Summary

This document provides details of downlink data from the FUNcube-1 satellite.

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Revised: DH

Checked: Graham

Approved: Graham

Revision Record

issue	date	total pages	Authorisation	affected pages	brief description of change
0.1 DRAFT	23.03.10			ALL	Initial draft.
0.2 DRAFT	28.03.10			ALL	Updated EPS channel count and more emphasis on the real time header.
0.3 DRAFT	24.04.10			ALL	Introduced two types of real time header to fit in all RF channels.
0.4 DRAFT	10.05.10			some	Added telemetry channel details.
0.5 DRAFT	06.09.10				Added refs to the PA Board and info on ANT data.
0.6 DRAFT	20.02.11			Lots	Updated EPS channel telemetry details, RTT1 / RTT2 details and fitter upload slots.
0.7 DRAFT	01.01.12				Added details of software status bits to RTT.
0.8 DRAFT	18.01.12				Changes due to GOM space EPS
0.9 DRAFT	14.02.12				Replaced 4 unused EPS Latch up channels with 3 Sun Sensor channels.
09b. DRAFT	24.5.12		Graham		Updated WOD as per Phil's note on the DMS
0.10 DRAFT	21.10.12				Updated software state bits of real-time telemetry, and order of high-res channels.
0.11 DRAFT	21.10.12				Updated to put back in the changes from 9 to 9b!
0.12 DRAFT	07.04.13				PA Forward/Reverse power reversed.
0.13 DRAFT	09.08.13				Sat Id updated
1.0 Final	05.03.14		Graham		Verified as the as flown version

List of TBD's and TBC's

TBC/TBD	*Location*	*Subject*	*Due date*	*Action by*

Table of Content

List of Acronyms

ANT	Antenna (board)
ADC	Analogue to Digital Converter
ACS	Attitude Control Subsystem
BCR	Battery Charge Regulator
BPSK	Binary Phase Shift Keying
CCT	Command Control and Telemetry (board)
EPS	Electrical Power Subsystem
FEC	Forward Error Correction
MSE	Material Science Experiment
PA	Power Amplifier (board)
RF	Radio Frequency (board)
RS	Reed Solomon (error-correction code)
SW	Software
TBC	To Be Confirmed
TBD	To Be Determined
TBW	To Be Written
TCS	Thermal Control Subsystem
TRX	Transponder

1 Overview

This document's an extension to the proposal by Howard Long on the 13 Nov 2009 to define the data downlink format. Both the content of each downlink frame and the transmission order of the different frame types will be addressed.

The encoding method and frame size remains unchanged from the original proposal:

"The basic starting point is to use 1200bps BPSK with both convolution and block coding based on the proven AMSAT OSCAR-40 FEC telemetry model, and work around that. If we start with a base 256 byte (2048 bit) data frame, once it has passed through a pair of RS(160,128) encoders, the scrambler, the convolution encoder and the interleaver, we have 5200 bits to transmit. Thus, ignoring pre- and post-amble, each data frame will take 4.3s to "transmit"

2 bits Sat Id 6 bits Frame Type	***440 bits Real Time Telemetry***	***1600 bits Payload***
2048 bits (256 byte) Frame		

Each frame consists of a 2 bit satellite id and a 6 bit frame type indicator then 440 bits of real time data followed by 1600 bits of payload data. This results in the required total frame size of 2048 bits (256 bytes). This also fixes the frame transmission rate to one frame every five seconds.

Additionally it is possible to configure the spacecraft to downlink debug status information in Fitter message slot 9.

2 Sat Id

The first 2 bits are the Sat Id currently defined as:

[0][0] = FUNcube-1 Engineering Model

[0][1] = FUNcube 2 on UKube

[1][0] = FUNcube-1 Flight Model

[1][1] = Extended protocol (look elsewhere for the Sat Id!)

3 Frame types

The next 6 bits will be transmitted MSB first and will indicate one of three main frame types, also which frame in the overall transmission sequence is currently being sent. Values can be found in the Transmission Schedule table at the end of the document.
Main, frame types:

- Whole orbit data.
- High resolution data.
- Fitter messages.

Real Time Telemetry
Although not a frame type in its own right as it is included with all frames, the real time information sends the state of all channels from the EPS, RF, PA, Antenna and software systems.

Whole Orbit Data
This is the science bit, intended to provide all the information required for the material science experiment. The data will be sampled once per minute for 104 minutes. The main focus of the data is the four analogue temperature readings sampled at the full 12 bit resolution, these coupled with the solar panel voltage and temperature readings should be enough to conduct the experiment. Also included are the battery voltage, system current and solar current collected. These will be a good indicator of the overall power state of the satellite over the course of an orbit.

High resolution
The purpose of the high resolution data is to be able to look at the tumbling rate of the satellite. This can be calculated by looking at the output from each solar panel at a relatively high sampling frequency. Thus the data collected is the 5 sun sensors, together with the photo and battery currents, sampled once per second for a minute.

Fitter Messages
These are the text messages received via DTMF from ground stations to be periodically retransmitted. Messages will not be broken up and sent over multiple frames, so the maximum length of a message is 200 bytes. The format of messages is transparent to the satellite, each received message will just be copied out verbatim.

Messages can uploaded to one of nine possible RAM slots or to one of ~27 FRAM slots, with the slot id specified at upload time. After an upload attempt status bits in the Real Time Telemetry will be set to indicate the slot id and success or failure. An authentication (not encryption) scheme will be used to verify message validity.

4 Data Collection/Transmission

This section details the rate at which data is collected and from which sensors. This is also the order and bit format for transmission.

Real Time Telemetry:
Collection Frequency: every 5 seconds
Storage Count: 0 (real time!)

Total Bits	Frame Type	Bits per source	Data Source	Bits Per Channel	Data Chanel Name
440 bits	***Real Time Telemetry***	**192**	**EPS**	16	Photo voltage 1
				16	Photo voltage 2
				16	Photo voltage 3
55 bytes				16	Total Photo current
				16	Battery voltage
				16	Total system current
				16	Reboot count

440 bits ***55 bytes***	***Real Time Telemetry***		16	EPS software errors
			8	Boost converter temp 1
			8	Boost converter temp 2
			8	Boost converter temp 3
			8	Battery temp
			8	Latch up count 5v1
			8	Latch up count 3.3v1
			8	Reset cause
			8	Power point tracking mode
		100	10	Sun Sensor X+
			10	Sun Sensor Y+
			10	Sun Sensor Z+
			10	Solar panel temp X+
			10	Solar panel temp X-
			10	Solar panel temp Y+
			10	Solar panel temp Y-
			10	3.3 bus voltage
			10	3.3 bus current
			10	5.0 bus voltage
		48	8	Receiver Doppler
			8	Receiver RSSI
			8	Temperature
			8	Receive current
			8	Transmit current 3.3V bus
			8	Transmit current 5.0V bus
		32	8	Reverse power
			8	Forward power
			8	Board temperature
			8	Board current
		20	8	Antenna temp 0
			8	Antenna temp 1
			1	Antenna deployment 0
			1	Antenna deployment 1
			1	Antenna deployment 2
			1	Antenna deployment 3
		48	24	Sequence number
			6	DTMF command count
			5	DTMF last command
			1	DTMF command success
			1	Data valid ASIB
			1	Data valid EPS
			1	Data valid PA
			1	Data valid RF
			1	Data valid MSE
			1	Data valid ANTS bus-B
			1	Data valid ANTS bus-A
			1	In eclipse mode
			1	In safe mode
			1	Hardware ABF On/Off
			1	Software ABF On/Off
			1	Deployment wait at next boot

Whole Orbit Data:
Collection Frequency: every 60 seconds
Storage Count: 104

Total Bits	Frame Type	Bits per source	Data Source	Bits Per Channel	Data Chanel Name
184 bits	***Whole Orbit Data***	**48**	**MSE**	12	Temp thermistor black chassis
				12	Temp thermistor silver chassis
				12	Temp thermistor black panel
23 bytes				12	Temp thermistor silver panel
		40	**BOB**	10	Solar panel temp +X
				10	Solar panel temp –X
				10	Solar panel temp +Y
				10	Solar panel temp -Y
		96	**EPS**	16	Photo voltage 1
				16	Photo voltage 2
				16	Photo voltage 3
				16	Total Photo current
				16	Battery voltage
				16	Total system current
(23 Bytes * 104 Storage Count) = 2392 bytes					
2392 bytes + 8 callsign = 2400					
2400 bytes / 200 (payload size) = 12 = Transmitted in 12 payloads					

High Resolution Data:
Collection Frequency: every 1 second
Storage Count: 60

Total Bits	Frame Type	Bits per source	Data Source	Bits Per Channel	Data Chanel Name
80 bits	***High Resolution Data***	**50**	**BOB**	10	Sun Sensor +X
				10	Sun Sensor +Y
				10	Sun Sensor -Y
10 bytes				10	Sun Sensor +Z
				10	Sun Sensor –Z
		30	**EPS**	15	Total Photo current
				15	Battery voltage
(10 Bytes * 60 Storage Count) = 600 bytes					
600 bytes / 200 (payload size) = 3 =Transmitted in 3 payloads					

Fitter Messages:
Collection Frequency: N/A
Storage Count: 9

Total Bits	Frame Type	Bits per source	Data Source	Bits Per Channel	Data Chanel Name
1600 bits	***Fitter Message Data***	**1600**	**RAM**	1600	Fitter message
200 bytes					
(200 Bytes * 9 Storage Count) = 1800 bytes					
1800 bytes / 200 (payload size) = 9 =Transmitted in 9 payloads					

5 Transmission Schedule

The above data collection strategy results in:

12 Whole orbit frames
3 High resolution frames
9 Fitter message frames

Each frame also contains the Real Time Telemetry information, so this will be sent every 5 seconds. The order of frames will be:

Frame Type	Frame Id	Frame type value
RTT + Whole Orbit	WO1	01
RTT + Whole Orbit	WO2	02
RTT + Whole Orbit	WO3	03
RTT + Whole Orbit	WO4	04
RTT + Whole Orbit	WO5	05
RTT + Whole Orbit	WO6	06
RTT + Whole Orbit	WO7	07
RTT + Whole Orbit	WO8	08
RTT + Whole Orbit	WO9	09
RTT + Whole Orbit	WO10	10
RTT + Whole Orbit	WO11	11
RTT + Whole Orbit	WO12	12
RTT + High Resolution	HR1	13
RTT + Fitter Message	FM1	14
RTT + Fitter Message	FM2	15
RTT + Fitter Message	FM3	16
RTT + High Resolution	HR2	17
RTT + Fitter Message	FM4	18
RTT + Fitter Message	FM5	19
RTT + Fitter Message	FM6	20
RTT + High Resolution	HR3	21
RTT + Fitter Message	FM7	22
RTT + Fitter Message	FM8	23
RTT + Fitter Message	FM9	24

With each frame requiring 5 seconds to transmit the sequence of frames will repeat every 120 seconds (two minutes).

6 Fitter Message Slot 9 data

To be added