DECODING MTCUBE-2 & CELESTA MISSIONS AND HAMRADIO CHALLENGE

1 INTRODUCTION

This document presents the new satellites of the University Space Center of Montpellier (CSUM): **MTCUBE 2** (Memory Test CubeSat 2) and **CELESTA** (**C**ern **L**atchup and radmon **E**xperiment **ST**udent s**A**tellite). It shows satellite characteristics, its mission and describes how to decode beacons received from both satellites. Also, this document provides information about the RadioHam Application running on both satellites and how members of the Amateur Radio community can use.

1 MTCUBE 2

MTCUBE 2 (ROBUSTA-1F) is a 1U CubeSat developed by the CSUM (platform) and the Laboratoire d'Informatique, Robotique et Micromécanique de Montpellier (LIRMM) on behalf of ESA (payload). MTCUBE-2's main mission is to test electronic components in space environment. Its payload aims at testing Single Event Effect (SEE) sensitivity of various memory technologies.

2 CELESTA

CELESTA (ROBUSTA-1D) is a 1U CubeSat developed by the CSUM (platform) and CERN (payload). The mission of CELESTA is also to test electronic components in space environment. Its payload is a module including a radiation monitor "RadMon" and a SEL (Single Event Latch-up) experiment, both developed by CERN.

3 Launch Information

Both satellites will be launched from French Guiana on 13th of July 2022 on VEGA-C maiden launch with main payload LARES-2. The satellites will be placed on a MEO orbit at a 5866,9 km altitude (70° inclination).

SATELLITE	PRELIMINARY TLE
MTCUBE-2	1 00002U 22078E 22194.55763890 .00001282 00000-0 12934-3 0 11 2 00002 70.1560 307.6409 0004000 06.3300 304.0400 06.42724331000001
CELESTA	1 00001U 22078F 22194.55763890 .00001282 00000-0 12934-3 0 10 2 00001 70.1585 307.6409 0004000 06.3100 304.0400 6.42724015000004

2 DECODING

2.1 PHYSICAL LAYER

PREAMBLE	MTCUBE-2	CELESTA
HAM RADIO CALLSIGN	FX6FRA	FX6FRB
DOWNLINK FREQUENCY	436.75 MHz	436.5 MHz
UPLINK FREQUENCY	435.75 MHz	435.5 MHz
MAX BANDWIDTH	20 kHz	20 kHz
MODULATION*	GMSK	GMSK
DATARATE (UP/DOWNLINK) *	2400 bps	2400 bps
PROTOCOL	AX25	AX25
BEACON INTERVAL (Default)	29 seconds	38 seconds
EXPECTED TIME FOR FIRST BEACON	14:10:00 UTC	14:10:00 UTC

** The platform allows the change of up and downlink modulation scheme during the mission. The following configuration are also possible. The HAMRadio community will be informed in case the RF link parameters are changed:*
- AFSK 1k2 bps – AX25 protocol.
- GMSK 9k6 bps – AX25 protocol.

2.2 BEACON PACKET

The following packet structures are valid for both MTCUBE-2 and CELESTA satellites. The only difference between these two platforms, in terms of beacon data, is the Payload Data inside the Beacon packet.

2.2.A AX25 PACKET

AX25 PACKET					
PREAMBLE	FLAG	AX25_HEADER	AX25_INFO	FCS (CRC)	FLAG
32 Bytes	1 Byte	16 Bytes	236 Bytes	2 Bytes	1 Bytes
0x55	0x7E			CRC-16/X.25	0x7E

2.2.B AX25 HEADER

AX25 HEADER					
ADDRESS				CONTROL	PID
DESTINATION*	DESTINATION SSID	SOURCE*	SOURCE SSID		
6 Bytes	1 Byte	6 Byte	1 Byte	1 Byte	1 Byte
0x8C689694B040	0xE0	SAT CALLSIGN	0xE1	0x03	0xF0

* In AX25 protocol, the destination and source callsigns are equal to the equivalent ASCII characters in hex shifted one bit to the left. Ex: F4KJX = 0x8C689694B040

2.2.C AX25 INFO/DATA

AX25 DATA							
Length	Frame Type	TS	OBDH	EPS	TTC	PAYLOAD	HAM MESSAGE
1 Byte	1 Byte	4 Bytes	16 Bytes	16 Bytes	16 Bytes	48 Bytes	134 Bytes
0xEA	0x10	UNIX Timestamp*					

** Sent with LSByte (Less Significant Byte) first. Ref: https://www.unixtimestamp.com/*

2.2.C.1 OBDH DATA

Field	Description	Length (bytes)	Value
OBDH Timestamp	Time at the OBDH system	4	Unix Timestamp, LSB
Temperature	Last recorded temperature by the OBDH	2	Signed Integer, Big Endian Unit: °C
Satellite Mode	Mode of the Satellite	1	0x00 -> STANDBY 0x01 -> DEPLOY 0x02 -> COMMISSIONNING 0x03 -> COMM_PL 0x04 -> MISSION 0x05 -> LOW_P_MISSION 0x06 -> TRANSMIT 0x07 -> SURVIVAL 0x08 -> SILENT

OBDH Mode	Mode of the OBDH subsystem	1	0x11 -> STANDBY 0x22 -> DEPLOY 0x33 -> COMMISSIONNING 0x44 -> COMM_PL 0x55 -> MISSION 0x66 -> LOW_POWER_MISSION 0x77 -> SILENT 0xFF -> POR
Bytes to transmit	Number of data bytes stored in memory to be downlinked	4	Unsigned Integer Big Endian
Number of Resets	Number of OBDH resets	2	Unsigned Integer Big Endian
Number of Errors	Number of errors that occurred in the OBDH	2	Unsigned Integer Big Endian

2.2.C.2 EPS DATA

Field	Description	Length (bytes)	Value
EPS Mode	Mode of the EPS subsystem	1	0x00 -> IDLE 0x11 -> SURVIVAL 0x22 -> STANDBY 0x33 -> DEPLOY 0x44 -> COMMISSIONNING 0x55 -> MISSION 0x66 -> LOW_POWER_MISSION 0x77 -> SILENT
Battery Voltage	Last Battery Voltage	1	=int(**byte**)*20 Unit: mV
Battery Temperature	Last measured battery temperature	1	Signed Int Unit: °C
Min Battery Voltage	Minimum Battery Voltage measured since reboot	1	=int(**byte**)*20 Unit: mV
Max Battery Voltage	Maximum Battery Voltage measured since reboot	1	=int(**byte**)*20 Unit: mV

Avg Battery Voltage	Average Battery Voltage measured since reboot	1	=int(**byte**)*20 Unit: mV
Avg Charge Current	Average Charge Current measured since reboot	1	=int(**byte**)*12 Unit: mA
Max Charge Current	Maximum Charge Current measured since reboot	1	=int(**byte**)*12 Unit: mA
Z- Face Temperature	Temperature measured at the –Z face of the satellite	1	Signed int Unit: °C
OBDH Current	Current consumption of the OBDH	1	Unsigned Int Unit: mA
EPS Current	Current consumption of the EPS	1	Unsigned Int Unit: mA
TTC µC Current	Current consumption of the TTC Microcontroller	1	Unsigned Int Unit: mA
TTC PA Current	Current consumption of the Power Amplifier of the TTC	1	=int(**byte**)*5 Unit: mA
DOSI Current	Current consumption of the Radiation Dosimeter Instrument	1	Unsigned Int Unit: mA
Charge Current	Total charge current of the battery	1	=int(**byte**)*12 Unit: mA

2.2.C.3 TTC DATA

Field	Description	Length (bytes)	Value
TTC Mode	Mode of the TTC subsystem	1	0x01 -> IDLE 0x11 -> BEACON 0x22 -> COMMISSIONNING 0x44 -> SILENT
Number of TTC Resets	Number of resets of the TTC subsystem	2	Unsigned Int
Last reset cause	Cause of last TTC reset	1	0x11 -> POR (Power supply reset) 0x22 -> WDTTO (Watchdog) 0x33 -> OSC (Oscillator Error)

			0x44 -> HW (Reset Pin) 0x55 -> DEBUG (Debugger Reset) 0x77 -> RI (Software Reset)
Number of Received valid packets	Number of received packets with valid CRC since reset	2	Unsigned Int
Number of transmitted packets	Number of transmitted packets since reset	2	Unsigned Int
Measured Transmission Power	Output RF power measured by TTC	2	Unsigned Int ADC counts (max: 4048)
Last Error Code	Cause of last error in the TTC	1	0x00 -> NULL 0x11 -> RADIO_HW_ERROR 0x22 -> TX_QUEUE_FULL 0x33 -> RX_QUEUE_FULL 0x44 -> TX_BUS_QUEUE_FULL 0x55 -> RX_BUS_QUEUE_FULL 0x66 -> OBC_TEMP_HW_ERROR 0x77 -> OBC_TEMP_H_LIMIT_ERROR 0x88 -> OBC_TEMP_L_LIMIT_ERROR 0x99 -> PA_TEMP_HW_ERROR 0xAA -> PA_TEMP_H_LIMIT_ERROR 0xBB -> PA_TEMP_L_LIMIT_ERROR 0xCC -> OBDH_NACK 0xDD -> PF_RESET_REQ 0xD1 -> TTC_RESET_REQ 0xEE -> RADIO_TASK_TIMEOUT 0xFF -> RADIO_UNQUEUE 0x01 -> OBDH_STATUS_REQ 0x02 -> OBDH_BDR_REQ 0xA1 -> FRAM_ID_ERROR 0xA2 -> FRAM_HW_ERROR 0xA3 -> FRAM_READ_ERROR 0xA4 -> FRAM_WRITE_ERROR 0xA5 -> EVENT_QUEUE_READ_ERROR
Power Configuration	Output Power Configuration	1	Unsigned Int Max = 120

Power Amplifier Temperature	Last Measured temperature of the Power Amplifier	1	Signed Int Unit: °C
RSSI of last received packet	Received Signal Strength Indicator of last received packet	1	-1 * Int(byte) Unit: dBm
Frequency Deviation of last received packet	Frequency Deviation of last received packet with valid CRC	1	17 * SignedInt(byte) Unit: Hz
Beacon period	Time interval between beacon transmissions	1	Int(byte) Unit: seconds

2.2.C.4 HAM RADIO MESSAGE

Field	Description	Length (bytes)	Value
Last Message RSSI	RSSI of the last accepted HAM Radio Message. See Section 3 for more information.	1	-1 * Int(byte) Unit: dBm
HAM Radio Message	HAM Message received by the satellite	133	ASCII Character

2.3 BEACON PACKET EXAMPLE

2.3.A MTCUBE-2

```
0x7E 0x8c 0x68 0x96 0x94 0xb0 0x40 0xe0 0x8c 0xb0 0x6c 0x8c 0xa4 0x82 0xe1 0x03 0xf0 0xea 0x10 0xc7 0x52
0x4a 0x5c 0x71 0x52 0x4a 0x5c 0xb5 0x01 0x02 0x33 0x78 0xb0 0x02 0x00 0x42 0x00 0xaf 0x00 0x44 0xb3 0x55
0xa8 0xbb 0xb3 0x00 0x00 0x81 0x0e 0x08 0x3c 0x1f 0x00 0x00 0x00 0x22 0x10 0x00 0x11 0x00 0x00 0x08 0x00
0xef 0x0e 0x00 0x64 0x22 0x00 0x00 0x1d 0x51 0x04 0xff 0x07 0x80 0x00 0x80 0x00 0x40 0x00 0x05 0x04 0xff 0x07
0xe0 0x00 0xc0 0x00 0x1e 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00
0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x03 0x00 0x00 0x52 0x4f 0x42 0x55 0x53 0x54 0x41
0x2d 0x31 0x55 0x20 0x46 0x58 0x36 0x46 0x52 0x41 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00
0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00
0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00
0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00
0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00
0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00
0xba 0x5f 0x7E
```

2.3.B CELESTA

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0x7E 0x8C 0x68 0x96 0x94 0x8A 0x40 0xE0 0xB0 0xB0 0x6C 0x8C 0xA4 0x84 0xE1 0x03 0xF0 0xEA 0x10 0xEE 0x20
0x80 0x60 0xD7 0x20 0x80 0x60 0xAB 0x02 0x04 0x55 0x50 0x0F 0x00 0x00 0x9D 0x00 0x00 0x02 0x55 0xC4 0x82
0xB3 0xCC 0xC3 0x00 0x00 0x81 0x0E 0x08 0x39 0x03 0x00 0x69 0x00 0x11 0x54 0x09 0x77 0x00 0x00 0x03 0x00
0x39 0x04 0x00 0x64 0x52 0x00 0x00 0x0A 0x52 0x0B 0xFF 0x07 0x20 0x00 0x80 0x00 0x08 0x00 0x00 0x00 0xFF
0x07 0x40 0x02 0x40 0x02 0x1E 0x00 0x0F 0x00 0x01 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00
0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x16 0x00 0x54 0x77 0x65 0x65 0x74 0x20 0x63
0x6F 0x6E 0x74 0x65 0x6E 0x74 0x20 0x20 0x20 0x20 0x20 0x20 0x20 0x20 0x20 0x20 0x20 0x20 0x20 0x20 0x20
0x20 0x20 0x20 0x20 0x20 0x20 0x20 0x20 0x20 0x20 0x20 0x20 0x20 0x20 0x20 0x20 0x20 0x20 0x20 0x20 0x20
0x20 0x20 0x20 0x20 0x08 0x08 0x08 0x08 0x08 0x08 0x08 0x08 0x08 0x08 0x08 0x08 0x08 0x08 0x08 0x08 0x08
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0x08 0x08 0x08 0x08 0x08 0x08 0x08 0x08 0x08 0x08 0x08 0x08 0x08 0x08 0x08 0x08 0x08 0x08 0x08 0x08 0x08
0x08 0x08 0x08 0x08 0x08 0x08 0x08 0x08 0x08 0x08 0x08 0x08 0x08 0x08 0x08 0x08 0x08 0x08 0x08 0x08 0x08
0x20 0x42 0x5D 0x7E
```

2.4 TOOLS FOR RECEIVING AND DECODING BEACONS

2.4.A CSUM GITHUB PAGE

CSUM's Github page provides a set of tools to decode signals from the satellites and send the packets directly to CSUM servers. More information can be found in the documentation page of the GitHub repository.

2.4.B CSUM DATA DIFFUSION PLATFORM

CSUM's Data Diffusion Platform (DDP) provide users direct access to radio packet decoded from our satellites. Amateur Radio members who push packets to CSUM's servers can see their packets decoded in real-time by accessing the DDP Public Page of MTCUBE-2 and CELESTA. In case you want to build your own decoder and send packets to CSUM's server, you can use the information below:

Parameter	Value
Protocol	Simple Downlink Share Convention (SiDS)
Endpoint	https://ddp.csum.umontpellier.fr/store_beacon
Method	HTTP POST
Data Structure (Minimum)	**source**: HAM Callsign of the receiving station **frame**: AX.25 received frame in hex (no Flag, no CRC) Example: {

	'source': 'F4KJX ', *'frame'*: '8c689694b040e08cb06c8ca482e103f0ea10c7524a5c71524a5cb501023378b002004200 af0044b355a8bbb30000810e083c1f0000002210001100000800ef0e00642200001d5104f f0780008000400005 04ff07e000c0001e0000000000000000000000000000000000000000 0000000000000003000052 4f42555354412d315520465836465241000000000000000000 000000000000000000000000000000000000000000000000000000000000000000000000 000000000000000000000000000000000000000000000000000000000000000000000000 000000000000000000000000000000000000000000000000000000000000000000000000 0' }

3 MESSAGE ME IF YOU CAN! (RADIO HAM CHALLENGE)

3.1 DESCRIPTION

Both satellites will be running a dedicated application for the HAM Radio community. In this application, the HAM Radio message continuously transmitted in the beacon packet will be modifiable by telecommand from amateur radio members around the world. The satellite will store the message received with the lowest measured power using the RSSI measurement mechanism onboard the TT&C subsystem. Once a message is received with a lower RSSI than the current one, the new message will replace the old one in the beacon. This process is restarted upon a reboot of the satellite or the TT&C.

As part of the commissioning procedures, the structure of precise mechanism of this application will only be made public after the satellite is put in MISSION mode. A more detailed document and a set of tools will then be provided to the community one week after the launch, provided the commissioning phase is nominal.

! Thank you for respecting the usual practices of our community!

4 CONTACT INFORMATION

In case you have questions about the information in this document or related to these two missions in general, do not hesitate to contact us through the following email address:

csu-radioham-contact@umontpellier.fr

Good luck to all!

73's