# Chapter 7 : Generic PROTEUS control ground segment

## CHANGE TRACEABILITY Chapter 7

Here below are listed the changes between issue N-2 and issue N-1:

Here below are listed the changes from the previous issue N-1:

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| Section | Sentence | Planned resolution |
|---|---|---|
| §7.8.1 | 1. An organisation bases on the standard one but complemented by a hot line service TBD hours-a-day using: | |

# 7. GENERIC PROTEUS CONTROL GROUND SEGMENT

## 7.1 PURPOSE

This chapter describes the architecture of the generic ground control segment for a satellite based on the PROTEUS platform, the operations concepts applicable to the various components, the data exchanges between the PGGS components and the data exchanges with other external components.

This architecture is broken down into the final orbit acquisition and station keeping phases.

## 7.2 SCOPE

This part is applicable to all missions using the PROTEUS platform for all concerning satellite control-command.

## 7.3 PGGS FUNCTIONS

For a given mission, the PROTEUS generic ground segment (PGGS) is part of the Mission Ground Segment. It does not ensure all the functions of the mission but those required for satellite final orbit acquisition and station keeping.

The PGGS functions are broken down according to the satellite life phase, the station keeping phase or the final orbit acquisition phase.

The PGGS is multisatellite for a given mission. The multisatellite configuration is limited to a cluster of 3 to 4 satellites.

To fulfil these functions, the PGGS consists of 3 components:

The Command Control Centre (CCC)

The Telemetry and Telecommand Earth Terminal (TTCET)

The Data Communication Network (DCN)

### 7.3.1 STATION KEEPING PHASE

- Satellite monitoring and technical control

The satellite monitoring and technical control consists in checking by processing monitoring telemetry data (HKTM) that the state of the satellite meets mission requirements, in transmitting telecommands intended to maintain the normal operation of the satellite, in transmitting telecommands intended to obtain additional diagnosis data, in transmitting telecommands to rectify abnormal situations or to call on onboard redundancies. The technical abilities of the CCC cover the platform and payload aspects for all that which may endanger the satellite survival.

- Satellite configuring

Even though the PROTEUS family satellites are highly autonomous thanks to automatic control of the onboard flight software, a certain number of systematic operations must be performed on the satellite to maintain it in an operational mode and to optimise its life (calibration of sensors, measurements on tanks, etc.). The frequency of these operations is very low, typically every three months. Operations procedures are associated with all these operations.

- Orbit and attitude controls

The calculations are done onboard by the AOCS from GPS data, attitude sensor information, data catalogue and models (magnetic fields, star catalogue, etc.). It consists in updating the UT/atomic time delta ; the parameters of the reference system change model at a very low frequency (typically every month) in delivering the control and orbit control instructions to the AOCS at a specific frequency according to mission requirements. Operations procedures are associated with all these operations.

- Payload service

Payload service consists in transmitting to the payload processing centres (MC) the telemetry data produced by the payloads (PLTM) received on the ground via the TTCET, checking the state of the payloads thanks to monitor telemetry processing (HKTM) and performing the programming operations according to mission requirements. Programming frequency depends on mission requirements, the long duration onboard programming storage capability are used. Operations procedures are associated with each programming operation.

- Satellite expert appraisal

Satellite expert appraisal consists in leading investigations in case of anomalies, making out operations reports for experience feedback especially for PROTEUS platform changes. These investigations and reports are performed from archived monitoring telemetry data (HKTM) and various generated operational data (logbooks, telecommand logs, orbitography data).

### 7.3.2 FINAL ORBIT ACQUISITION PHASE

During this phase, the PGGS ensures the same functions as the ones performed during the station keeping phase :

satellite monitoring and technical control

satellite configuring

orbit and attitude controls

satellite expert appraisal.

Except for the payload service, this function is not applied or reduced to the strict minimum defined specifically for each mission.

However, the activities related to orbit and attitude controls are completed by manoeuvres intended to reach mission orbit. These calculations are optimised for each mission and result from the mission analysis.

During this phase, the satellite is supposed to be, in relation to its nominal transfer orbit, inside the covariance matrix relevant to the launcher retained for the mission. Outside of this specification, maximum efforts must be made to recover the satellite without however being committed to a result.

## 7.4 OPERATIONS CONCEPTS AND OPERATIONAL ORGANIZATION

The operations concepts result from the general requirements and use the following platform characteristics :

Requirements:

To be able to perform the operations imposed by the platform during working hours.

To be compatible with multiform mission ground segment organisations: CNES mission, mission in co-operation with other agencies, commercial or export missions.

To be compatible with highly varied mission programming needs: once or twice per day, several times per month.

To be modular to indifferently cover final orbit acquisition and station keeping needs.

Platform characteristics:

The platform is robust and able to protect itself from emergency case which occurs under 72 hours. This satellite autonomy avoids ground mechanisms which monitor satellite under 72 hours.

The following concepts have been retained:

The TTCET operates without operator and is controlled by the CCC.

The CCC operates with operators working non-stop for final orbit acquisition.

The CCC operates with operators working normal hours for station keeping.

For final orbit acquisition and station keeping, presence of an operator at the CCC is required only for transmitting telecommands and preparing operation sequencing.

The onboard and ground items can be monitored automatically from the CCC, an anomaly must call for operator intervention within a variable delay specific to each mission.

All the CCC functions, other than telecommand transmissions, can be activated in automatic or manual sequencing mode.

Generation of satellite commands is divided out and attributed to groups with independent responsibilities; there are three groups in all: the platform command generator group, the AOCS command generator group and the mission command generator group.

Satellite expert appraisal is decentralised from the CCC; it can be performed directly by the expert from his work station.

The state of the TTCET is controlled through the state of the TM data that it delivers; there is no need for station equipment monitoring.

Satellite state is monitored in deferred time at a daily frequency varying according to mission requirements: from "after each pass" to "at least once every 7 days".

A PGGS architecture and an operational organisation for final orbit acquisition and station keeping result from these operations concepts. The operational organisation presented is specific to CNES missions.

### 7.5 ARCHITECTURE

The PGGS is presented as a set of three basic components: the CCC, TTC-ET and DCN, to which various options are added, these options being:

1. TTC-ET station duplication.
2. Use of Angular Measurements obtained by the 2GHz stations for first acquisition.
3. Use of a 2GHz station with PROTEUS TM/TC kit during the final orbit acquisition phase to increase operational availability (Option proposed within the scope of final orbit acquisition performed by CNES).
4. Use of a 2GHz station with the PROTEUS TM/TC kit during routine phase in case of serious failure to the operational TTC-ET station (Option proposed within the scope of a CNES mission).

Each component is based on the assembly of elementary building blocks.

For the TTCET, the elementary building blocks are the following ones:

1. "Antenna/Tracking" part
2. "TM/TC Processing" part
3. "Time Frequency" part

Notice: part 2 can itself be broken down into two sub elements: the TM and the TC.

For the CCC, the elementary building blocks are teh following ones:

1. "Onboard/Ground" interface part
2. "Orbit and Attitude" part
3. "Archiving" part
4. "Consultation/Expert Appraisal" part
5. "Operations Automation" part

The DCN consists in various networks supporting the IP protocol.

The generic characteristic of the PGGS for the various missions is obtained by assembling components including all or part of their elementary building blocks and options.

For example:

The PROTEUS TM/TC kit added to a 2GHz station corresponds to the elementary building blocks 2 and 3 of the TTCET.

For a single satellite mission, the CCC consists in 5 elementary building blocks; for a mission including several satellites, building blocks 1 and 3 are duplicated.

### 7.5.1 BASIC ARCHITECTURE

Figure 7.5-1 shows the basic PGGS.

In this configuration, it meets the final orbit acquisition and station keeping requirements for a mission:

Compatible with an operational availability, excluding launch, of 0.93.

Multisatellites without need for simultaneous access to satellites.

Use of a launcher with launch positioning errors in DELTA class.

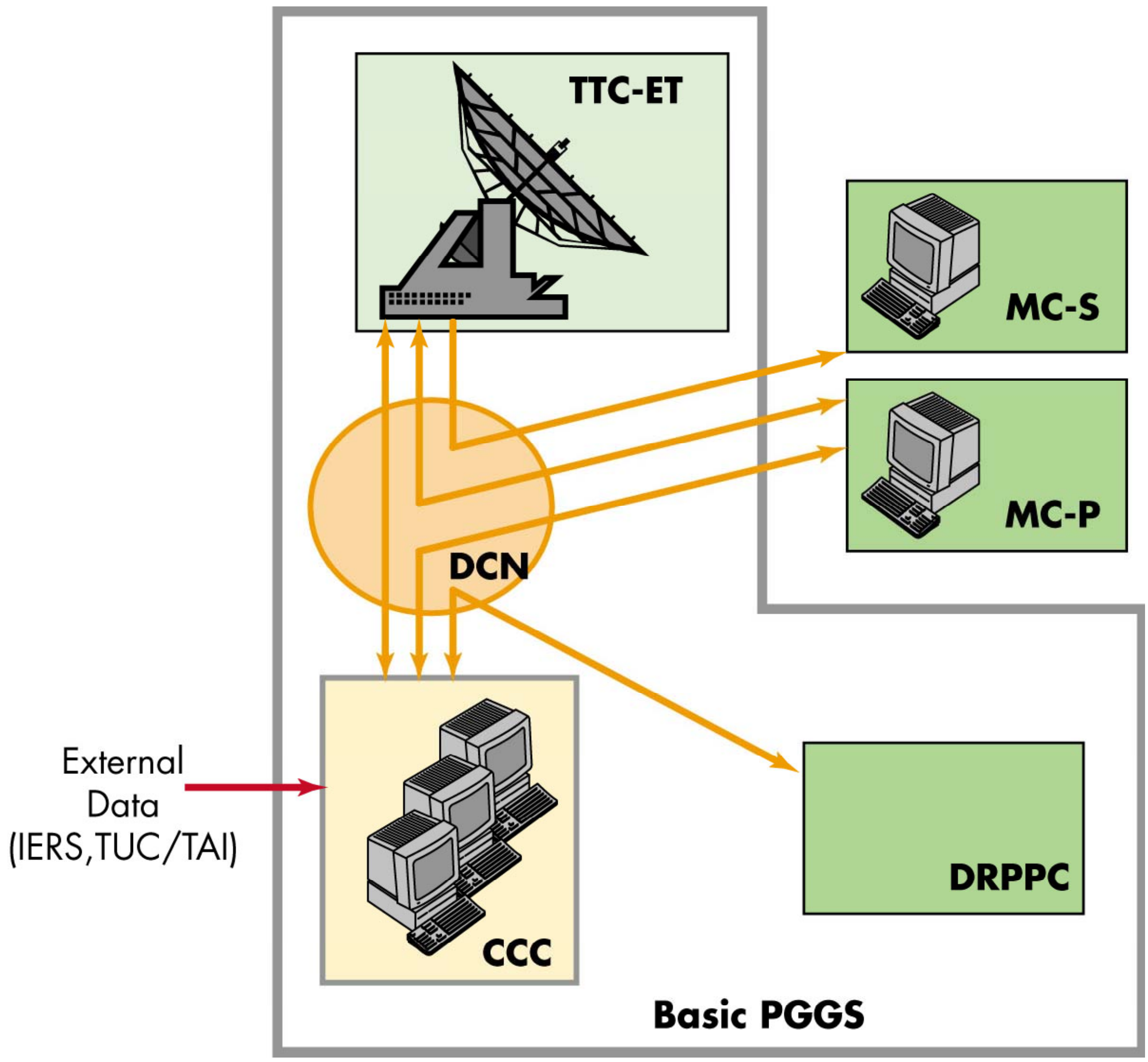


**Figure 7.5-1 : Basic PGGS diagram**

### 7.5.2 ARCHITECTURE WITH OPTIONS

Figure 7.5-2 shows the basic PGGS with its options. In this case, it meets the final orbit acquisition and station keeping requirements for a mission:

With operational availability requirements, excluding launch, better than 0.93.

Multisatellites.

Using all types of launchers identified for PROTEUS

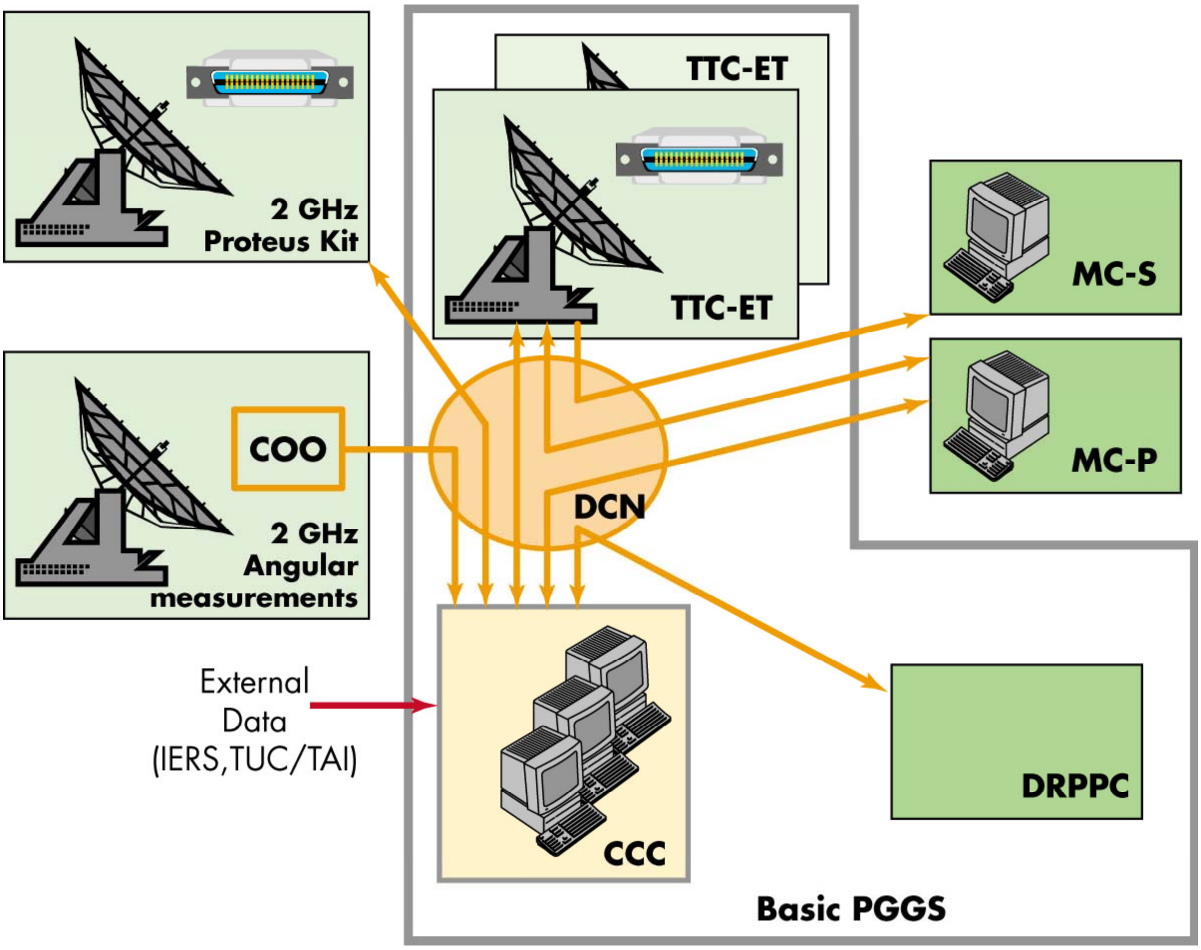


**Figure 7.5-2 : Diagram of PGGS with options**

### 7.5.3 SYSTEM TECHNICAL CHOICES FOR PGGS DEFINITION

- Communications protocol

The communications principle retained is "all IP" (UDP/IP or TCP/IP enabling file transfer (FTP), remote control (rlogin or telnet), remote execution (RPC) and real time transfer (socket stream or datagram).

To obtain IP communication protocol on WAN, we will interconnect the local network (Ethernet) of the Control Command Center (CCC) to the local network (Ethernet) of the station (TTC-ET) by a standard router via the WAN communication means retained for the mission.

The use of a standard router will enable us to more easily adapt to a later change in WAN communication means by simply replacing the router without modifying the CCC software or the TTC-ET.

-Exchange of telemetry data in server customer mode between CCC and TTC-ET and between MC and TTC-ET

In this mode, the TTC-ET, the recorded platform telemetry and payload telemetry data server and producer, places the data received, outside of the pass, at the disposal of the customers (CCC and MC). There is uncoupling between recorded platform telemetry or payload telemetry reception and its use by the customers. The customers take initiative for the exchange that they perform in accordance with their requirements. The real time telemetry is transmitted in real time to the CCC.

- CCC-SAT telecommand link in authenticated mode

The telecommands are segmented at the CCC and authenticated. Then all telecommand to onboard TC decoder are protected against intrusion.

- End-to-end telecommand retransmission protocol (CCC-SAT)

Transmission of telecommand segments is based on the COP1 protocol where the onboard automatism part is implemented in the onboard TC decoder, the ground automatism part is implemented in the CCC. Retransmission management covers the end-to-end link, from CCC work station to the onboard TC decoder output.

- Open loop antenna designation

The TTC-ET antenna is controlled by the designations calculated by the CCC. The simplification of the station equipment to comply with the cost reduction targets imposes this type of control mode.

- Interface with mission center

The PGGS receives the programming messages from a single mission center (MC-P). The programming messages are sets of ready-to-send TCs. Only segmentation and authentication are done by the PGGS.

- Multisatellite design

The PGGS software packages are established for a single satellite. Multisatellite implementation is achieved by duplicating the software on the same machine if operation is sequential or on different machines for simultaneous use.

### 7.5.4 COMMUNICATION ARCHITECTURE

The communication architecture is based on IP routers interfacable with the RNIC, the Integrated Services Digital Networks (ISDN), and dedicated lines (cf.Figure7.5-3).

The security of the information systems can be ensured in three ways:

by physical insulation of the IP network; this solution being well adapted to export use,

by use of PACTE,

or by use of a PGL.

The PACTE solution is adapted to CNES missions. The PGL solution, specific to PROTEUS, is the solution to be retained if mission operational availability constraints are not compatible with those of PACTE.

Data communication network (DCN) administration can be ensured in two ways:

by station integrated into the CCC; this solution is adapted to export use,

from one of the CNES network administration service stations for CNES missions.

The IP address range retained for a given mission will belong to the CNES address ranges for CNES missions.

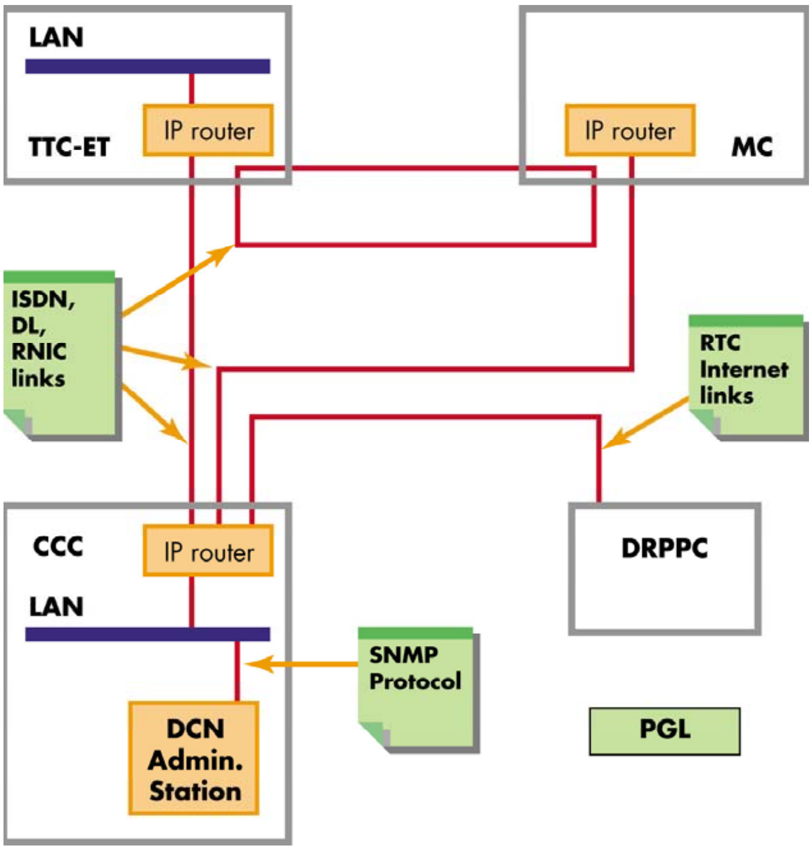


**Figure 7.5-3 : Communication architecture**

## 7.6 INTERFACES BETWEEN PGGS COMPONENTS

### 7.6.1 DIAGRAM AND LIST OF INTERFACES

The interfaces between the PGGS components are shown on Figure 7.6.1 and listed in details in Table 7.6-1.

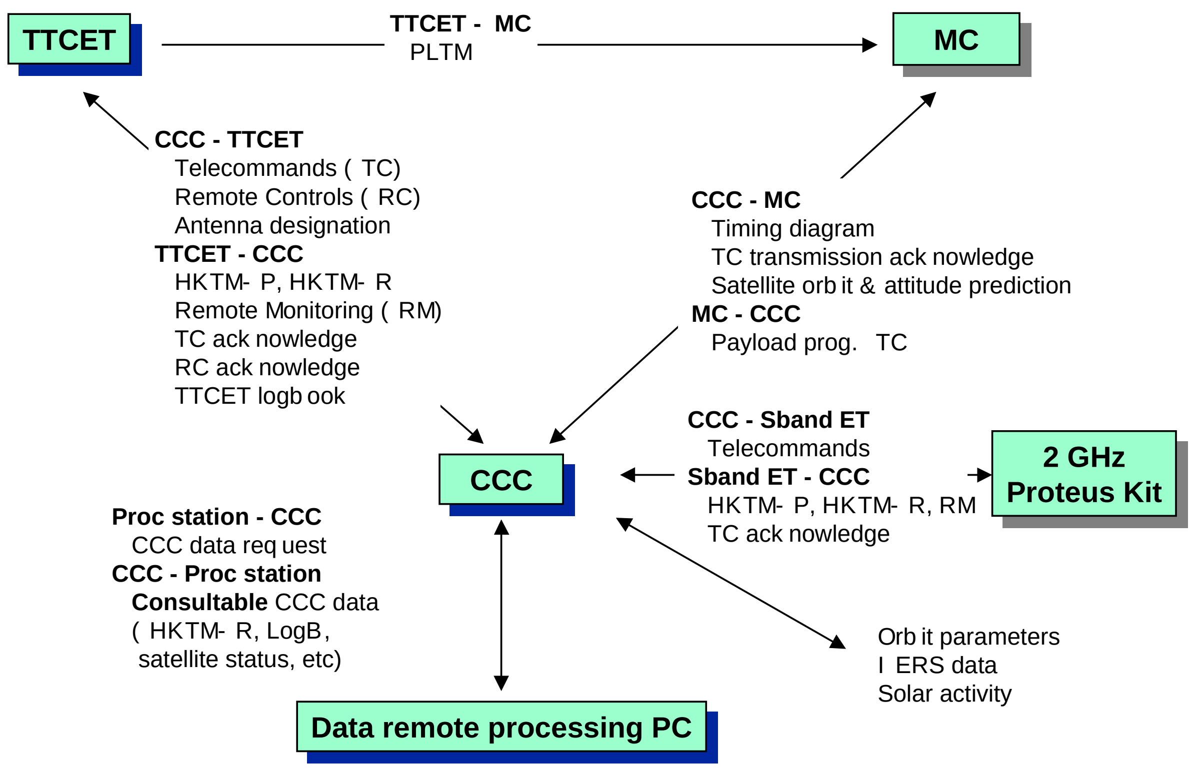


**Figure 7.6-1 : Interfaces between PGGS components**

| GENERIC NAME | ROLE |
|---|---|
| **CCC_MC_ORBIT_EVENTS** | **Timing diagram giving all predicted events related to the orbit, to station visibilities or to AOCS programming for orbit and attitude control** |
| **CCC_MC_PREDICTED_ATTITUDE** | **Predicted satellite attitude [orbit] elaborated by the CCC for x days duration** |
| **CCC_MC_PREDICTED_ORBIT** | **Predicted satellite orbit elaborated by the CCC for x days duration** |
| **CCC_MC_TC_LOGBOOK** | **Report of Payload TCs and Platform TCs transmitted by CCC to satellite** |
| CCC_OCC_ORBIT_PARAMETERS | Orbit parameters estimated by CCC and supplied to OCC (Orbit Computation Center) when recourse to CNES 2GHz network is required (acquisition on first orbits or survival). The OCC uses these parameters to calculate 2GHz network station designations |
| CCC_TTCET_PASS-PLANNING | Pass planning to be followed by TTCET sent by Main CCC |
| CCC_TTCET_POINTING | Antenna designations describing a pass of a visible satellite sent by the Main CCC to TTCET |
| CCC_TTCET_RC | All remote controls sent by Main CCC to TTCET |
| CCC_TTCET_TC | CLTU to CCSDS format containing the TCs sent by the Main CCC to TTCET |
| **MC_CCC_TCPL** | **Payload TCs sent by MC to CCC for mission programming** |
| OCC_CCC_IERS_DATA | Data delivered by IERS and transmitted to CCC via OCC |
| OCC_CCC_ORBIT_PARAMETERS | Orbit parameters delivered to CCC by OCC when recourse to CNES 2GHz network is required (acquisition on first orbits or survival) to locate the satellite (TTCET station designation accuracy insufficient). In this case, the OCC performs orbit determination from angular measurements and produces adjusted orbit parameters |
| OCC_CCC_SOLAR_ACTIVITY | Solar activity data delivered by the MEUDON observatory. Transmitted to CCC via OCC |
| TTCET_CCC_ACQRC | CCSDS Packets containing TTCET RC reception acknowledgments |
| TTCET_CCC_CLCW | CCSDS Packets containing the CLCWs extracted from TM frames and transmitted in real time by TTCET to Main CCC |
| TTCET_CCC_HKTMP | CCSDS Packets of real time telemetry transmitted in real time by TTCET to CCC (Main CCC and/or Secondary CCC) |
| TTCET_CCC_HKTMR | Files containing CCSDS packets of HKTM-R stored in TTCET |
| TTCET_CCC_LOGBOOK | Station logbook |
| TTCET_CCC_RM | CCSDS Packets containing TTCET remote monitoring information |
| **TTCET_MC_PLTM** | **Files containing payload telemetry stored in TTCET** |

**Table 7.6-1 : PGGS interfaces and their functions**

### 7.6.2 OPERATING MODES

#### 7.6.2.1 Telemetry processing operating mode

In TTCET

TM reception at station

Separation of TM flows

Transmission of pass TM to CCC in real time (HKTM-P)

Local storage of recorded TM (HKTM-R) in station and making available to CCC for 72 hours.

Local storage of payload TM (PLTM) in station and making available to Mission Centers (MC) for 72 hours.

In CCC

Reception, demultiplexing for TC function and transmission of real time telemetry to DRPPC in real time

Recovery of recorded plat-form telemetry after pass for archiving and processing (satellite monitoring, satellite state generation and orbit calculation).

In MCs

Specific mission processing operations

#### 7.6.2.2 Telecommand processing operating mode

In CCC

Elaboration of platform TCs and AOCS TCs.

Recovery of ready-to-send mission TCs from MC.

Authentication and Transmission of TCs to satellite with satellite current state checks.

In main MC

Elaboration of mission programming TCs

In TTCET

Setting up of onboard-ground link on CCC request.

Transmission of TCs to satellite.

Real-time transmission of TC acknowledgements received by satellite to CCC.

#### 7.6.2.3 TTCET station management processing operating mode

In CCC

Transmission of remote controls (RC) to TTCET to change TM digital rate, start and end of TC session, change of TC transmission polarization.

Reception of RC acknowledgement after each transmission.

Transmission of antenna designations and pass management at least every 72 h (12h for orbits at altitudes lower than 600 km).

Transmission of a station long loop test for diagnosis in case of CCC-Satellite link failure.

#### 7.6.2.4 CCC-Mission Center interface operating mode

From CCC

Transmission of event timing diagram related to orbit, station visibilities and station programming after orbit determination.

Transmission of TC transmission report after onboard loading.

Recovery of MC mission TCs at mission frequency.

#### 7.6.2.5 Angular measurement and 2GHz KIT option operating mode

At OCC for MA option

Elaboration of orbit parameters from MAs

Transmission of orbit parameters to CCC

At CCC for 2GHz KIT option

Elaboration of orbit parameters

Transmission of orbit parameters to OCC

At OCC

Elaboration of station designation with KIT

## 7.7 PERFORMANCE

### 7.7.1 PGGS MONOSATELLITE PERFORMANCE

Telemetry processing:

Once set up, the end-to-end link ensures a maximum telemetry frame loss rate of $10^{-8}$

Recovery at TTC-ET of recorded TM (HKTM-R) over one day (40Mb) in less than 16 minutes during pass on 40 Kbs channel.

Access by CCC to recorded TM (HKTM-R) of one day, stored at TTCET in less than 15 minutes outside pass on a 64 Kbs link between CCC and TTC-ET.

Telecommand processing:

The end-to-end link, once set up, ensures a telecommand frame rejection probability lower than 10-5.

The end-to-end link is protected by authentication guaranteeing probability of a successful attack (recognition of telecommand profile) lower than $10^{-12}$.

Maximum rate is fixed by the capacity of the Satellite/TTC-ET link, that is 4Kbs.

Designation:

- The accuracy of TTC-ET designation, all causes combined (station and designation accuracy) enables complete autonomy of TTC-ET greater than 72H for all orbits with an altitude higher than 600 km, a minimum autonomy of 12H for orbits between 500 and 600 Km.
- The accuracy of the designation data calculation (three-sigma angle) delivered by the CCC is guaranteed as better than:

± 0.3 deg over 72H for orbits of altitude > 1000 km,

± 0.5 deg over 72H for orbits of altitude between 800 and 1000 km,

± 0.7 deg over 72H for orbits of altitude between 600 and 800 km,

± 1 deg over 12H for orbits of altitude between 500 and 600 km.

Operational availability:

During the first 24 hours of final orbit acquisition PGGS availability is better than 0.97.

Maximum repair time is 12 hours for simple failures with equipment in stock

After the first 24 hours, PGGS availability is better than 0.93.

Maximum repair time is 72 hours for simple failures with equipment in stock

### 7.7.2 PGGS MULTISATELLITE PERFORMANCE

Same performance is guaranteed for multisatellite configurations with following constraints:

With a one TTC-ET configuration, two successive visibilities must be separated by at least 5 min.

Access time by CCC to recorded telemetry (HKTM-R) of one day, stored in TTCET, will be complied with outside pass time of any one of the satellites.

## 7.8 CNES OPERATIONAL ORGANIZATION

Figure7.8-1 indicates the relations between PGGS components and CNES multimission items.

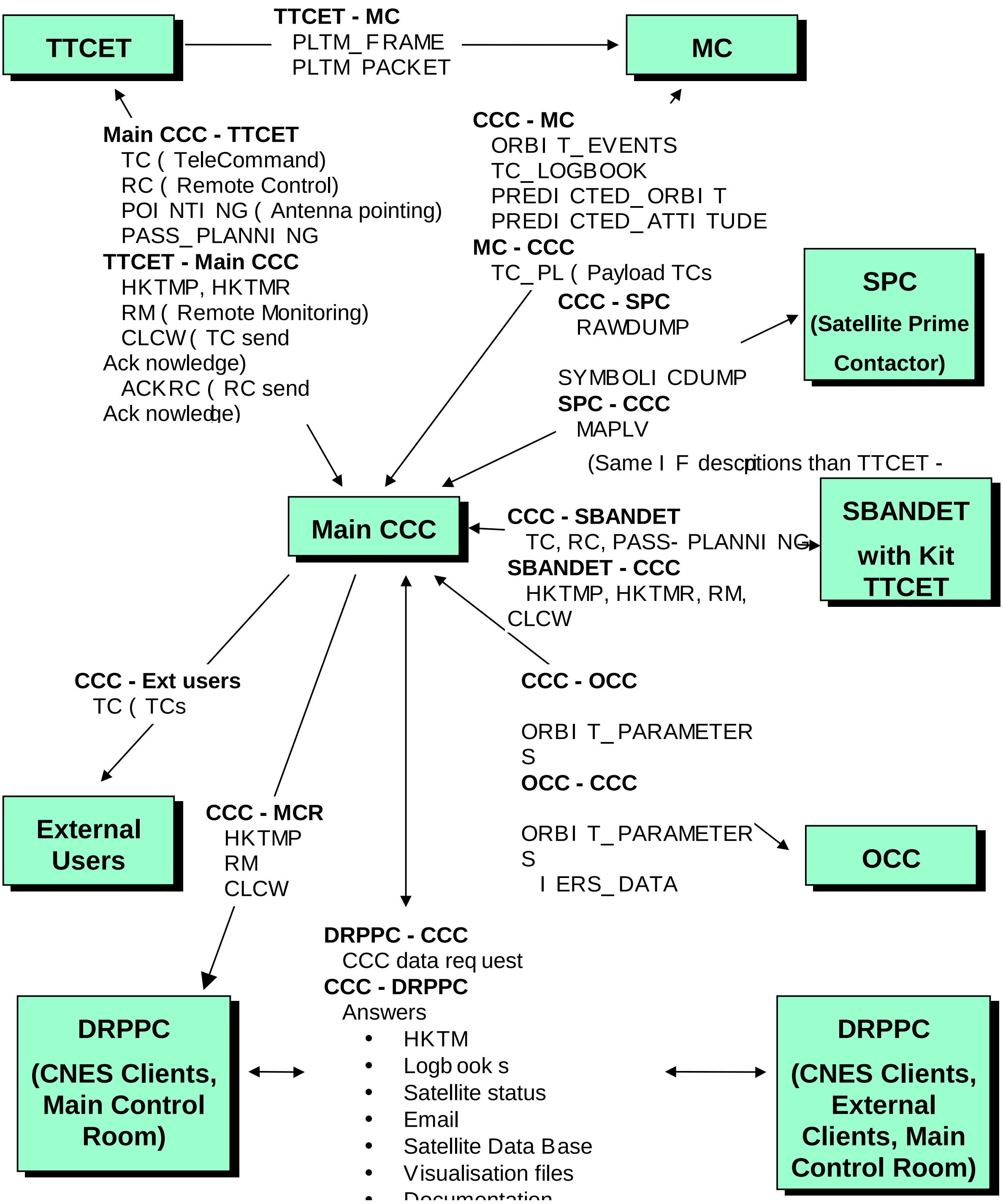


**Figure 7.8-1 : Relations between PGGS components and CNES multimission items**

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### 7.8.1 OPERATIONAL ORGANIZATION FOR STATION KEEPING

The platform design permits the following standard organisation for station keeping :

an operator station which performs all daily operational tasks during working hours,

a mission onboard-ground team (one or two engineers),

Data Communications Network monitoring performed during working hours by the network department.

The operator station is in charge of:

preparing the task sequencer work plan,

preparing platform telecommands,

transmitting platform, AOCS telecommands and telecommands received by Mission Centre,

monitoring Command Contrôle Centre data.

The mission onboard-ground team is in charge of:

analysing satellite operation,

optimising operation,

correction of anomalies.

However for the mission availability, two other organisation types are conceivable:

1. An organisation bases on the standard one but complemented by a hot line service TBD hours-a-day using:

the remote call function,

the Data Remote Processing Personal Computer.

2. If the previous organisation types do not meet scientific, preoperational or operational mission requirements (for example Jason 1 is a mission with 24 hours-a-day operations), a specific organisation shall be defined according to the mission needs.

### 7.8.2 OPERATIONAL ORGANIZATION FOR FINAL ORBIT ACQUISITION

For final orbit acquisition, operations are ensured non-stop.

The station keeping organisation is complemented by:

a corresponding Operational Computation Center (OCC) and Network Operations Center to handle MA processing, 2GHz station designation with PROTEUS KIT if these options are retained for the mission,

5 to 6 stations in Main Control Room for satellite experts.

END OF CHAPTER