A PROCESSING CENTRE for the CNES CE-GPS experimentation

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ABSTRACT

CNES is involved in a GPS (Global Positioning System) geostationary overlay experimentation. The purpose of this experimentation is to test various new techniques in order to select the optimal station synchronization method, as well as the geostationary spacecraft orbitography method. These new techniques are needed to develop the Ranging GPS Integrity Channel services.

The CNES experimentation includes three transmitting/receiving ground stations (manufactured by IN-SNEC), one INMARSAT II C/L band transponder and a processing centre named STE (Station de Traitements de l'Expérimentation).

Not all the techniques to be tested are implemented, but the experimental system has to include several functions; part of the future system simulation functions, such as a servo-loop function, and in particular a data collection function providing for rapid monitoring of system operation, analysis of existing ground station processes, and several weeks of data coverage for other scientific studies.

This paper discusses system architecture and some criteria used to its design, as well as the monitoring function, the approach used to develop a low-cost and short-life processing centre in collaboration with a CNES sub-contractor (ATT-DATAID), and some results.

Keywords : Ground System, Architecture, Software.

1. INTRODUCTION

The GPS system offers exceptional qualities (accuracy and worldwide coverage). But for civil aviation (see (1)), this system has three major drawbacks :

- insufficient integrity,
- limited availability,
- voluntary spatio-temporal degradation.

Ranging GPS Integrity Channel services (RGIC) should enable GPS to be used by civil aviation.

The experimentation prepared by CNES (see (2)) is dedicated to the technical validation of the Ranging GPS Integrity Channel concept that always needs :

- station synchronization better than 10 ns,
- GPS-type signals transmitting,
- geostationnary spacecraft orbitography better than 10 meters.

The CE-GPS (European complement to GPS) experimentation includes a master ground station transmitting a GPS-type signal to an INMARSAT 2 geostationary satellite. The repeater broadcasts this signal in L-band to the master station and to the other stations. These also have receiving and transmitting facilities for GPS-type signals.

Each ground station includes a computer and software to :

a) record broadcasted and raw data from several facilities,
b) process some of the data in a real time loop (0.6 seconds) to generate transmitting signals correctly,
c) control and monitor equipment,
d) make some of the data available to the processing centre.

Other data (such as orbital and some weather parameters) required to drive the system or for various scientific studies are centralised at the processing centre.

The functions of the processing centre (STE) are to :

a) prepare data for ground operation control station schedules,
b) collect data from ground stations and other sources,
c) archive and distribute these data to different scientific teams, sometimes after specific processing,
d) monitor ground station operations.

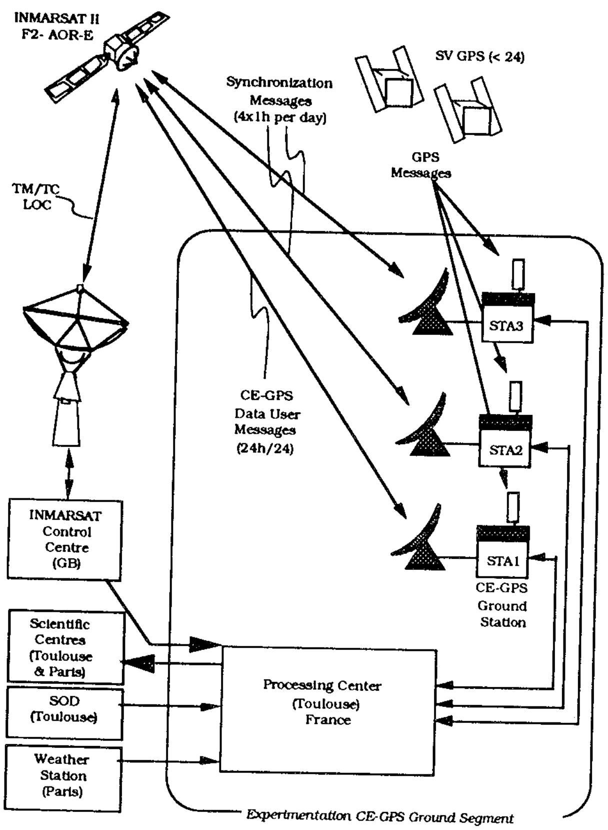

figure 1 : Experimentation CE-GPS overview

2. ARCHITECTURE

In this chapter, the architecture of the ground station and of the STE are presented.
After, an overview of the exchange system is given, then criteria used to distribute software between ground station, processing centre and scientific centres are listed.

2.1 Ground stations architecture

Each ground station is composed with multiple equipments connected to a main computer. All software ground station functions are centralized at this computer

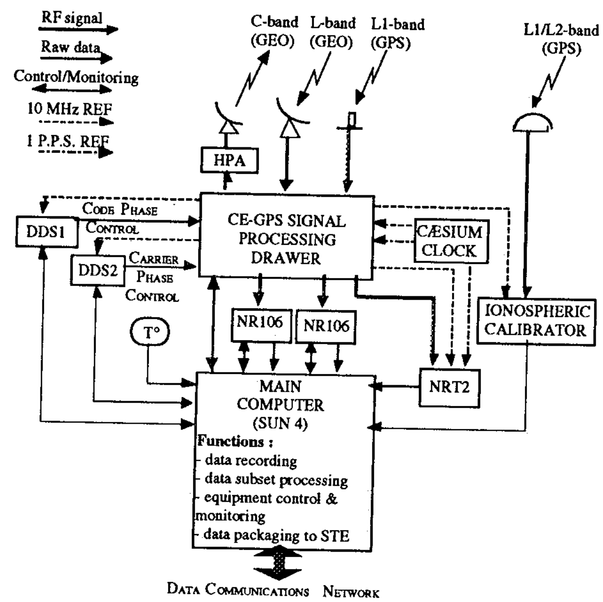

figure 2 : Ground station overview

2.2. processing centre architecture

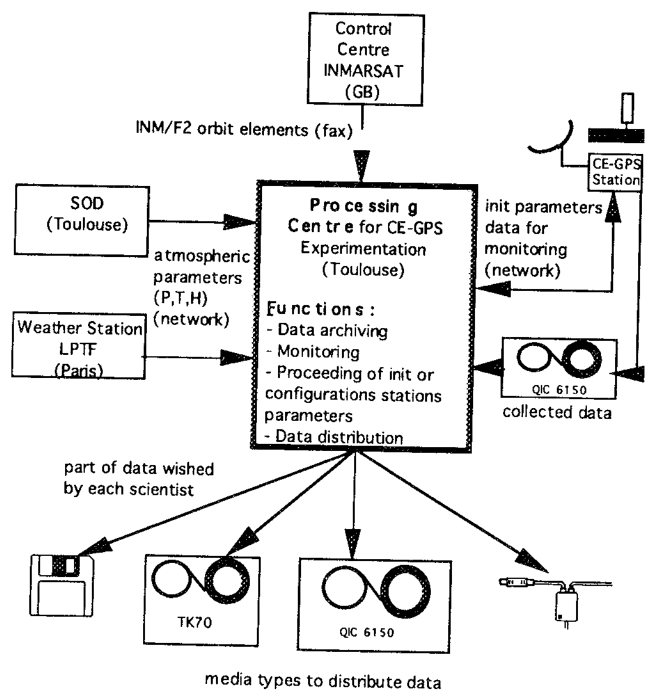

figure 3 : external links

The processing centre software architecture is decomposed in two blocks of functions (figures 4 & 5 below). These two blocks can be used together.

The diagram below shows functions that are only used when data are collected.

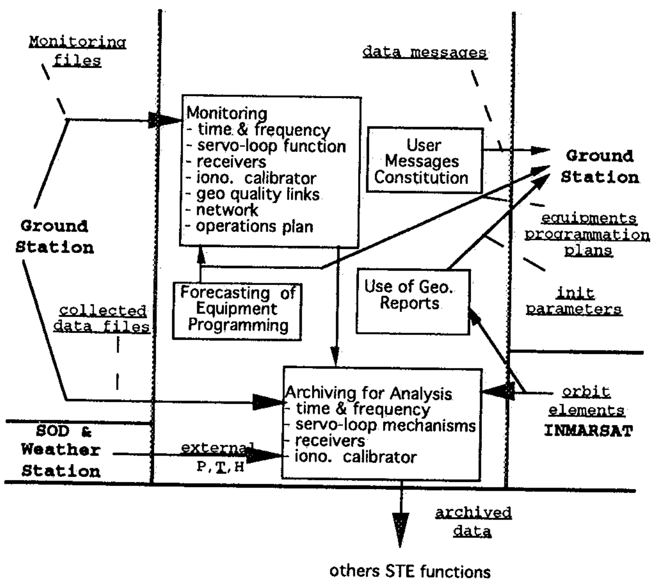

figure 4 : software architecture (1)

The diagram below shows functions that are only used when data are pre-processed and sent to a scientific centre.

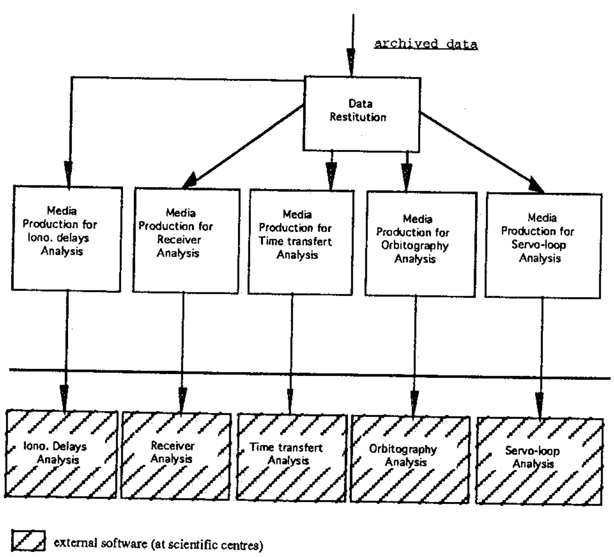

figure 5 : software architecture (2)

These different functions are activated and controlled through a man-machine interface displaying four main windows :

1) Function selection, after which a sub-function menu is displayed for input of various parameters.
2) Display of the number and type of tasks currently running.
3) Output of task messages.
4) System message output (console).

Other windows are available with OPENLOOK SUN system tools (file manager, calctool, cmdtool, etc.) and may be selected by the operator when required.

The diagram below shows the hardware architecture used to support the different functions.

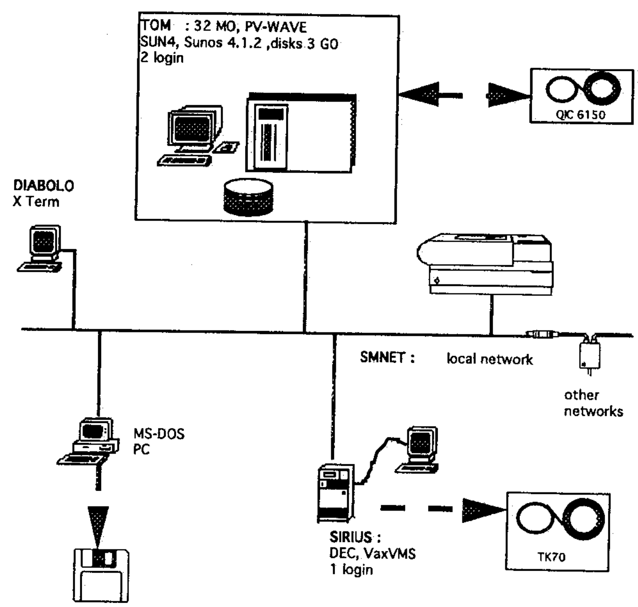

figure 6 : hardware architecture

PC/MS-DOS and DEC/VMS are only used to product adequate media for specific scientific centres.

2.3. exchange system

The system may use different configurations, with one, two or three ground stations. For example, this system was operating at the end of 1993 with two ground stations (Toulouse and Paris) but is operating with three in 1994

(Toulouse, Kourou in French Guyana and Hartebeesoek in South Africa).

As ground station locations might vary according to use with a different network at each configuration, the interfaces between ground stations and the processing centre had to be **standardised and easily modified**, so data-files are used for exchange between the processing centre and a ground station.
Thus, when a network is available, FTP (File Tranfer Protocol) is used to exchange subsets of data-files, QIC 6150 data-cartridges are used to tranfer the remaining data-files.
Else (when no network is avalaible : for example tranfer from one development site to another) all data can be saved and easily transported by using only cartridges.

This rule was also applied for the other exchanges between the processing centre and the scientific centres. Computers are not homogeneous between the processing centre and the scientific centres, so data in files are in ASCII format.
Each file tranfer is initiated by the STE processing centre.

2.4. Criteria for the distribution of software between ground stations and processing centre

In the operational phase, if one of the components were to fail (processing centre, ground station or network), the system would have to ensure that any data generated by the other components was not lost, but **without relying on any redundant facilities**.

As ground stations include a real-time loop to generate GPS-type signals, it was decided that the main **processing system in each ground station should receive each function with real-time constraint**, and thus should collect all data from all facilities through RS232 or IEEE links, even though the processing centre would be able to obtain data through a different link.
This provided **an uniform means of data exchange** between any ground station and the processing centre.

So, with the data-file exchange system, each ground station computer would then manage short-term file-saving (over a few days), while the processing centre would manage long-term archiving for all ground stations and all system configurations used.

One of the aims was to cut down manual operations in ground stations so that they would not need to be staffed on a permanent basis.
All operations where data has to be **keyed in manually are carried out in the processing centre**, and the results file is then transmitted to the ground station (before the operational phase, data may be input with a text editor as the data in these files is in ASCII format).
NB : The only manual operation needed under normal station operating conditions is a twice-weekly cartridge change.

Another point we observed was to **avoid allocating to ground stations any processing occurring at irregular intervals** as site and azimut angles processing, so that real-time loops would not be affected by a random load peak.
Any such processing is carried out at the processing centre and gives results files that are valid over the whole operational period and transmitted.
The ground station software only uses indirect time and date addressing to retrieve data when needed.

2.5. Criteria for the distribution of software between processing centre and scientific centres

The first criterion was to **avoid imposing specific types of equipment on scientists configuration**. Hardware for data exchange was defined for each scientific centre for its own data, STE processing centre which would be responsible for setting up a hardware and software configuration based on existing facilities at CNES.

The second criterion was to develop and operate at the processing centre any data **pre-processing software which would be common to at least two scientists**.

The third criterion was to **keep options open for specific software to be set up within the processing centre** to enable the operator to pre-process also scientific data, as the processing of raw data to obtain interpretable results can otherwise be very time-consuming for the scientists using them.

3. THE MONITORING FUNCTION

Station monitoring from the processing centre **is not carried out in real time**, for several reasons :

1) equipment is more and more reliable ;
2) operator at processing centre is only present 5 days per week, 8 hours per day even if each ground station is operational 7 days/7, 24 hours/24;
3) the loss of a few data-days is not a problem, but when the data collection function is operating, we have to be certain that the data is correct.

To meet this requirement, ground station software stores three types of data in monitoring files.
The first type is made up of raw data extracts, the second of extracts of equipment command data received and distributed by the servo-loop mechanism, while the third type consists of monitoring indicators generated on ground stations (watchdog function for the various flows of expected data, quality indicators for INMARSAT 2 satellite links as bit error rates, etc.).

These monitoring files are processed by dedicated software at the processing centre using simplified equations to describe observable phenomena. The operator can then display the resulting parameters in graph form. The curves change colour if values exceed monitoring thresholds, which take into account the simplifications in the equations.

The observable phenomena are :

- master or slave servo-loop,
- pseudorange and carrier phase measurements for pseudo random codes (1 to 32 : GPS constellation, 33 to 36 : back up for GPS, used in the CE-GPS experimentation,
- pseudorange residues,
- vertical Total Electron Content,
- two-way time transfer through INMARSAT 2,
- INMARSAT2/ground station link indicators.

4. APPROACH USED IN STE DEVELOPMENT

The processing centre software was to be written by a specialised firm, and to have it ready on schedule (development began in November 1992 for partial implementation at the end of March 1993), without the constraints involved in managing too large a team, the following considerations were applied.

1) As the processing centre would be operating for no more than 2 years, the **normal rules of management were made more flexible**. The alterations mainly concerned reviews at the end of each development phase and the documents to be managed within the configuration. For this processing centre, key-points with only the CNES and ATT-DATAID technical managers present were substituted for all reviews. This rule remained valid as long as no major differences arose between ATT-DATAID and CNES.

2) A study was carried out before the contract was signed, to assess the possibility of **including existing products** to meet requirements for all or some of the functions needed. Such products would be incorporated by adapting the new software packages to the interfaces. The functions delivered to ATT-DATAID thus included graph-plotting (developed in PV-WAVE command language), orbit computation functions for the geostationary and GPS satellites and computing routines for tropospheric delay factors.

3) Whenever existing **low-cost hardware could be used to resolve a particular problem**, this was acquired in preference to the development of specific software. For example, an additional 2 gigabit disk for file management was acquired instead of developing a file management system with existing compacting and decompacting tools, as the purchase price of the disk was equivalent to only a few days of software development.

4) File name specifications were set out from the start of the experimentation system definition phase, as well as the choice of the operating system for the main computers (UNIX) and a recommendation on the content of all files (ASCII). This enabled processing to be carried out with **tools which were incorporated within the operating system** and which were therefore easy to manipulate with "shell-scripts". The same reasoning was applied to the development of software for the ground stations.

5) **A large number of parameters** was incorporated into the processing centre software, either within configuration files to be handled by the text editor or as data to be keyed in through the man-machine interface. This last solution does not affect costs as the centre is permanently staffed (except at weekends) during system use.

6) In order to maintain autonomy between functions and to **avoid over-automation of the processing centre**, some data input is carried out by the operator even where such data can be deduced from available data in the processing centre.

7) The **software** for the processing centre **was delivered in several stages** :
- Stage 1 : man-machine interface ;
- Stage 2 : all data collection functions (see figure 4) ;
- Stage 3 : all data distribution with scientific data pre-processing ;
- Stage 4 : incorporation of specific processes when requested by a scientist.

This method enabled real progress in processing definition to be monitored without the need to program everything in advance.
Tasks were therefore not scheduled in the usual sequence for this type of development (definitions - specifications - realization).
This is not always advantageous (project management is more demanding), but the final product is better matched to the real needs of different users.

5. SOME RESULTS

5.1. about STE software

ATT-DATAID supplied 230 working days to write the processing centre software, starting on the 2nd November 1992 and ending with Stage 3 acceptance tests which were carried out on the 21st of April 1993.
For the STE project, the CNES work-load over the same period amounted to 70 days.

The software for this processing centre comprises 17 000 lines of source code without annotations (in FORTRAN, C, awk, shell), of which 4 000 were supplied by CNES. Certain functions were also directly supplied by CNES as binary codes.

Anomaly report number was :
16 after acceptance testing ;
29 after technical approval from the processing centre ;
34 at the beginning of the CE-GPS experimentation ground segment operational use with 2 ground stations (Toulouse and Paris) ;
47 on close of this operation.

Other scientists had access to the data collected, although they were not identified at the beginning of the project.
They required no specific processing. To enable the system to produce and distribute their data, declarative instructions were input into the parameter files then tested (1 day work load).

5.2. about STE/ground stations operations

The fact that STE is not staffed at weekends is just acceptable to detect a problem at a ground station, because the delay between the origin of a problem and its repair can be several days.
So, for a non experimental system, redundant facilities in ground station seem needful, operator should choice correct data. According the interrupt time acceptable by a mission of data collection, other solutions are possible (call by phone the operator after a detection of a problem, processing centre staffed at week-end, ...)

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