Electron-Ion Collider Plan

EIC Systems Engineering Management Plan

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REVISION HISTORY

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LIST OF ACRONYMS

CAM	Control Account Manager
CD	Critical Decision
DOE	Department of Energy
EDP	Engineering Design Plans
EIC	Electron-Ion Collider
ESH	Environmental Safety and Health
FMEA	Failure Mode and Effect Analysis
FRD	Functional Requirements Document
GLRD	Global Requirements Document
GRD	General Requirements Document
ICD	Interface Control Documents
IDD	Interface Definition Documents
IMP	Interface Management Plan
IRD	Interface Requirement Documents
ISG	Instrumentation Systems Group
KPP	Key Performance Parameters
L2M	Level 2 Manager or delegate
L3M	Level 3 Manager or delegate
L4M	Level 4 Manager or delegate
MICD	Master Interface Control Document
ORG	Organizational
PDN	Process Description
PLN	Plan
PPD	Project Planning Documents
PRD	Performance Requirement Document
PSD	Project Support Division
QA	Quality Assurance
QAG	Quality Assurance Group
QAP	Quality Assurance Plan
REF	Reference
RLS	Resource Loaded Schedule
RMP	Requirements Management Plan
SBMS	Standards Based Management System
SE	Systems Engineering
SEG	Systems Engineering Group
SEMP	Systems Engineering Management Plan
SEP	Systems Engineering Process

TBD	To Be Determined
TCCB	Technical Change Control Board
TS	Technical Specification
VE	Value Engineering
WBS	Work Breakdown Structure

EIC System Engineering Management Plan

1. PURPOSE

The EIC Systems Engineering Management Plan (SEMP) defines the technical management and engineering processes implemented for the Electron-Ion Collider (EIC). The SEMP establishes the Systems Engineering (SE) approach used for the technical activities conducted throughout the project lifecycle. The SEMP provides a framework for all SE activities such that the project can achieve its performance goals as developed through traceable requirements. The SE approach defined in this SEMP ensures that safety, quality, and integration are addressed and controlled throughout the project lifecycle such that EIC achieves the overall technical goals at the completion of the project. The SEMP also serves as a communication guide within the technical teams and establishes a formal link to the Project Management teams.

2. SCOPE

The SEMP provides requirements applicable to all EIC project engineering tasks, performed by or for the EIC Project as defined and organized in the EIC Work Breakdown Structure (WBS). This plan addresses the complete SE process including organizational roles and responsibilities and provides a methodology for managing of the following: requirements, interfaces, configuration and change control, design, risk mitigation, technical reviews, alternatives and value engineering analysis, quality planning, and acceptance and verification. The SEMP defines the processes and methodology used to develop and control supporting documents which define and control project requirements, ensure design integrity, and manage interfaces. The SEMP defines how Technical Integration will be organized and executed to ensure that the EIC Project meets all functional requirements and all deliverables at completion.

3. OVERVIEW

The BNL Standards Based Management System (SBMS) establishes the primary structure for engineering design and systems engineering processes at EIC. Any partner institution providing equipment to the EIC project must follow the relevant sections in the SBMS. The EIC SEMP provides specific guidance for the EIC Project within the framework established by the SBMS. Together, these documents govern the engineering aspects of the design, configuration, fabrication, construction, technical support of procurement process, acceptance and verification testing, and installation and commissioning of EIC in accordance with Laboratory plans and procedures and other Project documents [Section 5]. Figure 3-1 shows the EIC governing document hierarchy.

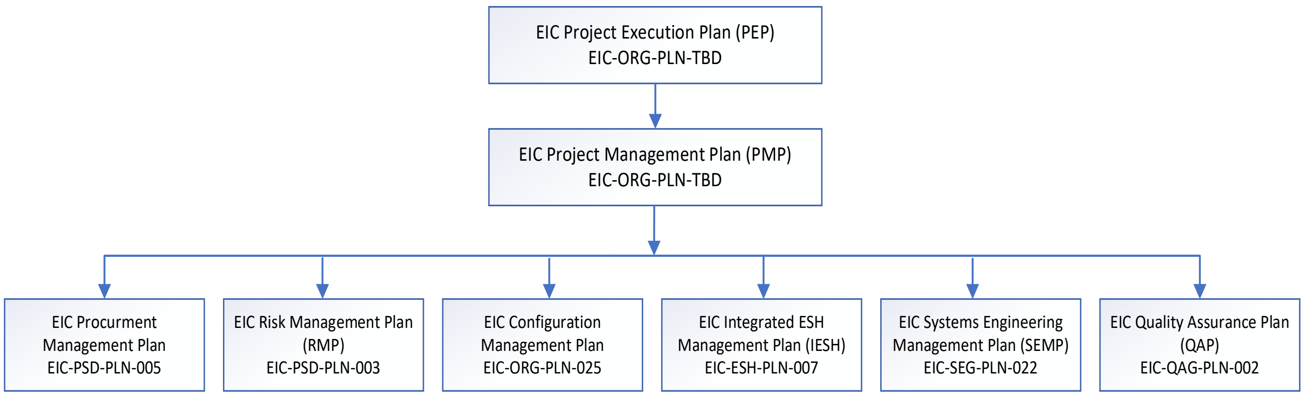

Figure 3-1: EIC Project Planning Document Hierarchy

The SEMP requires additional detailed planning documents for interface and requirements management, technical review planning, value engineering, and documentation management and control. Figure 3-2 shows the SEMP and subordinate document structure.

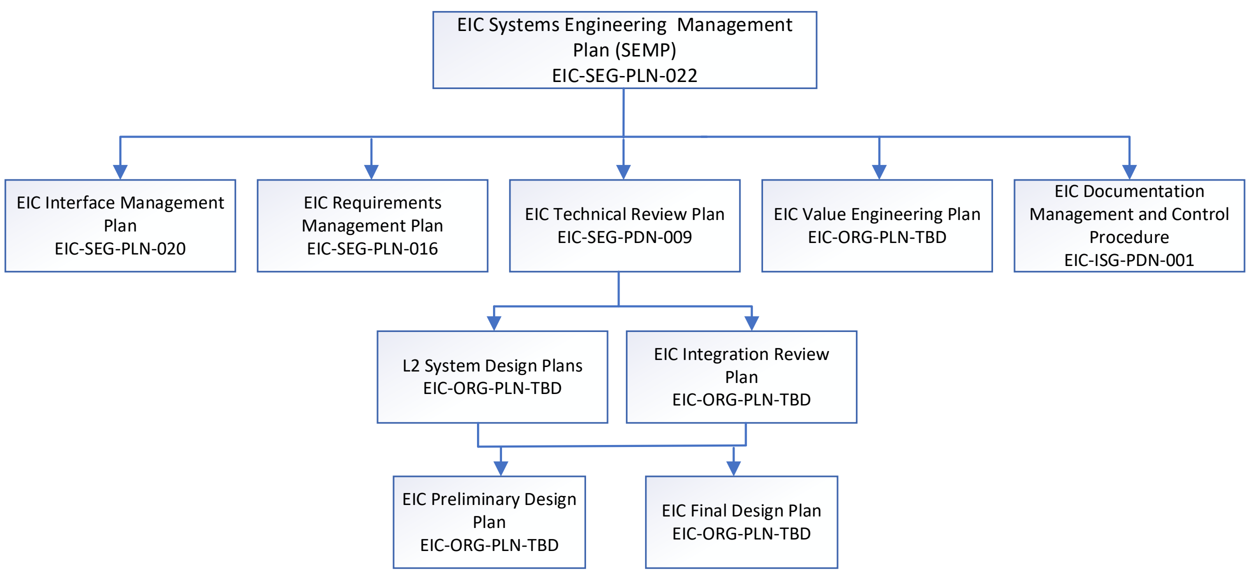

Figure 3-2: EIC SEMP document hierarchies

3.1. Project Roles and Responsibilities

The EIC project requires the implementation of a well-defined Systems Engineering approach through all phases of development, integration, and commissioning due to the overall complexities of the technical and organizational deliverables.

The SE has the responsibility to:

- Define and control general, functional and performance requirements
- Define and control interfaces
- Implement and manages Configuration Control
- Supports the process to manage technical risks
- Supports the identification and mitigation of hazards and safety risks
- Support the documentation of design activity and deliverables
- Support the technical review process and ensures requirements are achieved
- Support the implementation of Quality Assurance and Quality Control
- Establishes design acceptance and verification criteria
- Confirms acceptance and validation criteria have been met
- Supports the integration of environment, safety, and health considerations throughout project activities

The execution of this SEMP is the responsibility of all participants within the project under the coordination of each respective WBS Level 2 Manager (L2M).

L2Ms are the design authorities responsible for the delivery of their respective systems and for actively managing interfaces with interconnected systems. The design authority has the responsibility to:

- Establish technical specifications and requirements to meet project technical goals for the assigned scope.
- Develop the design plan, including technical review milestones and associated design deliverables.
- Provide leadership and coordination of a multidisciplinary technical team to execute the design plan, fabricate, test, and verify all deliverables.
- Ensure that technical reviews are conducted, technical goals are achieved and verified, and the technical documentation is completed in accordance with project's requirements.

L2Ms are also responsible for ensuring that deliverables meet all requirements established by this SEMP and other applicable EIC requirements described in the QAP.

WBS Level 3 and 4 Managers (L3M, L4M) can be responsible for developing and delivering their respective systems within the framework established by this SEMP and for managing internal interfaces within their respective sub-systems. The L3M or L4M is responsible for ensuring that the designs achieve the requirements of their subsystems.

International Partners providing designs and components to the Project are designated as the Designer of Record and are responsible for abiding by the principals of this SEMP and providing supporting documents within the framework and guidance of their own institutional requirements. The Designer of Record has the responsibility to:

- Provide expertise and leadership for the technical scope from concept through implementation.
- Develop, identify, and maintain all final and current engineering specifications, reports, drawings, design information, and calculations.
- Collaborate with the Design Authority in planning and execution of the design tasks, requirements and interface changes in accordance with project's requirements.

Project Planning Documents (PPD) are formalized on an individual Partner-to-BNL basis to establish bi-lateral expectations.

3.2. Project Structure and Timeline

The EIC WBS and WBS Dictionary represent the overall project definition and organizational structure. The WBS is organized by function and scope and is broken down into sub-systems, milestones, and activities. The WBS is organized to a base-level detail to capture all planned work. The WBS and associated Resource Loaded Schedule (RLS) are the primary organization and work control mechanisms. They are used to establish the complete project view and to define the full scope and cost and resulting schedule of the EIC Project. Effective Systems Engineering requires the implementation and execution of a mature WBS and RLS such that System Mangers and Control Account Managers (CAM) can successfully coordinate their activities within the framework of this SEMP.

The WBS and RLS are used for SE activities to:

- Assist in the identification and organization of system and sub-system requirements and interfaces within the WBS
- Identify and track deliverables, and links between subsystems and partners, for in-house or externally made components
- Aid configuration management and control of subsystem interfaces

The phases of technical maturity for the Project align with the corresponding Department of Energy (DOE) Critical Decision (CD) steps. The EIC Project supports reviews by the DOE Office of Science, following the criteria defined by DOE Order 413.3B which outlines a series of staged project approvals. Milestones for Critical Decisions are included in the RLS.

4. SYSTEMS ENGINEERING

The EIC Systems Engineering Process (SEP) is based on the development of formal requirements, specifications, interfaces, QA and design documents, which are reviewed, approved, and controlled at the project level to reduce cost and minimize the risk of delays through the project development phases. The project design, development, and implementation phases listed below establish the general framework to execute the SEP.

- Preliminary Design
- Final Design
- Production, Fabrication, and Assembly
- Acceptance Testing and QA
- Installation
- Check-out
- Commissioning
- Project close out

The minimum subset of documents required to implement the EIC SEP is listed below in Table 4-1. Figure 4-1 depicts SE documentation created as the EIC project proceeds through its design phases. Formal document definitions follow in subsequent sections.

Table 4-1: EIC SEP Minimal Documentation

• Systems Engineering Management Plan (SEMP), (this document)
• Work Breakdown Structure Dictionary (WBS Dictionary)
• Resource Loaded Schedule (RLS)
• Requirements Management Plan (RMP)
• Interface Management Plan (IMP)
• Global Requirements Document (GLRD)
• General Requirements Document (GRD)
• Functional Requirements Document (FRD)
• Performance Requirements Document (PRD)
• Technical Design Plans
• Technical Specifications (TS)
• Interface Requirements Documents (IRD)
• Interface Configuration Documents (ICD)
• Interface Definition Documents (IDD)
• Master Interface Configuration Document (MICD)
• Other Design Deliverable Documents including Engineering and Technical Notes
• Technical Design Review Reports
• Value Engineering
• Quality Control Plans
• Analysis of Alternatives
• Acceptance Plans
• Verification and Acceptance Criteria, and Test Reports
• Installation Plans
• Commissioning Plans

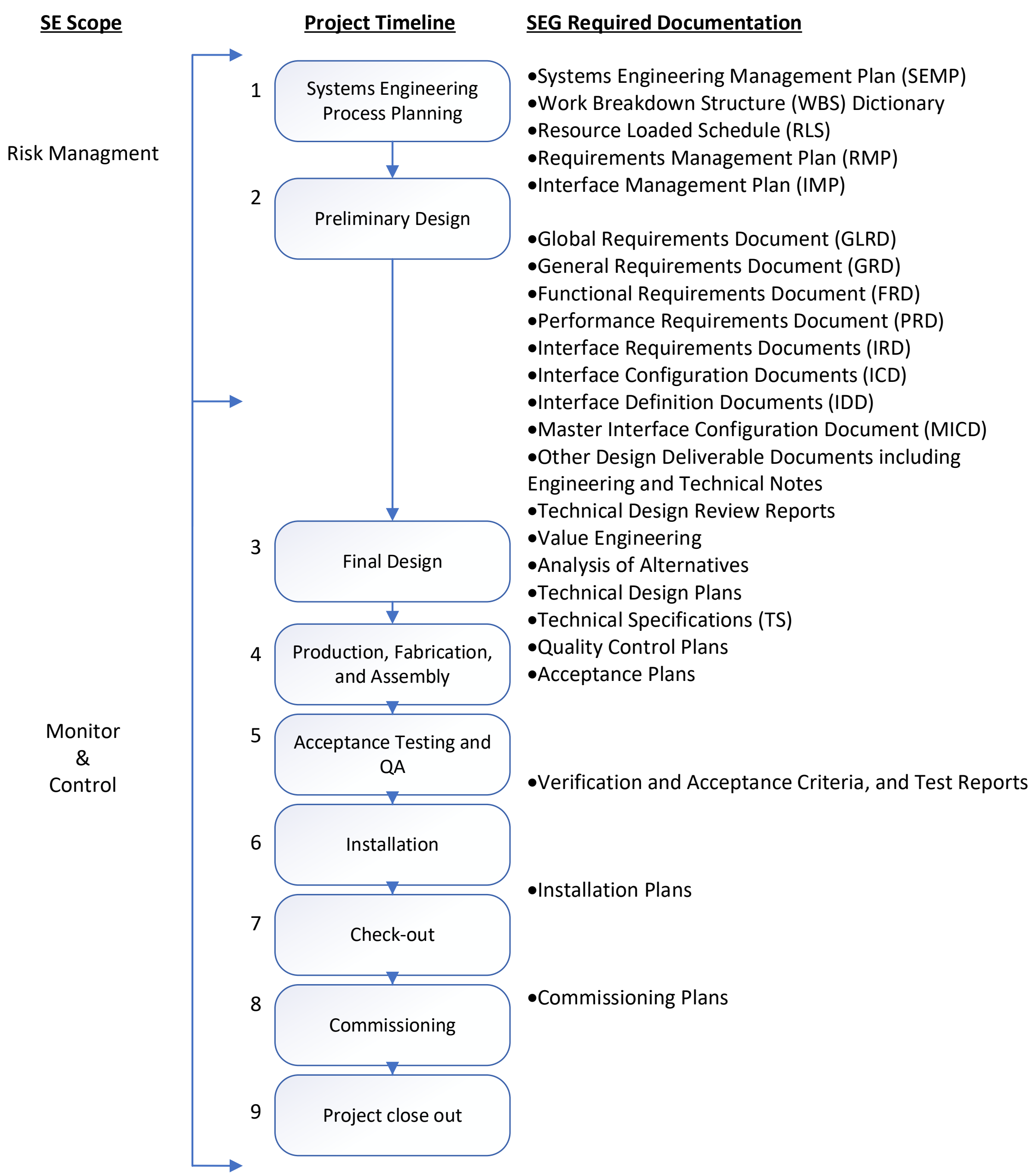

Figure 4-1: EIC SEP Project Phase and Minimal Documentation

4.1. Requirements and Interface Management

The EIC Project Execution Plan defines the Key Performance Parameters (KPPs) of the Project. The KPPs are included in the EIC Global Requirements Document (GLRD) which defines the highest-level physics requirements for the Project based on the Mission Need Statement. The requirements analysis and flow-down process involves converting the GLRD into GRDs broken out for the major systems, which flow down to the FRDs and PRDs. These documents in combination define the overall accelerator complex configuration required to satisfy the GLRD. Requirements are defined such that they are clear, unambiguous, consistent, and traceable to the higher-level requirements. Interfaces Requirements between systems are also defined and managed. Detailed technical specifications are developed as a response to the requirements and interfaces and used to produce hardware. All Requirements are actionable in the design process, the technical specifications meet requirements, and are verified prior to installation and commissioning. Brief descriptions for the requirements document are listed below and detailed description of the requirements management is in the Requirements Management Plan (RMP) [5.2] and Interface Management Plan (IMP) [5.3].

4.1.1. Global Requirement Document

The GLRD is the single global-level requirements document that specifies the performance requirements for the EIC Project. The scope of the GLRD is limited to the technical performance requirements related to the mission of the EIC Project. Generally, this serves as the highest-level physics requirement specification. Once approved the GLRD is subject to revision and change control processes.

4.1.2. General Requirement Documents

The GRD contain comprehensive, individual system physics requirements and constraints at WBS Level 2 derived from the Global Requirements Document (GLRD) at the highest-level hardware deliverable requirements. The GRDs clearly define the origin of individual systems requirements, operational context, and basic system boundaries. Once approved, GRDs are subject to revision and change control processes.

4.1.3. Functional Requirement Documents

The FRD are written for all Level 3 systems and for complex Level 3 sub-systems and devices that affect the overall performance of an Level 3 sub-system. The information contained in FRD documents describe how the system must perform to meet all higher-level requirements. FRDs must also contain all parameters required to initiate design activities thereby acting as a bridge between higher level requirements and design. L2Ms shall generate FRDs within their respective sub-systems according to the guidelines established in the EIC Requirements

Management Plan [5.2]. Once approved, FRDs are subject to revision and change control processes.

4.1.4. Performance Requirement Documents

PRD contain a comprehensive, structured, set of individual technical system requirements for Level 3 systems and sufficiently complex Level 3 sub-systems that affect the overall performance of the Level 3 system. A performance requirement pertains to the technical parameters that the system must fulfill or abide by and is often referred to as a constraint. PRDs are required for each Level 3 sub-system either as stand-alone comprehensive documents that aggregate all technical requirements within a Level 3 sub-system or as a set of PRDs written at the device level. Once approved, PRDs are subject to revision and change control processes. PRDs are often developed iteratively and mature through the design phases for complex systems and sub-systems. In addition, the PRDs provide a requirement baseline for the subsequent fabrication, assembly, installation, check-out and commissioning activities.

4.1.5. Interface Requirement Documents

The IRD contains a comprehensive, structured, list of interfaces types for the system/sub-system/component which it is contained. An IRD is required when the interface of one system/sub-system/component to another needs to be defined. The IRDs will contain all the requirements of the interface. Once approved, IRDs are subject to revision and change control processes.

4.1.6. Interface Control Documents

The ICD flows down from the IRD and is the detailed interface requirement document for the interface. The ICD contains a comprehensive, structured, set of individual requirements required to define any interface, which affects the overall system/sub-system/component performance in which it is contained. The ICD can either be a stand-alone comprehensive document for each interface which then aggregates to cover all interfaces of each system/sub-system/component or defined as an entire set of ICDs written at a system/sub-system/component level. The ICD must be sufficient to ensure the engineering design of any interface will meet the interface requirements defined for that interface. Once approved, ICDs are subject to revision and change control processes.

4.1.7. Interface Definition Documents

IDDs are required to support the complete specification of interface entries identified in the MICD. IDDs provide quantitative and other technical information to support the details contained in the MICD. Level 3 IDDs have a consistent document format, ensure traceability to MICD entries, and may reference high level mechanical drawings of interfaces, assembly details, communication protocols, and testing requirements directly; Examples of IDD reference documents include: engineering notes, schematics, drawings, engineering calculations, manufacturer data sheets, and analysis. These documents are considered the lowest level traceable elements and shall be referenced in the applicable IDD. Once approved, IDDs are subject to revision and change control processes.

4.1.8. Master Interface Control Document

The MICD is the data base of all ICD entries define the boundaries between one or more Level 2 and Level 3 systems as defined in the GRD. Once approved, MICD is subject to revision and change control processes.

MICD definitions include the following information:

- Unique identification number
- Interface Name
- Requirements Description
- System scope roles, and relationships
- Requirements source document
- Interface Specifications Documents
- Approval Status
- Verification Method
- Verification documents

4.2. Technical Configuration Control and Management

Engineering configuration control maintains the consistency of the design, function, and performance of all technical deliverables and the overall cost and schedule across the EIC Project and throughout its development lifecycle. Configuration control assures the latest approved documentation is utilized wherever required, that baseline designs are defined, baseline changes are not made without authorization, and all changes subject to configuration control are traceable. System Engineering works with the TCCB to make sure that changes to requirements are traced to ensure that all downstream affected systems are involved and informed as appropriate.

4.3. Design Responsibilities

The system, sub-system, and component designs are coordinated and completed according to the framework established in the RLS. L2M's are the design authorities for their respective systems. L2Ms develop the GDRs, FRDs and PRDs as a series of flow downs originating with the GLRD. The L2Ms are responsible for the production and utilization of the Requirement and

Interface documents. They assign the development of sub-system IRDs and ICDs and detailed design specifications to subordinate managers within the system. The System Engineers assist with the development of Requirements, Interfaces, and Technical Specifications.

The cognizant L3M/L4M's and CAMs, along with the engineering leads develop technical design plans that specify design tasks and identify all technical reviews and associated design deliverables. These plans are developed within the scope of work defined for the respective systems, in accordance with the EIC Technical Design Maturity Plan [5.1] and the EIC Technical Review Plan [5.4]. Technical reviews constitute key technical milestones in the RLS within each system's scope of work.

L2s are responsible for identifying, managing, and resolving design issues within their WBS. These issues include those that require configuration or change control, interface issues that span multiple WBS elements, and issues that affect project cost.

4.4. Design Deliverables

Design deliverables are the set of engineering documents required to specify, cost, produce, accept, validate, install, and commission a system, sub-system, or component. Subsystem technical design plans specify the expected deliverables at the technical design reviews in accordance with the EIC Technical Design Maturity Plan [5.1]and EIC Technical Review Plan [5.4]. Design deliverables are assessed during reviews to ensure thatthe elements under review satisfy technical requirements, have sufficient technical maturity and meet schedule and budget commitments.

4.5. Hazard and Risk Identification and Mitigation

The EIC Hazard Analysis Report for Electron-Ion Collider [5.5] identifies and mitigates the project hazards. This document is consistent with the project guidelines for managing hazards and risks.

Risk Analyses and Hazards Analyses are required as part of the overall system design process and are included in the design deliverables. L2s may elect to perform a Failure Mode and Effect Analysis (FMEA) to support risk mitigation.

4.6. Alternative Analysis and Value Engineering

The SE process requires alternatives analysis and Value Engineering (VE) principles to be performed throughout the Project lifecycle.

Alternatives analysis is incorporated throughout EIC starting at the highest-level accelerator complex technology evaluation described at the (need reference). At each system level, the L2s evaluate alternative design approaches down to sub-system components as necessary to be confident proper design and technology choices are incorporated in the overall configuration of EIC. Alternatives analysis considerations are expected to be presented during design reviews as appropriate.

EIC employs a value engineering process to ensure the most designs are chosen that achieve the lowest life cycle costs while meeting safety, reliability, and performance requirements. VE assessments at the system level should be part of the preliminary design phases. In some cases, a formal VE study may be required. Like alternative analyses, VE studies will be included as deliverables for design reviews.

4.7. Design Acceptance and Verification Criteria

Design acceptance and verification criteria are defined as early as possible in the design cycle. These criteria should focus on design features impacting safety and performance of a component or sub-system showing that the design requirements are met. These documents should be generated at the lowest practical level to ensure higher-level integration and system-level requirements are met.

Anticipated documents are:

- Acceptance Plans
- Acceptance Criteria and Verification Methodology
- Functional and Technical Test Plans and Procedures
- Verification Test Reports

4.8. Quality Assurance

Quality assurance and quality control are essential pillars of the SE process and required for the success of the EIC project. The EIC SE approach implements (needs reference) the EIC Quality Assurance Plan for the Electron-Ion Collider [5.6]. The SE process for QA is to ensure that the systems and sub-systems produced meets design requirements.

4.9. Prevention Through Design

Prevention through design is a process to integrate hazard identification and risk assessment early in the design process to eliminate or minimize risks throughout the lifecycle of the system being designed. The SE process mandates engineers and designers to control risks to workers and the environment to an acceptable level "at the source" or as early as possible in the life cycle of the equipment.

4.10. Technical Reviews

The EIC Technical Review Plan [5.4] details the process by which individual systems, sub-systems, and components are reviewed. The L2s shall develop engineering design plans which prepare for the series of reviews through the design maturity phases. Critical design reviews are included as milestones in the RLS to ensure that design development proceeds on schedule. The SE process ensures that the review is done independently.

4.11. Documentation Management

The EIC Requirements Management Plan [5.2] specifies how Project data are collected and managed to support Project-wide documentation consistency, control, and access.

5. REFERENCES

5.1. EIC-SEG-PDN-010, EIC Technical Design Maturity Plan

5.2. EIC-SEG-PLN-016, Requirements Management Plan

5.3. EIC-SEG-PLN-020, EIC Interface Management Plan

5.4. EIC-SEG-PDN-009, EIC Technical Review Plan

5.5. EIC-ESH-PLN-008, Hazard Analysis Report for Electron-Ion Collider

5.6. EIC-QAG-PLN-002, Quality Assurance Plan for the Electron-Ion Collider

5.7. BNL SBMS, BNL Subject Based Management System

5.8. EIC-ORG-PLN-025, Configuration Management Plan

5.9. EIC-ESH-PLN-007, Integrated Safety Management Plan

5.10. EIC-PSD-PLN-003, Risk Management Plan

5.11. EIC-SEG-PLN-022, Systems Engineering Management Plan