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DOCUMENT

GS inputs to on-board data architecture

European Space Agency
Agence spatiale européenne

APPROVAL

Title **GS input to on-board data architecture**	
Issue 1	**Revision** 5
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CHANGE LOG

Reason for change	Issue	Revision	Date
First issue	1	1	06-Nov-2014
Added req on PVT and Quaternions frames	1	2	12-Dec-2014
Clarified APID vs PUS usage	1	3	12-Mar-2015
Customised for CFDP	1	4	12-Dec-2018
Update with comments from EOP-G	1	5	21-Mar-2019

CHANGE RECORD

Issue 1	**Revision** 1		
Reason for change	**Date**	**Pages**	**Paragraph(s)**
First issue	06-Nov-2014	all	

Issue 1	**Revision** 2		
Reason for change	**Date**	**Pages**	**Paragraph(s)**
Added req on PVT and Quaternions frames	12-Dec-2014	8	

Issue 1	**Revision** 3		
Reason for change	**Date**	**Pages**	**Paragraph(s)**
Clarified APID vs PUS usage (added req 19 and 20)	12-Mar-2015	8	

Issue 1	**Revision** 4		
Reason for change	**Date**	**Pages**	**Paragraph(s)**
Renumbering of requirements	12-Dec-2018	all	
Evolution to support use of CFDP	12-Dec-2018	all	
Clarification of RAW and Level 0 product	12-Dec-2018	4	

Issue 1	**Revision** 5		
Reason for change	**Date**	**Pages**	**Paragraph(s)**
Corrections of typos and clarifications	21-Mar-2019	all	

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1 GLOSSARY

Observation data (OBS)	Instrument Source Packet (ISP) as generated by the Instrument and containing the measurements both in measurement/normal and calibration modes.
Ancillary data (ANC)	Source (Space) Packet as generated by any on-board source and needed for ground processing (e.g navigation, HKTM, temperature, AOCS, etc)
Raw data (RAW)	Concatenation of ISP and Ancillary Space Packets as are transmitted on the space to ground RF link without inclusion of any interleaved or appended annotation.
CFDP File (CFDP File)	Data File generated on-board or on-ground and subject to transfer on the space-to-ground link via CFDP protocol.
Level 0 product	Level 0 data files consisting of a ground segment header + a concatenation of Source (Space) Packets without inclusion of any annotation or, alternatively, composed by a ground segment header + a CFDP File
Level 1 product	Level 1 data files in the same format at the actual GS and as generated by L1PP
Level 2 product	Level 2 data files in the same format at the actual GS and as generated by L2PP
Auxiliary data (AUX)	Other data (static or dynamic) in format of files formatted as in the real GS to be used for configuration of the processor or as input to the processors (e.g. Restituted or Reconstituted Orbit File, Instrument Characterisation, Meteo data, Offset tables, etc). Some auxiliary data can originate from offline calibration activities.
Calibration Products (CAL)	Data files (products) generated during the processing of instrument data and used in the Ground Segment or in the L1 and higher level processing. They can be either dynamic (CAL) or static (CAL/AUX) (see nomenclature note in section 3.3.1).

2 PURPOSE AND SCOPE

This TN contains a list of inputs to define an on-board data architecture that allows an efficient, standardised and optimised ground processing and Ground Segment for Mission/Payload/Instrument Data Processing **(NB it does not apply to TT&C/S-Band data links).**

This TN also addresses the specificity introduced by the use of CFDP in addition to the pure Space Packet Protocol to ensure Space to ground data transfer. It is noted that CFDP has never been used in EO mission and that the operational profile of EO related to payload data downlink fundamentally differs from the one used in Space Science, both on the technical level (many short passes) as well as programmatically (Payload data ground station acquired as service from external providers and not operated by ESOC).

The requirements contained in this document comply therefore with the applicable CCSDS standards either the traditional CCSDS Space Packet or the newer CFDP, concepts and rationale; furthermore take into accounts the specificity of a typical EO mission data processing ground segment whereby:

- a multiplicity of physical or logical on-board sources generate data to be processed on-ground
- the data is produced by each source (Application) in data units formatted as :
    a. Space Packets
    b. CFDP Files containing data formatted in a Project specific fashion
    c. CFDP Files containing Space packets
- CFDP Layer uses as *Unitdata Transfer layer (UT)* the Space Packet Protocol.
- the same physical on-board source (instrument) produces measurement data in different modes (e.g. Calibration, Nominal, dual, interferometric, reduced, test, etc) that need to be processed differently
- on-board sources, different from the instrument, produce Ancillary data (e.g. Navigation or Thermal data)
- the different Space Packets types are identified via their Primary Space Packet Header
- different types of CFDP files are identified via their name.
- the different Space Packets types are processed on ground by the same or different data sinks
- different types of CFDP files are processed on ground by the same or different data sinks
- the end-to-end application level routing from on-board source to ground segment sink is performed based on the Primary Space Packet Header or based on the CDFP file type as identified by means of its name.
- common commercially available Ground Station Equipment conforming to CCSDS concepts (Demodulator and FEPs) is used with no modification.
- the end-consumer/sink of each data unit is the corresponding Level-1 Processor for each type of data product. (see Fig. 2)

- the Payload data downlink is executed preferably in a full open loop concept and the need of uplink to control CFDP operation during a Payload Data downlink is avoided[1].

These inputs (which are phrased as requirements) should be made applicable to the Space Segment for all the on-board data structures (i.e. CADU, TF, ISP, CFDP Files), which will then be downloaded to ground for processing or explicitely waived for a specific project (with a sound justification).

These ground system-level requirements aim to ensure that the on-board data architecture (generation and organisation of data like parameters, and packets and files) is such that it maximises the modularity and minimises the coupling between different types of on-board generated data,minimises the requirement, complexity and operation of the PDGS receiving elements and their commonality across missions.

This allows a natural, flexible and efficient processing, a simple one-way data flow from space to ground and a simple development of the data processing elements mitigating the risks and the impact caused by data format and organisation updates (e.g. allow late identification of additional ancillary parameter needed for ground processing without affecting format and structure of measurement data).

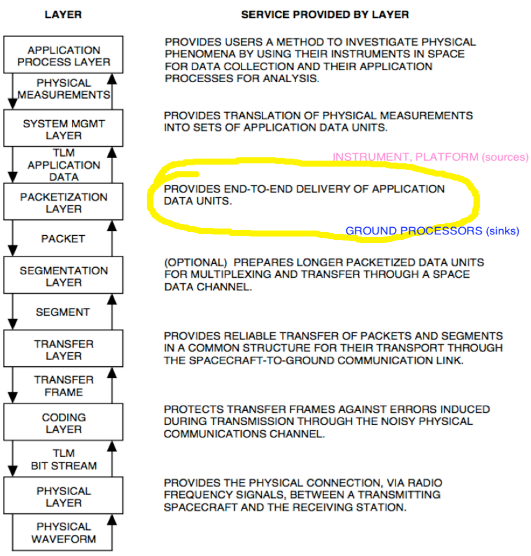

Fig. 1 Layered Telemetry Service model from [CCSDSTMR]

[1] Closed loop (Class 2 CFDP) considerably increases the system complexity and should not be considered as baseline unless it is confirmed that the required availability requirement end-to-end cannot be satisfied with any other mean (e.g. overlap, geographic diversity, improved link budget etc). Even in that case a immediate CFDP NAK is not desirable.

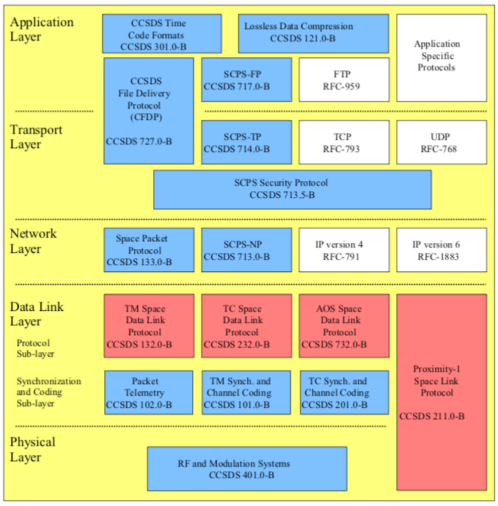

Fig. 2 Communication Protocol and Layers

generic overall payload data flow

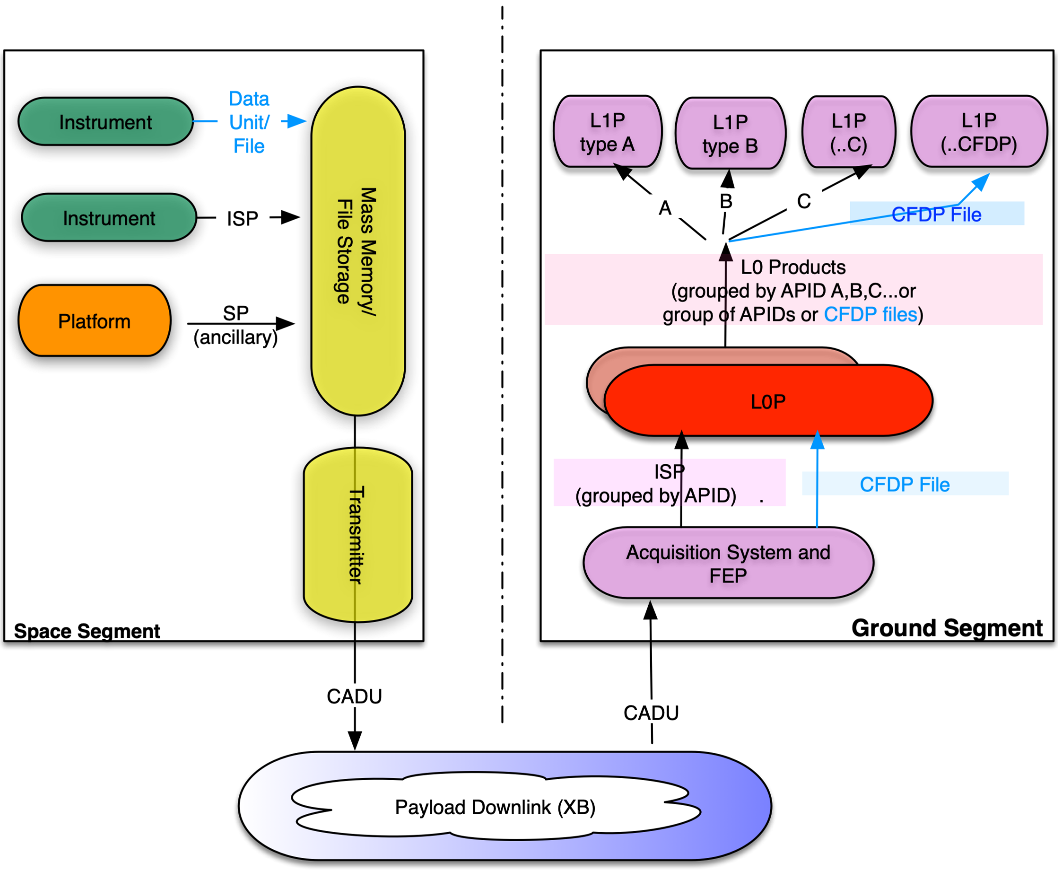

Fig 3. Ideal dataflow in ESA EO Ground System

3 REFERENCE DOCUMENTS:

Overview of Space Communications Protocols, CCSDS 132x0b1	[CCSOVP]
TM Rationale, CCSDS 100x0g1	[CCSTMR]
TM Space Data Link Protocol CCSDS 132x0b1	[CCSDLP]
AOS Space Data Link Protocol CCSDS 732x0b2	[CCSADL]
Space Link Identifiers CCSDS 135x0b3	[CCSSLI]
Telemetry Services, CCSDS, 103.0-B-2	[CCSTMS]
CCSDS File Delivery Protocol (CFDP) CCSDS 727.0-b4	[CCSFDP]
Unified Space data Link Protocol, CCSDS 732.1-b1	[CCSUDL]

4 INPUTS

The requirements/inputs here below address separately the various CCSDS communication layer and the corresponding Data Units.

4.1.1 Space Packets

R-01. The Space Packet APID and the Source Sequence counter within the Space Packet Header shall be used for the unique identification of the Application Data Unit type (the Space Packet) and for their end-to-end routing.

R-02. On a given satellite there shall not be different types of Space Packet with the same APID even if these packets are not sharing physical RF downlink channel (e.g. S and X band) or are transmitted via different Virtual Channels.

R-03. The content of each Space Packet shall be designed so that the information in the Source Packet Secondary Header or in the Space Packet Data Field (which is not accessible to any system except the final consumer/sink performing the processing) shall not be needed to determine the routing or to select the processing chain/facility.

R-04. Each instrument measurement mode requiring a different (ground) processing or ground routing shall be assigned a different APID. This includes, in particular, APID-differencing between internal calibration, external calibration and normal measurement as well as APID-differencing between observation modes (e.g Dual/full polarisation, wide/narrow swath, etc etc).

R-05. Each ancillary data set generated on board and needed for processing shall have different APID (e.g. Navigation ancillary Space Packet shall have different APID from Thermal acquisition Space Packet)

R-06. All the ancillary parameters needed for scientific/mission data processing shall be contained in dedicated independent ancillary Space Packets and not shared with TT&C monitoring packet (even if this results in having duplicated information between HKTM and Scientific/mission data).

R-07. All the ancillary parameters needed for scientific/mission data processing (e.g. PVT, attitude, etc) shall be contained in dedicated independent ancillary Space Packets and not included within the measurement data.

R-08. All the parameters in Ancillary Space Packets needed for scientific/mission data processing shall not be subcommutated.

R-09. All Space Packets needed for ground processing and including ancillaring, measurement and calibration shall include a Space Packet secondary header (data field header) either according to PUS or according to CCSDS which is common across all packet types.

R-10. All Space Packets needed for ground processing and including ancillaring, measurement and calibration shall contain in their Space Packet secondary header a time stamp with a single format across all packet types, a common Epoch and common position of the corresponding bitfield within the data, even if originated by different on-board clocks or sources.

R-11. Each APID shall have an independent Source Sequent Counter

R-12. Space Packets with the same APID shall have the same data field structure even when segmentation/grouping is used.

R-13. The PVT information located in ancillary Space packets (e.g. NAVATT) used for data processing shall be expressed in Earth Fixed frame of reference in accordance to the one used by the GPS units.

R–14. The attitude (quaternions) information located in ancillary space packet (e.g. NAVATT) used for data processing shall be expressed in inertial frame of reference according to the one used by the AOCS.

R-15. The baseline frequency of PVT data transmitted on ground shall be OSV at 1 Hz.

R-16. The baseline frequency of attitude data available on ground shall be Quaternions at 1 Hz assuming no on-board perturbation at higher frequency are present, however in specific cases a higher frequency might be warranted.

R-17. (goal) OSV and Quaternions with the same frequency shall be sampled and be associated at the same moment in time.

R–18. If the packet structure for payload data is formatted according as PUS, the Service Type/Subtype field shall not be used in the place of the APID to discriminate different type of data (as per req. R-04).

R–19. The packet structure of payload TM shall not make use of SID, i.e. a packet with a given APID shall always have the same physical structure and parameter content.

4.1.2 Space Data Link (Transfer Frames) and multiple RF channels

R-20. (goal) The AOS Transfer Frame structure [CCSADL] shall not make use of the insertion zone

R-21. Idle Space Packets generated to complete a TF shall be correctly formatted including in particular their length field and the APID set to 0x7FF.

R-22. Separate Virtual Channels shall make use of separate, independent Virtual Channel Frame Count.

R-23. In case more than one physical RF channel is used to downlink the Mission Data, the downlink of a specific packet store (allocated to a VC) shall not be split between different physical channels.

R-24. In case more than one physical RF channel is used to downlink the Mission Data it shall be possible to configure each packet store (using the VCID as key) to be downlinked on a specific physical channel.

4.1.3 CFDP

R-25. CFDP file shall be identify by a unique filename

R-26. The filename of each on-board file shall allow to fully identify file type and instance to allow proper on-ground routing to relevant processing facility without requiring inspection of file content.

R-27. Each CFDP file shall contain either only Space Packets or only mission-specific sequence of octets.

R-28. For CFDP the nominal file download order shall be:

a. TM-Files "Housekeeping TM" from oldest to latest.

b. Ancillary data files

c. Science Data Files. The assumed download order for science files is typically from oldest to newest (independent from instrument, i.e. no priority of an instrument);

R-29. (goal) the on-board payload data handling system and overall operational concept shall be designed to ensure the required performance and data avilability with an open-loop (CFDP Class-1) approach.

R-30. The on-board data handling system shall allow to autonomously issue CFDP.suspend and CFDL.resume service directive controlling the file payload data downlink only within ground station visibility with configurable margin.