SPOT4 OPERATIONAL CONTROL CENTER (CMP)

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ABSTRACT

CNES(F) is responsible for the development of a new generation of Operational Control Center (CMP) which will operate the new heliosynchronous remote sensing satellite (SPOT4).
This Operational Control Center takes large benefit from the experience of the first generation of Control Center and from the recent advances in computer technology and standards.

The CMP is designed for operating two satellites at the same time with a reduced pool of controllers.

The architecture of this CMP is simple, robust and flexible, since it is based on powerful distributed workstations interconnected through an Ethernet LAN.
The application software uses modern and formal software engineering methods, in order to improve quality and reliability, and facilitate maintenance.
This software is table driven so it can be easily adapted to other operational needs.

Operation tasks are automated to the maximum extent, so that it could be possible to operate the CMP automatically with very limited human interference for supervision and decision making.

This paper provides an overview of the SPOT4 mission and associated ground segment. It also details the CMP, its functions and its Software and Hardware architecture.

Key Words: Control Center, workstations, standards, flexible, automation.

1. INTRODUCTION

The SPOT system, conceived and designed by the CNES, the French Space Agency, is an earth observation system. Its aim is to manage and provide images acquired by SPOT satellites and transmitted to ground stations.
The SPOT satellites family consists of :

- SPOT1 launched in February 1986;
- SPOT2 launched in January 1990;
- SPOT3 launch planned in Sept. 1993;

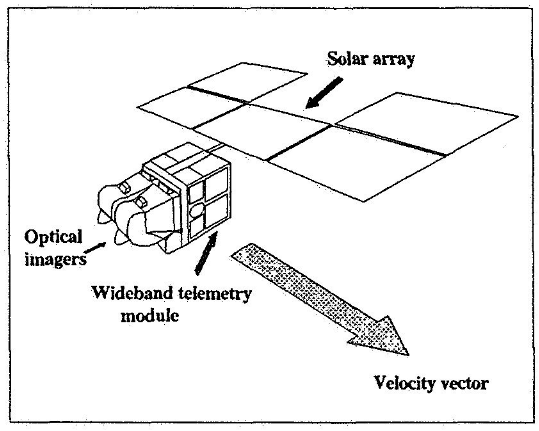
The continuity of this service is now ensured by the CNES SPOT4/5 programs up to 2000 and later (SPOT4 launch is planned for 1995).

Each component of the SPOT4 system has been designed to take into account the satellite evolutions (new sensors, ...) and the improvements provided by the acquired experience (6 years) and the increasing knowledge of the SPOT IMAGE clients' wishes.

2. SPOT4 SYSTEM DESCRIPTION

2.1 SPOT4 Satellite

The SPOT4 spacecraft is composed of :
. a standard platform that can be used for remote sensing missions other than SPOT;
. a payload consisting of optical imagers and an image telemetry system



SPOT4 belongs to a new generation of satellites compatible with the previous one.

The main characteristics of SPOT4 satellite are :
<u>*- identical to SPOT1,2,3*</u> :
. sun synchronous, polar orbit;
. mean altitude 832 km, cycle period : 26 days;
. nodal period : 101.4 mn, number of tracks : 369;
. maximum pass time : 785 s;
. width in vertical viewing : 60 km (117 km twinned instruments), adjustable viewing axis : $\pm 27°$;
. high resolution images : 10 and 20 m.
<u>*- main evolutions*</u> :
. life duration in orbit : 5 years;
. mass increased : 1/3, passengers as PASTEL, ...
. supplementary spectral band(Medium Infra Red),
. registration of all the spectral bands;
. capacity of Telemetry x 2 and Telecommand x 3;
. 50 Mbits/s data storage during 40 mn;
. new tape recorders, ...

2.2 SPOT4 Ground Segment

The evolutions of the ground segment take large benefit from the experience of the first ground segment designed for SPOT1. The new implementation tries to split the different independent functions and to affect them to each center.
To reduce the exploitation costs, a larger automation is requested for each component.
The Operational Control Center (CMP) is one of the elements of the SPOT4 ground segment.

The Ground segment is divided in two large parts corresponding to the two distinct missions it must carry out :

- monitoring and managing the satellite;
- exploiting the received image data.

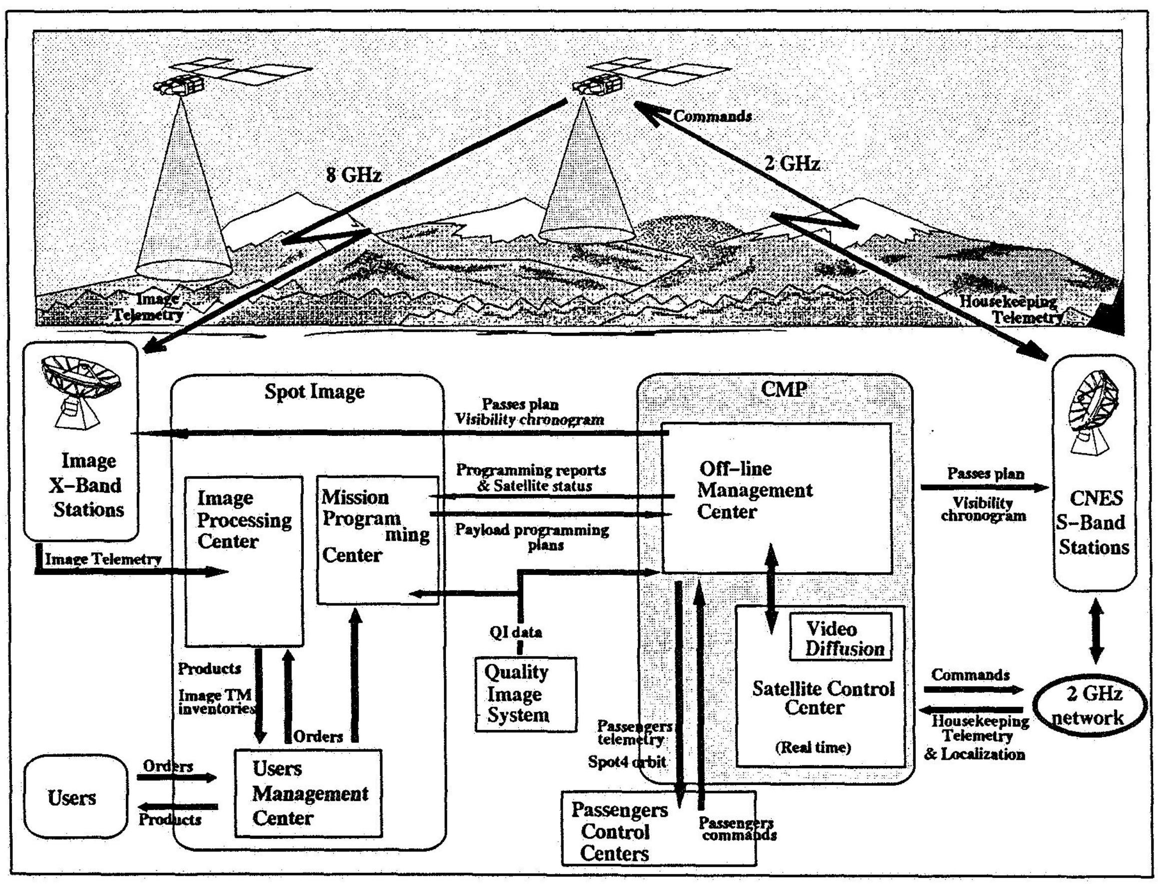
The first mission is ensured by the following components :

- the CNES (S-Band) Stations (belonging to the CNES 2GHz network) follow the satellite during the visibility period and interface it for all the data exchanged with the Control Center;
- the Operational Control Center (CMP) monitors the satellite and its passengers in real time by receiving the house-keeping telemetry, the localization data and transmitting telecommands to the satellite. It operates the planning of activities for the platform, the passengers and the payload, on the base of programming requests;
- the Quality Image System (QIS) checks, through repetitive measurements and calculations, the image performances in rough mode or after pre-processing.

The other components exploiting satellite image data are :

- the Image Reception (X-Band) Stations record the image telemetry on high density tapes;
- the Users Management Center (CGC) is in charge of relations with clients (reception of orders, product distribution, ...);
- the Mission Programming Center (CPR) programs the payload to optimize the load of the satellite and the use of the viewing instruments;
- the Image Processing Center (CAP) systematically archives the received image telemetry and pre-processes the required products.

Data flows between the main components of the SPOT4 ground segment are summarized on the following diagram.



3. SPOT4 OPERATIONAL CONTROL CENTER

3.1 Mission Requirements

The SPOT4 Operational Control Center (CMP) is located in Toulouse Space Center, France. It is presently designed to provide simultaneous control over 2 satellites.
The overall objectives are :

- technological monitoring of the satellite and control in real time and off-line modes through management of a technological data base;
- satellite commanding for on board configuration management;
- orbit calculation, in orbit positioning and station keeping maneuvers;
- payload programming, either in routine mode (generation of commands corresponding to the plan programmed by the CPR), or in special mode (under CMP responsibility) in case of payload failures, ...
- short and long term planning of all ground operational activities (availability of receiving stations, etc...);
- generation of all orbit data necessary for external facilities (Image Reception Stations, passengers control centers, ...);
- video images broadcasting to operation control rooms for the launch time and specific orbital maneuvers.

3.2 Operation Requirements

The CMP has to be operational in the following exploitation phases (for 2 satellites) :

- system qualification,
- launch and acquisition phase,
- flight acceptance,
- nominal exploitation (5 years foreseen).

The CMP may be operated automatically, only attended by a single operator during the routine phase in nominal exploitation. The exploitation activities run in cadence with the passes and must be planned and prepared in advance in order to run without operator's intervention.

The CMP is designed to follow 20 passes a day (two satellites). It must process the housekeeping telemetry TM (more than 2500 parameters by 16s frame) without loss in real time. The CMP has also strong requirements for the orbit maintenance to avoid degrading the optical performances of the system.

3.3 Functional Architecture

The functional architecture of the CMP is designed to provide both real time and off-line functions. It is based on a time driven concept.

The CMP is divided in two subsystems :

- the Satellite Control Center (CCS),
- the Off-line Management Center (CGS).

3.3.1 Satellite Control Center (CCS)

It is in charge of the real time (or near real time) functions and all its activities are linked to the passes. Its main functions are :

. *before the pass* :

- automatic test of the station,
- automatic preparation of the passes, taking into account commands from various subsystems of the CGS, scheduling the commands according to the visibility plan and generating a command plan to be automatically sent to the satellite.

. *during the pass* :

- reception of housekeeping telemetry,
- monitoring in real time and display of the processed parameters,
- acquisition of localization measurements for orbit monitoring,
- broadcast of TM synoptics to the video distribution system (launch and critical phases),
- automatic transmission of the command plan (previously prepared) to the satellite.

. *after the pass* :

- transmission to the CGS of the received and validated TM, localization measurements, acknowledged commands,
- telemetry replay of a previous visibility at original speed, at full speed or step by step under operator's control.

3.3.2 Off-line Management Center (CGS)

The Off-line Management Center performs off-line functions which are distributed in several subsystems :

. *Satellite Technological Monitoring (STS)*

- archiving telemetry and updating the technological data base;
- providing the CCS with TM for replay;

. *Orbital Maneuvers Management (OMGS)*

- orbit computation and control, delivery of orbit data to operations;
- automatic generation of routine commands for orbit management and maneuvers programming.

. *Dump and TC Block Handling (DUTCH)*

- on board software management, dumps analysis and on board configuration management.
- trending analyses

. *Payload Management (CGCU)*

- payload instrument resources management and programming.

. *Passengers Management (GTPA)*

- passengers technological monitoring;

4. HARDWARE ARCHITECTURE

4.1 Requirements

The CMP hardware architecture is designed to answer the following requirements :

- perform the mission,
- obtain a high level of reliability and availability,
- evolve easily,
- manage breakdowns by using a flexible design.

4.2 Choice

The architecture is based on powerful distributed workstations, interconnected through an Ethernet bus. Each subsystem is implemented on separated workstations. The level of redundancy is the subsystem level.

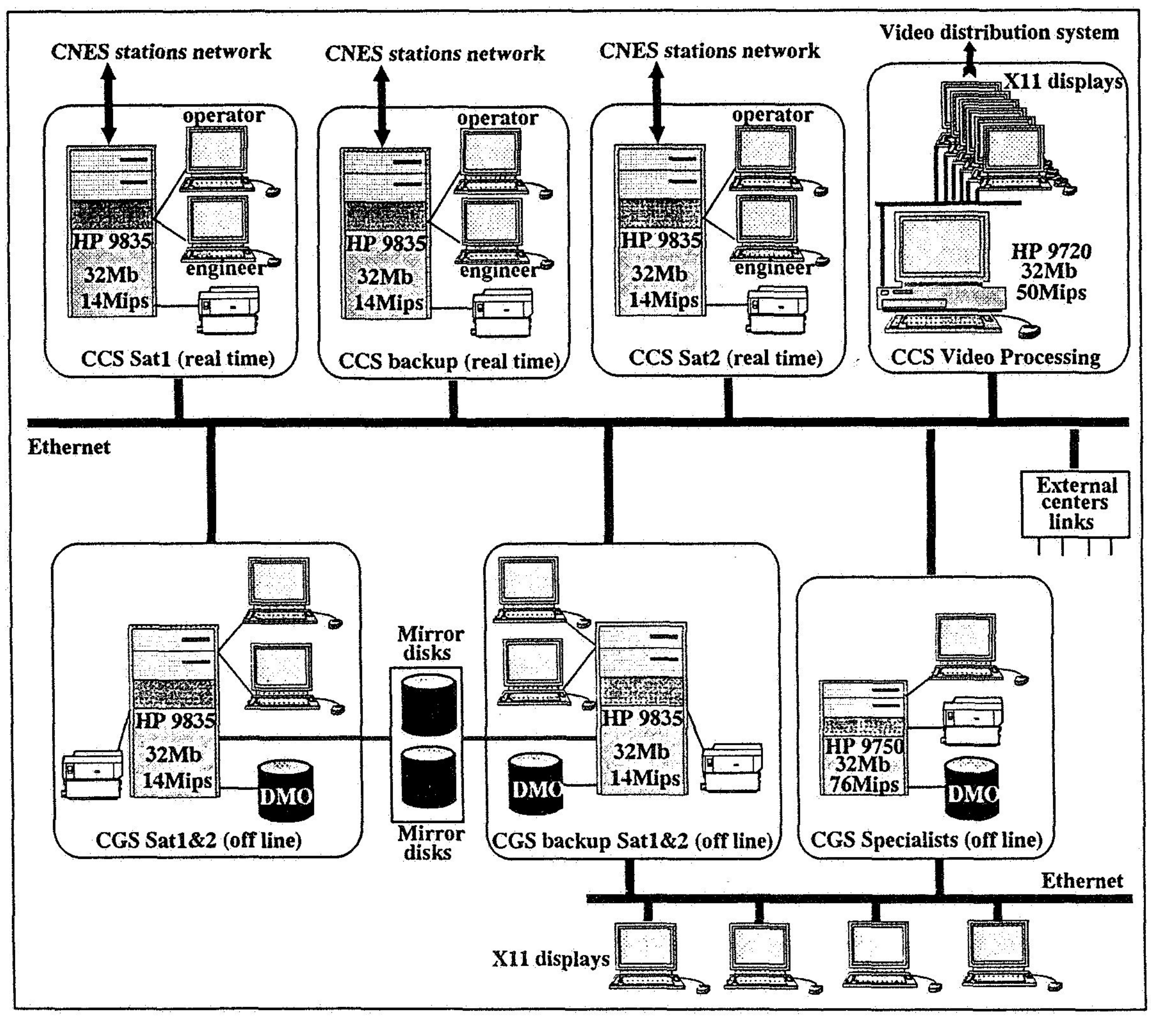
- workstations : HP 9000 series 835 and HP 9000 series 720 and 750 computers, RISC architecture;
- operating system : HP/UX SYSTEM V compatible;

The use of modern technology and standards has been maximized :

- 32 Mbytes memory, optical magnetic disk;
- disk mirroring management, bitmap, X11 displays;
- graphical interface : X11, OSF/MOTIF;
- coding source languages : C / FORTRAN;
- internal communication on TCP/IP, NFS;
- X25, HDLC drivers, ...

4.3 Evolutions

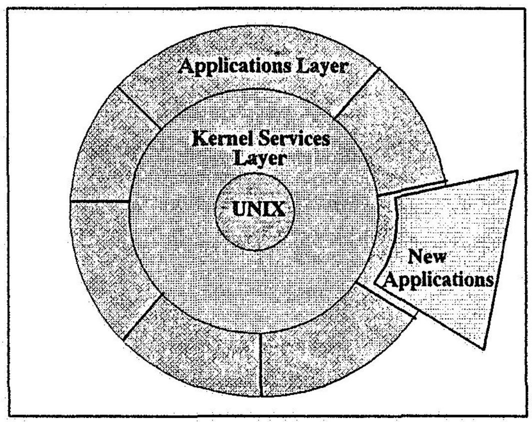
Evolutions taking into account increases in the mission requirements (providing control over a third satellite or increasing the number of TM synoptics to be broadcasted to the operation control rooms) are easy to design with such a hardware architecture. It consists often in adding a supplementary workstation with a potential resizing of the Ethernet network.



5. SOFTWARE ARCHITECTURE

The software architecture is composed of two layers above the System layer (HP-UX, OSF-MOTIF) :

- the Kernel and Services layer (CNS);
- the Application layer.



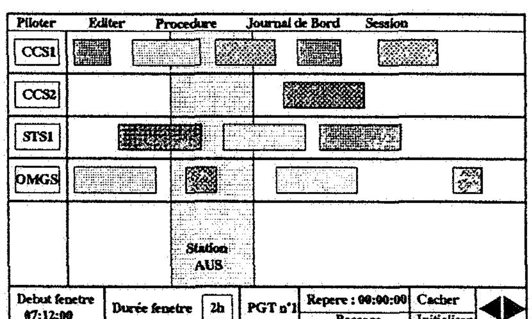
5.1 Kernel and Services Layer (CNS)

This layer consists of :

- libraries for system calls standardisation and common services access :
. message management (broadcasting to files, windows, printers,..),
. file management (ASCII files can be text edited),
. inter-process communication (message queues, shared memory, semaphores),
. inter-computer communication,
. time management (shifted time).

- utilities (general purpose applications)
. log file exploitation,
. hardware and software configuration control,
. archive tape management,
. computers time synchronisation.

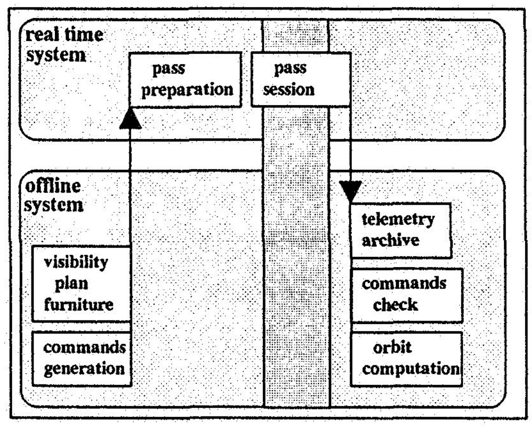
- Agenda and Procedure management
. easy and ergonomic work schedule definition,
. automatic applications execution as defined in the work schedule,
. standardised start/stop and control of application programs over the network,
. recovery steps on failure occurrence.



An Agenda (Ref.1) work plan scheme

5.2 Application layer

Each operational function is ensured by a software package called "procedure". These procedures are overlaid above the Kernel and Services layer.
A procedure is an autonomous task designed to run without operator's intervention and to be executed on one of the CMP's workstations. It can be activated automatically by the Agenda (Ref.1) or manually by the operator through an ergonomic man machine interface.
Building a work plan for one or several days consists in defining on the Agenda (Ref.1) work schedule the wished procedures.
Skeletons of work plan are available for the routine exploitation mode.
Example of a daily routine procedures sequence :



5.3 Standardisation and Reliability

5.3.1 Man Machine Interface

The Man Machine Interface is implemented on X11/Motif standards. High resolution screens (19" bitmaps and X11 displays) are available for the implementation of all the animated synoptic windows and the alphanumeric windows.

Ergonomic specifications (based on the OSF/MOTIF style guide) were drawn up to ensure that the CMP screens had an uniform design. In most cases mock-ups were built to be analysed by the future Center users.

5.3.2 Adaptation Capability

For each developed procedure, very strong rules have been established to increase the software adaptation capability :

- independence from satellite type by designing the software according to a table driven concept (characteristics in an Oracle database);

– systematic use of ASCII "SR6–10" files for the external or internal interfaces to facilitate integration and maintenance.

– independence in the real–time part (CCS) between a producer of data and the consuming task(s) (producer/consumer protocol);

– high level of software quality by using up–to–date and formal software engineering methods :

* SADT for the functional phase – tool : ASA,

* "Abstract Machines" for the design phase – tool : CALLIOPE,

* coding sources rules, test coverage and quality metrics – tool : LOGISCOPE,

* non–regression at process level and full validation at system level,

* configuration management since the integration phases – tool : CMF.

6. CMP EXPLOITATION

The new generation CMP has taken into account, at the beginning of the development, the cumulated experience (from SPOT1 and SPOT2) of the exploitation team.

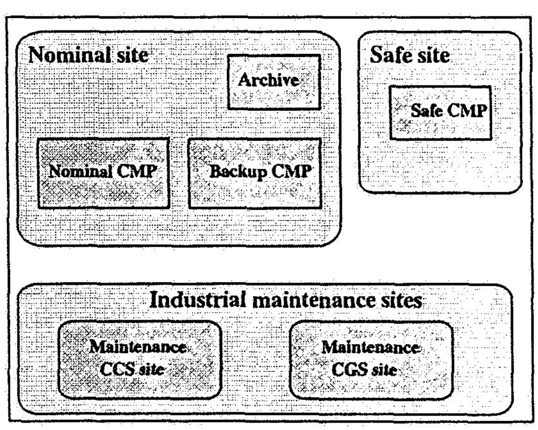
6.1 Human factors

Only one operator will be present in routine operations (1 operator/team; 2 teams/day). The operator interventions take place on failures or non conformances.
The engineering exploitation team will consist of configuration, documentation, quality assurance managers, ground and on board specialists.

About 25 persons will work at the CMP, including the management team.

Along with the operators team, satellite specialists work in the CMP for exceptional checks or in flight acceptance phase.

6.2 Configurations on Site



6.3 Documentation

As a result of the development phase, a fully documented software is provided to the exploitation team.
The documentation is produced through an automatic generation (interface manuals, design manuals, ...).

By using automatic generation of operational plans, hard copies of Agenda work plans, procedures libraries, etc ..., the exploitation documentation will be easier to manage than the previous documentation.

6.4 Failures

If a failure occurs, all the system is designed to avoid an untimely reaction from the operator.
The Agenda stops the procedures and all the means of investigation are given to specialists (graphical displays, printer outputs, log file, ...).
Each default occurring in communicating with the satellite (on board reception default, incorrect transmission conditions) or inside the CMP needs a manual intervention of an operator or a specialist.
In automatic mode, at any time the operator can break the automatic working of the CMP in order to command and control manually the required procedures.
Recovery procedures are pre–defined and easily started manually or through the Agenda.

7. STATUS

The CMP development should be completed by mid 1993.
Some of its subsystems (as the CCS) are already accepted.

8. REFERENCES

1. Fratter, I. 1992. Agenda: a task organizer and scheduler. In SpaceOps 92.