estec

Keplerlaan 1, 2200 AG Noordwik. The Netherlands
M +31-71-5656565

DOCUMENT

GS inputs to on-board data architecture

APPROVAL

Title GS input to on-board data architecture	
Issue 2	**Revision** 2
Author Michele Zundo. EOP-PEP	**Date** 04-11-2025
Approved by Pierre Viau, EOP-PE	**Date** 04-11-2025

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	05-Apr-2019
Document maintenance following BIOMASS experience	1	6	05-May-2020
Update for re-distribution as generic req.	1	7	15-02-2022
Amended after review for TRUTHS and FORUM	1	8	13-10-2023
Amended after review for Harmony	1	9	23-11-2023
Amended following discussions in Forum	2	0	07-03-2025
Clean-up following review of ERD 1.1 and discussion with NGGM and feedback from Harmony. Added justifications	2	1	24-10-2025
Added consideration for Start and Stop CFDP commanding	2	2	04-11-2025

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	05-Apr-2019	all	

Issue 1	**Revision** 6		
Reason for change	**Date**	**Pages**	**Paragraph(s)**
Update to req. numbering into separate groups Clarification on ancillary generation.	05-May-2020	all	

Issue 1	**Revision** 7		
Reason for change	**Date**	**Pages**	**Paragraph(s)**
Update header with ESA classification	15-Feb-2022	all	
Update comments on CFDP	15-Feb-2022	all	

Issue 1	**Revision** 8		
Reason for change	**Date**	**Pages**	**Paragraph(s)**
Additional definition in Glossary	13-Oct-2023	Section 1	
Rewritten section on CCSDS Space Packet: Reworded ambiguous requirements Negative requirements re-worded as positive Sorted the requirement per topic in dedicated subsections Removed requirement on SSC continuity as it is already part of CCSDS standard	13-Oct-2023	Section 4.1.1	

Renumbered the Requirements			

Issue 1	**Revision** 9		
Reason for change	**Date**	**Pages**	**Paragraph(s)**
Terminology clean-up	23-Nov-2023	all	
Removed Glossary	23-Nov-2023	5	
Simplification of introductory section	23-Nov-2023		Section 1
Removal of figures	23-Nov-2023		Section 1
Clarification of CFDP terminology to only refer to payload data and not to TT&C ones	23-Nov-2023		Section 3.1.3

Issue 2	**Revision** 0		
Reason for change	**Date**	**Pages**	**Paragraph(s)**
Added Requirements 16, 55 and 90	07-03-2025		
Amended req. 70	07-03-2025		

Reason for change	**Date**	**Pages**	**Paragraph(s)**
Re-introduced and extended acronyms and glossary sections following feedback from NGGN and Harmony	07-06-2025		
Corrected typo in change record for Issue 2.0	07-06-2025	3	
Reworded req. R-01 on use of APID	07-06-2025		
Reworded req. R-12 on subcommutation	07-06-2025		
Updated version of applicable CFDP standard to revision b5 (2020) as well as for CCSDS 103 and 132.	07-06-2025		Section 2
Reordered/renumbered reqs in the CFDP section.	24-10-2025		Section 4.1.3
Separating example/notes from requirement body (CFDP section)	24-10-2025		Section 4.1.3
Reworded req. R-73 to link data availability to CFDP file size.	24-10-2025		Section 4.1.3

Issue 2	**Revision** 2		
Reason for change	**Date**	**Pages**	**Paragraph(s)**
Created Req. 91 from 76 to generalise its implementation.	04-11-2025	15	

Table of contents:

1 PURPOSE AND SCOPE

This TN contains a list of inputs to define an on-board data architecture that allows an efficient, standardised payload CCSDS data analysis, data generation, data simulation, algorithm development and data processing on ground.

(NB it does not apply to TT&C/S-Band data links).

This TN also addresses the specificity introduced using 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 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 FOS).

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 :
    - Space Packets
    - CFDP Files containing Space packets
    - CFDP Files containing data formatted in a Project-specific fashion
- 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 and instances 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, PDU, CFDP Files), which will then be downloaded to ground for processing or explicitly waived for a specific project (with a sound justification).

2 REFERENCE DOCUMENTS:

[CCSDLP]	TM Space Data Link Protocol CCSDS 132x0b3
[CCSADL]	AOS Space Data Link Protocol CCSDS 732x0b2
[CCSSLI]	Space Link Identifiers CCSDS 135x0b3
[CCSTMS]	Telemetry Services, CCSDS, 103x0b3
[CCSFDP]	CCSDS File Delivery Protocol (CFDP) CCSDS 727x0b5
[CCSUDL]	Unified Space data Link Protocol, CCSDS 732x1b1
[PUS]	ECSS Packet Utilisation Service
[L0RAW]	EO generic RAW and L0 specification, PE-TN-ESA-GS-586

3 ACRONYMS & GLOSSARY

3.1 Acronyms

The acronyms below are used within the scope of this activity and within this document.

ANC	Ancillary Data
AOCS	Attitude and Orbital Control System
APID	Application Process ID (CCSDS)
AUX	Auxiliary Data
CAL	Calibration Data
CCDB	Characterisation and Calibration Data Base
CCSDS	Consultative Committee for Space Data Systems
DU	Data Unit
GNSS	Global Navigation Satellite System
GS	Ground Segment
HKTM	Housekeeping Telemetry
(I)CCDB	(Instrument) Characterisation and Calibration Data Base
I/F	Interface
ISP	Instrument Source Packets (formatted as CCSDS Space Packets)[2]
L0P	Level 0 Processor
L1	Level 1 product
L1OP	L1 Operational Processor
L1PP	L1 Processing Prototype
L2	Level 2 product
L2OP	L2 Operational Processor
L2PP	L2 Prototype Processor
MRD	Mission Requirements Document
PDGS	Payload Data Ground Segment
PVT	Position Velocity Time

[2] The term "*Source*" in the definition of ISP is due to legacy reason and does not have any semantic. The ISP acronym identifies the instrument generated data units.

RAW	RAW Data
RD	Reference Document
(S)CCDB	(Satellite) Characterisation and Calibration Data Base
SP	(CCSDS) Space Packet
SS	Space Segment

3.2 Glossary

The table below describes preferred terminology. Alternative terminology is also described but not recommended.

Observation data (OBS)	Data Units output of the Instrument and formatted as CCSDS Space Packets exactly as generated by the Instrument(s) when the stimuli correspond to the target to be observed per to mission objectives (e.g. radiance of the ground scene, of the atmosphere, echo of the ground target, in-situ properties, etc
Measurements data	(Alternative terminology). Same as **Observation data**.
Calibration data (CAL)	Data Units output of the Instrument and formatted as CCSDS Space Packets exactly as generated by the Instrument when the stimuli are internal or external targets or happen during special operation used for calibration purposes (e.g. internal black body, noise diode, internal receiving network, specific manouvres or external target like e.g. sun, moon, star, sea, ice, etc)
Auxiliary data (AUX)	Data needed, by the ground segment, to perform ground processing and not part of the measurement data set. This auxiliary data (static or dynamic) is 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. DEM, Land classification map, RTM lookup table, Orbit Files, Instrument Characterisation, Meteorological data, Offset tables, calibration coefficient, focal plane definition, etc.). Some auxiliary data can originate from offline calibration activities (see definition of calibration products). Within the E2ES they are supplied as part of the simulation scenario as an input e.g. to the scene generator module SGM, to the instrument simulation module ISM and to the Level 1 and Level 2 Processor Prototypes.
Ancillary data (ANC)	CCSDS Space Packet Data generated on-board in support of the observation data, both by the instrument and the platform, such as, navigation, temperature, Housekeeping Telemetry (HKTM), timing data and configuration. When generated by the instrument these data are called “***instrument ancillary***” when by the platform “***platform ancillary***”.
Payload Data, Sensor data, Instrument data, Science data.	(Alternative terminology). All data **generated by the payload** for purpose of scientific processing and composed of: Observation, Calibration, Instrument Ancillary data. It excludes Instrument HKTM and Platform Ancillary data.

	For clarity it is recommended to use only the term Payload data or Instrument data.
Timing Data	Data related to the timing of the parameters and packets, including: the timestamps and the correlation of times between instrument time, platform time and external reference time (e.g GNSS PPS time).
Raw data (RAW)	Sequence of concatenated Instrument and Ancillary Space Packets as are transmitted on the space to ground RF link with no header and no annotation.
Level 0 product	Level 0 data files in the same format at the actual GS (Ground Segment header + concatenation of CCSDS Space Packets).
Calibration Products	Data files (products) generated in the ground segment or by the L1PP during the processing of instrument data and used in the Ground Segment processing. Calibration Products can be either dynamic or static. 1) **Dynamic**/on-line calibration data (referred to as CAL) are **automatically produced and applied** by ground processors . 2) **Static**/off-line calibration data (preferably called AUX) are: a) **produced** automatically or manually(off-line), based on measurements, on other dynamic calibration, on long term trending, analysis, manual setting etc. b) **applied** as **manual operational decision** to the processing chain as configuration items (e.g., dead pixel, instrument alignment, bias, mis-pointing, etc.).
On-line and off-line calibration	***dynamic calibration*** data (also called ***on-line*** calibration data) are: **calculated** automatically and **produced** by the L1 processor during the processing of input data from nominal or calibration modes of the instrument **used/applied** automatically in the processing chain either internally or preferably externally by use of CAL data files
Dynamic and static calibration	**static calibration** data (also called **off-line** calibration data) are: a. parameters typically **derived** either from dedicated calibration modes, or from nominal data spanning multiple files or longer time-series. Both these cases have in common that these parameter values are not derived and applied instantly to the same dataset from which they are derived (in contrast to online calibration). b. **contained** in auxiliary files (of type AUX in the ground segment). c. **produced** either automatically or by manual trigger of any of the following:

	• the L1 processor itself, • a dedicated calibration processor • a Monitoring or Calibration Facility • any other tool. d. **used** in the processing chain only following human review/intervention or authorisation e.g., a permanent update of a table of sensor gain parameters (initially holding the launch CCDB value see [CCDBTN]) computed using some *ad-hoc* observation of a calibration target. From the point of view of data-flow the static CAL data are implemented in the GS as AUX data (see Fig.3.8 and 3.9).

4 INPUTS

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

4.1.1 CCSDS Space Packets

This section assumes all data is transported as CCSDS Application data Units (ADU) which are formatted as CCSDS Space Packets [CCSDLP]

4.1.1.1 Application Data Definition and Identification

R-01 For all telemetry packets containing payload scientific data or related ancillary, the CCSDS Space Packet Application Process Identifier (APID) and the Source Sequence Counter (SSC) in the Space Packet Primary Header shall be used as a logical stream ID and sole mechanism for the identification, and end-to-end Space-to-Ground data routing from Instrument and Platform to the individual Ground segment processes consuming them.

Note:

This requirement applies exclusively to payload scientific telemetry and does not relate to TT&C telemetry (e.g., telecommands or housekeeping telemetry), which is governed by separate requirements and may follow the ESA Packet Utilization Standard (PUS). The intent is :

- to assign to APID the role of a logical stream ID instead of on-board physical units (common instead in TT&C applications)
- to ensure international compatibility and avoid dependencies on ESA-specific standards for scientific data handling as payload data may originate from third-party instruments or international partners who do not implement PUS. Therefore, PUS secondary headers (such as Service Type and Subtype) would preferably not be used as the basis for routing or identification of payload telemetry packets. All required classification and sorting would be achieved using the CCSDS-compliant Primary Header fields only (APID and SSC).

R-02 On a given satellite, the APID, for each packet type, shall be unique even if these packets are downlinked in different physical RF channel (e.g. S and X band) or are transmitted via different Virtual Channels.

R-03 The content of each observation Space Packet shall be defined so that the information in the Packet Secondary Header, in the Space Packet Data Field or in separate ancillary packets shall not be needed to determine the data type transported by the Space Packet, routing or to select the algorithm/processing chain/facility.

R-04 Each instrument measurement mode that requires distinct ground processing or routing shall be assigned a unique APID. APID assignment shall not be constrained by physical hardware units but rather reflect logical application data streams. This includes, in particular, the assignment of separate APIDs for different internal calibration types, external calibration types, observation modes, and test modes.

Rationale:

The purpose of this requirement is to enable semantic separation of logically independent or parallel-processable data streams already at the source (onboard), through the use of distinct APIDs. This aligns the Space Packet stream structure with the ground segment data flow and facilitates mapping to distinct Level-0 products. In turn, each Level-0 product becomes the unique input to a specific Level-1 processing chain, where the APID acts as a discriminator.

While certain classes of data (e.g. internal calibration, external calibration, observation) are common across missions (see R-05, R-06, R-07), the optimal differentiation granularity—particularly among subtypes of calibration or measurement modes—shall be derived from the mission-specific processing architecture and data product structure.

R-05 All the Platform 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 observation data packet.

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

R-07 The CCSDS Space Packets containing ancillary data set generated on board by different sources e.g. by the Platform or by the Instrument, shall be distinct and have each a different APID (e.g. Navigation ancillary Space Packet shall have different APID from Thermal acquisition Space Packet)

4.1.1.2 Structure and format

R-10 All Space Packets needed for ground processing and including ancillary, measurement and calibration shall include a Space Packet secondary header (also called data field header) common across all packet types and formatted either according to PUS or according to CCSDS.

R-11 All Space Packets needed for ground processing including ancillary, 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-12 Each telemetry packet required for scientific or mission data processing shall include a complete and unambiguous representation of all parameter values it contains, such that their correct decoding does not depend on any external state, prior context, or future packets; all parameter values shall therefore be uniquely identifiable and fully reconstructable from the content of the packet itself.. In particular:

- *Round-robin* subcommutation (where the interpretation of a fixed field changes across packets) is not permitted.
- *Slice-based* subcommutation (where a single parameter is split across multiple packets) is not permitted.

R-13 Space Packets with the same APID shall have the same data field structure even when segmentation/grouping is used.

R-14 Whenever the packet structure for payload data is formatted according as PUS, the Service Type/Subtype field shall be ignored and not be used in the place of the APID to discriminate different type of data.

R-15 The packet structure of payload data shall not make use of SID, i.e. a packet with a given APID shall always have the same physical structure and parameter content.

R-16 The generated CCSDS Space Packets shall have a length to exactly contain the valid data i.e. not padding the Data Field in case data is shorter or of variable in size.

4.1.1.3 Navigation Data

IMPORTANT: The requirements in this section apply **only** to low-frequency data generated on board by the combined sensors of the position/attitude subsystem and the AOCS. These data are used as ancillary inputs to payload data processing for orbit and attitude determination, product generation, and Level-1 geolocation.

It does **not** apply to cases where data from these units—typically high-frequency or unprocessed (e.g., raw GNSS measurements, raw star-tracker quaternions)—are used as inputs to dedicated ground scientific algorithms or models. Such data are considered part of the **Observation** category, and their format, content, and acquisition rate are defined by the requirements of the specific scientific algorithm.

R-20 The PVT information located in platform ancillary Space packets (sometime called NAVATT) used for data processing shall be expressed in **Earth Fixed** frame of reference in accordance to the one used by the GNSS units.

R-21 The attitude (quaternions) information located in platform ancillary space packet (sometime called NAVATT) used for data processing shall be expressed in **Inertial** frame of reference according to the one used by the AOCS.

R-22 The baseline frequency of PVT data transmitted on ground shall be OSV at 1 Hz.

R-23 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 Absolute Pointing Knowledge (APK) requirements.

R-24 (goal) OSV and Quaternions with the same frequency shall be sampled and be associated at the same moment in time.

4.1.1.4 Ancillary Data availability

R-30 All the ancillary packets generated by the platform on-board (e.g. NAVATT, Thermal, etc) shall be available for downlink via the Payload data link regardless of the mode and state of the instrument i.e. also when the instrument is not measuring, in standby or OFF ensuring availability on ground outside the measurement interval.

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

R-50 (goal) The AOS Transfer Frame structure [CCSADL] shall not make use of the insertion zone

R-51 Idle Space Packets generated to complete a TF shall be correctly formatted including their length field and the APID set to 0x7FF.

R-52 Separate Virtual Channels shall make use of separate, independent Virtual Channel Frame Count.

R-53 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-54 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.

R-55 Fixed size CCSDS Transfer Frames shall be complete/padded when needed only using valid CCSDS Space Packets (idle or mission defined)

4.1.3 CFDP

R-70 The payload CFDP files shall be identified by a unique filename compliant with [RAWL0].

R-71 The filename of each payload on-board file shall allow to fully identify file type and instance (as defined in [RAWL0]) allowing direct on-ground routing to different processing facilities without requiring inspection of file content.

R-72 Each payload CFDP file shall contain either only Space Packets or only mission-specific sequence of octets and not a mixture of the two.

R-73 If different data types are to be processed independently while sharing the same VCID, each corresponding CFDP PDU shall use a distinct CFDP *DestinationID*
Note: *example use cases are: support for HKTM, payload data or host payload data to be routed to a different processing centers.*

R-74 The payload CFDP entity on-board shall allow to define a configurable priority for the download based on data type and file age.

Note: A typical default file download order is

1. *TM-Files "Housekeeping TM" from oldest to latest (if HKTM is transmitted on the payload data link)*
2. *ancillary data files (Instrument and Platform)*
3. *Science Data Files. The assumed download order for science files is typically from oldest to newest*

R-75 Data availability shall be evaluated considering the combined effects of the link budget and CFDP performance. In particular, for unreliable links using CFDP Class 1, the CFDP file size shall be selected to be sufficiently small so that, given the statistically expected RF link outages, the amount of unrecovered data is minimized.

R-76 (**goal**) the on-board payload data handling system and overall operational concept shall be designed to ensure the required performance and data availability with an open-loop (CFDP Class-1) approach.

4.1.4 Other

R-90 It shall be possible at any point in time to command and initiate the downlink all the data stored in the on-board payload mass memory regardless of the data size and of the way the data is stored on-board and the memory managed (e.g. also when the data is stored in incomplete memory pages, sectors, etc).

R-91 The on-board data-handling system shall be able to autonomously control the payload data downlink as a function of ground-station visibility, applying a configurable time margin after acquisition and before loss of contact.

Note: The implementation mechanism depends on the downlink protocol in use. It may consist of:

- *Commanding the dumping of Packet Stores,*
- *Issuing CFDP Suspend and CFDP Resume service directives, or*
- *Executing higher-level Downlink Manager Stop and Start commands.*