Title: **Satellite Ancillary Data ICD**

CI - No: 000000

DRL Refs :

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Change Record

Issue	Date	Sheet	Description of Change
1	30.09.2009	all	First formal issue of this Document to respond to System PDR RID SEAO-495.
2	24.06.2010	all	Update based on: • Clarification Meeting during System Progress Meeting PM#12 as per GS2.MN.ASD.SY.00293 and on e-mail 05.01.2010 by Claudia Isola.
		§3.2	• Introduced MSI Mission Data ICD updates as per GS2.ICD.ASF.MSI.00008 issue 4.
		§3.3.1 §3.3.3.1 §3.3	• ESA S2-CR-ESA-SY-00010: o Additional 12 GPSR TM packets enabled o One additional GPSR TM packets extraction by CSW o MMFU System Ancillary Data Store routing for PCAT 6 +12 in TM Data Flow figure 3.4-1
		§1.2.1	• Added Reference to Startracker PUS ICD
		§3.3.2	• Added TM_TDB “Tracker Data Block”
3	30.03.2011	All §3.3 §3.3.1 §3.3.2 §3.3.3 §3.3.3.1 §3.3.3.2 §3.3.3.3 §3.3.3.4 §3.3.3.5	Update after System CDR. ▪ Removed TBC as per Editorial RID ▪ Updated Figure 3.3-1: added PCAT 11+13 ▪ Updated list of GPSR Ancillary Data as per **SEO-ORV-57** ▪ Updated list of STR Ancillary Data ▪ Detailed CSW AOCS Ancillary Data as per **SEO-ORV-76** ▪ Removed comments as per **SEO-SW-50** ▪ Removed diagnostic GPSR packets: o Noise Histogram o Channel Status o Tracking State o AGC status ▪ CSW AOCS-TM1 Attitude Data ▪ CSW AOCS-TM2 Propagator Data ▪ CSW AOCS-GPSR Data ▪ CSW AOCS-STR Data ▪ CSW AOCS-IMU Data

4	15.07.2011	All §1.2.2 §2 §3 §3.1 §3.3 §3.3ff §3.3.1	Updates after ESA comments and clarification during System PM#19: ▪ Added RD-02 ▪ Deleted last sentence ▪ Reworded and added PCAT 11 and 13 to Sat.Ancillary Data. ▪ Reworded and added RD-02 ▪ Updated Figure 3.3-1 " TM Data Flow" ▪ Added chapter references for SAD-TM packet structure ▪ The following packet have been added, but only in diagnostics mode: • GPS Channel Status • GPS Tracking State • GPS Noise Histogram • GPS AGC Status ▪ The following packet have been added for completeness, but not for use: • GPS **S1** Navigation Solution • GPS **S1** IMT/GPST Correlation
		§3.3.3.1	Implementation of AI2 + AI3 from S2.MN.ESA.SY.261: ▪ AOCS mode and sub-mode information in AOCS-TM1 ▪ indication of equipment used by AOCS algorithm for position / attitude estimation and control task ▪ Introduction of gyro stellar estimator innovation estimates in AOCS-TM1 according PM#19 agreements ▪ AOCS-TM1 packet frequency changed from 1 Hz to 2 Hz corresponding to AOCS algorithm execution ▪ AOCS-TM1 and AOCS-TM2 data format clarified
		§3.3.3.2	▪ Orbit angle description changed to proposed definition according ESA presentation during PM#19.
		§3.3.3.4	▪ Removed the AOCS-STR TM_ADB packets for STR1,2 and 3.
		§3.3.3.5	▪ Re-assigned SIDs for AOCS-IMU packets. ▪ Added additional IMU parameters.
		§3.3.3.6	▪ Re-named "AOCS-THERM-Data" into "MSI-SAD Packet". ▪ Added MSI related parameters as agreed during PM#19.

Table of Contents

1. INTRODUCTION

1.1 Scope of the Document

In addition to the observation data, the S2 satellite provides **Ancillary Data** to support the on-ground image data processing. The following ancillary data are acquired on-board and transmitted by Sentinel-2:

- X-Band Ancillary data with
  - System Ancillary data
  - Compression Status
  - Image Ancillary data
- Satellite Ancillary data

This documents defines the content of each type of ancillary data.

1.2 References

1.2.1 Applicable Documents

Satellite

[AD-01]	Satellite to Ground Segment ICD	GS2.ICD.ASD.SY.00006
[AD-02]	Sentinel-2 Packet Utilization Standard	GS2.STD.ASD.SY.00001
[AD-03]	Satellite Assumptions for the Ground Segment	GS2.TN.ASD.SY.00032

MSI

[AD-10]	MSI Mission Data ICD	GS2.ICD.ASF.MSI.00008
[AD-11]	MSI Assumptions for the Ground Segment	GS2.TN.ASF.MSI.00074

GPSR

[AD-12]	Command and Housekeeping Interface Specification	S1-IF-AAE-SC-0001
[AD-13]	Measurement Data Interface Specification	S1-IF-AAE-SC-0002

Startracker

[AD-14]	Startracker PUS ICD	GS2.ICD.JOP.STR.02402

Inertial Measurement Unit

[AD-15]	IMU ASTRIX TM/TC ICD	FOG.0.ICD.177.T.ASTR

1.2.2 Reference Documents

Satellite

[RD-01]	Abbreviation List	GS2.LI.ASD.SY.00001
[RD-02]	Sentinel-2 On-Board Time Synchronization	GS2.TN.ASD.SY.00020

MSI

[RD-10]	MSI Software ICD	GS2.ICD.ASF.MSI.00004

2. TERMS AND DEFINITION

In line with [AD 02], the following definitions apply:

Observation data

All scientific data generated by the payload.

System Ancillary data

Data generated on-board by the payload and the platform in support of the observation data, such as

- Scene start time
- Time correction value and the MSI On Board Time synchronization status
- System operation information, i.e.
    - Observation Mode (Nominal or extended)
    - Calibration Mode (Dark signal, absolute radiometry, vicarious)
    - Raw Measurement Mode
    - Test Mode.

Image Ancillary data

Data generated on-board by the payload in support of the observation data, such as calibration, timing for each line acquisition, compression ratio, data validity flag (e.g. nominal SWIR detector temperature), needed to process the measurement data on ground.

Satellite Ancillary data

Data acquired on-board by the satellite in support of the observation data, such as orbit position, velocity and time (generated by GPSR), attitude (generated by the AOCS sensors) needed to process measurement data on ground.

3. ANCILLARY DATA

The System- and Image-Ancillary Data are provided in the Data Field Header of the science X-Band TM Source Packets. All Satellite HK-TM is collected by the Central Software (CSW) and routed to the MMFU. The MMFU stores those data in the "HK-TM Data Store". The Satellite Ancillary Data, which is a sub-set of the Satellite HK-TM, are marked by PCAT = 6, 11, 12 and 13. They are stored additionally in the MMFU "Satellite Ancillary Data Store", which are down-linked by X-Band.

3.1 Time Stamping of TM Source Packets

The On-Board time format is CUC (CCSDS Unsegmented Time Code) with Coarse Time (32 bits) representing the seconds and Fine Time (24 bits) representing the sub-seconds. It is maintained in the Central OBT (COBT) inside the OBC. The CSW synchronizes the COBT to GPS time within 1 µs accuracy and distributes it to the units/instrument by MIL-Bus message and a correlation PPS-Signal.

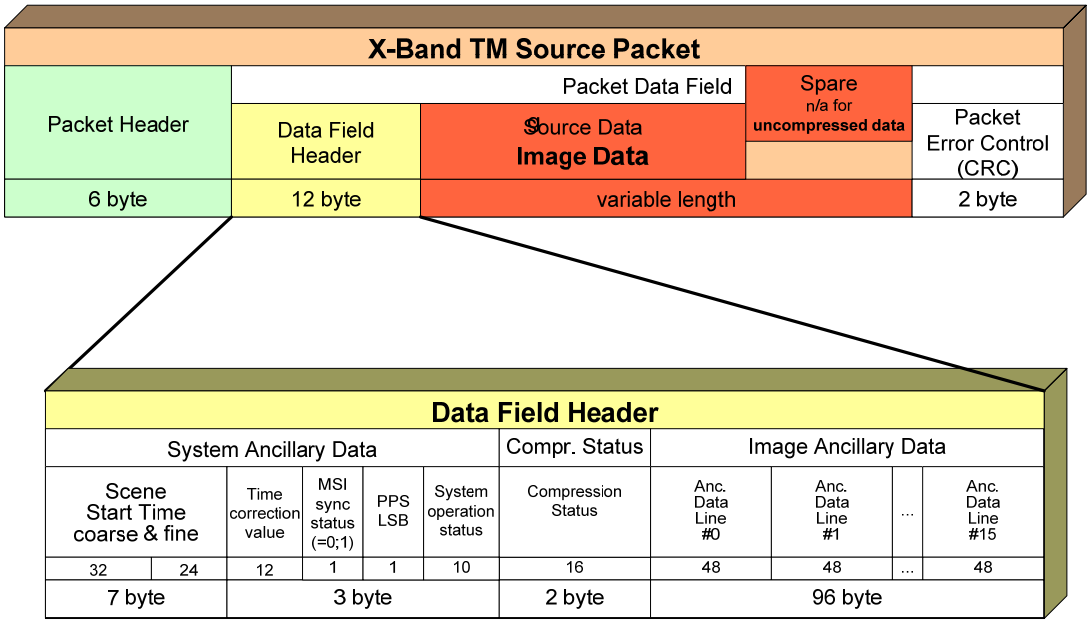
The PPS issued by the GPS receiver is synchronized to within 1 µs of GPS time.

Each TM Packet is time stamped with the COBT:

- Science TM packets contain the time stamp as defined in the System Ancillary Data §3.2. All TM packets belonging to one scene are time stamped with the same time i.e. with the scene start time.
- Satellite HK-TM packets are time-stamped with the current time at packet generation. Details on time synchronization can be found in [RD-02].
  In general two type of time stamping exist:
  - directly by the Central Software (CSW) inside the OBC
    I.e. applicable to all TM packets generated from the CSW Datapool.
  - indirectly by the unit/instrument Local On-Board Time (LOBT), which is synchronized with the COBT.

3.2 X-Band Ancillary Data

The X-Band Ancillary Data are provided in the Data Field Header of the science X-Band TM Source Packets as shown below:



3.2.1 System Ancillary Data

The System Ancillary Data consists of the following elements.

- Scene Start Time coarse and fine:
- Time correction value:
- MSI synchronization status:
- PPS LSB:
- System operation status

<table>
<tr><th>Bits</th><th>Name</th><th>Remarks</th></tr>
<tr><td colspan="3">System Ancillary Data (SAD) 80 bit</td></tr>
<tr><td>0…55
0…31
32…55</td><td>Scene Start Time
CUC coarse time
CUC fine time</td><td>CCSDS Unsegmented Time Code Coarse Time (seconds) (32 bits)
CCSDS Unsegmented Time Code Fine Time (subseconds) (24 bits)

<table>
<tr><th colspan="8">Course Time</th><th colspan="7">Fine Time</th></tr>
<tr><td>Bit Position</td><td>0</td><td>1</td><td>2</td><td>3</td><td>4…27</td><td>28</td><td>29</td><td>30</td><td>31</td><td>32</td><td>33</td><td>34…53</td><td>54</td><td>55</td></tr>
<tr><td>Seconds</td><td>2^{31}</td><td>2^{30}</td><td>2^{29}</td><td>2^{28}</td><td>2^{27} … 2^{28}</td><td>2^{3}</td><td>2^{2}</td><td>2^{1}</td><td>2^{0}</td><td>2^{-1}</td><td>2^{-2}</td><td>2^{-3}…2^{-22}</td><td>2^{-23}</td><td>2^{-24}</td></tr>
</table>
Smallest time period: 0x0000.001 = 2^{-24} seconds ≈ 59.6 ns
Largest time: 0xFFFF.FFF = $2^{32} - 2^{-24}$ seconds ≈ 136 years</td></tr>
<tr><td>56…67</td><td>Time Correction Value</td><td>It represents the MSI time deviation relating to PPS interval (12 bits)
The Time Correction Value is defined as the difference between the clock count between two PPS pulses measured on VCU side and the nominal clock count between two PPS pulses. The resolution is 1 / 8.37 MHz = 119 ns. Number representation is done in two's complement.</td></tr>
<tr><td>68…69
68

69</td><td>MSI Synchronization Status
Time status flag (CLK_ASYNC)

Time status flag PPS</td><td>
Indicates the validity of the time data.
1 : VCU clock is synchronised
0 : VCU clock is not synchronised

lsb of coarse time of last time synchronisation message</td></tr>
<tr><td>70…79</td><td>System Operation</td><td>Content defined by the system prime (10 bits)
It will be commanded by TC and will be forwarded by the VCU without any modifications.</td></tr>
</table>

Scene Start Time coarse (32 bit) and fine (24 bit)

Consists of CCSDS Unsegmented Time Code Course Time (32 bits) representing the seconds and Fine Time (24 bits) representing the sub-seconds. This time is provided by the MSI-clock, which is synchronized to the Central OBT by the PPS. The Central OBT is synchronized to GPS system time with about 1 µs accuracy.

System operation status (10 bit)

The system operation status reports the following MSI stati:

Mnemonic	*Value [hex]*	*MSI Mode (10 bit)*
INS-NOBS	**0x001**	Nominal Observation Mode
INS-EOBS	**0x002**	Extended Observation Mode
INS-DASC	**0x011**	Dark Signal Calibration Mode
INS-ABSR	**0x012**	Absolute Radiometry Calibration Mode
INS-VIC	**0x013**	Vicarious Calibration Mode
INS-RAW	**0x021**	Raw Measurement Mode
INS-TST	**0x022**	Test Mode
INS-DEC	**-**	*Decontamination will not be reflected as a Mode The related MIS-Mode is INS-SBY*

Table 3.2-1: System Operation Status

3.2.2 Compression Status

The Compression Status in the Data Field Header of the X-Band TM Data Field Header consists of the following elements. The Compression Status as per [AD-10] Table3.4-6 is detailed as follows:

Bits	Name	Remarks
Compression Status 16 bit		
0…2	MODOP	Status of the current compression (3 bits) Compress and Output Image Data: "000"
3…5	reserved	"110"
6	BYPNUC	Non-Uniformity Correction Active: "0" Bypass: "1"
7…8	reserved	"10"
9	SSE	Strip Sequence Error No error: "0" Error: "1" Error detected during a strip. It indicates that the MCI ASIC was not able to finish all the operations to be performed during this strip. This error occurs when the operating frequency is too low according to the input data rate or the output data rate.
10	GPI(1)	Status General Purpose Input (1) The MCI ASIC has two General Purpose Input pins. The GPI(1) signal is available for any function. The detailed meaning of this status is described in [tbd].
11	Reserved	"0"
12…13	Reserved	"00"
14…15	WMODE	WICOM Mode (2 bits) Compression Mode: "11" Remark: The WICOM modes "OFF", "INIT", and "IDLE" are never seen during data transfer.

3.2.3 Image Ancillary Data (IAD)

Image Ancillary Data are generated on-board by the payload in support of the observation data, such as calibration, timing for each line acquisition, data validity flag (e.g. nominal SWIR detector temperature), needed to process the measurement data on ground.

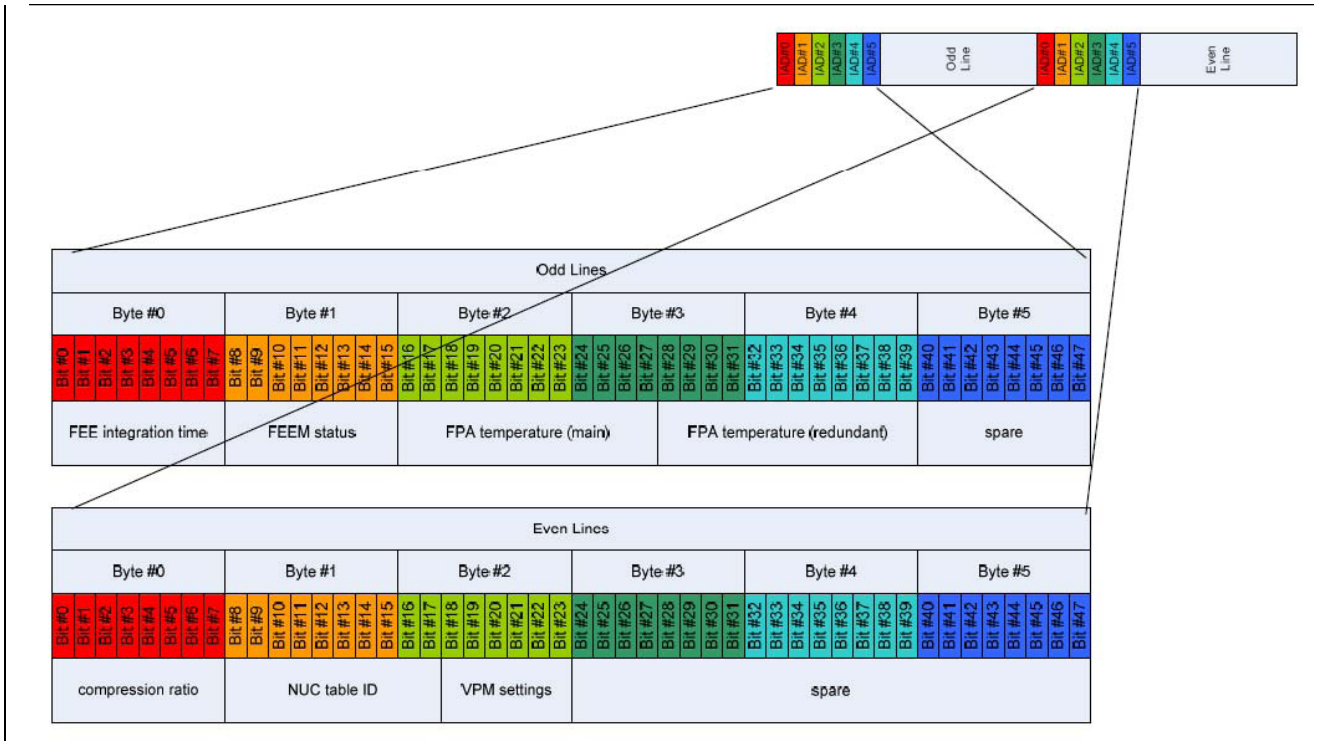
The IAD are transmitted in the Data Field Header of the science X-Band TM Source Packets. They are detailed as follows (as per [AD-10] Table3.4-7):

The IAD field is limited to 6 bytes per line and then to 96 bytes per strip transmission. The IAD implementation is described over 12 bytes. These data are repeated 8 times within the same strip.

The detailed definition of the 12 bytes is the following:

- Band integration time (8 bits)
- FEEM status (8 bits)
  - Error words coming from relevant FEEM by serial link
- FPA temperature (12 bits), thermal control, relevant to the detector transmission VNIR or SWIR
- FPA temperature (12 bits), monitoring, relevant to the detector transmission VNIR or SWIR
- Spare (8 bits)
- Band compression ratio (8 bits)
- NUC table ID (10 bits) : it identifies the correction coefficient table used in-flight. This ID figure will be loaded by the platform
- VPM control (6 bits)
  - TDI mode
  - Test generator status
- Spare (24 bits)

IAD transmission principle for Compressed mode: IAD are transmitted within IAD field over 96 bytes. IAD data are scattered over a 12 bytes brick. This elementary brick is repeated 8 times over the strip.



<table>
<tr><th>Bits</th><th>Name</th><th>Remarks</th></tr>
<tr><td colspan="3">Instrument Ancillary Data (IAD, ODD lines) 8 x 48 bit</td></tr>
<tr><td>0…7</td><td>INTTIME</td><td>FEE Integration Time (8 bit)
There are 13 different Integration Time values INTTIME0…INTTIME12. The values are unique for each band and correspond with the transmitted band number.
The allowed range is
<table>
<tr><th>Integration Times</th><th>Band</th><th>8 bit coding</th></tr>
<tr><td>INTTIME0</td><td>B1</td><td>Ti min = 0,0496 msec / Ti max = 1,5158 msec</td></tr>
<tr><td>INTTIME1</td><td>B2</td><td>Ti min = 0,0496 msec / Ti max = 1,5158 msec</td></tr>
<tr><td>INTTIME2</td><td>B3</td><td>Ti min = 0,0496 msec / Ti max = 1,5158 msec</td></tr>
<tr><td>INTTIME3</td><td>B4</td><td>Ti min = 0,0496 msec / Ti max = 1,5158 msec</td></tr>
<tr><td>INTTIME4</td><td>B5</td><td>Ti min = 0,0496 msec / Ti max = 3,0819 msec</td></tr>
<tr><td>INTTIME5</td><td>B6</td><td>Ti min = 0,0496 msec / Ti max = 3,0819 msec</td></tr>
<tr><td>INTTIME6</td><td>B7</td><td>Ti min = 0,0496 msec / Ti max = 3,0819 msec</td></tr>
<tr><td>INTTIME7</td><td>B8</td><td>Ti min = 0,0496 msec / Ti max = 3,0819 msec</td></tr>
<tr><td>INTTIME8</td><td>B8a</td><td>Ti min = 0,0363 msec / Ti max = 9,3458 msec</td></tr>
<tr><td>INTTIME9</td><td>B9</td><td>Ti min = 0,0363 msec / Ti max = 9,3458 msec</td></tr>
<tr><td>INTTIME10</td><td>B10</td><td>Ti min = 0,19568 msec / Ti max = 9,3456 msec</td></tr>
<tr><td>INTTIME11</td><td>B11</td><td>Ti min = 0,0496 msec / Ti max = 2,9315 msec</td></tr>
<tr><td>INTTIME12</td><td>B12</td><td>Ti min = 0,0496 msec / Ti max = 2,9315 msec</td></tr>
</table></td></tr>
<tr><td>8…15</td><td>FEE health status</td><td>FEEM health status (8 bit)
There are 8 unique status values (1 per FEEM). The value corresponds to the FEEM concerned by the detector number and the SWIR or VNIR type.
Bit 15 : Parity Error bit
Bit 14 : Stop bit Error bit
Bit 13 : Time Out Error Bit
Bit 11 : Latchup on the VDA voltage error bit (SWIR only)
Bit 12 : Latchup on the VDD voltage error bit (SWIR only)
Bit 10 : Latchup on the VDD0 voltage error bit
Bit 9 : Tbd
Bit 8 : Tbd</td></tr>
<tr><td>16…27</td><td>FPAT</td><td>FPA Temperature (12 bit) / Thermal control
There are 2 unique FPA Temperature values FPATM0, FPATM1 (1 for VNIR FPA, 1 for SWIR FPA).
The values corresponds to the FPA temperature provided by the thermistor used for the thermal control of the current detector type (VNIR or SWIR)

The allowed range is
<table>
<tr><th>Temperature</th><th>12 bit coding</th></tr>
<tr><td>VNIR</td><td>0 = 50°C up to 4095 = 0°C
Temperature evolution over the range will be characterised by several linear parts.</td></tr>
<tr><td>SWIR</td><td>0 = -95°C up to 4095 = -70°C
Temperature evolution over the range will be characterised by several linear parts.</td></tr>
</table></td></tr>
<tr><td>28…39</td><td>FPAT</td><td>FPA Temperature (12 bit) / Monitoring
There are 2 unique FPA Temperature values FPATR0, FPATR1 (1 for VNIR FPA, 1 for SWIR FPA).
The values corresponds to the FPA temperature provided by the thermistor used for the monitoring of the current detector type (VNIR or SWIR)

The allowed range is
<table>
<tr><th>Temperature</th><th>12 bit coding</th></tr>
<tr><td>VNIR</td><td>0 = 50°C up to 4095 = 0°C
Temperature evolution over the range will be characterised by several linear parts.</td></tr>
<tr><td>SWIR</td><td>0 = -95°C up to 4095 = -70°C
Temperature evolution over the range will be characterised by several linear parts.</td></tr>
</table></td></tr>
<tr><td>40…47</td><td>Spares</td><td>8 bit spares</td></tr>
</table>

<table>
<tr><th>Bits</th><th>Name</th><th>Remarks</th></tr>
<tr><td colspan="3">Instrument Ancillary Data (IAD, EVEN lines) 8 x 48 bit</td></tr>
<tr><td>0…7</td><td>CRATIO</td><td>Compression Ratio WICOM (8 bit)
The values represent the programmed output rate defined in number of bits per pixel (BPP) of the corresponded band. The following formula are valid:
CRATIO = 25 x BPP

The allowed range is
<table>
<tr><th>CRATIO</th><th>BPP</th><th>Remark</th></tr>
<tr><td>0 to 7</td><td>Reserved</td><td>Reserved</td></tr>
<tr><td>8 to 150</td><td>0.32 to 6.00</td><td></td></tr>
<tr><td>151 to 255</td><td>Reserved</td><td>Reserved</td></tr>
</table>
The value corresponds to the transmitted band number.</td></tr>
<tr><td>8…17</td><td>NUCTID</td><td>NUC Table ID (10 bit)
This ID is uniform for all transmitted bands</td></tr>
<tr><td>18…23</td><td>VPMSET</td><td>VPM settings (6 bits, 5 used)</td></tr>
<tr><td></td><td>18 : TMODE</td><td>Video Channel Source Select (1 bit)
Channel connected to ADC: “0”
Channel connected to Test Generator: “1”

Configurable for each Video Channel (48 unique values), value corresponds with transmitted band & detector</td></tr>
<tr><td></td><td>19 : SYNC</td><td>Test clock synchronisation to the sync of the 10m band (1bit)
Free running : “0”
Synchronized: “1”

Configurable for each VPM, value corresponds with transmitted band & detector</td></tr>
<tr><td></td><td>20 : NOISE</td><td>Noise Insertion in Test Mode (1 bit)
Noise OFF: “0”
PSR Noise ON: “1”
Configurable for each VPM, value corresponds with transmitted band</td></tr>
<tr><td></td><td>21-22 : TDI/A/B</td><td>TDI mode (2 bits)
TDI applied: “00”
TDI not applied, Line A transmitted “01”
TDI not applied, Line B transmitted “10”
No TDI band “11”

There are 48 unique values : 1 per detector (12) and per TDI band (4)</td></tr>
<tr><td></td><td>23 : Spare</td><td>Spare bit</td></tr>
<tr><td>24…47</td><td>Spares</td><td>24 bit spares</td></tr>
</table>

3.3 Satellite Ancillary Data

Data acquired on-board by the satellite in support of the observation data, such as orbit position, velocity and time (generated by GNSS), attitude (generated by the AOCS sensors) needed to process measurement data on ground. Depending on timing constraints (NRT product or not), these data will be post-processed on-ground to improve the accuracy of orbit and attitude restitution.

The Satellite Ancillary Data are provided within the non-Science TM Source Packets via X-band. These data are collected from all units/instruments by the On-Board Computer (OBC) and routed to a dedicated Satellite Ancillary Data Store. All Satellite Ancillary are marked in the packet header by PCAT = 6, 11, 12 or 13.

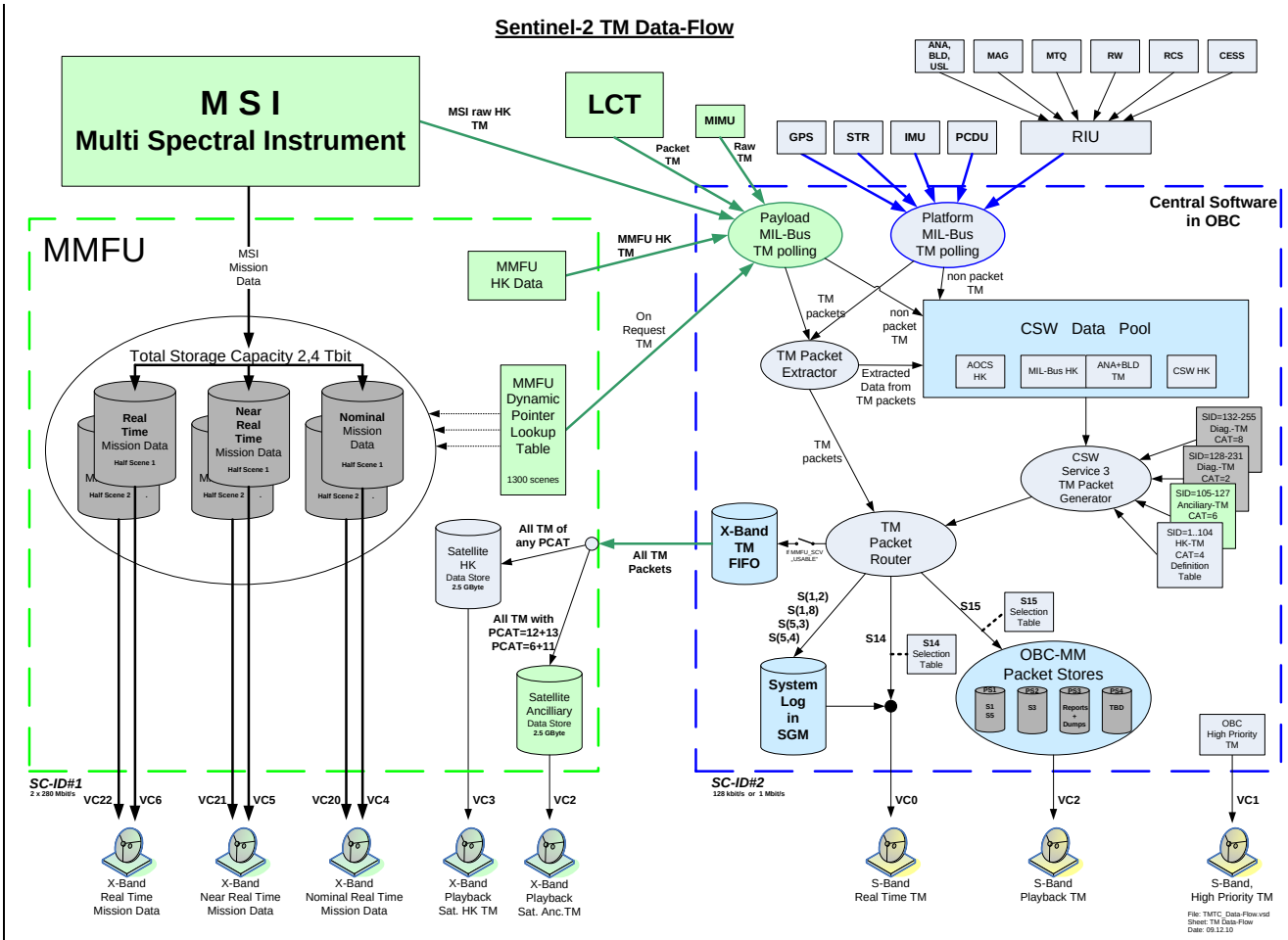


Figure 3.3-1 Sentinel-2 TM Data Flow with Satellite Ancillary Data Store

The Satellite Ancillary Data are composed by TM packets from the following units:

- GPS-Receiver
- Startracker
- Central Software with extracted data from the following sources:
  - AOCS Software attitude data (AOCS-TM1)
  - AOCS Software propagator data (AOCS-TM2)
  - Navigation Solution data from GPSR (AOCS-GPSR)
  - Time Correlation Parameter data from GPSR (AOCS-GPSR)
  - Inertial Measurement Unit data (AOCS-IMU)
  - Thermal Subsystem data (AOCS-THERM)

3.3.1 TM Packets from GPS-Receiver

The following Satellite Ancillary Data packets are provided by the GPS-Receiver (GPSR). Details can be found in [AD-12] §4.2 Table 4-2 "PCAT Values Definition", [AD-13] , §5 "MEASUREMENT DATA" and in the SRDB.

GPSR TM Packets at **1 Hz** with the following parameters:

- Sentinel Auxiliary Data by Service(212, 1, **PRID=GPSR**, **SID=218, PCAT=6**)

GPSR TM Packets at **0.1 Hz** with the following parameters:

- Satellites in view status by Service(212, 1, **PRID=GPSR**, **SID=223, PCAT=6**)
- Carrier Phase measurements by Service(212, 1, **PRID=GPSR**, **SID 225, PCAT=6**)
- Carrier Amplitude by Service(212,1, **PRID=GPSR**, **SID 226, PCAT=6**)
- Code Phase measurements by Service(212, 1, **PRID=GPSR**, **SID 227, PCAT=6**)

GPSR TM Packets **event driven** with the following parameters:

- GPS NAV Almanac by Service(212, 1, **PRID=GPSR**, **SID 230, PCAT=13**)
- GPS NAV Ephemeris by Service(212, 1, **PRID=GPSR**, **SID 231, PCAT=13**)
- GPS NAV UTC and Ionosphere by Service(212, 1, **PRID=GPSR**, **SID 232, PCAT=13**)
- Constellation status by Service(212, 1, **PRID=GPSR**, **SID 229, PCAT=13**)

The following GPSR TM Packets are marked as Satellite Ancillary Data. They are only used for diagnostic purpose and therefore they are DISABLED:

- GPS Channel Status by Service(212, 1, **PRID=GPSR**, **SID 224, PCAT=12**)
- GPS Tracking State by Service(212, 1, **PRID=GPSR**, **SID 215, PCAT=12**)
- GPS Noise Histogram by Service(212, 1, **PRID=GPSR**, **SID 235, PCAT=12**)
- GPS AGC Status by Service(212, 1, **PRID=GPSR**, **SID 234, PCAT=13**)

Note: When enabling additional GPS packets, the overall bit rate needs to be respected to avoid delay or loss of GPS packets.

The following GPSR TM Packets have been added for completeness, but not for use. Since they are not applicable for Sentinel-2, they are always DISABLED:

- GPS **S1** Navigation Solution by Service(212, 1, **PRID=GPSR**, **SID 216, PCAT=11**)
- GPS **S1** IMT/GPST Correlation by Service(212, 1, **PRID=GPSR**, **SID 217, PCAT=11**)

3.3.2 TM Packets from Startracker

The following Satellite Ancillary Data packets are provided by each of the three Startracker (STR), which are switched ON and in Tracking Mode. The STR TM packets are time stamped by STR itself, which is synchronized with the Central OBT. The content is according to STR PUS ICD [AD-14] §7.2.1, §7.2.3.

- TM_ADB “Attitude Data Block” TM packet(3, 25, **PRID=STR**, **SID 105, PCAT=6)** at **10 Hz**
- TM_TDB “Tracker Data Block” TM packet(3, 25, **PRID=STR, SID 106, PCAT=6**) **disabled, only available for diagnostic purposes**

3.3.3 TM Packets from Central Software

The Central Software (CSW) stores its Satellite Housekeeping data in the System Datapool including the Satellite Ancillary Data.

Dedicated telemetry parameter are collected from the System Datapool and provided as Satellite Ancillary Data TM(3,25, PRID=AOCS, PCAT=6+12) on S-Band and X-Band. All those TM packet are time-stamped directly by the Central Software.

The ancillary data include the raw equipment measurement data and processed measurement data, namely estimated position, velocity, attitude, and rate. Measurement processing is part of the CSW-AOCS algorithm software.

The CSW-AOCS Software runs twice per second inside the OBC. The CSW-AOCS software includes an orbit propagator, which updates its states with the GPSR measurements whenever a new and valid solution is available. Position and velocity are transformed from WGS84 to geocentric J2000 considering precession, nutation, and Earth rotation (using UT1). Similarly a gyro stellar estimator processes STR and IMU measurements to determine the attitude of the satellite reference frame with respect to J2000.

The following chapters describe the designated Ancillary Data TM packet types.

3.3.3.1 CSW AOCS-TM1 Attitude Data

The following **Attitude Data** are generated by AOCS-ALGO and a TM packet **AOCS-TM1(3,25,PRID=AOCS; PCAT=6; SID=121)** is generated at **2 Hz** by the CSW. The parameters with prefix “gse” are output of the gyro stellar estimator, which is a Kalman filter with fixed gains. Note that each packet contains 5 attitude samples and associated times corresponding to the 10 Hz readout of the IMU. All parameters expressed in physical units are provided as double precision. The representation in terms of mantissa and exponent is already the quantity in physical units. No scaling factor between LSB and physical unit is needed.

Parameters of AOCS-TM1

Variable Name	Description	Data Type	Size [byte]	Phys. Units
SCV-OPS Flag STR1	STR 1 "in-use" Flag	boolean	1	-
SCV-OPS Flag STR2	STR 2 "in-use" Flag	boolean	1	-
SCV-OPS Flag STR3	STR 3 "in-use" Flag	boolean	1	-
SCV-OPS Flag GPSR A	GPSR A "in-use" Flag	boolean	1	-
SCV-OPS Flag GPSR B	GPSR B "in-use" Flag	boolean	1	-
SCV-OPS Flag MSI A	MSI A "in-use" Flag	boolean	1	-
SCV-OPS Flag MSI B	MSI B "in-use" Flag	boolean	1	-
SCV-OPS Flag IMU1	IMU1 "in-use" Flag	boolean	1	-
SCV-OPS Flag IMU2	IMU2 "in-use" Flag	boolean	1	-
SCV-OPS Flag IMU3	IMU3 "in-use" Flag	boolean	1	-
SCV-OPS Flag IMU4	IMU4 "in-use" Flag	boolean	1	-
AOCS mode	Main AOCS mode identifier	uint8	1	-
AOCS subMode	AOCS submode identifier	uint8	1	-
gseIsValid	GSE (gyro stellar estimator) validity	boolean	1	-
gseAttQualId	GSE attitude quality, defined in table below	uint8	1	-
gseTimeCucRawVec	Time points of attitude estimates in cuc format	uint32	5 x (4+4)	-
gseAttEstVec_qVec_CJ	GSE Attitude quaternion estimate vector part	double	5 x (3x8)	-
gseAttEstVec_qSca_CJ	GSE Attitude quaternion estimate scalar part	double	5 x 8	-
gseImuRateEst_C	GSE Rate estimate at time of latest IMU rate input	double	3x8	rad/s
gseInnovStr1_U	Difference between GSE filter estimate and first in-use STR measurement (difference corresponds approx to 3 angles, valid for last time point)	double	3x8	-
gseInnovStr2_U	Difference between GSE filter estimate and second in-use STR measurement (difference corresponds approx to 3 angles, valid for last time	double	3x8	-

The GSE attitude quality index is defined as follows:

gseAttQualid	Description
0	Solution is invalid
1	Solution propagated, no STR update available
2	1 consolidated STR measurement available (estimated innovation for one STR is below a threshold)
3	2 consolidated STR measurements available (estimated innovations for all two STRs are below a threshold)

The AOCS-mode identifiers (mode, subMode) are defined as:

mode	subMode	0	1	2	3	4	5	6
0	SBM-							
1	IAM-	-DEP	-RD	-EA	-YA	-SS		
2	NOM-		-ACQ	-AH	-FP	-SL	-EFP	-BSL
3	OCM-		-ACQ	-SL	-STAB	-DV	-BSL	
4	SFM-	-DEP	-RD	-EA	-YA	-SL		

3.3.3.2 CSW AOCS-TM2 Propagator Data

The following **Propagator Data a**re generated by AOCS-ALGO and a TM packet **AOCS-TM2(3,25,PRID=AOCS; PCAT=6; SID=122)** is generated at **1 Hz** by the CSW. All parameters expressed in physical units are provided as double precision. The representation in terms of mantissa and exponent is already the quantity in physical units. No scaling factor between LSB and physical unit is needed.

Parameters of AOCS-TM2

Variable Name	Description	Data Type	Size [byte]	Phys. Units
oopIsValid	Valid flag for orbit propagator function	boolean	1	-
oopQualId	Oop solution quality index	uint8	1	-
oopPos_J	Propagated position in geocentric J2000 frame	double	3x8	m
oopVel_J	Propagated velocity in geocentric J2000 frame	double	3x8	m/s
oopOrbitAng	Orbit angle wrt WGS84	double	8	rad
oopOrbitNum	Orbit number incrementing at ascending node	uint32	4	-
oopTimeSec	Time stamp of propagated output data	double	8	s
mjdUt1	UT1 as modified julian date	double	2x8	day,fod

The orbit propagator quality index is defined as follows:

oopQualid	Description
0	Solution is invalid
1	Solution propagated, neither GPSR measurements nor recent update from ground available
2	Cyclic position update available

3.3.3.3 CSW AOCS-GPSR Data

The CSW extracts for internal processing from the GPSR the packet data field source data of the following TM packets and stores them in the System Datapool:

- Navigation Solution Data Record TM(3,25; **PRID=GPSR; SID =213, PCAT=4**)
- Time Correlation Data Record TM(3,25; **PRID=GPSR; SID =214, PCAT=4**)

GPSR Navigation Solution and Time Correlation data are newly packet by the CSW and marked as Ancillary data as follows:

- **AOCS-GPSR A Navigation Solution (3,25,PRID=AOCS; PCAT=6; SID=105)** at **1 Hz**
- **AOCS-GPSR A Time Correlation (3,25,PRID=AOCS; PCAT=6; SID=106)** at **1 Hz**
- **AOCS-GPSR B Navigation Solution (3,25,PRID=AOCS; PCAT=6; SID=108)** at **1 Hz**
- **AOCS-GPSR B Time Correlation (3,25,PRID=AOCS; PCAT=6; SID=109)** at **1 Hz**

The **AOCS-GPSR Navigation Solution** and **Time Correlation** packets contain the data fields inline with the layout as described in [AD-12] §4.2 Table 4-2 "PCAT Values Definition", [AD-13] §5 "MEASUREMENT DATA" and in the SRDB.

3.3.3.4 CSW AOCS-STR Data

The CSW extracts for internal processing from the STRs the packet data field source data of the following TM packets and stores them in the System Datapool:

- Attitude Data Block TM_ADB TM(3,25; **PRID=STR; SID =105, PCAT=6**)
- Status and Health Data Block TM_SDB TM(3,25; **PRID=STR; SID =1, PCAT=4**)

The original STR TM_ADB packet is already marked as Ancillary data and therefore not repeated here. The related STR data are already computed by the AOCS-ALGO. The related result is presented in the **AOCS-TM1**. Therefore **NO** AOCS-STR packet is generated per default by the CSW. But the related definition is available in the CSW as follows:

- **AOCS-STR1_TM_SDB(3,25, PRID=AOCS; PCAT=6; SID=124)** enabled, only if STR 1 is ON.
- **AOCS-STR2_TM_SDB(3,25, PRID=AOCS; PCAT=6; SID=125)** enabled, only if STR 2 is ON.
- **AOCS-STR3_TM_SDB(3,25, PRID=AOCS; PCAT=6; SID=126)** enabled, only if STR 3 is ON.

The **AOCS STR** data are inline with the layout as described in STR ICD [AD-14] §7.2.1, §7.2.3.

3.3.3.5 CSW AOCS-IMU Data

The following Satellite Ancillary Data packets are collected from the 4 Inertial Measurement Unit Channels (IMU) and stored in the System Datapool. They are time stamped by the Central OBT with the 10PPS.

The **10 Hz** IMU 1+2+3+4 data are packetized by the CSW and marked as Ancillary Data. The basic frequency of the AOCSThe 10 different **AOCS-IMU** packets are generated at 1 Hz. They report the data of the 4 IMUs at each different 10PPS pulse i.e. at each 100 msec slot within one second:

- **AOCS-IMU1234S1(3,25,PRID=AOCS; PCAT=6; SID=111)** acquisition 1 @ PPS
- **AOCS-IMU1234S2(3,25,PRID=AOCS; PCAT=6; SID=112)** acquisition 2 @ PPS + 100 msec
- **AOCS-IMU1234S3(3,25,PRID=AOCS; PCAT=6; SID=113)** acquisition 3 @ PPS + 200 msec
- **AOCS-IMU1234S4(3,25,PRID=AOCS; PCAT=6; SID=114)** acquisition 4 @ PPS + 300 msec
- **AOCS-IMU1234S5(3,25,PRID=AOCS; PCAT=6; SID=115)** acquisition 5 @ PPS + 400 msec
- **AOCS-IMU1234S6(3,25,PRID=AOCS; PCAT=6; SID=116)** acquisition 6 @ PPS + 500 msec
- **AOCS-IMU1234S7(3,25,PRID=AOCS; PCAT=6; SID=117)** acquisition 7 @ PPS + 600 msec
- **AOCS-IMU1234S8(3,25,PRID=AOCS; PCAT=6; SID=118)** acquisition 8 @ PPS + 700 msec
- **AOCS-IMU1234S9(3,25,PRID=AOCS; PCAT=6; SID=119)** acquisition 9 @ PPS + 800 msec
- **AOCS-IMU1234S10(3,25,PRID=AOCS; PCAT=6; SID=120)** acquisition 10 @ PPS + 900 msec

The AOCS-IMU packets are only enabled if the IMU is ON. The 10 Hz Data per IMU channel are defined by the so called Inertial Data as specified in [AD-15] §8.6.8 and are defined by the SRDB. The data per channel and acquisition time contains:

- Filtered angle
- Gyro channel health status word (bit 0 is validity bit)
- Organizer temperature
- SIA temperature
- Time tag
- Raw angle
- Optical source temperature
- Board temperature
- Temperature reference voltage offset
- Temperature reference voltage
- 10PPS time corresponding to the measurements (produced by the CSW)

3.3.3.6 CSW MSI-SAD Packet

The following MSI Subsystem Data are provided as Satellite Ancillary Data packets. They are generated at 0.1 Hz and time stamped by the Central OBT.

The following Data are gathered from the System Data Pool by the CSW and an **MSI-SAD(3,25,PRID=MSIC; PCAT=6; SID=123)** is generated at **0.1 Hz** by the CSW**:**

- MSI Mode MSI_INS_MODE_ID

➔ based on MSI Thermal ICD GS2.ICD.ASF.MSI.00003 §11.5.1:

- 5 (nominal only) Telescope temperatures (+X-Z; -X-Z; +Y; -Y; +Z)
- 3 (nominal only) Mirrors temperatures (M1 and M3 thermal sceen, M2 bracket)
- 4 (nominal only) Focal Plane temperatures (VNIR FPA+FEE, SWIR FPA+FEE)
- 2 (nominal only) Splitter temperatures (bott +X; top -X)

➔ based on S2 Thermal ICD GS2.ICD.ASD.MSI.00017 Table 6.5-2:

- 3 (one of the triplet) CSM-Diffuser temperatures (via RIU)
- 1 (one of the triplet) IMU sensor plate temperature (via RIU)
- 3 (one of the triplet) STR sensor plate temperatures (via RIU)
- 1 (one of the triplet) STR sensor plate base plate temperature (via RIU)
- 1 (one of the triplet) STR sensor plate back plate temperature (via RIU)

Note:

Focal Plane Assembly temperature information is provided twice i.e. in this packet and within the Image Ancillary Data as described in [AD-10] §3.2.3.

Sentinel 2

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