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SCHEDULING TOOLS DEVELOPMENT TO MANAGE CERN ACCELERATORS PROGRAMMED STOPS AND FACILITIES INSTALLATIONS

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Abstract

The Scheduling Tool Project (STP) scope is to support the scheduling and coordination of CERN accelerator programmed stops and facilities installation, managed by the Accelerator Coordination and Engineering (ACE) Group, inside the Engineering Department (EN) at CERN. The scheduling tools should consider all the activities, that take place in large facilities, composed of complex and interdependent systems, according to the safety rules and quality standards. The current goal of the STP is to consolidate the used scheduling tools, and to homogenize them through the different facilities, merging the user needs with the developer solutions. This will lead to be ready for the Long Shutdown 3 (LS3), due to start end 2025. This paper describes the tools used to manage CERN programmed stops, to build a coherent schedule, follow up and report activities progress. It gives the details of the requirements, code design and future works to create a linear view on a web interface and the first results. It also describes the specifications needed to implement a report indicator in this linear view (i.e., broken line curve).

INTRODUCTION

The Accelerator, Coordination and Engineering (ACE) group in the CERN engineering department is in charge of the coordination of the activities, interventions and changes of the Large Hadron Collider (LHC) and its injectors chain (the LINAC3&4, the Low Energy Ion Ring leir [LEIR], the Proton Synchrotron [PS] and the Super Proton Synchrotron [SPS]) [1]. This common coordination is based on the technical expertise of the group together with the project management standards. It provides a common understanding of the accelerator's lifecycle and the expected results [2].

The Organisation, Scheduling and Support (OSS) section of the ACE group, oversees the scheduling and execution of the interventions [3]. It manages the coactivities, defines the logistics associated and puts in place mitigation measures to anticipate potential delays while ensuring safety. Most of the activities take place during the so-called programmed stops: the foreseen time windows during which the conditions of the accelerators allow maintenance, upgrades or specific projects. Depending on the duration, programmed stops can be defined as Short Technical Stops (TS), around 1 week; (Extended) Year End Technical Stops (E-YETS), 3-4 months at the end of the year; or Long Shutdowns (LS), if more than one year. The next major milestones of the section are the preparation of the Long Shutdown 3 (LS3) and the previous programmed stops (shown in red and blue in Fig. 1).

This paper describes the Scheduling Tools Project (STP) established to upgrade, consolidate and homogenize the scheduling tools required for the next programmed stop, and the results obtained to date.

STP OBJECTIVES AND REASONS

The STP started in 2019 was triggered by the need to rationalize the provision of Microsoft Project® licenses at CERN. The idea is to create a web application which can be consulted by CERN users to visualize the existing planning files. The selected solution is to synchronize and transfer data from Project Online Cloud to a relational CERN Database.

Despite the primary objective to transfer data from MS Project/ Project Online® into a CERN database, other targets are established to consolidate the current tools and homogenize the methodology across the accelerators. All these tools are based on the common data exported to the CERN database to provide different views to read, create and follow up on the installation activities, fulfilling the needs of the coordination team. These developments shall ensure a collaborative approach with the other tools used at CERN. The main challenge is to rely on different tools that are based on the same data source.

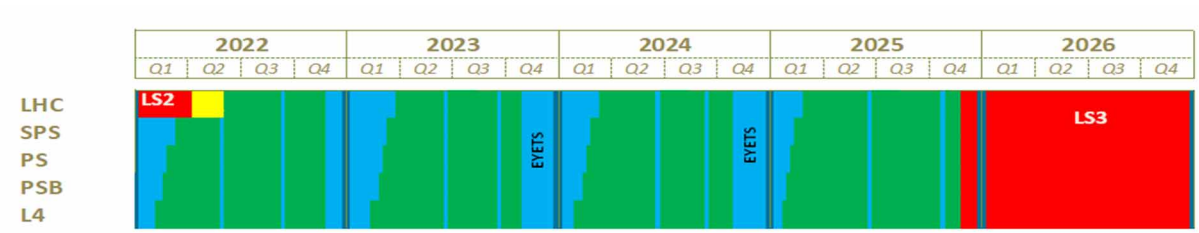

Figure 1: Extract of the Long Term Schedule for the CERN Accelerator Complex.

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TECHNICAL ANALYSIS

The architecture of the project is shown in Fig. 2. The key point of the project is that there is a cronjob running daily to synchronize (fetch, update) data from Project Online to the Database. The components constitute a web application architecture including a Backend application which connects to the Database and a Frontend application which is the presentation layer of the project. The Space & Time application is used to create presentations (PowerPoint) of activities in the Injectors using Python libraries.

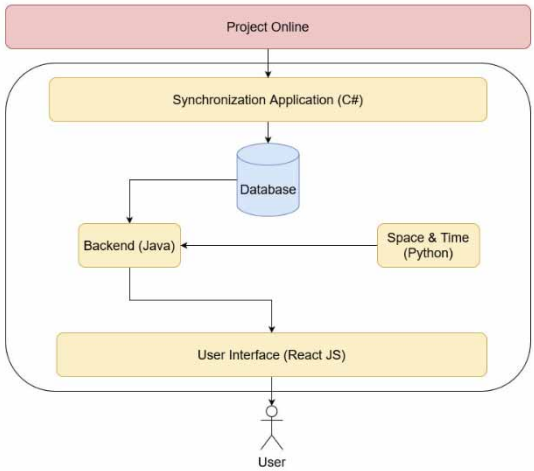

Figure 2: Overall Architecture.

Database

The database system is based on Oracle SQL. The schema and the model include independent tables as well as tables with relationships, such as one-to-many and many-to-one. The reason to select a relational database is that the software solution requires accuracy, integrity and consistency of data. Oracle Database is preferred over other SQL implementations because it is the official RDBMS (relational database management system) supported by CERN.

The schema and the model of the Database are shown in Fig. 3. The most important entities in this model are:

- Task
- Project
- Linear Planning

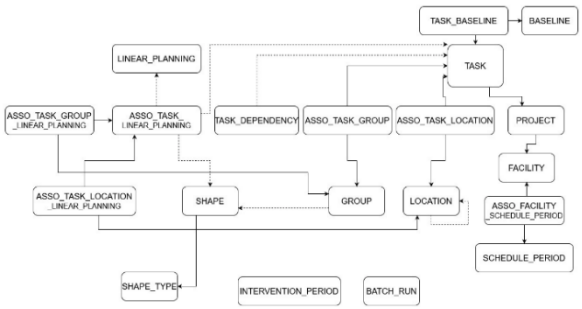

Figure 3: Database Entity-Relationship (ER) diagram.

More specifically, the Project Online structure is based on projects that make up the planning for the machines. Each project consists of several tasks with tens of attributes (e.g., start and finish date). Linear Planning corresponds to the latest feature of the project, which is analyzed subsequently.

The schema of the Database is subject to changes and improvements at the time a new functionality or feature is added.

Gantt

The Gantt view serves the organization and scheduling needs of the EN-ACE-OSS section, as well as other CERN users, allowing them to check the synchronized schedules without an MS Project license.

The tool is built using the DHTMLX library, which offers pure JavaScript client-side components. The usage of a plug-and-play library enables developers to implement faster the solution and configure the platform according to the needs. Data is consumed in JSON format from APIs requests, and they are fed to the Gantt library. The result is available in Fig. 4.

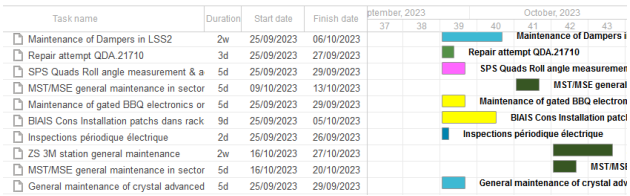

Figure 4: Gantt view.

Space & Time

The Space & Time tool is widely used by the Injectors' coordinators to assist them in their daily work as well as in technical and coordination meetings. The purpose of this tool is to automatically generate a representation of the activities foreseen for a given date and location, graphically represented in a 2D model layout of the accelerator. Given the large size and the number of activities, it has been decided not to implement this tool for the LHC, as it would not be readable.

It started as a desktop tool available for PS [4] using Microsoft Excel® files to create Microsoft PowerPoint® slides. In the second stage, the tool was integrated into the Scheduling Tools web application and offers a reliable solution for the activities in the Injectors. The view offers interactive as well as presentation modes and provides users with two ways to visualize the activities in the selected Injectors. The tool is based on ReactJS and SVG representation for the interactive mode, while the presentations (Microsoft PowerPoint slides) are created through the Python microservice. Further improvements are ongoing to expand the visualization into 3D models.

Linear Planning

Linear Planning is a graphical representation of the schedules where the vertical axis is a calendar that represents the time window, and the location is in the horizontal axis. The activities declared by the user are translated into shapes whose parameters give information about the task, such as cryogenic maintenance, magnet exchange, fire system consolidation, etc.

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The current implementation and generation of the Linear View for each machine are developed in Visual Basic and it is based on data exported from Microsoft Project to Microsoft Excel. LS2 and LS3 highlighted the need to develop a web-based version of the tool to provide users with a more flexible and easy way to generate Linear Planning, as shown in Fig. 5.

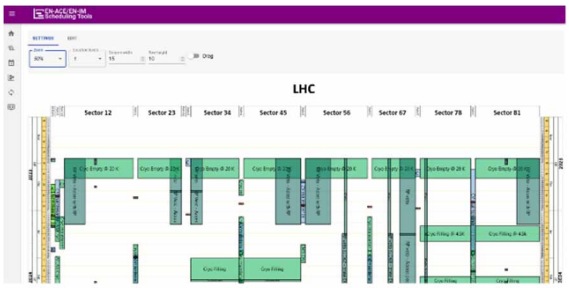

Figure 5: Linear planning in the web application.

The technical analysis of the implementation of Linear Planning in a web application as a grid included three main solutions:

1. SVG
2. Canvas
3. External libraries (e.g., DHTMLX)

The conclusion of the analysis showed that SVG is more suitable in this case because it provides a coordination grid, where shapes and lines can be plotted. In addition, the usage of the D3.js library makes the SVG adjustable, configurable and more powerful. For example, one of the requirements is that the user should be able to zoom in/out and interact with the planning (drag the shapes etc.), which is something easily handled in SVG but not in Canvas.

X and Y axis are based on the other two algorithms developed for this scope. The X axis (locations) requires building an algorithm to identify neighbour locations (on the same level, or different levels). The Y axis is a straightforward algorithm, which takes into consideration the selected dates for the linear planning and creates the plot in Years, Quarters, Months, Weeks and Days.

The representation of activities into shapes in the grid results from algorithms built in this scope. To create a shape, the algorithm takes into consideration the start/finish dates, as well as the location in which the activity takes place. The coordinates of these points are identified in the X and Y axis.

The forms which should be filled by the users during the creation of a Linear Planning are developed using MUI library, which provides customizable components in React (for example, dates, forms and select).

The delivery of the product takes place in several versions. In the first phase, the Linear Planning View includes the basic functionality for creating a planning and interacting with the grid. Hence, it provides the option for the user to drag/drop shapes, check information for each activity, zoom in/out, as well as change the size of the x, y axis. The first phase of the delivery proves the feasibility of this approach.

Linear planning allows the representation of report indicators, such as broken line curves. This functionality gives the current status of the activity with respect to the baseline graphically with two different indicators: the progress of the activity (typically represented by a grey shadow on the shape) and the forecast of completion (typically represented by a yellow line to illustrate the days missing to the end of the task).

Furthermore, the Linear Planning tool is used by the coordination team as the resource to show only the activities that generate access or system constraints to the accelerator. This support is utilized to easily communicate the accelerator status to the intervening teams.

RESULTS

The specifications and documentation of the different tools to be developed within the STP frame are available.

The migration process from MS Project/Project Online to a CERN database is successfully finished. However, the architecture evolves according to the needs of the coordination team.

The Gantt viewer is fully functional and tested during the last year.

The Time and Space tool is developed and tested for the whole Injector's chain. Further improvements to the tool are ongoing.

The Linear Planning Web Interface version 1 is in production. It considers the main functionalities of the new feature. However, it has demonstrated the feasibility and reliability of the development approach. The next versions will be delivered this year with the aim to have the final one by 2024-2025.

OUTCOME AND CONCLUSION

The next biggest challenge for the STP is to deliver the Linear Planning Web Interface fully operational, including the baselining process and broken line indicators.

The strong methodological approach to managing, scheduling, and coordinating the huge number of activities taking place in the accelerators requires powerful scheduling and coordination tools. A big effort has been set up to develop a reliable and accessible tools system, already working, that will continually improve to be a key to success for the next LS3 and CERN programmed stops.

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