

FM Downlink Format

TK2-SYS-E-25-0058

Version 1.0

Executive summary

This document describes the downlink data format for the Ten-Koh 2 satellite in FM modes. This document presents format data for housekeeping data and mission data. You can find out when Ten-Koh 2 will pass by checking satellite tracking services such as [Heavens-Above](#).

For mission updates and announcements, please refer to the official website of the Okuyama Laboratory:

- [Japanese version \(日本語\)](#)
- [English version](#)

Updates may also be posted on X (formerly Twitter) via [@LabOkuyama](#).

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1. About the FM Packet of Ten-Koh 2

The Ten-Koh 2 FM Packet is transmitted on-air as the Information field of an AX.25 UI frame. An AX.25 frame begins with a 14-byte address field (Destination and Source) followed by Control = 0x03 and PID = 0xF0.

In this document, Byte 0 of the Ten-Koh 2 FM Packet corresponds to the first byte after the “0x03 0xF0” header.

Depending on the decoder or TNC software used, the AX.25 address field may be

- output as raw hexadecimal,
- replaced by a formatted string (e.g., “from CALLSIGN to CALLSIGN”), or
- encapsulated within a KISS frame (C0 ... C0).

Regardless of format, the Ten-Koh 2 FM Packet always starts immediately after 0x03 0xF0.

Next, we describe the FM packet header of Ten-Koh 2.

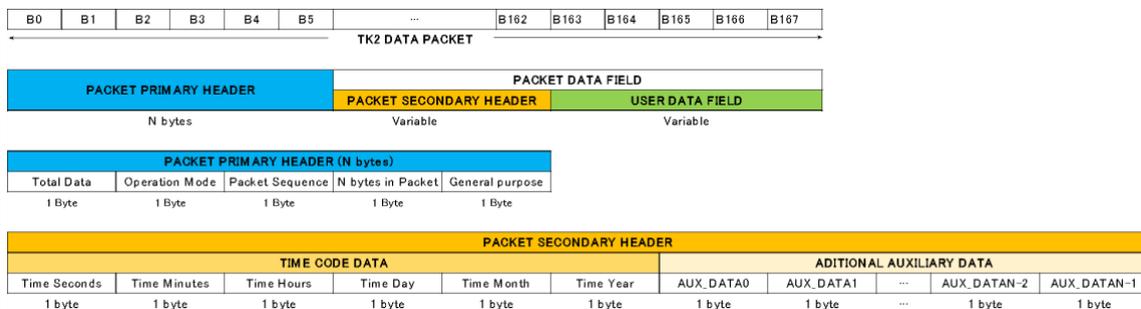


Figure 1 Format of Ten-Koh 2 FM Packet Header

Total Data Packets

Contains the total number of packets of 168 Bytes to be sent from the Subsystem or Satellite. For example, in the case of an image, the total image data is splatted into N data packets. The maximum per command is limited to 256 packets.

Operation Mode

Indicates the Subsystem operation mode when this applies. For example, in the case of the EPS, it indicates the EPS operation mode such as Mission mode, emergency mode and so on.

Packet Sequence Counter

Indicates the current data packet transmitted from a subsystem. For example, for an image splatted

in 100 packets, this Byte holds the current data packet number and increases from 1 to 100 as each data packet is sent.

N Bytes in Packet Data Field

Indicates the total number of Bytes contained in the Packet Data Field. This value varies for every Subsystem and every Subsystem mode of operation. The maximum value is 168 - N Bytes from the Packet Primary Header.

General Purpose Byte 1

If used, contains additional information required for the interpretation of the whole data packet or the Packet Data Field. For example, in the EPS subsystem this Byte indicates the current type of emergency mode.

Packet Secondary Header or PSH

It has the purpose to include auxiliary data (i.e. Time, data field format, satellite attitude, etc.) necessary for the interpretation of the information contained within the User Data Field.

2. Data contents

2.1. NU Mission

NU Mission is a student-driven mission, created in cooperation with various people at Nihon University. For example, artists from Nihon University College of Art and Nihon University High School students. The mission has the following 4 major goals.

1. Using the Raspberry Pi Pico and Python language and testing the usefulness of Raspberry Pi Pico in space.
2. Facilitating a satellite × music × art project. We would like to replace the various elements of the satellite with music and art to create various values.
3. Take a picture with Raspberry Pi Pico and downlink it. The photos will be used for the Ten-Koh 2 website.
4. Downlink Audio by digitalker that can be received with simple equipment to show people the familiarity of space development and amateur radio technology.

Information about the NU Mission's activities, data, and public transmissions will be posted on the official website of the Okuyama Laboratory ([JP](#) / [EN](#)) and on X (formerly Twitter) via [@LabOkuyama](#).

2.1.1. Digitalker mode

Ten-Koh 2 has a function called Digitalker, which repeats digitally recorded audio as a 435.860MHz FM modulated signal.

2.1.2. About NU Mission Packet Header

The FM packet data for the NU mission contains a 3-Byte packet header. This header functions as a

packet counter.

2.1.3. NU mission download mode

In this mode, users can download a sound file of the song “We Are the World” performed by the brass band of an affiliated high school.

Table 1 Music data downlink (1 packet)

Music data downlink	0	...	3	4	...	168
	Packet Header			Music data		

Audio Data Reconstruction Notes

- **Remove the 3-byte packet header from each packet, concatenate the remaining data fields in order, and save the result with the .mp3 extension.**
(In the NU mission download mode, the satellite transmits a standard WAV/MP3 audio file.)
- **The 3-byte packet header functions as a packet counter.**
It can be used to verify the correct sequence of packets and to check for packet loss during downlink.
- **Note:** Ensure that higher-layer headers such as AX.25 or KISS (the bytes before 03 F0) and the frame-end flag (C0) are **not included** in the reconstructed audio data.

2.1.4. NU camera mode

NU camera mode has SINGLE CAMERA SHOT MODE and CONTINUOUS CAMERA SHOT MODE. Image data is displayed in hexadecimal(hex). Acquired images will be available on the website. Data contents in one packet are shown below.

Table 2 Image data downlink (1packet)

Image data downlink	0	...	3	4	...	168
	Packet Header			Image data		

Image Data Reconstruction Notes

- **Remove the 3-byte packet header from each packet, concatenate the remaining data fields in order, and save the result with the .jpg extension.**
(The NU camera mode transmits JPEG image files divided into multiple packets.)
- **If the data is received through KISS/AX.25 frames, make sure to remove all higher-layer headers** such as the AX.25 header (before 03 F0), the 3-byte NU packet header, and the frame-end flag (C0) before concatenation.
- **Perform KISS un-escaping** if required: replace DB DC with C0 and DB DD with DB so that the original binary JPEG data is restored.

- The **3-byte packet header functions as a packet counter**, which can be used to verify the correct packet order and to identify any missing packets.
- The reconstructed binary stream should start with FF D8 (JPEG SOI marker) and can then be saved as a standard .jpg file viewable by any image viewer.

2.2. Material Mission

The Ten-Koh 2 material mission will observe the degradation of PEEK/CFRTP and PEEK materials made by a 3D printer in the space environment. Observations will be made using six strain gauges, three temperature sensors, and five photodiodes.

Here, we will describe the specific contents of data transmitted by FM. The contents of concrete downlink data are as follows.

Table 3 List of data to be downlinked during the Material Mission

Command	Description
Material Mission Real Time	Measurements will be taken as Ten-Koh 2 passes over the ground station at Nihon Univ., and the data will be immediately downlinked.
Read Material Mission Status	Ten-Koh 2 downlinks material mission status information such as file size, mode of operation at the time, and sampling time stored on the SD card.
Read SD card	Ten-Koh 2 reads and downlinks the material mission data stored on the SD card.

2.2.1. About Material Mission Header

Material Mission packet header of Ten-Koh 2 consists of 12 Bytes.

Table 4 Material Mission Packet Header

MM Packet Header	0	...	4	5	...	10	11
	Primary Header			RTC data and time information			SD card status

The meaning of each Byte of Primary Packet Header in Material Mission is shown below.

Table 5 Primary header in Material Mission Packet Header

header [0]	header [1]	header [2]	header [3]	header [4]
Total Data Packets	Op. Mode Register	Packet Sequence Counter	N Bytes in Packet Data Field	Slave ready/Readings

Slave ready/readings, header[4] in Material Mission primary packet header has several meanings and it varies depending on the kinds of command. Check each section for the details.

Table 6 Slave ready/readings value and meaning for each command

Command	Slave ready/Readings
Material Mission Real Time	0x01(fixed value)
Read Material Mission status	Indicated if the data in the slave buffer is ready or not: 0x00: data not ready 0x01 : data ready This Byte can be used by the OBC to ask to the Material Mission after a command to save data.
Read SD card	Indicated if the data is ready to be read: 0x00 : indicates no data ready 0x01 : indicates SD data ready

Table 7 below describes Operation Mode Register in Material Mission primary packet header.

Table 7 Operation mode register values in Material Mission and LIULIN Mission packet header

Material Mission_LIULIN Mission Op. Mode	Op. Mode register values
Initial (default) mode	0x00
Normal mode	0x01
MM Real time mode	0x02
MM set SD card write data sampling time	0x03
MM save mission data into SD card	0x04
Read MM data from last cmd	0x05
Read MM status	0x06
MM Read SD card	0x07
Read SD card file size	0x08
Delete SD card file	0x09
Format SD card	0x0A
LIU Real time mode	0x0B
LIU set SD card write data sampling time	0x0C
Read LIU data from last cmd	0x0D
Read LIU status	0x0E
Dummy SD card write	0x0F
Delete SD card file	0x10
LIU Read SD card	0x11

The meaning of each Byte of RTC data and the time information is shown below.

Table 8 Material mission Packet Secondary header

header [5]	header [6]	header [7]	header [8]	header [9]	header [10]	header [11]
RTC(S)	RTC(M)	RTC(H)	RTC(d)	RTC(m)	RTC(y)	SD_card_status

Table 9 RTC Units

header	means
RTC(S)	Second
RTC(M)	Minute
RTC(H)	Hour
RTC(d)	Day
RTC(m)	Month
RTC(y)	Year

Table 10 Material mission SD card status

Material mission SD card status	Status value
SD card status initial value	0xF0
Fail to write 0	0x00
Fail to write 1	0x01
Fail to write 2	0x02
Write success	0x03
Fail to read 0	0x04
Fail to read 1	0x05
Fail to read 2	0x06
Read success	0x07
Fail read file size 0	0x08
Fail read file size 1	0x09
Read file size success	0x0A
Fail to delete file error 0	0x0B
Fail to delete file error 1	0x0C
Delete file success	0x0D
Fail to format SD card	0x0E
Format SD card success	0x0F

2.2.2. Material Mission Real Time Downlink

The return values of the Material Mission Real Time command occupy Byte 12 through 91.

Table 11 Read Material Real Time command return value format

MM Real Time	12	13	14	15	16	17	18	19											
	SG0			VREF0			TEMP0												
	...																		
	54	55	56	57	58	59	58	59											
	SG5			VREF5			TEMP5												
	60	61	62	63	. . .			72	73	74	75								
	PD1A		PD1B					PD4A		PD4B									
	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91			
	TEMP1		TEMP2		TEMP3		PD5A		PD5B		TEMP4		VREF2V5		VREF2V				
	92	93	94	95	96	97	98	99											
	00	00	00	00	L	A	S	T											

Sample data (including a header)

```
0A0204570117271726042400FFD1187FB47C0CF8FFDE107FAB730CF8FFDF4F7FBAB80CFAF
FEF857FB9AB0D08FFD4C77FBCA50CF3FFE3E07FBEB70D0000510076005A0084008400F100
6F022B067B067A0679004F00740684064907FF000000004C415354
```

Note

- SG0: Strain gauge 0 is connected to material sample 1
- SG1: Strain gauge 1 is connected to material sample 1
- SG2: Strain gauge 2 is connected to material sample 2
- SG3: Strain gauge 3 is connected to material sample 2
- SG4: Strain gauge 4 is connected to material sample 3
- SG5: Strain gauge 5 is connected to material sample 3
- VREF: Voltage reference circuit
- TEMP: Temperature
- PD1: Photodiode1
- PD2: Photodiode2
- PD3: Photodiode3
- PD4: Photodiode4
- PD5: Photodiode5

2.2.3. Read Material Mission Status Downlink

The return value of the Read Material Mission Status command takes the form of the following table.

Table 12 Read Material Mission Status command return value format

Read MM status	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26		
	F i l e s i z e								:	SD card file size				Mission Number			
	27								28								
	Sampling Time OBC								Sampling Time Auto								

Converting the hexadecimal digits from Byte 12 to Byte 20 to ASCII yields “Filesize:”. The file size of an SD card is expressed as a 4-Byte hexadecimal number. This must be combined and then converted to a decimal number. The 25th and 26th Bytes represent the mission number. The 27th

Table 16 Primary header in LIULIN Mission packet header

header [0]	header [1]	header [2]	header [3]	header [4]
Total Data Packets	Op. Mode Register	Packet Sequence Counter	N Bytes in Packet Data Field	Slave ready/Readings

Slave ready/readings, header[4] in LIULIN Mission primary packet header has several meanings and it varies depending on the kind of command. Check each section for the details.

Table 17 Slave ready/Reading value for each command

Command	Slave ready/Readings
LIULIN Mission Real Time	Indicates the number of times to read LIULIN real time data. Be careful as 0×00 corresponds to spectrum 1, 0×01 to spectrum 2 and so on.
Read LIULIN Mission status	Indicated if the data is ready to be read: 0×00 : indicates no data ready 0×01 : indicates SD data ready
Read SD card	Indicated if the data is ready to be read: 0×00 : indicates no data ready 0×01 : indicates SD data ready

The meaning of each Byte of RTC data and the time information is shown below.

Table 18 LIULIN Mission Packet Secondary header

header [5]	header [6]	header [7]	header [8]	header [9]	header [10]	header [11]
RTC(S)	RTC(M)	RTC(H)	RTC(d)	RTC(m)	RTC(y)	SD_card_status

Table 19 Same as Table 9 (RTC Units)

header	means
RTC(S)	Second
RTC(M)	Minute
RTC(H)	Hour
RTC(d)	Day
RTC(m)	Month
RTC(y)	Year

Additionally, the Operation Mode Register in the primary packet header of the LIULIN Mission is detailed in Table 7 and the SD card status is described in Table 20.

Table 20 LIULIN SD card status

LIULIN mission SD card status	Status value
SD card status initial value	0xF0
Fail to write 0	0x00
Fail to write 1	0x01
Fail to write 2	0x02
Write success	0x03
Fail to read 0	0x04
Fail to read 1	0x05
Fail to read 2	0x06
Read success	0x07
Fail read file size 0	0x08
Fail read file size 1	0x09
Read file size success	0x0A
Fail to delete file error 0	0x0B
Fail to delete file error 1	0x0C
Delete file success	0x0D
Fail to format SD card	0x0E
Format SD card success	0x0F

2.3.2. LIULIN Mission real time downlink

Table 21 Packet composition for "LIULIN Mission real time" command

(1) LIULIN Mission real time①	12	13	14	15	16	17	18	19	20	...	23	24	...	163
	L	i	u	-	T	K		M	Block Counter			Channels data		
②	12	...										163		
	Channels data													
③	12	...									79	80	...	86
	Channels data											Health data		

Block counter

Table 22 Block counter value

Block counter[0]	Block counter[1]	Block counter[2]	Block counter[3]
OBC(MSB)	OBC(LSB)	COM(MSB)	COM(LSB)

44BB54AB649B748B847B946BA45BB44BC43BD42BE41BF40C03FC13EC23DC33CC43BC53
 AC639C738C837C936CA35CB34CC33CD32CE31CF30D02FD12ED22DD32CD42BD52AD629
 D728D827D926DA25DB24DC23DD22DE21DF20E01FE11EE21DE31C

040B043C0109041626042400E41BE51AE619E718E817E9160001EB14EC13ED12EE11EF10F00
 FF10EF20DF30CF40BF50AF609F708F807F906FA05FB04FC03FD02FE01FF0000000000000000
 00
 00
 00
 00

2.3.3. Read LIULIN Mission status downlink

Table 24 Packet composition for "Read LIULIN Mission status" command

(3) Read LIULIN Mission status	12	...	24	25	26	27	28
	SD file size information			Mission number		Sampling Time	

Sampling Time

Byte 27 - Returns the current SD card sampling time as OBC beacons.

Byte 28 - Returns the current SD card sampling time when saving data automatically.

Sample data (including a header)

010F0118014517162604240A46696C6553697A653A000000010000010200000000000000000000
 00
 00
 00
 00
 00

2.3.4. Read SD card (LIULIN Mission data read mode)

Table 25 Packet composition for "LIULIN Read SD card" command

(2) LIULIN Mission SD card	12	...	16	17	...	23	24	25	26	27	28	29	30	31	...	35
	Primary Header			RTC data and time information			L	i	u	-	T	K		M	Block Counter	

Block counter

The meaning of each Byte of Block counter is described in “2.3.2 LIULIN Mission real time downlink”.

2.4. EPS Data

Here, we will describe the specific contents of data transmitted by FM. The contents of concrete downlink data are as follows.

Table 26 Contents of downlink data

Contents	Description
EPS real time	Measurements will be taken as Ten-Koh 2 passes over the ground station at Nihon Univ., and the data will be immediately downlinked.
EPS beacon + housekeeping saving data	The beacon sends the ASCII value of the telemetry from the EPS controller.
Read EPS status	Ten-Koh 2 reads and downlinks the EPS status data stored on the SD card.

2.4.1. About EPS Packet Header

EPS packet header of Ten-Koh 2 consists of 12 Bytes.

Table 27 EPS Packet Header

EPS Packet Header	0	...	4	5	...	10	11
	Primary Header			RTC data and time information			SD card status

The meaning of each Byte of Primary Header in EPS is shown below.

Table 28 Primary header in EPS packet header

header [0]	header [1]	header [2]	header [3]	header [4]
Total Data Packets	EPS Op. Mode Register	Packet Sequence Counter	N Bytes in Packet Data Field	Emergency register

Table 29 below shows Operation mode register values.

Table 29 Operation mode register values in EPS packet header

EPS Op. Mode	Op. Mode register values
Initial (default) mode	0x00
Normal mode	0x02
Mission mode	0x03
Emergency mode	0x04
Real time mode	0x05
EPS status mode	0x0B
Read SD card	0x0F
Read SD card file size	0x10
Internal control modes	others

The meaning of each Byte of RTC data and the time information is shown below.

Table 30 EPS Packet Secondary header

header [5]	header [6]	header [7]	header [8]	header [9]	header [10]	header [11]
RTC(S)	RTC(M)	RTC(H)	RTC(d)	RTC(m)	RTC(y)	SD_card_status

Table 31 Same as Table 9 (RTC Units)

header	means
RTC(S)	Second
RTC(M)	Minute
RTC(H)	Hour
RTC(d)	Day
RTC(m)	Month
RTC(y)	Year

Table 32 EPS SD card status

EPS SD card status	Status value
SD card status initial value	0xF0
Fail to write 0	0x00
Fail to write 1	0x01

Fail to write 2	0x02
Write success	0x03
Fail to read 0	0x04
Fail to read 1	0x05
Fail to read 2	0x06
Read success	0x07
Fail read file size 0	0x08
Fail read file size 1	0x09
Read file size success	0x0A
Fail to delete file error 0	0x0B
Fail to delete file error 1	0x0C
Delete file success	0x0D
Fail to format SD card	0x0E
Format SD card success	0x0F

2.4.2. EPS real time downlink

Table 33 Packet composition for "EPS real time" command

(1) EPS real time	12	...	14	15	...	22	23	...	38
	[1] GPIO			[2] HK data			[3] Temperature data		

Table 34 Sample data of "EPS real time"

(1) Sample data	GPIO	HK data	Temperature data
	28FA03	08FE0BB30670067E	0688067D066A066F065A066D06620674

Sample data (including a header)

01050022005238110603240328FA0308FE0BB30670067E0688067D066A066F065A066D06620674

①Turn on power lines ②Turn off power lines ③Power Reset

The downlink data of the above commands are common to the downlink data of "EPS real time" command.

[1] GPIO (3Bytes)

Check GPIO expander (1Byte)

The GPIO (General Purpose Input/Output) is used to determine whether the satellite's GPIO pins are functioning correctly.

- A value of 28 indicates that the pins are operating without any issues.

Power Line Status Evaluation (2Bytes)

The following two bytes represent the ON/OFF status of each power line controlled by the EPS.

The first byte corresponds to Port A, and the second corresponds to Port B of the MCP23S17 GPIO expander:

- Port A (1 Byte): Controls the 5V and 3.5V power lines (e.g., 5V_CAM, 5V_PL, 5V_NUM, etc.)
- Port B (1 Byte): Controls the 12V power lines (e.g., 12V_ADSCS, 12V_LIU) and reserved bits.

Each line item corresponds to a specific bit in the respective port. Reference Table 37 for detailed bit-to-system mapping. By converting each byte from hexadecimal to binary, the ON/OFF status of each subsystem can be determined.

Active Level:

In this configuration:

- '0' indicates that the component is powered ON (Active Low)
- '1' indicates that the component is powered OFF

Bit Numbering Convention:

- Bits are described in the format [Voltage]_[System Name]
- Bit positions follow the order b7 (MSB) → b0 (LSB) for each port byte.
- Port A and Port B must be interpreted separately.

Table 35 Structure of the GPIO Section in the EPS Real-Time Downlink Data

Field Name	Byte Index	Data Format	Description
GPIO Expander Device ID	B12	1 Byte	Identifier byte used to confirm correct MCP23S17 configuration and communication.
Power Line Status (Port A)	B13	1 Byte	Each bit indicates the ON/OFF state of a 5V / 3.5V power line.
Power Line Status (Port B)	B14	1 Byte	Each bit indicates the ON/OFF state of 12V power lines and reserved lines.

Table 36 Breakdown of Power Line Status (Port A)

bit	Signal Name	Controlled Line	Active State
b7	5V_CAM	5V supply for Camera module	Active Low
b6	5V_PL	5V supply for Payload module	Active Low
b5	5V_NUM	5V supply for NU Mission payload (Nihon University Mission Unit)	Active Low
b4	3V5_JAMSAT	3.5V supply for JAMSAT module	Active Low
b3	3V3_ADCS	3.3V power supply for ADCS	Active Low
b2	5V_OBC	5V power supply for OBC main	Active Low
b1	5V_ADCS	5V power supply for ADCS	Active Low
b0	5V_COM	5V power supply for Communication subsystem	Active Low

Table 37 Breakdown of Power Line Status (Port B)

bit	Signal Name	Controlled Line	Active State
b7	Reserved	-	Active Low
b6	Reserved	-	Active Low
b5	Reserved	-	Active Low
b4	Reserved	-	Active Low
b3	Reserved	-	Active Low
b2	Reserved	-	Active Low
b1	12V_ADCS	12V power supply for ADCS	Active Low
b0	12V_LIU	12V power supply for LIULIN Module	Active Low

Note

COM: Communication

ADCS: Attitude Determination and Control Subsystem

JAMSAT: JAMSAT mission

NUM: NU mission

PL: Payload

CAM: Camera

LIU: Liulin mission

[2] HK data

Table 38 Breakdown of EPS HK data

Contents	Data amount
Battery current	2 Bytes
Battery voltage	2 Bytes
Battery temperature	2 Bytes
EPS PIC temperature	2 Bytes
SUM	8 Bytes

Note

TRP: Transponder

Battery Current (A) Evaluation

The battery current represents the flow of electric charge in the battery unit on the satellite.

1. Start by converting the provided 3-character hexadecimal string to its decimal equivalent.
2. To find the battery current in volts, use the formula:

$$\mathbf{B. current(volt) = adc(dec) * (5 / 4096)} \quad \mathbf{(2.4.1)}$$

3. Then, convert the voltage to current with the following formula:

$$\mathbf{B. current = (B. current(volt) - 2.5) / (200 * 0.001)} \quad \mathbf{(2.4.2)}$$

By following these steps, you can ascertain the flow of electric charge in the battery unit.

Note:

- If the result is greater than 0, it indicates Discharge.
- If the result is less than 0, it indicates Charge.

Battery Voltage (V) Evaluation

The battery voltage represents the current voltage level of the battery unit on the satellite.

1. Begin by converting the provided 3-character hexadecimal string to its decimal equivalent.
2. To determine the battery voltage, use the formula:

$$\mathbf{B.volt = adc(dec) * (5/4096)} \quad (2.4.3)$$

By following these calculations, you can ascertain the current voltage level of the battery unit.

Battery Temperature (°C) Evaluation

Battery temperature represents the current operating temperature of the battery unit on the satellite.

1. Begin by converting the provided 3-character hexadecimal string to its decimal equivalent.
2. To determine the battery voltage temperature, use:

$$\mathbf{B.temp(volt) = (adc(dec) / 4096) * 5} \quad (2.4.4)$$

3. To find the actual temperature in Celsius, apply:

$$\mathbf{B.temp = (B.temp(volt) * 147.06) - 273.15} \quad (2.4.5)$$

By following these calculations, you can ascertain the operational temperature of the battery unit.

[3] Temperature data

Table 39 Breakdown of temperature data

Contents	Data amount
RDS_PL	2 Bytes
RDS_BUS	2 Bytes
Reserved	2 Bytes
Nishimusen	2 Bytes
NU camera	2 Bytes
TRP	2 Bytes
Back frame	2 Bytes
Battery Box	2 Bytes
SUM	16 Bytes

2.4.3. EPS beacon + housekeeping saving data downlink

Table 40 Packet composition for "EPS beacon + housekeeping saving data" command

(2) EPS beacon + housekeeping saving data	12	...	17	18	...	29
	GPIO			HK data		

The meaning of each Byte of GPIO data and HK data is described in "Table 28 Breakdown of "[1] GPIO" data" and "Table 29 Breakdown of EPS HK data", respectively. Beacon sends the ASCII value of the telemetry from the EPS controller. ASCII is sent as two Bytes per content, one on the left and one on the right.

2.4.4. Read EPS status downlink

Table 41 Packet composition for "Read EPS status" command

(3) Read EPS status	12	...	14	15	...	49	50
	GPIO			EPS status			00

The meaning of each Byte of GPIO data is described in Table 35, Table 36 and Table 37. Details of "EPS status" are shown in "Table 42 Breakdown of "EPS status" data" below.

Table 42 Breakdown of "EPS status" data

Contents	Data amount
Reset information	8 Bytes
Heater status	1 Byte
WDU reset information	2 Bytes
SD file size information	13 Bytes
SOC min	2 Bytes
SOC med	2 Bytes
Battery temp min	2 Bytes
Battery temp rec	2 Bytes
Battery temp max	2 Bytes
SD sampling time	1 Byte
SUM	34 Bytes

Note

SOC min: minimum value of SOC

SOC med: warning value of SOC

Battery temp min: minimum battery temperature threshold setting

Battery temp rec: recovery battery temperature threshold setting

Battery temp max: maximum battery temperature threshold setting

SD sampling time: SD card sampling time setting

Heater status

A heater status Byte of 00 indicates off, and F0 indicates on.

WDU reset information

WDU reset information indicates the number of times a WDU reset has been performed, expressed as a 2-Byte hexadecimal number.

SD file size information

Each 1-Byte count SD file size information. The meaning of each Byte is shown below.

Table 43 Read EPS status downlink File Size Information

[0]	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]
0x46 (F)	0x69 (i)	0x6C (l)	0x65 (e)	0x53 (S)	0x69 (i)	0x7A (z)	0x65 (e)	0x3A (:)	M S B	Upper Middle	Lower Middle	L S B

SD sampling time

A value of 03 indicates that data is being saved to the SD card once every 3 beacons.

Sample data (including a header)

01020122000946170703240A28FA03000000000000000100000046696C6553697A653A00000750
0A1F0A710635064006DC0300

2.4.5. Read SD card

The data obtained by the Read SD card command of the EPS subsystem consists of a 12-byte header and multiple telemetry data blocks. Each telemetry data block is 39 bytes in length. Depending on the operational situation, up to four telemetry data blocks may be included.

Each telemetry data block is composed of a 12-byte header and a 27-byte real-time data section.

The format of the data obtained by the Read SD Card command is shown in the following table.

Table 44 Downlink Data Format for Read SD Card Command

Read SD card	12	...	16	17	...	22	23	24	...	26	27	...	34	35	...	50
	Primary Header			RTC data and time information			SD card		[1] GPIO		[2] HK data		[3] Temperature data			
2nd EPS Real Time Packet																
3rd EPS Real Time Packet																
4th EPS Real Time Packet																

For details on the breakdown of the real-time data, please refer to 2.4.2.EPS real time downlink.

Sample Data (including a header)

050F01A3005039130603240701020022000010120603240328FA0308680BD606720680068B068A
066C0674066F06710673067801020022004616120603240328FA0308630BCF06720680068A068B
066D0674066F06710673067801020022001223120603240328FA03085A0BCB06720680068B068
A066D0674066E06720674067801020022003330120603240328FA03085B0BBF06800681068B06
8B066D0675066E06710675067A

2.5. IFPV Data

This section describes the specific contents of the data transmitted via IFPV. The specific downlink data are as follows:

Table 45 Contents of downlink data in IFPV

Contents	Description
IFPV real time (RT) from all ADCs data	Measurements are performed while Ten-Koh 2 passes over Nihon University's ground station, and the data are immediately downlinked.
Read IFPV status	Represents the number of times data has been saved to the SD card, as well as the total amount of data stored on the SD card.
Read SD card	Downlinks the contents of the SD card.

Table 46 Downlink data contents (IFPV real time from all ADCs data)

IFPV real time (RT) from all ADCs data	12	...	93
	ADC Data		

Table 47 Downlink data contents (Read IFPV status)

Read IFPV status	12	13	...	21	22	...	24
	saving data time interval		FILESize:			SD card file size	

Table 48 Downlink data contents (Read SD card)

Read SD card	12	...	105
	SD card data		

2.5.1. About IFPV Packet header

IFPV packet header of Ten-Koh 2 consists of 12 Bytes.

Table 49 IFPV Packet header

IFPV Packet Header	0	...	4	5	...	10	11
	Primary Header			RTC data and time information			SD card status

The meaning of each Byte of Primary Header is shown below.

Primary Header

Table 50 IFPV Primary Header

header [0]	header [1]	header [2]	header [3]	header [4]
Data packets	Op. Mode Register	Packet counter	# Bytes	Slave ready

Data packets

The number of packets is displayed in hexadecimal when 168 Bytes is one packet. The maximum

number of packets per command is limited to 256 packets.

Op. Mode Register

It shows the operating mode of the relevant subsystem. The values for each subsystem are shown below.

Table 51 IFPV Operation Mode

IFPV Op. Mode	values
IFPV real time (RT) from all ADCs data	0x02
Read IFPV status	0x03
Read SD card	0x04

Packet counter

It shows the current data packet sent by the subsystem in hexadecimal. For example, for data divided into 100 packets, this Byte holds the current data packet number and is increased from 1 to 100 as each data packet is transmitted.

Bytes

It Shows the total number of Bytes in the packet data field in hexadecimal.

Slave ready

It returns “0” by default.

RTC data and Time information

The meaning of each Byte of RTC data and the time information is shown below.

Table 52 IFPV Packet Secondary Header

header [5]	header [6]	header [7]	header [8]	header [9]	header [10]	header [11]
RTC(S)	RTC(M)	RTC(H)	RTC(d)	RTC(m)	RTC(y)	SD_card_status

Table 53 Same as Table 9 (RTC Units)

header	means
RTC(S)	Second
RTC(M)	Minute

RTC(H)	Hour
RTC(d)	Day
RTC(m)	Month
RTC(y)	Year

SD Card Status

Table 54 IFPV SD card status

IFPV SD card status	Status value
SD card status initial value	0xF0
Fail to write 0	0x00
Fail to write 1	0x01
Fail to write 2	0x02
Write success	0x03
Fail to read 0	0x04
Fail to read 1	0x05
Fail to read 2	0x06
Read success	0x07
Fail read file size 0	0x08
Fail read file size 1	0x09
Read file size success	0x0A
Fail to delete file error 0	0x0B
Fail to delete file error 1	0x0C
Delete file success	0x0D
Fail to format SD card	0x0E
Format SD card success	0x0F

2.5.2. IFPV real time (RT) from all ADCs data

Table 55 Packet of ALL ADC DATA

(1) IFPV real time (RT) from all ADCs data	12	...	27	28	...	43	44	...	51	52	...	65	66	...	79	80	...	93	94	95
	RDS_ADC			PL1_ADC			PL2_ADC			SP1_ADC			SP2_ADC			SP3_ADC			00	00

0~4	5~11	12~27	28~43	44~51	52~65	66~79	80~93
------------	-------------	--------------	--------------	--------------	--------------	--------------	--------------

PRIMARY HEADER	RTC	RDS_ADC	PL1_ADC	PL2_ADC	SP1_ADC	SP2_ADC	SP3_ADC
-------------------	-----	---------	---------	---------	---------	---------	---------

Sample data (including a header)

0A02015900284918060324000E7F0E5F00540024004203A500010002004C100120D63001403550
016000700100001001204930010002103D2002367940025002600100001005200030004000500066
71R00001000200036694000500066710000

header [0]	header [1]	header [2]	header [3]	header [4]
Data packets	Op. Mode Register	Packet counter	# Bytes	Slave ready
0A	02	01	59	00

header [5]	header [6]	header [7]	header [8]	header [9]	header [10]	header [11]
RTC(S)	RTC(M)	RTC(H)	RTC(d)	RTC(m)	RTC(y)	SD_card_status
28	49	18	06	03	24	00

RDS_ADC	12~13	14~15	16~17	18~19	20~21	22~23	24~25	26~27
	RDS_0	RDS_1	RDS_2	RDS_3	RDS_4	RDS_5	RDS_6	RDS_7
	0E7F	0E5F	0054	0024	0042	03A5	0001	0002

LP1_ADC	28~29	30~31	32~33	34~35	36~37	38~39	40~41	42~43
	LP1_0	LP1_1	LP1_2	LP1_3	LP1_4	LP1_5	LP1_6	LP1_7
	004C	1001	20D6	3001	4035	5001	6000	7001

PL2_ADC	44~45	46~47	48~49	50~51
	PL2_0	PL2_1	PL2_2	PL2_3
	0000	1001	2049	3001

SP1_ADC	52~53	54~55	56~57	58~59	60~61	62~63	64~65
	SP1_0	SP1_1	SP1_2	SP1_3	SP1_4	SP1_5	SP1_6
	0002	103D	2002	3679	4002	5002	6001

SP2_ADC	66~67	68~69	70~71	72~73	74~75	76~77	78~79
	SP2_0	SP2_1	SP2_2	SP2_3	SP2_4	SP2_5	SP2_6
	0000	1005	2000	3000	4000	5000	6671

SP2_ADC	80~81	82~83	84~85	86~87	88~89	90~91	92~93
	SP3_0	SP3_1	SP3_2	SP3_3	SP3_4	SP3_5	SP3_6
	0000	1000	2000	3669	4000	5000	6671

RDS_ADC

Table 56 Packet of RDS_ADC

RDS_ADC	12~13	14~15	16~17	18~19	20~21	22~23	24~25	26~27
	RDS_0	RDS_1	RDS_2	RDS_3	RDS_4	RDS_5	RDS_6	RDS_7

The RDS_ADC portion is formatted as shown in the table above. The data obtained from these are described in the following sections.

Table 57 Packet Description of RDS_ADC

RDS_ADC		type
12~13	RDS_0	voltage
14~15	RDS_1	current
16~17	RDS_2	voltage
18~19	RDS_3	current
20~21	RDS_4	voltage
22~23	RDS_5	current
24~25	RDS_6	voltage
26~27	RDS_7	current

LP1_ADC

Table 58 Packet of LP1_ADC

LP1_ADC	28~29	30~31	32~33	34~35	36~37	38~39	40~41	42~43
---------	-------	-------	-------	-------	-------	-------	-------	-------

	LP1_0	LP1_1	LP1_2	LP1_3	LP1_4	LP1_5	LP1_6	LP1_7
--	-------	-------	-------	-------	-------	-------	-------	-------

The LP1_ADC portion is formatted as shown in the table above. The data obtained from these are described in the following sections.

Table 59 Packet Description of LP1_ADC

LP1_ADC		type
28~29	LP1_0	voltage
30~31	LP1_1	current
32~33	LP1_2	voltage
34~35	LP1_3	current
36~37	LP1_4	voltage
38~39	LP1_5	current
40~41	LP1_6	voltage
42~43	LP1_7	current

PL2_ADC

Table 60 Packet of LP2_ADC

PL2_ADC	44~45	46~47	48~49	50~51
	PL2_0	PL2_1	PL2_2	PL2_3

The LP2_ADC portion is formatted as shown in the table above. The data obtained from these are described in the following sections.

Table 61 Packet Description of LP2_ADC

PL2_ADC		type
44~45	PL2_0	voltage
46~47	PL2_1	current
48~49	PL2_2	voltage
50~51	PL2_3	current

SP1_ADC

Table 62 Packet of SPA_ADC

SP1_ADC	52~53	54~55	56~57	58~59	60~61	62~63	64~65
	SP1_0	SP1_1	SP1_2	SP1_3	SP1_4	SP1_5	SP1_6

The SP1_ADC portion is formatted as shown in the table above. The data obtained from these are described in the following sections.

Table 63 Packet Description of SP1_ADC

SP1_ADC		type
52~53	SP1_0	current
54~55	SP1_1	Temperature
56~57	SP1_2	current
58~59	SP1_3	Temperature
60~61	SP1_4	current
62~63	SP1_5	current
64~65	SP1_6	Not connect

SP2_ADC

Table 64 Packet of SP2_ADC

SP2_ADC	66~67	68~69	70~71	72~73	74~75	76~77	78~79
	SP2_0	SP2_1	SP2_2	SP2_3	SP2_4	SP2_5	SP2_6

The SP2_ADC portion is formatted as shown in the table above. The data obtained from these are described in the following sections.

Table 65 Packet Description of LP2_ADC

SP2_ADC		type
66~67	SP2_0	current
68~69	SP2_1	Temperature
70~71	SP2_2	current
72~73	SP2_3	Not connect
74~75	SP2_4	current
76~77	SP2_5	current

78~79	SP2_6	Temperature
-------	-------	-------------

SP3_ADC

Table 66 Packet of SP3_ADC

SP2_ADC	80~81	82~83	84~85	86~87	88~89	90~91	92~93
	SP3_0	SP3_1	SP3_2	SP3_3	SP3_4	SP3_5	SP3_6

The SP3_ADC portion is formatted as shown in the table above. The data obtained from these are described in the following sections.

Table 67 Packet Description of SP3_ADC

SP2_ADC		type
80~81	SP3_0	current
82~83	SP3_1	Temperature
84~85	SP3_2	current
86~87	SP3_3	Temperature
88~89	SP3_4	current
90~91	SP3_5	current
92~93	SP3_6	Temperature

Sample data (including a header)

```
0A02015900284918060324000E7F0E5F00540024004203A500010002004C100120D63001403550
016000700100001001204930010002103D2002367940025002600100001005200030004000500066
710000100020003669400050006671
```

2.5.3. Read IFPV status

The Read IFPV status function displays the number of times data has been saved to the SD card, as well as the amount of data stored on the SD card. The details are as follows:

Table 68 Downlink data contents (Read IFPV status)

Read IFPV status	12	13	...	20
	saving data time interval		IFPV-EPS	

2.5.3.1 saving data time interval

This indicates the number of times data has been saved to the SD card, represented in 1 byte.

