DESIGN INTEGRATION AND VISION SHARING FOR THE ILC

B. List#, L. Hagge, S. Sühl, N. J. Walker, N. Welle, DESY, Hamburg, Germany

Abstract

The design integration process for the International Linear Collider (ILC) involves a formal documentation of the requirements, specifications and processes for the construction of the ILC in a uniform and consistent manner. We discuss the benefits of such a process, how a central integration group can support the design integration, and how 3D models can be used to share a common vision of the project.

INTRODUCTION

The Global Design Effort (GDE) for the International Linear Collider (ILC) is currently preparing the Technical Design Report, which will be finalized by the end of this year and released in early 2013. The GDE is a truly global collaboration with many participating institutions around the world and no central host lab. The ILC is designed for sample sites in three regions (America, Asia, and Europe) with different topographies (flat and mountainous). All this makes the integration of the accelerator design a demanding task.

Design Integration

A complete design of any product, in this case the ILC, includes the requirements on the ILC, the specifications, and the processes to build, operate, and maintain the ILC as an experimental facility. The design has to address all areas relevant to the accelerator, such as physics performance, beam optics, design of individual components, tunnels and other buildings, electricity, cooling, access, safety, costs. The aim of design integration is to converge on a single design that is acceptable to all participants.

A central group can foster design integration by defining processes, e.g. for collaboration and communication, providing methods and tools, for instance for data management or CAD modeling, and setting standards, e.g. for structure and content of documentation.

In the following some topical examples of the design integration process at ILC are discussed, as well as the role of the Technical Design Documentation in this process.

APPLICATIONS

Lattice Integration

The foundation of a consistent and correct accelerator design is the lattice, which defines the layout of the machine. The ILC comprises six accelerator systems: electron and positron sources, damping rings, beam transfer and bunch compression (RTML: "ring to main linac"), main linac, and beam delivery system, which are all designed separately. During integration, the lattices are adapted to fit together geometrically and match optically. 3D visualization models (Fig. 1) can be used at this stage to study beamline geometries in crowded areas and make sure that beamlines avoid difficult areas such as large dumps or muon spoiler walls. A python program translates the survey output of MAD8 [1] directly into a VRML [2] 3D model, which can be rendered in viewing programs such as VisView[3]. Component shapes, their appearance and transverse dimensions are defined within the python program, the correspondence between groups of lattice elements and physical components is governed by steering files in Excel™ file format. These light-weight 3D visualizations of the lattice enable fast design cycles during the integration process, so that the lattices of the various accelerator systems can be made consistent and be arranged such as to allow an efficient tunnel layout.

During lattice integration the beamline geometry is fixed and specified in documents detailing treaty points (with Twiss functions) and additional way points; this geometry is mostly driven by functional requirements of the accelerator. Lattices of transport lines are then adapted to these specifications. This process is iterated when conflicts arise, for instance when large installations such as beam dump or target shieldings require that neighboring beamlines have to be moved or have sections devoid of magnets to facilitate penetration of shielding walls.

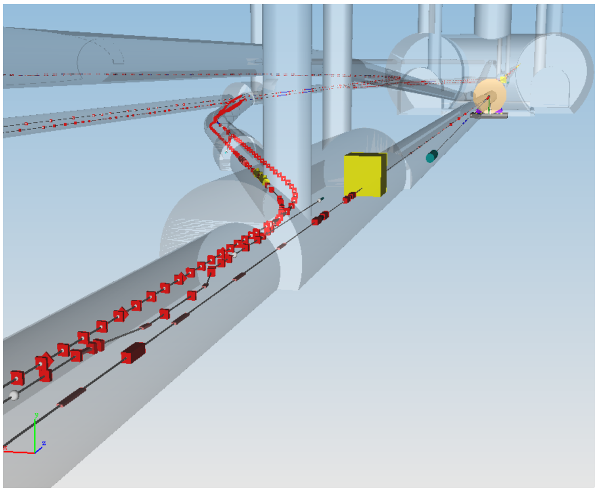

Figure 1: 3D lattice visualization: Transfer tunnel between Main Linac and Damping Ring (DR). Shown are visualizations of the accelerator lattice and the European region tunnel design [7].

#Benno.List@desy.de

ISBN 978-3-95450-115-1

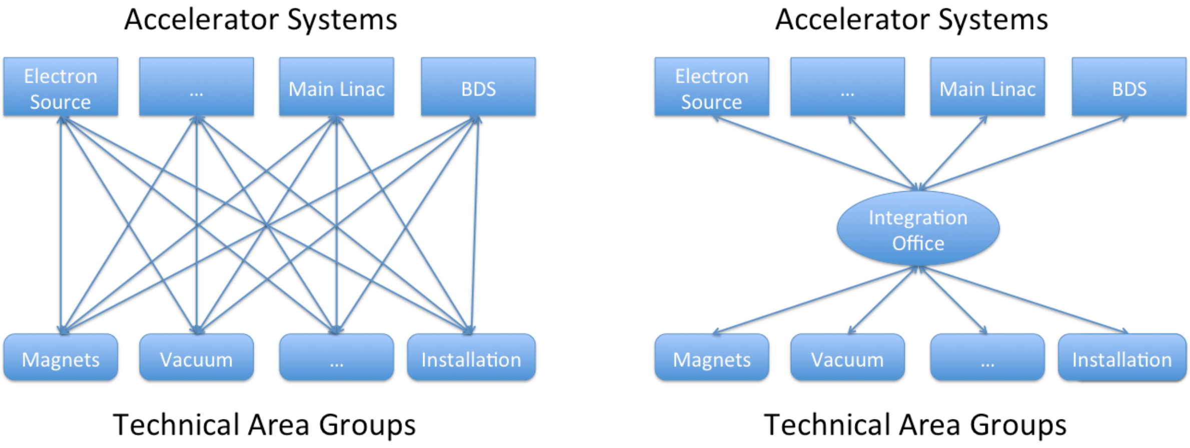

Figure 2: Communication paths without (left) and with (right) an Integration Office.

The lattices are collected centrally, checked for consistency, and after the necessary iterations released with accompanying information such as component lists.

Support of Technical Area Groups

While the Accelerator Systems are segmented according to function, technical areas such as magnet systems, vacuum systems, instrumentation, surveying or installation are the responsibility of dedicated Technical Area Groups (TAG) that provide designs across the whole accelerator. This necessitates communication paths between all Accelerator Systems and TAGs (Fig. 2 left). In such a scenario, processes how to capture requirements, arrive at specifications and procedures, and document the resulting design, vary considerably between different TAGs, leading to increased overhead in the design process. This can be a quite daunting task, as illustrated by the design of 13000 magnets [4].

A central design integration office can speed up this process by acting as a central information broker (Fig. 2 right) in addition to the existing direct communication channels. It can provide some information directly to the TAGs, in a uniform manner and quality, with consistent data over the whole accelerator. In other cases, the integration office lends support in the gathering of requirements and development of specifications by setting up appropriate processes and documentation. In all cases, the responsibility for the content of all documents remains within the existing groups, who have to review and sign off on any document drafted by the integration group.

Conventional Facilities

The ILC requires around 40km of tunnels and more than a dozen access shafts and underground caverns, accounting for more than a third of the total project cost [5]. An accurate and optimized design of these conventional facilities is therefore of high priority.

As a result of the design integration, geometrically consistent lattice files have been made available to the CFS ("Conventional Facilities and Siting") design groups of the three regions as Excel™ spreadsheets. Thus, the exact beamline geometry is available for the CFS design, facilitating the design of tunnel cross sections, alcoves, and caverns to accommodate beamlines and dumps, with a perfectly consistent geometry. Fig. 1 and 3 illustrate this for the European and Americas regions. The tight coupling of lattice and tunnel design at this early planning stage has also permitted to adjust the beamline geometry to take into account CFS requirements, such as access and installation space or escape routes.

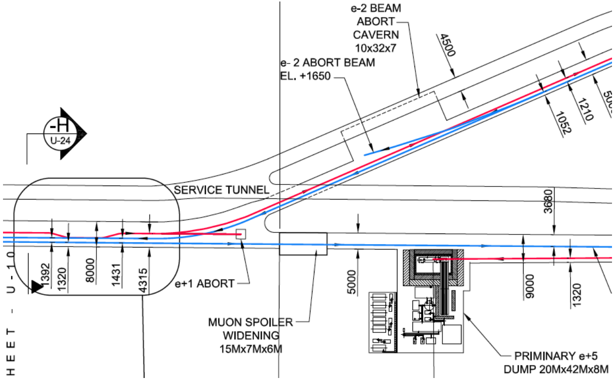

Figure 3: Detail of the Americas region tunnel design [6]; the same region as in Fig. 1 is depicted. The beamlines are drawn directly from imported lattice data.

Costing

Delivering a complete and accurate cost estimate for the ILC is a central goal of the Technical Design Phase. The Work Breakdown Structure (WBS) employed by the cost group structures the project according to the accelerator systems, and the accelerator system groups are responsible for providing accurate component counts and unit costs of their respective accelerator part. However, unit costs depend on the total quantities ordered, which is conventionally taken into account by a "learning curve" factor, and therefore unit costs have to be evaluated based on component counts across the whole project. The integration group maintains and provides such summaries to the cost engineers.

TECHNICAL DESIGN DOCUMENTATION

A prerequisite for design integration is a complete, consistent and correct body of design documents, the Technical Design Documentation (TDD). The TDD not only complements the Technical Design Report (TDR) that is finally produced as a human-readable condensate of the design work and preserves the detailed design for future use. During the design integration, the TDD plays a decisive role as a single point of information for all Accelerator Systems and TAGs, recording design decisions that have been met or changed for all affected parties. This "information integration" is a prerequisite and precursor for design integration.

The TDD is stored in an Engineering Data Management System (EDMS), where each version of document is assigned a unique ID. The preferred way to exchange documents is to communicate EDMS IDs, rather than sending files, which guarantees accurate information at all times. To make the EDMS information more accessible, a web portal [8] has been created that provides links into the EDMS system and is integrated in the central GDE web pages.

Completeness of the documentation is ensured by organizing it according to a Work Breakdown Structure (WBS) of the Technical Design Phase work. The WBS lists all work topics for which documentation is to be expected in a top-down manner. A list of mandatory documents such as parameter tables, treaty point definitions, or beamline overviews has been defined that are expected from each Accelerator System.

Correctness of the design documentation, and thus of the design itself, is ensured by subjecting documents such as parameter tables or treaty point definitions to a review and approval process: documents are sent to all stakeholders via EDMS for review and subsequently to the project managers for approval. Based in the comments made in the reviewing stage, the project managers either approve a document and thus make it binding, or reject it; after alterations have been made, this process can be repeated with a new version of the document.

Consistency of the design is maintained by showing relationships between design documents in EDMS through the use of links. Dependencies in particular can be captured in this way, supporting a correct propagation of changes through the whole design. Fig. 4 illustrates several design specifications are interrelated.

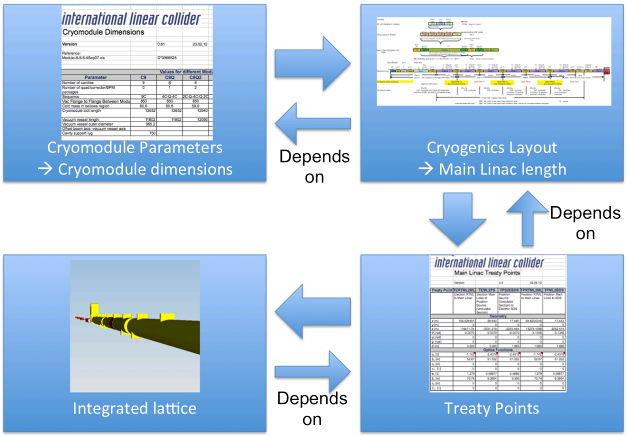

Figure 4: Design documents with interdependencies for the ILC Main Linac lattice.

CONCLUSIONS

A project as widespread and complex as the design of the ILC can benefit from a design integration group that acts as a catalyst to the communication between the various working groups within the project. An integration group can provide processes, tools, and standards, but it can also offer as a service the consolidation of existing information as needed by Technical Area Groups. The compilation of a complete Technical Design Documentation is of central importance for a successful and efficient design integration process.

REFERENCES

[1] H. Grote and F. C. Iselin, "The MAD program (methodical accelerator design) version 8.4: User's reference manual," CERN-SL-90-13-AP-REV.2 (1990).

[2] International Standard ISO/IEC 14772-1:1997; http://www.web3d.org/x3d/specifications/vrml/ISO-IEC-14772-VRML97/

[3] Siemens Lifecycle Visualization; http://www.plm.automation.siemens.com/

[4] C. M. Spencer *et al.*, "Overview of the 13,000 Magnets in the International Linear Collider," IEEE Trans. Appl. Supercond. **18** (2008) 342. DOI: 10.1109/TASC.2008.922396

[5] N. Phinney, N. Toge and N. Walker, "International Linear Collider Reference Design Report Volume 3: Accelerator," arXiv:0712.2361 [physics.acc-ph].

[6] T. Lakowski *et al.*, "Americas Tunnel Drawing Set for KILC12," http://ilc-edmsdirect.desy.de/ilc-edmsdirect/item.jsp?edmsid=D00000000898245

[7] J. Osborne and A. Kosmicki, "European region tunnel layout," EDMS ID D00000002343402.

[8] ILC GDE, "Technical Design Documentation," http://www.linearcollider.org/GDE/technical-design-documentation

ISBN 978-3-95450-115-1