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SUV

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SUV MISSION OPERATION AND GROUND SEGMENT
Preliminary Design Report

(Version 1.0)

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Mission Operation and Ground Segment

Spectrum UV is to be an astronomical **observatory-type mission** similar to many well known examples, like IUE, Exosat or HST: participation to the observations will be open to Guest Observers (GOs) in the participating countries and in the astronomical community at large in response to solicited Announcements of Opportunity (AO) for observing time. The possibility of core/key programs, and of reserved time for project teams is also being considered. The exact policy (either on joint or national basis) will be agreed during Phase A and will be reflected in a Memorandum of Understanding (MoU) between the mission participants.

This report considers the facilities and technological actions which have to be realized to provide: mission planning, implementation of spacecraft monitoring and execution of the observation program, telemetry data handling and science data reduction.

The *Ground Segment* (of which the *Mission Control Centre* is a fundamental part) will operate accordingly to the concepts and rules agreeed by the main participants to the mission. Those concepts and rules have to define:

- the baseline for observation program support
- the baseline for observation program execution
- general schemes for HK and science data handling and science data reduction
- the modalities for spacecraft and payload operation.

On other hand, the Ground Segment can be intended as a complex of facilities (antennas, communication network, computers, etc.) plus dedicated and non-dedicated personnel supporting all flight control operations.

The existence of a **dedicated** ground segment for each scientific space mission is part of current concept in the CIS. By *dedicated* we mean here that the allocation of specific ground stations (within the CIS space communication network) has to be included in the overall schedule of CIS space programs, since the earliest study phase of each mission.

The current practice of astronomical space missions performed by ESA and in the CIS have been considered as a starting point.

In particular, as a result of the assessment study, the concept of **real time observatory** has been adopted, taking full advantage of the fact that an high Earth elliptic orbit allows continuous contact with a single ground station for a very large fraction of the orbital period, and offers therefore notable advantages with respect to low Earth orbits, both in terms of longer uninterrupted observing time, and of simpler and more efficient operations.

The possibility of communicating and interacting with the spacecraft at any time during the times it is visible from the ground station, which are of the order of 10-18 hours per day will therefore be exploited when possible (on-line mode), while observations in automated mode (off-line mode) can be performed during the rest of the time (see 1.1.2 below for details). The optimization of the usage of the two modes to achieve the scientific objectives of the mission will be a task for the Phase A study, which may consider :

- Reserving long exposures (or long pointings with sequences of exposures insofar available on-board storage allows) on predefined targets in a preplanned instrument configuration for the off-line mode during non-contact intervals

- Use the on-line mode systematically during contact periods for sequences of shorter pointings and exposures. Concerning the degree of interactivity one has a nearly continuous spectrum of possibilities ranging from a totally unconstrained (IUE-like) observatory to a rigid schedule where only contingent changes to the science instrument configuration are allowed. The case most suitable for SUV will be defined after the phase A study.

We present here a block diagram with the basic data processing modules for the Spectrum UV mission (see figure FIG1). An additional data flow diagram, evidentiating the role of the different modules as well as the open areas to be defined during Phase A, is presented in figure FIG2.

Module 1 — includes all equipment which is placed between transmitting/receiving antennas on one side, and the computer system for telemetry and telecommand processing on the other side. Some relevant modules are described in 4.1

Module 2 — *Mission Dedicated Computer System* (MDCS) : this system will provide basic data processing for the General Operation Control Group support, and is described in 4.2

Module 3 — The *Real Time Operation* section of the Science Data Processing Systems (SDPS/RTO) : this system will support science data processing and science operation interaction in real time or near real time, and is described in 6

Module 4 — The *Science Operation Centre,* another section of the Science Data Processing Systems (SDPS/SOC) : this system will perform off-line data processing of science data, and is described in 7 (7.2 and 7.3)

Module 5 — *Observing Program Support* (OPS) functions constitute a further logical module (even if they will in practice make use of the facilities of the previous two modules), which is described in 7.1

In addition a sixth module is indicated as a reminder of the (internal and) external interfaces necessary for flight dynamics (or ballistics) support.

Each module, besides the relevant hardware, includes software, dedicated personnel.

Figure 1

Overall block diagram of the SUV Ground Segment

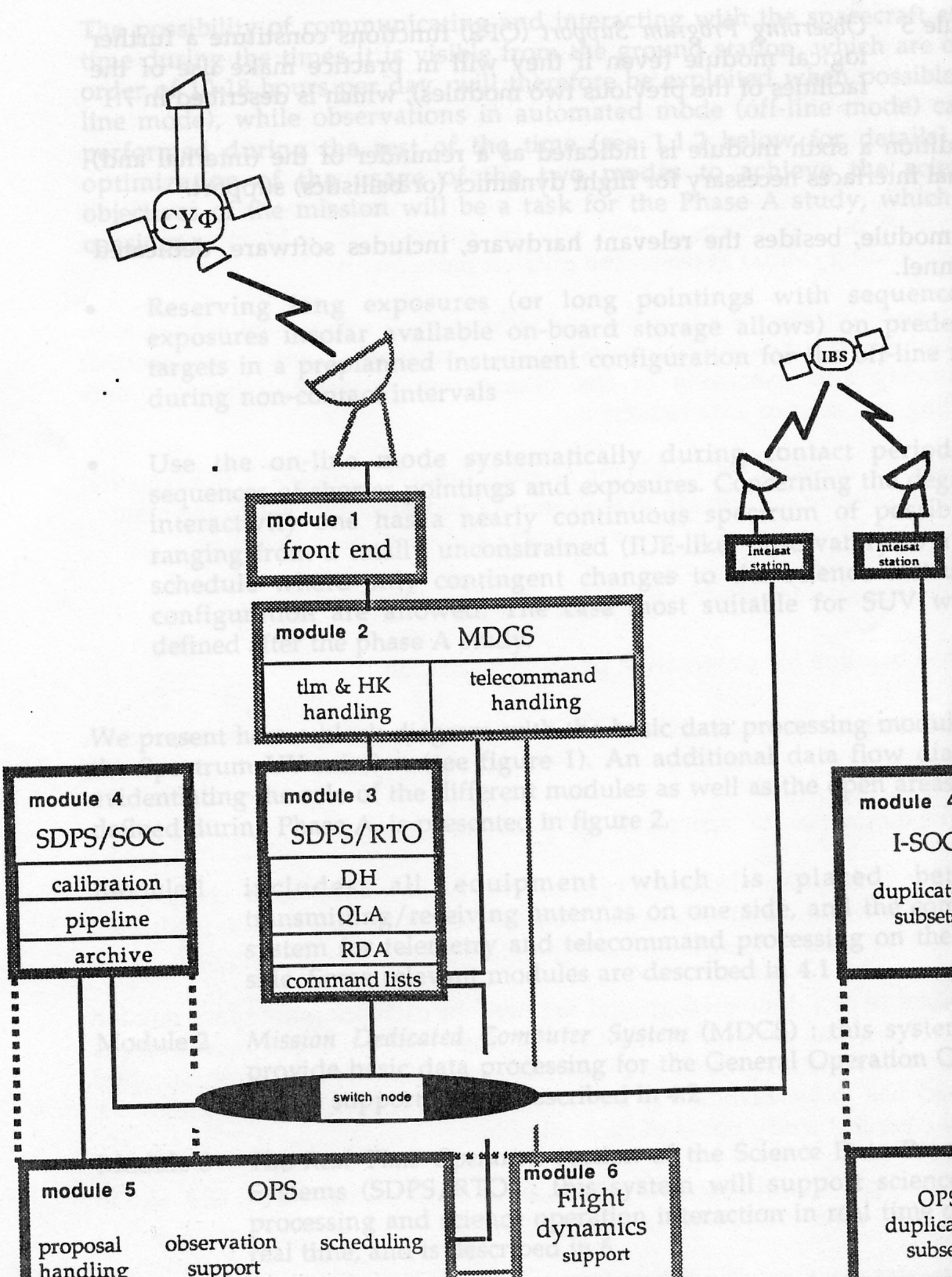
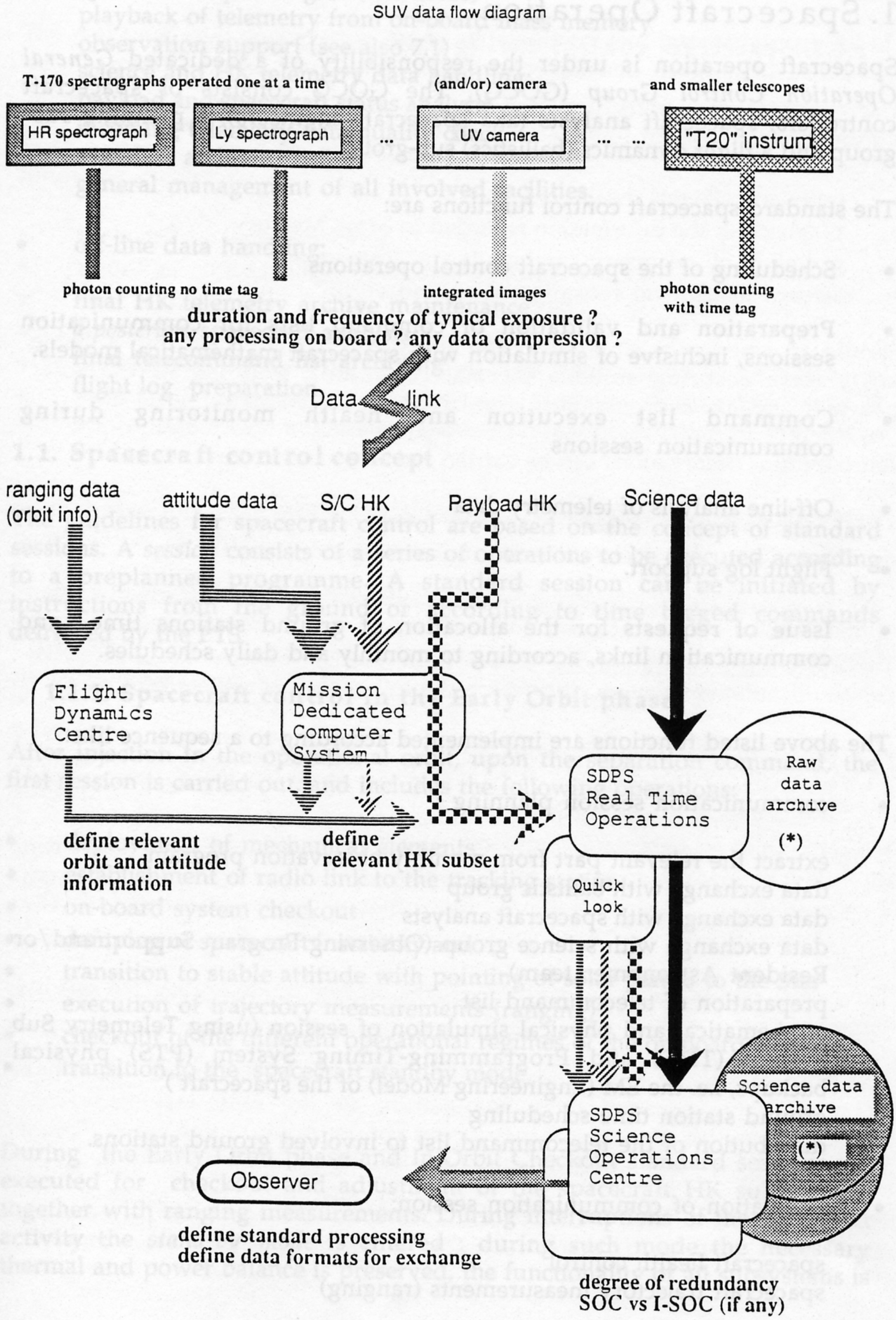


Figure 2


SUV data flow diagram
T-170 spectrographs operated one at a time
(and/or) camera
and smaller telescopes
HR spectrograph
Ly spectrograph
UV camera
"T20" instrum
photon counting no time tag
integrated images
photon counting
with time tag
duration and frequency of typical exposure ?
any processing on board ? any data compression ?
Data link
ranging data
(orbit info)
attitude data
S/C HK
Payload HK
Science data
Flight
Dynamics
Centre
Mission
Dedicated
Computer
System
SDPS
Real Time
Operations
Raw
data
archive
(*)
define relevant
orbit and attitude
information
define
relevant HK subset
Quick
look
Science data
archive
(*)
SDPS
Science
Operations
Centre
Observer
define standard processing
define data formats for exchange
degree of redundancy
SOC vs I-SOC (if any)

1. Spacecraft Operation

Spacecraft operation is under the responsibility of a dedicated *General Operation Control Group* (GOCG). The GOCG consists of spacecraft controllers, spacecraft analysts (aka spacecraft engineers), a planning sub-group and a flight dynamics (ballistics) sub-group.

The standard spacecraft control functions are:

- Scheduling of the spacecraft control operations
- Preparation and validation of command lists for communication sessions, inclusive of simulation with spacecraft mathematical models.
- Command list execution and health monitoring during communication sessions
- Off-line analysis of telemetry data
- Flight log support.
- Issue of requests for the allocation of ground stations time and communication links, according to monthly and daily schedules.

The above listed functions are implemented according to a sequence like:

- communication session planning :

  extract the relevant part from monthly observation program
  data exchange with ballistic group
  data exchange with spacecraft analysts
  data exchange with science group (Observing Program Support and/or Resident Astronomer team)
  preparation of telecommand list
  mathematical and physical simulation of session (using Telemetry Sub System (TMS) and Programming-Timing System (PTS) physical backups, i.e. the EM (Engineering Model) of the spacecraft)
  ground station time scheduling
  distribution of the telecommand list to involved ground stations.

- realization of communication session:

  spacecraft health control
  spacecraft trajectory measurements (ranging)

telecommand verification
spacecraft repointing (manoeuvres)
playback of telemetry from on-board mass memory
observation support (see also 7.1)
science and HK telemetry data handling;
payload and spacecraft status analysis
incoming telemetry data quality check
raw data archiving
general management of all involved facilities.

- off-line data handling:

final HK telemetry archive maintenance
a posteriori spacecraft analysis
final telecommand list archiving
flight log preparation.

1.1. Spacecraft control concept

The guidelines for spacecraft control are based on the concept of standard sessions. A *session* consists of a series of operations to be executed according to a preplanned programme. A standard session can be initiated by instructions from the ground or according to time tagged commands delivered by the PTS.

1.1.1. Spacecraft control in the Early Orbit phase

After injection in the operational orbit, upon the separation command, the first session is carried out, and includes the following operations:

- deployment of mechanical elements
- establishment of radio link to the tracking station
- on-board system checkout
- damping of spacecraft instability and
- transition to stable attitude with pointing of solar panels to the Sun
- execution of trajectory measurements (ranging)
- checkout of the different operational regimes of the on-board systems
- transition to the spacecraft standby mode

During the Early Orbit phase and In-Orbit Checkout standard sessions are executed for checkout and adjustment of the spacecraft HK subsystems, together with ranging measurements. During interruptions of the spacecraft activity the *stand-by mode* is entered : during such mode the necessary thermal and power balance is preserved, the functionality of all subsystems is maintained and the possibility of establishing the radio link to the Earth is guaranteed.

1.1.2. Spacecraft control during operational mission

The preparatory activities for a scientific observation during a communication session involve the following operations :

- on-board systems health checks
- playback of the information recorded in Mass Memory
- uplink of all necessary commands and instructions
- science instrument reconfiguration and verification

Should an emergency situation occur, the spacecraft is driven into a stable *safety mode* ensuring suitable thermal conditions, pointing of the solar panels to the Sun and possibility of establishing the communication link.

Astronomical observations can be carried out according to two modes:

- 1: *off-line mod*e (*automated session mode*)
- 2: *on-line mode* (*real time mode*, uninterrupted control)

1.1.2.1. Automated session mode

The automated session mode (aka off-line mode) is based upon standard communication sessions during which the following operations take place:

- on-board subsystem checkout
- playback of information recorded in the on board mass memory and transmission to the Earth
- uplink of all necessary commands and instructions
- slew manoeuvre to the target to be observed
- reconfiguration of science instruments in preparation of the observation

The actual astronomical observations in the off-line mode are carried out in-between contact periods.

The preparatory communication session (involving in the order : downlink of previously recorded data, manoeuvre to the new target, science instrument switch on, science instrument configuration) might take 2 to 7 hours, and the subsequent observation might take e.g. 10 to 40 hours.

The automated session mode necessitates a large memory capacity. This mode could be used to observe faint objects requiring long exposure times.

1.1.2.2. Real time operation mode

The real time on-line operation mode allows direct and interactive control of the observation procedures, allowing a more efficient usage of the mission lifetime.

In this case a session (= observation) will be carried out according to the following procedure:

- on-board systems check-out
- uplink of all necessary commands and instructions
- slew manoeuvre to the target to be observed
- reconfiguration of science instruments
- on-line observation with continuous data transmission to the Earth
- switch-off of science instruments or transition to standby mode (if appropriate). One might start another on-line observation or prepare an off-line one.

In this case the observation (alias session) can last as long as the contact period (10 to 18 hours).

Small adjustments of the operational procedures are possible during the course of astronomical observations, changing programmes by telecommand (using uplink rate of about 4 kbit/s with a significant content for operational instructions of about 3 kbit/s).

In order to improve the reliability of the control of spaceraft and payload operation, it would be required to insert HK data within the science data stream.

Such concept of spacecraft control concept significantly increases the overall operational time and requires supplementary ground facilities.

1.1.3. Spacecraft operation scheduling

Spacecraft control is carried out according to a monthly schedule. Monthly programmes are prepared by the General Operation Control Group (GOCG) according to the recommendations of the Observation Program Support (OPS) team.

The GOCG prepares a preliminary schedule of spacecraft use (inclusive of contact periods, ground station checkouts, etc.) and delivers it to OPS. The latter prepare the inputs for the observation session according to this monthly schedule.
The GOCG, on the basis of the input received from OPS, elaborates a final monthly schedule, and issues it to OPS three days in advance of the relevant observation.

For the optimization of information exchange among GOCG and OPS a standard format is to be adopted, and will be defined in a later phase of the project. This format should contain information on both the monthly programme carried out and the accomplished sessions including the relevant orbital parameters, emergencies and other telemetry parameters.

A *Functional-Logical Block Diagramme for the Spacecraft Flight Control* is available as a separate draft document and will be presented during the next study phase.

1.2. Preparation of command list

Telecommand lists may contain two types of data to be transmitted to the spacecraft.

a) Relay Commands (RC): 9-bit command words (during uplink);
b) Coded Control Words (CCW): 36-bit command words.

CCWs may contain 16 bits (size 1) or 30 bits (size 2) in the part to be finally delivered to the instruments.

Size 1 will be used for transmission of CCW through the memory of the PTS (which is to be considered as a *temporary storage* and will be used only if and when explicitly requested).

Size 2 will be used for *direct* transmission of CCW to Science Data Management Unit (SDMU) (or instruments) from decoder. The use of Size 2 shall be based on the capability of SDMU (and instruments) to perform verification and validation checks for received CCWs and to provide feedback (acknowledgments) in telemetry.

The telecommand preparation and transmission should consist of the following steps:

- a telescope operator prepares the telecommand file for payload (using an agreed file format and structure)
- the telescope operator delivers such telecommand file to the General Operation Control Group;
- a spacecraft operator prepares and verifies the final code;
- at the appointed time the telecommand file transmission starts automatically.

It is strongly recommended that lines in telecommand text include at least:

a) for RCs (relay command code) :
   name of RC;
   condition for RC execution;
   function of RC;
   the action to undo the RC;
   comment.

b) CCW lines must consist of the same fields if their functions are similar to RCs (i.e. if the whole CCW or part of it corresponds with a well determined function).

It should be considered the use of dedicated software modules e.g. in RTO or MDCS to construct a file in the requested format, in MDCS to verify the conditions for execution and to perform the coding.

1.3. Telecommand verification and validation.

The concept of telecommand verification and validation, and the usage of telecommand acknowledgment is introduced here. We preliminarily recall two definitions :

> *Command validation* : it is a *syntax* check that a command is legally formed (e.g. correctly typed or coded, or correctly received on board) as well as a *semantic* check that a command is allowed by the spacecraft condition at the moment it has to be executed (if this is verified by software on the ground it is called a *pre-transmission validation*)
>
> *Verification* : it is either the check on the ground that the command has been *received* on board (acknowledgment) and eventually that it has been received *correctly* (e.g. command echo in HK telemetry). Finally there is the check that the command has been *executed*, which occurs either looking at the result of the command (e.g. monitoring an HK parameter like an analog high voltage) or at an on-board register content echoed as HK parameter in telemetry (e.g. for memory load commands).

Telecommand text integrity has to be provided during all steps of telecommand editing, generation and transmission. Those steps are:

- editing telecommand text
- coding of the telecommand text
- uplink
- reception on board the spacecraft
- decoding
- conditional execution
- insertion of acknowledgments into telemetry.

As the Decoder will **not** provide telecommand safety test after uplink, verification and validation must be foreseen by users of telecommands (PTS, SDMU,...).

Before transmission, telecommand lists are processed in MDCS using a special software for pre-transmission validation. This software provides :

- check if the telecommand is valid consistently with a set of rules and constraints preliminarily prepared and formalized for each spacecraft housekeeping subsystem
- telecommand feasibility check according to current spacecraft status
- issue of warnings in case of use of telecommands which are foreseen for emergency situations

It is usual practice to terminate telecommand preparation with the signature of the final text by both spacecraft and payload representatives.

Telecommand verification has to be foreseen at all steps of telecommand transmission, starting in MDCS and ending in the on-board subsystem which will execute the telecommand. The final step of verification is the receipt and check of an acknowledge on the ground.

1.4. Uplink bit rate.

Telecommand for spacecraft subsystems and for payload will be transmitted using two different modes:

a) slow rate : 1 RC every 2 or 6 s

b) fast rate : 2,4,8,... 4096 baud (increment in powers of 2), including error correction code.

1.5. Spacecraft subsystem status analysis

Analysis of spacecraft status and health monitoring occurs via :

- HK monitoring done "on-line" via software (presumably in Module 2 more than in Module 3). This should involve automatic limit checking done on all HK data (as specified by the parameter characteristics file), to verify each parameter is within tabulated limits, and to issue an alarm if limits are exceeded. Both limits on the range of parameters, and on the rate of change (delta-limits) could be considered. The details have to be worked on during the next phase.

- HK monitoring done "on demand" looking at selected HK parameters on a display. This is visual inspection of results of a software elaboration. Could occur in Module 2 or 3 under spacecraft controller, telescope operator or resident astronomer request.

2. Payload operation

From the point of view of the General Operation Control Group, payload operation is at all similar to spacecraft operation.

During the scheduling of individual sessions, a common list of both spacecraft and payload telecommands is generated, but there are two technical pecularities concerning the payload during telecommand and telemetry processing.

The first one is the presence of the high data rate telecommand stream, exclusively to allow real-time observations.

The second one is the existence of the high rate science telemetry stream. The ground station cannot receive both (HK and science) telemetry streams at the same time. As a consequence, spacecraft health monitoring will be impossible during long periods of continuous science telemetry downlink. There are two possibile ways to resolve this problem and to improve the reliability of the mission:

insert into the session program appropriate short intervals for HK telemetry, interrupting the science telemetry stream;

include relevant portions of HK information into the science telemetry stream.

The final decision on this problem has to be agreed by spacecraft and SDMU designers.

The telemetry data containing payload HK parameters will therefore be transmitted either on the slow or on the fast TM channel. MDCS will process and display payload HK parameters extracted from the slow TM stream, and it will provide this information to all involved persons. Some HK parameters in the science data stream may also be processed by MDCS according to the parameter characteristics file prepared by payload engineers.

A functional model of spacecraft operations is to be used during scheduling (similar to the one being proposed for Mars 94, where the software is being prepared by JPL, and Russia will feed the software with basic data). This model will then take into account the impact of spacecraft constraints/limitations (power, telemetry) on payload operation.

2.1. Quality control of science data.

Quality control of science data is expected to be implemented on three levels:

- hardware level (in Module 1): synch word examination
- software level (Module 2, Module 3): checksum verification, frame length and

structure analysis, or any other algorithm based on the formulas provided by on-board software;

- intelligent level : visual analysis under responsibility of the telescope operator.

The first two levels are essentially confined to the verification of the data link quality (to verify that integrity of the data has been preserved over the communication channel). As such they are confined to module 1 and 2 (and they are the same for both spacecraft and payload data).

The third level is the health monitoring described above in 1.5.

- The check of scientific performance is done by RA (quick look at SDPS/RTO see 6)

- The best data reduction choice is a task for RA again (at SDPS/SOC see 7.2).

3. Spacecraft Communication

The structure of the ground segment network is shown in Fig. FIG3. The main center for Flight Control and science data acquisition will be located at the Eupatoria tracking station.

Two 25-m antennas provide uplink and downlink as well as spacecraft ranging. The two redundant antennas ensure the required reliability and continuous control of the spacecraft during visibility periods.

Similar antennas are located in the Moscow region and in Ussurijsk. They will be used for ranging and as redundant units for command uplink and telemetry acquisition.
Baikonur antennas could be used for Early Orbit tracking only.

The Deep Space Communication Centre (DSCC) in Eupatoria is equipped with all necessary facilities for communication with tracking stations, flight dynamics centers and other network elements.

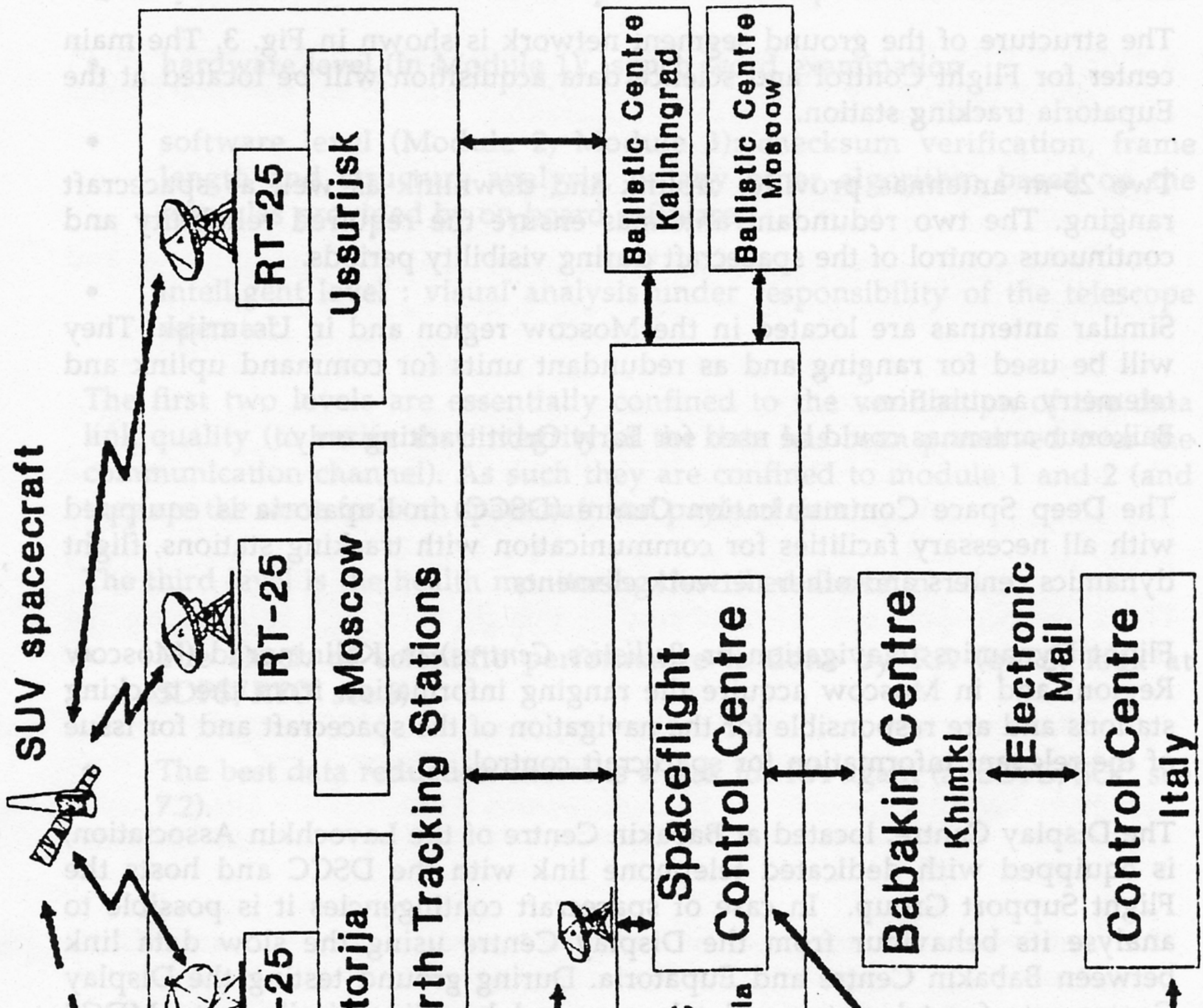
Flight Dynamics (Navigation or *Ballistics Centres*) in Kaliningrad (Moscow Region) and in Moscow acquire the ranging information from the tracking stations and are responsible for the navigation of the spacecraft and for issue of the relevant information for spacecraft control.

The Display Centre, located at Babakin Centre of the Lavochkin Association, is equipped with dedicated telephone link with the DSCC and hosts the Flight Support Group. In case of spacecraft contingencies it is possible to analyse its behaviour from the Display Centre using the slow data link between Babakin Centre and Eupatoria. During ground testing the Display Centre acts for telemetry and telecommand handling similarly to MDCS during flight control.

The SUV ground segment facilities are to support the characteristics of the missions, which can be summarized as:

- downlink data rate up to 2 Mbit/s (TBD)
- uplink data rate up to 4096 bit/s (TBD)
- 24 hour/day operations of ground facilities (TBD)
- daily contact with the spacecraft

Figure 3



SUV spacecraft
Earth Tracking Stations
RT-25
Ussurisk
RT-25
Moscow
RT-25
Evpatoria
RT-12
KrAO
Ballistic Centre
Kaliningrad
Ballistic Centre
Moscow
RRL
DSCC
Evpatoria
Spaceflight
Control Centre
Scientific Data
Processing Centre
at KrAO
Babakin Centre
Khimki
Electonic
Mail
Control Centre
Italy
Earth Station
Earth Station
Intelsat
satellite

4. Mission Control Centre

The SUV Mission Control Centre (MCC) will be located within the Deep Space Communication Centre (DSCC) at Eupatoria, and will perform the following functions :

- Spacecraft operation.
- Payload operation.
- HK telemetry data processing and archiving.
- Science telemetry processing and archiving in real time.
- Ballistic support.
- Handling of mission dedicated antennas and telecommunications control.

The following facilities will be included in MCC :

- Module 1, which is connected with the main antenna for up- and downlink in Eupatoria DSCC;

- Mission Dedicated Computer System (MDCS, Module 2);

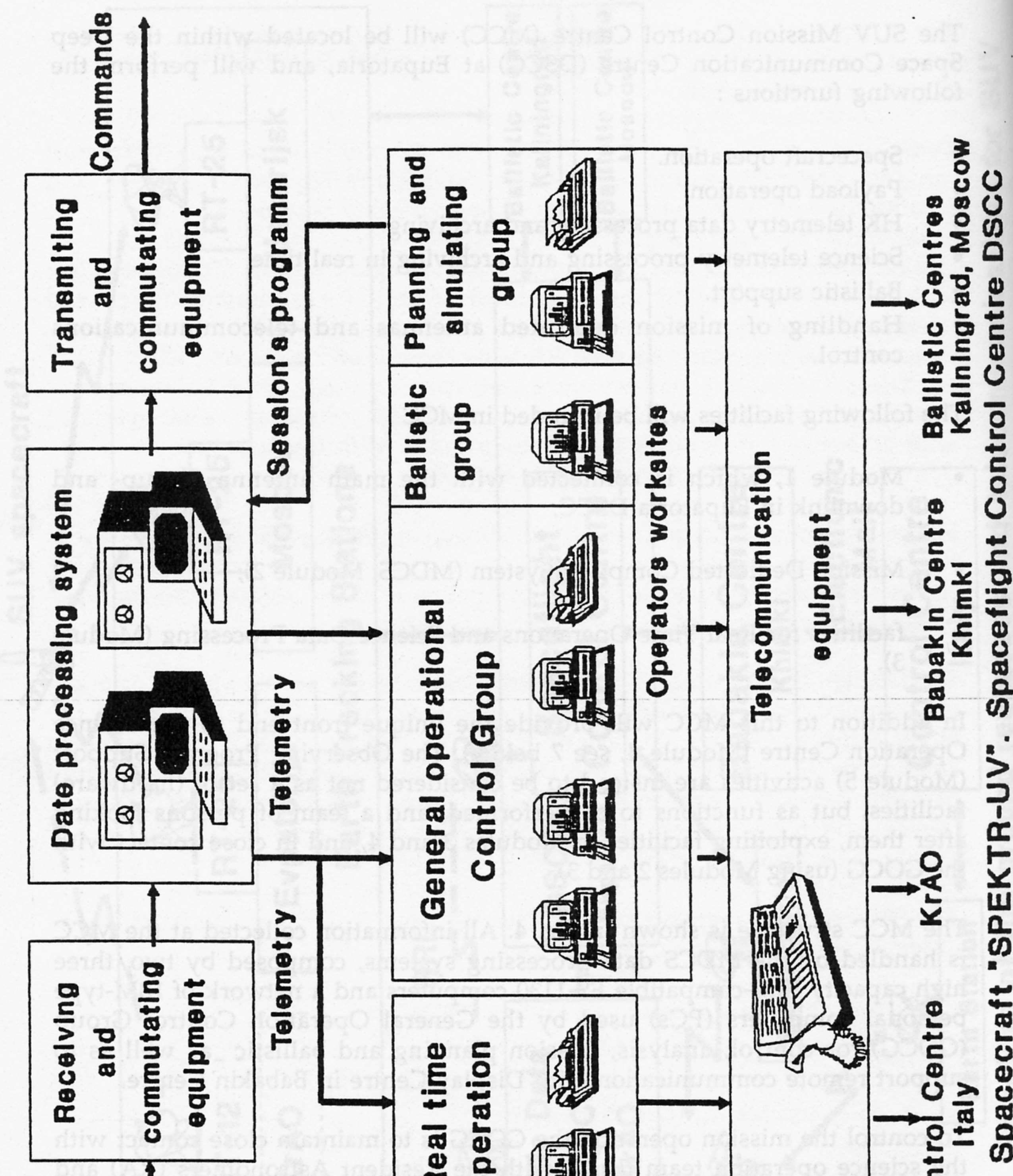
- facilities for Real Time Operations and Science Data Processing (Module 3).

In addition to this MCC will provide the unique front end to the Science Operation Centre (Module 4, see 7 below). The Observing Program Support (Module 5) activities are instead to be considered not as a set of (hardware) facilities, but as functions to be performed, and a team of persons looking after them, exploiting facilities in Modules 3 and 4, and in close contact with the GOCG (using Modules 2 and 3).

The MCC structure is shown in Fig. FIG4. All information collected at the MCC is handled by the MDCS data processing systems, composed by two/three high capacity IBM-compatible ES-1130 computers and a network of IBM-type personal computers (PCs) used by the General Operation Control Group (GOCG) for control, analysis, mission planning and ballistic as well as to support remote communication with Display Centre in Babakin Centre.

To control the mission operation the GOCG is to maintain close contact with the science operation team *that is* with the Resident Astronomers (RA) and *through them with* the Guest Observers (GO). These groups shall be supplied with all relevant information on their displays in order to trace the operation of on-board subsystems and the science instrument performance, so that it is possible to make timely decisions about science and spacecraft operation.

Figure 4



Telemetry
Receiving and commutating equipment
Date processing system
Transmiting and commutating equipment
Commands
Telemetry
Telemetry
Session's programm
Real time operation group
General operational Control Group
Ballistic group
Planning and simulating group
Operators worksites
Telecommunication equipment
Control Centre Italy
KrAO
Babakin Centre Khimki
Ballistic Centres Kaliningrad, Moscow
Spacecraft "SPEKTR-UV". Spaceflight Control Centre DSCC

function block diagram for the management of the SUV mission control centre

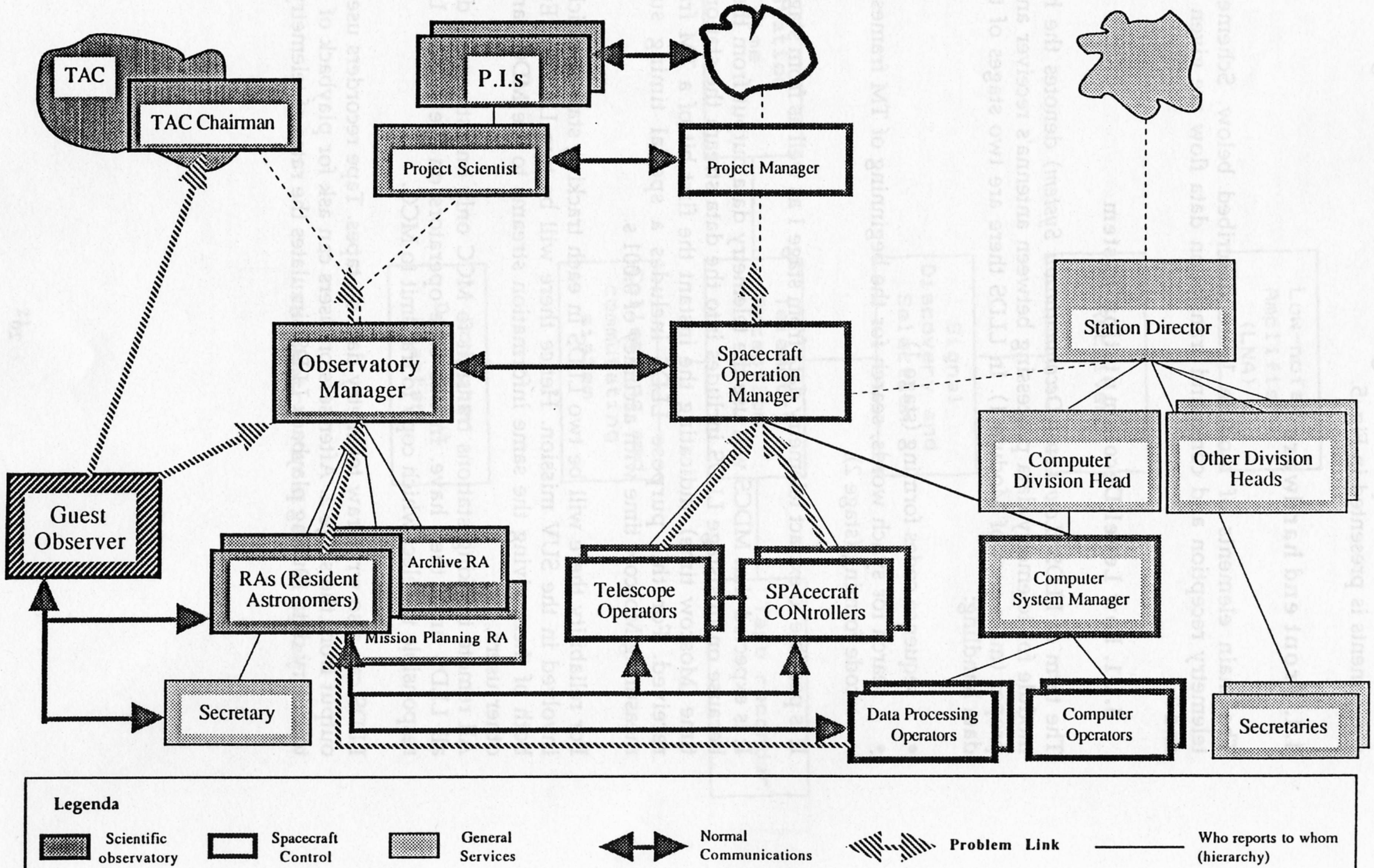


Figure 5

A scheme for the management of the MCC showing the inter-relationships between the General Operation (flight control), scientific and general support components is presented in Fig. FIG5.

4.1. Front end hardware

The main elements of module 1 are described below. Schemes of the telemetry reception and command translation data flow are given in Fig. FIG6 and FIG7

4.1.1. Low Level Decommutation System

The term of LLDS (*Low Level Decommutation System*) denotes the hardware module for telemetry data processing between antenna's receiver and MDCS proper (main part of Module 1). In LLDS there are two stages of telemetry data handling:

- sequence codes forming (stage 1)
- search for synch words, search for the beginning of TM frames, parallel code forming (stage 2).

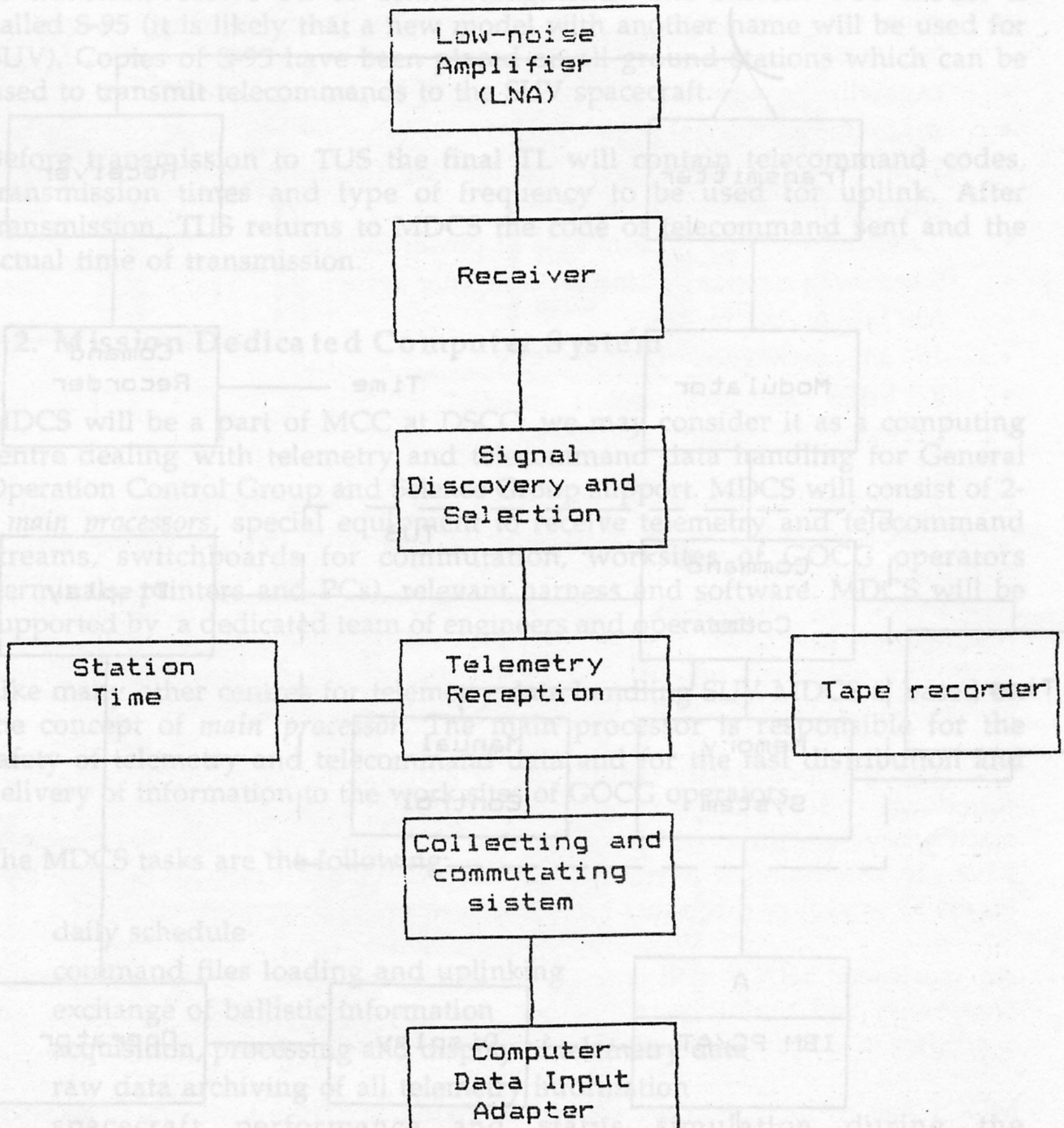
It is possible to extract telemetry data from stage 1 as well as from stage 2.

It is expected that MDCS will use the telemetry data output from the stage 2, because on this stage LLDS includes into the data stream the station ground time (Moscow time), indicating the instant the first bit of a TM frame was received. For this purpose LLDS includes a special timing subsystem measuring Moscow time with accuracy of 0.001 s.

For reliability there will be two LLDS in each tracking station which will be involved in the SUV mission. Hence there will be two LLDS in Eupatoria, both of them giving the same information streams to the MDCS and to the other users.
All remote tracking stations transmit to MCC only one stream of data from all LLDS units they have. In this case operators on the remote LLDS are responsible to select which copy to transmit to MCC.

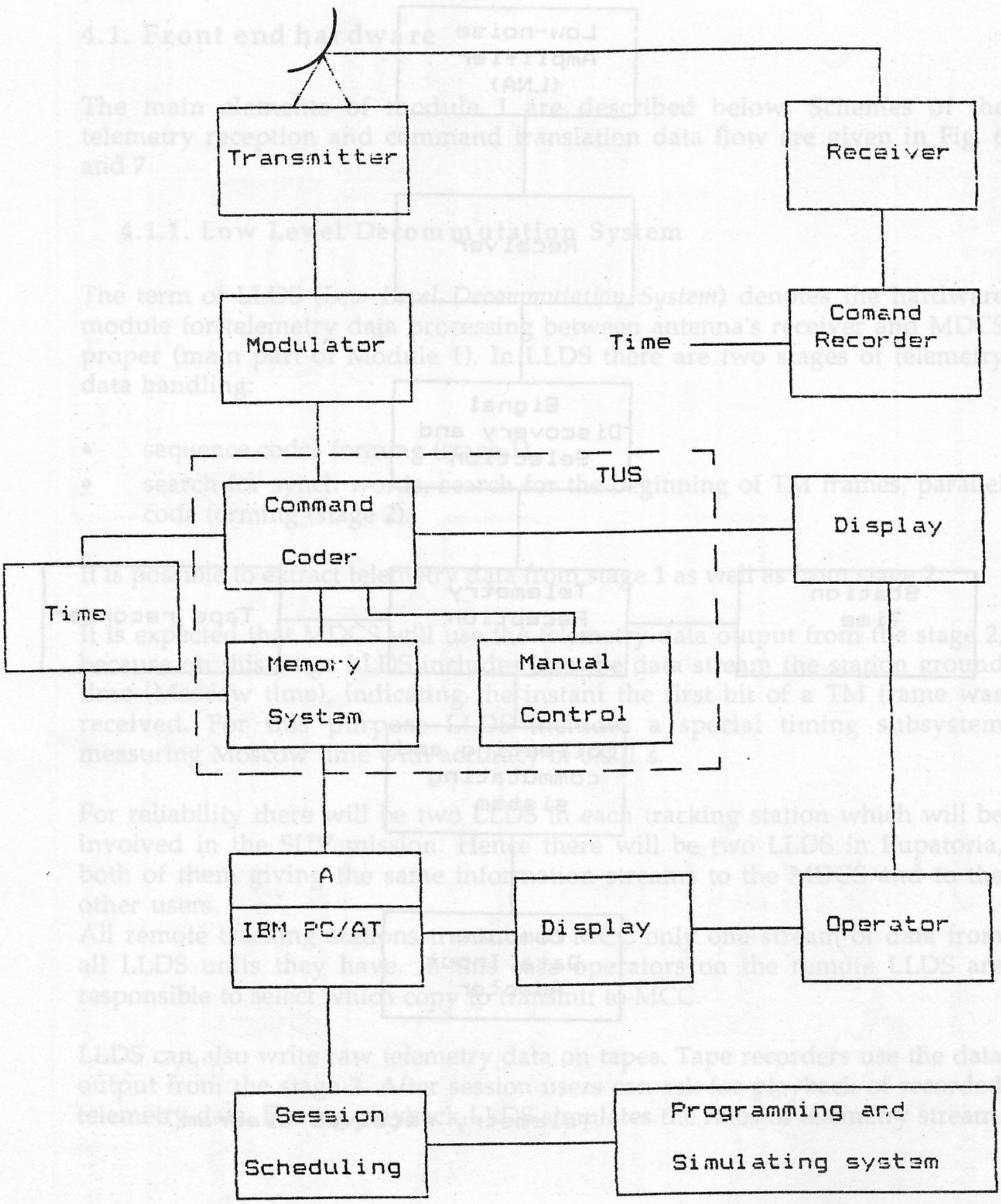
LLDS can also write raw telemetry data on tapes. Tape recorders use the data output from the stage 2. After session users can ask for playback of recorded telemetry data. During playback LLDS simulates the rates of telemetry stream.

Figure 6



Telemetry receives diagram

Figure 7



Comand Translating diagram.

4.1.2. Telecommand Uplink System (TUS)

The Telecommand Uplink System has a single contact point towards MDCS to transmit/receive TL or acknowledgments. The current TUS model is called S-95 (it is likely that a new model with another name will be used for SUV). Copies of S-95 have been placed on all ground stations which can be used to transmit telecommands to the SUV spacecraft.

Before transmission to TUS the final TL will contain telecommand codes, transmission times and type of frequency to be used for uplink. After transmission, TUS returns to MDCS the code of telecommand sent and the actual time of transmission.

4.2. Mission Dedicated Computer System

MDCS will be a part of MCC at DSCC: we may consider it as a computing centre dealing with telemetry and telecommand data handling for General Operation Control Group and Science Group support. MDCS will consist of 2-3 *main processors*, special equipment to receive telemetry and telecommand streams, switchboards for commutation, worksites of GOCG operators (terminals, printers and PCs), relevant harness and software. MDCS will be supported by a dedicated team of engineers and operators.

Like many other centres for telemetry data handling SUV MDCS is based on the concept of *main processor*. The main processor is responsible for the safety of telemetry and telecommand data and for the fast distribution and delivery of information to the work sites of GOCG operators.

The MDCS tasks are the following:

- daily schedule
- command files loading and uplinking
- exchange of ballistic information
- acquisition, processing and display of telemetry data
- raw data archiving of all telemetry information
- spacecraft performance and status simulation during the communication session
- acquisition and display of information on the performance of the MCC

MDCS will handle spacecraft HK data (which are critical for mission safety) and will also handle payload HK data (which are critical for science instrument safety). For what scientific performance is concerned payload HK and science data are processed at SDPS/RTO level (see 6)

4.2.1. MDCS hardware configuration

The MDCS hardware is characterized by the following parameters:

- each main processor is able to select one of four telemetry streams (sources)
- capability of simultaneous control up to two spacecrafts
- up to 32 operational terminals
- 1 Mbit/s maximum telemetry bit rate (maximum value allowed by current TM commutator)
- 7 minute recovery time in case of power failure
- 5 sec swap time to redundant computer system.
- 800 Mbyte disk memory
- 150 Mbyte magnetic tape memory
- 2.5 MIPS main processor
- up to 4 independent uplink systems.

DSCC will include four main processors (see Fig. FIG8); all of them are available to be involved in SUV data processing. Usually only two processors (that is, two data processing systems) will work on SUV flight control and science data processing support : one for data processing and display, another in hot redundancy. It is usual practice in flight control to have 2 backup processors to provide extremely reliable data processing, when loss of data - or delays in processing - is dangerous for the safety of the entire mission.

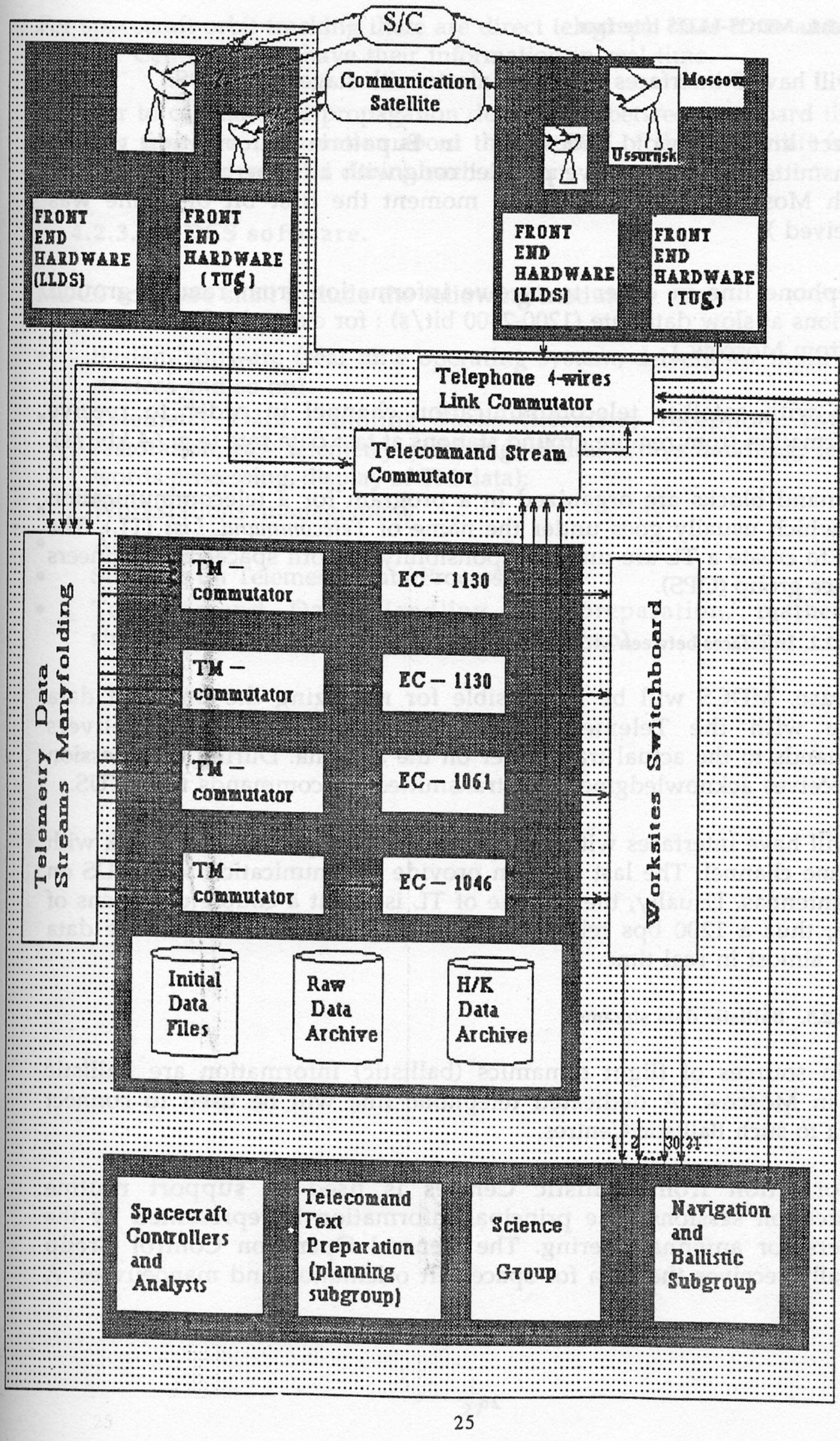
The principal peculiarity of the MDCS hardware configuration is absolute functional independence of all of the main processors. Therefore, with 3 main processors there will be 3 identical data handling systems. All of them have separate lines for telemetry and telecommand streams; all of them have access to worksites through a commutator.

As worksites MDCS will use dumb (non-intelligent) terminals, personal computers and remote printers. The distance between main processor and worksites must be less than 1.2 km.

MDCS has to include a set of switchboards and commutators to provide, independently on every workstation, the selection of any source or any receiver of information. Implementation of this technology has so far ensured the solution of two very critical problems for spacecraft control, because MDCS must :

provide permanent availability of actual information in real time on all worksites
absolutely exclude the loss of telemetry data because of MDCS

Figure 8


S/C
Communication Satellite
Moscow
Ussurisk
FRONT END HARDWARE (LLDS)
FRONT END HARDWARE (TU$)
FRONT END HARDWARE (LLDS)
FRONT END HARDWARE (TU$)
Telephone 4-wires Link Commutator
Telecommand Stream Commutator
Ballistic and Navigation Centres (Moscow Kaliningrad)
Telemetry Data Streams Manyfolding
TM – commutator
EC – 1130
TM – commutator
EC – 1130
TM – commutator
EC – 1061
TM – commutator
EC – 1046
Worksites Switchboard
Initial Data Files
Raw Data Archive
H/K Data Archive
1 2
30 31
Spacecraft Controllers and Analysts
Telecommand Text Preparation (planning subgroup)
Science Group
Navigation and Ballistic Subgroup

4.2.2. MDCS interfaces

4.2.2.1. MDCS-LLDS interface

MDCS will have 3 interfaces to communicate with stage 2 in LLDS:

- direct lines to two LLDS units in Eupatoria (information can be transmitted by consecutive parallel code with a frame begin mark and with Moscow time code of the moment the first bit of frame was received)

- telephone line in order to receive information from remote ground stations at slow data rate (1200-2400 bit/s) : for example, from Ussurijsk or from Moscow)

- link with satellite telecommunication channel in order to receive information from remote ground stations at fast data rate (e.g. 64 kbit/s)

Telecommand blocks are organized in a program for a telecommunication session, which usually goes under the name of *Telecommand List* (TL). The activities to create a TL are under responsibility of both spacecraft engineers and science group (OPS).

4.2.2.2. Interfaces between MDCS and TUS.

In any case, MDCS will be responsible for managing the link and data exchange with the Telemetry Uplink System (TUS). TUS delivers telecommands to the actual transmitter on the antenna. During each session MDCS receives acknowledgments of transmitted telecommands from TUS.

MDCS will have interfaces with two TUS units in Eupatoria and a link with a telephone channel. The last one can provide communication with TUS on backup antennas. Usually, the volume of TL is about a couple of dozens of kilobytes; thus a 1200 bps telephone channel is sufficient to provide data exchange almost in real time.

4.2.2.3. Ballistic data streams.

The main sources of flight dynamics (ballistic) information are Ballistic Centres in Moscow. A dedicated telephone line will be used to connect Eupatoria to such Ballistic Centres.

The information from Ballistic Centres is used to support routine communication sessions. The principal information is represented by the parameters for antenna steering. The General Operation Control Group additionally receives the data for spacecraft orientation and manoeuvres. A dedicated personal computer within MDCS will be used to exchange data with Ballistic Centres.

For spacecraft orbit tracking there are direct telegraph lines from antennas to Ballistic

Centres. They have their information in real time.

In order to calculate the propagation delay (shift between on-board time and Moscow time) the information about the distance of the spacecraft from the ground station is received during each session.

4.2.3. MDCS software.

MDCS software shall include the following modules:

- System software (real time operating system, drivers for input/output devices and so on)
- Telemetry Data Handling Tasks (telemetry reception, TM frame restoration, raw telemetry archiving, digital arrays handling, telemetry words processing, display of TM data);
- Workstations management
- Auxiliary Tasks
- Statistics on Telemetry Data Processing
- Telecommand Data Handling (TL preparation, mathematical simulation, telecommand execution check-up).

5. Science Data Processing System

The term *Science Data Processing System* (SDPS) indicates here the set of facilities (Modules 3 and 4) necessary to support science operations and in general the activities necessary for the realization of the observing program (Module 5), that is the following :

1 Observing Program Support (see 7.1):

a Preliminary definition of the structure and characteristics of the support to the astronomical community.

b Support to the preparation of observing proposals and provision of the infrastructure for reviewing the applications for observing time.

c Schedule the observing program (in close cooperation with GOCG), and in particular coordinate the observing schedule with those of other space- and ground-based astronomical facilities.

2 Science Real Time Operation:

a Initiate real-time requests to the MCC for spacecraft pointing and instrument operations (it is assumed that the Observer is either present or in contact via a network; Service Observing is also considered).

b The Observer selects targets and observation parameters and identify the targets. The Resident Astronomer staff provides the interface between Observer and instrument control software and GOCG.

3 Scientific quick-look: to enable the Observer to judge the quality of the data and permit real-time optimization of the observing program.

4 Scientific instrument health monitoring and preliminary trend analysis (using relevant HK data)

5 Data reduction: Provide a standard data reduction processing which removes instrument dependent effects.

6 Data logging, archiving and retrieving.

As a result of the assessment study it has been concluded that the above activities can be divided in two groups : activities which have to be performed in real time (or near real time), like above items 2, 3, 4 (and 6 for what concerns raw data), and therefore in closest contact with MCC, and off-line activities which are to be performed either in advance (item 1 above), or some time after the observations (items 5 and 6 above).

Therefore SDPS has been split, for what its facilities are concerned, in two modules. The former is termed *Real Time Operation* (SDPS/RTO, Module 3, described in 6 below), and the latter is called *Science Operation Centre* (SDPS/SOC,Module 4, described in 7 below). *Observing Program Support* activities are logically identified as a separate module (Module 5), but are consistently described under SOC in 7.1).

6. Science Data Processing System : Real Time Operations (SDPS/RTO)

6.1. Rationale

The main rationale for the existence of the Real Time Operation (RTO) module (Module 3) of the Scientific Data Processing System (SDPS) is to provide the closure of the interaction loop of the real-time observation mode (see 1.1.2 for definitions, and the SDMU design report for its implications at space segment / SDMU level).

As such it will include the facilities to allow the Resident Astronomer to evaluate the quality of the scientific data and the health of the Science Instruments, to determine the next actions, modifying to some extent the current observation plan, to prepare the telecommands to be uploaded to the spacecraft and to interact with the General Operation Control Group (GOCG) and with the subsystem of the Ground Station dedicated to the final telecommand list preparation, validation and transmission.

A way to save all the scientific data and the related information will also be provided, to maintain a stable raw data archive, that will constitute the input to the next processing phases of the Science Operation Centre (SOC, see 7).

The partial duplication of the Science Operation Centre located in Italy is described in section 7.5. A link is foreseen which will allow some kind of remote interaction, and is described in section 7.5.1. It is naturally assumed that the latter link will be managed by the RTO module, in order to provide to the remote observer an environment similar, even if with obviously degraded performances, to the one available to the local scientific personnel.

According to the tasks listed above, it seems quite obvious that the natural location for the RTO system will be the Eupatoria Ground Station, co-located and directly interfaced with the spacecraft control systems.

6.2. Interfaces & data handling

The RTO module will be interfaced with the Ground Station modules from which it will receive the scientific data and the HK parameters, or to which the telecommand list will be provided, while on the other side the RTO module will transmit the original scientific data to the Science Operation Centre, for the standard processing.

6.2.1. Interface with the MDCS

The tasks and the characteristics of the Mission Dedicated Computer System are described in section 4.2. The full processing and integrity checking of the telemetry streams will be guaranteed by such system.

Some worksites will be dedicated to the control of the scientific portion of the telemetry and a temporary storage for the whole telemetry data will in any case be provided by MDCS.

The RTO module will therefore receive through this interface from the MDCS the (preprocessed) HK and scientific telemetry streams.

The hardware characteristics and the protocol of this interface will be defined later. An important point to be agreed during phase A is in any case the time delay between the reception of the data from the spacecraft and the time at which they will be available to the RTO system. To enhance the realtime characteristics of the mission, this time delay should be kept to a minimum.

The same interface between RTO and MDCS will moreover handle the output to the MDCS of the part of the telecommand lists dedicated to the Science Instruments. As described in section 1.3 telecommands will be uplinked by TUS, which is directly interfaced only with the MDCS. MDCS will be in charge of the final validation phase (see section 6.4).

6.2.2. Interface with the SOC

The scientific data and the relevant HK parameters shall be stored by the RTO module in a stable form. This data will be transmitted to the Science Operation Centre, with a delay to be defined, for the subsequent processing steps.

The SOC and its location is discussed in section 7.3. It should be noted here that if the SOC will be co-located with the RTO system, a unique computer network could be - and will be - implemented while if the SOC will reside elsewhere (at CrAO for instance, see the discussion on this item in the introduction to section 7) a more complex interface will be needed, both from hardware and software point of view, since there shall be the need to connect to remote computer networks.

6.2.3. Interface to the SOC located in Italy

A last interface will exist with the Italy-located SOC. If this centre will be implemented, this interface will therefore manage a set of remote communication facilities , described in section 7.5.1.

6.3. The Quick Look Analysis

The Quick Look Analysis of the incoming scientific data is the main facility provided to the Resident Astronomer (or to the Guest Observer assisted by a RA), to evaluate the quality of the data. Quality is meant here from the astronomical point of view (verification that the performance of the observation is consistent with its scientific objectives) , since the integrity of the data themselves is checked by the Mission Dedicated Computer System, as a part of the integrity check of the whole telemetry stream (see 2.1).

This module should enable the scientific operator to quickly evaluate the health of the Science Instruments and the quality of the astronomical data, and to react, e.g. deciding whether continuing the exposures, optimizing the instrument parameters and/or the observation plan, or stopping it taking the appropriate actions.

This module constitutes therefore a fundamental element in the interaction loop of the real time observation mode.

The analysis performed by this module is twofold. The availability of the HK parameters of the whole scientific payload and of a relevant subset of the spacecraft HK will enable the evaluation of the health of the instrumentation, making available to the scientific operator the real time status of the payload and/or some form of trend analysis and HK statistics. On the other hand a set of standard tools for high speed image processing and display will be available for the scientific data.

It must be noted that this kind of preprocessing shall not affect in any way the original data, but shall work on a temporary copy only for the real time evaluation purposes.

6.4. Telecommand preparation

The analysis of the quality of both astronomical data and HK parameters will determine the next action. The observations programs previously uploaded could be modified. The extent of this modification, ranging from the modification of the exposure parameters to the change of the target, will be defined during the phase A.

In any case a software module for the creation of telecommand lists, under the supervision of the General Operation Control Group, should be present in the RTO system, in order to avoid manual procedures. The same module could be the final step even for the standard procedure of the Observation Planning, receiving the input from the relevant module of the Observation Support System working in the environment of the SOC, as described in section 7. The output of the telecommand preparation module should be later validated by the GOCG in the MDCS.

The concept of this software has to be agreed upon soon in the next phase of the study.

6.5. Real time operations

During the on-line sessions, the above described sub-modules constitutes the interaction loop, closed on the spacecraft.

The scientific operator is in this way enabled to receive the HK and scientific telemetry streams from the MDCS, to evaluate the astronomical quality of the data and the payload health, and to react according to the input data optimizing the observation parameters or starting some other actions, providing the telecommand list to be uploaded to the GOCG or to MDCS/TUS system for validation and transmission.

A schematic of the full interaction loop, considering both space and ground segment, is shown in figure FIG9. The 'real-time' role of the MDCS and of the TUS system is defined in 4.2 and 1.3.

The same modules will in any case be used even for the preparation of standard operations (telecommand list preparation) or at the end of a long observation during automated sessions, when a great amount of data will be downloaded, and a real time astronomical quick look will not be possible. The HK telemetry stream of the payload will be analyzed and displayed to verify the status of the payload after the automated mode and at the beginning of a new real-time session.

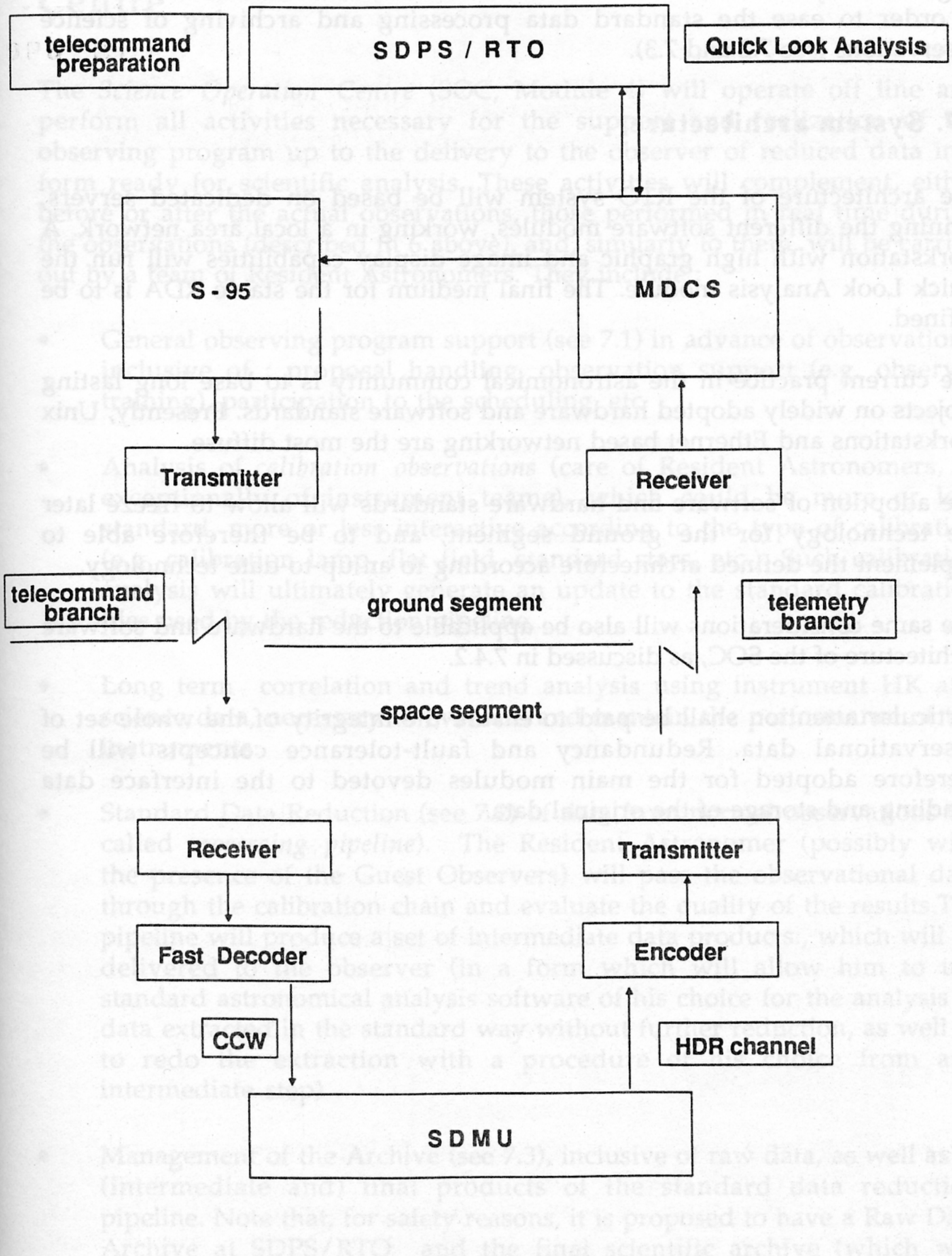
6.6. Raw data Archive

The original data will be stored to form a Raw Data Archive (RDA). As stated elsewhere, it will include also all the payload HK parameters, a selected set of the spacecraft HK parameters, and whatever data about the orbit and the spacecraft that could be of interest to the scientific observations.

These data will be at the end transmitted to the SOC, for the standard data reduction stage (and duplicated in the Science Data Archive), but the original data will be frozen in the RDA will be maintained in a stable form, to preserve the integrity of the original data.

If the RTO system and the SOC will be co-located the archives, in raw and final form could , in a way to be defined, be physically managed together. If the two systems will be remote, the existence of a stable RDA will be even more necessary.

Figure 9



Interaction loop schematics

The RDA is not supposed to be distributed to the astronomical community, since the original data will be anyway part of the final scientific archive. The format and organization of this archive can be therefore defined at a later stage. It is anyhow advisable to select FITS as the format for science raw data, in order to ease the standard data processing and archiving of science observations (see 7.2 and 7.3).

6.7. System architecture

The architecture of the RTO system will be based on dedicated servers, running the different software modules, working in a local area network. A workstation with high graphic and image display capabilities will run the Quick Look Analysis module. The final medium for the stable RDA is to be defined.

The current practice in the astronomical community is to base long lasting projects on widely adopted hardware and software standards. Presently, Unix workstations and Ethernet based networking are the most diffuse.

The adoption of software and hardware standards will allow to freeze later the technology for the ground segment, and to be therefore able to implement the defined architecture according to an up-to-date technology.

The same considerations will also be applicable to the hardware and software architecture of the SOC, as discussed in SYSREF7.4.2.

Particular attention shall be paid to ensure the integrity of the whole set of observational data. Redundancy and fault-tolerance concepts will be therefore adopted for the main modules devoted to the interface data handling and storage of the original data.

7. Science Data Processing: Science Operation Centre

The *Science Operation Centre* (SOC, Module 4) will operate off line and perform all activities necessary for the support and realization of the observing program up to the delivery to the observer of reduced data in a form ready for scientific analysis. These activities will complement, either before or after the actual observations, those performed in real time during the observations (described in 6 above), and, similarly to them, will be carried out by a team of Resident Astronomers. They include :

- General observing program support (see 7.1) in advance of observations, inclusive of : proposal handling, observation support (e.g. observer training), participation to the scheduling, etc.

- Analysis of *calibration observations* (care of Resident Astronomers, or exceptionally of instrument teams), which could be more or less standard, more or less interactive according to the type of calibration (e.g. calibration lamp, flat field, standard stars, etc.). Such calibration analysis will ultimately generate an update to the standard calibration files used by the reduction pipeline.

- Long term correlation and trend analysis using instrument HK and science data, necessary to evaluate and mantain the performance of the instruments.

- Standard Data Reduction (see 7.2) of data from normal observations (so called *processing pipeline*). The Resident Astronomer (possibly with the presence of the Guest Observers) will pass the observational data through the calibration chain and evaluate the quality of the results.The pipeline will produce a set of intermediate data products., which will be delivered to the observer (in a form which will allow him to use standard astronomical analysis software of his choice for the analysis of data extracted in the standard way without further reduction, as well as to redo the extraction with a procedure of his choice from any intermediate step).

- Management of the Archive (see 7.3), inclusive of raw data, as well as of (intermediate and) final products of the standard data reduction pipeline. Note that, for safety reasons, it is proposed to have a Raw Data Archive at SDPS/RTO and the final scientific archive (which will remain also after the end of the mission) at SDPS/SOC.

The site where the above activities will be performed, inclusive of necessary hardware and software, will be the main Science Operation Centre and will be located in the territory of the CIS. A partial duplication of a limited subset of functions in a Centre in Italy is being considered (see 7.5).

One of the most definite results of the assessment study is that a number of science data processing functions (those assigned to the RTO module) need to be performed at the same site of the MCC, in order to mantain the highest degree of interactivity. On the other hand it is still in progress the evaluation whether SDPS/SOC is to be colocated with SDPS/RTO at Eupatoria, or located elsewhere (e.g. at the Crimean Astrophysical Observatory (CrAO)).

In the latter case, as baseline, the science information obtained from the spacecraft could be transmitted from Eupatoria to the SDPS/SOC for standard data analysis via conventional communication link (radio relay line)

Installation at CrAO of a 12-m dedicated receiving antenna might also be envisaged.

In such latter case a front end to the spacecraft (duplicating most of Module 1 and MDCS functions) will be needed between the dedicated receiving antenna and SOC; even in case of a ground data link from Eupatoria to SDPS/SOC some form of front end processing is anyhow necessary.

Other practical complications might arise from the separation between two sites (Resident Astronomer team and Guest Observers shall travel between RTO and SOC, and response time for feedback will be impaired).

In any case it is deemed mandatory that, whatever solution is adopted, it shall be operative at launch and mantained throughout the entire mission. An handover between two different sites for the control centre (given the fact that at least RTO and MCC shall be colocated) after the beginning of the mission will require an unacceptable disruption of the activities.

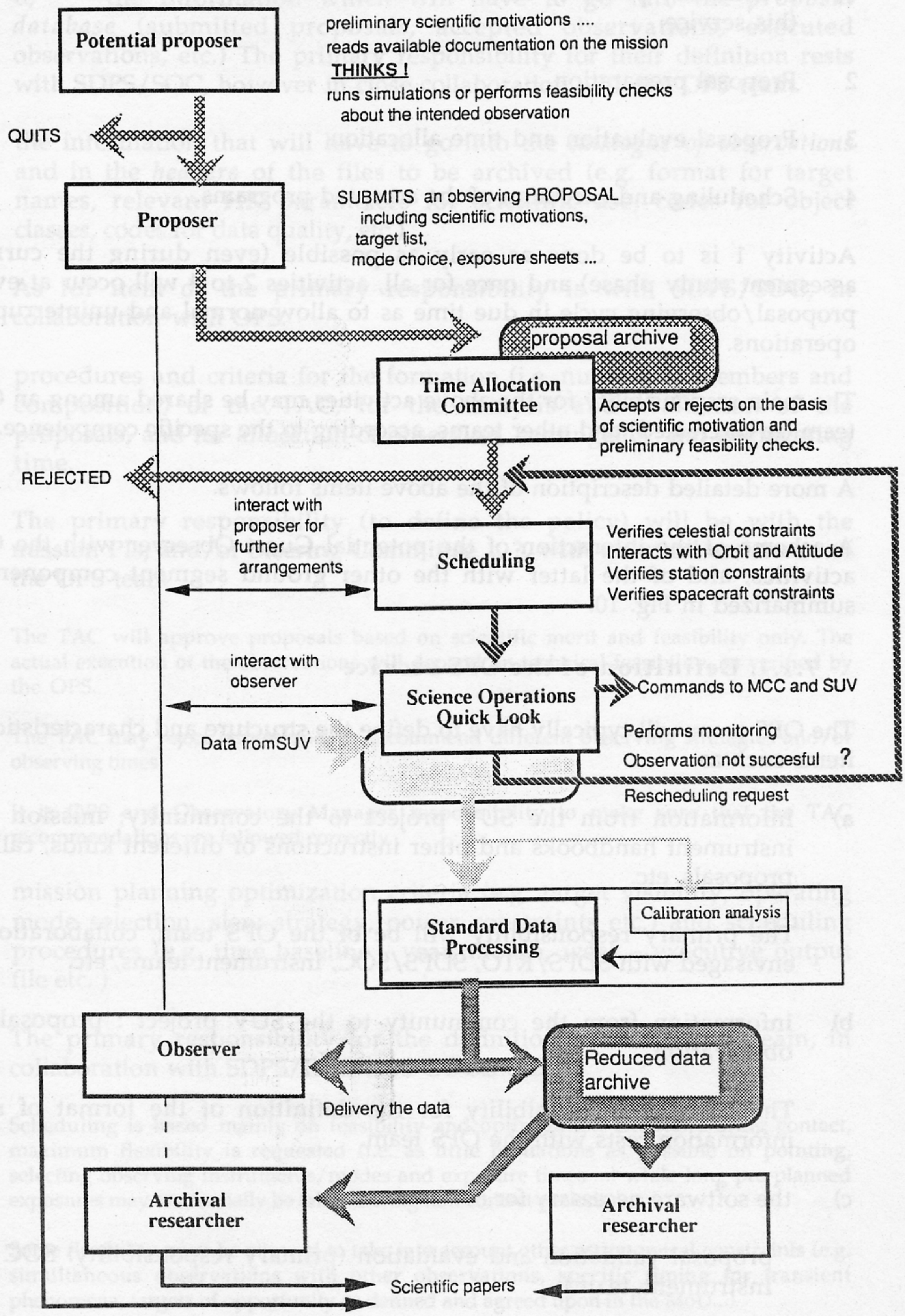
It is anyhow assumed that the link between the main CIS-located SOC and the secondary centre located in Italy (I-SOC), as well as any link with RTO and ultimately MCC for mission control interaction and planning, will occur only through SDPS/RTO. Technical details about the possibilities for such link are given in section 7.5.1 below.

7.1. Observing Program Support

The Observing Program Support (OPS) appears in Fig. FIG1 as a separate module (Module 5), but, unlike the two components of the Science Data Processing Systems it is not to be intended as an ensemble of hardware facilities, but as a set of functions to be performed by a *science team* of Resident Astronomers (sometimes this is referred to as "*the Observatory*", hence its manager is called Observatory Manager). The OPS team shall act in close contact with the GOCG, and make use, to perform its functions, of the hardware and software facilities provided by SDPS/RTO and SDPS/SOC.

Figure 10

Figure 10


Potential proposer
preliminary scientific motivations ....
reads available documentation on the mission
THINKS !
runs simulations or performs feasibility checks
about the intended observation
QUITS
Proposer
SUBMITS an observing PROPOSAL
including scientific motivations,
target list,
mode choice, exposure sheets ...
proposal archive
Time Allocation
Committee
Accepts or rejects on the basis
of scientific motivation and
preliminary feasibility checks.
REJECTED
interact with
proposer for
further
arrangements
Scheduling
Verifies celestial constraints
Interacts with Orbit and Attitude
Verifies station constraints
Verifies spacecraft constraints
interact with
observer
Science Operations
Quick Look
Commands to MCC and SUV
Data fromSUV
Performs monitoring
Observation not succesful ?
Rescheduling request
Standard Data
Processing
Calibration analysis
Observer
Reduced data
archive
Delivery the data
Archival
researcher
Archival
researcher
Scientific papers

The aim of the OPS is to provide support to the astronomical community in the use of Spectrum UV. Such support can be roughly divided in four phases:

1 Preliminary phase of definition of the structure and characteristics of this service.

2 Proposal preparation.

3 Proposal evaluation and time allocation.

4 Scheduling and execution of the accepted programs.

Activity 1 is to be done as early as possible (even during the current assesment study phase) and once for all, activities 2 to 4 will occur at every proposal/observing cycle in due time as to allow normal and uninterrupted operations.

The main responsibility for the above activities may be shared among an OPS team (to be created) and other teams, according to the specific competence.

A more detailed description of the above items follows.

A scheme of the interaction of the potential Guest Observer with the OPS activities, and of the latter with the other ground segment component is summarized in Fig. FIG10.

7.1.1. Definition of the OPS service

The OPS team will typically have to define the structure and characteristics of items such as:

a) information from the SUV project to the community: mission and instrument handbooks and other instructions of different kinds, call for proposals, etc.

   The primary responsibility will be of the OPS team, collaboration is envisaged with SDPS/RTO, SDPS/SOC, Instrument teams, etc.

b) information from the community to the SUV project : proposals of observation

   The primary responsibility for the definition of the format of such information rests with the OPS team.

c) the software necessary for :

   proposal validation and evaluation (primary responsibility: SOC and Instrument team)
   time allocation (primary responsibility: OPS team)
   scheduling (primary responsibility: RTO team or GOCG (TBD))

d) the information which will have to go into the *proposal database* (submitted proposals, accepted observations, executed observations, etc.) The primary responsibility for their definition rests with SDPS/SOC, however in close collaboration with the OPS team.

e) the information that will have to go into the *catalogue of observations* and in the *headers* of the files to be archived (e.g. format for target names, relevant HK parameters for scientific use, codes for object classes, codes for data quality, etc.)

As for item d, the primary responsibility is with SDPS/SOC, in collaboration with OPS.

f) procedures and criteria for the formation (i.e. number of members and composition) of the TAC, for the analysis and evaluation of the proposals, and for allocation of observing, contingency and engineering time.

The primary responsibility (to define the policy) will be with the mission PIs, and/or Steering Committee ... ?, with technical assistance of the OPS team

The TAC will approve proposals based on scientific merit and feasibility only. The actual execution of the observations will depend on technical feasibility, as verified by the OPS.

The TAC may reject targets and/or recommend different observing strategies and/or observing times

It is OPS and Observatory Manager responsibility to make sure that the TAC recommendations are followed correctly

g) mission planning optimization criteria (e.g. target visibility, operating mode selection, slew strategy, power constraints etc.) and scheduling procedures (e.g. time baseline - year, month, week - executive output file etc.)

The primary responsibility for the definition is of the OPS team, in collaboration with SDPS/RTO (and GOCG (TBD))

Scheduling is based mainly on feasibility and optimization criteria. During contact, maximum flexibility is requested (i.e. as little limitations as possible on pointing, selecting observing instruments/modes and exposure times ...) while long pre-planned exposures may tendentially be taken during non-contact periods.

Some flexibility must be allowed to take into account other astronomical constraints (e.g. simultaneous observations with other observations, specific timing for transient phenomena, targets of opportunity as defined and agreed upon in the MoU...)

The policy for overruling schedule in exceptional cases, under the Observatory Manager responsibility is TBD

h) Real Time observing procedure: role of the Resident Astronomer (RA), interaction with Guest Observer (GO), interaction with technical RTO staff, duties and responsibilities.

The primary responsibility for such definition belongs to OPS/RTO and MDCS, also in collaboration with SDPS/SOC

i) scientific, technical (and logistic, if necessary) support to observers during the pre-proposal phase, the observations, and the data reduction phase (if necessary).

This is clearly primary responsibility of the OPS team

7.1.2. Proposal preparation

This activity is directed towards providing the astronomical community all the necessary information during the phase of preparation of the proposals.

The main activities include:

a) preparation (or supervision) and distribution of the Manuals containing the description of the telescope, information on the spacecraft and the mission (only what is relevant for astronomical use, e.g. orbit and manoeuvering characteristics, visibility and avoidance zones, influence of radiation belts, *et sim.*), on scientific instruments and observing modes, on policies and procedures, etc. , as well as of Call for Proposals, Forms, Instructions, etc.

This activity may be done jointly by the parties involved in the project, or separately but in a coordinated way, or on national basis (TBD).

b) formation of a team of experts to answer questions on technical and scientific problems, as well as questions on policy matters. For reasons of simplicity (language problems, communication facilities) it is suggested to arrange this service on national basis (TBD).

c) running the previously prepared software for simulations and exposure time calculation (which should be made accessible to the astronomical community), access to accurate position measuring device (if necessary) or finding chart preparation facility (TBD), use of software for the proposal evaluation, etc....

d) collection and handling of the proposals, and extraction of the relevant information (for evaluation and time allocation, and for ingestion in the proposal database).

Each proposal will typically contain:

- target list (identification, coordinates and object class)
- observing modes and exposure times
- scientific justification and scientific feasibility assessment

This type of activity will require the availability and use of:

- fast and efficient word-processor, copying and mailing facilities (including dedicated personnel)
- good phone and/or e-mail service
- access to adequate computers and dedicated software staff

7.1.3. Proposal evaluation and time allocation

This phase will strictly exclude the presence of the astronomical community.
The activities include:

a) formation of the scientific panels that will evaluate the proposals and allocate the observing time (TAC, *Time Allocation Committee*)

b) Calling the panel meeting, and providing assistance (scientific, technical, logistics, etc) during the meeting. Two types of OPS personnel should typically attend the TAC meeting, i.e. Observatory Manager and one person in charge of scheduling.

c) Dealing with the approved observations: archive, notification to the observing proposal PIs (both accepted and rejected proposals need to be notified).

d) Preparation of the list of all approved targets (yearly basis) and reference stars, and whatever scientific information is needed for scheduling. Some oversubscription factor should be envisaged in case of feasibility problems with some targets. This phase may include some interaction with the General Observer (GO) for further information.
Software validation of the target list, and its inter-relations with the science archive database are described in 7.3.1.

e) Assistance to SDPS/RTO (or GOCG (TBD)) during scheduling. This includes:

- the preparation of the Data Base (i.e. astronomical constants, orbit updated parameters, and all relevant constraints, in addition to the list of approved targets and corresponding reference stars)

  It is worth listing here the main constraints :

  Sun and Earth constraints with respect to spacecraft axes
  Pointing constraints of the High Gain Antenna
  Sun, Earth and Moon interference with star trackers
  Presence of enough guide stars in FOV of star trackers or FGS
  Ground station contact constraints (elevation anlge, angular velocity, dead cone thru zenith)
  Earth and Moon eclipse
  Other spacecraft constraints which may be known after launch (due to onboard failures etc.)
  Sun and Earth constraints relevant for payload instruments
  Altitude constraints (radiation belts)

the impact of the choice of orbit on the visibility interval from the ground station, and therefore on the amount of real time operations is discussed in a separate document.

- the Initial Data (i.e. list of selected targets and scientific payload configurations, mission optimization criteria and operation mode selection)
- running the scheduling software for a general yearly plan, and for the detailed plans on a monthly and weekly basis, and produce the executive output file for RTO.

This type of activity will require good logistic organization during the meetings, and access to good computer facilities.

7.1.4. Execution of the observations

Note that Real-Time operations do not fall under OPS responsibility and are therefore discussed above in Section 6.

The following type of assistance from OPS will be required during Real-Time observations:

a) observations shall be attended by Resident Astronomers (RAs), acting as interface between the General Observers (GOs) and the Telescope Operators (TOs). The GOs may or may not be present during observations.

   - The RA must be an astronomer with a detailed knowledge of the SUV technical characteristics.

   - The RA will have full scientific responsibility of Real Time observation sessions, including target identification in absence of the GO, if necessary.

   - The RA will define the best parameters to optimize the data reduction procedure (if needed).

   - The RA will evaluate the data quality for the archive.

   - A *minimum* of 6 RAs are needed to support 24 hrs RT operations.

b) Quick-look facilities for the incoming scientific data.

c) software for exposure time calculation and simple simulations (see 7.1.2 item c above).

d) possibility to make finding charts or measure positions if necessary (see 7.1.2 item c above).

e) an astronomical library adequate to the needs (e.g Catalogs, Atlases, etc.).

f) logistics, i.e. office space, meals, overnight accommodation for the RA, and the same for the visiting GO.

h) fast links with external world (e.g. telephone, fax, e-mail network *et sim.*) for communication and data exchange.

It shall also be noted that one post-observation activity, namely the preparation of a log of observations (which is a fundamental item for the final archive, see 7.3 below) shall begin before observation scheduling (see 7.1.3, item e above) and be updated during observation execution in a software assisted way.

7.2. Standard Data Processing

Once the observations are actually executed, the related data are handled in SDPS/RTO (Module 3) as described in section 6, until they are stored in the raw data archive. The means of transfer of the raw data archive from SDPS/RTO (Module 3) to SDPS/SOC (Module 4) are still TBD. However, let us assume here that the raw observation data are actually accessible by the SDPS/SOC software system.

All data from normal observations will undergo standard "pipeline" calibration, consisting of N steps. Pipeline steps are instrument- and detector-dependent and are to be defined in collaboration with the instrument definition teams.

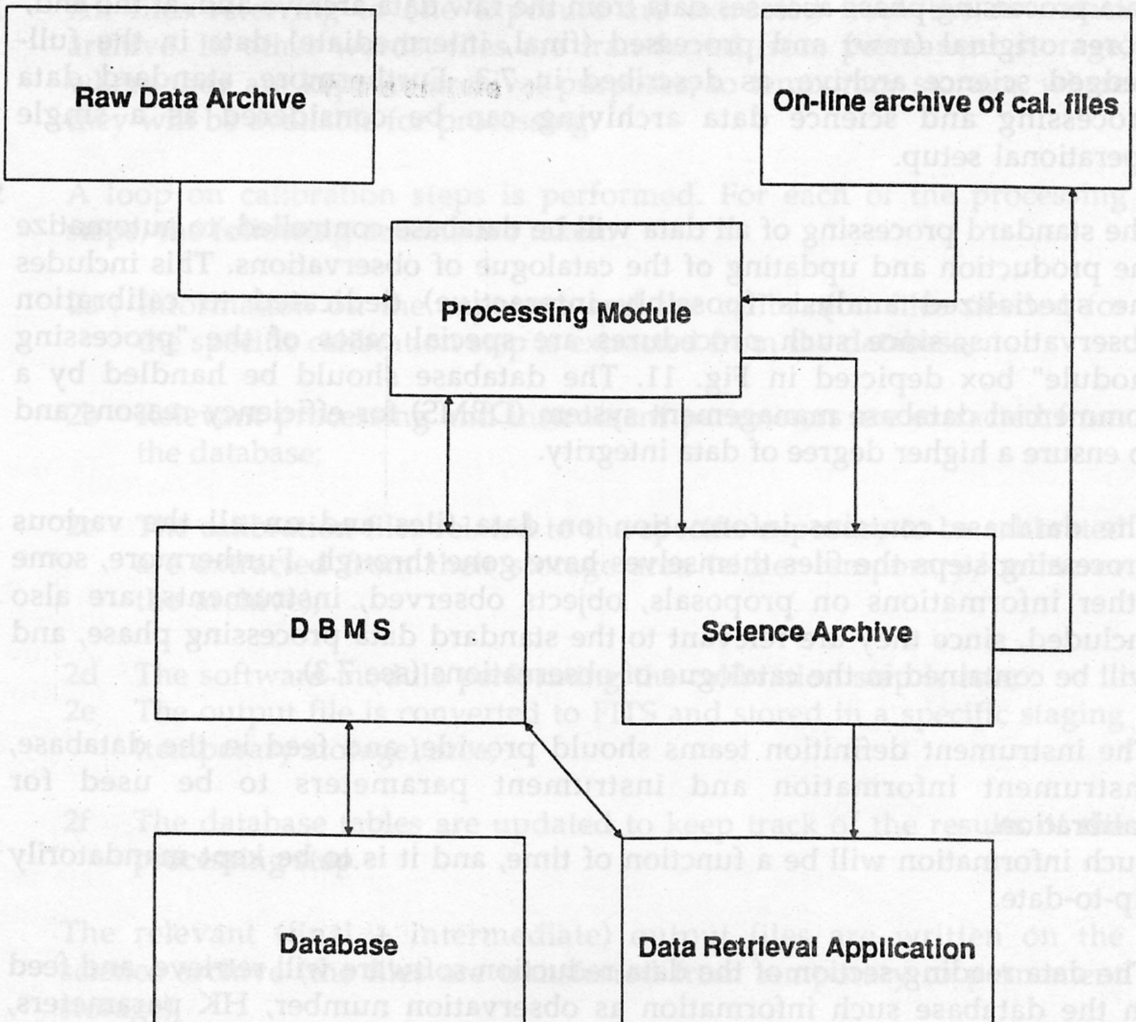
All of the final data products and some of the intermediate ones will be distributed to the observer and archived in the science data archive. Which of the intermediate data products will actually be distributed and archived, respectively, will be defined at a later stage in collaboration with the instrument definition teams.

Calibration is normally project responsibility in the practice of astronomical space projects, and such customary policy is proposed also for SUV.
This means that the responsibility of building the standard calibration procedures and of taking standard calibration observations lies with the project. If a user wishes to use specialized calibration procedures, their development is entirely his/her responsibility, and the relevant calibration observations (if any) are taken during the user's observing time.

Calibration observations will undergo a more specialized analysis than standard observations, in order to produce a set of standard calibration files. Such files are to be kept up-to-date and on on-line storage, for ease of use in the Standard Data Processing pipeline. Specialized processing dedicated to calibration observations will be carried out by the Resident Astronomers with consultancy, when needed, of the instrument definition teams.

A diagram showing the logical operations and the data flow relevant to the Standard Data Processing and Science Archive operations is shown in Fig. FIG11. Such a diagram will be discussed in the following sections.

Figure 11


Raw Data Archive
On-line archive of cal. files
Processing Module
D B M S
Science Archive
Database
Data Retrieval Application

7.2.1. Concepts

Let us assume that the raw data archive is somehow available at the SDPS/SOC (colocation with SDPS/RTO, duplication via communication networks, duplication via hard media transfer, ...). In this case, the standard data processing phase accesses data from the raw data archive and, at the end,
stores original (raw) and processed (final, intermediate) data in the full-fledged science archive, as described in 7.3. Furthermore, standard data processing and science data archiving can be considered as a single operational setup.

The standard processing of all data will be database-controlled, to automatize the production and updating of the catalogue of observations. This includes the specialized analysis (possibly interactive) dedicated to calibration observations, since such procedures are special cases of the "processing module" box depicted in Fig. 11. The database should be handled by a commercial database management system (DBMS) for efficiency reasons and to ensure a higher degree of data integrity.

The database contains information on data files and on all the various processing steps the files themselves have gone through. Furthermore, some other informations on proposals, objects observed, instruments, are also included, since they are relevant to the standard data processing phase, and will be contained in the catalogue of observations (see 7.3).

The instrument definition teams should provide, and feed in the database, instrument information and instrument parameters to be used for calibration.
Such information will be a function of time, and it is to be kept mandatorily up-to-date.

The data reading section of the data reduction software will retrieve, and feed in the database such information as observation number, HK parameters, observer's comments, data quality info, etc., including pointers to file names.

Each processing step will provide an output file, containing in its header self-descriptive information on the processing the observation has already gone through. At the same time, the database contents are updated to reflect the changes in the processing status of the observation. In such a way, at any time during the standard data processing phase, it will be possible by a simple query to the database, to know which of the calibration steps have already been performed. Some of the informations kept in the database are volatile, and will be deleted at the end of the standard data processing phase; some other information on the processing will be kept as a part of the catalogue of observations.

7.2.2. Operational overview

In the following, the operations performed for standard data processing on a SUV exposure (the observation of one target may include more exposures) are reviewed (also with reference to Fig. FIG11 on specific items).

1 All files referring to one exposure are extracted from the raw data archive. In other words, files are transferred from permanent storage, where they are kept for archival purposes, to temporary storage, where they will be available for processing.

2 A loop on calibration steps is performed. For each of the processing steps, the following actions are taken:

   2a Information on the exposure and the calibration files needed for the specific calibration step is extracted from the database;

   2b Relevant processing and instrument parameters are extracted from the database;

   2c The calibration files related to the specific exposure to be calibrated are extracted from their storage area (either temporary/online or the archive);

   2d The software module performing the calibration step is run;
   2e The output file is converted to FITS and stored in a specific staging (temporary storage) area;

   2f The database tables are updated to keep track of the results of the processing step.

3 The relevant (final + intermediate) output files are written on the science archive (the files are transferred from temporary to permanent storage).

4 The relevant (final + intermediate) output files are written on hard media such as magnetic tapes, Digital Audio Tapes (DATs), 8mm cartridges (Exabytes), quarter-inch tapes (QIC), etc. for distribution to the observer (the files are transferred from temporary storage to distribution media). The possibility of storing temporarily the output files on magnetic disk for wide area network access will be a matter of discussion, at least for the Italy-located SOC.

7.3. Science Archive

7.3.1. Concepts

As previously discussed, the raw data archive can be considered as the core of a full-fledged science archive, which contains all data (raw observation files, calibration files, calibrated data), and the catalogue of observations. The catalogue stores information on the observations. Its data come either from the proposals database, or from the headers of the files contained in the raw data archive, or from the standard data processing phase.

The proposal preparation operations, described in 7.1.3, could also contain (as a part of step d), a software-controlled validation step: from this software, such information as proposal number, object coordinates, object name(s), object class, etc could be extracted and fed in the global database. In the proposal validation software, an object name server could be used either directly or via a network access to SIMBAD and/or NED, in order to find known aliases for the name of the object being proposed for observation.

However, it should be always possible to rebuild the catalogue from the information contained in the headers of the data files.

The catalogue of observations is a database by itself, and will be run by a DBMS. Ideally the DBMS should be commercial (Sybase, Oracle, Ingres, Informix, ...), to be run on a general-purpose computer. This would ensure the availability of an efficient, stable and maintainable product. A public-domain SQL library may be considered a second-choice option. In any case, availability of a run-time library, callable from FORTRAN and C application programs is mandatory.

The archive proper (data bank) stores observational and calibration data on high-capacity storage media not to be kept necessarily on-line, such as optical disks. Archiving media obviously need to guarantee data storage durable in time, and should have reached technological stability when operations are started. The current technology allows guaranteed and tested usage of 6.5 GB optical disks, while 9 GB disks are already available. Alternate new media, such as the CREO optical tapes, might be already stable by the time SUV becomes operational.

The on-line availability of observational data should be maximized, using a number of different system features, such as separation of calibrated from raw data on the archive media, use of juke-boxes, etc.

The possibility for an archive researcher to browse the archive could be considered in a later perspective. This feature could be accomplished through a quick-look facility accessing a compressed on-line subset of the whole archive.

7.3.2. Populating the Science Archive

The Science Archive will be populated with a number of subsequent steps:

1 When a proposal is made for an observation, initial information is stored in the proposal database.

2 When a proposal is approved, the proposal database information is updated.

3 When the proposed observation is actually performed, an entry is made in the catalogue of observations. After some time of quasi-on-line operations, the related data will be available on permanent storage on the raw data archive.

4 For each observation, a new entry in the catalogue is created by the first data processing module, where the information contained in the headers of the raw data files is stored in the database. At each data processing step, the information in the catalogue is updated, and intermediate data products are stored as files on magnetic disk, containing in their headers new relevant information.

5 After standard data processing, archivable data products are stored on rewritable optical disks. This ends the "on-line" phase of standard data processing.

6 The catalogue information is subsequently checked for consistency using the headers of the calibrated data files.

7 Production of final archive media (on 6.5 to 9 GB optical disks with current technology) and catalogue checking can be performed as an off-line activity since it is not time-critical. At this stage, it would be convenient if different data products could be stored on different disks, as stated in 7.3.1 (e.g. raw data, final calibrated data and intermediate data stored on three different disks). This procedure would optimize access to archived data at retrieval time, since data most likely to be accessed (calibrated data?) could be stored on-line by means of some juke-box mechanism.

7.3.3. Accessing the Science Archive

The concept of public access of science observations to bona-fide scientists is reflected in the Memorandum of Understanding. The public availability of data should follow a proprietary period of TBD length (e.g. 6 months to 1 year) during which the approved Guest Observer is the sole owner of the data.

After the proprietary period has expired, the data are publicly available for scientists to retrieve from the archive. In principle, data could be retrieved for and delivered to an archival researcher with the same mechanism already used for the observer's data (see 7.2.2, item 4).

The concept for data access and distribution is depicted in Fig FIG12.

1 Users access the Science Archive uniquely through a user interface. Such interface allows browsing of the catalogue of observations,
through a number of queries to the database, made by specifying some specific constraints on the database fields.

2 Using the user interface, the user can also specify a request to retrieve some or all of the files related to a specific observation. To do so, a selection mechanism will be available in the user interface, which sends the request to a request handling process.

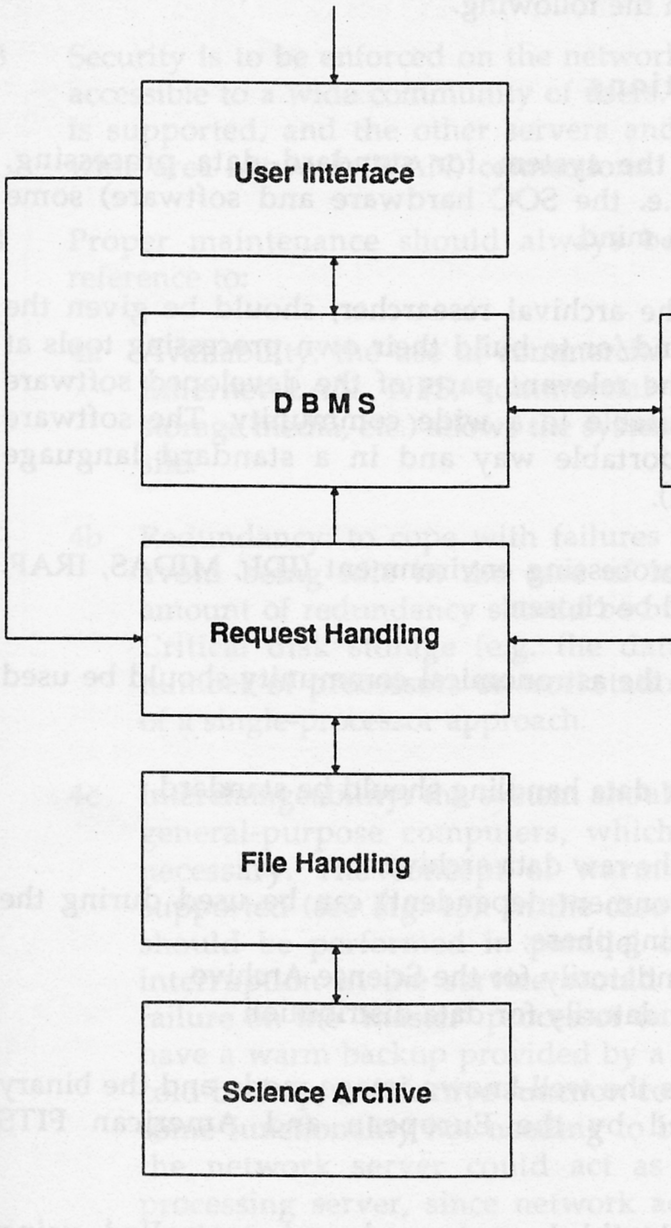
3 The request handling process checks the proprietary status of the files and identifies their location on the data bank permanent storage media. This information is then passed to a file handling process.

4 The file handling process accesses the permanent storage where the bulk observational data are kept, performs the actual data retrieval, and prepares the distribution media (magnetic tapes, DATs, Exabytes, ...) for the user, or makes data available for computer network access.

5 The request handling process warns the user of the status of the files requested (successfully retrieved, not available, still proprietary, etc.) and updates the user information in the database. The *user information* contains a "static" part, namely the information given by the user him/herself at registration time (name, address, e-mail address, etc.), and a "dynamic part (number of files retrieved, size of serviced requests, number of tapes received, etc.). At this stage, obviously, only the "dynamic" information is updated.

Figure 12

Figure 12


User Interface
D B M S
Database
Request Handling
File Handling
Science Archive

7.4. Software and Hardware considerations

As a general consideration, the same concepts already stated in 6.7 (dedicated servers, use of hardware and software standards, integrity of observational data, etc.) apply here as well. Some considerations more specific to the structure of the SOC are made in the following.

7.4.1. Software considerations

In designing and developing the system for standard data processing, archiving, and user support (i.e. the SOC hardware and software) some considerations should be kept in mind.

1 The observer and, later, the archival researcher, should be given the possibility to re-calibrate and/or to build their own processing tools at their home institutions. The relevant parts of the developed software must therefore be distributable to a wide community. The software should be written in a portable way and in a standard language (FORTRAN 77 is suggested).

2 A suitable software data processing environment (IDL, MIDAS, IRAF, AIPS, ..., all, none ?) should be chosen.

3 Standards agreed upon by the astronomical community should be used in all cases.

4 In particular, the format for data handling should be standard.

  4a. FITS is suggested for the raw data archive;
  4b. A TBD format (environment-dependent) can be used during the Standard Data Processing phase;
  4c. FITS is to be used mandatorily for the Science Archive
  4d. FITS is to be used mandatorily for data distribution

  The FITS standard includes the well-known image mode and the binary tables, recently approved by the European and American FITS committees.

5 Software development should be managed and controlled using suitable configuration control tools.

7.4.2. Hardware and system considerations

In the following, the basic concepts underlying the design of the hardware system for the SOC are enumerated. In particular:

1 The system (see also Fig. FIG13) includes Unix workstations and servers of

adequate processing power (with reference to instrument dataflow, still TBD), connected in an Ethernet Local Area Network (LAN) using the Network File System (NFS).

2 The peripheral devices needed (disks, magtape, optical disks, QICs, DATs, Exabytes) are accessible through the LAN.

3 Security is to be enforced on the network server, since this computer is accessible to a wide community of users. On the network server no NFS is supported, and the other servers and workstations are invisible to wide area network (WAN) connections.

4 Proper maintenance should always be guaranteed, with particular reference to:

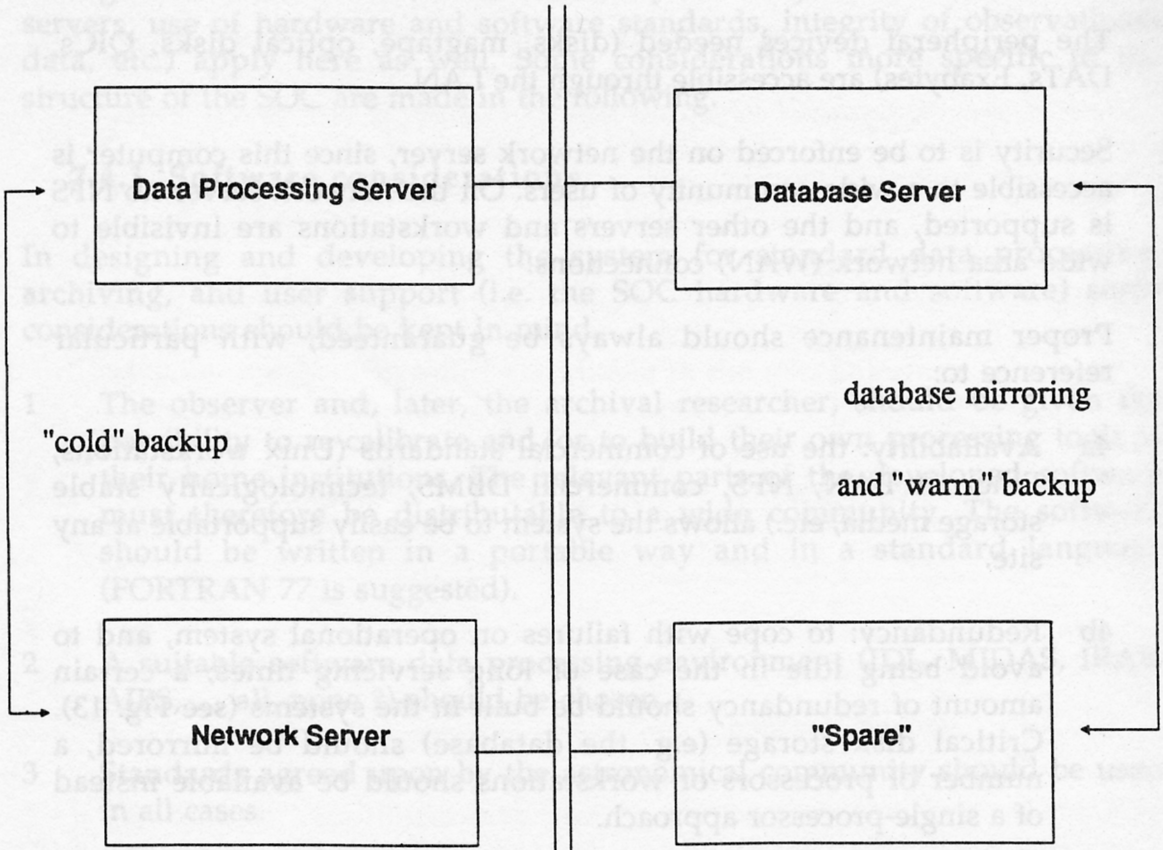
4a Availability: the use of commercial standards (Unix workstations, Ethernet LAN, NFS, commercial DBMS, technologically stable storage media, etc.) allows the system to be easily supportable at any site.

4b Redundancy: to cope with failures on operational system, and to avoid being idle in the case of long servicing times, a certain amount of redundancy should be built in the systems (see Fig. FIG13). Critical disk storage (e.g. the database) should be mirrored, a number of processors or workstations should be available instead of a single-processor approach.

4c Interchangeability: the system should be composed of a number of general-purpose computers, which could easily switch tasks if necessary. The concept of warm and cold backup should be supported (see Fig. FIG13). In the case of warm backup, critical tasks should be performed in parallel on two processors, so that no interruption in the service would be necessary in the case of a failure on the "master" processor (e.g. the database server needs to have a warm backup provided by a spare processor). In the case of cold backup, a defective function could be replaced by suppressing some functionality not needing to be continuously supported (e.g. the network server could act as a cold backup for the data processing server, since network access for remote archive users could be interrupted for a while with no loss of operational functionality).

4d The availability of spare parts on site (and obviously of technical staff capable of mounting it) could avoid long interruptions in the service in the case the hardware support is not completely satisfactory.

Figure 13


Data Processing Server
Database Server
database mirroring
"cold" backup
and "warm" backup
Network Server
"Spare"

7.5. The Italian Science Operation Centre

The existence of a single point of contact at an Italian site, called the Italian Science Operations Centre (I-SOC), might be considered.

The I-SOC could act as the point of contact, i.e. the terminal of the data link, with the SDPS in the CIS, could duplicate some of the SOC functions in Italy as described below, and could support the data dissemination towards GOs in Italy and in the Western countries (i.e. acting as a SUV Data Centre).

The duplication of the following SOC activities in Italy is being considered :

> The data reduction pipeline could run at I-SOC, at least for a share of the data. This way only the raw data or the raw uncalibrated images (plus relevant HK subset and auxiliary data) have to be transferred from the CIS, somehow lessening the burden of data transfer. Also the delivery of data products to observers (which may avail of electronic links) and archiving could be handled by I-SOC.
>
> The calibration analysis and the associated updates of the standard calibration files used by the pipeline processing could also run at I-SOC. This will make easier the distribution of up-to-date calibration data to observers (again via electronic link), and the communications with the instrument teams in Italy in the case of non-routine calibrations which require expert intervention. Anyhow official updates to calibration files or to the reduction pipeline shall always be agreed jointly.
>
> A subset of OPS activities like the feasibility and constraint verification in support to proposal selection, and a preliminary scheduling (possibly up to the submission of command lists) of approved observations, for the Italian share of observing time.

The feasibility of remote observing for the Italian share of observing time (in the sense that the Guest Observer may perform some quick look directly from I-SOC, being in contact with an RA at SDPS/RTO) will be evaluated during Phase A. Some preliminary elements in this respect are given below in LINKREF7.5.1

The policy for public access to SUV data after the observers' data rights have expired will be agreed in the MoU. It is however expected that at some time at least the entire set of raw data will be available in Italy (to be processed through standard reduction pipeline to create a final science archive) or that a copy of the original final science archive from SDPS/SOC is copied to I-SOC. Such archives should then be open for interrogation, retrieval, and in general archival research over a computer network

Concerning the types of data to be exchanged one may consider what follows :

HK subset and auxiliary data (including updates to the observation log) should be sent to Italy with priority and in their totality (i.e. for all observations irrespective of the data rights) and with a minimum delay (i.e. making use of a computer link).

The raw data (telemetry or raw images) of all the calibration observations should also be sent to Italy as soon as possible at the next priority level

The raw data of the observations belonging to the Italian share of time should also be sent to Italy, at the next priority level, and as the type of link allows. These data could be processed through the reduction pipeline at I-SOC, and the results archived there and delivered to the GO. Access to such data in the CIS will be regulated by the MoU.

The raw or final data of the observations belonging to the CIS share of time should also be sent to Italy at low priority, to be archived at I-SOC as mentioned above. Access to such data (particularly if that the data transfer occurs in advance of the release date) will be regulated by the MoU.

Information about target list and desired observing configurations for the Italian share of time may be forwarded from Italy to CIS making use of the existing link

The link should also be used for a reciprocal exchange of any updates to the calibration files and to the standard reduction software.

Concerning data dissemination, it seems advisable that SDPS/SOC and I-SOC have responsibility for the delivery of the products of the standard reduction to the respective observers in the CIS and in Italy.

Updates to calibration files of interest to the general observer will also be delivered to observers (in this case the usage of computer networks is highly recommended).

7.5.1. Communications and Data Transfer

The existence of a Science Operation Centre located in Italy, as a partial replica of the main Crimea-located SOC has been stated as highly desirable.

This centre will therefore receive the observational data as a copy of the original Raw Data Archive.

The set up of a remote link with the SDPS/RTO system will make this remote centre fully operational, even taking into account the degradation due to the delay in data transfer.

A double channel configuration may be devised: the first channel will be based on a low speed conventional dedicated line, to ensure continuous voice and e-mail communication, and the transmission of small quantities of data, as the payload HK parameters, that could e.g. be used by the italianinstruments groups to verify the status of the payload, or for transfer of calibration observation data.

The second channel will be based on a high speed satellite link, for the transmission of large quantities of data, as the astronomical images. According to the speed of this link, that could range typically from 64 Kbps up to 2 Mbps, the performance of the remote italian SOC will be consequentely different.

Considering the typical data production rate of the scientific instrumentation, as described in the SDMU design report with a speed of the link of 64 Kbps, the time taken by the transfer of the data will be such not to allow time responses typical of an interactive environment. We will therefore have a "fast availability" of the data for the remote centre.

If the speed of the link will be on the contrary of the order of 0.5 - 2 Mbps, the time responses will be typical of interactivity. We will have in this case a remote real-time environment. We will be able to talk in this case of the possibility of "remote observations" from the italian SOC.

From the technical point of view, even the latter solution is currently feasible. The only limitation is overall cost.

It must be noted however that the high speed channel, that will constitute the major part of the cost, will be active only during the time-windows in which there will be a real time session for the mission and some observing time will be allocated to an italian observer. The availability of remote observations will moreover reduce travel and stay costs for the share of the total time allocated to the italian partner.