



Aistechsatsat-2

# Aistechsatsat-2 TLM codes, modulation and format

81000-Platform\_Operations\_SW

<b>Issue:</b>		<b>V1.0</b>	
	<b>Name</b>	<b>Date</b>	<b>Signature</b>
<b>Written by:</b>	Josep Pino	12/21/2018	
<b>Reviewed by:</b>	Guillermo Valenzuela	12/28/2018	
<b>Authorized by:</b>	Carles Franquesa	1/2/2019	

# Table of Contents

- Table of Contents..... 2
- List of Tables ..... 3
- 1. Document Control Data ..... 4
  - 1.1 Document Change Log..... 4
  - 1.2 Applicable Documents ..... 4
  - 1.3 Reference Documents ..... 4
  - 1.4 Acronyms and Abbreviations ..... 4
- 2. Physical layer ..... 6
- 3. Data link layer ..... 7
- 4. Network layer ..... 8
- 5. Transport layer ..... 9
- 6. Application layer ..... 10
  - 6.1 Housekeeping Reports Packets Description ..... 10
  - 6.2 Beacons Description..... 11
    - 6.2.1 Beacons telemetry content ..... 11
- 7. GNU Radio Code..... 16

## List of Tables

Table 1. Aistechsat-2 TTC physical layer characteristics .....	6
Table 2. Aistechsat-2 TTC data link layer characteristics .....	7
Table 3. Aistechsat-2 TTC network layer characteristics for CSP .....	8
Table 4. Aistechsat-2 TTC Transport layer characteristics on the TM transfer frames .....	9
Table 5. Aistechsat-2 TTC Application layer characteristics .....	10
Table 6. Aistechsat-2 Housekeeping report characteristics .....	10
Table 7. Aistechsat-2 Housekeeping beacons characteristics .....	10
Table 8. OBC Beacon 1 contents .....	12
Table 9. EPS Beacon 2 contents.....	13
Table 10. TTC and GSSB Beacon 3 contents.....	14
Table 11. AOCS Beacon 4 contents .....	15
Table 12. Temperatures Beacon 5 contents.....	15

## 1. Document Control Data

### 1.1 Document Change Log

Reason for change	Issue	Revision	Date
All New	0	1	21/12/2018
Internally reviewed	0	2	28/12/2018
Released	1	0	02/01/2019

### 1.2 Applicable Documents

ID	Document Title	Issue	Date
AD01			

### 1.3 Reference Documents

ID	Document Title	Issue	Date
RD01			

### 1.4 Acronyms and Abbreviations

Acronym / Abbrev.	Description
<b>AD</b>	Applicable Document
<b>AOCS</b>	Attitude and Orbital Control System
<b>ASM</b>	Application Specific Messages
<b>BPSK</b>	Binary Phase-shift keying
<b>CCSDS</b>	Consultative Committee for Space Data Systems
<b>CRC</b>	Cyclic redundancy check
<b>CSP</b>	Cubesat Protocol
<b>ECSS</b>	European Cooperation for Space Standardization
<b>EPS</b>	Electric Power System
<b>GFSK</b>	Gaussian frequency shift Keying
<b>GSSB</b>	GomSpace Sensor Bus
<b>HMAC</b>	Hash message authentication code
<b>LHCP</b>	Left-Handed Circular Polarization
<b>OBC</b>	On board Computer

Acronym / Abbrev.	Description
<b>RDP</b>	Remote Desktop Protocol
<b>RF</b>	Radio Frequency
<b>RHCP</b>	Right-handed circular polarization
<b>Rx</b>	Receiver
<b>TC</b>	Telecommand
<b>TM</b>	Telemetry
<b>Tx</b>	Transmitter
<b>UHF</b>	Ultra High Frequency
<b>XTEA</b>	Extended Tiny Encryption Algorithm

## 2. Physical layer

The description of the TTC component at the physical layer level is shown in the table below:

TTC Characteristics	
<b>TTC frequency</b>	436,730 MHz
<b>S/C EIRP</b>	30 dBm
<b>S/C antenna</b>	Turnstile
<b>S/C polarization</b>	RHCP / LHCP

*Table 1. Aistechsatsat-2 TTC physical layer characteristics*

### 3. Data link layer

The description of the TTC component at the data link layer level is shown in the table below:

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

*Table 2. Aistechsatsat-2 TTC data link layer characteristics*

## 4. Network layer

The CSP (Cubesat Space Protocol) protocol developed by GOMSpace has been implemented on the network layer of the satellite to transmit the packets.

The CSP library can be found in <https://github.com/libcsp/libcsp>.

The characteristics of Aistechsatsat-2 are shown below:

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

*Table 3. Aistechsatsat-2 TTC network layer characteristics for CSP*



## 5. Transport layer

Aistechsat-2 has implemented TM transfer frames inside the CSP data field which are used to encapsulate upper layer data.

This TM transfer frames are an adaptation of CCSDS TM transfer standards which can be found in

<https://public.ccsds.org/Pubs/132x0b2.pdf>

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
<b>2 bits</b>	10 bits	4 bits	8 bits	11 bits	1 bit	1 bit	2 bits	1 bit	Var.	16 bits	16 bits	16 bits
<b>0x00</b>	0x01	0x01	Variable	0x00	0x00	0x01	0x03	0x00	Var.	Variable	Var.	Var.

*Table 4. Aistechsat-2 TTC Transport layer characteristics on the TM transfer frames*

## 6. Application layer

The application layer has implemented the TM transfer frames transport standard based on the CCSDS Space Packets and applying ECSS PUS services.

The description of the PUS packets can be found in <https://ecss.nl/standard/ecss-e-st-70-41c-space-engineering-telemetry-and-telecommand-packet-utilization-15-april-2016/>

The description of the CCSDS Space packets can be found in

<https://public.ccsds.org/Pubs/133x0b1c2.pdf>

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

Table 5. Aistechsatsat-2 TTC Application layer characteristics

### 6.1 Housekeeping Reports Packets Description

The description of housekeeping report packets (TM[3,25]) is included below in order to make easier the beacons decoding from Aistechsatsat-2:

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

Table 6. Aistechsatsat-2 Housekeeping report characteristics

ID	Parameters
<b>16 bits</b>	Variable
<b>Variable</b>	Variable

Table 7. Aistechsatsat-2 Housekeeping beacons characteristics

## 6.2 Beacons Description

Aistechsat-2 is transmitting 5 housekeeping packets every 30 seconds called beacons.

Each packet contains a TM frame with a single Space Packet inside.

The PUS service number 3 (a.k.a. Housekeeping) is used to format these Space Packets.

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

- **ID=1 - OBC:** Telemetry from the main on-board computer.
- **ID=2 - EPS:** Telemetry from the power subsystem.
- **ID=3 - TTC+GSSB:** Telemetry from the TTC and the antenna deployment system.
- **ID=4 - ADCS:** Telemetry from the ADCS subsystem.
- **ID=5 - Temperatures:** Temperatures of different components of the satellite platform.

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

### 6.2.1 Beacons telemetry content

#### 6.2.1.1 OBC (Beacon ID=1)

The first beacon is showing the status of the OBC component:

ID=1-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

ID=1-OBC	Type	Units
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	

Table 8. OBC Beacon 1 contents

### 6.2.1.2 EPS (Beacon ID=2)

The second beacon is showing the status of the EPS component:

ID=2-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_CURROUT_0	uint16	mA
P_EPS_CURROUT_1	uint16	mA
P_EPS_CURROUT_2	uint16	mA
P_EPS_CURROUT_3	uint16	mA
P_EPS_CURROUT_4	uint16	mA
P_EPS_CURROUT_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

ID=2-EPS	Type	Units
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	

Table 9. EPS Beacon 2 contents

### 6.2.1.3 TTC and GSSB (Beacon ID=3)

The third beacon is showing the status of the TTC and GSSB components:

ID=3-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

ID=3-TTC_GSSB	Type	Units
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	

Table 10. TTC and GSSB Beacon 3 contents

#### 6.2.1.4 AOCS (Beacon ID=4)

The fourth beacon is showing the status of the AOCS component:

ID=4-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	

ID=4-AOCS	Type	Units
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

Table 11. AOCS Beacon 4 contents

### 6.2.1.5 Temperatures (Beacon ID=5)

The fifth beacon is showing the temperature status of the satellite components:

ID=5-Temperatures	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

Table 12. Temperatures Beacon 5 contents

## 7. GNU Radio Code

A GNU Radio demodulator and decoder is made available in github for the Amateur community

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