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GOCE

Ground Segment

Concept and Architecture

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6	4.2	Fig. 4-1: introduction of PDGS	
9	5.3	Consolidation of selected ground segment locations for the various ground segment elements	
13	6.2.2	Fig. 6-2: new figure describing the PDGS	
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1 Introduction

1.1 Background

The GOCE (Gravity Field and Steady-State Ocean Explorer) mission is the first core mission in the framework of the Earth Explorer Programme. The goal of the Earth Explorer Programme is research on fundamental problems of the physics and chemistry of the solid and fluid earth.

1.2 Purpose and Scope

The document describes the GOCE Ground Segment covering:

- ❖ mission objectives
- ❖ mission overview
- ❖ ground segment assumptions and constraints
- ❖ ground segment architecture and functions
- ❖ mission planning
- ❖ data processing
- ❖ scientific data distribution
- ❖ calibration and maintenance
- ❖ time correlation
- ❖ orbit and attitude control
- ❖ data circulation
- ❖ ground segment validation and testing
- ❖ ground segment operations
- ❖ ground segment implementation

1.3 Acronyms

AO	-	Announcement of Opportunity
ASH	-	Accelerometer Sensor Head
CDAF	-	Command and Data Acquisition Facility
CDMU	-	Command and Data Management Unit
CMF	-	Calibration/Monitoring Facility
DB	-	Database
DFACS	-	Drag-Free and Attitude Control System
DPA	-	Data Processing Archive
ECMWF	-	European Centre for Medium-range Weather Forecast
EGG	-	Electrostatic Gravity Gradiometer
EGG-C	-	European GOCE Gravity Consortium
ECP	-	External Calibration Products
FOCC	-	Flight Operation Control Centre



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FOS	- Flight Operations Segment
GOCE	- Gravity Field and Steady-State Ocean Explorer
GPS	- Global Positioning System
GS	- Ground Segment
HK	- Housekeeping
HLOP	- High Level Operations Plan
HPF	- High Level Processing Facility (L2)
IGS	- International GPS Service
IPF-1	- Instrument Processing Facility
LEOP	- Launch and Early Orbit Phase
LRR	- Laser Retro-Reflector
LTA	- Long Term Archive
MSS	- Mean Sea Surface
MUS	- Multi-Mission User Service
NRT	- Near Real-Time
OBCP	- On-board Control Procedures
OBT	- On-board Time
OFL	- Off-Line
PDS	- Payload Data System
POD	- Precise Orbit Determination
QLP	- Quick-Look Products
RF	- Radiofrequency
RPF	- Reference Planning Facility
SLR	- Satellite Laser Ranging
SPC	- Satellite Prime Contractor
SMF	- Software Maintenance Facility
UTC	- Universal Time Coordinated
VC	- Virtual Channel
SST	- Satellite-to-Satellite Tracking
SSTI	- Satellite-to-Satellite Tracking Instrument
SVT	- System Validation Test
S/W	- Software
TC	- Telecommand
TM	- Telemetry



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2 Applicable and Reference Documents

2.1 Applicable Documents

- [AD - 1] GOCE Mission Requirements Document, GO-RS-ESA-SY-0001
- [AD - 2] GOCE System Requirements Document, GO-RS-ESA-SY-0002
- [AD - 3] GOCE Operations Interface Requirements Document (OIRD), GO-ESC-RS-5006

2.2 Reference Documents

- [RD - 1] Gravity Field and Steady-State Ocean Circulation Mission, Reports for Mission Selection, SP-1233(1)
- [RD - 2] Earth Explorer Mission Conventions Document, CS-MA-DMS-GS-0001
- [RD - 3] Earth Explorer Ground Segment File Format Standard, CS-TN-ESA-GS-0154
- [RD - 4] GOCE Master ICD, GO-ID-ESA-GS-0037
- [RD - 5] GOCE Ground Segment Overall Validation Plan, GO-PL-ESA-GS-0042
- [RD - 6] GOCE Ground Segment Implementation Plan, GO-PL-ESA-GS-0038
- [RD - 7] GOCE Data Recording & Dumping Strategy, GO-TN-ESA-GS-0039
- [RD - 8] Mission Analysis Report, GO-RP-AI-0014
- [RD - 9] GOCE Products Definition Document (PDD), GO-EGG-PDD-1100
- [RD - 10] GOCE Architecture Design Document, no reference
- [RD - 11] Gradiometer Calibration Plan, GO-PL-AI-0039



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3 Mission Objectives

The primary aim of the GOCE mission is to provide unique models of the Earth's gravity field and of its equipotential reference surface, as represented by the geoid, on a global scale with high spatial resolution and to a very high accuracy. In particular, the GOCE mission covers the following fields

❖ marine geoid and its impact on ocean circulation

precise determination of the geoid to support the derivation of the ocean dynamic topography by comparing the geoid with the results of altimetric measurements of the mean sea surface (MSS); the MSS is presently known to several centimetres accuracy whereas the accuracy of geoid determination is on the level of decimetres

❖ geodynamics

high resolution determination of the earth gravity field to support research related to the structure and composition of the continental lithosphere as well as to the dynamics of the ocean lithosphere at ocean ridges and subduction zones

❖ geodesy

provision of height determination reference

The measurement principle of GOCE is gravity gradiometry combined with satellite-to-satellite tracking in the high-low mode (SST-hl) as described in more detail in ref. [AD - 1] and ref. [RD - 1]. The orbit determination is further supported by a laser retro-reflector (LRR).



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4 GOCE Mission Overview

The GOCE mission is composed of

- ❖ the GOCE Space Segment covering the spacecraft and the payload
- ❖ the GOCE Ground Segment covering
 - ◆ the Flight Operations Segment (FOS)
 - ◆ the Payload Data Segment (PDS)
 - ◆ the High Level Processing Facility (HPF)
 - ◆ the Reference Planning Facility (RPF) and the Calibration/Monitoring Facility (CMF)
 - ◆ the supporting elements with the Long Term Archive (LTA) and the Multi-Mission User Service (MUS)
 - ◆ external elements like the auxiliary data providers and the satellite prime contractor
- ❖ the GOCE User Community

4.1 GOCE Space Segment

The GOCE Space Segment is composed of

- ❖ the platform, including the propulsion system, the thermal control system, the Drag-Free and Attitude Control System (DFACS), the electrical power system and the data handling and communication system
- ❖ the payload consisting of
 - ◆ Electrostatic Gravity Gradiometer (EGG)
 - ◆ Satellite-to-Satellite Tracking Instrument Receiver (SSTI)
 - ◆ Laser Retro-Reflector (LRR)

The propulsion system includes the ion-propulsion sub-system and cold-gas thrusters, the latter are only used for calibration.

The communication system consists of an S-band communication link which is used for TM/TC as well as for the downlink of science data.

4.2 GOCE Ground Segment Facilities

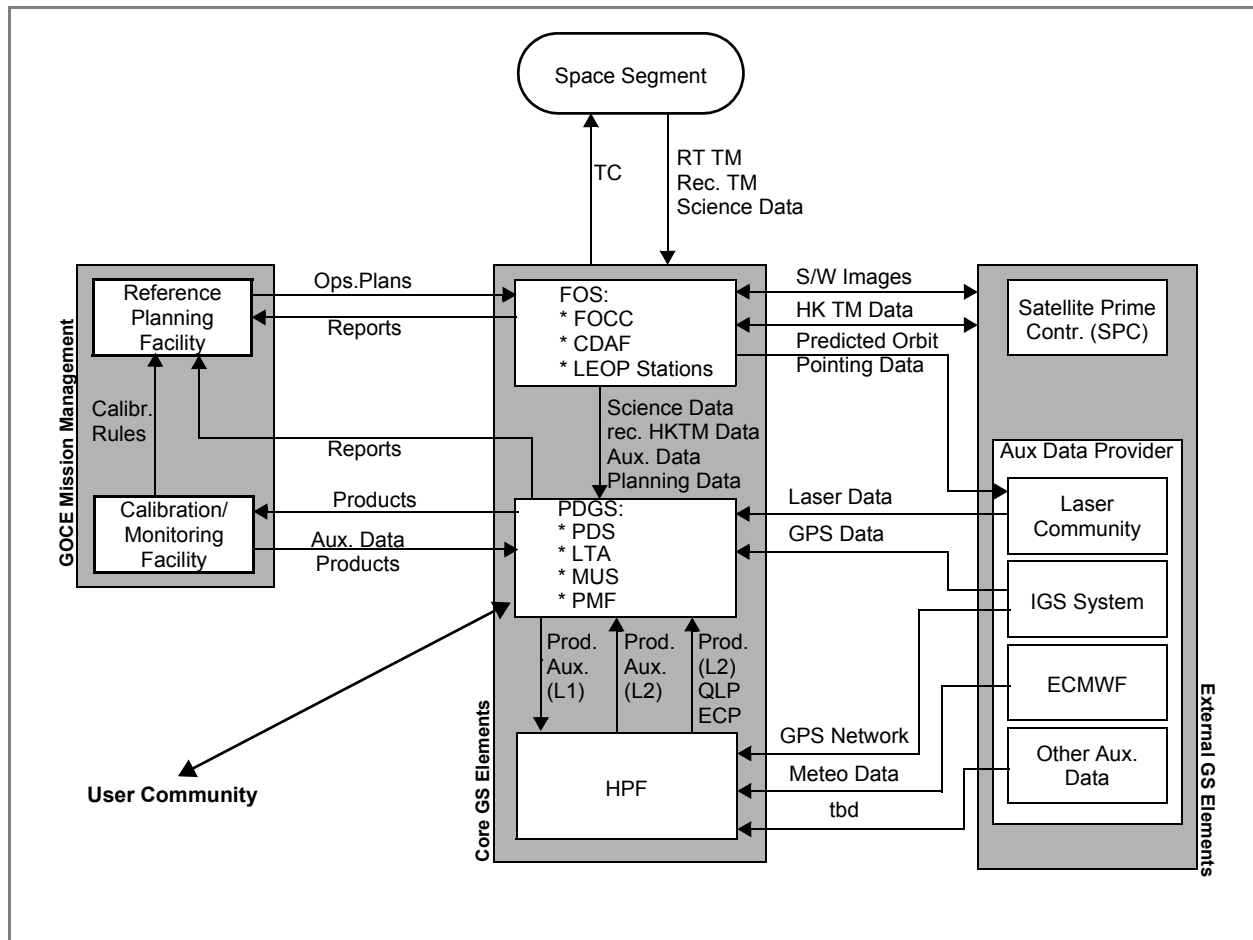
Fig. 4-1 provides an overview of the GOCE ground segment architecture.



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Fig. 4-1: Overview of GOCE Ground Segment Architecture



The GOCE Ground Segment is composed of ESA-controlled elements as well as external (non-ESA) elements:

❖ Core Ground Segment Elements (ESA-controlled)

- ◆ GOCE Flight Operations Segment (FOS), consisting of the Flight Operations Control Centre (FOCC) and the Command and Data Acquisition Facility (CDAF), charged with:
 - ☞ mission planning
 - ☞ command and control of the GOCE satellite and payload
 - ☞ monitoring satellite and payload systems
 - ☞ monitoring and control of the FOS ground segment facilities
- ◆ GOCE Payload Data Ground Segment (PDGS), consisting of the Payload Data Segment (PDS) including the Instrument Processing Facility (IPF1), the Long-Term Archive (LTA), the Performance Monitoring Facility (PMF) and the Multi-Mission User Service (MUS), charged with:
 - ☞ generation of L0 and L1 products, including calibration and scientific monitoring products, and distribution of L1 products including associated auxiliary data to the High-Level Processing Facility (HPF) and to the Calibration and Monitoring Facility (CMF)
 - ☞ monitor the performance of the PDGS with the PMF



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- ☞ checking the quality of the products
- ☞ archiving the PDS products and the products and reports generated by the CMF and PMF in the Long Term Archive (LTA) and providing access to these products via the Multi-Mission User Service (MUS)
- ◆ High-Level Processing Facility (HPF) charged with
 - ☞ the generation of L2 products and acquisition of the auxiliary data needed to generate the products
 - ☞ sending of L2 products (auxiliary, intermediate and final) to the PDGS
 - ☞ generation and provision of QL and ECP products
- ❖ GOCE Mission Management (ESA-controlled), consisting of
 - ◆ the Reference Planning Facility (RPF) charged with the provision of mission and calibration rules as well as on-board and on-ground configuration parameters
 - ◆ the Calibration/Monitoring Facility (CMF) charged with the calibration of the space segment and with the evaluation of products and monitoring data from the PDS, in order to assess the performance and health of the space segment
- ❖ External Ground Segment elements
 - ◆ Auxiliary Data Providers (ADP)s including (list not exhaustive) the
 - ☞ International GPS Service (IGS) to provide Global Positioning System (GPS) satellite orbit data required for the orbit determination by the PDS, and GPS ground station network data and GPS satellite orbit data required for the precise orbit determination by the CMF/RPF
 - ☞ other auxiliary services (e.g. ECMWF) to provide data to the CMF/RPF
 - ☞ ILRS to provide laser ranging and orbit data, which will be archived in the PDS and may be used as cross-check (and back-up) for orbit determination by the PDS
 - ◆ the Satellite Prime Contractor (SPC) to
 - ☞ operate the Software Maintenance Facility (SMF) to provide patches of the on-board software and of the on-board control procedures (OBCP)
 - ☞ provide house-keeping telemetry (HK TM) data recorded during Assembly Integration and Testing (AIT) activities
 - ☞ receive HK TM data recorded on-board to support satellite operations during the initialisation phase and for trouble-shooting

4.3 GOCE Users

The GOCE products archived in the LTA and will be made accessible to external users via the ESA Multi-Mission User Service (MUS) Facility. This covers the validated L1b and L2 products (see chap. 9).



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5 GOCE Assumptions and Constraints

5.1 Mission Phases

The mission is broken down into the following phases:

- ❖ Launch and Early Orbit Phase (LEOP): expected duration 2 weeks; covering launch, separation, safe pointing mode acquisition, S-band link acquisition and initial S/C check-out
- ❖ Commissioning Operational Phase (COP): expected duration 1.5 month including S/C nominal operations and satellite check-out, verification of the DFACS, activation and check-out of the gradiometer, SSTI receiver and SREM (tbc)
- ❖ First Payload Calibration Operational Phase (POP1): expected duration 1.5 month including the calibration of the gradiometer, the SSTI receiver and the DFACS
- ❖ First Measurement Operational Phase (MOP1): expected duration 6 month with continuous payload operations in nominal mode, the output of this phase are the geoid and earth gravity field products i.e. the mission scientific output, it ends at the beginning of the season of long eclipses
- ❖ First Hibernation Operational Phase (HOP1): expected duration 4.5 month covering orbit raise to a higher altitude and the subsequent orbit decay to the nominal altitude of POP2
- ❖ Second Payload Calibration Operational Phase (POP2): expected duration 2 weeks covering the re-activation of the DFACS and the re-activation and re-calibration of the gradiometer
- ❖ Second Measurement Operational Phase (MOP2): expected duration 6 month with the same operations than MOP1
- ❖ Extended Mission: consisting of the second hibernation phase (HOP2) and a third payload calibration phase (POP3) and measurement operation phase (MOP3)

The nominal mission has an expected duration of 20 month. The decision to extend the mission will be done at the end of the nominal mission depending of the overall system performance status at the end of the nominal mission. The maximum total duration of the extended mission is 30 month.

The processing and re-processing of L1b and L2 products as well as the distribution of data does not end with the MOPs. Due to the delay between L1b and L2 processing (see chap. 9), the final L2 products will be available after the end of the MOPs. In addition, re-processing of the L1b may be done after the satellite is not any more operational.

5.2 Assumptions on GOCE orbit and data downlink

During the calibration and measurement phases, the GOCE satellite will be positioned in circular sun-synchronous orbit with the following altitudes:

- ❖ POP1 and MOP1: 250 km
- ❖ POP2 and MOP2: 240 km
- ❖ POP3 and MOP3: 240 km (tbc)

The altitudes at the separation from the launcher and at the beginning of the hibernation phase HOP1 (HOP2) must be compatible with the altitudes for the respective payload calibration phases and will be between 270 km and 300 km.



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The GOCE spacecraft will be operated from a single ground station at Kiruna during all mission phases except LEOP. The Ground Segment will be, however, compatible with the retrieval of the downlinked data from a second ground station at Svalbard, if this is required.

The data downlink will be done with one S-band channel containing interleaved Virtual Channels with:

- ❖ real-time HK TM data downlink during the pass (channel VC0)
- ❖ real-time high priority HK TM data downlink during the pass (channel VC1)
- ❖ recorded HK TM data recorded during the entire orbit including the pass (channel VC3)
- ❖ science data recorded during the entire orbit including the pass (channel VC2)

The following assumptions are relevant for the data downlink:

- ❖ the GOCE orbit has on the average 3 passes over the Kiruna station twice per day, the two sequences of passes are separated by 12 h maximum
- ❖ in nominal cases, all passes will be used to downlink the telemetry data
- ❖ one pass in the afternoon will nominally be used to uplink telecommands
- ❖ the on-board telecommand storage capacity will be compliant with the above assumption for uplink
- ❖ the on-board telemetry storage capacity will be compliant with the above assumption for downlink
- ❖ on-board data storage capability for up to 72 h will be ensured for deferred dump of data in case of loss of frames

5.3 Assumptions on GS location

The following assumptions are relevant for the location of the various ground segment elements:

- ❖ The following ground station elements will be located at Kiruna¹:
 - ◆ the CDAF for telecommanding and telemetry acquisition (part of the FOS)
- ❖ The following ground station elements will be located at ESOC (Darmstadt):
 - ◆ the remaining part of the FOS namely the Flight Operation Control Centre (FOCC) for mission planning, telemetry retrieval and processing, telecommand and CDAF schedule generation
- ❖ The following ground station elements will be located at ESRIN (Frascati):
 - ◆ the PDS and the CMF/RPF
 - ◆ the PMF, the MUS and the LTA
- ❖ The High Level Processing Facility will be distributed over several locations where the infrastructure and experience are available.

5.4 Assumptions on On-Board Operations

The command and data storage capacity on-board the satellite will be compliant with a 72 h autonomy.

1. Kiruna as the only ground station for telecommanding and data acquisition is the baseline. However, the FOS and the PDS are compatible with the use of a second ground station in Svalbard if needed.



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The instrument operations are purely driven by eclipse periods. The instrument operations during POP and MOP phases will be continuous.

5.5 Assumptions on On-Ground Operations

The COP and POP phases operations will require extensive real-time support from the FOS operations team, the satellite prime contractor, the PDS and the GOCE project team. This will require a joint effort using the RPF and the CMF as the major tools.

The MOP phases operations will be compatible with support during normal working hours.

5.6 Assumptions on Processing

It will be possible to re-process the entire data collected during the mission, if required. This re-processing may either be done in the PDS or at another location.

5.7 Models, Constants and Units

All models, constants and units used in the GOCE Ground Segment are detailed in ref. [RD - 2].

6 Ground Segment Architecture and Functions

6.1 Overview

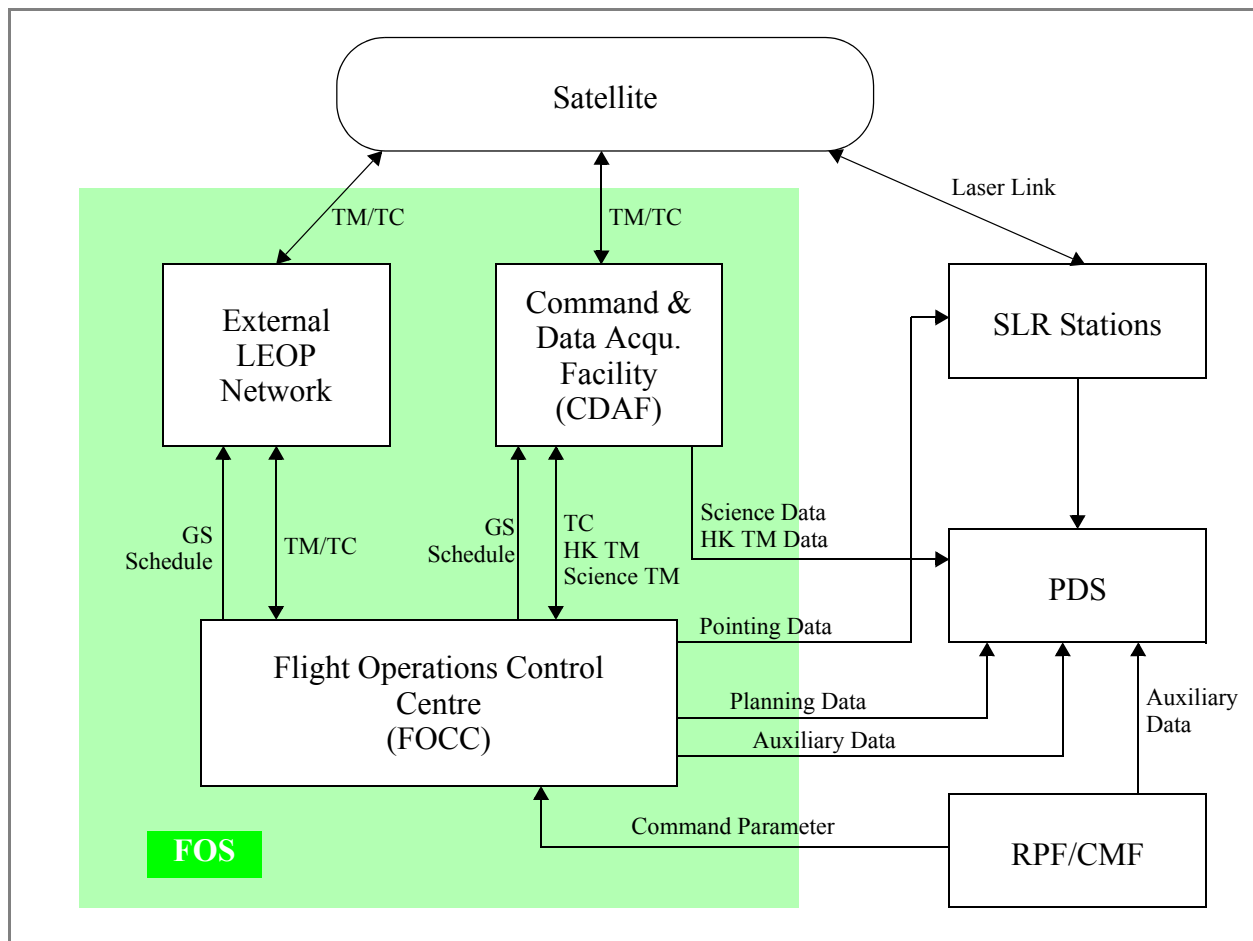
An overview of the GOCE Ground Segment is provided in section 4.2 and fig. 4-1

6.2 Core GS Elements (ESA Controlled)

6.2.1 FOS

The FOS system is provided in fig. 6-1.

Fig. 6-1: GOCE Flight Operations Segment



The main functions of the FOS are:

- ❖ planning and execution of the nominal platform operations
- ❖ planning and execution of the nominal instrument operations
- ❖ planning and execution of the CDAF operations at Kiruna and the station of the LEOP network
- ❖ monitoring the satellite platform and instrument status
- ❖ recovery from contingencies in case of satellite, instrument or FOS anomalies



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- ❖ quality checks of on-board S/W images and OBCPs and uplink of patches (provided by the SPC)
- ❖ generation and distribution of auxiliary data (e.g. orbit prediction)
- ❖ interface with
 - ◆ Reference Planning Facility for mission planning and reporting
 - ◆ the PDS providing planning data, science data, recorded HK TM data and auxiliary data
 - ◆ SLR stations providing the GOCE orbit prediction
 - ◆ Satellite Prime Contractor for on-board software maintenance, maintenance of on-board control procedures (OBCP) and exchange of HK TM data

6.2.2 PDGS

The PDGS system is provided in fig. 6-2.

The main functions of the PDGS are:

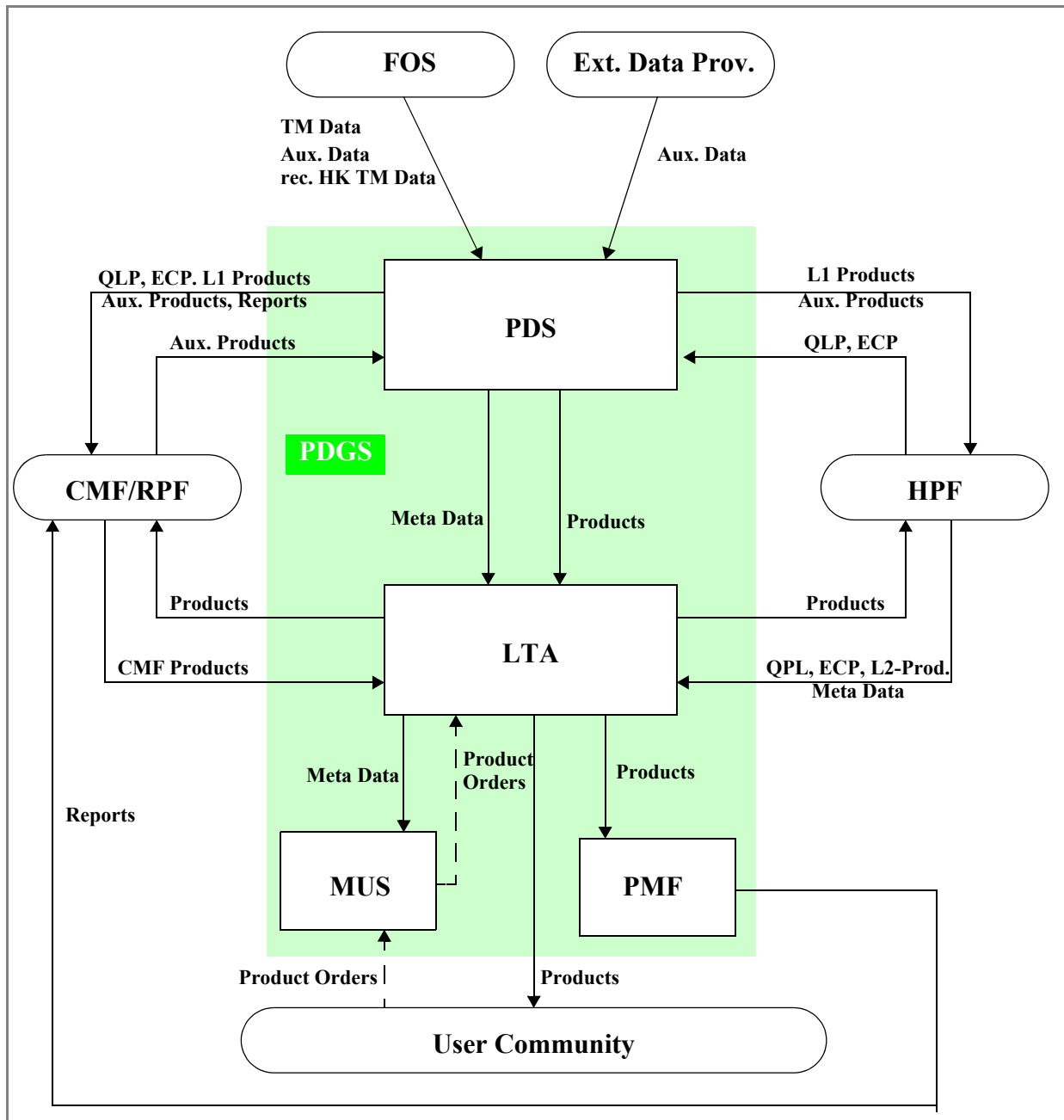
- ❖ processing the science data up to level L1b including the calibration products; this covers also the consolidation of data in case of gaps
- ❖ orbit determination using GPS data with an accuracy of 10 m
- ❖ archiving products (L0, L1b, L2, QLP, ECP) and auxiliary data for the entire mission duration and beyond (PDGS/LTA)
- ❖ monitoring the performance of the ground segment and generation of monitoring products
- ❖ provision of access to GOCE products for external users via the Multi-Mission User Service
- ❖ interface with
 - ◆ the HPF to provide L1 products incl. auxiliary data and to receive L2 products incl. auxiliary data and QLPs and ECPs
 - ◆ the CMF/RPF to provide L0, L1, L2 products, QLP and ECP and to receive auxiliary data
 - ◆ the FOS to receive science data, recorded HK TM data and auxiliary data
 - ◆ external auxiliary data providers (e.g. SRL, IGS) to receive auxiliary data required for L1 processing



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Fig. 6-2: GOCE Payload Data Ground Segment





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6.2.3 High Level Processing Facility (HPF)

The main functions of the HPF are

- ❖ pre-processing of L1 products received from the PDS to validate the product quality and to generate Quick-Look and External Calibration Products
- ❖ processing the L1 products to L2 including the Precise Orbit Determination using GPS data
- ❖ interfacing with the
 - ◆ PDGS/PDS to receive the L1 products and to provide the results of the pre-processing
 - ◆ PDGS/LTA to provide the L2 product (intermediate and final products) for archiving
 - ◆ external auxiliary data providers (e.g. IGS, ECMWF) to receive auxiliary data required for L2 processing and POD

As result of the pre-processing, the HPF will generate Quick-Look Products (QLP) and sent them to the PDS archive. These products are analysed by the CMF together with the PDS generated products to monitor the status of the spacecraft and the quality of the L1b products.

6.3 Reference Planning and Calibration/Monitoring Facility

The RPF and CMF support the Mission Management with the following main functions:

- ❖ definition the mission profile
- ❖ provision of parameters specifying the various mission phases
- ❖ interfacing with the FOS to provide the planning inputs
- ❖ monitoring the performance of the satellite, the on-board instruments and the generated products
- ❖ analyse results of calibration and performance monitoring of products and request extra calibration activities or switching to Getter Mode (tbc)
- ❖ modification of on-board and on-ground configuration parameters as result of the above analysis (tbc)

6.4 External GS Elements (Non-ESA Controlled)

6.4.1 Auxiliary Data Providers

There are several external auxiliary data providers supporting the GOCE mission and requiring a continuous exchange of data:

- ❖ the International GPS Service (IGS) providing GPS data to the PDGS and HPF
- ❖ the European Centre for Medium-range Weather Forecast (ECMWF) providing meteo data to the HPF
- ❖ the Laser Community providing Satellite Laser Ranging (SLR) data to the PDGS used as a back-up means for orbit determination
- ❖ other auxiliary data providers tbd



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6.4.2 Satellite Prime Contractor (SPC)

The function of the satellite prime contractor during the GOCE mission is the development and verification of patches to the on-board S/W and on-board control procedures on request of the FOS.

During the initial phase of the mission and for trouble shooting, the FOS will provide recorded HK TM data to the SPC.

In addition, the SPC will provide HK TM data recorded during AIT activities to the FOS for testing.



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7 Mission Planning

7.1 Flight Operations Planning

The planning of on-board operations is based on the mission profile, which will be specified by the mission management. Updates and modifications will not be required on a short term.

The spacecraft planning covers the following activities:

- ❖ routine commanding and monitoring of the satellite and instruments
- ❖ dumping of the on-board memory during Kiruna passes including deferred dumping in case of contingencies
- ❖ planning and execution of manoeuvres to change the GOCE orbit at the end of the MOPs
- ❖ reconfiguration of the space segment during long eclipse periods
- ❖ regular and on-request calibration and maintenance activities

7.2 Data Processing Planning

Scientific data processing is data-driven, i.e. availability of data triggers the processing. This covers the processing of data, which are dumped with a delay (deferred dump) due to malfunctions of the on-board or on-ground communication systems.

Planning input regarding recording/dump schedule, calibration activities etc. will be provided by the FOS.

Manoeuvres and calibration activities are carried out asynchronously.

The processing at PDS covers the generation of L0 and L1b products. The validation of these products is part of the PDS tasks, so that no feed-back from the HPF is needed to fully validate the PDS products. Quick-look Products generated by the HPF will be used to confirm the product quality of the PDS generated products.

Processing requires auxiliary data from external providers and, in particular, the GPS data from the IGS for the orbit determination.

During routine operations, no near-real time (NRT) processing is required. The L1b products will be generated after each pass and provided to the HPF as soon as they are available.

During COP and POP phases as well as for calibration activities during MOPs, NRT processing up to level 1b (tbc) is required to support close loop testing.

7.3 Data Distribution Planning

The PDS L1 product will be systematically disseminated to the HPF after each pass, which is responsible for the generation of the final GOCE L2 products.

A copy of L0, L1 and L2 products will be systematically sent to the LTA.

No on-request dissemination of products will be done by the PDS.



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Quick-Look Products and External Calibration Products will be provided by the HPF within 1 week after the reception of the corresponding L1b products at HPF. The final L2 products will be available typically 9 month after the MOPs.



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8 Data Processing

Details of the data reception and processing strategy are provided in ref. [RD - 7].

8.1 House-Keeping Telemetry Processing by FOS

8.1.1 Telemetry Reception

The HK/TM data will be downlinked with one S-band channel containing:

- ❖ real-time HK TM data downlink during the pass (channel VC0)
- ❖ real-time high priority HK TM data downlink during the pass (channel VC1)
- ❖ recorded HK TM data recorded during the entire orbit including the pass (channel VC3)
- ❖ science data recorded during the entire orbit including the pass (channel VC2)

The real-time HK TM data will be used by the FOS for real-time satellite and instrument monitoring. The science data will be used by the FOS for orbit restitution and for the detection of gaps in the data stream (lost frames).

Both, the science data (channel VC2) and the HK TM data (channel VC3) will be extracted from the downlink data stream and provided to the PDS after the dump is terminated without any processing. The science data channel contains the instrument science data and selected HK TM data, which are required to generate the GOCE L1b products. Selected data from the HK TM channel are required for calibration processing; additional HK TM data may be used for monitoring purposes.

8.1.2 Telemetry and Telecommand Archiving and Retrieval

The FOS will archive the following data:

- ❖ satellite and instrument command history data
- ❖ satellite and instrument HK TM data downlink in real-time during the pass
- ❖ satellite and instrument HK TM data recorded on-board during the entire orbit

The HK TM data will be stored as raw data (raw telemetry bits). In addition, all attributes and calibration curves needed to process these data will be stored. Calibrated data (meaningful values in engineering units) can be generated from the raw data on request.

The FOS will make available the archived data to the GS entities, which require these data. The archived data will be accessible

- ❖ interactively via a web-based retrieval system
- ❖ systematically via regularly generated retrieval files

The retriever of the data will be able to specify

- ❖ which HK TM data to be retrieved
- ❖ the time window for data retrieval



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- ❖ the frequency of the distribution of these data
- ❖ the choice between raw and calibrated data.

The details of the retrieval mechanism are specified in specific ICDs and user manuals.

8.2 Scientific Data Processing

8.2.1 Data Reception

The scientific data and the HK TM data, i.e. the VC2 and VC3 data streams, will be provided to the PDS by the FOS in form of files containing the telemetry frames. The data will be provided nominally during each pass containing the data recorded since the previous pass. In case of malfunctions of the on-board or on-ground communication systems, the data downlink and/or the acquisition of data on ground may fail during a pass. This will result in gaps in the received data. In this case, the FOS will initialise a deferred dump of the missing data and sent them to the PDS. The FOS will inform the PDS on the planning of deferred dumps.

In addition to these data, the FOS will provide the following auxiliary data:

- ❖ predicted orbit data
- ❖ satellite mass history data, centre-of-mass variation
- ❖ attitude and manoeuvre data

8.2.2 Data Processing

The following data will be generated and archived in the PDS:

- ❖ Level 0 products: time ordered raw measurement data as measured by GOCE and downlinked during the passes; these products contain science and HK TM data (see sec. 8.1) including data from the attitude and orbit control and the drag free control systems; the data are time tagged and annotated with telemetry quality information
- ❖ Level 1b products: time series along the orbit with calibrated and corrected instrument and satellite data including gravity gradients and SSTI positions, linear accelerations, thruster activity parameters, attitude control data and orbit data

Details of the processing chains and the products to be generated by the PDS are provided in ref. [RD - 9].

The following data will be generated in the HPF and archived in the LTA:

- ❖ Level 2 products: global and regional gravity field models, derived quantities from these models (grids of geoid heights and gravity anomalies) and related quality parameters and the POD
- ❖ Quick-Look Products (QLP) and External Calibration Products (ECP), which will be used by the CMF for analysis

The format of the product files will comply to ref. [RD - 3].

The time constraints for processing in nominal cases are:



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- ❖ L0 products are processed after each dump within the duration of one orbit (i.e. before the next dump starts)
- ❖ L1 products are generated systematically as soon as the L0 products and corresponding HK TM data are available nominally after each pass
- ❖ L1 products will consolidate systematically by re-processing the L0 products a configurable time after the first processing; this will ensure, that possible gaps in the original L0 products are recovered by deferred dumps and, therefore, the L1b products will be complete
- ❖ during the POP and COP phases and for calibration activities during the MOPs, the processing cycle described in chap. 10 is required to generate the calibration products for EGG and SSTI.

8.2.3 Data Circulation

The PDS will provide the L1 products together with the required auxiliary data to the HPF after each pass where they are processed to L2. The final GOCE products will be available at the end of each of the Measurement Operational Phases with a delay of typically nine months (MOPs, see sec. 5.1) (tbc). The following feed-back from the HPF to the PDS is required:

- ❖ QLPs and ECPs as result of pre-processing, which are sent to the PDS to be archived in the Data Processing Archive (PDS-DPA)
- ❖ the L2 intermediate and final products are sent to the PDS to be archived in the Data Processing Archive (PDS-DPA)

All products and auxiliary data will be archived in the LTA.



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9 Mission Phases and Product Generation

Fig. 9-1: Product Generation and Mission Phases

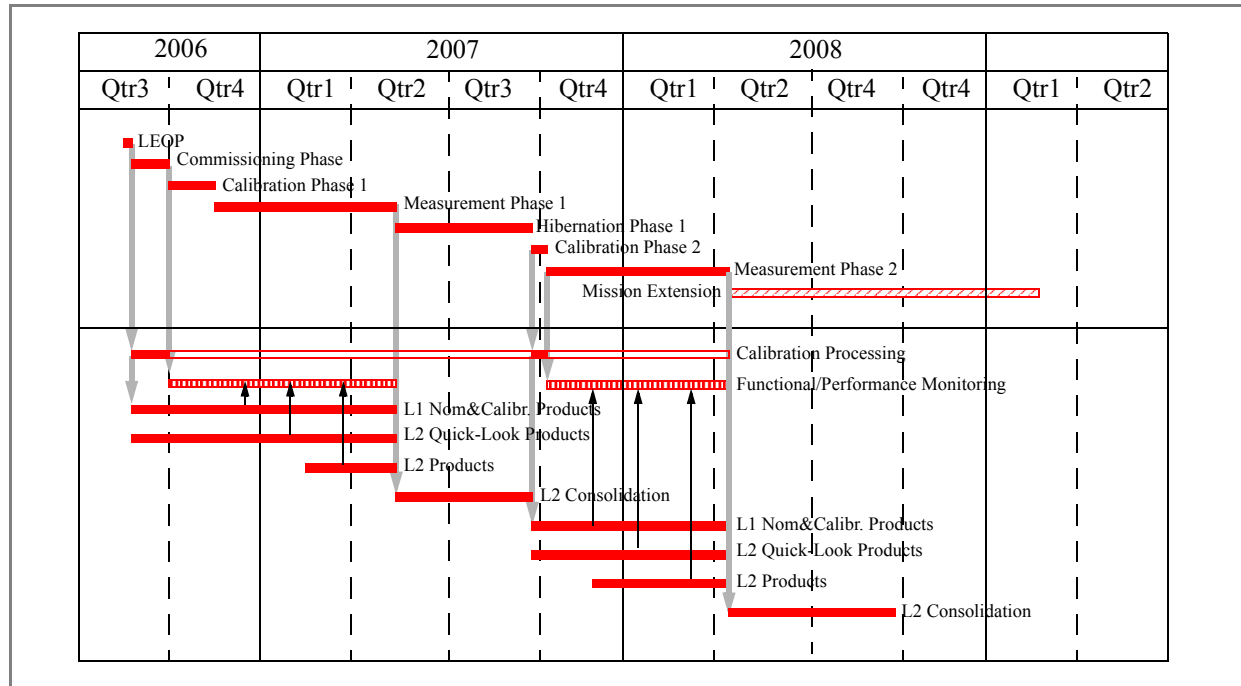


Fig. 9-1 provides an overview of the relationship between the mission phases of GOCE and the generation of products. The generation of the final L2 products (geoid and gravity anomalies, POD) will start with a delay wrt the start of the MOPs and will not be available just at the end of the MOPs but typically nine month after the reception of the L1b products at HPF (see ref. [RD - 9]). During the MOPs, the HPF will provide Quick-Look Products (QLP) and External Calibration Products (ECP), which will support the monitoring of instrument and product performance and the validation.

The final L2 GOCE products (geoid and earth gravity anomalies) will serve as a standard for a wide variety of applications of different scientific communities. The products will be made available to external users from the LTA using the Multimission User Service (MUS) of ESA. The external users will have access to the products via a web-based interface (tbc).

In addition, the Level-1b products will be made available to selected users via the same path. The distribution of validated L1 products to the users will start as soon as they are available in the LTA.



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10 Calibration and Maintenance

The EGG instruments requires two types of on-board calibration, namely the Inverse Calibration Matrix (ICM) determination and the K2 Factor determination. Both types of calibration has to be carried out during COP1 and COP 2. The ICM determination must also be done with a shorter duration during the MOP1 and MOP2.

The SSTI requires an Interchannel Bias (ICB) determination, which is carried out during HOP1.

The a.m. calibration activities are described in more detail in the following sections (for further details see ref. [RD - 11]).

10.1 EGG ICM Determination

The elements of the Inverse Calibration Matrix (ICM) are pre-defined on-ground before launch, but the knowledge of the ICM must be improved by on-board calibration.

The determination of the ICM elements is done by shaking the satellite randomly about all axis for a duration of 1 day (tbc). The common-mode and differential-mode accelerations together with the satellite attitude measurements of the star sensors are used to determine the ICM elements.

10.1.1 Input Parameters

To carry out the measurement of the elements of the ICM, the FOS has to uplink the sequence of acceleration to be commanded to the Ion Propulsion Assembly (IPA) and the Gradiometer Calibration Device (GCA, i.e. gold gas thrusters). This is done by uplinking a patch of the CDMU software.

10.1.2 Data Processing

The following inputs need to be processed by the PDS to generate the corresponding level 1b product:

- ❖ the accelerometer control voltage (gradiometer science data)
- ❖ the star sensor quaternions (satellite HK data)
- ❖ the DFACS HK TM data to determine the start/stop of calibration (DFACS in calibration mode)

An iterative processing is carried out by the PDS to determine the elements of the ICM. The resulting products are sent to the CMF for analysis.

10.2 EGG K2 Factor Determination

The purpose of this calibration is to determine the gradiometer common and differential quadratic factors during the mission. These factors must be kept below a pre-defined limit. In case, these factors increase beyond this limit, the results of the calibration measurement can be uplinked to the satellite to be used by the SSTI.

The K2 Factor determination is done by applying a series of high frequency sinusoidal accelerations to the accelerator proof masses by means of the control electrodes. These accelerations are applied to the proof mass in addition of the regular acceleration applied to keep the proof mass in the middle of its cage.



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More detailed descriptions of the calibration method can be found in ref. [RD - 11]. In the following, the operational concept and data processing concept is described.

10.2.1 Input parameters

To carry out the K2 Factor determination, the sinusoidal profile has to be uplinked to the satellite by ground command. The uplink covers:

- ❖ the identification of the Accelerometer Sensor Head (ASH) and degree of freedom selected for a specific profile
- ❖ the acceleration voltages which represent the profiles

The total duration for the calibration of all ASHs requires 5300 sec (tbc).

10.2.2 Data Processing

The following inputs need to be processed by the PDS to generate the corresponding level 1b product:

- ❖ the EGG science data which contain the information required to identify, which source packets belong to the calibration, in particular,
 - ◆ the accelerometer (A_i) and the accelerometer axis (k) on which the periodic acceleration has been applied
 - ◆ the start and end times during which the acceleration signal was applied to the specified accelerometer and axis
 - ◆ the polarization voltage applied to the accelerometer proof mass
- ❖ the commanded amplitudes and frequencies of the calibration signal, which will be provided to the PDS as an auxiliary data file generated by the CMF
- ❖ the EGG DFACS 10 Hz data which contain the accelerometer data to be processed to the calibration level 1b product

Due to the fact, that the calibration product is generated from the DFACS 10 Hz data, the EGG science data which are downlinked during the calibration period, will be processed to the nominal SSTI product.

The resulting calibration products (K2 Factors) are analysed by the CMF. If required, the CMF converts these products into a Task Parameter File (TPF) to be sent to the FOS for uplink to the satellite. After uplink, the calibration must be repeated with the new K2 Factors on-board to verify the result of the calibration.

10.3 SSTI ICB Determination

The purpose of this calibration is to determine the differences in the delays of the various receiver channels. This calibration is done on-ground before the mission and an ICB correction table is loaded on-board to correct these differences. Once during the mission, the calibration is repeated to check the variation of the ICB and, if required, to update the on-board correction table by ground command. This is done during the HOP1 phase.

The calibration is carried out by putting the signal of one GPS satellite to all receiver channels. This ICB correction table is derived from the pseudorange measurements by comparing the result of one master



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channel with all other channels. If the differences of the pseudorange between the master channel and the other channels are different from zero, the on-board correction table must be uplinked by ground command.



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11 Time Correlation

The two main instruments of GOCE, namely the EGG and the SSTI, both have a local oscillator to provide a time counter. The two instruments are synchronised with the on-board time by the CDMU.

The FOS will provide standard time correlation to correlate the on-board time (OBT) with the UTC of the receiving station. In addition, the SSTI data are time stamped with the GPS time.



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12 Orbit and Attitude

12.1 Orbit Determination

Orbit determination will be done using the SSTI instrument on-board the satellite. There are three levels of orbit determination:

- ❖ on-board navigation solution used as input to the DFACS (accuracy 100 m)
- ❖ orbit determination carried out by the PDS using GPS data (GPS satellite orbits, accuracy 10 m)
- ❖ precise orbit determination (POD) carried out by the HPF (accuracy typically a few centimetres)

In addition, the FOS will process the GPS data for orbit restitution. The LRR data will be archived and may be used as a back-up for orbit determination.

12.2 Orbit Control

The FOS will perform precise orbit control based on

- ❖ the orbit parameters for the various mission phases provided by the RPF
- ❖ orbit determination and prediction based on the SSTI data downlinked in the science data stream

12.3 Attitude Determination and Control

The SSTI on-board navigation product will be used to determine the local orbit reference frame. SSTI and EGG data will be used by the DFACS to precisely control the attitude of the satellite.



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13 Data Circulation

All interfaces shown in fig. 4-1 are controlled using ref. [RD - 4].

The transfer of data between the interfaces is mainly done by off-line exchange of computer files through network connections. Exceptions are:

- ❖ telecommands and telemetry between the GOCE satellite and the ground segment via real-time RF transmission
- ❖ interactive retrieval of data from the FOS archive using interactive web sessions
- ❖ exchange of L1 and L2 products between the PDS, the HPF and the LTA using physical media (CD-ROM or DVD) or electronic links

The dissemination of the final GOCE products to the external users is via the internet (tbc) or on physical media.

The coherency of the various interfaces is controlled by ref. [RD - 3] and ref. [RD - 4].

14 GS Validation and Testing

14.1 Overall Interface Validation

The ground segment interfaces are controlled by ref. [RD - 4] together with specific ICDs for each of the interfaces providing the necessary detailed specifications.

The testing of the interfaces will be done based on the specific ICDs.

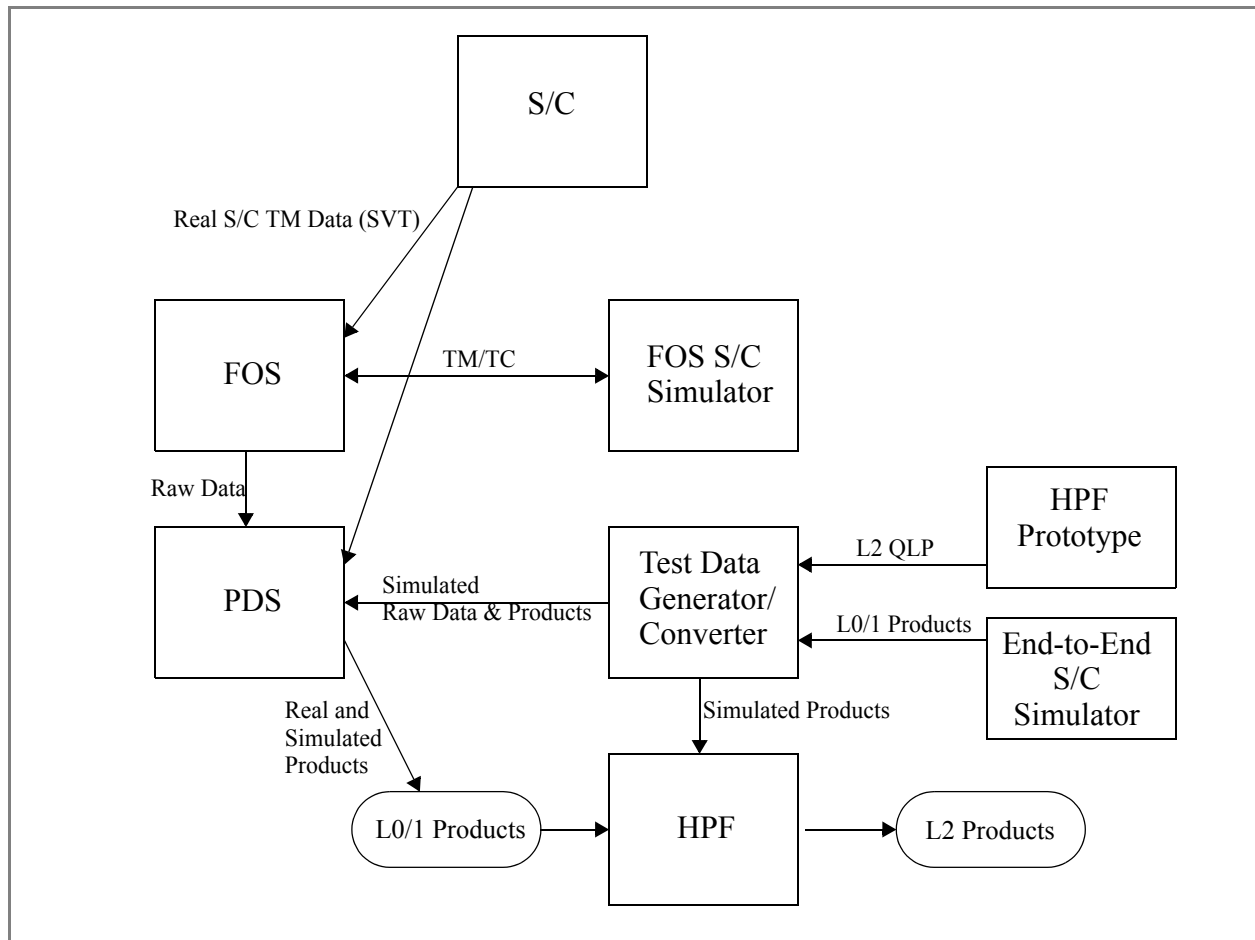
Integrated or end-to-end tests will be performed according to test scenarios involving multiple facilities and defined in ref. [RD - 5].

14.2 Satellite to Ground Interface Validation

14.2.1 Overview

An overview of the satellite to ground interfaces and test data used for interface testing is provided in 14-1.

Fig. 14-1: Overview of Satellite-to-Ground I/F Test Data Requirements





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14.2.2 Interface Validation with FOS

14.2.2.1 Simulated Telemetry Tests

The satellite prime will provide recorded telemetry data (recorded during the AIT phase) to the FOS and the PDS to verify the structure of the telemetry packets and to test and verify the HK TM L0 processing.

14.2.2.2 RF Compatibility Test

The satellite prime will provide an RF suitcase to the FOS to test uplink and downlink functional and performance characteristics. The suitcase is build using flight representative hardware (e.g. engineering models).

14.2.2.3 SVT Tests

The Satellite Verification Tests will be used to provide increasing confidence in the Satellite to Ground interface and, in particular, to verify the satellite TM/TC database.

The tests include:

- ❖ satellite commanding from the FOS
- ❖ data flow tests between satellite and FOS
- ❖ real-time and playback telemetry data processing at FOS (channels VC0, VC1, VC2, VC3)
- ❖ provision of science data (if available, channel VC2) as test data to the PDS
- ❖ provision of extracted HK TM data (channel VC3) as test data to the PDS

14.2.2.4 Tests with Satellite Simulators

The FOS satellite simulator will be used to a limited extend to test the TM/TC interface with the spacecraft and to validate intermediate versions of the satellite TM/TC DB.

The end-to-end satellite simulator may be used as an off-line data source for the full string of telemetry data, i.e. including meaningful science data, which may not be available from the SVT tests or the FOS satellite simulator.

14.3 Validation of the Interface with PDS and the Data Processing S/W

Before launch, the interfaces with the FOS and the S/W for science data distribution as well as the processing S/W will be validated using two sources of science data:

- ❖ real satellite data generated during SVTs and provided to the PDS via the FOS/CDAF to validate both, the interface and the processing chain up to Level-0
- ❖ simulated raw data generated by the end-to-end simulator (L-0 and L1 products) and the HPF prototype (Quick-look Products and L2 products) providing the complete science data stream

The test data, generated by the end-to-end simulator and the HPF prototype have to be adapted to the various test scenarios (communication scenarios, dump/recording intervals etc.). In particular, the L-0 simulated products shall be used to generate the VC-2 raw data stream as input to test the entire processing chain of the PDS.



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14.4 Post-Launch Data Processing S/W Validation

The processing will be validated in orbit during each of the Payload Calibration Operational Phases (POPs, see sec. 5.1). The feed back from the in-orbit validation may require update of the processing S/W and/or update of on-board and on-ground configuration parameters.

The performance of the processing will be continuously monitored during the MOPs by the CMF, using the products (nominal and calibration products) and the monitoring data from the PDS and the QLPs and ECPs from the HPF.



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15 Ground Segment Operations

15.1 FOS Operations

The FOS GS operations concept will be compliant with the 72 h autonomy requirement throughout the GOCE mission.

During LEOP, both the FOCC and the CDAF will be operated 24 h a day, 7 days per week with support from the satellite prime contractor.

During the commissioning operational phase and during the payload calibration operational phases, both the FOCC and the CDAF will be operated during normal working hours, 7 days per week (tbc).

During the measurement operational phases and during the hibernation phases, the FOCC will be operated during normal working hours, 7 days per week. The CDAF will be operated during normal working hours, 5 days per week. During unmanned periods, the CDAF will be remotely monitored by the FOCC. Engineering support will be available in case of contingencies by an on-call service for both, the CDAF and the FOCC.

15.2 PDGS Operations

The PDGS will be operated during normal working hours, 5 days per week. Engineering support will be available in case of contingencies by an on-call service.



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16 GS Implementation

The GOCE ground segment will be implemented according to ref. [RD - 6].