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Digital transformation of a Spaceport: Kourou Space Centre example

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Abstract

An operating spaceport is always torn between reliability and innovation. On one hand its hey objective is to ensure launch success thanks to reliable and proven technologies, dating from several years. On the other hand the space sector has to cope with competitors and needs to innovate by using cutting edge technologies and new radical launchers. Historically, the number of launch operations was very limited, but the New Space revolution is going to strongly increase this number. Therefore, a Spaceport must evolve to attract these new players (mini-launchers, reuseable launcher, constellation satellite operators) that come with new requirements: reduced teams, reduced costs, strong requirements in communication and reactivity.

To do so the Kourou Space Center has undergone its digital revolution for several years, in partnership with CNES and ESA.First step was the start-up of the CSG-NG project (Centre Spatial Guyanais - Next Generation), with its flagship, the CDO (Centre des Operations – Operation Center).Massive use of digital technologies in the operational heart will allow reducing costs and reconfiguration time between launches. The objectives of the new CDO are operational efficiency, parallelization and flexibility, versatile means and human resources, news missions and services, availability and resilience

But it quickly appeared that, to optimize the overall space center functioning, and to keep the CSG in the 21st Century, Digitalization should not be limited to launch operations but should concern all activities in the space centre: that's why a second step, named "Digital Transformation" was decided.

The aim of this paper is to describe the concept of the Digital Transformation, the main requirements, and the first actions.

1. Context

As any other sector, the space sector is facing a strong competition, not only with the arrival of new American players such as Blue Origin or Space X, which now figures as a key actor, but also with the emergence of micro-launcher developers, that are looking for modern high end Space Centres to ensure reliable and low-cost launches.

This competition pushes historical actors to evolve by innovating and modernising their launchers as well as their launch complexes so that they stay competitive in economic terms. But it's not only a matter of survival, indeed this modernisation must also offer modern and powerful tools to the staff which would increase the potential for creativity and innovation, and in the end, it would allow seizing new opportunities in the space market. In addition, the modernisation must ensure a good e-reputation and so to attract high potential staff.

The Centre Spatial Guyanais (CSG) – French Guiana Space Centre – is a complex spaceport where many players are working together in close collaboration: Institutional primes, launch operators, satellite customers and operators, launcher manufacturers, subcontractors. Smooth and efficient running of the space centre with these numerous players requires processes, tools and common facilities. CNES is the leader of the space centre masterplan, and as well oversees its security. As such, it leads the overall modernisation and in particular the Digital Transformation

program, with ESA funding support, considering that several players have still undergone, or are currently running their own digital transformation.

Digital Transformation is not the first CNES program to modernize the Kourou Space Centre. Post Seville Ministerial council in 2019, with ESA funding Support, CNES started a programmed named CSG-NG (Centre Spatial Guyanais - Next Generation) [1], [2], with its flagship, the CDO (Centre des Operations – Operation Centre) [4], [7] (see Fig 1):

Fig. 1: view of future CDO (Operation Centre) (artist's view)

Massive use of digital technologies in the operational heart will allow to reduce costs and reconfiguration time between launches [3], [5], [6]. The objectives of the new CDO are operational efficiency, parallelization and flexibility, versatile means and human resources, news missions and services, availability, and resilience.

But it quickly appeared that, to optimize the overall space centre functioning, and to keep the CSG in the 21st Century, Digitalization should not be limited to launch operations but should concern all activities in the space centre: that's why a second step, named "Digital Transformation" was decided. It aims to reach 3 high-level objectives derived from major trends of CSG development:

- Attractiveness for new launch operators, and so economic development of space ecosystem
- Operation cost reduction for an equivalent service level
- Reduction of time for reconfiguration between launches

Attractiveness is tightly linked to the perception clients will get of the Space Centre. To reach this goal we must provide simple and helpful services. Simplicity will also serve costs reduction, but operation cost reduction is only possible at the express condition that we can easily manage the future infrastructures and applications landscape. This means that cost reduction should not reduce the service level. Finally, reduction of reconfiguration time is tightly linked to the capacity of integrating all operations in order to reduce manual activities and reach an automation level that will ensure both efficiency and quality gains.

2. Early phase of Digital Transformation

As Space Agency, CNES is in charge of ground facilities that ensure the security of the launchers on the space centre itself, and during the early phases of the launches. It also operates the facilities that welcome satellites and their respective pre-launch operations.

Therefore, we had several customers:

- the different launch operators and manufacturers using Kourou Space Centre, especially for next generation Ariane 6 (see Fig 3.1) and Vega C (see Fig 3.2) launchers
- and the various satellites owners

Fig. 3.1: Ariane 6 Launcher

Fig. 3.2: Vega C Launcher

The first item of our approach has been to listen all these customers in order to clearly identify their requirements, in the current context, and for the near future. Our goal was to give new strengths to our customer so that they can increase their market share.

The second point was to collaborate with the CSG-NG teams to get an overview of the Space Centre's digital transformation, and if necessary to complete certain activities

3. On-going Digital Transformation

5.1 Main concepts

Based on the objectives of the Digital Transformation (or digitalisation) for the Kourou Space Centre and the requirements of industrialists, many possible improvements have been raised and declined into potential activities of the Digital Transformation program.

These activities have been analysed in a second step to assess their priority and their compliance with the high-level objectives (Attractiveness, Operation cost reduction, Reduction of reconfiguration time), this process allowed to select the topics that should be improved first.

Even though many improvements have been raised, some are unlinked subjects that serves a specific mean for a specific activity. Consequently, the development of optimal solutions (with regards of the high-level objectives) for each item may lead to an overall unoptimized system as some solutions may impact the efficiency of others.

Leading unitary projects without any intelligence and vision on how they will fit together is not sufficient. The digitalisation process must consider a way to cleverly manage the complexity resulting from the new information systems that will emerged with the development of solutions. This is what the '**urbanisation process**' is about.

Like in urbanisation, if you develop a city focusing on addressing every single need without a coherent view you will end up with a patchwork of buildings, public services and infrastructures that might intersect each other. Alternatively, if all the needs expressed are analysed and addressed in order to mutualize the infrastructures. Everyone will get the service he requires but it will be far easier to maintain and less expensive to build (see Fig 5.1.1)

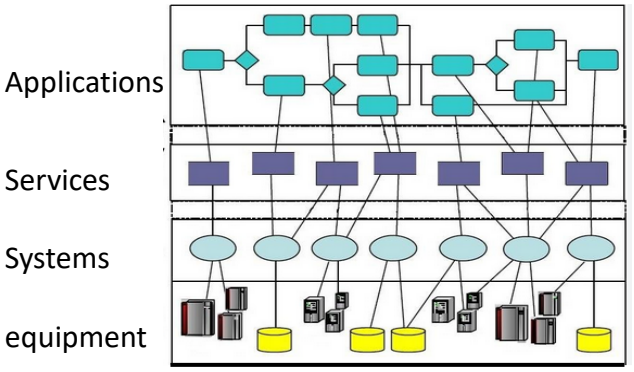

Fig 5.1.1 : Information System urbanization

Like in the city the considered 'activities' are the buildings and quarters in the city. The digitalization must bring the coherence so that each activity could reuse major infrastructures blocks. The specificities must be added on top on those meta-infrastructures.

Let us get into the reality of this concept with few examples. Several requests had been identified about automated workflows for the daily life. Each unit raised a case thinking only about its own specific need. When looking at this from the urbanisation perspective, all those requests could be summed up into a single unified system that will address all the requests. Regarding data management, with the upcoming technologies such as Internet of Things (IoT), the amount of data is becoming both critical to handle and to share. The digitalisation must ensure that datasets can be easily broadcasted to each industrial partner for use cases such as energy consumption analysis or supply chain optimisations. Implementing separated systems to meet each use case would be very difficult. The Digitalisation through urbanisation has the duty to study a unified solution to fulfil this function.

These concepts of coherence and mutualisation are already at work in the program CSG-NG which is currently setting up reliable basis upon which the Digitalization will be based. The middleware for instance will be a pillar of data management for the next steps foreseen through the digitalisation projects.

Finally, digitalisation is certainly not only about developing and setting up projects. It goes beyond by integrating a real vision of how the base should work in the future. If the program has an end, it should also introduce the notion of everlasting change. This implies that the digital transformation should, in addition to the technical aspects, bring a new way of considering the IT systems that are and will remain in constant evolution. The Space Centre's digitalisation will not stop after the end of the project itself. Its purpose is to set a frame/framework inside of which all future evolutions will be possible besides the end of the program.

5.2 Quickwins

Digitalization is tightly linked in everyone's mind to efficiency, reactivity, and agility. This process does not rely entirely on long-term, highly structural projects. Some actions that are compatible with the general urbanized vision, but on a smaller scale and with fewer difficulties, can be carried out in parallel or in anticipation of major projects, with, most of the time, results that are quickly visible to users. These projects called "quickwins" are a good way to improve and ease daily work of staff, and in consequence get as many people as possible on board to join the necessary process of digital evolution.

As explained, several requests were made to improve daily work such as the ability to submit workflows and suppress Mails/PDF and paper signature processes. Digital forms and signatures applications had been identified as solutions to address all those needs. Currently a solution is being deployed and will be tested during the first months of 2023 First, this solution will be internally deployed at the CNES level to ensure it fits all the requirements. The second step will be to open this service to the CSG industrial partners.

In the same way, different requests were made to better communicate onsite, to have an easy access to information, and facilitate the localization of the different areas. To do so, two smartphone applications were designed up to the end of 2022. Test phases are planned for early 2023, on time for new operators as for micro-launchers (see Fig 5.2.1)

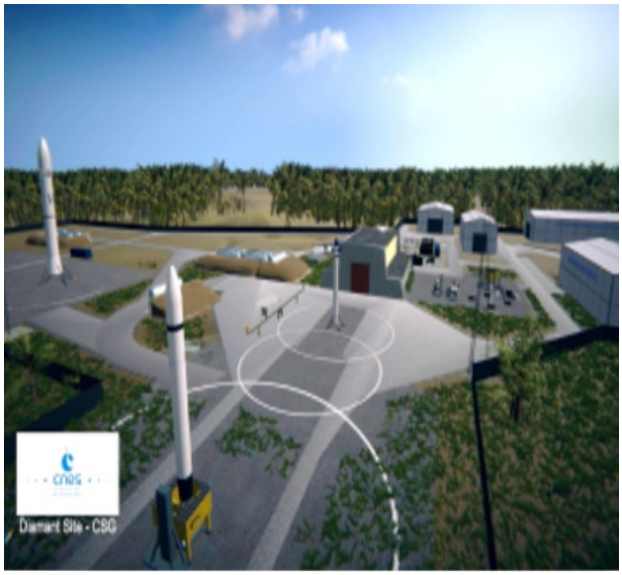

Fig 5.2.1: Future Microlaunchers launchpad (artist's view)

Possibly, other proofs of concepts are on their way such as the ability to display energy data on smartphones in order to optimize the maintenance activities on the installations

5.3 New requirements from historical launch operators

5.3.1 Scheduling

One launch campaign requires the coordination of many industrial partners. Until now, each actor in the Space Centre uses its own scheduling solution. Everyone has its own responsibility when preparing a launch campaign, yet, all activities are linked together. As it isn't possible to share the different schedules, the coordination of activities requires a lot of communication and time between the different teams. Having the possibility to know the scheduling evolution of one another is a key factor to streamline the operation before the launch

A key evolution regarding the scheduling process will be to enable schedule sharing across all in order to ensure a unified vision of the tasks to perform. One main aspect is probably the ability to share schedule evolutions on a synchronous basis. This will ensure to monitor milestones across all industrial partners' platforms. This optimisation will also enable to share tasks that could not be achieved by others.

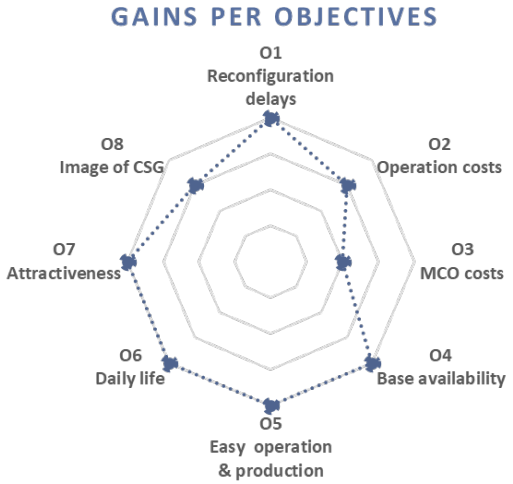

Fig 5.3.1.1: Performance assessment of general digital scheduling.

A study carried out in 2022 showed that a general scheduling interface would help reduce the reconfiguration delays and would improve workers organisation and daily life (see Fig 5.3.1.1).

Beyond the schedule module sharing, the digitalisation also propose to link tools such as the Computerized Maintenance Management System so that both work force but also asset availability could be considered before starting a new task.

This demonstrates how the digitalisation intends to take in account all functional aspects in order to ensure to optimize the overall process. The interface improvement with all industrial partners is one aspect of the expected gains of Digital Transformation. The overall target will be reached by implementing all identified functional activities.

5.3.2 Cost reduction

The Digital Transformation program aims to reduce operation and MCO (Maintien en Condition Opérationnelle – Maintenance and repair) costs by simplifying daily life of workers, by mutualising processes, by monitoring data thanks to IoT which will enable to better manage equipment and assets.

It is also expected that Digitalisation would help to better manage energy. Indeed, the CSG represents 18% of the energy demand in French Guiana (approximately 125 GWh/year), of which 60 to 70% is used for air conditioning of buildings. More particularly solid propellant, launchers and satellites preparation requires a very controlled air

conditions in facilities of great sizes and volumes. The CSG actors have been constantly improving the infrastructures and reducing the energy demand. But digitalisation offers an opportunity to significantly improve the monitoring and control of energy demand for every system. To be more specific, digitalisation allows to

- Have a centralised monitoring and management of energy and other systems, and no limited to every establishment
- Develop automatised management of energy demand and other systems with human intervention limited to control
- Adapt systems to the activity in facilities (for instance satellite operations in clean rooms see Fig. 5.3.2.1) or weather conditions
- Collect and analyse data to make further improvement.

With the implementation of the CSG low carbon trajectory, which aims to produce locally 90% of energy from renewable sources, Digitalisation will allow CSG to adapt the energy demand to the variation of renewable energy production and storage.

All this will be possible thanks to the arrival of new technologies and protocols such as the Internet of Objects.

We might also speak about the radar maintenance automation. Similarly, IoT will make possible to master all useful parameters remotely to pilot radars and detect any malfunction. This will allow maintenance to be reduced to what is necessary, and limit human intervention to remote control of radars.

Finally, some cost reductions are simply expected through the rationalisation the IT infrastructures. One good example is related to 5G. The digitalisation program aims to develop 5G to extend networks in remote areas. This would improve the reliability of network and offer new possibilities to connect IoT (Internet of Objects) in remote areas instead of investing in wired connections which are associated with significant earthworks and in the end results in higher costs of maintenance.

However, this will not be possible if the different systems do not evolve. Indeed, along with the development of digital technologies comes the renewal of systems and hardware to make these systems flexible and able to communicate with the digital monitoring and control.

Fig 5.3.2.1: Satellite in clean room

5.4 New services for all people

5.4.1 *Digital procedures*

Digitalization addresses multiple items. Some of them are easier to identify as being direct contributors to the Space Center's goal: Satellites Launch. Other ones appear to be less connected to this objective. Still, what nowadays will make the difference in between two space ports is not related to the native mission which is considered as a 'must have' but the ability to offer services that will make everyday life easier, ensure a better productivity and enhance the global efficiency. This is not necessarily done by bringing high value business applications but through productivity tools.

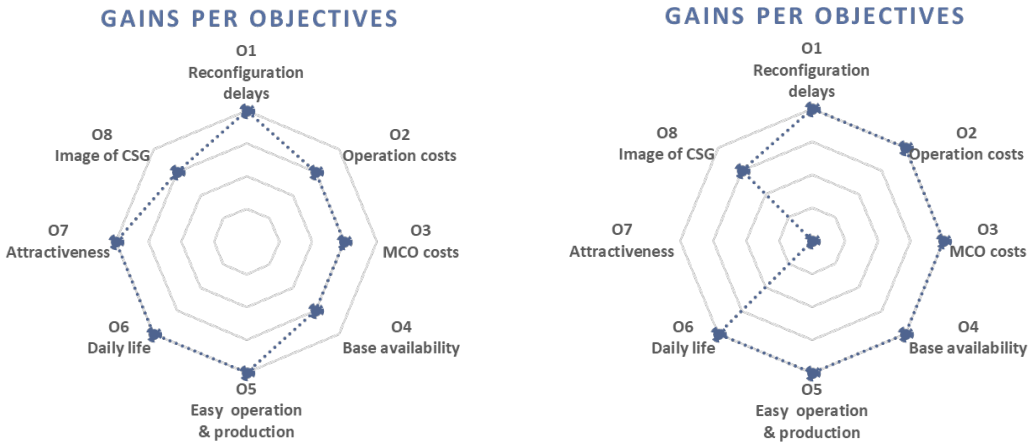

Fig 5.4.1.1: expected gains for dematerialisation of procedures (left) and of work requests (right).

During an operation, procedures must be applied and are described on paper task lists. The goal is to digitalize these procedures to facilitate access to the forms and to set up workflows that will help with their follow-up and processing. Dematerialisation of procedures (as assessed in fig.5.4.1.1) is expected to have a great impact in improving daily life of workers and consequently reduce time of reconfiguration between two launches. In addition, on the CSG base, work orders are currently registered on stations, but the information is not automatically spread to all relevant parties. Digitalising the entire work order process, is expected to improve workflows and, ideally, the developed application could be directly linked to planning and to the CMMS which would drastically improve daily of workers, reduce costs and time of reconfiguration.

The digital transformation aims to digitalise most procedures and workflows in order to gain in flexibility. In parallel of developing these applications, the urbanisation must play a key role to ensure that all developed tools would interface one another smoothly.

5.4.2 BIM/SIG

An important part of digitalisation concerns the management of assets, networks and infrastructures. On a 700 km territory, regrouping launch activities and sensitive industrial activities (production of propellants for example), it is obvious that the modelling of all the installations, various pipelines and large networks will allow optimizing the interventions and the investigations on anomalies.

BIM (Building Information Management) and GIS (Geographic Information System) will play a significant role in the transformation of the CSG: they will provide digital models of:

- buildings: rooms and internal network and equipment description (power supply, data, water, cooling system), using a BIM application
- extended networks and roads outside of buildings, using a GIS application (see Fig 5.4.3.1)

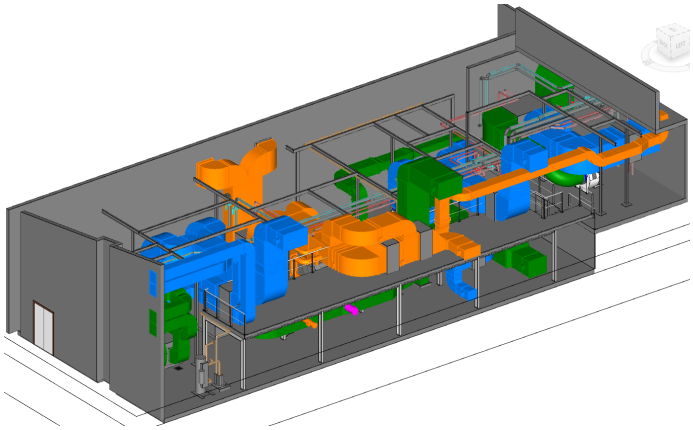

Fig. 5.4.3.1 Example of BIM digital model

These digital maps of networks and buildings will first improve the planification and the intervention in of anomalies but also it will help the project development phases. Secondly, associated with CMMS (Computerised Maintenance and Management System), the maintenance of assets will be enhanced by these digital tools. Finally, in the long run, with the help of AI, we could imagine that a major failure would be more easily identified based on this geographical information associated with logs of all systems and IoTs. Both applications, linked to IoT and backbone network initiatives will also allow to optimize energy saving and to improve maintenance of the buildings, that quickly degrade in equatorial climate.

5.5 New technologies

5.5.1 *5G Network*

The European Space centre spreads over 700 square kilometres with only 10% of this area used for all infrastructures that are distant from one another. To this day, networks were mostly based on fibres and formerly copper cables. Many different network and technologies are used to communicate with equipment, sensors, or infrastructures. There is no central backbone network to unify the way data could be gathered. In addition, nomadism is only possible within each establishment but not between them.

Thanks to its new bandwidth, 5G offers new possibilities and becomes now a real alternative to ensure a global network coverage across the whole Space Center. 5G network allows to drastically simplify our network infrastructure and increase its performance and availability as it also enables the interconnection of other protocols either low or high capacity (such as Lorawan, or NBIoT) to gather data anywhere on site. 5G will also enable to convert the signal into Wi-Fi for indoor network connectivity.

With a private 5G backbone covering the entire CSG territory and capable of both high throughput and hosting real-time exchanges, the base will be able to provide advanced services in addition to traditional communication services. These advanced services include:

- triangulation, necessary for example to optimize maintenance operations by geolocation the nearest available tool
- the collect and centralization of IoT data
- broadcasting of alert or evacuation messages in case of accident

5.5.2 IoT (energy consumption monitoring, mobile asset monitoring)

As explained in the previous paragraph, IoT will be a key feature to ensure cost reduction over the Kourou space base. Currently the applications of IoT are targeting the monitoring of energy consumption, maintenance assets, and the supply chain. Other domains might emerge. For instance, IoTs associated with BIM/SIG could allow doing numerous things such as: automated detection of occupied rooms, hygrometric and temperature sensors to analyse the environment for clean rooms and so on.

Beyond this, the digitalization aims to think farther and a platform to share IoT data sets with all industrial partners is currently under study.

It is nevertheless mandatory to recall that without the proper network infrastructures and data management tools IoT will be useless. Indeed, network infrastructures are necessary to rigorously collect data. IoT, data analysis and data management come together to offer the opportunity to get a clear vision of the Kourou space base environment and interact with it.

6 Cybersecurity

Cybersecurity is of course a major issue in the Digital Transformation, considering that many players are interested to get and share data, as they are working together.

Therefore, cybersecurity has been taken into account in the early phases of Digital Transformation, in order to adjust the countermeasures to the right level of risk.

7 Conclusion

Therefore, Digital Transformation is an important step in Kourou Space Center life. With the new tools and skills it will bring, it will be a key point to turn the spaceport towards "New Space", and to maintain Europe among the leaders of space activity. This experience can pave the way for Digital Transformation of other space centres, still existing or being built.

Acknowledgements

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