y- | 17.8 °C |
| Bus Voltage 3V3 | 3280 mV |
| Bus Current 3V3 | 111 mA |
| Bus Voltage 5V0 | 4956 mV |

AntS

| | |
|----------------|----------------|
| Temperature A | 20.1 °C |
| Temperature B | 20.1 °C |
| VHF A Deployed | VHF B Deployed |
| UHF A Deployed | UHF B Deployed |

paSummary

| | |
|---------------------|---------|
| forwardPower | 19.5 mW |
| reversePower | 4.1 mW |
| paDeviceTemperature | 22.6 °C |
| paBusCurrent | 30.6 mA |

Please note: The data is continuously being monitored. There is no need to contact us when items indicate red. Also note that FUNcube is

SONY



BBC 1 Breakfast News report

The BBC 1 Breakfast news reported on the launch of FUNcube and its educational outreach. The video can be viewed at <http://youtu.be/tnDoq9sRZpk>



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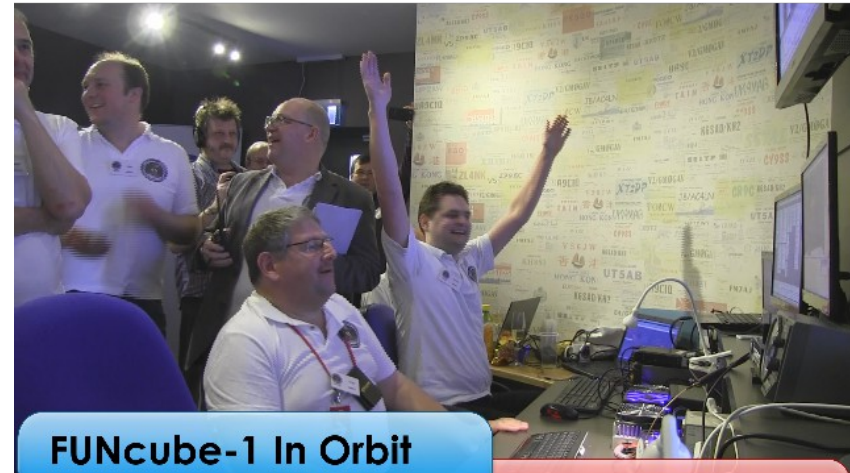


How soon should we send the first command?

We had to wait until the second orbit over the UK in order to have enough elevation.

5 seconds after the command was decoded and validated by the satellite it went from safe (30mW) mode into sunlight (310mW) telemetry mode.

It stayed in that mode for the next 24 hours.



FUNcube-1 In Orbit

FUNcube-1 commanded into high power telemetry mode



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First command video

The first command video was shown to the audience. It is available for viewing at:

<https://youtu.be/AhCj1D2Sg78>



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outreach

Schools are just starting to include FUNcube

We now have a “product” to sell

We are getting response from all over the world





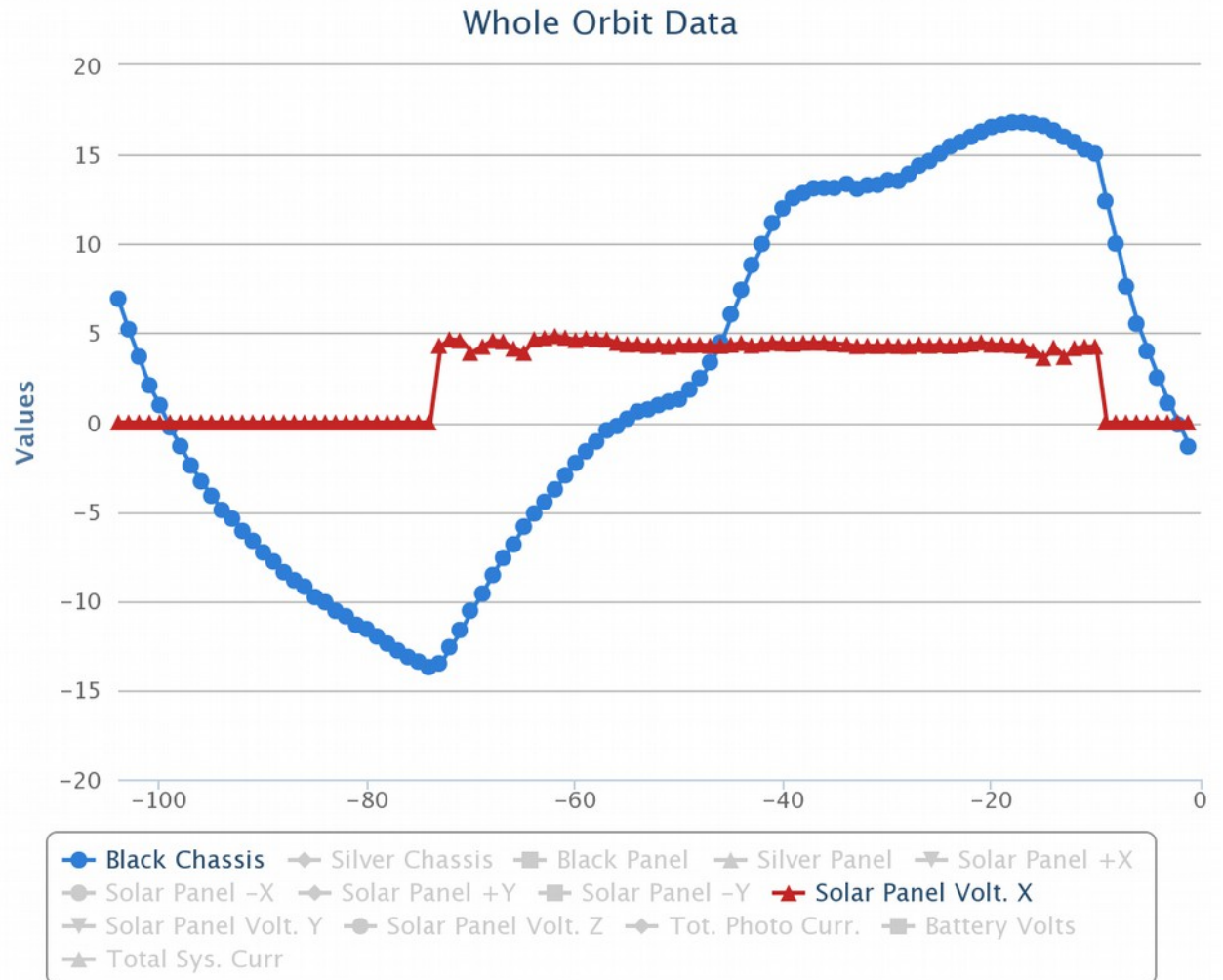
Some statistics

935 registered users
530 regularly uploading data
5030 2k packets decoded and uploaded per day
3 resets since launch, one of these by the team

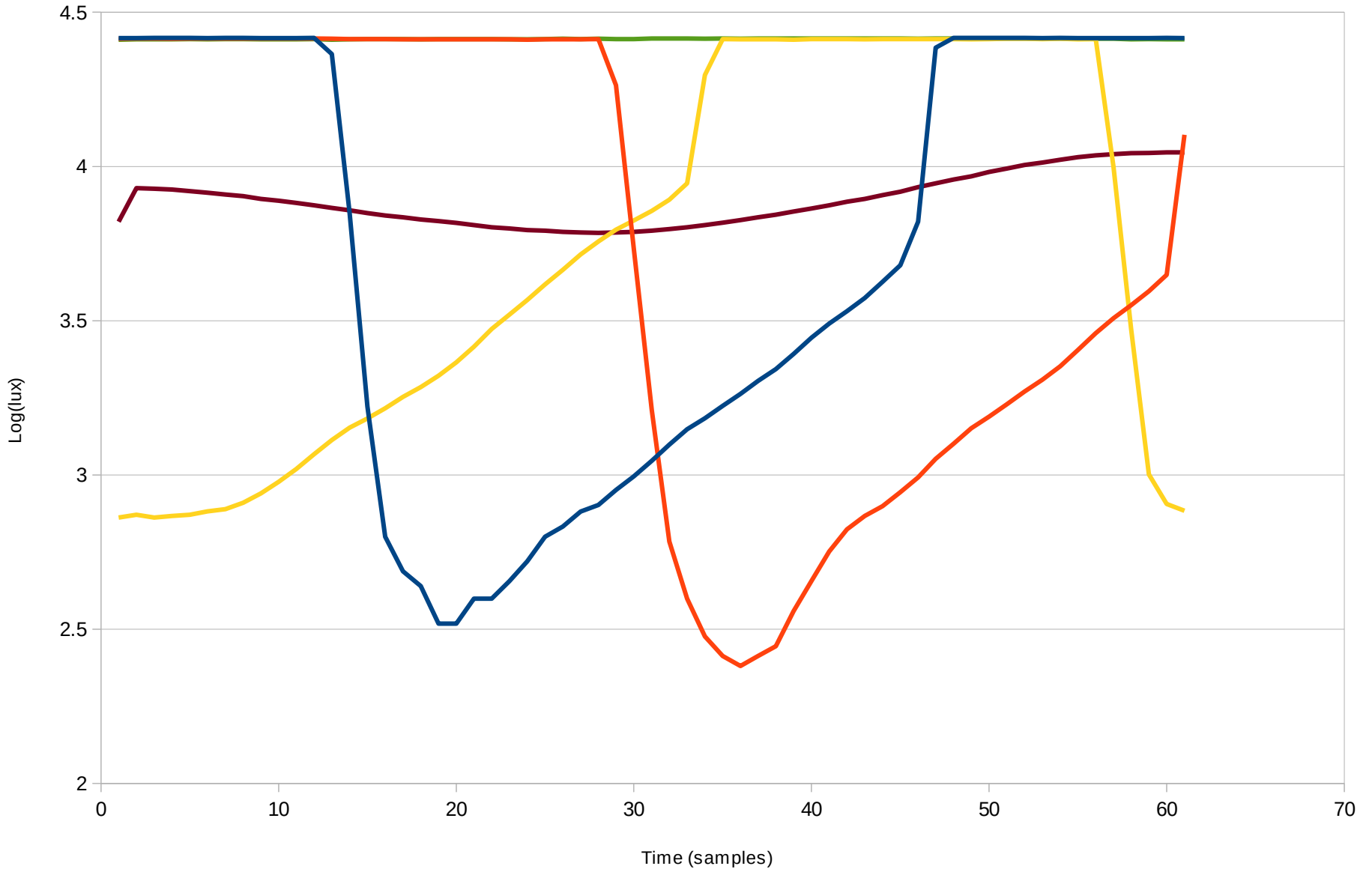




Temperature vs sunlight

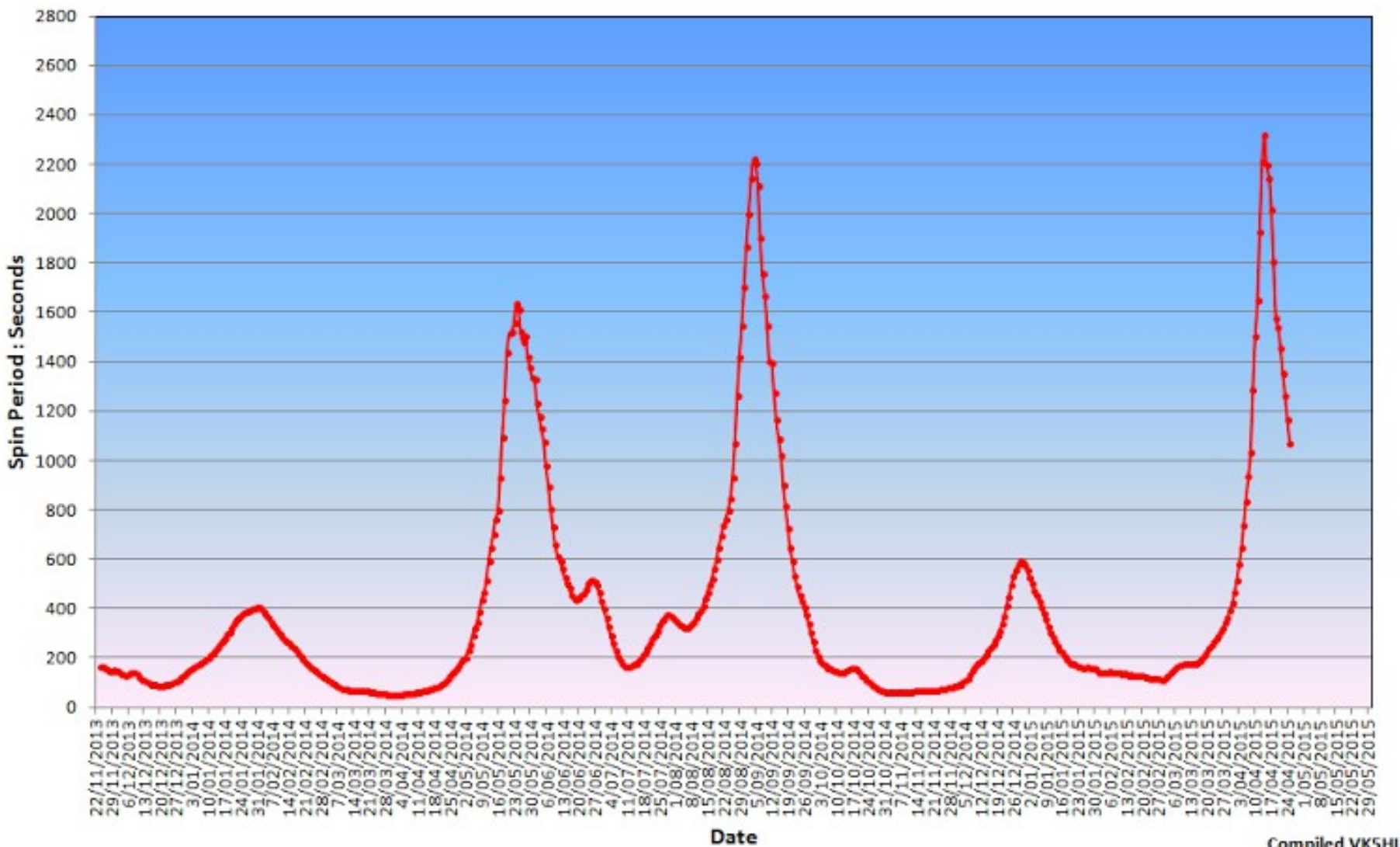


High-resolution sun sensor data



Sun Sensor +X log Lux Sun Sensor +Y log Lux Sun Sensor -Y log Lux Sun Sensor +Z log Lux Sun Sensor -Z log Lux

AO-73 : Spin Period (Averaged Data - 5 values)



Compiled VK5HI



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Data recovery

FC1 has broadcast 2.3GB of data, of which 552MB of realtime information has been recovered by ground stations around the world. (~25%)

Whole Orbit Data (WOD): recovered 83%

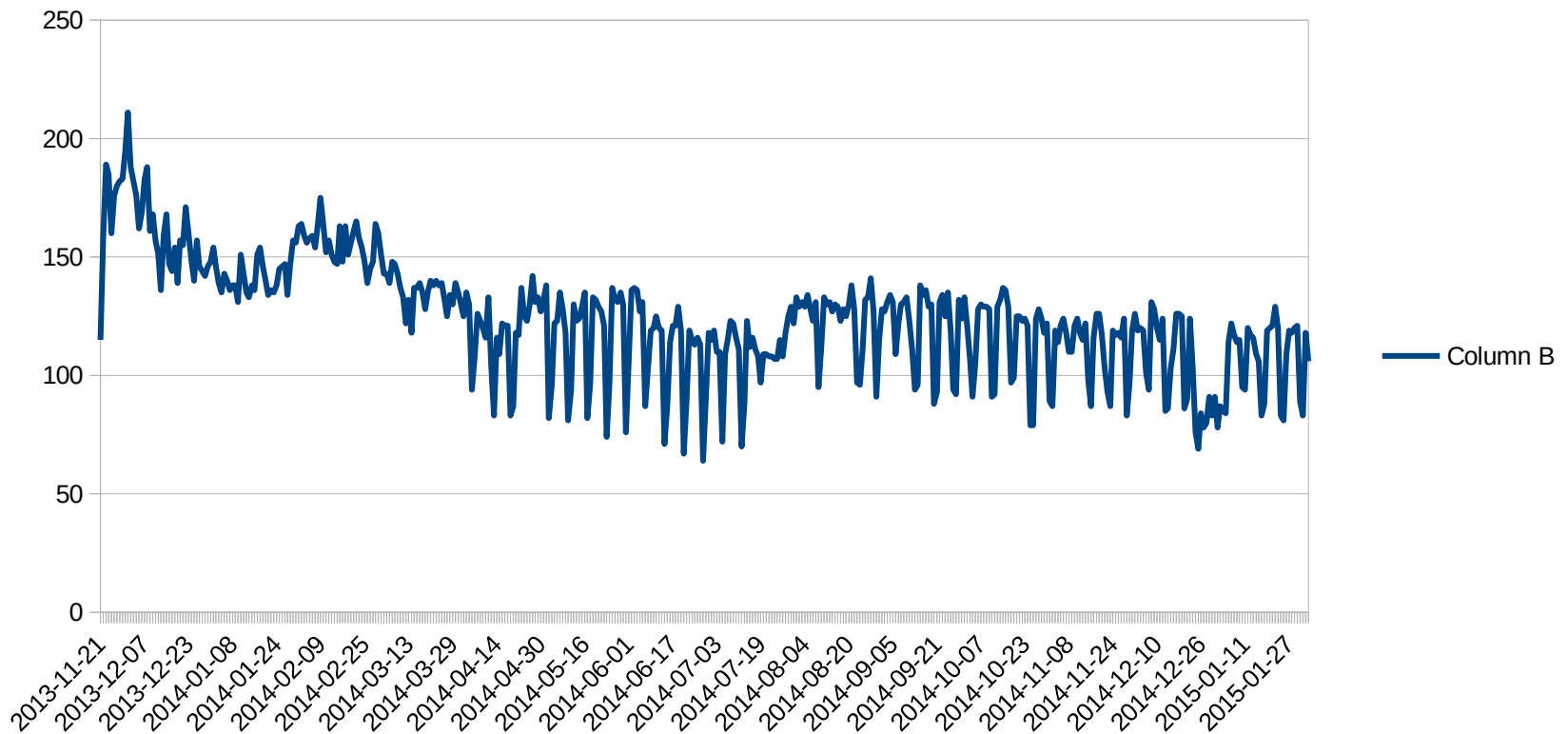
High Resolution Data (HiRes): recovered 20%



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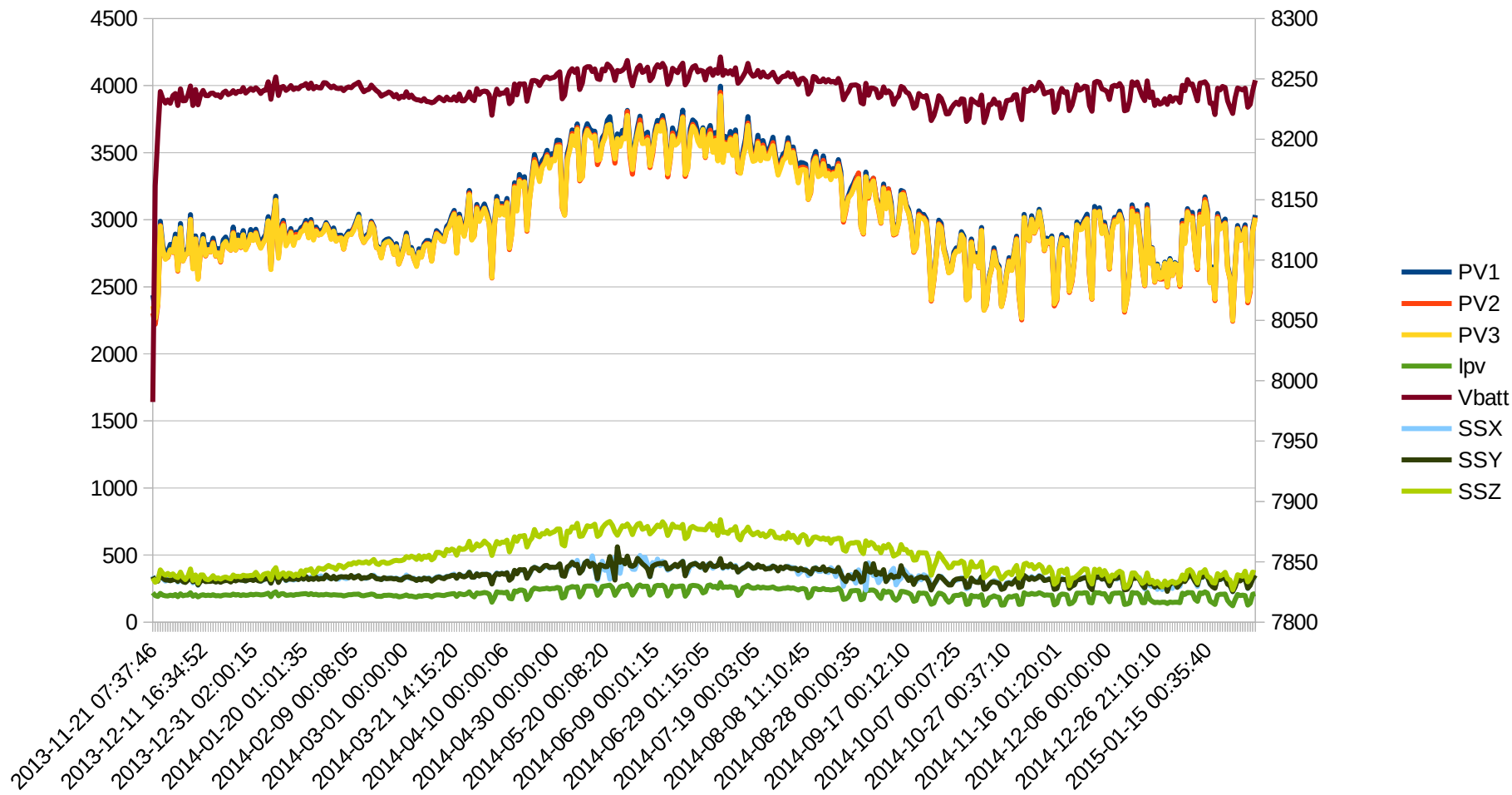
Amount of active users per day



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Yearly cycle





MinMax

Min-max external temps: -22 to +31 C

Min-max internal temps: -9 to +20 C

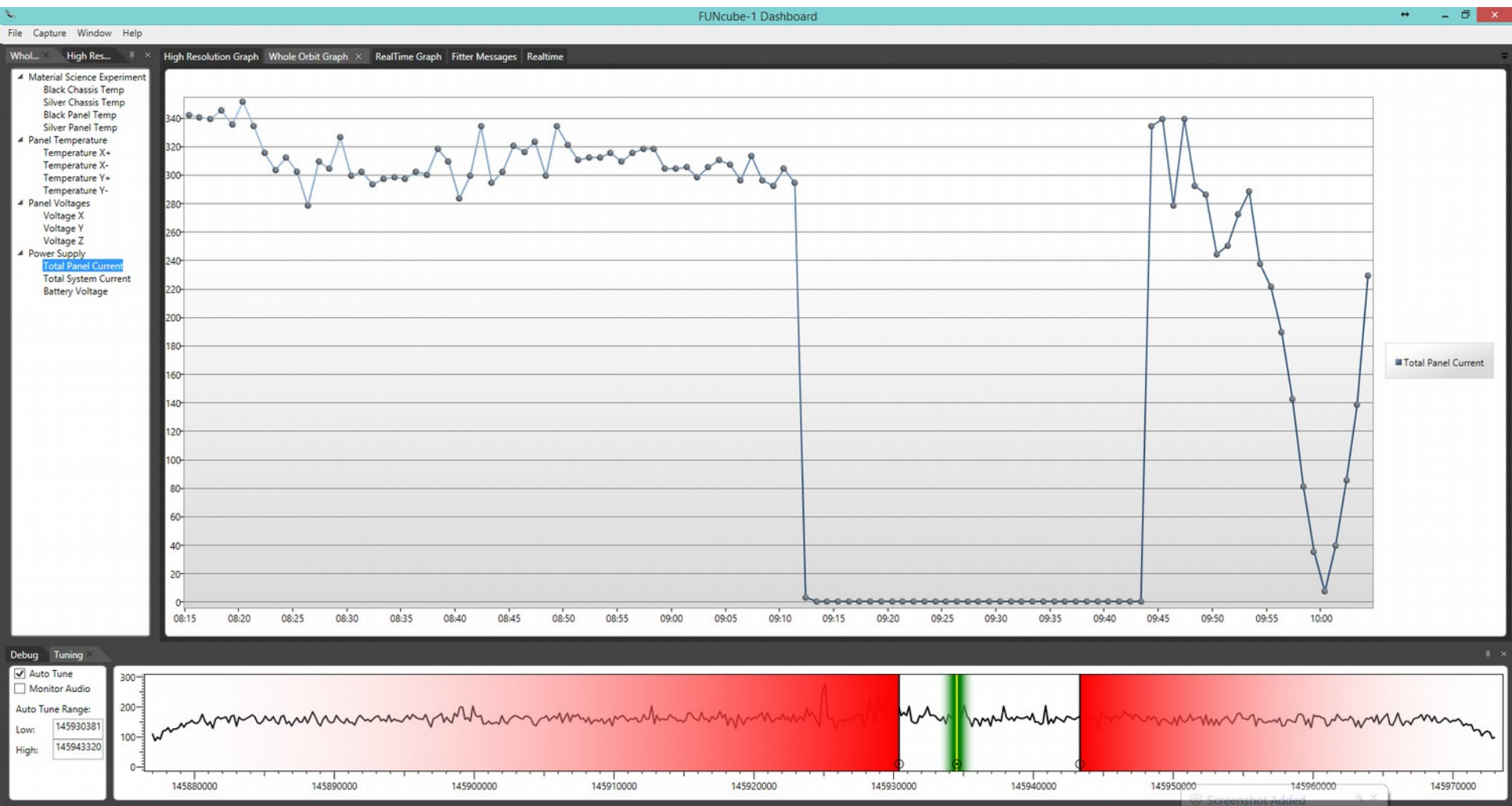
Min-max battery volts:: 8.01 to 8.4 V



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Solar eclipse 20th of May 2015



/: Within 1 week, within 2 weeks, greater than 2 weeks

| Site Id | Count | Position |
|---------|--------|----------|
| g0mjlw | 281774 | 1 |
| OM3BC | 240561 | 2 |
| KC0BMF | 188788 | 3 |
| SP8CGR | 172055 | 4 |
| HB9MFL | 167326 | 5 |
| VK5HI | 165453 | 6 |
| SP5ULN | 142858 | 7 |
| PB0AHX | 140356 | 8 |
| VK5GU | 136608 | 9 |
| wa6fwf | 126900 | 10 |
| n8mh | 124836 | 11 |
| lu4eou | 121226 | 12 |
| K9CIS | 109366 | 13 |
| 7J1ADJ | 107725 | 14 |
| ISIS | 105730 | 15 |
| dk3wn | 103550 | 16 |
| N7ZO | 102945 | 17 |
| PE1DRN | 97957 | 18 |



Comparison of Delfi-C3 and FUNcube-1 data return

Number of registered users: 1529 for FUNcube-1, 388 for Delfi-C3

Number of active users: 818 vs 204

percentage of active users: 53.5% vs 52.6%



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Multiple missions!

FUNcube-1 was just the start:

- FUNcube-2 on Ukube-1
- FUNcube-3 on QB50p1
- FUNcube-4 on ESEO
- FUNcube-5 on Nayif-1



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FUNcube-2 on Ukube-1



FUNcube payload on Ukube-1, UKSAs first CubeSat

Contains CCT, RF and PA boards

Runs telemetry and transponder



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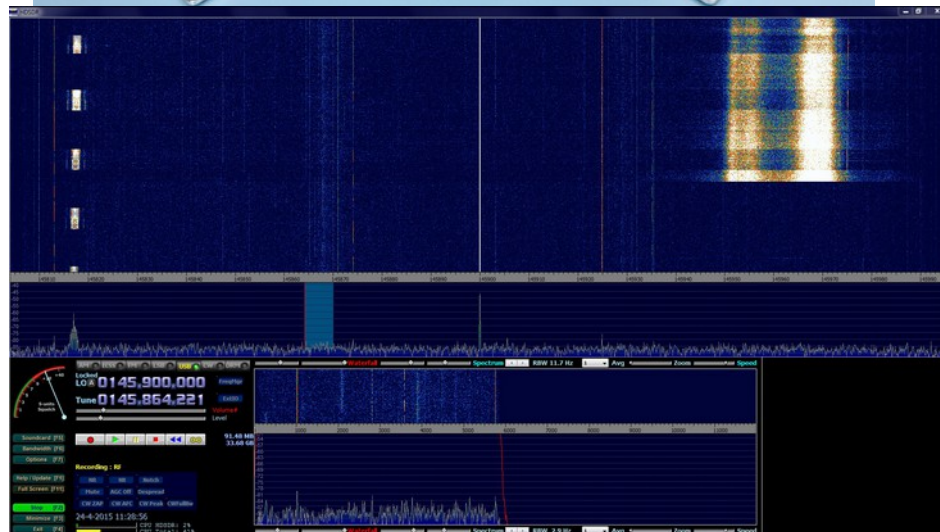
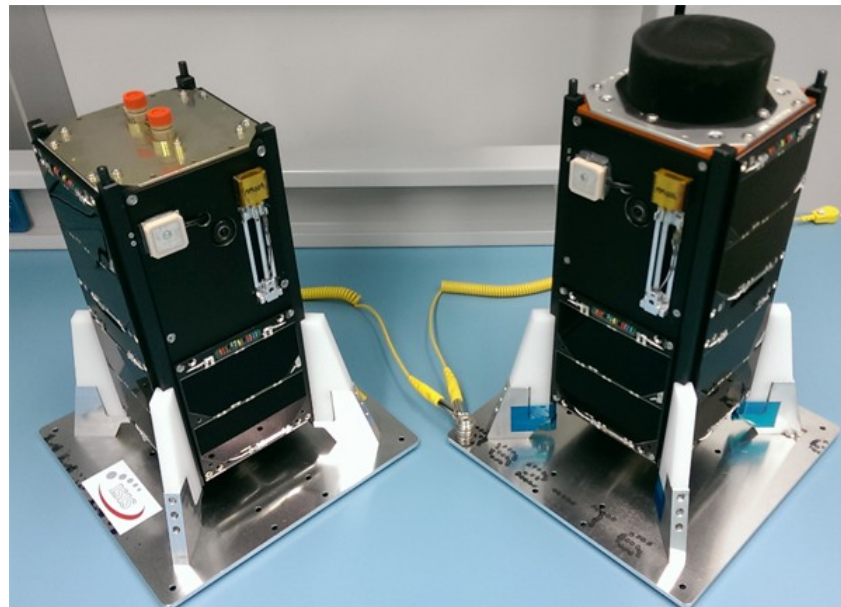
FUNcube-3 on QB50p1 (EO-79)

QB50 project precursor satellites

Contains only RF and PA boards

No FUNcube telemetry downlink

Only transponder when main mission is over



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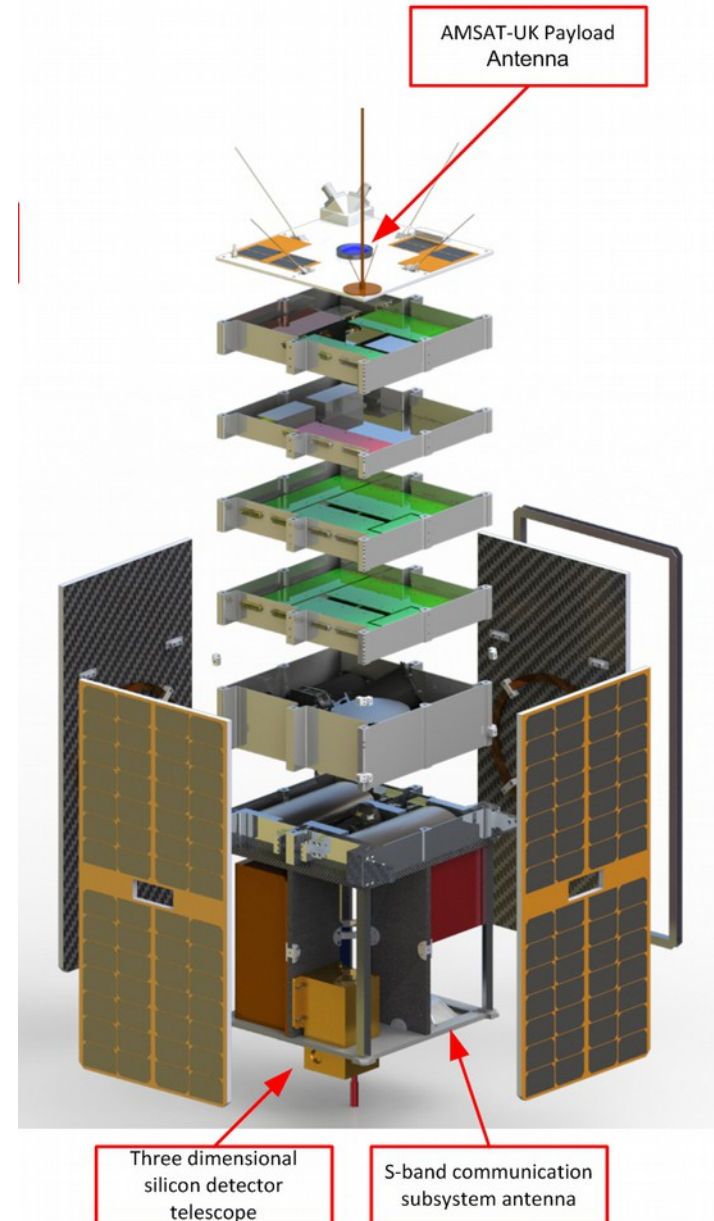
FUNcube-4 on ESEO

ESA project!

Complete redesign
to fit ESA guidelines

Will have FUNcube
telemetry downlink

Will have L-band
uplink for FM
transponder



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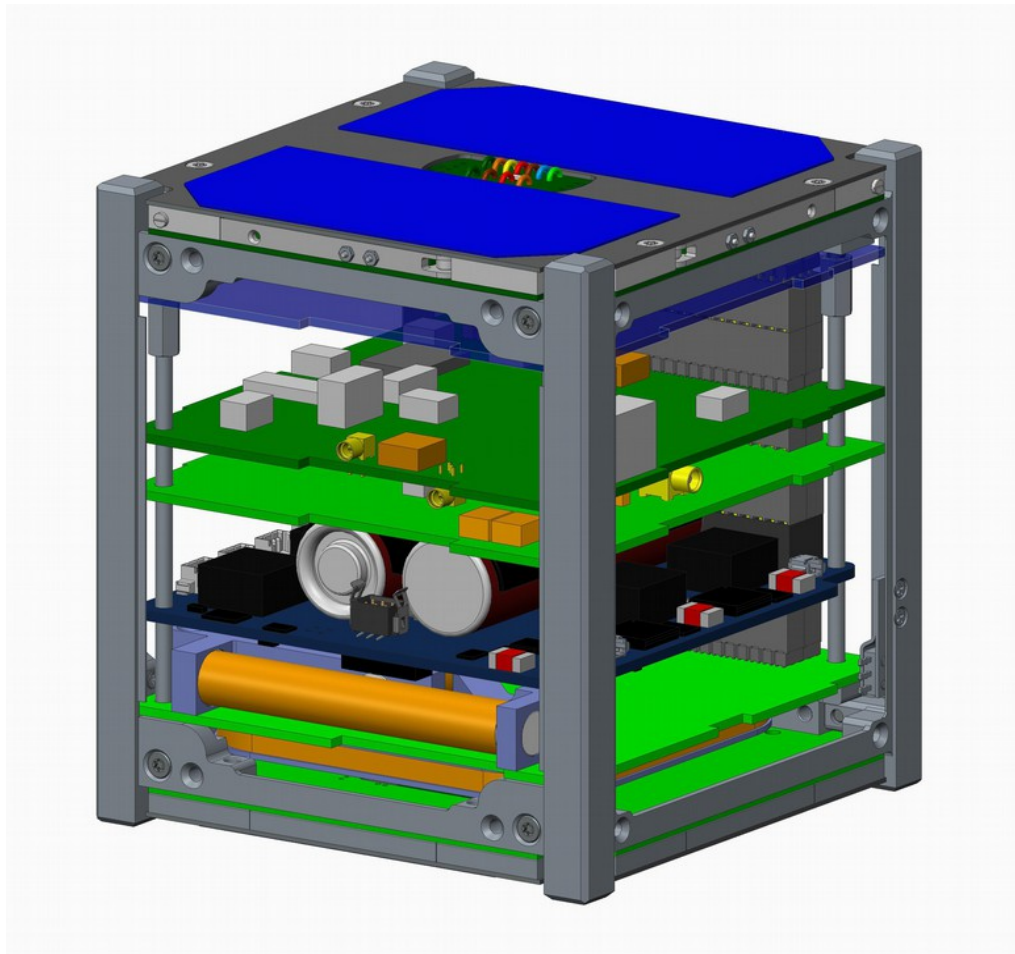
FUNcube-5 on Nayif-1

Complete mission!

Will contain the same systems as FUNcube-1

Will function in a similar fashion

Announced to the community TODAY



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Nayif-1 details

FUNcube communications package selected as payload
Provide Emirati students with a tool to design and test systems in space.

Developed by the Emirates Institution for Advanced Science and Technology (EIAST) in partnership with American University of Sharjah (AUS)

New, enhanced, UHF to VHF linear transponder

Collaboration with support partner, ISIS - Innovative Solutions In Space B.V.

Launch scheduled to take place towards the end of this year



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Thanks for your attention!

Any questions?

Wouter Weggelaar: pa3weg@amsat.org

FUNcube websites: <http://funcube.org.uk>
and <http://funcubedongle.com>

AMSAT-UK website: <http://amsat-uk.org>

AMSAT-NL website: <http://amsat-nl.org>

