FIRST

SCIENCE OPERATIONS CONCEPT

AND

GROUND SEGMENT DOCUMENT

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ACRONYM LIST

*It is assumed that an overall **FIRST** acronym list will be available at a later time. The present list therefore only contains the acronyms which are used in the context of the FIRST operations and Ground Segment definition.*

ADC	Analog to Digital Converter
AIV	Assembly Integration Verification
AMS	Archive Management System
AND	Alphanumeric Display
APID	Application Packet Identifier
AO	Announcement of Opportunity
AOCS	Attitude & Orbit Control System
AOS	Acquisition of Signal
AOT	Astronomical Observation Template
APH	Attitude Pointing History
CC	Configuration Control
CCS	Central Command Schedule
C/O	Check-Out
CRP	Contingency Recovery Procedure
CUS	Calibration Uplink System
DBI	Digital Bus Interface
DBU	Data Bus Unit
Dec	Declination
DPU	Data Processing Unit
EGSE	Electrical Ground Support Equipment
EID	Experiment Interface Document
EMC	Electro-magnetic Compatibility
EMI	Electro-magnetic Interference
ESD	Electro-static Discharge
FCP	Flight Control Procedure
FD	Flight Dynamics
FFT	Fast Fourier Transform
FINDAS	FIRST Integrated Network & Data Archive System
FIRST	Far Infrared & Submillimeter Telescope
FITS	Flexible Image Transport System
FOP	Flight Operations Plan
FOV	Field Of View
FSC	FIRST Science Centre
FSO	FIRST Science Operations
FTP	File Transfer Protocol
FWHM	Full Width Half Maximum

GO	Guest Observer
GRD	Graphic Display
GUI	Graphical User Interface
GT	Guaranteed Time
Gb	GigaBit
HK	Housekeeping
H/W	Hardware
IA	Interactive Analysis
ICC	Instrument Control Centre
ICD	Interface Control Document
ICS	Instrument Command Sequence
IFOP	Instrument Flight Operations Plan
IFCP	Instrument Flight Control Procedure
ICRP	Instrument Contingency Recovery Procedure
JD	Julian Day
KAL	Keep Alive Line
Kb	KiloBit
LAN	Local Area Network
LEOP	Launch & Early Orbit Phase
LOS	Loss Of Signal
Mb	MegaBit
MCR	Main Control Room
MDB	Mission Data Base
MIRD	Mission Implementation Requirements Document
MIP	Mission Imlementation Plan
MMI	Man Machine Interface
MMU	Mass Memory Unit
MOC	Mission Operations Centre
OBDH	On Board Data Handling
OBSW	On Board SoftWare
OHF	Observation History File
OTAC	Observation Time Allocation Committee
PC	Personal Computer
PES	Proposal Entry System
PH	Proposal Handling
PI	Principal Investigator
PID	Packet Identifier
POF	Planned Observation File
PROM	Programmable Read Only Memory

PS	Project Scientist
PV	Performance Verification
PWG	Payload Working Group
QLA	Quick Look Assessment
Ra	Right Ascension
RAM	Random Access Memory
RMS	Root Mean Sqared
ROM	Read Only Memory
RTA	Real Time Assessment
SAG	Science Advisory Group
SCOS	SpaceCraft Operations Control System
SCP	Satellite Commissionning Phase
S/C	Spacecraft
S/W	Software
SEU	Single Event Upset
SIRD	Science Implementation Requirements Document
SIP	Science Implementation Plan
SOC	Science Operations Centre
SOL	Sequenced Observations List
SPACON	Spacecraft Controller
SPR	Software Problem Report
SRD	Software Requirements Document
S/N	Signal to Noise
TBC	To Be Confirmed
TBD	To Be Defined
TC	Telecommand
TM	Telemetry
TOO	Target Of Opportunity
TTC	Telemetry, Tracking & Commanding
URD	User Requirements Document
UT	Universal Time
UTC	Universal Time Cordinated
WIMP	Windows, Icons, Mouse and Pull-down menus
WWW	World Wide Web

1. SCOPE AND STRUCTURE

This document describes the FIRST "Science Operations Concept" as well as the overall Ground Segment structure necessary to implement it for all phases of the FIRST mission. The concept has been elaborated by the "FIRST Science Operations Definition Group" (FSODG) set up by the FIRST Project.

Issue 1 of the document will be available on 31 October 1996, Issue 2 (the final issue) on 31 January 1996. It is expected that for Issue 2 all open points concerning the mission characteristics will have been resolved. If this is not the case Issue 2 will be delayed accordingly.

Upon approval this document will serve as input for the FIRST "Science Management Plan", "Mission Requirements Document" (MRD), "Mission Implementation Requirements Document" (MIRD), and the FIRST "Science Implementation Requirements Document" (SIRD).

The structure of the document is as follows;

- Chapter two provides a general introduction.
- Chapter three lists the assumptions made on the type of mission, satellite and key operational features in order to derive a viable implementation and operational concept.
- Chapter four presents the overall concept, the key operational features and the major building blocks. It includes a preliminary costing.
- Chapter five gives a detailed description of the FIRST Integrated Network and Data Archive System (FINDAS) which is the backbone of the overall system in the proposed concept.
- Chapters six, seven and eight provide a detailed description of the tasks and responsibilities of the "Instrument Control Centres" (ICCs), "FIRST Science Centre" (FSC) and "Mission Operations Centre" (MOC) respectively.
- Chapter nine presents a description of the physical and operational interfaces between the centres as well as a list of the major deliverables.
- Chapter ten provides a -short- conclusion.

1.1 APPLICABLE DOCUMENTS

AD.1 : FIRST Satellite System Specification
(PT-SP-00211)

AD.2 : ESA Packet Telemetry Standard
(PSS-04-106)

AD.3 : ESA Packet Telecommand Standard
(PSS-04-107)

1.2 REFERENCE DOCUMENTS

RD.1 : FIRST Red Book
(SCI(93)6)

RD.2 : FIRST Payload Definition Document (PDD)
No ref.

2. INTRODUCTION

The overall aim in designing the science operations concept for FIRST is to ensure that the requirement of maximising the scientific return of the mission is met, while at the same time minimising the complexity and cost of the science operations.

FIRST is a multi-user observatory-type mission with a science payload complement of three sophisticated instruments. The science operations requirements include choosing the optimum balance between observations of various types of objects and use of the instruments, to carry out the observations, and to provide the data and the necessary tools to do astronomy with the data to the observers.

Although the scientific operational needs for FIRST are similar to those of ISO, the concept for the scientific ground segment of FIRST is considerably different from that of ISO.

The original ISO concept foresaw that ESA would, with its own resources, design, develop and operate the science ground segment. The ground segment would cover all activities from support for observation proposals to the delivery of processed observation data to the observers.

At the outset the magnitude of the task, as well as the amount of detailed knowledge required was severely underestimated. Insufficient resources were allocated. During the development, it became apparent that the Agency needed, to a great extent, personnel from the PI teams to develop and support the specifically instrumental parts of the ISO ground segment.

The opportunity has been taken for FIRST, to build upon the ISO experience and arrive at a concept which could, if implemented, provide equally effective operations for a lower cost.

3. ASSUMPTIONS

To arrive at a viable implementation and operational concept at this stage of FIRST definition, certain assumptions have to be made on the type of mission, the satellite and key operational features.

Mission

- FIRST is an observatory which will be used to make observations for both the collaborators involved in the implementation of the instruments and ground segment, and the astronomical community. This implies some Observers having a detailed knowledge of instrument functionality, capabilities and performance, and others having knowledge limited to only the scientific capabilities. It is likely that survey-type programmes (TBC) will have to be supported within FIRST overall observatory concept. This has not been taken into account so far.

- The active observation lifetime will be three years but the Ground Segment will be dimensioned in such a way that a longer lifetime could be supported if required. Following this, there will be a period lasting several years for scientific work from an archive.

- Observing time will be allocated by a committee after a review of proposals.

- Observational data will be proprietary for a limited period after the observation. After expiration of the period, data goes to the public domain.

Satellite

- FIRST is a 3 axis stabilized satellite with 3 instruments.

- Only 1 instrument at a time will be prime, i.e. carrying out a defined observation. The other 2 instruments may be on and be gathering data in a unique mode. All instruments may be in their unique modes during slews.

- Satellite telemetry (TM) and telecommand (TC) will be in accordance with ESA packet standards. The raw TM data acquisition rate on board, for three instruments, will be 68 Kbs (not transmission)

- The satellite will be provided with a mass data store which will contain :

  - all commands for the observation schedule during 1 orbit
  - telemetry data gathered during the period when the satellite is out of view of the ground station. This data will be transmitted in parallel with real time data when the satellite is in view of the ground station. The transmission data rate will be 100 Kbs.

- The satellite will have autonomous safety features.
- Observations cannot be made during eclipses or when the satellite is within the earth's trapped radiation belts (assumed below 40.000 kms).
- Satellite pointing will be constrained by permissible earth and sun angles and be restricted by other bright celestial bodies.
- The orbit will most likely be either a 24 hour eccentric orbit as ISO (current assumption) or a 48 hour eccentric orbit as XMM. A Lissajous-type orbit is also currently investigated but has not been considered in the operations concept.

Operations

- In routine phase, all operations will be conducted through a single ground station. The observation schedule will normally be executed autonomously from telecommands stored on-board. The command schedule will be up-linked daily from the ground station.

  Telemetry gathered during periods of non-visibility will be stored on-board and transmitted in parallel with real-time data when in view of the ground station.
- The observation pattern will be similar to ISO i.e. single instrument observations lasting from minutes to hours. The other two instruments may be on, gathering data in a unique mode. They will not point at the prime target.
- The scheduling of observations will maximise observing efficiency. It will be stochastic but will permit some fixed observation times.
- A mechanism to handle Targets of Opportunity (TOOs) quickly and efficiently must be provided.
- Spacecraft and instrument control will be performed by a single Mission Operations Centre (MOC) according to procedures. Specialists from the instrument developers will not be required during routine operations but provisions must be made to accommodate these and their equipment for early orbit testing.
- All TM, TC and other operational data will be provided by the MOC to a data repository. Data delay requirement is variable, near real-time (say 1 minute) to hours depending on circumstances. The data repository may be in a different location to the MOC.
- Technologies are available such that observers can at their own Institutes, perform processing of raw TM data using software and calibration data provided by the FIRST ground segment.

4. FIRST OPERATIONS OVERVIEW

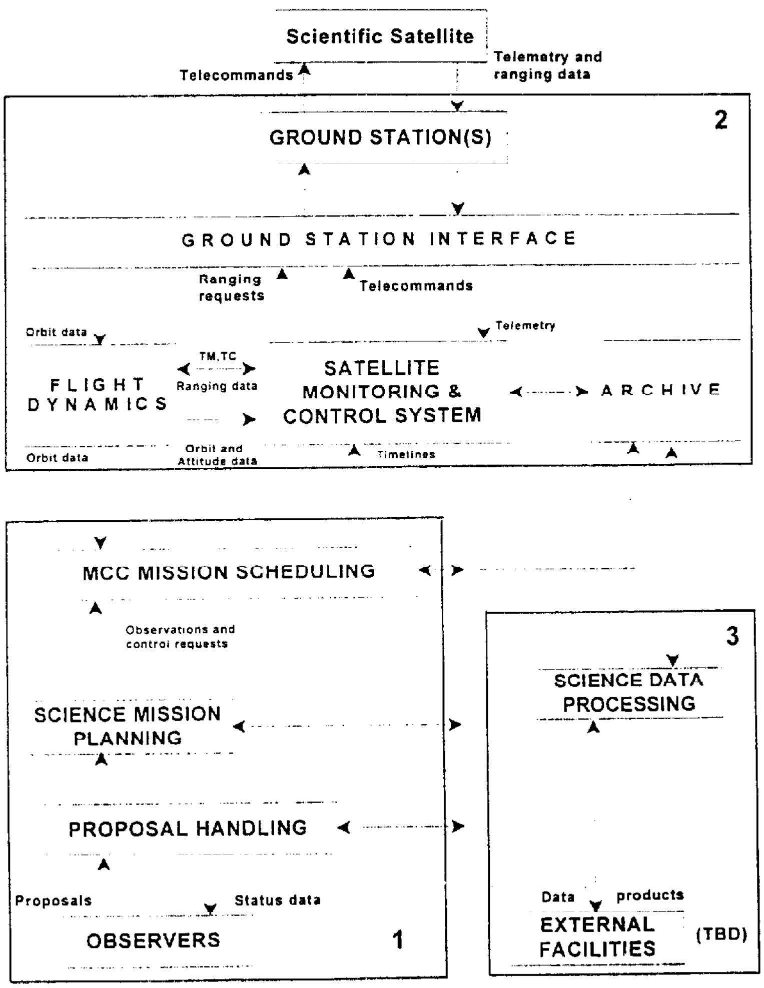


Fig. 4.1 Ground Segment Overview (Standard)

4.1 STANDARD GROUND SEGMENT FUNCTIONALITY

As shown in figure 4.1, the Ground Segment for any scientific satellite can be split into three functional blocks:

1. Generation of Uplink
2. Real-time Operations
3. Data Processing

Blocks 1 and 3 generally include substantial parts associated with the scientific operations of the satellite and their content depends to a large degree on the type of science mission being flown.

4.1.1 Generation of Uplink

This consists of three functions covering:

- the definition of the observing programme(s); call for proposals, analysis and peer review. Entry, storage and editing of all observations which have been allocated observing time. This is the "Proposal Handling System".

- selection of a set of observations to be executed over a given time period (e.g. 2 weeks) in order to ensure that the scientific programme is carried out. This is the "Science Mission Planning System".

- allocation of a time slot to an observation in a particular orbit. This is the "Mission Scheduling System".

4.1.2 Real-time Operations

This consists of 4 functions covering:

- real-time commanding and monitoring of the satellite and instruments. This is the "Satellite Monitoring and Control System".

- communication with the Ground Station(s). This is the "Ground Station Interface System".

- collection, storage and distribution of all data generated by the satellite and ground systems. The "Archive System".

- generation/monitoring of satellite orbit and attitude data. The "Flight Dynamics System".

4.1.3 Data processing

This consists of 2 functions:

- processing of raw data using instrument specific knowledge to provide a set of 'standard' products. This is the "Science Data Processing System".

- provision of additional facilities to process and distribute science data products. The "External Facilities System"

4.2 FIRST OPERATIONS CENTRES

As an aid to minimising costs the following tenets are applied to the operations concept for FIRST:

- a function should be carried out by the group and at the location with the expertise and experience to perform that function rather than attempt to transfer expertise by documentation and training. Thus, for example, instrument groups will perform the functions that require instrument expertise. This leads to the concept of a distributed Ground Segment.

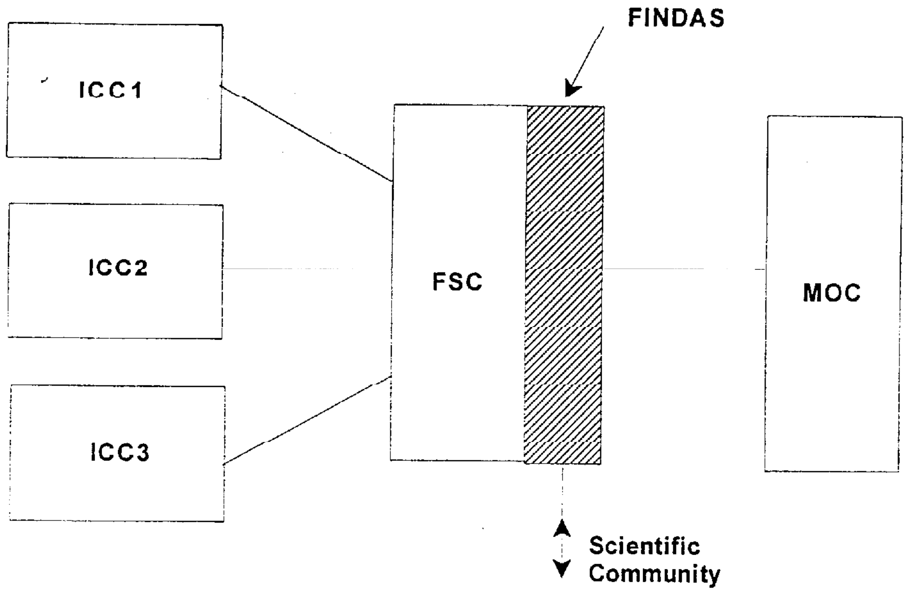
- A distributed Ground Segment requires easy access to the mission data from all the participating centres. A central role, therefore, is provided by the facility for storing and distributing this data (an 'archive'). It should be noted that distribution of telemetry in near real-time will be required at some stages of the mission.

- A high degree of commonality between AIV and operations is desirable in order to minimise the rewriting of code and procedures. Instrument groups should remain responsible for operations of their instrument throughout all phases of the mission. Note: this will require the archive, or equivalent, to be available during AIV.

- Instruments should be treated as subsystems of the Satellite, as far as control and health and safety monitoring of their operation is concerned. This allows use of standard Satellite operations software in the "Satellite Monitoring and Control System".

- Data processing of science data should not be carried out routinely. Users will extract data from the archive through an interface which delivers the data, 'unprocessed', with software to allow processing in the currently accepted 'best' way.

With these considerations in mind the recommended FIRST Ground Segment configuration is as shown in figure 4.2. This consists of 5 centres:



- MOC PROVIDED BY ESOC
- ICCs PROVIDED BY THE PI-INSTITUTES
- FSC : TWO POSSIBILITIES
  1) FSC PROVIDED BY ESA
  2) FSC PROVIDED BY A EUROPEAN INSTITUTE

Fig. 4.2 - FIRST OPERATIONAL SCENARIO

4.2.1 The Mission Operations Centre (MOC)

This is responsible for all the real-time operations of the satellite and instruments. It combines the functions of the;

- "Satellite Monitoring and Control System"
"Ground Station Interface System"
"Flight Dynamics System"
(part of) "Mission Scheduling System"

The MOC responsibilities and tasks are described in detail in chapter 8.

4.2.2 The Instrument Control Centres (ICCs)

These will be co-located with the instrument groups and carry out, in addition to their responsibility for instrument development and operations, the functions of the;

"Science Data Processing System"
"External Facilities System" (TBC)

There is one ICC per instrument.

The ICC responsibilities and tasks are described in detail in chapter 6.

4.2.3 The FIRST Science Centre (FSC)

This provides a central facility for dealing with the scientific programme of FIRST and the distribution of data and software. It combines the functions of the;

"Science Mission Planning System"
"Proposal Handling System"
"FIRST Archive System"
(part of) "Mission Scheduling System"

The FSC responsibilities and tasks are described in detail in chapter 6.

4.3 CONCEPT ADVANTAGES

This concept provides;

- isolation of real-time operations from the rest of the Ground Segment. The MOC can continue to function and control the satellite independently for up to 2 weeks (TBC). All other operations functions are performed off-line.

- coordination of the FIRST science programme at a central facility where the knowledge of the complete programme resides.
- complete responsibility of the ICCs for their instrument operations, calibrations and data processing software made available to observers. The ICCs have no direct contact with observers.
- a single, central data source with single interface to all users. This includes the point of contact for help for all proposers and observers.
- the possibility of attracting an additional PI/institute responsible for setting up and running the FSC. This would introduce additional funding to the Ground Segment, potentially reducing the costs to other participating groups.

4.4 OTHER KEY FEATURES

4.4.1 Communication between the centres

The introduction of a distributed ground segment concept based on "competence" centres (Instrument Control Centres - ICCs, FIRST Science Centre - FSC and Mission Operations Centre - MOC) requires a backbone network of dedicated lines with a bandwidth of at least 128 kbits/sec between the ICCs, MOC and FSC. The availability of such lines at the time when they are needed (around the year 2000) should be no problem, they should also be reasonably cheap.

The interfaces between the various centres are described in detail in chapter 9.

4.4.2 FIRST Integrated Network and Data Archive System (FINDAS)

The FIRST Integrated Network and Data Archive System (FINDAS) is central to all FIRST operations, starting already at Instrument Level Tests. Because of its importance to the overall concept, early prototyping will be required. In the proposed concept FINDAS is physically located at the FSC. Regardless of its location, however, it will be accessible by all participants (ICCs, MOC, FSC and the observers) taking into account relevant access rights.

The FIRST Archive System is not only a data and software repository, but also the communication centre for the different FIRST users (instrument people, science operations team, real-time operations team, end-users). It will contain all data generated during ground tests and during the mission, auxiliary data like star catalogues, the whole mission data base and all software and documentation necessary to carry out FIRST operations. The various S/W subsystems will also (when required) communicate via FINDAS, rather than directly, e.g. update of calibration tables, mission planning, etc. For critical data items, e.g. S/C data base, a working copy at other locations might be needed in addition to the master copy kept in the

FIRST Archive System.

The great advantage of the FIRST Archive System is that it provides easy access to all data files for all users and it requires much less data management than separate archives for different data types.

FINDAS is described in detail in chapter 5.

Appendix 3 provides a list of the major FINDAS data components.

4.4.3 Commonality between instruments

Commonality between instruments is one of the major goals of the FIRST mission. It will help to simplify the mission operations and it will hopefully encourage the instrument teams to develop the instruments in the same way or even develop specific software or hardware components, e.g. Fabry-Perots in common for all instruments. It is foreseen to:

- use identical interfaces to the spacecraft.
- use the same type of microprocessors and the same programming language (e.g. ADA) for all instruments, also to facilitate the development of Instrument Simulators.
- use identical internal redundancy concepts.
- use identical on-board management techniques.
- use the same commanding scheme (e.g. macro commands) and similar structures for down-link telemetry (packet telemetry).
- use telecommand buffers (part of S/C data system) to decouple up-link from down-link.

4.4.4 Instrument autonomy

The instruments shall be made as autonomous as possible. The instrument microprocessor should be able to check the major health and safety parameters of the instrument, including detector saturation, and take corrective actions if necessary. (it is recalled that with one ground station a large proportion of observations will be executed autonomously outside MOC control) Essential instrument parameters, like primary voltages and currents, will be checked by the spacecraft.

4.4.5 Instrument Calibration

The instruments shall be completely calibrated during instrument level tests and a set of calibration tables shall be available. The calibration shall comprise a detailed radiation analysis and comprehensive detector model which shall be used as input for the Instrument Simulator in order to generate meaningful detector output. This would also facilitate the testing of the quick-look (QLA) and science software especially during mission simulation.

The results of these calibrations shall be incorporated into the Acceptance Data Packages delivered by the instrument teams with the flight instruments.
The results of the particle radiation tests, in particular an assessment of the possible radiation effects on the instrument, shall be included in the Acceptance Data Package.

5. FIRST INTEGRATED NETWORK AND DATA ARCHIVE SYSTEM (FINDAS)

5.1 INTRODUCTION

The FIRST Integrated Network and Data Archive System (FINDAS) is the heart of the FIRST ground segment. It is *the* system for configuration control of *all* FIRST components. It will provide a facility for controlled storage of data and software for all groups involved in the (development of) the FIRST ground segment.

FINDAS will contain *all* information relevant for the mission within a single, if need be distributed, database. All information implies that *data*, *software* and *miscellaneous other pieces of information* are all stored as objects in the same (relational) database. The database will be designed and implemented using Object Oriented techniques. Thus FIRST software will be implemented as methods belonging to the data objects, and will be stored in a fashion which directly reflects this.

Being the heart of the system clearly implies that what goes in and out *must* be fully traceable. This means that the configuration control system must be completely integrated with the database. Rigorous, however, *must not* automatically translate into inflexible. The system must allow easy but controlled access by a large number of different teams, likely from a number of different locations. All teams must be able to do exactly what *they* want and need to, without having to wait too long.

Given the fact that the archive is used to store and retrieve data and software, it automatically becomes a very important - if not the most important - means of communication between the different teams involved in the FIRST project. Where needed the archive system and the database relations will be tailored to support this communication function as well.

It is the intention to develop the database as early as feasible. This will allow the MOC, FSC as well as the ICC's to use its facilities in the preparatory phases. Also such early use of the configuration control and communication protocols will function as extra archive test.

The obvious advantage of such an overall design is that any FIRST team member or scientist can directly associate all pieces of relevant mission data with each other without having to go through human and/or paper interfaces, and still be able to find out who did what, when, with those data. Also by starting development early this can be done already in the instrument build and test phase. In the ideal case queries to the mission database will directly give information about the observation specifications, the telemetry quality etc.. However queries can also yield processed data which can be used for scientific analysis. In such cases the processing algorithms, for which the version specification can be specified in the query, are applied on-the-fly to the raw data which is extracted from the archive.

5.2 TOP LEVEL ARCHIVE REQUIREMENTS

5.2.1 Configuration control

Configuration control for archive objects and methods must be very rigorous. *No* object shall enter the system without proper information as to its origins.

Configuration control shall be *strict but **not** prohibitive*, its first aim is to *track* changes, not to stop them.

The configuration control system *must be* flexible enough to cope with a rapid development cycle (e.g. in PV times) equally well as with long term changes (i.e. during routine operations).

All objects (and methods) shall have full documentation detailing their production process. For man made objects (part of) this history probably has to be written by the creators of the object, procedurally generated objects shall have automatically generated history information.

Wherever possible configuration control shall work (semi-)automatically.

Configuration control procedures *must* support remote retrieval, updates etc. because the clients will be located in many different institutes.

The availability of test environments is imperative for proper configuration control. Where appropriate (e.g. software, calibration files, possibly even observation specifications) objects shall initially enter the configuration control system as *'object under test'*, accessible only to 'testers'. These objects have to be *actively* promoted to official system objects (i.e. for general use,... by those having the appropriate access rights). Note that setting access rights for different people differently for 'test' and 'system' objects automatically defines the group of test people (see below).

5.2.1.1 Integration of configuration control and testing

To guarantee the proper working of all 'software' components in the ground segment, rigorous testing of new or updated modules is always required. Testing stages can be easily tracked and standardized by integrating the test strategy with the configuration control system. In the initial FINDAS implementation at least two different levels are foreseen for *all* objects; **TEST** and **SYSTEM**.

Objects are always inserted as **TEST** objects. This means they are visible only to those people/groups that actually do the testing of their object or need pre-warning of imminent changes.

RESERVE and **UPDATE** can be given to a larger group of people.

As an example of use of these access rights an ICC member working on development of 'pipeline' type software would get all rights except **PROMOTE** on that instrument's 'pipeline' **TEST** version. The ICC manager (and/or deputy) would have the **PROMOTE** right. On the other hand astronomers observing with FIRST will be given only **EXTRACT** permission for data for which they are PI. Due to the object oriented nature of the database, the methods (i.e. the *relevant analysis software*) for those data are directly coupled to the data object, *thus giving the astronomer direct access to those methods* as well.

Beyond the above possibly one more access right is needed if (classes of) objects should (generally) not be made into a local copy;

- **READ** - gives the user the right to *look* at , i.e. read and *don't copy*, this object.

One candidate for this could be documentation e.g. on instrument performance and user documentation; (most) users should *always* look at the most recent version, and therefore should *never* make a local copy of such documentation.

5.2.1.3 The configuration control cycle

Using the above defined concepts the typical development cycle for an object in the archive will be as follows (assuming the object has already been **CREATED** in the past):

1. A problem (or a possible improvement) is found for an object. The relevant group appoints an expert to do the improvement.

2. The expert **RESERVES** the object. For the reservation information will have to be supplied detailing the grounds for the proposed changes. The reservation process automatically sends messages to people/groups who should be aware of this imminent change (i.e., testers, potential users, team managers...). As a result of the reservation no further **RESERVE** are allowed, and **UPDATE** is allowed *only* for the expert.

3. The expert **EXTRACTS** the object and implements improvements/changes in his private development environment. This includes as much testing as possible and documenting the changes as well as the executed tests.

4. The expert **UPDATES** the module, including the prepared documentation. All ingredients (object itself, documentation etc.,) are checked (automatically) on adherence to whatever standards are defined, where appropriate on compilability etc.

Once approved for general use - possibly after repeated update-test cycles (see below) - objects can be 'promoted' from **TEST** to **SYSTEM**. Once an object has attained **SYSTEM** status it automatically is the de-facto operational version and therefore is used in the day-to-day work.

Possibly, experience with FINDAS will show the need for multiple levels. If so these can be implemented easily.

5.2.1.2 Access rights for configuration control

Configuration control is implemented by setting access rights for all (classes of) objects for all (groups of) archive clients. The defined access levels are (at least) as follows:

- **CREATE** - gives the user the right to create an object of this type.
- **RESERVE** - gives the user the right to reserve an object for changing and subsequent updating. A **RESERVE**d object cannot be **RESERVE**d by any other user. As a consequence **RESERVE** also functions as a notification: *'I am changing this object!'*. **RESERVE** is un done by **UPDATE** (possibly an un-reserve is needed as well).
- **EXTRACT** - gives the user permission to *take*, i.e. read and create a local copy of, this object from the archive. The extract operation is automatically logged in the FINDAS access log.
- **UPDATE** - allow the user to put a modified object back *into* the archive. The update procedure will only allow the **UPDATE** operation when the same user has previously **RESERVE**d *and* **EXTRACT**ed the object. This operation will have to (as much as possible) check correctness of the incoming object (compilability, documentation, history information etc..).
- **PROMOTE** - *promotes* the object from **TEST** to **SYSTEM**. If possible this step will be even more strictly/monitored/checked than **UPDATE**. Here e.g. test reports will be inserted as well.
- **REMOVE** - allows a user to delete an object.
- **ROLLBACK** - allows the user to initiate a *rollback* - i.e. re-instate the previous version - for an object. **ROLLBACK** is only possible on **SYSTEM** (TBC).
  Note that such a rollback operation can have far reaching consequences as it can generate an avalanche of rollback operations on other objects that are related to the object for which the rollback is invoked.

Clearly the allocation of these access rights needs to be done carefully. Especially the **PROMOTE**, **REMOVE** and **ROLLBACK** will only be given to persons who are in a position to have the full overview of the consequences of these operations.

5. If *all* checks are OK, the object is installed in the **TEST**, environment. A message is sent to the appointed test team to inform them that the object is available for testing. If one of the checks fails, the expert will have to redo his own work.

6. After having tested the object, the tests are documented and the test team decides whether the improvement is successful or not. If so the object is **PROMOTED** to **SYSTEM** making it available to all relevant groups for operations. In this case the expert and all potential clients get a message. If the object fails the test the expert (or group) is informed and the whole process goes back to step 2 (or 1).

5.2.2 Accessibility

All teams need *constant* access to all archive objects (as permitted given the access rules). This means that the archive must be accessible over high speed links, that its design must be hardware (and operating system?) independent and that read access rights should be handed out generously.

Another consequence of the requirement that all teams have quick and easy access is that objects must be available for a long time. In principle *all* objects from the start of the project (with their history!) should be available through the archive. If *any* form of slower long term storage medium is used this should be completely transparent to the users. Note that it is likely that at the time of operations when the physical size of the archive really becomes an issue mass storage prices will be low enough to allow on-line storage of the full contents of the archive system.

5.2.3 Cloneability and mergeability

The archive shall be designed such that (parts of) its structure can be easily ported to local (e.g. ICC, MOC) machines. This will allow teams to also independently use centrally created and tested tools to support 'local' work. This will be especially necessary in the preparatory phases.

There shall be a possibility to 'merge' objects from a 'local' archive copy (e.g. pre-flight calibration objects) with the central archive. Note that the use of a 'cloned' archive almost guarantees that also in the 'local' copy full configuration control procedures were used.

It is highly desirable that the archive system allows teams to build 'independent' subsystems in the central archive, and *based on the archive design* to do internal data and software management. This will guarantee that coding conventions, history tracking, configuration control etc. of the independent teams are mutually understood and accepted.

5.2.4 Communicating through an archive

The transfer of objects from one team to the next is carried out by storing them in the database and notifying the other team (see above). Clearly a sophisticated messaging system must be developed for this. Likely this can be partly automated as extra configuration control deliverables (what message, where to send it to).

Such messaging will only work with proper feedback, thus for each object transfer operation a handshake mechanism must be provided.

5.3 DESIGN AND IMPLEMENTATION PHASES

It is the intention to start using the archive *as soon as possible* in the FIRST development phase. This will have to be done from the start by a joint MOC-FSC-ICC team to make sure that all requirements from all teams are dealt with properly.

As FINDAS is such an important part of the FIRST ground segment, early prototyping should be done. The availability of prototypes early on in the development phase will firstly provide an early test of the concepts of the archive, secondly allow better understanding of the archive design and development and thirdly provide FINDAS-like functionality early in the development phase which will facilitate discussions with the FINDAS users to fully specify the requirements.

The initial design should go in the following order:

1. Configuration control
2. Definition of storage form of software objects (methods)
3. Communication protocol
4. Structure of raw telemetry objects
5. Structure of storage for 'CUS'-type observation specifications
6. Structure of storage of 'AOT'-type observation specifications
7. Further design of data types and object relations

In the design and implementation plan the importance of the configuration control system is directly reflected; it must come first because the integrity of the database system is defined by the poorest controlled objects.

Note that a number of 'procedural' steps in the archive (this is especially valid for the configuration control sections) which in principle should be done automatically, can initially be implemented as a manual procedure (e.g. checking documentation standards).

6. FIRST SCIENCE CENTRE (FSC)

The FSC is the interface between the ICCs, the astronomical community and the MOC. It plays a fundamental role in the FIRST operations concept. In particular it ensures overall science coordination, houses the FIRST Central Archive, houses and provide the required logistical support to the FIRST Science Operations (FSO) Team.

The FSC can either be provided by a PI-type European institute (cheaper overall option) or by ESA. In the first case it is assumed that the FSC will be selected via an AO issued by ESA.

It is assumed that;

- The FSC is responsible for its own accommodations, organisation and management.
- The FIRST Ground Segment Steering Group will monitor the FSC performance in order to establish if the necessary level of resources (funds, manpower, facilities, etc.) are made available by the FSC to carry out its obligations.

In order to size the effort required to set up and operate the FSC it is further assumed that;

- The FSC is manned 8 hours/day, 5 days/week (nominally).
- The FSC will be set up shortly after instrument selection and will support the orbital operations -nominally 3 years-, the post operations and the archive phases of the FIRST mission.

The FSC is responsible for the following tasks;
(the most important tasks only are listed -a detailed list is available-)

6.1 MISSION PREPARATION

- Set up FINDAS. This includes:
  - Definition (jointly with ESA, ICCs and MOC) of all the data items to be stored in the Archive and their relationships.
  - Definition, procurement and set up of the required hardware and software facilities. This includes the FIRST Archive Management System and Archive Server for communication with the ICCs, the MOC and the Community.
  - Management of the Archive (pre- and post-launch).

- Support to the OTAC and the Science Community. This includes tasks such as:

  • Issue Call(s) for Proposals, as well as related tools and forms.

  • provide a central help-desk service to handle all requests from the Community.[1]

  • publish news-letters

  • provide statistics to OTAC and ESA

  • make available (through FINDAS) to the authorised users the data and science processing software required to process their observations

- Proposal Handling. This includes:

  • reception, filing and checking of the observing proposals (individual observers and/or key programmes and/or survey-type programmes)

  • preliminary screening of proposals (technical feasibility, etc.) [2]

  • detection and flagging of duplicate proposals

  • submission to OTAC, acceptance/rejection and grading by OTAC

  • generation and maintenance of the Observation database following the proposal selection process.

- Scientific Mission Planning. This includes:

  • Selection and sequencing from the Observation database of a set of observations based on priority or any other scientific or technical consideration. Sequences will be valid for a specific revolution (orbit).

  • Transmission of this set -the "Sequenced Observation List (SOL)" - to the MOC. Each observation in the list will contain target direction, required instrument commands, ground processing commands as dummy instrument

[1] Requests which call upon specialised instrument knowledge not available in the FSC will be relayed by the FSC to the relevant ICC. The ICC answers will be addressed to the FSC who will forward them to the original requesters. This mechanism off-loads the ICCs from the burden of communicating with the external community. It is expected that such specialised requests will only represent a small percentage of all queries addressed to the FSC.

[2] It is expected that the FSC staff will acquire the necessary instrument knowledge through participation in the relevant ICC activities (mechanism, e.g. co-location, exchange of staff, etc. is TBD).

command (cf. ISO TDATA) and schedule info (e.g. for fixed time observation).

- Support to survey-type activities. This includes:
  - support in the definition of survey-type programmes.
  - overall coordination of survey-type programmes.
  - processing of survey inputs (via Proposal Handling).
  - scientific processing and analysis of the survey-type observations
  - publication of the results (mechanism TBC).
- Design, implementation, testing, validation and maintenance of all S/W packages required to carry out the tasks listed above.
- Liaison with the ICCs and the MOC
- Ensuring adherence to all commonality standards agreed with ESA, the ICCs and the MOC.
- Provision of the building(s) and other infrastructure necessary to operate the mission.

6.2 MISSION OPERATIONS

During the operations additional tasks will be required from the FSC in order to respond to situations which could not be foreseen prior to launch e.g. spacecraft and/or instrument anomalies or which will require changes in procedures and/or software (e.g. change in instrument sensitivity, radiation environment, spacecraft and instrument performance etc.). This is likely to lead to :

- requirement to change observing parameters;
- requirement to re-do failed observations;
- requirement to cancel planned observations;
- requirement to plan and execute specific engineering-type observations;
- requirement to change operational procedures;
- increased level of configuration control;
- increased software maintenance activities;
- increased communications with the scientific community (dissemination of information via WWW);
- increased communications with ICCs and MOC.

The FSC must be set up in such a way that it can cope with this increased level of activity which, by definition, is difficult to quantify.

In addition, the tasks carried out for the preparation of the mission (e.g. OTAC and Community support, Proposal Handling, Scientific Mission Planning, Archive management, etc.) still have to be performed.

These preparatory tasks are required in order to process the Calls for Proposals which are issued subsequent to launch (it is assumed that calls will be issued with a periodicity of 9 months to one year - TBD -).

The FSC must be set up in such a way that it allows these activities to proceed smoothly in *parallel* with the actual operations.

7. INSTRUMENT CONTROL CENTRES (ICCs)

In the FIRST operations concept, based on the principle that operations and ground segment related matters shall be carried out, in each case, by the most suitable entities, the ICCs are in charge of all activities requiring a detailed knowledge of the instruments.

There will be a dedicated ICC for each of the instruments making up the FIRST payload.

It is assumed that;

- Each ICC is located at the corresponding PI-Institute (other schemes are possible, such as location at a Co-I facility or another related centre, but it is likely that this would be less efficient).
- Each ICC is responsible for its own accommodations, organisation and management.
- The list of tasks to be executed by an ICC will be detailed in an "agreement" between ESA and the ICC after instrument selection.
- Each ICC will set up a Team to carry out the tasks entrusted to it. The goal is that each Instrument Team collectively possesses all the instrument knowledge necessary to execute the necessary mission preparations (and later mission operations) tasks.
- The FIRST Ground Segment Steering Group will monitor each ICC 's performance in order to establish if the necessary level of resources (funds, manpower, facilities, etc.) are made available by the ICC to carry out its obligations.

In order to size the effort required to set up and operate the ICCs it is further assumed that;

- The tasks to be carried out are *identical* for all ICCs
- The ICC is manned 8 hours/day, 5 days/week (nominally). Extended working hours are however expected at times e.g. PV phase.
- The ICC will be set up shortly after instrument selection and support nominally 3 years of orbital operations.

Each ICC is responsible for the following tasks;
(the most important tasks only are listed -a detailed list is available-)

7.1 MISSION PREPARATION

- Monitoring of instrument design and development. [1]
- Ensuring that the commonality standards (instrument design and software) defined jointly with ESA and other groups are adhered to.
- Production of an Instrument User's Manual.
- Generation and validation of the Instrument Flight Operating Procedures (nominal and contingency).
- Design, implementation, test and validation of the S/W required for the Scientific Processing of the instrument data. This includes:
  - Off-line RTA/QLA for trouble shooting.
  - Trend Analysis for long term behaviour of instrument and detectors
  - Calibration Analysis
  - Interactive Science Analysis
  - Scientific Processing S/W.
  - Any ad-hoc tool
- Set-up and management of the instrument ground calibration data base.
- Definition (pre launch) of the set of ICSs, and an initial set of AOTs required to carry out the instrument operations.
- Provision of an Instrument Command Translator (ICT). The ICT translates the "symbolic" instrument command language (mnemonics + parameter) into the binary patterns to be uplinked by the MOC.
- Provision of a "time estimator" for the instrument.
- Design, implementation, test and validation of the S/W Instrument Simulator.
- Instrument on-board S/W maintenance (pre- and post-launch).

7.2 MISSION OPERATIONS

The ICC Team members in charge of the operations have to carry out the following tasks for their instrument;

[1] It is expected that the ICC staff will be involved in ILT- and AIV-type activities to gain the necessary instrument knowledge. They should however not be responsible for ILT/AIV nor included in the AIV-dedicated manpower.

Note: none of these tasks *require* real time operations although near-real time operations are feasible and (possibly) desirable.

- Delivery, as required, of calibration requests, instrument "engineering" (e.g. detector curing) requests, and on-board S/W memory load requests to FINDAS.

- Operation off-line (or near real-time when required) of the RTA/QLA in order to carry out checks on observations or instrument trouble shooting.
  Note: real time instrument monitoring is carried out by the SPACONs at the MOC using the MOC RTA.

- Production and validation of the "tools" required by the observers to generate their science data products.

- Generation of the required calibration data parameters and storage in FINDAS.

- Quality Control on selected sets of "standard" output products in order to assess validity of scientific processing S/W.

- Performance of Trend Analysis for assessment of long term behaviour of instruments and detectors.

- Standard maintenance and further development activities (ICC infrastructure, operational S/W, IFOP and procedures, AOTs, etc.)

8. FIRST MISSION OPERATIONS CENTRE (MOC)

The MOC is responsible for all real time operations and control of the satellite and instruments, detailed scheduling of all satellite and instrument commands and the provision of TM and other data required for science processing and planning.
Fig. 8.1 provides a functional overview of the FIRST MOC.

8.1 OPERATIONS CONCEPT

a. FIRST will be operated through stations of the ESA 15 m S-band network. For LEOP, several stations will be set to give near continuous station coverage. For the Science Mission phases, a single ground station, VILSPA 2 (TBC) will be used to provide station coverage for about 13 hours per orbit.

b. FIRST spacecraft and instrument operations will be conducted from ESOC. For LEOP, control of the spacecraft will be exercised from the ESOC Main Control Room.
For the Science Mission Phases, spacecraft and instrument operations will be conducted from the FIRST Mission Operations Centre (MOC) in ESOC.
FIRST operations will be conducted according to procedures laid down in the Flight Operation Plan (FOP) drawn up by ESOC operations staff and based upon the Spacecraft User's Manual provided by the satellite contractor and the Instruments User Manuals provided by the ICCs. The real-time spacecraft and instrument operations will be conducted by a team of Satellite Controllers (SPACONS).

c. The Observation Schedule will be uplinked daily, stored on-board and executed under the control of the on-board computer of the OBDH. Since single station operations are planned, up to 40% of observations will be executed autonomously, outside of MOC control. The resulting instrument data will be stored on-board and transmitted to the ground station during its coverage period. Thus the station and MOC will receive real-time data and stored data in parallel.

d. The TM data necessary for satellite and instrument control will be processed and acted upon as necessary. TM data packets will be delivered to FINDAS over data comms circuits. Data will be delivered to FINDAS in near real time (say 1 minute delay) or with delay (hours) depending on operational requirements. In addition all other data required for science processing, instrument performance checking and observation trouble shooting will be delivered to FINDAS. This includes : command history, T data (actually contained in TM), attitude and orbit history and performance analysis. Data necessary for Science Mission Planning will be provided to FINDAS for the FSC: orbital elements, target visibility parameters and software, slew duration predictor. Provision will be made for the installation of ICC RTA/QLA facilities at the MOC for mission phases which require close interaction between ICC and MOC personnel e.g. instrument commissioning and performance verification. During routine phase, ICC personnel will not normally be present at the MOC.

e. All instrument commands will be defined by the ICCs. The actual commands will however be generated by the MOC from instrument command translators (MNEMONICS to command codes) provided by ICCs. For fixed instrument command sequences not used for observations e.g. activation and deactivation of instruments, serendipity or parallel operations, contingency switch off, etc., so-called Permanent Command Sequences (PCS) will be provided by the ICCs to the MOC via FINDAS.

   Instrument Commands associated with observations, instrument calibrations and more complex instrument testing will be provided through the FSC Mission Planning System.

f. The FSC will provide the MOC with files of sequenced (time-ordered) observations on an orbit by orbit basis for detailed scheduling. For routine operations, a delivery will typically cover two weeks of operations. The observation will contain : instrument, target direction, sequences of commands (ICSs), T data (science processing flags) as dummy ICSs, relative times and fixed schedule times when applicable. The MOC Mission Scheduling System will check this "Sequenced Observation List (SOL)" for visibility constraints, plan the manoeuvres and schedule the observations according to rules agreed with the FSC. The Observation Schedule will be placed on FINDAS together with the actual command schedule.

g. The MOC will generate and deliver to FINDAS an Observation Log (daily or more frequently) containing all anomalous events associated with an observation to permit the FSC to judge the apparent quality of the observation. "Good" observations would be flagged as such in the Mission Data Base by the FSC, and would not be included in future POLs unless subsequently deflagged (FSC - Observer interaction).

8.2 MISSION OPERATIONS CENTRE FACILITIES

The MOC to be established for FIRST will be based to the maximum extent possible on existing operations centre facilities in ESOC. Existing facilities will include control centre accommodation, telemetry and command system infrastructure, flight dynamics system infrastructure, communication system for ground station interfaces. The existing facilities will be tailored for FIRST operations. Before MOC implementation begins, all facilities will be assessed to determine the extent of tailoring and how much new development is required.

8.2.1 Operations Areas

- Main Control Room from where the Flight Control Team will conduct LEOP operations (spacecraft only)

- Ground Configuration Control Room

- Dedicated Control Room for spacecraft and instrument control.
- Project Support Room (normally LEOP only).
- Instrument Support Area (normally commissioning and PV phases only).

8.2.2 Flight Control System

This will include facilities for instrument functional monitoring and control but not for assessment of observation quality.

- Telemetry reception facilities for acquisition, quality checking, filing and distribution of telemetry.
- Telemetry analysis facilities for status checking, limit transgression and trend evolution and facilities for maintenance of system budgets (power, propellant).
- Telecommand processing facilities for the generation of command schedules for uplink to the spacecraft, for the validation of command before submission for uplink, for the transmission to the ground station, and for the verification of successful uplink.
- On-board software (spacecraft and instruments) management facilities.
- Operations log generation.

8.2.3 Mission Scheduling System

This may be incorporated into the Flight Control System.

- Acceptance of Sequenced Observation Lists (SOL) from the FINDAS/FSC.
- Detailed scheduling of observations from SOL.
- Detailed scheduling of spacecraft commands and operational activities.
- Transmission of observation and command schedules to FINDAS.

8.2.4 Flight Dynamics System

- orbit determination
- long range sky visibility predictions

- target visibility definition and software for FSC and MOC internal use.
- attitude planning
- AOCS operations functions
- attitude pointing history generation
- AOCS performance and calibration

8.2.5 Telemetry Off-line Evaluation System

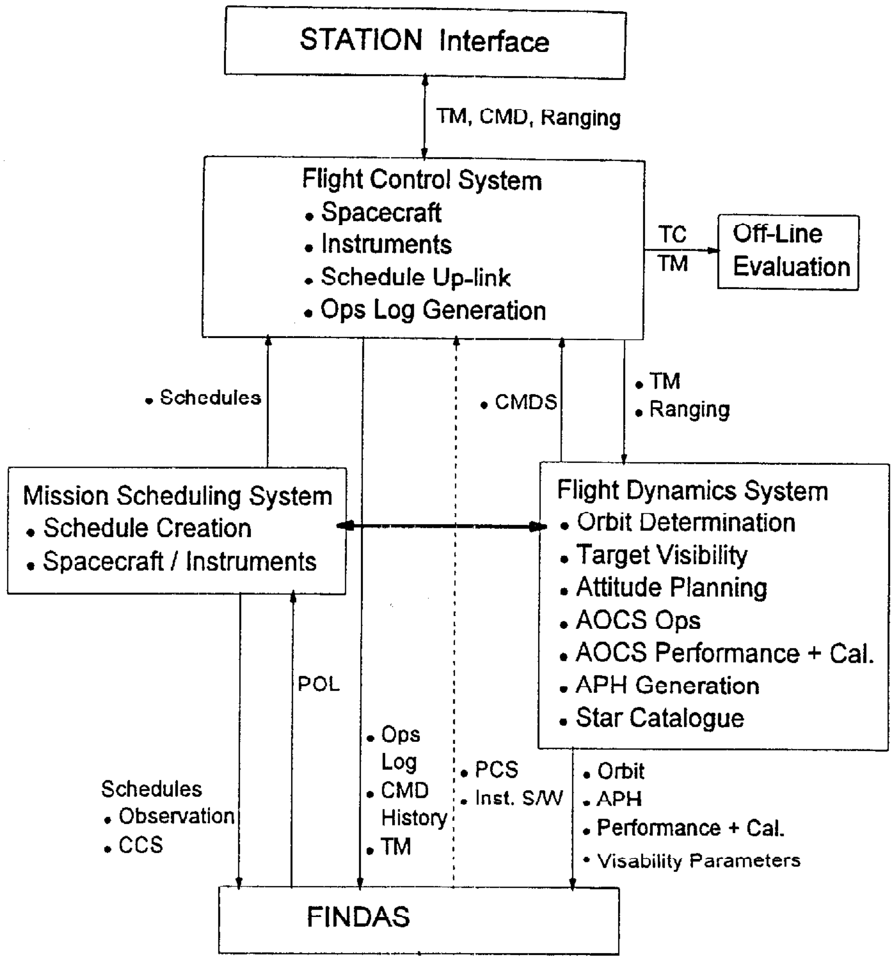
This will be used for anomaly investigations and spacecraft sub-system performance evaluation.

8.2.6 Satellite Simulator

This will include simulation of the behaviour of the spacecraft and the functionality (telemetry responses to commands) of the instruments. The ICCs will deliver appropriate software models of the instruments for integration into the Satellite Simulator.

The Simulator will be used for :

- MOC Testing
- Operational procedure testing and validation
- Operator training
- functional validation of on-board software changes
- End-to-End (MOC, FSC, ICC) testing.



FIRST Mission Operations Centre

Fig. 8.1

9. INTERFACES

This chapter describes the interfaces between the main elements of the FIRST Ground Segment, namely the ICCs, the FSC and the MOC.

There are no operational requirements for the ICCs to formally interact with one another (although it is expected -and probably desirable- that the ICCs maintain informal contacts).

Three levels of interfaces are defined; (i) physical interface, (ii) operational interface, (iii) formal (managerial) interface.

Whereas the physical interfaces are not expected to change with time (TBC), the operational interfaces and to a lesser extent the managerial interfaces are likely to be different in the various phases of the FIRST mission i.e. development/check-out, simulations, LEOP, satellite commissioning phase, PV phase, routine phase, post orbital operations and archive phase.

In all cases the operational interfaces will be defined through a set of agreed procedures.

This chapter only describes the interfaces relevant to the routine phase. Extension to the other phases of the mission should be straightforward.

9.1 ICC TO FSC INTERFACE

9.1.1 Physical Interface

- One dedicated 128-Kb line and one back-up (same capacity) -TBC-
- WWW, Internet, E-mail.
- Fax and phone, surface mail

9.1.2 Operational Interface

- Through agreed procedures.
- custodian: FSC

9.1.3 Formal Interface

- Through an Interface Control Document (ICD) between ICCs and FSC
- custodian: FSC (ICD put under strict configuration control)
- Approval: FIRST Project Manager

9.1.4 Deliveries ICC to FSC

Most deliveries are made to FINDAS rather than directly to the FSC (or MOC). Once on the Archive a given item is accessible by whoever has the necessary access rights (can be MOC and/or other ICCs and/or observers). The general scenario is the following:

1. ICC delivers the item to a temporary Archive scratch area.
2. FSC is notified of the transfer via FINDAS.
3. FSC performs whatever checks are required (as defined in procedure).
4. If checks are OK, FSC moves the item to the appropriate place in the Archive and put under Configuration Control.
5. FSC, and if required other parties (e.g. MOC) are notified via FINDAS of availability of item.
6. If checks are not OK, ICC is alerted and process restarts at step 1.

Some specific items such as the instrument "time" estimators, pre-launch Instrument Calibration Data Base or updates to the AOTs, ICSs, sensitivity tables, etc. involve a different mechanism. For each specific case delivery will take place according to an ad-hoc ICC-FSC agreement.

Regardless of the type of transaction involved, the required functionality is provided by FINDAS.

(Only the major ICC to FSC deliverables are mentioned - a detailed list is available).

- Instrument User's Manual (IUM) - also delivered to the MOC
- Scientific Processing S/W and tools (source + executable + build procedures)
- AOTs
- ICSs and PCSs - also delivered to the MOC.
- Software Problem Reports (SPRs)
- Instrument Anomaly Reports
- Calibration Proposals
- Engineering Proposals
- Calibration Tables
- Trend Analysis Results (TBC)

9.1.5 Deliveries FSC to ICC

Deliveries are made to FINDAS rather than directly to the ICCs. Once on the Archive a given item is accessible by whoever has the necessary access rights. Notification of availability (if required) will be handled by FINDAS. By default the latest version of any item stored in the Archive is returned upon request.

This mechanism covers all deliveries from the FSC to the ICCs.

9.2 ICC TO MOC INTERFACE

The interface between the ICCs and the MOC should be a minimum, during routine science operations. Direct interaction ICC-MOC is necessary however during the development phase and critical operational period.

9.2.1 Physical Interface

- WWW, Internet, E-mail.
- Fax and phone, surface mail

9.2.2 Operational Interface

- Through agreed procedures.
- custodian: MOC

9.2.3 Formal Interface

- Through an Interface Control Document (ICD) between ICCs and MOC
- custodian: MOC (ICD put under strict configuration control)
- Approval: FIRST Project Manager

9.2.4 Deliveries ICC to MOC

(only the major ICC to MOC deliverables are mentioned -a detailed list is available-)

- Instrument S/W simulator:
- TM and TC packet definition:
- List of Instrument Health and Safety parameters to be monitored by MOC
- Instrument TM and TC Data-Bases:
- On-board software memory load images
- Instrument Flight Operations Procedures (nominal + contingency)
- Instrument Command Translators.

9.2.5 Deliveries MOC to ICC

There are no specific deliveries from MOC to the ICCs. The ICCs access, as required, the raw TM, TC, and any required spacecraft data or software stored by the MOC into FINDAS.

9.3 MOC TO FSC INTERFACE

9.3.1 Physical Interface

- One dedicated 128-Kb line and one back-up (same capacity) -TBC-
- WWW, Internet, E-mail.
- Fax and phone, surface mail

9.3.2 Operational Interface

- Through agreed procedures.
- custodian: MOC

9.3.3 Formal Interface

- Through an Interface Control Document (ICD) between MOC and FSC
- custodian: MOC (ICD under strict configuration Control)
- Approval: FIRST Project Manager

9.3.4 Deliveries MOC to FSC

Deliveries are made to the Archive rather than directly to the FSC. Once on the Archive a given item is accessible by whoever has the necessary access rights. By default the latest version of any item stored in the Archive is returned upon request. Notification of availability (if required) will be handled by FINDAS.

The following items are delivered by the MOC;
Note: most items are of interest both to the ICCs and to the FSC

- Observation History File (OHF)
- Raw TM
- TC History
- Aperture Pointing History (APH)
- Orbit File
- Various summaries, e.g. Central Command Schedule summary
- Software Problem Reports (SPRs) and S/C Anomaly reports
- Flight Operations Plan and Procedures (spacecraft and instruments)
- AOCS Calibration and Guide Star Catalogue
- MOC S/W for Science Data Analysis (e.g. slew time predictor)

9.3.5 Deliveries FSC to MOC

- Deliveries are made to FINDAS, access will be restricted to those with access rights.
- New versions of deliveries will only be made after operational liaison with the MOC.

The following items are delivered:

- Sequenced Observation List (SOL) which will contain the sequence and details of the observations to be scheduled by the MOC. The SOL will be on an orbit by orbit basis and normally be delivered in batches covering 2 weeks (TBD).

- During commissioning, PV or for TOOs, SOL may consist of a single or few observations.

- Permanent Command Sequences (PCS) to be used for activation/de-activation, resets, contingency switch offs, etc.. Delivery will be as required.

- Instrument Command Sequences (ICSs) to be used for observations.

- Instrument software memory load images.

The last three items originate in the ICCs. Additionally the ICCs will provide other items directly (not through the FSC) to the MOC (see 9.2.4)

9.4 FSC TO EXTERNAL USERS INTERFACE

There are several categories of external users:

(i) FIRST users, i.e. observers and potential observers
(ii) The time allocation committee
(iii) The wider astronomical community
(iv) The press
(v) The general public

For the users in categories (i) and (ii) the FSC is the single point of contact for everything regarding obtaining FIRST observation time. For users in the other categories the FSC will be one of several places where information can be obtained, this is especially true for (iii). It is important, however, that the needs of the press and the general public are considered upfront and not added on as an afterthought.

External users will be assumed to communicate, using their own resources, with the FSC through normal means such as the World Wide Web (WWW), electronic mail (E-mail) and other Internet services, fax, and phone. In some cases visits to the FSC may be an option (TBC).

The FSC will not normally make deliveries to the external users. It will make available, through the use of the FIRST Integrated Data and Archive System (FINDAS), the requested information, forms, and/or data and software. Users with the proper access rights will be able to connect to FINDAS and to retrieve the required items. E-mail exploders to various mailing lists may be the best option in informing various user groups of the availablity of (new) information (newsletters, science results, press releases, meetings, etc.), important updates, events and bringing important developments to the attention of the relevant people in each of the external user groups.

9.4.1 Interaction with FIRST users

As already mentioned the FSC is the single point of contact for getting FIRST observation time and data. The whole chain starts with getting the relevant information necessary to consider using FIRST for addressing a particular astronomical problem, writing and submitting proposals, getting the observation done, obtaining the data and the means to use the data for doing astronomy.

The list of items available includes:

- General FIRST information. This will reside on the WWW. It should be accessible by everyone, accurate and helpful. It should contain links to information relevant for all kinds of external users. For most of the special information referred to in the following the WWW will also be the primary means of dissemination. (TBC, would be true today).

- FIRST user handbook. Overall information about the scientific capabilities of FIRST and of how to proceed to apply for time, find additional information, interact with the FSC etc. This is the read-me-first document.

- Instrument user handbook (one per instrument). More detailed information about each instrument detailing capabilites in terms of all relevant parameters e.g. sensitivity as function of wavelength coverage, spatial and spectral resolution, operating modes, time estimators, etc.

- Call for proposals. Includes proposal forms and all required information (or reference to it, e.g. instrument handbooks) and tools to complete and submit them properly.

- Observation entry form (TBC). A form used to supply additional information for successful proposals.

- Observation status list. This list contains all observations entered which potentially could be observed. It will be updated to show, for each observation, whether put on the "short list", scheduled, executed, checked OK, subject to rescheduling, date when data become public.

- Observation statistics.
- List of publications (TBC).
- Newsletter.
- PR material. Press releases etc. are not directly aimed for FIRST users, but will be of interest, and some users will be asked to draft/or supply material for press releases.

9.4.2 Interaction with the FIRST observing time allocation committee (FOTAC)

After a proposal has been submitted, it is screened for technical feasibility by the FSC. It is the task of the FOTAC to assess the scientific merit of each proposal, and to allocate observation time accordingly.

In addition to general information (handbooks, newsletters etc.) the FOTAC will specifically need:

- Proposals. The members of the FOTAC will need access to subgroups of the total amount of proposals according to the way they split the work, e.g. by subject matter: planetary, ISM, normal galaxies, active galaxies, etc.
- Proposal evaluation aids. The FOTAC will need tools to identify "duplicate"proposals, e.g. multiple proposals requiring the same kind of observation of the same object(s), and other tools.
- Proposal grading form. A simple manner for the FOTAC to put the result of their work into the proposal database.

9.4.3 Interaction with the wider astronomical community

The wider astronomical community includes a vast number of potential FIRST users. Access should be possible for anybody who wants to obtain accurate information about all aspects of FIRST, how to become a FIRST user, and results of observations. It should be possible to obtain this information from links from the FIRST WWW home page.

Astronomers in general will also be interested in the newsletter and in the press releases and science highlights (cf. 9.4.4).

9.4.4 Interaction with the press

PR material should be included in the planning from the start. Press releases are important, and (in cooperation with/funded by the Agency PR department ?) professionals (science journalists, artists, etc.) should be able to help FSC staff/FIRST users to produce high quality press releases and other PR material. All of this should be available on the WWW.

- Press releases, mainly aimed for quick dissemination.

- Highlights. Particularly interesting results, aimed for the somewhat more ambitious "special" press or special science sections of the "quality" press.

9.4.5 Interaction with the general public

Material for the general public, and especially for two categories: the interested layman and for schools, should also be produced by professionals. Obviously the press is an important channel, but there are other e.g. TV, planetaria, etc.

9.5 FSC INTERFACE TO OTHER OBSERVATORIES

There will be at least three different scenarios where good interaction between the FSC and other observatories (here meant to cover all kinds, whether ground-, airplane-, balloon-, or space-based) will be important:

(i) Preparatory programmes
(ii) Joint observing programmes
(iii) Targets of opportunity

Before the FIRST launch these preparatory programmes can be foreseen to take place e.g. in the field of calibration. These programmes could involve observations of a set (or sets) of objects with a number of instruments at a number of wavelengths at a number of observatories.

During the orbital operations of FIRST it is conceivable that there will be observations which would greatly benefit from being carried out (quasi-) simultaneously with observations being carried at other observatories.

Targets of opportunity could offer unforeseen potentially exceptionally rewarding observations to be made, however, they require relatively quick decision making processes and subsequent action.

In these (and potentially other) cases where interaction between FIRST and other observatories is needed, the FSC will be the contact point.

10. CONCLUSIONS

The decentralised "competence" centre concept (ICCs, MOC, FSC) with a dedicated backbone network and the FIRST Archive System as its communication centre fulfills the requirements for FIRST operations throughout all mission phases, from ILT to Routine Operations.

This concept, if implemented, should provide effective operations for the minimum cost.
Allocating tasks to the most competent contributors should avoid duplication of effort and wastage of resources.

In addition the systematic search for commonality in instrument design and operations should bring significant benefits in reducing the overall effort required for software implementation, documentation, testing and training.

The major prerequisite for the success of the concept is the early implementation of the required elements (in particular FINDAS) and the close cooperation between the centres throughout all stages of development, testing and operations.

A Ground Segment Steering Group, consisting of members of the different centres, the FIRST project scientist and a project representative, will be set up to coordinate and supervise the implementation of the concept. It will advise the FIRST Project Manager, which in case of problems will take corrective actions.

The centre concept could be modified, if required, in a way that the FSC is no longer an independent centre, but part of the MOC and also located on the MOC premises. The functional tasks of the FSC would not change, but this would lead to an overall increase in costs (see section 4.6)

APPENDIX 1: FINDAS USERS AND VIEWS

Different groups of FIRST users will have different views on the various components of the archive. A non-exhaustive list of the various views that are needed is given below:

1. the observer as a scientist
2. the observer as an instrument calibrator
3. the scheduler
4. the real time operator
5. the data (distribution) manager
6. operations and science management

All these archive end users have different demands on what they see of the archive. Inspecting each of them will give an idea of what tools are needed and what type of archive design should be aimed for.

The observer scientist

A scientist is mainly interested in specifying his observation and looking at the calibrated data. Note that 'specifying' in general means changing, not just specifying once, but really adapting to the changing properties of both the instruments and the scientific aims of a given project. As a result he will want to be able to get various types of overviews of the following kinds:

- listings of the specifications of his observations
- listings of the status of his observations
- listings of the status/operations of the satellite
- listings of his data

The tools he needs are the following:

- a -safe- observation editor to introduce and change the parameters of the observations in the data base that have not been scheduled yet and a real-time and science data problems correlator to link real time events to locations in the standard products (e.g. through time keys).
- 'state-of-the-art-but-standard' data processing. This means only a set of well defined data products which are of use for science analysis work.

The calibration scientist and satellite engineer

An instrument calibration scientist as well as the satellite engineer are interested in the same things as the observer scientist, but may need more freedom. Definitely his queries to the database should not have long turn around times, as he will be expected to react fairly quickly to changed instrument and/or satellite conditions. Besides the views of the scientist observer he will want additional views:

- listings of the uplinked commands
- listings/views of the telemetry

The additional tools he needs are the following:

- uplink-downlink correlators to find the connection(s) between uplinked commands and downlinked telemetry (e.g. tying TM packets directly to parts of the instantiated observation).
- 'telemetry' viewers to display in various ways the raw telemetry and all possible data products.
- 'state-of-the-art-and-nonstandard' data processing to allow him to generate data products (standard and non standard) using the telemetry frames as input . These tools should also allow him to make intermediate products and they should give maximum flexibility in terms of processing configuration

The scheduler

A scheduler needs to be able to get an overview of schedulable (i.e. visible, right observation length, time constraints etc.) observations. Possibly he wants to run a prefilter over the data base to get a selection of suitable candidates for say the next week or so. Clearly he also wants to see what the schedule looks like. Thus he needs the following views;

- a list of schedulable observations
- a schedule display

To do his job he will need the following tools to operate on the database;

- an observation filter to create a smaller database of schedulable observations
- a scheduler to make a list of instantiated observations

The real time operator

The real time operator has to monitor the instrument health, therefore he needs to be able to see exactly what goes up and what comes down. Thus he wants the following view; a combination of instantiated observations and downlink telemetry with clear identifications of the links between the two.

The data (distribution) manager

The data (distribution) manager will be looking at the archive from the point of view of deciding what data is good, what observations are still left for scheduling, and who uses what data; lists of data access rights, lists of data processing stages/quality (observed/not observed, good data/bad data, calibratable yes/no, is used by, has been accessed by, can be accessed by)

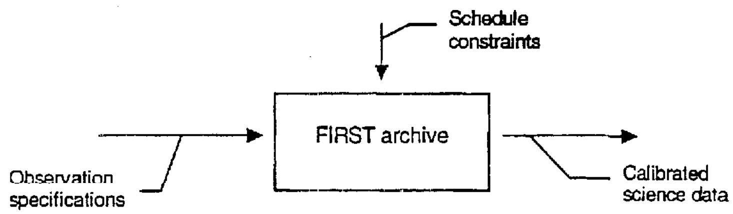
Operations and science management

Operations and science management will be primarily interested in overall statistics of e.g. number of observations carried out, time spent on given target etc. Summaries of these should all be easily generated with simple data base queries.

APPENDIX 2: FINDAS BASIC DESIGN ELEMENTS

Data flow overview

There are three obvious basic data streams in and out of the archive; observation specifications and schedule constraints go in, data come out:



The observation specifications come from various sources; observers, calibration scientists, instrument and satellite engineers. The Schedule constraints come from the physics of the orbit, the telescope avoidance areas, possible science policy constraints etc. The output, calibrated data, are the most general form of calibrated data, i.e. also satellite housekeeping type of data.

Archive components

The archive will have a series of clearly defined components with interrelations such that information needs to be present only in one place. A first set of components are given below, their interrelations are given in the following figure.

1. **Schedule**
   The schedule is a self-contained unit identifying a series of observations and associated instantiations of these observations. The schedule determines the order in which the instantiated observations are sent to the satellite.

2. **Observations**
   Observations are the units that defines the complete observation; the observation specification, the telemetry associated with the observation, data products associated with the observation....
   The contents of an observation is generated 'automatically' and cannot (normally) be changed by end users.

3. **Observation specifications**
   Observation specifications hold the instrument/satellite specifications for the measurements. These are -more or less- human readable and editable entities. Editing can be done *as long as the observation has not been scheduled*. The scheduling process translates the observation specification into instrument commands in the instantiated observation.

4. Instantiated observations

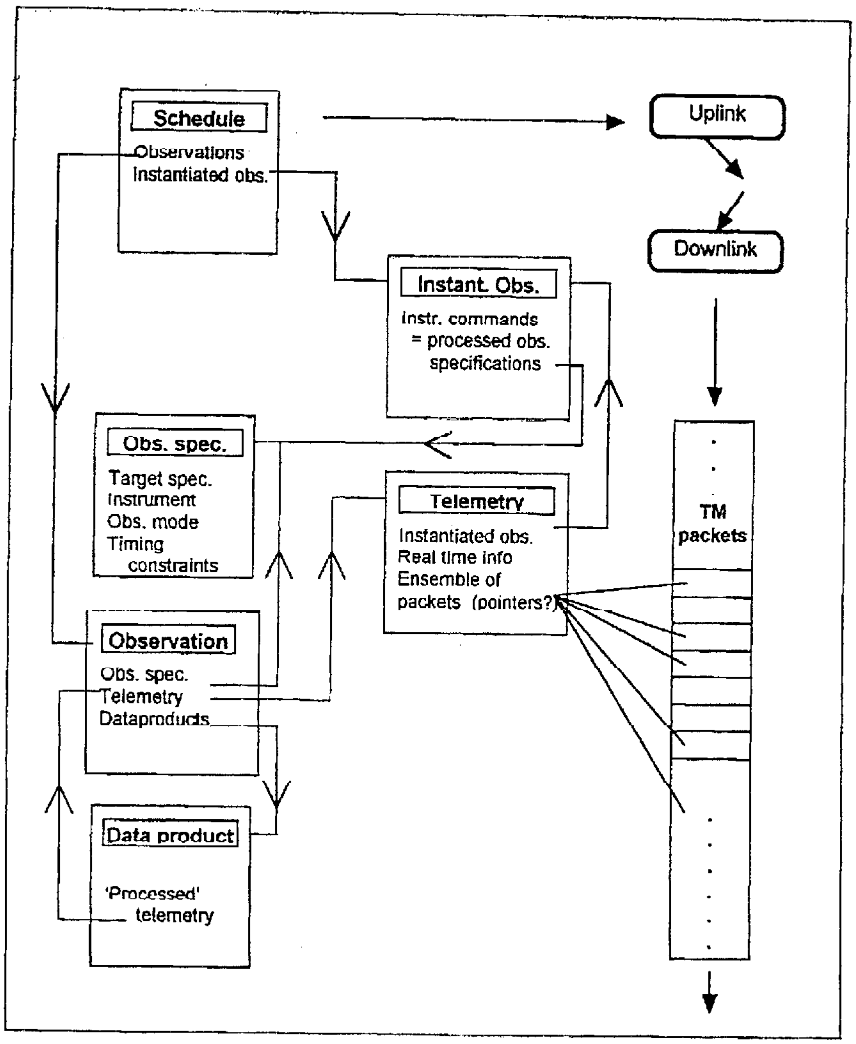
Instantiated observations contain the commands needed to control both spacecraft and instruments. In principle one instantiated observation can be uplinked independently of the state of the instrument/satellite and generate a valid set of telemetry packets.

5. Data products

Data products can be generated per observation by filtering and or processing those telemetry packets valid for one observation.

6. Observation telemetry

The observation telemetry is defined by a set of (pointers to) telemetry packets *containing* information valid for the specific observation. The telemetry also contains references to real time information (telemetry drops, instrument problems) and to the uplinked commands in the form of the instantiated observation


Schedule
Observations
Instantiated obs.
Uplink
Downlink
Instant. Obs.
Instr. commands
= processed obs.
specifications
Obs. spec.
Target spec.
Instrument
Obs. mode
Timing
constraints
Telemetry
Instantiated obs.
Real time info
Ensemble of
packets (pointers?)
TM
packets
Observation
Obs. spec.
Telemetry
Dataproducts
Data product
'Processed'
telemetry

APPENDIX 3: FIRST ARCHIVE -MAJOR DATA COMPONENTS-

It is anticipated that by the time FIRST is launched it will be possible to keep the entire Archive on-line. For each data object listed below the entry "on-line storage" specifies the minimum duration the object has to be accessible on-line in case complete on-line storage is not feasible. It is estimated that the size of the entire Archive will be 2 Tera-bytes (twice the TM rate -68 Kbits/sec- over a period of three years)

ARCHIVE MANAGEMENT

- **Archive catalogue**
- One entry per instance (version) for each data object recorded in the Archive.
- on-line storage: permanent
- size: TBD
- responsibility: FSC

- **Archive Access Log History**
- One entry per access to the Archive.
- on-line storage: Last 100 days
- size: TBD
- responsibility: FSC

SATELLITE DATA

- **Raw TM**
- S/C HK TM packets + Science TM packets. Stored in Short History File (SHF)
- on-line storage: Last 100 days
- size: 68 Kbit/sec x 20 hours/day
- responsibility: MOC
- Note: When required access in near real-time (less than 1 minute) shall be provided.

- **TC History**
- contains uplinked S/C and Instrument commands
- stored in Command History File (CHF)
- on-line storage: Last 100 days
- size: 1 Kbit/sec x 24 hours/day
- responsibility: MOC
- Note: When required access in near real-time (less than 1 minute) shall be provided.

- **Attitude Pointing History (APH)**
- on-line storage: Last 100 days
- size: TBD (small)
- responsibility: MOC
- Note: Near real-time access is required.
- Note: must include the guide star used.

- **Observation History File (OHF)**
- one entry per observation with status (e.g. scheduled, executed, failed)
- on-line storage: permanent
- responsibility: FSC and MOC jointly
- size: TBD

- **Orbit File**
- on-line storage: permanent (TBC)
- size: TBD (small)
- responsibility: MOC

DEFINITIONS

- **TM Data-Base (S/C + Instruments)**
- assume 2000 parameters in total (including derived parameters)
- includes parameters "calibration curves"
- includes Display Definition Files
- on line storage: permanent
- size: TBD (small)
- responsibility: MOC (provided to MOC by FIRST Project Team)

- **TC Data-Base (S/C + Instruments)**
- assume 1000 commands
- on line storage: permanent
- size: TBD (small)
- responsibility: MOC (provided to MOC by FIRST Project Team)

- **AOT definitions**
- one (current) set per instrument
- on line storage: current set
- responsibility: ICCs
- size: TBD (small)

- **ICSs**
- one (current) set per instrument
- on line storage: current set
- responsibility: ICCs
- size: TBD (small)

- **CUS verbs**
- one (current) set per instrument
- on line storage: current set
- responsibility: FSC (provided to FSC by ICCs)
- size: TBD (small)

- **FIRST AOCS Calibration and Guide Star Catalogue**
- on-line storage: permanent
- size: TBD
- responsibility: MOC

OPERATIONS PLANNING

- **Proposal Data-Base**
- Guaranteed-time Proposals (TBD) -responsibility: FSC-
- Survey-type Proposals (TBC) -responsibility: FSC-
- Key Programmes (TBC) -responsibility: FSC-
- General Observer Proposals -responsibility: FSC-
- Calibration proposals -responsibility: ICCs-
- Engineering proposals -responsibility: ICCs-
- Cross-calibration Proposals -responsibility: FSC-
- TOOs - responsibility: FSC-
- assume 1000 proposals per Call
- assume Calibration + Engineering Proposals = 20% of all proposals
- assume 50 observations per proposals
- assume oversubscription factor of 3
- assume one Call covers 1 year of mission
- on line storage: one Call (i.e. one year)
- size: TBD

- **Mission Planning & Scheduling**
- Visibility Data-Base
  - provides sky visibility constraints
  - covers the entire mission
  - on-line storage: permanent
  - responsibility: MOC
  - size: TBD

- SOL (Sequenced Observations List)
  - covers a variable number of orbits as required (say 2 weeks - TBC -)
  - on line storage: TBD
  - responsibility: FSC
  - size: TBD

- CCS (Central Command Schedule) -binary-
- covers one orbit
- on line storage: last 100 orbits
- responsibility: MOC
- size: TBD

- CCS Summary (ASCII)
- covers one orbit
- on line storage: last 100 orbits
- responsibility: MOC
- size: TBD

- Long Range Observing Plan
- covers 6 months (TBD)
- on line storage: current plan
- responsibility: FSC
- size: TBD

- Mission Data Base
- covers whole mission
- contains all schedulable "observations" (including calibration & engineering)
- on line storage: permanent
- responsibility: FSC
- size: TBD

CALIBRATIONS

- **Calibration Data-Base**
- Pre-launch Instrument Calibration DB
- one Data-Base per instrument but common design/format
- contains all pre-launch *significant* calibration data
- on line storage: TBD
- responsibility: ICCs
- size: TBD

- External Calibration DB
- contains data from ground-based preparatory programme and from other satellites.
- on line storage: permanent
- responsibility: FSC
- size: TBD

- Calibration Target List (consolidated)
- contains relevant reference data
- on line storage: permanent
- responsibility: FSC (provided to FSC by ICCs)
- size: TBD

- S/C Calibration DB
- contains pointing offsets, aperture offsets, alignment offsets, etc.
- on-line storage: permanent
- responsibility: MOC
- size: TBD

- Instrument Calibration Files
- one per instrument per mode (TBD)
- coverage: TBD - from a few days to a few weeks-
- on line storage: 3 latest versions
- responsibility: ICCs
- size: TBD

MISCELLANEOUS

- **Operation Plans and Procedures**
- FOP + FCPs + CRPs
- on line storage: current set
- responsibility: MOC
- size: TBD

- IFOP + IFCPs + ICRPs
- on line storage: current set
- responsibility: MOC (provided to MOC by ICCs)
- size: TBD

- **Test Plans and Procedures**
- contains all test plans and procedures used from Instrument Level tests till final Ground Segment Simulations.
- on line storage: current set
- responsibility: MOC + FSC + ICCs
- size: TBD

- **On-board S/W management data**
- S/C on-board S/W memory load images (e.g. ACC, OBDH, etc.)
- on-line storage: 3 latest versions
- responsibility: MOC
- size: TBD

- Instruments on-board S/W memory load images
- on-line storage: 3 latest versions
- responsibility: MOC (images provided by ICCs)
- size: TBD

- Memory dumps (S/C and Instruments)
• on-line storage: TBD
• responsibility: MOC
• size: TBD

- **Trend Analysis Results**
- on-line storage: TBD
- responsibility: ICCs
- size: TBD

- **Administrative Data**
- "official" (sub-set) of FIRST documentation
• on-line storage: TBD
• responsibility: FSC (origin: FIRST Project Team)
• size: TBD

- User Manuals (S/C + Instruments)
• on-line storage: TBD
• responsibility: FSC (origin: FIRST Project Team and ICCs)
• size: TBD

- S/W User Manuals (S/W sub-systems; e.g. PH, Mission Planning)
• on-line storage: TBD
• responsibility: FSC (origin: ICCs, FSC, MOC)
• size: TBD

- Call for Observing Proposals
• Executive Summary
• FIRST Observer's Manual
• Instrument Observer's Manuals
• List of Guaranteed-Time Targets (TBD)
• on-line storage: duration of Call
• responsibility: FSC
• size: TBD

- FIRST news-letters
• on-line storage: All news-letters
• responsibility: FSC
• size: TBD

- Reports and Statistics (e.g. to OTAC, ESA, etc.)
• on-line storage: All reports and statistics
• responsibility: FSC
• size: TBD

- Software Problem Reports (SPRs)
  - on-line storage: All SPRs pre- and post-launch
  - responsibility: FSC (origin: MOC, ICCs, FSC)
  - size: TBD

- Anomaly Reports (ANRs)
  - cover spacecraft and instruments ANRs
  - on-line storage: All Reports (post-launch only)
  - responsibility: FSC (origin: MOC and ICCs)
  - size: TBD

- **Auxiliary (Science) Data**
- Astronomical Stars Catalogues
  - IRAS Catalogue (TBC)
  - ISO Catalogue (TBC)
  - Hipparcos Catalogue (TBC)
  - Bright Stars Catalogue (TBC)
  - on-line storage: TBD
  - responsibility: FSC
  - size: TBD

- List of references to FIRST scientific papers (TBC)
  - on-line storage: permanent
  - responsibility: FSC
  - size: TBD

- **Software and Tools**
- MOC software
  - includes "integrated" Simulator, "Visibility Constraints Parameter and Software" and "Slew Predictor"
  - contains sources + executables + "build" procedures.
  - on-line storage: 3 latest versions (sources + executables)
  - responsibility: MOC
  - size: TBD

- FSC software
  - includes "Remote Proposal Submission System" and forms
  - contains sources + executables + "build" procedures.
  - on-line storage: 3 latest versions (sources + executables)
  - responsibility: FSC
  - size: TBD

- ICC software
• includes "Science Processing" software, "time-estimators" and "instrument-simulators" (TBC)
• contains sources + executables + "build" procedures.
• on-line storage: 3 latest versions (sources + executables)
• responsibility: ICC (Configuration Control done by FSC)
• size: TBD

- Scripts
• various "scripts" (e.g. to produce "standard" data products and/or statistical data)
• on-line storage: 3 latest versions
• responsibility: FSC and ICCs (Configuration Control: FSC)
• size: TBD

APPENDIX 4: COST BREAKDOWN FOR ICC AND FSC

(To be provided with next issue)