Title: **Space to Ground ICD**

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Change Record

Issue	Date	Sheet	Description of Change
1	14.11.2008	all	first issue
2	17.07.2009	12,13 21-24, 26 24,27 28 36 43 6-7 6-7 32 47-49	AI SR-OPS-025 of RID SR-SY-019 AI SR-OPS-024 of RID SR-SY-019 AI SR-OPS-017 of RID SR-SY-020 results on Action Item EL #59 on RID No. SRR-EN-306 AI SR-OPS-018 of RID SR-SY-169 updated link budget summary Figure 4.1-1 updated (GS SRR) Figure 4.3-3 update for readability Figure 4.3-3 updated EC SRR RID SR-EN-250 EC SRR RID SR-SY-020 Minor update chapter 4.2.4 Chapter 5 updates
3	18.11.2011	All	Document has been reworked. • ESA comments includet • Villafranca removed from the document • Section 2.4 updated with respect to CPR sea surface calibration mode plus mode constraints. • Chapter 3 updated. • Chapter 4.1 updated in order to consider changed MMFU functionality. • Chapter 5 uppdated to cover changers toInstrument related PUS services. • Chapter 6 updated. • Chapter 2.3.3.2 split in 2.3.3.2, 2.3.3.3 and 2.3.3.4 • Table 2.3-1, Table 2.3.-2: MLST updated
4	05.04.2013	 27	Document updated in response to GS-OCIDR and EarthCARE VCB.. SGICD-503 Deleted according to OCIDR-SAT-3 SGICD-818 Reference and Test Method updated due to VCB2 Rid 1, DH OPS for Time Packet aspect, S-Band for the remaining

Issue	Date	Sheet	Description of Change
		81	SGICD-1166 Reference updated due to VCB2 Rid 2, DH_OPS added;
		39	SGICD-1206 Reference and Test Method updated due to VCB2 Rid 1;
		40	SGICD-1231 Reference and Test Method updated due to VCB2 Rid 1
		40	SGICD-3796 Reference and Test Method updated due to VCB2 Rid 1
		48	SGICD-1432 Reference and Test Method updated due to VCB2 Rid 1
		51	SGICD-1638 Reference added due to VCB2 Rid 3
		56	SGICD-1757 Verfication References added, Verfication Method updated, PUS Services are verified via CSW SSS V3 (strawmen Test Report added) due to VCB2 Rid 4
		57	SGICD-1798 Reference added (PDHT IST) due to VCB2 Rid 3
		57	SGICD-1799 Verfication References added, Verfication Method updated, PUS Services are verified via CSW SSS V3 (strawmen Test Report added) due to VCB2 Rid 4
		58	SGICD-1901 Verfication References added, Verfication Method updated, PUS Services are verified via CSW SSS V3 (strawmen Test Report added) due to VCB2 Rid 4
		61	SGICD-2234 Verfication References added, Verfication Method updated, PUS Services are verified via CSW SSS V3 (strawmen Test Report added) due to VCB2 Rid 4
		64	SGICD-2433 Verfication References added, Verfication Method updated, PUS Services are verified via CSW SSS V3 (strawmen Test Report added) due to VCB2 Rid 4
		68	SGICD-2819 Verfication References added, Verfication Method updated, PUS Services are verified via CSW SSS V3 (strawmen Test Report added) due to VCB2 Rid 4
		70	SGICD-3052 Verfication References added, Verfication Method updated, PUS Services are verified via CSW SSS V3 (strawmen Test Report added) due to VCB2 Rid 4
		74	SGICD-3737 Verfication References added, Verfication Method updated, PUS Services are verified via CSW SSS V3 (strawmen Test Report added) due to VCB2 Rid 4

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TABLES

FIGURES

1 INTRODUCTION

1.1 Scope of the Document

This document defines the data interfaces between the EarthCARE satellite (including the instruments) and the EarthCARE ground segment, embedding all S-Band and X-Band ground stations, the Flight Operation Segment as well as the Payload Ground Segment. It is the central part for the command and control as well as for data processing and distribution of monitoring and control data received via S-Band and X-Band. It provides basic information for the science data received via X-Band.

The RF communication interface is also provided herein. A summary of the Link budgets are presented, which are described in more detail in the EarthCARE Link Budget document [RD-09].

The detailed structure and interpretation of the payload science data as provided in X-Band is further detailed in the Instrument Measurement Data Definition (IMDD), which is based on the packet definitions of the EarthCARE Packet Utilization Standard [AD-110]. The EarthCARE Level 0 Product definitions [RD-07] define the individual parameters and their usage for the scientific products processing in detail..

The operations interface will be provided by the EarthCARE Satellite User Manual [RD-08]. In phase B before the Satellite User Manual is available the operations related information is provided via the Mission and Operation Definition Report [RD-04] and the FDIR Concept and Implementation Document [RD-03]. Both documents will become part of the EC Satellite user manual[RD-08]. The design of the satellite is given in the EarthCARE Satellite design description [RD-02].

1.2 References

1.2.1 Applicable Documents

In case no issue of a document is stipulated, the latest issue shall apply. The Configuration Item Data List (CIDL) will provide the information upon issue and issue date of these documents at certain time instances like formal reviews and deliveries

1.2.1.1 Higher Level Documents

[AD-99]	EarthCARE Satellite Design Specification	EC.RS.ASD.SY.00005
[AD-110]	EarthCARE Packet Utilization Standard	EC.STD.ASD.SY.00001

1.2.1.2 Lower Level Documents

The following documents form part of this document to the extent defined herein.

[AD-02]	EC Satellite Ancillary Data ICD	EC.ICD.ASD.SY.00026
[AD-05]	EC Central Software TM/TC ICD´	EC.ICD.ASD.CSW.00033
[AD-10]	OBC User Manual	GS2.TN.RSE.OBC.00015
[AD-15]	MMFU User Manual	EC-UM-SYD-MMFU-00001
[AD-20]	STR PUS ICD	GS2.ICD.JOP.STR.02402
[AD-25]	GPSR Command and Housekeeping Data Interface Specification	S1-IF-AAE-SC-0001
[AD-26]	GPSR Measurement Data Interface Specification	S1-IF-AAE-SC-0002

[AD-02]	EC Satellite Ancillary Data ICD	EC.ICD.ASD.SY.00026
[AD-40]	ATLID ACDM Application SW ICD	EC-IC-SSL-ATL-0001
	Note: for the present issue, private PUS services listed in EC.LI.SEA.BBR.0042_i4.3 overrule AD-40	
[AD-50]	BBR Application SW ICD	EC-IC-SSL-BBR-0006
	Note: for the present issue, private PUS services listed in EC.LI.SEA.BBR.0042_i4.3 overrule AD-50	
[AD-51]	BBR Boot Software Interface Control Document	EC-IC-SSL-SY-0008
	Remark: This ICD is also applicable for ATLID and MSI since the ATLID, BBR and MSI ICU software is developed by the same company.	
[AD-60]	MSI Application SW ICD	EC-IC-SSL-MSI-0001
	Note: for the present issue, private PUS services listed in EC.LI.SEA.BBR.0042_i4.3 overrule AD-60	
[AD-70]	CPR Operation and Software Technical Note	EC-N-T-10063

1.2.2 Normative Documents

[ND-107]	CCSDS TM Synchronisation and Channel Coding. Blue Book	CCSDS 131.0-B-1,
[ND-111]	Telecommand Part 1 - Channel Service	CCSDS 201.0-B-3-S
[ND-112]	Telecommand Part 2 - Data Routing Service	CCSDS 202.0-B-3-S
[ND-115]	Time Code Formats (ISO 11104)	CCSDS 301.0-B-3
[ND-142]	Communications - Part 1: Principles and requirements	ECSS-E-50 Part 1A
[ND-143]	Telemetry Synchronization and Channel Coding	ECSS-E-50-01 Draft 0.11
[ND-144]	Ranging and Doppler Tracking	ECSS-E-50-02A
[ND-145]	Telemetry Transfer Frame Protocol	ECSS-E-50-03 Draft 1.8.1
[ND-146]	Space data links - Telecommand protocols, synchronization and channel coding	ECSS-E-50-04A Draft 1.13
[ND-147]	Radio frequency and modulation	ECSS-E-50-05A
[ND-150]	Ground systems and operations - Part 1: Principles and requirements	ECSS-E-70 Part 1A
[ND-151]	Ground systems and operations - Part 2: Document Requirements Definitions (DRD)	ECSS-E-70 Part 2A

[ND-107]	CCSDS TM Synchronisation and Channel Coding. Blue Book	CCSDS 131.0-B-1,
[ND-152]	Space Engineering - Space Segment Operability	ECSS-E-70-11A
[ND-153]	Space Engineering: Test and operations Procedure language	ECSS-E-70-32A
[ND-229]	World Geodetic Standard 84	WGS84

1.2.3 Reference Documents

[RD-01]	Abbreviation List	EC.LI.ASD.SY.00001
[RD-02]	Satellite Technical Description	EC.TN.ASD.SY.00021
[RD-03]	FDIR Definition and Implementation Report	EC.RP.ASD.SY.00015
[RD-04]	Mission and Operation Definition Report	EC.RP.ASD.SY.00016
[RD-05]	EarthCARE Orbit Analysis	EC.TN.ASU.SY.00001
[RD-06]	EarthCARE Ground station characteristics	EC-GF-TN-1001-OPS-ONV 1.1draft Dec 2008
[RD-07]	EarthCARE Product Definitions - Volume 0 - Introduction	EC.ICD.ASD.SY.00004
[RD-08]	EarthCARE Space Segment User Manual	EC.UM.ASD.SY.00001
[RD-09]	EarthCARE Link budget	EC.TN.ASD.SY.00020

1.3 Definitions

1.3.1 General Terms

Geodetic Altitude [km]: is the distance above the reference earth ellipsoid WGS84 [ND-229], measured along the local normal to the ellipsoid. The geodetic altitude of EarthCARE is changing along the orbit; the frozen orbit concept preserves an identical geodetic altitude as a function of latitude.

Spherical Altitude [km]: is the mean Kepler semi-major axis of the spacecraft orbit minus the equatorial radius of the Earth. The spherical altitude of EarthCARE is a constant value, several km lower (less, below) than the minimum geodetic altitude.

Surface Altitude [km] is the distance above the Earth surface, measured along the local normal to the ellipsoid.

Surface Height [km] is the geodetic altitude of the surface of the Earth. Note that Surface altitude = Geodetic altitude - Surface height.

Geo-location and Position: For calculation of geo-location and position the reference ellipsoid WGS84 [ND-229] will be used.

Orbit Dynamics: The gravity model from EGM96 will be used for calculation of orbital dynamic (e.g. when using spherical harmonic coefficients: J2, J3, J4, ...)

Critical Solar Incidence Area: is defined as 6° TBC halfcone around the satellite z-axis pointing towards Nadir with an offset of 3° in -X direction (LOS of ATLID)

1.4 Abbreviations

General EarthCARE abbreviations are given in [RD-01].

Specific abbreviations used in this document are given here below.

1PPS	Pulse Per Second
LOS	Line of Sight
Mbps	10^6 bits per second
TTR	Telemetry, Telecommand & Reconfiguration

2 EARTHCARE SYSTEM OVERVIEW

2.1 General Overview

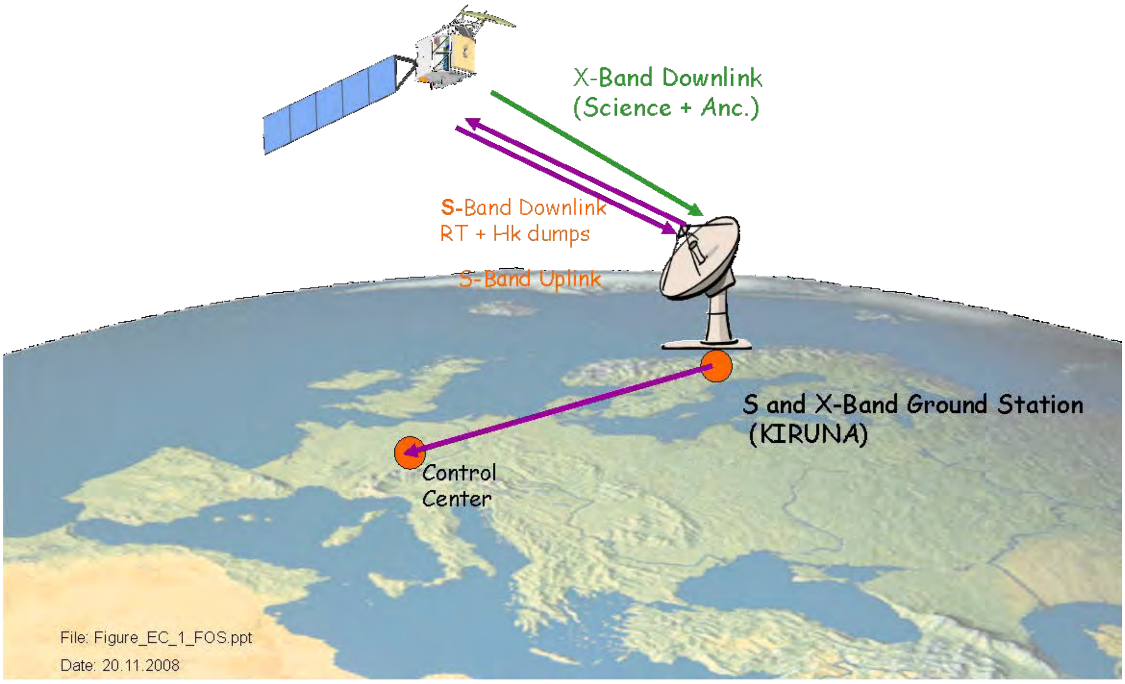


Figure 2.1-1: Satellite to Ground Segment Interfaces

The EarthCARE system is constituted by the EarthCARE space segment, i.e. the satellite, and the ground segment.

The satellite consists of two major parts, the platform and the payload. The platform provides for the needed resources in terms of power, attitude, orbit characteristics, and command and control to support the scientific objective of the payloads. The payload includes the 4 scientific instruments, ATLID, BBR, CPR and MSI as complex scientific sensors, as well as the MMFU for science data storage and the X-Band System for their transmission to ground.

The Ground Segment is provided by ESA and builds up on existing TT&C ground stations, the Flight Operation Control Center and the Payload Data Segment.

Figure 2.1-1 depicts an overview on the EarthCARE System.

2.2 EARTHCARE Ground Segment

2.2.1 Ground Segment Overview

The communication between the satellite and the ground stations will be arranged via the S-Band system for tracking, telemetry and commanding (TT&C) and via the X-Band system for payload data transmission.

The mission operation activities will be conducted by the European Operations Centre (ESOC) with the following ground stations listed in Table 2.2-1.

Please note, independent to the individual performance data of the ground stations listed in Table 2.2-1, the satellite S-Band system is designed such that is compliant to the requirements in [AD-99] and related amendments provided by ESA (tbc). This means that at least for the Kiruna and Svalbard Ground Stations, the satellite is compliant to, in particular w.r.t. the link budget and related margins. Compatibility to other Ground stations is subject to ESA link budget analysis.

The following table lists identified ground stations for support of the EarthCARE mission

Station	Nominal Operation S-Band TT&C and Science Data Transmission	LEOP & Contingency S-Band TT&C	Commissioning S-Band TT&C and Science Data Transmission
Kiruna 15 m	YES	YES	YES
Kiruna 13 m	Back-up	Back-up	Back-up
Svalbard 13 m	NO	YES	Back-up (no science data)
Troll 7.3 m	NO	YES (≥10 deg elev.)	Back-up (no science data)

Table 2.2-1: Mission Supporting Ground Stations

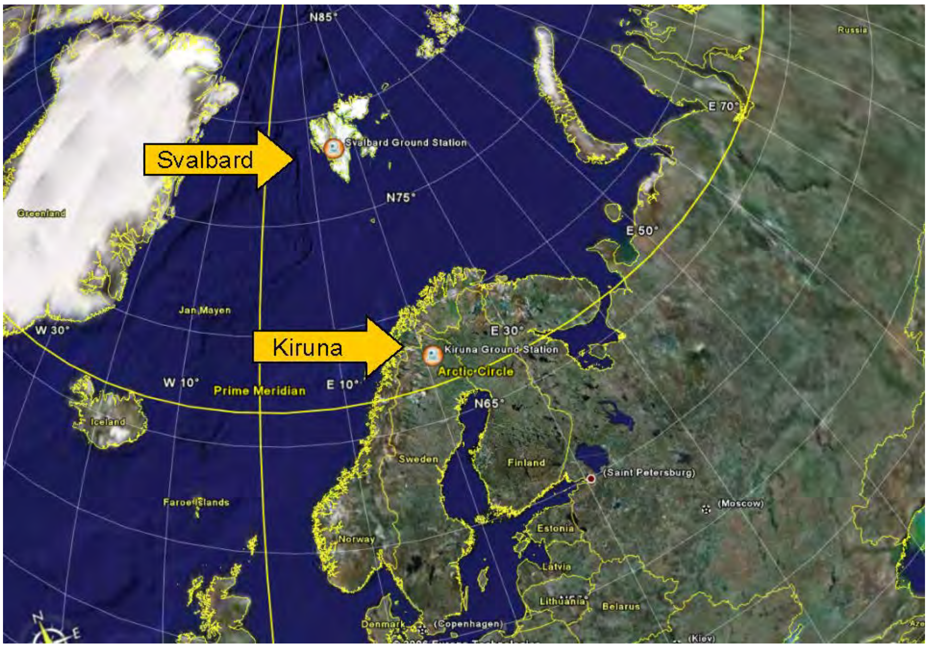


Figure 2.2-1: Kiruna and Svalbard Ground Station Location

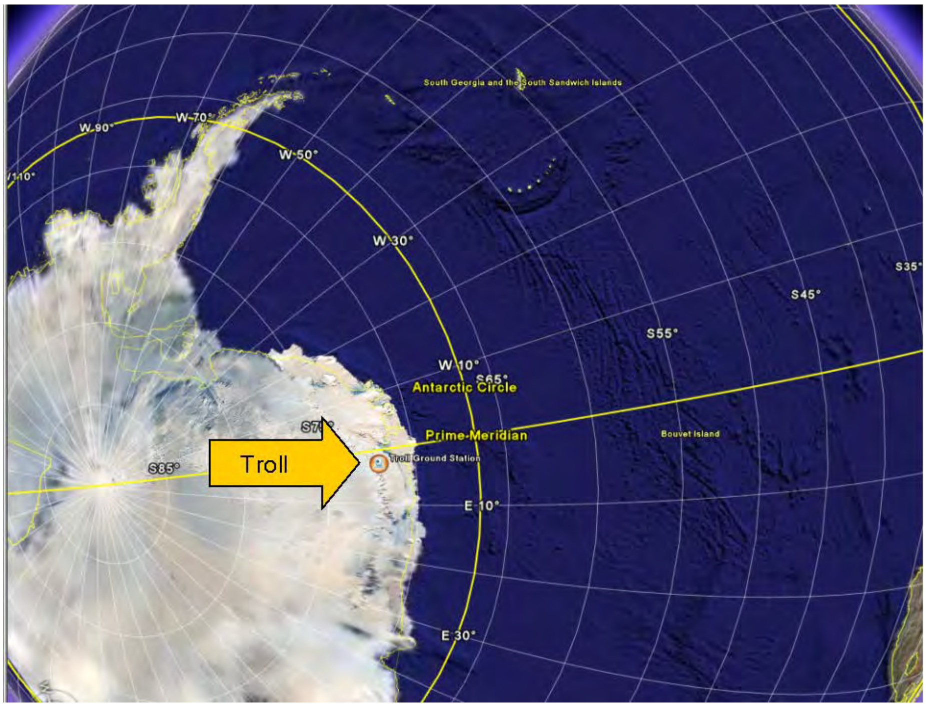


Figure 2.2-2: Troll Ground Station Location

2.2.2 Nominal TT&C Network

Only one ground station (Kiruna 15m, TBC) will be used for S-Band TT&C and X-Band payload data downlink during the routine operation of the satellite.

The Ground Station is located in Kiruna, Sweden (longitude: 20°58' E and latitude: 67°51' N). The Kiruna 15m station will cover full tracking (range and range rate), telemetry and telecommand service in S-Band during all mission phases (routine, LEOP and contingency), and will also cover the X-Band payload data downlink during routine phase (including commissioning and validation phase). The station analysis shows a maximum number of 7 blind orbits per day.

The Kiruna 13m antenna may be used as a back-up and will support all the above mentioned services in S-Band.

Other Ground Stations may be used to disseminate science data via X-Band. These ground stations have the same characteristics like the Kiruna 15m G/S.

2.2.3 External TT&C Network

During the Launch and Early Orbit Phase (LEOP), as well as in case of any emergency further TT&C networks may be used to support the mission.

Those external S-Band TT&C networks are (tbc):

- Svalbard, Norway (longitude: 15,24° E; latitude: 78,13°N)
- Troll, Antarctica (longitude 2° E, latitude 72° S)

Those stations will cover full tracking (range and range rate), telemetry and telecommand service in S-Band. No payload data downlink service is considered for those ground stations.

2.2.4 Link Geometry

The geometrical and dynamic parameters to be considered for satellite to ground segment interface definition and calculation of link budgets are taken from [RD-05] and listed in Table 2.2-2 below:

Parameter	Kiruna 13m	Kiruna 15m	Svalbard 13m	Troll 7.3m
maximum angular velocity of S/C in elevation and azimuth referring to supporting G/S [deg/sec]	tbd	tbd	tbd	tbd
nominal satellite altitude of science phase orbit [km]	< 430	< 430	< 430	< 430
minimum elevation angle used for communication between S/C and supporting G/S [deg] (see also Note below)	5	5	5	10
maximum slant range between S/C and supporting G/S [km]	< 1900	< 1900	< 1900	< 1900
maximum along track velocity between S/C and supporting G/S [km/sec]	< 7.2	< 7.2	< 7.2	< 7.2

Table 2.2-2: Ground Station Link Geometry Parameters

Notes: 1) TC uplink is limited to angles >5 degrees by ITU regulations.

2) Link budget calculation only for Kiruna G/S

For the downlink the situation is more complex:

- the visibility mask of the station is to be considered (Kiruna and Svalbard)
- time delay to allow for G/S receiver synchronisation;
- the uncertainty in the orbit in case the "start time to dump" is based on mission timeline based commands instead of orbit position scheduled

Based on previous project experience, the following approach is suggested (tbc):

- the elevation angle to be considered in downlink is 5 degree
- downlink scheduling is primarily being done via orbit position scheduling during nominal operation to cover all uncertainties of the 8 days nominal mission phase autonomy.
- in case mission timeline based scheduling is applied downlink visibility times are calculated considering the uncertainty in the position of the S/C due to three days of autonomy and the time needed to synchronise the G/S demodulator
- no margin is taken at the end of visibility period because the uncertainty caused by position uncertainty can be recovered following the satellite at elevation (slightly) below 5 degrees.

2.3 EarthCARE Satellite

2.3.1 Satellite Overview

The EarthCARE space segment is made up by a single satellite with 4 scientific instruments on board. The satellite platform provides all the resources needed for the instruments to fulfil the mission objective.

The satellite platform consists of a CFRP based sandwich structure with a central tube and sandwich equipment panels.

A 3-axes AOCS provides for the required orientation of the satellite in nominal mission phase and also for external instrument calibration. The AOCS is equipped with Star Trackers, Rate Measurement Unit, Coarse Earth and Sun Sensor (CESS), GPS Receivers, and Magnetometer as sensors, and it uses Magneto Torquers, Reaction Wheels and cold gas reaction control system as actuators.

The needed power is collected by a Solar Array (SA). The 5 segments of the SA are stowed for launch and deployed in orbit. The SA is rotatable around the satellite x-axis. The Power Control and Distribution Unit (PCDU) is based on an unregulated primary power bus (20 …34 V) for all primary power users. Solar array power accommodation is accomplished by maximum power point tracking (MPPT). Power is stored in a battery for eclipse operation.

As baseline the TT&C is implemented as S-Band with 64 kbps uplink and two different downlink modes: 128 kbps, PM/SP-L modulated, and 2048 ksps (1024 kbps data) OQPSK modulated. The downlink bit rate is selectable by command.

Two omni-directional antennas ensure 360° coverage. One antenna is mounted on the zenith panel; one antenna is mounted on the nadir panel. The Nadir Antenna is Right Hand Circular Polarised (RHCP). The Zenith Antenna is Left Hand Circular Polarised (LHCP).

The payload consists of the 4 scientific instruments ATLID, BBR, MSI and CPR, and of the Mass Memory and Formatting Unit (MMFU) and the X-Band downlink for scientific data dissemination. The MMFU stores the science data in form of CCSDS packets, generated by the instruments. Emission of the filtered RF signal is performed by the left handed circular polarised (LHCP) shaped beam helix antenna.

The TM downlink data rate of the X-Band is 150 Mbps.

2.3.2 Orbit Definition

In order to fulfil the mission objective the satellite is operated on different orbits with different repeat cycles for calibration and validation activities and for nominal measurement activities. The satellite orbits are defined as given in

- Table 2.3-1: Parameters of CAL/VAL Reference Orbit
- Table 2.3-2: Parameters of Nominal Reference Orbit

The repeat cycle of 25 days for the nominal orbit allows to guarantee the global coverage within one month considering the MSI swath. The Cal/Val orbit is selected to have an exact repeat after 9 days allowing to fly over dedicated calibrations sites within a reasonable short time interval.

For more details, see [RD-05].

Parameter	Mean Kepler
Semi-major axis	a = 6772.57 km
Eccentricity	e = 0.001283
Inclination (sun-synchronous)	i = 97.055°
Argument of perigee	ω = 90°

Parameter	Mean Kepler
Mean Local Solar Time, Descending Node	MLST = 14:00
Repeat cycle / cycle length	9 days, 140 orbits
Orbital duration	5554.3 km
Mean Spherical Altitude	394.43 km
Minimum Geodetic Altitude	399.6 km
Maximum Geodetic Altitude	427.3 km
Average Geodetic Altitude	409.7 km

Table 2.3-1: Parameters of CAL/VAL Reference Orbit

Parameter	Mean Kepler
Semi-major axis	a = 6771.28 km
Eccentricity	e = 0.001283
Inclination (sun-synchronous)	i = 97.050°
Argument of perigee	ω = 90°
Mean Local Solar Time, Descending Node	MLST = 14:00
Repeat cycle / cycle length	25 days, 389 orbits
Orbital duration	5552.7 s
Mean Spherical Altitude	393.14 km
Minimum Geodetic Altitude	398.4 km
Maximum Geodetic Altitude	426 km
Average Geodetic Altitude	408.3 km

Table 2.3-2: Parameters of Nominal Reference Orbit

2.3.3 Operations Architecture

Within the EarthCARE operations architecture the application process hierarchy is a central element of S/C operation in line with the ECSS operation standards. This hierarchy defines effective TC and TM routing paths as well as responsibilities upon lower and higher level failure handling.

One central element is a common capability set which is supported for all on-board application and which offer an essential and effective interaction between the on-board applications and the FOS application, designed in line with the ECSS operation standards.

The following services of [AD-110] are commonly supported by all on-board application processes:

- TC acknowledgement service

- HK & Diagnostic services
- Function service providing application dedicated capabilities
- Connection Test
- Event Generation service
- Monitoring service
- Event action service
- Parameter Management

For the highest level application of each on-board equipment and instrument PUS packet terminal additional common application characteristics are provided via application SW services:

- Direct Commanding
- Memory Management (in one application per equipment)

For the EarthCARE satellite these are

- Data Management System (DMS) application for the OBC
- each instrument application

The highest level operational application layer is the Flight Operation Segment (FOS). It is the central command and control authority as well as the highest level failure detection, isolation and recovery for the EarthCARE satellite.

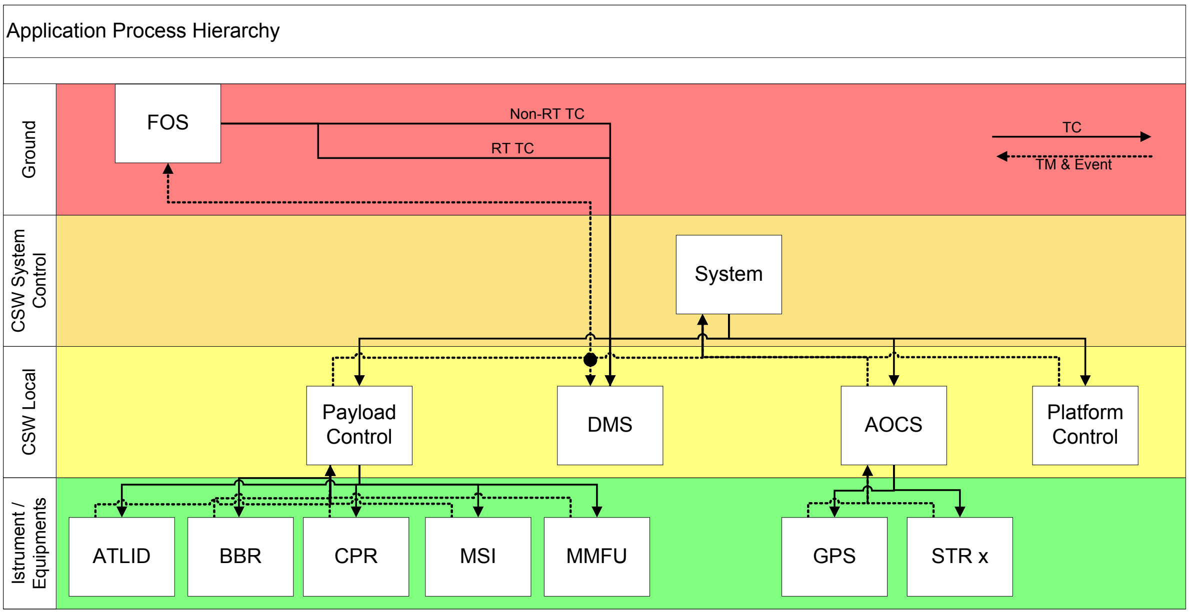


Figure 2.3-1: EC Application Process Hierarchy Specific Application Process Capability Definition

2.3.3.1 Flight Operation System Application

The Flight Operation system application is provided by a SCOS based monitoring control system embedding ECSS ground operation standard and rules compatible telecommand packet encoding and telemetry packet decoding as well as monitoring and event detection capabilities.

2.3.3.2 System Control Application

The system control application establishes the highest level on-board SW application process.

- the system initialization

- Providing the highest level SW FDIR instance resolving those issues which can not be completely solved on lower level

2.3.3.3 Data Management System Application

The data management system application links the various on-board application with ground by routing the TC and TM packets through the on-board system and providing access to the core data handling units of the spacecraft. Thus the DMS application is responsible for

- the central TC & TM routing services including the command and control of the S-band TMTC equipment
- Master schedule and orbit position schedule operations
- On-board Computer (OBC) HW & SW management
- Remote Interface Unit (RIU) equipment and module management
- OBC HW configuration & Device commanding
- Memory patch and dump
- Providing the data management system FDIR instance

2.3.3.4 Platform Control Application

The platform control application is responsible for .

- Thermal Control for the platform as well as the payload and instrument interfaces
- Power Management

2.3.3.5 Attitude and Orbit Control Application

The AOCS application is responsible for

- AOCS TC & TM processing
- AOCS equipment data acquisition, processing and control incl. propulsion
- AOCS functions & algorithms
- AOCS dedicated FDIR

The AOCS application is embedded in the central software of the OBC, therefore no specific memory management sub-service is required for the AOCS application

2.3.3.6 Payload Control Application

The Payload Control application, which is part of OBC central software, is responsible for

- TC routing to instruments
- TM collection from instruments
- Instrument and PDHT dedicated FDIR which can not be resolved on lower level
- Provision of instrument operation support functions e.g. by provision of the S/C State Vector information to the instruments
- Monitoring of high level instrument interfaces and supervisor for actions requiring control of S/C level interfaces based on instrument events

2.3.3.7 Instrument Applications

The instrument ICU SW Applications and equipments acting as EC PUS packet terminals provides in addition to the common application capability set

- Instrument specific functional mode and state handling
- Science data management service
- Nominal Instrument Thermal Control
- Instrument device commanding
- Instrument internal FDIR based on the common services set and extended by special HW and SW functions within the instrument

2.3.3.8 Equipment Applications

The equipments acting as EC PUS packet terminals provides in addition to the common application capability set identified in chapter 2.3

- Equipment specific functional mode and state handling
- Specific functional data management service e.g. MMFU data storage and retrieval service
- Equipment device commanding
- Equipment memory management service

On EarthCARE the following equipments will act as PUS terminals:

- MMFU
- GPS
- STR

COTS equipments are treated equivalent to other non-intelligent equipments, which means:

- the equipment TM is provided as part of the telemetry of the controlling application,
- TC's destined to the equipment are acknowledged by the controlling application, considering the communication as well as the equipment command acknowledgement,
- for packet terminals private services are provided for TC as well as TM packet forwarding.

2.4 Reference Mission Profile

The EarthCARE Mission is subdivided in 4 major phases:

- LEOP: Launch, autonomous Earth oriented attitude acquisition and SA deployment, ground commanded CPR deployment
- COP: Commissioning of platform and payload, first calibration, test of nominal calibration sequence
- MOP: Standard operations, science data generation, orbit manoeuvres, standard calibrations.
- EOP: passive atmospheric re-entry after fuel dumping

During MOP, all instruments are operational. The satellite attitude is nadir pointing. Scientific data are collected in the MMFU, other HK in the OBC internal mass memory and forwarded in addition to the MMFU for storage and downlink together with science data via X-Band.

Deleted.

Internal and external instrument calibrations are performed following a planned schedule at nominal satellite attitude (nadir pointing), while nominal operations of other instruments are continued.

Only for the CPR sea surface calibration mode, the satellite executes specific attitude maneuver arround the roll axis to obtain sea surface scattering in various incident. Nominal operations of other instruments are suspended. CPR sea surface calibration mode is executed in non-visibility periods.

For orbit maintenance manoeuvres nominal instrument operations are suspended at highest possible operational level to re-commence nominal mission operation quickly after the manoeuvre.

For details please refer to [RD-04] chapter 13.2.5 Orbit Control Manoeuvre Sequence.

3 SATELLITE TO GROUND RF INTERFACE

3.1 S-Band RF Interface

3.1.1 Ground Station S-Band TT&C Characteristics

The baseline design is for uplink to take place from Kiruna Ground station in Sweden. Details are presented below, based on values from ESA document [RD-06].

The following assumptions were also made in [RD-06]:

- S-Band ground station specifications only available
- Cortex XL backend equipment
- Downlink bit rates below 10 Mbit/s
- Randomisation and Reed-Solomon are assumed
- Uplink data rates of 64 kbps
- Turnaround ratio (fup/fdown) to be 221/240 [ND-147].

Ground Segment Nominal values		Notes /Reference
Frequency	2050.5116 MHz	
RF Stability over 1 hour	TBD	See [ND147]
Transmit polarisation	RHC or LHC	
Tx antenna axial ratio	1.0 dB	
EIRP, 15 m antenna	63.7 dBW	
TC Modulation Index (MI)	1.00	Adverse 1.05, Favourable 0.95
RNG Modulation Index (MI)	0.60	Adverse 0.63, Favourable 0.58

Table 3.1-1: Uplink Characteristics of Kiruna Ground Station

Ground Segment Nominal values		Notes /Reference
Frequency	2050.5116 MHz	
RF Stability over 1 hour	TBD	
Transmit polarisation	RHC or LHC	
Tx antenna axial ratio	0.5 dB	Adverse 1 dB
EIRP, 13 m antenna	63.7 dBW	
Antenna pointing loss	0.05 dB	Adverse 0.12 dB
TC Modulation Index (MI)	1.00	Adverse 1.05, Favourable 0.95
RNG Modulation Index (MI)	0.60	Adverse 0.63, Favourable 0.58

Table 3.1-2: Uplink Characteristics of Svalbard Ground Station (SG-3, SG-4: 13 meter)

Ground Segment Nominal values		Notes /Reference
Antenna description	TR-1, 7.3m diameter	
Frequency	2050.5116 MHz	
RF Stability over 1 hour	TBD	
Transmit polarisation	RHC or LHC	
Tx antenna axial ratio	1.5 dB	
EIRP, 7.3 m antenna	52 dBW	Adverse 51.8 dBW, Favourable 52.2
TC Modulation Index (MI)	1.00	Adverse 1.05, Favourable 0.95
RNG Modulation Index (MI)	0.60	Adverse 0.63, Favourable 0.58

Table 3.1-3: Uplink Characteristics of Troll Ground Station

3.1.2 Satellite S-Band TT&C Characteristics

3.1.2.1 General

The spacecraft configuration for S-Band transmit and receive is shown in Figure 3.1-1.

There are two S-Band Transponders, each equipped with a receiver and a transmitter which are combined by a Diplexer to one input/output. The receivers are operated hot redundant, i.e. they are always powered, whereas the transmitters are operated cold redundant, i.e. at any given time only one transmitter shall be switched on or both shall be switched off. The two S-Band Transponders are connected to two antennas by means of a Coupler.

Within each S-Band Transponder there are two links between the receiver and the transmitter:

- If there is a ranging signal within the uplink RF spectrum, the receiver extracts this ranging signal and provides it to the transmitter for re-transmitting it to the ground station.
- In coherent mode, the receiver defines the exact transmit carrier frequency (based on the received carrier) and provides it to the transmitter.

There are installed two S-Band antennas on the S/C, one on the zenith face (left handed circular polarized) of the spacecraft and the other on the nadir face (right handed circular polarized). Simultaneous transmission and receiving from both antennas shall assure contact with the ground station in any S/C attitude. In nominal operation the nadir antenna will receive the signal, whereas in all other attitudes the nadir and/or the zenith antenna will contribute to receiving/transmission.

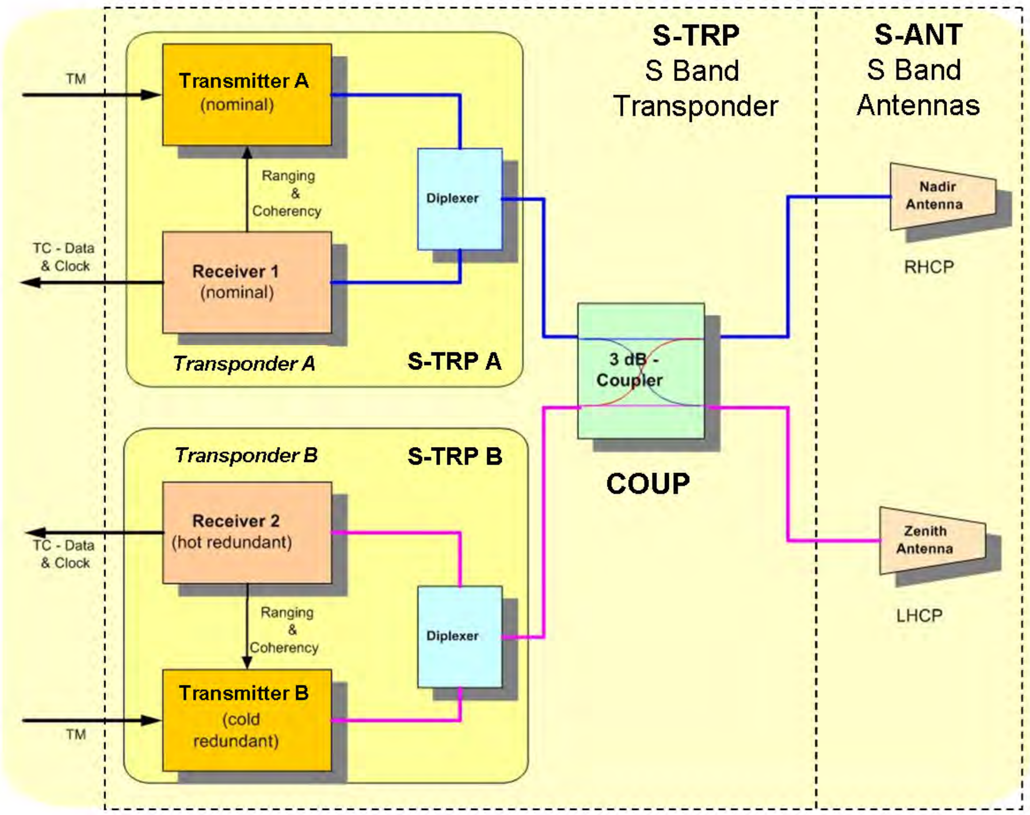


Figure 3.1-1: EarthCARE Onboard S-Band TT&C Architecture

3.1.2.2 Telecommand Uplink

SGICD-670/SDS-2845, SDS-2879/A

The mission supporting ground station transmits an RF signal that is phase modulated by either a telecommand signal or a ranging signal or by both simultaneously compliant with the uplink characteristics of the spacecraft.

Please note, that also a state without modulation, i.e. transmitting the unmodulated carrier only, is possible during sweep of uplink.

Spacecraft Parameter	Unit	Nominal	Adverse	Favourable
Receiver Bandwidth (3 dB)	MHz	6		
S/C Ant. gain	dBi	1.0		
S/C Ant. Axial Ratio	dB	4.50		
RX Circuit loss	dB	5.00		
RX Receiver threshold	dBm	-128		
RX tracking range	kHz	fo +/- 140		

Spacecraft Parameter	Unit	Nominal	Adverse	Favourable
S/C Ant. VSWR	:1	1.30		

Table 3.1-4: Uplink Characteristics of Spacecraft

The gorund station telecommand characteristics are

Telecommand Parameter	Characteristics
Physical Layer of Operational Procedure	PLOP-2
Frame acceptance report mechanism	Shall be in line with CCSDS-202-B-3 Part 2, Data Routing Service [ND-112]
Idle sequence	After Rx acquisition / lock, an idle TC bit stream of 128 bits as preamble is required
Telecommand transmission rate	64 kbps
Randomization	according to CCSDS 201.0-B-3
TC bit error rate (BER)	$< 10^{-5}$
Stability of TC bit rate	$\pm 5 * 10^{-6}$ over 24 h (TBC)
Telecommand modulation	PCM telecommand bit stream SP-L coded PSK modulated onto the carrier modulation index tbc
Sweep Range / Sweep Rate	+/- 90 kHz / 32 kHz/sec
Max Doppler offset	51 kHz (carrier 2.1 GHz, 399 km orbit)
TC bit transition density	>125 in any sequence of 1000 consecutive symbols. Max. string of 0 or 1s limited to 64. [ND-147]

Table 3.1-5: Telecommand Characteristics

The ground station shall use the same polarisation for uplink as the received downlink signal to have the maximum possible signal level on the S/C side independent on S/C's attitude. This is in particular important for LEOP, directly after separation, if the satellite attitude is not yet correct and ground may receive TM from both antennas (right handed and left handed polarised).

3.1.2.3 Telemetry Downlink

The S-Band downlink provides two different downlink rates for TM

SGICD-765/SDS-7260/R

- *Low Data Rate mode: 128kbit/second*

- Phase modulation with residual carrier
- The PCM data shall be PM/SP-L modulated on the carrier with a modulation index of 1.2 radrms.
- The PCM waveform shall be a filtered SP-L

SGICD-769/SDS-7266/R

- *High Data Rate mode: 2048k symbols/second corresponding to 1024 kbps data throughput*
- Phase modulation with suppressed carrier.
- The PCM data shall be OQPSK modulated on the carrier.
- The PCM waveform shall be NRZ-L which is converted to an I and Q signal for OQPSK modulation.
- The PCM waveform shall be square root raised cosine (SRRC) filtered immediately before applying to the modulator.

In the Low Data Rate mode, the spacecraft transmits telemetry data with or without ranging signal.

SGICD-775/SDS-7261/R

The telemetry data are provided by the OBC which applies

- Pseudo-Randomization and Reed Solomon encoding for the Low Data Rate mode
- Pseudo-Randomization and Concatenated Encoding (with Outer Code = Reed Solomon Encoding and Inner Code = Convolutional Encoding) for the High Data Rate mode

If RANGING function is commanded the receiver extracts the ranging signal out of the uplink signal and provides it to the transmitter which additionally modulates it onto the downlink carrier.

SGICD-779/SDS-2879/A

The S-band downlink signal is simultaneously transmitted via both the nadir and the zenith antenna to have an omni directional transmission which guarantees reception at the ground station for each S/C's attitude according to following RF downlink characteristics

Spacecraft Parameter	Unit	Nominal	Adverse	Favourable
Frequency	MHz	2226.8*		
Power at Transponder Output	dBm	21.5 dBm	21.0	22.0
Tx circuit losses from Transponder to Antennae	dB	5.80	6.0	5.6
VSWR, overall	:1	1.50		
S/C TX Ant. gain	dBi	1.50	0.6	2.0

* Turnaround ratio (fup/fdown) 221/240 [ND-147].

Table 3.1-6: RF Downlink Characteristics of the S-Band

SGICD-818//T

The following S-band telemetry characteristics will be applied

Telemetry Parameter	Characteristics
RS Code Block	1275 Bytes
Transfer frame length	8920 bits
Frequency of S/C time source packets	Defined in EC-PUS section 6.8 [AD-110]

Telemetry Parameter	Characteristics
Telemetry rate	Mode 1: 128 kbps (after RS encoding) Mode 2: 2048 ksps (after RS and convolutional encoding)
TM frame loss rate	$<10^{-7}$
Stability of TM bit rate	Tbd
TM baseband waveform	Mode 1: Phase Modulation with an SP-L coded PCM waveform Mode 2: OQPSK with an NRZ-L coded PCM waveform

Table 3.1-7: Telemetry Characteristics

3.1.2.4 Ranging

SGICD-849/SDS-2841/R

The ranging scheme applied is hybrid tone and code ranging in accordance with [ND-144] according to following table

Ranging Parameter	Unit	Nominal	Adverse	Favourable
Ranging tone frequency	kHz	448 kHz		
RNG uplink modulation index (G/S)	Rad pk	0.6	0.63	0.58
RNG frequency range (S/C)	kHz	100 kHz - 1.5 MHz		
RNG bandwidth (S/C)	MHz	1.3 MHz		
Group delay stability (S/C) (at RNG tone frequency)	nsec	20 ns/12 h pp		
RG channel implementation loss (S/C)	dB	1.5		
S/C RG modulation index	rad pk	0.5	0.53	0.48
RG loop bandwidth (G/S)	Hz	1		

Table 3.1-8: Ranging Characteristics

3.1.2.5 Link Budgets

The summary of the S-Band link budget is presented in Table 3.1-9 and Table 3.1-10. These tables show the margins for the worst cases, i.e. 64 kbps uplink and 128 kbps downlink with ranging. More detailed link budgets can be found in [RD-09]

EarthCARE S-Band Link Budget Margins					
Link Scenario	**Uplink Data rate**	**Downlink Data rate**	**Link Margin (dB)**		
	(uncoded)	(encoded)	**Nominal**	**Adverse**	**Favourable**
Uplink Only, Kiruna 13m, TC recovery	64 kbps	---	**28.9**	**26.8**	**30.1**
Uplink +Downlink incl. RNG , Kiruna 13m	64 kbps	128 kbit/s			
TC recovery			**28.1**	**25.9**	**29.4**
TM recovery			**8.8**	**6.0**	**10.9**
RNG			**27.0**	**23.0**	**29.9**
Downlink Only, Kiruna 13 m (Conv +R-S enc.)	---	2048 ksym/s	**4.8**	**2.1**	**6.7**

Table 3.1-9: EarthCARE S-Band Link Budget Margins for COM and NOM station

The following table presents a summary of nominal link margins for the LEOP stations

EarthCARE S-Band Link Budget Margins					
Link Scenario	**Uplink Data rate**	**Downlink Data rate**	**Nominal Link Margin (dB)**		
	(uncoded)	(encoded)	**Kiruna (15m)**	**Svalbard (13m)**	**Troll (7.3m)**
Uplink Only, TC recovery	64 kbps	---	**26.7**	**26.7**	**14.4**
Uplink +Downlink including RNG	64 kbps	128 kbit/s			
TC recovery			**25.1**	**25.1**	**12.9**
TM recovery			**12.3**	**7.1**	**3.1**
RNG			**27.3**	**22.6**	**18.3**
Downlink Only, (Conv +R-S enc.)	---	2048 ksym/s	**10.6**	**5.9**	**-1.8**

Table 3.1-10: EarthCARE S-Band Link Budget Margins for LEOP stations

3.1.3 S-Band RF Compatibility Test

These tests will be described in a later version of this document.

3.2 X-Band RF Interface

3.2.1 Ground Station X-Band Characteristics

The ground station shall be capable of receiving data in the X-Band (8.1 - 8.4 GHz), at a net bitrate up to 131 Mbps (Encoded bit rate: 150 Mbps). The modulation type used is OQPSK, as described in [ND-147].

The ground station characteristics are taken from [RD-06].

3.2.2 Satellite X-Band Characteristics

An outline of the spacecraft X-Band architecture is shown in Figure 3.2-1.

The X Band System architecture is built of a dual redundant signal generation part and a non-redundant RF routing part. Each of the both signal generation parts are equipped with

- one OQPSK modulator (X-MOD),
- one Solid State Power Amplifier (X-SSPA).

The dual redundant signal generation parts are combined within the non-redundant RF routing part which is built of

- one Waveguide Switch (X-WS),
- one Filter (X-FIL),
- one Antenna (X-ANT).

The components of the non-redundant part are interconnected by waveguides.

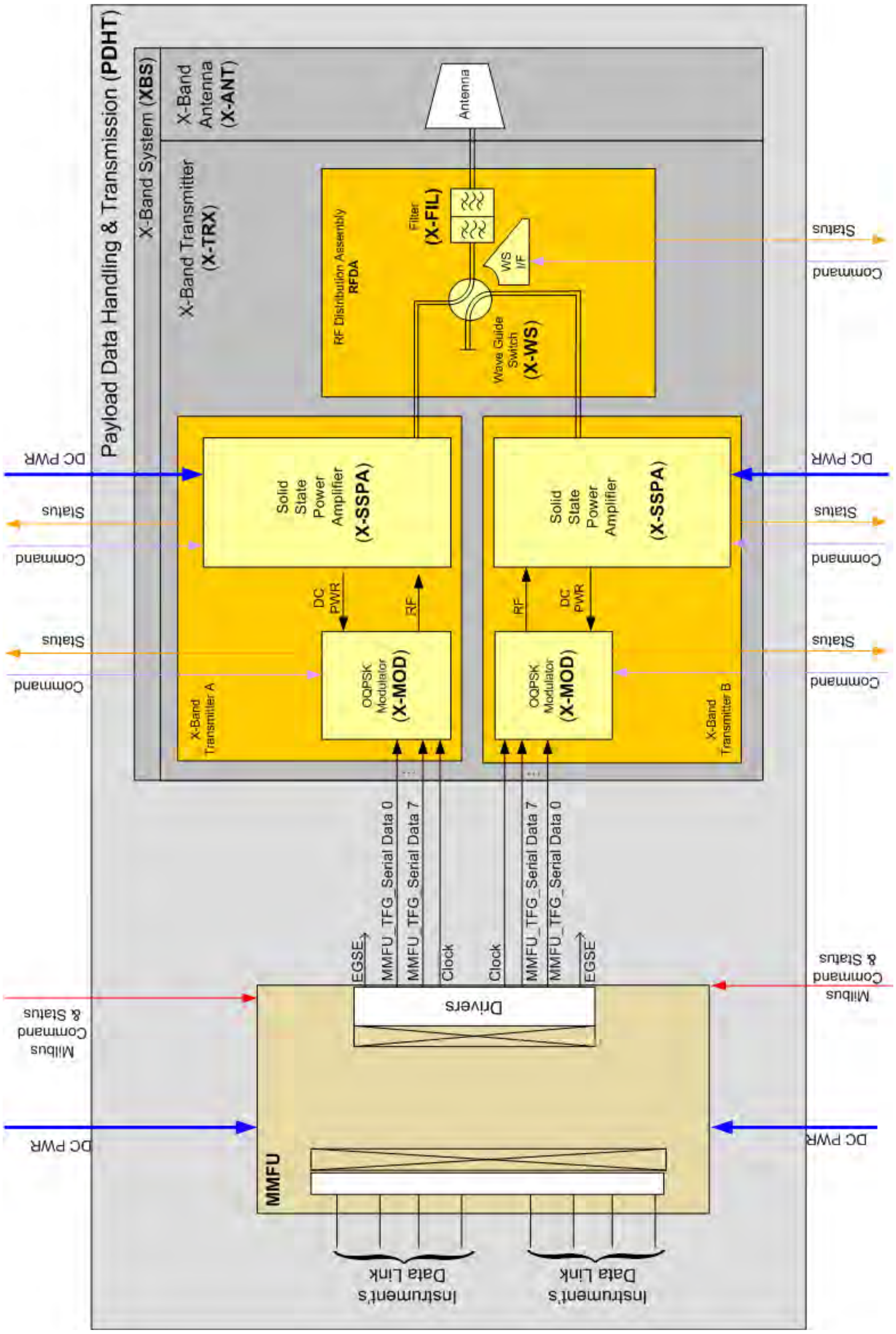
The OQPSK Modulator receives telemetry data from the MMFU via 8 parallel data lines (4 lines I and 4 lines Q signals) and the associated clock. These signals are serialized into an I and Q data stream and are OQPSK modulated directly onto the X-band carrier which is generated within the modulator. The modulated RF is routed to the SSPA's Power Amplifier Unit (PAU).

The Solid State Power Amplifier (X-SSPA) amplifies the modulated signal to the required RF power. The RF is routed to the Waveguide Switch via an RF-Isolator. The X-SSPA's DC/DC Converter Unit supplies the X-SSPA as well as the Modulator.

The Waveguide Switch (X-WS) selects one of the two RF outputs and routes it to the Filter.

The Filter (X-FIL) is a combination of a bandpass followed by a lowpass filter. The bandpass filter is tuned to the designed part of the X-band transmit frequency band. The lowpass filter suppresses unwanted emissions outside the transmit band.

The filtered RF signal is emitted to ground via the right handed circular polarised (RHCP) shaped beam Antenna. (X-ANT) mounted on the S/C's nadir panel. Use of the X-Band downlink is therefore only possible when the spacecraft is in normal flight attitude.



Note: EGSE links are not cross-strapped

Figure 3.2-1: EarthCARE Onboard PDHT Architecture

3.2.2.1 Science Data Downlink

SGICD-1041/SDS-2888/A

The X-Band downlink provides one downlink rate for Science Data with characteristics defined below as well as in table Table 3.2-1

- The 150 Mbps PCM waveform is NRZ-L and is converted to an I and Q data stream for OQPSK modulation.
- The PCM data is directly applied to the modulator for hard keyed O-QPSK modulation on the carrier (suppressed carrier).

Data Downlink Parameter	Characteristics
RF Modulation Type	OQPSK (as described in [ND-147])
Data rate	131 Mbps (before encoding) 150 Mbps with encoding
TM frame rejection rate	$<10^{-7}$
Stability of bit rate	Tbd

Table 3.2-1: RF Downlink Characteristics of the X-Band.

SGICD-1047/SDS-7269/R

The telemetry data are provided by the MMFU which applies

- Pseudo-Randomization and Reed Solomon encoding.

3.2.2.2 Link Budgets

The summary of the X-Band link budget is presented in Table 3.2-2. This shows the margins for the case of the nominal 150 Mbps downlink.

More detailed link budgets can be found in [RD-09].

EarthCARE X-Band Link Budget Margins				
Link Scenario	**Downlink** **Data rate**	**Link Margin** **(dB)**		
	(before coding)	**Nominal**	**Adverse**	**Favourable**
Downlink Only, Kiruna 13m	131 Mbps	**3.6**	**1.5**	**3.8**

Table 3.2-2: EarthCARE X-Band Link Budget Margins

3.2.3 X-Band RF Compatibility Test

These tests will be further described in updated versions of this document.

4 SATELLITE TO GROUND MONITORING AND CONTROL DATA INTERFACE

4.1 Monitoring and Control Data Flow and Configuration

The EarthCARE Monitoring and Control configuration of the spacecraft is implemented

- by the S-Band downlink and uplink for satellite monitoring and control, and
- by the X-Band downlink for transmission of the scientific and ancillary data.

The overall configuration is depicted in Figure 4.1-1. For details on the virtual channels see Section 4.3.

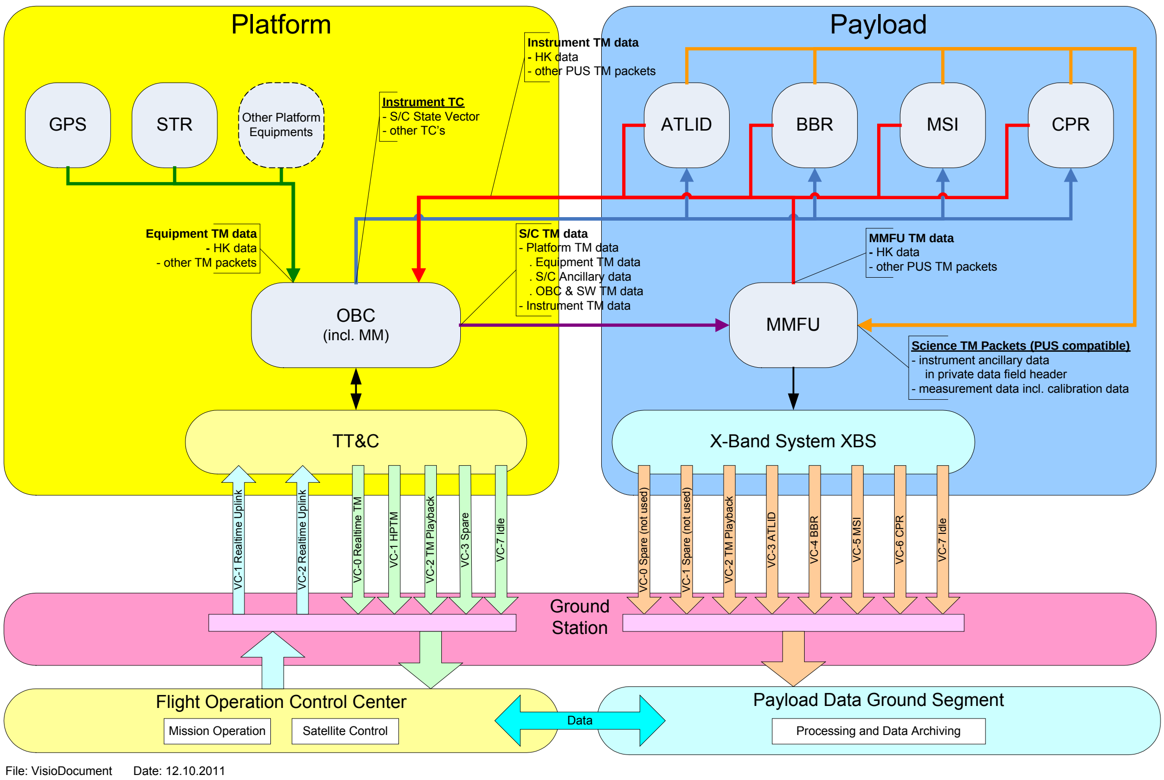


Figure 4.1-1: Monitoring and Control System Configuration & Instrument Data Flow

The TT&C system is in charge of providing all Tracking, Telemetry and Command services for the satellite and its payload.

The satellite to ground data interface is implemented by several Virtual Channels, where each channel is assigned for a dedicated purpose. Different spacecraft identifiers are assigned for the S-Band and the X-Band. Virtual Channel identifiers for TM downlink are assigned individually for S-Band and X-Band downlink, i.e. same VC numbers are used for S-Band and X-Band. The identifier pair {Spacecraft ID, Virtual Channel ID} is unique.

For details on MAP IDs, Spacecraft Identifiers, and Virtual Channels, see Section 4.3.

For TC uplink, different MAP IDs are used to address either the Command Pulse Distribution Unit (CPDU) or the application software. The S-Band uplink includes all TC addressed to the platform and the instruments. The S-Band receiver is selected by ground via the appropriate Virtual Channel. The X-Band system does not include an uplink channel.

All virtual channels received via the S-Band are processed on ground in the Flight Operation Control Center. The S-Band telemetry includes all platform HK as well as all payload HK, except the instrument science data.

During ground contacts, satellite TM is transmitted in real time via VC-0. High Priority TM, purely hardware generated with out software, is transmitted in VC-1. Outside ground contacts, the satellite TM is stored in the OBC internal mass memory. The OBC internal mass memory content is transmitted to ground during ground contacts upon command via VC-2.

The RF characteristics of the S-Band system are described in Section 3.1.

The instrument Science and Ancillary data are stored in the MMFU. They are sent to ground during ground contacts upon command via X-Band and directly distributed to the Payload Data Ground Segment for further processing and archiving. S/C TM is also stored in one packet store of the MMFU and sent to ground via X-Band. For each instrument, one specific packets store and one VC is allocated.

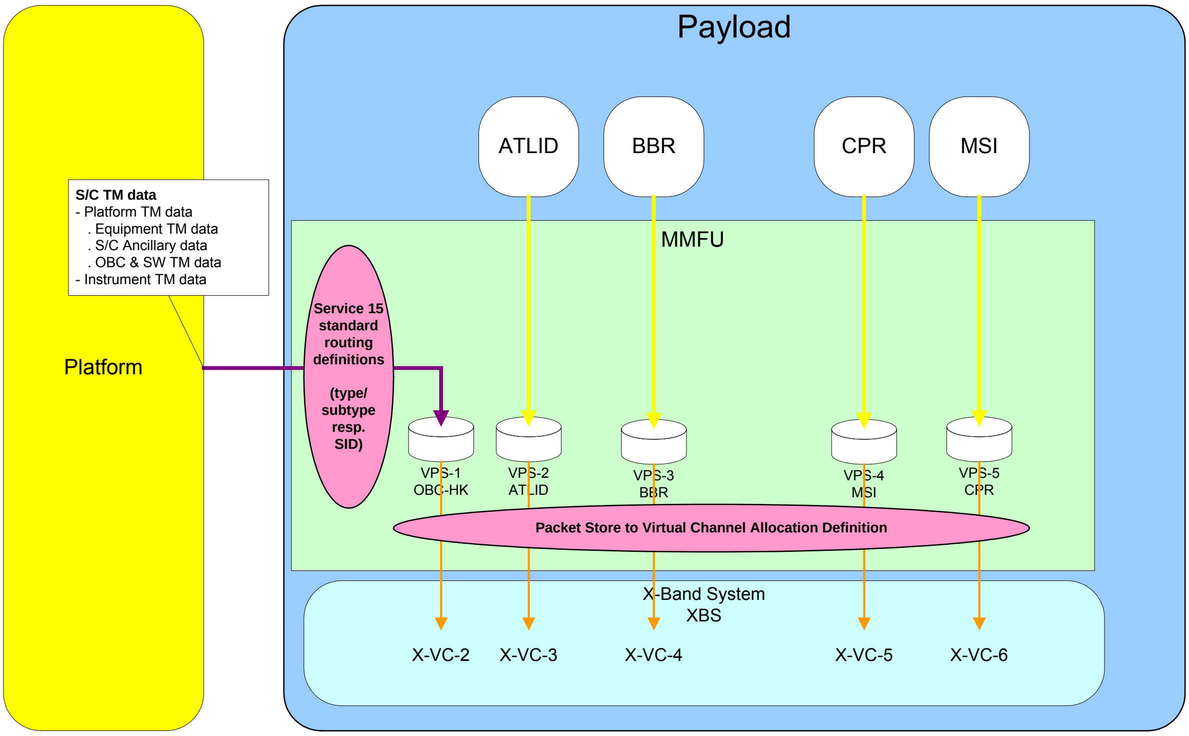


Figure 4.1-2: Mission Data Management for X-band downlink

The RF characteristics of the X-Band system are described in Section 3.2.

4.2 Time Synchronisation

Details on the Time Synchronization are described in the Satellite Technical Description [RD-02].

4.2.1 On-board Time Management Concept Overview

The EarthCARE on-board time (OBT) system is shown in Figure 4.2-1. It consists of

- An Absolute Time Provider, the GPS receiver issuing a synchronization signal identifying the GPS time system 1 second roll-over and a GPS time message either as dedicated TM packet or as part of the PVT solution
- A Central On-board Time (COBT) master as part of the OBC, also call On-board Time Reference (OBTR), mastering that one and only one time is used across the satellite by distribution on-board time synchronization messages and signals and that this time is known to ground for time correlation to UTC
- The time report packet (STSP, TM(9,2)), identifying the on-board transmission time of a repetitive unique bit in the downlink data stream to ground, which is transmitted to Ground allowing correlation of the OBT to Ground UTC
- A number of datation users, each comprising a Local On-board Time (LOBT) function for standalone operation, which is to be synchronized to the COBT to ensure consistent and full performance operation.
- There are two classes of datation users defined depending on the accuracy of the synchronized operation:
    - Class A datation users will be synchronized by dedicated HW line, the 1PPS signal
    - Class B datation users will be synchronized by communication protocol embedded synchronization reference, which is the start of the major frame of the MIL-Bus Protocol.

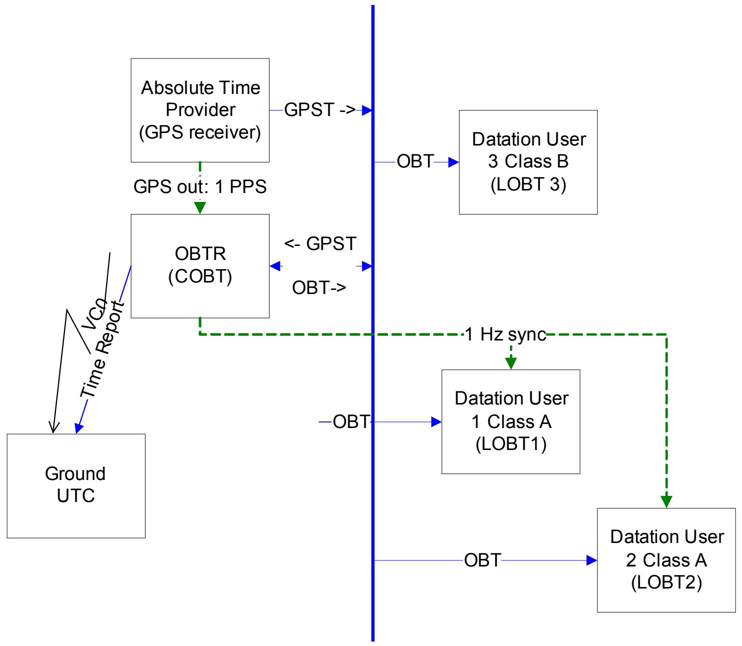


Figure 4.2-1: On-board Time Concept

The COBT is distributed as part of the communication via the on-board time synchronization message, which is provided well before the next synchronization reference signal and which contains the OBT of the next synchronization reference. For Class A users this is the 1 PPS signal from the OBC, for Class B users this is the major frame start of the MIL-Bus Protocol as depicted in Figure 4.2-2.

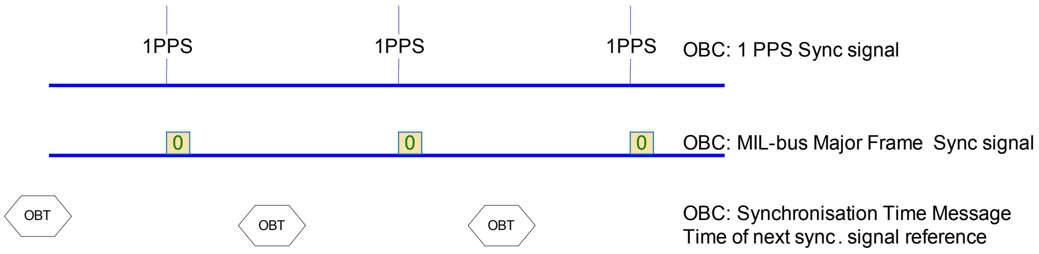


Figure 4.2-2: On-board Time Synchronisation Concept

4.2.2 On-board Time Reference Concept

SGICD-1133/I/T,R

For nominal operation the on-board time of EarthCARE satellite is maintained w.r.t. the GPS time reference system, via synchronization of the OBC On-board time reference (OBTR) function to the GPS receiver output. The GPS receiver provides a 1 Hz sync signal at each full second of the GPS time reference system and absolute datation information of this 1PPS Signal as part of the GPS PVT information or via dedicated datation TM packet. This GPS provided datation information is taken by the OBC central SW to update its own OBTR function, thus performing a precision datation of the occurrence of the next 1PPS output signal.

Note: The GPS 1PPS active edge identifies precisely the start of an integer second of the GPS time reference system.

In order to perform smooth transitions from unsynchronized to synchronized state as well as to bridge in an optimum way GPS sync signal outages the OBTR function, which has typically a resolution of at least 55 bit, allows determination of the clock offset of its own oscillator w.r.t. the GPS provided 1PPS signal. Based on the determined clock offset and via a Numerical Controlled Oscillator (NCO) the OBTR function of the OBC drives its own clock and thus the OBTR 1PPS output close to the GPS-Time sync-pulse frequency. The accuracy between active edge of the GPS-Sync-Pulse and the 1PPS is better than 1 µsec under synchronized conditions.

By this mechanism the COBT of the On-Board Computer is synchronized to GPS-Time as long as the synchronization to the GPS receiver is enabled and GPS navigation solutions and the GPS 1 Hz sync signal are available.

SGICD-1137/I/T,R

In order to cope with situations where the GPS is not working, the following principle is implemented to support on-board time to ground UTC time correlation according [AD 110], clearly with reduced accuracy:

The telemetry frame generator merges the packets from the various Virtual Channels, adds the encoding blocks and the CADU headers (i.e. the Attached Synchronisation Marker) to produce a continuous stream of TM frames for downlink to the ground. To allow the ground to correlate on board time to UTC acc. ECSS E-70-41A, the Frame Generator produces a TM Strobe on transmission of the leading edge of the first bit of the Attached Synchronisation Marker of every 32nd (default after power on) VC0 TM frame. The TTR OBT of the TM Strobe is latched in TTR Sample Register. The OBC Central SW is then required to produce a Spacecraft Time Source Packet (see [AD-110], §6.8.1, TM(9,2)) containing this sampled time for transmission before the next VC0 TM frame that will generate the next Time Strobe.

The ground station records the receive time of the TM Frame. The ground can then correlate the OBT value contained in the TM packet with the recorded receive time of that TM frame, which triggered the generation of the Spacecraft Time Source Packet.

4.2.3 On-board Time Synchronization

The clock synchronization of equipments and instruments within EarthCARE is fundamentally based on a 1Hz Pulse Per Second (1PPS) signal distributed by the OBC. The 1PPS signal is generated at each full second by the OBC independent if the GPS receiver provides valid data and synchronization signals. The central on-board time (COBT) maintained by the OBTR Function of the OBC is distributed via MIL Bus message to all equipments and instruments connected to any MIL-Bus. The time distributed over the MIL Bus message identifies the time at the occurrence of the next 1PPS signal from the OBC.

At the active edge of the 1PPS, each equipment and instrument latches the received time value of the MIL-Bus Time-Broadcast in the local OBT register and synchronizes its local on-board time (LOBT).

Units, which do not need precision time synchronization and therefore do not receive a 1PPS, shall use the start of a MIL-Bus-Major-frame to latch the received time value of the MIL-Bus Time-Broadcast in the local OBT register. Thus also these units have a synchronized LOBT.

4.2.4 Datation Concept

All TM packets are dated by the time stamp provided in the packet data field header. This time stamp denotes the packet generation time. The relation of the sampling time of house keeping parameters is deterministically known w.r.t. this packet time stamp. For TM parameters and science data requiring higher datation accuracy explicit time stamps are embedded in the packet data field.

The time status embedded in the TM packet header uniquely identifies the synchronisation state of the data generating entity.

4.2.5 In Flight Time Correlation

The spacecraft generates a continuous TM real-time data downlink stream and provides these data via virtual Channel 0 to the receiving ground station. The data stream is generated by the Frame Generator, merging the packets from the various Virtual Channels, adding the Reed-Solomon encoding blocks and the CADU headers (i.e. the Attached Synchronisation Marker). To allow the ground to correlate on board time to UTC the Frame Generator produces a TM Strobe on transmission of the leading edge of the first bit of the Attached Synchronisation Marker of every 32nd VC0 TM frame (Virtual Channel Frame count = 0, 32, 64, 96, 128, 160, 192, 224). The OBTR of this TM Strobe is latched to a dedicated register of the OBC. The CSW is then required to produce a Spacecraft Time Source Packet containing this sampled time for transmission before the next VC0 TM frame that will generate the next Time Strobe.

When the GPS Receiver is active the EarthCARE OBT is kept synchronised to GPST. When the GPS receiver is off the EarthCARE OBT is free running and will gradually diverge from GPST.

In order to command and control EarthCARE the ground will need to be able to convert from UTC to OBT and vice versa. While OBT is synchronised to GPST this conversion is simply a matter of adding the appropriate number of leap seconds.

However, while the OBT is free running the FOS will need to determine the correlation between OBT and UTC using the regularly S/C Time Report as follows;

- During each ground station pass, record the UTC of reception of the rising edge of each VC0 TM frame with Virtual Channel Frame count equal to 0, 32, 64, 96, 128, 160, 192, and 224.
- Extract the OBT at which the transmission of each of these frames started from the Spacecraft Time Source Packets. There should be one Spacecraft Time Source Packet between each 32nd VC0 TM frame giving the transmission time of the previous relevant VC0 TM frame.
- Using the spacecraft predicted orbit, correct the VC0 TM frame reception UTC for the spacecraft to ground station propagation delay. Thus for each 32nd VC0 TM frame both the OBT and UTC of the instant of transmission are known.

- Perform least square fit over the whole ground station pass to achieve a simple correlation of UTC to OBT of the form; OBT=(UTC-UTCref)*m+OBTref where UTCref, OBTref and m are the outputs of the linear correlation.

It should be noted that nominally the GPS Receiver will always be on, so OBT should be synchronised to GPST except in LEOP before the GPS receiver is first switched on, in Safe Mode and in ASM when returning from Safe Mode or following a OBC reset or reconfiguration.

For the indicated operation periods of free wheeling OBT, which do not include normal operation with science data acquisition an accuracy of better than 0.5 (TBC) msec should be sufficient. In order to serve as backup during normal mission operation a significant higher correlation accuracy of better than 0.1 (TBC) msec would be required.

4.2.6 COBT Synchronisation Verification

The onboard system will detect and recover from failures of the on-board time management system. However, the onboard system is dependent on the GPS Receiver giving a correct GPST and continuing to provide its sync signal on increment of the GPST seconds. In particular the on-board system will be unable to detect an initial error on GPST and will be unable to detect a slow drift of OPPS with respect to the GPST until the difference between GPST and OBT is greater than 1 (TBC) seconds. However, these failures can be detected very easily by the ground regularly performing the time correlation function. Therefore the ground should perform the following monitoring activities;

- Following in flight OBT synchronisation to GPST perform a time correlation to confirm that OBT is set to GPST (i.e. UTC plus the appropriate number of leap seconds);
- During all S-Band passes perform a time correlation and compute the delta between OBT and GPST. An alarm should be raised if this exceeds 10 (TBC) milliseconds.

This monitoring function is expected to be an autonomous on-ground function

4.3 EarthCARE Packet Utilization Standard

4.3.1 Communication Protocol Format Definitions

4.3.1.1 S-Band

SGICD-1166//T

Different spacecraft identifiers are assigned to the satellite for S-Band and X-Band. The Spacecraft IDs assigned to the different models for the S-Band are given in Table 4.3-1.

Model	S-Band Spacecraft Identifier			
	Uplink		Downlink	
	HEX	DEC	HEX	DEC
STB	0x227	551	0x227	551
SVF	N/A	N/A	N/A	N7A
EFM	0x221	545	0x221	545
PFM	0x223	547	0x223	547

Table 4.3-1: S-Band Spacecraft Identifiers

SGICD-1206//T

Virtual Channel identifiers for TM downlink are assigned individually for S-Band and X-Band downlink, i.e. same VC numbers are used for S-Band and X-Band. The identifier pair {Spacecraft ID, Virtual Channel ID} is unique. The Virtual Channel IDs assigned to the S-Band Downlink are given in Table 4.3-2. They are valid for all models.

Virtual Channel ID S-Band Downlink	Usage
VC-0	Real-time HK
VC-1	High Priory Telemetry (HPTM)
VC-2	Playback HK from OBC MM
VC-3	Spare Channel from OBC PM
VC-4 to VC-6	unused
VC-7	Idle Frames

Table 4.3-2: S-Band Downlink Virtual Channel Identifiers

SGICD-1231//T

Virtual Channel identifiers for TC uplink are assigned for S-Band uplink only. They are given in Table 4.3-3 and are identical for all models. All Telecommand Transfer Frames received on-board are routed to both TC Decoders (A and B). but only processed by that TC Decoder, which is addressed by the VC ID.

Virtual Channel ID S-Band Uplink	Usage
VC-1	Command Decoder A
VC-2	Command Decoder B

Table 4.3-3: S-Band Uplink Virtual Channel Identifiers

SGICD-1243/SDS-5082/T,R

The MAP identifiers as given in Table 4.3-4 are assigned to the S-Band uplink. They are identical for all models. The MAP IDs are specific for the selected OBC.

MAP ID S-Band Uplink	Usage
0	HPC-1 CPDU Commands
1	Commands to the active processor to be processed by CSW
5	Reinit TM/RM/HPTM/OBT
6	*Set TC Only* MAP command

Table 4.3-4: S-Band Uplink MAP Identifiers

SGICD-1261//T,R

The S-Band uplink formats for TC Source Packet, TC Transfer Frame and CLTU are pictured in Figure 4.3-1.

SGICD-3796//T

The S-Band downlink formats for TM Source Packet, TM Transfer Frame and CADU are pictured in Figure 4.3-2.

SGICD-1262/SDS-5082/T,R

The parameters of the S-Band uplink formats are given in

- Table 4.3-5: S-Band TC Transfer Frame Fields (Header and Trailer)
- Table 4.3-6: S-Band TC Uplink Characteristics

SGICD-1265/SDS-5082/T,R

The parameters of the S-Band downlink formats are given in

- Table 4.3-7: S-Band TM Transfer Frame Fields (Header and Trailer)
- Table 4.3-8: CLCW Parameters
- Table 4.3-9: S-Band TM Downlink Characteristics

The parameters of the Source Packet Headers and Source Packet Data field Headers are explained in [AD-110].

TC COP-1 procedure is according [ND-146].

SGICD-1271//T,R

The Telecommand Transfer Frames are of 3 types (AD, BD and BC service is supported by the spacecraft) as indicated by the Bypass Flag and the Control Command Flag. The definition and the use of these flags are detailed in Table 4.3-5.

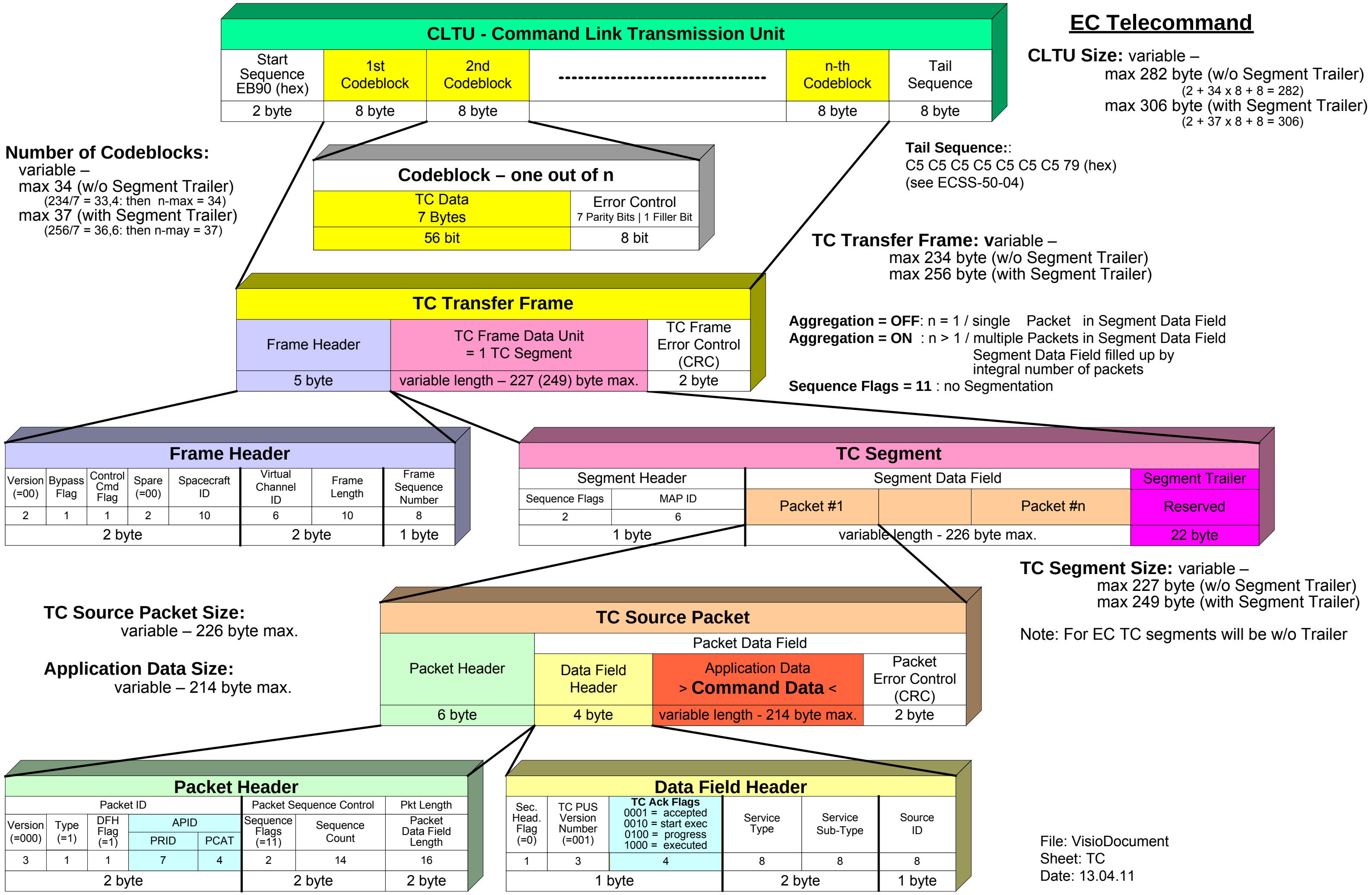
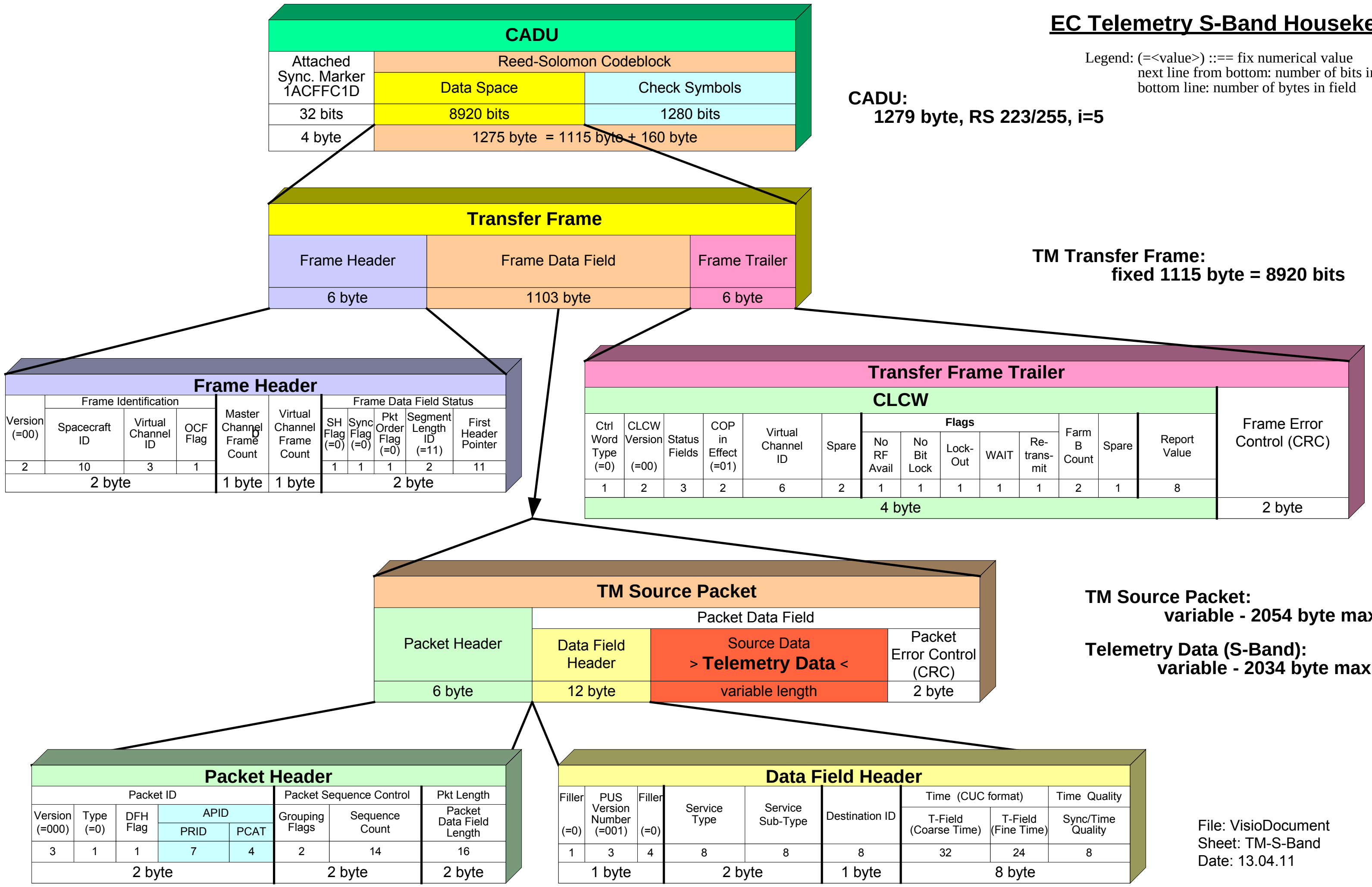

EC Telecommand
CLTU Size: variable –
max 282 byte (w/o Segment Trailer)
(2 + 34 x 8 + 8 = 282)
max 306 byte (with Segment Trailer)
(2 + 37 x 8 + 8 = 306)
CLTU - Command Link Transmission Unit
Start Sequence EB90 (hex)
1st Codeblock
2nd Codeblock
n-th Codeblock
Tail Sequence
2 byte
8 byte
8 byte
8 byte
8 byte
Number of Codeblocks:
variable –
max 34 (w/o Segment Trailer)
(234/7 = 33,4: then n-max = 34)
max 37 (with Segment Trailer)
(256/7 = 36,6: then n-may = 37)
Codeblock – one out of n
TC Data
7 Bytes
56 bit
Error Control
7 Parity Bits | 1 Filler Bit
8 bit
Tail Sequence::
C5 C5 C5 C5 C5 C5 C5 79 (hex)
(see ECSS-50-04)
TC Transfer Frame: variable –
max 234 byte (w/o Segment Trailer)
max 256 byte (with Segment Trailer)
TC Transfer Frame
Frame Header
5 byte
TC Frame Data Unit
= 1 TC Segment
variable length – 227 (249) byte max.
TC Frame Error Control (CRC)
2 byte
Aggregation = OFF: n = 1 / single Packet in Segment Data Field
Aggregation = ON : n > 1 / multiple Packets in Segment Data Field
Segment Data Field filled up by
integral number of packets
Sequence Flags = 11 : no Segmentation
Frame Header
Version (=00)
Bypass Flag
Control Cmd Flag
Spare (=00)
Spacecraft ID
Virtual Channel ID
Frame Length
Frame Sequence Number
2
1
1
2
10
6
10
8
2 byte
2 byte
1 byte
TC Segment
Segment Header
Sequence Flags
MAP ID
2
6
1 byte
Segment Data Field
Packet #1
Packet #n
variable length - 226 byte max.
Segment Trailer
Reserved
22 byte
TC Segment Size: variable –
max 227 byte (w/o Segment Trailer)
max 249 byte (with Segment Trailer)
Note: For EC TC segments will be w/o Trailer
TC Source Packet Size:
variable – 226 byte max.
Application Data Size:
variable – 214 byte max.
TC Source Packet
Packet Header
6 byte
Packet Data Field
Data Field Header
4 byte
Application Data
> Command Data <
variable length - 214 byte max.
Packet Error Control (CRC)
2 byte
Packet Header
Packet ID
Version (=000)
Type (=1)
DFH Flag (=1)
APID
PRID
PCAT
3
1
1
7
4
2 byte
Packet Sequence Control
Sequence Flags (=11)
Sequence Count
2
14
2 byte
Pkt Length
Packet Data Field Length
16
2 byte
Data Field Header
Sec. Head. Flag (=0)
TC PUS Version Number (=001)
TC Ack Flags
0001 = accepted
0010 = start exec
0100 = progress
1000 = executed
1
3
4
1 byte
Service Type
Service Sub-Type
8
8
2 byte
Source ID
8
1 byte
File: VisioDocument
Sheet: TC
Date: 13.04.11

Figure 4.3-1: S-Band Uplink - Data Format and Content

EC Telemetry S-Band Housekeeping

Legend: (=<value>) ::== fix numerical value
next line from bottom: number of bits in field
bottom line: number of bytes in field



CADU:
1279 byte, RS 223/255, i=5

TM Transfer Frame:
fixed 1115 byte = 8920 bits

TM Source Packet:
variable - 2054 byte max.

Telemetry Data (S-Band):
variable - 2034 byte max.

File: VisioDocument
Sheet: TM-S-Band
Date: 13.04.11

Figure 4.3-2: S-Band Downlink - Data Format and Content

Parameter	Description	Range or value
Version	Transfer Frame Version Number	"00"
Bypass Flag / Control Command Flag	Flags used to control the PTD operation	"00" Type-AD. Frame Data Field carries TC data (e.g., Packets or Segments), subject to acceptance check under control of the FARM. These Frames use the Sequence-Controlled (or AD) Service of the COP.
		"01" Reserved
		"10" Type-BD. Frame Data Field carries TC data (e.g., Packets or Segments), with all frame acceptance checks bypassed under control of the FARM. These Frames use the Expedited (or BD) Service of the COP.
		"11" Type-BC. Frame Data Field carries FARM Control Commands, with all frame acceptance checks bypassed under control of the FARM. These Frames control the Sequence- Controlled Service of the COP.
Spare		"00"
Spacecraft ID	These ten bits carry the identification code for the spacecraft being commanded. The Secretariat of the CCSDS assigns the SPACECRAFT IDENTIFIER to each vehicle within a particular mission	See Table 4.3-1
Virtual Channel ID	VC Id Identifier used to address a single physical channel to be logically multiplexed on a frame-by-frame basis.	See Table 4.3-3

Parameter	Description	Range or value
Frame Length	This 10-bit field contains a length count "C" which equals one fewer than the total octets in the TC Transfer Frame. The count is measured from the first bit of the FRAME HEADER to the last bit of the FRAME ERROR CONTROL FIELD (if present), or the last bit of the FRAME DATA FIELD if the error control is omitted. The size of this field limits the maximum length of a TC Transfer Frame to 1024 octets. The length count "C" is expressed as: *C = (Total Number of Octets) - 1*	234 bytes max
Frame Sequence Number	up-counting binary number which is assigned to each TC Frame by the TC Transfer layer,	0 .. 2^8-1
TC Frame Error Control	Provides frame error control information (CRC)	CRC (as specified in [ND-112])

Table 4.3-5: S-Band TC Transfer Frame Fields (Header and Trailer)

Item	Value (w/o Segment Trailer)	Value (with Segment Trailer)
TC Application Data:	Max. 214	Max. 214
TC Packet Header	6 byte	6 byte
TC Datafield Header	4 byte	4 byte
TC Source Packet size	max. 226 byte	max. 226 byte
TC Segment Size	max. 227 byte	max. 249 byte
TC Transfer Frame Size	max. 234 byte	max. 256 byte
Encoding	NRZ-L	NRZ-L
CLTU Code Blocks	max. 34 code blocks	max. 37 code blocks
CLTU Size	max. 282 byte	max. 306 byte

Table 4.3-6: S-Band TC Uplink Characteristics

TC segments will be without trailer for EarthCARE.

Parameter	Description	Range or value
Version	Transfer Frame Version Number	"00"
Spacecraft ID	These ten bits carry the identification code for the spacecraft being commanded. The Secretariat of the CCSDS assigns the SPACECRAFT IDENTIFIER to each vehicle within a particular mission	See Table 4.3-1
Virtual Channel ID	VC Id Identifier used to address a single physical channel to be logically multiplexed on a frame-by-frame basis.	See Table 4.3-2
Operational Control Flag	indicate the presence or absence of the OPERATIONAL CONTROL FIELD.	**0** : OPERATIONAL CONTROL FIELD **NOT** present; **1** : OPERATIONAL CONTROL FIELD present This is the project default
Master Channel Frame Count	Wrap around counter, incremented for each frame	0 to 255
Virtual Channel Frame Count	Wrap around counter, incremented for each frame of the specific virtual channel	0 to 255
Secondary Header Flag	contains the TRANSFER FRAME SECONDARY HEADER FLAG	**0** : SECONDARY HEADER **NOT** present This is the project default **1** : SECONDARY HEADER present
Sync Flag	signals the type of data which are inserted into the TRANSFER FRAME DATA FIELD.	**0** : byte synchronized and forwarded SOURCE PACKETs or idle data **1** : PRIVATELY DEFINED DATA
Packet Order Flag	In conjunction with *Sync Flag* , Reserved for future use	Always "0"
Segment Length Id	In conjunction with *Sync Flag*	**"11" :** if *Sync Flag = 0* **Undefined:** if *Sync Flag = 1*
First Header Pointer	If the *SYNC FLAG* is set to “0”, the FIRST HEADER POINTER shall contain information on the position of the first SOURCE PACKET within the TRANSFER FRAME DATA FIELD.	**"11111111111":** no PACKET PRIMARY HEADER starts in the TRANSFER FRAME DATA FIELD **"11111111110":** TRANSFER FRAME DATA FIELD contains idle data any other value between 0 and 1102dec indicates the start address of a new source packet
Operational Control Field Data	See Table ý4.3-8	

Parameter	Description	Range or value
TM Frame Error Control	Provides frame error control information (CRC)	CRC (as specified in [ND-112])

Table 4.3-7: S-Band TM Transfer Frame Fields (Header and Trailer)

SGICD-1432//T

The CLCW parameters are explained in Table 4.3-8. The CLCW is retrieved from the command decoders, once per transmitted frame, alternating between the two decoders. CLCW with VC ID = 1 is transmitted in Transfer Frames with an even value of the Master Channel Frame count. CLCW with VC ID = 2 is transmitted in Transfer Frames with an odd value of the Master Channel Frame count (TBC).

Field		Size and Meaning	Fixed
CWT	MSB b_0	1-bit ,**Control Word Type** specifies that the structure is a CLCW	0b
VN	b_1-b_2	2-bit field ,**Version Number**, reserved by CCSDS	00b
SF	b_3-b_5	3-bit field, **Status Field**, reserved by CCSDS	000b
COP	b_6-b_7	2-bit field, **COP in Effect** is used to indicate which of the CCSDS-defined COP (Command Operation Procedure) is in use, in this standard only COP-1 is specified, which corresponds to COP=**01**	01b
VCID	b_8-b_{13}	6-bit field, **Virtual Channel Identifier** contains the TC Virtual Channel number. Only the 3 least bits (b_{20}-b_{18}) are used for coding.	-
RES	b_{14}-b_{15}	2-bit field, **Reserved Field** and is set to **00**	00
NRFF	b_{16}	1-bit , **No RF Available Flag** represents the status of RF system, which corresponds to NRFF=**1** (RF not available) and NRFF=**0** (RF available)	-
NBLF	b_{17}	1-bit, **No Bit Lock Flag** monitors the presence of the S/C demodulation, if NBLF=**1** all TC Active Signals (0 to 5) are zero at the PTD inout pins, and if NBLF=**0** one of the TC Active signals is set to 1	-
LOF	b_{18}	1-bit, **LockOut Flag** indicates, if LOF=1 , that the FARM-1 is in the „Lockout“ state	-
WF	b_{19}	1-bit, **Wait Flag** indicates, if WF=1 , that the FARM-1 is in the „Wait“ state	-
RTMF	b_{20}	1-bit, **Retransmit Flag** indicates, if RTMF =1 , that an frame has been lost in transmission or has been discarded because there was no buffer space available	-
FBC	b_{21}-b_{22}	2-bit field, **FARM-B Counter** field contains a wraparound up-counter (modulo 4) of each TC frame of type BC or BD	-
REPT	b_{23}	1-bit, **Report Type** is always set to REPT=**0**	0b
REPV	b_{24}-b_{31}	8-bit field, **Report Value** field is maintained by the FARM-1 and contains the next expected frame sequence number V(R)	-

Table 4.3-8: CLCW Parameters

Item	Values for 128 kbps	Values for 2048 ksps
Attached Synchronisation Marker	1ACF_FC1D (hex)	1ACF_FC1D (hex)
TM Source Data:	max 2034 byte	max 2034 byte
TM Packet Header	6 byte	6 byte
TM Datafield Header	12 byte	12 byte
TM Source Packet size	max. 2054 byte	max. 2054 byte
TM Transfer Frame Size	fixed 1115 byte	fixed 1115 byte
Reed-Solomon encoding	223/255	223/255
interleave	5	5
convolutional encoding	no	yes
pseudo-randomisation	yes	yes
Encoding	NRZ-L	NRZ-L
CADU Size	fixed 1279 byte	fixed 1279 byte

Table 4.3-9: S-Band TM Downlink Characteristics

The OBC Telemetry Frame Generator manages the supports virtual channel management via a bandwidth allocation table (BAT) and supports the following two modes according [AD-10]:

<u>Bandwidth Allocation:</u>

For each Transfer Frame, all entries in the BAT are scanned once, starting and ending on the same entry. Consequently a VC may receive between 0 and 33 polls for each Transfer Frame being output, depending on the BAT programming.

<u>Priority Selection:</u>

The BAT pointer is reset to restart at the first entry in the BAT (address 0) at the beginning of each transfer frame. Since this occurs after each selection (Transfer Frame), the result will effectively be a priority VC selection. Except for the repeated resetting the selection process works exactly as in the case of Bandwidth Allocation.

<u>Satellite Defaults</u>

The default settings for Virtual channel management and idle packet insertion in the OBC PROM are

•Priority Mode

•VC channel processing sequence : VC0 - VC1 - VC3 - VC2 -VC7

The definition is based on an assessment of the distribution of the downlinked data across the virtual channels and the intention to

- optimally use the available downlink bandwidth

•minimize idle frame insertion while still no avoiding unnecessary idle packet insertion.

Idle packet insertion is controlled by definition the number of polls, i.e. checks applied in each virtual channel before a partially filled frame data field is filled up with idle packets and downlinked. The default settings of this parameter for the individual settings are shown in Table 4.3-10.

		VC-0		VC-1		VC-3		VC-2	
TM Frame	TM rate	N_polls	Time	N_polls	Time	N_polls	Time	N_polls	Time
bytes	bit/sec	-	sec	-	sec	-	sec	-	sec
1279	1.00E+06	16	0.16	1	0.01	16	0.16	0	0.00
1279	1.28E+05	16	1.28	1	0.08	16	1.28	0	0.00

Table 4.3-10: Dwell Time for idle packet insertion per virtual channel

These settings ensure that real-time telemetry is delivered first to achieve minimum delay from packet generation to availability on ground, while minimizing idle packet insertion on VC-0. High Priority TM is built at once, if available it will be delivered almost immediately. VC-3 is connected to the processor module, therefore a realtime TM channel, but not used in EarthCARE. The polls of VC-2 are set to zero since the alternative to sending a partially filled VC2 TM frame with idle packets is to send idle frames, which wastes bandwidth. The consequence is that there will by few VC-2 TM frames with idle packets not only at the end of a data downlink but also at begin, when the internal transfer from OBC Mass Memory is started. VC-7 Idle Transfer Frames are inserted if no other Transfer Frame is ready (filled with enough data) to be sent.

All settings can be changed by normal commands and reset to default by MAP 5 command.

The Attached Synchronisation Marker is not submitted to R/S encoding and is not submit to pseudo-randomisation.

4.3.1.2 X-Band

SGICD-1581//T,R

Different spacecraft identifiers are assigned to the satellite for S-Band and X-Band. The Spacecraft IDs assigned to the different models for the X-Band are given in Table 4.3-11.

Model	X-Band Spacecraft Identifier	
	HEX	DEC
STB	N/A	N/A
SVF	N/A	N/A
EFM	0x222	546
PFM	0x224	548

Table 4.3-11: X-Band Spacecraft Identifiers

SGICD-1607/SDS-2112/T

Virtual Channel identifiers for TM downlink are assigned individually for S-Band and X-Band downlink, i.e. same VC numbers are used for S-Band and X-Band. The identifier pair {Spacecraft ID, Virtual Channel ID} is unique. The Virtual Channel IDs assigned to the X-Band Downlink are given in Table 4.3-12. They are identical for all models.

Virtual Channel ID X-Band Downlink	Usage
VC-0	Spare
VC-1	Spare
VC-2	HK Playback
VC-3	ATLID Science TM
VC-4	BBR Science TM
VC-5	MSI Science TM
VC-6	CPR Science TM
VC-7	Idle Frames

Table 4.3-12: X-Band Downlink Virtual Channel Identifiers

SGICD-1637/SDS-5082/T,R

The X-Band downlink formats for TM Source Packet, TM Transfer Frame and CADU are pictured in Figure 4.3-3

SGICD-1638//T

The parameters of the X-Band downlink formats are given in

- Table 4.3-13: X-Band TM Transfer Frame Fields
- Table 4.3-14: X-Band TM Downlink Characteristics

The parameters of the Source Packet Headers and Source Packet Datafield Headers are explained in [AD-110].

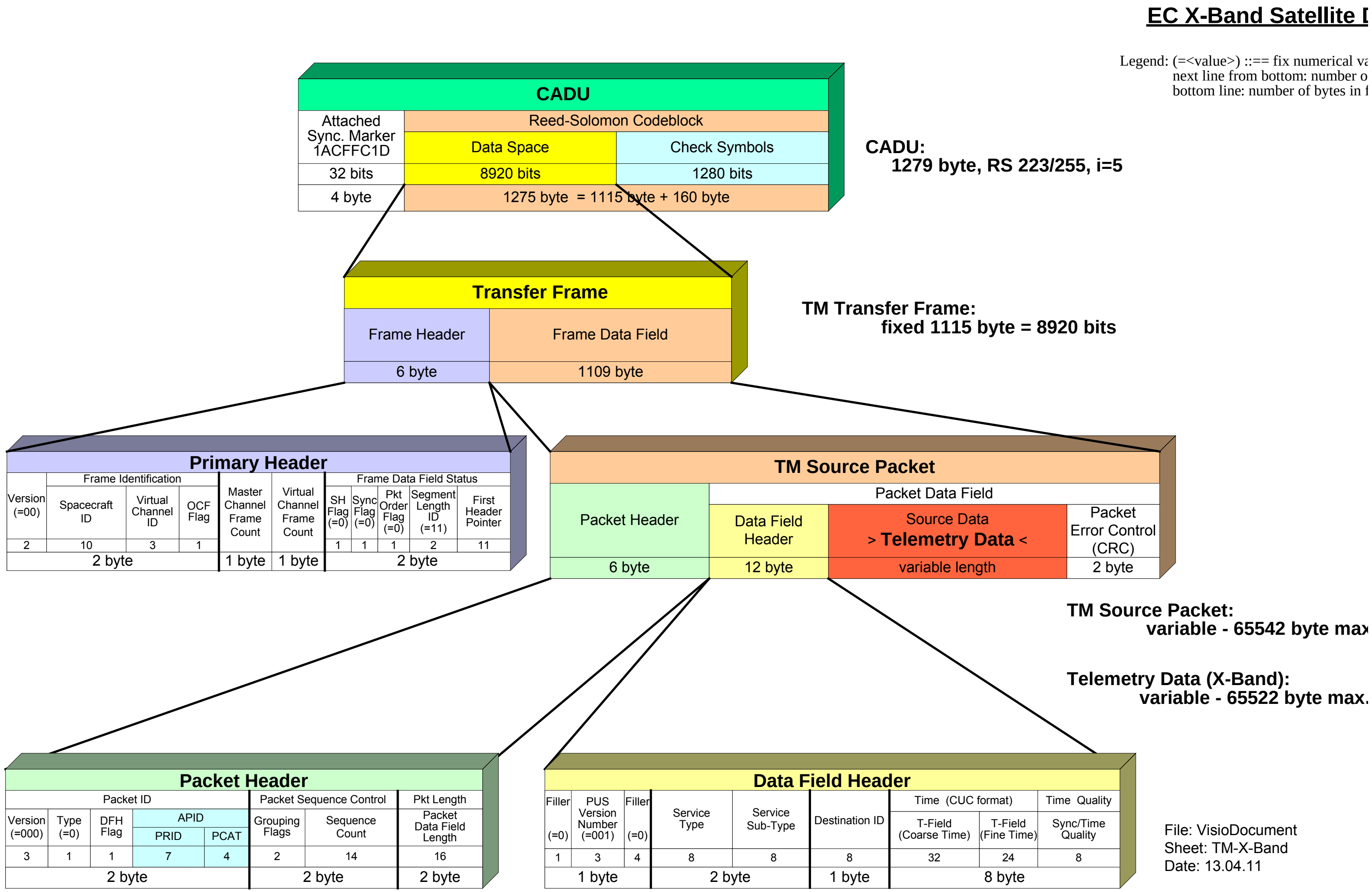

EC X-Band Satellite I
Legend: (=<value>) ::== fix numerical va
next line from bottom: number o
bottom line: number of bytes in f
CADU
Attached Sync. Marker 1ACFFC1D
32 bits
4 byte
Reed-Solomon Codeblock
Data Space
8920 bits
Check Symbols
1280 bits
1275 byte = 1115 byte + 160 byte
CADU:
1279 byte, RS 223/255, i=5
Transfer Frame
Frame Header
6 byte
Frame Data Field
1109 byte
TM Transfer Frame:
fixed 1115 byte = 8920 bits
Primary Header
Version (=00)
Frame Identification
Spacecraft ID
Virtual Channel ID
OCF Flag
Master Channel Frame Count
Virtual Channel Frame Count
Frame Data Field Status
SH Flag (=0)
Sync Flag (=0)
Pkt Order Flag (=0)
Segment Length ID (=11)
First Header Pointer
2 10 3 1 1 1 1 2 11
2 byte
1 byte
1 byte
2 byte
TM Source Packet
Packet Header
6 byte
Packet Data Field
Data Field Header
12 byte
Source Data
> Telemetry Data <
variable length
Packet Error Control (CRC)
2 byte
TM Source Packet:
variable - 65542 byte max
Telemetry Data (X-Band):
variable - 65522 byte max.
Packet Header
Packet ID
Version (=000)
Type (=0)
DFH Flag
APID
PRID
PCAT
Packet Sequence Control
Grouping Flags
Sequence Count
Pkt Length
Packet Data Field Length
3 1 1 7 4 2 14 16
2 byte
2 byte
2 byte
Data Field Header
Filler (=0)
PUS Version Number (=001)
Filler (=0)
Service Type
Service Sub-Type
Destination ID
Time (CUC format)
T-Field (Coarse Time)
T-Field (Fine Time)
Time Quality
Sync/Time Quality
1 3 4 8 8 8 32 24 8
1 byte
2 byte
1 byte
8 byte
File: VisioDocument
Sheet: TM-X-Band
Date: 13.04.11

Figure 4.3-3: X-Band Downlink - Data Format and Content

Parameter	Description	Range or value
Version	Transfer Frame Version Number	"00"
Spacecraft ID	These ten bits carry the identification code for the spacecraft being commanded. The Secretariat of the CCSDS assigns the SPACECRAFT IDENTIFIER to each vehicle within a particular mission	See Table 4.3-11
Virtual Channel ID	VC Id Identifier used to address a single physical channel to be logically multiplexed on a frame-by-frame basis.	See Table 4.3-12
Operational Control Flag	indicate the presence or absence of the OPERATIONAL CONTROL FIELD.	**0** : OPERATIONAL CONTROL FIELD **NOT** present; **1** : OPERATIONAL CONTROL FIELD present This is the project default
Master Channel Frame Count	Wrap around counter, incremented for each frame	0 to 255
Virtual Channel Frame Count	Wrap around counter, incremented for each frame of the specific virtual channel	0 to 255
Secondary Header Flag	contains the TRANSFER FRAME SECONDARY HEADER FLAG	**0** : SECONDARY HEADER **NOT** present This is the project default **1** : SECONDARY HEADER present
Sync Flag	signals the type of data which are inserted into the TRANSFER FRAME DATA FIELD.	**0** : byte synchronized and forwarded SOURCE PACKETs or idle data **1** : PRIVATELY DEFINED DATA
Packet Order Flag	In conjunction with *Sync Flag* , Reserved for future use	Always "0"
Segment Length Id	In conjunction with *Sync Flag*	**"11" :** if *Sync Flag = 0* **Undefined:** if *Sync Flag = 1*
First Header Pointer	If the *SYNC FLAG* is set to “0”, the FIRST HEADER POINTER shall contain information on the position of the first SOURCE PACKET within the TRANSFER FRAME DATA FIELD.	**"11111111111":** no PACKET PRIMARY HEADER starts in the TRANSFER FRAME DATA FIELD **"11111111110":** TRANSFER FRAME DATA FIELD contains idle data any other value between 0 and 1102dec indicates the start address of a new source packet

Table 4.3-13: X-Band TM Transfer Frame Fields

Item	Value
Attached Synchronisation Marker	1ACF_FC1D (hex)
TM Source Data:	max 65522 byte
TM Packet Header	6 byte
TM Datafield Header	12 byte
CRC	2 byte
TM Source Packet size	max. 65542 byte
TM Transfer Frame Size	fixed 1115 byte
Reed-Solomon	223/255
interleave	5
convolutional encoding	No
pseudo-randomisation	Yes
Encoding	NRZ-L
CADU Size	fixed 1279 byte

Table 4.3-14: X-Band TM Downlink Characteristics

Idle packets may be inserted in all VCs, except VC-7.

Idle Transfer Frames are inserted in VC-7 if no other Transfer Frame is ready (filled with enough data) to be sent.

The Attached Synchronisation Marker is not submit to R/S encoding and is not submit to pseudo-randomisation.

4.3.2 Core PUS service definitions

The PUS implementation details, the service types, service subtypes, structures of the TC application data fields and structures of the TM source data fields are given in [AD-110], Volume A and are contained in the SRDB.

4.3.3 PUS annexes (incl. High priority TM)

SGICD-1747/SDS-5321, SDS-7085/R

All data tables which are common for all application processes on EarthCARE are defined in [AD-110], Volume B, "Common Data Tables".

4.4 CSW Application Data ICD

The CSW provides the central control of the EarthCARE satellite and comprises the following applications processes:

- DMS
- AOCS
- Platform Control
- Payload Control
- System

The CSW data ICD defines the format of all CSW application TM and TC packets and parameters as well as the related default values and it is established by [AD-05]

All CSW data definitions are contained in the SRDB.

SGICD-1757/SDS-5322/T,R

The CSW applications are essentially operated via standard services of the Core PUS [AD-110]. Within the CSW the following private services are defined consistently with [AD-110] Volume B.

CSW			
Private Services	type	subtype	Description
DMS			
AOCS			
Platform Control			
Payload Control			
System			

Note: The CSW private service types are not yet available

Table 4.4-1: ***CSW private service type summary table***

SGICD-1793/SDS-5322/R

Within the CSW the following detailed private service type and sub-type extensions are defined:

Note: Detailed definitions of CSW private service types and sub-types are not yet available

Table 4.4-2: ***CSW private service type and sub-type definition table***

4.5 MMFU Data ICD

The MMFU data ICD defines the format of all MMFU TM and TC packets and parameters as well as the related default values and is established by [AD-15].

All MMFU data definitions are contained in the SRDB.

SGICD-1798//T,R

The MMFU is operated via standard services of the Core PUS [AD-110]. No additional private services are defined for the MMFU. The MMFU data storage and retrieval functions are controlled via service 15 of the EarthCARE Core PUS [AD-110].

SGICD-1799/SDS-5322/T,R

Following extension of the service 15 Data Storage and Revtrieval service sub-type definitions of the Core PUS [AD-110] are agreed for the EarthCARE MMFU:

MMFU			
Service	Sub Service		Name
			Service 15 - Data Storage and Retrieval
15	216	TC	Packet Index Table Report Request
15	217	TM	Packet Index Table Report
15	218	TC	Report Block Link Table
15	219	TM	Block Link Table Report

Table 4.5-1: ***MMFU private service sub-type definition table***

4.6 STR Data ICD

The STR data ICD defines the format of all Star Tracker TM and TC packets and parameters as well as the related default values and is established by [AD-20]

All STR data definitions are contained in the SRDB.

SGICD-1901/SDS-5322/T,R

The STR's are operated via standard services of the Core PUS [AD-110]. For the Star Tracker the following private services are defined consistently with [AD-110] Volume B

Star Tracker	STR		
Private Services	type	subtype	Description
Monitoring and Control	220		STR MODE MANAGEMENT
	221		STR SPECIFIC TABLE LOAD/DUMP
	222		Not used
	223		STR SPECIFIC MEMORY HANDLING
	224		STR SPECIFIC PARAMETER MANAGEMENT

Table 4.6-1: ***STRprivate service summary table***

SGICD-1940/SDS-5322/R

For the Star Tracker the following detailed private service type and sub-type extensions are defined:

STR			
Service	Sub Service		Name
			Service 220 - STR MODE MANAGEMENT
220	1	TC	PASS TO STANDBY MODE
220	2	TC	PASS TO AAD MODE
220	3	TC	PASS TO PHOTO MODE
220	4	TC	PERFORM RESET
			Service 221 - STR SPECIFIC TABLE LOAD/DUMP
221	1	TC	UPLOAD PART1 OF SENSOR CALIBRATION DATA
221	2	TC	UPLOAD PART2 OF SENSOR CALIBRATION DATA
221	3	TC	UPLOAD PART3 OF SENSOR CALIBRATION DATA
221	4	TC	UPLOAD PART4 OF SENSOR CALIBRATION DATA
221	5	TC	UPLOAD PART5 OF SENSOR CALIBRATION DATA
221	6	TC	UPLOAD PART6 OF SENSOR CALIBRATION DATA
221	7		N/A

STR			
221	8		N/A
221	9		N/A
221	10	TC	UPLOAD PREPROCESSOR REGISTER CONFIGURATION
221	11	TC	UPLOAD ALGORITHM CONTROL PARAMETERS
221	12	TC	UPLOAD PART OF THE GSC TABLE
221	13	TC	UPLOAD PART OF THE GSC INDEX TABLE
221	14		N/A
221	15		N/A
221	16		N/A
221	17		N/A
221	18		N/A
221	19		N/A
221	20	TC	DUMP SENSOR CALIBRATION DATA
221	21	TC	DUMP PREPROCESSOR CONFIGURATION
221	22	TC	DUMP ALGORITHM CONTROL PARAMETERS
221	23	TC	DUMP PART OF THE GSC TABLE
221	24	TC	DUMP PART OF THE GSC INDEX TABLE
221	25		N/A
221	26		N/A
221	27		N/A
221	28		N/A
221	29		N/A
221	30	TM	CALIBRATION DATA DUMP
221	31	TM	PREPROCESSOR CONFIGURATION DUMP
221	32	TM	ALGORITHM PARAMETER TABLE DUMP
221	33	TM	GUIDE STAR CATALOGUE DUMP
221	34	TM	GSC TILE INDEX LIST DUMP
			Service 223 - STR SPECIFIC MEMORY HANDLING TCs
223	1	TC	ENABLE TC(6,5) AND TC(6,9) FOR A SPECIFIED MEMID
223	2	TC	ENABLE TC(6,2) FOR A SPECIFIED MEMID

STR			
223	3	TC	DISABLE TC(6,5) AND TC(6,9) FOR A SPECIFIED MEMID
223	4	TC	DISABLE TC(6,2) FOR A SPECIFIED MEMID
223	5		N/A
223	6		N/A
223	7		N/A
223	8		N/A
223	9		N/A
223	10	TC	COPY THE APSW FROM EEPROM TO THE TEST APPLICATION AREA
223	11	TC	COPY THE APSW FROM THE TEST APPLICATION AREA TO EEPROM
			Service 224 - STR SPECIFIC PARAMETER MANAGEMENT
224	1	TC	ENABLE/DISABLE THE TC_TEMPERATURE COMMAND
224	2		N/A
224	3		N/A
224	4	TC	UPDATE PRECESSION CORRECTION PARAMETERS
224	5	TC	UPDATE ABERRATION CORRECTION PARAMETERS
224	6	TC	SET UPPER LIMIT FOR X AND Y COMPONENTS OF THE RATE
224	7	TC	SPECIFY TARGET DETECTOR TEMPERATURE
224	8	TC	SET COUNTERS TO ZERO

Table 4.6-2: ***STR private service type definition table***

4.7 GPS Data ICD

The GPS data ICD defines the format of all GPS Receiver TM and TC packets and parameters as well as the related default values and is established

- By [AD-25] for all GPS monitoring and control related data
- By [AD-26] for GPS measurement data

All data definitions are contained in the SRDB.

SGICD-2234/SDS-5322/T,R

The GPS Receiver is operated via standard services of the Core PUS [AD-110].

For the GPS Receiver the following private services are defined consistently with [AD-110] Volume B

GPS Receiver	GPSR private service overview		
Private Services	type	subtype	Description
Monitoring and Control	210		GPS Mode Service
	211		GPS Parameter Service
	212		GPS Science Data Service
	213		GPS Periodic Memory Diagnosis Service

Table 4.7-1: ***GPS private service summary table***

SGICD-2267/SDS-5322/R

For the GPS receiver the following detailed private service type and sub-type extensions are defined:

GPSR private service type/sub-type definitions			
Service	Sub Service		Name
			Service 5 - EVENT Management Service
5	210	TC	Enable Event Packet Generation
5	211	TC	Disable Event Packet Generation
5	212	TC	Report Disabled Event Packets
5	213	TM	Disabled Event Packets Report
			Service 6 - Memory Management Service
6	210	TC	Copy Memory
6	211		N/A
6	212	TC	Load Memory using Absolute Addresses
6	213		N/A
6	214		N/A
6	215	TC	Dump Memory using Absolute Addresses
6	216	TM	Memory Dump using Absolute Addresses Report

GPSR private service type/sub-type definitions			
6	217		N/A
6	218	TM	Memory Check Report using Absolute Addresses
6	219	TC	Check Memory using Absolute Addresses
			Service 210 - GPS MODE Management Service
210	1	TC	MODE CHANGE
			Service 211 - GPS FUNCTION PARAMETER HANDLING
211	1	TC	Pre-Load GPS Function Parameter
211	2	TC	Report GPS Function Parameter
211	3	TM	GPS Function Parameter Report
			Service 212 - GPS Measurement (Science) Data Reporting
212	1	TM	GPS Measurement (Science) Data Reports (supporting 17 different SID's)
			Service 213 - GPS Periodic Memory Diagnosis Service
213	1	TC	GPS periodic Memory Diagnosis
213	2	TM	GPS periodic Memory Diagnosis Report
213	3	TC	GPS Abort Memory Service Command

Table 4.7-2: ***GPS private service type and sub-type definition table***

5 SATELLITE TO GROUND INSTRUMENT DATA INTERFACE

5.1 Instrument Data Flow and Configuration

The instrument data flow is depicetd in Figure 4.1-1. All instrument commanding is performed via the S-Band uplink. The TCs addressed to an instrument are received by the OBC and forwarded to the instrument addressed by the TC header parameter PRID, which is completely in charge of the TC acceptance and execution checks.

Instruments generate HK data in form of PUS TM Source Packets. They are routed to the OBC and inserted in the S-Band real time downlink. In parallel they are stored in the OBC internal mass memory. The stored HK is transmitted to ground during ground contacts upon command.

The instrument insert its measurement as well as calibration data together with high rate ancillary data in PUS compatible TM Science Packets. These are stored in the MMFU for later transmission to ground. In addition, slowly varying instrument ancillary data are provided in private data field headers.

Any telemetry packet contains in the secondary packet header a time status field indicating the on-board synchronisation state of the instrument w.r.t. the central on-board time reference.

In addition instrument science TM packets contain in the private data field header a 32 bit S/C State Vector quality field indicating

- the validity of the S/C information used by the instrument.
- the high level S/C state
- the synchronisation state of the COBT w.r.t. GPS time system

The S/C sends to each instrument the S/C state vector command, which contains the S/C state vector quality parameter and the propagated orbit information to perform realtime corrections based on orbit position. Each instrument extracts all S/C state vector command parameters into its data pool. The first parameter (32 bit field) contains the S/C State Vector quality parameter. This parameter is embedded by the instrument into in the reserved field in the private data field header. Details of the information are provided in [RD-04].

Any of this information can be taken for initial quality control of the provided data w.r.t. S/C support functions

5.2 ATLID Data ICD

The ATLID data ICD defines the format of all ATLID TM and TC packets and parameters as well as the related default values and is established

- By [AD-51] for operation in INS-INI mode
- By [AD-40] for operation in all higher instrument modes

All data definitions are contained in the SRDB. The instrument science packet structures are defined in the SRDB-D, but exported and provided as IMDD files to the ground segment. The EarthCARE Level 0 Product definitions [RD-07] define the individual parameters and their usage for the scientific products processing in detail.

SGICD-2433/SDS-5322, SDS-6704/T,R

ATLID is essentially operated via standard services of the Core PUS [AD-110].

For ATLID the following private services are defined consistently with [AD-110] Volume B

Instrument	ATLID		
Private Services	type	subtype	Description
Science Data Services	225	1	DRD-M data LIDAR
	225	2	DRD-M data RONC
	225	3	DRD-M data Imaging
	225	4	DRD-M data UPD
	226	1	DRD-C CAS data
	226	2	Investigation data
Monitoring and Control Services	227		Operational Parameters
	228		Serial Lines
Common Reporting Service	199		Instrument Reports

Table 5.2-1: ***ATLID private service summary table***

SGICD-2500/SDS-5322/R

For ATLID the following detailed private service type and sub-type extensions are defined:

ATLID private service type and sub-types			
Service	Sub Service		Name
			Service 149 - Thermal Control Service
149	160	TC	Start Thermal Control
149	161	TC	Stop Thermal Control
149	162	TC	Enable Thermal Control Loop
149	163	TC	Update Thermal Control Loop Parameters

ATLID private service type and sub-types			
149	164	TC	Report Thermal Control Loop Parameters
149	165	TM	Thermal Control Loop Parameters Report
149	166	TC	Update Thermal Control Loop Temperature Sensor
149	167	TC	Update Thermal Control Loop Set Point Temperature
149	168	TC	Update Thermal Control Table
149	169	TC	Report Thermal Control Table
149	170	TM	Thermal Control Table Report
149	171	TC	Load Thermal Control Table
149	172	TC	Set Heater Line
149	173	TC	Switch Thermal Control Power ON
149	174	TC	Switch Thermal Control Power OFF
			Service 227 - Operational Parameters Service
227	1	TC	Modify BRC_SYN Parameters
227	2	TC	Report BRC_SYN Parameters
227	3	TM	BRC_SYN Parameters Report
227	4	TC	Modify CA_BSM Parameters
227	5	TC	Report CA_BSM Parameters
227	6	TM	CA_BSM Parameters Report
227	7	TC	Modify FSC_TLE Parameters
227	8	TC	Report FSC_TLE Parameters
227	9	TM	FSC_TLE Parameters Report
227	10	TC	Modify CSC_TLE Parameters
227	11	TC	Report CSC_TLE Parameters
227	12	TM	FSC_TLE Parameters Report
227	13	TC	Modify LTDA_TLE Parameters
227	14	TC	Report LTDA_TLE Parameters
227	15	TM	LTDA_TLE Parameters Report
227	16	TC	Modify EM_DEF Parameters
227	17	TC	Report EM_DEF Parameters
227	18	TM	EM_DEF Parameters Report

ATLID private service type and sub-types			
227	19	TC	Modify BKGE_TEMP Parameters
227	20	TC	Report BKGE_TEMP Parameters
227	21	TM	BKGE_TEMP Parameters Report
227	22	TC	Modify TLE_OP_TABLE Parameters
227	23	TC	Report TLE_OP_TABLE Parameters
227	24	TM	TLE_OP_TABLE Parameters Report
227	25	TC	Modify IDE_OP_TABLE Parameters
227	26	TC	Report IDE_OP_TABLE Parameters
227	27	TM	IDE_OP_TABLE Parameters Report
227	28	TC	Modify BSM_OP_TABLE Parameters
227	29	TC	Report BSM_OP_TABLE Parameters
227	30	TM	BSM_OP_TABLE Parameters Report
227	31	TC	DT3 Counter Reset
227	32	TC	Report DT3 Counter
227	33	TM	DT3 Counter Report
			Service 228 - Serial Lines Service
228	1	TC	Enable IDE TM Request
228	2	TC	Disable IDE TM Request
228	3	TC	IDE Serial Command
228	21	TC	Enable BSM TM Request
228	22	TC	Inhibit BSM TM Request
228	23	TC	BSM Serial Command
228	25	TC	Set BSM Position
228	26	TC	Set BSM Nominal Position
228	41	TC	Enable TLE TM Request
228	42	TC	Inhibit TLE TM Request
228	43	TC	TLE Serial Command
			Service 199 - Instrument Reports Service
199	1	TC	Reset Boot Report
199	2	TC	Dump Boot Report

ATLID private service type and sub-types			
199	3	TM	Boot Report
199	4	TC	Dump Death Report
199	5	TM	Death Report
199	6	TC	Reset History Area
199	7	TC	Dump History Area
199	8	TM	History Area Report

Table 5.2-2: ***ATLID private service type and sub-type definition table***

5.3 BBR Data ICD

The BBR data ICD defines the format of all BBR TM and TC packets and parameters as well as the related default values and is established

- By [AD-51] for operation in INS-INI mode
- By [AD-50] for operation in all higher instrument modes

All data definitions are contained in the SRDB. The instrument science packet structures are defined in the SRDB-D, but exported and provided as IMDD files to the ground segment. The EarthCARE Level 0 Product definitions [RD-07] define the individual parameters and their usage for the scientific products processing in detail.

SGICD-2819/SDS-5322, SDS-6704/T,R

BBR is essentially operated via standard services of the Core PUS [AD-110]. For BBR the following private services are defined consistently with [AD-110] Volume B

Instrument	BBR		
Private Services	type	subtype	Description
Science Data Services	230	1	Processed data
	230	65	Raw data
Monitoring and Control Services	231		Calibration Target Drive
	232		Black Body PWM Control
	233		Chopper Drum Control
Common Reporting Service	199		Instrument Reports

Table 5.3-1: *BBR private service summary table*

SGICD-2868/SDS-5322/R

For BBR the following detailed private service type and sub-type extensions are defined.

BBR			
Service	Sub Service		Name
			Service 149 - Thermal Control Service
149	100	TC	Start Thermal Control
149	101	TC	Stop Thermal Control
149	102	TM	Modify Thermal Contro Settings Table
149	103	TC	Down Link Heater Control Table
149	104	TM	Heater Control Table
149	105	TC	Modify PRT Health Status Table
			Service 231 - Calibration Target Drive

BBR			
231	2	TC	Get CTM Profile Table Report
231	4	TC	Orbital TW CAL Interval Profile
231	7	TC	Activate SW/PD CAL MCMD
231	8	TC	Activate Nominal Calibration Cycle
231	9	TC	Deactivate Nominal Calibration Cycle
231	10	TM	CTM Profile Table Report
231	11	TC	Abort Ongoing Long Duration Slew
231	12	TC	CTM to Viewing Position from Parked
			Service 232 - Black Body PWM Control
232	1	TC	Set Black Body PWM Control
232	2	TC	Get PWM Control Report
232	3	TM	PWM Control Report
			Private Service 233 - Chopper Drum Control
233	1	TC	Start Chopper Drum
233	2	TC	Stop Chopper Drum
			Service 199 - Instrument Reports Service
199	1	TC	Reset Boot Report
199	2	TC	Dump Boot Report
199	3	TM	Boot Report
199	4	TC	Dump Death Report
199	5	TM	Death Report
199	6	TC	Reset History Area
199	7	TC	Dump History Area
199	8	TM	History Area Report

Table 5.3-2: ***BBR private service type and sub-type definition table***

5.4 MSI Data ICD

The MSI data ICD defines the format of all MSI TM and TC packets and parameters as well as the related default values and is established

- By [AD-51] for operation in INS-INI mode
- By [AD-60] for operation in all higher instrument modes

All data definitions are contained in the SRDB. The instrument science packet structures are defined in the SRDB-D, but exported and provided as IMDD files to the ground segment. The EarthCARE Level 0 Product definitions [RD-07] define the individual parameters and their usage for the scientific products processing in detail.

SGICD-3052/SDS-5322, SDS-6704/T,R

MSI is essentially operated via standard services of the Core PUS [AD-110]. For MSI the following private services are defined consistently with [AD-110] Volume B.

Instrument	MSI		
Private Services	type	subtype	Description
Science Data Services	235	1	Processed data
	235	65	Raw data
Monitoring and Control Services	236		VNS Mechanism Control
	237		Flat Field Control
	238		FEE Register Control
	239		TIR Mechanism Control
Common Reporting Service	199		Instrument Reports

Table 5.4-1: ***MSI private service summary table***

SGICD-3101/SDS-5322/R

For MSI the following detailed private service type and sub-type extensions are defined.

MSI			
Service	Sub Service		Name
			Service 149 - Thermal Control Service
149	130	TC	Start Thermal Control
149	131	TC	Stop Thermal Control
149	132	TC	Enable Thermal Control Loop
149	133	TC	Update Thermal Control Loop Parameters
149	134	TC	Report Thermal Control Loop Parameters
149	135	TM	Thermal Control Loop Parameters Report

MSI			
149	136	TC	Update Thermal Control Loop Temperature Pair
149	138	TC	Set Peltier Cooler Constant Current
149	140	TC	Set Heater Constant Power
			Service 236 - VNSOU Mechanism Control Service
236	1	TC	Power ON VNSOU Mechanism Encoders
236	2	TC	Power OFF VNSOU Mechanism Encoders
236	5	TC	Set VNSOU Mechanism to Solar Diffuser View 1
236	6	TC	Set VNSOU Mechanism to Solar Diffuser View 2
236	7	TC	Set VNSOU Mechanism to Dark View
236	8	TC	Set VNSOU Mechanism to Nadir View
236	10	TC	Command VNSOU Mechanism
236	11	TC	Report VNSOU Mechanism Position
236	12	TM	VNSOU Mechanism Position Report
236	13	TC	Abort VNS Mechanism Operation
236	15	TC	Set VNSOU Mechanism Final Deceleration Phase
236	16	TC	Set VNSOU Mechanism Low Speed Coasting Phase
236	20	TC	Start VNS Mechanism Seek
236	21	TC	Generate VNS Reference Set
236	22	TC	Set VNS Pointing Direction
			Service 237 - Flat Field Control Service
237	1	TC	Load TIR Flat Field Reference Set
237	2	TC	Load VNS Flat Field Reference Set
237	3	TC	Set Flat Field Average Number
237	4	TC	Dump Flat Field Band
237	5	TC	Read Flat Field Band from FPGA
237	6	TM	Flat Field Band Report
			Service 238 - FEE Control Service
238	1	TC	Power ON FEE
238	2	TC	Power OFF FEE
238	3	TC	Set Timing Pulse Interval

MSI			
238	4	TC	Write FEE Register
238	5	TC	Read FEE Register
238	6	TM	FEE Register Response
238	7	TC	FEE Load Register
238	8	TC	FEE Check Register
238	9	TC	FEE Status Register Request
238	10	TC	FEE Internal Voltage Register Request
238	11	TC	Start FEE Memory Test
238	12	TC	Enable FEE Memory Test
238	13	TC	Abort FEE Memory Test
238	14	TC	FEE Clear EDAC Error
238	15	TC	FEE Register Test
238	16	TC	Start FEE-controlled FEE Memory Test
			Service 239 - TIROU Mechanism Control Service
239	1	TC	Power ON TIROU Mechanism Encoders
239	2	TC	Power OFF TIROU Mechanism Encoders
239	5	TC	Set TIROU Mechanism to Cold Space View
239	6	TC	Set TIROU Mechanism to Black Body View
239	7	TC	Set TIROU Mechanism to Nadir View
239	10	TC	Command TIROU Mechanism
239	11	TC	Report TIROU Mechanism Position
239	12	TM	TIROU Mechanism Position Report
239	13	TC	Abort TIR Mechanism Operation
239	15	TC	Set TIROU Mechanism Final Deceleration Phase
239	16	TC	Set TIROU Mechanism Low Speed Coasting Phase
239	20	TC	Start TIR Mechanism Seek
239	21	TC	Generate TIR Reference Set
239	22	TC	Dwell at TIR Cold Space View
239	23	TC	Dwell at TIR Black Body View
239	24	TC	Set TIR Pointing Direction

MSI			
			Service 199 - Instrument Reports Service
199	1	TC	Reset Boot Report
199	2	TC	Dump Boot Report
199	3	TM	Boot Report
199	4	TC	Dump Death Report
199	5	TM	Death Report
199	6	TC	Reset History Area
199	7	TC	Dump History Area
199	8	TM	History Area Report

Table 5.4-2: ***MSI private service type and sub-type definition table***

5.5 CPR Data ICD

The format of these packets are defined in [AD-70], appendix 3 and 4, and are contained in the SRDB.

SGICD-3737/SDS-5322, SDS-6704/T,R

CPR is essentially operated via a reduced set of standard services of the Core PUS [AD-110]. The supported standard services are identfied in [AD-70]. For CPR the following private services are defined consistently with [AD-110] Volume B.

Instrument	CPR		
Private Services	type	subtype	Description
Science Data Services	240	1	Processed data (TBC)
Monitoring and Control Services	241	1	Maintenance
	242		not used
	243		not used
	244		not used

Note: The CPR private service types are not yet available

Table 5.5-1: *CPR private service summary table*

SGICD-3637/SDS-5322/R

For CPR following detailed private service types and sub-ytpe extensions are defined:

CPR			
Service	Sub Service		Name
241	1		Telemetry output Interruption

CPR			

Table 5.5-2: ***CPR private service type and sub-type definition table***

Note: Detailed definitions of CSW private service types and sub-types are not yet available

6 SATELLITE ASSUMPTIONS ON THE GROUND SEGMENT

6.1 Ground Segment Function Summary

The EarthCARE Ground System encompasses at least Flight Operations Segment and a Payload Data Ground Segment.

The Flight Operations Segment provides

- Mission control for commanding and monitoring the Satellite in orbit
- Flight dynamics for manoeuvring one Satellite at a time, for orbit prediction and restitution, and for generation of Ground Stations acquisition data
- Simulation of the Satellite for operations rehearsals and training, for LEOP, Commissioning, and routine Operations
- Support functions for PDGS provided instrument mission operation and mission data management

The Payload Data Ground Segment provides

- Acquisition of Mission data from the Satellite, decompression, processing, archiving and dissemination of User products (Level of products TBD)
- Product quality control and instrument calibration
- Mission planning for operation of all four EarthCARE instruments.

The FOS is operated by ESA/ESOC in Darmstadt/Germany, whereas the PDGS operations is managed by ESA/ESRIN in Frascati/Italy

The Mission operations start at switch-over to satellite internal power and commence at separation of the satellite from the launcher and continue until disposal at the end of the mission. The mission operations will be conducted by the ground station network given in Section 2.2.2

Mission operations will include the following tasks:

- Mission Planning will operate the satellite according to a High Level Operations Plan to be provided by ESA/ESOC. ESOC will detail mission operations in a Flight Operations Plan. Satellite related information will be provided by the satellite prime
- Satellite status monitoring by means of processing the housekeeping telemetry such that the status of all satellite sub-systems can be monitored. Monitoring includes attitude monitoring.
- Satellite control taking control actions by means of immediate or time-tagged or orbit position scheduled telecommands following the Flight Operations Plan and responding to monitoring anomalies. From the available TM and the commands sent to the S/C, the FOS is able to compute the occupation of the MTL and OPS schedules accurately. In line with the basic system requirements, the FOS acquires the HK telemetry every orbit (apart from blind orbits). The FOS is also able to initiate ground recovery if the TM indicates to do so.
- Orbit determination and control using tracking data both provided by the sensors of the attitude and orbit control system and by ground tracking and implementing orbit manoeuvres to change the satellite velocity such that required orbital conditions are achieved.
- Attitude determination and monitoring based on the processed attitude sensor data in the satellite telemetry.
- On-board software maintenance
- Acquisition, processing, archiving and distribution of scientific data products. Efficient embedding of the EarthCARE ground processor into the science data processing chain is a key element to achieve the EC mission objective.

The operations support activities for the EarthCARE satellite will be conducted according to the following concept:

- All Satellite operations will be conducted by ESA/ESOC/ESRIN according to procedures laid down in the Flight Operations Plan established by ESA.
- Satellite control during the operational phase will be quasi ‘off-line’ according to the mission settings. Real time operations will be reduced to a minimum. For command and control, only one Ground

Station will be used. The contacts between the Mission Operations Control Centre and the satellite will primarily be used for pre-programming of those autonomous operations functions on the spacecraft, and for housekeeping and payload data collection for off-line status assessment and anomalies detection

- Satellite compatibility with the ESA station network is ascertained by the Satellite to Ground Interface Document.
- The measurement data provided by the instruments are in big-endian number representation, which will be appropriately handled within the data reception and processing chain of the ground segment.
- Efficient data distribution and processing is ascertained in the ground segment

6.2 Detailed Assumptions on the Ground Segment

6.2.1 Spacecraft Command and Control

Spacecraft command and control operation is based on the assumption that

(1) The FOS mission control system (MCS) supports the agreed EarthCARE Packet Utilization Standard [AD-110] and all monitoring and control data interfaces defined in Section 4 and Section 5

(2) The MCS is capable to generate and send commands with

- CRC
- Source ID set according to the on-board command source identified by the upload command
- Source sequence counter generated by on-board command source dedicated algorithm

embedded into upload commands for all service sub-types identified in [AD-110]

(3) The ground segment supports time correlation between on-board time and UTC based on the [ND-145] compatible telemetry frame synchronisation and datation concept of [AD-110]. During operation phases, where the on-board GPS receiver is not operated, the OBT to UTC time correlation is provided by this capability supporting those phase with an adequate number of ground station passes to maintain the required OBT to UTC time correlation performance.

(4) From the available TM and the commands sent to the S/C, the FOS is able to compute the occupation of the MTL and OPS schedules accurately.

(5) Onboard schedule conflicts between MTL and OPS are detectable at FOS level. Potential conflicts shall be solved prior to the related telecommand uplink.

(6) The generation of the MTL and OPS command schedule is compatible with the following command slot assignment:

- Within 1 second, there are 10 commanding slots with 100 ms each
- Each slot can be assigned either assigned to OPS or MTL commands
- The number of telecommands per second is limited to 10 in total (max. 5 x OPS + 5 x MTL).

(7) Ground commands for immediate execution shall use the same slots. In case of conflicts, ground commands get priority and might delay the OPS/MTL commanding, i.e. the OPS/MTL commands will be queued until the next free OPS/MTL slot. Priority is given to the MTL commands.

(8) Maximum effective commanding through-put data rate to the S/C is 20 kbit/sec or 10 TC's per second of arbitrary size

(9) In COP and MOP the complete HK recording onboard is available to and processed by the FOS within 3 (TBC) hour from S- or X-band downlink.

(10) Especially in LEOP the complete HK recording onboard shall be available to and processed by the FOS within 1 hour from S-band downlink. Reaction to onboard anomalies requiring ground intervention can be initiated.(TBC)

(12) For contingency handling FOS shall provide a capability to initiate ground based recovery actions based on specific TM provided by the satellite

(13) The routine and maintenance instrument operation schedule shall be generated by the EC GS and uploaded to the spacecraft after resolution of potential on-board scheduling conflicts.

(14) The EC G/S shall generate and upload the on-board mission plan for CPR routine instrument operation including the required instrument operation sequences required for protection of radio astronomy sites according to the regulations of the Space Frequency Coordination Group (SFCG) w.r.t. CPR radar emissions.

(15) The EC G/S shall implement the orbit control manoeuvre strategy defined in [RD-06] and

generate and upload the related on-board mission plan based on the operational sequences defined in EC Space Segment User Manual

(16) S- and X-band operation schedule shall be generated by the EC G/S and loaded into the on-board orbit position scheduler acc. to the station availability of the next autonomy period

(17) Data correlation is based on correlation of TM parameter related time stamps which are either explicitly provided or which can be implicitly derived from the packet time according to a pre-defined relation. Remark: Details are given in [RD-04] chapter 9.5 On-board Packet Routing and Storage Concept.

6.2.2 Mission Data Reception and Processing

Mission data management is based on the assumption that

(1) The EC GS shall able to receive and process all spacecraft telemetry as depicted in Section 4 and Section 5

(2) All instrument parameters required for measurement data processing are embedded in the data stream received via the instrument science data specific X-band virtual channel as instrument ancillary data either as part of the instrument source packets or as dedicated instrument ancillary data source packets

(3) S/C ancillary data are part of the S/C telemetry, which is downlinked in a dedicated X-band virtual channel

(4) Instrument Housekeeping data are not used for instrument science data processing

(5) S/C playback telemetry received via X-band downlink can be forwarded to FOS

(6) PDGS shall decode and use satellite ancillary data limited to GPS and STR, whilst TM for instrument health monitoring shall be extracted by FOS and provided to PDGS.

(7) Data correlation is based on correlation of TM parameter related time stamps which are either explicitly provided or which can be implicitly derived from the packet time according to a pre-defined relation.

(8) The level 0 and 1B products shall comply with [RD-07]

(9) Based on S/C ancillary data defined in [AD-2] the EarthCARE G/S shall be able to perform EarthCARE orbit restitution on ground with the following performance:

	GPS Absolute Measurement			
	Along Track RMS	Across Track RMS	Radial RMS	
Position	20	20	20	m
Velocity	0.03	0.03	0.03	m/s

(10) The on-ground orbit restitution process shall be compatible with maximum data gaps of on-board navigation products in the S/C ancillary data of 1 orbit maximum

(11) Based on S/C ancillary data defind in [AD-02] the EarthCARE G/S shall be able to perform EarthCARE attitude restitution on ground with the following performance:

	Attitude Absolute Measurement Error									
	roll			pitch			yaw			
	Bias	Harmonic	Random	Bias	Harmonic	Random	Bias	Harmonic	Random	
Requirement (RMS)	90	5	40	90	5	40	90	5	50	µrad

(12) The on-ground attitude restitution process shall be compatible with maximum data gaps of on-board attitude products in the S/C ancillary data of 30 (TBC) seconds maximum.

Requirement/Section Cross Reference

In case of MoM, Action Items have been put in AIDA

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