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JQLRRK

VERSION CREATED ON / VERSION / STATUS

04 Jul 2025 / 3.0 / Approved

EXTERNAL REFERENCE / VERSION

Technical Requirements Specification

01_Diagnostics Plant I&C Design Process (SRS and SDS) with link to templates and examples

This document describes the Diagnostics Plant Instrumentation & Control (I&C) methodology, providing a structured framework for the design, development, verification, and validation of I&C systems for ITER diagnostics. Rooted in systems engineering principles, the methodology draws its foundations from the Plant Control Design Handbook (PCDH).

Note: This methodology is limited to conventional control. For Plant Interlock System (PIS) and Plant Safety System (PSS), if applicable to the diagnostic, please refer to the separate methodology for high integrity systems as detailed in the PCDH and its satellite documents.

Approval Process			
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Information Protection Level: Non-Public - Unclassified *RO: Simrock Stefan EXT*			
Read Access	**LG: I and C IPT IO Member, LG: Contracts, AD: ITER, AD: External Collaborators, AD: IO_Director-General, AD: External Management Advisory Board, AD: IDM_Controller, AD: Nuclear Safety Inspectors, AD: OBS - Data and Connectivity and Software Project (DCS), AD: Auditors, AD: ITER Management Assessor, ...**		

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<table>
<tr><th colspan="4"><i>Change Log</i></th></tr>
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<tr><th><b><i>Version</i></b></th><th><b><i>Latest Status</i></b></th><th><b><i>Issue Date</i></b></th><th><b><i>Description of Change</i></b></th></tr>
<tr><td>v1.0</td><td>Approved</td><td>02 Sep 2013</td><td></td></tr>
<tr><td>v1.1</td><td>Approved</td><td>24 Sep 2013</td><td>Operation and Maintenance Manual referance added</td></tr>
<tr><td>v1.2</td><td>Approved</td><td>14 Nov 2013</td><td>Added functional breakdown template link</td></tr>
<tr><td>v1.3</td><td>Signed</td><td>24 Nov 2013</td><td>Updated with New Functioanl Brakdown Template</td></tr>
<tr><td>v1.4</td><td>Approved</td><td>25 Nov 2013</td><td>Updated with Operation procedure</td></tr>
<tr><td>v1.5</td><td>Approved</td><td>20 Mar 2014</td><td>Update with new links</td></tr>
<tr><td>v1.6</td><td>Approved</td><td>27 May 2014</td><td>Updated with Improved SRS, SDS Link, SVN link for Source Codes</td></tr>
<tr><td>v1.7</td><td>Approved</td><td>30 Sep 2014</td><td>Updated IDM links for design documentation
Added Table for Plant I&C Design deliverables mapping to SRS and SDS
Updated SRS and SDS chapter descriptions
Updated with Inteface sheet example (Interface sheet to PBS 45)</td></tr>
<tr><td>v1.8</td><td>Approved</td><td>16 Feb 2015</td><td>Updated for
1. Plant I&C Design Workfolw
2. EA User Manual Ref.
3. PSOS Example
4. SRS Chapter
5. SDS Chapter</td></tr>
<tr><td>v1.9</td><td>Approved</td><td>29 Jul 2015</td><td>Updated example links in Table 1
Added Section 3.3 Checklist for design review
Added Section 3.4 Plant I&C design Maturity
Added Section 3.5.1 EA Version
Updated section 3.11 Interface sheet for Plant I&C</td></tr>
<tr><td>v1.10</td><td>Approved</td><td>06 Feb 2017</td><td>Updated with new templates and examples links
Added glossary</td></tr>
<tr><td>v2.0</td><td>Approved</td><td>29 Apr 2019</td><td>Updated for
Plant I&C Design Maturity
Functional Breakdown Structure
Variable Naming</td></tr>
<tr><td>v3.0</td><td>Approved</td><td>04 Jul 2025</td><td>The new version includes all the latest updates, with enhanced clarity through comprehensive descriptions and a more objective, operational approach.

Importantly, there are no changes to the core content of the document.</td></tr>
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DIAGNOSTICS PLANT I&C METHODOLOGY

Guideline

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List of Abbreviations

Abbreviation	Expanded Form
BOM	Bill of Materials
CBD	Cabling Diagram
CDR	Conceptual Design Review
CODAC	Control, Data Access and Communication
COS	Common Operating States
COTS	Commercial Off-The-Shelf
DAN	Data Archiving Network
DPP	Document Production Plan
EA	Enterprise Architect
EPICS	Experimental Physics and Industrial Control System
FAT	Factory Acceptance Test
FBS	Functional Breakdown Structure
FBSE	Functions-Based Systems Engineering
FDR	Final Design Review
GOS	Global Operating States
HMI	Human Machine Interface
HVAC	Heating, Ventilation, and Air Conditioning
I&C	Instrumentation & Control
IDEF0	Integration Definition for Function Modeling
IDS	Interface Data Sheet
IO-CT	ITER Organization Central Team
IO-DA	ITER Organization-Domestic Agency
IOC	Input/Output Controller
IS	Interface Sheet
MAN	Manufacturing and Delivery
MBSE	Model-Based Systems Engineering
MCR	Main Control Room
MDB	Manufacturing Database
MDP	Manufacturing Design and Preparation
MIP	Manufacturing Inspection Plan
MRR	Manufacturing Readiness Review
NDS	Nominal Device Support

OMM	Operations and Maintenance Manual
OOSEM	Object-Oriented Systems Engineering Method
PA	Procurement Arrangement
PCDH	Plant Control Design Handbook
PDR	Preliminary Design Review
PFD	Process Flow Diagram
PID	Piping and Instrumentation Diagram
PNI	Part Number of ITER
PON	Plant Operation Network
PSOS	Plant System Operating States
PSP	Plant System Profile database
QC	Quality Classification
RD	Reference Document
RHEV	Red Hat Enterprise Virtualization
SADD	Software Architecture and Design Description
SAT	Site Acceptance Test
SCoO	System Concept of Operation
SDIP	Software Development and Inspection Plan
SDN	Synchronous Databus Network
SDS	System Design Specification
SEMP	Systems Engineering Management Plan
SLD	Single Line Diagram
SMS	System Manufacturing Specification
SRS	System Requirement Specification
STP	System Test Plan
STR	System Test Report
SUP	Supervision
SVN	Subversion
SWIL	Software Integrity Level
SXP	SEE Electrical Expert
SysML	Systems Modeling Language
TCN	Time Communication Network
TRO	Technical Responsible Officer
V&V	Verification and Validation

1 Introduction

1.1 Purpose and Scope

This document describes the Diagnostics Plant I&C methodology, which is limited to conventional control.

This methodology is a structured approach used to manage complex systems such as ITER Diagnostics. It includes methods, processes, techniques, and principles for analysis, design, implementation, testing, operation, and maintenance throughout the system's lifecycle. The methodology draws its foundations from the Plant Control Design Handbook (PCDH) [RD2]. Section 2 explains the methodology, while section 3 provides the working instructions.

In alignment with the PCDH, this methodology uses the engineering diagrams (PFD, SLD, PID, CBD) as inputs for I&C design and does not govern the lifecycle of the related engineering designs.

The System Concept of Operation (SCoO) document of a diagnostic describes how the diagnostic will be used in the context of Tokamak operation. The operational principles outlined in this document are a key input for aligning the I&C development with these principles.

This document establishes the rules and methods for implementing the methodology, focusing on outlining the 'what' and 'how'. However, it does not prescribe the exact depth or granularity required for every aspect, particularly for subjective topics where the appropriate level of detail is context dependent. In this sense, the document is not prescriptive and does not provide exhaustive instructions for every scenario.

In this document, "Diagnostic Plant I&C" refers to a Plant System I&C (a PCDH term) where the Plant System is a diagnostic. Additionally, both "system" and "Plant I&C," when used on their own, specifically refer to Diagnostic Plant I&C.

Note: For Plant Interlock System (PIS) and Plant Safety System (PSS), if applicable to the diagnostic, please refer to the separate methodology for *high integrity* systems as detailed in the PCDH and its satellite documents.

1.2 Reference Documents [RD]

Table 1-1: Reference Documentation

Ref. No	Reference Name	Reference Link
[RD1]	ITER Systems Engineering Management Plan (SEMP)	ITER_D_2F68EX
[RD2]	Plant Control Design Handbook (PCDH)	ITER_D_27LH2V
[RD3]	Functional Breakdown for Diagnostics Plant I&C	ITER_D_LAJF9S
[RD4]	Diagnostics Plant I&C Use Cases Guideline and Example	ITER_D_X7VG4C
[RD5]	Requirement Management Guideline	ITER_D_UNL5VW
[RD6]	Diagnostics Plant I&C variable Naming Guideline	ITER_D_X7R88V
[RD7]	State Machine Design Guideline	ITER_D_UKHVM5
[RD8]	Guidelines for PSOS SM management by COS SM	ITER_D_AC2P4J
[RD9]	Enterprise Architect User Manual	ITER_D_Q77FFP
[RD10]	EA Project Structure for Diagnostics Plant I&C	ITER_D_6UER9M
[RD11]	Diagnostic I&C System Manufacturing Specification template	ITER_D_6375ZU

[RD12]	Diagnostic I&C Manufacturing and Inspection Plan - pre-filled template	ITER_D_8NTN95
[RD13]	Template for Software Development and Inspection plan for Diagnostic I&C	ITER_D_8TV987
[RD14]	List of Acceptance Criteria	ITER_D_6JL6ZQ
[RD15]	Template - Diagnostics Plant I&C System Test Plan (STP)	ITER_D_TVR6LS
[RD16]	Documentation Production Plan (DPP) Template for PBS 55	ITER_D_RZJ4LM
[RD17]	ITER System Design Process (SDP) Working Instruction	ITER_D_4CK4MT
[RD18]	NDS v3 EPICS Device Support User Manual	ITER_D_S977XP
[RD19]	HMI Guideline for Diagnostic I&C systems	ITER_D_9X7BNF
[RD20]	How To - Industrialization and Lifetime Management of Plant System Specific Fast I/O	ITER_D_QARUAC
[RD21]	I&C cubicle internal configuration	ITER_D_4H5DW6
[RD22]	NDS v3 System Sample User Manual	ITER_D_2Q2RGW
[RD23]	Working Instruction for Manufacturing Readiness Review	ITER_D_44SZYP
[RD24]	SEQA-45 - Software Engineering and Quality Assurance for CODAC	ITER_D_2NRS2K
[RD25]	Template - I&C Operation & Maintenance Manual	ITER_D_CME4U8
[RD26]	Software Architecture and Design Description Template	ITER_D_6S6B8E
[RD27]	Plant system I&C Integration plan	ITER_D_3VVU9W
[RD28]	I&C Integration Procedures	TYLFYC
[RD29]	Working Instruction for the Delivery Readiness Review	ITER_D_X3NEGB
[RD30]	Diagnostics Clarifications	ITER_D_CSQEFT
[RD31]	Template for PBS 55 Cubicle Layout and Wiring Diagram	ITER_D_9NCWYN
[RD32]	User Manual for CODAC Operational Applications	ITER_D_RUZCJ9
[RD33]	CODAC System / Software Development Standard Descriptions	6SQJ4C
[RD34]	Master Controller for COTS Intelligent Devices	ITER_D_AXXNDT

1.3 Organization of the methodology related documentation

Figure 1 depicts the organization of Diagnostics Plant I&C methodology related documentation. There are three key documents, along with a set of guidelines, document templates and checklists:

- This core document (ITER_D_JQLRRK), which explains the Plant I&C development methodology.
- EA Project Structure for Diagnostics Plant I&C [RD10], which documents how the Plant I&C design must be documented in the EA project.
- Enterprise Architect User Manual [RD9], which explains how to use the IO-CT developed EA add-ins to document design in the EA project.

The role of each of the documents shown in this figure will be explained in this document.

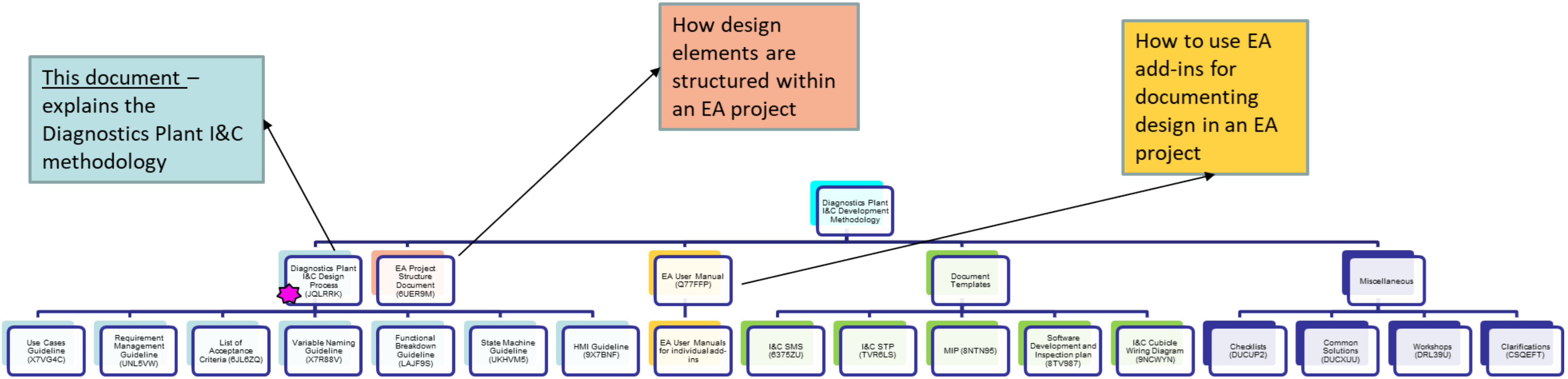

This document – explains the Diagnostics Plant I&C methodology
How design elements are structured within an EA project
How to use EA add-ins for documenting design in an EA project
Diagnostics Plant I&C Development Methodology
Diagnostics Plant I&C Design Process (JQLRRK)
EA Project Structure Document (6UER9M)
EA User Manual (Q77FFP)
Document Templates
Miscellaneous
Use Cases Guideline (X7VG4C)
Requirement Management Guideline (UNL5VW)
List of Acceptance Criteria (6JL6ZQ)
Variable Naming Guideline (X7R88V)
Functional Breakdown Guideline (LAJF9S)
State Machine Guideline (UKHVM5)
HMI Guideline (9X7BNF)
EA User Manuals for individual add-ins
I&C SMS (6375ZU)
I&C STP (TVR6LS)
MIP (8NTN95)
Software Development and Inspection plan (8TV987)
I&C Cubicle Wiring Diagram (9NCWYN)
Checklists (DUCUP2)
Common Solutions (DUCXUU)
Workshops (DRL39U)
Clarifications (CSQEFT)

Figure 1: Methodology related documentation

1.4 Workshops

The IDM location DRL39U provides links to the various CODAC Workshops on Diagnostics Plant I&C held since 2018.

1.5 Clarifications

IO-CT understands that it may not be possible to address every possible question through this document. As users raise additional questions related to requirements, design, manufacturing, testing, and commissioning, IO-CT will provide further clarifications. These clarifications will be documented in [RD30] document regularly.

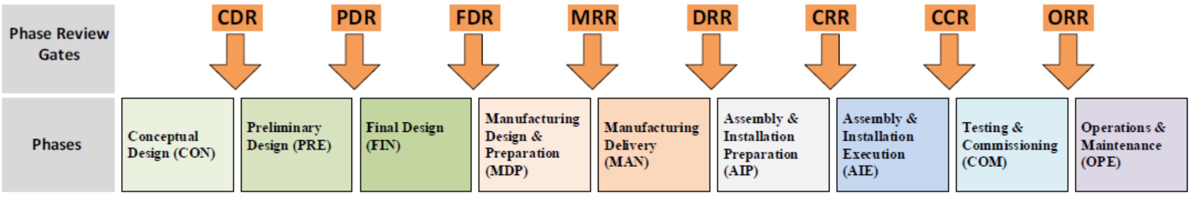
2 Methodology Description

Systems Engineering principles have been applied to the ITER project since the very beginning, and the Diagnostics Plant I&C methodology is also based on them.

There is a lot of literature available on the key foundations of systems engineering such as systems thinking, interdisciplinary approach, lifecycle view, requirements engineering, design optimization and iterative development. This document is not meant to describe systems engineering in detail but rather describe its application to the design and development of Diagnostics Plant I&C systems.

2.1 System Lifecycle Phases

Diagnostic Plant I&C systems must follow the ITER wide lifecycle phases and the corresponding phase review gates as shown below. [RD1]


Phase Review Gates
CDR
PDR
FDR
MRR
DRR
CRR
CCR
ORR
Phases
Conceptual Design (CON)
Preliminary Design (PRE)
Final Design (FIN)
Manufacturing Design & Preparation (MDP)
Manufacturing Delivery (MAN)
Assembly & Installation Preparation (AIP)
Assembly & Installation Execution (AIE)
Testing & Commissioning (COM)
Operations & Maintenance (OPE)

Key: **CDR**: Conceptual Design Review **PDR**: Preliminary Design Review **FDR**: Final Design Review
MRR: Manufacturing Readiness Review **DRR**: Delivery Readiness Review **CRR**: Commissioning Readiness Review
CCR: Construction Completion Review **ORR**: Operation Readiness Review

Figure 2: ITER Phase Review Gates and Phases

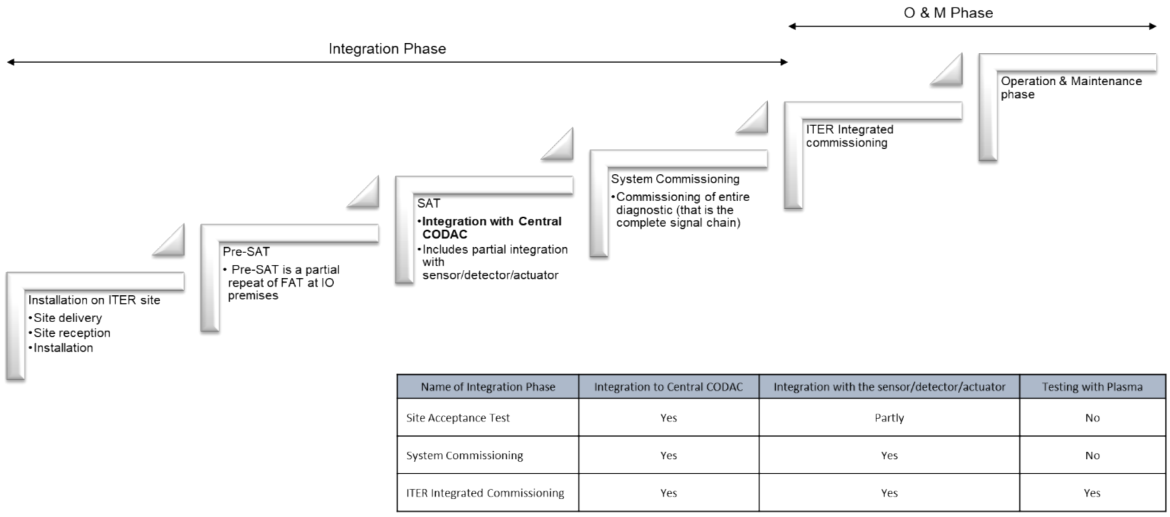
The PCDH [RD2] to which this methodology is compliant, discusses these phases from an I&C perspective. The corresponding text (section 3.3 from PCDH v7.1) has been copied verbatim below, for easy reference.

"

- *A **design phase** in two steps - plant system I&C design followed by a project review …. The two steps are repeated for conceptual, preliminary and detailed design.*
- *A **manufacturing phase** in two steps – plant system I&C manufacture and factory acceptance test. Individual tests of I&C equipment shall be performed during manufacture.*
- *An **integration phase** in three steps – plant system I&C installation on ITER site followed by site acceptance test and system commissioning. Site acceptance test includes integration of plant system I&C subsystems and acceptance tests of the whole plant system I&C if applicable.*

"

For Diagnostic Plant I&C systems, the activities of the integration phase are detailed further in Figure 3. This was presented during the 5th CODAC workshop on Diagnostics Plant I&C, ITER_D_4UKKLT, and is explained in section 2.1.1.


O & M Phase
Integration Phase
Operation & Maintenance phase
ITER Integrated commissioning
System Commissioning
•Commissioning of entire diagnostic (that is the complete signal chain)
SAT
•Integration with Central CODAC
•Includes partial integration with sensor/detector/actuator
Pre-SAT
• Pre-SAT is a partial repeat of FAT at IO premises
Installation on ITER site
•Site delivery
•Site reception
•Installation

Name of Integration Phase	Integration to Central CODAC	Integration with the sensor/detector/actuator	Testing with Plasma
Site Acceptance Test	Yes	Partly	No
System Commissioning	Yes	Yes	No
ITER Integrated Commissioning	Yes	Yes	Yes

Figure 3: Integration Phases Scheme

2.1.1 Integration Phases

Installation on ITER Site

Installation includes the following activities:

- Receiving I&C cubicles at ITER site.
- Inspection of the delivered cubicles (primarily visual).
- Transport of cubicles to their final designated locations.
- Securing the cubicles in place.
- Termination of cables to the I&C cubicles.

IO-CT teams are responsible for this activity:

- Cubicle Installation: PBS 55 issues the HOP (Handover Package), and the Construction Team carries out the installation.
- Cable Termination: PBS 55 (either IO-CT or IO-DA) issues a termination report, which is provided to PBS 44 for HOP issuance. The Construction team then performs cable terminations in the cubicles according to the termination diagram.

Pre-Site Acceptance Test

The Pre-Site Acceptance Test (Pre-SAT) is an optional step that allows partial or full repetition of Factory Acceptance Test (FAT) procedures on ITER site. This is done after the cubicles are installed and power is supplied to the equipment. It is important that the cable terminations do not interfere with the FAT test conditions.

IO-CT (PBS 55) executes or oversees the Pre-SAT. IO-DA supports the execution of the system tests, as needed.

Site Acceptance Test

Site Acceptance Test (SAT) is conducted once the cubicle is fully connected to Central CODAC. The integration with Central CODAC, both physical and functional, is the centrepiece of SAT. Depending on the diagnostic schedule, these tests may be conducted with or without connected sensors and actuators.

IO-CT (CODAC) is responsible for integrating the system with Central CODAC networks and services. IO-CT (PBS 55) is responsible for acceptance testing of the integrated system to ensure that it meets the requirements. IO-DA supports the execution of the acceptance tests, as needed.

System Commissioning

System commissioning involves validation of all diagnostic system functionalities for acceptance, independently of other diagnostics or plant systems. It includes execution of all system functions without plasma. System commissioning begins once all field cables have been fully connected to the I&C cubicles.

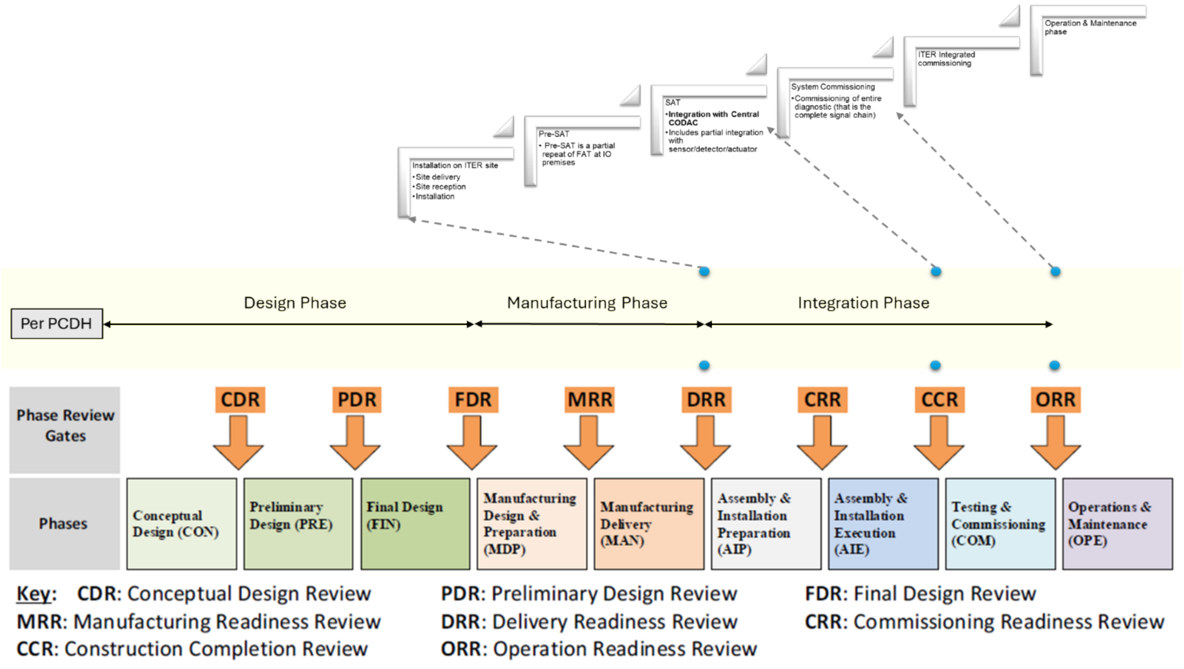
IO-CT (PBS 55) leads the system commissioning for acceptance, with support from IO-DA and IO-CT (CODAC).

Integrated Commissioning

Integrated commissioning, which starts after the end of integration phase, verifies the correct functioning of the diagnostic during plasma pulse operation, together with other diagnostics and plant systems.

IO-CT (Operations) is responsible for integrated commissioning. IO-CT (Diagnostics and CODAC) and IO-DA support the execution of these tests.

Note: The phase review gates depicted in Figure 2, will also be systematically applied to the activities shown in Figure 3. Figure 4 superimposes the two figures.


Installation on ITER site
•Site delivery
•Site reception
•Installation
Pre-SAT
• Pre-SAT is a partial repeat of FAT at IO premises
SAT
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•Includes partial integration with sensor/detector/actuator
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Phase Review Gates
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PDR: Preliminary Design Review
FDR: Final Design Review
MRR: Manufacturing Readiness Review
DRR: Delivery Readiness Review
CRR: Commissioning Readiness Review
CCR: Construction Completion Review
ORR: Operation Readiness Review

Figure 4: Lifecyle Phases Superimposed

2.2 System Lifecycle Model

Vee system lifecycle model has been chosen for development of Diagnostics Plant I&C because of its emphasis on rigorous verification and validation.

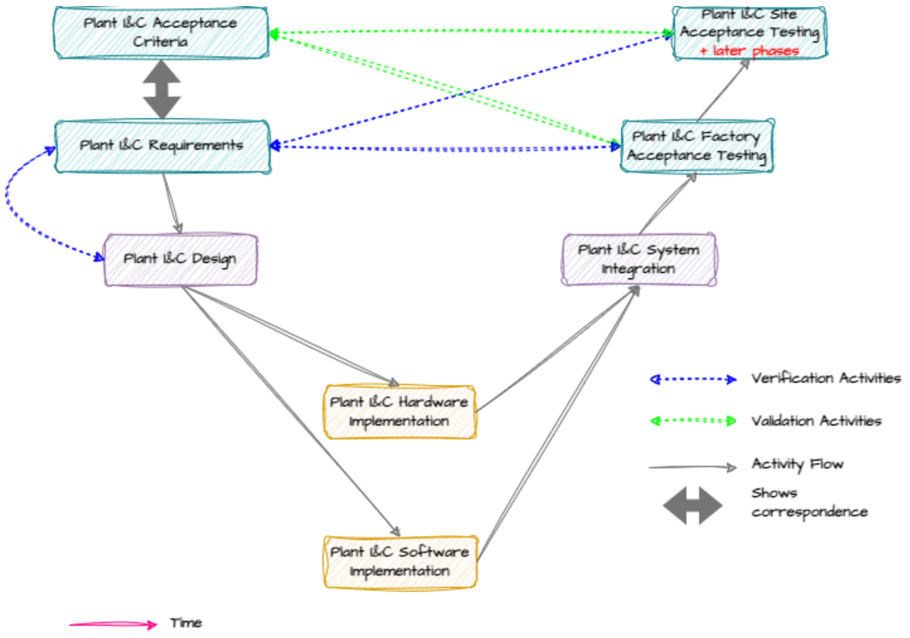

Plant I&C Acceptance Criteria
Plant I&C Site Acceptance Testing + later phases
Plant I&C Requirements
Plant I&C Factory Acceptance Testing
Plant I&C Design
Plant I&C System Integration
Plant I&C Hardware Implementation
Plant I&C Software Implementation
Verification Activities
Validation Activities
Activity Flow
Shows correspondence
Time

Figure 5: System Lifecycle Vee Model

On the left side of the Vee, activities like defining requirements and developing the design focus on system decomposition and planning. The bottom of the Vee represents the implementation phase culminating in integration. The right side of the Vee addresses system validation and testing, including Plant I&C Factory Acceptance Testing and Plant I&C Site Acceptance Testing, ensuring the system meets its operational goals.

Verification activities, represented by blue dashed lines, ensure compliance with requirements at each phase, while validation activities, represented by green dashed lines, confirm that the system fulfills its intended purpose. Acceptance criteria are used for validating the system.

Various activities shown in Figure 5 are also discussed in section 3.5.

2.3 Systems Engineering Process and Method

This section explains the systems engineering process and method (see Figure 6) chosen as part of the methodology. Each aspect of this figure is explained in detail in the following two sections (2.3.1 and 2.3.2).

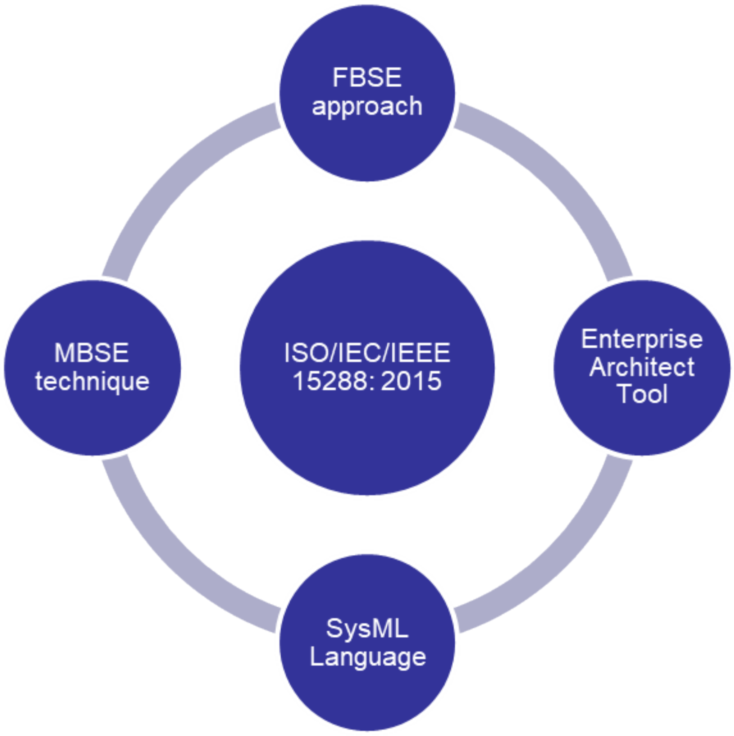


Figure 6: Systems Engineering Process and Method

2.3.1 Systems Engineering Process (The What)

The systems engineering process defines a structured set of activities which are followed to develop, operate, and manage a system throughout its lifecycle. Focuses on **what** needs to be done.

This methodology is based on the systems engineering process standard **ISO/IEC/IEEE 15288:2015**. This standard stands out as the most widely used systems engineering standard due to its international acceptance, comprehensive lifecycle coverage, and adaptability across various industries. The focus of this methodology are the technical processes (6.4.x) only, see Figure 7. These processes can be consolidated as:

- Requirements Management
- Design Definition
- Manufacturing
- Verification and Validation
- Operation and Maintenance

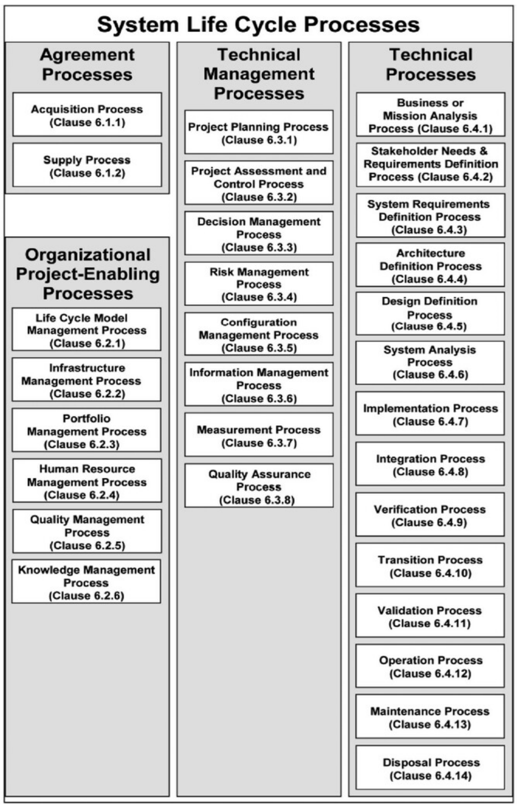

System Life Cycle Processes
Agreement Processes
Acquisition Process (Clause 6.1.1)
Supply Process (Clause 6.1.2)
Organizational Project-Enabling Processes
Life Cycle Model Management Process (Clause 6.2.1)
Infrastructure Management Process (Clause 6.2.2)
Portfolio Management Process (Clause 6.2.3)
Human Resource Management Process (Clause 6.2.4)
Quality Management Process (Clause 6.2.5)
Knowledge Management Process (Clause 6.2.6)
Technical Management Processes
Project Planning Process (Clause 6.3.1)
Project Assessment and Control Process (Clause 6.3.2)
Decision Management Process (Clause 6.3.3)
Risk Management Process (Clause 6.3.4)
Configuration Management Process (Clause 6.3.5)
Information Management Process (Clause 6.3.6)
Measurement Process (Clause 6.3.7)
Quality Assurance Process (Clause 6.3.8)
Technical Processes
Business or Mission Analysis Process (Clause 6.4.1)
Stakeholder Needs & Requirements Definition Process (Clause 6.4.2)
System Requirements Definition Process (Clause 6.4.3)
Architecture Definition Process (Clause 6.4.4)
Design Definition Process (Clause 6.4.5)
System Analysis Process (Clause 6.4.6)
Implementation Process (Clause 6.4.7)
Integration Process (Clause 6.4.8)
Verification Process (Clause 6.4.9)
Transition Process (Clause 6.4.10)
Validation Process (Clause 6.4.11)
Operation Process (Clause 6.4.12)
Maintenance Process (Clause 6.4.13)
Disposal Process (Clause 6.4.14)

Figure 7: System Life Cycle Processes as per ISO 15288

ISO/IEC/IEEE 15288:2015 must be tailored to the specific project needs, which means that the specific processes should be customized based on the complexity, scale, and objectives of the system being developed.

Section 3, explains the adaptation of these processes for Diagnostic Plant I&C development.

2.3.2 Systems Engineering Method (The How)

A systems engineering method describes how the activities are performed and the kinds of systems engineering artifacts that are produced. Focuses on **how** the tasks are performed.

MBSE technique

For Diagnostics Plant I&C development, the Model Based Systems Engineering (MBSE) technique has been chosen. The International Council on Systems Engineering (INCOSE) defines MBSE as "the formalized application of modeling to support system requirements, design, analysis, verification and validation activities beginning in the conceptual design phase and continuing throughout development and later life-cycle phases.

MBSE provides substantial benefits compared to the traditional document-centric approach by resolving inefficiencies, redundancies, and inconsistencies associated with managing fragmented documents across engineering processes. Unlike the document-centric method, where vital design information is dispersed across various formats, MBSE consolidates the design data into a unified, consistent model. This approach enhances traceability, minimizes errors, and boosts productivity through automation of tasks like document generation.

The model enables efficient communication between the stakeholders involved in developing the diagnostic. The model is not intended to be executed (for simulation, code generation).

It is important to note that MBSE is not a simple button; one cannot just push it and expect good things to pop out.

But in truth, MBSE does not (and cannot) eliminate the difficult work of architecting and designing a system well. It does not eliminate the need for engineering rigor during system specification and design—the same rigor that has always been necessary to produce any successful system. (Delligatti, 2013)

FBSE approach

In terms of approach, Functions-Based Systems Engineering (FBSE) approach has been chosen against the Object-Oriented Systems Engineering (OOSEM) approach. This is in line with the PCDH [RD2] view. FBSE’s focus on functional decomposition provides a straightforward framework to design, verify, and validate these systems efficiently. Furthermore, the multidisciplinary nature of design and development teams makes FBSE's simpler, universally understood methodology ideal for ensuring clarity and collaboration.

The key steps in this function-first perspective approach are functional decomposition based on the requirements, allocation of functions to hardware components, and finally the verification and validation against the requirements. Examples of design artifacts of this approach are behavior diagrams and functional flow block diagrams.

Modeling Tool and Language

SysML, the modeling language most widely used among MBSE practitioners has been chosen as the modelling language.

The PCDH recommends Enterprise Architect as the systems engineering tool.

2.4 Architecture Framework (Ontology)

In the realm of MBSE, architecture frameworks are formal structures that are used to organize and manage information expressed in system models. They utilize modeling languages to define and group system views, enabling a comprehensive and structured representation of system behavior and properties. **Ontology** is an important part of the architecture framework, defining the specific vocabulary and relationships within the framework, acting as a "dictionary" for clear communication.

The mains elements of the architecture framework of the Diagnostics Plant I&C methodology are depicted in Figure 8 and Figure 9. The ontology of the MBSE model is depicted in Figure 10. These figures must be seen in conjunction.

This section describes the various elements of the ontology. Figure 8 and Figure 9 are not explained explicitly here but become implicitly clear though the content of this document.

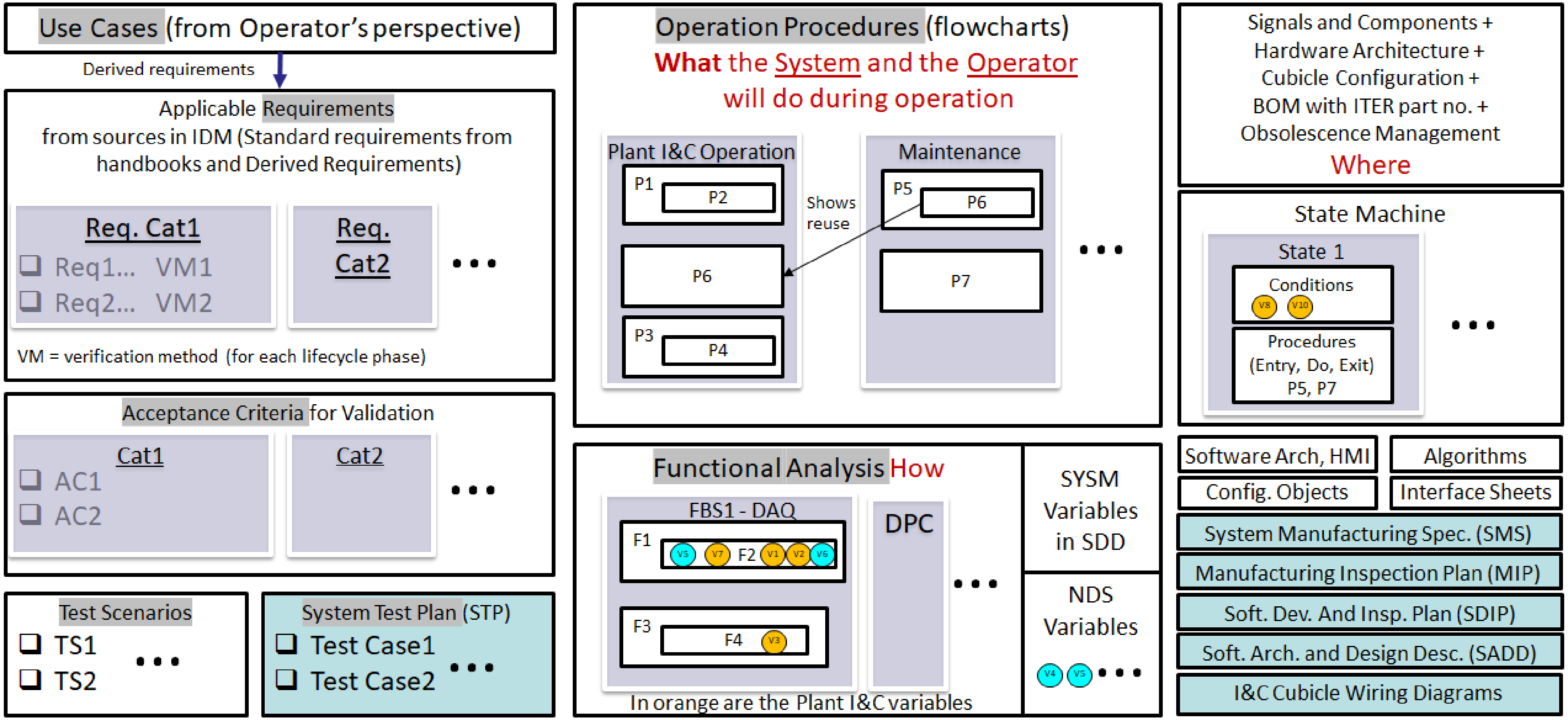


Figure 8: Main Elements of the Architecture Framework

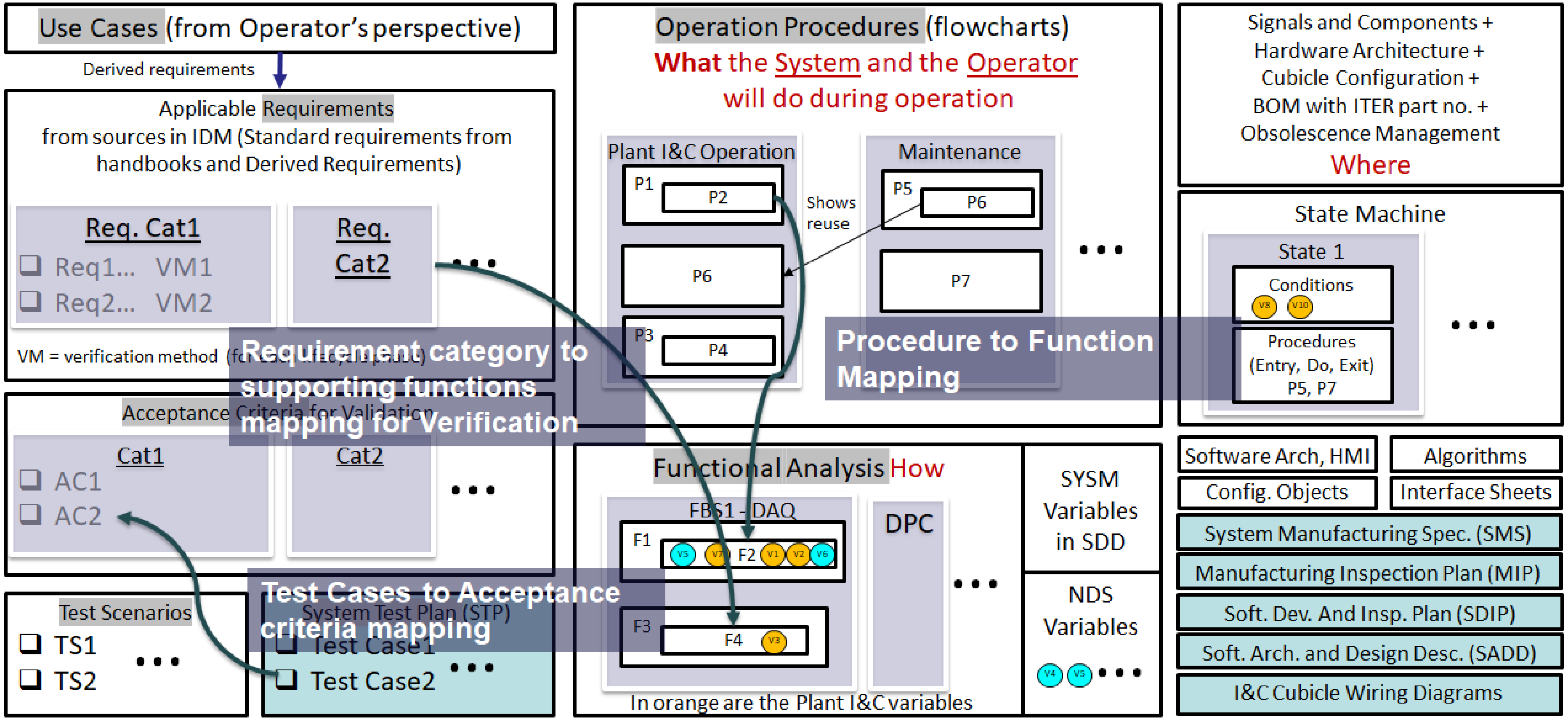

Use Cases (from Operator's perspective)
Derived requirements
Applicable Requirements
from sources in IDM (Standard requirements from handbooks and Derived Requirements)
Req. Cat1
❑ Req1… VM1
❑ Req2… VM2
Req. Cat2
• • •
VM = verification method (for selected input)
Requirement category to supporting functions mapping for Verification
Acceptance Criteria for Validation
Cat1
❑ AC1
❑ AC2
Cat2
• • •
Test Scenarios
❑ TS1
❑ TS2
• • •
System Test Plan (STP)
Test Cases to Acceptance criteria mapping
❑ Test Case1
❑ Test Case2
• • •
Operation Procedures (flowcharts)
What the System and the Operator will do during operation
Plant I&C Operation
P1
P2
P6
P3
P4
Shows reuse
Maintenance
P5
P6
P7
• • •
Procedure to Function Mapping
Functional Analysis How
FBS1 - DAQ
F1
V5
V7
F2
V1
V2
V6
F3
F4
V3
DPC
• • •
In orange are the Plant I&C variables
SYSM Variables in SDD
NDS Variables
V4
V5
• • •
Signals and Components +
Hardware Architecture +
Cubicle Configuration +
BOM with ITER part no. +
Obsolescence Management
Where
State Machine
State 1
Conditions
V8
V10
Procedures (Entry, Do, Exit) P5, P7
• • •
Software Arch, HMI
Algorithms
Config. Objects
Interface Sheets
System Manufacturing Spec. (SMS)
Manufacturing Inspection Plan (MIP)
Soft. Dev. And Insp. Plan (SDIP)
Soft. Arch. and Design Desc. (SADD)
I&C Cubicle Wiring Diagrams

Figure 9: Main Elements of the Architecture Framework (with relations shown)

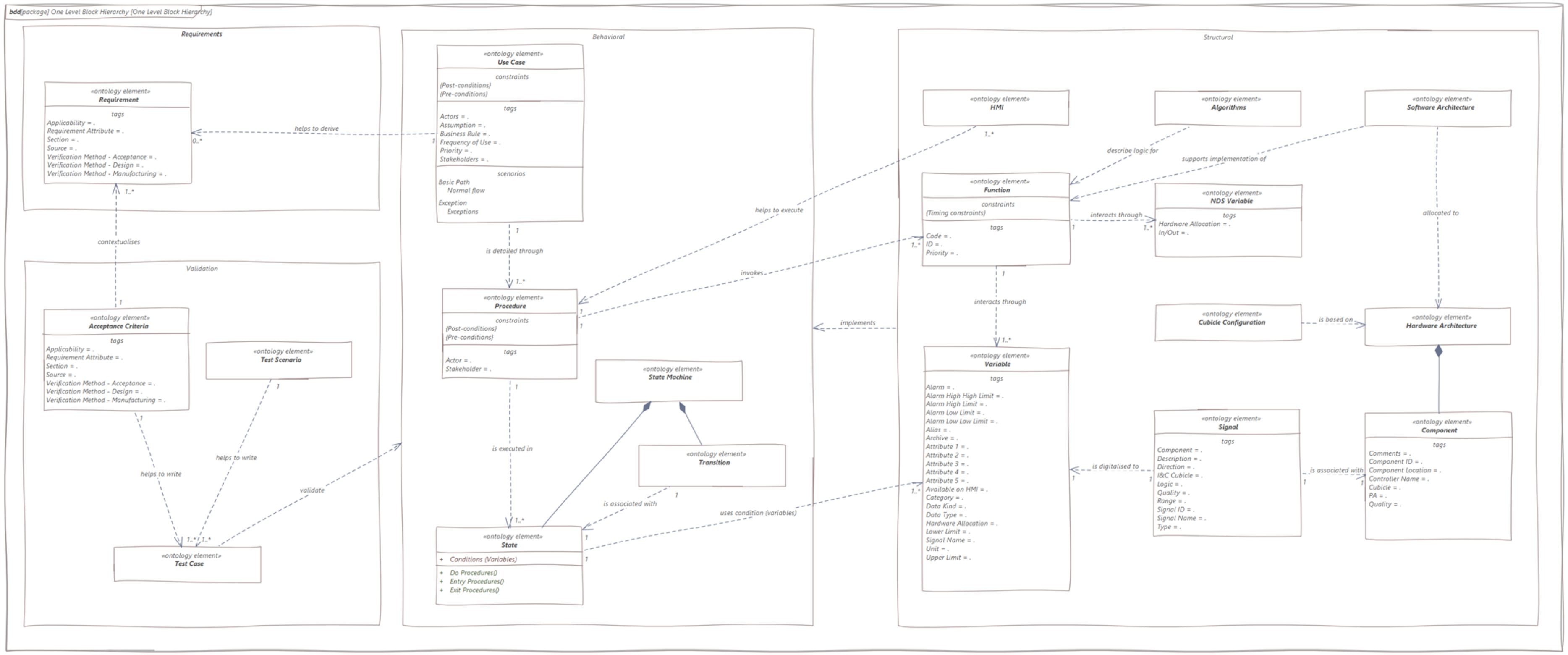


Figure 10: Ontology Diagram

2.4.1 Use Cases

A use case is a statement that expresses an outcome-based capability the user requires from a system, product, or service to enable their achievement of a specific mission or task objective [Wasson, 2015].

In this methodology, defining the use cases is the first step in the consolidation of requirements for a Diagnostic Plant I&C. Through the definition of the use cases, additional requirements — more specifically constraints and elaborations — can be derived for the system. These additions do not expand the requirement scope beyond what is already there in the Procurement Arrangement (PA). A use case may or may not lead to additional constraints and elaborations.

The normal flow of a use case is written from the operator's (user's) perspective specifically focusing on system usage from the Main Control Room (MCR).

2.4.2 Requirements

A requirement is a statement that identifies a system, product, or process characteristic or constraint. It should be unambiguous, clear, unique, consistent, stand-alone (not grouped), and verifiable. Additionally, it must be deemed necessary for stakeholder acceptability [INCOSE, 2010].

In this methodology, the set of applicable requirements are collected mainly from PCDH [RD2] and System Requirement Documents (SRDs, sub-SRDs). These requirements are primarily used for system verification activities.

2.4.3 Acceptance Criteria

As per PCDH [RD2], "*For functional, including process control, and performance test purpose, the plant system shall be tested under a scenario and **acceptance criteria** provided by the ITER plant system RO. This scenario shall include the individual tests of every plant system I&C function with the real process, as much as possible, connected to the plant system I&C and the test of the plant system as a complete autonomous system as close as possible. The full test with the process is part of system commissioning and out of scope of PCDH.*"

Acceptance criteria define the specific conditions that must be met for the system to be considered complete and acceptable. They serve as benchmarks for validating that the requirements have been correctly implemented and meet their intended purpose in the context of the plant system.

Requirements focus on *what the system should do*, while acceptance criteria outline the specific conditions and benchmarks used to validate that a feature or functionality *meets the expectations* of users or stakeholders. While requirements may not always be directly testable, especially if they are high-level or abstract, acceptance criteria are always testable and measurable.

Importantly, acceptance criteria are derived directly from existing requirements and do not introduce new requirements. They facilitate the development of test cases and procedures, bridging the intent of the requirement with the practical assessment of its fulfilment (validation). In other words, acceptance criteria contextualize the requirements for validation. An acceptance criterion may relate to one or more requirements.

Note: Colloquially, a single acceptance criterion is often referred to as acceptance criteria.

2.4.4 Procedures

Operation procedures (or simply procedures) are comprehensive, systematically documented sequences of activities that describe "what the system and operator must do during operation" to achieve specific operational objectives. These procedures model flow-based behavior and support various use cases throughout the system lifecycle, ensuring consistent, safe, and effective system operation.

Operation procedures are modeled as Activity Diagrams (similar to flowcharts) in a hierarchical manner. At the lowest level, the procedure is typically broken down into a few actionable steps (4-5). These steps, in turn, invoke the I&C functions, see section 2.4.5.

Formally, an activity represents a flow of functional behaviors, optionally including data flows [SysML.org]. Flows can be sequential or parallel, with parallelism indicated by Fork and Join Nodes. In this methodology, the definition of data flows is not anticipated to reduce complexity in the design.

Each procedure is sufficiently detailed to encompass all activities necessary to achieve its objectives. Even when tasks are automated (i.e., implemented in the I&C logic), all underlying steps must still be explicitly documented.

These procedures address all facets of operation, including tokamak operation, expert operation, maintenance, system conditioning, exception detection, exception handling, FAT, SAT, system commissioning, ITER integrated commissioning, plant protection, and occupational safety.

The use cases for the system are further detailed through the definition of operation procedures. In other words, use cases provide the conceptual framework for system interaction, while operation procedures break this framework down into practical, executable steps.

Note 1: Sequence diagrams, which model message-based behavior are not officially part of the ontology. However, if such diagrams are required, they can be documented (see section 2.4.6).

Note 2: Another way to look at activity diagrams is that they describe “how” the system behaves.

2.4.5 Functions

According to ISO/IEC/IEEE 24765:2010, functional design is defined as the specification of the functions of a system’s components and the working relationships among them.

This methodology, defines functional design through a Functional Breakdown Structure (FBS), also referred to as functional analysis. The FBS is a hierarchical decomposition of the system's functional architecture into its constituent functions (precisely I&C functions) and their associated variables. A key outcome of this process is the list of variables, which serve as the functional interface with Central I&C.

While procedures describe what the system and operator do to achieve operation goals, functions and variables define how these capabilities are implemented within the system.

The methodology differentiates between **Plant I&C variables** and **device support variables,** each of which has its own naming convention.

Note 1: Defining functions with inputs and outputs primarily focuses on the system's functional architecture (structural modeling), which is a static description of its capabilities. Conversely, procedures represent behavioral modeling, describing how the system behaves from an operational perspective during function execution.

Note 2: Another way of looking at functions is that they describe “what” the system is functionally capable of achieving, independent of its operational context.

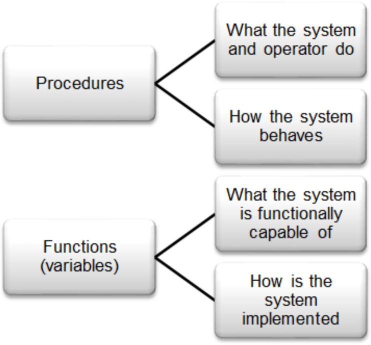

Procedures
What the system and operator do
How the system behaves
Functions (variables)
What the system is functionally capable of
How is the system implemented

Figure 11: Conceptual Understanding - Procedures and Functions

Note 3: The logic behind each function is explained in its description. If the logic is complex, it is documented as algorithms (section 2.4.6). Also, the names of functions and variables often give useful information about what they do.

2.4.6 Algorithms

An algorithm is a well-defined computational process that takes input data, processes it according to specific rules, and generates output data [Cormen et al., 2009].

In this ontology, the algorithms represent the processes required to produce the final diagnostic measurements relevant for all roles (machine protection, basic control, advanced control, physics or maintenance). As shown in Figure 10, algorithms describe the (complex) logic implemented by functions.

2.4.7 State Machine

As per ISO/IEC/IEEE 24765:2010, finite state machine is a computational model consisting of a finite number of states and transitions between those states, possibly with accompanying actions.

In this ontology, the state machine represents the Plant System Operating State (PSOS) state machine that must be implemented as per PCDH [RD2] Requirement 122.

Key elements of every state in the state machine are the procedures (entry, do, exit), conditions and transitions (triggers, guards).

- Procedures: Behaviors associated with each state:
  - Entry procedures execute when the system enters the state.
  - Do procedures execute while the system remains in the state.
  - Exit procedures execute when the system exits the state.
- Conditions: Specific conditions (represented by variables) that hold true while the system is in a state.
- Transitions: Define movement between states. A transition occurs when a trigger is activated and, if necessary, when a guard condition evaluates to true.

2.4.8 Hardware Architecture

The hardware architecture is a view of the physical architecture that represents the hardware components and their interrelationships [Friedenthal, 2015].

In this architecture framework, the hardware architecture is modeled through the definition of signals and components. It is documented using detailed diagrams and textual descriptions, offering insights into the system's physical structure, strategies for integrating COTS intelligent devices (or simply COTS devices) into the CODAC environment, and managing obsolescence. For definition of a COTS device, refer section 3.4.7.1.

2.4.9 Software Architecture

Formally, software architecture is defined as a “set of structures needed to reason about the system, which comprise *software elements, relations among them, and properties of both*” [SWEBOK v3].

This ontology element documents the software architecture of the system. It corresponds to the hardware architecture (2.4.8) and must be consistent with the CODAC Core System development guidelines [RD24].

2.4.10 HMI

As per ISO/IEC/IEEE 24765:2010, a Human Machine Interface (HMI) enables information to be passed between a human user and hardware or software components of a computer system.

HMI screens enable the execution of procedures and support capabilities such as monitoring, control, visualization, diagnosis, and management. In this ontology, they represent mockups and descriptions of the proposed HMI screens.

2.4.11 Cubicle Configuration

The Cubicle Configuration ontology element represents the design and configuration of I&C cubicles based on the hardware architecture (2.4.8). It includes detailed specifications for local control and signal conditioning cubicles, addressing key design aspects such as bills of materials, electrical power load calculations, heat dissipation, electromagnetic compatibility requirements, and cooling system design. Additionally, it incorporates mechanical considerations, including enclosure types, cable entry design, weight distribution, and the spatial layout of the cubicles, ensuring a comprehensive and holistic approach to cubicle configuration and design. Location-specific installation requirements are also taken into account.

2.4.12 Test Scenarios

Test scenarios define precisely what needs to be tested and conceptually how it will be tested. They reflect the technical responsible officer's expectations for testing the system (and can be thought of as testing use cases).

2.4.13 Test Cases

IEEE 1012-2004, defines a test case as documentation specifying inputs, predicted results, and a set of execution conditions for a test item.

In this ontology, test cases are more granular, implementation-specific descriptions of how the system will be tested. They are typically developed during the manufacturing phase and outline the precise steps involved in testing.

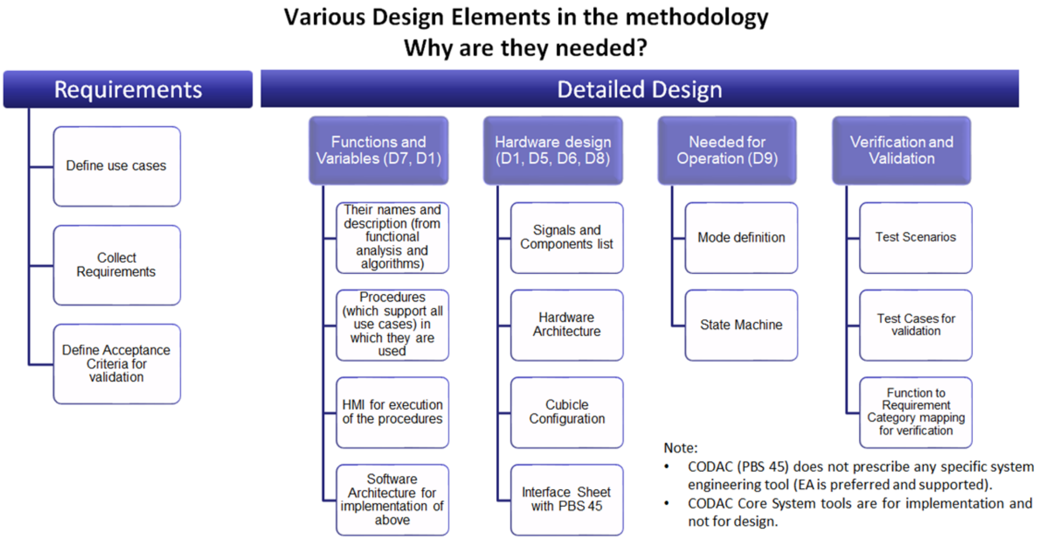
Test Scenarios (2.4.12) and Acceptance Criteria (2.4.3) help to write detailed test cases for validating the system.

2.5 Additional Notes

2.5.1 Why are the Various Design Elements Needed?

Figure 12 illustrates the mapping between the design elements and their alignment with the PCDH deliverables list. Detailed design involves defining functions and variables, designing hardware, and fulfilling operational needs. Verification and validation activities are indispensable in this process.

The primary interface with CODAC includes both physical networks (as described in the IS) and logical interfaces (variables/functions detailed in the IDS). The design documentation provides complete information about the use of functions in operational procedures via the HMI. A mere list of functions and variables, without the relevant context, is of limited value. These functions are implemented in hardware installed within the I&C cubicles.


Various Design Elements in the methodology
Why are they needed?
Requirements
Define use cases
Collect Requirements
Define Acceptance Criteria for validation
Detailed Design
Functions and Variables (D7, D1)
Their names and description (from functional analysis and algorithms)
Procedures (which support all use cases) in which they are used
HMI for execution of the procedures
Software Architecture for implementation of above
Hardware design (D1, D5, D6, D8)
Signals and Components list
Hardware Architecture
Cubicle Configuration
Interface Sheet with PBS 45
Needed for Operation (D9)
Mode definition
State Machine
Verification and Validation
Test Scenarios
Test Cases for validation
Function to Requirement Category mapping for verification

Note:
- CODAC (PBS 45) does not prescribe any specific system engineering tool (EA is preferred and supported).
- CODAC Core System tools are for implementation and not for design.

Figure 12: Why are the Various Design Elements Needed?

2.6 List of Document Deliverables

Table 2-1 lists the various document deliverables (compliant with [RD16]) that are required to be produced. The figure also indicates the stage at which they are required and their corresponding maturity levels. The different maturity levels, as defined in [RD17] (except MT which is an addition for additional precision), are as follows:

- ✕: Not Required
- PL: PreLiminary
- CS: ConSolidated (**~detailed**)
- CP: ComPlete (**~final**)
- UD: UpDate of CP, if requirements changed
- MT: Maintenance of CP, if implementation changed

In line with [RD23], this methodology considers both PDR (Preliminary Design Review) and FDR (Final Design Review) as **detailed designs**, and the scope of design work has been divided between PDR and FDR (section 3.4.1).

Table 2-1: List of Document Deliverables

Lifecycle Stage / Document Deliverables	CDR	PDR	FDR	MRR	FAT	SAT	System Commissioning
I&C Deliverables Overview	**CS**						
IS (Interface Sheet) with PBS 45, PBS 47 (if applicable)	**PL**	**CS**	**CP**	UD/MT	UD/MT	UD/MT	UD/MT
I&C SRS (System Requirement Specification)	X	**CS**	**CP**				
I&C SDS (System Design Specification) Note: The I&C SDS includes I&C Cubicle Configuration, Hardware Architecture, and Software Architecture documentation, which may also be provided as separate IDM document(s) referenced within the I&C SDS.	X	**CS**	**CP**				
I&C STP (System Test Plan)	X	X	**PL**[*]	**CS**[#]	**CP**	**CP**	**CP**
I&C SMS (System Manufacturing Specification)	X	X	X	**CP**	UD/MT	UD/MT	UD/MT
I&C SADD (Software Architecture and Design Description) for QC2 and QC3 systems	X	X	X	**CS**	**CP**	UD/MT	UD/MT
I&C Cubicle Wiring Diagrams	X	X	X	**CP**	UD/MT	UD/MT	UD/MT
I&C OMM (Operations and Maintenance Manual)	X	X	X	X	**CS**	**CS**	**CP**
I&C STR (System Test Report)	X	X	X	X	**CP**	**CP**	**CP**
EA Project	X	**CS**	**CP**	UD/MT	UD/MT	UD/MT	UD/MT

* - At FDR, the I&C STP is expected to include only the test scenarios.

# - At MRR, the I&C STP is expected to outline the test cases, excluding granular, minute-level details. For a test case, its *Name*, *Description*, *Associated Acceptance Criteria* and *Pass/Fail Criteria* is expected. If known, high level *Procedure* steps can also be added.

Also, refer Appendix I for a mapping between PCDH I&C Design Deliverables to I&C SRS and SDS documents. Table 2-1 is also consistent with the rest of the PCDH deliverables.

Note: The I&C STP and I&C STR are displayed in different colors for the FAT, SAT, and System Commissioning stages to reflect the fact that each stage will have a distinct test plan, although there will be some overlap in content. This approach is explained in [RD5].

3 Methodology Execution

This chapter presents the working instructions for implementing the Diagnostics Plant I&C methodology. For this guideline documents and user manuals are referred to.

The goal is to specifically identify the expected outputs for every systems engineering process (see section 2.3.1).

3.1 Supporting Resources

This section introduces some resources (guidance, tools and source code) which are available to support the Plant I&C designer/developer in their work. These resources have been introduced at the very beginning, and therefore the details of these resources may appear overwhelming at first. But their relevance will become apparent as one gains a fuller understanding of the broader context.

3.1.1 Common Solutions Repository

In the spirit of collaboration, a collection of common solutions has been compiled. These resources, **spanning diverse topics/areas**, aim to support reuse and reduce duplication of effort where possible.

While some solutions are more mature than others, all have been made available with the hope that they will prove useful in part or in whole. The repository can be explored at the IDM location DUCXUU, and contributions or feedback are always welcome as these resources continue to evolve.

3.1.2 Checklists

In addition, checklists have been created to support work in specific areas. These checklists are available to designers, developers and reviewers at the IDM location DUCUP2.

3.2 For CDR

At the CDR stage, the focus is on defining the I&C use cases. Use cases form an essential aspect of conceptual design, focusing on operational principles. For CDR, a basic document (I&C Deliverables Overview) needs to be produced. Please refer IDM location DCMQHS, for examples of this.

3.3 Requirements Management

The two subtopics of requirements management are the consolidation of I&C requirements and the definition of acceptance criteria.

3.3.1 Consolidation of I&C requirements

The key activities to be done as part of requirements management include writing the use cases (section 2.4.1) and consolidating the I&C requirements (section 2.4.2). At a broader level, an Excel file needs to be populated with the use cases and requirements (see Figure 13). The artifact (outcome) produced from this activity is the I&C SRS document.

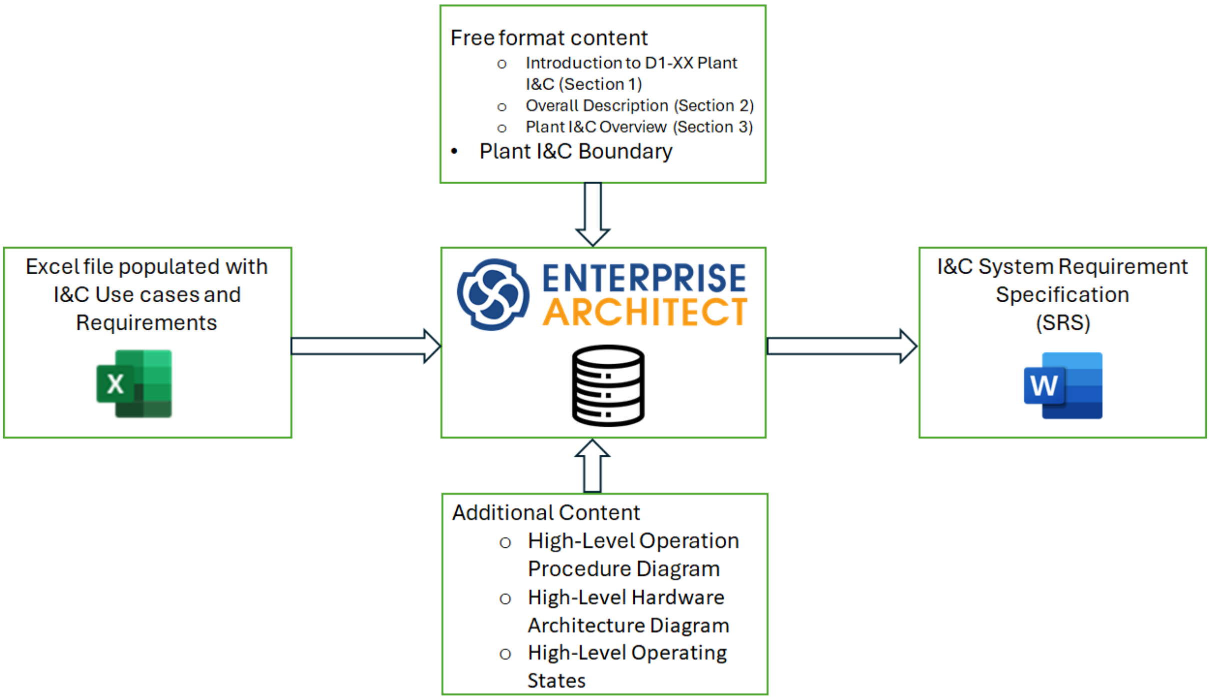

Free format content
Introduction to D1-XX Plant I&C (Section 1)
Overall Description (Section 2)
Plant I&C Overview (Section 3)
Plant I&C Boundary
Excel file populated with I&C Use cases and Requirements
ENTERPRISE ARCHITECT
I&C System Requirement Specification (SRS)
Additional Content
High-Level Operation Procedure Diagram
High-Level Hardware Architecture Diagram
High-Level Operating States

Figure 13: Requirements Management - High Level Overview

The detailed steps are as follows:

3.3.1.1 Core Content of the I&C SRS

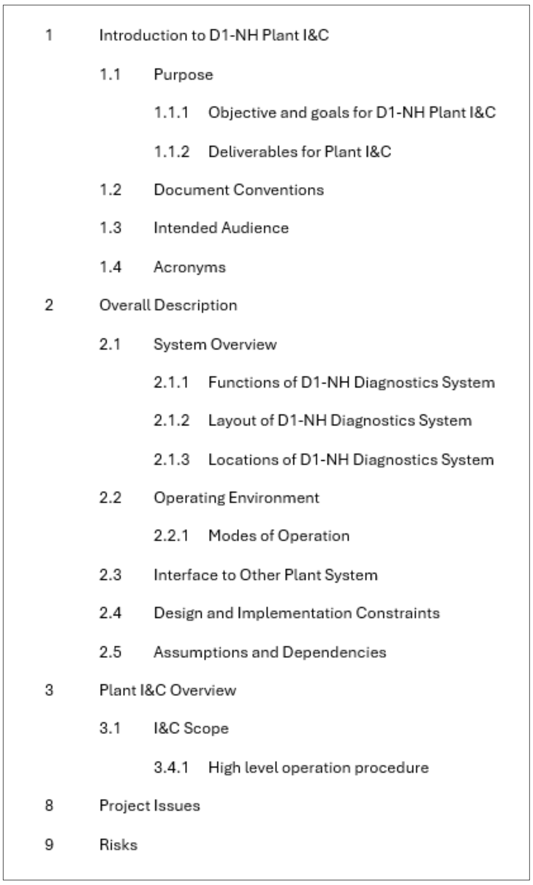
1. As explained in section 2.4.1, use cases are the first step in consolidating requirements for a Diagnostic Plant I&C. [RD4] provides instructions for writing use cases, along with examples. Additionally, refer to location CG2V3X in IDM, which contains links to good examples of I&C use cases.
2. After defining the use cases, use [RD5], which provides instructions for consolidating the I&C requirements. Specifically, refer to the sections titled "Diagnostics Plant I&C Requirements" and "Steps for Writing Requirements" in [RD5].
   To extract additional requirements, more specifically constraints and elaborations, refer to the section titled "Requirement Propagation from Use Cases to S-SRD" in [RD5].

   Note: As part of the instructions for consolidating the I&C requirements, it is essential to define a specific verification method for each phase. These phases are
   - Design (verification at FDR)
   - Manufacturing (verification at FAT)
   - Acceptance (verification at SAT and subsequent review gates)

   This should be done for each applicable requirement. Defining verification methods by phase supports the verification activities (section 3.5). If the verification method is not defined for future phases (that is Manufacturing and Acceptance) by the time of the FDR, it must be defined at a minimum by the MRR.
3. Once the Excel file has been populated, use the *Plant I&C Requirements add-in [RD9]* to import this Excel file into the Enterprise Architect (EA) project.
4. Free-format sections
   i. The free-format sections should be directly entered into the corresponding *document artifacts* in the EA project. Figure 14 shows the different free-format chapters/sections in the document, along with their section numbers.

ii. These *document artifacts* are automatically created when an EA project is initialized using the *EA Model Verification and Configuration add-in [RD9]*. To determine which document artifact corresponds to each I&C SRS section, refer to the "Free Format Chapters" section in [RD10].

Please refer to I&C SRS examples in location CW6FYE to understand the information expected in these free-format sections. There is no fixed guideline about what to include in these sections.



1 Introduction to D1-NH Plant I&C
1.1 Purpose
1.1.1 Objective and goals for D1-NH Plant I&C
1.1.2 Deliverables for Plant I&C
1.2 Document Conventions
1.3 Intended Audience
1.4 Acronyms
2 Overall Description
2.1 System Overview
2.1.1 Functions of D1-NH Diagnostics System
2.1.2 Layout of D1-NH Diagnostics System
2.1.3 Locations of D1-NH Diagnostics System
2.2 Operating Environment
2.2.1 Modes of Operation
2.3 Interface to Other Plant System
2.4 Design and Implementation Constraints
2.5 Assumptions and Dependencies
3 Plant I&C Overview
3.1 I&C Scope
3.4.1 High level operation procedure
8 Project Issues
9 Risks

Figure 14: Free-Format Chapters/Sections in I&C SRS

5. References (I&C SRS section 1.5) - In the I&C SRS, references (reference documents) are populated from the *D1-XX Reference Documents* package in the EA project. This package is populated when the EA project is initialized using the *EA Model Verification and Configuration add-in [RD9]*. These references can be edited as required.
6. Plant I&C Boundary - For defining the Plant I&C Boundary, refer to the section titled "Plant I&C Boundary" in [RD10].

3.3.1.2 Additional Content of the I&C SRS

7. The I&C SRS also includes other information that, while primarily part of the I&C SDS, is included in the I&C SRS at a high level. These include:
    a. High-Level Operation Procedure Diagram: This is the Level 0 activity diagram for Tokamak operation procedures. Refer to section 3.4.3.
    b. High-Level Hardware Architecture Diagram: Refer to section 3.4.7.
    c. High-Level Operating States: Refer to section 3.4.6.
8. Using the *Plant I&C Document Generation add-in [RD9]*, the I&C SRS document can be generated.

3.3.1.3 Summary of contents of the I&C SRS (beginner-friendly)

- Section 2 focuses on the diagnostic from an I&C perspective, providing context to the I&C SRS document. It discusses the system's functions, layout, specific installation locations, operational modes, functional interfaces with other plant systems, design and implementation constraints, as well as assumptions and dependencies within the Plant I&C.
- Section 3 presents the operational principles plant I&C, including its main operation procedures, scope, actors, stakeholders, and boundaries, giving an overview of its operational aspects.
- Section 4 details the system's use cases and requirements, representing the core of the document. It includes functional requirements, non-functional requirements, interlock requirements, and safety requirements. Designers are tasked with defining a verification method for each requirement, choosing from inspection, test, engineering review, or analysis. A verification method must be assigned for each lifecycle phase: design (at FDR), manufacturing (at FAT), and acceptance (at system commissioning).
- Section 5 identifies the list of requirements that do not apply and provides reasons for their exclusion.
- Section 6 outlines the high-level functional breakdown of the Plant I&C. This breakdown, extending up to level 2, is different from the diagnostics IDEF0 scheme.
- Section 7 includes a high-level I&C hardware architecture diagram and a depiction of high-level operating states (PSOS states).
- Sections 8 and 9 capture the issues and risks associated with the design and implementation of the Plant I&C.

3.3.2 Definition of Acceptance criteria

Section 2.4.3 describes the ontology element acceptance criteria. Acceptance criteria should be defined and then imported into the EA project using the *Verification and Validation add-in [RD9].* IO-CT has provided a standard list of acceptance criteria [RD14], which does not focus on measurement acceptance criteria. Therefore, designers must ensure that they also define the relevant measurement acceptance criteria (which are derived from existing requirements) for their system, along with the Diagnostic TRO (Technical Responsible Officer).

Note 1: Acceptance criteria are not included in the I&C SDS document.

Note 2: Acceptance criteria support the validation activities (section 3.5).

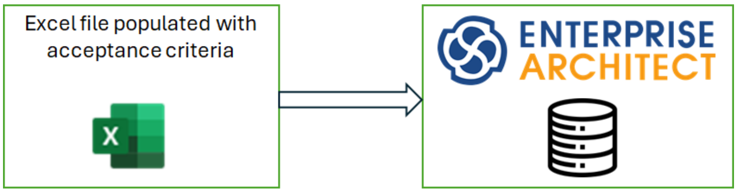


Figure 15: Acceptance Criteria: High Level Process Overview

3.4 Design Definition

3.4.1 Split of work between PDR and FDR

The design elements within this methodology can be divided between PDR and FDR phases. Table 3-1, presents a proposed split, but teams may choose to structure their work differently. Items with a light blue background are expected to be completed during the FDR phase.

The 'Weightage' column indicates the estimated average effort required by experienced designers to complete each item. The actual effort may differ from system to system and depending on the team's experience. The weightage for the hardware architecture assumes the use of CODAC-supported hardware from the catalog. However, integration of new COTS devices requires additional effort, which is not reflected in the weightage. Additionally, the weightage assumes a proficient team for the manufacturing phase.

In the proposed split, PDR work aims to complete more than 50% of the total design work (which means that at PDR, not all PDR topics are fully completed). It is important to note that even with 50% of the total work completed at PDR, the system would be considered to have reached 100% (50%*2) PDR maturity. However, a minimum of 90% PDR maturity is desired to proceed with the PDR meeting. Similarly, a minimum of 90% FDR maturity is desired to proceed with the FDR meeting.

Table 3-1: Proposal for split of work between PDR and FDR

Topic (total weightage)	Sub-topic	Weightage (5 units = 1 person month)
Procedures (15)	Operation Procedures	8
	Exceptional Detection and Handling Procedures	2
	Procedures to Function Mapping	5
Functions and Variables (40)	Functions including Device Support functions	12
	Acceptance Criteria (for Validation)	3
	Function Processing Diagrams/ Input variables[1]	5
	Algorithms	2.5
	Function to Requirement Category Mapping (for Verification)	2.5
	Variables with name attributes 1 and 3. Also includes Device Support variables, Smart Conditions	10
	Variable name attributes 2,4,5 and non-name attributes (importantly Hardware Allocation)	5
Hardware Architecture (33)	Signals and Components	5
	Hardware Architecture (includes software architecture)	13
	Obsolescence management plan[2]	2
	Cubicle Configuration	7
	Bill of Materials (BOM)	4
	ITER Part Number[3]	2
State Machine (7)	States	4
	Allocation of procedures to states, mapping of conditions to states	3
HMI (3)	HMI	3
Test scenarios (2)	Test scenarios	2

1 - This item refers to defining input variables for the Plant I&C functions.

2 - This item is not a separate artifact. The obsolescence management strategy should be explained along with the hardware architecture.

3 - The Part Number of ITER (PNI) identifies interchangeable parts. A PNI is required for all items in the Bill of Materials (BOM) at MRR stage. It remains included in Table 3-1 to encourage early generation of PNIs for finalized items, assuming they have not already been generated. The I&C components are registered in SmartPlant and SEE Electrical Expert (SXP) databases.

3.4.2 Line of thought

When designing the Plant I&C, care should be taken to ensure that *familiar* (to the development team) I&C hardware and software **do not dictate** the Plant I&C use cases, requirements, and operational procedures.

Note: As per the PCDH, it is recommended that first preference must always be given to selecting products from the PCDH catalogues. This ensures that the selected solutions are integrated within the ITER I&C system and promote standardization. Only when no suitable solution exists in the PCDH catalogues should the COTS market be explored, to identify an appropriate product.

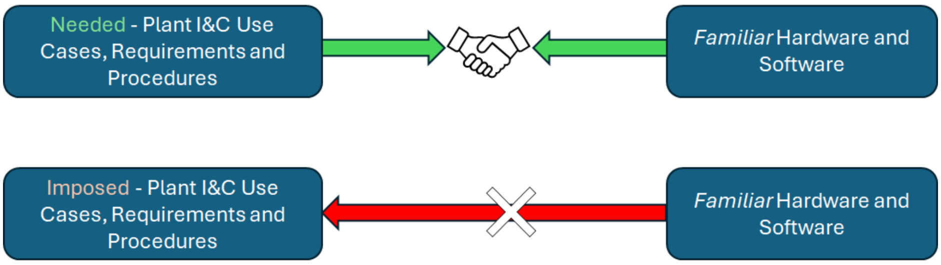

Needed - Plant I&C Use Cases, Requirements and Procedures
Familiar Hardware and Software
Imposed - Plant I&C Use Cases, Requirements and Procedures
Familiar Hardware and Software

Figure 16: Line of Thought

3.4.3 Operation Procedures

Section 2.4.4 describes the ontology element operation procedure. The operation procedures can be developed either using the empty Excel template (recommended, see Figure 17) or using the *Activity Diagram add-in [RD9]* editor. Both these methods are explained in the user manual of *Activity Diagram add-in [RD9].*

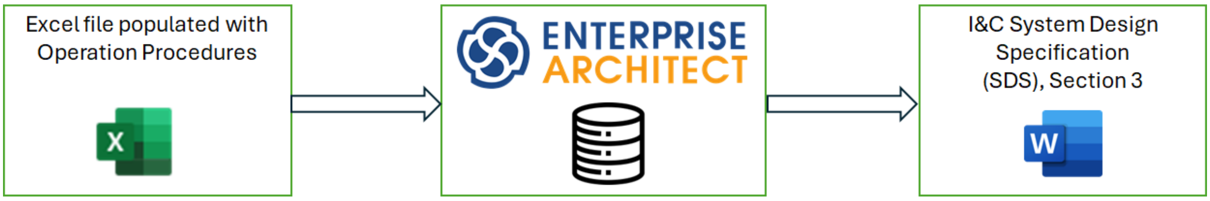

Excel file populated with Operation Procedures
X
ENTERPRISE ARCHITECT
I&C System Design Specification (SDS), Section 3
W

Figure 17: Operation Procedures: High Level Process Overview

For examples of operation procedures, refer to IDM location CG356F. Some concepts to keep in mind while developing these procedures are explained below.

3.4.3.1 Fixed Level 0 procedures

The Level 0 procedures are fixed, namely:

- **Tokamak Operation** (procedures executed during pulse operation).

- **Expert Operation** (specialized procedures executed by the diagnostic expert, e.g., calibration)
- **System Conditioning** - Conditioning applies mainly to high power devices like gyrotrons, waveguides, lasers and high voltage power supplies. Power levels are slowly raised to achieve nominal performance at the end of conditioning. It is a preparatory process required for a subsystem to achieve its intended performance.

  Tuning and warm-up procedures are also considered part of system conditioning. For example, laser's warm-up process.
- **Plant Protection** (procedures, if any, for protection of Plant I&C components). These are not *interlock* grade procedures coordinated by PBS 46. For e.g., in the event of a fan failure within an I&C cubicle, the plant protection procedure ensures that timely action is taken to prevent overheating and protect sensitive components from potential damage.
- **Safety Procedure** (procedures for occupational safety, implemented as part of conventional control). These are not *occupational safety* procedures coordinated by PBS 48.
- **Exception Detection** (procedures to identify abnormal behavior and faults in the system).
- **Exception Handling** (procedures that define the system's fault response strategy)
- **Maintenance Procedure** (maintenance related procedures). The maintenance procedures documented in the EA project should focus on the maintenance of non-standard components specific to the diagnostic system. This information can later be used to complete all maintenance related documentation.
- Special Procedure (a placeholder for procedures not covered under any of the other categories)
- FAT Procedure
- SAT Procedure
- System Commissioning (procedures for the commissioning of individual diagnostic)
- Integrated Commissioning (procedures for ITER integrated commissioning involving the specific diagnostic, in coordination with other diagnostics and plant systems)

The procedures in **bold** are the most significant to define during the design phase. The other procedures can be defined at a conceptual level. These exist because, initially, it was unclear whether the test cases (section 2.4.13) — containing the detailed test procedures — would be documented in the EA project or not. Later, it was decided to leave this information outside the EA project. However, the test scenarios (section 2.4.12) and the acceptance criteria (section 2.4.3) remain documented in the EA project.

Note: In the EA project, the procedure "Tokamak Operation" appears with a **legacy** name "Plant I&C Operation (Tokamak Operation)". Similarly, the procedure "Plant Protection" appears with a legacy name "Plant Protection (Interlock)".

3.4.3.2 Understanding the Essence of Procedures

The different types of tasks (activities/steps) that can be carried out in a procedure are:

- Manually by operator using I&C functions (e.g., moving optics using stepper motor)
- Manually by operator, without using an I&C function (e.g., physically turning on a power supply). This is the less preferred option for obvious reasons.
- Through automation - Tasks relying solely on I&C functions, will have the option to be completely automated.

  Note 1: Complete automation may not be possible, as the operator will need to remain in the loop for certain tasks.

  Note 2: Procedures can be automated using state machine or a sequencer.

<u>When documenting the operation procedures, always document them as if they are to be executed manually. Otherwise, detailed design will never get documented. Automation can be introduced later.</u>

For example, to perform the "obtain new calibration coefficients" task, all the related activities/steps must be defined such as

1. Switch on the calibration light source.
2. Move optics to the calibration position.
3. Measure light input from the calibration source.
4. Measure light output from the optical instruments.
5. Calculate calibration maps for the optical instruments.
6. Save calibration maps to the calibration database.
7. Move optics back to the measurement (resting) position.
8. Switch off the calibration light source.

In the activities/steps listed above, it is possible (if only I&C functions are used) for all activities/steps to be automated. However, the design must still list all these activities/steps and not condense them into a single step such as "Click on button - obtain new calibration coefficients."

3.4.3.3 Concept of Reference Procedures

Reference procedures are modular, reusable procedures that other procedures can utilize. The main idea is to avoid duplicating the same procedure in multiple locations. For more information on this concept, see the section titled "Concept of Reference Procedures" in [RD10].

3.4.3.4 Exception Detection and Handling Procedures

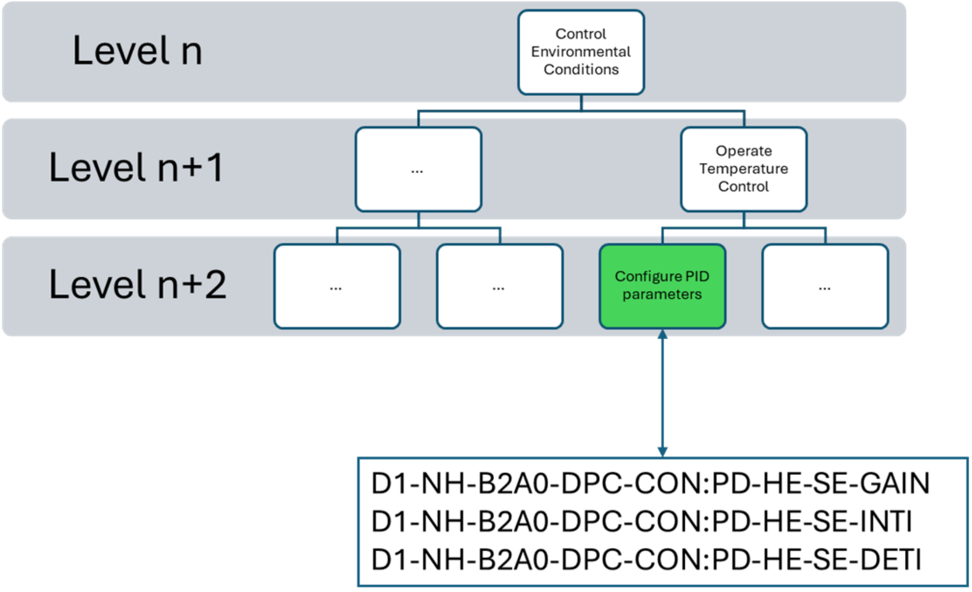
The exception detection and exception handling procedures in the EA project must be linked together to understand how the different exceptions are handled.

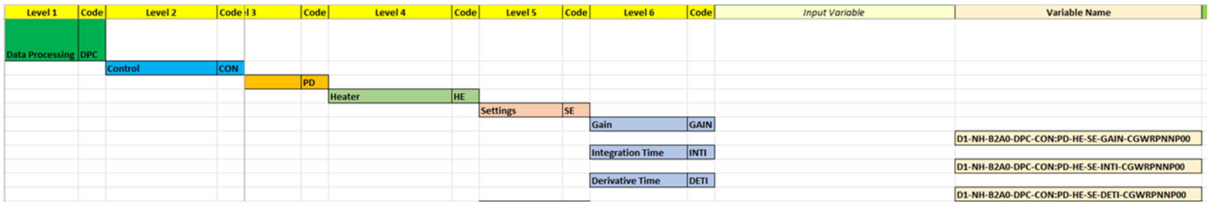
This link can either be created within the EA project itself, or a separate document or table (for example, this document) can be developed to illustrate this connection. This document may be submitted as an attachment to the I&C SDS in IDM, or alternatively, the table can be incorporated as a free-format chapter in the EA project, following the guidelines outlined in section 2.16.8 of [RD10] v1.1.

3.4.3.5 Linking Procedures to Functions

The methodology requires that operational procedures be linked to the functions (specifically Plant I&C functions, section 3.4.4). This is sometimes referred to as procedure-to-function mapping and is required to ensure that all procedures have the necessary functions explicitly defined in the design. This linking can be achieved either by defining the corresponding functions in the procedures Excel file or by using the *Design Mapping Editor add-in [RD9].* The method of defining functions in the procedures Excel file is explained in the user manual of the *Activity Diagram add-in [RD9].*

An example of procedure to function mapping is shown in Figure 18. The lowest level procedure, “Configure PID parameters”, is mapped to three Plant I&C functions. The definition of these functions in the Plant I&C FBS is also shown at the bottom.


Level n
Control Environmental Conditions
Level n+1
...
Operate Temperature Control
Level n+2
...
...
Configure PID parameters
...
D1-NH-B2A0-DPC-CON:PD-HE-SE-GAIN
D1-NH-B2A0-DPC-CON:PD-HE-SE-INTI
D1-NH-B2A0-DPC-CON:PD-HE-SE-DETI



Level 1	Code	Level 2	Code	l 3	Code	Level 4	Code	Level 5	Code	Level 6	Code	*Input Variable*	Variable Name
Data Processing	DPC												
		Control	CON										
					PD								
						Heater	HE						
								Settings	SE				
										Gain	GAIN		
													D1-NH-B2A0-DPC-CON:PD-HE-SE-GAIN-CGWRPNNP00
										Integration Time	INTI		
													D1-NH-B2A0-DPC-CON:PD-HE-SE-INTI-CGWRPNNP00
										Derivative Time	DETI		
													D1-NH-B2A0-DPC-CON:PD-HE-SE-DETI-CGWRPNNP00

Figure 18: Procedure to Function Mapping Example

3.4.4 Functions

Section 2.4.5 describes the ontology element functions. The key activities to be done include defining the **Plant I&C FBS** and **device support variables**. To better understand these terms, Figure 19 is helpful. It illustrates the different Plant I&C software layers. The **Plant I&C FBS** corresponds to the *Plant I&C* layer, while the **device support variables** correspond to the *Device Support* layer.

The Nominal Device Support (NDS) EPICS Device Support, based on the NDS-Core library v3, provides a standardized framework for developing and integrating EPICS device drivers. It is particularly suited for DAQ, image processing, and timing synchronization devices. [RD18] offers a detailed overview of NDS v3, explaining its core concepts and its usage within the context of the ITER CODAC Core System.

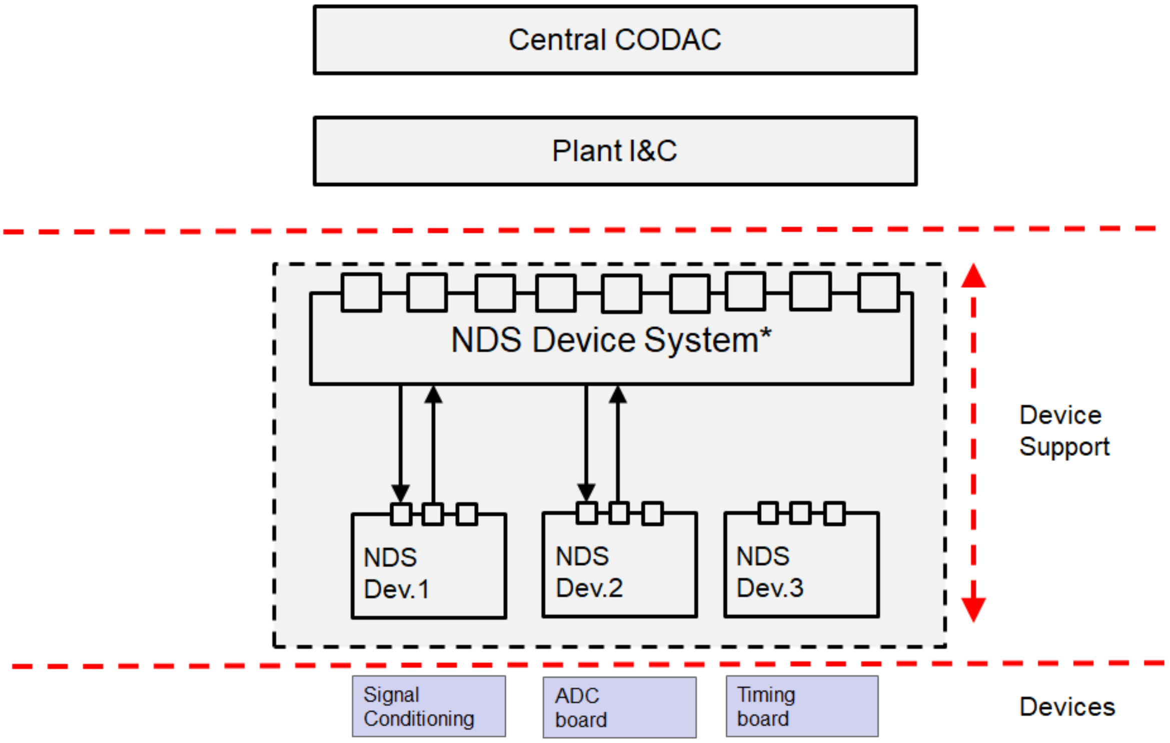


Figure 19: Plant I&C Software Layers

* - [RD22] provides information about the concept and example of NDS Device System.

3.4.4.1 Development of Plant I&C FBS

The Plant I&C FBS can be developed either using the empty Excel template (recommended, see Figure 20) or using the *Plant I&C Functional Analysis add-in [RD9]* editor. Both these methods are explained in the user manual of *Plant I&C Functional Analysis add-in [RD9].* For examples of Plant I&C FBS, refer to IDM location CG73B5.

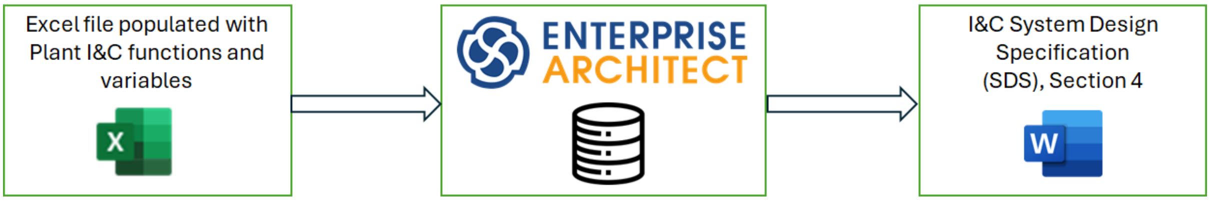
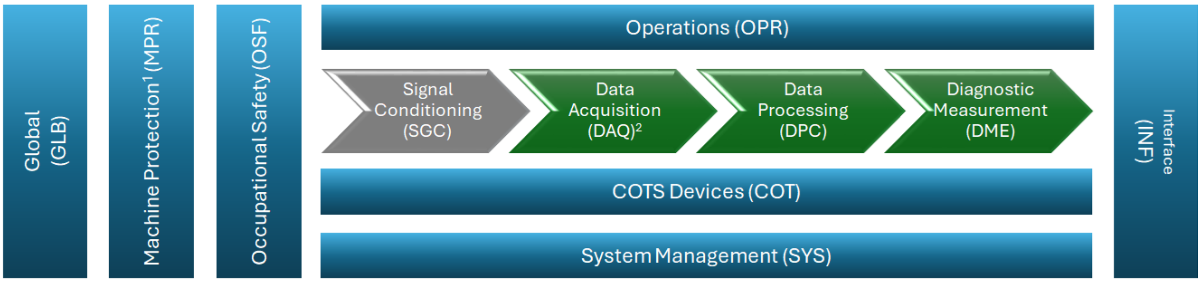

Excel file populated with Plant I&C functions and variables
ENTERPRISE ARCHITECT
I&C System Design Specification (SDS), Section 4

Figure 20: Plant I&C FBS: High Level Process Overview

Although [RD3] establishes the formal basis for Plant I&C FBS, the operational guidance is captured in in the user manual of *Plant I&C Functional Analysis add-in [RD9]*. [RD6] is also fundamental for this topic.

3.4.4.1.1 Conceptual Model - FBS Level 1 or FBS1 functions

For developing the Plant I&C FBS, it is crucial to understand the FBS Level 1 breakdown to categorize functions under appropriate FBS1 categories. FBS Level 1 functions are fixed and can be better understood using the conceptual model in Figure 21.



1 – Contains Plant Protection functions + PBS 46 exchange
2 – Contains Pre-Processing functions as well.

Figure 21: Conceptual Model - FBS Level 1 or FBS1 functions

The measurement signal chain (or signal processing chain) comprises the following four FBS1 functions:

- Signal Conditioning (SGC) - Functions like signal interface, amplification, drive, signal isolation, attenuation, multiplexing, and filters are defined here, if the diagnostic includes instrumented signal conditioning.
- Data Acquisition (DAQ), including pre-processing functions - Includes functions related to A/D conversion, D/A conversion, frame grabbing, digital I/O, timing, and pre-processing. Note that the digital measurement signal chain starts at the Data Acquisition (DAQ) function.
- Data Processing (DPC) - Includes intermediate processing functions required for calculating diagnostic measurements.
- Diagnostic Measurement (DME) – Ensures diagnosticians can find (in the Plant I&C FBS) the final measurements delivered by the diagnostic. The last function in the measurement signal chain is defined here.

To better understand the flow of functions in the measurement signal chain, consider a weak analog signal *a* from magnetic sensors:

i. **The weak signal is amplified**:

$$s_{\mathrm{SGC}} = G \cdot a$$

The signal conditioning function (and variable s_{SGC}) falls under Signal Conditioning (**SGC**). The variable G, the amplification factor, also has a corresponding configuration function under Signal Conditioning (**SGC**); G is the output variable of that function.

ii. **The amplified signal is digitized**:

$s_{\mathrm{DAQ}}(n) = s_{\mathrm{SGC}}(nT_s)$, where T_s is the sampling interval.

This digitization function (and variable s_{DAQ}) falls under Data Acquisition (**DAQ**).

iii. **Additional (pre-processing) functions** can refine the digitized signal:

a. Noise filtering using a low-pass filter,

$$s_{\mathrm{filtered}}(n) = \alpha \cdot s_{\mathrm{DAQ}}(n) + (1 - \alpha) \cdot s_{\mathrm{filtered}}(n - 1)$$

b. Normalization to standardize the signal,

$$s_{\mathrm{normalized}}(n) = \frac{s_{\mathrm{filtered}}(n) - \min\left(s_{\mathrm{filtered}}\right)}{\max\left(s_{\mathrm{filtered}}\right) - \min\left(s_{\mathrm{filtered}}\right)}$$

These pre-processing functions (and variables $s_{\mathrm{filtered},}\, s_{\mathrm{normalized}}$) also fall under Data Acquisition (**DAQ**).

iv. **Advanced processing**, such as spectral analysis, identifies critical plasma behaviors like magnetic island precursors. For example, a Discrete Fourier Transform (DFT) computes the signal's frequency spectrum:

$$S[k] = \sum_{n=0}^{N-1} s_{\text{normalized}}(n) \cdot e^{-j\frac{2\pi kn}{N}}$$

This processing function (and variable *S*) falls under Data Processing (**DPC**). There may be a chain of such functions as well.

v. **The final step delivers the diagnostic measurement**. For instance, the magnitude of spectral components can be compared against thresholds to detect anomalies:

$$\text{Disruption Warning} = \begin{cases} 1 & \text{if } |S[k_{\text{critical}}]| > \text{Threshold} \\ 0 & \text{otherwise} \end{cases}$$

This disruption warning function (and variable Disruption Warning) falls under Diagnostic Measurement (**DME**).

The other FBS1 functions, which are applicable to the entire measurement signal chain are explained in the table below.

Table 3-2: FBS Level 1 functions

Level 1 Function (FBS1)	Description
Global (GLB)	If the diagnostic interfaces with other plant systems (including other diagnostics), the associated functions and variables should be defined under Global (GLB). Note 1: Variables sent to CODAC (PBS 45) are not intended to be included here, as they are typically PON, SDN, or DAN variables already defined under other Level 1 functions in the FBS. However, if the system requires variables from CODAC (e.g., from SUP), those variables may be defined here as needed. Note 2: The implementation of interfaces with other diagnostics, whether done through SUP or D1 control group, requires an implementation-specific assessment. Note 3: If information needs to be exchanged with PBS 46 and PBS 48, then these functions and variables should be categorized under FBS1 Machine Protection and Occupational Safety, respectively.
System Management (SYS)	Functions related to managing the Plant I&C, such as cubicle management, controller (fast and slow) management, and I/O Board management, should be categorized under System Management. Note 1: Many functions required for system management are provided by CODAC through a set of SYSM variables (ITER_D_35XFCY). These variables should not be duplicated in the Plant I&C FBS but can be used as inputs for additional functions as necessary. Note 2: If system monitoring functions or variables beyond those provided by CODAC are identified, they should be defined here. For example, detailed diagnostic information of individual data acquisition modules in PLC remote chassis.
Operation (OPR)	Functions related to the operation of the Plant I&C system include: a) COS-PSOS b) Smart conditions for state identification, events c) Initialization (networks, devices) d) Configuration (plant, device) e) Control and Monitoring (as needed)

Level 1 Function (FBS1)	Description
Machine Protection (MPR)	Functions related to plant or machine protection which are not *interlock* grade should be defined under this category.
Occupational Safety (OSF)	Any functions related to occupational safety that are implemented as part of conventional control, should be defined under this category.
COTS (COT)	Functions associated with Commercial Off-The-Shelf (COTS) devices should be defined under COTS. Scientific analysis packages, such as real-time magnetic reconstruction systems, can also be considered as COTS devices. Note: If the COTS device is part of the measurement signal chain, then the corresponding functions and variables can also be defined under Data Acquisition. This decision is at the discretion of the designer.
Interfaces (INF)	Functions related to network interfaces should be categorized under Interfaces. This includes configuration and monitoring of DAN, PON, SDN, TCN.

3.4.4.1.2 Note about FPGA logic

Functions and variables used only inside the user-programmable FPGA and not exposed to the CODAC networks don’t need to be included in the I&C design documentation. **This is not allowed** if hidden data prevents meeting system requirements.

Optional Documentation: If desirable, teams may choose to document their internal FPGA functions and variables in the Plant I&C FBS. To do so, these should be marked with Attribute 3 set as "Internal" to clearly distinguish them.

Note: This concept above is also applicable for COTS devices.

3.4.4.1.3 Configuration Objects

Configuration objects play a central role in the context of Plant I&C Configuration. At a high level, a configuration object is a set of configuration variables and constraints. Although this is primarily an implementation-level concept, it has been included in Figure 8 to highlight its importance and to promote early awareness during the system design phase.

For more details on this topic, refer to [RD32].

3.4.4.2 Definition of Device Support variables

For the preferable EPICS device support implementation as a Nominal Device Support (NDS), the Plant I&C developer must define the corresponding NDS variables in the EA project. In justified cases, such as for simple streaming devices with only a few vendor-provided functions, the device support variables must be documented only in the I&C SADD.

Plant I&C Functional Analysis add-in [RD9] should be used for defining the NDS variables. For examples of NDS variables, refer to IDM location CW7VA4.

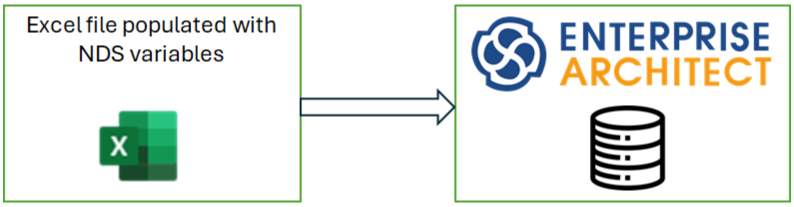


Figure 22: NDS variables: High Level Process Overview

3.4.4.2.1 Conceptual Model for NDS

The definition NDS variables for any device can be understood through Figure 23.

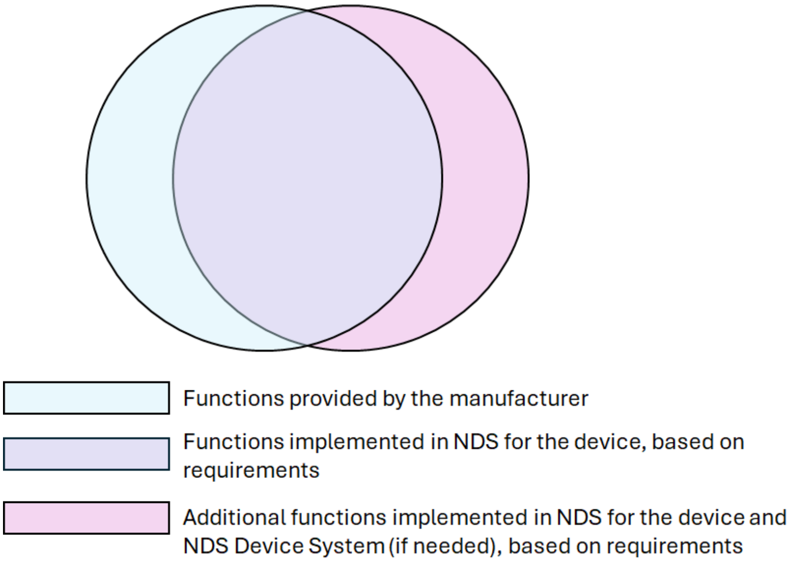

Functions provided by the manufacturer
Functions implemented in NDS for the device, based on requirements
Additional functions implemented in NDS for the device and NDS Device System (if needed), based on requirements

Figure 23: Conceptual Model – NDS variables

FDR Stage Requirements:

- Device manual must be submitted. This manual should include a comprehensive list of all functions provided by the manufacturer.
- The Plant I&C functions and variables (related to this device) must be fully defined within the EA project.

MRR Stage Requirements:

- NDS functions and variables for the device must be defined within the EA project.

3.4.5 Algorithms

Section 2.4.6 describes the ontology element algorithms. Algorithms to be implemented in the Plant I&C must be documented for FDR. For PDR, a conceptual description in plain English is sufficient, whereas for FDR, the algorithms must be described in greater detail (e.g., using equations).

Algorithms should be documented as a free-format chapter in the EA project, following the instructions outlined in the section titled “Algorithms” in [RD10]. For examples of Algorithms, refer to IDM location CK2C9F.

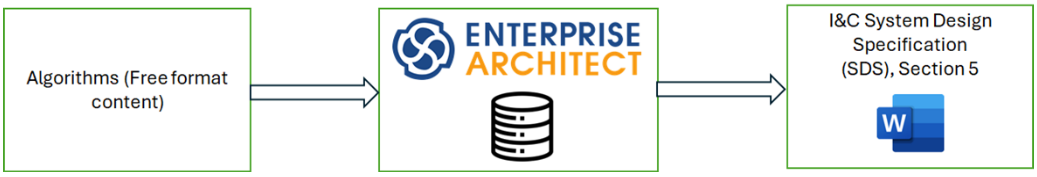

Algorithms (Free format content)
ENTERPRISE ARCHITECT
I&C System Design Specification (SDS), Section 5

Figure 24: Algorithms: High Level Process Overview

3.4.6 State Machine

Section 2.4.7 describes the ontology element state machine. [RD8] and [RD7] provide the theoretical basis for this subject, while the section titled 'State Machine' in [RD9] provides instructions for defining the state machine in the EA project. In addition, there is some free-format content associated with the state machine, which needs to be added as per the instructions outlined in the section titled “Plant Automation” in [RD10].

For examples of state machines, refer to IDM location CRTW9V.

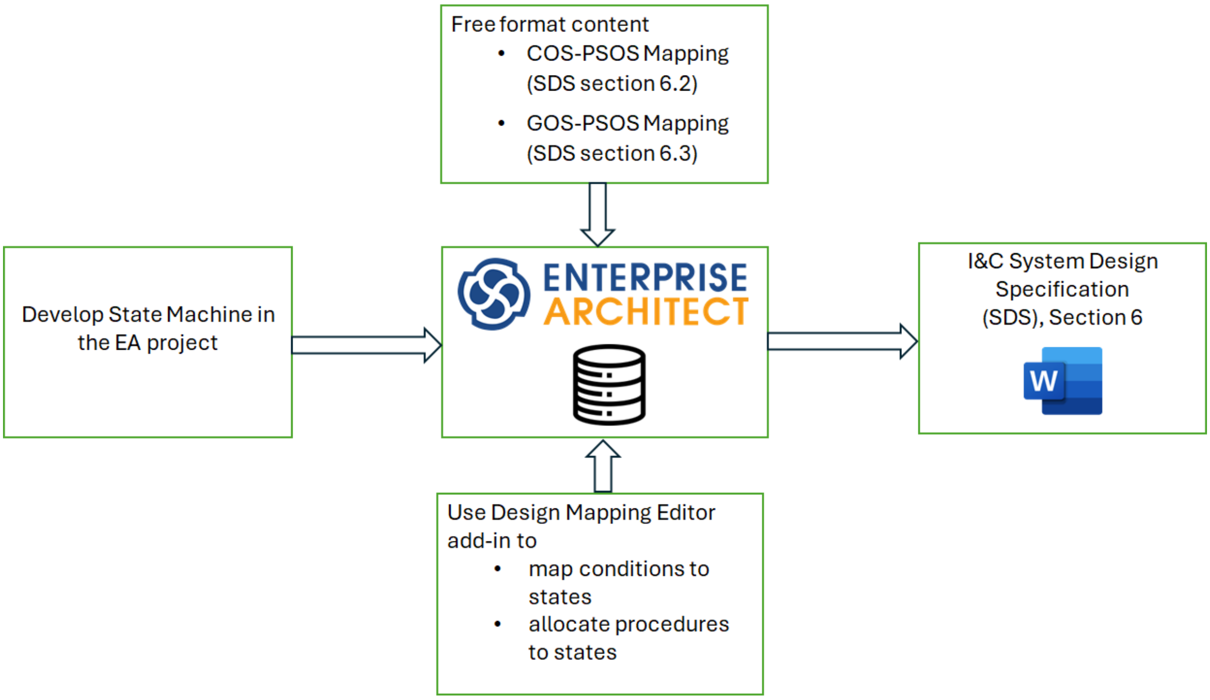

Free format content
• COS-PSOS Mapping (SDS section 6.2)
• GOS-PSOS Mapping (SDS section 6.3)
Develop State Machine in the EA project
ENTERPRISE ARCHITECT
I&C System Design Specification (SDS), Section 6
Use Design Mapping Editor add-in to
• map conditions to states
• allocate procedures to states

Figure 25: State Machine: High Level Process Overview

Note: The requirement to provide the PSOS/COS mapping table was removed from PCDH version 7.1 (June 2023). This change also applies to GOS mappings. Some I&C SDS documents delivered prior to this update may still include these mappings. Having said that, this document continues to provide guidance on this topic, and the corresponding content has not been removed. This is because, these mapping tables will have to be anyway defined and configured later by IO-CT.

3.4.7 Hardware Architecture

Section 2.4.8 describes the ontology element Hardware Architecture. Hardware Architecture must comply with the PCDH guidelines [RD21]. A Master Controller [RD34], running the CODAC Core System, should be used to securely manage and interface non-qualified COTS devices with CODAC networks.

Hardware Architecture should be defined following the instructions outlined in the section titled “Hardware Architecture” in [RD9].

The Hardware Architecture may also be provided as a separate IDM document, referenced within the I&C SDS. For examples of Hardware Architecture, refer to IDM location CG75C6.

For defining the Signals and Components, *Signals and Components Editor add-in [RD9]* should be used. For examples of Signals and Components, refer to I&C SDS examples at IDM location CW6GXM.

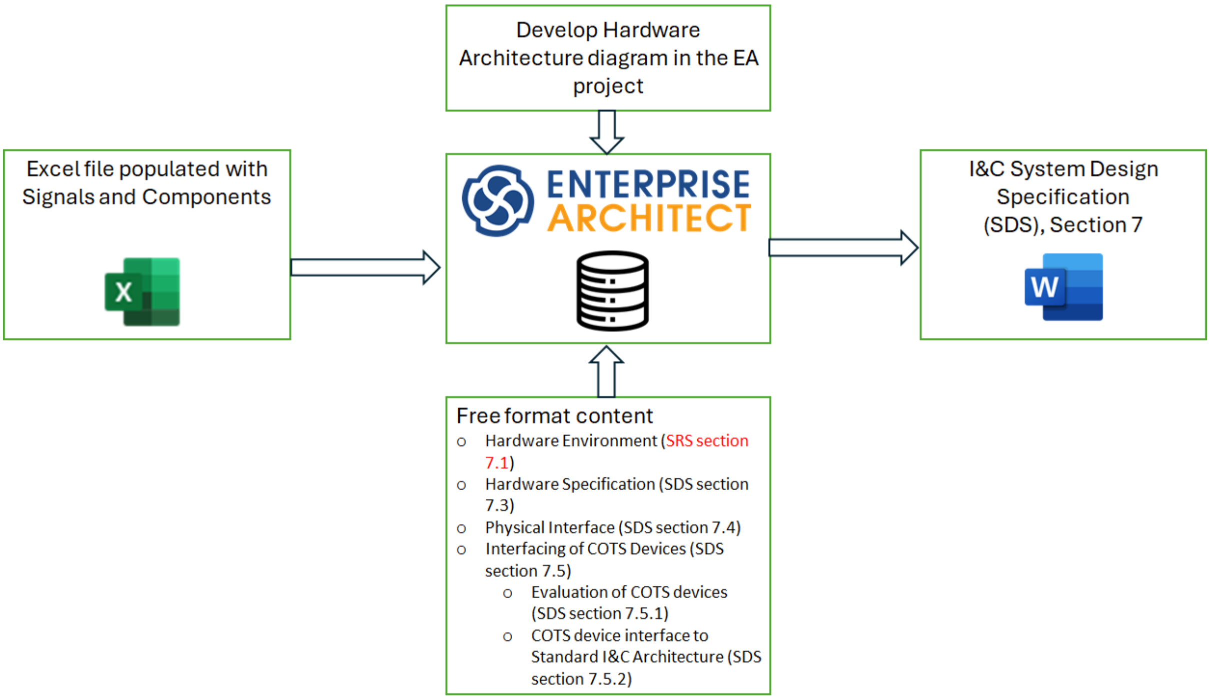

Develop Hardware Architecture diagram in the EA project
Excel file populated with Signals and Components
ENTERPRISE ARCHITECT
I&C System Design Specification (SDS), Section 7
Free format content
Hardware Environment (SRS section 7.1)
Hardware Specification (SDS section 7.3)
Physical Interface (SDS section 7.4)
Interfacing of COTS Devices (SDS section 7.5)
Evaluation of COTS devices (SDS section 7.5.1)
COTS device interface to Standard I&C Architecture (SDS section 7.5.2)

Figure 26: Hardware Architecture: High Level Process Overview

Note: The “Hardware Environment” free-format content is for the I&C SRS only.

3.4.7.1 Evaluation of COTS Devices (I&C SDS Section 7.5.1)

To recap,

> as per PCDH, there are three types of plant system controllers: the fast controller (PCF), the slow controller (PLC) and the plant other controller (POC).
>
> The POC can be further classified into two types:
>
> - Devices that can run EPICS IOCs directly.
> - Devices that require an external interface IOC (EPICS Device Support).
>
> POC controllers are also referred to as COTS intelligent devices, or simply COTS devices.
>
> Note: Boards within a standard fast controller I/O chassis are not considered POC controllers.

This free-format chapter presents the evaluation of different integration options for COTS devices with standard controllers. It excludes COTS devices integrated using slow controllers, which use a standardised approach documented in the PCDH.

Note: Some COTS devices like cameras which can be integrated using boards in a standard fast controller I/O chassis, are also not concerned by this chapter.

A table like Table 3-3, which serves as the integration option selection decision matrix, needs to be filled for each COTS device.

Table 3-3: COTS Integration Evaluation Table

Y = YES - N = No I = Impossible R = Requires Work P = Perf. Issue	**Native Software support in both ends**	**Black Box (Ethernet + IOC)**	**FC integration with RHEL Linux**	**FC with RHEL virtualized Windows with shared memory**	**Implementation in standard fast controller with CCS**
	For understanding the different options see the explanations below the table.				
Configuration (User)					
Measurement					
Real Time (SDN)					
Timing					
Raw Data Acquisition					
Archiving (DAN)					
Health Management					
Calibration					
Automation (PSOS)					
Production State					
Quality Flag					
HW Obsolescence					
SDD Integration					

The rows represent the checklist of prominent requirements from [RD20], that the integration option should meet. The columns represent the different integration options.

For every COTS device, fill the column that indicates how the device is proposed to interface with CODAC. Each cell in the table should be completed using one of the following values: Y (Yes), N (No), R (Requires Work), I (Impossible), or P (Performance Issue), which indicate the feasibility or limitations of a given integration option for a specific requirement. If multiple options are available for interfacing, fill in multiple columns to compare the options. In such cases, clearly state the chosen interface option in the corresponding table.

The definition of the different integration options is below:

- **Native Software support in both ends** - This is not an integration option but rather is used to check which functionality and performance is supported by the manufacture provided (native) software for a COTS device (usually standalone measurement software provided by the manufacturer, typically a Windows application). In the integration options we can then check which of this functionality and performance is maintained after integration or which additional functionality and performance can be added.

- **Black Box (Ethernet + IOC)** - This option utilizes a COTS device with an embedded operating system (such as VxWorks) that supports EPICS. The EPICS IOC is created and run on the device's embedded OS, with communication handled over Ethernet.
- **FC integration with RHEL Linux** - In this approach, the COTS device includes its own computer, which is capable of running Red Hat Enterprise Linux (RHEL). The EPICS IOC is installed and executed on the RHEL system within the device.
- **FC with RHEV virtualized Windows with shared memory** - Here, the native measurement software runs on a virtualized Windows instance hosted on a Master Controller [RD34] using Red Hat Enterprise Virtualization (RHEV). Communication between the native software and EPICS IOC is achieved through shared memory. Please note that this is the least favorable option.
- **Implementation** (of interface) **in standard fast** (master) **controller with CCS** – In this option, the EPICS device support IOC runs on a Master Controller [RD34]. Justified exceptions to not use a master controller may be granted.

  The name of the column *Implementation in standard fast controller with CCS* has been kept as is for historical reasons. It should be read as *Implementation (of interface) in standard fast (master) controller with CCS.*

Note: There is another design option where the COTS functions are implemented in a standard fast controller with CCS (thus replacing the need for the COTS device) – In this white box option, COTS functions are implemented on a standard fast controller. The EPICS IOC runs directly on the standard ITER fast controller and standard I/O devices are used.

3.4.8 Software Architecture

Section 2.4.9 describes the ontology element Software Architecture. Software architecture should be defined following the instructions outlined in the section titled “Software Architecture” in [RD10]. The software architecture must be consistent with the CODAC Core System development guidelines [RD24], [RD33].

Note that the designer can decide to not draw the Software Environment diagram in EA and use the free-format chapter (I&C SDS section 8.1) for it.

The Software Architecture may also be provided as a separate IDM document, referenced within the I&C SDS. For examples of Software Architecture, refer to IDM location CG75C6.

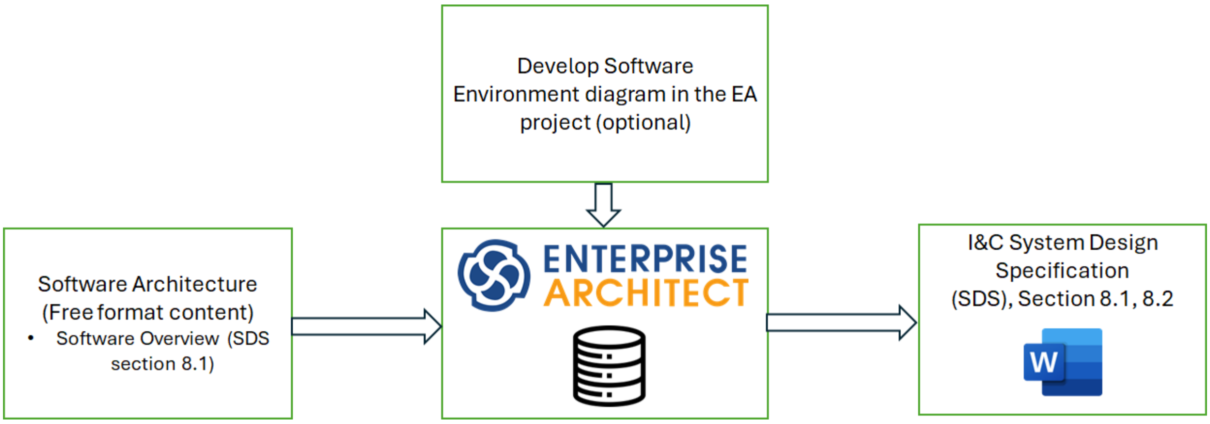

Develop Software Environment diagram in the EA project (optional)
Software Architecture (Free format content)
• Software Overview (SDS section 8.1)
ENTERPRISE ARCHITECT
I&C System Design Specification (SDS), Section 8.1, 8.2
W

Figure 27: Software Architecture: High Level Process Overview

3.4.9 HMI

Section 2.4.10 describes the ontology element HMI. HMI must be defined in accordance with the guideline [RD19].

HMI should be documented as a free-format chapter in the EA project, following the instructions outlined in the section titled "User Interface (HMI) (I&C SDS Section 8.2*)" in [RD10]. For examples of HMI, refer to IDM location CGH7LJ.

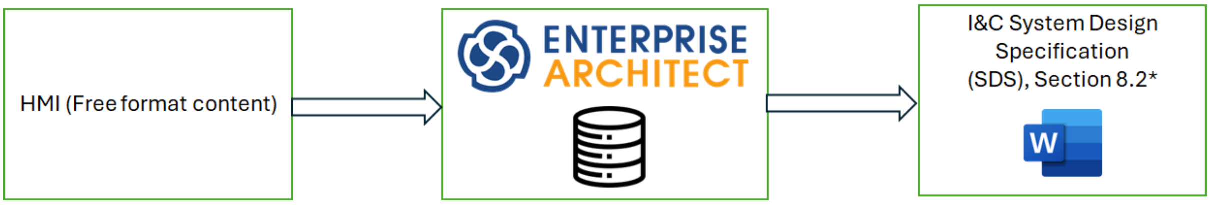

HMI (Free format content)
ENTERPRISE ARCHITECT
I&C System Design Specification (SDS), Section 8.2*
W

Figure 28: HMI: High Level Process Overview

3.4.10 Cubicle Configuration

Section 2.4.11 describes the ontology element Cubicle Configuration. Cubicle Configuration should be documented as a free-format chapter in the EA project, following the instructions outlined in the section titled "I&C Cubicle Configuration (I&C SDS section 9)" in [RD10]. Cubicle Configuration must comply with the PCDH guidelines [RD21].

The Cubicle Configuration may also be provided as a separate IDM document, referenced within the I&C SDS. For examples of Cubicle Configuration, refer to IDM location CH3L8E.

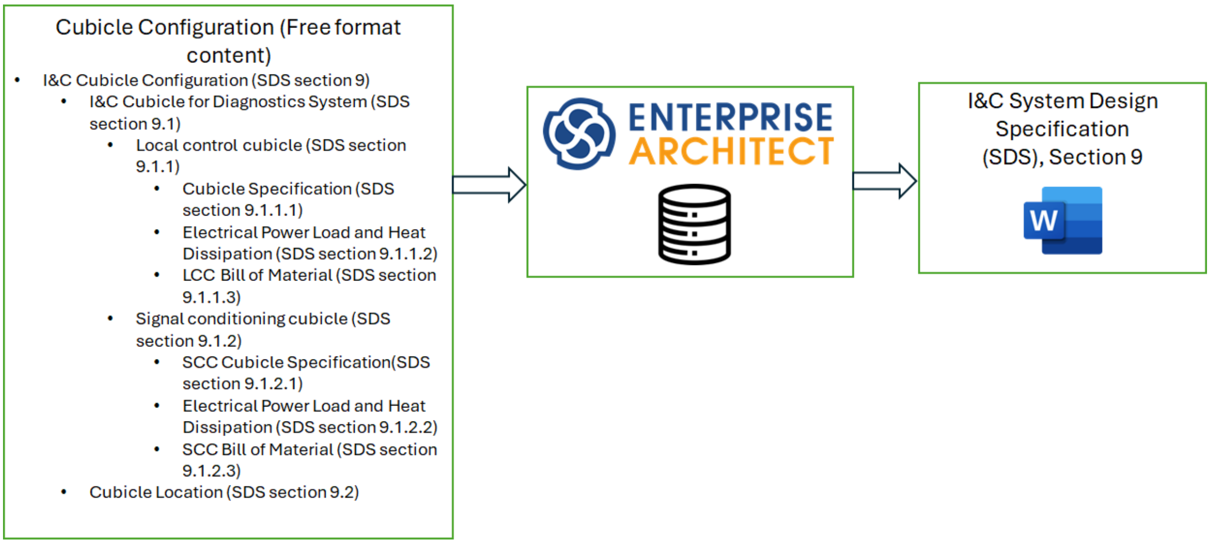

Cubicle Configuration (Free format content)
I&C Cubicle Configuration (SDS section 9)
I&C Cubicle for Diagnostics System (SDS section 9.1)
Local control cubicle (SDS section 9.1.1)
Cubicle Specification (SDS section 9.1.1.1)
Electrical Power Load and Heat Dissipation (SDS section 9.1.1.2)
LCC Bill of Material (SDS section 9.1.1.3)
Signal conditioning cubicle (SDS section 9.1.2)
SCC Cubicle Specification(SDS section 9.1.2.1)
Electrical Power Load and Heat Dissipation (SDS section 9.1.2.2)
SCC Bill of Material (SDS section 9.1.2.3)
Cubicle Location (SDS section 9.2)
ENTERPRISE ARCHITECT
I&C System Design Specification (SDS), Section 9
W

Figure 29: Cubicle Configuration: High Level Process Overview

3.4.11 Test Scenarios

Section 2.4.12 describes the ontology element Test Scenarios. Test Scenarios should be documented as a free-format chapter in the EA project, following the instructions outlined in the section titled "Test Scenarios (I&C SDS section 10)" in [RD10]. For examples of Test Scenarios, refer to IDM location CW6GXM.

Note that the Test Scenarios are also documented in the I&C STP document (empty template, [RD15]). So, the examples of Test Scenarios can also be found at the IDM location CWNS5V.

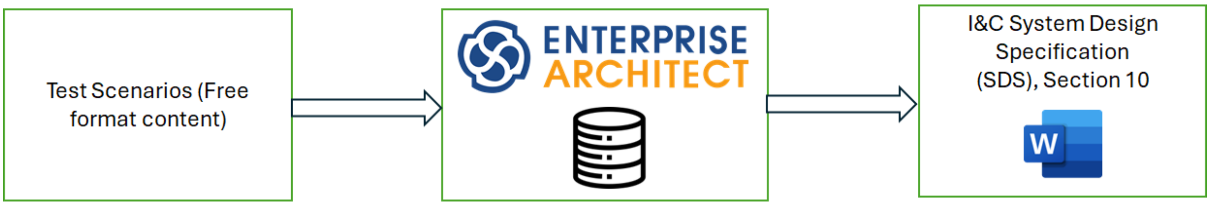

Test Scenarios (Free format content)
ENTERPRISE ARCHITECT
I&C System Design Specification (SDS), Section 10
W

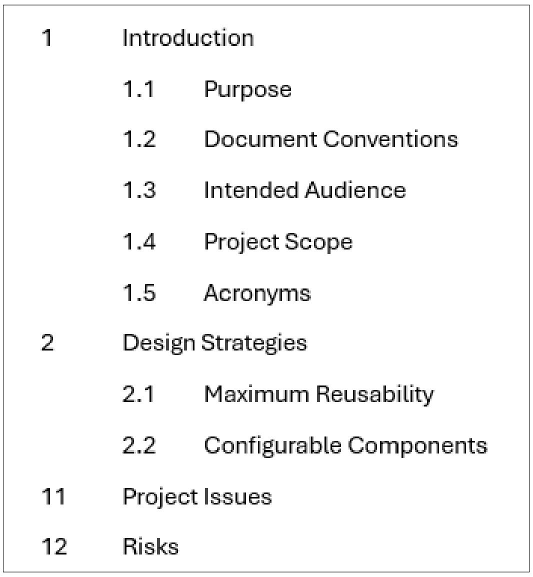
Figure 30: Test Scenarios: High Level Process Overview

3.4.12 Additional Free-Format Content of the I&C SDS

In addition to the information in the preceding sections, the free-format chapters shown in Figure 31 are also part of the I&C SDS. These free-format sections should be directly entered into the corresponding *document artifacts* in the EA project. These *document artifacts* are automatically created when an EA project is initialized using the *EA Model Verification and Configuration add-in [RD9]*. To determine which document artifact corresponds to each I&C SDS section, refer to the "Free Format Chapters" section in [RD10].

Please refer to the I&C SDS examples in location CW6GXM to understand the information expected in these free-format sections. There is no fixed guideline about what to include in these sections.

Note: The sections "Acronyms", "Project Issues" and "Risks" are also present in the I&C SRS. For these sections, there are no separate *document artifacts* in the EA project for I&C SRS and I&C SDS.



1 Introduction

1.1 Purpose

1.2 Document Conventions

1.3 Intended Audience

1.4 Project Scope

1.5 Acronyms

2 Design Strategies

2.1 Maximum Reusability

2.2 Configurable Components

11 Project Issues

12 Risks

Figure 31: Free-Format Chapters/Sections in I&C SDS

3.4.13 Auxiliary documents (not a mandatory deliverable)

Beyond the required details mentioned above, development teams are expected to create supplementary documents that support their work. These auxiliary materials can also be incorporated into the EA project within appropriate free-format sections. Examples of such documents include:

- Signal chain diagrams
- COTS device selection decision matrices
- Table mapping detected exceptions to their corresponding handling methods (see section 3.4.3.4)

For examples of auxiliary documents, refer to IDM location CVAUMS.

3.4.14 Summary of contents of the I&C SDS (beginner-friendly)

Using the *Plant I&C Document Generation add-in [RD9]*, the I&C SDS document can be generated. There is an option to generate a concise (compact) reader friendly I&C SDS document. This version does not include the topics procedures, functions, signals, and components which are easier to review through the EA project and the associated excel tables.

The concise I&C SDS is the preferred option for uploading to IDM, while the full I&C SDS can be optionally added as an attachment.

It is also permitted, if needed, to produce standalone design documents in IDM which are referred to in the generated I&C SDS document. For example, a separate Cubicle Configuration document may be created. This approach can also be applied to Hardware architecture and Software architecture documentation.

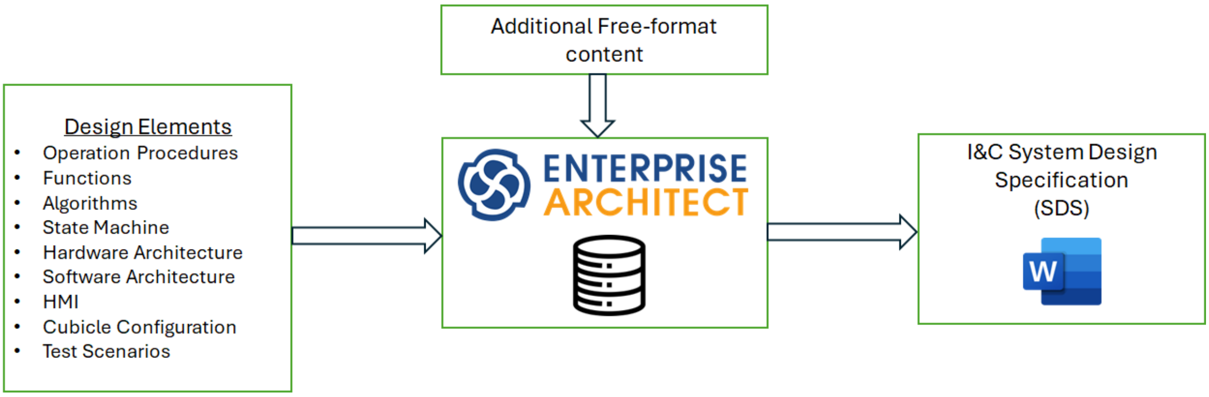


Figure 32: I&C SDS: High Level Process Overview

- Section 2 is about the design strategies used by the designer. Some strategies may focus on maximum reusability based on configurable components which has been proposed by IO-CT. The Plant I&C designer should add/modify and describe other strategies they are following (or considering).

- Section 3 describes the operation procedures for this Plant I&C in the form of activity diagrams (flowcharts). The operation procedures specifically answer the question “what the system and operator must do during operation” to support the various use cases.

  Note: If a concise (or compact) I&C SDS has been generated, then for the contents of this section, one can directly view the operation procedures in the EA project.

- Section 4 provides the comprehensive documentation of the detailed hierarchical functional breakdown (or analysis) of Plant I&C (called FBS). The primary objective of preparing this functional breakdown is to derive a detailed list of Plant I&C variables (along with their essential attributes like CODAC network interface, hardware to which they are allocated, units, availability on HMI, and others) that will be implemented in CCS (CODAC Core System). Essentially, the section provides a functional breakdown, yielding a set of Plant I&C functions alongside their corresponding input and output variables. This breakdown is different from the diagnostics IDEF0 analysis (which also includes non-I&C functions).

  Additionally, readers can find function processing diagrams for individual functions, illustrating the specific input and output variables. Notably, certain input and output variables in the function processing diagrams may also be nominal device support (NDS) variables (having the identifier "HWCF" in their names).

  Note 1: If a concise (or compact) I&C SDS has been generated, then for the contents of this section, one will need to directly view the FBS in the EA project or generate the FBS Excel sheet from the EA project.

  Note 2: In Section 3, operation procedures are organized in a hierarchical structure. At the lowest level, these procedures must be mapped to individual Plant I&C functions (at the lowest level), as defined in Section 4. If this mapping (available in the procedure tables) is missing, it either indicates that plant I&C functions are not needed for that procedure; or it highlights that the corresponding plant I&C functions haven't been mapped to by the Plant I&C designer; or that the relevant Plant I&C functions are missing.

  Note 3: Within Section 4, an additional layer of insight emerges as the functions are presented in tables. Notably, these tables include a mapping that associates each function with specific requirement categories. This mapping is a crucial input to the verification process, requiring Plant I&C designers to link Plant I&C functions to the requirement categories they support.

- Section 5 describes the algorithms of this system. These algorithms will be implemented through I&C functions documented in Section 4.
- Section 6 provides details about the PSOS state machine. The state machine consists of states, with each state allowing the execution of specific procedures provided the necessary conditions are fulfilled.
- Section 7 is a pivotal section that describes Plant I&C's hardware architecture. Within this section, a comprehensive list of signals (electrical) is detailed. The hardware architecture is explained using a detailed diagram and textual descriptions (hardware specification), providing insight into the system's physical structure and preferably the obsolescence management strategy. The section also describes the physical interface between Plant I&C and PBS 45 (but this information does not supersede the information in IS 45-55.XX).

  This section also explains the integration of various COTS devices with the CODAC environment. The COTS integration tables in section 7.5.1, showcase diverse options (columns) for integrating the various COTS devices. The option that is chosen, must meet a set of requirements (rows) taken from ITER_D_ QARUAC. By specifying the preferred method chosen by the Plant I&C designer, this section provides a clear understanding of how COTS devices will be seamlessly integrated into the CODAC environment.

  Note: If a concise (or compact) I&C SDS has been generated, then the list of signals is not added to this section. One will need to directly view the signals list in the EA project or generate the signals Excel file from the EA project.
- Section 8 describes the software architecture for the Plant I&C, and documents HMI design.
- Section 9 is a comprehensive documentation of the Plant I&C cubicle configurations. This section details the design aspects of both types of cubicles: the local control cubicle and the signal conditioning cubicle. The different facets related to cubicle design are thoroughly covered, including heat dissipation calculations, electrical power load calculations, bill of materials for each cubicle, and the cooling design. Beyond that, it extends its coverage to encompass topics such as cubicle enclosure types, cable entry design, and the spatial layouts of the cubicles.
- Section 10 documents the test scenarios for the Plant I&C. Test scenarios document "What" needs to be tested. "How" it will be tested is documented in the I&C System Test Plan document. Additionally, for referring the list of applicable acceptance criteria, directly view them in the EA project or generate the acceptance criteria Excel sheet from the EA project.
- Sections 11 and 12 capture the issues and risks associated with the design and implementation of the Plant I&C.

3.5 Verification and Validation

Verification and validation topic is elaborated in extensive detail in [RD5].

It outlines the comprehensive strategy for verification and validation (V&V) of the Diagnostic Plant I&C systems. It describes how **requirements are verified** across lifecycle phases **through methods** such as inspection, analysis, testing, and engineering reviews, ensuring the system is built according to specifications. It also details how **validation** confirms that **the implemented system** fulfils its intended operational purpose within the target environment, **using acceptance criteria** and associated test cases.

Key artifacts and tester (acceptor of the system) responsibilities are also covered. The approach aligns with Figure 5 and reflects the outcomes of CODAC workshops on Diagnostics Plant I&C.

Note: I&C SRS and I&C SDS document deliverables contain all necessary information to demonstrate design compliance to I&C requirements during design reviews.

3.5.1 Requirements Categories to Function Mapping

Verification using *Engineering Review* method is demonstrated by mapping requirement categories to functions. For this use, *Verification and Validation add-in [RD9].* The key requirement categories for mapping were presented in the 5th CODAC Workshop on Diagnostics Plant I&C (ITER_D_4WDZXW, slide 7).

3.5.2 Requirement Traceability

Figure 33 is an adaptation of Figure 8 focusing on requirement traceability during verification and validation of Diagnostics Plant I&C.

- Requirement categories – containing applicable requirements – are mapped to supporting I&C functions within the EA project, thereby establishing the verification path (refer section 3.5.1).
- Each category of acceptance criteria maps to a corresponding group of requirements as specified in [RD14].
- Finally, test cases in the I&C STP are mapped to acceptance criteria, ensuring end-to-end traceability from requirements to validation through testing.

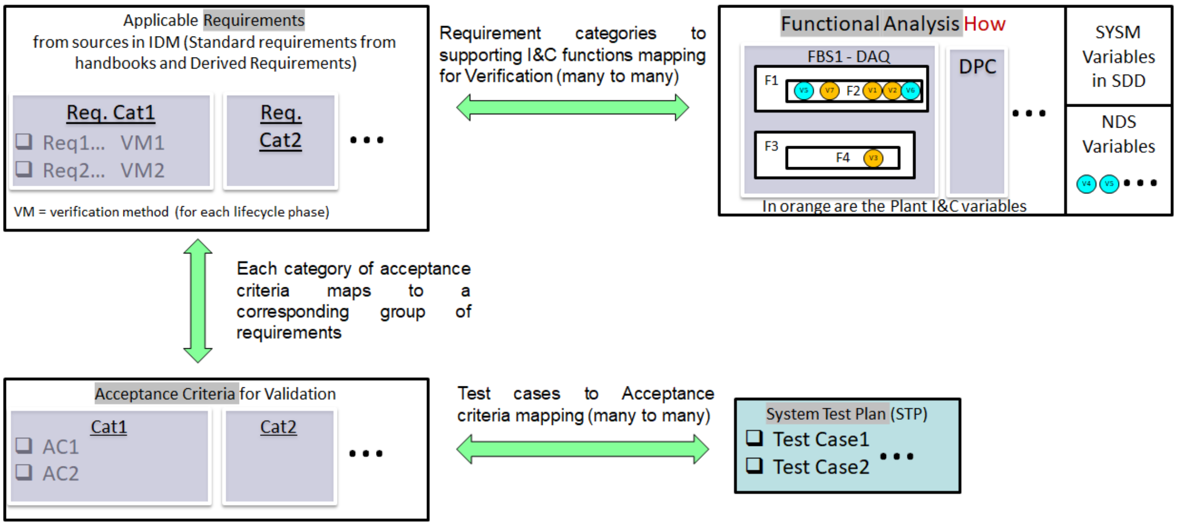

Applicable Requirements
from sources in IDM (Standard requirements from handbooks and Derived Requirements)
Req. Cat1
❑ Req1… VM1
❑ Req2… VM2
Req. Cat2
• • •
VM = verification method (for each lifecycle phase)
Requirement categories to supporting I&C functions mapping for Verification (many to many)
Functional Analysis How
FBS1 - DAQ
F1
V5 V7 F2 V1 V2 V6
F3
F4 V3
DPC
• • •
In orange are the Plant I&C variables
SYSM Variables in SDD
NDS Variables
V4 V5 • • •
Each category of acceptance criteria maps to a corresponding group of requirements
Acceptance Criteria for Validation
Cat1
❑ AC1
❑ AC2
Cat2
• • •
Test cases to Acceptance criteria mapping (many to many)
System Test Plan (STP)
❑ Test Case1
❑ Test Case2
• • •

Figure 33: Requirement Traceability - Verification and Validation

3.6 Manufacturing

Following the completion of the design phase, the next step in the development of Plant I&C is the *Manufacturing Design and Preparation (MDP)* and *Manufacturing and Delivery (MAN)* phases. Figure 34 is an adaptation of Figure 2.

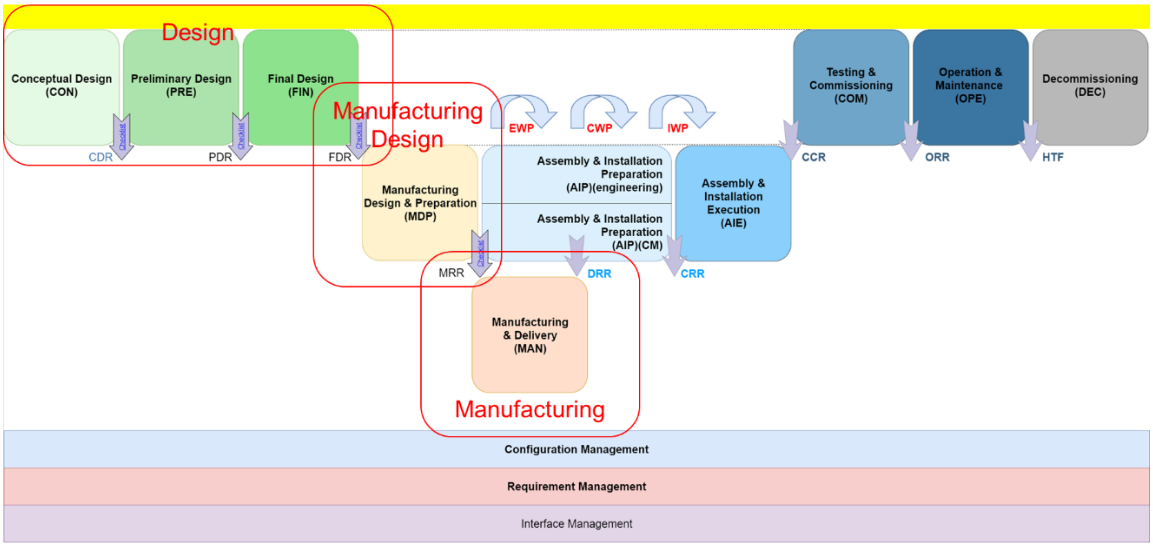

Design
Conceptual Design (CON)
Preliminary Design (PRE)
Final Design (FIN)
CDR
PDR
FDR
Manufacturing Design
EWP
CWP
IWP
Testing & Commissioning (COM)
Operation & Maintenance (OPE)
Decommissioning (DEC)
CCR
ORR
HTF
Manufacturing Design & Preparation (MDP)
Assembly & Installation Preparation (AIP)(engineering)
Assembly & Installation Preparation (AIP)(CM)
Assembly & Installation Execution (AIE)
MRR
DRR
CRR
Manufacturing & Delivery (MAN)
Manufacturing
Configuration Management
Requirement Management
Interface Management

Figure 34: ITER Phase Review Gates and Phases - Adaptation

3.6.1 Manufacturing Design and Preparation (MDP)

The gate review for the MDP phase is the Manufacturing Readiness Review (MRR). One MRR is expected for one Plant I&C.

Manufacturing is broadly defined as the assembly of electronic and electrical components into I&C cubicles.

Electronic/electrical component can be a:

- ITER I&C catalogue component [RD2]
- Commercial-off-the-shelf (COTS) device
- Bespoke/Custom component
- Bespoke/Custom assembly of COTS devices

Note: Manufacturing or assembly of bespoke/custom components is not in the scope of an I&C MRR. The technical specifications related to these components must still be produced and reviewed as required by [RD16]. The I&C MRR panel member may request further information on these documents at their discretion.

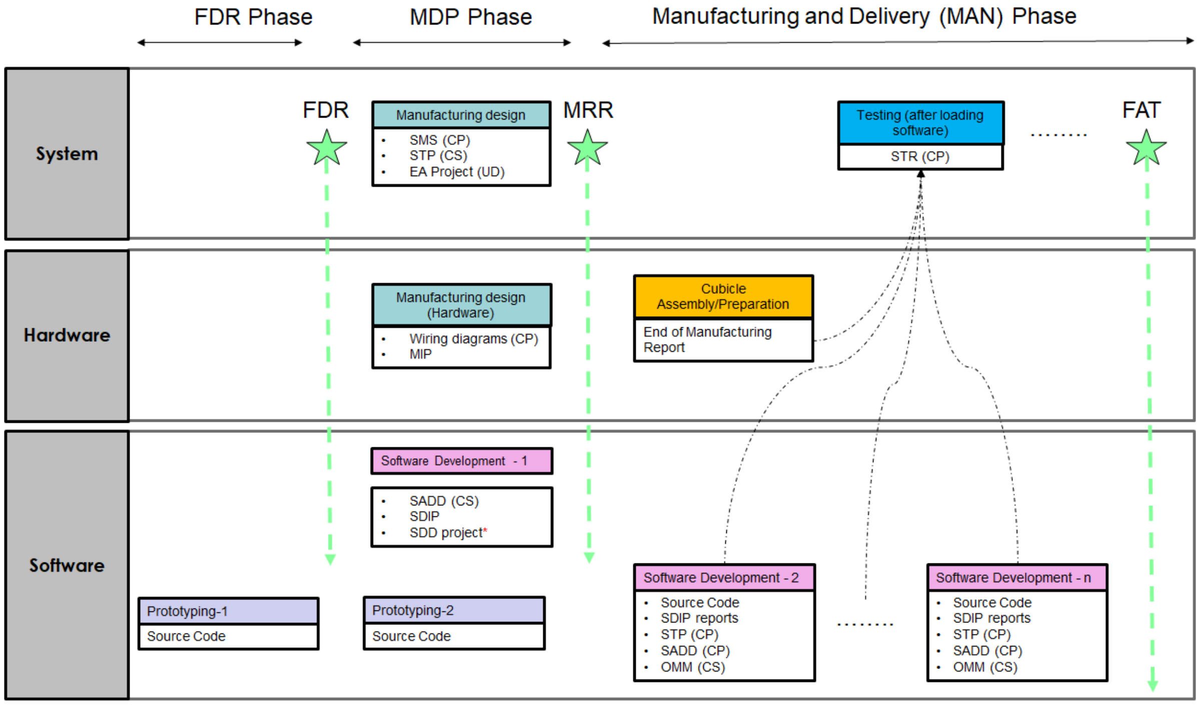
3.6.1.1 Essence of Manufacturing Readiness

As per [RD23], MRR consists of:

> "
>
> *a set of verification activities to be performed before the start of manufacturing activities in order to assure:*
>
> *- The required activities are adequately and ready to be effectively performed according to approved documents;*
>
> *- The relevant technical criteria of the manufactured component are specified in approved documents including for on-site storage, on-site assembly and installation, maintenance and preservation after installation, commissioning, operation and maintenance;*
>
> "

When specifically applied to a Diagnostic Plant I&C, the essence of manufacturing readiness is as follows (also refer to Figure 35) :

- **System Level**: The design is fully finalized, incorporating all necessary updates following the Final Design Review (FDR). The system can move into manufacturing without any anticipated changes to key hardware.
- **Hardware Level**: Every detail of the design, down to the lowest level (such as electrical enclosure wiring diagrams and interconnection diagrams), is complete. The manufacturing process is clearly defined and documented. An exception to this is possible, if the risk is well identified and documented.
- **Software Level**: The software design has reached a level of maturity that confirms the selected hardware meets all requirements. Prototyping results, where needed, should be used to assess this maturity. The software development process is well-documented, ensuring clarity. **Note**: Software development can begin before MRR and continue after.



* - Only with design information loaded from the EA project (signals, components, functions, variables)

Figure 35: View of Manufacturing Activities – Hardware and Software

3.6.1.2 Deliverables for MRR

3.6.1.2.1 I&C SMS (System Manufacturing Specification)

The I&C SMS document consolidates all details for the manufacturing of the Diagnostic Plant I&C. It outlines all technical, procedural, and quality requirements necessary to initiate and control the MAN phase, including both hardware and software components. It also includes details regarding standards compliance, inspection protocols, component traceability, deliverables (consistent with PCDH) and logistics.

The official pre-populated template for this document is [RD11]. It is an adaptation of [RD23] for Diagnostics Plant I&C. For examples of I&C SMS, refer to IDM location DLPDUN. At MRR, a complete (~final) I&C SMS is needed.

Note: Many processes to be followed have been built into this template to ensure consistency and alignment.

For the purpose of inspection during the MAN phase, two plans (which are referenced in the I&C SMS document) should be prepared. These plans outline how the inspections will be carried out during manufacturing. These are:

- Manufacturing Inspection Plan (MIP) focusing on the hardware. The official pre-filled template for this document is [RD12]. For examples of MIP, refer to IDM location DM23M4.
- Software Development and Inspection plan (SDIP) focusing on the software. The official empty template for this document is [RD13]. For examples of SDIP, refer to IDM location DMMZHH.

3.6.1.2.2 I&C STP (System Test Plan)

The official template for this document is [RD15]. Examples of I&C STPs can be found at the IDM location CWNS5V. **At MRR**, the I&C STP is expected to outline the test cases, excluding granular, minute-level details. For a test case, its *Name*, *Description*, *Associated Acceptance Criteria* and *Pass/Fail Criteria* are expected. If known, high level *Procedure* steps can also be added. It is crucial to ensure that all applicable acceptance criteria have corresponding test cases at MRR.

Note: The detailed test cases of the I&C STP are not documented within the EA project. However, the operation procedures (developed in section 3.4.3) are expected to be testable through the execution of the defined test cases.

3.6.1.2.3 I&C SADD (Software Architecture and Design Description)

SEQA-45 [RD24], applies to the development of the CODAC System (PBS 45). Plant system I&Cs (PBS interfacing with CODAC) prepared in the scope of the ITER Plant Control Design Handbook are also subject to these requirements.

As per SEQA-45, the key milestones and deliverables for different SWIL levels are:

Table 3-4: Key milestones and deliverables for different SWIL levels

Milestones & Deliverables	SWIL-1	SWIL-2	SWIL-3
Software Requirements Review	SRS	SRS	SRS
Preliminary Software Design Review	SADD-β, STP-β	–	–
Final Software Design Review	SADD, STP	SADD, STP	–
Preliminary Software Implementation Review	SRC-β, STR-β, SUM-β	–	–
Final Software Implementation Review and Acceptance	SRC, STR, SUM	SRC, STR, SUM	SRC, STR, SUM

Table 3-5: ITER CODAC software integrity levels

ITER QC	Software Integrity Level	QA Degree
QC1	N/A (no such systems in CODAC)	

QC2	SWIL-1 – CODAC critical systems	- Full traceability of requirements - 100% code coverage - Performance tests - Regression tests - Backward compatibility control - Specific release / deployment procedures - Full user and developer documentation
QC3	SWIL-2 – CODAC regular systems	- Requirement / architecture documents - Unit and integration testing - Standard release / deployment procedures - User and developer documentation
QC4	SWIL-3 – CODAC auxiliary systems	- Reduced QA (requirements, user documentation) - Tests are optional

Most diagnostics have been classified as QC 3. Therefore, SWIL-2 applies to them, and I&C SADD needs to be produced. The aim is to capture lower-level software architecture and design information in this document, and the official template is [RD26]. At MRR, a consolidated (~detailed) I&C SADD is needed. Other software specific processes like quality assurance, change management, configuration management, verification and validation must be described in the I&C SMS. Examples of I&C SADDs can be found at the IDM location DMZGZ6.

Note: Other deliverables required for SWIL-2 are already covered by Table 2-1.

3.6.1.2.4 I&C Cubicle Wiring Diagrams

At MRR, complete (~final) electrical enclosure wiring diagrams and interconnection diagrams developed in SXP (SEE Electrical Expert) are required to be produced. [RD31] provides the template for developing these diagrams for Diagnostics (PBS 55). Key instructions and guidelines related to this topic were collated and presented during the 11th CODAC workshop on Diagnostics Plant I&C, ITER_D_CCWS32. The examples of wiring diagrams can be found at the IDM location DN7WU3.

To develop these diagrams, it is essential to start with clear and well-defined inputs. This includes selecting electronic components with detailed specifications and ensuring that the cubicle configuration is thoroughly planned, considering factors such as weight, heat dissipation, cable and wire length, and accessibility. Additionally, the cabling diagram should be fully finalized, with all cables confirmed and approved. Prototyping plays a crucial role in this process, as it allows for a better understanding of the components beforehand, making it easier to provide accurate inputs to the SXP technician.

Effective planning and resource management are also vital, with components sometimes requiring 2-3 months for entry into the SXP database (also refer PNI topic in section 3.4.1), followed by an electrical wiring preparation diagram phase that takes approximately 1-2 months per cubicle. The wiring diagram must then undergo a thorough review and finalization process, which typically lasts about a month. Key personnel involved in this process include the SXP technician, Diagnostic TRO, Plant I&C designer, Plant I&C manufacturer, and IO-CT experts, all of whom contribute their expertise to ensure accuracy and efficiency. The final output should be a single comprehensive wiring diagram that serves as the reference for cubicle manufacturing, cable installation, and ongoing maintenance.

3.6.1.2.5 SDD Project

At this stage, an SDD project containing only the design information loaded from the EA project is required. The design information includes signals, components, functions and variables.

3.6.1.2.6 EA project

EA Project incorporating all necessary updates following the Final Design Review (FDR). The I&C SRS and I&C SDS document do not need to be updated. The official location for the EA project delivery is on the ITER SVN (which needs separate permissions for access).

Path is https://svnpub.iter.org/codac/iter/codac/icdev/units/m-DX-XX/trunk/src/main/ea

For earlier stages like PDR and FDR, it is acceptable to add the EA project as an attachment to the I&C SDS in IDM.

3.6.2 Manufacturing and Delivery (MAN)

3.6.2.1 Cubicle Assembly

As shown in Figure 35, the assembly of I&C cubicles takes place during this phase. Before the MRR, the MIP exists as an Excel file, which is subsequently imported into the Manufacturing Database (MDB). Throughout the MAN phase, task tracking and follow-ups are managed within the MDB, ensuring that each manufacturing step is systematically recorded, including reports and images for documentation.

Once the cubicle assembly is complete, tests are conducted in accordance with the MIP. Upon successful completion of these tests, an end-of-manufacturing report can be automatically generated within the MDB. At this stage, the software can be loaded, and testing can commence as soon as the software is ready.

Note: End of manufacturing is independent of the software development.

3.6.2.2 Software development

Software development is more or less independent of the MRR, as shown in Figure 35. The development process should adhere to the CODAC Core System development guidelines [RD24], [RD33].

During the MAN phase, inspections will be conducted in accordance with the SDIP. The Plant I&C comprises multiple software elements organized into categories and sub-categories, each associated with specific packages and configuration files. The SDIP captures these details in a structured format, listing package names, file names, and descriptions. It also records the source repository path, versioned dependencies, and target control units for deployment. Additional columns track development status, including current and delivered versions, last modifications, and review history. Reference documentation, bug tracking, and reviewer feedback ensure traceability and quality assurance. This plan serves as a comprehensive means for managing and reviewing all software components.

The test cases of the I&C STP document are detailed to the lowest in this phase. It is expected that the operational procedures (developed in section 3.4.3) will be testable through the execution of the defined test cases.

The I&C SADD is finalized during the software development phases.

3.6.2.3 Testing leading up to FAT

As shown in Figure 35, the development teams conduct multiple internal test cycles, addressing any identified bugs along the way until the system is ready for Factory Acceptance Testing (FAT).

Note: From [RD27]- System is accepted by IO-CT when the system commissioning tests have passed successfully.

The Site Acceptance Test (SAT) is when IO-CT decides whether to accept or reject the component based on the test results. The SAT will be initiated upon site reception and concludes at system commissioning.

From Table 2-1, the key deliverables for FAT are:

- I&C STP (CP)
- I&C STR (CP)
- I&C SADD (CP)
- I&C OMM (CS, ~detailed)

The official template for the I&C OMM document is [RD25]. Please note that Version 1.0 of this template is not the final version, and further refinements will be made in Version 2.0 and beyond. Examples of I&C OMMs can be found at the IDM location DQ5NCH. I&C OMM is not automatically generated from the EA project since the contents of an I&C OMM need to be optimized for the operations perspective.

Once FAT is successfully completed, the I&C cubicles are ready to be prepared for delivery to ITER site. The broader list of deliverables required post-manufacturing are listed in [RD11].

The preparation for delivery must follow the instructions in [RD29].

3.6.3 Installation (AIP, AIE) and Testing and Commissioning (COM)

This refers to the integration phase in Figure 3. The phases involved from Figure 2 are:

- Assembly and Installation Preparation (AIP)
- Assembly and Installation Execution (AIE)
- Testing and Commissioning (COM)

Section 2.1.1, details the activities, responsibilities, and interactions among IO-CT and IO-DA teams during the integration phase. Please also refer Figure 4 to view the different lifecycle phases superimposed.

Once the cubicles have been installed, the next set of integration phases can be executed. These are pre-SAT, SAT and System Commissioning.

As required by PCDH, source code and configuration data must be provided for all relevant project phases, including FAT, SAT, system commissioning, and integrated commissioning. **It is important to recognize** that these deliverables may evolve/change along the different phases. Certain aspects, such as configuration, may not be fully developed or finalized at the time of FAT. These aspects must be completed and delivered as appropriate during the relevant phase, after due discussions/agreements with IO-CT.

As decided in [RD5], a different I&C STP needs to be developed for SAT, to cater to changes between FAT and SAT, notably the integration with Central CODAC. Separate test plans should be developed for FAT, SAT, and System Commissioning, although significant commonalities may exist between them. The central CODAC integration procedures (relevant from SAT) which also need to be complied to are documented at [RD28].

From Table 2-1, the key deliverables for SAT are:

- I&C STP (CP)
- I&C STR (CP)
- I&C OMM (CS, ~detailed)

Similarly, from Table 2-1, the key deliverables for System Commissioning are:

- I&C STP (CP)
- I&C STR (CP)
- I&C OMM (CP)

Note: The system can be only accepted at system commissioning if the pre-requisites for integrated commissioning have been fulfilled.

3.7 Operation and Maintenance (OPE)

This refers to *Operations and Maintenance* (OPE) phase in Figure 2 and *O & M Phase* in Figure 3. In this phase, the system will be operated using I&C OMM.

Appendix I Mapping to PCDH deliverables for design

Table 3-6: I&C Design Deliverables Mapping to I&C SRS and SDS Document

Deliverables	Detailed Description from PCDH satellite document (ITER_D_353AZY)	I&C SRS Chapter/Section	I&C SDS Chapter/Section
D1A	D1A target is to collect all inputs from I1 to I8 in a single document. In addition, the CBS down to level 2 is specified. The plant system equipment interfaced to the plant system I&C are listed but not in details.	Chapter 2.2, Chapter 2.3 Chapter 3.4, Chapter 7.2, Chapter 6, Chapter 8, Chapter 9	Chapter 11, 12
D1B	D1B provides the functional specifications for the control functions. Several D1B documents may be required for covering a plant system depending on its D1 complexity. Conventional, Interlock and Safety controls are addressed.	Chapter 6 (Level 2 Functional Breakdown)	Chapter 3, Chapter 4 (Detailed Functional breakdown Level 4/5), Chapter 5
D1C	D1C is the compilation of the D1Bs for determining the physical architecture and functional of the plant system I&C. The control functions are allocated to controllers depending on performance, suitability and location. The controller network interfaces are identified, functionally and physically specified. This deliverable is required for specifying the interface of the plant system I&C with the central I&C systems.	Chapter 7.1 (High Level)	Chapter 4, Chapter 7 (Detailed)
D5	D5 provides the specifications of I&C controller type (slow/fast), (conventional/interlock, Safety) and network configuration. The details of these specifications will be determined by the I&C supplier.	Chapter 7.1 (High Level)	Chapter 7 (Detailed)
D6	D6 provides the list of signals connected to the plant system I&C including name, type, sampling rate, allocation to I&C cubicles and location. This deliverable is required for specifying the configuration of the controllers and the data interfaced to central I&C systems.		Chapter 7, EA, PSP

Deliverables	Detailed Description from PCDH satellite document (ITER_D_353AZY)	I&C SRS Chapter/Section	I&C SDS Chapter/Section
D7	D7 is the list of data at central I&C interface.		Chapter 4, PSP, EA
D8	D8 provides the hardware configuration of I&C cubicles. D8 includes for each I&C cubicle: the enclosure type and the HVAC configuration if some interface (e.g. chilled water is required). This deliverable is required for specifying the configuration of the cubicle interface with the buildings, power supply and cable trays.		Chapter 9
D9	D9 provides the state machines specifications for the Plant System Operating States (PSOS) ~~and the mapping with the Common Operating States (COS)~~. This deliverable is required for preparing the integrated operation of the plant system.	Chapter 7.2 (high level)	Chapter 6
D71	A proactive management plan for obsolescence describing the strategies for identification and mitigation of the effects of obsolescence throughout all stages of I&C life cycle. This management plan shall be produced during the design phase and maintained through all the phases.		Chapter 7.3