

University of Vigo - LUME-1 satellite

Dashboard telemetry modulation, codes and format

Physical layer

TTC frequency	437,060 MHz
S/C EIRP	30 dBm
S/C antenna	Turnstile
S/C polarization	RHCP / LHCP

Data link layer

Modulation	GFSK
Bitrate	4800 / 9600 bps
Sync word	0x930B51DE
Frame format	ASM+Golay (AX100 mode 5)
Bit encoding	NRZ, most significant bit first
Scrambling	CCSDS randomization
Channel coding	Reed-Solomon (255, 223)

A demodulator and decoder based on GNU Radio is available:

<https://github.com/mndza/gr-sattools>

Network layer - CSP

All the packets transmitted by the satellite use the CSP (Cubesat Space Protocol) protocol (<https://github.com/libcsp/libcsp>).

Priority	Source	Destination	Destination Port	Source Port	Reserved	HMAC	XTEA	RDP	CRC	Data
2 bits	5 bits	5 bits	6 bits	6 bits	4 bits	1 bit	1 bit	1 bit	1 bit	Variable
0x02	0x01	0x0F	0x0E	Variable	Variable	0x00	0x00	0x00	0x00	Variable

Transport layer - TM transfer frames

Inside the CSP data field, TM transfer frames are used to encapsulate upper layer data. The TM transfer frames are an adaptation of CCSDS TM transfer standards.

Version number	S/C ID	Virtual channel ID	Virtual channel frame counter	First header pointer	Empty frame	OCF presence	Sequence flags	Fixed length frame	Data	Packet Errors	Frame Errors	Frame Error Control
2 bits	10 bits	4 bits	8 bits	11 bits	1 bit	1 bit	2 bits	1 bit	Var.	16 bits	16 bits	16 bits
0x00	0x41	0x01	Variable	0x00	0x00	0x01	0x03	0x00	Var.	Variable	Var.	Var.

Application layer - CCSDS Space Packets + ECSS Packet Utilization Standard (PUS)

TM transfer frames transport standard CCSDS SpacePackets implementing ECSS PUS services. A detailed description of PUS packets can be found in “ECSS, Telemetry and telecommand packet utilization. ECSS-E-ST-70-41C. 15 April 2016”.

Packet Version	Packet Type	Secondary Header Flag	Application Process Id	Sequence Flags	Packet Name	Packet Data Length	Secondary Header	User Data	PEC
3 bits	1 bit	1 bit	11 bits	2 bits	14 bits	16 bits	Variable	Variable	16 bits
0x00	0x00	0x01	0x01	0x03	Variable	Variable	Sub-struct. A	Sub-struct. B	Var.

For clarity, a description of housekeeping report packets (TM[3,25]) is included below in order to make easier the decoding of dashboard beacons from the satellite:

PUS Version	Time Reference	Service Type	Message Subtype	Type Counter	Destination Id	Day	Milliseconds of the day
4 bits	4 bits	8 bits	8 bits	16 bits	16 bits	16 bits	32 bits
0x01	Variable	0x03	0x19	Variable	0x03e8	Variable	Variable

ID	Parameters
16 bits	Variable
Variable	Variable

Dashboard telemetry beacons

The satellite transmits a burst of 5 packets every 30 seconds. Each packet contains a TM frame with a single SpacePacket inside. Standard PUS service 3 (Housekeeping) is used to format these SpacePackets

Five different beacons are transmitted, each one with a different ID:

- **ID=1 - B1-OBC:** Telemetry from the main on-board computer.
- **ID=2 - B2-EPS:** Telemetry from the power subsystem.
- **ID=3 - B3-TTC+GSSB:** Telemetry from the TTC and the antenna deployment system.
- **ID=4 - B4-ADCS:** telemetry from the ADCS subsystem.
- **ID=5 - B5-Temps:** temperatures of different subsystems of the satellite platform.

All the parameter values are calibrated, no calibration equations are needed.

Dashboard telemetry beacons contents

ID=1		
B1-OBC	Type	Units
P_OBC_BOOT_CAUSE	uint32	
P_OBC_BOOT_COUNT	uint16	reboots
P_OBC_CLOCK	uint32	seconds
P_OBC_CURFLASH	uint16	mA
P_OBC_FS_MOUNTED	uint8	
P_OBC_RAM_IMAGE	int8	
P_OBC_TEMP_A	int16	(x0.1) degC
P_OBC_TEMP_B	int16	(x0.1) degC
P_OBC_TICKS	uint32	ticks
P_OBC_MAG_X	float	
P_OBC_MAG_Y	float	
P_OBC_MAG_Z	float	
P_OBC_OBC_MEMFREE	uint32	bytes
P_OBC_OBC_BUFFERFREE	uint32	bytes
P_OBC_OBC_UPTIME	uint32	bytes
P_OBC_GYRO_X	float	deg/s
P_OBC_GYRO_Y	float	deg/s
P_OBC_GYRO_Z	float	deg/s
P_OBC_GYRO_TEMP	float	degC
P_OBC_FLASH_TOTAL	int64	bytes
P_OBC_FLASH_USED	int64	bytes
P_OBC_FLASH_FREE	int64	bytes
P_OBC_GPIO_TEST	uint8	
P_OBC_GPIO_SW	uint8	
P_OBC_GPIO_PWR	uint8	
P_OM_STATE	uint8	
P_OM_SW_VERSION	string[32]	
P_OP_TR_CONN	uint8	
P_OP_TR_CONN_ACTIVE	uint8	

ID=2		
B2-EPS	Type	Units
P_EPS_OUTPUT_OFF_DELTA_0	uint16	ms
P_EPS_OUTPUT_OFF_DELTA_1	uint16	ms
P_EPS_OUTPUT_OFF_DELTA_2	uint16	ms
P_EPS_OUTPUT_OFF_DELTA_3	uint16	ms
P_EPS_OUTPUT_OFF_DELTA_4	uint16	ms
P_EPS_OUTPUT_OFF_DELTA_5	uint16	ms
P_EPS_OUTPUT_OFF_DELTA_6	uint16	ms
P_EPS_OUTPUT_OFF_DELTA_7	uint16	ms
P_EPS_OUTPUT_ON_DELTA_0	uint16	ms
P_EPS_OUTPUT_ON_DELTA_1	uint16	ms
P_EPS_OUTPUT_ON_DELTA_2	uint16	ms
P_EPS_OUTPUT_ON_DELTA_3	uint16	ms
P_EPS_OUTPUT_ON_DELTA_4	uint16	ms
P_EPS_OUTPUT_ON_DELTA_5	uint16	ms
P_EPS_OUTPUT_ON_DELTA_6	uint16	ms
P_EPS_OUTPUT_ON_DELTA_7	uint16	ms
P_EPS_WDT_CSP_PINGS_LEFT_0	uint8	
P_EPS_WDT_CSP_PINGS_LEFT_1	uint8	
P_EPS_BOOTCAUSE	uint8	
P_EPS_CURSUN	uint16	mA
P_EPS_CURIN_0	uint16	mA
P_EPS_CURIN_1	uint16	mA
P_EPS_CURIN_2	uint16	mA
P_EPS_CUROUT_0	uint16	mA
P_EPS_CUROUT_1	uint16	mA
P_EPS_CUROUT_2	uint16	mA
P_EPS_CUROUT_3	uint16	mA
P_EPS_CUROUT_4	uint16	mA
P_EPS_CUROUT_5	uint16	mA
P_EPS_CURSYS	uint16	mA
P_EPS_TEMP_0	uint16	degC
P_EPS_TEMP_1	uint16	degC
P_EPS_TEMP_2	uint16	degC

P_EPS_TEMP_3	uint16	degC
P_EPS_TEMP_4	uint16	degC
P_EPS_TEMP_5	uint16	degC
P_EPS_BATTMODE	uint8	
P_EPS_PPTMODE	uint8	
P_EPS_COUNTER_BOOT	uint32	reboots
P_EPS_LATCHUP_0	uint16	latchups
P_EPS_LATCHUP_1	uint16	latchups
P_EPS_LATCHUP_2	uint16	latchups
P_EPS_LATCHUP_3	uint16	latchups
P_EPS_LATCHUP_4	uint16	latchups
P_EPS_LATCHUP_5	uint16	latchups
P_EPS_COUNTER_WDT_CSP_0	uint32	
P_EPS_COUNTER_WDT_CSP_1	uint32	
P_EPS_COUNTER_WDT_GND	uint32	
P_EPS_COUNTER_WDT_I2C	uint32	
P_EPS_OUTPUT_0	uint8	
P_EPS_OUTPUT_1	uint8	
P_EPS_OUTPUT_2	uint8	
P_EPS_OUTPUT_3	uint8	
P_EPS_OUTPUT_4	uint8	
P_EPS_OUTPUT_5	uint8	
P_EPS_OUTPUT_6	uint8	
P_EPS_OUTPUT_7	uint8	
P_EPS_WDT_GND_TIME_LEFT	uint32	
P_EPS_WDT_I2C_TIME_LEFT	uint32	
P_EPS_VBATT	uint16	volts
P_EPS_VBOOST_V_0	uint16	volts
P_EPS_VBOOST_V_1	uint16	volts
P_EPS_VBOOST_V_2	uint16	volts
P_EPS_WDTCSPC_0	uint8	
P_EPS_WDTCSPC_1	uint8	

ID=3		
B3-TTC_GSSB	Type	Units
P_GSSB_NX_REBOOT_COUNT	uint8	reboots
P_GSSB_NX_CURRENT_STATE	uint8	
P_GSSB_NX_ANTENNA_STATE	uint8	
P_GSSB_NX_ATTEMPTS_TOTAL	uint16	attempts
P_GSSB_NY_REBOOT_COUNT	uint8	reboots
P_GSSB_NY_CURRENT_STATE	uint8	
P_GSSB_NY_ANTENNA_STATE	uint8	
P_GSSB_NY_ATTEMPTS_TOTAL	uint16	attempts
P_GSSB_PX_REBOOT_COUNT	uint8	reboots
P_GSSB_PX_CURRENT_STATE	uint8	
P_GSSB_PX_ANTENNA_STATE	uint8	
P_GSSB_PX_ATTEMPTS_TOTAL	uint16	attempts
P_GSSB_PY_REBOOT_COUNT	uint8	reboots
P_GSSB_PY_CURRENT_STATE	uint8	
P_GSSB_PY_ANTENNA_STATE	uint8	
P_GSSB_PY_ATTEMPTS_TOTAL	uint16	attempts
P_TTC_TEMP_BRD	int16	(x0.1) degC
P_TTC_LAST_RFERR	int16	Hz
P_TTC_LAST_RSSI	int16	dBm
P_TTC_TOT_RX_BYTES	uint32	bytes
P_TTC_RX_BYTES	uint32	bytes
P_TTC_TOT_RX_COUNT	uint32	packets
P_TTC_RX_COUNT	uint32	packets
P_TTC_TOT_TX_BYTES	uint32	bytes
P_TTC_TX_BYTES	uint32	bytes
P_TTC_TOT_TX_COUNT	uint32	packets
P_TTC_TX_COUNT	uint32	packets
P_TTC_TEMP_PA	int16	(x0.1) degC
P_TTC_BOOT_CAUSE	uint32	
P_TTC_BGND_RSSI	int16	dBm
P_TTC_ACTIVE_CONF	uint8	
P_TTC_BOOT_COUNT	uint16	reboots
P_TTC_LAST_CONTACT	uint32	

P_TTC_TX_DUTY	uint8	
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ID=4		
B4-AOCS	Type	Units
P_AOCS_EXTMAG_VALID	uint8	
P_AOCS_EXTMAG_X	float	
P_AOCS_EXTMAG_Y	float	
P_AOCS_EXTMAG_Z	float	
P_AOCS_GPS_POS_DEV_X	float	
P_AOCS_GPS_POS_DEV_Y	float	
P_AOCS_GPS_POS_DEV_Z	float	
P_AOCS_GPS_POS_X	float	
P_AOCS_GPS_POS_Y	float	
P_AOCS_GPS_POS_Z	float	
P_AOCS_GPS_VALID	uint8	
P_AOCS_GYRO_VALID	uint8	
P_AOCS_GYRO_X	float	
P_AOCS_GYRO_Y	float	
P_AOCS_GYRO_Z	float	
P_AOCS_MAG_X	float	
P_AOCS_MAG_Y	float	
P_AOCS_MAG_Z	float	
P_AOCS_MAG_VALID	uint8	
P_AOCS_STATUS_RUN	int8	
P_AOCS_ACS_MODE	int8	
P_AOCS_ADS_MODE	int8	
P_AOCS_EPHEM_MODE	int8	
P_AOCS_BDOT_DETUMB	uint8	
P_AOCS_BOOT_CAUSE	uint32	
P_AOCS_BOOT_COUNT	uint16	reboots
P_AOCS_CURGSSB1	uint16	mA
P_AOCS_CURGSSB2	uint16	mA
P_AOCS_CURPWM	uint16	mA
P_AOCS_CURGPS	uint16	mA

P_AOCS_CURWDE	uint16	mA
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ID=5		
B5-Temps	Type	Units
P_AOCS_SUNS_TEMP_PX	float	degC
P_AOCS_SUNS_TEMP_NX	float	degC
P_AOCS_SUNS_TEMP_PY	float	degC
P_AOCS_SUNS_TEMP_NY	float	degC
P_AOCS_SUNS_TEMP_PZ	float	degC
NOT_USED	float	N/A
P_AOCS_EXTMAG_TEMP_32	float	degC
P_AOCS_FSS_TEMP_PX	float	degC
P_AOCS_FSS_TEMP_NX	float	degC
P_AOCS_FSS_TEMP_PY	float	degC
P_AOCS_FSS_TEMP_NY	float	degC
P_AOCS_FSS_TEMP_PZ	float	degC
NOT_USED	float	N/A
NOT_USED	float	N/A
NOT_USED	float	N/A
P_AOCS_GYRO_TEMP_32	float	degC
P_AOCS_TEMP_A	int16	(x0.1) degC
P_AOCS_TEMP_B	int16	(x0.1) degC
P_EPS_TEMP_0	int16	degC
P_EPS_TEMP_1	int16	degC
P_EPS_TEMP_2	int16	degC
P_EPS_TEMP_3	int16	degC
P_EPS_TEMP_4	int16	degC
P_EPS_TEMP_5	int16	degC
P_OBC_TEMP_A	int16	(x0.1) degC
P_OBC_TEMP_B	int16	(x0.1) degC
P_OBC_GYRO_TEMP	float	degC
P_TTC_TEMP_BRD	int16	(x0.1) degC
P_TTC_TEMP_PA	int16	(x0.1) degC