



document title/ *titre du document*

FIRST GROUND
SEGMENT

DESIGN DESCRIPTION

prepared by/ <i>préparé par</i>	FGSSE
reference/ <i>référence</i>	FIRST/FSC/DOC/0146
issue/ <i>édition</i>	0
revision/ <i>révision</i>	1
date of issue/ <i>date d'édition</i>	05 September 2000
status/ <i>état</i>	Draft
Document type/ <i>type de document</i>	Technical Note
Distribution/ <i>distribution</i>	

a

A P P R O V A L

Title <i>titre</i>	FIRST Ground Segment System Design Description	issue 0 <i>issue</i>	revision 1 <i>revision</i>
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author <i>auteur</i>	FGSSE	date 05/09/00 <i>date</i>
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approved by <i>approuvé by</i>		date <i>date</i>
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C H A N G E L O G

reason for change / <i>raison du changement</i>	issue / <i>issue</i>	revision / <i>revision</i>	date / <i>date</i>
First draft	0	1	05/09/00

C H A N G E R E C O R D

ISSUE: 0 REVISION: 1

reason for change / <i>raison du changement</i>	page(s) / <i>page(s)</i>	paragraph(s) / <i>paragraph(s)</i>

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1 INTRODUCTION

1.1 *Scope & purpose*

This document describes the top level design of the FIRST GS. It identifies the major systems and functional sub-systems of the FIRST GS and goes into some details in the identification of the interfaces between these systems/sub-systems.

The document covers the FIRST GS design for instrument tests (ILT and IST), in-orbit operation and post missions. In-orbit covers the Commissioning, PV and Routine phases.

This document serves a number of purposes:

- to document the FIRST GS top level design to all relevant parties, i.e. project, FSC, ICC and MOC
- to identify the systems, functional sub-systems and interfaces of the FIRST GS.
- To identify the systems/sub-systems and interfaces which are to be re-used over different phases of the FIRST (concept of smooth transition)
- To give some insight into the physical design of the major FGS systems/sub-systems

This document is intended to:

- FGS managers who needs to get a broad understanding of the FIRST GS design
- The FGSSE to identify interface requirements and ICDs between the FGS systems and functional sub-systems
- The architects of the different FGS Systems to get the understanding of the constraints put by the entire FIRST GS on their own system.

This document does not constitute the architectural design document of any of the FIRST GS systems or functional sub-systems.

This document is structured as follows:

- Section 2 introduces the operation concepts(2.1) and consequent design concepts (2.2) which are driving the FGS design as a whole.
- Section 3 presents the FGS design for all the FGS phases, with the description of the main components and interfaces in each phase
- Section 4 discusses the HW resources aspects (TBW)
- Section 5 traces the FGS design with FGS requirements (IRD) (TBW)

1.2 *Reference documents*

- [RD-1] FIRST Operation Scenario Document, issue 0.95, 22/02/2000
- [RD-2] FGS Interface Requirement Document, FIRST/FSC/DOC/0117, issue 1.0, 09/05/00
- [RD-3] FSCS URD (to be renamed FCSS URD), FIRST/FSC/DOC/0115
- [RD-4] EGSE URD, FIRST-SPI-DOC-000102

1.3 *Acronyms and Definition*

See FSCDT list at <http://astro.estec.esa.nl/FIRST/FINDAS/fscdt.html>

2 SYSTEM OVERVIEW

2.1 *Operation concepts*

This section identifies the satellite tests and operations concepts that are driving the FGS design.

- Satellite DTCP
- Smooth transition across phase ILT, IST, in-orbit, post mission
- Geographical distribution
- Commonality between instruments

This section is largely an extract from the FIRST operation document [RD-1] and the IRD [RD-2]. The operational concepts are presented here to make this document self-standing and easier to read.

2.1.1 GEOGRAPHICAL DISTRIBUTION

In in-orbit phase and post mission phase the FGS will be deployed over the following operational centres:

- The MOC (in-orbit phase only). The MOC is responsible for all aspects of S/C operation as well as the safety of the instruments. This includes:
 - Generating all commands to be up linked to the satellite based on input from the FSC, the ICCs and its own subsystems.
 - Receiving, recording for safekeeping, consolidation of the telemetry data and making these data available to the rest of the Ground Segment..
 - Ensuring the health and safety of the satellite and all its subsystems, including that of the science instrument complement.
 - Maintaining the instrument and spacecraft databases shared by the MOC, ICCs, and FSC, and of the SCOS-2000 system used (TBC) by the MOC and ICCs.
- The FSC is the single-point interface to the outside world for all FIRST observatory matters. In particular, it is responsible to:
 - Issue calls for observing time proposals, and the handling of proposals,
 - Provide general community support throughout all mission phases, acting as single-point input
 - Give support to ESA PR and science communications activities
 - Coordinate cross-calibration between FIRST instruments, and between FIRST and other facilities,
 - Perform detailed scientific mission planning,
 - Provide quality control information on all observational data,
 - Provide, manage, and maintain the central FIRST data base, and all the FSC software subsystems,
 - Populate the FIRST database with characterisation, science, and operational data,

- Provide the framework and the interfaces with the astronomer for all community interaction, e.g. for information gathering, proposing, data browsing and retrieval, on-demand data processing, and generation of quick-look products,
- Ensure overall ground segment consistency with respect to instrument configuration, including onboard software,

- The ICCs (at least one centre per instrument). The ICCs are responsible for the successful operation of their respective instruments, and for making possible the processing of the resulting data. The ICCs are responsible for most instrument related operational issues; instrument monitoring and calibration, developing and maintaining instrument specific software and procedures, and supporting operations. Each ICC performs tasks dedicated to their particular instrument. In particular the responsibilities include:
 - The monitoring of instrument development, testing, characterisation and calibration.
 - Status and health monitoring, and maintenance of the instrument.
 - The provision to the FSC of instrument ‘time estimators’ and command generation facilities.
 - The maintenance of the instrument onboard software that has been generated and validated by the instrument teams.
 - The provision of all software required for error correction, calibration, and generally for the scientific processing of the data from the instruments, including interactive analysis tools and scripts and/or ‘recipes’ allowing the generation of ‘standard’ data products.
 - Instrument calibration; all aspects of the instrument calibration during all phases of the mission.

The FGS is decentralised. The assumptions are that the MOC will be located at ESOC, and the ICCs at (or near) the PI institutes. The FSC will be located at a suitable place in an ESA member state, e.g. Vilspa.

The FGS operational centres and their interfaces are presented in the Figure 2.1-1. The figure introduced the notion of consolidated TM, NRT TM and the ICC@MOC operational centre. These are introduced and explained in 2.1.2 below.

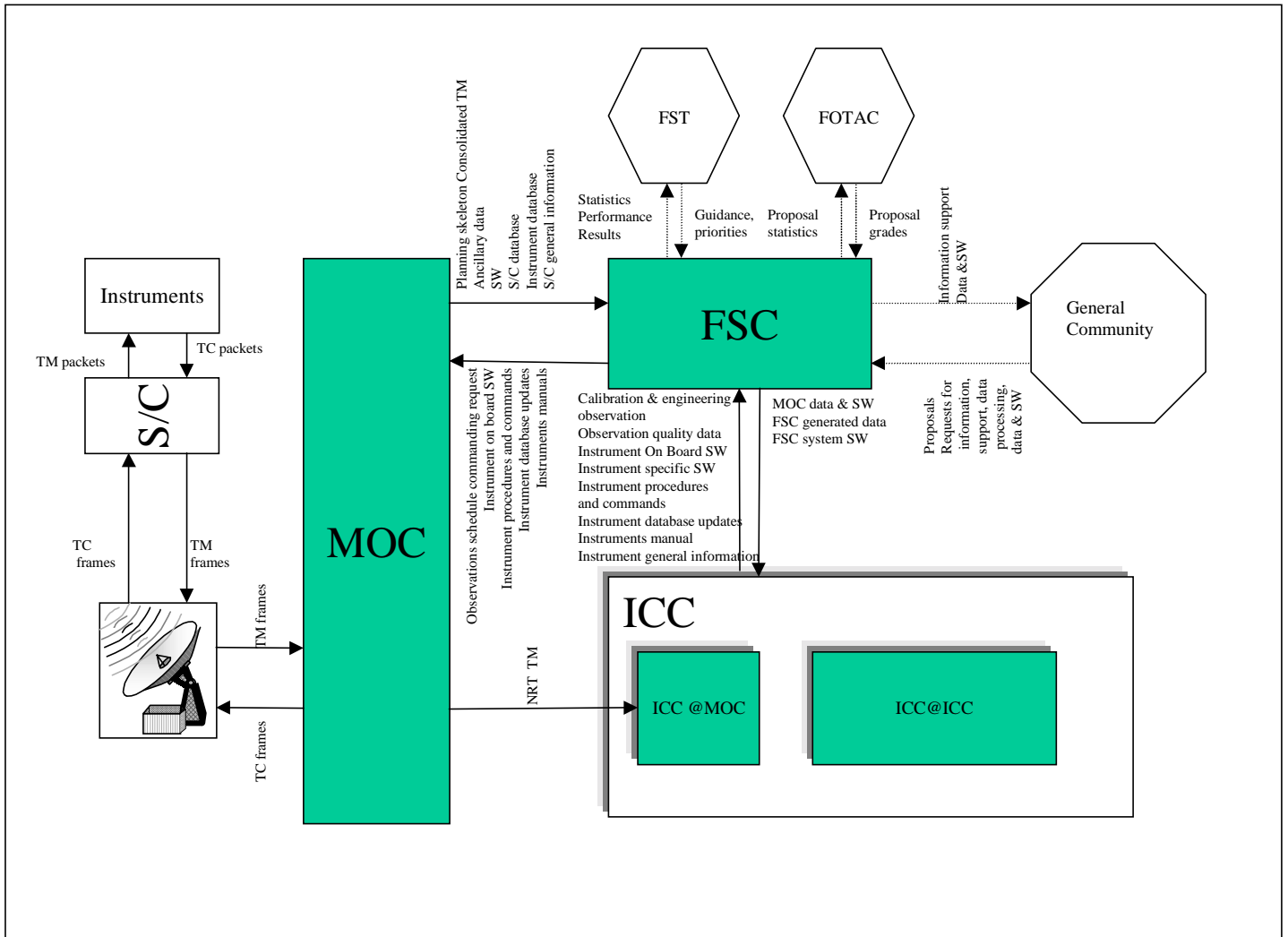


Figure 2.1-1: The FIRST Ground Segment Centres

2.1.2 SATELLITE DTCP

The ground coverage of the S/C will be limited to a few hours per operational day (nominally 3 hours in routine phase). At all times, the S/C will record on board on a mass memory all the S/C and instruments TM. The recorded TM of the last operational day will be downloaded during the period of ground coverage. During this period, the S/C will also transmit live the S/C and instruments TM.

Consequently, the S/C will transmit during a given DTCP to MOC (via the Ground Station) four different TM data flows summarised in the following table:

Live HK TM	HK TM generated during the DTCP and downloaded live
Live Science TM	Science TM generated during the DTCP and downloaded live
Dump HK TM	HK TM generated during the previous OD and downloaded during DTCP
Dump Science TM	Science TM generated during the previous OD and downloaded during DTCP

The MOC will make available the TM received from the Ground Station in NRT (i.e. with a delay limited to the time needed by MOC to relay a TM packet) and later in a consolidated form.

The consolidation of TM takes place over a period of time. Consolidated TM data will be guaranteed by MOC to be:

- Complete and transmission error free over the consolidation period (to the extent that the TM data have been successfully received on ground, i.e. data lost in the space/ground link will not be recovered),
- (On-board generation) time ordered.

For all instrument calibration that can be carried out off-line and for science activities, the ICCs will normally work from consolidated TM. The FSC is expected to work exclusively from consolidated TM.

For instrument operation purposes, the ICCs will be interested in monitoring the live TM of their own instruments in NRT during certain phases of the mission (commissioning) or following emergencies.

For NRT TM monitoring to make sense, it should be associated with the possibility for the ICCs to command their instruments in RT, i.e. during the period of ground coverage. RT commanding of an instrument will only be possible from the MOC mission control system which leads to having the ICCs RT operations located at the MOC (ICC@MOC).

Consequently, the following types of TM data flow originating from MOC need to be considered:

Near Real Time (NRT) TM data flow	TM distributed as is and as soon as received by MOC. It includes both live TM (HK and science) and dump TM (HK and science).
Consolidated TM data flow	TM made available after consolidation over a period of time. S/C HK, instruments HK and science can be consolidated separately.

2.1.3 SMOOTH TRANSITION ACROSS PHASES

To facilitate transfer of knowledge and procedures, as well as for reducing conversion efforts, it is very desirable to have the same (or at least a similar) environment through all FIRST mission phases from ILT to post operations.

In the ILT phase the instrument teams will be performing the first characterisation of their instruments. In the subsequent Integrated System Test (IST) phase the integrated satellite system will be tested. In both phases a special test set-up will be created to command the S/C (IST only), the instruments and the test environments. The commanding and the handling of the test outcomes in ILT and shall be closely resembling the final operational environment. The ILT and IST set-up should subsequently smoothly adapt into the in-orbit phase operations environment.

The in-orbit phase operational environment related to the FSC and the ICCs is then expected to support, largely as is the post mission phase. In particular the science and instrument calibration data should be made available to the science community, using the in-orbit phase operational environment.

2.1.4 COMMONALITY BETWEEN INSTRUMENTS

TBW

2.2 *The FIRST GS design concepts*

2.2.1 INTRODUCTION

At the highest level, the FGS is split into a number of systems which interface with each others in order to support the FGS operation from ILT to post missions.

The systems are the following:

- the MOC System which supports the MOC operation
- the ILT Electric Ground Support Equipment (EGSE-ILT) which supports the test executions in ILT
- the Central Check-Out Equipment (CCE) which supports the test execution in IST
- the FIRST Common Science System (FCSS) which supports the functions common to instrument and science operations from ILT to post-mission. (see 2.1.3).
- the Real Time Analysis (RTA) system which complements the FCSS in the area of instrument HK TM Real Time Analysis
- the On Board Software Maintenance (OBSM) system which complements the FCSS in the area of instrument On Board SW Maintenance.

Each of these systems and their interfaces at the different mission phases will be described in section 3. This section will further detail these systems only to explain how they support the two main FGS operational concepts: the smooth transition across phases (see 2.2.3) and the geographical distribution (see 2.2.4)

The FCSS is key to supporting these operational concepts, the next section 2.2.2 introduces the FCSS.

2.2.2 THE FIRST COMMON SCIENCE SYSTEM

The FCSS groups all FGS functionalities that are common to the science and instruments operations. It includes the major following functions.

- Definition of proposals and observations
- Scheduling of observations
- Observations commanding generation
- Analysis of the instrument science data
- Processing and quality assessment of observation science data
- The storage and retrieving of all instrument and science relevant data

Each of these major functions are implemented by an FCSS subsystem or component. The FCSS includes the following subsystems:

- CUS: definition of observation templates and observation commanding generation
- PHS: definition of proposals and observations
- MPS: scheduling of observation
- CCS: Configuration control system for FCSS data and SW
- Browsers
- IA/QLA: analysis of the instrument science data
- QCP: processing and quality assessment of observation science data

At the heart of the FCSS is a storage mechanism for all the artefacts relevant to science and instruments operations. This storage mechanism is known as FINDAS. FINDAS will act as a data server for each of the FCSS sub-systems defined above as well as for RTA and the OBSM. All the above FCSS sub-systems, as well as RTA and OBSM are acting as clients to FINDAS and are using FINDAS to retrieve/store their inputs/outputs

The FCSS sub-systems, RTA, the OBSM and FINDAS are represented in the Figure 2.2-1 below.

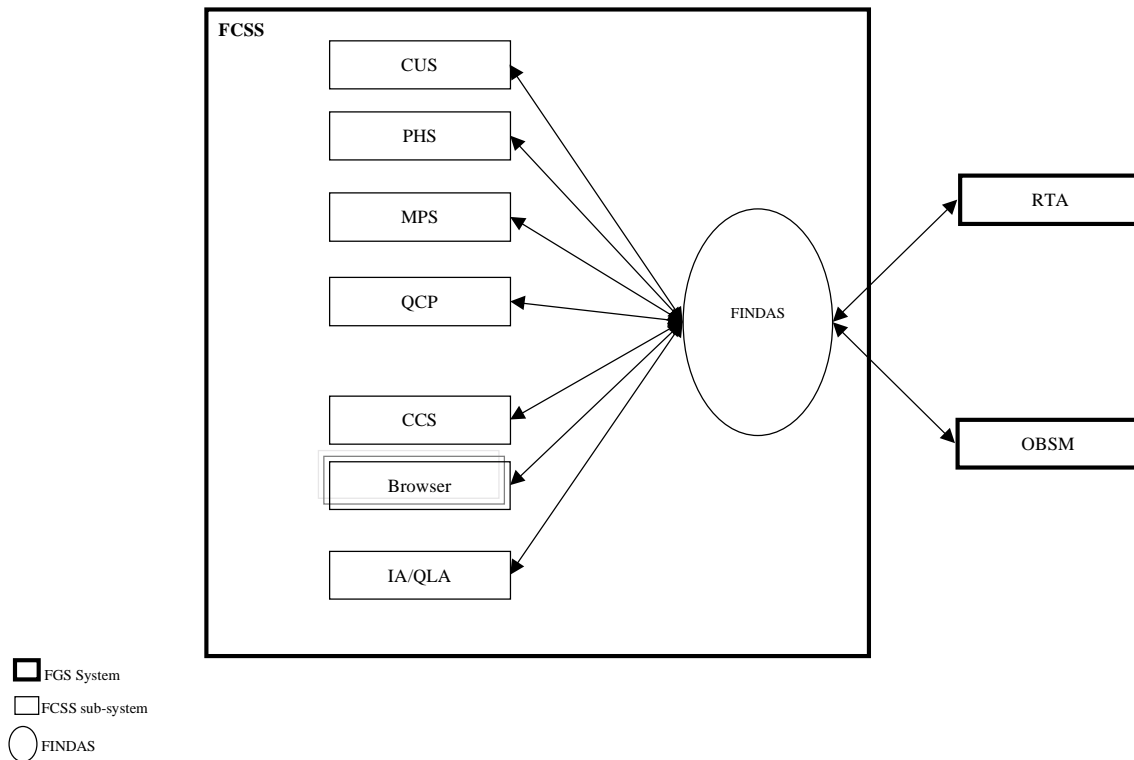


Figure 2.2-1: The FIRST Common Science System, RTA & the OBSM

A more detailed description of each of these components can be found in 3.1.2

2.2.3 SMOOTH TRANSITION ALONG MISSION PHASES

The smooth transition concept regards the science and instrument part of the FIRST GS, i.e. the FCSS, RTA and the OBSM. Smooth transition across phases mean that 1) SW development for a given phase can be largely re-use in the following phase (SW compatibility), 2) data collected in a given mission phase can still be accessed/processed in the following phases (data compatibility).

1) & 2) above point to a compatibility in the data produced/consumed by the FCSS across the different mission phases and by extension to a compatibility in the data (and their format) exchanged between the FCSS and the rest of the FGS at ILT, IST and in-orbit phase, i.e. of the data exchanged with respectively the EGSE-ILT, the CCE and the MCS. This concept is depicted in the Figure 2.2-2 below. It shows that the FCSS sub-systems, RTA and the OBSM are reused across the different mission phases. Conceptually the

only functions of the FCSS that are subject to changes are the ones dealing with the import/export of data from/to the other systems. Providing that data relevant to different phases are produced with the same content and format, the archiving and retrieval of these data in the FCSS/FINDAS can be kept mission phase independent.

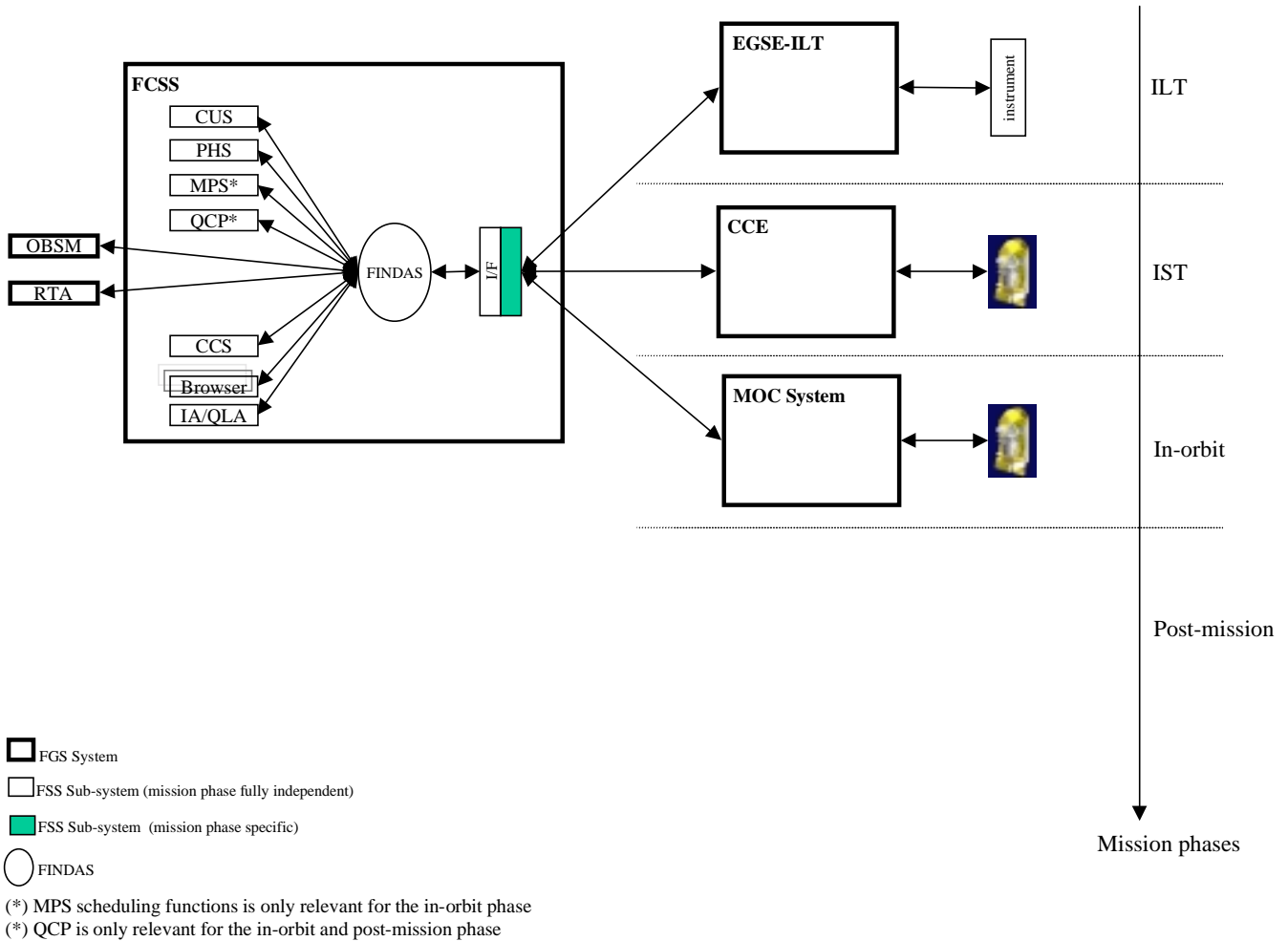


Figure 2.2-2: the FGS Smooth transition between phases

The basic data flow between the FCSS and these 3 systems are 1) commands (instrument commands, S/C commands or test environments commands) exported from the FCSS and 2) TM and ancillary data received by the FCSS.

The data compatibility across phases then points to the following:

- 1) the commanding in the context of ILT and IST should be compatible with the commanding in the context of the in-orbit mission.

In both cases, commanding will proceed from observations using the CUS (see 3.1.2.1). Observations in ILT and IST will cover the commanding of the test environment (EGSE-ILT or CCE) as well as the commanding of the system under test (instrument).

- 2) the TM and ancillary data collected in the different mission phases shall be compatible. Practically, this means that
- TM produced by the instruments, the S/C and the test environment in ILT and IST follow the ESA TM standard format
 - ancillary data produced by EGSE-ILT, CCE or MCS for the same purpose (e.g. TC history) have the same content and follow the same format.
- This point is partially guaranteed by the fact that the EGSE-ILT, the CCE (TBC) and the MOC system shall all be SCOS-2000 based.

Although data compatibility will be sought from the start of ILT, it is most likely that the data format (e.g. TM packets) will change from one phase to another or within a phase especially in the early one: ILT. For this purpose it is important that FINDAS supports the access to data in old format or the reformatting of data (see FINDAS in 3.1.2.8)

2.2.4 GEOGRAPHICAL DISTRIBUTION ACROSS DIFFERENT CENTRES

For the in-orbit and the post mission phase, the FCSS will be deployed in the FSC and in the different ICCs. Conceptually, the FSC and the ICCs will share through the FCSS the same applications (FCSS sub-systems) and the same data. The distribution of data and application across the different centres is supported by FINDAS. Conceptually, FINDAS can be seen as one single database that can be accessed from the FSC and the different ICC centres.

In each of the operational centre, there will be a FINDAS node which will hold and serve local data and which will support remote access of data at any of the other FINDAS node in a transparent manner. Therefore any FCSS sub-systems at any operational centre will be able to access in the same and transparent way all FCSS data, be local or remote. This concept of distributed client/server architecture is presented in the Figure 2.2-3 below. This figure shows the FSC and the three ICCs for the three FIRST instruments. This will be the standard configuration supported by the FSC. It does not exclude that the FCSS can be deployed in other centres, e.g. additional instrument centres, however this shall be transparent to the FSC. One example of additional centres is the commissioning phase where the FCSS will be deployed in the ICC@MOC (see 3.6).

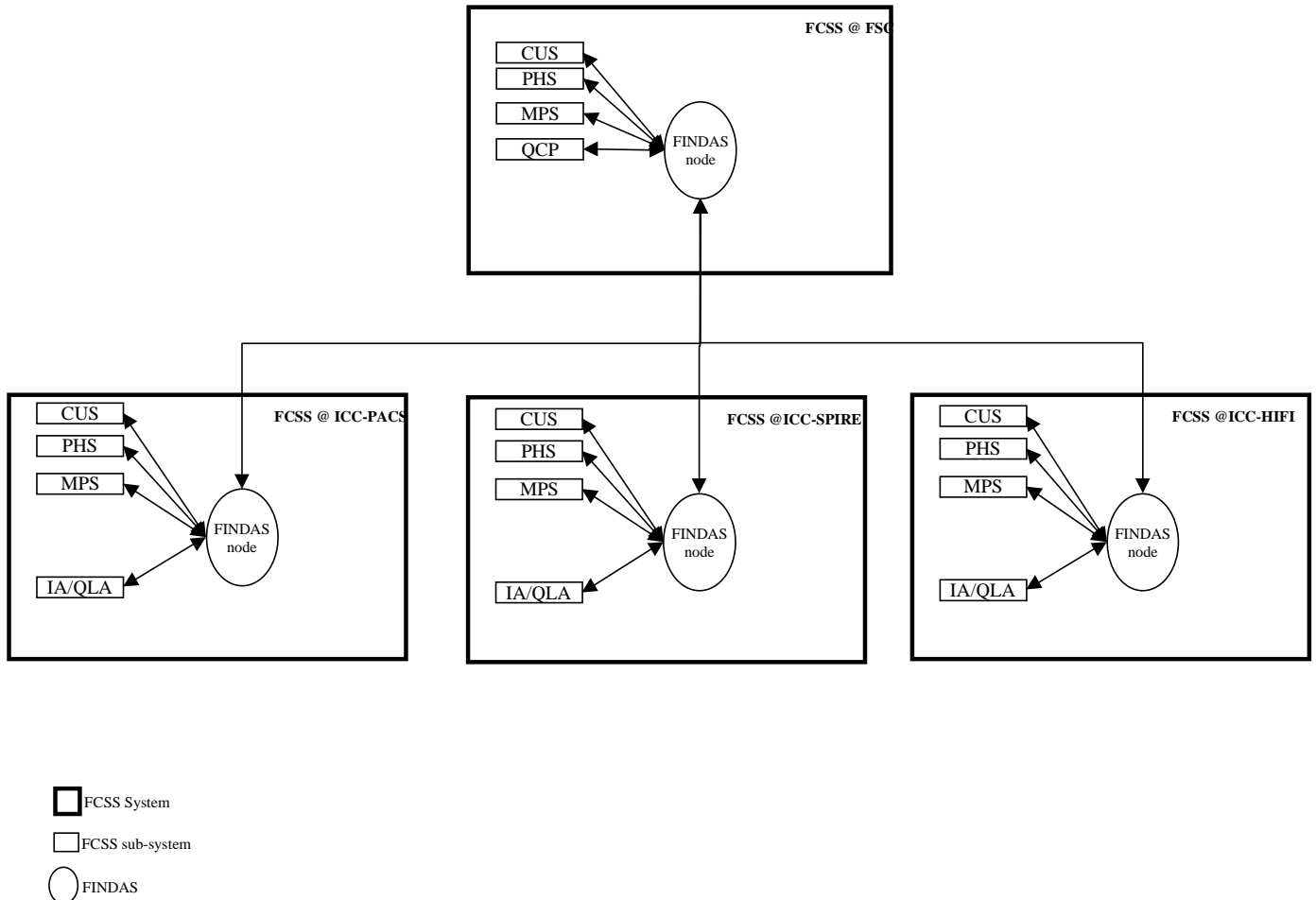


Figure 2.2-3: the FCSS distribution across centers

The figure shows also that only part of the FCSS can be deployed in a given site depending on the operational responsibility of the site. E.g. the QCP is not deployed in the ICC, the IA/QLA is not deployed in the FSC.

3 SYSTEM DESIGN

This section is structured along the different mission phases, starting with the routine phase.

It describes the FIRST GS in term of centers, systems, and sub-systems (or components) for the different phases of the mission with a particular focus on the data interfaces between the systems and/or between the centers.

It documents how the FIRST GS evolves along the different mission phases and in particular identifies those functional sub-systems and data interfaces which are common to the different phases of the mission (smooth transition).

3.1 *Routine phase*

3.1.1 INTRODUCTION

In routine phase, the FIRST GS will be composed of the following systems, the MOC System, the FCSS, RTA and the OBSM. The FCSS will be deployed at the FSC and at the 3 instrument ICCs. The FCSS may also be deployed at other instrument centers than the 3 ICCs, this is however considered architectural consideration internal to the ICCs and is out of scope of this document.

The FIRST GS is for the routine phase is presented in Figure 3.1-1 below.

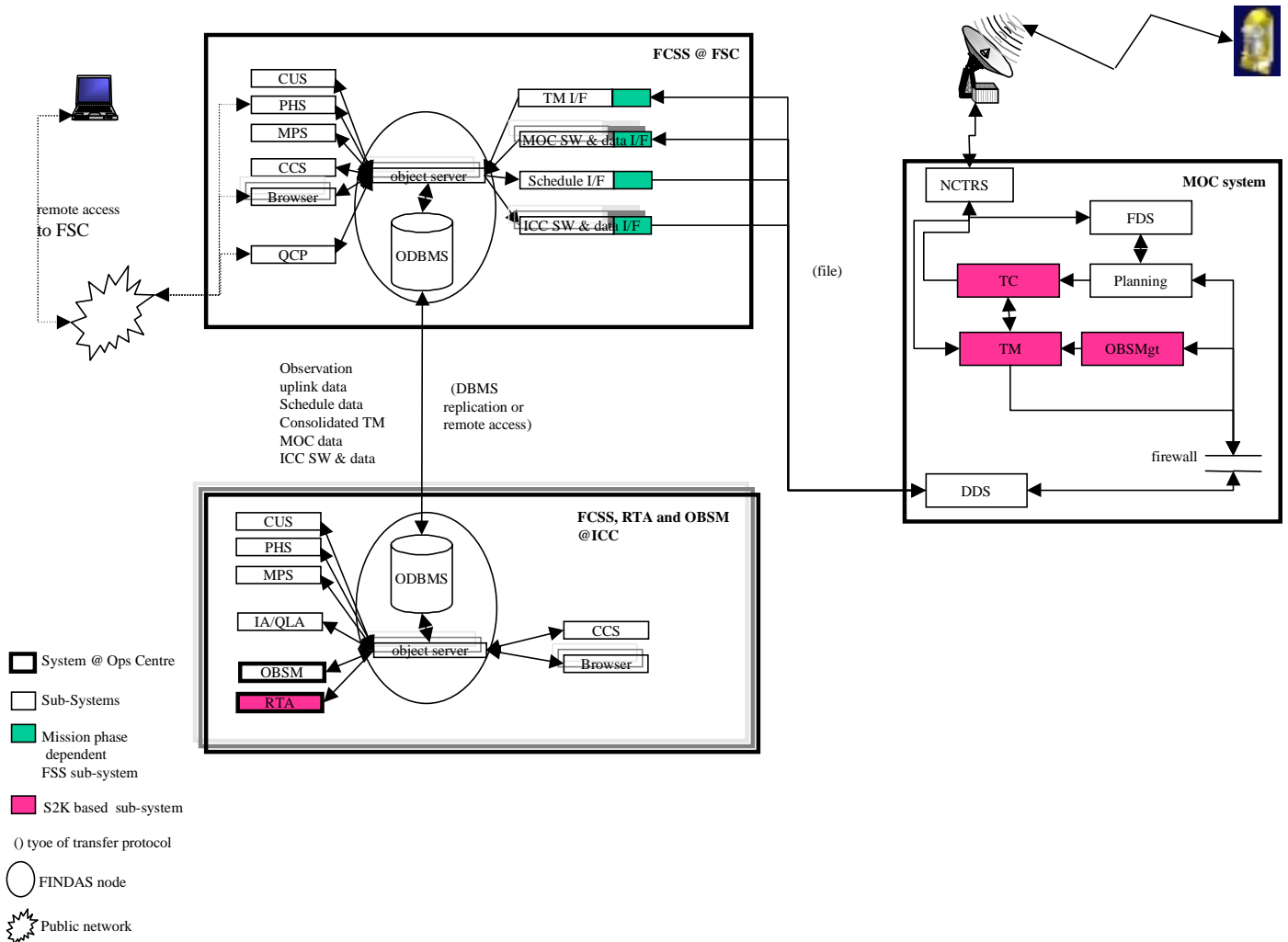


Figure 3.1-1: The FGS in routine phase

3.1.2 FCSS COMPONENTS

3.1.2.1 CUS

The Common Uplink System (CUS) is a set of functionalities that processes various types of input and generates a sequence of relative time-tagged commands, e.g. instrument commands, test environment and/or pointing commands.

The input to the CUS is a type of observation associated with specific parameters. The observation can be a general user observation (AOT), a calibration observation or an engineering observation.

The CUS is expected to handle all these types of instrument measurements in a uniform way. It will be used during instrument testing (ILT + IST) for the generation of instrument test sequences and calibration and

instrument characterisation measurements as input for the EGSE Test Control system. The general FIRST user (astronomer) will use the same CUS to process standard astronomical observations and determine the observing time. During routine operations the CUS will be used to process standard astronomical observations as well as calibration and engineering observations into instrument command sequences.

The output of the CUS is a sequence of instrument commands that make up an instrument measurement or observation. The instrument commands will be time-tagged relative to the start of the observation. The sequence will be incorporated into a schedule by the FSC and further processed by the MOC for uplink. Calibration scientists and instrument engineers will be able to define observations and underlying building blocks, e.g. in a scripting language especially tuned for the CUS.

Additionally, the CUS should be able to calculate the total duration (observing time) of the requested observation and will be used as a time estimator during proposal handling and during scheduling/mission planning.

The CUS will also be used to generate Instrument Command Sequences (ICS) for manual commanding of the instruments by the MOC. ICSs will be generated from specific observations requests and/or observation building blocks (TBC).

The CUS will be identical for all three instruments on FIRST.

3.1.2.1.1 The CUS abstraction levels

The CUS concept is based on four levels of abstraction, which are described in Figure 3.1-2 below. All instrument uplink procedures should be defined using this stack of abstraction levels.

The **observation** level defines the scientific, calibration or engineering observation and its associated parameters. This level represents the common entry point for the CUS. For general users who use the proposal handling system where an observation type can be selected and parameters specified in a user-friendly environment. For instrument specialist and calibration scientists a more complex interface will be provided according to requirements specified in [EGSE-URD or FSC-URD]. This abstraction level will typically also define scheduling constraints or instructions.

The **observation type definition** contains the definition of the observation defined e.g. in a typical scripting language. The definition defines how the observation type and parameters should be translated into a sequence of observation building blocks. During this translation all input is checked for correct syntax and parameter range and validity. In ISO terms, the type definition corresponds to the AOT logic, the COBs and TPFs.

The **observation building blocks** are the next level of abstraction and define how the measurement is functionally structured by a sequence of measurement building blocks. It corresponds to a high level description of the observation in the user domain, typical building blocks are e.g.

`do_dark_measurement` or `perform_scan (start, stop)`.

The building blocks are defined in the **building block definitions**, which are defined in the same way as for the observation type definition, e.g. a specific scripting language. The definition defines how the building blocks should be translated into a sequence of commands. Since observation building blocks can also take parameters, the translation step performs parameter validity and range/limit checks next to syntax checking.

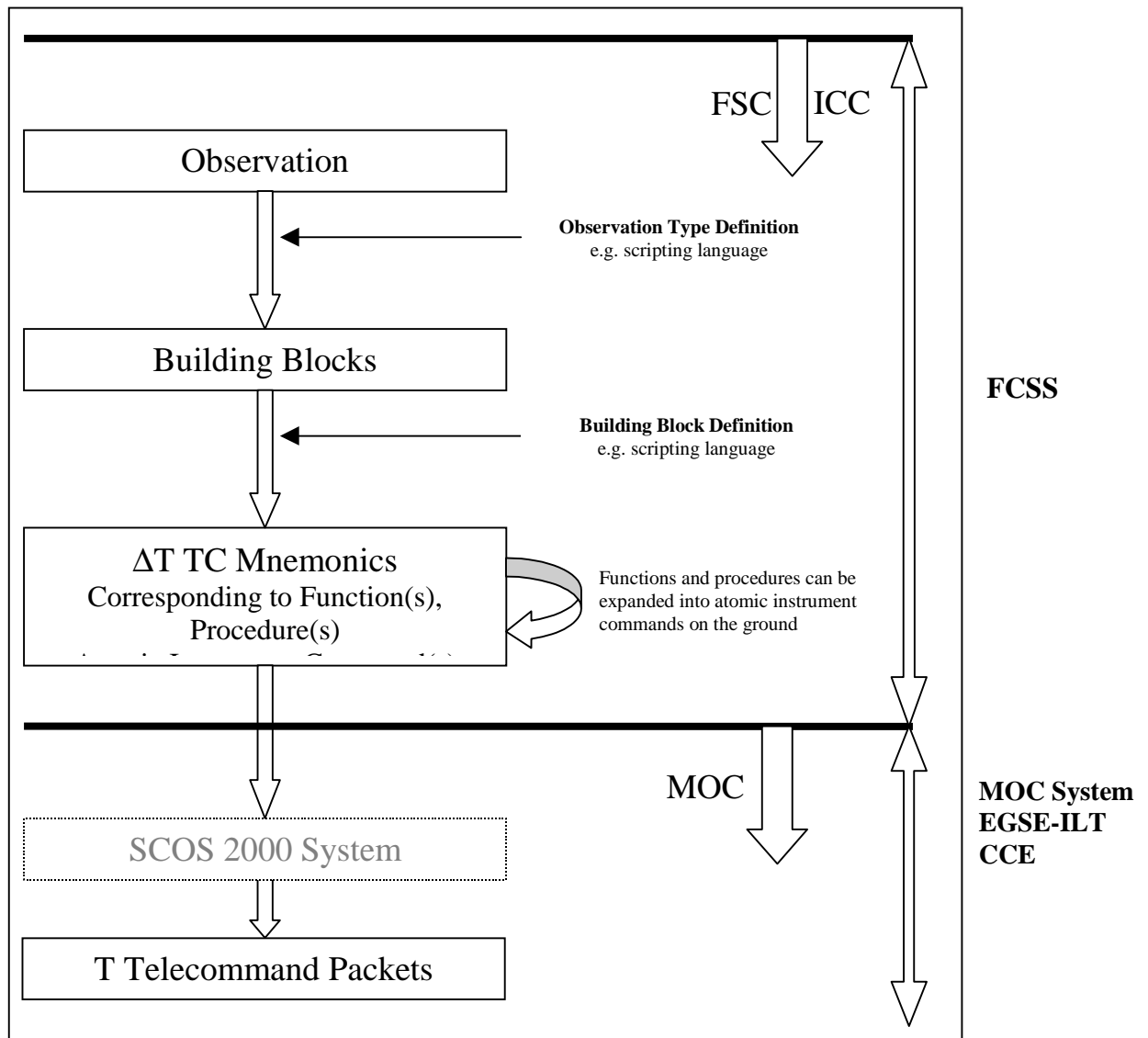


Figure 3.1-2: The abstraction levels of the CUS

The next abstraction level is then a sequence of **relative time-tagged telecommand (TC) mnemonics**. These are instrument commands, which correspond to an on-board function or command procedure (OBCP) or a more fundamental instrument command that needs no further expansion/translation by the DPU/ICU. The difference between this abstraction level and the observation building blocks (OBBs) is somewhat artificial since OBBs could also be defined as OBCPs. From the user or developer point of view this difference is nevertheless important since (1) observation building blocks are defined in the user domain where on-board command procedures are defined in the instrument domain, and (2) data reduction algorithms may benefit if the downlink (telemetry) organisation (data model) is based on observation building blocks.

On-board functions and command procedures are normally expanded on-board by the DPU/ICU and provide a way to optimise or minimise the uplink telecommand stream and thereby cope with the limited uplink data

rate. It is nevertheless necessary that the CUS can expand these OBCPs on the ground into a sequence of fundamental or atomic instrument commands for testing and engineering purposes.

The sequence of ΔT TC mnemonics is handed over to the MOC and translated into a sequence of absolute timed telecommand packets ready for uplink.

The first three levels in this stack are part of the FIRST Common Science System that will be developed jointly by the FSCDT and the three ICCs. This part of the CUS concept is identical for all mission phases. The last translation step into the telecommand packets is part of the MCS, the EGSE-ILT and the CCE and may differ between mission phases.

3.1.2.2 PHS

In essence, the PHS will support the definition and submission of proposals and observations based on observation templates and building blocks as previously defined with the CUS.

Because the CUS defines in the same way observations templates and observation building blocks for all type of observations (science, calibration, engineering, ILT and IST observations). A core PHS can be designed to support the definition of all types of observations and be used across phases (TBC).

The main outputs of the PHS are so-called observation requests which are inputs to the MPS (see below). A observation request will capture all the information needed for the observation to be executed. The observation requests will be stored into FINDAS by the PHS.

On top of this core functionality, in routine phase, the PHS will allow to validate the observation definition parameters (to the extent that the parameters validity domains are defined in the observation template) and will allow, using the CUS command generation functionality, to compute the duration of an observation.

In summary, in routine phase, the PHS will support the following activities:

- Create and update scientific proposals
- Create and update observation request
- Fill-in observation request template
- Estimate 'observing time'
- View observation building blocks for observation
- View instrument commands for observation
- Submit observation for scheduling
- Grading observations/proposals
- Managing observation scheduling priority

In routine phase, the PHS will be accessible locally at the FSC for the proposal handler to update/modify proposals and observations, locally at the ICC for the instrument engineers and the calibration scientist to define and submit engineering and calibration observations and remotely by the astronomers to define and submit scientific observations.

The FCSS will support remote access to the PHS at the FSC, using (TBC) WWW technologies and network.

3.1.2.3 MPS

In essence, the MPS will support 1) the elaboration of a schedule (or sequence) of observations from observation requests as defined by the PHS and 2) the generation of the commands corresponding to the scheduled observation. The schedule information will be stored into FINDAS.

In routine phase, the MPS schedule elaboration will take into account the following constraints :

- the satellite operational constraints as defined by MOC in the planning skeleton (see 3.1.8.3)
- the S/C Attitude constraint as defined by MOC (see 3.1.8.3)
- S/C slew time and path predictor SW & data as defined by MOC (see 3.1.8.3)
- Instrument inherent constraints

In routine phase, the MPS will schedule observations at absolute time, based on absolute observation time windows given in the planning skeleton. The commands generated by the MPS will correspond to S/C commanding requests and instrument TC mnemonics. Instrument TC mnemonics will be generated using the CUS commanding generation capabilities.

In routine phase the schedule will be exported to MOC (see 3.1.8.5) for further processing, uplink and eventually on-board execution (see MOC mission planning 3.1.3.6).

The MPS will support the multiple scheduling (and therefore execution) of an observation request. In effect, the MPS will create an instance of observation, each time an observation request will be scheduled. The observation instance will be stored into FINDAS. The TM resulting from the observation execution will then be linked to this instance of observation (see TM archiving in 3.1.8.2). For this purpose, the MPS will generate as part of the instrument commands related to an observation, TC mnemonics carrying the observation instance id (OBSID) and observation building block instances ids (BBID) . These TC will be decoded by the instruments and will allow the instruments to tag their TM with the current OBSID and BBID allowing in turn the linking of TM to the corresponding observation and building block instances.

In summary, in routine phase, the MPS will support the following activities:

- create observation schedules
 - in manual or automatic mode
 - taking into account constraint handling
 - with optimisation (automatic mode only)
- create of observations and building block instances for scheduled observations with unique OBSIDs and BBIDs
- generate TC mnemonics (using CUS) corresponding to scheduled observations.
- perform long term planning

In routine phase, the MPS is to be used by the mission planner locally at the FSC.

3.1.2.4 QCP

The QCP will support the reduction of the science data associated with a science observation. It serves two purposes:

- 1) the generation of quality data for a science observation allowing to assess the quality of the science data

2) the generation of science products attached to the observation.

The QCP will be used in batch mode or in interactive mode (on-demand processing).

The QCP will be used by the FSC operation team and remotely by the astronomers to perform on-demand processing. The FCSS will support the remote access to the QCP at the FSC, using (TBC) WWW technologies and network.

3.1.2.5 CCS

The CCS will support the definition and control of data and SW configuration relevant to the FCSS. For data the CCS is expected to be based on the FINDAS version management (see 3.1.2.8). For SW, it is TBD, as FINDAS may not support SW storage and versioning. The CCS shall in any case allow to build configuration mixing data and SW, so as to maintain the consistency between the data and the version of the SW used to create the data or which can be used to process the data.

The CCS will include an SCR system allowing to identify and track changes between different SW and data configurations.

3.1.2.6 Browsers

Browsers will support the navigation through and access to data stored in FINDAS. The browsers will have a GUI to browse the data as well as will support data queries in a dedicated language (see FINDAS, section 3.1.2.8)

It is expected that different browsers will be developed to match the specific needs of the different types of FCSS users.

Some browsers will be accessible remotely to allow astronomers to browse and access authorised data at the FSC. The FCSS will support the remote access to browsers at the FSC, using (TBC) WWW technologies and network

3.1.2.7 IA/QLA

ICC specialists will use the IA/QLA component to analyse TM stored in FINDAS to further the understanding of the instrument and its operations and to generate calibration parameters. Archive browse functions will be used to select particular types of data (e.g. particular types of observations, particular types of scientific sources, particular observation building blocks etc.) for analysis. Subsequently the different available IA algorithms will be used to process these data. Specific display routines will be used to visualise (intermediate) processing results. When relevant products that are generated will be saved in FINDAS for use in further processing.

For updates to calibration parameters change request will be issued such that after generation and verification the updated parameters can be made available for use in the standard processing algorithms.

Astronomers can use the IA algorithms to generate calibrated data from the raw TM and to further analyse these data to obtain scientifically useful parameters.

It should be noted that initially –especially in the development and early operations phases- the IA/QLA component will be fully optimised only for doing instrument behaviour analysis and calibration. Optimisation for and adding facilities to do astronomical analysis will come at the later stages.

3.1.2.8 FINDAS

In essence, FINDAS is the FCSS database. It will store all FCSS produced artefacts (e.g. observation templates, observation requests, observation instances, schedule, calibration data, data products) as well as the TM and ancillary data retrieved from the MOC.

FINDAS is expected to be based on an ODMBS. Artefacts will be stored as objects in FINDAS. FINDAS can be seen as an object server allowing retrieval and storage of objects from the FCSS sub-systems.

As already mentioned in section 2.2, FINDAS is key to the implementation of the FCSS geographical distribution (see 2.2.4) and the smooth transition between mission phases (see 2.2.3). This is expected to be supported by the FINDAS ODBMS in the following way:

The data distribution across centres (i.e. concept of one single data base for the FSC and the ICCs) is expected to rely largely on the ODBMS replication and remote access services.

Replication allows for objects to be pushed automatically from the site where they have been created to other sites (at the time of creation or at regular time intervals) therefore making them accessible locally at these sites. Remote access allows for objects to be pulled from the site where they have been created when accessed from a remote site.

For the FCSS, it can be expected that data will be stored primarily where the data is produced or first imported and will be replicated to other sites, if "heavy" use is made of these data at the other sites.

Otherwise data will be remote accessed from these other sites. For instance, it can be expected that TM data of a given instrument that will be primarily stored at the FSC will be replicated at the corresponding ICC. The decision to replicate data or not across centres will be made to optimise the data access performances and the load on the communication lines between centres

Data will flow between the different centres (FSC and ICC main centres) through dedicated communication lines who will be set-up for the duration of the in-orbit phase and post mission.

The sizing of the communication lines between the centres is further discussed in 4.

In terms of smooth transition, the ODBMS is expected to support the evolution of data format which are likely to occur along the FIRST mission. This is expected to be supported in two ways:

- 1) Reformatting of data. Data created in a given format can be reformatted to match new format. The ODBMS "schema evolution" feature is expected to give some support in this area
- 2) Access to old format data. FINDAS is expected to maintain the relation between the data and the version of the SW which created the data as well as the version of the SW which can be used to process the data, allowing data in old format to be accessed and reprocessed. The ODBMS support in this area is TBD.

On top of this, the FINDAS ODBMS is expected to have the following other features to support the FCSS:

- Storage/retrieval of object relationships: object relationships (e.g. link between an observation instance and its corresponding TM) are expected to be stored in FINDAS
- Object versioning: it shall be possible to have different versions of an FCSS artefact stored in FINDAS. Linked with the CCS (see 3.1.2.5), this will allow for the definition and storage of data configuration within FINDAS.
- Multi-users access: the FCSS database shall be accessible by multiple users in parallel. This calls for some locking mechanism at the ODBMS level to ensure the FCSS data consistency. External users (i.e. astronomers external to FSC or ICC) are not expected to access FINDAS directly so as to control and limit (in numbers) their access to the database
- Object query languages to support browsing.
- Security: it shall be possible to restrict the access to the FCSS database according to user name and groups (e.g. an observation request shall only be accessible to the astronomer who owns the request and to the FSC/ICC)
- Notification: it shall be possible to automatically notify users on the occurrence of a given event (e.g. upon execution of an observation request, the astronomer owner of the request can be notified).
- Test environment: FINDAS support is expected for creating test environments, so that software testing can be carried out, without altering the data in the operational database. The ODBMS support in this area is TBD.

Except for RTA and the OBSM (TBC), all FCSS sub-systems are expected to be direct client of the FINDAS-ODMBS. These applications will directly manipulate objects which will be stored/retrieved in/from FINDAS.

3.1.3 MOC SYSTEM COMPONENTS

The MOC design concept has been defined taking into account the SMP, the mission definition, preliminary space segment design and the FIRST Operations Scenario (RD 3)

The MOC consist of the following elements:

1. LEOP and routine phase Ground Station Network;
2. Mission Control Centre;
3. Mission Control Centre to FSC and ICC communications;
4. Mission Control Centre to System Validation Test (SVT) site communications;
5. Mission Control Centre to Centre Spatial Guyanais (CSG) communications.

Figure 3.1-3 shows the overall system configuration.

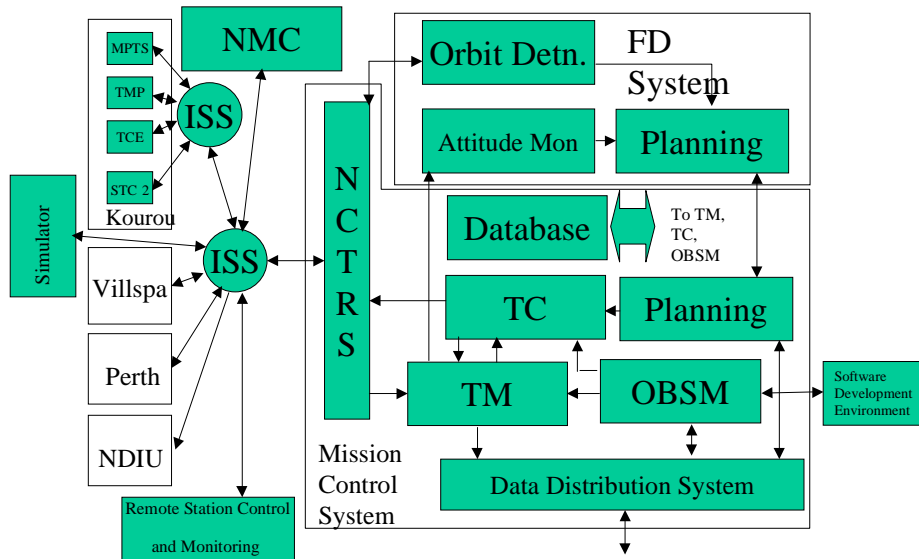


Figure 3.1-3: The FIRST MOC System

3.1.3.1 Ground Station Network

3.1.3.1.1 Ground Station Network Description

The prime station for FIRST operations will be the Perth 35m station. The ESA S-Band LEOP Stations Kourou and Villafranca will support the LEOP. The network will be configured for the FIRST and Planck satellites and commissioned starting from L-3 months. The ESOC Portable Simulator system will be configured for MSG to act as a Telemetry source and Telecommand sink at the ground station.

The Perth 35m antenna will be able to receive simultaneously right and left hand circular polarized signals in 2 GHz- (S-band) and 8 GHz-band (X-band) and in addition will be able to transmit signals with either right or left hand circular polarisation in 2 GHz and 7 GHz band, simultaneously to reception. The antenna is already prepared to be upgraded later for Ka-band (32 GHz band) reception. All specified performances can be met with program tracking, however Ka-band auto-tracking can be added optionally.

The overall mechanical/RF concept is a Turning Head (TH) structure with an integrated Beam Wave Guide (BWG) feeding concept. The TH structure provides good reflector surface and pointing accuracy in all operating conditions including wind disturbances and minimises thermal effects compared to a Wheel and Track design. The BWG design with solid and dichroic mirrors allows for optimisation of illumination, efficiency, gain and sidelobe performance for each band and permits simultaneous operation in all specified bands. With this concept all critical electronic equipment like High Power Amplifiers (HPA) and cryogenic

cooled Low Noise Amplifiers (LNA) can be placed into the equipment room at ground level and thus eases operation and maintenance. The optional Ka-band equipment will be located in the upper azimuth portion and will be rotated in azimuth.

The X-band up-link and down-link chains will be redundant. Tracking measurements will be made by the IFMS. The antenna position will be controlled by a Front-end Controller, based on current systems. Telemetry will be processed and stored by Telemetry processors (TMP), which provide the source of the data to be transmitted to the NCTRS at ESOC. Telecommand messages from the MCC will be processed by the Telecommand encoder (TCE Mk IV) for uplink. A Portable Simulator System will be configured to represent FIRST to support ground station testing, and the interfaces to the control centre for telemetry and telecommand.

3.1.3.1.2 Availability of the Network

The architecture of the ESA stations is such that all the essential parts of the stations with the exception of the antenna are redundant. In addition, all the stations subsystems are thoroughly tested and validated in their operational environment before being declared operational, and prove to be very reliable.

In addition to the redundancy, each station is equipped with a set of the most important spares, leaving to the station personnel the possibility in case of equipment failure to make a simple unit exchange while continuing to provide the required functionality with the redundant chain.

It has to be noted as well that each station is equipped with its own power supply based on Diesel generators and static converters for provision of Short Break and No Break power. During critical phases of supported missions, the stations are functioning on Internal Power, the Public power supply being available as backup.

The availability of the ESA Network, based on these architecture principles, has been excellent for previous missions.

3.1.3.2 Communications

3.1.3.2.1 Operational Communications Network

The current ESA Operational Communications Network consists of X25 nodes (ISS) deployed at each ESA station and at ESOC, interconnected via leased or public ISDN communications lines. By 2007 X.25 will have been replaced by TCP/IP. Figure 3.1-4 shows an indicative overall topology of the communications.

As shown in Figure 3.1-4, it is proposed to provide redundant communication lines to each of the stations: one permanent (leased line), and a redundant (ISDN type) procured at L-3 months.

3.1.3.2.2 LEOP Control Centre to SVT site Communications

In order to support the System Validation Tests, using the spacecraft, a redundant interface for TM/TC and voice, using a Network Data Interface Unit and ISDN lines will be set up between the Mission Control Centre and the Integration facilities in TBD. In order to ensure the availability of the equipment the NDIU

will be shipped with spare parts, and for the period of interface establishment, an ESOC technician will be present. For at least one of the tests a full NDIU will be used, the rest may use an NDIU_{lite}.

3.1.3.2.3 Mission Control Centre to FSC Communications

The interface to the FSC for the exchange of data (telemetry, auxiliary data, mission planning data, data bases, software maintenance data) will be based on the generic Data Distribution System.

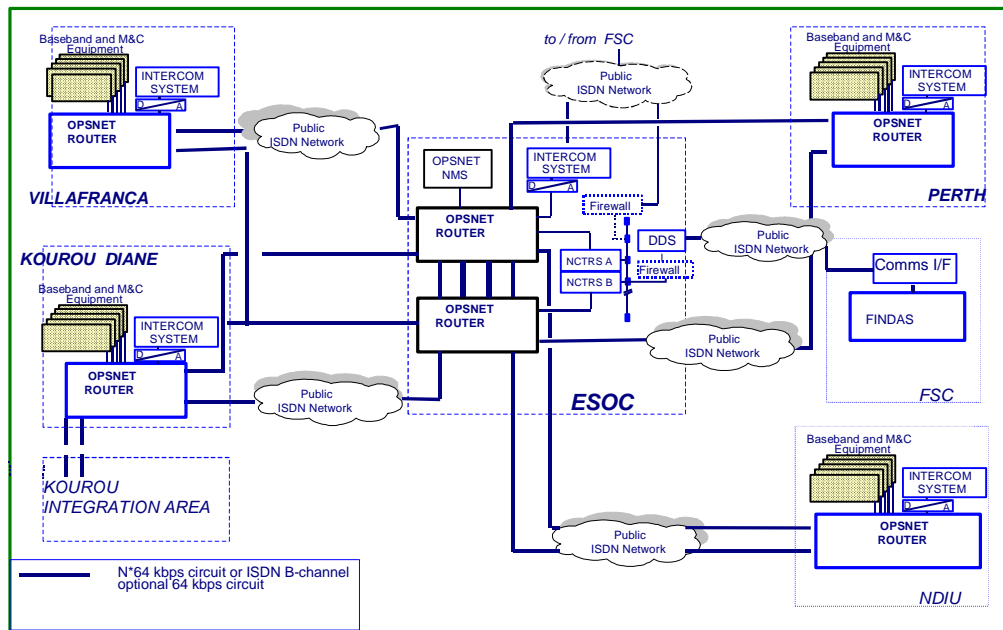


Figure 3.1-4: Overview of the communication network

3.1.3.2.4 LEOP Control Centre to CSG Communications

In order to monitor the status of the satellite after its shipment to Kourou, while it is either in the Integration area or on the launcher during the last days before the lift-off, an interface (TM and voice) will be provided between the LEOP Control Centre at ESOC and the CSG Interface in Kourou via the CSG's private fibre optic Network (ASTRE).

These links to CSG shall be established from Launch minus 30 days.

3.1.3.3 Mission Control Centre

The FIRST Operations will be conducted from ESOC, Darmstadt.

ESOC is equipped with the requisite facilities and staffing to ensure 24 hrs spacecraft monitoring and control capability (within the constraints of ground station coverage), including a no-break power system, independent of the local supplier (HEAG).

The major elements of the FIRST control system are the following:

- Facilities and internal communications
- Interface to the Network
- Mission Control System
 - Mission Archive
 - Performance Evaluation
 - External Interfaces
 - On-board Software Maintenance (Management)
- Flight Dynamics Services
- The simulator
- Mission Planning
- Data distribution and file transfer services
- On-board Software development and maintenance

3.1.3.3.1 Operations Control Centre Facilities

The operations will be conducted from the Main Control Room (LEOP) and the DCA, Flight Dynamics Services will be provided from the Flight Dynamics Room (LEOP), Communication and Network operations from the Ground Configuration Control Room. The Project Support Room (LEOP) will be made available for the FIRST support team. Other facilities for infrastructure services will be made available as required. Figure 3.1-5 depicts the ESOC computer and local area network configuration for FIRST support.

The operations control facilities are free of single points of failures. The availability of the infrastructure is based on redundancies. Details can be found in the description of the individual elements.

3.1.3.3.2 Interface to the Network

The interface between the ground station network and the Mission Control system will be provided by the generic NCTRS.

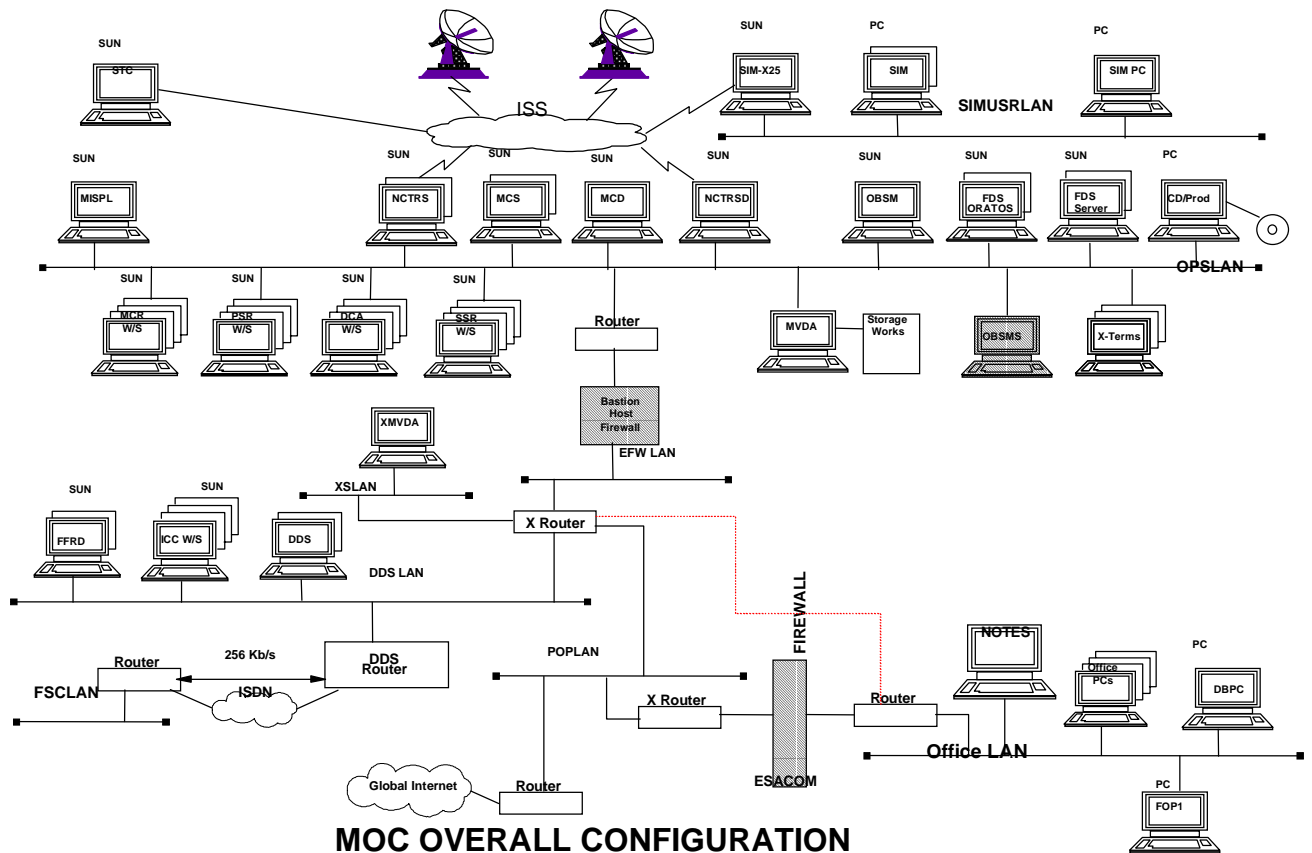


Figure 3.1-5: Representative MOC Computer and Network configuration for FIRST

3.1.3.3.3 Mission Control System (MCS)

The FIRST Mission Control System will be based on the SCOS-2000 control system. In addition to the standard telemetry and telecommand facilities it will include on-board software maintenance facilities for the management of software maintenance operations (configuration control, patch generation from images, dump and comparison operations). The facilities for platform software development and modification shall be installed at ESOC and accepted. For the first year software maintenance will be the responsibility of the Prime contractor.

Whilst many of the FIRST requirements can be covered by the configuration of the generic SCOS 2000 facilities, there will be some specific developments which cover e.g.:

- System management and configuration components
- Monitoring components, covering both spacecraft and non-spacecraft data monitoring
- Commanding components
- Spacecraft systems modelling

- Data storage components
- External interfaces to Flight Dynamics, Mission Planning, the DDS, the ICC@MOC and the ground segment
- On-board memory management
- The mission archive

3.1.3.3.4 *Data base*

The requirements on the Prime contractor prescribe a common database for ground and flight operations. It is assumed that a Rosetta-like implementation will be pursued, with a master and mirror sites, and the data base having domains which are specific to the user site. The MCS runtime data base will be derived from an export from the data base in a SCOS 2000 compatible format.

3.1.3.3.5 *Procedure Preparation Tool*

The WINFOPS/MOIS software suite will be used for procedure production. WinFOPS is a Flight Operations Plan (FOP) procedure text editor. It has an MS Excel based HMI front end and stores all the procedure information in a normalised relational MS Jet database; one per FOP procedure. The WinFOPS development has been running in parallel with the Mission Office Information System (MOIS) study. The MOIS study provides a COTS based framework for FOP Procedure development, configuration control and validation. In this respect, WinFOPS can be considered as another COTS tool to be integrated into this MOIS framework.

WINFOPS/MOIS will access the data base to retrieve data and to store resulting sequences.

3.1.3.3.6 *Performance Evaluation*

The Performance evaluation will be based on the generic PE system, which provides an access mechanism to archived data, so that the retrieved information can be conveniently used by a data processing software suite such as PV-wave or Excel.

3.1.3.3.7 *On-board Software Management*

The generic SCOS 2000 OBSM system will be configured for the Platform and Payload processors, assuming that they support incremental patching as a means of memory maintenance. Small incremental patches are assumed as the normal case in keeping with the limited uplink bandwidth and the restricted contact times. The OBSM utilities provide for

- Import of images from a software development environment
- configuration management of the on-board systems
- maintenance of a reference on-board image
- patch generation by image comparison
- command sequence generation for loading the patch
- command sequence generation for dump operations
- comparison of dumps with images.

3.1.3.3.8 *Mission Control System Hardware Configuration*

The FIRST SCOS-2000 system will consist of 2 server machines, and up to 18 user workstations. The server workstations will run the OPSNET interface, common processing and the filing. The user workstation will run the user interface and local processing. The user workstations will be located in the MCR, the DCR and the project support room. In addition 2 workstations will be provided to the ESOC operation staff for the database update and the FOP production.

In case of hardware failure of one server, the client workstations are still able to receive and process without interruption (hot stand-by back-up system) the telemetry data from the other server. The failing equipment is replaced and the data restored with no delay by the in-house support staff. During the actual LEOP, Computers and Local Area Network support is provided on site 24 hours. An exhaustive set of spare parts is stored in-house, so that failing items can be replaced immediately.

In case of hardware failure of a client workstation, the tasks can be taken over by another client workstation. The failed equipment will be replaced analogous to a server failure case.

The availability of the FIRST can be assumed to be equivalent to the availability of other mission configurations, for which statistical data based on experience are provided:

- No Computer / LAN down time has been registered so far in any of the LEOP missions operated by ESOC.
- The availability of the operational systems currently in use at ESOC is close to 100% (without scheduled downtimes).

3.1.3.4 *Flight Dynamics Service*

The Flight Dynamics system is based on the ORATOS software infrastructure. The functionality required for FIRST will have to be developed, but advantage will be taken of the ISO, XMM and Integral experience as much as possible.

3.1.3.4.1 *Hardware Description*

The current infrastructure is described as it is considered indicative of any infrastructure in place in 2007.

The flight dynamics operational software resides on a computer infrastructure dedicated to Flight Dynamics, based on SUN workstations presently running under Solaris. This infrastructure is organised as follows:

- Development platform composed of one file server interconnected through a common LAN to which individual clients are attached, for software development and maintenance work;
- Integration platform made of one file server and three clients, connected to the same LAN mentioned before, used to integrate and test operational software before its release to the operational platforms (see below);
- LEOP platform, made of two redundant file servers equipped with mirrored disc systems (ensuring high availability), several clients (including so-called number-crunchers and X25 connection to ESA ground stations used for STDN) connected to the servers through two redundant network branches: the full platform is connected to the completely isolated ESOC operational LAN and is available in the flight

dynamics room and its Annexes. The usage of this platform will be shared with Planck (and possibly other missions) during mission preparations (system tests and simulations) and LEOP operations.

- Routine operations platform, made of one file server, several clients (including so-called number crunchers and X25 connection to ESA ground stations used for STDM), connected to operational LAN: this platform will be used for routine operations of other ESA missions and also as backup to the LEOP platform.

This computer hardware infrastructure has been used for all projects supported by the Flight dynamics division at ESOC since 1994. It is therefore fully operational and permanently maintained, and its configuration is carefully kept up to date. This infrastructure offers a full operational availability without any single point of failure thanks to internal redundancy. The LEOP platform can be re-configured within a few minutes to its mirrored disc system or its backup servers, which is sufficient for nominal LEOP operations (and of course SVT). During critical operations the software will run simultaneously on the LEOP and the routine operations platforms connected respectively to the prime and backup SCOS-2000 telemetry servers (so-called hot backup configuration). In this configuration, one can carry on operations without interruption should anyone of the hardware component fail. This set-up provides, if needed, 100% availability and is absolutely free of any potential single point of failure.

3.1.3.4.2 *Software Description*

Flight Dynamics support for FIRST based on the ISO experience will provide for :

- Orbit determination for the transfer to L2 and for the Lissajous orbit at L2
- Orbit control for the transfer to L2 and for the Lissajous orbit at L2
- Mission Planning Support:
 - Delivery of planning tools to the FSC (slew predictors etc.)
 - Preparation of mission planning products: (PSF, etc.)
- Attitude determination and Control
 - AOCS monitoring and Calibration
 - AOCS command parameter generation
- Product Quality checking

3.1.3.4.3 *FDS Services*

Flight dynamics will provide support:

- to the ground segment integration and test
- to the LEOP and transfer operations
- to the Commissioning and PV Phases
- to the routine operations.

3.1.3.5 *Spacecraft Simulator*

The FIRST simulator will be used intensively during the Mission Preparation Phase in support of the following activities:

- test and validation of the spacecraft control and monitoring system

- test and validation of the flight control procedures for nominal and contingency cases
- training of flight control staff
- rehearsals of mission scenarios during the simulation programme

The behaviour of the spacecraft subsystems and dynamics relevant for the operations are required to be simulated realistically. The interface between the spacecraft control and monitoring system and the simulator will be at the level of the OCC communications node, i.e. the simulator will model the behaviour of the various telemetry and telecommand ground station equipment used during the FIRST operations.

3.1.3.5.1 Hardware configuration

The simulator will be based on an Intel platform running Windows 2000[®] with the interface to the network via a Sun running the OSI Stack

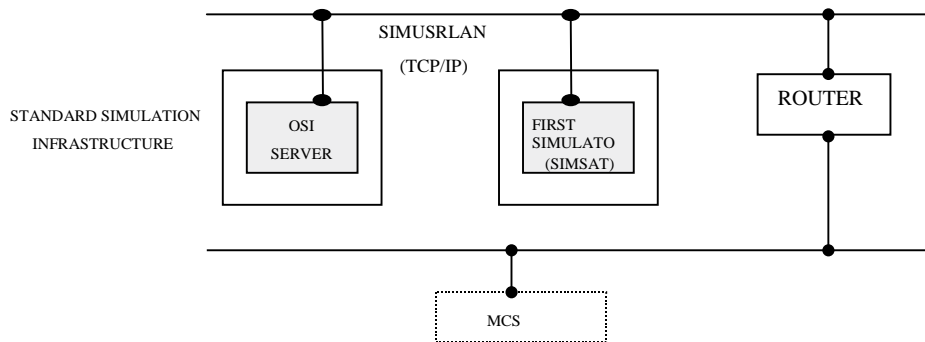


Figure 3.1-6: standard simulation infrastructure

3.1.3.5.2 Software Description

The simulator will be based on the SIMSAT-NT infrastructure, and assumes the re-use of existing emulations of on-board processors, and existing simulations of other on-board equipment.

The Payload is assumed to be simulated at the level of the engineering reaction and responses to telecommands as seen in the instrument housekeeping telemetry. Science telemetry will be generated only to provide a representative stream into the MOC.

The diagram shows the software structure for the simulator, showing the relationship between infrastructure, operating system and software developed for FIRST.

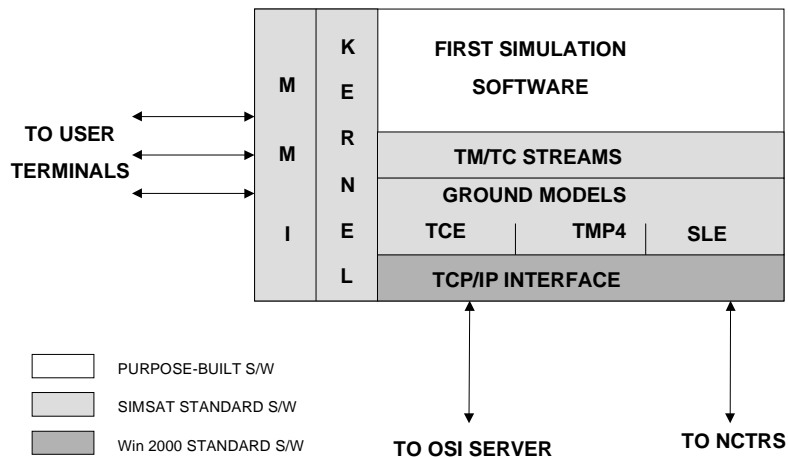


Figure 3.1-7: Simulator SW structure

3.1.3.6 Mission Planning

Mission Planning is a multistage process, partly performed by the MOC and partly by the Science Ground Segment. It is assumed that a process similar to the ISO mission planning will be followed. Figure 3.1-8 shows a preliminary planning flow, resulting in a plan for the space and ground station operations.

At about 3 weeks before the operations on the basis of the schedule for the Perth station passes and the requirements for orbit maintenance manoeuvres a Planning Skeleton File will be produced and put on the DDS for retrieval by the FSC. This file will include the attitude and other operational constraints, and slots allocated for spacecraft engineering tasks which exclude observations (manoeuvres etc.) for an approximately one day period.

About two weeks before the operations the FSC will provide to ESOC an Observation and Command Request File, which will include the requested observations (target, scan mode, etc.) and the instrument commands (in the form of mnemonics and parameters with associated times) and resource requirements (e.g. data rate). This will be processed by FDS to produce the commands for the AOCS, and the result combined with the detailed engineering requirements from the MOC expressed in the planned spacecraft operations file to generate the command schedule to be loaded on-board the satellite.

The schedule for the ground station will be generated at the same time. This will define the operations to execute:

- Station equipment configuration for FIRST

- The pre-pass tests
- The acquisition
- The ranging operations
- The acquisition of high rate data
- The post pass operations

The results of the planning cycle will be posted on the DDS. If the planning cannot be accomplished as expected the FSC will be informed and a new Observation plan solicited.

MISSION PLANNING FLOW

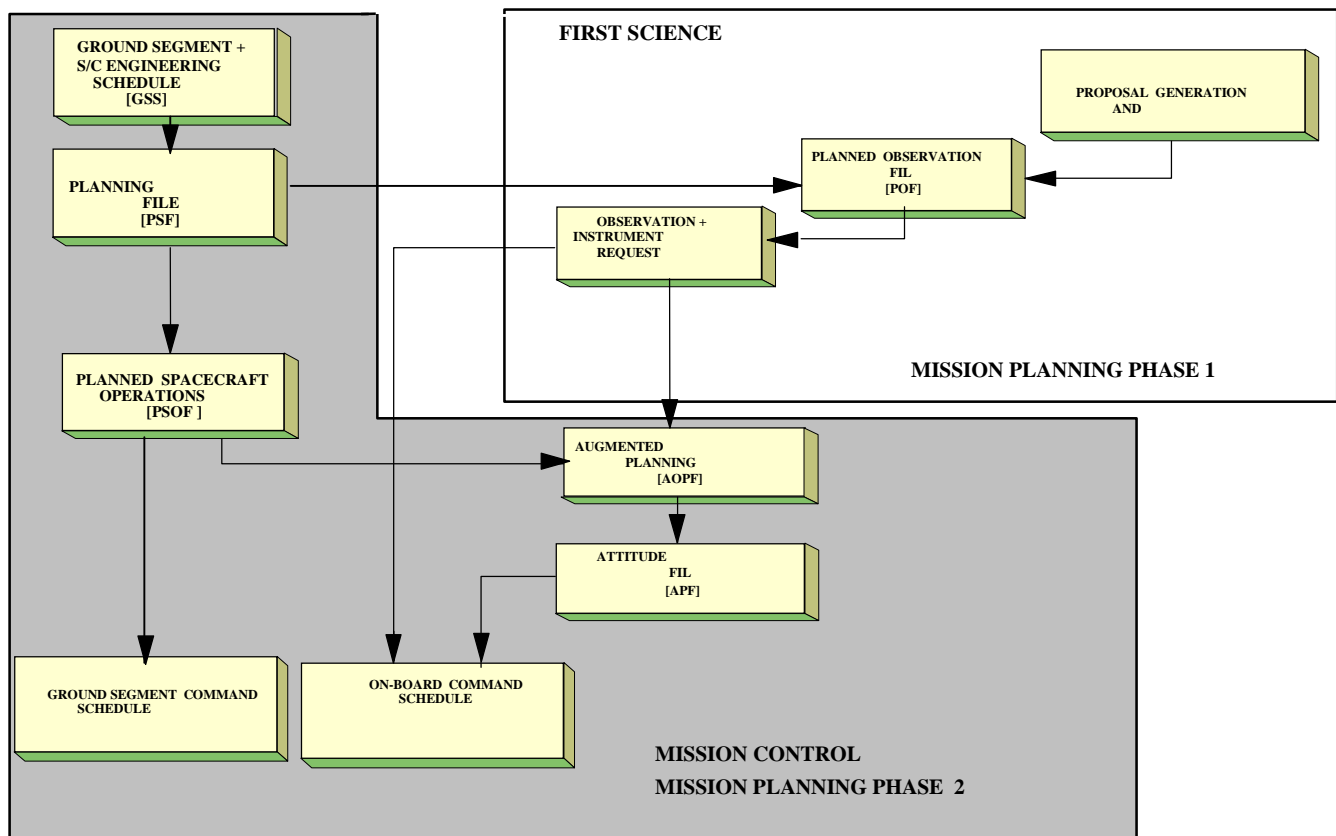


Figure 3.1-8: Mission planning Flow

3.1.3.7 Data Distribution System

The DDS will support the interface to the FCS for the transfer of data from the MOC to the FSC and vice versa. All data required for the operations is assumed to be transferred via the FSC, regardless of the originator. The data to be transferred is typically as follows:

FSC to MOC

Data	Form
Observation Plan	Files

MOC to FSC

Data	Form
Skeleton Plan	Files
Final Plan	Files
Commanding Timeline Summary	File
Telemetry	File
Time correlation	File
Telecommand History	File
Orbit and attitude reconstituted	File
Reporting	Document
FOP	Document
Database	File
SSO DB	File
Operations Status Info	Document

ICC to MOC (via FSC)

Data	Form
Data base	File
Command Sequences	File
On-board software images	Files
Software memory maps/definition	Files/document
Procedures	Document
Instrument Apertures and Pointing	File
Misalignment	

MOC to ICC (via FSC)

Data	Form
Database	File
FOP	Document

All data recorded will be dumped (i.e. the data which is received in real time will be duplicated at the MOC).

The telemetry at the MOC will be archived in the Data Distribution System as files of data (probably for 7-10 days), from which it is accessible to the FSC (and to the ICCs). The telemetry will be organised by type, application ID and time¹:

¹ The data may be also organised and accessible by observation.

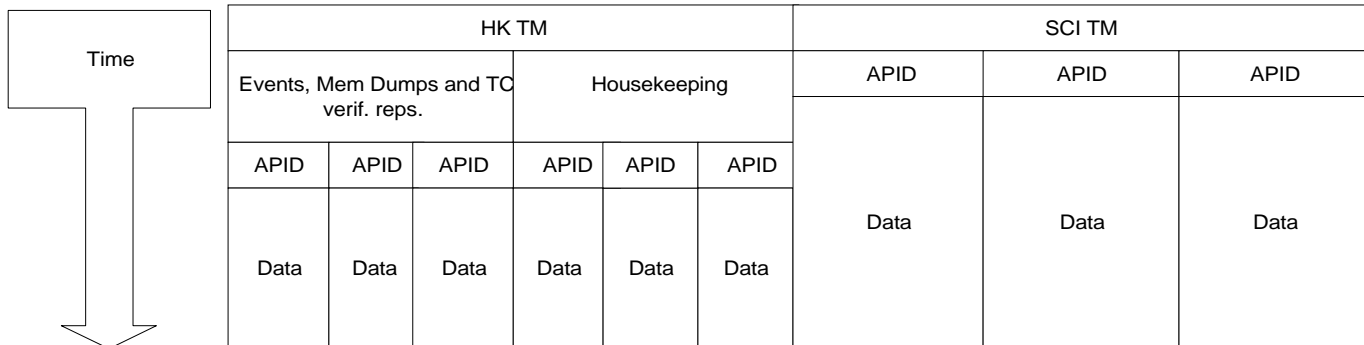


Figure 3.1-9: The DDS structure

3.1.3.7.1 *Extraction of data from the DDS*

Access to the data from the data distribution system can be via a catalogue, which defines (for telemetry) on an AP ID basis the data which is available on the DDS. The system can be designed so that data is placed immediately on the DDS and the catalogue defines the last data arrived and also the time for which the data which are considered to be complete, either because they are, or because the “consolidation time “ has expired. (The consolidation time is the time after which no more data can be expected to be received pertaining to the time period for which the data is being merged into a time ordered stream.) It may be practical to declare the consolidation time earlier for certain types of data (e.g. events and TC reports) so that they appear in the archive as consolidated very quickly.

The advantage of such a system is that real-time data can be made available to a user almost as soon as it arrives, without waiting for consolidation.

The DDS is a near real-time processing system, which provides data access on a demand driven basis, i.e. the PIs or FSC are responsible for respective data requests. The MOC will not “push” data to the FSC . It is assumed that the user (ICC or FSC) will request data from the data archive (DDS) by APID and time period as required. The data / message transmission will be via transfer only.

TM data is provided as raw data and therefore the users will need the MOC data base to interpret the non-science data.

DDS Interfaces will be governed by the Data Disposition Interface Document (DDID). This document will be issued and agreed with all users (FSC and PIs). It will be put under configuration control as ESOC's formal delivery commitment. The DDID will describe the formatting of delivered data down to the necessary level of detail to enable users to retrieve science data and any required housekeeping or auxiliary data.

3.1.3.8 *On-board Software development and maintenance*

The Prime contractor will deliver a software development environment and software validation system to ESOC for the maintenance and configuration management of the on-board software in the various subsystems. The output from the system will be new software images which are passes to the OBSM system for the generation of new patches to be transferred to the spacecraft

The hardware/software for the system is TBD.

3.1.4 RTA

The RTA will support the extraction, conversion and display of housekeeping parameters from a stream of instrument HK TM as well as the monitoring of these parameters against their expected value or status. In addition it will support command verification, on-board memory checking and the monitoring of events.

RTA features two modes. The Real time mode and the play-back mode. The real time mode is not used in routine phase, it is described in 3.2.3.

In its 'playback' mode, the RTA component will retrieve TM data FINDAS (see 3.1.10). In this mode the relevant interfaces shall accommodate a data flow corresponding to 10 (TBD) times the on-board data rate.

RTA will be based on the SCOS-2000 system during all phases of the mission.

3.1.5 OBSM

The OBSM is used to generate new instrument on-board software images. It consists of a dedicated system to generate a new version of the OBSW, to compile it, to generate checking parameters (checksum etc.) and to test its functional performance.

The OBSM will generate an image in the form as required by the MCS for uplinking. This image will be transferred to FINDAS for the project scientist 's approval.

3.1.6 INSTRUMENT DATABASES

The instrument databases contains information about the configuration of the instrument and satellite monitoring software (SOCS 2000), the uplink (TC) and downlink (TM) data of each instrument and the spacecraft.

The database contains the following information:

- Configuration of the SCOS 2000 system, e.g. views, calibration tables, derived parameters definition, mimic displays...
- Definition of downlink telemetry, e.g. structure and definition of instrument house keeping telemetry, as well as information to detect out-of-limit values in the telemetry.
- Definition of uplink, e.g. command mnemonics, command parameters, command packets, command sequences...

The instrument databases will have the same format for all three instruments, they will be generated by the database editor supplied with SCOS-2000. They will be generated as plain ASCII files and will be imported in the different systems using them: the MOC system, RTA, EGSE-ILT, CCE and the FCSS.

The run time version of these databases is expected to be different for the FCSS than for the MOC system, RTA and EGSE-ILT which are all SCOS-2000 based.

3.1.7 INSTRUMENT SIMULATOR

The 'Instrument Simulator' as required in the original AO from ESA is a software simulator of the whole instrument. It will be used by the FIRST Ground Segment to:

- 1) To train operations staff (by simulating typical housekeeping and science telemetry, providing anomalous situations e.g. out of limits in housekeeping data etc)
- 2) To allow the Ground Segment procedures to be exercised
- 3) To test new command sequences and observation
- 4) To test updates to OBSW

This simulator will be delivered to ESOC for integration into their S/C simulator (see 3.1.3.5) where it will run in a TBD environment.

3.1.8 FSC–MOC INTERFACES

The interface between the FSC and the MOC will be file based. It will be supported on the MOC side by the DDS sub-system which will serve files to the FSC upon request or which will store files exported from the FSC. The FSC will implement a number of functions to interface to the DDS. These functions are further described in this section

3.1.8.1 *The TM I/F towards MOC*

This side of the interface covers the importation of consolidated TM from the MOC to the FSC. It is operational throughout the following mission phases: Commissioning, PV, Routine. The consolidated TM are expected to include the derived parameters and Out Of Limits information generated by MOC (see IRD 3.1). They will be included in the form of TM packets with their own APIDs (TBC).

This I/F has the following functions:

1. Request files of consolidated TM to the DDS, the request will include the following parameters: time range (wrt on board time at which the TM have been generated), APID. It is expected that the APID will differ according to instruments but also according to the category of TM, i.e. HK or science.
2. Import files of TM from the DDS
3. Interface with the TM archiving function.

Wrt to point 1)

- The request of TM will be triggered by the availability of consolidated TM. This assumes that this information (i.e. availability of consolidated TM per APID) can be requested from the DDS (see 3.1.3.7).
- Upon availability, the instrument HK TM will be requested first to meet performance requirements (see IRD-3.5-20)
- The consolidated TM I/F function is expected to request TM files to the DDS in an automatic fashion, the frequency of request may depend on the mission phase in order to meet the different performance requirements for TM availability at ICCs (see IRD 3.5-20).

- The TM I/F function has the responsibility of not missing TM and of is expected to be smart enough to avoid importing TM packets twice.

Wrt point 2), An ftp based protocol is expected to be used. As TM transfer may involve large files (e.g. up to 1 GB), it is expected that the protocol will be able to recover from communication failure without having to restart the transfer from the start.

Wrt point 3), the TM archiving function is expected to be the same for NRT TM and consolidated TM (see 3.1.8.2) and therefore only have one implementation independently of whether it archives consolidated or NRT TM. The TM archiving function should receive NRT TM as a stream of packets. Consequently, the consolidated TM I/F should translate files of TM data as received from the DDS into a stream of TM packets.

3.1.8.2 The TM I/F towards FINDAS

This side of the interface covers the archiving of the TM into FINDAS where they can then be retrieved by the different FCSS applications. In addition to routine phase, the archiving function is expected to be operational throughout the following mission phases: ILT, IST, Commissioning, PV.

Although in routine phase in the FSC this function will only ingest consolidated TM, the TM archiving function is indeed expected to be the same for consolidated TM, NRT TM (see 3.6.7) and largely the same for TM from the EGSE-ILT or the CCE (see discussion below).

In all cases the TM archiving function is expected to receive TM data as a stream of TM source packets formatted according to ESA standard packets.

The TM archiving function will archive TM as TM source packets (i.e. as generated by the instrument or the S/C), this is important as application like RTA rely on TM (note RTA only consumes HK TM) in this format downstream , i.e. no processing of TM packets is expected to be performed at the time of archiving the TM. In particular:

- The science TM packets data segment will be in a compressed format
- The TM packets data field header will include the packet generation on board time (OBT). The FSC and ICCs may have to convert OBT to UTC using the time correlation information from MOC (see below).
- The parameters will be delivered in raw format that will have to be converted (using the instrument database) into engineering units as part of data processing.

The ingestion of TM shall be such that any TM packets can be related by users to their originating observation and observation building block when relevant, i.e. the observation building block execution during which they have been generated. This will include TM related to parallel and serendipity observations. To this effect each instrument TM packet will have been tagged by the instrument OBSW with the current OBSID and BBID. The non instrument TM, will be related to the observation and observation building block by the TM archiving function thanks to their on-board generation time tags. The on-board time tag will in TAI while the reference time for the FGS will be UTC. A conversion will therefore have to take place in the FCSS to relate TAI with UTC.

The observation and observation building block context and id will be generated as part of the schedule and transmitted to the instruments as part of dedicated TC (see also MPS in 3.1.2.3).

The TM archiving function will also have to deal with TM which are not related to an observation. The following cases can be identified:

- Instrument HK TM for the instruments not involved in the observation (i.e. HK TM from the non prime instrument). The archiving of these TM shall be such that they can be easily related to the observation in order to study possible interference between instruments. The archiving of these could be done based on generation time.
- Instrument TM that results from commanding by the MOC outside a mission timeline (manual commanding) or within a mission timeline but outside the context of an observation. Manual commanding by MOC will be done at the level of instrument command sequences that can be map in the CUS concept to observation building blocks (see 3.1.2.1). The TM archiving will relate these TM to the to the instrument command sequences in the FCSS/FINDAS. For this purpose, Instrument command sequences will be associated with an id by the MOC, so that all instrument TM packets generated as a result of this instrument command sequence will be tagged by the instrument OBSW with this id. At the time of ingestion, these TM will be related to the relevant instrument command sequence.
- S/C TM that results from manual commanding by the MOC. The archiving of these TM is TBD.

The TM archiving function shall not make any assumptions on the sequence of the stream of TM it will received, in fact it should be possible to store each TM packet independently from the its predecessor and or successor. In Routine phase, he will most likely receive TM packets ordered by APID and then, for each APID, according to the TM generation time. For NRT TM, see 3.6.7, the TM archiving will receive TM sorted by VC (HK and science TM with no further distinction made per APID). In addition, for NRT TM , the time sequence of TM packets cannot be guaranteed as TM packets lost between the ground station and MOC can be later retrieved by MOC and transmitted via the DDS.

The TM archiving function will have to meet the following real time constraints. It will have to be able to ingest TM data at a higher rate than the on-board TM data generation rate (i.e. 100kbps) (FSC-URD-3.2-0170) and it shall be such that the delay between the start of the ingestion and the retrieval of this packet at a FINDAS local node does not exceed one minute (FSC-URD-3.2-0200).

3.1.8.3 The MOC SW & data I/F towards MOC

This side of the interface covers the importation of the MOC SW and data (at the exclusion of TM) from the MOC to the FSC. In addition to routine phase, this function is operational throughout the following mission phases: Commissioning, PV.

This covers the following data (from IRD 3.1):

- S/C orbit predictor SW & data
- S/C Attitude constraint SW & data
- S/C slew time and path predictor SW & data
- planning skeleton data
- observations schedule status information
- commanding timeline summary

- TC history
- S/C orbit data (reconstituted)
- S/C attitude history
- Time correlation
- Instrument memory image
- S/C and instruments databases
- Instrument aperture pointing misalignment
- SSO database

All of these data will be imported from MOC to the FSC as files. An ftp based protocol is expected to be used.

At this point, one should distinguish between the data periodically produced (i.e. for each operational day) and the ones produced on a one-off basis. The former are:

- planning skeleton data
- observations schedule status information
- commanding timeline summary
- TC history
- S/C orbit data (reconstituted)
- S/C attitude history
- Time correlation

For these ones produced on a regular basis, the import from MOC is expected to be automatically triggered (versus manually), based on time or on notification from MOC (TBC).

3.1.8.4 MOC SW and data I/F towards FINDAS

These set of interfaces cover the ingestion of MOC SW & data (see 3.1.8.3) into FINDAS where they can then be retrieved by the different FCSS applications. Wrt archiving, one should distinguish between ancillary data, SW and other data

3.1.8.4.1 Ancillary data

The ancillary data are the following data:

- commanding timeline summary
- TC history
- S/C orbit data (reconstituted)
- S/C attitude history
- Time correlation

In addition to routine phase, this function is expected to be operational throughout the following mission phases: Commissioning, PV and ILT/IST for the TC history and the Time correlation data.

For TC history and Time correlation, the archiving function is expected to be largely the same for the data generated by the MCS and the ones generated by the EGSE-ILT and the CCE. As already mentioned this is partially guaranteed by the fact that all three systems, the EGSE-ILT, the CCE(TBC) and the MCS will be

SCOS-2000 based. The archiving of ancillary data in ILT and IST are further discussed respectively in 3.2 & 3.3.

The same comments as for TM (see 3.1.8.2) applies for those ancillary data which cannot be related to an observation.

It should be pointed here that Time Correlation information may not be needed by FSC and ICC during in-orbit phase. Indeed MOC has the requirement (see OIRD??) to maintain the on-board time correlated with ground time with an accuracy of 30 ms. This could already meet the FSC and ICC performance requirements on time correlation (see IRD 3.1-430).

3.1.8.4.2 *MOC SW & data*

The MOC SW & data are the following:

- S/C orbit predictor SW & data
- S/C Attitude constraint SW & data
- S/C slew time and path predictor SW & data

The archiving function for these SW & data are TBD. They are relevant to the in-orbit phase only.

3.1.8.4.3 *Others*

Other MOC data which will be archived by the FCSS are the following:

- planning skeleton data
- observations schedule status information
- Instrument memory image
- S/C and instruments databases
- SSO database
- Instrument aperture pointing misalignment

The archiving functions for these data are TBD. They are relevant to the in-orbit phase only.

The S/C and instrument databases will be indeed exchanged between the MOC and the FSC/ICC as a file (e.g. Microsoft access) (see 3.1.6). For run time purpose, this file will have to be ingested in a run-time data base which can then be accessed by the relevant FCSS application (e.g. IA/QLA or QCP) (TBD).

3.1.8.5 *The schedule I/F towards MOC*

This side of the interface will cover the exportation to the DDS of the schedule produced by the FSC (see MPS in 3.1.2.3). In addition to routine phase, this function will be operational throughout the following mission phases: Commissioning, PV.

The schedule will be exported to the DDS from the FSC as a file. An ftp-based protocol is expected to be used.

3.1.8.6 *The schedule I/F towards FINDAS*

This side of the interface will cover the extraction of the schedule data from FINDAS as generated by the MPS and the formatting of these data into a file to be exported to MOC. There will be one schedule file for each operational day. In addition to routine phase, this interface will be operational throughout the following mission phases: Commissioning, and PV.

The schedule file is expected to be constituted of the planning skeleton data as imported from MOC and the TC mnemonics generated by the MPS implementing the observations schedule.

3.1.8.7 *The ICC data I/F towards MOC*

This function covers the exportation to the MOC of the schedule produced by the FSC and ICC data needed to operate the MOC. In addition to routine phase, this function is operational throughout the following mission phases: Commissioning, PV.

This will include the following data (from IRD 3.4):

- Instrument on board SW updates
- SSO database updates
- Instruments database updates
- Instruments procedures and command sequence updates
- Instrument apertures pointing misalignment updates

All of these data will be exported to MOC from the FSC as files. An ftp-based protocol is expected to be used.

Instrument procedures -i.e. (mostly) manual instrument procedures to be invoked by MOC personnel in contingency situations- are generated using the same tools as used by the MOC for the satellite procedures; MOIS/WINFOPS (TBC).

3.1.8.8 *The ICC data I/F towards FINDAS*

This side of the interface covers the extraction of data (see 3.1.8.3) from FINDAS and the formatting of these data into files (when relevant) for export to MOC. In addition to routine phase, this interface is operational throughout the following mission phases: Commissioning, PV and also to ILT and IST for the instrument database and instrument on-board SW (TBC).

3.1.9 FSC-ICC INTERFACES

These interfaces will be object based. Objects created in any of the FSC or ICC (e.g. as a result of the archiving of TM in FSC or new instrument calibration parameters in ICC) will be (when relevant) accessible in a transparent manner to any of the other centre. As mentioned in 2.2.4, the FSC-ICC interfaces will rely on FINDAS and in fact on the ODBMS remote access or replication mechanism.

Interfaces between ICCs (e.g. between PCAS-ICC and HIFI-ICC) will flow a priori flow through the FSC-ICC dedicated lines and the FSC-FINDAS node. However, it cannot be excluded that for data that are of no

interest to the FSC, data flows directly between the ICCs through ICC managed communication lines. This is to be supported by FINDAS.

3.1.10 FCSS-RTA INTERFACES

FCSS/FINDAS and RTA will interface through a "receiver"(SCOS-2000 terminology) which will act as a front-end to RTA. SCOS-2000 documentation defines the minimum functionality to be supported by the receiver (e.g. detection of missing TM packets, TM packets bufferisation,). The receiver will be developed by the ICCs.

The TM packet ingested into FINDAS will not include SCOS-2000 headers. SCOS-2000 headers will be added to TM packets for RTA purpose by the receiver.

No SCOS-2000 functionalities will be lost having FINDAS between the TM I/F and RTA, in particular it should still be possible to play back TM and automatically resynchronise with RT monitoring.

3.1.11 FCSS-OBSM INTERFACES

TBW

3.2 *Instrument level tests*

3.2.1 INTRODUCTION

In the Instrument Level Test (ILT) phase, the most obvious difference with respect to routine operations (see section 3.1) is that there is no satellite and no MOC between the instrument engineers and calibrators and the instrument. Since the instrument communicates to the outside systems through its spacecraft interface, spacecraft behaviour has to be simulated. In the same vein instrument specialists have an 'interface' to their instrument and its data via MOC/FSC systems and procedures, part of that behaviour also has to be simulated in ILT. These functions have to be simulated in such a way that most -if not all- operations systems that could be used for ILT can be exploited to their fullest during the in-orbit phase without significant changes. The aim is to be able already during ILT to operate the instrument using 'observations' as the basic containers for both commanding as well as for data archiving and reduction.

As an extra component that is not present in operations, during ILT various types of additional test equipment will be used. Some of this equipment will maintain and monitor the environmental conditions of the instrument under test, some of it will be used to give stimuli to the instrument.

Note that in early parts of the ILT phase much testing will be done by directly commanding the instrument. In this (short) period most of the GS functions will not be used.

3.2.1.1 *Specific GS functions that have to be emulated*

To be able to (efficiently) using the observation as a basic entity in the ILT phase to encapsulate instrument test command 'scripts' and the resulting data, all ILT operations and procedures have to mimic the operational environment. This is done by emulating a number of GS functions that do not exist as such

during ILT and by using –as much as feasible- standard GS interfaces between the different functions. When needed (slightly) adapted versions of these interfaces will be adopted during ILT.

The FSC/MOC functions that have to be emulated for ILT are the following:

- Generate an ‘observation’
- Make a schedule of one or more observations
- Transfer schedule (with TBD auxiliary information) to EGSE-ILT system (test control)
- Send commands according to schedule to ILT equivalent of satellite (test control)
- Receive telemetry from instrument
- Do real time monitoring of telemetry
- Archive telemetry and monitor products

The satellite functions that have to be emulated in ILT are:

- Send command packets to instrument at time corresponding to time tag
- Send other relevant command packets to the instrument (e.g. time synchronisation, safety shutdown)
- Receive telemetry from instrument and forward to ILT ‘downlink’ system
- Invocation and execution of autonomous procedures (e.g. shut instrument down when HK indicates non-nominal situation)

3.2.1.2 *The ILT set up*

Figure 3.2-1 shows the set-up for the ILT phase. Within the EGSE-ILT system a number of MOC and satellite functions are replaced by specific ILT functions.

First of all there is a TM/TC interface, which towards the instrument functions as the satellite bus. On the GS side this interface functions as a TM/TC relay station, which can also relay TC/TM to ILT test equipment. The uplink function represent all MOC/FSC activities which are needed to get time tagged commands to the satellite, the downlink function represents the activities to get TM back to ‘ground’. The test control function encompasses all activities related to running test procedures, doing manual interaction/intervention and –together with the RTA function- on board autonomy procedures. These functions need to be implemented specifically for ILT and will not (likely) be reused during operations.

The remaining functions are –more or less- standard GS functions; RTA and IA/QLA for data monitoring and analysis, PHS and MP for generating and scheduling ‘test observations’.

Whenever possible the interface as defined for operations will be honoured.

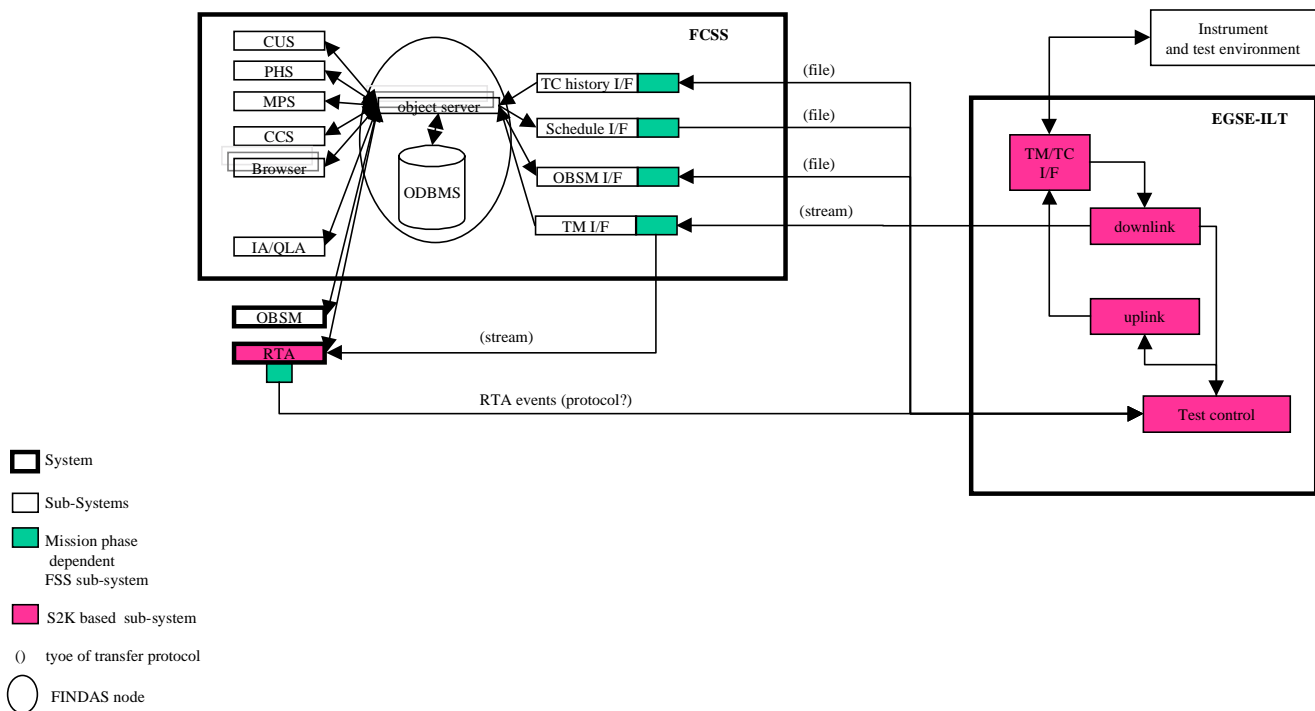


Figure 3.2-1: The FGS in ILT

3.2.2 FCSS COMPONENTS FOR ILT

3.2.2.1 CUS

During ILT CUS functions will be used as in operations to be able to generate the commands necessary to test the instrument. Like in operations observations will be created using PHS from building blocks and individual instrument commands. To create and/or modify building blocks and templates standard CUS procedures will be used.

Specifically for ILT a number of commands and building blocks that are used for controlling test equipment will be generated from the CUS. Similarly specialised blocks/commands will be generated to support the

procedural nature of tests to be executed in ILT (e.g. commands to Test Control like ‘wait for go’ or even ‘if condition switch to alternate schedule’). From CUS, PHS and MPS point of view, these extensions will behave exactly as normal instrument or S/C commands. As an example like standard building blocks these special building blocks will also have a building block identifier (BBID) such that in the telemetry resulting from a test also the data generated by test equipment in a given test has a unique OBSID-BBID combination.

3.2.2.2 PHS

The Proposal Handling System will be used to generate test/engineering ‘observations’. Since no observation proposals are involved and all ‘observation’ are generated by instrument specialists in practice this means that only a few specific PHS functionalities are required for ILT:

- Create observation request
- Fill template
- Estimate ‘observing time’
- View observation building blocks for observation
- View instrument commands for observation
- Submit observation for scheduling

In ILT this function also has to generate test equipment and Test Control commands as part of observations.

Explicitly the following PHS functionalities will not be used in ILT:

- Handling (scientific) proposals
- Grading observations/proposals
- Managing observation priority

3.2.2.3 MPS

In ILT the Mission Planning System will be only used to *sequence* several test ‘observations’ generated in PHS into a test schedule. The resulting schedule is stored in FINDAS through standard procedures, and thus available for export to test control through the schedule export interface.

Only a very limited subset of the MPS functionalities is required for ILT:

- Create new empty schedule (there are no pre-conditions for a schedule apart from maybe setting the start time i.e. the default schedule template is totally empty)
- Select observation from available set of observations (note ‘available’ here only is meant as ‘is valid’ and possibly ‘has execution flag not set to done’)
- Add observation (multiple times) to schedule and assign a unique OBSID to it
- Delete observation from schedule (and free the OBSID)
- Generate TC mnemonics from scheduled observation (using CUS)
- Save schedule
- Mark schedule as ‘ready for export’

The schedule generated by MPS will be compliant with (a subset of) the MOC-FSC schedule interface.

Explicitly the following MPS functions will not be used in ILT:

- Automatic schedule generation
- Scheduling constraint handling
- Observation priority handling
- Disabling and enabling observation modes
- Long term scheduling

MPS can generate TC mnemonics with absolute or relative time (TBD).

3.2.2.4 *QCP*

N/A

3.2.2.5 *CCS*

Same as in operations, see section 3.1.2.5

3.2.2.6 *Browsers*

Same as in operations, see section 3.1.2.6

3.2.2.7 *IA/QLA*

Same as in operations, see section 3.1.2.7

TM will be retrieved from FINDAS for processing and products will be stored in FINDAS. The data interfaces must be the same as in operations; the actually available IA/QLA analysis functionalities will be less extensive as in operations (as they are still under development).

3.2.2.8 *FINDAS*

In all cases where items are stored in or retrieved from FINDAS this will be done according to the standards defined for operations. This includes the setting of access rights and version control.

In practice all active ILT personnel will get very liberal access rights for all data entered into the system.

In the ILT phase an instrument group will have one master FINDAS node, which is the node directly associated with the test environment. The full FINDAS replication mechanisms are not expected to be in place in this phase, therefore when other FINDAS nodes require data and/or (newly developed) software from that node some form of 'manual replication' will have to be used. This could range from -manually initiated- export-FTP-ingest type operations to –again possibly manually initiated- low level ODBMS based replication.

At some point (after?) ILT the contents of the three instrument FINDAS nodes will have to be merged back into the single truly distributed FINDAS system as it will be available in operations. This will be done in a TBD manner.

The mechanism by which the FCSS is kept in synch with FINDAS development at the ILT sites is TBD.

3.2.3 EGSE-ILT COMPONENTS

3.2.3.1 *Test Control*

The Test Control function in ILT mimics the MCS as well as the CDMS functions.

As part of the Test Control, it will be possible (TBC) to construct test procedures, including flow control logic as well as references to ‘test schedules’ containing ‘observations’ generated by MPS, using the MOIS/WINFOPS system. The MOIS/WINFOPS generated test procedures are stored and managed within the Test Control environment. As a consequence the full procedures are not known to the FCSS.

At run time, the Test Control takes commands from a test schedule and sends them through the Uplink component to the TM/TC interface to be forwarded to the instrument or test equipment. Also when required a schedule can be altered or aborted from Test Control. These activities under Test Control functions emulate the on-board schedule.

When Test Control receives event packets from RTA Test Control will react by executing predefined procedures (automatically or under user control). This loop emulates the on-board autonomy function. < it is not clear what we mean by test procedures, how do test procedures relate to test schedules?> From Test Control also manual commands can be sent to the instrument and test equipment, thereby emulating the CDMS as master controller as well as direct ground to satellite commanding.

The TM received from the Downlink component is compared to the commands sent to the Uplink component to construct the TC History. The TC history is subsequently transferred to the FCSS for further processing and archiving.

3.2.3.2 *Uplink*

The Uplink component receives commands from Test Control, converts them to TC packets, verifies these and when valid sends them to the TM/TC interface.

3.2.3.3 *TM/TC interface*

The TM/TC interface distributes TC packets to the different systems used in the ILT; the instrument and test equipment. From these systems the interface receives TM packets that it forwards to the Downlink component.

3.2.3.4 *Downlink*

The Downlink component verifies the TM packets and sends them on to the FCSS for further processing (archiving and analysis). The packets are also sent to Test Control to allow it to check progress on the commands it issued and to be able to construct the TC history.

3.2.4 RTA

In its 'playback' mode during ILT the RTA component will function exactly like it will during operations (see 3.1.3).

In the 'real time' mode RTA will be fed either by a TM stream directly from the TM I/F or by a stream retrieved from FINDAS generated synchronously with the TM archiver feeding the TM stream from the instrument into the archive. It is still TBD which of these two options will be used.

In ILT RTA 'real time' also is part of the 'autonomy functions' chain in the sense that RTA is needed to monitor (critical) HK and event packets that trigger autonomous processes. For this purpose RTA must be configured such that monitoring of these specific packets can result in the generation of 'RTA events' that are sent to the 'test control' function for further processing. Since this loop is used emulate the on-board autonomy functions it puts a timing requirement on the system (feedback should occur on the same time scale as the on-board autonomy procedures). Alternatively, this 'autonomy' interaction could also be handled within the SCOS 2000 based parts of the Test Control component (TBC).

Products generated by RTA real time (e.g. OOL events or derived parameters) will be stored in FINDAS through the same interfaces as used in operations.

3.2.5 OBSM

Same as in operations, see section 3.1.3.

OBSW updates are generated in the OBSM facility and archived in FINDAS. From there it gets retrieved and sent to test control through the OBSM I/F.

Any configuration control processes associated with OBSW updates during operations will be used in the same manner during ILT.

3.2.6 FCSS - EGSE-ILT INTERFACES

3.2.6.1 *Schedule I/F*

The schedule interface component has to retrieve a test schedule from FINDAS and forward it to the test control component of the EGSE-ILT. Test control will be based on SCOS2000 and, the interface may be required to do some conversion to make the schedule directly suitable for use in SCOS2000.

In practice the schedule interface between FINDAS and EGSE-ILT is essentially the same as for operation. It covers the extraction of the schedule data from FINDAS as generated by the MPS and the formatting of these data into a file to be exported to the EGSE-ILT/Test control. There will be one schedule file for each 'test schedule'. In addition to routine phase, this interface will be operational throughout the following mission phases: Commissioning, and PV. The schedule file is expected to consist of relative (TBC) time tagged TC mnemonics generated by the MPS implementing the observations schedule.

Retrieval of a new schedule is initiated by a request from test control. Such requests are probably generated automatically from a test procedure.

The generation of a schedule will often be done under control of an autonomous process. In this case the Test Control component of the EGSE-ILT will invoke MPS methods to generate and retrieve a new schedule.

The generation and of a test schedule upon request from the test control is expected to be done in real time as part of the execution of the test procedure.

3.2.6.2 *OBSM I/F*

Towards FINDAS the OBSM I/F will be identical to what will be implemented for operations; essentially this will be an OBSW image in a TBD format.

Test control will have to create the necessary uplink packets from a new OBSW image. This will be done using standard SCOS2000 functionalities (which are also be expected to be used in operations by the MOC). Therefore this side of the interface will be entirely defined by what is optimal for use with SCOS2000.

3.2.6.3 *TM I/F*

Exactly like in operations the TM interface will have to store telemetry in standard telemetry objects and associate that telemetry with the appropriate ‘observations’ and building blocks in the database. This association can be done by correlating the observation ID’s and the absolute times specified in the ILT TM packets with data from the TC history file to connect TM packets to command mnemonics of observations in ‘exported’ test schedules generated by MPS.

The TM interface will have to be able to cope with the instrument data rate (currently this implies about 400 kbit/s as in the PACS burst mode). TM packets generated by the instrument will have to be processed and ingested into FINDAS in real time.

On its receiver side the TM interface will need to have an ILT dedicated adapter to be able to receive a telemetry stream as coming from the EGSE-ILT downlink function.

On the transmission side it will need to interface with FINDAS. This part is (essentially) the same as in the ‘consolidated TM interface’ used in operations.

A second output port is possibly needed to forward the TM stream to the RTA ‘real time’ function. Since RTA is SCOS2000 based, the interface here must be SCOS2000 compatible.

3.2.6.4 *TC history interface*

The TC history interface component will be used as in operations. It will archive a TC history object and associate it with the appropriate observation and/or telemetry object(s) according to the practice used in operations.

The TC history interface will get the TC history information from the downlink component in a TBD form.

The time tags given in the TC history and TM packets will allow the correlation of uplink command stream with downlink TM stream.

3.2.7 RTA EVENTS -> TEST CONTROL

The real time HK telemetry is analysed by RTA component. Parameters are being checked against pre-set limits. When parameters go out of limits messages will be issued for logs. For certain conditions RTA will issue event packets for the Test Control component to react on. As a result of such an event packet Test Control will change the test procedure path (e.g. by requesting a new schedule to be executed) or even entirely abort the test. This mechanism will be used to emulate the on-board autonomy functions of the spacecraft.

The issued event packets should be logged together with the telemetry.

The format and transfer mechanism of these event packets is still TBD.

This 'autonomy' interaction can also be handled within the SCOS 2000 based parts of the Test Control component (TBC).

3.3 *Integrated system tests*

3.3.1 INTRODUCTION

The Integrated System Test (IST) phase will cover many aspects of instrument operations, from functional tests to the validation of engineering observations and AOTs. During these tests the only difference with respect to routine operations phase is that there is no MOC. As the instrument specialists have an interface to their instrument and its information via the MCS/FCSS, part of this behaviour has to be simulated in IST.

These tests will be conducted at the prime contractor's premises (TBC) using the Central Checkout Equipment (CCE). The FIRST Ground Segment set-up during IST is shown in Figure 3.3-1.

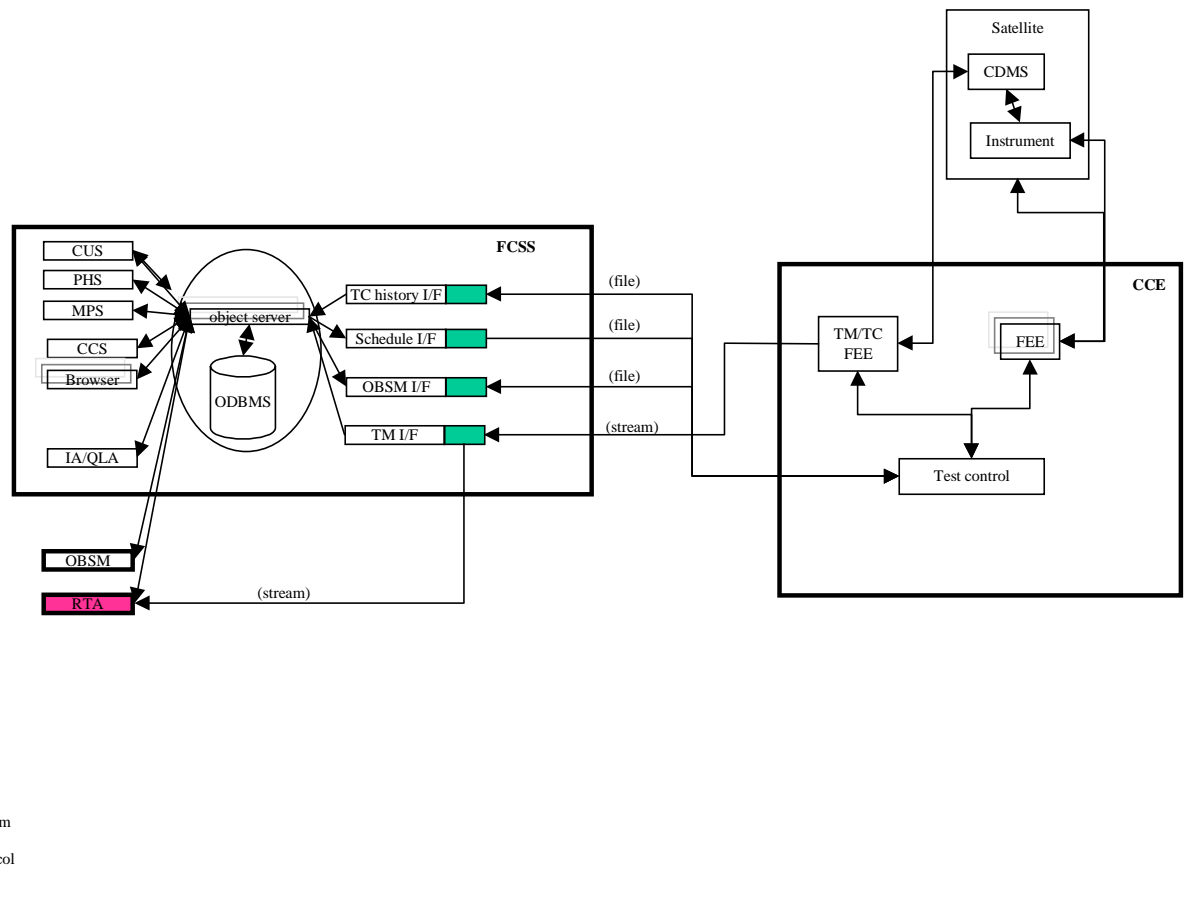


Figure 3.3-1: The FGS in IST

3.3.1.1 GS FUNCTIONS TO BE SIMULATED

The GS functions that need to be simulated for IST are the following:

- Generate an 'observation'
- Make a timeline of one or more observations
- Transfer timeline (including test procedures) with TBD auxiliary information to IST 'uplink' system, i.e. the Central Checkout Equipment (CCE)
- Generate RAM images
- Generate events
- Receive telemetry from instrument
- Perform real time monitoring of telemetry
- Analysis of science data

- Archive telemetry and monitor products

3.3.1.2 *THE IST SETUP*

Figure 3.3-1 shows the set-up for the IST phase. The MOC functions are replaced by specific IST functions in the CCE. The TM/TC Front End Equipment (TM/TC FEE) represents all MOC/FSC activities which are necessary to get time tagged commands to the satellite and receive telemetry from it. The FEE for each ICC represents the test equipment and environment needed to interact with the instrument during tests. The Test Control function encompasses all activities related to running test procedures. It should be noted that only bona-fide test procedures generated during the ILT phase will be implemented in these tests and that manual interaction/intervention will be severely restricted.

The remaining functions are similar to GS functions: RTA and IA/QLA for data monitoring and analysis, PHS and MP for generating and scheduling 'test observations'.

3.3.2 FCSS FUNCTIONS

3.3.2.1 *CUS*

Same as for ILT, see section 3.2.2.1

3.3.2.2 *PHS*

Same as for ILT, see section 3.2.2.2

3.3.2.3 *MPS*

Same as for ILT, see section 3.2.2.3

3.3.2.4 *QCP*

N/A

3.3.2.5 *CCS*

Same as in operations, see section 3.1.2.5

3.3.2.6 *Browsers*

Same as in operations, see section 3.1.2.6

3.3.2.7 *IA/QLA*

Same as in ILT, see section 3.2.2.7

3.3.2.8 *INDAS*

Same as in ILT, see section 3.2.2.8

3.3.3 CCE COMPONENTS

3.3.3.1 *Test Control*

The Test Control function in IST mimics the MOC System functions. It takes commands from a schedule and sends them through the TM/TC FEE to be forwarded to the instrument via the satellite CDMS. It can also allow direct communication with the satellite or instrument via the FEE.

The Test Control will be capable of receiving events addressed to it from RTA and take appropriate action.

3.3.3.2 *TM/TC FEE*

This component essentially simulates the MOC function of sending time tagged commands to the satellite and receiving telemetry from it.

The CCE should allow the upload of OBSW images at a faster (TBD) rate than possible during in-orbit operations, with the instrument DPU/ICU bus providing the only constraint.

3.3.3.3 *FEE*

The FEE covers all the test equipment needed to interact with the instrument during the tests.

3.3.4 RTA

Same as in ILT, see section 3.2.3 except for the support to the autonomy functions' chain. In IST there will be no automatic real time feed back from RTA to the CCE for driving the test execution. Staff monitoring the RT TM at the RTA will communicate with the CCE staff through a voice loop.

3.3.5 OBSM

Same as in ILT, see section 3.2.5.

3.3.6 FCSS-CCE INTERFACES

3.3.6.1 *Schedule I/F*

Same as in ILT, see section 3.2.6.1

3.3.6.2 *OBSM interface*

Same as in ILT, see section 3.2.6.2

3.3.6.3 *TM interface*

Same as in ILT, see section 3.2.6.3

3.3.6.4 *TC history interface*

Same as in ILT, see section 3.2.6.4

3.4 ***Ground segment tests***

Same as commissioning

3.5 ***Launch and early operations phase (LEOP)***

TBW

3.6 ***Commissioning***

3.6.1 INTRODUCTION

During commissioning phase, the FIRST Ground Segment will be composed of the same basic systems as for the routine operations, i.e. the Mission Control System (MCS), the FIRST Common Science System (FCSS), RTA and the OBSM. With respect to routine operations, the FGS will be extended with respect to routine operations with an additional centre, the ICC located at the MOC (ICC@MOC).

This section describes in detail the ICC@MOC centre and the specific interfaces that are set-up for this phase. All differences in components and interfaces with respect to routine operations will be explained in specific sections. The FIRST GS system design for commissioning phase is also valid during calibration and performance verification phase and in a reduced set-up during contingencies in routine operations.

3.6.1.1 *The ground segment set-up during commissioning phase*

The FIRST Ground Segment set-up as during commissioning phase is presented in Figure 3.6-1. The most obvious difference with routine operations is the additional ICC@MOC centres.

The ICCs will set up a specific environment to perform real-time activities at the MOC during this phase. The environment will consist of a RTA system, the OBSM system and the QLA subsystem of interactive analysis (IA/QLA). All software systems interface with a local FINDAS node that receives (near) real-time telemetry from the MOC system and communicates with other FINDAS nodes to distribute and collect requested data objects.

The real-time requirement for delivering the TM data from the MOC to the ICC@MOC is defined in the FGS IRD , see [RD-2], requirement FGS-IR-3.3-40 and copied here for convenience:

"During the commissioning phase and for instrument emergencies, the MOC shall make available to an ICC@MOC its instrument TM not later than 1 minute after the TM packet has been received by MOC"

The non-consolidated TM is stored in the local FINDAS node from which it is requested by (or pushed to) the RTA system. These two interfaces, i.e. from a TM archiver into FINDAS and from FINDAS into RTA are also liable to real-time requirements, i.e. not more than one minute delay between the ingestion and retrieval of TM data [FGSSE#5 MoM].

The FINDAS node is responsible for making the non-consolidated TM data objects available to other ICC centres

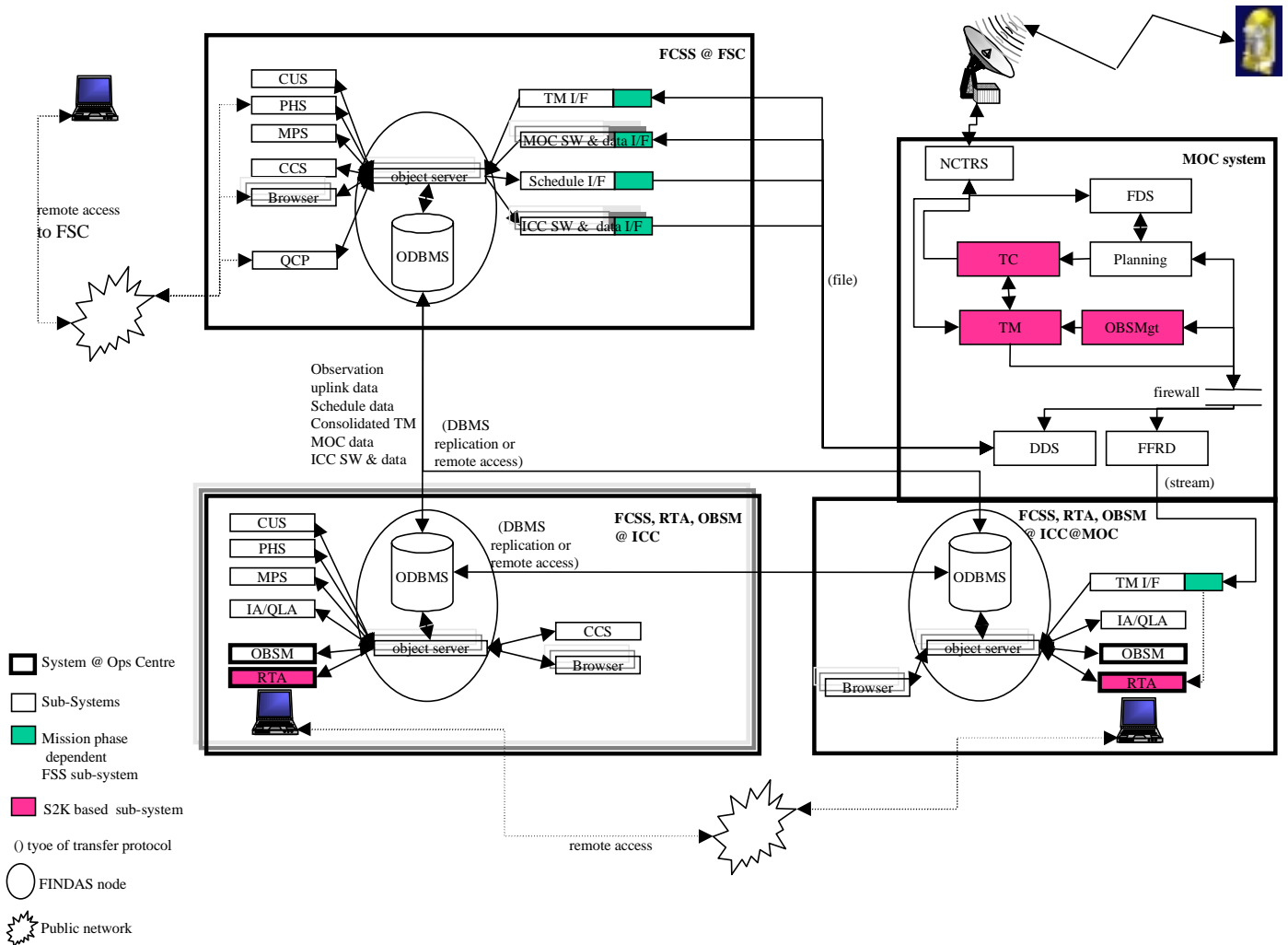


Figure 3.6-1: The FGS in Commissioning phase

3.6.2 THE FCSS COMPONENTS FOR COMMISSIONING PHASE

3.6.2.1 CUS

Same as in routine operation, see 3.1.2.1

3.6.2.2 PHS

Same as in routine operation, see 3.1.2.2 with the precision that in commissioning, the PHS will be used to generate the test/engineering observations. Only a limited number of PHS functionalities may then be required, in particular the notion of proposal may not be used (TBC).

3.6.2.3 MPS

Same as in routine operation, see 3.1.2.3

3.6.2.4 QCP

N/A

3.6.2.5 CCS

Same as in routine operations, see section 3.1.3.5.

3.6.2.6 Browsers

Same as in routine operations, see section 3.1.3.6.

3.6.2.7 IA/QLA

Same as in routine operation, see 3.1.2.7

3.6.2.8 FINDAS

Same as in routine operations, see 3.1.2.8

3.6.3 MOC SYSTEM COMPONENTS

The MOC system is essentially the same in commissioning as in the routine phase, except for the facilities which is used to deliver the TM in NRT to the ICC@MOC, see below.

3.6.3.1 FIRST Frame Decommutator

During the FIRST Commissioning and Calibration / Performance Verification Phases most activities will be conducted by ICC staff at the MOC. This requires a working ICC software environment at MOC (the ICC@MOC). A communication link from the FIRST MCS to the ICC W/Ss is used to provide the TM (HK and Science) in near real time.

The FIRST MCS is located on ESOC's Operational LAN (OPSLAN). For this LAN there exists the security requirement that no external node may be able to connect to any internal node. Therefore special measures are applicable. Core of these measures is the security bridge between the OPSLAN and the Data Distribution LAN (DDSLAN). To achieve communication of data to the ICC workstations at MOC via this barrier, the data is buffered on the FIRST Frame Decommutator (FFRD) that is located on the DDSLAN (see Figure 3.1-4). The connectivity for both MCS – FFRD and FFRD – ICC W/S is by means of TCP/IP task to task communication.

This solution allows:

- ICC equipment not to be directly connected to the OPSLAN
- Access to the ICC W/Ss from the outside world via global Internet and/or ISDN lines

The FFRD functionality is as follows:

- Connect to the MCS and the ICC W/Ss
- Control and manage the links
- Receive and process all Telemetry Frames extracting Housekeeping and Science Telemetry Source Packets
- Forward extracted source packets to the relevant PI s nodes (selected APIDs)
- Provide telemetry selection capability to define and customise the list of packets requested by each PI

The following constraints apply to the FFRD :

- There will be no replay capability (i.e. if for any reason delivery of on-line telemetry will fail, no capability to recall the missed telemetry will be supported by the near real time TM distribution infrastructure)
- There will be no data archiving functionality both at transfer frame and at packet level
- Interface to the ICC W/Ss is a one way interface, i.e. no TC I/F from the ICC W/S to the MCS will be provided
- There is only one application at a time onto each ICC W/S in charge to receive TM source packets at any one time

Two likely implementations of the FFRD can be considered:

1. All received packets (including science data dumped from the SSMM)
2. Real time science packets + those packets processed in real time by the MCS

The selection of 1 or 2 has to consider the following:

1. the load on the systems dealing with the data traffic (FFRD and ICC @ MOC) and hence the cost of the hardware required to deal with the data rates
2. the response time which is required for reaction to events detected in data which is already old at the time of reception, and which has not been recorded by the instrument as an exception.

3. the possibility to retrieve the data “off-line” from the DDS with an additional time penalty, which can however be optimised by setting the appropriate consolidation time.

3.6.4 RTA

In its ‘playback’ mode the RTA component will function exactly like it will during routine operations; TM data will be retrieved from FINDAS and will be analysed using standard RTA functionalities. In this mode the relevant interfaces shall accommodate a data flow corresponding to 10 (TBD) times the on-board data rate.

In the ‘real time’ mode RTA will be fed either by a TM stream directly from the TM I/F or by a stream retrieved from FINDAS generated synchronously with the TM archiver feeding the TM stream from the instrument into the archive. Which of these two options will be used is still TBD.

Products generated by RTA in ‘real time’ mode will be stored in FINDAS through standard interfaces.

3.6.5 OBSM

Same as in routine operations, see section 3.1.5.

The need for the OBSM at ICC@MOC is TBC.

3.6.6 FSC- MOC INTERFACES

The interfaces between the FSC and the MOC will be as during routine operations. See section 3.1.8 for a full description of all interfaces and archive and retrieval functions.

If there are additional information wrt routine phase, this is TBD.

3.6.7 ICC@MOC- MOC INTERFACES

The interface between the ICC@MOC and the MOC is a ‘near real-time’ (NRT) interface contrary to the interface between the FSC and the MOC, which is file based. NRT TM data (non-consolidated) is received from the FFRD as a stream based on the TCP/IP protocol and fed into the TM interface. The front-end of this interface (the receiver side) is therefore different with respect to the same interface between FSC and MOC.

Alternatively, a second output port is possibly needed to forward the NRT TM stream to the RTA ‘real time’ function. Since RTA is SCOS 2000 based, the interface here must be SCOS 2000 compatible (see also section 3.2.4).

The TM I/F will have to be able to cope with the instrument data rate (currently this implies about 400 kbits/s as in the PACS burst mode). TM packets generated by the instrument will have to be processed and ingested into FINDAS in (near) real time.

The function of importing the NRT TM stream into standard TM objects in the database and associate those with the appropriate observations is essentially the same as for the equivalent interface between the FSC and the MOC and is explained in section 3.1.8.2.

3.6.8 FSC - ICC@ICC INTERFACES

Same as in routine operations, see section 3.1.5.

3.6.9 ICC@ICC - ICC@MOC INTERFACES

This interface is in principle the same as between the FSC and the ICC@ICC, i.e. FINDAS based. Objects created in any of the FSC or ICC will be accessible in a transparent manner to any of the other centres. The FINDAS node which is physically located at the ICC@MOC takes care of the distribution (and collection) of all requested data objects. There is no real-time requirement for this interface.

The TM received by ICC@ICC will be ingested in ICC@ICC in FINDAS in a database separate from the one including the consolidated TM (TBC). It is expected that FINDAS will allow to automatically switch from non-consolidated TM to consolidated TM when the latter are made available by the FSC.

There is also the possibility to use remote login from and to both (or more) ICC centres. This is made possible as the ICC@MOC is outside the ESOC firewall.

3.7 *Calibration/ performance verification phase*

Same as routine phase or commissioning phase (in early stage).

3.8 *Science demonstration phase*

Same as routine phase

3.9 Post operations phase

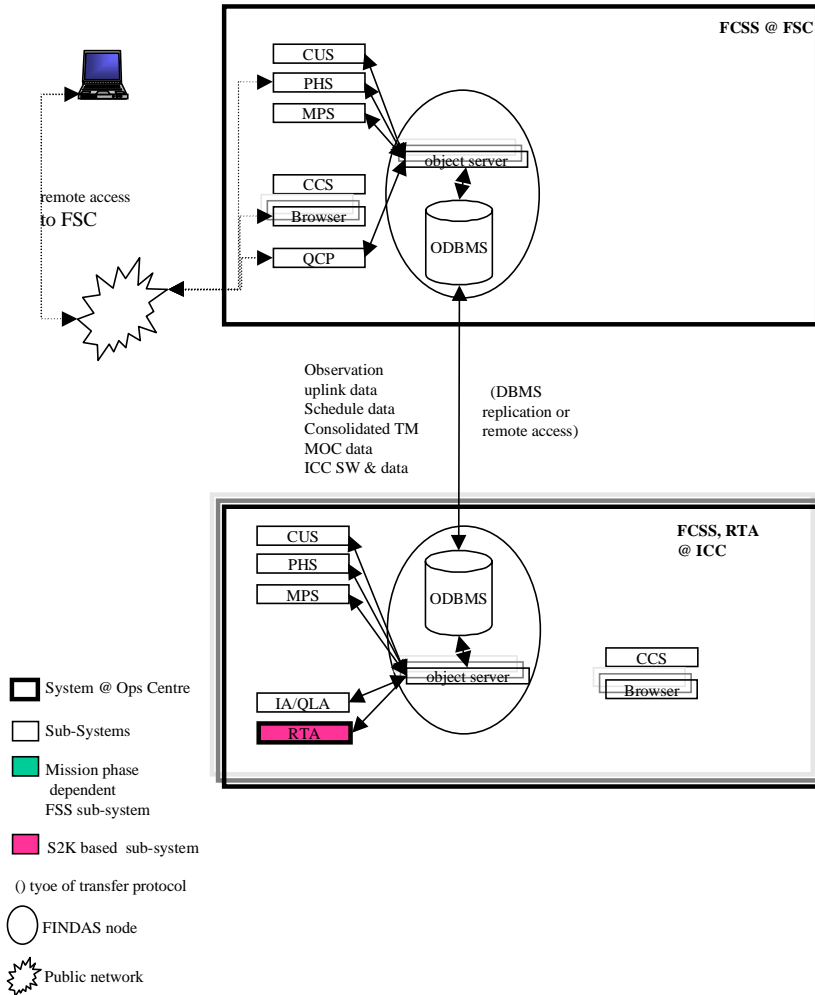


Figure 3.9-1: The FGS in post-mission phase

TBW

4 FEASIBILITY AND RESOURCE ESTIMATES

Data link required capabilities

TBW