

Telemetry formats and equations of Painani-2 Satellite

Uplink and Downlink telemetry commands have a special format. This commands have 2 bytes as header (the header always will be the same, it is 'M','X' in ASCII value), 1 byte with the total number of bytes of the command, "n" number of bytes as argument and finally 2 bytes as CRC to verify the information.

Header	Total number of bytes	Command number	Arguments	CRC-16
2 bytes	1 byte	1 byte	n bytes	2bytes

CRC code:

```
uint16 CRC16(uint8 *data_p,uint16 longitud)
{
    #define    POLY        0x8408

    unsigned char i;
    unsigned int data;
    unsigned int crc = 0xffff;

    if (longitud == 0)
        return (~crc);
    do
    {
        for (i=0, data=(unsigned int)0xff & *data_p++;
            i < 8;
            i++, data >= 1)
        {
            if ((crc & 0x0001) ^ (data & 0x0001))
                crc = (crc >> 1) ^ POLY;
            else  crc >>= 1;
        }
    } while (--longitud);

    crc = ~crc;
    data = crc;
    crc = (crc << 8) | (data >> 8 & 0xff);
    return (crc);
}
```

The commands are as follows:

Command 0x00: Disable beacon message

The beacon message is sent each 2 minutes to keep contact with any Earth Station anywhere in the world. This uplink command disables the beacon message for 30 minutes.

Uplink command:

Header	Num of bytes	Num Command	CRC
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0x4D, 0x58 (MX)	0x06	0x00	0x1770
2 bytes	1 byte	1 byte	2 bytes

Downlink command:

Header	Num of bytes	Argument	CRC
M X (ASCII)	0x0D	Painani2 (ASCII)	-
2 bytes	1 byte	8 bytes	2 bytes

Command 0x01: Instant telemetry

This command gets a basic telemetry of the satellite. With this command Ground station is able to know the Satellite state in that moment.

Uplink command:

Header	Num of bytes	Num Command	CRC
0x4D, 0x58 (MX)	0x06	0x01	0x9E61
2 bytes	1 byte	1 byte	2 bytes

Downlink command:

Header	Num of bytes	Name	VI's	Temps	Images	CRC
MX(ASCII)	0x2F (47)	Painani2 (ASCII)	-	-	-	-
2 bytes	1 byte	8 bytes	26 bytes	7 bytes	1 byte	2 bytes

Description of the downlink command:

VI's: Voltages and currents. All data is defined in a 2-byte word. The data order and conversion factors in the response data package is showed in the next chart.

β = decimal value

Parameter	Conversion formula	Units
% Battery charge	$\beta / 256$	%
Voltage OBC (3.3V)	$\beta / 1000$	V
Current OBC	$(\beta / 125) - 1.5$	A
Voltage EPS (3.3V)	$\beta / 1000$	V
Current EPS (3.3V source)	$(\beta / 1000) - 1.5$	A
Voltage EPS (5.0V)	$(\beta / 500)$	V
Current EPS (5.0V source)	$(\beta / 1000) - 1.5$	A
Voltage Comms (3.3V)	$\beta / 1000$	V
Current Comms (3.3V source)	$(\beta / 1000) - 1.5$	A
Voltage Comms (5.0V)	$(\beta / 500)$	V
Current Comms (5.0V source)	$(\beta / 1000) - 1.5$	A
Voltage Battery	$(156.25 * 10e-6) * \beta$	V
Current Battery	$(\beta / 500) - 3$	A

Temps: Temperature data is stored as 8-bit sign two's complement format. Temperature data is calibrated in Celsius degrees. In this command there are only 7 temperatures. The order of the temperature data in the response data package it is as follows:

1. OBC
2. EPS
3. Battery 1
4. Battery 2
5. COMMS
6. ADCS
7. ADCS drivers

Images: Number of images stored by the Satellite. It is a hexadecimal value.

Command 0x02: Intermediate telemetry

This command get and sends 400 samples of the stored telemetry. A sample is stored automatically every 20 min in a circular buffer.

Uplink command:

Header	Number of bytes	Num. of Command	CRC
0x4D, 0x58 (MX)	0x06	0x02	-
2 bytes	1 byte	1 byte	2 bytes

Downlink command:

Ground Station will receive 400 samples with this same format.

Header	Num of bytes	VI's	Temps	Num latch-up	Satellite Date	Mag (XYZ)	CRC
MX(ASCII)	0x67	-	-	-	-	-	-
2 bytes	1 byte	66 bytes	20 bytes	1 byte	5 bytes	6 bytes	2 bytes

Samples with 0xFF as data value are empty data.

Description of the downlink command:

VI's: Voltages and currents of all Satellite, the next table shows the data conversion. All data is defined in 2-byte word. The data have the same order as the table.

β = decimal value

Parameter	Conversion formula	Units
% Battery charge	$\beta / 256$	%
Voltage Panel X+	$\beta * 0.006$	V
Current Panel X+	$(\beta / 1000) - 1.5$	A
Voltage Panel X-	$\beta * 0.006$	V
Current Panel X-	$(\beta / 1000) - 1.5$	A
Voltage Panel Y+	$\beta * 0.006$	V
Current Panel Y+	$(\beta / 1000) - 1.5$	A
Voltage Panel Y-	$\beta * 0.006$	V
Current Panel Y-	$(\beta / 1000) - 1.5$	A
Voltage OBC (3.3V)	$\beta / 1000$	V
Current OBC	$(\beta / 125) - 1.5$	A

Voltage EPS (3.3V)	$\beta / 1000$	V
Current EPS (source 3.3V)	$(\beta / 1000) - 1.5$	A
Voltage EPS (5.0V)	$(\beta / 500)$	V
Current EPS (source 5.0V)	$(\beta / 1000) - 1.5$	A
Voltage ADCS (3.3V)	$\beta / 1000$	V
Current ADCS (source 3.3V)	$(\beta / 125) - 1.5$	A
Voltage ADCS (7.4V)	$(\beta / 500)$	V
Current ADCS (source 7.4V)	$(\beta / 1000) - 1.5$	A
Voltage COMMS (3.3V)	$\beta / 1000$	V
Current COMMS (source 3.3V)	$(\beta / 1000) - 1.5$	A
Voltage COMMS (5.0V)	$(\beta / 500)$	V
Current COMMS (source 5.0V)	$(\beta / 1000) - 1.5$	A
Voltage GPS(3.3V)	$\beta / 1000$	V
Current GPS(source 3.3V)	$(\beta / 1000) - 1.5$	A
Voltage GPS (7.4V)	$(\beta / 500)$	V
Current GPS (source 7.4V)	$(\beta / 1000) - 1.5$	A
Voltage Camera (5.0V)	$(\beta / 500)$	V
Current Camera	$(\beta / 1000) - 1.5$	A
Voltage S Band (3.3V)	$\beta / 1000$	V
Current S Band	$(\beta / 1000) - 1.5$	A
Voltage Battery	$(156.25 * 10e-6) * \beta$	V
Current Battery	$(\beta / 500) - 3$	A

Temps: Temperatures data are stored as 8 bit sign two's complement format. Temperature data is calibrated in Celsius degrees. In this command we have 20 temperatures. The order of the temperatures are as follows in the next chart:

Subsystem	Number of sensors	Bytes
OBC	4	8
EPS	2	4
Battery 1	2	4
Battery 2	2	4
COMMS	2	4
ADCS	4	8
ADCS drivers	4	8

Num latch-up: Number of single event latch-up presented in the Satellite's life. It is a hexadecimal value.

Satellite Date: Date of On Board Computer's (OBC) Real time clock (RTC). The date is given as 8 bit word per data and it is coded in the Binary Code Decimal (BCD). Satellite's date has this format: minute, hour (24-hour mode), day, month and year. The next chart shows an example:

minute	hour	day	month	Year
0x22	0x20	0x06	0x03	0x16

The date is **06-March-2016** time **20:22**

Mag (XYZ): Data of the Magnetometer 3 axial embedded in the OBC. The data is a 16 bit sign two's complement format and the data conversion is 0.92 [mGauss/LSB]. The order of data is given as follows: X, Y, Z.

Command 0x03: Advance Telemetry

This command downloads inertial navigation data in two different ways, sample in real-time in line of view with Ground Station or previously stored data.

Uplink command:

Header	Num of bytes	Num of command	Argument	CRC
0x4D, 0x58 (MX)	0x07	0x03	0xFF or 0x00	-
2 bytes	1 byte	1 byte	1 byte	2 bytes

Argument:

- 0xFF data stored of inertial navigation telemetry (200 samples)
- 0x00 line of view (10 samples)

Downlink command:

Header	Num of bytes	LLA	MAG (XYZ)	Gyros (XYZ)	x 4	CRC
MX(ASCII)	0x65	-	-	-	-	-
2 bytes	1 byte	12 bytes	6 bytes	6 bytes	72 bytes	2 bytes

To reduce “overhead” we send 4 samples of LLA, MAG and Gyro in one Downlink command.

Samples with 0xFF as data value are empty data. This case can only be presented with the argument 0xFF because in the other case (0xFF), you get the samples in line of view.

Description of the downlink command:

LLA: This values contain data about latitude, longitude and altitude in this order. Data are given in 32 bit-word and IEEE-754 floating point format.

MAG: This value contain data about ADCS’s Magnetometer. Data is a 16 bit sign two’s complement format. The data conversion is 142.9 [μ Gauss/LSB]. The data is given as follows X,Y,Z.

Gyros: This value contain data about ADCS’s Gyroscope. Data is a 16 bit sign two’s complement format. The data conversion is 0.01 [$^{\circ}$ /sec/LSB]. The data is given as follows X,Y,Z.

Command 0x05: Orbital propagation data

This command downloads data refers to orbital propagation of the Satellite. Data is previously stored with other executed command.

Uplink command:

Header	Num of bytes	Num of command	CRC
0x4D, 0x58 (MX)	0x06	0x05	-

2 bytes	1 byte	1 byte	2 bytes
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Downlink command:

First of all, Ground Station receive a message with the number of samples stored with a maximum of 50.

First command: Earth Station receive number of packages stored in OBC.

Header	Num of bytes	Number of packages	CRC
MX(ASCII)	0x06	-	-
2 bytes	1 byte	1 bytes	2 bytes

Second command: Immediately, Earth Station receive “n” number of samples.

Header	Num of bytes	LLA	Date	x 5	CRC
MX(ASCII)	0x65	-	-	-	-
2 bytes	1 byte	12 bytes	6 bytes	72 bytes	2 bytes

To reduce “overhead” we send 5 samples of LLA and Date in one Downlink command.

Description of the downlink command:

LLA: This values contain data about latitude, longitude and altitude in this order. Data are given in 32 bit-word and IEEE-754 floating point format.

Date: Date of GPS. The date is given as 8 bit word per data and it is coded in the Binary Code Decimal (BCD). Date has this format second, minute, hour (24-hour mode), day, month and year. The next table is shown as an example:

Second	minute	hour	day	month	Year
0x58	0x22	0x20	0x06	0x03	0x16

The date is **06-March-2016** time **20:22:58**

Command 0x06: Download large images

Dedicated to downloading images command. Ground Station knows the number of images stored in OBC with command 0x01. Ground Station chooses number of image with uplink command and immediately it receives the image in stream mode.

The monochrome image is in BMP format with a resolution of 752 x 480 pixels. Ground Station will receive 2852 packages defined in the downlink command as follows.

Uplink command:

Header	Num of bytes	Num of command	Argument	Num of image	CRC
0x4D, 0x58 (MX)	0x08	0x06	0xCC	-	-
2 bytes	1 byte	1 byte	1 byte	1 byte	2 bytes

Maximum image = 255

Downlink command:

Header	Num of bytes	Defined Value	Num of package	Data image	CRC
MX (ASCII)	0x87	/ (ASCII)	0 – 2851	-	-
2 bytes	1 byte	1 byte	2 bytes	127 bytes	2 bytes

Description of the downlink command:

Header Value: Value used by Ground Station software. This value always will be the same.

Command 0x08: Contact with satellite

Ground Station sends a message and it only receives an echo of the message to be sure that the link has been made.

Uplink and downlink command:

Header	Num of bytes	Num of command	CRC
0x4D, 0x58 (MX)	0x06	0x08	-
2 bytes	1 byte	1 byte	2 bytes

Command 0x09: Download small images

Dedicated to downloading the same image as command 0x06 but in small size. Ground Station knows the number of images stored in OBC with command 0x01. Ground Station chooses number of image with uplink command and immediately it receives the image in stream mode.

Ground Station will receive 184 packages defined in the downlink command as follows.

Uplink command:

Header	Num of bytes	Num of command	Num of image	CRC
0x4D, 0x58 (MX)	0x07	0x09	-	-
2 bytes	1 byte	1 byte	1 byte	2 bytes

Maximum image = 255

Downlink command:

Header	Num of bytes	Defined Value	Num of package	Data image	CRC
MX (ASCII)	0x87	/ (ASCII)	0 – 184	-	-
2 bytes	1 byte	1 byte	2 bytes	127 bytes	2 bytes

List of acronyms:

ADCS: Attitude Determination Control Subsystem

COMMS: Communication Subsystem

CRC: Cycling Redundancy Check

EPS: Electrical Power Subsystem

OBC: On Board Computer