Fusion Engineering and Design 87 (2012) 1945–1948

Contents lists available at SciVerse ScienceDirect

Fusion Engineering and Design

journal homepage: www.elsevier.com/locate/fusengdes

Software solutions manage the definition, operation, maintenance and configuration control of the National Ignition Facility

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HIGHLIGHTS

- NIF is a complex experimental facility composed of ~4 million components.
- We describe business tools to define, build, operate, and maintain all components.
- CAD tools generate virtual models and assemblies under configuration control.
- Items requiring preventive, reactive, and/or calibration maintenance are tracked.
- Radiological or hazardous materials undergo additional controls.

ARTICLE INFO

Article history:
Received 5 August 2011
Received in revised form 28 July 2012
Accepted 21 September 2012
Available online 7 November 2012

Keywords:
Computer aided design
Configuration management
Change control
Data replication
Enterprise resource planning
Enterprise asset management
Radiological inventory management

ABSTRACT

The National Ignition Facility (NIF) is the world's largest laser composed of millions of individual parts brought together to form one massive assembly. Maintaining control of the physical definition, status and configuration of this structure is a monumental undertaking yet critical to the validity of experimental data and the safe operation of the facility. A major programmatic challenge is to deploy software solutions to effectively manage the definition, build, operation, and maintenance, and configuration control of all components of NIF. The strategy for meeting this challenge involves deploying and integrating an enterprise application suite of solutions consisting of both Commercial-Off-The-Shelf (COTS) products and custom developed software.This paper describes how this strategy has been implemented along with a discussion on the successes realized and the ongoing challenges associated with this approach.

1. Introduction

The National Ignition Facility at the Lawrence Livermore National Laboratory (LLNL) is a stadium-sized structure that contains a 192-beam, 1.8-Megajoule, 500-Terawatt, ultraviolet laser system together with a 10-m diameter target chamber with room for multiple experimental diagnostics. NIF is the world's largest and most energetic laser experimental system. NIF's laser beams are designed to compress fusion targets to conditions required for thermonuclear burn, liberating more energy than required to initiate the fusion reactions.

The advancement of complex software solutions plays a significant role in managing the task of tracking and controlling the definition and physical configuration of any given product or system. Using an integrated approach, NIF has deployed a framework of commercial and custom products that enables the movement of "various aspects of the product record into the necessary enterprise solutions" [1] to achieve a best-in-class software toolset for the diverse and unique challenges facing NIF. To effectively and safely manage the definition, build, operation, maintenance and configuration control of all components and materials that make up the facility, our strategy was to implement solutions that:

- capture and maintain an accurate physical description of the system,
- promote a single source of data to reduce the need for replication,
- effectively track changes and their impact on surrounding systems,
- provide visibility into what components are installed in a given location at a given time,
- promote a safe environment,

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http://dx.doi.org/10.1016/j.fusengdes.2012.09.011

- make full use of vendor-supported and industry standard interfaces.

While software plays a significant role in supporting the task of change and configuration control, it is important to note that software can only supplement a well defined and followed configuration management and change control policy.

2. The integrated solutions

This implementation effort was managed and executed with emphasis on several key areas:

- Subject matter experts (SMEs) from all areas were utilized.
- Substantial commitment of IT resources.
- Common technology base (Oracle DB, consistent mid-tier, Java apps, Windows/Office desktops).
- Close liaison with customer base.
- Focused on consensus standards such as EIA-649/GEIA HB-649 [2], industry best practices such as CMII [3], and industry leaders where applicable.

The resultant solution has proven to be very effective in meeting the programmatic challenges and adhering to the desired strategies as set forth early in the NIF project. A detailed description of the functions and interactions of the applications follows.

2.1. Physical definition of NIF

NIF utilizes a suite of commercial Computer Aided Design (CAD), Analysis, and Data Management software applications for the three dimensional virtual definition of the facility. The implementation and utilization of this suite of applications has aided in making the physical NIF a reality.

The process of capturing a virtual design begins by creating a model for each individual component within the facility. These individual models are joined to create virtual assemblies of all of the NIF subsystems. NIF's designers and engineers ensure the fit and function of the millions of objects that make up the facility by using the virtual models to run interference checks. In addition, finite element analysis applications are used to ensure that designs are able to withstand the mechanical and thermal stresses introduced by the operation of the system. A CAD data management application that works in conjunction with NIF's modeling packages enables concurrent design and a single point data storage location. This application manages over 40 million relationships that exist between all of the 3D models and also tracks design iterations and history.

Once modeled, the design with its components and subassemblies is documented through the use of engineering drawings. Engineering drawings provide a visual definition of the design and include a list or Bill of Material (BOM) of the components that make up the design. The relational nature of the software maintains a one to one relationship of the modeled assembly and the (BOM) found on the drawing. The CAD model and its associated information becomes the data source for many downstream applications such as the Enterprise Configuration Management System (ECMS) and Enterprise Resource Planning (ERP) (Fig. 1). The integrity and accuracy of this data are of critical importance.

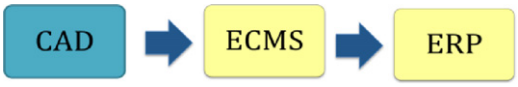

Fig. 1. The virtual CAD model defines all component parts and is the origin of the single source of record for all downstream applications.

Fig. 2. Component part and assembly bills of material data are passed from CAD modeling tools to the Configuration Management System.

The CAD data management application is integrated with LLNL's institutional Configuration Management system, ECMS. Together they control the creation, approval, release, and revision of every 3D model and drawing associated with NIF.

2.2. Data structure and formal change control

Once the virtual design is finalized and ready for review, approval and release, the individual part information and the BOM is passed electronically from the CAD data management system into ECMS. This electronic data transfer eliminates human intervention and significantly reduces errors thus maintaining the accuracy of the data (Fig. 2).

Here, product design information is made available to other NIF groups and functions outside of engineering, such as procurement, assembly technicians, production control, NIF operations, for final review and approval. ECMS is also where the 'as designed' configuration is captured through the use of the officially released Engineering Bill of Material (EBOM) [4]. Once the design is approved, it is released for production use. A released design cannot undergo any changes without prior approval.

Change control is a key function of ECMS and the system has been configured to allow for different levels of change control rigor depending of the level of impact. A simple change typically has no functional or systematic impact and therefore requires no formal review prior to creating a new revision and implementing the change. A standard change does have impact on the form, fit or function of the system. This requires the initiation of a formal change request where the proposed change is documented and reviewed for functional impact. Once change approval is obtained, the modification to the design can be implemented. A Configuration Item (CI) change proposal requires an additional level of analysis and review. CIs are systems whose failure could have negative impact on environmental and worker safety and thus require the higher level of scrutiny when changes are proposed. ECMS has been configured to provide visual indicators to alert users when dealing with CIs. In addition, the need for increased rigor in impact analysis and review is systematically imposed such that individuals responsible for the configuration and control of the CI must be included in the change approval process.

When change approval is obtained and implemented, the updated design is released in ECMS. Upon release, part and EBOM information is transferred into the NIF ERP system.

2.3. Tracking system assembly and installation

The NIF ERP system is a software application used to manage the assembly, installation, and maintenance of specialized laser and diagnostic equipment. The product lifecycle in NIF ERP begins with product planning. From the NIF project management tools, high level product definitions and installation dates are established. These are used to create demand in the form of planned orders in ERP. The next phase in the product lifecycle is product definition, which begins with ECMS creating parts and assemblies in ERP via the production release process. Upon release from ECMS, information is transferred electronically to the ERP system (Fig. 3).

The ERP master catalog is built from the bottom up by first creating child parts, then adding parent parts, and finally bringing these parts together into assemblies. The fully automated nature of the