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A NEW PRODUCT LIFECYCLE MANAGEMENT PLATFORM FOR CERN'S ACCELERATOR COMPLEX AND BEYOND

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Abstract

Particle accelerator projects are complex, and CERN's current engineering tools already manage millions of documents that follow various Lifecycles and Workflows. Future projects will push size and complexity to yet higher levels, in addition to increased collaboration with external partners. As reliable data is critical for success of complex system design, CERN is now implementing a new PLM (Product Lifecycle Management) platform that outperforms previous disparate design data management systems in several aspects: Consolidation of legacy data in a consistent data model; Federation of data from different systems and external partners in a common structure; Processes with flexible Workflows and Lifecycles; Integration with Simulation, Manufacturing, Maintenance, and other services dealing with design and product data. The overarching goal for the new PLM platform is to act as a catalyser for improved quality and traceability of data (often known as the "Digital Thread") and to serve as the foundation for Digital Twins of current and future accelerators with the aim to drastically reduce development times as well as operation and maintenance cost.

BACKGROUND

CERN is currently in the process of replacing two data management systems with a new PLM platform. The systems host around 2.5 million CAD objects representing the designs and drawings of its accelerators, services, infrastructure, and most of the experiments.

Some of the core goals of a PLM is to provide means of storing information, managing, and safeguarding product data in a collaborative environment and to assure that any applied changes are traced and follow the defined change management rules for the stored information. Typical needs are to store, find, and explore design, production, and installation information.

CERN has a long history of management of accelerator designs and there are still drawings of equipment dating back from the mid-20th century in the current systems. Over time, several disparate engineering data management systems emerged with disconnected data stores and heterogenous engineering processes as a result. Connecting the data of the different legacy systems has proven to be difficult and error prone, often requiring manual correction.

To support the increasing size and complexity of future accelerator projects, it became clear that the PLM landscape had to be both simplified and improved. All the mechanical CAD designs from the main mechanical CAD tools were stored in a dedicated CAD data management system (SmarTeam), and all the official 2D drawings, independent of CAD tool, were stored in CERN's Drawing Directory (CDD). After the vendor announcement of SmarTeam being discontinued, it was decided to launch a PLM project. The scope of the initial implementation is to replace both SmarTeam and CDD, improve support for multiple CAD tools, and allow for extending PLM platform use at CERN and with collaborating institutes.

A commercial product, ARAS Innovator, was selected to build the new PLM platform. It provides an extensible architecture, and it allows for all CERN partners to access and actively collaborate on projects. It is accessible through a web interface protected by the CERN's Single Sign On (SSO). Any user with a CERN account can access the PLM from anywhere using a web browser. There are advanced visualisation capabilities to explore 3D model directly in the browser, as well as navigating through its links and associated data in a unified platform, are important advantages.

DATA MODEL

When designing the data model in the new PLM, business processes of different units and services at CERN were studied and the new data model was elaborated with a few key principles in mind:

- **Future proof** and extensible to allow additional use cases.
- **Generic** to favour unified processes over specific ones.
- **Following industry and international standards** to ease terminology and foster understanding inside CERN as well as external collaborators.

The core object types are typical to most PLM systems, being **Parts**, **CAD Documents**, and **Documents**. **Folder** objects were added to allow for organising information in independent structures. The folders have proven an appreciated concept to organise data in the past.

The data model is thus organized with a **Part centric** perspective. The Part represents a system, an equipment, or a component of the equipment. A Part that is composed of other elements has a Part structure, also called Bill of Materials (BOM) (see Fig. 1). Information to define and describe a Part are attached to the Part in form of Documents and CAD models are attached to the Part as CAD Documents. These objects are versioned in order to track a Part's definition over time. This allows for managing change of components and systems. The design data is then used for manufacturing and the produced assets are represented in a maintenance management system where the asset links back to the specific version of the Part corresponding to the design data used for its production.

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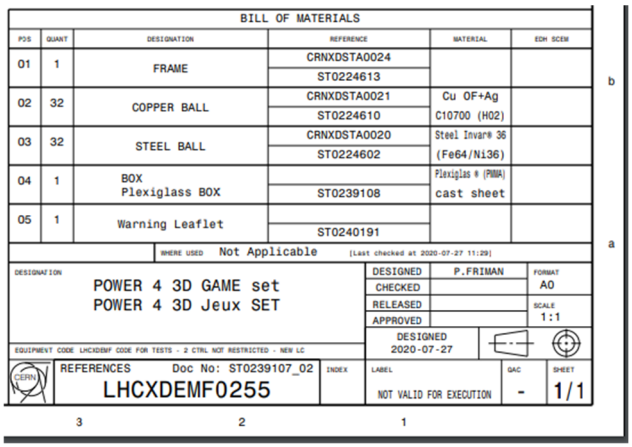

Figure 1: Part and Bill of Materials information as displayed on a drawing.

Flexible role-based access rights are allowing for collaboration and allow projects to adapt them to their needs. Access for collaborating partners can be defined for the respective projects. The default access rights are configured to encourage transparency of information and minimizing overhead.

WORKFLOWS AND LIFECYCLES

The validation and consolidation processes of diverse services were analysed. With flexibility and simplicity as cornerstone, this resulted in a simple Lifecycle with a limited set of statuses (see Fig. 2) in combination with dedicated workflows for the different processes (see Fig. 3).

Figure 2: The Lifecycle states.

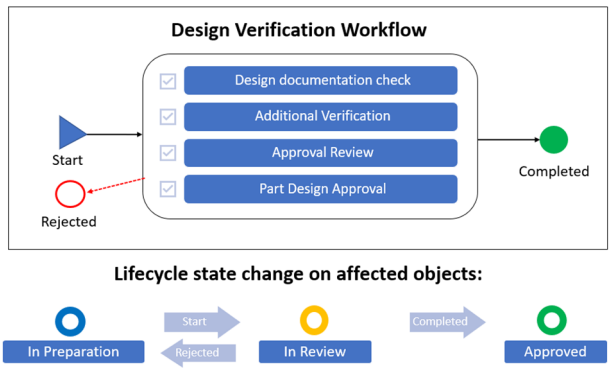

Figure 3: Example with Design Verification Workflow map and lifecycle state changes.

The Lifecycle states are defined as a fixed set of generic states based on industry and ISO standards. The workflow results are visible on the affected objects, removing the need to use dedicated Lifecycle states for each process. Changes and quality procedures can be managed using the workflows that keep the history of the change (see Fig. 4).

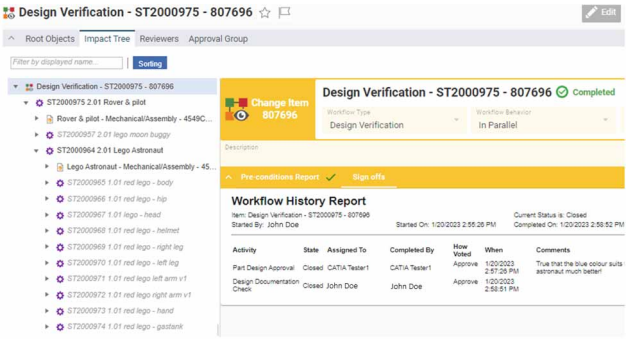

Figure 4: Change Item with affected objects and history report.

AUTHORING TOOLS

While SmarTeam was tightly integrated with CERN's main mechanical CAD tool CATIA, the only support for other CAD tools was for uploading 2D drawings for approval in CDD.

In contrast, the PLM allows for collaborating on projects independent of the CAD tool used. Viewable files such as PDF and 3D viewable are generated for most file formats in order to display them in the common viewer available in the PLM platform.

By extending the data management support to more CAD and other authoring tools, the users of these tools can profit from collaborating across disciplines on a central product structure (BOM). This can include authoring tools for mechanical and electronic design, manufacturing, simulation, as well as tools for system modelling.

Simple connectors were developed for the main CAD tools at CERN to ease and unify the CAD data management and enforce equal quality constraints across the tools. This also includes tools to draw the CERN drawing title blocks, and parts list on the drawings with data taken directly from the PLM to assure its correctness. Hence multiple interfaces are offered to the engineers to interact with the PLM in addition to the web interface [1]:

- A dedicated CATIA connector deeply integrated with CATIA.
- MultiCAD connectors for simple but uniform access to PLM from several CAD tools (AutoCAD, Revit, Inventor, BricsCAD and more).
- Batch import tools to import large sets of data (e.g., coming from external supplier) with verification of business rules are also available.

FEDERATION OF DATA

Currently, not all data is managed in the PLM but in other informatics systems. To build one common entry point for all engineering use cases, the PLM allows to connect to other systems in an efficient manner, allowing for

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searching and showing external information as well as linking to related information from objects in the PLM. For example, until the legacy CAD data management and Drawing archive are completely phased out, the PLM is connected to these legacy systems and allows searching and viewing the CAD models and drawings through the PLM. CERN's Engineering Document Management System (EDMS) is also connected, allowing to link to EDMS Documents from the PLM. Drawing stored in the PLM are made available in EDMS to support existing use cases.

MIGRATION & ROLL-OUT

The designs of the current accelerator complex at CERN are stored in SmarTeam and CDD. Hence, a migration pipeline was built that merges the data from these legacy systems into one coherent Part centric data model in the PLM. The versions and audit data of the drawing approvals of CDD are used to reconstruct the history of the Part. As such, the migrated Parts are versioned based on the historical data despite no Part versions existing in the legacy systems. As a result, migrated data looks like and behaves the same as new data created directly in the new system. It also allows to reconstruct data links that were not persisted in the legacy systems.

The migration is incremental where pre-migrated data becomes available read-only in the new PLM. It's possible to continue to work on new versions in the legacy systems during the pre-migration and then migrate those as new versions in the new PLM. When the ownership of a dataset is switched to the new PLM, modifications get blocked in the legacy systems. This approach allows for a successive transition, minimising the risk of disrupting the ongoing work of the users of the system.

The roll-out of the PLM is done in steps, first step was to allow search, navigation, and viewing of SmarTeam and CDD data, then users of AutoCAD were moved on to the platform (followed by Revit and Inventor). The following steps are then to move all CDD use cases which includes running Design Verification Workflows on any design data in the PLM before finally moving the CAD designers from SmarTeam.

DIGITAL TWINS

A Digital Twin is the concept of a digital representation of an equipment or a system that allows for exploring and simulating events and changes without changing or accessing the real objects. At CERN this also includes important advantages such as preparing interventions in restricted areas and planning future upgrades.

The introduction of a new PLM will additionally provide an information platform of managed and structured engineering data that can serve as foundation for future Digital Twins. Building a Digital Twin on connected, structured, and controlled engineering data will not only be more efficient, but it will also allow keeping it up to date with the continuous evolution. A framework to visualize CERN's accelerators with connected data from other systems in an interactive and dynamic 3D navigation is being implemented [2].

CONCLUSION & OUTLOOK

CERN's new PLM platform allows for better collaboration and improved data management by replacing two disparate legacy design data management tools with a unified system and data model. The conditions for data consistency and quality are improved. A major challenge for the data migration is the varying data quality in the legacy systems (some accelerators are more than 60 years old). However, this data quality work is a valuable investment for the future.

In the fields of CAD data management, the increased support for several CAD tools is already appreciated by AutoCAD and Revit users and the MultiCAD connector is planned to be extended to support more tools (e.g., BricsCAD as well as ECAD and possible simulation tools in the future).

The integration with EDMS will be enhanced and engineering data processes, such as accelerator hardware baselines (that are closely related to Parts and BOMs) currently in EDMS, will be unified in the PLM. Support for additional engineering processes such as Accelerator Configuration Management will also be added.

Integration with CERN's Asset and Maintenance Management will be done once the move of the CAD data management phase is completed. An integration with CERN's Fabrication Job Management System is also planned to allow closing the loop from Design to Maintenance via the production of the Assets.

By extending the use of the PLM, the data also becomes available across services. This, in turn, enables accelerator design and upgrade projects to increase efficiency by collaborating on up-to-date data across disciplines, and in doing so manage change and lower the risk for errors (and thus cost and time). Further, with a unified up-to-date data set describing an accelerator complex, new possibilities such as building dynamic digital twins become possible.

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