

IMPROVEMENTS IN THE PROJECT MANAGEMENT METHOD USED BY THE FIBRE OPTICS AND CABLING SECTION FROM CERN DURING THE LONG SHUTDOWN 2

by

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*I want to thank all my family and friends for their help and support over these years.
Without them, all this journey would not have been the same.*

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**Some images have been modified to be compliant with CERN's data privacy policy*

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1. ABSTRACT AND OBJECTIVES

Due to the workload increase expected at CERN for the *Long Shutdown 1* (LS1), the Support unit was created inside the Fibre Optics and Cabling (FC) section with the purpose of backing the project managers on the development of their activities, while improving the project management system present in the section until that moment.

The tools developed by the Support unit for the FC section since the beginning of the LS1 have been mostly oriented to the Monitoring step, leading to the creation of the *FC Monitoring System* (FCMS). The initial objectives of this system were to establish a **unified system** to follow-up the FC projects, and to **improve the treatment** of the incoming **data** to obtain more precise information.

During the LS2, period in which the contributions done by the author are framed, new objectives were considered. These new objectives were mainly:

- ✚ **Consolidation** of the tools already developed
- ✚ Development of new tools to **visualize** the data
- ✚ Improve even more the data treatment to have **information** as **accurate** as possible about the projects (this objective was maintained)
- ✚ **Automate** as possible the process that was already working

The present document is divided into 3 main parts.

A first one (*Introduction*), introducing CERN and explaining the way in which the FC section is structured.

A second one (*The project management in the FC section*), describing how does the project management process take place in the FC section.

A third part showing the evolution of the FCMS since the LS1 (*The FC monitoring system before the LS2*) and focusing on the developments in which the author contributed during the LS2 (*Developments in the FC monitoring system during the LS2*).

Finally, a point about the possible future developments of the FCMS is included.

2. INTRODUCTION

A first introduction about CERN is firstly included: how it was created, what it is, and how it is structured. To then talk about the Fibre optics and Cabling (FC) section: how it is organized and how are the projects managed inside the section.

2.1. CERN

The European Organization for Nuclear Research, from its acronym in French “Conseil Européen pour la Recherche Nucléaire” (CERN) is a European Organization created after World War II with the purpose of uniting scientists, allowing them to share knowledge and the costs of nuclear physics facilities.

Initially, 12 countries signed the CERN creation in 1953¹. Since then, other European and non-European countries have joined², until the present number of 23 Member States. Nowadays, CERN has collaboration contracts and agreements also with other countries all over the globe (see Figure 1).

About its geographical area, Geneva was chosen to hold the installations for 3 main reasons. Due to Swiss neutrality during the war, due to its central location in Europe and since it was already hosting several international organizations such as the United Nations.

This geographical situation caused the adoption of French and English as the two official languages of CERN. Nowadays, the organization is trying to push more English in the working environment to make it accessible to everyone. But still, a considerable amount of the terminology and working language used is French.

Since its creation, outstanding investigations and discoveries in the field of physics have taken place at CERN. But even though the aim of the organization is directed towards physics, it has always been a union between physics and engineering. This is due to the engineering challenges that developing and maintaining all the infrastructure needed for the experiments represents.

Consequently, remarkable people in the world of engineering have also taken part in the organization throughout time, leading to developments like the development of the World Wide

¹ Belgium, Denmark, France, the Federal Republic of Germany, Greece, Italy, the Netherlands, Norway, Sweden, Switzerland, the United Kingdom and Yugoslavia

² Austria (1959), Spain (1961-1969, re-joined 1983), Portugal (1985), Finland (1991), Poland (1991), Czechoslovak Republic (1992), Hungary (1992), Bulgaria (1999), Israel (2014), Romania (2016) and Serbia (2019). Yugoslavia left CERN in 1961 and the Czech Republic and Slovak Republic re-joined after their mutual independence in 1993 [1]

Web³ protocol. And not only people but also organizations from all over the world have taken part, allowing CERN to use cutting edge technologies in different engineering fields such as electromagnetism (e.g. magnets or superconductors) or electronics (e.g. supersensitive sensors) [2].

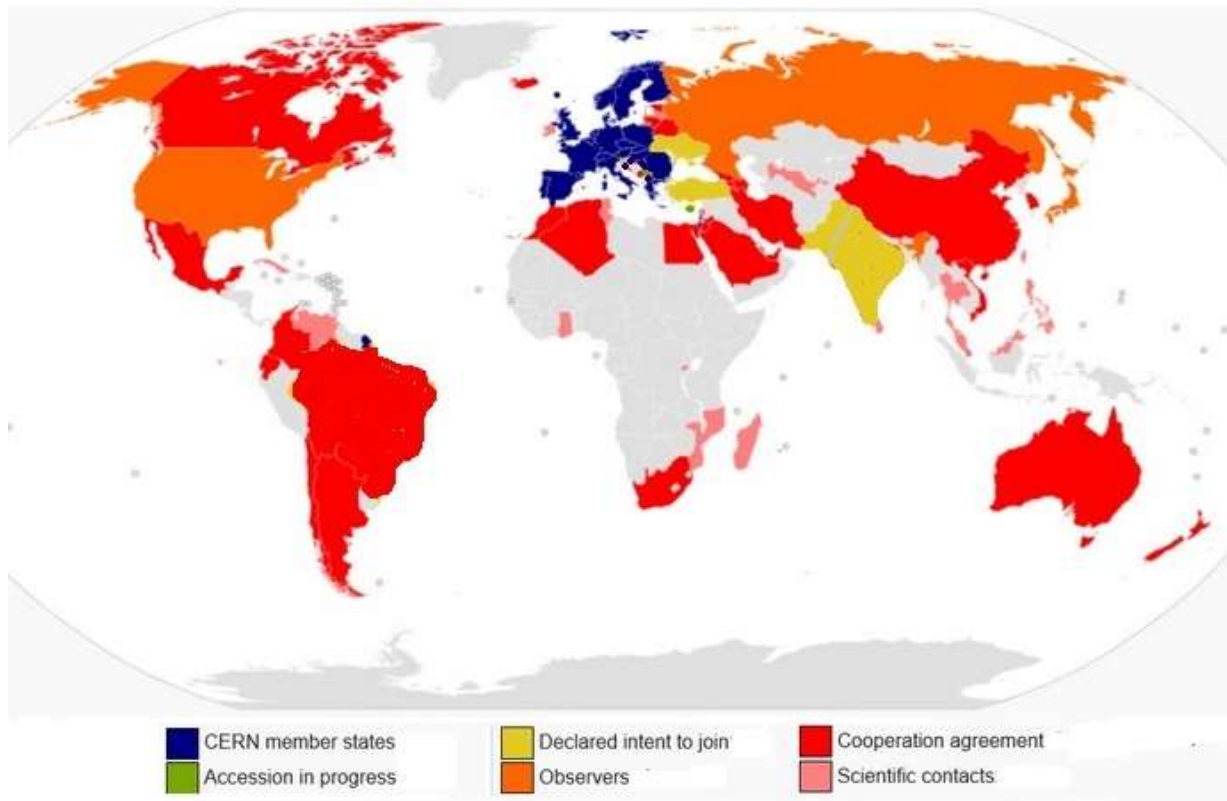


Figure 1 — CERN member states and countries with cooperation contracts

Over time, CERN installations have developed and grown, since the development of the first accelerator⁴, until the present number of 8 accelerators and 2 decelerators (see Figure 2). Particles start accelerating in the LINACs⁵ and then they are distributed among the different experiments as desired.

³ Developed by Sir Berners-Lee in 1990 at CERN

⁴ The *Synchrocyclotron* developed in 1957

⁵ LINear ACcelerators (LINAC) where the particles reach 2/3 of their final speed (the final speed is over 99% of the speed of light)

The CERN accelerator complex *Complexe des accélérateurs du CERN*

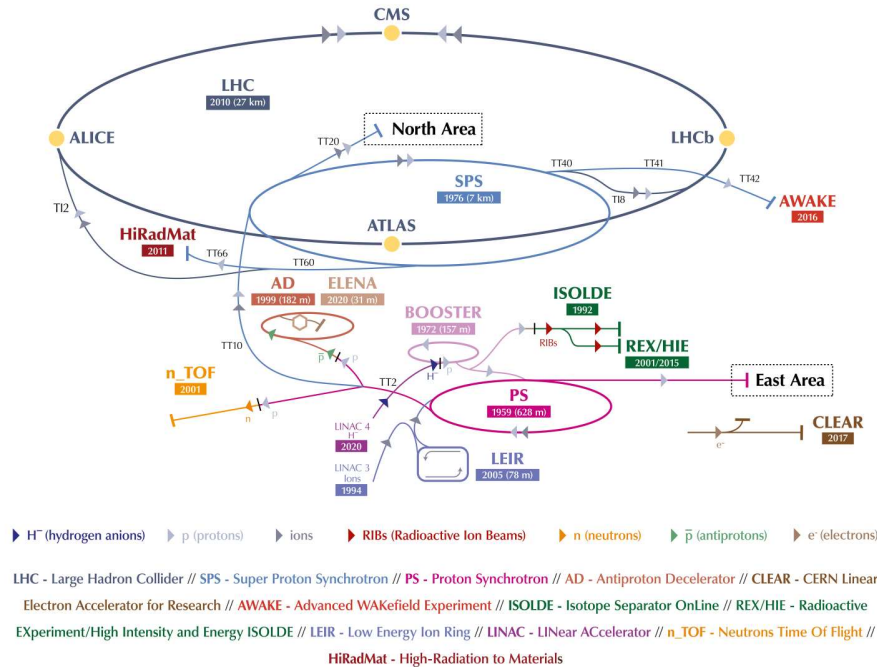


Figure 2 – Scheme of the accelerators present at CERN before the LS2 works (2019), with the type of particles used in each, the length and the year it was created

Since the construction of the LHC⁶ in 2008, the years are divided into periods. These periods (see Figure 3) are alternatively Runs and Long Shutdowns (LS). The *Long Shutdowns* are technical stops, of between 1 and 2 years long, with the purpose of maintaining and progressively upgrading the LHC. During this period, all experiments are stopped for security reasons, so maintenance and upgrading of the rest of the installations are also carried out. The periods in between the LS are called Runs. During the Runs the installations are working, and therefore, only surface maintenance (without accessing the tunnels) can take place. Until now there have been Run 1 (2008 – 2013), LS1 (2013 – 2015), Run 2 (2015 – 2019) and LS2 (2019 – 2021).

⁶ The *Large Hadron Collider (LHC)*, is the last accelerator built at CERN, and the world's largest and most powerful built until now, with a length of 27 Km [3] [4]

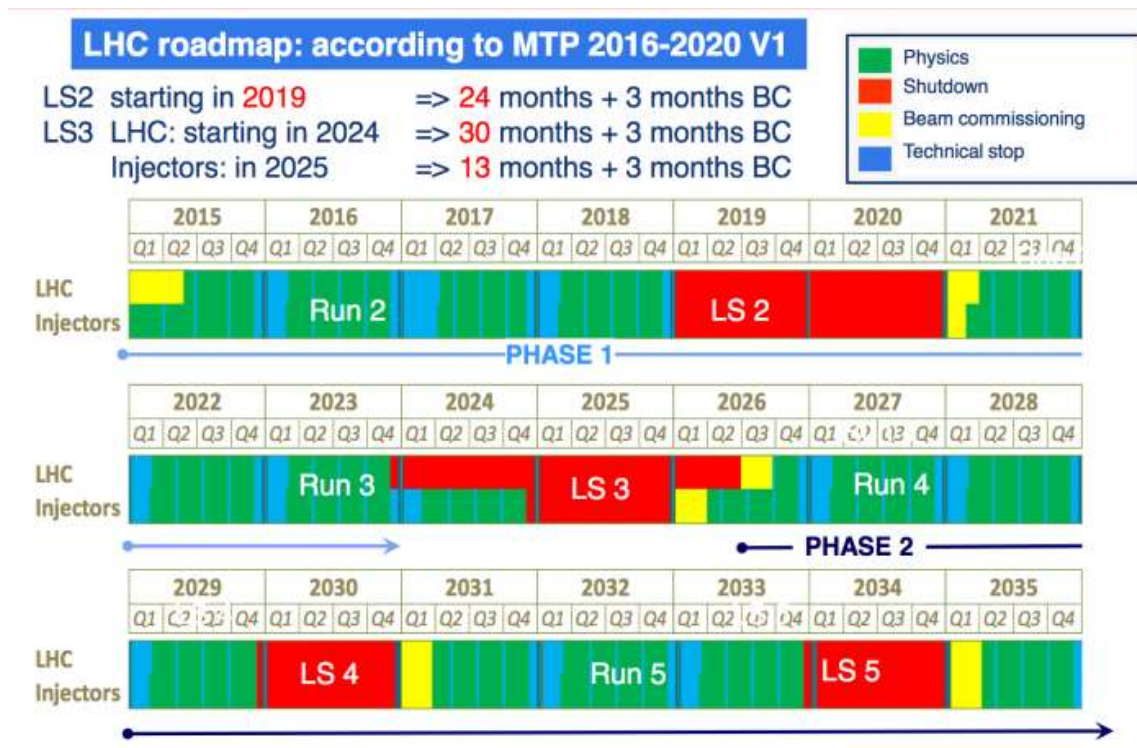


Figure 3 – Schedule of the different periods at CERN forecasted from 2015 until 2035. The thick blue periods that are at the end of each year represent the YETS and EYETS previously mentioned.

At the end of each Run year, there is always a 2 months long technical stop called YETS⁷. In the case of greater quantity of works to be developed, some years this period can be extended into an EYETS⁸.

The LS1 was a big challenge for all the engineering side at CERN, as the workload increased drastically compared with previous periods. Therefore, the methods and tools used before had to be readapted and developed, as we will see.

The motto of CERN is: “*Safety* first, *Quality* second and *Schedule* third”. This helps understanding the priorities that CERN has, and consequently, the way in which the *working structure* is designed and managed. We will see that specially *safety* is taken extremely seriously at CERN, with extremely cautious procedures when developing any risky work and strict control of the radiation received while working in radioactive areas, among other measures.

⁷ Year End Technical Stop. It is like a shorter LS where all the installations are also stopped and maintenance activities take place

⁸ Extended Year End Technical Stop

In terms of organization, CERN is respectively divided as represented in Figure 4, from bigger to smaller, into Sectors, Departments, Groups, Sections and Units [5].

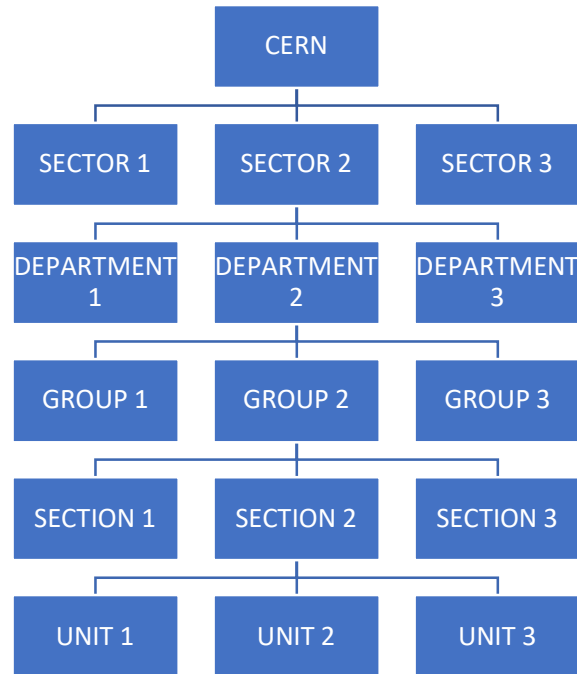


Figure 4 – Hierarchy of the different sectors at CERN

2.2. THE FC SECTION

In our case, the study is going to be focused on the *Fibre optics & Cabling (FC)* section. This section belongs to:

*Accelerators and Technology (AT) sector → Engineering (EN) department →
→ Electrical (EL) group.*

2.2.1. Organization of the FC Section

The FC section provides engineering support to CERN users, centralizing their cabling requests and organizing the installation activities through external entities referred as *contractors*. The section also provides support to the EN-EL group in the planning and the resources coordination⁹.

It is presently divided into 3 units:

- *Cabling unit*: responsible for the installation and maintenance (removal or replacement) of signal copper cables and DC power cables in the accelerator complexes at CERN. It also performs the installation of standardized racks for CERN users.
- *Fibre Optics unit*: responsible for maintenance and upgrade of the fibre optics network of the CERN installations.
- *Support unit*: in-charge of giving support to the other two units.

Both the *Cabling* and *Fibre Optics* units are composed by a *Unit Coordinator*, several *Project Managers (PMs)* and several *Job Supervisors*¹⁰.

- *Unit Coordinator*: responsible for the supervision of all the activities taking place in the unit.
- *Project Manager (PM)*: responsible for the planning and development of the projects he has been assigned.

⁹ procurement and logistics of cables, connectors and low-voltage accessories for electrical installation works and radiation safety related aspects

¹⁰ The number of *Project Managers* and *Job Supervisors* working for the section varies depending on the workload of the period (higher number during the *LS* than during the *Runs*)

- Job Supervisor: they give support to the PMs, doing a more in-depth follow-up of the work developed on-site by the *Contractor*¹¹.

2.2.2. Terms Definition

There are several terms used in the FC section that have obtained specific meanings over time. These and some other words that are going to be used during the document with a specific meaning, are described below:

- Need: necessity that gives place to the creation of the project. It must be fulfilled by the result.
- Activity: a project is composed of activities (referred as **Affaires** inside the FC section). Inside a project the activities can all be the same type, or there can be different types of activities.
- Status: values of the main variables from a given activity or project at a certain moment.
- Goal: result aimed in the planning of the project, before starting the works.
- Work: all the material modifications that are effectively put in place during the project. The consecution of the work leads to the result.
- Result: final outcome obtained once the works are finished.

The *result* might fulfil the *need* but not be identic to the *goal*, due to modifications done during the development of the project (e.g. quality differences). In this case the differences between the goal and the result must be considered by the caller to decide whether the result is accepted or not.

- Caller: entity that has the need and starts the process of creation of the project.
- Responsible: entity in-charge of the project, contacted by the *caller* to solve the *need*. Also referred as *Project Manager (PM)*.
- Workers: entity that carries out the *work*. In the FC section they are the *Contractor*.
- Installations: aggregation of all the equipment managed by the FC section (i.e. cables, racks, cable trays).

¹¹ The work on-site is performed by subcontracted companies (referred as *Contractor*) that do not belong to the section

- Workplace, worksite or site: place where the *works* are developed.
- Constraints: restrictions imposed to the main variables for the development of the *project*. We differentiate 3 types depending on the entity that imposes them:
 - Caller constraints: imposed by the *caller*. Such as limiting the price that they are willing to pay for the installation (*budget restriction*).
 - Responsible constraints: imposed by the *responsible*. Such as the responsible availability during the desired dates (*schedule restriction*).
 - External constraints: imposed by other entities involved in the project. Such as the maximum number of people that the contractor can provide (*manpower restriction*), the availability of the workplaces during the specific dates given by the CERN management (*schedule restriction*) or the radiation limit imposed to the workers in Impact (*radiation dose restriction*).

And we differentiate 2 types based on the moment in which they appear:

- Initial constraints: constraints already known when the *activity* is being planned.
- Arising constraints: constraints that appear during the development of the activity and cannot be considered in the planning.
- Problem: any event during the development of the *project* that hinders the achievement of the *goal* (e.g. accidents, defective material installed). They normally lead to arising constraints.
- Specifications: description of the *need* and the *result* desired. 2 types can be distinguished:
 - Proposed specifications: description of the need and the caller constraints, given by the *caller* to the responsible during their first interaction. Referred in the FC section as **Requests**.
 - Agreed specifications: final specifications agreed between the caller and the responsible, after putting together the proposed specifications with the responsible and the external constraints. Referred in the FC section as **OSVC**.
- Technical file: file developed by the responsible by putting together the *agreed specifications* with the information available about the installations. It must describe all the technical aspects for the development of the *activity* and the way in which the work is going to be organised.

2.2.3. Type of activities

Even though different types of activities are developed inside both Fibre and Cabling unit projects, fibre activities are all treated the same way during the monitoring step (so no difference is done between them along this document), while for cabling activities they are differently considered.

Inside the Cabling unit projects we can differentiate the following types of activities:

- Cable Installation: activities for the installation of new cables. They are subdivided in the following subtasks, but they don't need to have the 3 of them:
 - Pulling or Tirage: first part in which the cables are put in place.
 - Raccordement or Connectique: second part in which the connection between the different cables is done. This connection step is done after all the cables are put in place to avoid tensions between them.
 - Test: third part in which the installed cables are tested to check that no losses or anomalies in the electricity transmission are occurring.
- Mechanical works: activities for the installation of all kind of equipment that are not cables. Such as rack installations, supports fixing, drilling the walls to create the path for the cables, etc.
- Watercool cables: activities for the installation of special cables that are treated differently to the Cable installation activities. These cables are recovered by a hose with a water flow that helps cooling down the interior cable.
- De-cabling: activities consisting in the removal of cables and/or other electrical infrastructure due to failure or aging.

2.2.4. Main variables

In every FC section project, there are some common variables that need to be settled and monitored, and to which we will refer as *main variables*:

- Progress: percentage of the total work that has been developed at a certain moment.
- Schedule: start and end dates defined for a certain activity.

With the purpose of keeping track of the modifications that the schedule can experiment since the creation of the activity, for each activity, there are 3 scheduling dates that are kept:

- *Baseline*: first start and end dates declared when the activity is created.
- *Forecast*: start and end dates declared when the activity starts.
- *Actual dates*: the declared dates at a given moment during the development of the activity.

The 3 dates can be the same one if the forecasted dates do not change during the activity.

- Cable Volumes: quantity of cables used for an activity. They are measured in:
 - *Number of cables*¹² used.
 - *Total length of cable* used.

- Manpower: number of workers needed per day to develop an activity.

It is monitored per week. Therefore, the value is constant for all the days of the same week. It is obtained doing an average (dividing the total number of people that have worked during that week by the number of working of that week).

- Budget¹³: money needed to carry out the work.
- Radiation Dose: dose received by the workers during activities that take place in radiation areas. It is measured in micro Sieverts (μS). Due to the importance that safety has at CERN, it is the only *main variable* that is defined through a specific platform.

Both a *global* and a *per worker* maximal doses are established for each project taking place in a radiation area, making a work dose planning. Depending on these values, the activities are

¹² For the fibre optic activities also the total *number of fibre* inside the cables installed are declared

¹³ Data related to budget is not included along the document as it is protected

given a level of radiation, called ALARA level¹⁴ [6]. If any of the established limits is surpassed, the activity has to stop and the PM needs to make a new work dose planning, analyse why did the estimation fail and see whether it is possible to increase the limits to continue the activity.

- Procurement: follow-up of the arrival, at CERN, of the cable needed to be installed in the Cable installation activities. It is only used for the Cabling unit projects, and it is the only variable that is followed-up before the start of the activity. It must be 100% before the activity starts.

¹⁴ As Low As is Reasonably Achievable. Level of radiation in which activities taking place in radiation areas are classified, being 0 the lowest and 3 the highest

2.2.5. Code Evolution

Figure 5 represents the code evolution followed by the FC section project managing process that will be used during chapter 4:

- *Multi-user projects* (declared in the *FTE file* and identified by a *Project Code*) lead to one or several Plan IDs.
- *Plan IDs*¹⁵ (declared in *Plan*) lead to one or more Requests.
- One or more *Requests*¹⁶ (declared in *Snow*) are grouped in OSVCs (declared in *Gesmar*), and can lead to one or more *Affaires*. As it is, as we saw before, in the transition from Request to Affaire that the transition from the caller side to the responsible side project takes place. Therefore, the way of organizing the work changes completely and one Request can be split in several *Affaires* as well as several Requests can be grouped in the same *Affaire*.
- *Affaires* (declared in *Gesmar*) occurring in the same place and time are grouped into *Code Etudes* (also declared in *Gesmar*)

The transition in Figure 5 from the blue to the red boxes represents the transition from tools that are used by all CERN to a tool that is only used in the EL group (Gesmar). The Code Etude box is in purple because this code is only used in the FC section, while the rest of the codes are used in all EL group projects.



Figure 5 – Code evolution followed by the FC section projects. On top of each boxes appears the code name used and, on the bottom, the tool in which they are declared.

¹⁵ Big single-user projects are declared at the Plan ID level

¹⁶ Small single-user projects are declared at the Request level

2.2.6. Geographical Areas

Even though CERN is registered in Switzerland, it has two sites, one in Switzerland and another one in France:

- Meyrin site: it is in Switzerland and has the official address of CERN (bottom part of Figure 6). It was the first one to be built.
- Preveessin site: it is in France and was built afterwards (in the middle of Figure 6).

To organize the work and treat the information, the FC section divides CERN in 4 main geographical areas:

- LHC: all the activities that take place in the LHC tunnels.
- SPS or Preveessin: all the activities that take place in the different Preveessin site installations or in the SPS¹⁷.
- PS or Meyrin: all the activities that take place in the different installations from the Meyrin site or in the PS¹⁸.
- Intersites: when an activity starts in one of the previous areas and finishes in a different one. It can either be included in the area where the biggest part of the work is done, or it can be included in this fourth group, followed by the 2 geographical areas involved.

¹⁷ Super Proton Synchrotron. For more info see Figure 2

¹⁸ Proton Synchrotron. For more info see Figure 2

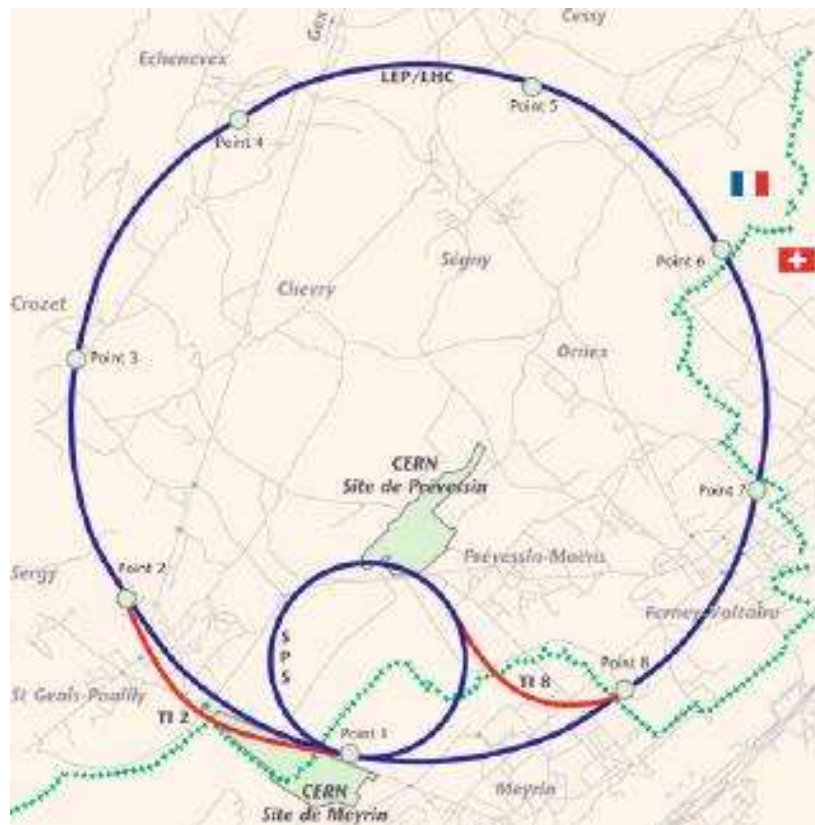


Figure 6 – Representation of the LHC (big blue circle) and the SPS (small blue circle) accelerators, along with the *Meyrin* site (in the Swiss side) and the *Preessin* site (in the French side)

3. THE PROJECT MANAGEMENT IN THE FC SECTION

In this chapter, the project management process followed nowadays by the FC section projects is described.

Firstly, a definition of the different types of projects is done. Then, each one of the steps followed by the FC section projects, along with the tools that take place in each of these steps and some challenges that need to be faced in each step, are described. The steps considered are:

1. Creation
2. Planning
3. Monitoring
4. Validation & Data update (*referred sometimes just as Validation*)
5. Information & Experience sharing (*referred sometimes just as Experience sharing*)

For each step, there will be an *input* (information entering the step), an *output* (information coming out from the step), one or more *actors* (entities that modify the input to obtain the output) and one or more *factors involved* (different factors that can modify the way in which the work has to be developed, and therefore, need to be taken into consideration by the agent).

3.1. PROJECT STRUCTURE

We can define an engineering project as an activity that appears with the purpose of giving a solution to a problem or need of significant complexity, in the field of one or several engineering domains [7]. Therefore, it generally consists in several people with different knowledges and abilities, working together to achieve a common goal: give a solution to the need.

In the case of CERN projects, we can differentiate two different ways of grouping the work:

- **Caller side project**: it corresponds to the way of grouping the work from the *caller* point of view. Therefore, we will only refer to it during the Creation step.

Depending on their extension, we can differentiate between:

- Single-user projects: small projects developed by a single section and managed by project managers (PM) from the section. There are *big single-user projects* (workload higher than 1 week) and *small single-user projects* (workload lower than 1 week).
- Multi-user projects: bigger projects that need the intervention of several sections and are managed by a project leader (PL). They are divided into smaller entities per section involved, each of them with a PM assigned.

And depending on the entity that acts as the caller, we can also differentiate between:

- Internal projects: projects created by the section itself (the caller and the responsible belong to the same section).
- External projects: the caller and the responsible belong to different sections.

Anyway, it is common in the FC section to have external and internal activities inside the same project. As external activities are normally profited to perform any internal maintenance activity needed in the area where the project takes place (e.g. removing some old cables).

- **Responsible side project** (referred as *Code Etude* inside the FC section): once the proposed specifications (*Requests*) are settled, the activities are organised in the way that is more convenient for the *responsible* to perform the works: activities that take place in the same area and can be performed during the same dates are grouped together and carried out at the same time.

This leads to a new way of organising the work, as represented in Figure 7. We will refer to this way of organising the activities during the rest of steps (planning, monitoring, validation and experience sharing).

The Request is the smallest entity used through the project management process and, as shown in Figure 7, it is the point of transition from the caller side to the responsible side projects. Therefore, *Requests* from different caller side projects are grouped in the same *Code Etude* if they take place in the same place and schedule.

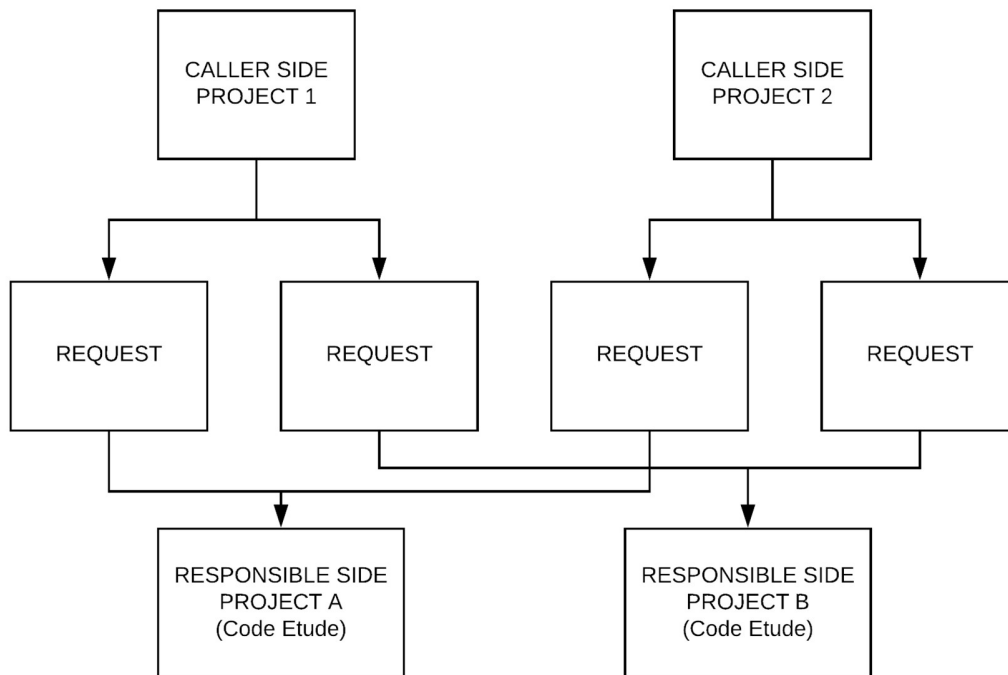


Figure 7 – Transition diagram from caller side projects to responsible side projects

3.2. PROJECT MANAGEMENT STEPS

In this point, the different steps followed during the project management process are described, along with the different tools involved and the main challenges faced in each step.

3.2.1. Creation

This first step is divided into two sub-steps: the first one only concerning the caller, while the second one concerns both the caller and the responsible.

The **first sub-step** starts with the occurrence of a need (*input*) to the caller (*actor*). During this phase, the caller must define the need and the caller constraints (*factors involved*) and find an entity that can develop the work needed (the responsible). Both, the need and the caller constraints, are transmitted to the responsible through the Requests (*output*).

The **second sub-step** starts with the reception of the Requests (*input*) by the responsible (*actor*). At this point, the responsible needs to put together the proposed specifications with the external constraints (*factors involved*) imposed by different external entities, to see if everything is compatible. Once a way to fulfil both the need and the external constraints is found, the OSVC (*output*) is developed.

Tools involved:

3.2.1.1. FTE file

Excel file containing all the *multi-user projects*¹⁹ to be developed by the EL group, each of them identified by a unique *project code*.

An excel extraction²⁰ is done from this file with only the FC section related projects. This extraction contains information, per project code, about its **geographical area**, **priority**, **unit responsible** (cabling or fibre), daily **manpower** that needs to be deployed and total **cable volumes** length required.

Each multi-user project declared in the FTE file leads to one or several Plan IDs declared in Plan.

¹⁹ Single-user projects are not declared in the FTE file

²⁰ This extraction and others that we will see afterwards, are done to be inserted in the Technical Panel (tool described in the monitoring step). No Figure is included in this case, from this extraction, due to data privacy reasons

3.2.1.II. Plan tool

Webtool developed to provide each section with a clear overview of all the activities that the section needs to carry out. Providing the priority and the workload that each one represents, to prevent the section from overloading.

Before the development of this tool, it could happen that a multi-user project was distributed and accepted by all sections involved. Some of them did not have the capacity to finish it as they were already overloaded during that period (e.g. LS, EYETS), but they were not aware of it. Leading to partially developed projects. This way, once a PL requests the contribution of the different sections required for a multi-user project, each section can easily see in Plan their priorities and workload to accept, postpone or cancel the work.

Plan contains big single-user projects and divisions of the multi-user projects declared in the FTE file²¹. Each one is identified by a unique Plan ID. Therefore, each FTE project leads to one or several Plan IDs, while, in the case of the big single-user projects, these Plan IDs do not belong to any FTE Project.

PLAN ID	Activity status	Caller group	Person Responsible	Accepted periods	Responsible Group	PROJECT code
10006	APPROVED	EN-STI	Responsible 1	2018,2016,2017	EN-EL	MEYDLW0
10196	POSTPONED	BE-ABP	Responsible 2	LS2	EN-EL	LHCDLW0
10592	APPROVED	TE-VSC	Responsible 3	2016-YETS-2017,2017-YETS	EN-EL	SPSLIU0
10351	APPROVED	TE-EPC	Responsible 4	LS2	EN-EL	PSRLIU0
10726	POSTPONED	BE-ICS	Responsible 5	2018	EN-EL	ICSVRW0
10764	CANCELLED	BE-ICS	Responsible 6	2017	EN-EL	SP6CRC0
11493	APPROVED	BE-RF	Responsible 7	2017	EN-EL-EIC	MEYDLW0
10973	APPROVED	BE-CO	Responsible 8	2020-Semester 2	EN-EL	-
11228	APPROVED	TE-EPC	Responsible 9	2018,2017	EN-EL	EPCVRW0

Figure 8 – PLAN Extraction²²

An excel extraction is also done from this tool containing only the information concerning the FC section activities (see Figure 8). This extraction contains, per Plan ID, information about the **status** of the activity (depending on the availability of the section), group the **caller** belongs to,

²¹ Small single-user projects are not declared in PLAN as their impact in the workload of the section is not significant enough

²² Some data has been modified in compliance with CERN's data protection regulation

responsible, **periods** in which the activity can be performed, group **responsible** and the **FTE project** they belong to (empty for the big single-user projects).

Each Plan ID leads to one or several Requests declared in Snow.

3.2.1.III. Snow tool

Online ticketing system that puts in contact the caller and the responsible. It contains small single-user projects and divisions of the activities declared in Plan, called *Requests*. Each Plan ID leads to one or several Requests, while small single-user project Requests do not belong to any Plan ID.

Information related to the FC section activities is daily extracted in 5 different excel files²³ with the same structure: per Request ID and from left to right in Figure 9, they contain information about the **caller**, **geographical area**, **period** in which the activity has to be finished, **Plan ID** it belongs to if any, **FC responsible**, **OSVC codes** it is linked to and **status** of the work.

Request ID	Caller	Geo Area	Final deadline	Plan ID	Responsible	OSVC	State
RQF1188725	Caller 1	PS COMPLEX	LS2	11617	Responsible 1	S213AFD584	Closed
RQF1065643	Caller 2	SM18	LS2		Responsible 2	S213AHC186	In Progress
RQF1064664	Caller 3	SM18	LS2		Responsible 3	S213AHC185	In Progress
RQF1173069	Caller 4	PS COMPLEX	LS2	11617	Responsible 4	S213AFD581	Closed
RQF1224039	Caller 5	PS &	LS2	11110	Responsible 5	S213AFD108, S213AFD161	In Progress
RQF1125521	Caller 6	LHC	LS2		Responsible 6	S213AHC194	In Progress
RQF1254995	Caller 7	SPS North	LS2		Responsible 7	S213AGE115	In Progress
RQF1053380	Caller 8	LHC	LS2	11032	Responsible 8	S213AHD116	In Progress
RQF1499658	Caller 9	Site Meyrin	LS2		Responsible 9	S213AFE124	In Progress

Figure 9 – Snow Extraction

This tool also offers the possibility of addressing the Request to the adequate entity for you. This way, callers can create a Request explaining the need without knowing which section can take care of it, and this Request is directly addressed, by the Snow support, to the appropriate section.

²³ 5 extractions respectively about *Fibre optics supply*, *Fibre optics installation*, *Rack installation*, *Signal cables installation* and *Direct current cables installation*

The main *challenges* to overcome during the creation step are:

1. The *agreed specifications* need to properly describe the *need*

It is important to note that the need itself is only known by caller, so the responsible only has access to the proposed specifications to understand this need. Therefore, a poor description in the proposed specifications may lead to misunderstandings and the development of some agreed specifications that no longer satisfy the need.

This point is not checked by the tools involved. It must be the caller who ensures that the need is properly described, asking the responsible for help in case of lack of knowledge to define it.

2. The *agreed specifications* must respect all the *constraints*

This means that all the restrictions present (e.g. time, manpower, budget) must be properly respected for the definition of the agreed specifications.

This was always done by each section itself, but the development of the *Plan tool* represented a huge improvement, preventing the sections from overloading.

3. Divide and structure all the workload among the responsables

The quantity of work requests treated is huge. Therefore, a robust system to treat and organise all this information is needed.

This is granted by all the 3 tools involved in this point, organising hierarchically the projects, and making much easier the work distribution among the different sections and PMs. Specially Snow is a dedicated platform to manage the Requests and follow up their status until the work is finished, allowing caller and responsible to specify and discuss all the technical requirements through it.

3.2.2. Planning

Once the OSVC (*input*) is defined, it comes the time for the responsible (*actor*) to plan and technically define the project. As we saw, a rough forecast of the main variables is already done in the OSVC during the creation step, to see if all the constraints are respected. But the precise definition of the global main variables, along with the week-by-week work plan²⁴, are defined in the technical file (*output*) during this step. This technical file is normally a pdf file.

Tool involved:

3.2.2.1. GESMAR

Database developed inside CERN to manage the activities from the Electrical group. It is divided into two main tools that are used during the FC section project management process:

- **Project Management tool** (for both cabling and fibre activities)

Tool used by the PMs to create and update the OSVCs, Affaires and Code Etudes and all their related information. Here is where the responsible side project organization is defined: the transition from the Requests to the Affaires, and which Affaires are grouped in each Code Etude.

It is in this tool that all the main variables²⁵ are precisely forecasted per Affaire. These forecasted values must be coherent with the ones included in the Technical File. The Code Etude main variables are automatically obtained by summing the main variables of the Affaires that are grouped inside. The Affaire's progress update during the monitoring step is also done in this tool.

- **Cablothèque** (only for cabling activities)

Database where all the cables present in the CERN's electrical scheme are declared. Therefore, if any cable is modified (added or removed), this modification is registered here. It is used during the monitoring and the validation steps.

²⁴ Estimation of the evolution of the main variables per week, along with technical information about the activity (e.g. position and characteristics of the cables that need to be removed, characteristics of the buildings in which the activity takes place, etc.).

²⁵ All the main variables are defined in Gesmar except the Radiation Dose, which is defined in Impact. This tool is described in the Monitoring step.

Contrat		
OSVC		
DT Num		
Bâtim - Nom/Num		
Responsable		

	Fin Trav Prévu	Début	% Avancement	Fin	Fermeture	Solde
Dates						
	Suivi engagements					
Voir EDH		DETAILS	OV			
Avenants	OSVC					
Voir EDH		DETAILS	OI			
Nb		Affaire(s)				

Statut OSVC	
-------------	----------------------

Préparer l'envoi EDH		Synchr. après annulation EDH	
----------------------	--	------------------------------	--

Figure 10 – Project Management tool interface

As we can see, Gesmar is the base for the FC section project managing, as it is where the most part of the planning is done. Also during the monitoring step, it is the source of most of the information displayed by the monitoring tools.

The main *challenges* to be faced during the planning step are:

1. In-depth forecast of the main variables and description of the process

It is important to note that all the *work supervisors* and the *Contractor* know about the works to be performed is what is written in the technical file, as they do not have access to the OSVC itself. Therefore, the quality and level of detail of the technical file will consequently affect the result obtained.

To ensure precision in these estimations, it is very important the availability and quality of data about the *worksite* and the *installations*, as well as from previous projects. This information comes from the experience sharing step.

2. Problem anticipation

The capacity of anticipating problems that may appear during the development of the works will avoid delays and stops during the monitoring step.

For this the personal experience of the PMs along with information shared by other PMs during the experience sharing step is very important to help avoiding problems that may have already happened in the past.

3.2.3. Monitoring

The monitoring step begins with the start of the works²⁶. During this step, the work is developed by the contractor (*actor*) according to the technical file (*input*), until the result (*output*) is accomplished. With the follow-up of the PM, unit coordinator and Support unit (*actors*). The arising constraints (*factors involved*) can highly impact the development of the monitoring step.

Figure 11 shows the different tools involved in the FC section monitoring process, as well as the flow of information going on between them. The tools are divided into Inputs (they introduce information to the process), Middle tool (it processes and organizes the information coming from the brown input tools, to generate information to be displayed by the outputs) and Outputs (they display the final information to the user).

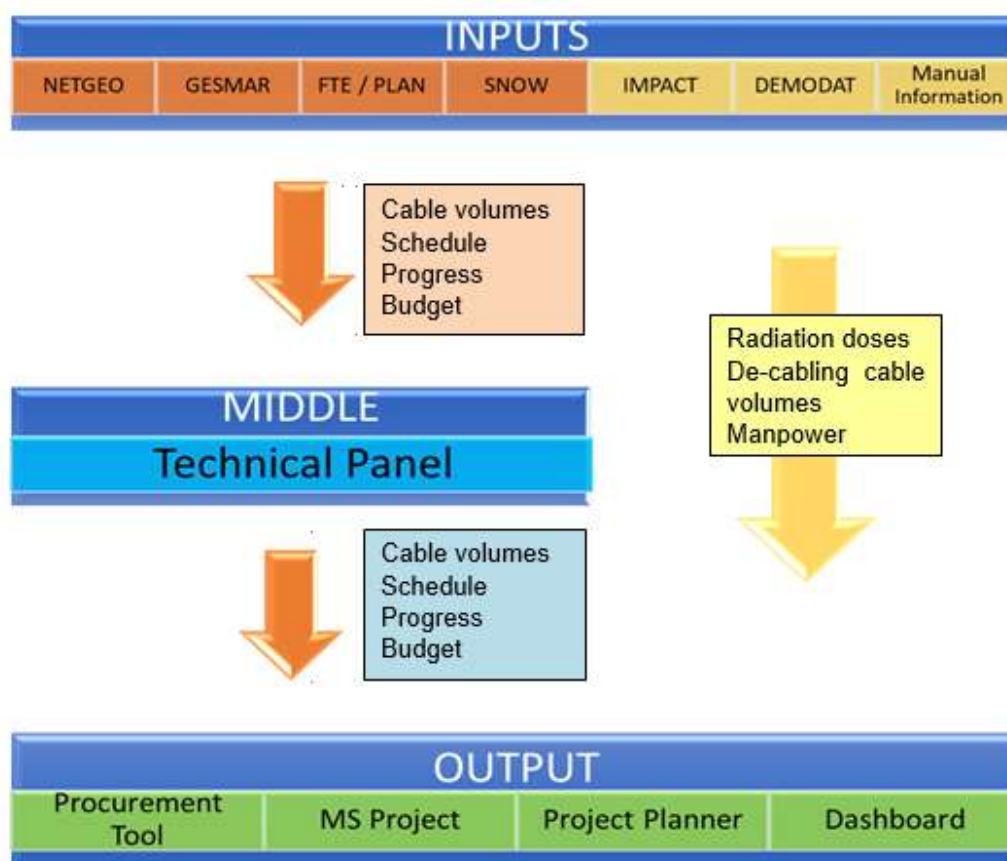


Figure 11 – Different tools intervening in the Monitoring process and the dataflow among them (the Manual Information is explained inside the Dashboard point)

²⁶ Except in the case of the procurement, that is followed-up before the start

As represented in Figure 11, the information coming from the Input tools in brown goes through the Technical Panel before being inserted in the different output tools, as it needs to be processed and grouped before being displayed. This information has to do with the *progress*, *budget*, *cable volumes* and *schedule* of the different activities.

On the other hand, the information coming from the Input tools in yellow flows directly into the Dashboard (as the other 3 output tools only take information from the Technical Panel). This data has to do with the *manpower* (manual info), the *radiation doses* (Impact) and data about *cable volumes* from the de-cabling activities (Demodat).

Tools involved:

3.2.3.I. GESMAR

Two excel extractions are daily done, with information about the FC section activities, from the two Gesmar sub-tools described in the planning step (*Project Management* tool and *Cablothèque*):

- **CAU12** (Figure 12): it contains, for cabling and fibre activities, information **per Code Etude** from the Project Management tool such as the *responsible* and several dates (*start*, *end*, when the project was *created* and when was the last *modification* of data done).

It is the Project Manager's responsibility to keep this information updated in Gesmar.

Code Etude	Responsible	Start Date	End Date	Creation Date	Last Modification Date
ADRELN0-FL201	Responsible 1	03-feb-20	21-feb-20	10-jul-18	03-jun-19
ADREXT0-CL201	Responsible 2	05-oct-20	23-oct-20	05-mar-20	
ADREXT0-CL202	Responsible 3	23-jul-20	31-jul-20	05-mar-20	21-jul-20
ADREXT0-CL2D1	Responsible 4	06-jul-20	17-jul-20	05-mar-20	15-jun-20
ADRINT0-CL201	Responsible 5	15-jun-20	03-jul-20	16-feb-18	03-jul-20
CCCFSF0-FL201	Responsible 6	03-feb-20	12-feb-20	10-feb-20	10-feb-20

Figure 12 – CAU12 extraction from the Project Management tool

- **CME12**: it contains, for cabling and fibre activities, information **per Affaire** from the:
 - *Project Management* tool (green squares in Figure 13): from left to right, *Code Etude* they are linked with, *start* and *end dates* and *global progress* of the Affaire. Also, the *budget* involved in the activity and the status of the payment are included in the extraction, but not in the image due to data protection reasons.

- Cablothèque (blue squares in Figure 13): from left to right, total *cable length* to install, *number of raccordements* to do, *number of tests* to do and *progress of the pulling, raccordement and test*.

It only gives information for the Cabling unit cable installation activities.

Campagne	Date début	Date fin	Affaire	Lg totale (	Nb Racc tc	Nb Test tc	% Global	% Pose	% Racc	% Test
ISOGMT0-FL201	30-01-20	30-01-20	S214AFD406003	324	0	8	100	100		100
ISRGMT0-FL201	30-03-20	31-03-20	S214AFD406004	60	0	1	100	100		100
LH1DLW0-FL201	10-02-20	18-03-20	S214AHE209001	918	0	6	100	100		100
LH1FAS0-FL201	09-03-20	17-03-20	S214AHE201001	1271	0	31	100	100		100
LH1FAS0-FL201	09-03-20	17-03-20	S214AHE201002	80	6	3	100	100	100	100
LH1FIC0-FL201	01-01-19	31-12-20	S214AHD213001	36	12	6	100	100	100	100
LH1FIC0-FL201	01-01-19	31-12-20	S214AHD259001	177	8	8	100	100	100	100
LH1FIC0-FL201	01-01-19	31-12-20	S214AHE203001	356	4	2	100	100	100	100

Figure 13 – CME12 extraction from the Project Management tool (squares in green) and the Cablothèque (squares in blue)

3.2.3.II. NETGEO

Database developed to manage CERN's fibre infrastructure. Once the Affaires are declared and defined in the Gesmar *Project Management* tool, the fibre Affaires and all the information related to them is automatically imported in this platform. Once the activity starts, the cables installed or removed (cable volumes) are declared here, while the progress is directly updated in the Gesmar's *Project Management* tool by the PM.

Therefore, the only information extracted from this tool are the cable volumes, as the rest of the main variables are updated in Gesmar.

Figure 14 shows the data extracted from Netgeo to be inserted in the Technical Panel. This data are the *number* and *length* of *cables* and *fibres* to install for each Affaire.

CODE	CABLES			
	CABLE [Qty]	CABLE LENGTH [m]	FIBRE [Qty]	FIBRE LENGTH [m]
S214AGD935002				
S214AGD936002				
S214AGD938001	7	619	96	8880
S214AGD943001	1	200	48	9600
S214AGD943002	3	1868	18	11208
S214AGD952001				
S214AGD952002				
S214AGD958001	1	222	48	10656
S214AGD971001	1	38	12	456

Figure 14 – Netgeo extraction

3.2.3.III. IMPACT

Webtool containing information about the doses received by the workers during the development of the activities in radiation areas. Only activities classified as ALARA 2 and ALARA 3 (high-radiation activities) are followed-up. Each one of these activities are identified by a unique 6 digits code (*Impact number*) that identifies them in the platform.

The information is extracted from the tool in excel format and directly inserted in the Dashboard through a macro. Impact extractions are composed of 3 parts:

- **Header** (top table from Figure 15): a table with the *Impact number*²⁷, and the *max. collective*, *individual* and *daily doses* allowed for the activity in μSv .
- **Daily dose** (bottom-left table from Figure 15): a second table with the *doses undergone by each worker per day* in μSv .
- **Overall** (bottom-right table from Figure 15): a third table with the *overall dose taken per worker* until the present date, in μSv .

²⁷ Not included in Figure 15 for data protection reasons

Estimated Collective Dose: 4195 µSv		Estimated Individual Dose: 351 µSv		Estimated dose alarm per intervention:		50 µSv																	
26-Aug-2019 to 12-Dec-2019		September-2019																					
	Totals (µSv)			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Worker 1	263	Worker 1						4				5	1	0	3	9			4	8	23	15	17
Worker 2	0	Worker 2														0							
Worker 3	21	Worker 3										0	0	0	0	0							
Worker 4	4	Worker 4												0	0	6							
Worker 5	19	Worker 5														4							
Worker 6	11	Worker 6												0	4	10							

Figure 15 – Collage of the 3 main tables present in an Impact extraction

3.2.3.IV. MANUAL INFORMATION

The manpower used is weekly given in pdf format by the contractor to the Support unit (Figure 16) and manually inserted per Code Etude, in the *Insertion* sheet of the Dashboard, by the Support Unit.

Campagne	N° AFFAIRE	S11	S12	S13
EXEEHU0-CD03	AFD505002			
EXEEHU0-CD03	AFD505003			
EXEEHU0-CD03	AFD575001			
EXEEHU0-CD03	AFD589100			
EXEEHU0-CD04	AFD504001			
EXEEHU0-CD04	AFD576001			
EXEEHU0-CM01	AFD917001			
EXEEHU0-CM01	AFD917002			
EXEEHU0-CP01	AFE700001		3	
EXEEHU0-CP02	AFE703001	6	3	3
PSRLIU0-CP06	AFD924001			

Figure 16 — Manpower per Affaire weekly sent by the Contractor. It shows the manpower deployed during the past week (S11), and the manpower forecasted for both the present (S12) and the next week (S13)

3.2.3.V. DEMODAT

Database created in Microsoft Access containing information about the cables removed during the Cabling unit de-cabling activities. It is daily updated, when de-cabling activities are taking place, with the information given by the contractor about the cables removed that day.

This information is afterwards extracted from Demodat and treated in excel. Once treated, that excel extraction is inserted through a macro in the Dashboard *de-cabling sheet* to follow-up the progress of the de-cabling activity. That extraction is also kept to update the electrical network scheme in the *Cablothèque* during the validation step.

3.2.3.VI. TECHNICAL PANEL

Tool developed by the FC Support unit to treat and group the data from the input tools in brown in Figure 11, inserted through the excel extractions mentioned during the creation step²⁸ (*Netgeo*, *FTE file*, *Plan Tool*, *SNOW*, *CAU 12* and *CME 12*).The tool itself consists in an excel file with 3 sheets, each of the sheets containing a table:

Snow Tickets Sheet (Figure 17): sheet developed to put together all Requests and related information.

The information is organized per **Request** and taken from Snow, Plan and the FTE file extractions. The sheet contains information like the *Plan ID* and *Project Code* they are linked to, or the *geographical area* where the activity takes place (*Complex*).

PLAN Tool Project Code	SNOW PLAN ID	SNOW PLAN Title	PLAN Tool Group Name	SNOW Request ID	SNOW Complex
VSCVRW0	11639	Renovation of damaged cables in	TE-VSC	BQF1038768	SPS North Area
VSCVRW0	10733	Additional Sectorization	TE-VSC	BQF0810607	LHC
EPCVRW0	11627	Supply new converters to	TE-EPC	BQF1054255	SPS North Area
EPCVRW0	11627	Supply new converters to	TE-EPC	BQF1054256	SPS North Area
EPCVRW0	11627	Supply new converters to	TE-EPC	BQF1250865	SPS North Area
EPCVRW0	11627	Supply new converters to	TE-EPC	BQF1109555	SPS North Area
EPCVRW0	11603	Supply new control for the	TE-EPC	BQF0967012	PS COMPLEX LEIR
EPCVRW0	11551	Supply new converters for the	TE-EPC	BQF0909233	PS & Transfer Lines
EPCVRW0	11526	Supply new converter for REX	TE-EPC	BQF0880311	PS COMPLEX Isolde
EPCVRW0	11443	Consolidate PQPS Capacitors	TE-EPC	BQF1157559	PS & Transfer Lines
EPCVRW0	11443	Consolidate PQPS Capacitors	TE-EPC	BQF0851826	PS & Transfer Lines
EPCVRW0	11388	Supply new converters for PSB BDL	TE-EPC	BQF1028407	PS Booster
EPCVRW0	11388	Supply new converters for PSB BDL	TE-EPC	BQF0893242	PS Booster
EPCVRW0	11388	Supply new converters for PSB BDL	TE-EPC	BQF0893186	PS Booster
EPCVRW0	11388	Supply new converters for PSB BDL	TE-EPC	BQF0908687	PS COMPLEX CLEX

Figure 17 — View of the *Snow Tickets* sheet from the Technical Panel

As shown in Figure 18, there is a defined color code for the Requests to easily know the status of the Request while reading it.

RQF0967228	Request included in the extraction and not yet completed and closed
RQF0967228	Request included in the extraction and already completed and closed
RQF0967228	Request not included in the extraction anymore

Figure 18 — Color code for the Request and Project codes

²⁸ In the header of each table, it is reported from which extraction or tool is the data coming from (see Figure 17, Figure 19 and Figure 21)

Gesmar Affaire Sheet (Figure 19): sheet developed to put together all the Affaires and related information.

The information is organized per **Affaire**, and it is coming from Snow, Plan, Gesmar and the FTE file extractions. The sheet shows the *Project Code*, *Snow Request* and *Code Etude* they are linked to, and information about the *cable volumes* and the status of the *procurement*. Also, the *budget* involved in each activity appears in this sheet, but it is not included in the images.

PLAN Tool	SNOW	SNOW	GESMAR CME12	(FORMULA) Nbre câbles Best Estimation	(FORMULA) Qté câbles [m] Best Estimation
Project Code	Request ID	PLAN ID	Num Affaire		
LHCDLW0	RQF1362105	11626	S213AHE110002	7	630
LHCDLW0	RQF1362105	11626	S213AHE110001	7	630
LHCHILO	RQF0908671	10823	S213AHE108001	4	300
LHCHILO	RQF0943607	11214	S213AHE107001	2	37
LHCDLW0	RQF0902672	11524	S213AHE106001	18	
LHCHILO	RQF0943607	11214	S213AHE105001		
LHCHILO	RQF0908671	10823	S213AHE104003		
LHCHILO	RQF0908671	10823	S213AHE104002	9	
LHCHILO	RQF0908671	10823	S213AHE104001	13	
ICSVRW0	RQF0970045	11505	S213AHE103002	51	880
ICSVRW0	RQF0970045	11505	S213AHE103001	11	2494
LHCHILO	RQF0912378	11214	S213AHE102003	11	936
LHCHILO	RQF0912378	11214	S213AHE102002	5	159
LHCHILO	RQF0912378	11214	S213AHE102001	4	256

GESMAR CME12 Cables Reserved (Km)	GESMAR CME12 Cables being procured (Km)	GESMAR CME12 Difference (Km) Procured - To install
0.000	0.000	-0.630
0.000	0.000	-0.630
0.300	0.000	0.000
0.000	0.000	-0.037
0.000	0.000	0.000
0.000	0.000	0.000
0.000	0.000	0.000
0.000	0.000	0.000
0.000	0.000	0.000
0.000	0.000	-0.880
3.830	0.000	0.000
0.000	0.000	-0.936
0.407	0.000	0.192
0.000	0.000	-0.256

Figure 19 — Views from the *Gesmar Affaire* sheet from the Technical Panel

As shown in Figure 20, there is also a defined color code for the Affaire codes.

S214AGA911200	Affaire included in the CME12 extraction and not yet finished
S214AGA911200	Affaire included in the CME12 extraction and finished
S214AGA911200	Affaire not included in the CME12 extraction anymore

Figure 20 — Color code for the Affaire codes

Code Etude Sheet (Figure 21): sheet developed to put together all the *Code Etudes* and related information.

The information is organized per **Code Etude**, and it is coming from the Gesmar CME12 and CAU12 extractions and the Affaire sheet. The sheet shows information about *cable volumes*, different partial *progresses*, *schedule* and the status of the *procurement*.

GESMAR CAU12 Campaign	AFFAIRS Cables	AFFAIRS Length [km]	GESMAR CME12 %Global - Aff	GESMAR CME12 %Global - Cb	GESMAR CME12 %Pulling	GESMAR CME12 %Racc	GESMAR CME12 %Test
ADREXT0-CL202	88	1.395	0	0	0	0	0
EXEEHU0-CD01	1377	34.409	100	0	0	-	-
EXEEHU0-CD02	703	13.131	100	0	0	-	-
EXEEHU0-CD03	758	51.516	95	0	0	-	-
EXEEHU0-CD04	1433	54.394	97	0	0	-	-
EXEEHU0-CM01	0	0.000	49	-	-	-	-
EXEEHU0-CM02	0	0.000	0	-	-	-	-
EXEEHU0-CP01	90	1.122	73	76	100	2	100
EXEEHU0-CP02	232	3.391	15	30	36	38	8

GESMAR CAU12 Start Date	GESMAR CAU12 End Date	GESMAR CME12 Cables Reserved (Km)	GESMAR CME12 Cables being procured (Km)	GESMAR CME12 Difference (Km) Procured - To install
13-04-2020	01-05-2020	0.961	0.000	-0.434
10-12-2018	17-01-2019	0.000	0.000	-34.409
10-12-2018	17-01-2019	0.000	0.000	-13.131
09-09-2019	29-11-2019	0.000	0.000	-51.516
01-07-2019	20-08-2019	0.000	0.000	-54.394
27-01-2020	10-03-2020	0.000	0.000	0.000
18-05-2020	10-07-2020	0.000	0.000	0.000
24-02-2020	06-03-2020	1.065	0.000	-0.057
09-03-2020	17-04-2020	3.858	0.000	0.467
		0.000	0.000	-1.300

Figure 21 — View from the *Code Etude* sheet from the Technical Panel

As shown in Figure 22, there is also a defined color code for the *Code Etude* codes.

PSBLIU0-CP08	Campaign included in the CAU12 extraction and not yet finished
MEYMDS0-FYB01	Campaign included in the CAU12 extraction and finished
LH8UPT0-FYC01	Campaign not included in the CAU12 extraction anymore
LH8UPT0-FYC01	New campaign added or dates modified in the last 7 days
LH8UPT0-FYC01	All this row is manually edited and it is not updated by the macro

Figure 22 — Color code for the *Code Etude* codes

The information flowing to the outputs from the Technical Panel comes solely from the Code Etude sheet. And the main variables flowing to each output tools are:

- To the *Dashboard*: actual schedule, cable volumes, progress and budget.
- To *MS Project*: actual schedule and progress.
- To the *Project Planner*: baseline and actual schedules, status of the cable procurement, and global and partial progress
- To the *Procurement Tool*: cable volumes and status of the cable procurement.

3.2.3.VII. DASHBOARD

The Dashboard is a tool developed by the FC support unit, that displays information about ongoing and already finished activities from a specific period (e.g. LS2), with the purpose of:

- Following-up their progression
- Generate statistics
- Use this information to improve future forecasts

The data used comes from the *Technical Panel* (schedule, volumes, progress and budget), *Impact* (radiation doses) and *Demodat* (cable quantities removed).

The tool is composed of 5 types of sheets: *Insertion sheet*, *Activity Progress sheet*, *Statistics sheet*, *Decabling sheet* and *Dose Follow-up sheet*. And the dataflow between them is as shown in Figure 23.

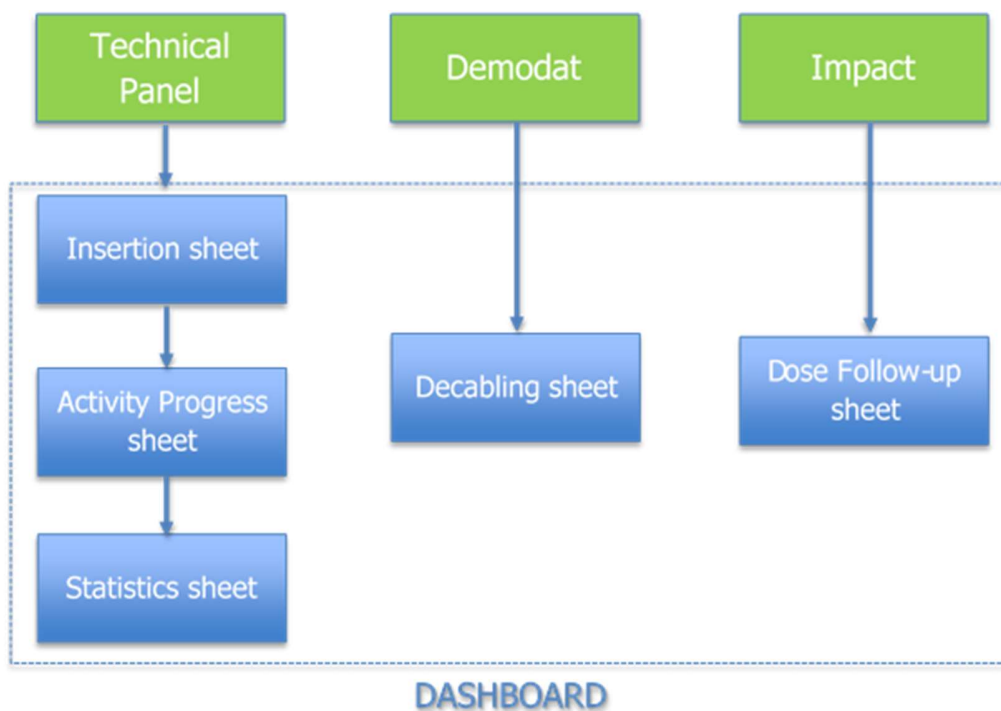


Figure 23 — Dataflow between the 5 different types of sheets present in the Dashboard

Insertion sheet: sheet created to insert the manpower manually, and the information coming from the *Code Etude* sheet (Technical Panel) through a macro. All this information is weekly updated.

The data is sorted per **Code Etude** and gathers information about *cable volumes*, *budget*, *schedule*, *manpower* and *progress*.

Activity Progress sheet (Figure 24): sheet created as a database to keep, for each of the LS2 weeks, the information present in the *Insertion* sheet. The information is weekly inserted from the *Insertion* sheet through a macro.

					C	Feb				Mar		
Code	Volume		Schedule			6	7	8	9	10	11	12
LHC	Length	135.3	Start date	10-12-18	Activity Actual	72.92	77.43	80.28	81.25	82.40	82.64	82.65
	No. Cable	1402	End Date	20-10-20	Activity Forecast	75.90	78.49	80.15	81.12	82.09	83.46	85.76
			Duration	681.00	Manpower Actual	9	8	8	8	8	8	8
	Weight	3.35791274			Manpower Forecast	11	17	13	10	10	6	6
	Weight Bas	2.98372872			Length Actual	99.005	105.797	110.514	112.024	113.216	113.584	113.596
					Length Forecast	100.992	104.973	107.961	109.526	111.091	112.746	115.676
					No. Cables Actual	1018	1072	1101	1112	1133	1136	1136
					No. Cable forecast	1086	1116	1130	1140	1151	1172	1207
LHC1	Length	15.042	Start date	13-12-18	Activity Actual	21	40	65	73	78	80	80
	No. Cable	116	End Date	29-09-20	Activity Forecast	21.967	33.67124	45.84577	55.15804	64.47031	73.78258	83.09484
			Duration	656.00	Manpower Actual	4	6	6	6	6	6	6
	Weight	0.33072294			Manpower Forecast	3	9	9	6	6	6	6
					Length Actual	3.384	6.481	10.618	11.843	12.627	12.995	12.995
					Length Forecast	3.384	5.445	7.506	8.995	10.484	11.973	13.462
					No. Cables Actual	23	41	66	74	79	81	81
					No. Cable forecast	23	34	45	55	65	74	84
LHIHIL0-CC03	Length	3.826	Start date	10-02-20	Activity Actual	0	34.544	62.5	78	87.8	87.8	87.8
	No. Cable	22	End Date	17-03-20	Activity Forecast	0	16.66667	33.33333	50	66.66667	83.33333	100
	Manpower	3	Duration	36.00	Manpower Actual							
	Weight	0.08			Manpower Forecast	0	3	3	3	3	3	3
LHIUDT0-CL201	Length	1.047	Start date	10-02-20	Activity Actual	0	11.55891	86.78571	96.33333	100	100	100
	No. Cable	7	End Date	17-03-20	Activity Forecast	0	16.66667	33.33333	50	66.66667	83.33333	100
	Manpower	0	Duration	36.00	Manpower Actual							
	Weight	0.02			Manpower Forecast	0	0	0	0	0	0	0

Figure 24 — View of the "Activity Progress" sheet from the Dashboard

Statistics sheets: sheets created to plot the information present in the *Activity Progress* sheet. There are 4 different blocks (*Progress*, *Cable Volumes*, *Manpower* and *Budget*), each one with graphs per geographical area for both cabling and fibre projects.

The *Progress* and *Volume* graphs are normally composed of 3 lines (as shown in Figure 25):

- *Baseline* (first prediction done when the work was initially planned)
- *Forecast* (modification of the baseline done before the start of the activity)
- *Actual* (real values obtained from the development of the activity)

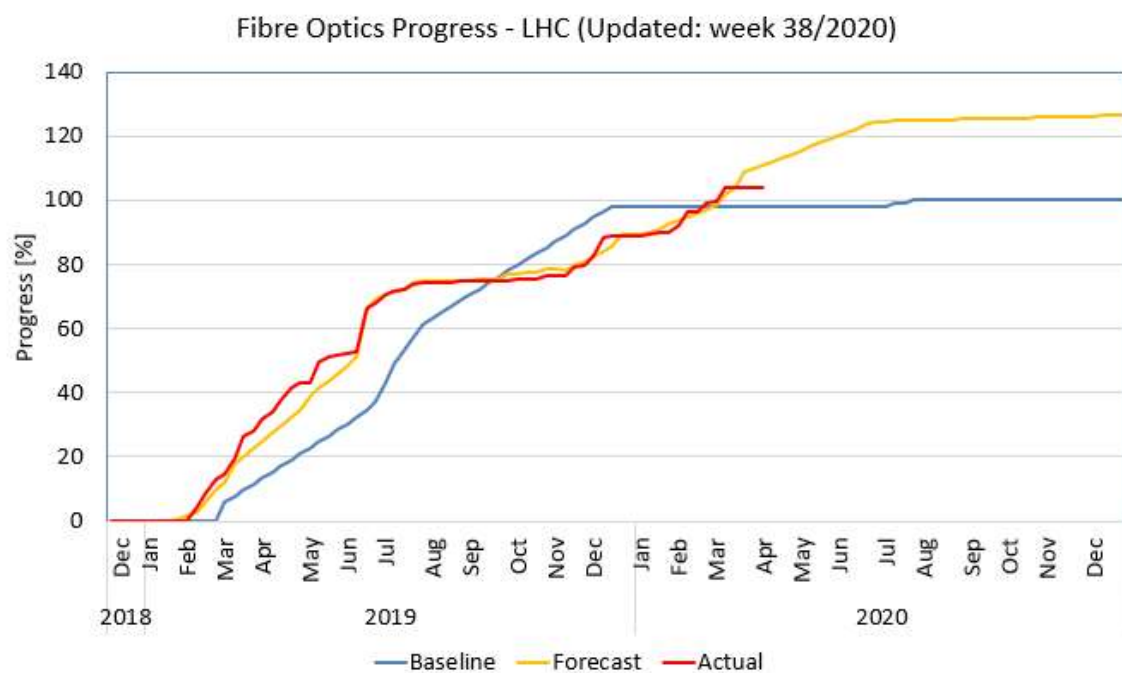


Figure 25 — Progress graph present in the “Progress” sheet from the Dashboard

De-cabling sheet: sheet developed to follow-up the de-cabling campaigns. It contains information from Demodat about *progress*, *de-cabling volumes* and *manpower*, and correlations between them.

For each de-cabling campaign several graphs (Figure 26) are showing the information present in the data table (Figure 27).

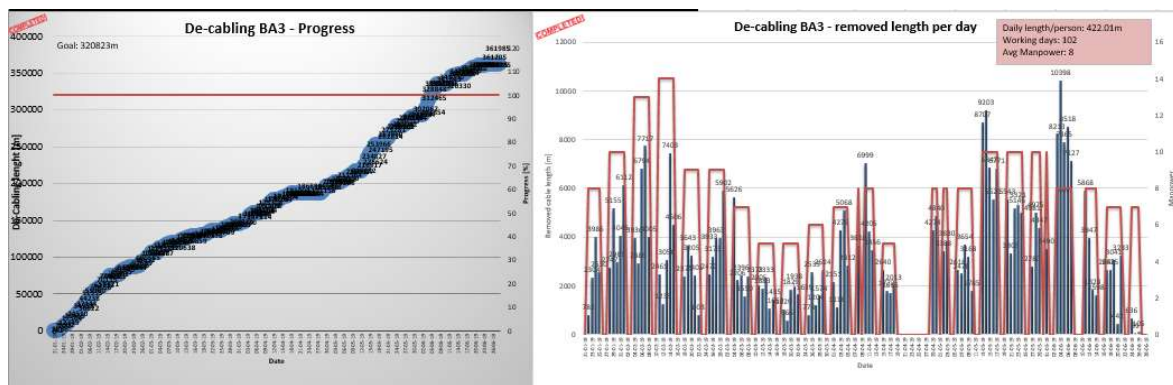


Figure 26 — Graphs from the De-cabling sheet from the Dashboard

Date →	22-01-19	23-01-19	24-01-19	25-01-19	26-01-19	27-01-19	28-01-19
Goal →	320823	320823	320823	320823	320823	320823	320823
Length per Day →	782	2304	3986	2530	0	0	2747
Cummulated Length →	782	3086	7072	9602	9602	9602	12349
Percentage of Finishing →	0.24374811	0.9619011	2.2043307	2.9929276	2.9929276	2.9929276	3.8491629
Activ. Monitoring: Actual →	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	10
Activ. Monitoring: Forecast →	0.88	1.76	2.64	3.52	3.52	3.52	4.4
Activ. Monitoring: Baseline →	0.88	1.76	2.64	3.52	3.52	3.52	4.4
Manpower →	8	8	8	8	0	0	10
Length per day/person →	97.75	288	498.25	316.25	#N/A	#N/A	274.7
Number cables / day →	19	119	93	24	0	0	51
Cummulated Nb Cb →	19	138	231	255	255	255	306

Figure 27 — Data table present in the De-cabling sheet from the Dashboard

Dose follow-up sheet: sheet created to follow-up the radiation dose taken by the workers during activities that take place in radiation areas. The information is directly taken from Impact. For each FC section activity declared in Impact there is one dose follow-up sheet in the Dashboard with the following structure:

- **Main Table** (Figure 28): table with the main information about the Impact activity (*max. collective* and *individual doses*). Together with some information (*schedule*, *weight* and *progress*) about the different code etudes that are included in the Impact activity.

Max. Estimated Collective Dose [μ Sv]:		5224		
Max. Estimated Indiv. Dose [μ Sv]:		668		
CAMPAIGN	Start Date	End Date	Weight	Progress
Overall	06-01-20	13-03-20	0.14	96%
SP2FSF0-CC02	06-01-20	28-02-20	0.09	100.00%
SP2UTT0-CL202	06-01-20	28-02-20	0.01	47.50%
SP2UTT0-CL2D1	06-01-20	28-02-20	0.04	96.00%
SP2NLF0-CC02	03-02-20	13-03-20	0.01	100.00%
SP2PPS0-CC03	06-01-20	28-02-20	0.04	100.00%

Update the Dose Information

Publish the Graphs

Overall Controls

Figure 28 — Main table present in the Dose Follow-up sheets of the Dashboard

- **Radiation Graphs** (Figure 29): 3 graphs showing, respectively, the global dose taken, the individual doses taken by CERN personal and the individual doses taken by the contractor workers.

For each graph, the green dashed line represents the progress and the various continuous lines represent the doses taken. The horizontal red line on the top represents the maximum dose allowed (for the continuous lines) and the point where the activity finishes (for the dashed line).

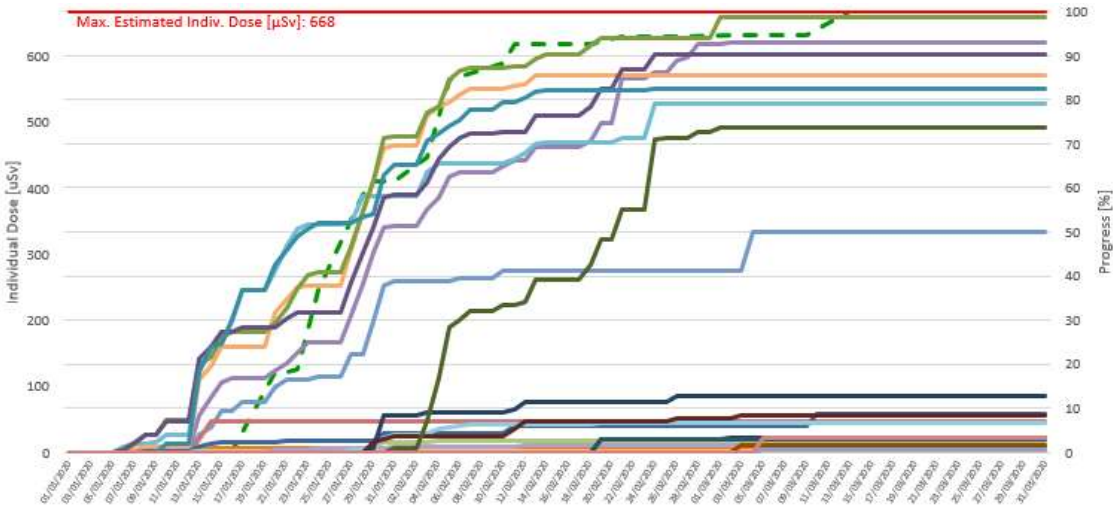


Figure 29 — Radiation graph present in the Dose Follow-up sheets of the Dashboard

•

- **Doses Table** (Figure 30): chart where the information coming from the Impact extractions is inserted. It is the information used to plot the graphs. It shows the cumulated dose taken per day and per person.

		Absorbed Coll. Dose →	960	1102	1188	1305	1305	1305	1480	1620	1739	1793
		Max. Indiv. Dose →	668	668	668	668	668	668	668	668	668	668
		Max. Collective Dose →	5224	5224	5224	5224	5224	5224	5224	5224	5224	5224
		Activity Progression →	0 0,399122 18,07993 18,07993 18,93464									
Company	Name	14/01/2020	15/01/2020	16/01/2020	17/01/2020	18/01/2020	19/01/2020	20/01/2020	21/01/2020	22/01/2020	23/01/2020	
Contractor	Worker 1	38	63	63	76	76	76	100	110	110	111	
Contractor	Worker 2	48	48	48	48	48	48	48	48	48	48	
Contractor	Worker 3	4	4	4	4	4	4	4	4	4	4	
Contractor	Worker 4	84	105	113	113	113	113	124	136	150	166	
Contractor	Worker 5	153	164	198	246	246	246	275	313	339	345	
CERN	Worker 6	2	2	2	2	2	2	2	2	2	2	
Contractor	Worker 7	130	153	153	153	153	153	213	233	251	253	
Contractor	Worker 8	12	15	15	15	15	15	15	18	18	18	
Contractor	Worker 9	1	1	1	1	1	1	2	2	2	2	
Contractor	Worker 10	145	174	183	183	183	183	197	218	249	269	
Contractor	Worker 11	153	183	183	190	190	190	190	204	213	213	
Contractor	Worker 12	153	165	200	245	245	245	284	306	327	339	
Contractor	Worker 13	6	6	6	6	6	6	6	6	6	6	
CERN	Worker 14	4	4	4	4	4	4	4	4	4	4	
Contractor	Worker 15	1	1	1	1	1	1	1	1	1	1	
Contractor	Worker 16	2	2	2	2	2	2	2	2	2	2	
CERN	Worker 17	5	5	5	5	5	5	5	5	5	5	
Contractor	Worker 18	1	1	1	1	1	1	1	1	1	1	

Figure 30 — Doses table present in the Dose Follow-up sheet of the Dashboard

The main improvements obtained with the Dashboard are:

Availability of information about past activities: with the data from previous activities gathered in the *Activity Progress* sheet. This helps the PMs estimating the main variables based on the results of previous activities, and the development of graphics.

3.2.3.VIII. PROCUREMENT TOOL

Excel table developed by the Support unit with the purpose of visualizing the status of the procurement per Code Etude.

The tool consists of a table (see Figure 31) that includes, for each code etude, the *length being procured* and already *procured*, the *difference* between the sum of both and the *total length* declared in the *Cablothèque* and an empty column to add any comment that the procurement responsible may want to add.

All this information is taken from the *Code Etude* sheet and daily updated.

Row Labels	Description	Km Being Procured	km Procured	Km Difference	ProcurementComment
2019					
Qtr4					
Oct					
Nov					
Dec					
LH2HILO-CC01	LHC2G HILUMI LOCAL LOI	0.000	17.190	-0.827	Campaign Checked
LH2UGT0-CL201	CABLAGÉ LS2 - POINT2 G.	0.000	0.706	-0.117	Campaign Checked
PSBLIU0-CP08	CABLAGÉ DC LIU PSB BHP	0.000	11.683	-1.372	Campaign Checked
PSRLIU0-CP04	CAMPAGNE CABLAGÉ DC I	0.000	0.100	-0.029	Campaign Checked
SP1LIU0-CC01	CABLAGÉ CONTROL SURF	0.000	5.508	0.029	Campaign Checked
SP4UTT0-CL202	CAMPAGNE DE CABLAGÉ I	0.000	0.153	0.014	
PSRINT0-CL207	CAMP. CABL. INT. PS - FIN	0.000	0.343	-0.002	Campaign Checked
PSRLIU0-CC22	CABLAGÉ CONTROL PSR/I	0.000	0.705	-0.157	Campaign Checked
SP4SMT0-CL202	CAMPAGNE DE CABLAGÉ I	0.000	0.000	0.000	
ZOPPS0-CC01	CAMPAGNE CABLAGÉ ZON	0.000	3.250	0.944	
PSRLIU0-CP06	TETES HT 6KV SMH42 - LS	0.000	0.000	0.000	
M18TBU0-CW08	WCC UPGRADE HFM INSTA	0.000	0.000	0.000	

Figure 31 — Procurement tool interface

3.2.3.IX. MS PROJECT

Microsoft Project is used with the double functionality of planning and following-up the FC section activities.

As shown in Figure 32, it contains information about the *schedule* and the *progress per group of code etudes*. As code etudes taking place in the same area and during similar dates are normally carried out at the same time by the PMs.

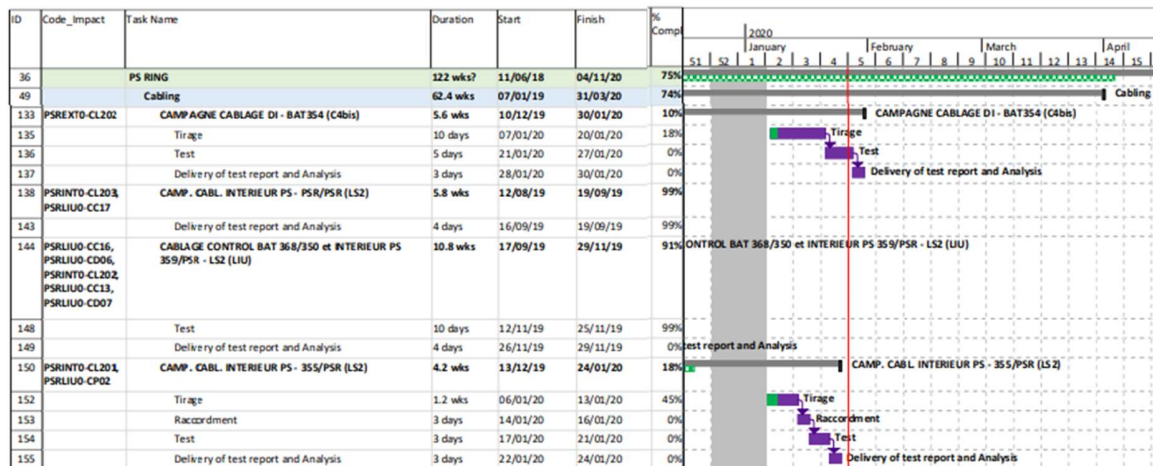


Figure 32 — MS Project Interface

3.2.3.X. PROJECT PLANNER

Tool developed in excel with the main purpose of visualizing the data present in the Technical Panel's Code Etude sheet. It consists of a table with information about the FC activities per Code Etude and a Gantt diagram. All is daily updated by a VBA macro with information from the Technical Panel's Code Etude sheet.

As shown on the left part of Figure 33, the table contains information per Code Etude²⁹ about the *geographical area*, *schedule*, status of the cable *procurement* and the *global and partial progresses* (Pulling, Raccordement and Test).

On the right side of Figure 33, a Gantt Diagram represents the global progress of the project with a yellow bar that fills with green. A low horizontal black line represents the baseline dates. Code etudes starting on the same date are grouped, like in the MS Project, through a thick vertical black line on the left of the yellow bars. The progress of this group of Code Etudes is shown on the left of the vertical black line.

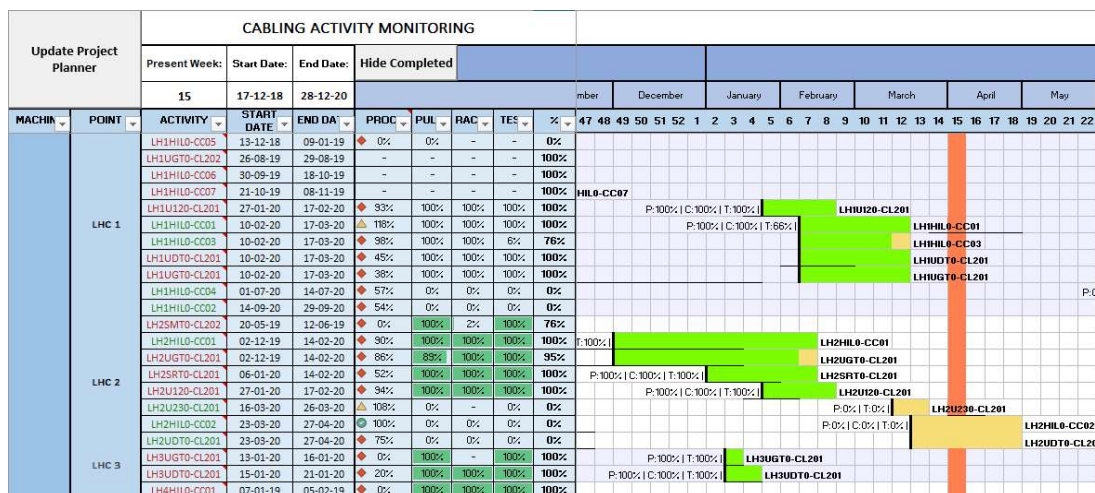


Figure 33 — Project Planner interface view

The main challenges present in the monitoring step are:

1. The work must be feasible for the responsible and the workers:

²⁹ The color code used is the same one as in the *Code Etude* sheet.

Both the responsible and the workers need to have enough technical knowledge to develop the work. If this is not the case, they should warn the rest of the team to find an alternative.

2. Development of an accurate monitoring system:

This allows the responsible to know at each moment the status of the ongoing activities. From the main variables, the only two followed-up³⁰ during the *Monitoring* step are:

- the **radiation dose**: it is followed-up using the data from *Impact* visualised in the *Dashboard*.

If the radiation dose surpasses either the individual or the global established limits, the activity stops. The PM needs then to find the reason why the estimations were not accurate to see if these limits can be increased to continue the works.

- the **progress**: it is followed-up using the data from the *Technical Panel* visualised in the *Dashboard*, the *Project Planner* or the *MS Project*.

If the progress becomes lower than forecasted, the monitoring system must be able to show it to the PM and the unit coordinator to, based on it, decide if correction actions must be triggered. For example, in the case of an activity A going slower than planned and another activity B going faster, some manpower could be temporarily transferred from activity B to A to balance their progression. This kind of actions are only possible with a proper monitoring system that accurately shows the progress of the activities.

3. Fast transmission of the arising constraints to the responsible:

The responsible must be constantly posted on any new event that can affect the project. Anticipation is vital as arising constraints are very unpredictable and they may take time to coordinate an alternative. For this, the Support unit plays an important role due to the information they search and receive about these arising constraints (e.g. elevators maintenance during one day preventing the access to some underground facilities), that has to be addressed as fast as possible to the PM.

Even in this case, having a precise monitoring system hugely helps a PM to react to an arising constraint. For example, in the case of an activity A, for which the *worksites* is not accessible during a certain period, a possible solution would be to stop or slow down the works in that

³⁰ Even though these are the only two variables directly followed-up, the cable volumes and the schedule are also indirectly used. Cable volumes are sometimes used to calculate the progress, and the schedule is used to relate the progress left with the time left to know whether the activity is going on time or it is delayed.

activity A, transferring some of its manpower to another activity B. And once the constraint is finished, use some of the activity B manpower (that by then should be more developed than initially planned) for activity A. All this is not evident to do if the progress of the different activities is not accurately known.

A deficient control of the 2nd and 3rd challenges (the arising constraints are not anticipated or the progress of the activity does not follow what was planned, but no action is put in place) is what normally leads to delays or even failing to finish the activity and achieve the goal.

3.2.4. Validation & Data Update

Once the *work* is finished, the *result* is firstly discussed between the *responsible* and the *workers* to check that it respects what was defined in the *technical file*. Then, it is inspected by the *responsible* and the *caller* to see if it fulfils what was settled in the *agreed specifications*.

In the case that any of these two checks are not satisfied, the *works* will have to resume and the project will go back to the monitoring process, or even to the planning process, if the project needs to be restructured or any of the main variables needs to be re-forecasted.

3.2.4.1. De-cabling activities management:

For most of the activities, the modifications done to the *installations* are registered in the different platforms (Gesmar, Netgeo, Demodat) while the *work* is being developed. But, for the Cabling unit de-cabling activities, this data update process needs to be done once the activity is finished. This is because all the information obtained from the de-cabling activity needs to be compared before been inserted in the Cablothèque. The tools used are:

- **Demodat**: Microsoft Access database where all the cables removed in a specific de-cabling activity are daily registered to be treated (with the help of some excel templates) before been inserted in the Cablothèque.
- **Cablothèque**: as previously described, it is a database where all the cables present in the CERN's electrical network are registered, along with data as their position, length or type.

The Cabling unit de-cabling activities represent a big challenge for the FC section due to the huge number of cables present in the cabling network³¹, and because the cables removed need to be identified to remove them from the Cablothèque database. This point is going to be structured as follows:

1. Information needed for a cable to be defined
2. Management of the electrical scheme database over the years
3. Main problems found when trying to identify a removed cable.

³¹ In the present, there are about 400000 cables declared in the cabling Cablothèque database

1. Information needed to define a cable:

- Cable Number: unique number code that is given to each cable to identify it. The 2 first numbers of the code represent the geographical area, and the following ones are given by chronological order.
- Origin: code of the place where the cable starts from. Everything at CERN (e.g. buildings, rooms, material) has a unique code to be able to identify them. This way, the *origin code* is composed of these codes in a similar way to how an address is composed of the city, street, number and floor.
- Destination: code, with the same format as the *origin code*, of the place where the cable ends.

Another important information that can help identifying the cable, but they are not mandatory to define the cable, is the *cable type*.

2. Electrical scheme database management:

In the beginning, the database was a paper template that was manually filled (see top of Figure 34). This method had potential loss of information due to: unclear handwritings, erase of the data (sometimes written by pencil to be modified in the future if needed) and blurry data after several modifications.

Therefore, templates started to be digitally filled, keeping both a digital and a printed version. This way the data was clear and still. And in case any information needed to be modified, the affected page could be digitally modified and reprinted (see bottom image in Figure 34). Nevertheless, this method still had some constraints, as they were .pdfs, such as the impossibility of reordering or filtering the cables.

VG

CABLE N°	TYPE	LONG.	ECH.	SYSTEME	ORIGINE	CONNECT.	DESTINATION	CONNECT.	OBSERVATIONS
56421	2x 0.5	1		à tirer	PRSHM 16	TS	CJH 51 F2	TS	Emergency Switch
2	2x 0.5	2		à tirer		TS			Flow Meter
3	2x 0.5	3		à tirer		TS			Valve
4	4x 0.5	4		à tirer		TS	CJH 52 F1	TS	Safety
5	RG 58	5		à tirer		BNC Pm	CRH 15	C-75 Pm	I Magnet
6	2x 0.5	6		à tirer		TS	CRH 18	T-2 Pf	Vacuum
7	18x 0.5	7	numéros à changer	exist. (36173)		TS	CRH 119	B-13 Pm	Ext Indic
8									
9	RG 214	12		à tirer		BNC Pm	TR-SS 16	BNC Pm	I Magnet
56430	TRIOX	13		à tirer		BNC Pm	TR-SS 16	BNC Pm	"
1	2x 0.5	14	numéros à changer	exist. (36057)		TS	MNR 11	2-L-0 P	PLS Condition
2	RG 58			5-down 88		BNC Pm	CRH 119	BNC Pm	PLS
3									
4									

CABLE No	TYPE	ORIGINE				DESTINATION				OBSERVATION
		Rack	Chassis	Position Chassis	Connecteur	Rack	Chassis	Position Chassis	Connecteur	
55 001	3 x 0,75	A1	Dual Trig amp unit	220V	Feller 3 pins Pf	A1	Module Pow Contr.unit	Trig amp supply	Metronic 3 pins Pm	
55 002	RG 59	"	"	Pulse output,MS	BNC P	Module A	Main Switch	Trig	BNC P	
55 003	RG 316	"	"	Pulse input,MS	Lemo 00 P	A1	Thy. Prot. unit	MS Trig	Lemo 00 P	
55 004	RG 59	"	"	Pulse output,DS	BNC P	Module A	Dump Switch	Trig	BNC P	
55 005	"	"	"	Pulse input,DS	BNC P	M1	Timing unit	OutA-DS	BNC P	
55 006	3 x 0,75	"	Thy. Prot. unit	220V IN	Feller 3 pins Pf	A1	Distribut. unit	Output	Metronic 3 pins Pm	
55 007	RG 59	"	"	MS Trig	BNC P	M1	Timing unit	OutA-MS	BNC P	

Figure 34 – Two examples of papers used to declare the cables installed. Each row represents a different cable and there is an *Observations* column that allows the PM to add any extra information about the cable if needed.

Therefore, excel files with the cables and the Gesmar Cablothèque database were developed. As we can see the methods used have to constantly adapt to the exponential increase in the number of cables over the years (e.g. construction of the LHC).

3. Main problems for the identification of a removed cable:

When a cable is installed, a sticker with its unique *cable number* is stuck to the cable in both endings. This way when it is removed, doesn't matter by which side, it can be identified and removed from the database. The problem comes when the sticker is no longer present, or it is damaged. This is normally the case for old cables:

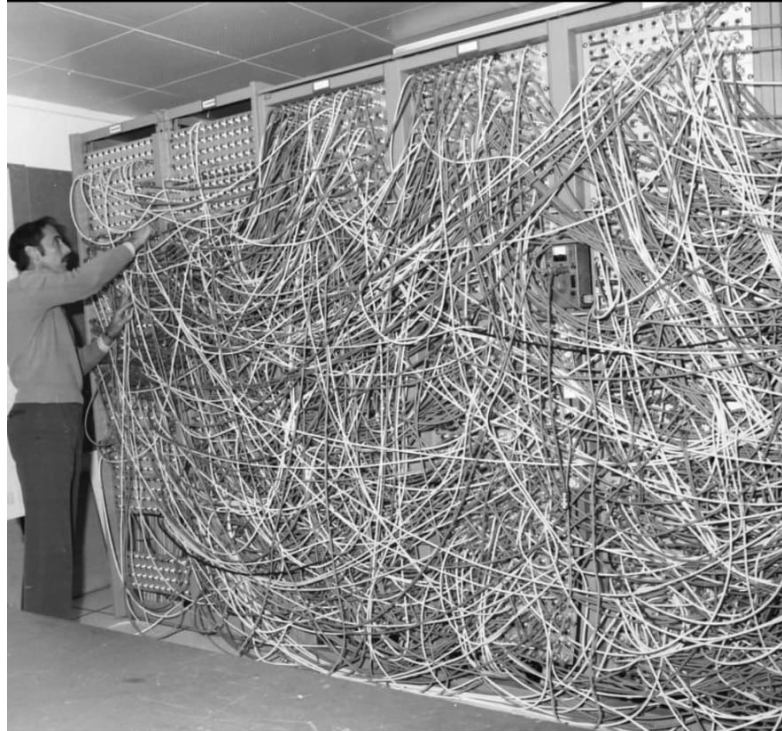


Figure 35 – Installation of line No. 1000 to a terminal used for the preparation of the Large Electron-Positron (LEP) collider physics by the Data-handling Division at CERN.

- Cables with no sticker: cables which's sticker has detached over time. They are present in the database because they were registered when they were installed, but there is no way to find out the cable number.
- The dye on the sticker is blurry and some numbers are not readable: normally due to aging. As in the previous case, some research is done with the characteristics of the cable. In this case, the fact of knowing some numbers narrows the search.
- Some cable numbers are incorrectly noted down by the Contractor: errors are quite common in the documents sent by the Contractor with the cables removed.

In all these cases, some research is done by checking the characteristics of the removed cable with the cables present in the database (e.g. *origin*, *destination* or *type* of the cable), to try to find a coincidence. But sometimes, it is not possible to find them, and all these cables may stay forever in the Cablothèque database, even though they have been removed.

3.2.5. Information & Experience sharing

This step consists in the transmission of both relevant data or the PMs insight, as it can help other PMs developing their projects in the future. This part is not strictly required for the development of the project, but its presence makes the project management process improve. The main content shared can be grouped in:

- **Data**: historic of the evolution of the main variables from a specific project, along with the forecasts previously done. This data is mainly gathered in the **Dashboard statistics sheet**, where it is accessible to all the people belonging to the section during and after the development of the projects.

It specially helps in the forecasting of the main variables for future projects. Especially time related variables such as *progress*, *cable volumes* and *manpower*, and correlations between them adapted to each specific worksite and activity characteristics.

- **Information**: once the activities are finished, it is common to elaborate documents with relevant technical information about the work developed. This documentation is mainly written in a CERN platform called **EDMS** where the author decides which people can have access to the document. This information can be about:
 - Problems found during the development of the activity and the way they were overcome.
 - Specific technical information of a certain worksite that can help for the development of future works. Or modifications that have been made to the worksite during the project.
 - Definition of new working rules to organise future works, trying to improve any working aspect.
- **Experience**: once the activities are finished, it is also common that the PM shares his feedback of the activity. This is done through weekly **meetings** that are held inside the FC section, in which 10-15 mins are dedicated each week to a PM to share their last project managing experiences.

Anyway, even though the PM's experience is shared, it is important to note that the statistics show that PMs working in projects with similar characteristics to previous projects they have previously developed, do significantly better estimations and have more facility foreseeing problems. This shows that, in the end, experience requires practice and cannot be completely transmitted theoretically.

As we can see, this point is the one that makes the process evolve, learning from the work already done. Otherwise, the only improvement would be the personal experience gained by each PM.

4. THE FC MONITORING SYSTEM BEFORE THE LS2

Once described the way in which the FC section projects are managed in the present, in this point we will go through the different developments experimented by the *FC Monitoring System (FCMS)* since its creation in 2012, until the LS2.

Until 2012, the year before the start of LS1, the FC section was solely composed by the Cabling and the Fibre Optics units. The process and tools used by each PM in the follow-up of the projects were not the same. Thus, it was difficult to put together the information from each PM (as each one had a different format) to have a global view of the status of the section.

This way of working was possible with a reasonably low quantity of activities taking place. Therefore, with the great workload increase foreseen for the LS1 in 2013, it was decided in 2012 the creation of the *Support* unit to:

- Unify the tools and data format used by the PMs during the monitoring step.
- Give support to the PMs with any problem they may have and provide them information (e.g. inform about arising constraints, grant data from previous projects).
- Periodically check the status of the activities to trigger corrective actions if needed.

To achieve the mentioned goals, some new tools were developed and linked between them and other existing tools, obtaining the *FCMS*. This FCMS, developed by the Support unit, has progressively evolved since its creation at the beginning of LS1.

4.1. THE FCMS BEFORE LS1

As shown in Figure 36, there was no FCMS before LS1. All the information was coming from Gesmar and personal files from the PMs. As mentioned before, each PM could decide how he wanted to follow-up his projects and organise all the data concerning the activities he was responsible for. Some common tools used were *MS Project* to schedule the activities or *Excel* as database.

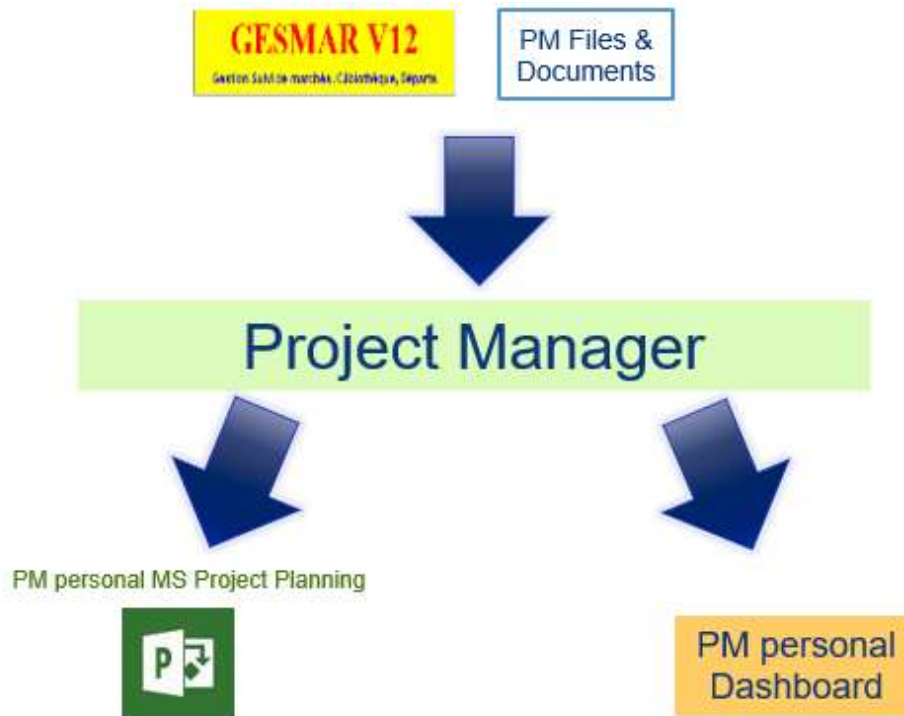


Figure 36 — Link between the different tools used before the LS1. Blue arrows mean manual data insertion

This system is very convenient at the PM level, as it gives them plenty of freedom in the way they want to manage their projects. But it hinders the unification of the data format, and therefore, putting it together to work with it.

4.2. THE FCMS DURING THE LS1 AND THE RUN2

During the LS1, some input tools were developed at CERN level³² (i.e. Plan and Snow), which meant more information to treat. To overcome the lack of unification mentioned in the previous point and the mentioned increase in the input data, some tools were internally developed leading to the creation of the FCMS [8] [9].

³² The workload increase during the LS1 affected all the engineering related sections at CERN. Therefore, developments at the level of CERN were also done

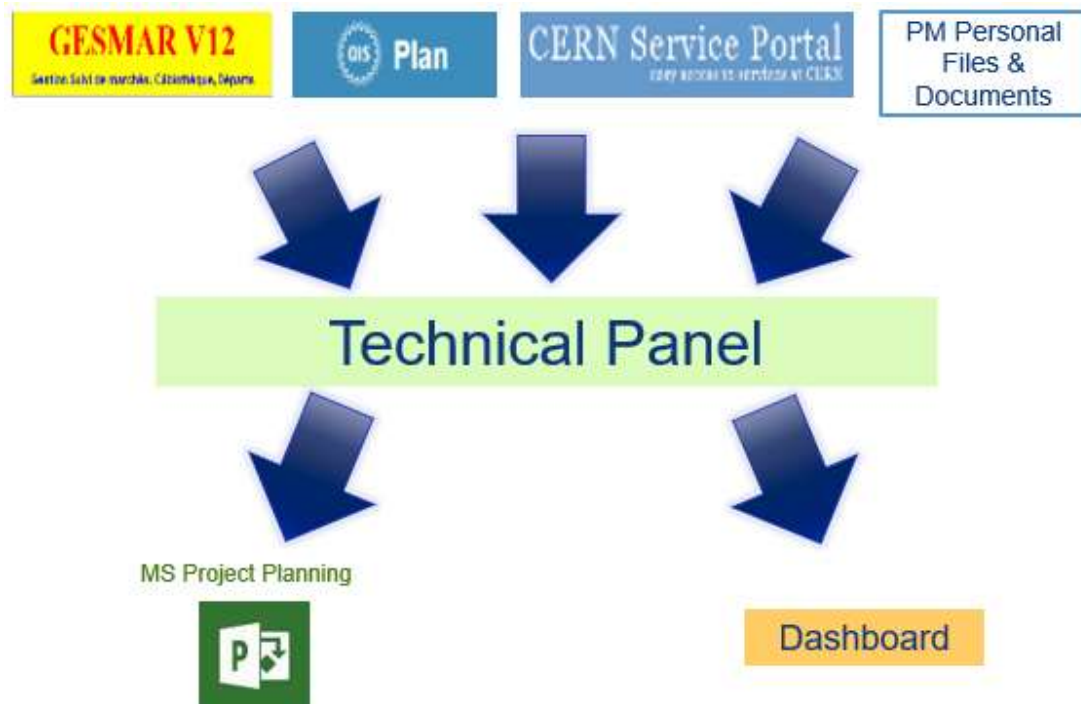


Figure 37 — Link between the different tools used during the LS1. Blue arrows means manual data insertion

The main improvements aimed with this FCMS were:

- Unification of the process and the tools used in the monitoring process, in order to unify the data used.
- Find a way to properly group and sort the data
- Find a way to store all the data produced

4.2.1. Unification of the data format

The unification of the data format was only possible with the creation of a common process (the FCMS), based in the development of some common tools, through which the information needed to go during all the monitoring step. These tools were the *Technical Panel* and the *Dashboard*, developed by the Support group.

This data standardization allowed the treatment of all of it at the same time, making it easier to spot errors. This unification made possible future improvements, described in the following points.

4.2.2. Data Grouping

Another important step was the creation of internal to the section codes, as the *Affaires* and *Code Etudes*, to allow a more convenient organization of the work (all the responsible side organization of the work). This way, PMs were able to set the same schedule for activities taking place in the same area if that was fine for the caller.

It was also necessary a tool to organize all the incoming information and link all the different codes used. This necessity was satisfied with the development of the *Technical Panel*. With this tool, the PMs could not only check all the codes and links between them (i.e. Project Code → Plan ID → Request → Affaire → Code Etude). But they had also all the information they needed about each one of the codes in the same tool, avoiding losing time accessing the different input tools (i.e. FTE file, Plan, Snow).

The insertion of information in the Technical Panel was already done with VBA macros, but they were still basic (basically copy paste of information from the extractions without doing any further calculation), compared with the development achieved in the LS2.

4.2.3. Data Storing

The last main improvement was the development of the *Dashboard* as a database, keeping all the data present in the Technical Panel over the time. This allowed the plotting of evolution of the progress (like the one in Figure 41), to compare it with the forecasts and the baselines in order to know in the present if the activity is going well, and to learn from forecasting errors for future activities.

With the time, the Support unit decided to start analyzing this data to obtain average values and relations between variables such as cable quantities, manpower and time needed. These values were extremely helpful for future forecasts and for the normalization of the data (like in the formula from Figure 42).

5. DEVELOPMENTS IN THE FC MONITORING SYSTEM DURING THE LS2

In this point we will point out the development experimented by the FCMS during the LS2, focusing on improvements were the author contributed.

The improvements done during LS2 were in line with:

- Consolidation of the already developed tools (Dashboard and Technical Panel) and development of some new functionalities.
- Improving the data treatment.
- Automation of processes that were done manually until that moment, to save time and ensure that the data was regularly updated
- Development of some specific output tools to better visualize the available data (i.e. Project Planner and Procurement Tool).

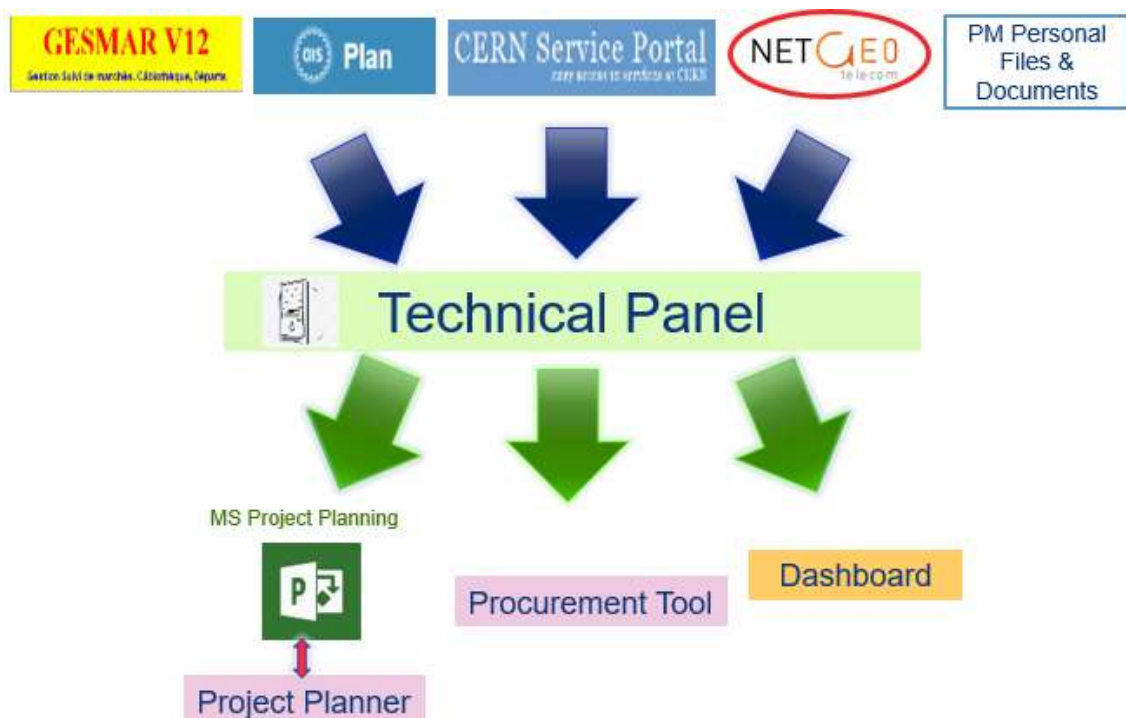


Figure 38 — Link between the different tools used during the LS2. Blue arrows mean manual intervention in the data insertion, while the green ones are completely automated.

In Figure 38, we can see the scheme of the FCMS at the end of the LS2. The main differences with the scheme previously seen for the RUN 2 are:

The Netgeo data inclusion in the process as input (fibre cable volumes information).

The development of an automated overnight update of the Technical Panel (represented in Figure 38 by the white computer picture on the left of the Technical Panel's box).

The automation of the information flow from the Technical Panel to the different output tools (arrows in green in Figure 38). We can see that the arrows going from the input files to the Technical Panel are still in blue, as the different extractions are manually done. This is one of the possible points to improve for the future.

The main contributions from the author to the system can be grouped in the contributions done to the *Dashboard*, *Technical Panel* and *Project Planner*.

5.1. DASHBOARD

The contributions to the Dashboard were few and mainly in line with the tool's **consolidation**, as no new functionalities needed to be added to what had already been developed previously. This consolidation mainly consisted in the resolution of errors in the data format and the modification of the code to make it more robust.

5.2. TECHNICAL PANEL

Several contributions were performed to the Technical Panel, in line with the two main following points:

- Improvement of the data treatment: enhance of the progress calculation precision
- Consolidation of the tool: consolidation of the overnight data update

5.2.1. Improvement of the data treatment: Progress calculation

The fact of having, since the LS1, access to a better organized data, allowed the possibility of treating all the incoming data together, generating more quantity and better-quality information. This made easier to point out awkward values or incoherences in the information, as all the

information was together. But more than that, the most important development that it allowed was the obtention of a more precise calculation of the progress during the monitoring step.

As it was already discussed in the monitoring point, the precision achieved in the progress calculation is key for avoiding problems or knowing how to react to them. Therefore, the Support unit worked hard to improve the progress accuracy. There are 3 ways of obtaining the progress:

- **Gesmar progress**³³: each **Affaire** has a progress assigned, manually introduced in the Gesmar *Project Management* tool by the PM (see the orange column in Figure 39). The progress per Code Etude is obtained as an average of all the Affaires included in it, treating all the Affaires equally (not weighted). This calculation is done in the Technical Panel (*Code Etude sheet*).
- **Progress given by the Contractor and the PMs during the meetings**: this progress is given per **groups of Code Etudes**³⁴. It is weekly updated through meetings in which the PMs and the Contractor talk about the ongoing projects and define this global progress. This is the progress used in the MS Project follow-up.

Those were the progresses used during the LS1. But there was an accuracy problem: in the Dashboard the progress needs to be inserted per Code Etude. Therefore, with the meetings progress it was not possible to know the progress of each Code Etude, as only the whole group of Code Etudes progress value was known. To use this value in the Dashboard, the progress of each group of Code Etudes (that was an average of the progress of all the Code Etudes inside the group) was assigned to each Code Etude belonging to that group. So, the progress introduced for each Code Etude was the average of the group it belonged to, and not the real progress of each Code Etude.

On the other hand, the Gesmar progress per Code Etude was coming from a not weighted average of the Affaires contained in that Code Etude. Therefore, long Affaires were considered with the same weight as short ones, also leading to inaccurate values. Another problem about this progress was that the values were, in general, not regularly updated by the PMs.

Therefore, for the Dashboard statistics, it was decided to use each time the progress was calculated, the best progress between the Gesmar and the Meetings Code Etude progress. Therefore, the progress used was, on average, slightly higher than the real one. To improve this aspect, the Support unit worked on the development of a more complex but more precise way of calculating the progress, the Cablothèque progress.

³³ Data from the Gesmar *Project Management* tool (CAU12 extraction)

³⁴ As PMs and Contractor normally work in each worksite with several Code Etudes at the same time

- Cablothèque progress³⁵: unlike the case of the Gesmar progress, in the Cablothèque there are some partial progresses and values declared (see Figure 39) that allow the weighting of the Affaires, but only for the cable installation activities³⁶. For these activities, all the cables that need to be **pulled** and the number of **raccordements** and **tests** to be done, are declared in the Gesmar Cablothèque prior to the start of the activity.

Affaire	Lg totale (	Nb Racc tc	Nb Test tc	% Global	% Pose	% Racc	% Test
S213AFB126001	324	0	8	100	100		100
S213AFB126002	60	0	1	100	100		100
S213AFB130001	918	0	6	100	100		100
S213AFB132001	1271	0	31	100	100		100
S213AFB133001	80	6	3	100	100	100	100
S213AFB134001	36	12	6	100	100	100	100
S213AFB135001	177	8	8	100	100	100	100
S213AFB137001	356	4	2	100	100	100	100

Figure 39 — CME12 Extraction. All the columns come from the Gesmar *Cablothèque*, except the one inside the orange rectangle, that comes from Gesmar *Project Management* tool

From left to right: Total length to pull, Total number of Raccordements, Total number of Tests, Global progress, % of pulling completed, % of raccordements completed, % of tests completed

In the case of the mechanical, watercool cables and de-cabling activities all the values would appear empty or "0", except for the Global progress

Once the activity starts, each cable pulled, or each raccordement or test done, needs to be registered in the Cablothèque by the contractor. Leading this way to three different partial progresses for each cable installation Affaire:

- Pulling: obtained as the length already installed divided by the total length to install.
- Raccordement: number of raccordements already done divided by the total number of raccordements to be done.
- Test: number of tests already done divided by the total number of tests to be done.

³⁵ Data from the Gesmar *Cablothèque* tool (CAU12 extraction)

³⁶ These partial values are not included for the Mechanical, Watercool cables and De-cabling activities

Not all the cable installation activities need to have all these 3 partial progresses (e.g. they may not have raccordement). The global progress of the Affaire is obtained giving to each partial progress the weight expressed in Figure 40.

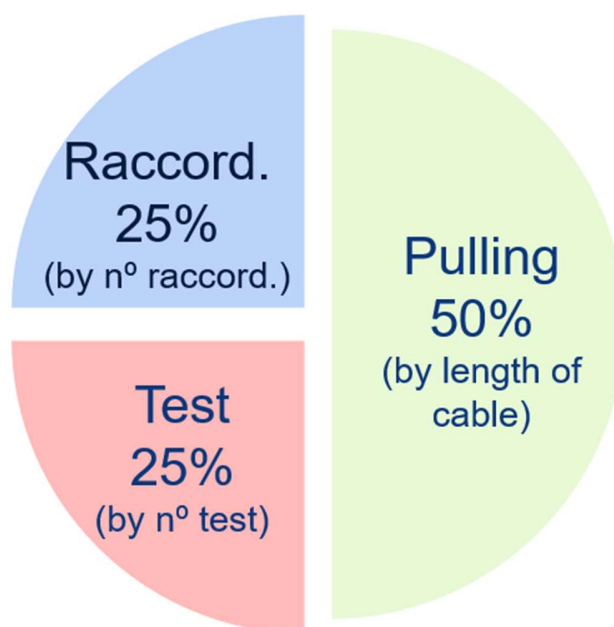


Figure 40 — Weight assigned to each part (Pulling, Raccordement and Test) for the cabling activities in the Cablothèque progress

When it comes to the calculation of the Code Etude progress with the Cablothèque data, we can have three cases:

- All the Affaires are not cable installation type: we have no Cablothèque data about these activities, so the Gesmar progress is used without weighting.
- All the Affaires are cable installation type: the pulling, raccordement and test partial progresses are calculated at the Code Etude level, and the global Code Etude progress is calculated following the weights from Figure 40.
- Some Affaires are cable installation type and some are not: this can only happen between cable installation, mechanical and de-cabling activities (cable installation and watercool activities cannot be together). In these cases, the mechanical and the de-cabling activities are normally relatively small³⁷, so they are not considered in the Code Etude progress

³⁷ If a big mechanical or de-cabling work needs to take place it usually becomes an independent Code Etude with only mechanical or de-cabling activities

calculation. Therefore, only the cable installation activities are considered, so we are in the same case as the previous point.

As we can see, this method only gives more precise information for cable installation activities. But this is the case of the most part of the Cabling unit activities, so it represents a considerable improvement.

Until now we have described different ways of calculating the *Affaire* and the *Code Etude* progresses. But there is still another problem to solve: how to calculate the global progress of all the Cabling unit activities at a given moment, as in Figure 41.

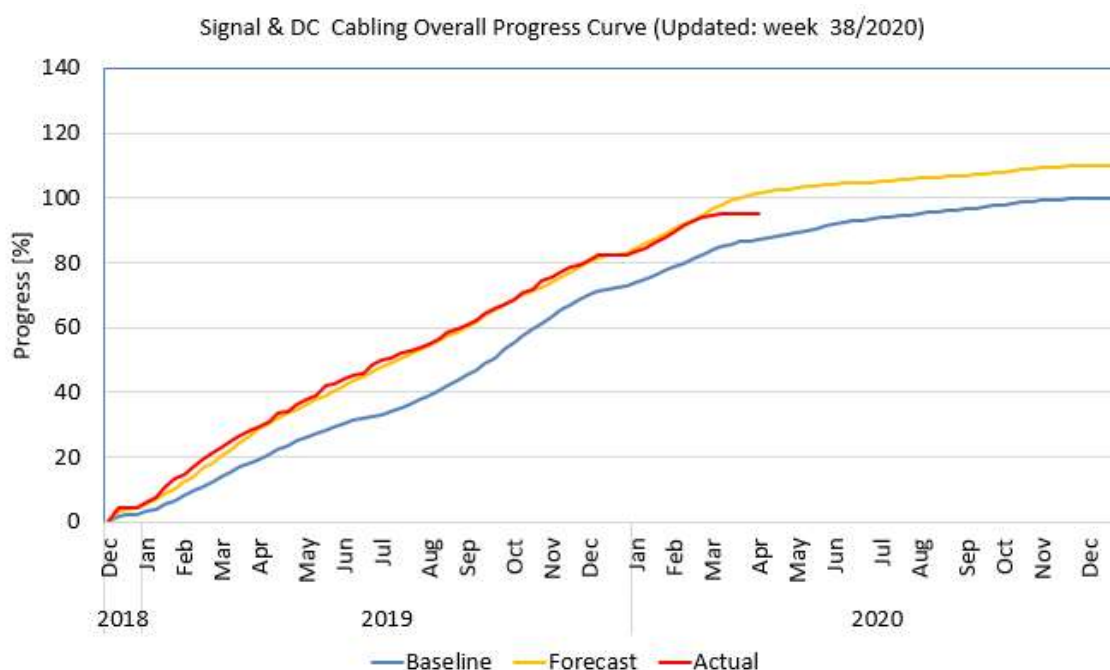


Figure 41 — Progress graph present in the *Activity Progress* sheet from the Dashboard representing the global progress of all the Cabling unit activities

Initially this was done without weighting the projects, just an average between the different Code Etudes. This was not very accurate, so it was decided to develop a formula to compare the workload that each project represented, based on the information gathered from previous campaigns (see Figure 42).

The different values (468 | 36.37 | 3 * 468 | 3 * 36.67) are the average number of cables and length that a single person can install or uninstall (depending on the case) during a year, based on data from previous activities. This way the values from the different campaigns are normalised and can be summed up and compared.

$$W^{cabling} = \left(\frac{\text{No. Cables}}{468} + \frac{\text{Length [km]}}{36.37} \right)^{\text{new cabling}} + \left(\frac{\text{No. Cables}}{3 * (468)} + \frac{\text{Length [km]}}{3 * (36.37)} \right)^{\text{de-cabling}}$$

Figure 42 — Formula developed to calculate the weight of cable installation and de-cabling projects.

"No.Cables" and "Length [km]" refer, respectively, to the number of cables and the length in kilometers to install (in the case of the first parenthesis) or remove (second parenthesis) in the project.

With this formula the problem was solved for the cable installation and de-cabling projects. But the rest of the projects were given a weight = 0, so they were not considered in the global progress calculation. This was acceptable as the number of projects in the FC section without cables are a minority.

Anyway, to try to solve this problem, another method was recently developed using the *manpower budget* to weight the different Code Etudes. As it is generally related with the workload that the project represents. In the present, this method has already been implemented and it is being used in parallel with the formula method.

5.2.2. Consolidation of the tool: overnight data update consolidation

The other main source of contributions was in line with the addition of new information (inclusion of some new columns) and the consolidation of the tool (resolution of errors and improvement of the code to make it more robust).

In this line, another important improvement was the consolidation of the overnight data update. The data present in the Technical Panel is updated through 4 VBA macros and an automated overnight update. In Figure 43, the macros used are listed by order of execution, with information about: the input files and/or sheets used by the macro, the sheets from the Technical Panel that are modified and a brief description of the process.

Macro Name	Input files or sheets	TP sheets Modified	Description
GESMAR	CME12 extraction	Gesmar Affaire sheet (GAs)	In the GAs, the affaires are linked to their Code Etude, and Gesmar info is added.
SNOW	SNOW extractions	Snow Tickets sheet (STs) & Gesmar Affaire sheet (GAs)	In the GAs, the affaires are linked to their Snow Request ID and Plan ID, and Snow info is added. In the STs, the Snow Requests are linked to their Plan ID, and Snow info is added.
PLAN	PLAN & FTE extractions	Snow Tickets sheet (STs) & Gesmar Affaire sheet (GAs)	In the GAs, the affaires are linked to their Project code, and info from Plan and the FTE file is added. In the STs, the Snow Requests are linked to their Project code, and info from Plan and the FTE file is added.
Campaign	CME 12 & CAU 12 extractions Gesmar Affaire sheet	Code Etude sheet (CEs)	In the CEs, the information present in the GAs is gathered per code etude and added. In the CEs, info from the CAU12 is added and some info from the CME12 that wasn't added before to the GAs. In the CEs, the code etude are linked to their groupement of code etude.

Figure 43 — Macros intervening in the overnight Technical Panel update (in order of execution)

The general process followed by all the macros during the codes update³⁸ is that all the codes are firstly colored black. Then, the information related to the codes that are found in the extractions is updated and the code's color becomes green³⁹ (if ongoing) or red (if finished). If the code is not found in the extraction, it remains black. The codes present in the extraction and not present in the sheet, are added in a new row with their corresponding information.

The disadvantage of these macros was that they had to be manually executed. And as macros kept on growing with time, about the beginning of LS2 they were taking between 30 and 60 minutes to run. The main problem was that during that time no Microsoft tool could be used in the computer where they were being executed. Therefore, the solution implemented was the automation of an overnight execution of the macros when the computer was not used.

The four macros executed overnight are linked, so that when each one finishes, the last line of the code invokes the next macro. This way, only the first macro needs to be executed by the overnight automation.

The overnight update was properly working most of the nights, but some days it was not finishing the whole update, stopping at some point of the macros and giving an error. This was a big problem as it meant that the update needed to be done manually the next day's morning, losing around 30 to 60 mins without being able to use any Microsoft software.

As the error was not saying in which part of the code it was stopping, the first approach was to include in a cell of one of the sheets a number representing the macro that was being executed at each moment. When the first macro started, a 1 was written. When it entered the second one, the 1 was replaced by a 2, and so on until the fourth macro was finished, and then the 4 was removed. This way, if the overnight update stopped half-way, it was possible to know the macro in which it had stopped.

It was observed that the macro in which it was stopping was not always the same one, being most of the times either the third or the fourth one. Therefore, this meant that the problem was not in a specific point of the code.

The next approach was to search on the internet for similar problems reported. It was found that the problem were all the calculations automatically done when the numbers were written in the cells by the macros, due to the excessive size of the file. This way, by changing the *automatic calculations* to *manual* in the excel configuration, as represented in Figure 44, all those automatic calculations were no longer done during the code execution, and no error was given during the overnight update.

³⁸ Remember that *black* color means present in the Technical Panel but not in the extraction anymore, *red* means finished and *green* means ongoing

³⁹ Blue in the case of the Requests codes present in the Snow Tickets sheet

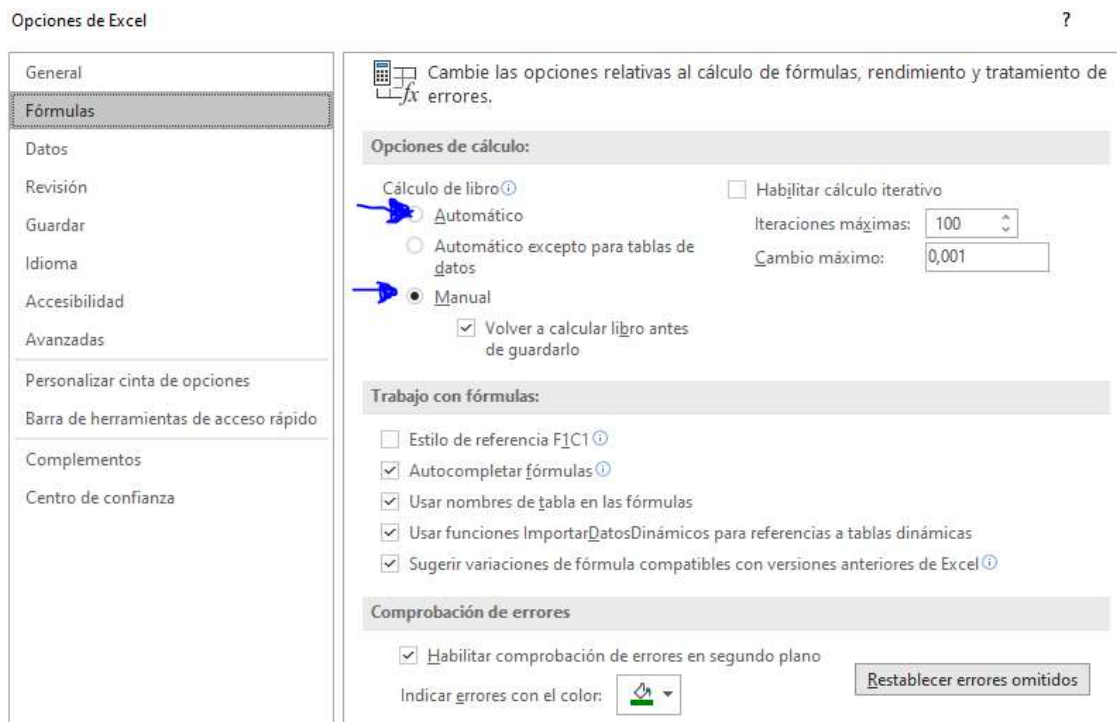


Figure 44 — Configuration for the manual update of the formulas

Even though, to further consolidate the process, it was decided to create a virtual machine (VM) to perform these overnight updates. This way the computer could be turned off during the night and the macros could also be executed at any moment in the VM, allowing the user to keep on using his Microsoft tools during the update. This VM was created in *Openstack*⁴⁰, accessing it through the Windows' *Remote Desktop Connection*.

⁴⁰ Opensource cloud computing infrastructure [10]

5.3. PROJECT PLANNER

Tool mostly developed by the author to visualize the information present in the Technical Panel per Code Etude. It was already described in the Monitoring step. Therefore, this point will be focused on the main improvements that the Project Planner represents with respect to the tool that was used before with this follow-up purpose, the MS Project.

The main factors that motivated its development were:

- The necessity of developing a way to visualize the data present in the Technical Panel that could be automatically updated. Until that moment, MS Project was the tool being used with that purpose, and it needed to be manually updated.
- The CERN's *MAIt*⁴¹ project. Some FC section members were only using MS Project to visualize planning files (they were not creating new MS Project files). Therefore, the idea was to cut down the number of MS Project licenses to just the people that needed it to create new MS Project files, as the Project Planner would take over the visualization functionality.

But, other than these first motivations, it also represents some other advantages with respect to MS Project:

- As the Project Planner has been developed inside the section, its development is oriented to the format and way of working of the section. And the code can be easily modified by the section for future needs.
- It provides extra information about the activities, that was not present in the MS Project (e.g. *baselines*, status of the *procurement*).
- Errors could happen during the manual transcription of data from the Technical Panel to MS Project. With the Project Planner, the information displayed is automatically taken from the Technical Panel (no transcription errors).
- More precision is achieved in the progress information displayed. As the Project Planner uses the Cablothèque progress, instead of the meetings progress used by the MS Project.

⁴¹ *Microsoft ALTERNatives*. CERN used to have "Academic Institution" licenses for Microsoft software. But recently, Microsoft stopped giving them to CERN, what supposes an increase of about 10 times the fees previously paid. Due to this CERN has started the MALT project, which looks for alternative open source or internally developed software. Internal developed solutions are preferred as open source software might compromise CERN's data and does not have any technical support [11] [12]

About its data update, the Project Planner is daily updated overnight after the Technical Panel does. The last line of the last Technical Panel's update macro is programmed to invoke the VBA macro that updates the Project Planner. The data is taken from the *Code Etude sheet* from the Technical Panel.

The way in which the macro updates the projects in the Project Planner is similar to the macros used for the Technical Panel update: it firstly deletes the projects from the Project Planner that are no longer present in the Technical Panel (old or cancelled projects). And then, the projects from the Technical Panel that are present in the Project Planner are updated, and the ones that are not present in the Project Planner, are included.

6. POSSIBLE FUTURE DEVELOPMENTS FOR THE FC MONITORING SYSTEM

Some improvements can still be implemented to the process, most of them in the field of the process automation. Some possible future developments could be:

-The automation of the data extractions: all the extractions done from the input tools need manual intervention. And some of them, like the CAU12 and CME12 extractions from Gesmar, take a considerable time to be performed.

In this line, a project to automate the extraction of these two Gesmar extractions has already started. It consists in a *mouse recorder* that would automatically and overnight perform in Gesmar the clicks needed to download that data. This improvement is still under development.

-Automate the manpower insertion in the Dashboard: until now the manpower is received from the contractor in a pdf file, so it is not possible to automate the insertion process with a macro. It has already been discussed the possibility of receiving this data in an excel file in the future, allowing the development of a VBA macro for its insertion in the Dashboard.

-Add more functionalities to the Project Planner: as this tool has just been developed, more functionalities will surely appear as feedbacks from the PMs, or to adapt to new necessities.

7. RESULTS AND CONCLUSION

We can say that the overall objectives of the Support unit have been achieved, and even beaten. Now there is a completely defined process and tools scheme (the FCMS) to manage the projects, and a global system that has become more robust during LS2.

We have seen that the quality of the data has considerably improved over these years. And the process is still getting better and more automated day by day. All these improvements are reflected in the positive results obtained from the FC section performance during the LS1 and LS2, despite the workload increase experimented.

More specifically, about the objectives aimed by the author for the LS2:

- Tools like the Dashboard and the Technical Panel have been further developed and **consolidated**, learning from the errors, and leading in the present to two considerably robust tools.

In this line, we have improvements like the substitution of the formula-based data calculation in the excel sheets, by the macro direct calculation of the values. This prevents the system from the errors usually generated by the formula-based calculations.

- The **data treatment** has been **improved**, allowing the availability of new and more precise information.

For example, the development of a more precise *Cablothèque progress* calculation; or the storage and use of the Baseline and Forecast dates for each Code Etude.

- A **better visualization** of the data has been achieved with tools like the Project Planner. As this tool plots in a user-friendly way all the relevant information present in the Technical Panel database.
- Several processes have been **automated**, lightening employees' workload and granting a regular update of the data.

For example, the overnight Technical Panel update, that saves between half an hour and one hour per day for the person responsible for its update.

Even though the system can still improve, and some functionalities can still be developed (as this will always be the case), we can say that the FC section Monitoring System is finished, and both the global Support unit and the personal author objectives have been achieved.

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Source: CERN Facebook (<https://www.facebook.com/CERNLibrary/posts/10156201164336970>)

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