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ENGINEERING DATA MANAGEMENT FOR THE ILC SITE SPECIFIC DESIGN PHASE

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Abstract

In August 2013, the Japanese ILC Site Evaluation Committee has recommended the Kitakami area in northern Japan as the technically preferred site for the International Linear Collider (ILC) in Japan. With this decision, the ILC planning has moved into a new stage where the Technical Design Report baseline design has to be adapted to the specific site, and refined in preparation for a possible construction project.

Engineering data management provides the methods and supporting tools to create and maintain the design data throughout the entire life of the ILC project.

The Management and integration of engineering data from the design teams around the globe that contribute to the ILC requires a carefully structured body of documentation, clearly defined processes including configuration control, and efficient vision sharing through 3D modelling.

INTRODUCTION

Shortly after the completion of the Technical Design Report (TDR) [1] for the International Linear Collider (ILC) in spring 2013, Japan conducted a review of two possible sites for the ILC, one near Fukuoka in the south and one in the Kitakami area in the north, which was recommended by the Site Evaluation Committee in August 2013. Thus the design work has progressed to into a new stage, from a design for a generic site with only general characteristics (such as flat or mountainous topography) to a design for a specific site with specific boundary conditions from geology, topography, road access, infrastructure, neighbours or nature conservation, to name just a few. At the same time, the ILC project becomes relevant to a wider audience, not only to the scientists and engineers from the high energy physics and accelerator community, but to national and local governments, politicians, and average citizens.

The ILC design is particularly challenging because a highly complex system is being been planned by design teams distributed around the globe, with no central laboratory that dominates the design work. The Global Design Effort (GDE) and the Linear Collider Collaboration (LCC) as its successor have adopted Engineering Data Management (EDM) concepts in order to meet these challenges. Engineering Data Management, EDM, better known as Product Lifecycle Management, PLM, is a conceptual approach to information management and process automation in the product lifecycle, i.e. in the areas of design, development, fabrication, quality assurance, operation and maintenance, and recycling.

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ACTIVITIES

Lattice Integration

The basis of the design of an accelerator is given by the lattice, which defines the positions and properties of all the components that guide the beams. The ILC comprises more than 70km of beamlines that belong to six different accelerator systems and are designed by separate groups. A complete and consistent lattice is necessary as basis for the civil engineering design work. For the TDR, these lattices were integrated so that they fit together geometrically and functionally and thus can serve as the basis for the design of the underground structures such as tunnels and caverns. Treaty points were defined and documented for the interfaces between the accelerator systems, and waypoints were defined for systems sharing the same tunnel in order to minimise the required tunnel cross section where possible.

During the lattice integration, interferences between beamlines from different systems were identified and resolved. Detecting cases where beamlines intersect each other are detected easily. Certain areas, however, require more space around the beamline for bulky infrastructure, such as the positron source target with its surrounding radiation shielding (Fig. 1).

Design Integration

The purpose of *design integration* [2] is to achieve a consistent, complete and correct design for the whole project. For this, it is important to provide a consistent view on the design in its entirety to the various stakeholders involved in or affected by the ILC project. All design contributions are entered into the EDM system. During the design integration, the data from different accelerator systems (such as damping rings or

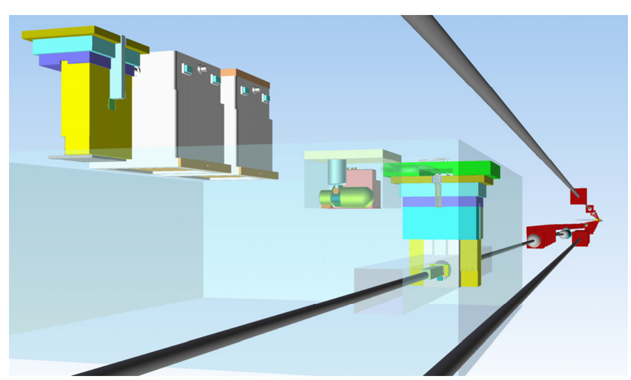

Figure 1: Example of design integration: the region around the positron source target requires heavy shielding (shown as translucent block); the beamlines from the other accelerator systems that share the same tunnel are required to have no magnets in that region.

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main linacs) and technical areas (e.g. magnets or vacuum systems) are brought together, in particular in the form of 3D models, so that inconsistencies, interferences and missing items can be identified. Fig. 1 shows an example of the positron target region where a detailed model of the target is checked against the lattices of neighbouring accelerator beamlines.

Visual Modelling

Our approach to design integration is heavily based on the use of 3D visualisation. We have developed efficient methods to translate a lattice design directly into a visual model, taking into account the shapes and sizes of components as far as they are known. This lattice visualization is then combined with an integration model of the civil infrastructure such as tunnels and caverns, and can be augmented by individual models of special installations such as the positron source target (Fig. 1), or detailed models of tunnel sections. It is also possible to add realistic surface models, based on high-precision digital elevation models (DEMs) overlaid with actual aerial photographs (Fig. 2).

The three-dimensional models can be interactively manipulated and explored on a wide range of hardware ranging from tablets or laptops to a full virtual reality room, and by persons with different backgrounds and degrees of experience; this supports vision sharing in a powerful way that can hardly be achieved by other means such as texts or technical drawings.

The creation of the visual model requires the compilation of large all available engineering data on components such as magnets, and a documentation, which physical components correspond to which lattice elements. This leads to a more realistic design at an earlier stage, which reduces the necessary design changes later on.

The creation of an integrated model of a full accelerator is impossible without a hierarchical structure for the model. This structure necessarily is related to the structure of the design work that is being performed, as captured by the project's Work Breakdown Structure

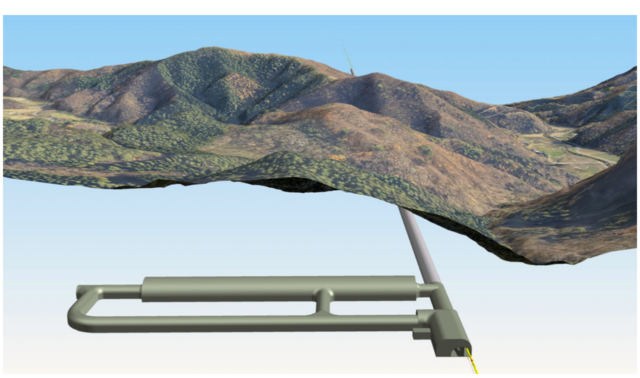

Figure 2: CAD model of the underground civil structures together with a digital elevation model of the surface. The position of the tunnel has been changed for artistic purposes.

(WBS), as well as the Parts Breakdown Structure, or Manufacturing Bill of Materials (MBOM) of the accelerator. Creating the visual model shows missing items (empty spaces where hardware would be expected), missing or overlapping responsibilities, or unclear parts segmentation at a relatively early stage in the project and therefore helps to identify missing items or interface definitions. Thus visual modelling turns out to be useful not only to judge the consistency and completeness of the design itself, but also to sharpen the product structure and even the project structure themselves.

Support for Siting Studies

While CAD systems are the tool of choice for the engineering design of the accelerator and civil facilities, positioning those facilities in the landscape is clearly something that requires a Geographic Information System (GIS), not least because the 30km length of the ILC requires careful consideration of the earth's curvature and scale or shape distortions introduced by map projections. Most of the ILC will follow the earth curvature and thus be "flat", rather than laser-straight. Integrating the civil engineering with the site studies therefore requires a Coordinate Reference System (which comprises a geodetic datum and a map projection) that has defines rectangular coordinates with minimal distortion to be used for CAD modelling and has an unambiguous geographic meaning. With the definition of such a CRS, the location of accelerator components and buildings can be shown accurately in CAD and GIS systems alike (Figs. 2 and 3), and both can be used for planning purposes.

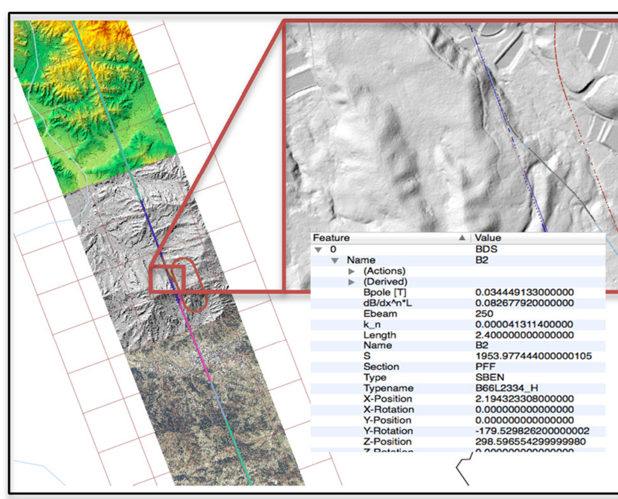

Figure 3: Position of the beamline elements in a GIS system, together with information about a single magnet element. The accelerator location has been altered for artistic purposes. The coloured strip shows (from top to bottom) a color-coded digital elevation model (DEM), a shaded relief, and aerial photographs, overlaid with an 1km grid of the Coordinate Reference System (CRS) used for the planning.

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Document Management

While visualisation of engineering data is important and highly useful as discussed above, the full body of design documents encompasses much more, such as requirements, specifications, parameter lists, calculations, detailed CAD models for fabrication with associated drawings, budget calculations, schedules, and so on. This body of documents constitutes the *Technical Design Documentation* (TDD) of the ILC, which is the foundation of the description given in the TDR.

The TDD is structured according to a Work Breakdown Structure (WBS) that was defined for the Technical Design Phase. A new WBS for the site-specific design phase is under development, which will also serve as starting point for the WBS of a full construction project.

Careful document management with a single point of information that provides complete, up-to-date and authoritative documentation is of particular importance for the ILC, where design teams from all over the world contribute to a common project. For instance, a distinction is needed between a design study and an accepted baseline design that is endorsed by the management. This distinction is made by linking the official documents to the WBS, which also puts them under change control.

Change Management

It is an important goal for the site-specific design phase that has started now to preserve, and gradually improve, the degree of consistency and completeness of the design that has been achieved at the end of the Technical Design Phase (TDP) that ended with the completion of the TDR.

To this end, the Linear Collider Collaboration (LCC) is again setting up a change management process where changes to the design as embodied by the TDD require a formal change, similar to the situation during the TDP. The formality thus introduced has the goal of making sure that the relevant stakeholders are aware of design changes that affect them, and to keep a tally of all approved or pending changes and to which degree they have already been incorporated into the design documentation. The proposed change control process will initially be lightweight and flexible, with the option to progress to a full CMII-like process [3] as the project becomes more complex and mature.

BENEFITS

It is well known that as the design of an accelerator becomes more detailed and elaborate, the cost for design changes rises, because more and more work has to be undone to implement the change. Having an integrated design from early on, when the design is still relatively malleable, makes it possible to remove or altogether avoid interferences between systems that would require extensive redesign later on. Particular examples from the European XFEL project [4] are the early reservation of space for transport, installation, escape routes and surveying, and allocation of space for supplies of electricity, water and gases [5]. As Fig. 1 demonstrates, a similar process has been started at ILC for the lattice design, which already incorporates space requirements from neighbouring systems in the layout.

Carrying the design integration one step further to include the specifics of the site that has now been chosen will enable the design team to assess the impact of the site on the accelerator, for example identify likely sources of vibration such as roads or rivers and their relative location to sensitive parts of the machine, in particular the final focus system. Big changes such as shifting the interaction point are currently still possible, but will become expensive as soon as detailed geological studies and preparations for the necessary land acquisition have started. Providing accurate, up-to-date information to the stakeholders and making sure all participants share a common vision of the project helps to conduct this process in an efficient way.

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