

The new CNES station scheduling system: both an operational and simulation tool

Damien Servant¹ and Isabelle Hernandez Marcelin.²
CNES, 31401 Toulouse, France

Patrick Charlot³
CNES, 31401 Toulouse, France

With the increasing number of satellites and the anticipated cross utilization of the various CNES ground networks by several of them, the need arose of a global network management and a centralized scheduling system tool to replace the existing ones: the “Outil Central de Planification” (OCP). Its main objective is first to perform station and other multi-mission resource allocation and then scheduling management in case of modifications.

The paper will first provide an overview of the OCP system. It will then focus on the combining of long term reservations and short notice modifications, or for mixing an operational system with a simulation tool. The conclusion will include lessons learned and recommendations to developers and users of similar systems.

I. Introduction

A. CNES scheduling before OCP

Until the implementation of the OCP project, the CNES missions were scheduled by a set of three specific softwares to cover the station allocations and then the aggregation of the schedules. The process was heterogeneous: the scheduling was performed sequentially depending on a mission order without the global research of an optimal solution. Conflicts were then manually resolved by the scheduling office. Moreover depending on the historical use of the stations, a part of the ground network was only scheduled in a dedicated software.

With the CNES network supporting 20 satellites over 16 stations in routine operations, this approach was reaching its limits. In order to efficiently manage an increasing number of satellites, stations and cross-supports, a new optimized system was called for.

B. Need for a new system

The OCP implementation sought to meet the following objectives:

- Cope with the increasing number of satellites and stations by automating the main scheduling activities,
- Harmonize the scheduling process by a global management of the full network,
- Optimize the utilization of human resources by centralising the scheduling coordination,
- Reduce operation costs of missions,
- Ease the interoperability between CNES and external ground networks
- Prepare new missions by simulating their network allocation,
- Simulate evolution or modification of the network.

¹ Ground Network Manager, “Network & Operational Supports” DCT/OP/SR, Damien.Servant@cnes.fr .

² Ground Network Manager, “Network & Operational Supports” DCT/OP/SR, Isabelle.Hernandez-Marcelin@cnes.fr .

³ Technical System Manager, “Network Systems Support and Maintenance” DCT/OP/MR, Patrick.Charlot@cnes.fr

C. The “Outil Central de Planification” (OCP) software

The OCP was developed on a client/server architecture linked to a central database. The client is developed in java to run on a PC/Linux computer and is accessible through an internet webpage. The system used a redundant infrastructure to guarantee a high level of availability. The automation of scheduling activities is performed by a commercial constraint resources allocation solver, IBM Ilog Solver, which is adapted to the satellite network context.

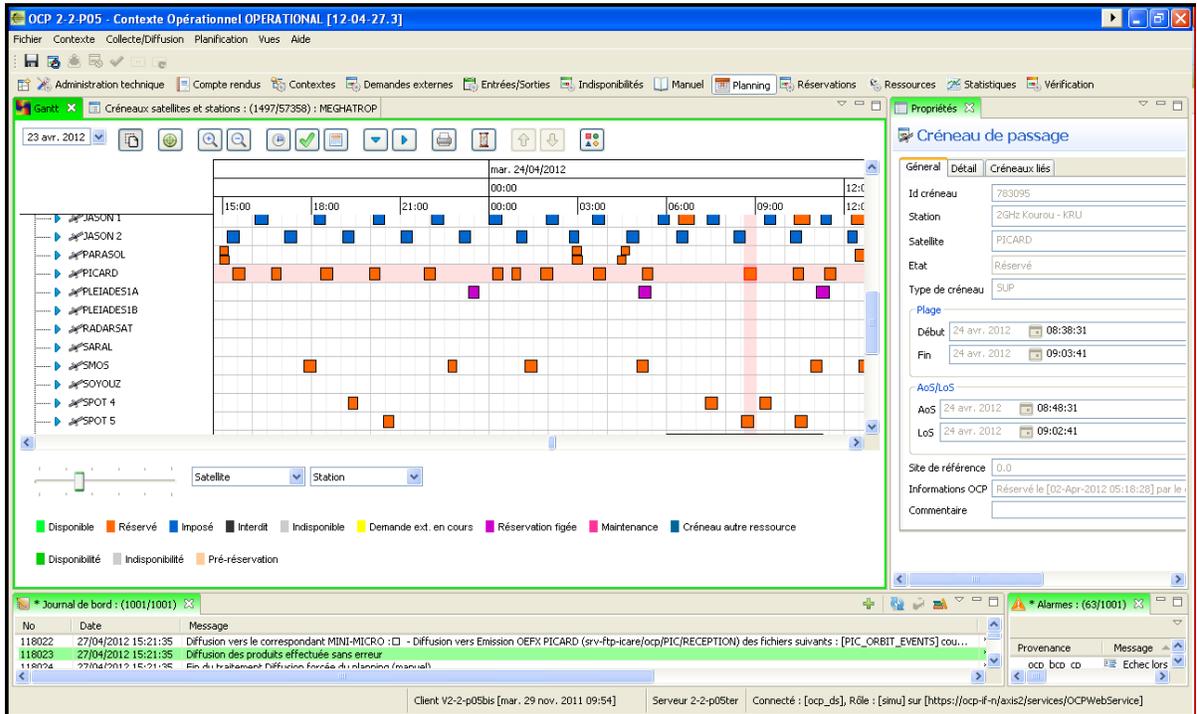


Figure 1. A view of OCP GUI.

II. Station allocation process

The station allocation can be divided into two asynchronous processes:

- A predictable scheduling based on the mission rules. The automation will elaborate the routine planning a few weeks ahead.
- An event triggered scheduling due to extra requirements, adjustments of the current planning, LEOP station allocation,... This can happen up to few hours before the pass. These adjustments can be received from CNES user or from external entities.

The scheduling process will use source data from Orbit Computation Center (OCC) as input: ground visibilities, satellite interference and potential visibility masks.

After station allocation for the short and long terms, the scheduling office is responsible for solving conflicts, checking the mission rules against the new schedule and issuing the validated schedule to all entities. This validated context contains the full 4 weeks schedule allocated automatically by the solver and manually by CNES missions, external entities and the scheduling office operator.

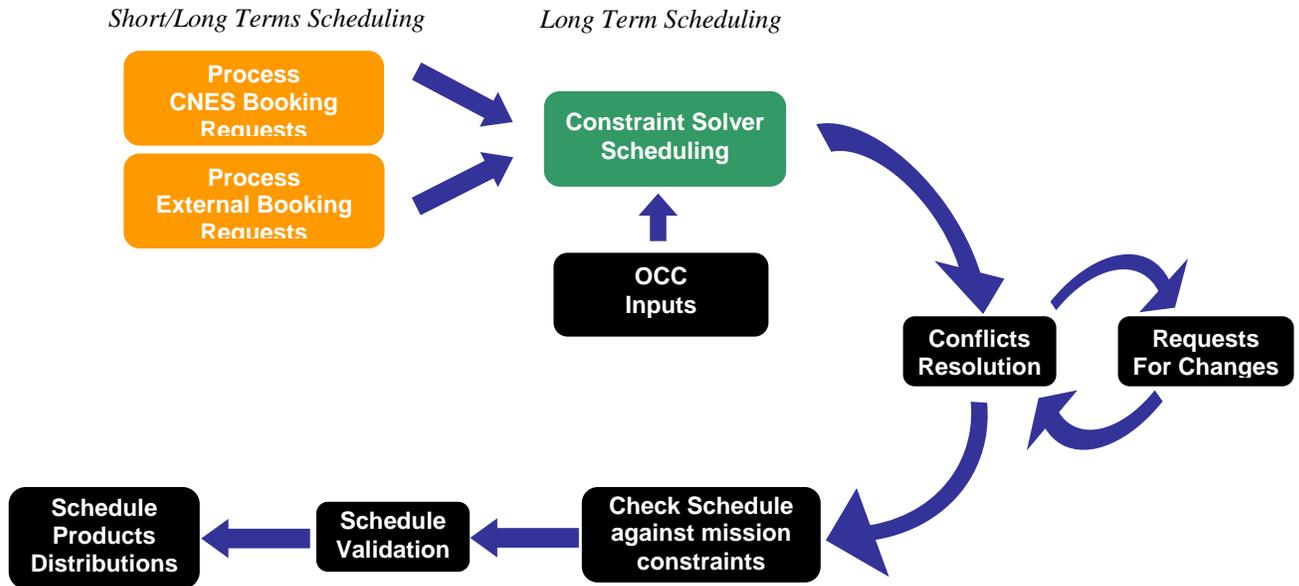


Figure 2. Overall scheduling process.

A. Long term scheduling by the constraint solver

The algorithm to elaborate the long term schedule is based on the constraint programming concepts using IBM ILOG Solver.

Each satellite is defined in the system by its mission requirement rules to generate the routine planning. The constraints from missions are a combination of one or multiple rules amongst the following:

- Minimum or maximum number of slots per period of time over a stations group
- Minimum duration of a slot over a certain elevation
- Station priority for this mission
- Minimum or maximum interval between two booked slots
- Minimum or maximum cumulated slot duration over a one day period
- Maximum number of simultaneous slots during a period of time for a set of satellites

These constraints cover different types of missions that have very different needs. Two constraints can be combined to describe a more complex requirement: for instance, 80 minutes of ground contact over a day with at least 2 hours between each slot.

In addition, OCP defines the stations capabilities by ground requirements rules:

- Maximum number or cumulated duration of supports per day
- Satellites priority over the station
- Daily or weekly maintenance duration

Each week and with a planning over the 4 weeks ahead, OCP takes into account all constraints and searches for a global solution which fulfils all mission and station requirements.

Three sets of constraint levels are defined for each satellite and station: nominal, reduced and minimal. If the solver is not able to find a solution with the nominal set, it can be automatically restarted with a lower level for all missions or manually by selecting the applicable constraint level for each satellite.

Results are then stored in a central data base and can be retrieved by all of the connected clients.

B. Short term schedule

Answering also the requirements for short notice modifications of the schedule, the OCP provides interactive interfaces with each user facility (control or mission centre) via a specific client which allows the users to display their planning and the available supports and to make adjustments or additional reservations.

Up to a few hours before the pass, the schedule can be modified to integrate the new requirements. If the time slot is available it will be directly scheduled. Otherwise, when a conflict has to be resolved the notice has to be extended in order to have time to negotiate with the other mission.

Before issuing the results to all entities, the planning is checked against the station conflicts and the mission rules to validate the combination of long term schedule and short term adjustments. The scheduling operator can accept or reject the user requests depending on the result. This consistency report will then be available to user facilities.

C. Interfaces to OCP

Using bidirectional interfaces, internal and external users can request for modification of the station allocation or be informed of the new schedule.

1) Internal interfaces

In the CNES environment, OCP uses two communication channels between the server and the users:

- Webservices are implemented between the client and the server for user interactions. Users can request extra pass or adjustments of the schedule. These requests are displayed in real time on the scheduling operator client. In other direction, operator can inform users about their request status, ground station unavailability or a new schedule issue.
- Planning products (internal event mission files and schedules) are transferred via FTP or email to human users and mission systems.

2) External interfaces

Ad hoc interfaces are planned in order to cope with the need for increased ground network requirements in specific satellite mission phases or with demands of interagency supported missions.

File formats are described to allow:

- The scheduling of external ground stations from CNES users. Waiting for the answer from the external network, the time slot will be kept in a pending state.
- The scheduling of CNES stations from external control centers. After validation by the scheduling operator, the request will be combined with the existing short and long terms allocations.

Each request file is linked to an answer file to accept or reject a booking.

Theses interfaces allow antenna sharing within station partnership, booking of external ground stations during LEOP, routine cross support for interagency cooperation,...

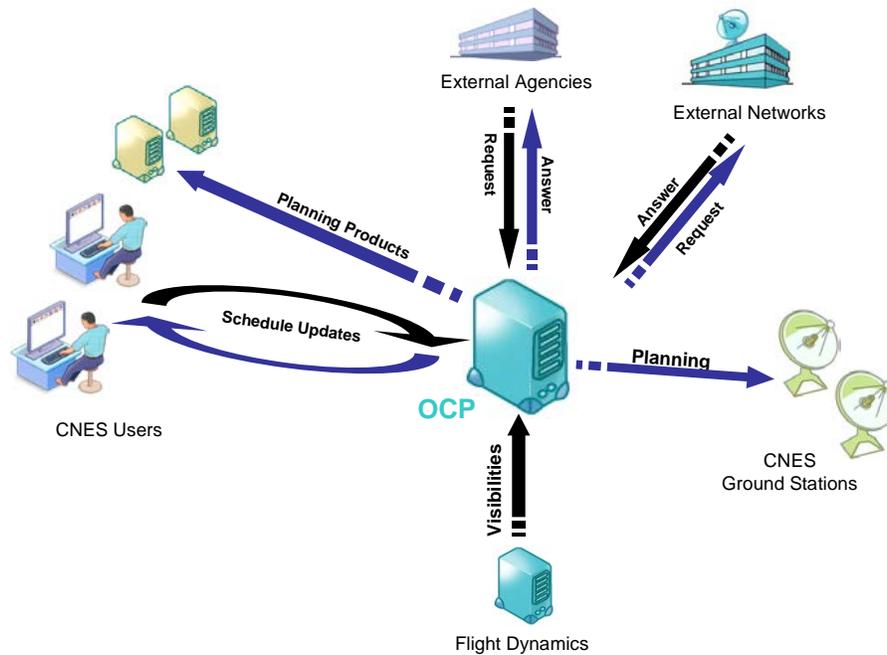


Figure 3. OCP in its operational context.

III. Simulation

In addition, based on the same long term schedule algorithm, the OCP provides features for simulations and analysis of various operational contexts: ground network loading, management of planned station maintenance, addition of a future mission in the network, launch postponement scenarios, etc...

The simulation environment can be generated from an operational context. By exporting the current context, the user can benefit from all mission models and ground station characteristics to simulate modifications of the ground network. The simulation context can also be built up from scratch by using the embedded visibility generator with satellite orbit bulletins or simulated data from flight dynamics.

The same capabilities are available in simulation as in operations and don't interfere with the operational OCP environment. Using their own context, missions can simulate the full scheduling loop up to the generation of planning products in simulation spaces. Using this independent context, missions can also simulate new constraints sets before integrating them in the operational environment.

This simulation part of OCP allows the anticipation of ground network evolution. For instance, the heat map shown below, depicts the routine workload at the CNES network operation center during the last months of the year 2012. It has been generated from the operational context, by removing the next deorbited satellites, adding the mission model of the next launch and extrapolating the scheduling of the routine missions to the end of the year. This simulation allows anticipating future staffing needs at NOC during specific times of the day.

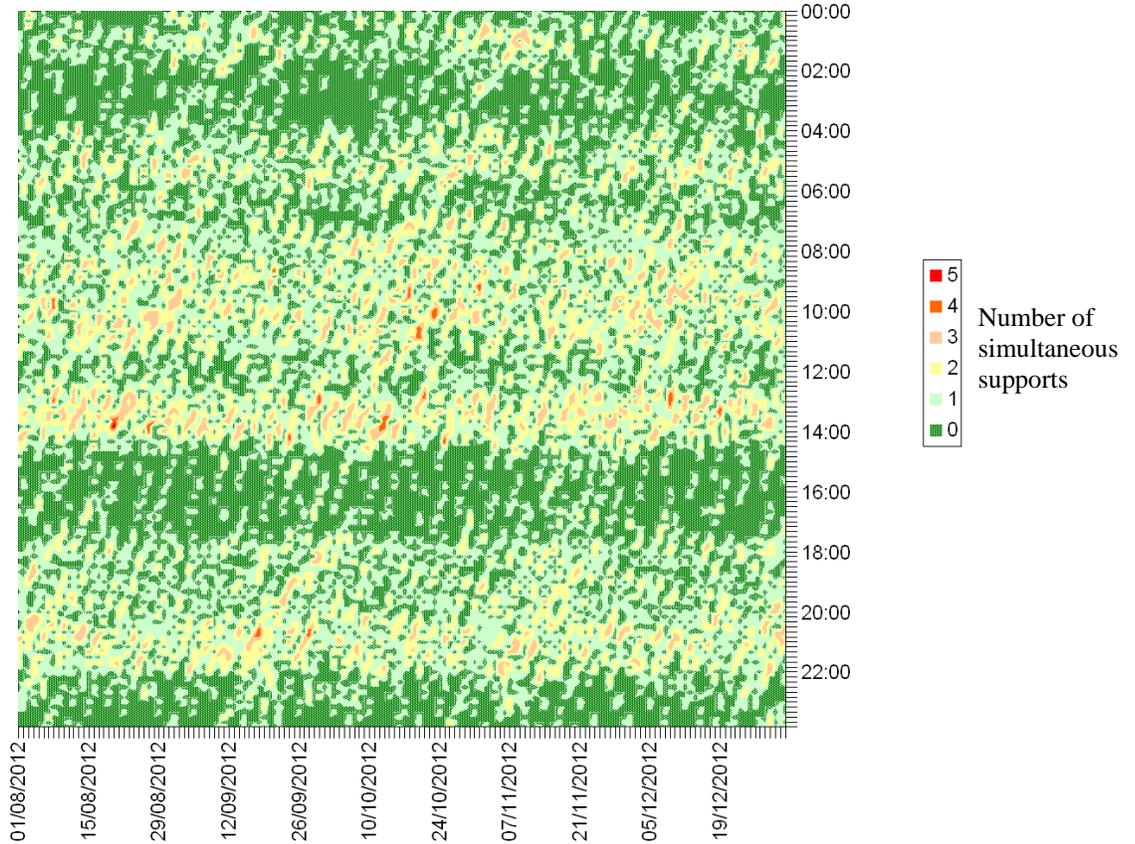


Figure 4. OCP simulation of Network Operation Center workload at the end of the year

After reaching the objective with the simulation, the OCP operational manager may decide whether to retrieve the full simulation context or a time slot only, or pieces of simulation models and to inject this result in the operational context. For instance, before a LEOP, at least three simulation contexts are prepared for each postponement case (nominal at D, backups at D+1 and D+2). Each simulation context is processed as being operational: conflicts are resolved and plannings are validated. When the scheduling operator is informed that the launch is postponed, he can directly integrate the new scenario in the operational context.

IV. Conclusion

After one year of technical and operational qualifications, the new OCP system replaced the 3 old scheduling softwares in October 2011. Due to high integration level of the old softwares in the control center process, the migration was performed in “one shot”, by stopping the scheduling with the old systems on Sunday midnight and starting the new one using OCP for all subsequent allocations.

The new scheduling with a global approach by constraints modified the usual “shape” of missions planning. The constraint solver sometimes gives a consistent solution different from the one manually booked out of habit. This led to adjustments of constraints and also to changes in the usual procedures at the mission centers to give more flexibility in the planning.

The main drawback of the solver programming is the “everything or nothing” solution. If one rule results in an over constrained environment, the solver will only indicate that there is no solution. It is not able to distinguish in the global context, which constraint is preventing a solution result. Thus no indication will be given to help the operator. In that case, his good knowledge of the mission planning characteristics and his experience with previous conflict resolutions will help him to manually adjust the planning and find a solution. The solver becomes, in that context, a tool to help the operator in finding a solution by scheduling a set of satellites and then adding the next ones step by step. This characteristic of the system requires full control of the mission and station constraints sets. Every modification of the model can have an impact on the overall environment. Thus every evolution is first evaluated in a simulation context before being integrated into the operational model.

The future versions of OCP will consider:

- The addition of operator support tools to help the resolution of “nothing solution” described above. Automatic algorithm will help him to generate the optimal planning by trying different combinations of constraint levels.
- The external interfaces will be more open to other systems by using new generic XML format. This will ease the request/answer booking protocol and the interoperability between CNES and partners. The exchanged files will contain more details on the available supports, the type of requested supports, the selection of RF band(s) for a pass,... , to increase the interactivity of these interfaces.