FUN in Space

The story of FUNcube-1 (AO-73)

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FUNcube Team
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?
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
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
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.
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
Radio Hardware – RF Board

Designed by PA3WEG

Contains:
- Command receiver
- 19kHz UHF-VHF transponder
- 6 telemetry channels
Radio Hardware – PA Board

Designed by G0MRF

Contains:
RD02MUS1 FET
4 channels of telemetry
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
The “Ground Segment” - the FUNcube dongle
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)
FUNcube-1 in its POD
(it’s the one in the middle!)
FUNcube – telemetry reception
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
Antenna deployment test

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

http://youtu.be/ddR-IIZHNBw
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
Launch video

The launch video was shown to the audience. It is available for viewing at:
https://youtu.be/0W6hIXXAFcE
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...
Antenna deployment at T+27 minutes. First telemetry approx 1 min later

Safe mode  30mW BPSK beacon
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.
### Last data sequence number: 470

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<th>DATA COLLECTION STATE</th>
<th>RF BOARD</th>
<th>EPS</th>
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<tbody>
<tr>
<td>ASIB VALID</td>
<td>RF Board Temperature</td>
<td>Total Photo Current</td>
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<tr>
<td>PA VALID</td>
<td>Receiver Current</td>
<td>Battery Voltage</td>
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<tr>
<td>MSE VALID</td>
<td>Transmitter Current 3V3</td>
<td>Total System Current</td>
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<tr>
<td>ANTS BUS A VALID</td>
<td>Transmitter Current 5V0</td>
<td>Battery Temperature</td>
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<tr>
<td>IN SUNLIGHT</td>
<td>14.6 °C</td>
<td>13 °C</td>
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<tr>
<td>SAFE MODE</td>
<td>40 mA</td>
<td>7866 mV</td>
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</table>

**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: Deployed
- VHF B Deployed: Deployed
- UHF A Deployed: Deployed
- UHF B Deployed: 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 monitored by members of the AMSAT-NL team.
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
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.
First command video

The first command video was shown to the audience. It is available for viewing at:
https://youtu.be/AhCj1D2Sg78
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

Time (samples)

Log(lux)
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%
Amount of active users per day
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
Solar eclipse 20th of May 2015
Within 1 week, within 2 weeks, greater than 2 weeks

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</table>
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%
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
FUNcube-2 on Ukube-1

FUNcube payload on Ukube-1, UKSAs first CubeSat
Contains CCT, RF and PA boards
Runs telemetry and transponder
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
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
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
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
Thanks for your attention!

Any questions?

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

AMSAT-UK website: http://amsat-uk.org
AMSAT-NL website: http://amsat-nl.org