

PIP-II Systems Engineering Management Plan

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Document Approval

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1. Purpose

The *PIP-II Systems Engineering Management Plan* (SEMP) defines the technical management and engineering processes implemented for the Proton Improvement Plan-II Project (PIP-II) within the constraints defined by the *Project Management Plan for the PIP-II Project* (PMP) [1]. 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 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 PIP-II achieves the overall technical goals outlined in the project Mission Need Statement 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 and Integration Management teams.

2. Scope

The SEMP provides requirements applicable to all PIP-II project engineering tasks, performed by or for the PIP-II Project as defined and organized in the PIP-II 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 at the PIP-II Project meets all functional requirements and all deliverables at completion.

Revision control of this document will occur upon initial release.

3. Acronyms

BCR	Baseline Change Request
CAM	Control Account Manager
CCB	Change Control Board
CD	Critical Decision
CMP	PIP-II Configuration Management Plan
DCB	Design Change Board
DDD	Design Deliverables Document
DOE	Department of Energy
FDR	Final Design Review
FEM	Fermilab Engineering Manual
FESHM	Fermilab ES&H Manual
FMEA	Failure Mode and Effect Analysis
FRCM	Fermilab Radiological Control Manual

FRS	Functional Requirements Specification
GRD	Global Requirements Document
ICD	Interface Control Document
IRR	Installation Readiness Review
ISD	Interface Specification Document
KPP	Key Performance Parameter
L2M	WBS Level 2 Manager
L3M	WBS Level 3 Manager
L4M	WBS Level 4 Manager
PDR	Preliminary Design Review
PEP	PIP-II Project Execution Plan
PIP-II	Proton Improvement Plan II Project
PMP	Project Management Plan for the PIP-II Project
PPD	Project Planning Document
PRD	WBS Level 2 Physics Requirements Document
PRR	Production Readiness Review
QAM	Fermilab Quality Assurance Manual
QAP	PIP-II Quality Assurance Plan
RDS	Room Data Sheet
RLS	Resource Loaded Schedule
SDP	Level 2 System Design Plan
PtD	Prevention through Design
SE	Systems Engineering
SEMP	PIP-II Systems Engineering Management Plan
SEP	Systems Engineering Process
SME	Subject Matter Expert
SPC	Partner Sub-project Coordinator
SPM	Fermilab Sub-project Manager
TRP	PIP-II Technical Review Plan
TRS	Technical Requirements Specification
WBS	Work Breakdown Structure

4. Reference Documents

1	Project Management Plan for The Proton Improvement Plan-II Project DocDB # 172
2	Fermilab Engineering Manual
3	Fermilab Environmental Safety and Health Manual
4	Fermilab Radiological Control Manual
5	Fermilab Quality Assurance Manual
6	PIP-II Quality Assurance Plan DocDB # 142
7	PIP-II Integrated Environment, Safety, and Health Management Plan TC ED0008512
8	PIP-II Configuration Management Plan DocDB # 2937
9	PIP-II Preliminary Project Execution Plan DocDB # 115
10	PIP-II Organizational Chart DocDB # 2309
11	PIP-II WBS Dictionary DocDB # 599
12	PIP-II Mission Need Statement DocDB # 152
13	Global Requirements Document TC ED0001222
14	PIP-II Requirements Management Plan TC ED0008235
15	PIP-II Room Data Sheets TC ED0009544
16	PIP-II Interface Management Plan TC ED0007941
17	PIP-II Technical Review Plan TC ED0008163
18	PIP-II Hazard Analysis Report DocDB # 140
19	PIP-II Risk Register DocDB # 1233
20	Risk Management Plan for The Proton Improvement Plan-II Project DocDB # 163
21	Fermilab Risk Management Procedure for Projects
22	Analysis of Alternatives: Proton Improvement Plan - II DocDB # 107
23	PIP-II Value Engineering Plan DocDB # 2830
24	PIP-II Prevention through Design TC ED0008508
25	PIP-II Documentation Management and Control Procedure DocDB # 2946

5. Overview

The *Fermilab Engineering Manual* (FEM) establishes the primary structure for engineering design and systems engineering processes at Fermilab [2]. The PIP-II SEMP provides specific guidance for the PIP-II Project within the framework established by the FEM. 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 PIP-II in accordance with Laboratory manuals and other Project documents: *Fermilab Environment, Safety and Health Manual* (FESHM), *Fermilab Radiological Control Manual* (FRCM), *Fermilab Quality Assurance Manual* (QAM), *PIP-II Quality Assurance Plan* (QAP), *PIP-II Integrated Environment, Safety, and Health Management Plan* (IESH) and the *PIP-II Configuration Management Plan* (CMP) [3,4,5,6,7,8]. Figure 5.1 shows the PIP-II governing document hierarchy.

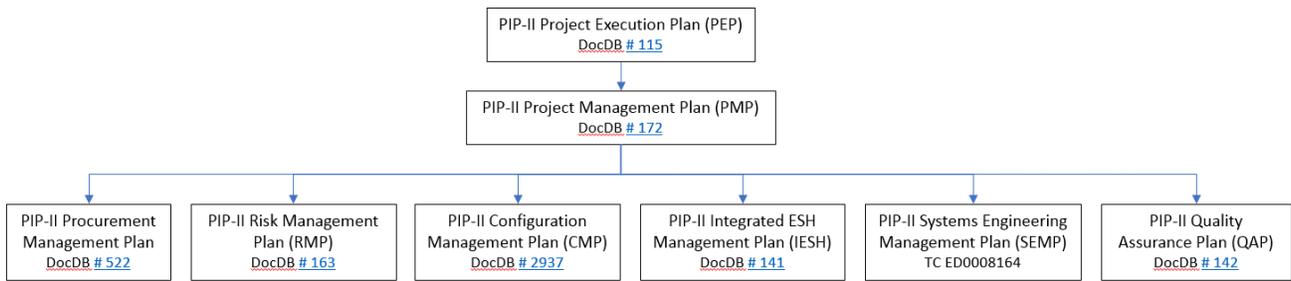


Figure 5-1. PIP-II Project planning document hierarchy

The SEMS requires additional detailed planning documents for interface and requirements management, technical review planning, value engineering, and documentation management and control. Figure 5-2 shows the SEMS and subordinate document structure.

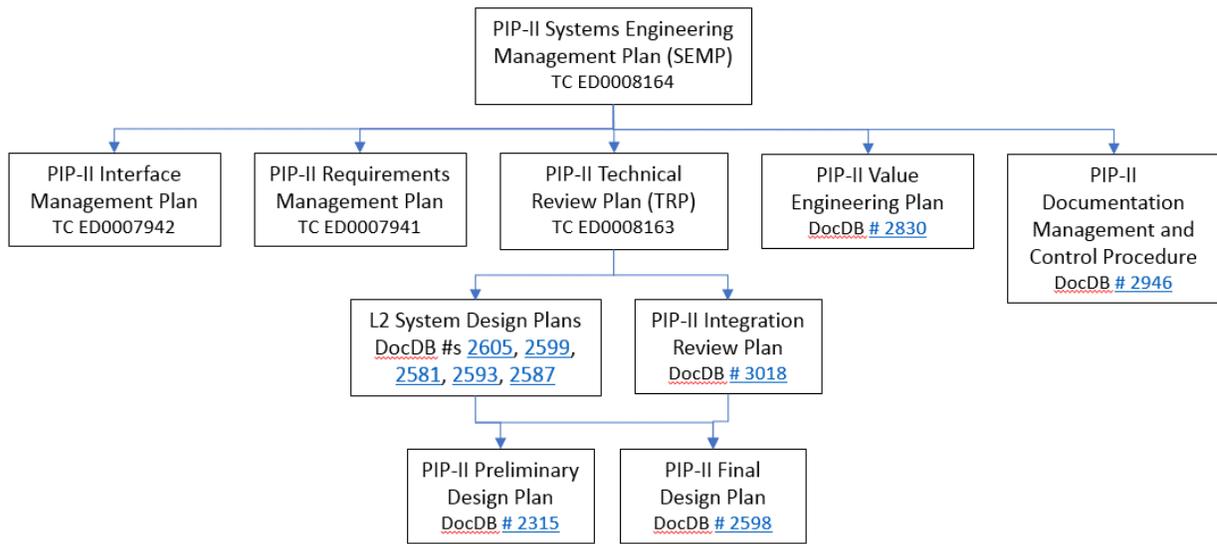


Figure 5-2. PIP-II SEMS document hierarchies

The QAP and IESH are parallel and equivalent pillars to the SE process defined in the SEMS. These plans require the development of subordinate documents to fully define the QA/QC and safety and environmental planning activities throughout the Project. Figure 5-3 shows the QAP and IESH and subordinate document structure.

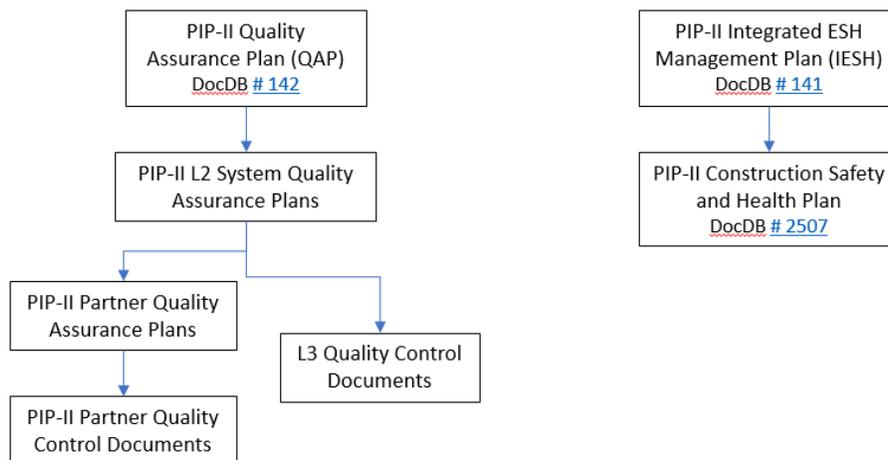


Figure 5-3. PIP-II QAP and IESH document hierarchies

6. Project Roles and Responsibilities

The PIP-II Project organizational and management oversight structure, described in the *PIP-II preliminary Project Execution Plan (PEP)*, is designed to accomplish the Project’s mission effectively and safely [9]. The PEP describes the organizational relationships and key personnel responsibilities, authorities, and position descriptions.

In support of the PEP, the PMP establishes the constraints under which the SEMP and associated technical activities are conducted and describes in greater detail the responsibilities and authorities of Fermilab management and advisory committees as well as key PIP-II Senior Project Management positions including; Project Director, Technical Director, Project Manager, and other essential Project Office roles.

The PIP-II Project is organized in three offices with interfacing sets of responsibilities: Project Director (Executive Office), Project Management, and Technical Integration [10]. Combined, the three organizational offices control and are responsible for the full execution of the PIP-II Project.

The Technical Integration Office is responsible for the management of the SEMP and QAP implementation throughout the Project. 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. L2Ms are also responsible for ensuring that deliverables meet all requirements established by this SEMP and other applicable PIP-II requirements described in the QAP.

WBS Level 3 and 4 Managers (L3M, L4M) are 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.

International Partners providing designs and components to the Project are responsible for abiding by the principals of this SEMP and supporting documents within the framework and guidance of their own

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

7. Project Structure and Timeline

The PIP-II WBS and WBS Dictionary represent the overall project definition and organizational structure [11]. The WBS is divided into major systems (L2 systems) which are organized by function and scope and are subsequently 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 used to establish the complete project view and to define the full scope and cost and resulting schedule of the PIP-II Project. Effective systems engineering requires the implementation and execution of a mature WBS and RLS such that L2Ms and L3Ms/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:

- Identify and organize all planned work
- Identify and track deliverables links between WBS elements
- Aid configuration management and control of subsystem interfaces
- Organize and track technical and procurement readiness reviews
- Organize and track system and sub-system technical performance achievement
- Track Partner milestones and interface logic

A high-level timeline for the PIP-II project is shown in Figure 7-1. The phases of technical maturity for the Project align with the corresponding Department of Energy (DOE) Critical Decision (CD) steps indicated by the CD numbers. The PIP-II 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 defined in Table 7-1. Milestones for Critical Decisions are included in the RLS.

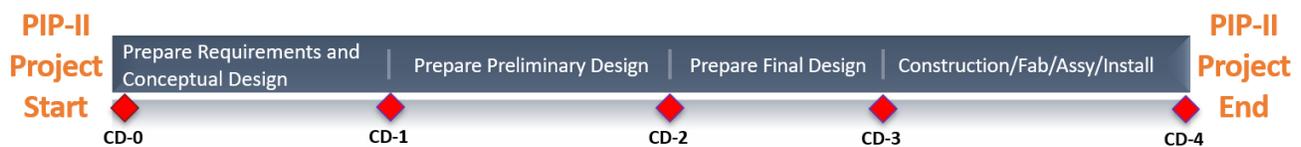


Figure 7-1. PIP-II Critical Decision Process Timeline

DOE Critical Decision Milestone	Definition
CD-0	Approval of mission need
CD-1	Approval of selected alternative, cost and schedule
CD-2	Approval of the preliminary design and the baseline scope, cost and schedule

CD-3	Approval of the final design and start of construction
CD-4	Approval of project completion

Table 7-2. PIP-II Critical Decision definition

8. Systems Engineering Process

8.1. Systems Engineering Approach

The PIP-II 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 approach focuses on achieving the following objectives:

- Defines and controls Scientific, Functional, and Technical requirements
- Defines and controls interfaces
- Implements and manages Configuration Control
- Defines design responsibilities and scope
- Establishes the process to manage technical risks
- Identifies and mitigates hazards and safety risks
- Documents design activity deliverables
- Conducts technical reviews to ensure requirements, interfaces, and planned performance are achieved
- Considers, documents, and evaluates alternative design approaches
- Defines and documents preferred design alternatives
- Implements Quality Assurance and Quality Control
- Establishes design acceptance and verification criteria
- Demonstrates acceptance and validation
- Integrates Environment, Safety, and Health considerations throughout Project activities

8.2. Systems Engineering Process

The PIP-II 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 PIP-II SEP is listed below. Formal document definitions follow in subsequent sections.

- Systems Engineering Management Plan (SEMP), (this document)
- Work Breakdown Structure Dictionary (WBS)
- Resource Loaded Schedule (RLS)
- Global Requirements Document (GRD)
- Physics Requirements Documents (PRD)
- System Design Plans (SDP)
- Functional Requirements Specifications (FRS)
- Interface Control Documents (ICD)
- Interface Specification Documents (ISD)
- Technical Requirements Specifications (TRS)
- Room Data Sheets (RDS)
- Design Deliverable Documents including Engineering and Technical Notes
- Design Review Reports
- Quality Assurance Plans
- Analysis of Alternatives
- Acceptance Plans
- Verification and Acceptance Criteria, and Test Reports
- Installation Plans
- Commissioning Plan

8.3. Requirements Definition and Management

The overall requirements framework for the PIP-II project is established in the *PIP-II Mission Need Statement* [12]. Summarized:

“The current beam power of 700 kW is insufficient to meet the P5 goal of delivering 120 MW-kton-years by 2035. Increasing the beam power to 1.2 MW would roughly double the DUNE data-taking rate, significantly increasing the competitive edge of the experiment by halving the time it would take to achieve significant scientific results. This in turn raises the probability that the U.S. neutrino physics program will continue to outperform the Japanese program – the closest competitor – in the 2020s.

This need for higher proton beam power comes at a time when many components of the existing Fermilab accelerator complex that delivers beam to the Main Injector – especially the linear accelerator (linac) and the Booster – are approaching 50 years old. Thus, a proton beam power upgrade is proposed to meet two main capability gap and mission need goals:

1. *To reduce the time for LBNF/DUNE to achieve world-first results.*
2. *To sustain high reliability operation of the Fermilab accelerator complex.”*

The *PIP-II Project Execution Plan* defines preliminary Key Performance Parameters (KPPs) of the Project. The KPPs are included in the *PIP-II Global Requirements Document* (GRD), which defines the highest-level physics, performance, and functional requirements for the Project based on the Mission Need Statement [13]. The requirements analysis and flow-down process involves converting the GRD into PRDs that in combination define the overall accelerator complex

configuration required to satisfy the GRD. These requirements are further refined into FRSs and TRSs for the PIP-II sub-systems and components at an appropriate control level. Requirements are defined such that they are clear, unambiguous, consistent to the higher-level requirements and cross-cutting interfaces, and actionable in the design process and verifiable prior to installation and commissioning. Figure 8-1 shows the requirements flow-down from Mission Need down to technical requirements.

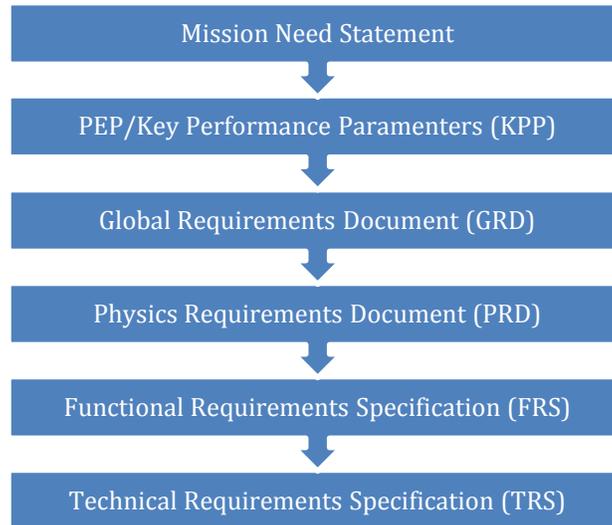


Figure 8-1. Requirements Flow-down

Functional Requirement Specifications drive the downstream technical designs and subsystem configurations. Generally, the design flow-down from the FRS is shown in Figure 8-2.

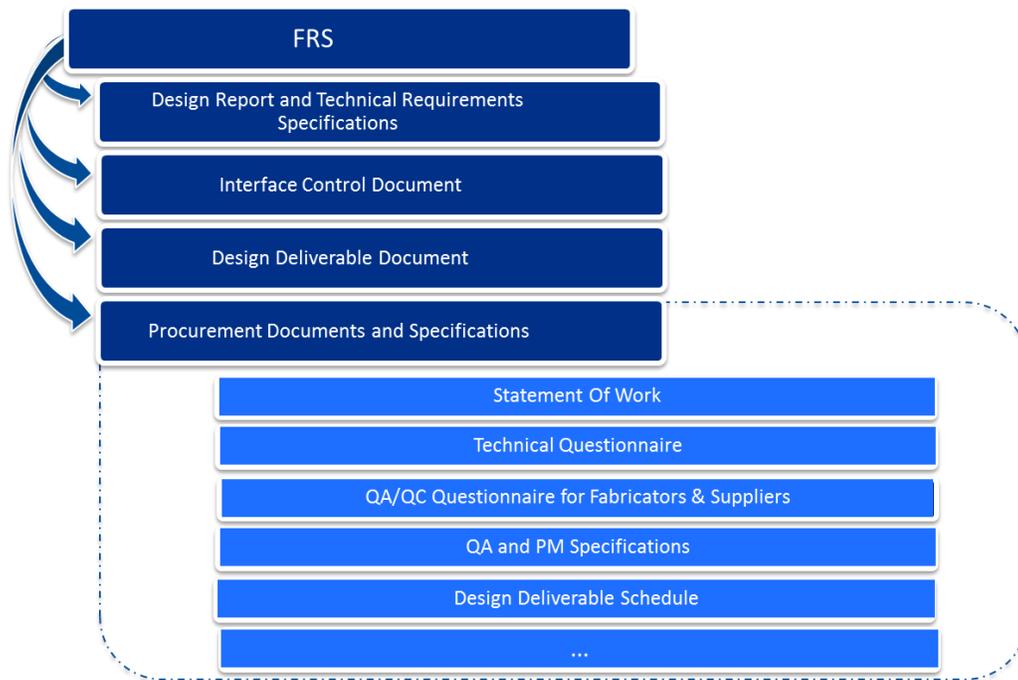


Figure 8-2. Design Flow-down

8.3.1. Global Requirements Document

The Global Requirements Document (GRD) is the single global-level requirements document that specifies the performance requirements for the PIP-II Project. The scope of the GRD is limited to the technical performance requirements related to the mission of the PIP-II Project. Generally, this serves as the highest-level physics requirement specification.

8.3.2. Physics Requirements Documents

The Physics Requirements Documents (PRD) contain comprehensive, individual system physics requirements and constraints at WBS Level 2 derived from the Global Requirements Document (GRD). The PRDs also define high-level hardware deliverable requirements. The PRDs clearly define the origin of individual systems requirements, operational context, and basic system boundaries. In addition, the PRDs provide a requirement baseline for the subsequent fabrication, assembly, installation, check-out and commissioning activities.

L2Ms shall generate PRDs for their respective systems. Once approved, PRDs are subject to revision and change control processes.

8.3.4. Functional Requirements Specifications

Functional Requirements Specifications (FRS) are written for all L3 systems and for complex L3 sub-systems and devices that affect the overall performance of an L3 sub-system. The information contained in FRS documents describe how the system must perform to meet all higher-level requirements. FRSs must also contain all parameters required to initiate design activities thereby acting as a bridge between higher level requirements and design.

L2Ms shall generate FRSs within their respective sub-systems according to the guidelines established in the *PIP-II Requirements Management Plan* [14]. Once approved, FRSs are subject to revision and change control processes.

8.3.5. Technical Requirements Specifications

Technical Requirements Specifications (TRS) contain a comprehensive, structured, set of individual technical system requirements for L3 systems and sufficiently complex L3 sub-systems that affect the overall performance of the L3 sub-system. A technical requirement pertains to the technical parameters that the system must fulfill or abide by and is often referred to as a constraint.

Technical Requirements Specifications are required for each L3 sub-system either as stand-alone comprehensive documents that aggregate all technical requirements within a L3 sub-system or as a set of TRSs written at the device level. Once approved, TRSs are subject to revision and change control processes. TRSs are often developed iteratively and mature through the design phases for complex systems and sub-systems.

8.3.6. Room Data Sheets

Room Data Sheets (RDS) are conventional facilities (CF) documents that specify the facility dimensions and service requirements for each of the conventional systems. These documents are provided to the Architect/Engineer as 'design-to' documents and provide a basis for design reviews. The *PIP-II RDS* is an aggregation of many CF interfaces and requirements [15].

8.4. Interface Definition and Control

The PIP-II SE process requires formal technical interface management. Top-level requirements originating at the GRD flow-down through the PRDs to FRSs and finally to the individual component requirements. To achieve the requirements at the system level, many cross-cutting interfaces exist between L3 systems. Each L3M shall generate ICDs to identify and define interfaces between L3 systems in accordance with the *PIP-II Interface Management Plan* [16]. ICDs reference subordinate ISDs that provide the necessary background details to establish the interfaces. The purpose and function of ICDs and ISDs are defined below.

8.4.1. Interface Control Documents

ICDs define the boundaries between one or more L2 and L3 systems as defined in the GRD and are subject to configuration control and management as described in 8.7.

Interface 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

L3 ICDs may reference high level mechanical drawings of interfaces, assembly details, communication protocols, and testing requirements directly; or they may reference a specific Interface Specification Document.

Sub-system interfaces are defined in lower-level ICDs and managed within the L3 sub-systems. Lower-level ICDs address details of interfaces developed through the design cycle such electrical, controls, instrumentation, flows and other technical elements. Nominal operating points, ranges and interface testing requirements shall be defined for these type interfaces, as applicable.

8.4.2. Interface Specification Documents

ISDs are required to support the complete specification of interfaces identified in the L3 ICDs as well as for internal ICDs within L3 systems. ISDs provide quantitative and other technical information to support the details contained in the ICDs. Examples of ISDs are 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 ICDs.

8.5. Configuration Control and Management

Configuration control maintains the consistency of the design, function, and performance of all technical deliverables and the overall cost and schedule across the PIP-II 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.

The PIP-II Project will manage the technical, cost, and schedule baselines in accordance with the *PIP-II Configuration Management Plan (CMP)*. Changes to the PIP-II Project Baseline require a Baseline Change Request (BCR) initiated by the L2M. The L2M submits the BCR to the Design Change Board (DCB) for technical change review and the Change Control Board (CCB) for cost and schedule change review. The DCB and CCB and associated review processes assure all relevant stakeholders are involved and informed as appropriate.

8.6. Design Responsibilities

L2Ms are the Design Authorities of their respective systems. L2Ms develop PRDs that flow-down from the requirements defined in the GRD. The PRDs define the system level requirements such that the overall configuration information is enough to initiate design activities. The L2Ms are responsible for the production and utilization of the PRD and system level ICDs. The L2Ms assign the development of sub-system ICDs and FRSs to subordinate managers within the L2 system, which in most cases, are the L3Ms and L4Ms. The Technical Integration office assists with the FRS and ICD development.

The L2Ms also develop System Design Plans (SDP) that identify all technical reviews and design deliverables within the scope of work defined for the respective systems in accordance with the *PIP-II Technical Review Plan (TRP)* [17]. Technical reviews constitute key technical milestones in the RLS within each system's scope of work.

System, sub-system, and component designs are coordinated and completed by the L3Ms and L4Ms according to the framework established in the RLS. Design deliverables, defined in 8.7, constitute the minimum design content to complete the review stages: conceptual, preliminary, final, production readiness.

L2Ms are responsible for identifying, managing and resolving design issues within their systems. Issues that require configuration or change control, like design changes that span L2 or L3 systems, are subject to the processes defined in the *PIP-II Configuration Management Plan*.

8.7. Design Deliverables

Design deliverables are the set of engineering documents required to specify, produce, accept, validate, install, and commission a system, sub-system, or component. The *WBS Level 2 System Design Plans* specify the expected deliverables at the conceptual, preliminary, final, procurement, and manufacturing readiness reviews. Design deliverables are assessed during the series of design reviews to ensure that the element(s) under review satisfy technical requirements and meet schedule and budget commitments. L2Ms establish the set of expected design deliverables for each review stage for all sub-systems based on the guidance provided in the TRP.

8.8. Hazard and Risk Identification and Mitigation

There are three governing documents in the PIP-II Project that establish the process to identify and mitigate project hazards and risks; *PIP-II Hazard Analysis Report*, *PIP-II Risk Register*, and the *Risk Management Plan for the PIP-II Project* [18,19,20]. These documents are consistent with Fermilab guidelines for managing hazards and risks described in FESHM and the *Fermilab Risk Management Procedure for Projects* [21].

Risk Analysis and Hazards Analyses are required as indicated in the FEM as part of the overall system design process and included in the design deliverables. At the Systems Level (L2), a Failure Mode and Effect Analysis (FMEA) is recommended.

8.9. 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 PIP-II starting at the highest-level accelerator complex technology evaluation described at the Project level in the *Analysis of Alternatives: Proton Improvement Plan-II* [22]. At each system level, the L2Ms and L3Ms 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 PIP-II. Alternatives analysis considerations are expected to be presented during design reviews as appropriate.

The *PIP-II Value Engineering Plan* defines the value engineering process the Project incorporates to ensure the most cost-effective designs are chosen to achieve the lowest life cycle costs while meeting safety, reliability, and performance requirements [23]. As indicated in the PEP, the Technical Integration Office organize VE assessments at the system level as part of the preliminary design phases. In some cases, a formal VE study may be required. Like alternatives analyses, VE studies will be included as deliverables for design reviews.

8.10. Design Acceptance and Verification Criteria

Design acceptance and verification criteria are defined as early as possible in the design cycle and focus on design features impacting safety and performance of a component or sub-system. L2Ms shall delegate the responsibility for generating acceptance plans and criteria documents and design verification plans to the L3Ms. These documents should be generated at the lowest practical level to ensure higher-level integration and system-level performance are not impacted.

Anticipated documents are:

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

8.11. Quality Assurance

Quality assurance and quality control are essential pillars of the SE process. The PIP-II SE approach implements the *Fermilab Quality Assurance Manual (QAM)* and the *PIP-II Quality Assurance Plan (QAP)* through the Project lifecycle.

The QAP establishes the line management authority and responsibility to implement QA/QC process throughout design, deliverables development, transportation, fabrication and acceptance testing, integration, installation and commissioning phases. These QA/QC processes are defined in specifications, QA Plans, QC documents, fabrication and test procedures, and travelers.

The PIP-II Technical Director and the PIP-II Quality Assurance Manager, L2Ms/L3Ms managers are responsible for the development, integration, implementation and assessment of the QAP.

The L2Ms may institute a graded approach to QA/QC throughout the development of their systems by assessing Partner or vendor expertise commensurate with the potential for environmental, safety, health or quality impacts. Each L2M shall develop a system-level (L2) QAP that:

- Describes the scope of the system
- Identifies associated Partners, vendors, or subcontractors
- Defines partner and/or Fermi Research Alliance vendor oversight plans
- Defines expectations for managing nonconformances
- Identifies activities that present significant ES&H and/or quality risk
- Defines activities that require quality control and oversight
- Evaluates risk and control choices
- Documents and defines the application quality control within the system

Each L3M shall develop subsystem-level (L3) QC Plans for deliverables that:

- Describes the scope of the system
- Describes the scope of the plan
- Identifies inspection and acceptance testing criteria
- References travelers, procedures, or checklists

- Defines criteria for how work process requirements will be met
- Defines in-process monitoring and measurement activities (e.g. MIPs)
- Identifies verification methods and activities
- Documents deliverable documentation and records
- Identifies associated equipment and related calibration records
- Describes traceability for parts and components
- Describes training and qualification requirements
- Defines Partner and/or vendor visits and interactions
- Defines processes to correct nonconformances
- References component/assembly handling and transportation requirements

8.12. Prevention through Design

Prevention through Design (PtD) 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 process the PIP-II Project requires, as defined in the *PIP-II Prevention through Design* document, encourages 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 [24].

The benefits of controlling risks early in the design process:

- Prevent or reduce occupationally related injuries, illnesses, and fatalities
- Increase productivity
- Reduce operating costs
- Reduce retrofitting to correct design shortcomings

8.13. Technical Reviews

The *PIP-II Technical Review Plan* (TRP) details the process by which systems, sub-systems, and components are reviewed. L2Ms shall use the TRP to develop SDPs which guide the planning required to prepare for and conduct the series of reviews for their respective systems and sub-systems through the design maturity phases. Critical design reviews are included as milestones in the RLS to ensure that design development proceeds on schedule.

The completion of a given design review facilitates the following: establishes expectations of design and planning content and maturity at each review phase/class; provides guidance to managers to define scope and schedule of work for incorporation into the PIP-II RLS; and provides other stakeholders relevant information about the status of work for interfacing activities.

Generally, major review decision gates for designed, procured, and installed components are the Preliminary Design Review (PDR), Final Design Review (FDR), Procurement Readiness Review (PRR), Installation Readiness Review (IRR), and Accelerator Readiness Review (ARR). These key decision gates are needed in a disciplined systems engineering process since they represent significant milestones which, when successfully completed, determine the project readiness to proceed to the next phase.

8.14. Documentation Management

The *PIP-II Documentation Management Plan* specifies how Project data are collected and managed to support Project-wide documentation consistency, control, and access [25].

8.15. Communication

The following meetings are organized to maintain effective communication within the project team and with stakeholders. An action-items list is made for each meeting with each item assigned to an owner responsible for closure. Meeting agendas, presentations, and minutes are stored on the [PIP-II Sharepoint site](#).

Meeting Name	Chair	Participants	Purpose	Frequency
Technical Integration	Technical Director	Int. team, L2Ms Stakeholder L3Ms and SPMs/SPCs	Provides forum to discuss system level integration, international technical integration, and technical scope management	weekly
Systems Engineering	Deputy Project Engineer	Int. team Stakeholder L2Ms, L3Ms, Subject Matter Experts (SME)	Coordinate systems engineering processes including requirements clarification and management; engineering design forum; cross-boundary systems engineering effort and impact	bi-monthly
Space Allocation	Integration Coordinator	Stakeholder L2Ms, L3Ms, CAD model manager, design team	Coordinate space required; Identify and resolve space conflicts	as-needed
Systems Integration	Integration Coordinator	Int. team, Stakeholder L2Ms, L3Ms, SMEs, design team	Coordinate requirements flow down; manage internal interface development;	as-needed
Engineering Safety	Project Engineer + ESH Manager	Int. team, L2Ms, L3Ms, Project members	Coordinate safety requirements for design; review safety incidents; assess Prevention through Design implementation	bi-monthly
Design Change Board	Technical Director	DCB members	Review change requests to baseline designs and configurations	as-needed
Change Control Board	Project Director	CCB members	Review change requests to the PIP-II Project baseline.	as-needed
G9	Project Director	L2Ms, PM, TD, ESH Man., QAM, Proj. Eng., Proj. Scientist	Technical and programmatic Project coordination between L2Ms, Project Management, and Technical Integration.	weekly
iG9	Project Director	TD, PM, L2Ms, SPMs	Technical and programmatic Project coordination for Partner activities between SPMs, L2Ms, Project Management, and Technical Integration.	weekly
SPM/SPC	Sub-project Manager	Topic specific SPM and SPCs, SMEs	Technical development meetings associated with list of sub- projects aligned with WBS level 3 and level 4 topics. Direct technical link between FNAL SPMs and Partner SPCs.	weekly

8.16. Software Tools

As of this writing, the following software tools are used for PIP-II at Fermilab:

- Mechanical Design:
 - [Siemens NX](#)
- Electrical/Electronics Design and Verification:
 - Altium
 - AutoCAD
 - ADS
 - CST
 - SPICE
- Architectural Design
 - AutoCAD
 - Revit
- Engineering Documentation Management with revision control:
 - [Siemens Teamcenter 11](#)
 - [GitHub](#) (software repository)
 - [CVS Repository](#) (software repository)
- Engineering document sharing for DAE information transfer: Sangam
- Project Management Documentation: [PIP-II DocDB](#)
- RLS: Primavera (P6)
- General Documentation Management: [PIP-II Project Sharepoint site](#)
- Traveler and non-conformance management: [Vector](#)
- Meeting/Conference Documentation: [PIP-II Indico site](#)
- Findings & Recommendations Management: [iTrack](#)
- Analysis tools: ANSYS, COMSOL, MARS, Matlab, MathCAD

Partners use many other software tools to produce designs and manage work.