The FUNcube Project – the background

Given that:

Cubesats are “cheap”

Cubesats can be built quickly

Cubesats should be “simple”

So in 2009 we asked ourselves:

Could we create an educational outreach mission?

Could it also have a amateur transponder?

Could we create a team of volunteers with the skills/passion?

Could we develop the actual educational outreach?

Could we fund it?

AMSAT-UK

AMSAT-UK FUNcube Fun in space with Amateur Radio

The FUNcube Project – primary objective

- EDUCATIONAL OUTREACH
- STEM subjects
  - Radio – practical understanding of communication
  - Electronics – how radios work
  - Physics – Data from 40+ 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

AMSAT-UK

The spacecraft transmits 1k2 BPSK telemetry on 145.915MHz

AMSAT-UK FUNcube Fun in space with Amateur Radio

Amateur radio operations

- During the local night (eclipse) the sub-system switches into amateur radio mode:
- Receives on UHF (435.080 – 435.060 MHz) and transmits on VHF (145.930 – 145.950 MHz)
- 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

AMSAT-UK

AMSAT-UK FUNcube Fun in space with Amateur Radio

The “Ground Segment”- the FUNcube dongle

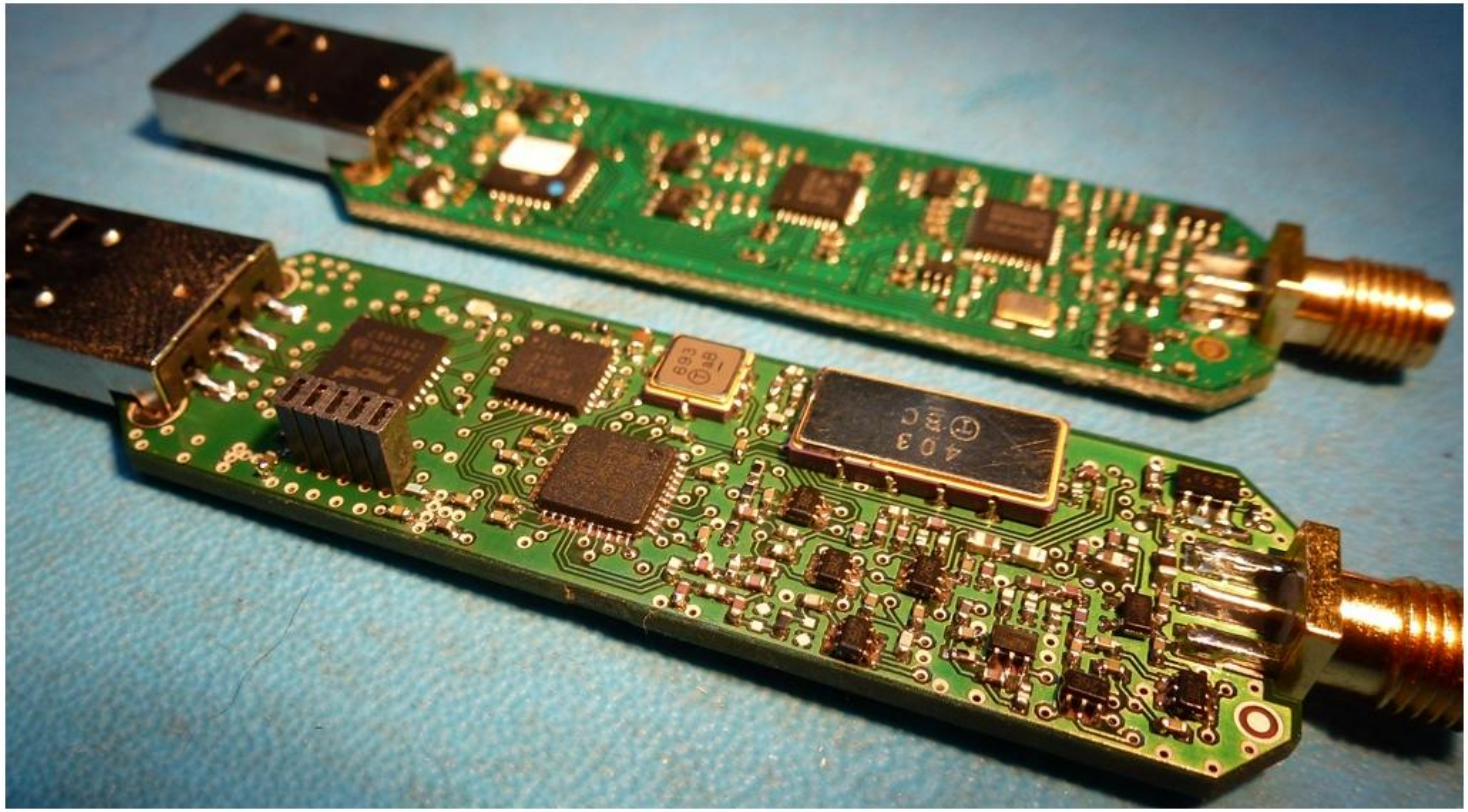
- An SDR radio designed and built by Howard Long G6LVB
- The Pro+ version covers 150 KHz -1.9 GHz
- 192kHz bandwidth I/Q output – works with all freeware SDR software & any OS
- Possibilities for remote reception networks /parallel processing

AMSAT-UK

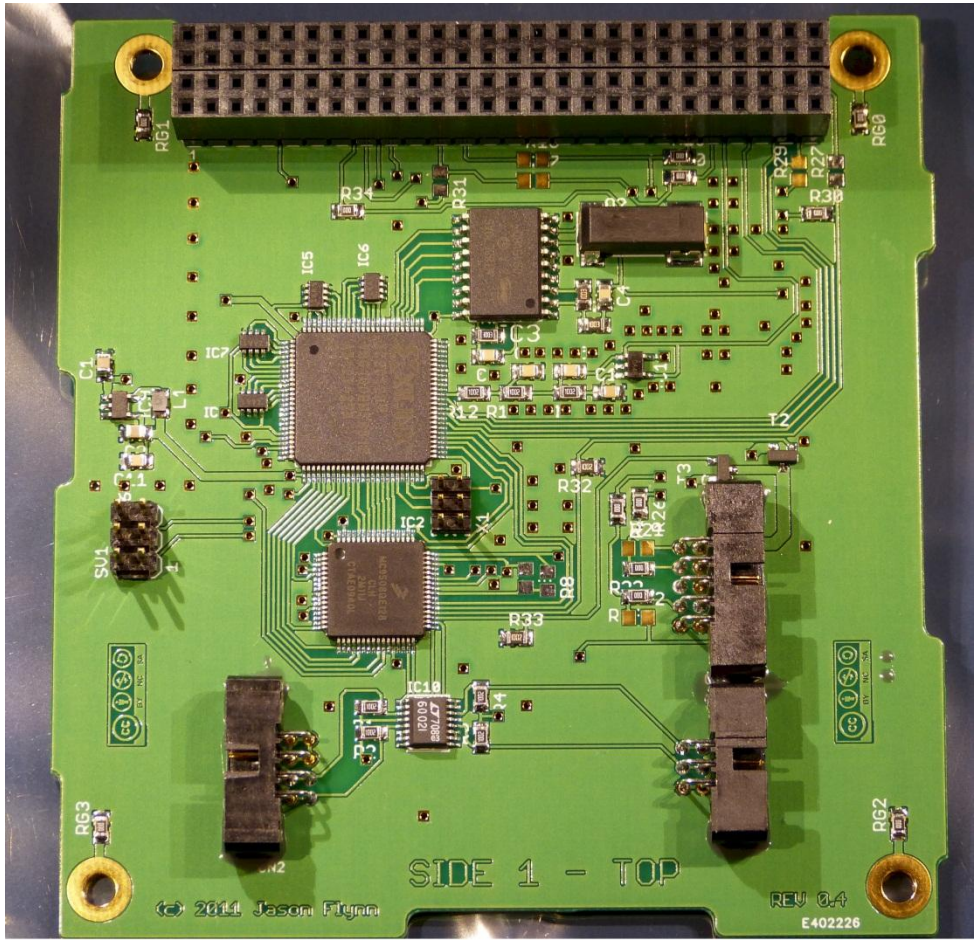
AMSAT-UK FUNcube Fun in space with Amateur Radio

AMSAT-UK

The “Ground Segment”- the FUNcube dongle



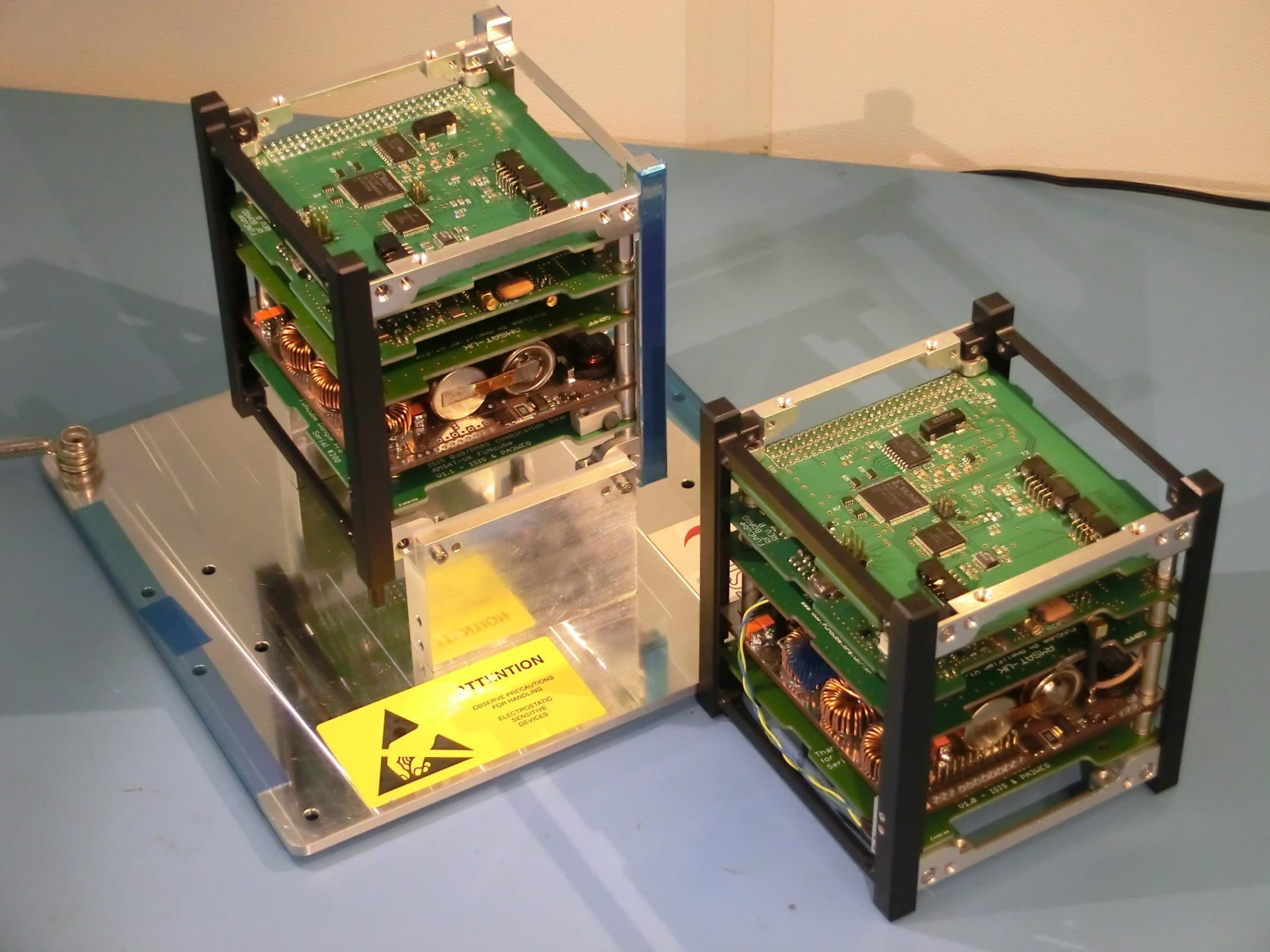
FUNcube-1 Hardware



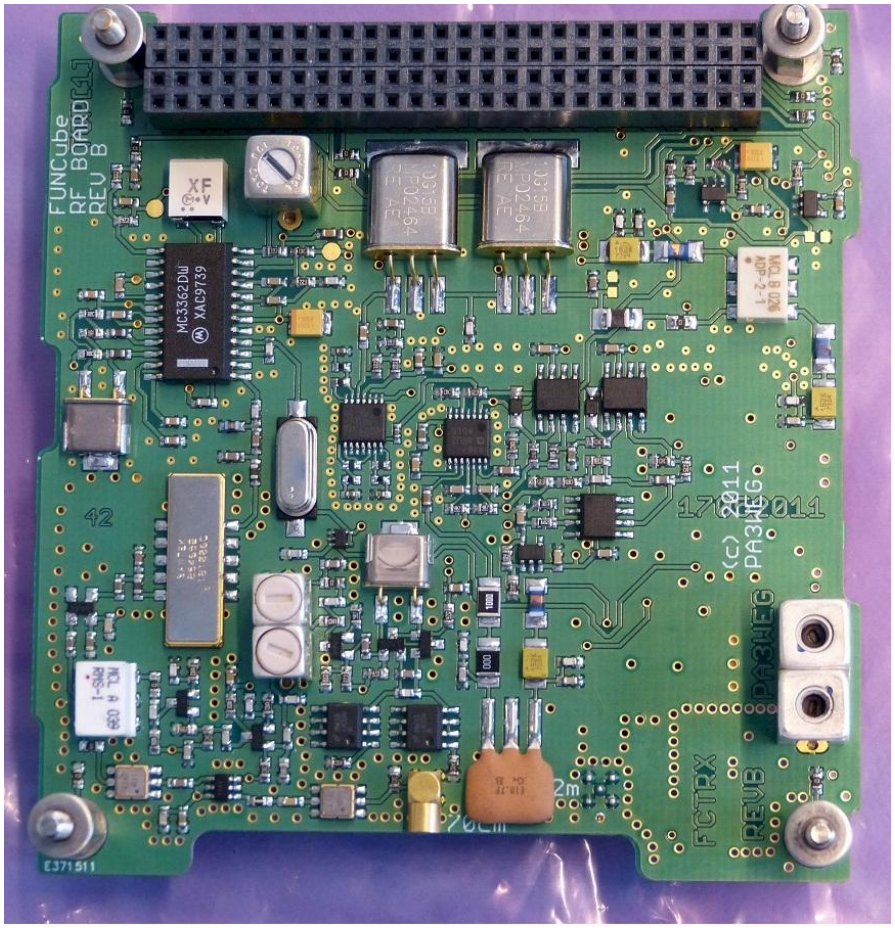
Command Control + Telemetry Board

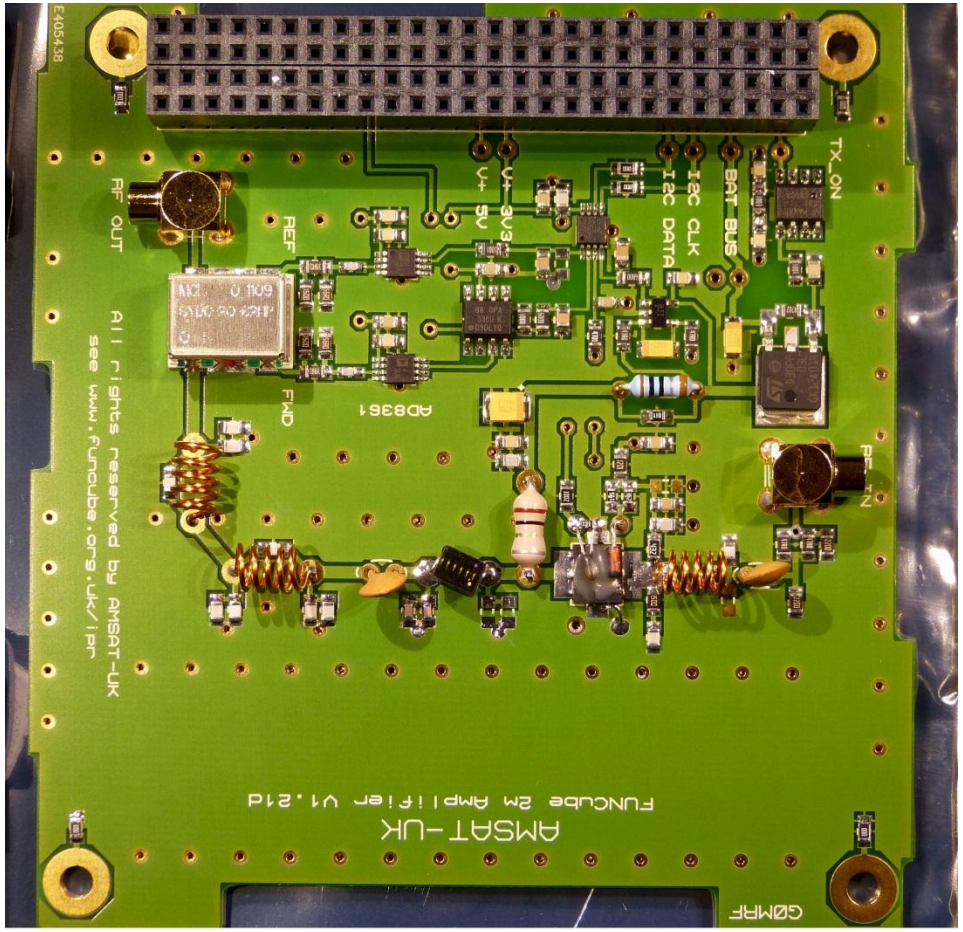
- Xilinx CPLD command decoder
- Freescale CPU for telemetry generation
- 2 x I2C Bus

- 3.3V supply
- Average power consumption 15mW
- Peak power 33mW


ATTENTION
OBSERVE PRECAUTIONS
FOR HANDLING
ELECTROSTATIC
SENSITIVE
DEVICES

FUNcube-1 Hardware

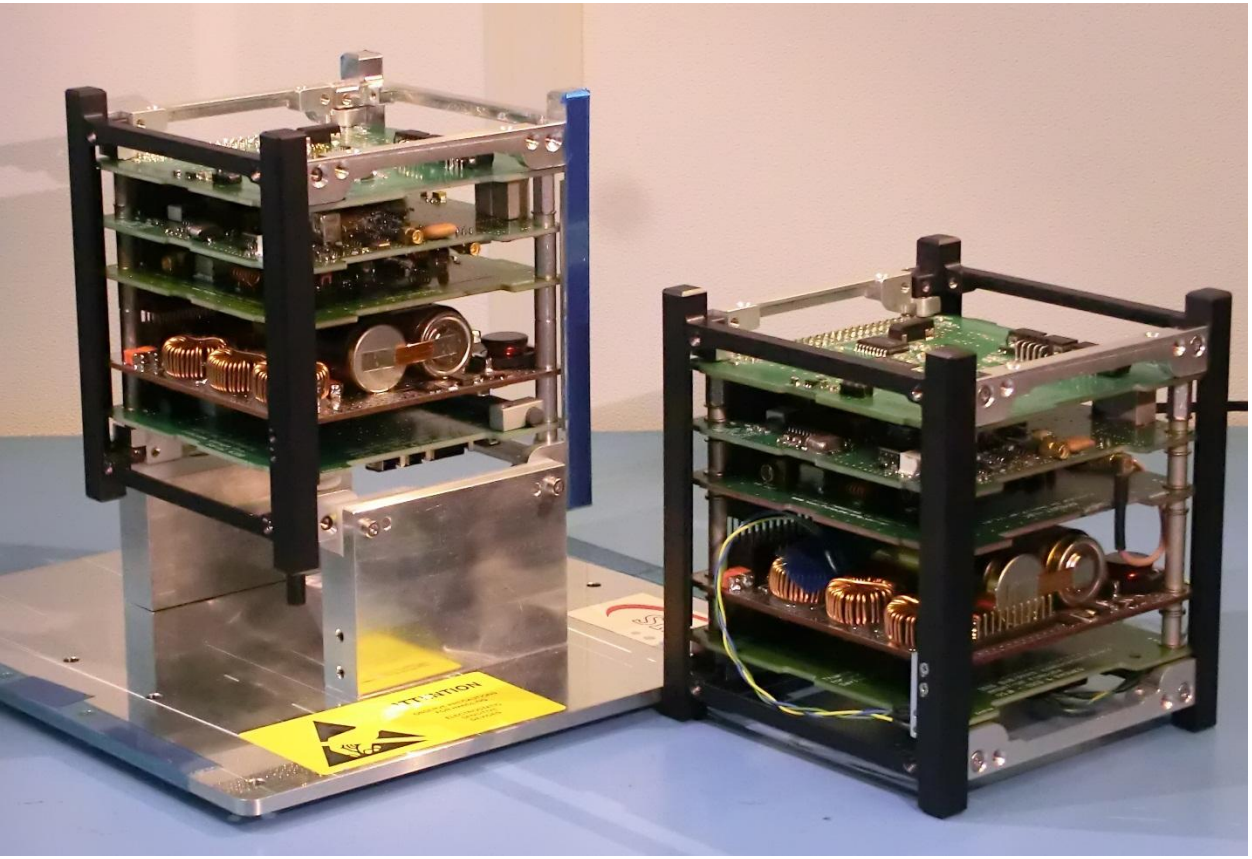




RF Board PA3WEG
Command receiver + 19kHz UV transponder
Also (end of life) FM to DSB

145 MHz Amplifier G0MRF
RD02MUS1 FET + 4 channels of telemetry
via I2C bus

FUNcube-1 Hardware



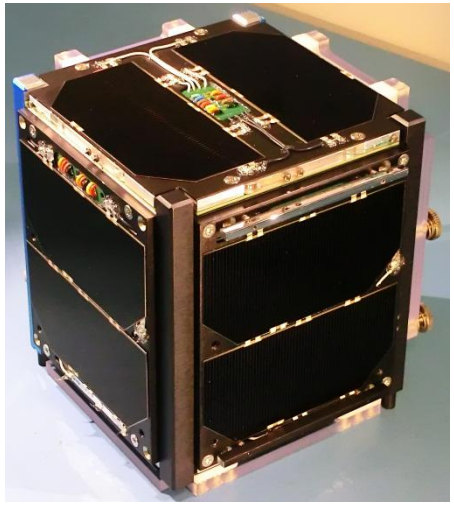
Flight model

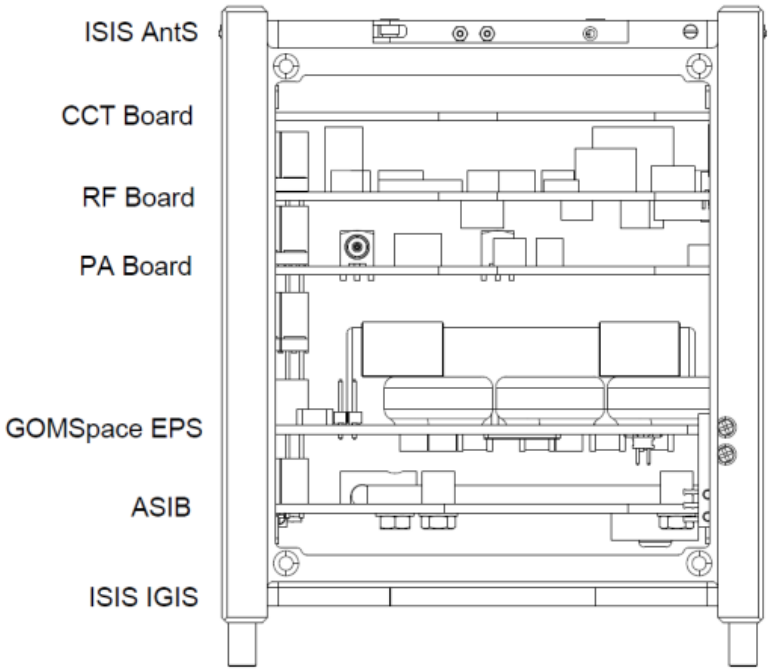
Engineering model

CCT board AMSAT-UK
Transponder AMSAT-NL
2m Amplifier AMSAT-UK
Power system Denmark
Structure ISIS (Netherlands)
Antenna system ISIS

Solar panels:
Solar cells Germany
Aluminium mounting Israel
Assembled in Italy

FUNcube-1 Telemetry





1200 BPS BPSK with forward error correction with 54 Telemetry channels

Telemetry is sent in 24 x 5second 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

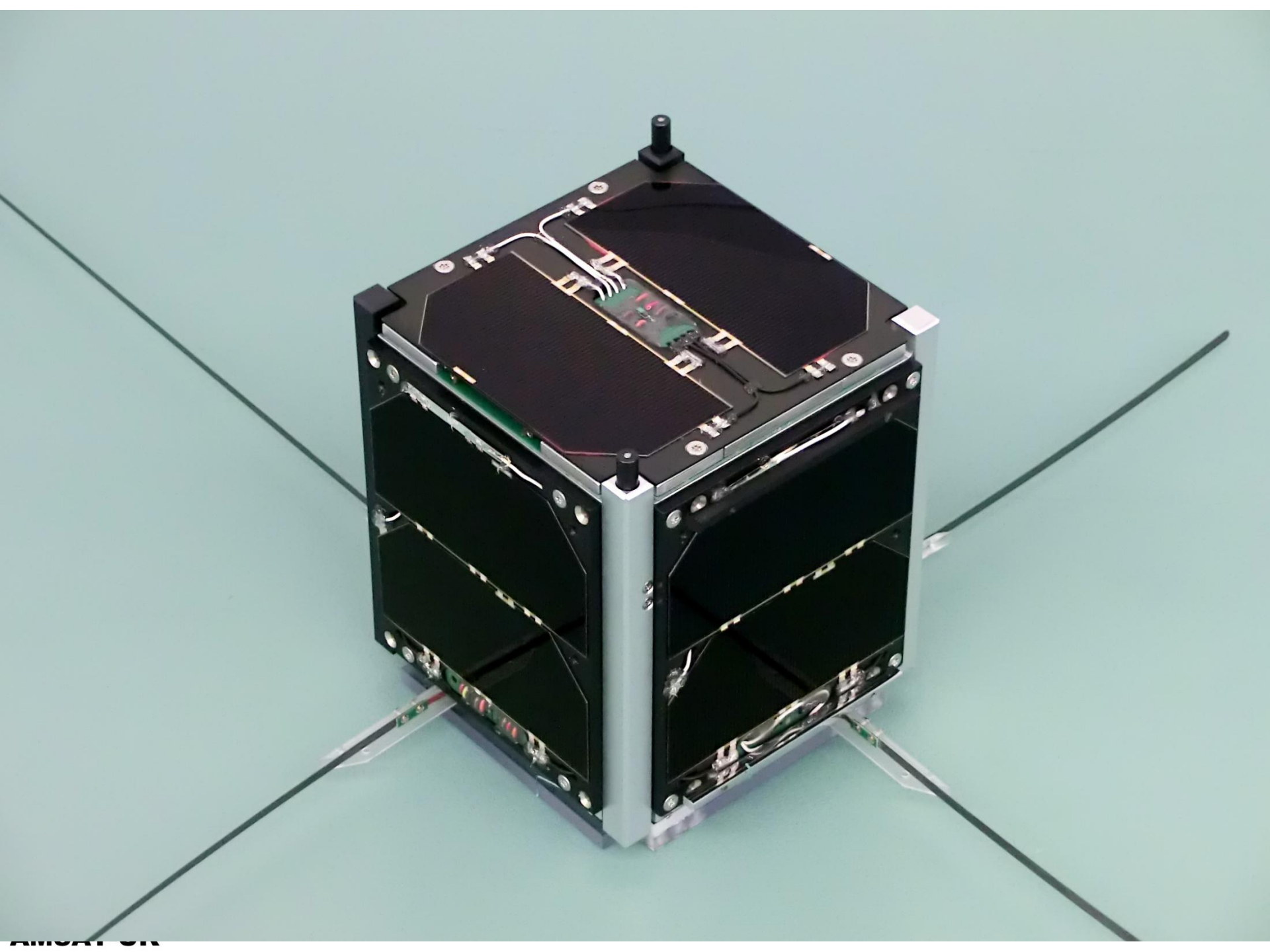
Very distinctive sound to enable easy identification
4.3 seconds of data + 0.7 seconds of BPSK mark tone

The FUNcube Project

The final frequencies

Downlink	FUNcube FM	Ukube FM	FUNcube EM	Ukube EM
Transponder passband low	**145.950 Mhz**	**145.930 Mhz**	**145.960 Mhz**	**145.940 Mhz**
Transponder passband high	**145.970 Mhz**	**145.950 Mhz**	**145.980 Mhz**	**145.960 Mhz**
Passband center	145.960 Mhz	145.940 Mhz	145.970 Mhz	145.950 Mhz
Bandwidth	20.000 kHz	20.000 kHz	20.000 kHz	20.000 kHz
Telemetry	**145.935 Mhz**	**145.915 Mhz**	**145.955 Mhz**	**145.935 Mhz**
Uplink				
Transponder passband low	**435.130 Mhz**	**435.060 Mhz**	**435.060 Mhz**	**435.040 Mhz**
Transponder passband high	**435.150 Mhz**	**435.080 Mhz**	**435.080 Mhz**	**435.060 Mhz**
Passband center	435.140 Mhz	435.070 Mhz	435.070 Mhz	435.050 Mhz
Bandwidth	20.000 kHz	20.000 kHz	20.000 kHz	20.000 kHz

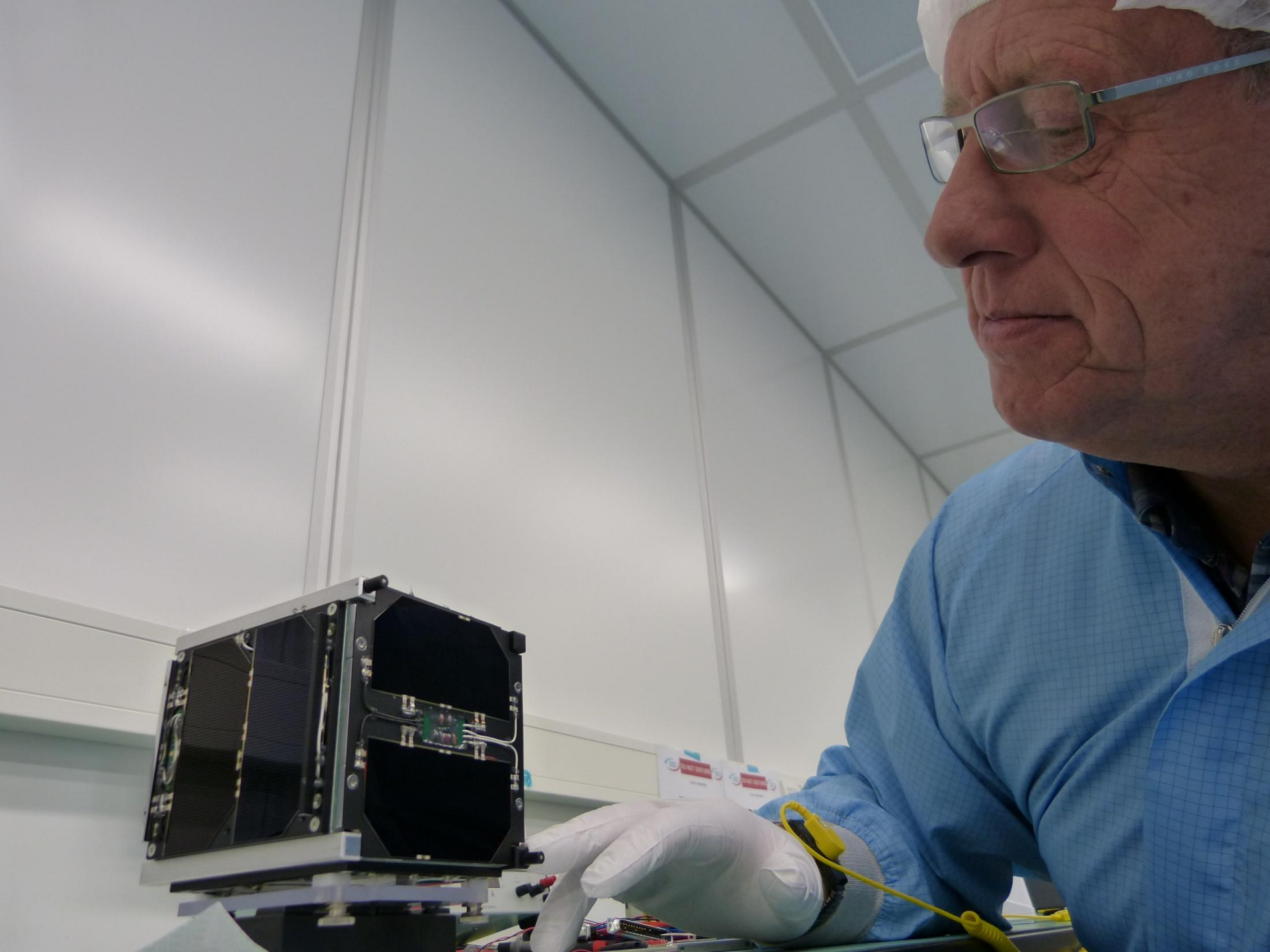
AMSAT-UK



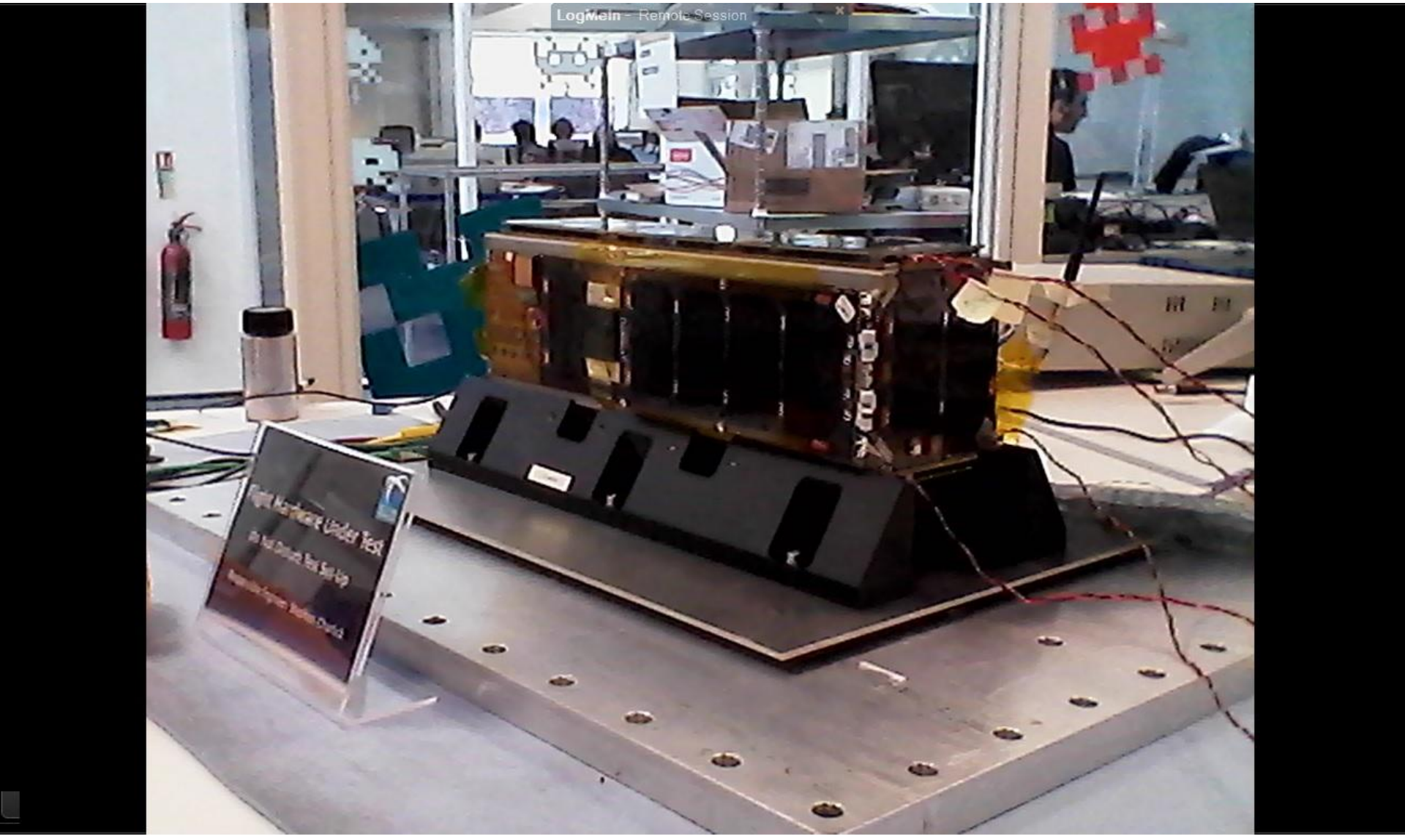
The FUNcube Project – ants deployment video

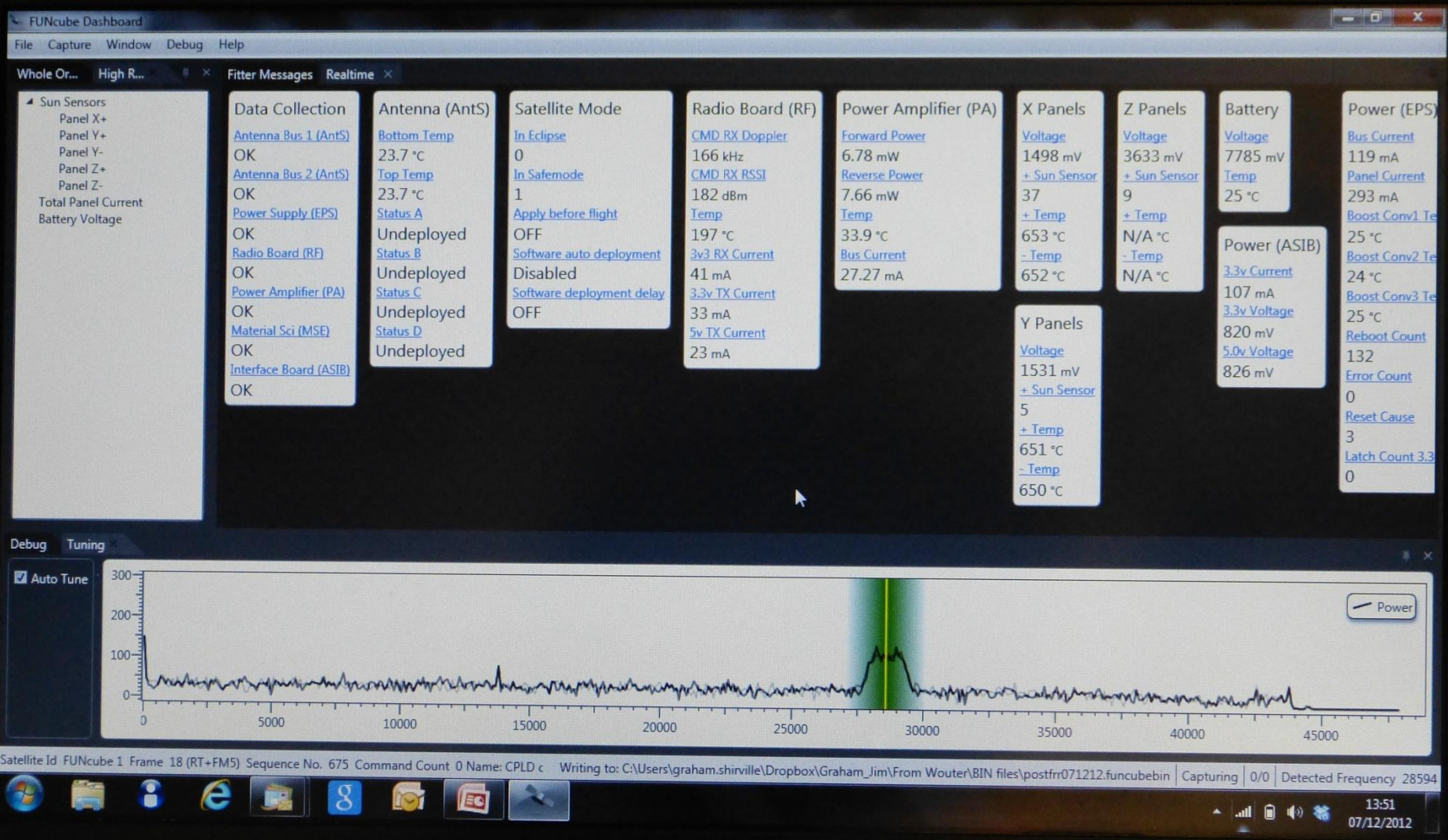
http://FUNcube-1 video

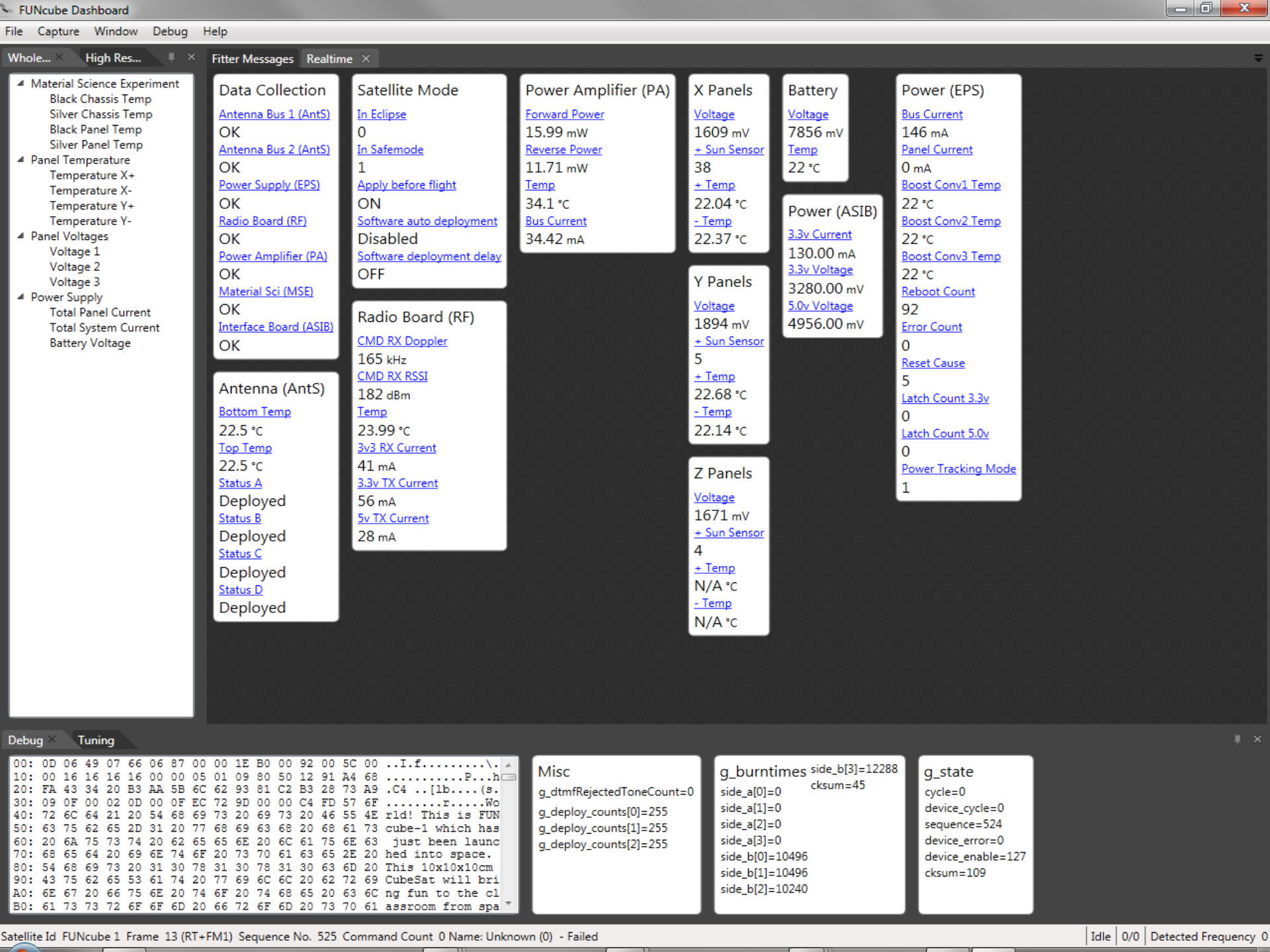
AMSAT-UK



The FUNcube Project – FC2 status




FUNcube Dashboard
File Capture Window Debug Help
Whole Or... High R...
Sun Sensors
Panel X+
Panel Y+
Panel Y-
Panel Z+
Panel Z-
Total Panel Current
Battery Voltage
Fitter Messages Realtime
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
23.7 °C
Top Temp
23.7 °C
Status A
Undeployed
Status B
Undeployed
Status C
Undeployed
Status D
Undeployed
Satellite Mode
In Eclipse
0
In Safemode
1
Apply before flight
OFF
Software auto deployment
Disabled
Software deployment delay
OFF
Radio Board (RF)
CMD RX Doppler
166 kHz
CMD RX RSSI
182 dBm
Temp
197 °C
3v3 RX Current
41 mA
3.3v TX Current
33 mA
5v TX Current
23 mA
Power Amplifier (PA)
Forward Power
6.78 mW
Reverse Power
7.66 mW
Temp
33.9 °C
Bus Current
27.27 mA
X Panels
Voltage
1498 mV
+ Sun Sensor
37
+ Temp
653 °C
- Temp
652 °C
Y Panels
Voltage
1531 mV
+ Sun Sensor
5
+ Temp
651 °C
- Temp
650 °C
Z Panels
Voltage
3633 mV
+ Sun Sensor
9
+ Temp
N/A °C
- Temp
N/A °C
Battery
Voltage
7785 mV
Temp
25 °C
Power (ASIB)
3.3v Current
107 mA
3.3v Voltage
820 mV
5.0v Voltage
826 mV
Power (EPS)
Bus Current
119 mA
Panel Current
293 mA
Boost Conv1 Te
25 °C
Boost Conv2 Te
24 °C
Boost Conv3 Te
25 °C
Reboot Count
132
Error Count
0
Reset Cause
3
Latch Count 3.3
0
Debug Tuning
Auto Tune
300
200
100
0
0 5000 10000 15000 20000 25000 30000 35000 40000 45000
Power
Satellite Id FUNcube 1 Frame 18 (RT+FM5) Sequence No. 675 Command Count 0 Name: CPLD c
Writing to: C:\Users\graham.shirville\Dropbox\Graham_Jim\From Wouter\BIN files\postfrr071212.funcubebin
Capturing
0/0
Detected Frequency 28594
13:51
07/12/2012


FUNcube Dashboard
File Capture Window Debug Help
Whole... High Res...
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
Fitter Messages Realtime
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
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
Antenna (AntS)
Bottom Temp
22.5 °C
Top Temp
22.5 °C
Status A
Deployed
Status B
Deployed
Status C
Deployed
Status D
Deployed
Debug Tuning
00: 0D 06 49 07 66 06 87 00 00 1E B0 00 92 00 5C 00 ..I.f.....\.
10: 00 16 16 16 16 00 00 05 01 09 80 50 12 91 A4 68 ....P...h
20: FA 43 34 20 B3 AA 5B 6C 62 93 81 C2 B3 28 73 A9 .C4 ..[lb....(s.
30: 09 0F 00 02 0D 00 0F EC 72 9D 00 00 C4 FD 57 6F ....r.....Wo
40: 72 6C 64 21 20 54 68 69 73 20 69 73 20 46 55 4E rld! This is FUN
50: 63 75 62 65 2D 31 20 77 68 69 63 68 20 68 61 73 cube-1 which has
60: 20 6A 75 73 74 20 62 65 65 6E 20 6C 61 75 6E 63 just been launc
70: 68 65 64 20 69 6E 74 6F 20 73 70 61 63 65 2E 20 hed into space.
80: 54 68 69 73 20 31 30 78 31 30 78 31 30 63 6D 20 This 10x10x10cm
90: 43 75 62 65 53 61 74 20 77 69 6C 6C 20 62 72 69 CubeSat will bri
A0: 6E 67 20 66 75 6E 20 74 6F 20 74 68 65 20 63 6C ng fun to the cl
B0: 61 73 73 72 6F 6F 6D 20 66 72 6F 6D 20 73 70 61 assroom from spa
Misc
g_dtmfRejectedToneCount=0
g_deploy_counts[0]=255
g_deploy_counts[1]=255
g_deploy_counts[2]=255
g_burntimes
side_a[0]=0
side_a[1]=0
side_a[2]=0
side_a[3]=0
side_b[0]=10496
side_b[1]=10496
side_b[2]=10240
side_b[3]=12288
cksum=45
g_state
cycle=0
device_cycle=0
sequence=524
device_error=0
device_enable=127
cksum=109
Satellite Id FUNcube 1 Frame 13 (RT+FM1) Sequence No. 525 Command Count 0 Name: Unknown (0) - Failed
Idle 0/0 Detected Frequency 0

FUNcube Dashboard

File Capture Window Debug Help

High Resolution

- Panel Voltages
  - Fixed X
  - Fixed Y
  - Fixed Z
  - Deployable +Y
  - Deployable -Y
- Batteries
  - Current 0
  - Current 1
  - Current 2

Whole Orbit | High Resolution

Fitter Messages | Realtime

Antenna (AntS)
Bottom Temp 255.0 °C
Top Temp N/A °C
Status A 4
Status B 4
Status C 4
Status D 4

Radio Board (RF)
CMD RX Doppler 0.00 mV
CMD RX RSSI 0.00 mV
Temp 193.67 °C
3v3 RX Current 0.00 mA
3.3v TX Current 0.00 mA
5v TX Current 0.00 mA

Active Magnetic Attitude Control
Magnetometer 0 0
Magnetometer 1 1
Magnetometer 2 19275
Temp 260

Satellite Mode
In Sunlight 1

Power Amplifier (PA)
Forward Power 0.00 mW
Reverse Power 0.00 mW
Temp 88.0 °C
Bus Current 2.54 mA

Panel Fix X
+ Current 1023 mA
- Current 1023 mA
Temp N/A °C

Panel Dep +X
+ Current 1023 mA
- Current 628 mA
Temp 0 °C

Battery 0
Voltage 40 mV
Cell Voltage 160 mV
Current 226 mA
Current Direction 0
Temp 141 °C

Battery 2
Voltage 39 mV
Cell Voltage 160 mV
Current 227 mA
Current Direction 0
Temp 142 °C

Panel Fix Y
+ Current 1023 mA
- Current 1023 mA
Temp N/A °C

Panel Dep +Y
+ Current 1023 mA
- Current 1023 mA
Temp N/A °C

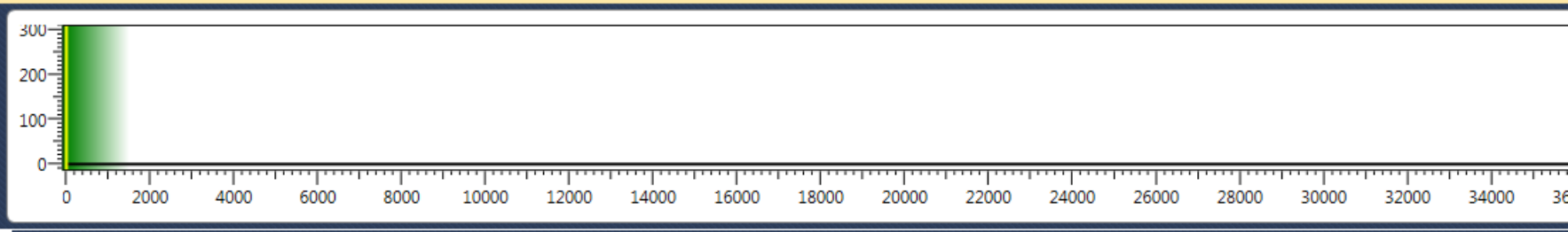
Battery 1
Voltage 40 mV
Cell Voltage 160 mV
Current 227 mA
Current Direction 1
Temp 141 °C

Panel Fix Z
+ Current 1023 mA
- Current 1023 mA
Temp N/A °C

Panel Dep -Y
+ Current 1023 mA
- Current 1023 mA
Temp N/A °C

Tuning

Auto Tune

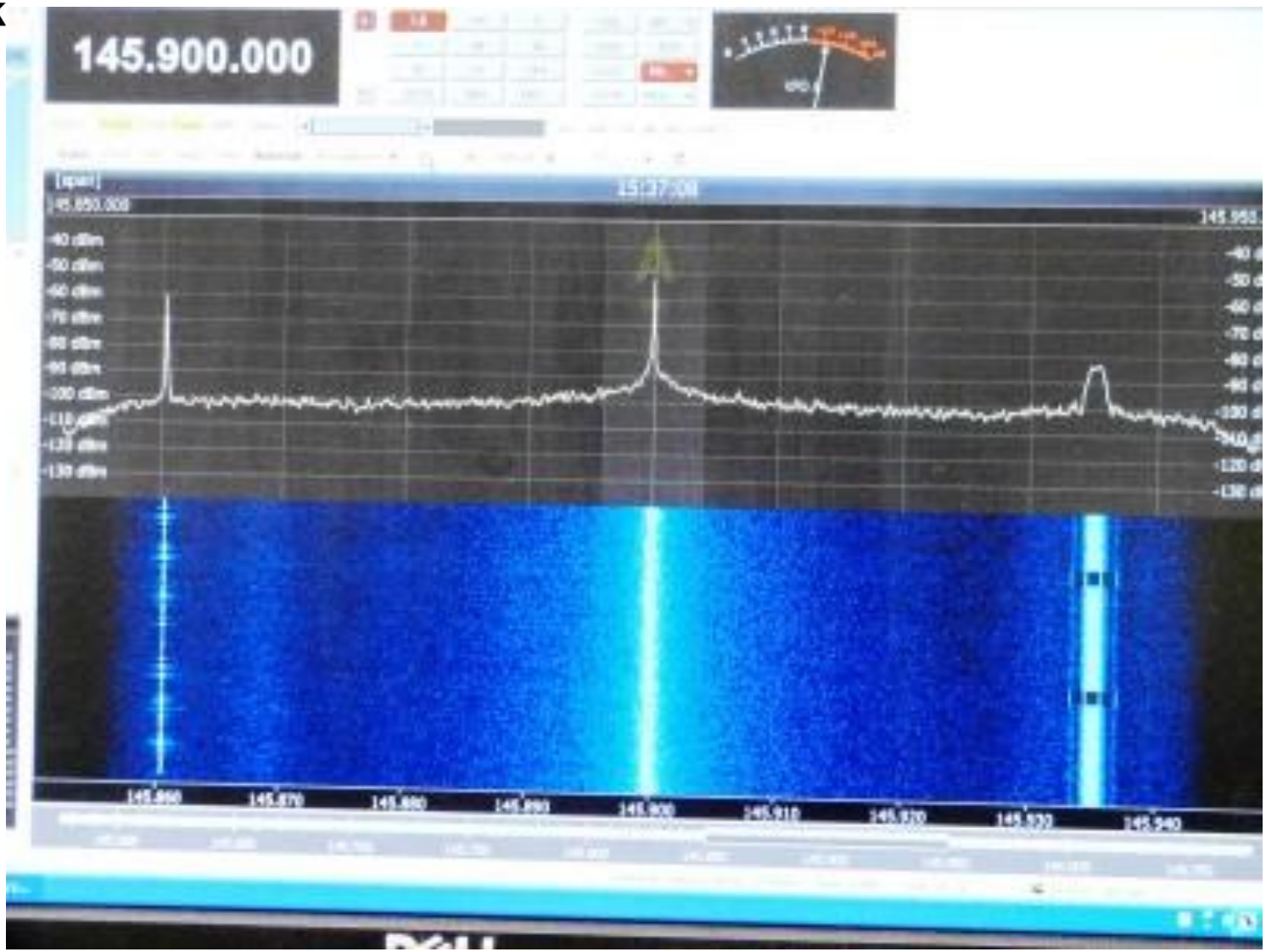


Debug | Tuning

Satellite Id FUNcube 2 on UKube Frame 18 (RT+FM5) Sequence No. 12504517 Command Count 0 Name: Unknown (0) - Failed

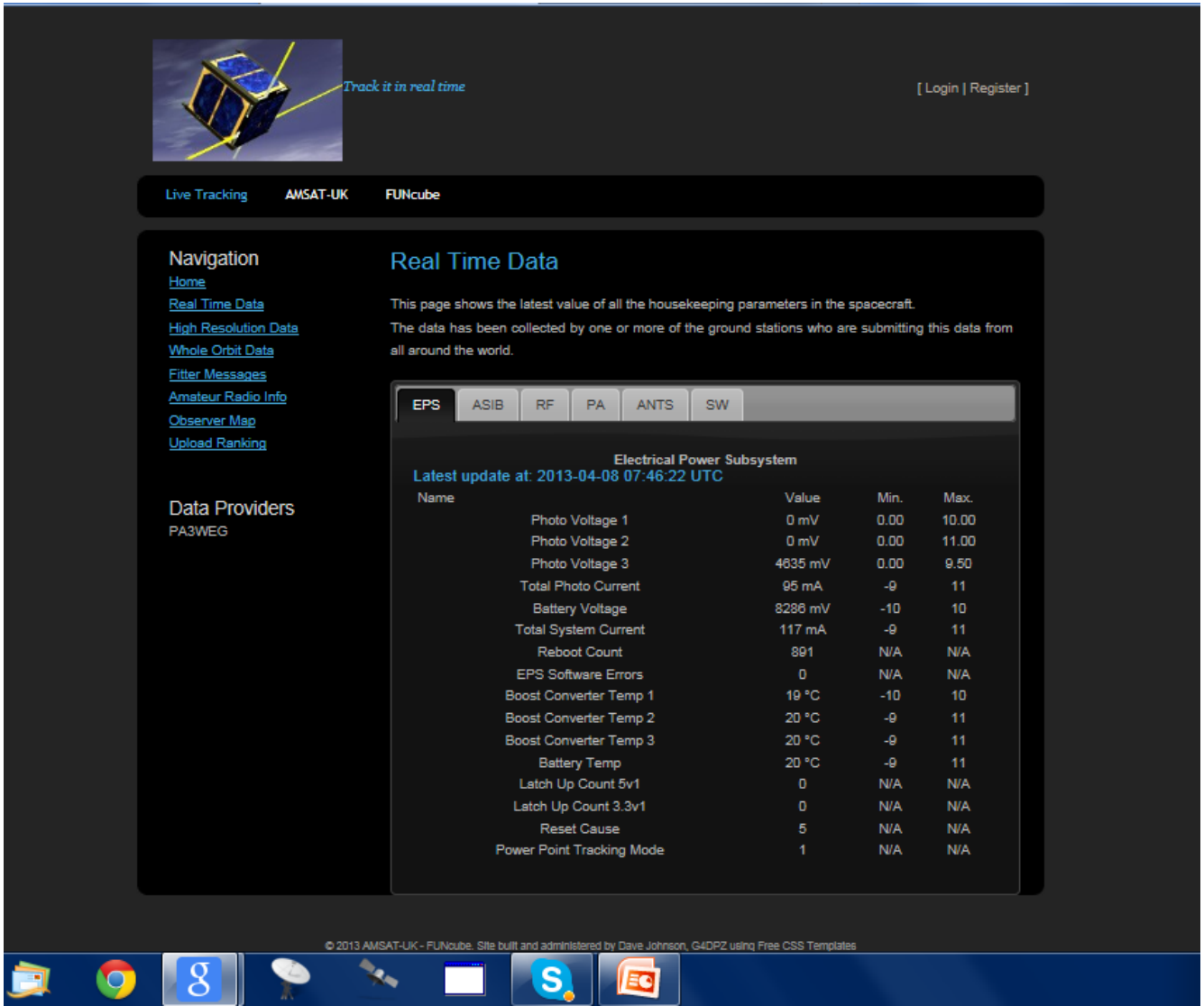
AMSAT-UK

What we expect to see after launch!



AMSAT-UK

The “Ground Segment”- The Data Warehouse

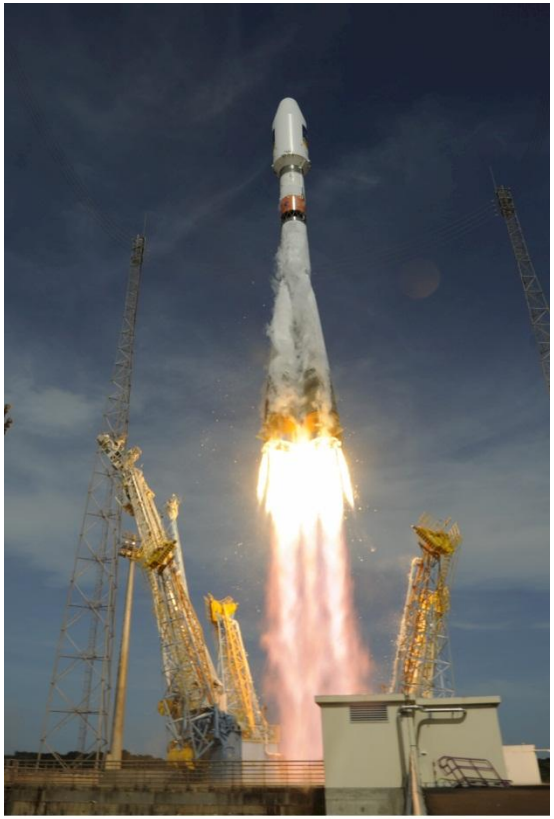


Launch status

FUNcube-1

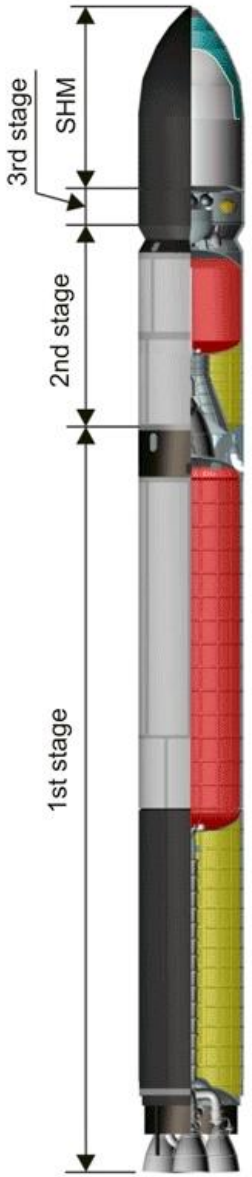
Dnepr Launch from Yasny, Russia
November 2013

FUNcube-2 sub system on UKube



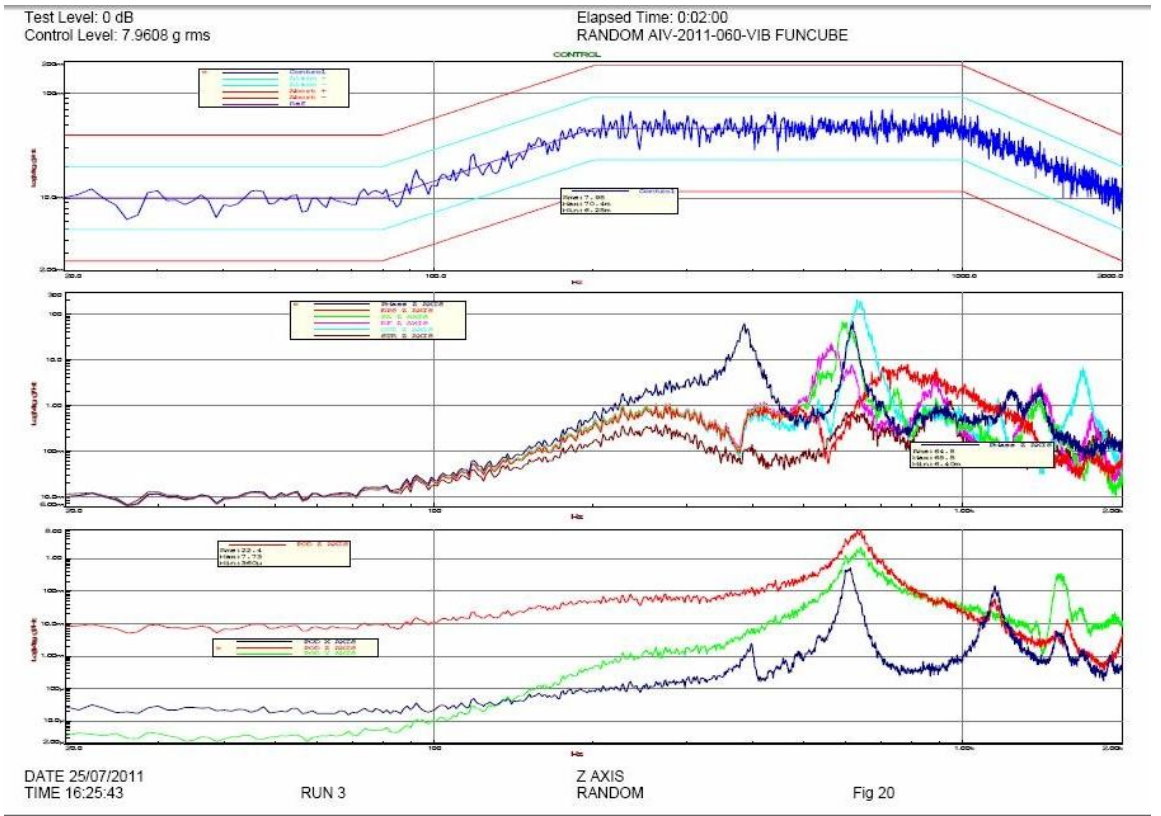
Soyuz launch from Baikonur, Khazakstan
October 2013

Dnepr Launch - SS-18 Intercontinental ballistic missile

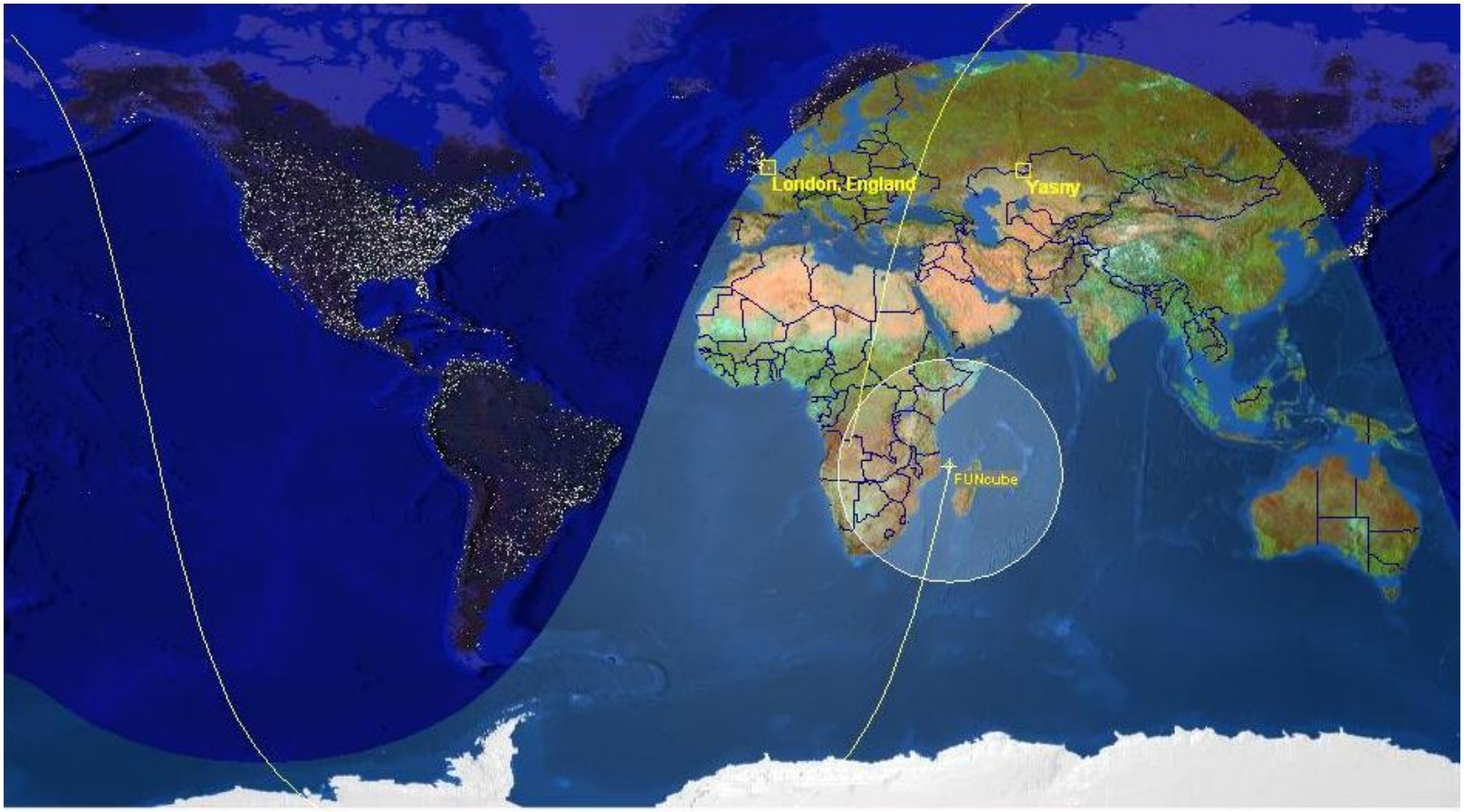


- Primary payload DubaiSat-2
  19 secondary micro and nanosat payloads

- Launch from underground silo.
  Inclination 98.2 degrees
  'near circular' Sun synchronous orbit
  Approx altitude 600x685 km



FUNcube-1 LEOP -orbit



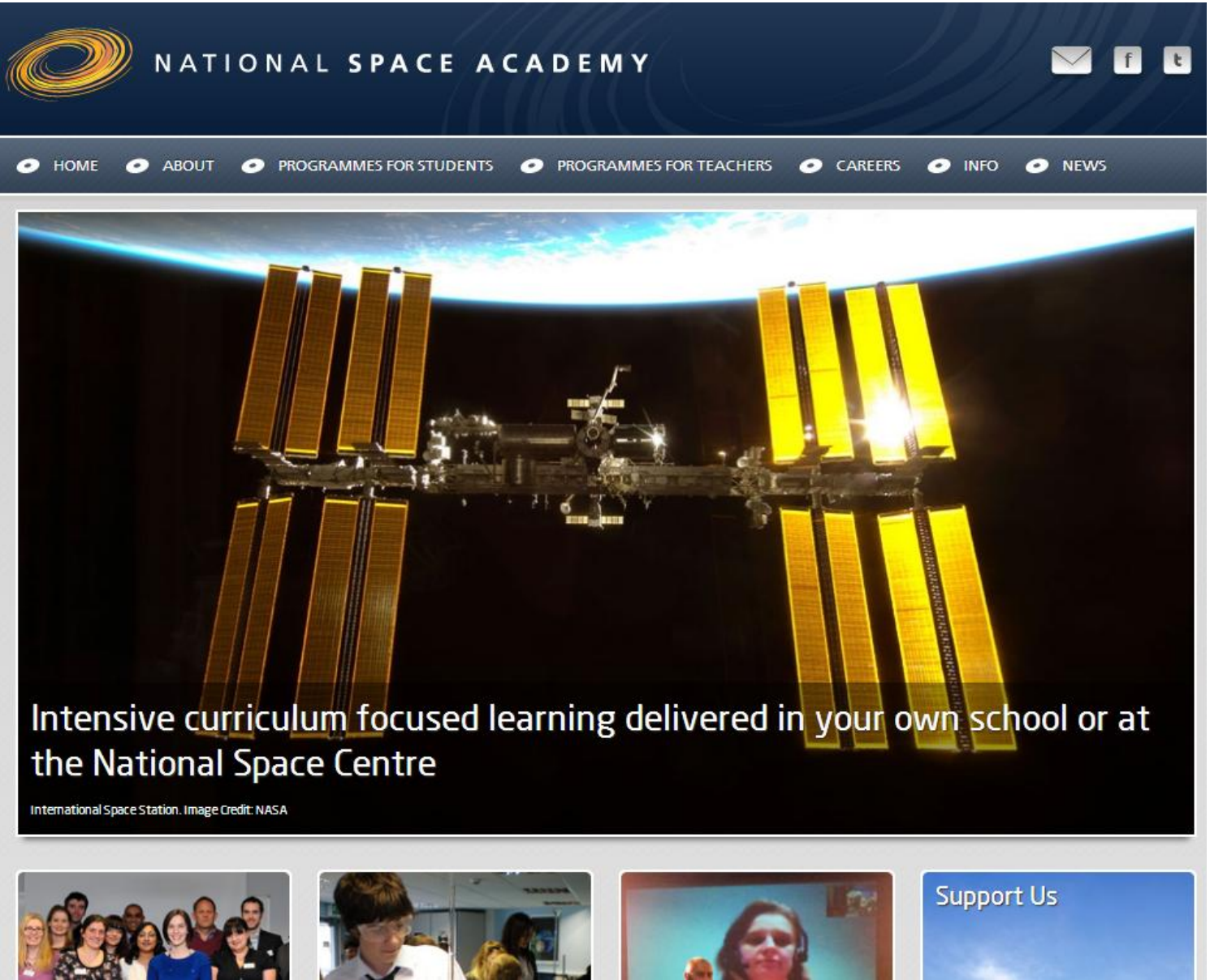
Antenna deployment at L+26 minutes.

Safe mode 50mW BPSK beacon

FUNcube-1 LEOP- Bletchley Park

FUNcube-1 LEOP- Bletchley Park

The FUNcube Project – educational outreach status



Anu Ojha - Director of the National Space Academy

The FUNcube Project – educational outreach

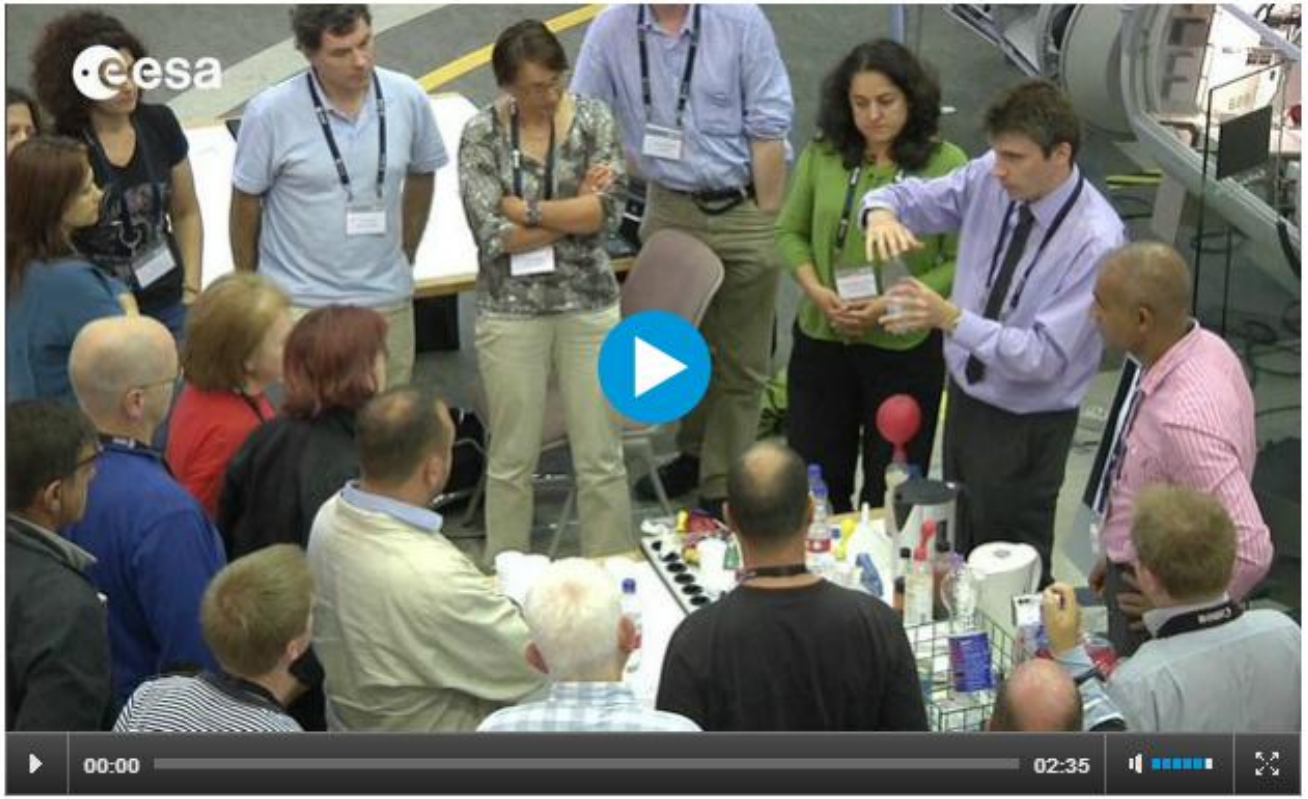
ESA | EDUCATION | TEACHERS' CORNER | ESA KIDS

ESA in your country
- The European Space Education Resource Office (ESERO) project

Classroom Resources
- Solar System and Universe
- Earth and Environment
- Astronauts and International Space Station
- Rockets and Technology Resources

Training for Teachers
- Continuous Professional Development
- Annual ESA Summer Teacher Workshop
- Galileo Teacher Training Programme

ESA > Education > Teachers' Corner



ESA summer workshop for teachers 2012

Nearly 40 school teachers took part in an intensive four day hands-on workshop at ESTEC, Noordwijk, the Netherlands, from 10 to 13 July 2012.

Access the video

Archive

Corner

The FUNcube Project

- FUNcube-1 Engineering Model “hands on” demo

AMSAT-UK