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Whole Orbit Data Packet Format

QB50 Project

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Von Karman Institute for Fluid Dynamics	DOCUMENT REVISIONS TRACEABILITY SHEET Whole Orbit Data Packet Format		
Rev. 1	***Date:*** 27 Sep 2013	***Status:*** initial	No. of pages: 7
Author(s): T. Scholz Features: initial version			
Rev. 2	***Date:*** 06 Nov 2013	***Status:*** final	No. of pages: 7
Author(s): T. Scholz Features: byte-order included, N/A of parameters included, clarification of the battery parameters, frequency corrected			
Rev. 3	***Date:*** 02 Apr 2014	***Status:*** final	No. of pages: 7
Author(s): T. Scholz Features: average value for multiple sensor entries			
Rev. 4	***Date:*** 23 Oct 2014	***Status:*** final	No. of pages: 9
Author(s): T. Scholz Features: corrected min/max order and example added			

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1 Introduction

1.1 Purpose

This document defines the data packet format to be implemented on the QB50 CubeSats for the transmission of the Whole Orbit Data.

1.2 Definitions

Whole Orbit Data (WOD) is a set of and important house-keeping data (HSK) data collected over the whole orbit once a minute. The parameters (satellite mode, battery voltage, battery current, regulated bus currents, temperature of COMM system, EPS and batteries) are defined as important by QB50 and serve the purpose to identify the health status of the CubeSat over the mission period. The WOD shall be sent by the teams to the QB50 server (**QB50-SYS-1.7.9** [1]).

1.3 Acronyms

EPS	Electrical Power System
HSK	House-Keeping Data
MCU	Micro-Controller Unit
OBC	On-Board Computer
WOD	Whole Orbit DATA
PCB	Printed Circuit Board
SU	Science Unit

2 Whole Orbit Data Format

The whole orbit data consists of the CubeSat status, raw battery voltage, battery bus current, currents of the regulated bus 3V3 and 5V and temperatures of the COMM system, EPS and batteries collected over the whole orbit with a frequency of 1/60 Hz (once a minute, **QB50-SYS-1.4.1** [1]). The data shall be stored on-board, transmitted to ground and send to the QB50 storage server using the whole orbit data packet format specified in Table 1.

Table 1 Whole Orbit Data Packet Format

Whole Orbit Data Packet (1856 bits)				
Time	Data set 1	Data set 2	…	Data set 32
32 bits	57 bits	57 bits	1653 bits	57 bits

The packet consists of 32 data sets (32 measurements covering 32minutes) and the time of the first measurement (data set 1). Using the specified frequency and the time for consecutive packets, the time of the intermediate measurements can be precisely reconstructed. The size of generated WOD packets during a day will be approximately 84kbits (10kB) assuming the frequency of 1/60Hz. If a packet is requested for transmission without 32 data sets available, the packet shall be filled with trailing zero up to the next complete octet to archive a packet length of multiple octets. For example, a packet with only one data set will be completed by 0b000000 (seven zeros), for 11 data sets, 5 zeros (0b00000) have to be appended to archive a length of 664 bits or 83 octets.

A data set consists of the battery voltage, battery and regulated bus currents beside temperatures obtained at the same time from different systems. The format of one data set is given in the following Table 2.

Table 2 Data set format

Data set X (57 bits)							
Mode	Bat. voltage	Bat. current	3V3 bus current	5V bus current	Temp. Comm	Temp. EPS	Temp. Battery
1 bit	8 bits	8 bits	8 bits	8 bits	8 bits	8 bits	8 bits

If a parameter is not available on-board of the CubeSat, the specific field shall be set to 0x00 either directly on-board of the CubeSat before transmission or after reception on-ground. If assembled on-ground, the order of fields for each data set and the complete packet shall be kept consistent with the format specified here.

In the following, the parameters are described in more detail and the used encoding or conversion formula is given:

The *Time* flag holds the number of seconds passed from the reference epoch of QB50 (01/01/2000 00:00:00 UTC, **QB50-SYS-1.4.4** [1]) as defined in the requirements document. A *32-bit unsigned integer* is used to represent the elapsed seconds. *Little Endian* encoding (*least significant byte first*) shall be used for the byte order.

The *Status* bit indicates the operational status of the CubeSat. If the satellite is in normal operation mode with science unit (SU) functional, the bit shall be set to 0b1. If the CubeSat is in safe mode or no science measurements can be performed, the bit shall be set to 0b0.

The *Battery Voltage* contains the measured raw battery voltage value in Volt using an *8-bit unsigned integer* for representation. Following equation shall be used on-board of the CubeSat to convert the floating-point voltage level to unsigned integer.

$$U_{UI8} = \max(0, \min(2^8-1, \text{floor}((20 * U) - 60))) \tag{1}$$

This allows monitoring voltages in the range from 3V to 15.75V with a resolution of 50mV.

The *Battery Current* represents the battery (dis-)charge rate at the time-point of the measurement. The current (given in Ampere) is defined by the difference of incoming and outgoing power divided by the battery voltage. Positive values represent a charging of the battery. Using information of the active sub-systems, the incoming power can be derived from the current. The measured current shall be converted to an 8-*bit unsigned integer* using the following equation.

$$I_{UI8} = \max(0, \min(2^8-1, \text{floor}(127 * I) + 127)) \tag{2}$$

This allows monitoring currents from -1A to 1.008A with a resolution of 7.87mA.

The *3V3* and *5V bus current* represents the power consumption on-board of the CubeSat on the specific bus – a sum shall be used for each bus to take every 3V3 or 5V power line/rail into account. The sub-system status and activities can be derived from the consumption by comparison with ground-tests or datasheet values. The currents, given in Ampere, shall be converted to an 8-bit unsigned integer using the following equation.

$$I_{UI8} = \max(0, \min(2^8-1, \text{floor}(40 * I))) \tag{3}$$

This allows monitoring currents from 0A to 6.375A with a resolution of 25mA.

The *Temperature COMM/EPS/Battery* fields represent the measured temperatures in ºC at the specific locations on the communication system (MCU or PCB temperature), EPS (MCU or PCB temperature) and battery surface temperature. If multiple batteries or sensors on the boards are available, the measured values shall be averaged to obtain the value for the specific field. An *8-bit unsigned integer* shall be used for the transmission obtained with the following equation for the conversion.

$$T_{UI8} = \max(0, \min(2^8-1, \text{floor}((4 * T) + 60))) \tag{4}$$

This allows monitoring temperature levels from -15ºC to 48.75ºC with a resolution of 0.25ºC.

3 Examples

In the following, two examples with a single dataset and two datasets are shown to illustrate the WOD packet structure. The input parameters used for the datasets are shown in the following table in original units and converted hex values.

Table 3 Input parameters for WOD packets

#No.	Mode [-] / [HEX]	UBAT [V] / [HEX]	IBAT [A] / [HEX]	I3V3 [A] / [HEX]	I5V0 [A] / [HEX]	TCOMM [°C] / [HEX]	TEPS [°C] / [HEX]	TBAT [°C] / [HEX]
1	0 / 0b0	8.50 / 0x6E	0.55 / 0xC4	0.40 / 0x10	0.20 / 0x08	5.50 / 0x52	15.10 / 0x78	38.30 / 0xD5
2	1 / 0b1	8.90 / 0x76	0.65 / 0xD1	0.50 / 0x14	0.12 / 0x04	6.30 / 0x55	14.80 / 0x77	41.50 / 0xE2

In the case of a single dataset (first) at epoch T=1009876s, the WOD packet representing the dataset in hex and binary format is shown in the following including the added zeros to complete the last octet.

d4 68 0f 00 37 62 08 04 29 3c 6a 80

Written in binary, the specific parameters can be identified easily and have been color-coded according to the input parameter table. The additional seven zeros are shown with black italic font. The MODE bit has been underlined and highlighted with bold font

1101 0100 0110 1000 0000 1111 0000 0000 **0**011 0111 0110 0010
0000 1000 0000 0100 0010 1001 0011 1100 0110 1010 1*000 0000*

For the second example with two datasets, the hex and binary representation is shown in the following using a epoch T=2009876s. The binary representation has again the zeros included to fill the octet. Due to the second dataset, only six zeros are required to complete the packet.

14 ab 1e 00 37 62 08 04 29 3c 6a dd b4 45 01 15 5d f8 80

0001 0100 1010 1011 0001 1110 0000 0000 **0**011 0111 0110 0010
0000 1000 0000 0100 0010 1001 0011 1100 0110 1010 1**1**01 1101
1011 0100 0100 0101 0000 0001 0001 0101 0101 1101 1111 1000
10*00 0000*

Due to the discrete representation of the data, the converted output from the WOD packets does not have to coincide with the input parameters as shown in Table 4 where changed values are highlighted red.

Table 4 Output parameters of WOD packet examples

#No.	Mode [-]	UBAT [V]	IBAT [A]	I3V3 [A]	I5V0 [A]	TCOMM [°C]	TEPS [°C]	TBAT [°C]
1	0	8.50	0.543	0.40	0.20	5.50	15.00	38.25
2	1	8.90	0.646	0.50	0.12	6.25	14.75	41.50

4 Bibliography

[1] D. Masutti, "QB50 System Requirements and Recommendations, Issue 6," Von Karman Institute for Fluid Dynamics, Sint-Genesius Rode, 2014.