INTER-DISCIPLINARY MECHANICAL AND ARCHITECTURAL 3D CAD DESIGN PROCESS AT THE EUROPEAN XFEL

N. Bergel, L. Hagge*, T. Hott, J. Kreutzkamp, S. Sühl, N. Welle, DESY, Hamburg, Germany

Abstract

This paper describes procedures and tools which are used in mechanical and civil engineering of the European XFEL and reports benefits and experience. The procedures in use allow negotiation of requirements among the work packages, distributed 3D-CAD design, visualization of the facilities, running approval and change management procedures and optimized document management. Tools in use include a requirements database, 3D-CAD systems and an engineering data management system.

INTRODUCTION

Challenge: Collaborative Design

Realizing the European XFEL involves creating and coordinating 3D design models for subsystems such as underground buildings, accelerator systems, photon beam lines, utilities and infrastructure [1]. Design engineers in different work packages contribute CAD data of components, accelerator modules and subsystems to the master model of the XFEL facility, which is maintained by a central CAD integration and quality assurance team.

Example

Figure 1 illustrates the scenario for the design of the XFEL buildings. Designers from the different trades – e.g. civil engineering, water, rf and power supplies, ventilation, cryogenics, transportation, survey and alignment, general safety and of course the beamline components –contribute CAD models to the master model. The CAD QA & integration team assembles the various models into the master model and performs compliance analysis and collision checks. The results are communicated back to the designers, who have to resolve the issues and provide updated CAD data.

Process Definition

To enable efficient work, procedures for communication, cooperation and CAD data exchange have to be defined. The following topics have to be addressed:

- **Design standards** for building 3D design models
- **Processes** for data exchange and collaboration
- **Data management** policies and procedures
- **Tools** like 3D CAD and EDMS incl. visualization

The following sections explain the approach which has been chosen for the European XFEL.

DESIGN STANDARDS

In mechanical engineering, "design" refers to the construction of geometric models, including their validation by e.g. FEM calculations and functional simulations.

Design models have to be adapted to their specific purpose. For example, accelerator design requires 3D models to manage space requirements and ensure that components connect properly and do not intersect. Civil construction is on the other hand a 2D trade which relies on floor plans and sections of buildings. Tendering procedures and (prototype) production require detailed design models, while integration should be conducted with placeholder models with reduced geometry and complexity. Figure 2 shows (a) a detailed and (b) a place-

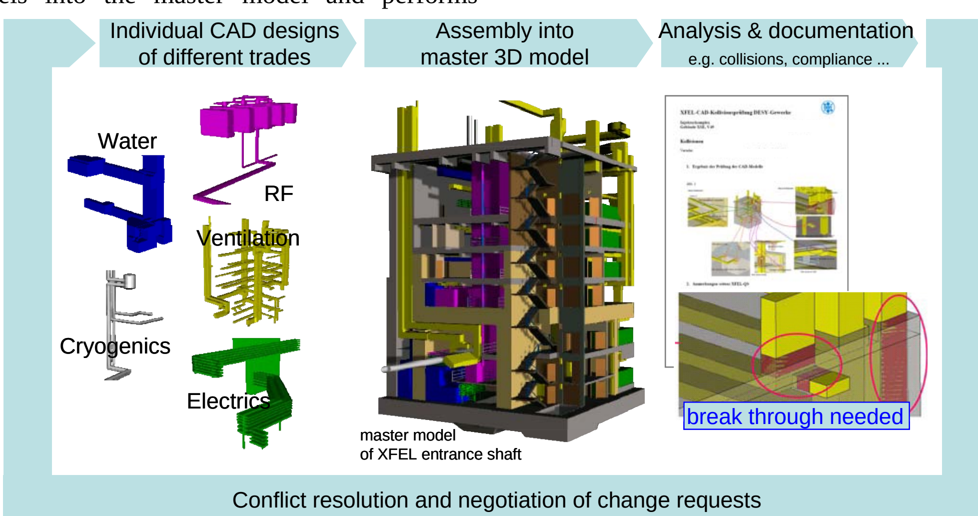

Figure 1: Schematic of collaborative design process for XFEL buildings, infrastructure and accelerator.

*communicating author: lars.hagge@desy.de

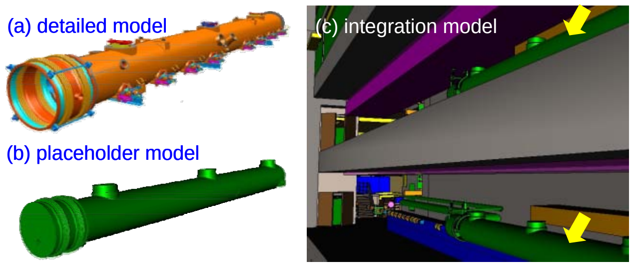

Figure 2: Different models for different purposes

holder model of an accelerator module and (c) the use of the latter for integration and space management.

Creating purpose-made design models implies that the same component may have to be modelled several times with different properties. At first glance this seems to increase the designer's work load, but in the long term it saves efforts as engineering processes gain in effectiveness.

PROCESSES

The engineering process defines the set of necessary activities for obtaining the facility master model. It includes for example component design, communication, coordination, documentation, and change management.

Figure 3 displays the information flow in the engineering process. It is shown for one work package which communicates with the central CAD QA & integration team and employs additional third-party manufacturers. The complexity of collaborative design arises from multiple information flows between several parties which are executed asynchronously and in parallel.

If for example CAD QA identifies an issue with a CAD model, a straight forward approach would be to fix the issue and send the corrected model back to the work package. But CAD QA does not know whether the work package has to re-run simulations for validation before accepting the change or not. Also, the CAD model might have already been sent to a manufacturer, which started follow-up processes. Therefore, CAD QA has to send a change request to the original author of the CAD data to ensure that all impacts of the change can be taken into account. Change requests may also originate from other sources, e.g. manufacturers might propose optimizations

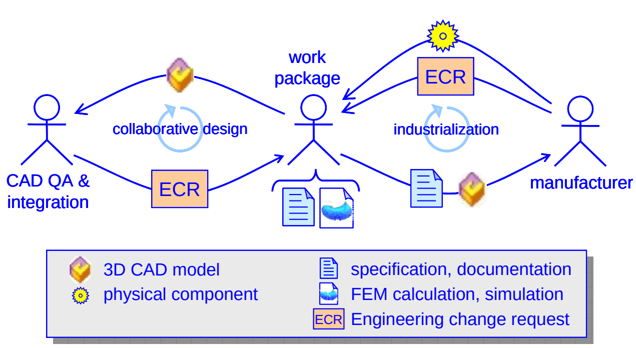

Figure 3: Data flow in collaborative engineering process

with respect to production costs, and other work packages might request changes in interfaces or occupied space.

As a result, the engineering process is an iterative process which is executed only "downstream" (Figure 1). To implement the process, the owners of the master model and those of the individual component models have to be defined, and data management has to be implemented.

DATA MANAGEMENT

Data management summarizes the policies, practices and procedures for collecting, organizing and retrieving (design) data. It provides functionalities for version control, history tracking, configuration and change management, review and approval workflows, and access control.

Data management is an essential ingredient for engineering processes since 3D models are very complex data structures. It ensures that changes are propagated and keeps track of the compatibility of versions. In data exchange, it ensures that only compatible models or models with known states are transferred. Furthermore, data management ensures that models are only modified by their owners, and that intellectual property is protected against unauthorized access.

The data management policies and practices are summarized in design standards, which cover e.g. global coordinate systems, naming conventions, model reference structures, quality assurance criteria, and process descriptions. Figure 4 illustrates how data management controls hierarchical design models (so-called part breakdown structure) and keeps track where individual parts are (re-) used. Data management is the most complex task in the engineering process. It has to be mastered by the designers and requires a strong tool support.

TOOLS

Figure 5 shows the tools which are used in the XFEL collaborative design process. The process is based on DESY's Engineering Data Management System (EDMS). The EDMS offers powerful data management capabilities, provides workflow support and interfaces directly with 3D CAD systems [2]. The EDMS is fully web based and provides full data access for all project stakeholders, including visualization of the CAD models.

Designers emphasize the functionality and usability of design tools as key factors for the efficiency of design activities, thus engineers from different trades prefer different CAD systems. Work packages which are basically concentrating on the development of specific accelerator components adopted a mid-range 3D CAD system with good acceptance for its usability. For integration & QA activities and the design of the accelerator modules, a high-end 3D CAD package with strong process support and data management capabilities is used. Employing two 3D CAD systems generates additional workload in data exchange, but increases the overall efficiency. The com-

Figure 4: Data management controls the hierarchical structure of design models (left) and keeps track of part usage (right).

plexity of data management is to a large extent handled by the central CAD QA & integration team. This way, designers in the work packages can concentrate on modelling, while the data management infrastructure ensures the longevity of the data for the entire project lifetime.

For designing the XFEL buildings and technical infrastructure, an architectural CAD system is used for creating building models and drawings according to official standards and regulations. The building models are manually synchronized with the mechanical engineering models and updated only when a new stable version of a 3D building model is available.

The architectural CAD system interfaces with a facility management system, which maintains a room inventory for the XFEL, and a requirements database which tracks requirements on space and technical infrastructure [3].

EXPERIENCE

The collaborative design process has been successfully implemented for the design of the XFEL facilities. The cycle time for a full iteration of the process involving all 11 trades is two weeks, starting with the distribution of change requests to the work packages and covering subsequent conflict resolution, design updates, updates of the master model, and analysis and QA.

Challenges were less of technical but more of cultural nature. Due to the tight interaction of the work packages and the high complexity of the models, many design standards and guidelines had to be put into place. Users had to be trained in handling the tools and were at first overwhelmed by the complexity. Acceptance was gained by intensive support and coaching on the job. The process had its breakthrough when the persons involved started experiencing benefits in their daily work.

As key benefit, the process tightens the cooperation between scientists and designers, who can share models and communicate feedback within one platform. The use of purpose-made models reduces the complexity for the individual and increases the efficiency of the entire process. The use of placeholder models reduces the inter-trade conflicts and enables engineers to develop optimized designs, while still being able to incorporate late R&D-driven design changes within subsystems.

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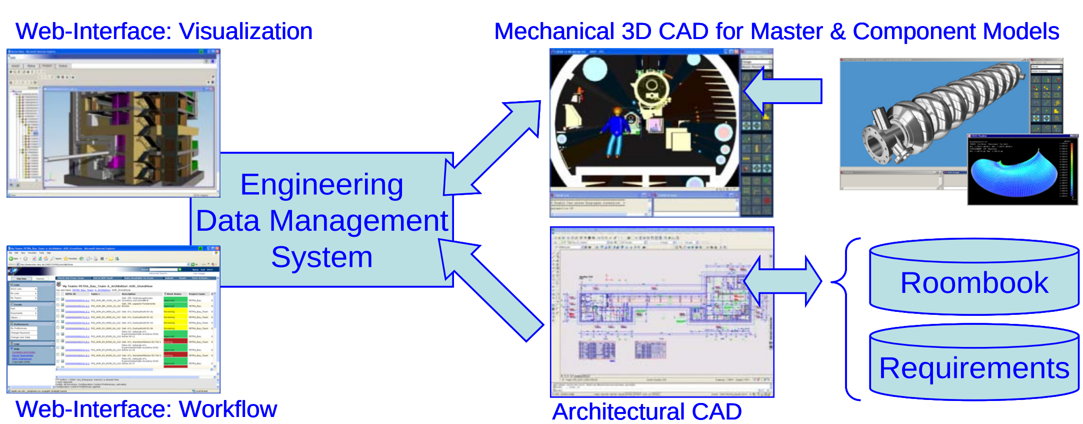

Figure 5: Tools in the XFEL collaborative design process.