OrigamiSat-1

FM Down Link Data Format

(English version)

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ORIGAMI

PROJECT

Revision history

Date	Version	Contents
2019/01/09	1.0, 1.1	Translated from Japanese document OP-S1-0110, ver. 2.3. (Sakamoto, Kurosaki)
2019/01/17	1.2	Revised based on OP-S1-0110 (Japanese version), version 2.6. - Mission data formats are added. - IMU calculation equation is corrected. Updates are shown in red.
2019/01/18	1.3	Eqs. (10) and (11) are corrected.

1. Overview

This document specifies the FM (Frequency Modulation) downlink data format for 3U Cubesat OrigamiSat-1 (JS1YAX).

2. Data format

The overview of FM downlink data is shown in Table 1.

Table 1 FM downlink data overview

Item	Detail
Modulation	AFSK1200bps (NRZL code)
Protocol	AX.25
Data contents	(I) HK[1] data (size: 122 byte) (II) Mission data - Picture data (size: several kbyte) - IMU[2] data (size: several kbyte) - Thin-film solar cell I-V data (size: 8 byte) - Extensible mast encoder values (size: several bytes) (III) Echo back (size: 32 byte)
Call sign	"JQ1YCZ" (Tokyo Tech ground station) "JS1YAX" (OrigamiSat-1 satellite)

OrigamiSat-1 carries out FM packet communication based on AX25 protocol.

2.1. Data format details

There are four kinds of data formats. (I) HK data and (II) Mission data correspond "Data format 1." And, (III) Echo back is described as "Data format 2."

2.1.1. Data format 1 ((I) HK data & (II) Mission data)

Overview of "Data format 1" is shown in Table 2. Data is divided into 32 byte size and each is transmitted from the satellite. However, size of the last packet is the reminder left after the size of entire data is divided by 32 byte.

Each downlink data has a packet number before the data. The packet number is a sequential serial number presented by 3 byte hexadecimal number. Same packets are downlinked repeatedly for the "X" times specified where "X" is determined by a command

[1] HK: House Keeping data (data to monitor satellite conditions)
[2] IMU: Inertial measurement unit (measures acceleration and angular velocity in 3 axes (x, y, z)).

from the ground station. The next data downlinked is started after the prescribed repetition.

Table 2　FM Data format 1

		Packet number			HK data or Picture data					
Flag	Call sign +control	0x01	0x01	0x01	DATA(32byte)				Flag	Repeated X times
					#0	#1	・・・	#31		
Flag	Call sign +control	0x02	0x02	0x02	DATA(32byte)				Flag	Repeated X times
					#32	#33	・・・	#63		
Flag	Call sign +control	0x03	0x03	0x03	DATA(32byte)				Flag	Repeated X times
					#64	#65	・・・	#95		
				・						
				・						
				・						
Flag	Call sign +control	N	N	N	DATA(32byte)				Flag	Repeated X times
					##	##	・・・	##		

2.1.2. Data format 2 ((III) Echo back)

"Echo back" is 32 byte data downlinked for reception confirmation, just after an uplink command is transmitted from the Tokyo Tech ground station to the satellite. Echo back's data format is shown in Table 3. Echo back is also repeated for "Y" times where Y is determined by an uplink command.

Table 3　FM Data format 2 (Echo back)

		Echo back					
Flag	Call sign +control	DATA(32byte)				Flag	Repeated Y times
		#0	#1	・・・	#31		

2.2. Data distinction method

Figure 1 shows how (I) HK data, (II) Mission data, and (III) echo back, can be distinguished from each other.

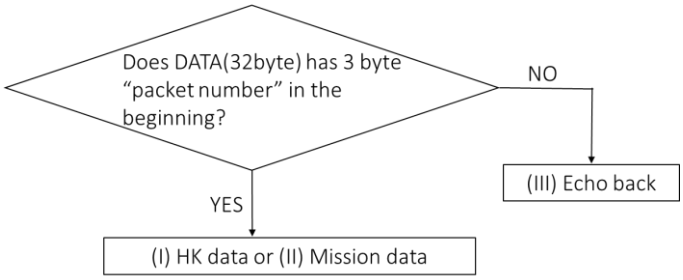

Figure 1　Method to distinguish data format

3.　Data contents in "Data format 1"

Telemetry data has two data formats: (I) HK (housekeeping) data, and (II) Mission data.

3.1.　HK data downlink

HK data is 122 byte in total. The contents of HK data is shown in Table 4. When there was an error in reading data from the satellite memory (EEPROM), a value becomes 0xFF. And all data are big-endian.

Each data items are explained in detail in the subsections below. The configuration of satellite components, such as EPS, OBC, and TX/RX is shown in Figure 2.

Table 4　HK downlink data format

説明の項目	byte	内容	byte 数
3.1.1	#0	Latest executed ID (OBC)	1
3.1.2	#1	OBC command status	1
3.1.3	#2-#7	Data obtained time	6
3.1.4	#8-#11	Battery voltage and current	4
3.1.5	#12	Battery status	1
3.1.6	#13-#14	EPS switch status	2
3.1.7	#15	EPS bus status	1
3.1.8	#16	Stellate mode	1
3.1.9	#17-#20	SAP voltage and current	4
3.1.10	#21-#30	SAP 1-5 generated power	10
3.1.11	#31-#38	SAP 1~4 current	8
3.1.12	#39-#54	Temperature	16
3.1.13	#55-#60	Acceleration X~Z	6
3.1.14	#61-#66	Angular velocity X~Z	6
3.1.15	#67	Raspberry Pi latest executed	1

		command ID	
3.1.16	#68	Raspberry Pi's mode, command execution status, LED status	1
3.1.17	#69-#100	EPS switch 1-10 voltage, current	32
3.1.18	#101-#104	EPS 3.3V BUS voltage, current	4
3.1.19	#105-#108	EPS 5V BUS voltage, current	4
3.1.20	#109-#112	EPS 12V BUS voltage, current	4
3.1.21	#113-#118	BCR1-3 voltage	6
3.1.22	#119-#120	SAP 5 current	2
3.1.23	#121	5.8GHz 12V voltage	1
Total			122

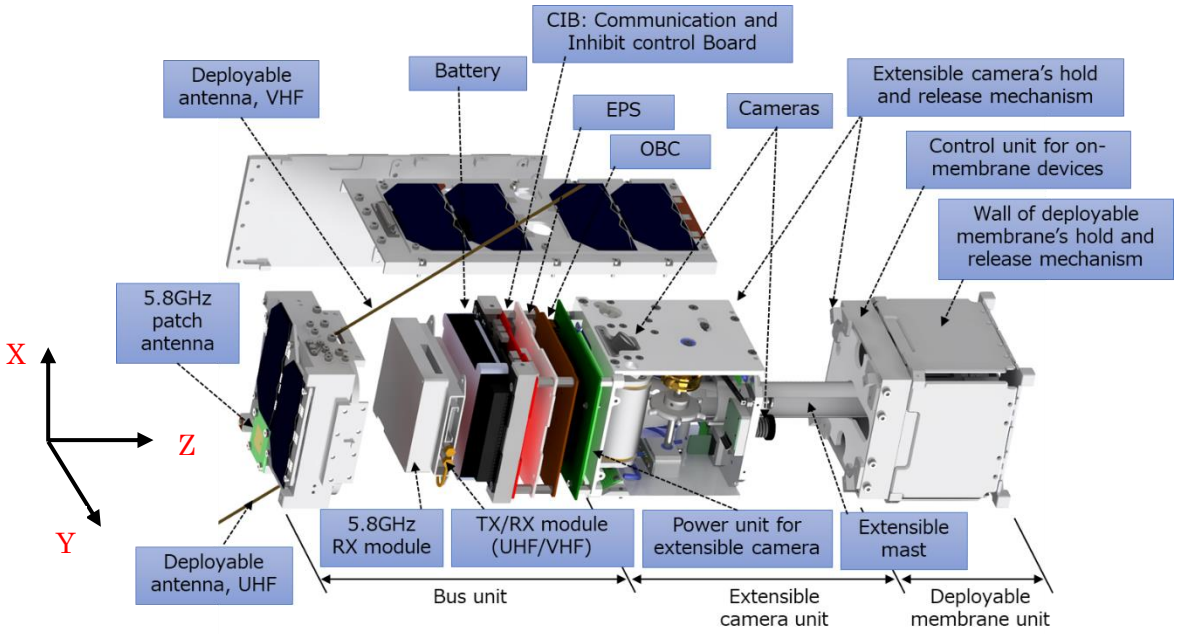

Figure 2 OrigamiSat-1 configuration

3.1.1. Latest executed command ID (OBC)

Latest executed command ID shows the final command ID executed by OBC.

3.1.2. OBC command status

"OBC command status" shows the results of OBC's command execution. Table 5 shows the values and respective contents.

Table 5　Values of OBC command status

エラーステータス	エラー内容
0x00	Normal
0x02	SD card processing error (undefined parameter)
0x03	SD card processing error (file open)
0x04	SD card processing error (too many parameters)
0x05	SD card processing error (I2C)
0x0F	Other error
0x3A	5.8GHz com module enable/disable check, enable
0x55	5.8GHz com module enable/disable check, disable
0xF0	Time out error
0xF2	Command format error
0xF3	EEPROM address page error
0xF4	Over flow error
0xF5	Status error of module
0xF6	File open error
0xF8	Undefined parameter error
0xFC	Too many parameter error

3.1.3. Time obtained data

The time that shows when obtained the HK data has the format in Table 6. Each value is 1 byte.

Table 6　Data obtained time

byte	内容	byte 数	値
#2	Data obtained time – Year (last 2 digits of A.D.)	1	0x00 - 0xFF
#3	Data obtained time – Month	1	0x00 - 0x0C
#4	Data obtained time – Day	1	0x00 - 0x1F
#5	Data obtained time – Hour	1	0x00 - 0x17
#6	Data obtained time – Minute	1	0x00 - 0x3B
#7	Data obtained time – Second	1	0x00 - 0x3D

3.1.4. Battery voltage and current

Table 7 Battery voltage and current

Number	byte	内容	byte 数
(i)	#8-#9	Battery voltage	2
(ii)	#10-#11	Battery current	2

(i) Battery voltage

Battery voltage value is calculated by Eq. (1). The obtained 2 byte hexadecimal number (HEX) should be converted to a decimal number (DEC); then substituted into "DATA". (The same process is also required in (ii).)

$$\text{Voltage [V]} = 0.009971 \times \text{DATA} \quad (1)$$

(ii) Battery current

Battery current value is calculated by Eq. (2).

$$\text{Current [A]} = 0.005237 \times \text{DATA} \quad (2)$$

3.1.5. Battery status

Battery status monitors the voltage and current of the battery. "0" is normal, and "1" shows error, as shown in Table 7.

Table 8 Battery status

7bit(MSB)	6bit	5bit	4bit	3bit	2bit	1bit	0bit (LSB)
---	---	---	---	---	---	Battery voltage	Battery current

3.1.6. EPS switch status

EPS switch status shows whether the voltage and current values for each of EPS switches are normal or not. "0" is normal, and "1" shows error. Table 9 shows the meaning of each bit.

Table 9　EPS switch status

15bit (MSB)	14bit	13bit	12bit	11bit	10bit	9bit	8bit
switch 1 voltage	switch 1 current	switch 2 voltage	switch 2 current	switch 5 voltage	switch 5 current	switch 6 voltage	switch 6 current

7bit	6bit	5bit	4bit	3bit	2bit	1bit	0bit (LSB)
switch 7 voltage	switch 7 current	switch 8 voltage	switch 8 current	switch 9 voltage	switch 9 current	switch 10 voltage	switch 10 current

Additionally, Table 10 shows the components connected to each EPS switch.

Table 10　Details of EPS switches

EPS Switch#	Connected component	EPS Switch#	Connected component
1	Motor for extensible mast (12V 1.5A)	6	LED for cameras (5V)
2	12V power supply	7	5.8GHz transmitter power (5V)
3	Battery voltage	8	MDC power (3.3V, 4A)
4	Battery voltage	9	Nichrome cutter in Deployable membrane unit (3.3V, 4A)
5	Extensible camera unit power (5V, 4A)	10	Nichrome cutter for UHF/VHF deployable antenna (3.3V, 4A)

3.1.7.　EPS bus status

EPS bus status shows whether the voltage and current values for 3.3V BUS, 5V BUS, and 12V BUS, are normal or not. “0” is normal, and “1” shows error. Table 11 shows the meaning of each bit.

Table 11　EPS bus status

7bit(MSB)	6bit	5bit	4bit	3bit	2bit	1bit	0bit(LSB)
---	---	3.3V BUS voltage	3.3V BUS current	5V BUS voltage	5V BUS current	12V BUS voltage	12V BUS current

3.1.8.　Satellite mode

Table 12 shows the information in this data section. There are three satellites modes, depending upon battery voltage. Table 13 explains each modes in detail.

Table 12　Data contents of “satellite mode”

7bit(MSB)	6bit	5bit	4bit	3bit	2bit	1bit	0bit(LSB)
Satellite mode				SEP switch status		RBF switch status	

Table 13　Explanation of each satellite mode

Satellite mode	Satellite mode contents
Nominal mode	Mode for nominal operation.
Saving mode	This mode is used when battery voltage is relatively low. To reduce power consumption, only minimal communication functions are active, and the battery voltage is resumed. CW downlink data format is unchanged from the nominal mode; however, OBC is turned off in this mode. As a result, the data from OBC are not updated in this mode.
Survival mode	This mode is used when battery voltage is critically low. Only PIC microcomputers are active and all most all the other devices are turned off. In this mode, CW data transmission is not implemented. This mode concentrates charging the battery.

Table 5 shows the data representation for “satellite mode” in Table 14.

Table 14　Satellite mode representation

Satellite mode	7 bit	6bit	5bit	4bit
Nominal mode	0	1	0	1
Saving mode	0	1	1	0
Survival mode	1	0	1	0

“SEP” and “RBF” in Table 12 are the switches, switched according to the satellite mode. SEP switches ON/OFF of the bus power line from EPS. RBF switches ON/OFF between EPS and battery. Therefore, if the switches function normally, both SEP/RBF are ON in Nominal mode; whereas only SEP is on in Saving mode and Survival mode. In binary number (BIN), the switch status is 0b10 when a switch is ON; and it is 0b01 when a switch is OFF. Table 15 summarize this.

Table 15　Summary of “satellite mode” data

Satellite mode	SEP	RBF	Data (BIN)	Data (HEX)
Nominal mode	ON	ON	0b01011010	0x5A
Saving mode	OFF		0b01100110	0x66
Survival mode			0b10100110	0xA6

3.1.9. SAP (Solar Array Panel) voltage and current

Table 12　SAP (Solar Array Panel) voltage and current

番号	Byte	内容	byte 数
(i)	#17-#18	SAP voltage	2
(ii)	#19-#20	SAP current	2

(i)　SAP voltage

SAP voltage value is calculated by Eq. (3). The obtained 2 byte hexadecimal number (HEX) should be converted to a decimal number (DEC); then substituted into “DATA”. (The same process is also required in (ii).)

$$\text{Voltage [V]} = 0.008993157 \times \text{DATA} \tag{3}$$

(ii) SAP current

SAP current voltage value is calculated by Eq. (4).

$$\text{Current [A]} = 0.014662757 \times \text{DATA} \tag{4}$$

3.1.10. SAP 1~5 power

This shows the SAP power. If this is above the reference value, 0x0200, the SAP generates some power. The relation between SAP numbers and the panel directions is (1, 2, 3, 4, 5) = (+X, -X, +Y, -Y, -Z).

3.1.11. SAP 1~4 current

Table 13　SAP current

byte	内容	byte 数
#31-#32	SAP 1 (+X) current	2
#33-#34	SAP 2 (-X) current	2
#35-#36	SAP 3 (+Y) current	2
#37-#38	SAP 4 (-Y) current	2

Current value for each SAP is calculated by Eq. (5). The obtained 2 byte hexadecimal number (HEX) should be converted to a decimal number (DEC); then substituted into "DATA".

$$\text{Current [A]} = 0.0009775 \times \text{DATA} \tag{5}$$

3.1.12. Temperature data for each component

Figure 3 and Table 18 show the locations of temperature sensors (1)-(14).

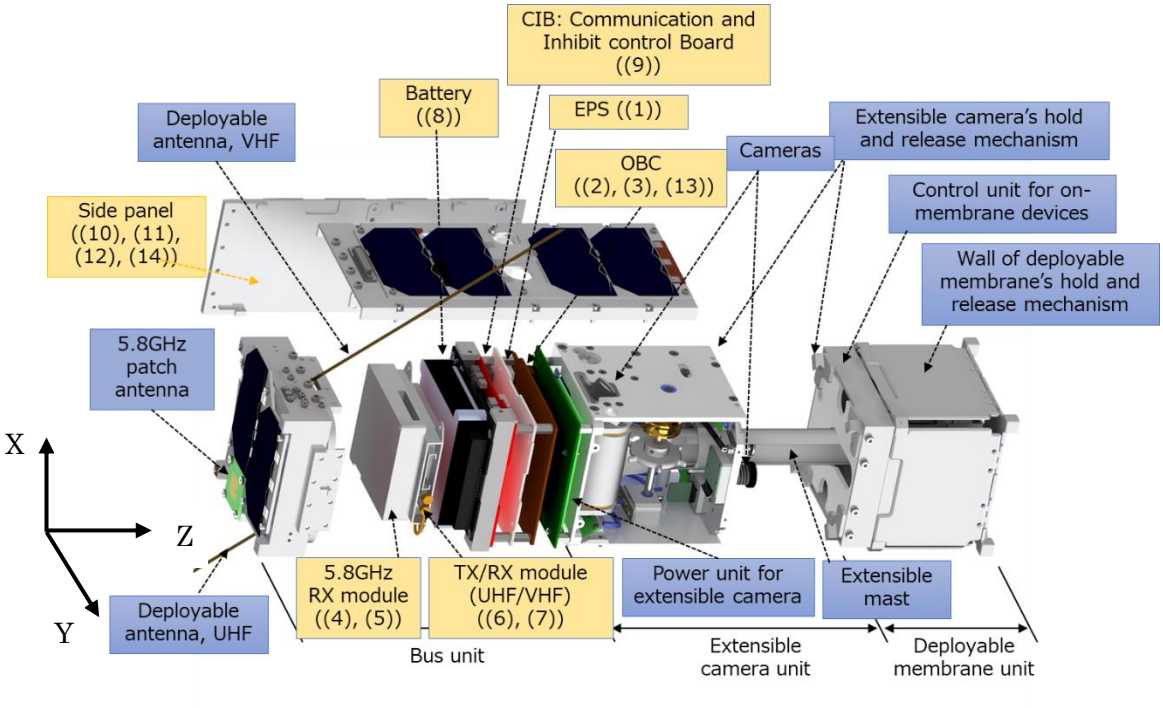

Figure 3 Location of temperature sensors

Table 14 Location of temperature sensors

Number	byte	内容	byte 数
(1)	#39-#40	EPS temperature	2
(2)	#41	OBC temperature 0	1
(3)	#42	OBC temperature 1	1
(4)	#43	5.8GHz amplifier temperature	1
(5)	#44	5.8GHz radiator plate temperature	1
(6)	#45	TX temperature	1
(7)	#46	RX temperature	1
(8)	#47-#48	BAT motherboard temperature	2
(9)	#49	CI Board (DC-DC)	1

(10)	#50	Side panel +Y	1
(11)	#51	Side panel +X	1
(12)	#52	Side panel –X	1
(13)	#53	OBC (GPU) temperature	1
(14)	#54	Side panel –Y	1

(1) EPS temperature

The temperature value is calculated by Eq. (6). The obtained 2 byte hexadecimal number (HEX) should be converted to a decimal number (DEC); then substituted into "DATA". (The same process is required for all (1)-(14).)

$$\text{EPS temperature}\left[°\text{C}\right] = (0.372434 \times \text{DATA}) - 273.15 \tag{6}$$

(2)&(3) OBC temperature

OBC temperature is given by Eq. (7).

$$\text{OBC temperature}\left[°\text{C}\right] = \frac{\frac{DATA \times 2493.0}{1023} - 424}{6.25} \tag{7}$$

(8) BAT (motherboard) temperature

BAT (motherboard) is given by Eq. (8).

$$\begin{aligned} \text{X} &= \frac{330 \times DATA}{1024 - DATA} \\ \text{Temperature}\left[°\text{C}\right] &= \frac{1.0}{\frac{1.0}{4390.0}\log\frac{X}{100.0} + \frac{1.0}{25.0 + 273.15}} - 273.15 \end{aligned} \tag{8}$$

Others (4)-(7), (10)-(14)

These temperatures are given by Eq. (9).

$$\begin{aligned} X &= \frac{330 \times DATA}{255 - DATA} \\ \text{Temperature}\,[°\text{C}] &= \frac{1.0}{\frac{1.0}{4390.0}\log\frac{X}{100.0} + \frac{1.0}{25.0 + 273.15}} - 273.15 \end{aligned} \tag{9}$$

3.1.13. Satellite bus's acceleration X~Z

Table 15　Satellite bus acceleration

byte	内容	byte 数
#55-#56	Satellite acceleration X	2
#57-#58	Satellite acceleration Y	2
#59-#60	Satellite acceleration Z	2

The acceleration value is calculated by Eq. (10). The obtained 2 byte hexadecimal number (HEX) should be converted to a decimal number (DEC); then substituted into "DATA".

$$X = 2 \times 9.8 \times \frac{DATA}{32767} \tag{10}$$

3.1.14. Satellite bus's angular velocity X~Z

Table 16　Satellite bus angular velocity

byte	内容	byte 数
#61-#62	Angular velocity X	2
#63-#64	Angular velocity Y	2
#65-#66	Angular velocity Z	2

The angular velocity value is calculated by Eq. (11). The obtained 2 byte hexadecimal number (HEX) should be converted to a decimal number (DEC); then substituted into "DATA".

$$X = 500 \times \frac{DATA}{32767} \tag{11}$$

3.1.15. Raspberry Pi latest executed command ID

RasPi's command also has command IDs. And the latest executed command ID is downloaded here.

3.1.16. RasPi mode and command execution status, LED status

As shown in Table 21, RasPi's mode is in 7-6 bit, command execution status is in 5-4 bit, and LED status is in 3-0 bit.

Table 17　Details about Raspberry Pi data

7bit(MSB)	6bit	5bit	4bit	3bit	2bit	1bit	0bit(LSB)
00: initial value		00 : STANDBY		LED 4	LED 3	LED 2	LED 1
01: executing		01 : RUN		0 : OFF	0 : OFF	0 : OFF	0 : OFF
10: error		10 : STOP		1 : ON	1 : ON	1 : ON	1 : ON

3.1.17. EPS switches 1-10's voltage and current

Table 18　EPS voltage and current for each switches

Number	Byte	Contents	byte
(1)	#69-#70	EPS switch 1 voltage	2
(2)	#71-#72	EPS switch 1 current	2
(3)	#73-#74	EPS switch 2 voltage	2
(4)	#75-#76	EPS switch 2 current	2
(5)	#77-#78	EPS switch 5 voltage	2
(6)	#79-#80	EPS switch 5 current	2
(7)	#81-#82	EPS switch 6 voltage	2
(8)	#83-#84	EPS switch 6 current	2
(9)	#85-#86	EPS switch 7 voltage	2
(10)	#87-#88	EPS switch 7 current	2
(11)	#89-#90	EPS switch 8 voltage	2
(12)	#91-#92	EPS switch 8 current	2
(13)	#93-#94	EPS switch 9 voltage	2
(14)	#95-#96	EPS switch 9 current	2
(15)	#97-#98	EPS switch 10 voltage	2
(16)	#99-#100	EPS switch 10 current	2

The equations to convert (1)-(16) values to physical data are shown below.

(1), (3) EPS voltage (switch 1, 2)

The voltage value is calculated by Eq. (12). The obtained 2 byte hexadecimal number (HEX) should be converted to a decimal number (DEC); then substituted into "DATA". (This process is required for all (1)-(16).)

$$\text{EPS voltage [V]} = 0.01349 \times \text{DATA} \qquad (12)$$

(4), (7), (9) EPS voltage (switch 5, 6, 7)

The voltage value is calculated by Eq. (13).

$$\text{EPS voltage } [V] = 0.005865 \times \text{DATA} \quad (13)$$

(11), (13), (15) EPS voltage (switch 8, 9, 10)

The voltage value is calculated by Eq. (14).

$$\text{EPS voltage } [V] = 0.004311 \times \text{DATA} \quad (14)$$

(2), (4), (6), (8), (10), (12), (14), (16) EPS current (switch 1, 2, 5, 6, 7, 8, 9, 10)

The voltage value is calculated by Eq. (15).

$$\text{EPS current [A]} = 0.001328 \times \text{DATA} \quad (15)$$

3.1.18. EPS 3.3V BUS voltage and current

Table 19 EPS 3.3V BUS voltage and current

Number	byte	Content	byte
(1)	#101-#102	EPS 3.3V BUS voltage	2
(2)	#103-#104	EPS 3.3V BUS current	2

(1) EPS 3.3V BUS voltage

The voltage value is calculated by Eq. (16). The obtained 2 byte hexadecimal number (HEX) should be converted to a decimal number (DEC); then substituted into "DATA". (This process is also required in (2).)

$$\text{Voltage [V]} = 0.003988 \times \text{DATA} \quad (16)$$

(2) EPS 3.3V BUS current

The current value is calculated by Eq. (17).

$$\text{Current [A]} = 0.005237 \times \text{DATA} \quad (17)$$

3.1.19. EPS 5V BUS voltage and current

Table 20 EPS 5V BUS voltage and current

Number	byte	Content	byte
(1)	#105-#106	EPS 5V BUS voltage	2
(2)	#107-#108	EPS 5V BUS current	2

(1) EPS 5V BUS voltage

Again, the voltage value is calculated by Eq. (18). The obtained 2 byte hexadecimal number (HEX) should be converted to a decimal number (DEC); then substituted into

"DATA". (This process is also required in (2).)

$$\text{Voltage [V]} = 0.005865 \times \text{DATA} \tag{18}$$

(2) EPS 5V BUS current

The current value is calculated by Eq. (19).

$$\text{Current [A]} = 0.005237 \times \text{DATA} \tag{19}$$

3.1.20. EPS 12V BUS voltage and current

Table 21 EPS 12V BUS voltage and current

Number	byte	Content	byte
(1)	#109-#110	EPS 12V BUS voltage	2
(2)	#111-#112	EPS 12V BUS current	2

(1) EPS 12V BUS voltage

The voltage value is calculated by Eq. (20). The obtained 2 byte hexadecimal number (HEX) should be converted to a decimal number (DEC); then substituted into "DATA". (This process is also required in (2).)

$$\text{Voltage [V]} = 0.01349 \times \text{DATA} \tag{20}$$

(2) EPS 12V BUS current

The current value is calculated by Eq. (21).

$$\text{Current [A]} = 0.00207 \times \text{DATA} \tag{21}$$

3.1.21. BCR1~3 voltage

Table 22 BCR 1~3 voltage

byte	内容	byte 数
#113-#114	BCR 1 voltage	2
#115-#116	BCR 2 voltage	2
#115-#116	BCR 3 voltage	2

BCR (Battery Charge Regulator) voltages are calculated by Eq. (22). The obtained 2 byte hexadecimal number (HEX) should be converted to a decimal number (DEC); then substituted into "DATA".

$$\text{Voltage [V]} = 0.0249 \times \text{DATA} \tag{22}$$

3.1.22. SAP 5 (-Z) current

SAP (Solar Array Panel) 5 (-Z)'s current is given by Eq. (23). The obtained 2 byte hexadecimal number (HEX) should be converted to a decimal number (DEC); then substituted into "DATA".

$$\text{Current [A]} = 0.0009775 \times \text{DATA} \tag{23}$$

3.1.23. 5.8GHz 12V voltage

The voltage value is calculated by Eq. (24). The obtained 2 byte hexadecimal number (HEX) should be converted to a decimal number (DEC); then substituted into "DATA".

$$\text{Current [A]} = 3.3 \times \frac{DATA}{255} \times \frac{78}{10} \tag{24}$$

3.2. Mission data downlink

3.2.1. Picture data downlink

Table 27 shows Picture data downlink format.

Table 23 Picture data downlink format

Content	Value
Header	0xFF
	0x20
Picture data	0xFF
	0xD8
	・ ・ ・
	0xFF
	0xD9
Shooting date in HEX	Year (last 2 digits of A.D.)
	Month
	Day
	Hour
	Minute
	Second
Footer	0xFF

	0x1E

3.2.2. IMU data downlink

IMU data consists of acceleration values and angular velocity values. Table 28 shows the data format. Data should be converted by the same method described in 3.1.13 and 3.1.14. But please note that the acceleration value is little-endian, whereas the angular velocity value is big-endian.

Table28 IMU data format

Contents	Value
Start time 6 byte	Year
	Month
	Day
	Hour
	Minute
	Second
Garbage 12byte	0xFF
Number 2byte	0x0000-0xFFFF
X acceleration 2byte	0x0000-0xFFFF
Y acceleration 2byte	0x0000-0xFFFF
Z acceleration 2byte	0x0000-0xFFFF
Temperature 2byte	0x0000-0xFFFF
X angular velocity 2byte	0x0000-0xFFFF
Y angular velocity 2byte	0x0000-0xFFFF
Z angular velocity 2byte	0x0000-0xFFFF
End time 6 byte	Year
	Month
	Day

Repeated for number of sampling.
Measurement rate:
-Mast extension 50Hz
-Membrane deployment 150Hz

	Hour
	Minute
	Second
Garbage 12byte	0xFF

3.2.3. Thin-film solar cell I-V properties

On the multi-functional membrane, thin-film solar cells are attached. The current and voltage (I-V) can be measured.

Table29 Thin film solar cell I-V properties

内容	値
Voltage 2byte	0x0000-0xFFFF
Current 2byte	0x0000-0xFFFF
Garbage 4byte	

3.2.3.1. Thin-film solar cell's voltage conversion

The voltage is in little-endian. Table 30 shows the data structure, and Eq. (25) shows the conversion.

Table 30 bit structure

15bit - 4bit	3bit - 0bit
Voltage data	0: positive 1: negative

$$\text{Voltage}\,[V] = 3.3 \times \frac{DATA}{4095} \times 10 \qquad (25)$$

3.2.3.2. Thin-film solar cell's current conversion

The current is in little-endian. Table 31 shows the data structure, and Eq. (26) shows the conversion.

Table 31 bit structure

15bit - 4bit	3bit - 0bit

Current data	0: positive 1: negative

$$\text{Current } [A] = 3.3 \times \frac{DATA}{4095} \times \frac{1}{10} \tag{26}$$

3.2.4. Encoder data

Extensible mast is extended by a motor with an encoder. The data structure is shown in Table 32. 2 byte HEX number (two's compliment) is converted to DEC number. Mast contraction is positive, and extension is negative. The sample rate is once per second. Thus the maximum duration period is 16 s. The data is little-endian.

Table 32 Encoder data format

Contents	Value
Count 1	0x0000-0xFFFF
Count 2	0x0000-0xFFFF
Count 3	0x0000-0xFFFF
・ ・ ・	・ ・ ・
Count 16	0x0000-0xFFFF

(End of document)

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