The SILEX experiment system operations

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ABSTRACT

The European Space Agency is going to conduct an inter orbit link experiment which will connect a low Earth orbiting satellite and a Geostationary satellite via optical terminals. This experiment has been called SILEX (Semiconductor Inter satellite Link EXperiment). Two payloads will be built. One called PASTEL (PASsager de TELecommunication) will be embarked on the French Earth observation satellite SPOT4. The future European experimental data relay satellite ARTEMIS (Advanced Relay and TEchnology MISsion) will carry the OPALE terminal (Optical PAyload Experiment).

The principal characteristic of the mission is a 50 Megabits flow of data transmitted via the optical satellite link. The relay satellite will route the data via its feeder link thus permitting a real time reception in the European region of images taken by the observation satellite. The PASTEL terminal has been designed to cover up to 9 communication sessions per day with an average of 5. The number of daily contact opportunities with the low earth orbiting satellite will be increased and the duration will be much longer than the traditional passes over a ground station. The terminals have an autonomy of 24 hours with respect to ground control. Each terminal will contain its own orbit model and that of its counter terminal for orbit prediction and for precise computation of pointing direction. Due to the very narrow field of view of the communication laser beam, the orbit propagation calculation needs to be done with a very high accuracy.

The European Space Agency is responsible for the operation of both terminals. A PASTEL Mission Control System (PMCS) is being developed to control the PASTEL terminal on board SPOT4. The PMCS will interface with the SPOT4 Control Centre for the execution of the PASTEL operations. The PMCS will also interface with the ARTEMIS Mission Control System for the planning and the coordination of the operation. It is the first time that laser technology will be used to support inter-satellite links in Europe. Due to the complexity and experimental character of this new optical technology, the SILEX experiment control facilities will be designed to allow as much operational flexibility as possible.

INTRODUCTION

The European Space Agency (ESA) has initiated the SILEX experiment to test the optical technology for intersatellite communications. This experiment will provide a high data rate Inter-Orbit Link (IOL) between the low earth orbiting terminal (called PASTEL) mounted on the French SPOT4 earth observation satellite and the geostationary terminal embarked on the ARTEMIS data relay satellite. The launches of these two satellites are currently foreseen in 1997. ESA in collaboration with CNES (the French space agency) has setup a ground segment to control the experiment.

SILEX MISSION CHARACTERISTICS

The optical terminals involved in the SILEX experiment have been designed such that the following system specifications can be respected. The link capacity can transmit 50 Mbps of useful data from the SPOT4 satellite to be relayed by ARTEMIS via its feeder link to the ground image receive station. The wavelength range is 800 to 850 nm. The optical power shall not exceed 60 mWatts during the communication period and 500 mWatts for the beacon required on the LEO terminal during the acquisition and the link establishment. The routine link acquisition shall not require more than 150 seconds with a success probability of 95 %. The terminal shall have an autonomy of 24 hours with respect to the ground control. The terminal has its own computer and software to provide on board monitoring and control of its equipment such that it will be able to reconfigure itself in a safe mode in case of anomaly in order not to interfere with the SPOT4 satellite. The PASTEL terminal is located on the non-earth facing panel of SPOT4 and the OPALE terminal is located on the earth facing panel of ARTEMIS. The current design of the optical link foresees up to 9 communication sessions per day between the two satellites with an average of 5 per day. Figure 1 shows the available visibility area which allows optical terminal communications between the SPOT4 satellite and the ARTEMIS satellite located at 16.4 deg. East. Some constraints need to be taken into account for the definition of the visibility area such as the mounting of the PASTEL terminal on SPOT 4 and its limitation in angular speed. Figure 2 gives a sample for one day of possible contact between the two optical terminals during the SPOT4 satellite day time.

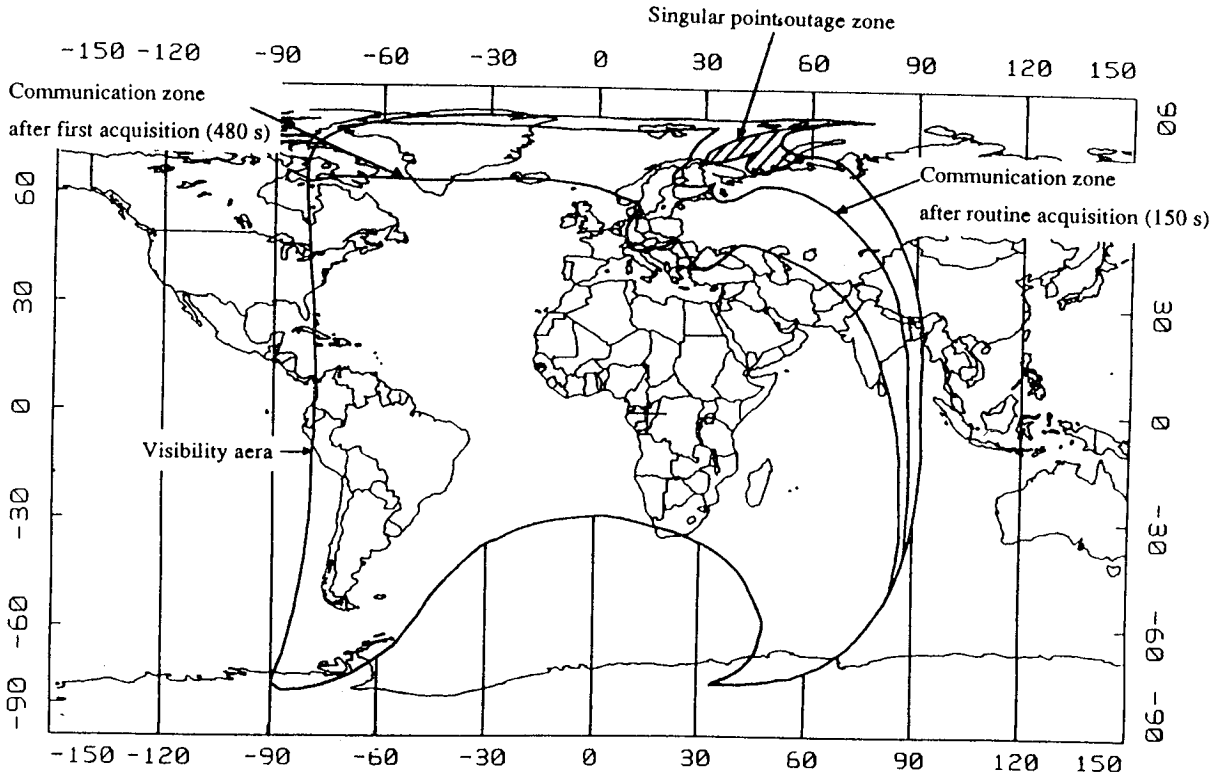

Figure 1: Optical visibility between SPOT4 and ARTEMIS

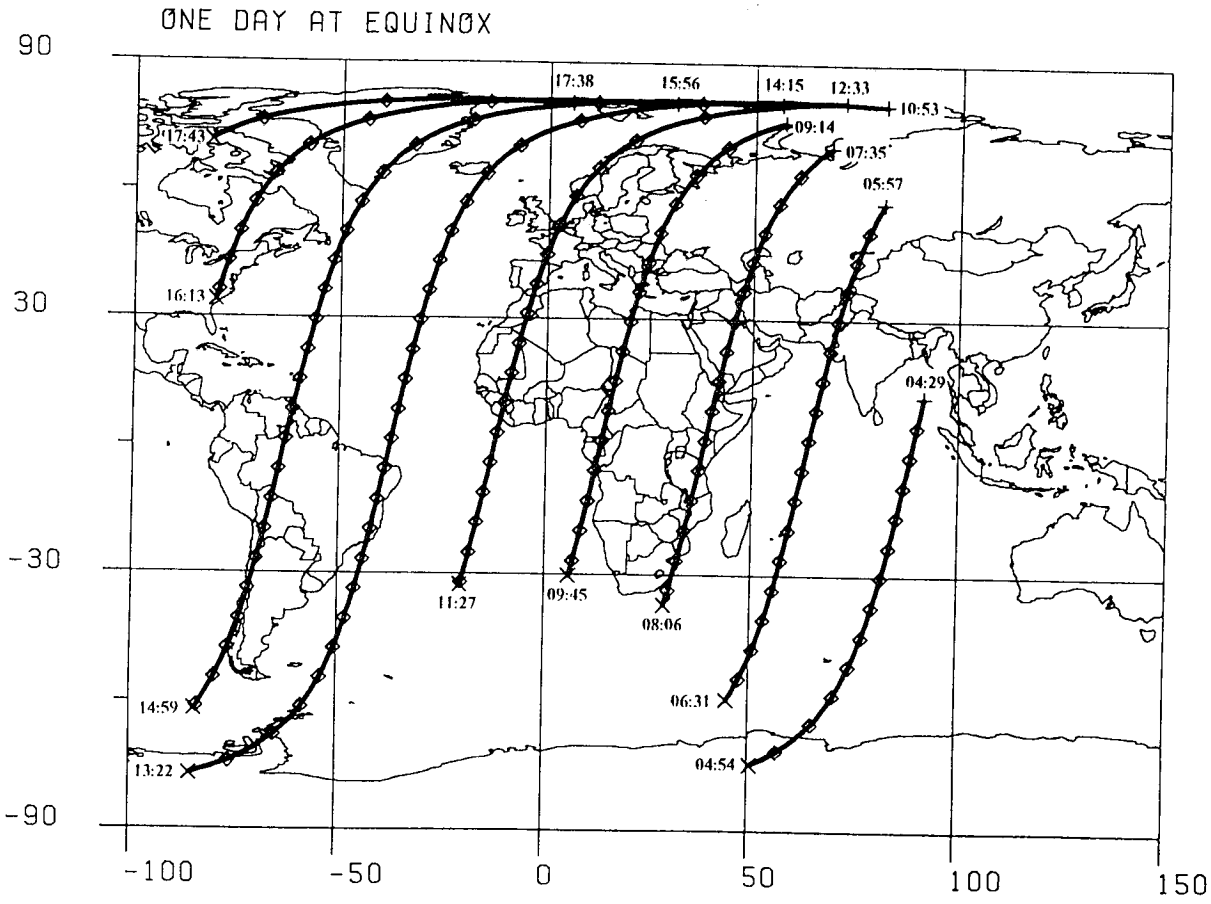

Figure 2 : Visibility between PASTEL and OPALE at Equinox during SPOT4 day time.

OVERALL GROUND AND SPACE SEGMENT

Figure 3 is an overview of the ground segment involved in the SILEX experiment. One part of the ground segment is under the control of ESA and the second is the responsibility of CNES. ESA is responsible for the operations of the PASTEL mission control system located in Redu (Belgium), the ARTEMIS mission control system located in Italy which controls the ARTEMIS spacecraft via the Tracking, Telemetry and Command (TTC) antenna and the Payload test facilities to monitor and check the ARTEMIS payload (PTL/IOT). CNES is responsible for the control and monitoring of the SPOT4 satellite from its control centre (CMP) located in Toulouse (France) connected to its S-band control station network and for the reception of the images taken by the SPOT4 satellite via either the ARTEMIS feeder link on the SRIP station or directly from the SPOT4 satellite when in visibility of the SRIP station. CNES is also coordinating the SPOT4 mission with its commercial operator for the scheduling of the image recordings. ESA is responsible for the operations of the two optical terminals PASTEL, on board SPOT4, and OPALE on board ARTEMIS. For the control and monitoring of the PASTEL terminal, ESA and CNES have setup an interface to exchange all the data needed for the terminal control and scheduling of PASTEL usage.

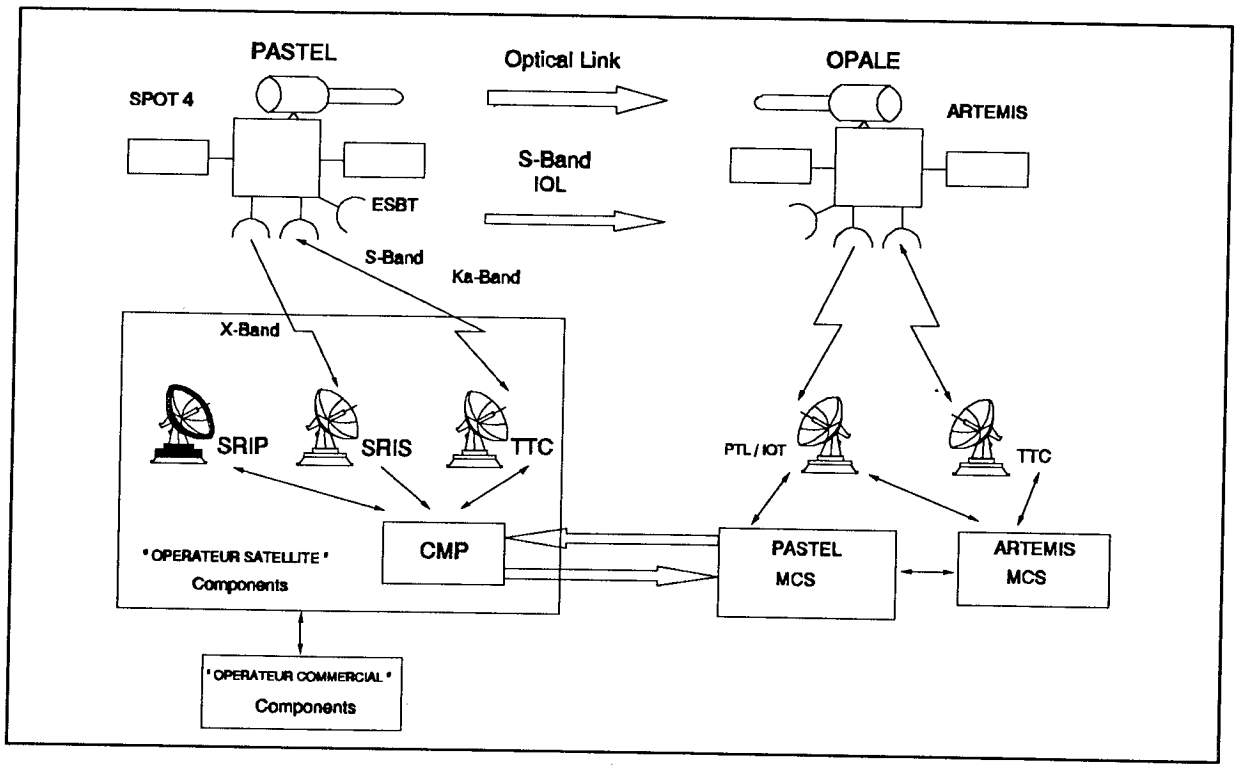

Figure 3: SILEX Experiment Ground Segment

OPTICAL TERMINAL OPERATIONS CONCEPT

The OPALE terminal is controlled from the ARTEMIS mission control system in Italy and the PASTEL terminal is controlled from the PASTEL mission control system in Belgium via the SPOT4 control centre (CMP) located in France. This constraint has led to the following operations concept for PASTEL:

* The PASTEL Telemetry and Telecommand interface function is accomplished by the SPOT4 TTC subsystem via CNES ground stations and SPOT4 control centre.
* The PASTEL routine operations are conducted from the PASTEL mission control system in an off-line manner.
* For PASTEL monitoring, the full SPOT4 raw telemetry is provided to the PMCS about 30 minutes after each pass of SPOT4 over one of its ground stations.
* For PASTEL commanding, telecomand files are generated by the PMCS and sent to the SPOT4 control centre by 1800 hours every day to be ready for an uplink on an evening pass of SPOT4 over the Aussaguel station located near Toulouse.
* Two categories of telecommand are foreseen. The first TC type is that executed directly by the SPOT4 on board computer to activate the PASTEL terminal. The second TC type is that transferred by the SPOT4 on board computer to the PASTEL on board computer which will execute it to control the terminal. The first category of TC is not directly coded into a binary format by the PMCS. These TCs are translated using a pseudo language for security reason and sent within TC files from the PMCS to the CMP which manually inserts them in their next TC uplink plan. The second category of TC is directly coded in binary format by the PMCS and sent to the SPOT control centre which will encapsulate them in the TC uplink format of SPOT4 after checking that they are addressed to PASTEL and not to another payload of SPOT4.
* In addition to the TM/TC files, scheduling information for the planning of PASTEL and OPALE usage will be exchanged on a well defined scenario between the SPOT4 CMP, the ARTEMIS mission control system and the PASTEL mission control system
* On top of the routine operations foreseen for PASTEL and OPALE , contingency scenarios have been defined between the two control centres such that the outage of the optical link between the two satellites can be minimised.

PASTEL MISSION CONTROL SYSTEM

The PASTEL mission control system is fully responsible for the operations of the PASTEL terminal and the scheduling of the OPALE terminal. This centre is interfacing with the ARTEMIS control centre for the operations of the OPALE payload and with CNES for the operations of the PASTEL terminal on board SPOT4. As the optical terminal operations require an orbit determination accuracy such that both terminals know the position of the other to be able to establish the optical link, the interface between the SPOT4 CMP and the PASTEL mission control has been designed to ensure that the daily flow of information needed for the optical link operations is exchanged in a minimum of time. Figure 4 gives an overall view of the PMCS components.

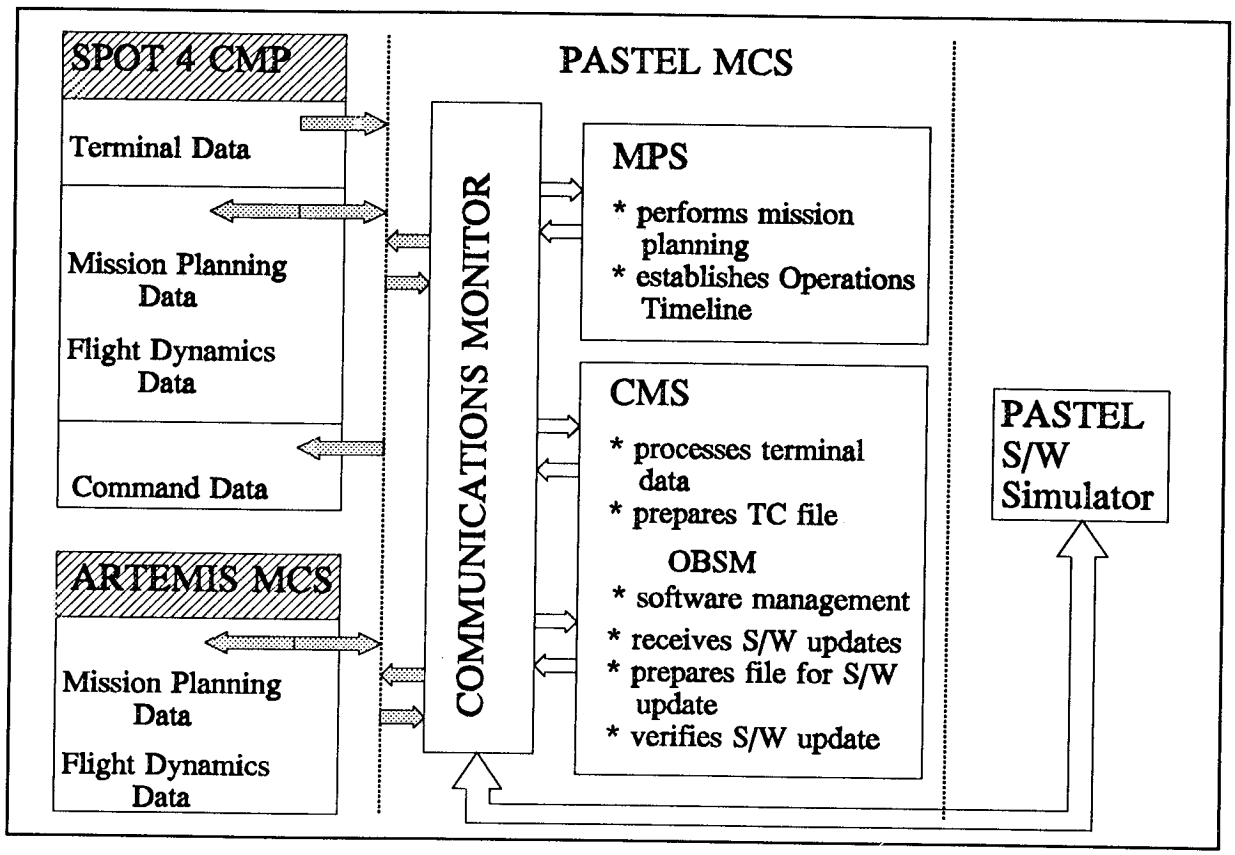

Figure 4: PASTEL MCS Configuration

The PASTEL mission control system includes the following elements :

- The Communication Monitor which controls and monitors all the files exchanged between the SPOT4 control centre, the ARTEMIS mission control system and the PASTEL mission control system. This Communication Monitor normally works automatically but for special situations such as communication network degradation or a switch to the back up PMCS or CMP computers, it can be operated manually.
- The PASTEL Mission Planning System (MPS) will provide all the functions needed to plan the execution of the optical link operation. This system will plan and coordinate with CNES and the ARTEMIS mission control system the usage of the optical link several weeks in advance. One week before the operations, the detailed operations timeline to be executed by the ARTEMIS and PASTEL mission control systems is issued.
- The PASTEL control and monitoring system (CMS) will include all the functions needed for the in orbit operations of the PASTEL terminal on board of SPOT4. The CMS will process the SPOT4 telemetry related to the PASTEL terminal. It will generate the TC request file on a daily basis based on the operations timeline provided by the MPS. The CMS will also include the on board software management system (OBSM) for the management of the software loaded into the PASTEL computer. The OBSM will be able to receive new releases of the on board software from the manufacturer and to generate the appropriate telecommands to update the PASTEL on board software. The OBSM will also receive dumps of the on board software such that correct loading can be verified.
- A PASTEL software simulator has been attached to the PMCS to allow the PMCS to validate new operational procedures for PASTEL or to validate any new PMCS software release without the need of the SPOT4 CMP.

CONCLUSIONS :

The European Space Agency has initiated the development and operation of the first European free space optical communications system. The demonstration of optical technology in space will be proved by the SILEX experiment and the European Space Agency is conducting further research to minimise the weight of optical terminals and to improve their performance. The SILEX experiment is still under development with launch dates foreseen in 1997 for the two satellites (ARTEMIS and SPOT4) with their optical terminals.