

IMPLEMENTING A SUITABLE CONFIGURATION MANAGEMENT SYSTEM FOR INFORMATION MANAGEMENT AT DEEP GEOLOGICAL REPOSITORY SITES

Shaikh, Shanu

Nuclear Waste Management Organization (NWMO), Toronto, Ontario, Canada

sshaikh@nwmo.ca

Abstract

The management and preservation of critical design basis and licensing basis technical information is essential to demonstrate the long-term safety of a radioactive waste Deep Geological Repository (DGR) and its related facilities, structures, systems, equipment and components throughout its entire lifecycle (which includes planning, site selection, design, procurement, construction, commissioning, operations/maintenance and decommissioning/post closure).

Extra ordinarily long project time scales and numerous iterations of conceptual and preliminary designs and requirements results in unique challenges that are faced in preservation of the critical design and licensing basis technical information at radioactive waste DGR sites. Implementation of a suitable Configuration Management (CM) system will result in systematic management and retention of critical information and provision of traceable history of key changes to the design and licensing basis technical information.

This paper will provide a brief discussion on what CM means and how it can be applied in retention of critical design and licensing basis technical information for DGR facilities, which have lifecycles spanning many decades. This paper will also include a case study on implementation of a CM System at NWMO, which will provide detailed information on the process that was utilized to develop and implement the new CM system. It will also provide high level information on the Document Control, Engineering Change Control and Requirements Management software modules that were implemented.

1. Introduction

A managed process must be applied to the entire lifecycle (i.e. design, procurement, construction, commissioning, operation, maintenance and decommissioning/post closure) of a radioactive waste DGR and its related facilities, structures, systems, equipment and components. Given the long duration of repository projects and several iterations of conceptual and preliminary design, a proper CM program needs to be established which provides a traceable history of key changes to the design and its requirements to facilitate licensing and knowledge management.

Efficient configuration management is essential for the projects undertaken by the organizations responsible for design, procurement, construction, operation and maintenance of radioactive waste DGR based on their unique characteristics, such as:

- One of a kind distinct multidisciplinary projects;
- Lengthy initial design and development phase (10-20 years);
- Lengthy operations and subsequent monitoring phase (many decades);
- Extensive regulatory oversight and reporting;
- Numerous evolutions/iterations of conceptual and preliminary designs;
- Large quantity of design and scientific data to be managed; and
- Large number of requirements (design, licensing, regulatory, owner specific etc.) to be met.

2. Fundamentals of Configuration Management

2.1 Configuration Management – A Brief Introduction

CM is the systematic approach for ensuring that the physical configuration of a facility (i.e. actual installed physical structures, systems, equipment and components) is understood in relation to the Design Requirements and the Facility Configuration Information (FCI) so that the structures, systems, equipment and components are constructed/manufactured, installed, operated, maintained and decommissioned within the Design Basis and Licensing Basis. Unlike other nuclear facilities it is critical in case of DGRs to manage geosphere, underground excavation and construction data in one database due to its impact on the long term safety case. It is an integrated management process that ensures:

- a. The facility design is fully documented and traceable to the Design Basis and Licensing Basis and that the rationale for the basis is understood;
- b. Installed or as-built facility, system and equipment physical and functional characteristics match the Design Basis, Licensing Basis and the facility documentation;
- c. Facility, system and equipment operation and maintenance conform with the Design Basis and Licensing Basis;
- d. All changes are controlled throughout their lifecycle (from design to implementation to decommissioning) and are appropriately reviewed and approved prior to implementation; and
- e. Operating, training, modification, maintenance and decommissioning processes are consistent within the Design Basis and Licensing Basis conditions and the rationale for the basis is understood.

2.2 Importance of CM at Radioactive Waste DGR Facilities

A typical radioactive waste DGR facility lifecycle is shown in **Figure 1**. There are multiple overlapping phases from design to decommissioning. A facility lifecycle may also involve multiple individual projects being executed simultaneously. There will be multiple work groups using, inputting, updating, reviewing and approving configuration information, often simultaneously, which may create complex interfaces and information flows.

A very important aspect of CM is to establish the linkages between the various documents that make up the relative data set. These links allow a quick and traceable impact analysis to be performed if any documents or physical installations are required to be changed. For example, a change in a single requirement may affect a number of systems and their associated documents. Similarly, a design or field change may affect a number of documents. The affected items are easy to identify if they are all linked properly.

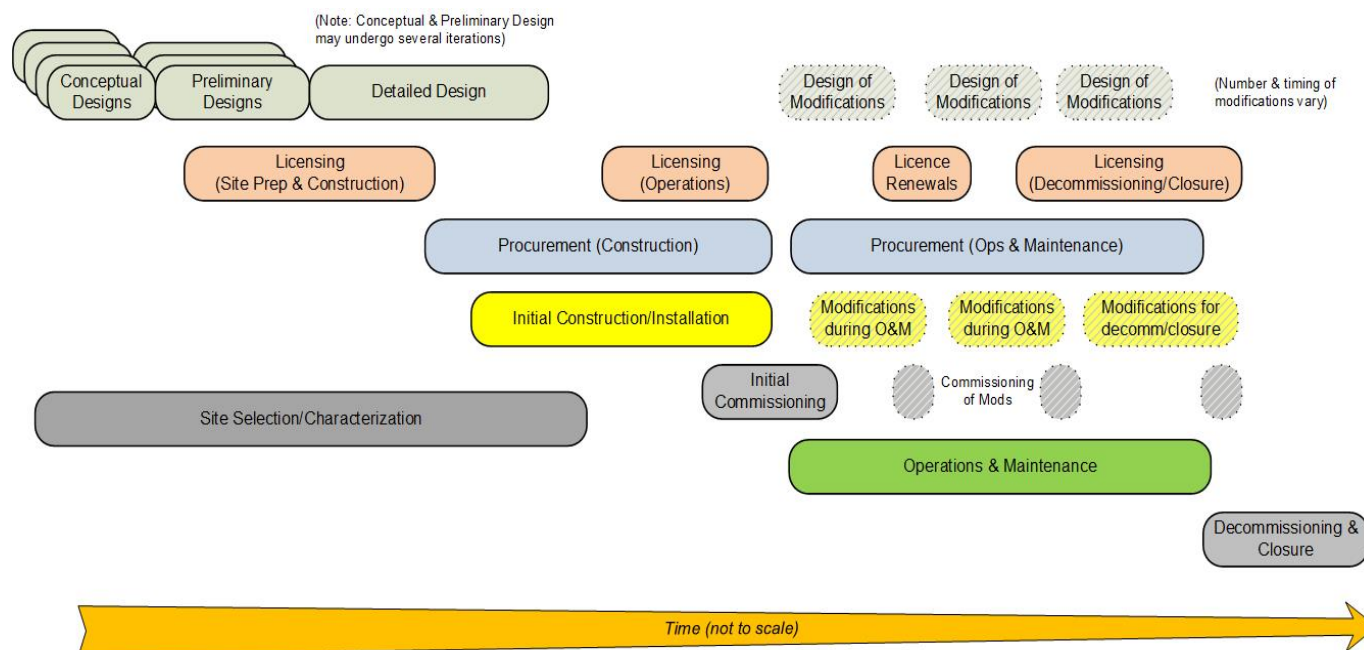


Figure 1: Typical Nuclear Waste Facility Lifecycle

2.3 CM during Design, Procurement and Construction Phases

It will be noted in **Sections 2.3** and **2.4** the establishment and management of configuration control is slightly different in the Design and Construction phase vs. the Operations and Maintenance phase.

The design and construction phase establishes the initial or baseline configuration of a facility, as depicted in **Figure 2**. In the design phase, there is no existing “physical configuration”. As such, the focus in this phase is on establishing the requirements and documenting a design to meet these requirements. This may go through several design iterations before arriving at a “final” or approved for construction design.

A suitable Configuration Management Information Repository needs to be developed early in the design stage, which can be used as a single source of information to support subsequent activities and the establishment of CM Alignment. The planning and development of the data repository begins in the initial phases of the facility lifecycle to identify and capture/collect the design and licensing data. The data to be managed will

originate from a variety of sources such as the facility owner, external contractors, regulatory agencies and equipment vendors.

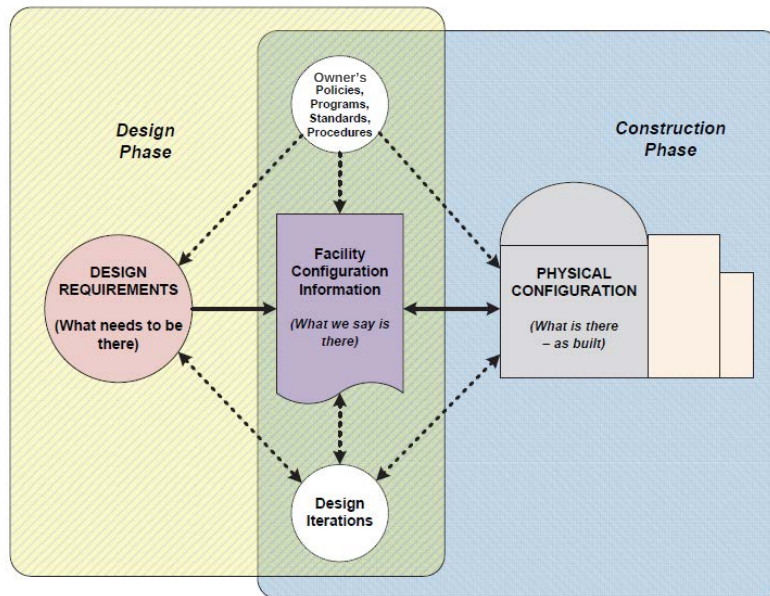


Figure 2: Configuration Management during Design, Procurement and Construction Phases

To establish and maintain CM Alignment, it is essential that design requirements and licensing commitments are known and documented to ensure conformance and analyze future changes. Suitable data management system(s) providing traceability between requirements, facility configuration information and future facility SSEC are required. Similarly, changes to either the facility physical configuration (which includes underground excavations) or FCI during construction/installation and commissioning phases need to be supported by, and be consistent with, the design requirements and licensing commitments.

In general, construction of a radioactive waste facility starts on receipt of a site preparation and construction licence. Prior to start of construction, the design basis is established which satisfies all mandatory design requirements. Design change control processes should be in place during the design phase to track changes and identify/ analyze the impact of changes on the design basis and existing documentation. This is especially important during the underground excavation of the facility as construction methods and layouts may change from what was proposed in the design based on actual ground condition. Like any other construction project, equipment(s) and bulk material are procured from suppliers and vendors which undergo receiving inspection and based on the inspection results, equipment is either issued in the field for installation or sent back to the vendor with a Non Conformance Report (NCR). Following issuance of required material and equipment to the field, installation, construction and testing activities begin.

During procurement, construction/installation and commissioning phases, it is essential that the inevitable field and design changes are controlled and managed by field change and

design change control processes to ensure consistency of the design is maintained (i.e. virtual/paper facility = actual physical facility).

2.4 CM during Operations and Maintenance Phases

Once a radioactive waste DGR facility has been constructed, a “physical configuration” will exist. At this point, “Configuration Alignment” or “Equilibrium” can be established and maintained. **Figure 3** displays the configuration alignment model for an established facility in its operations and maintenance phase. The key purpose of implementing a configuration management system at a DGR facility is to ensure alignment among design requirements, the facility’s physical configuration exists and the associated configuration information can be achieved and maintained in order to reduce risk of errors and associated costs [1].

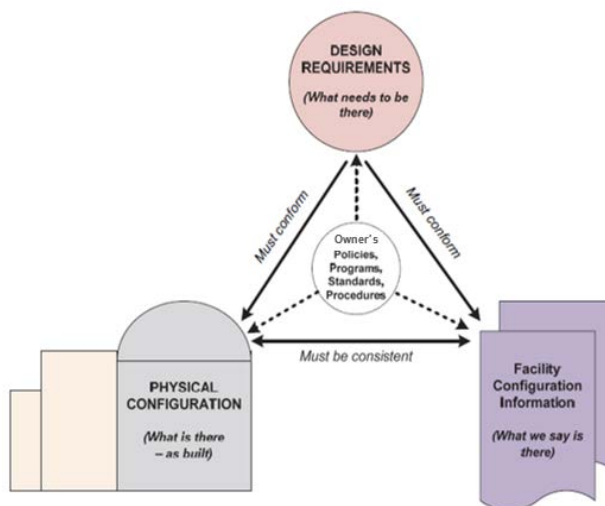


Figure 3: Configuration Alignment for an Established Facility

3. Case Study: Implementation of a CM System at NWMO

3.1 Project Background

The primary objective of this project was to implement a suitable CM IT system at NWMO which would load engineering data and its associated hierarchy, maintain its integrity, provide traceability and modify it with an approved in-built change control process.

This objective was met by implementing the following interconnected functional modules which manages engineering data in a *data-centric environment* as shown in **Figure 4**.

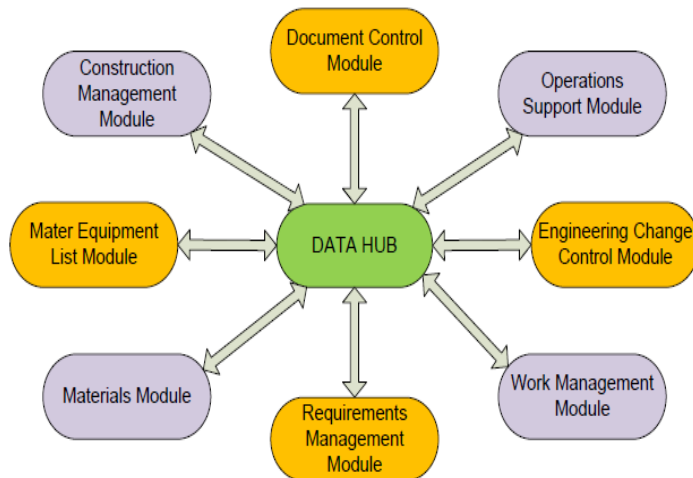


Figure 4: “HUB Architecture” depicting relationship between various Modules

- Document Control Module
- Engineering Change Control Module
- Requirements Management Module
- Master Equipment List Module

A data-centric environment is created when software architecture is organized around a common "shared information model" that spans to multiple systems or modules. The data in different modules is smartly interlinked with each other leading us to a condition where data is controlled and easily available for use.

Following are some highlights on how the project of implementing a new CM system at NWMO was executed:

- Detailed requirements for each module to be procured were listed in a Scope of Work (SOW) document which became a part of the Request for Proposal (RFP) Package.
- The RFP was then listed for inviting proposals from competent proponents.
- Proposals submitted by the proponents were evaluated by NWMO core team comprising of members from engineering, IT, Procurement, Legal, Performance Assurance, Project Control and Management groups.
- Based on technical and cost evaluations preferred vendor was selected to provide required services. Stage gated approach was used in implementing the CM system by executing the project in following two phases:
 - Phase 1: Initial Sandbox Testing Phase
 - Phase 2: Full Implementation Phase
- A semi configured system was implemented for Phase 1, which provided NWMO users with an opportunity to test the functional capabilities of the CM system prior to full production phase implementation. It also allowed the project core team to collect feedback and comments from NWMO users, to be used to enhance the system configuration in the production phase (Phase 2).
- Numerous requirement gathering sessions were held during the first quarter of Phase 2 to finalize the business process workflows, document numbering schema and the tailor-made user interface (unique to NWMO) to be configured in the CM system.
- After the system was fully configured on the development server, it was transposed to the User Acceptance Testing (UAT) server, where it was tested rigorously to ensure all functional requirements listed in the SOW were met.
- The bugs discovered during the UAT testing were fixed on the development server and updated the configuration was reloaded on the UAT server for further testing.
- After completion of UAT testing, the configured system was loaded on the production server, where it was retested using specific predetermined test cases to ensure configuration integrity.
- Deployment on the production server was phased and module based. Modules like Document Management and Requirements Management which had immediate need were deployed first followed by Change Control and Master Equipment List Module.
- Preparation of user manuals and training of staff was done in parallel with production server deployment to save time by using IT resources efficiently.
- The full CM system deployment was declared live in-service in May 2015. Since then the project core team is maintaining a future scope list where all issues, improvement requests and recommendations provided by the user community are recorded.

3.2 Document Control Module

The primary objective of the document control module is to collect, control and manage the document and its associated subordinates (i.e. review process archives, references etc.) throughout the document lifecycle.

The CM system document control module allows user to customize a unique personal “My Home” page, which is the default window user see on every login. This “My Home” page consists of three panes namely Navigation Pane, Component Pane and Data Pane as shown in **Figure 5**. These panes work in tandem and allows users to select objects, navigate hierarchies, view attributes and meta-data, perform impact analysis, review audit history and access other object related detailed information. The system allows user to create personal folders on “My Home” page to organize data (similar to MS Windows[®] explorer).

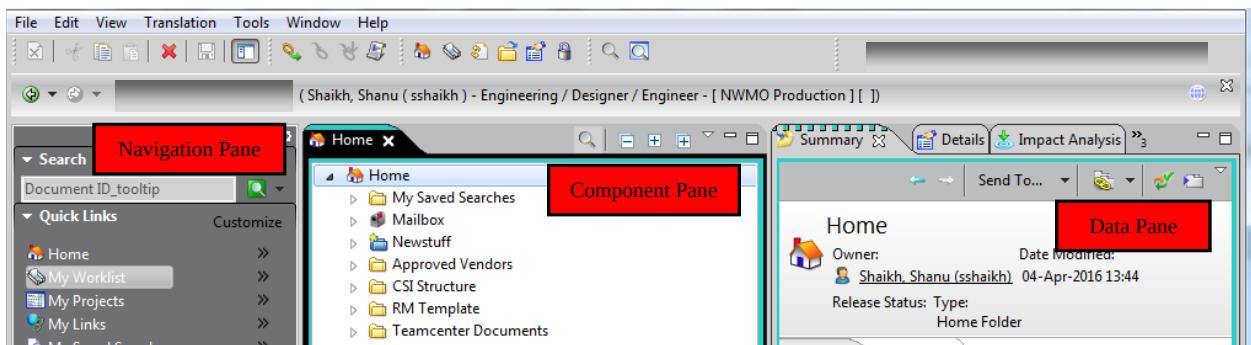


Figure 5: “My Home” Page

User can freely copy, paste and remove other business object (i.e. document or design change notice etc.) to these personalized folder for their day-to-day use. While it appears that folders contain other objects (because that is what user see), the folder actually contain references to those objects. The distinction is subtle but very critical. Several folders can contain references to the same object, however, that object is only stored once in the system database. This reference capability allows information to be shared in between different CM System modules without having to make multiple physical copies of the data as shown in **Figure 6** and helps in achieving the CM principle of having single source of truth.

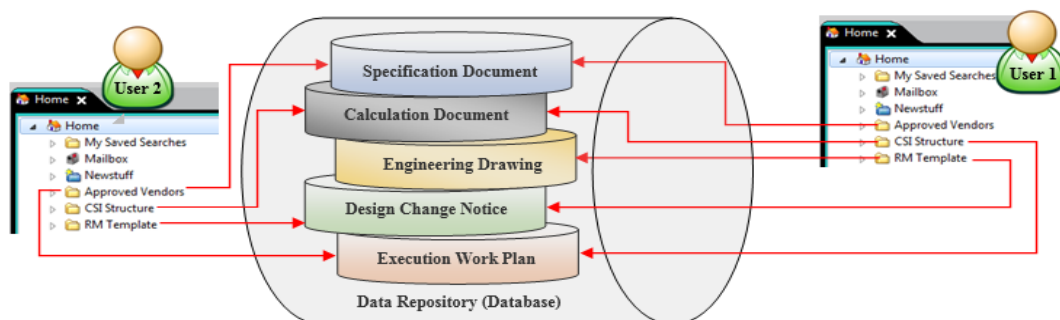
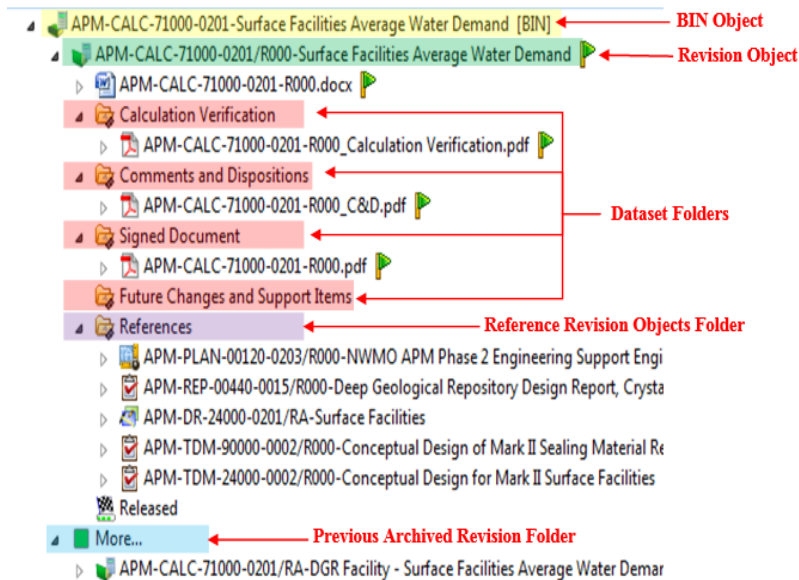


Figure 6: Reference Linking of Information

BIN business objects and Revision business objects are the fundamental data objects that are used in the CM system to manage information. Each BIN business object has at least one Revision business object. The datasets (MS Word[®] file, Adobe Acrobat[®] file, AutoCAD[®] file etc.) are stored inside the structured standard folders listed beneath the Revision business object. A sample data tree structure for a document is shown in **Figure 7**.



The linkages between the various documents that make up the relative data set is established by inserting revision business objects of reference documents in the References folder as shown in **Figure 7**. These links allow user to perform a quick and traceable impact analysis when parent document or referenced document is to be changed and revised.

Figure 7: Data Tree Structure of a Sample Document

The document review process is conducted within the CM system by routing the business revision object through a process workflow. The user will assign the review participants and then route the business revision object through a suitable workflow. The CM system employs smart distribution which results in each review participant receiving a notification email in their MS Outlook[®] inbox to perform the review task.

For a business object composed in MS Word[®], the process of entering comments by the review participant and dispositioning of the reviewer comments by document author is carried out within the MS Word[®] dataset using markup and track changes capability as shown in **Figure 8**. For a drawing business object created in CAD softwares like AutoCAD[®], SolidWorks[®] etc., the process of entering comments by the review participant and dispositioning of the reviewer comments by document author is carried out in extended Adobe Acrobat[®] copies exported out from the CAD softwares as shown in **Figure 9**. Multiple review participants are allowed to provide comments in the same MS Word[®] or Adobe Acrobat[®] dataset, which eliminates duplicate comments from different reviewers as comments are visible to all members of the review panel.

After completion of a successful review process, user routes the updated business object through a suitable workflow for final review and application of digital signatures. The digital signatures are applied on the extended Adobe Acrobat dataset as a part of the process workflow and are encrypted and password protected.

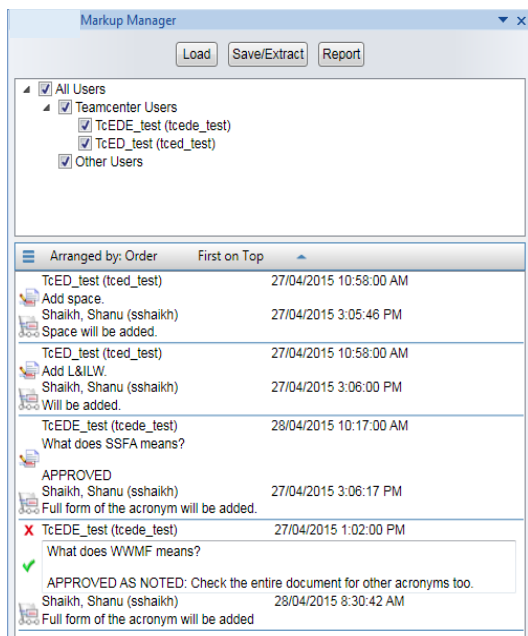


Figure 8: Markup in MS Word® Datasets

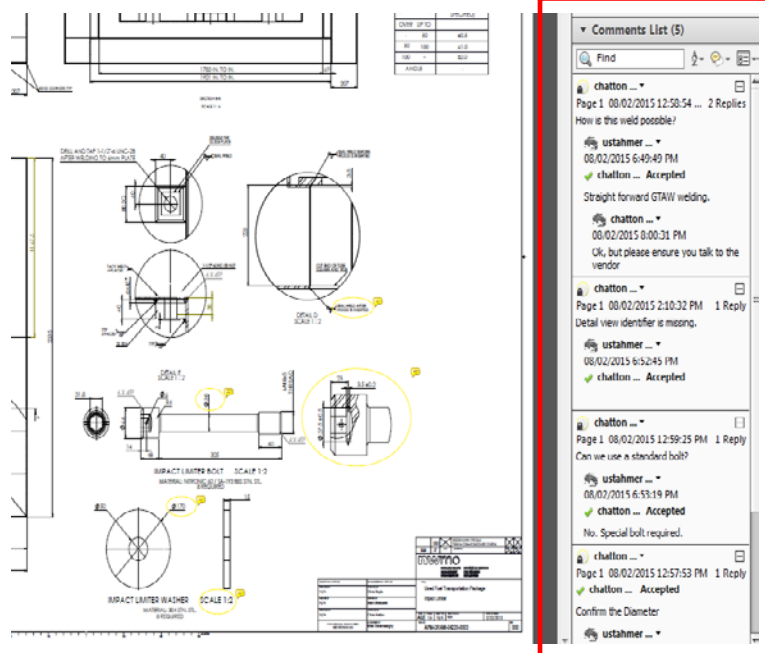


Figure 9: Markup in Adobe Acrobat® Datasets

Maturity status (like draft, in-review, released, revised and obsolete) assignment to the Revision business objects is controlled by workflow advancement. Data integrity of a Revision business object and its associated datasets is controlled by Check-In and Check-Out features. The contents of the business revision object are locked for any future editing once it is assigned with a Released maturity status. If changes are required, a new revision must be created, which then undergoes its own review and approval cycle.

3.3 Engineering Change Control Module

The primary objective of the engineering change control module is to manage engineering changes initiated during various phases of facility lifecycle and ensure all engineering data and/or field equipment(s) associated with the requested change are evaluated by qualified personnel prior to its approval and execution.

To initiate the change process, the user is required to create a new DCN business BIN object in the CM system which identifies it with a unique tag (e.g. DCN-00001). The creation of the DCN BIN object automatically creates a DCN business version or revision object based on user requirements. User can then populate the MS Word® DCN form to describe the change, which is automatically created upon creation of the DCN BIN object. The data tree structure for a sample DCN business object is shown in **Figure 10**. The “Impacted Items” folder in the data tree contains business revision objects that are being impacted and will be required to be changed and revised as a result of the change process. The “Implemented By” folder contains the Design Change Implementation Notice (DCIN), which will implement the DCN after it’s approved by the review team. The “Reference Item” folder contains business revision objects that reference related information and are not required to be changed and revised as a result of the change process. The “Comments

and Dispositions” folder contains the archived comments resulting from the review process, whereas the “Signed Document” contains the extended Adobe Acrobat[®] dataset of the digitally signed DCN form.

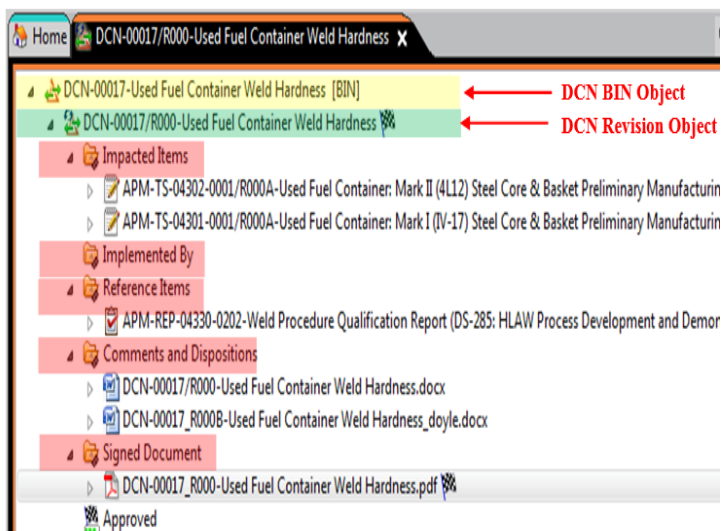


Figure 10: DCN Data Tree Structure

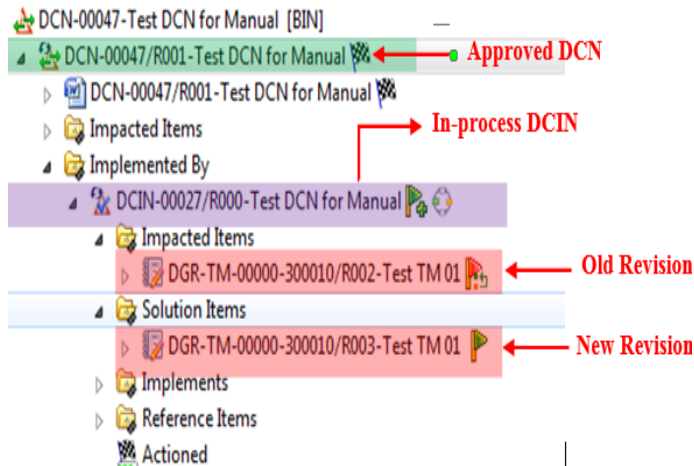


Figure 11: DCIN Data Tree Structure

The DCN review and approval process is conducted within the CM system by routing the DCN version object through an approval process workflow. After the DCN is approved, the DCN originator initiates the process of implementing the approved DCN by creating one or numerous DCIN(s). DCIN implementer(s) are assigned who are responsible for revising the impacted business revision objects to incorporate required changes, get the changes reviewed/approved and released status assigned to them. The DCIN implementer is then required to copy the reference of the newly revised object in the Solution Items folder of the DCIN business object and then initiate the process to close the DCIN. The data tree structure for a sample DCIN business object is shown in **Figure 11**. After all associated DCINs are closed, the DCN originator will then close the DCN.

3.4 Requirements Management (RM) Module

The primary objective of the Requirements Management module is to record, consolidate, store, analyze, track and manage requirements throughout all the phases of the facility life cycle. Following are some high level features of the RM module:

- Design Requirements (DR) are initiated in MS Word[®] and then imported in the CM system where they are decomposed into individual requirements and paragraphs with unique IDs. Upon decomposition, hierarchical tree structure is produced in the RM module, which is shown in **Figure 12**.
- The tree structure can be exported out in NWMO’s MS Word[®] DR document template to produce a document that can signed/sealed and issued to for regulatory review.

Item Id	Num...	Rev Name	Trace Link	Requirement Type	Requirement...	Method of Verification /	Body Cleartext
0201		Transfer and Emplacement - Sli...					
000554	1	INTRODUCTION AND SCOPE					
000555	1.1	Introduction					The Mark II emplacement concept
000556	1.2	Purpose and Scope					The purpose and scope of this
000557	2	FUNCTIONAL REQUIREMENTS					
REQ-000047	2.1	Requirement # 1		Functional Requirements	Design Basis	Commissioning Test Verification	The Slip Skid Prototype Mechanism
REQ-000048	2.2	Requirement # 2		Functional Requirements	Design Basis	Commissioning Test Verification	The Slip Skid Prototype Mechanism
000558	3	PERFORMANCE REQUIREMENTS					
REQ-000049	3.1	Design Life		Performance Requirements	Design Basis	Commissioning Test Verification	The Slip Skid Prototype Mechanism
REQ-000050	3.2	Lifting Load		Performance Requirements	Design Basis	Commissioning Test Verification	The Slip Skid Prototype Mechanism
REQ-000051	3.3	Pulling Force		Performance Requirements	Design Basis	Commissioning Test Verification	The Slip Skid Prototype Mechanism
REQ-000052	3.4	Emplacement		Performance Requirements	Design Basis	Commissioning Test Verification	Emplacement should meet the
REQ-000174	3.5	Actuators speed		Performance Requirements	Design Basis	Commissioning Test Verification	Actuators shall permit adjustable

Figure 12: Hierarchical Tree Structure in RM Module

- Each requirement object can be linked to other requirement, document, equipment tag and change objects. Trace links are used to establish a directional relationship between related business objects. In this relationship, one business object *defines* a condition with which the other business object(s) must *comply*. A given business object may define some objects and itself may also comply with other objects as shown in **Figure 13**.
- Establishing proper trace links helps user in performing Impact Analysis, which is a type of Traceability Analysis. Impact Analysis helps the user to determine what other information (business objects) in the development might be affected if a selected business object is changed. This illustrated in **Figure 14**. The impact is potential, detailed analysis is to be carried out by the responsible engineer to determine the exact nature and magnitude of the impact, if any.

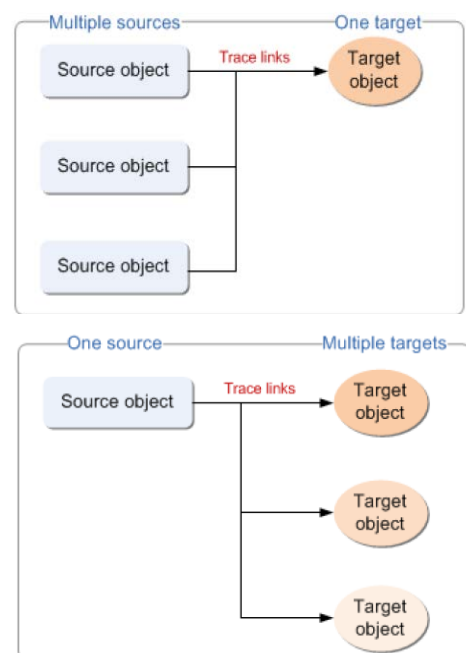


Figure 13: Trace Link Relationships between Business Objects

- As illustrated in [2], organizing requirements into a structure using a suitable database tool can assist in:
 - Minimizing the number of requirements
 - Understanding large amount of data efficiently
 - Grouping of similar or standard requirements (consistency)
 - Detecting duplications and irrelevant data
 - Eliminating conflicts between requirements
 - Maintaining requirements iteration (revisions) efficiently
 - Evaluating, Categorizing and Linking of requirements
 - Reusing of standard requirements across various project

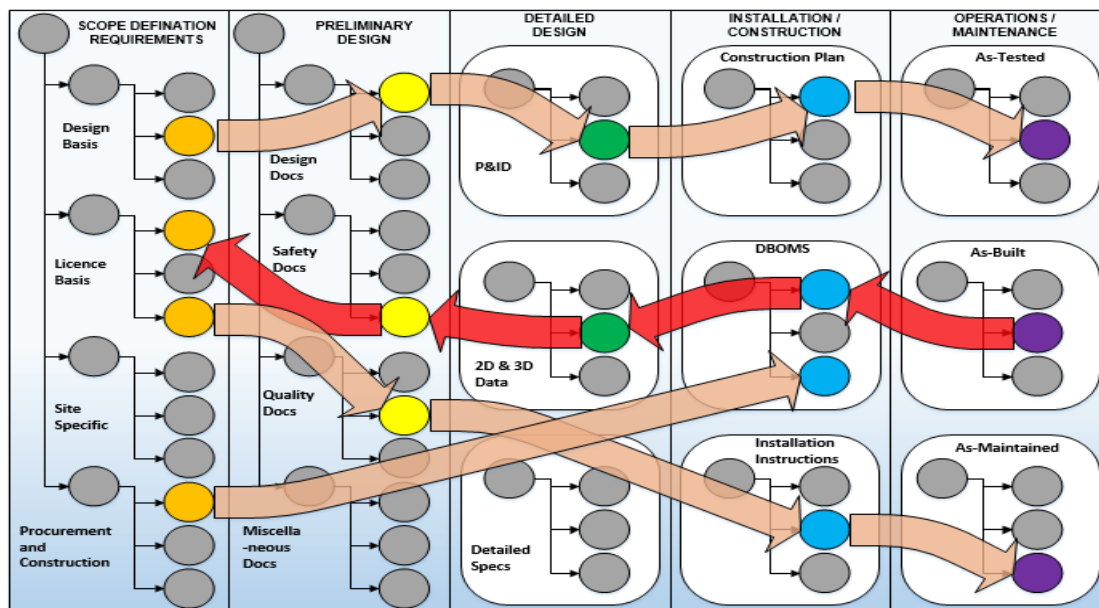


Figure 14: Impact Analysis

4. Conclusion

Implementation of a suitable CM system results in systematic management and retention of critical information and provision of traceable history of key changes to the design and licensing basis technical information. Inadequate CM can lead to extensive delays in the licensing process leading to significant cost and schedule over-runs. Efficient CM extends its benefits to all phases of a project lifecycle. During the operations phase, inadequate CM may lead to loss of ability to perform safety functions when needed. It can also impact on reliability of the facility's equipment(s) and system(s) as right information is not available at the right time and in the right format to engineering, operations and maintenance staff resulting in serious economic and/or safety consequences.

5. References

- [1] "American National Standard for Guidelines for Configuration Management of Nuclear Facilities", ANSI/NIRMA CM 1.0-2007.
- [2] Hull, E., Jackson, K and Dick, J (2011) – Requirements Engineering (Third Edition)

Following is the list of some generic references that were reviewed to understand the fundamental concepts of CM and their applicability to Nuclear Facilities.

- International Atomic Energy Agency (IAEA), Application of Configuration Management in Nuclear Power Plants, IAEA Safety Report Series No. 65, December 2010
- Electric Power Research Institute (EPRI), Elements of Pre-Operational and Operational Configuration Management for a New Nuclear Facility, TR-1022684, April 2011
- Institute of Nuclear Power Operations (INPO), Configuration Control Process Description, AP 929, May 1998
- US Department of Energy (DOE), DOE Standard – Configuration Management, DOE-STD-1073-2003, October 2003