3D CAD COLLABORATION AT EUROPEAN XFEL AND ILC

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Abstract

Particle accelerators are complex facilities consisting of several sub-systems, such as e.g. buildings and tunnels, accelerator systems, supply lines and other technical infrastructure. High-level 3D models of the sub-systems are created and integrated into a master model, which guarantees interface compatibility and makes sure components fit into their complex environments. A "collaborative design process", which supports efficient, interactive and inter-disciplinary cooperation of design groups from different institutes, has been successfully developed and established at the European XFEL. The process is supported by the DESY Engineering Data Management System, DESY EDMS, and allows the combination of 3D models from multiple 3D CAD systems. Following the good experience at the European XFEL, the same process is now established at the Global Design Effort for the ILC.

OBJECTIVE

Particle accelerators are complex facilities consisting of several sub-systems, such as e.g. buildings and tunnels, accelerator systems, supply lines and other technical infrastructure. The various sub-systems are designed and developed by different groups who are working independently and may be located at different collaborating institutes. While each group creates and maintains 3D models of their individual sub-systems and components, an integrated model of the facility is needed for coordination purposes. The integrated 3D model should ensure interface compatibility and make sure components fit into their complex environments.

The groups usually have design tool environments in place. These environments include 3D CAD systems, which may be different at different labs and which are incompatible by nature. A process has been developed at the European XFEL which enables integrating the 3D sub-system models while working with the existing available CAD systems [1]. The process requires the participating institutes to provide their component models in a neutral 3D format called STEP AP214. At DESY, the different models are imported, integrated and published in the Engineering Data Management Systems, EDMS [2]. Collaboration partners can then access, review and mark up 3D models through the web-based EDMS.

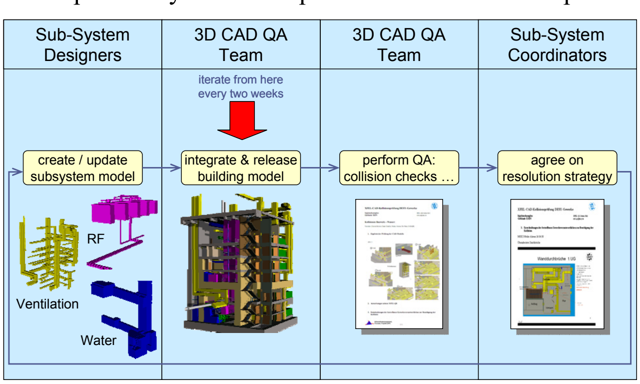

Figure 1: Process for 3D CAD collaboration (here: examples from XFEL).

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DESIGN PROCESS

The 3D CAD collaboration process has four major steps (Figure 1):

1. Designer in the collaborating groups create or update sub-system models
2. A dedicated 3D CAD quality assurance (QA) team, which is in place at DESY, integrates the sub-system models into a 3D model of the facility
3. The same 3D CAD QA team performs compliance analysis including collision checks
4. The analysis results are distributed to the sub-system coordinators, who have to communicate and agree on conflict resolution strategies

The last step results in change requirements, which are routed to the responsible design engineers and thus iterate the process from step 1.

The described process has been successfully established at the European XFEL and is now implemented at the Global Design Effort for the ILC [3][4].

3D CAD COLLABORATION AT XFEL

The 3D CAD collaboration has been first established for the planning approval procedure of the XFEL, which is a mandatory step in the approval of large public projects. Once planning approval has been granted, design changes which impact externally visible dimensions or general resource consumption are no longer acceptable. Hence when the planning approval documentation is submitted, already a complete model of the accelerator facility which contains all sub-systems possible has to be available to ensure that e.g. buildings and tunnels can accommodate the accelerator and all its infrastructure, and paths for transportation and installation activities are available.

The process started using high-level placeholder geometries, which are refined as necessary once more information about the components becomes available. It has since been further developed to accommodate the needs of detailed design activities and is now used for component development, installation planning and coordinating civil construction.

The process involves more than a dozen contributing groups with more than 40 design engineers and iterates as fast as once per week per building. Figure 2 shows an illustration of the injector complex, a 7-storey, 100x30x40 m^3 underground building. Figure 3 shows a 3D model of the XFEL tunnel.

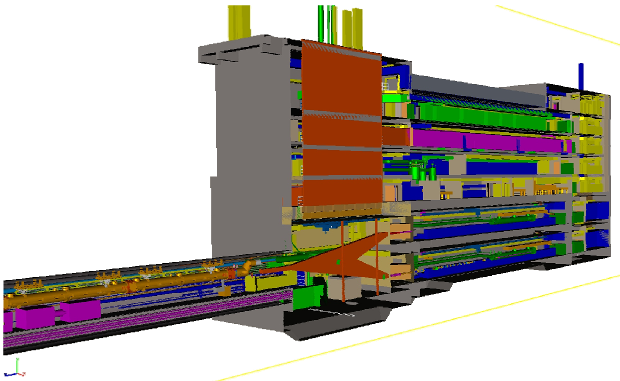

Figure 2: Example 3D model of the injector complex of the European XFEL.

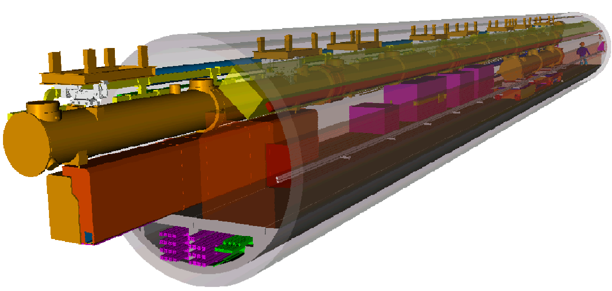

Figure 3: 3D model of the XFEL tunnel.

A closer look at the tunnel model reveals that the accelerator systems, which are the major components from a physics perspective, require only a small part of the available tunnel space, while large space is needed for supply lines, infrastructure or transportation activities. The tunnel model includes the following sub-systems:

- Accelerator systems
- Transportation
- Ventilation
- Gases, including pressurize air
- Water supplies
- Conventional electric power
- RF supplies
- Cryogenics, e.g. helium lines
- Controls and Diagnostics
- Survey (lines of sight)
- Safety and Radiation Safety

Geometry in model contains all kinds of space requirements from the different sub-systems, which include the geometry of components, but also reserved spaces for e.g. emergency escape routes, survey lines of sight and transportation options. Collision checks ensure the compatibility of the sub-systems, ranging from general layout considerations to details such as the position of openings in walls for supply lines. White lists and black list define whether collisions are acceptable or not. Acceptable collisions include e.g. overlap of emergency escape routes with doors, survey lines of sight and even transportation options, as long as transport vehicles do not prevent possible escape. Inacceptable collisions are interference of component geometries, or allocations of the same space to more than one system (or, more general, everything which is not explicitly labelled acceptable).

3D CAD COLLABORATION AT ILC

After good experience at the European XFEL, the same process for 3D CAD collaboration is also established at the global design effort (GDE) for the ILC for machine design and integration efforts. An initial model has been successfully created to prove the feasibility of the concept [4]. Figure 4 shows the scenario which has been used to demonstrate the process: Four institutes in different countries and time zones using three different 3D CAD systems contribute 3D models, which are then integrated and published to EDMS at DESY [3].

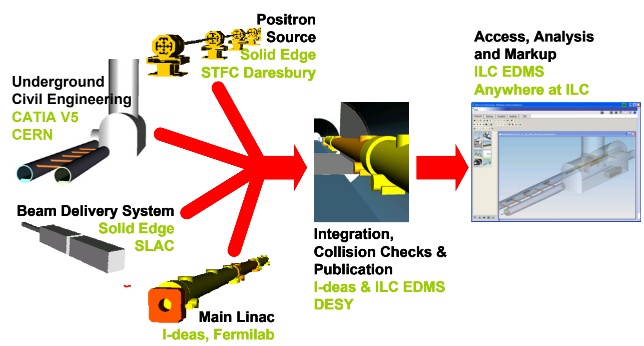

Figure 4: 3D CAD collaboration test scenario at ILC.

Figure 5 shows the first prototype model of the ILC. The tunnel is still “empty”, but it will fill soon as the 3D CAD work extends to include all sub-systems.

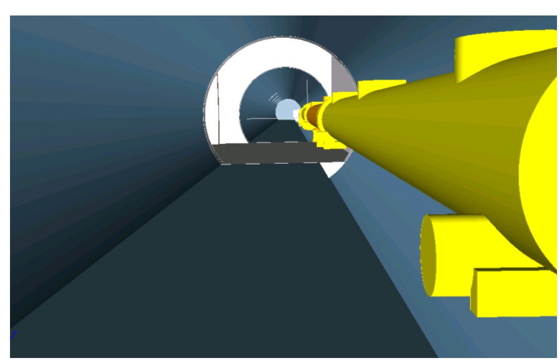

Figure 5: Prototype model of the ILC containing tunnel segment, cavern and shaft and the main linac, positron source and beam delivery systems.

WORKING WITH PLACEHOLDERS

Placeholders are one of the essential design elements in the described process. Placeholders describe the maximum space required by a component – usually the

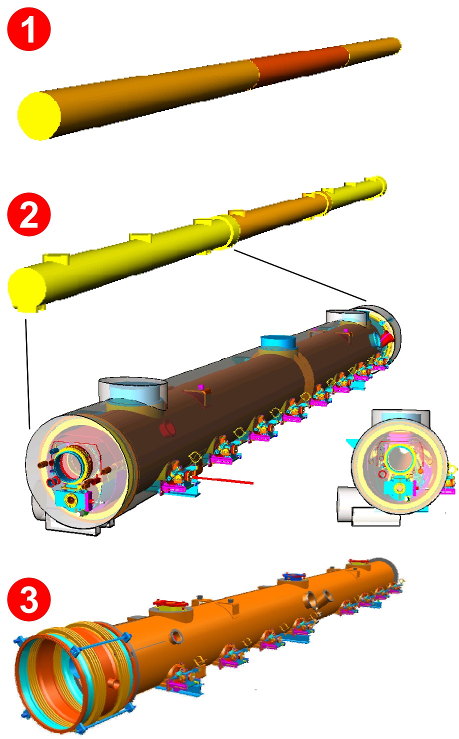

Figure 6: Lattice (1), accelerator made up of placeholders (2) and detailed component models (3). Placeholders link and decouple component design and facility planning.

component envelope plus space for e.g. tolerances, tooling and fixtures for transportation. Placeholders link facility planning and component design. They enable coordinating the entire facility, while at the same time decoupling detailed design from facility layout and planning processes.

Figure 6 illustrates working with placeholders: The design process is driven by lattices which define the physics requirements of the accelerator. Lattices identify the accelerator components in use by type and optical length and list their nominal positions (1). For each component, placeholder models are created which identify the component's maximum space occupation, and the entire machine is visualized by arranging the placeholders according to the lattices (2). The placeholder model is then included in the integrated model of the facility for further analysis. Detailed component models can now be developed and only need to be checked against the placeholders. They are "safe" as long as they do not protrude from the placeholder.

TOOLS

The integrated 3D CAD models are published and maintained in the DESY EDMS. The EDMS is a fully web-based system including a 3D viewer which enables any collaboration partner to inspect, analyse and add comments to the integrated CAD models [2]. Figure 7 shows the prototype ILC model in the EDMS and its viewer.

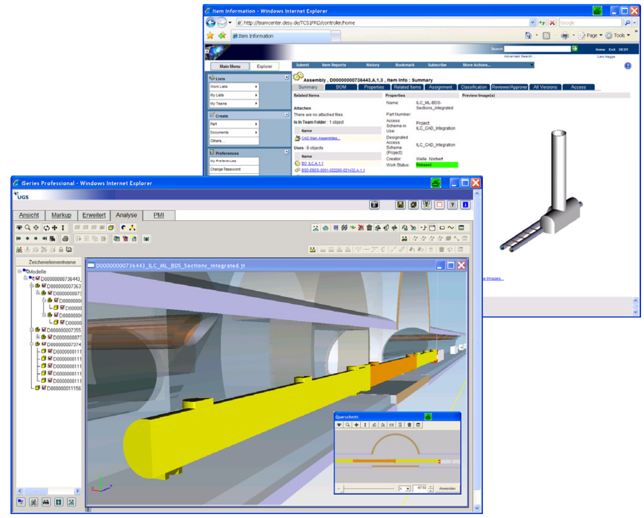

Figure 7: Prototype 3D model of the ILC available in ILC EDMS.

EXPERIENCE

The 3D CAD collaboration process is straight forward and easy and fast to implement. Integration requires that the different 3D models are created according to common standards and best practices, such as e.g. common coordinate systems, naming conventions and usage of placeholders. Placeholders are often initially perceived as additional work, but they are soon accepted when the complexity of the models grows and their benefits become obvious. The process fosters communication of scientists and engineers, who can access and use the models in the EDMS to negotiate space allocation and resolve potential conflicts.

REFERENCES

[1] N. Bergel, L. Hagge, T. Hott, J. Kreutzkamp, S. Sühl, N. Welle, "Inter-Disciplinary Mechanical and Architectural 3D CAD Design Process at the European XFEL", EPAC'08, Genoa, June 2006

[2] J. Bürger, J. A. Dammann, S. Eucker, L. Hagge, A. Herz, J. Kreutzkamp. .S. Pantó, S. Sühl, P. Tumidajewicz, D. Szepielak, N. Welle, "DESY and ILC EDMS", PAC'09, Vancouver, May 2009 (these proceedings)

[3] L. Hagge, "ILC Goes 3D!", TILC'09, Tsukuba, April 2009

[4] "Let me not to the marriage of three CADs …", ILC Newsline, April 23, 2009, http://www.linearcollider.org/newsline/readmore_20090423_ftr1.html