

Preparation of functional/engineering specifications for HL-LHC



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The HLumi LHC Design Study is included in the High Luminosity LHC project and is partly funded by the European Commission within the Framework Programme 7 Capacities Specific Programme, Grant Agreement 284404



Contents

- Project documentation
- Specifications approach
- Specifications contents, inputs & outputs

Preparation of functional/engineering specifications for HL-LHC

Project documentation



Documentation types

Baseline documentation:

Documentation that will have to be stored and updated until the dismantling of the LHC

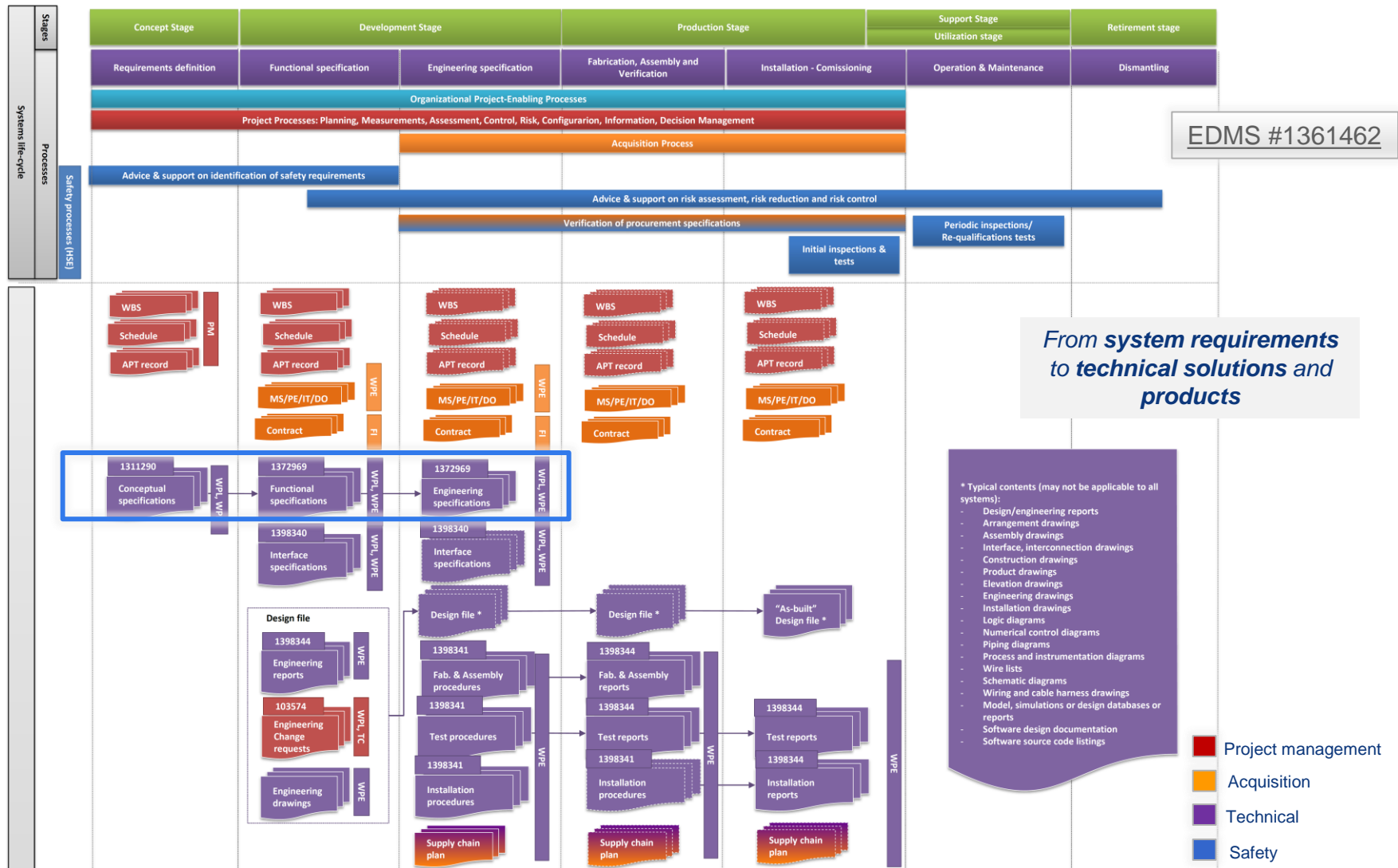
➤ *Functional and engineering specifications are included*

Non-baseline documentation:

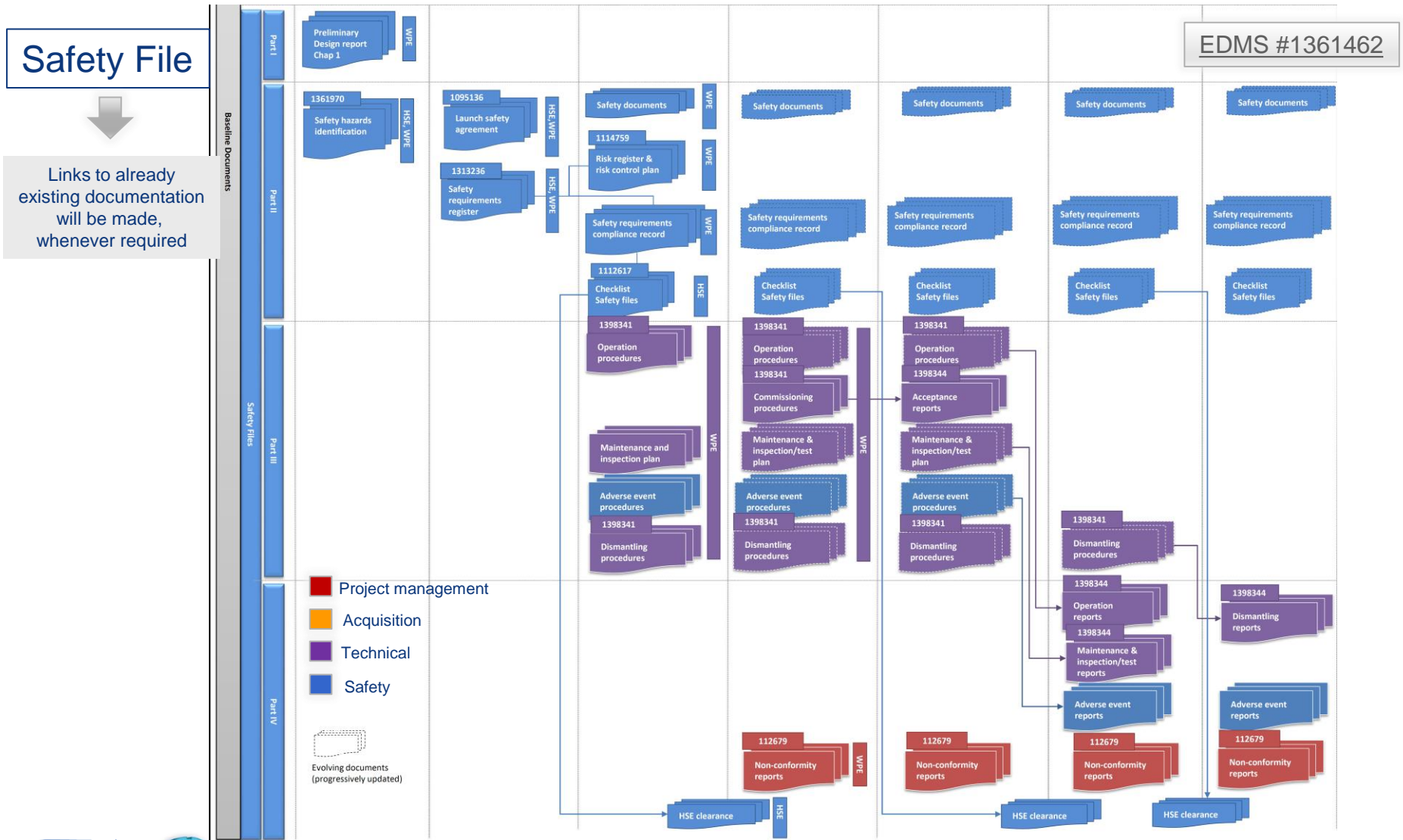
Documentation that are required for the well functioning of the project but which storage will not be considered critical after the commissioning phase.

HL-LHC is an upgrade of LHC and therefore all documents will be stored and managed according to the LHC procedure

Baseline documentation (1/2)



Baseline documentation (2/2)



Documentation storage

Baseline documentation

Non-baseline documentation

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- Accelerators
- CERN Departments
- Computing
- Design & Equip. Catalogues
- EU Projects
- Experiments
- LHC Machine
 - LHC Project Management
 - LHC Hardware Baseline**
 - LHC Hardware Commissioning
 - LHC Design - Parameters & Layouts
 - LHC Equipment Codes
 - LHC Controls
- HL LHC - High Luminosity LHC
- LIU - LHC Injectors Upgrade
- Management & Committees
- Operation
- Health, Safety & Environment
- External Collaborations
- Others

HL Nodes in the LHC Hardware Baseline

- HL Layout & Integration
- Long Straight Section
- Cryogenics
- Radiofrequency System
- DC Powering
- Vacuum

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 - HL-LHC High Luminosity LHC Project**
 - Quality guidelines
 - Guidelines
 - C High Luminosity
 - LHC High Luminosity
 - Guidelines
- LIU - LHC Injectors Upgrade
- Management & Committees
- Operation
- Health, Safety & Environment
- External Collaborations
- Others



Image in the HL-LHC Project Documentation

- HL-LHC High Luminosity LHC Project
 - Project Governance
 - Project Management
 - Work Package Workspace
 - HL Nodes in the LHC Hardware Baseline

Work Package Workspace

- Accelerator Physics and Performance (WP2)
- Magnets Design (WP3)
- Crab Cavities (WP4)
- Collimation (WP5)
- Cold Powering (WP6)
- Machine Protection (WP7)
- Collider-Experiment interface (WP8)
- Cryogenics (WP9)
- Energy Deposition and Absorber (WP10)
- 11T Dipole Two in One for DS (WP11)
- Vacuum (WP12)
- Beam Diagnostics (WP13)
- Beam Transfer & Kickers (WP14)
- Integration & De-installation (WP15)
- Hardware Commissioning (WP16)
- Safety
- Technical Infrastructure
- Logistics

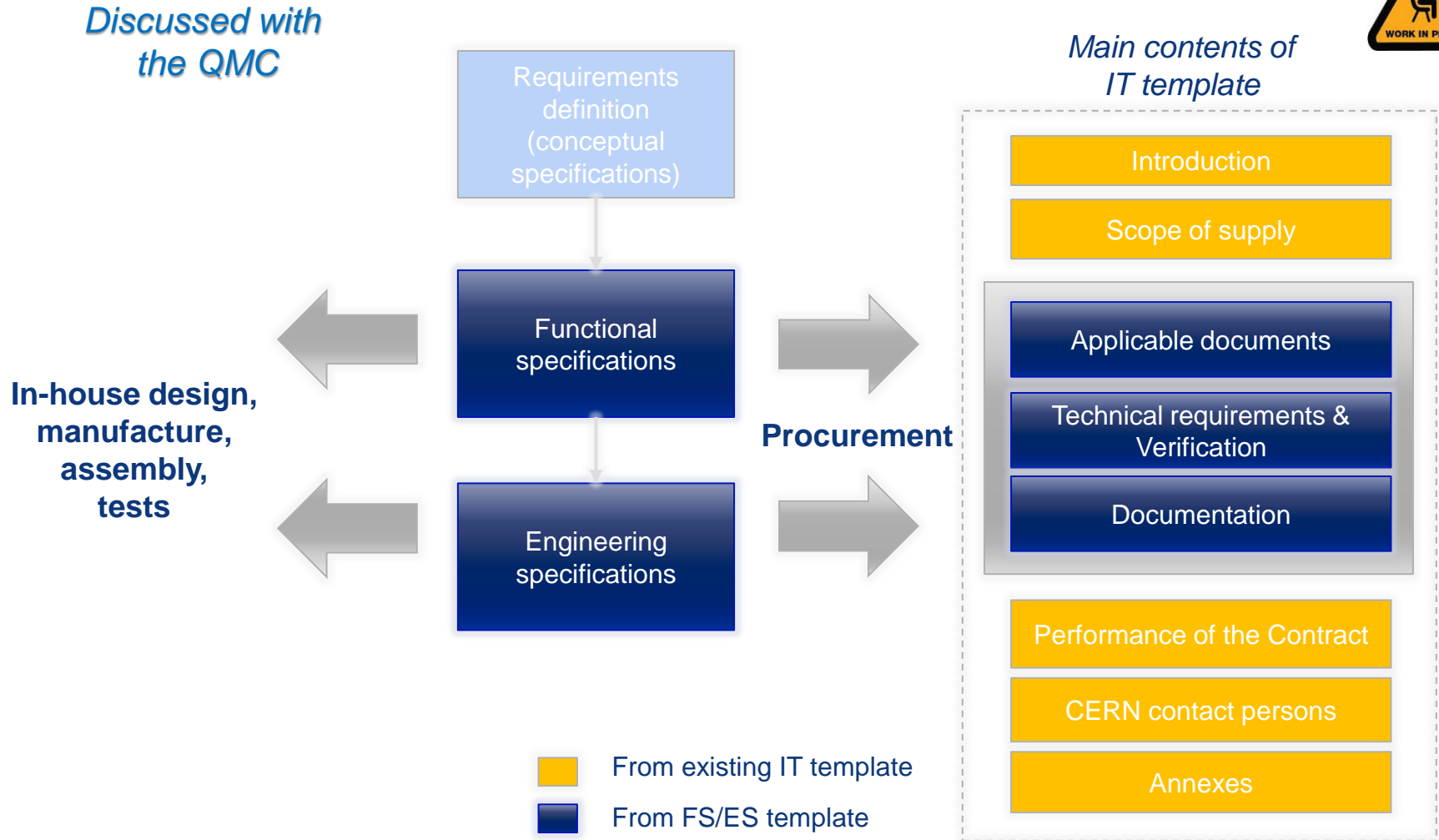
Create documents in **context**:
HL-LHC-WP: High Luminosity LHC Workpackages

Preparation of functional/engineering specifications for HL-LHC

Specifications approach



The role of the specifications



Differences between Functional and Engineering specifications

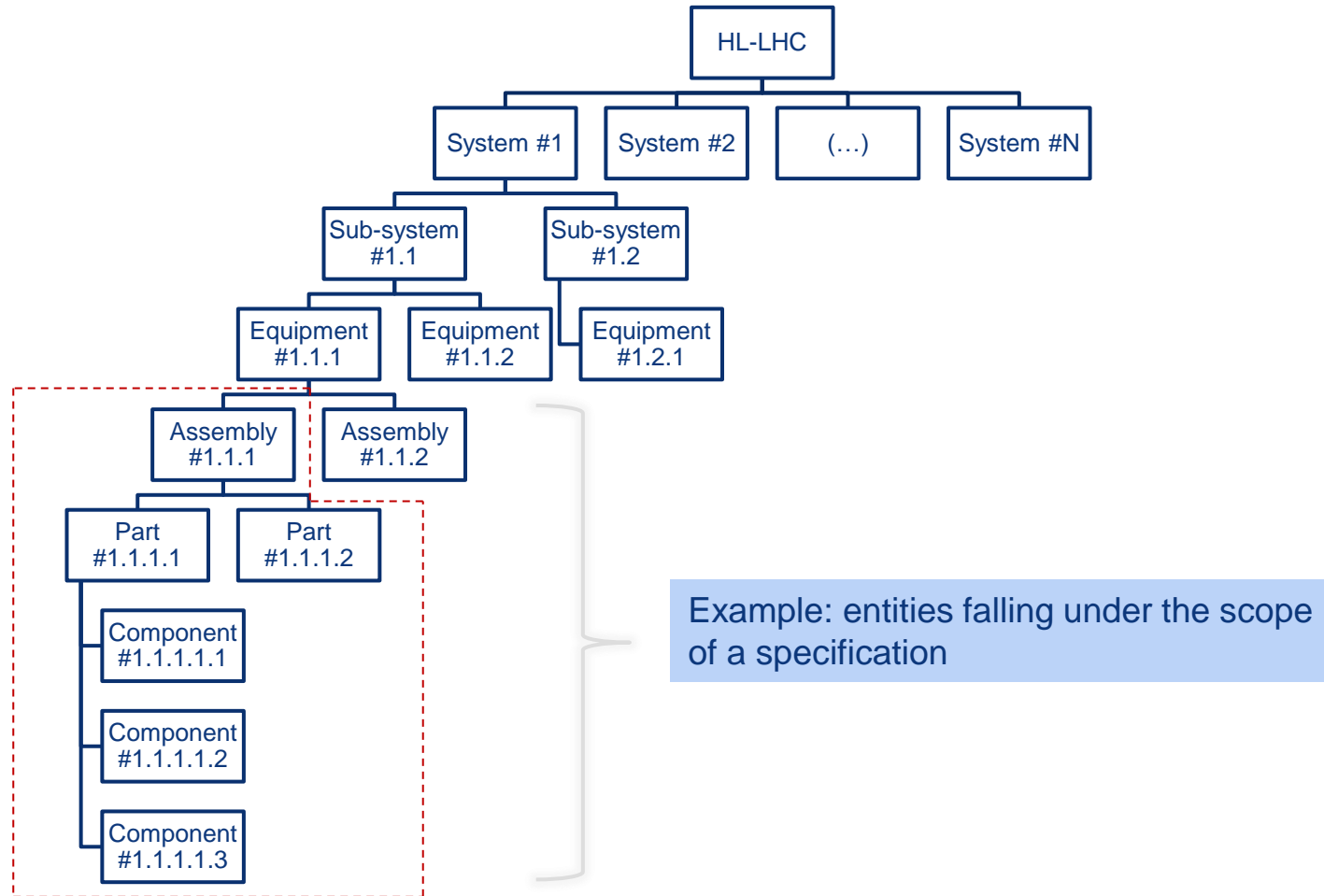
- Functional (“Performance”, “Design-to”)
 - States the requirements in terms of the **required results and the criteria for verifying compliance**, without specifically stating how the results are to be achieved
 - Describes the functional requirements for an item, its capabilities, the environment in which it must operate, and any interface, interoperability, or compatibility requirements
- Engineering (“Detail”, “Build-to-print”)
 - Provides **preconceived solutions to requirements and describes exactly how an item is to be produced**.
 - Identifies materials to be used, specific parts and components, and how the item is to be fabricated and assembled

Functional specifications are used during the systems development and preliminary design while engineering specifications are produced in the detailed design phase although in they are usually a **mix of functional and engineering specifications**

Fundamental aspects

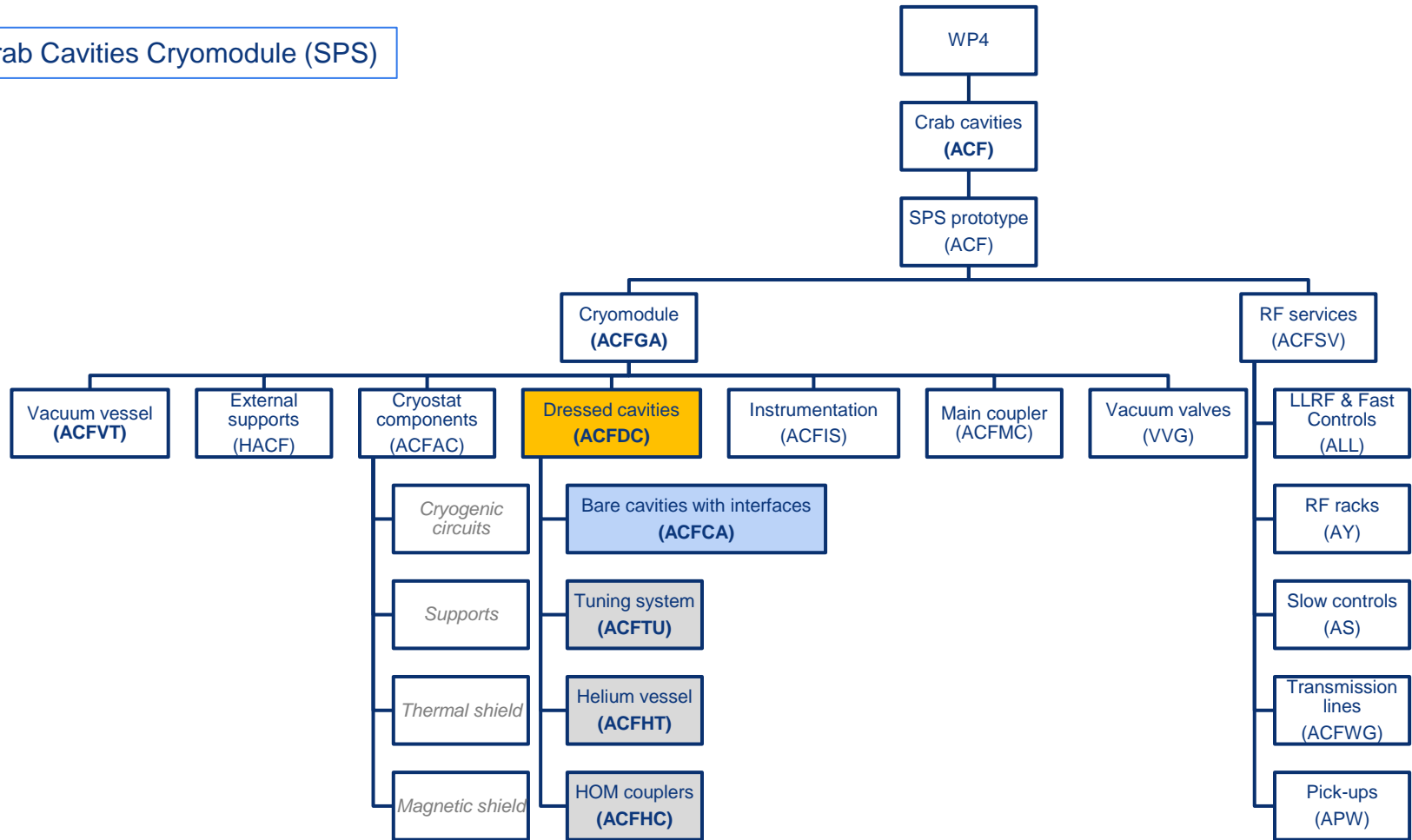
- The **approach** to the specifications is based on:
 1. Identification of the “entities” falling under the scope of the specification, and their architecture
 2. Identification of the processes through which the “entities” are obtained

Entity architecture

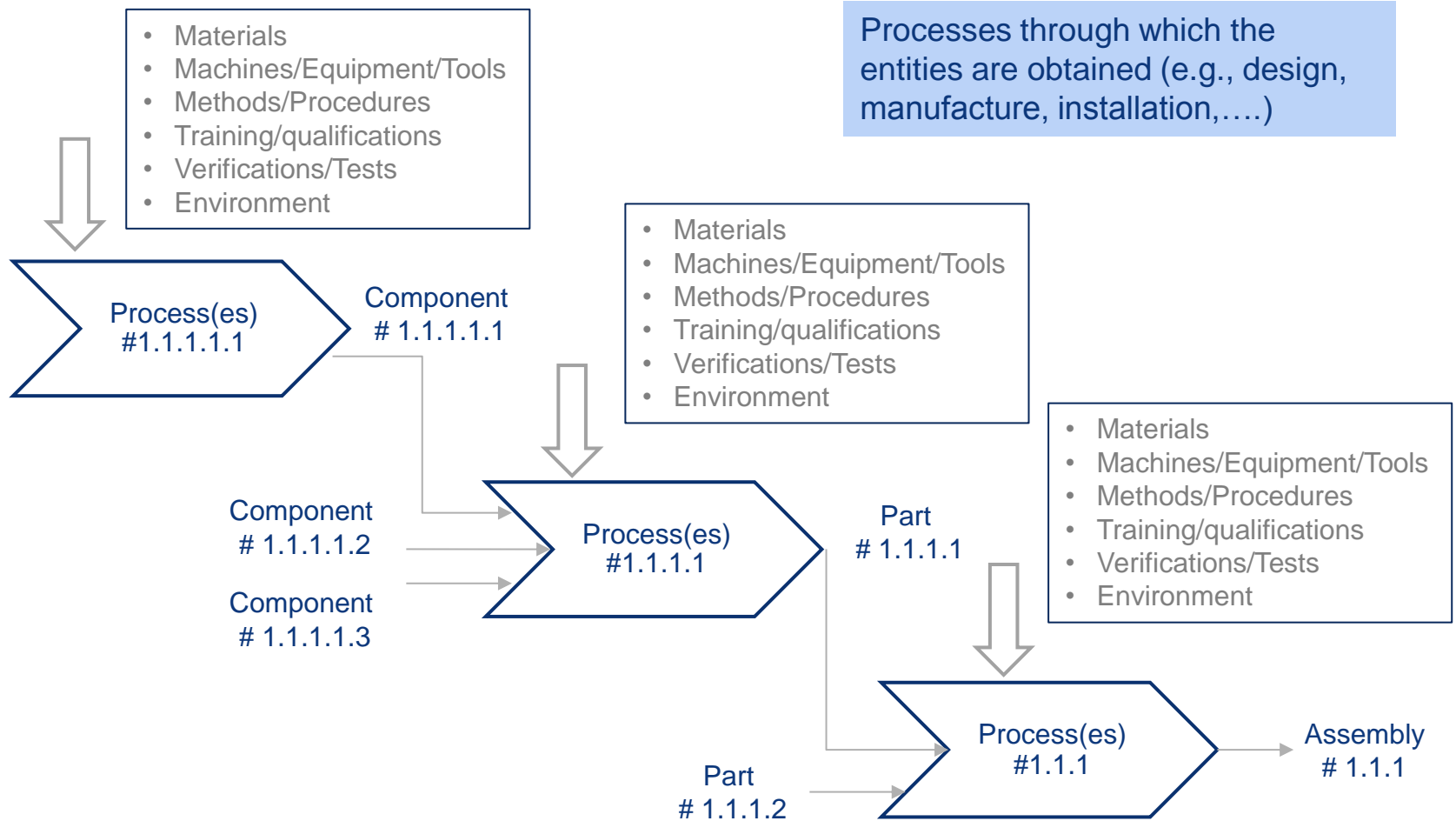


Example

Crab Cavities Cryomodule (SPS)



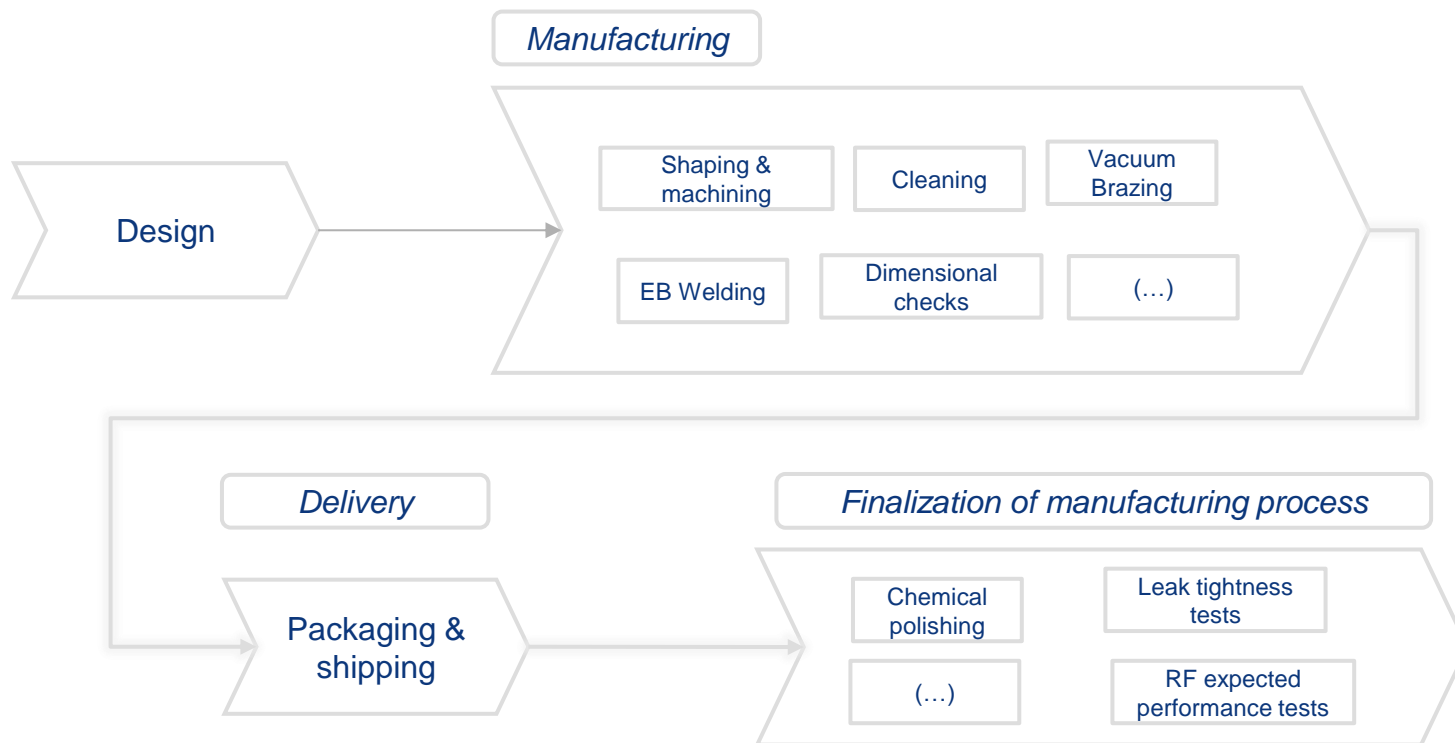
Processes



Example

To obtain the required “entities”, or products, previously identified

Simplified processes for **bare cavities (with interfaces)**



Preparation of functional/engineering specifications for HL-LHC

Specifications contents, inputs & outputs



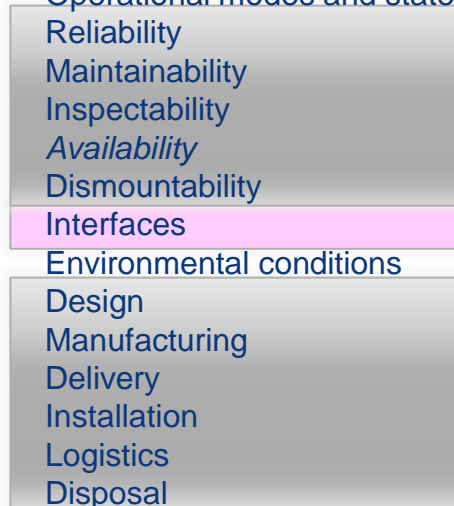
Main contents

EDMS #1372969

- **Scope**
 - Description
 - Life-cycle overview
 - Identification on the HL-LHC system architecture
 - Processes identification on the HL-LHC system life-cycle
- **Applicable documents**
- **Technical requirements for [Entity #1]**
 - Description
 - Materials
 - Physical characteristics
 - Operational modes and states
 - Reliability
 - Maintainability
 - Inspectability
 - *Availability*
 - Dismountability
 - Interfaces
 - Environmental conditions
 - Design
 - Manufacturing
 - Delivery
 - Installation
 - Logistics
 - Disposal
 - Any other requirements...

- **Verification of [Entity #1]**
 - (...)
- **Technical requirements for [Entity #N]**
 - (...)
- **Verification of [Entity #N]**
- **Documentation**
- **Appendix(es)**

Flexibility: sections can be **added** if needed or **removed** (when not applicable)



Qualitative assessment
(supported by TQO)

Completed by
Interface specifications

Processes definition
(supported by TQO)

Main inputs & outputs

- **Inputs**

- Requirements definition (conceptual specifications)
- Launch safety agreement (HSE guideline)
- *Safety requirements register*
- Actions from safety risk assessments
- Actions from reliability, maintainability assessments
- Technical standards guideline (EDMS #1360646)

- **Outputs**

- Baseline documentation (including safety documentation) - EDMS #1361462

Hazards assessment

EDMS #1361970

Required to obtain
Launch Safety Agreement from HSE Unit

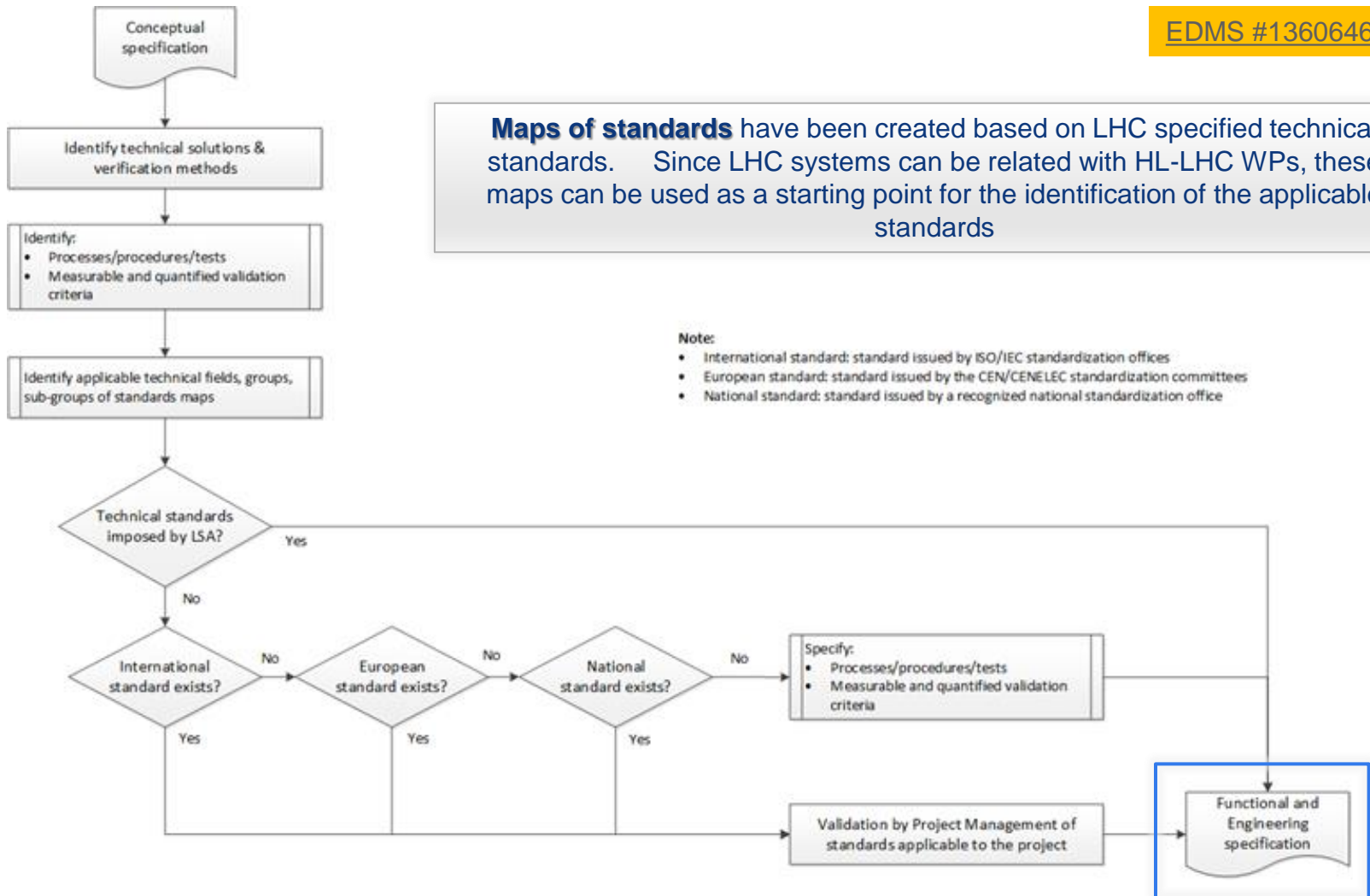
- Per individual entities or,
 - Per entity life-cycle
- Example:*
- Dismantling (old)
 - Construction (design, manufacture)
 - Installation
 - Operation/Maintenance/Interventions
 - Dismantling (new)

Optimization will be made
whenever hazards are identical

Presence of Hazards	Short description	CERN location	
		CH	FR
Mechanical Safety			
Pressure equipment [pressure][bar]; [volume][l]	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Vacuum	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Lifting/handling equipment	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Machinery/machine Tools	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Mechanical energy (moving parts)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Mechanical properties (sharp, rough, slippery)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Industrial Vehicles	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Hot Work (e.g. welding, grinding)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Hot/cold surfaces	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Vibration	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Cryogenic Safety			
Cryogenic fluids [phase] [fluid]	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Structural Safety			
Shielding walls	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Earthworks, drainage (excavation, underground networks etc.)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Bearing structures	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Platforms, walkways, guards rails, stairs and ladders	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Electrical and electromagnetic Safety			
Electrical equipment / installation [voltage] [V], [current][A]	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
High voltage equipment	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Magnetic field [magnetic field] [T]	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Equipment in potentially explosive atmospheres	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Chemical Safety			
Hazardous chemical agent (HCA)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Selection of technical standards

EDMS #1360646



Identification of technical standards

Global overview
EDMS: [1380880](#)

ICS Field	Group	Sub-group	EDMS	LHC / Related HL-LHC WPs									
				Magnets	RF	Collimators	Powering	DC powering and quench protection	Cryogenics	Vacuum	Beam monitoring	Transfer lines, injection and beam dumping	
				3	4	5	6	6&7	9	12	13	14	
01.060	Generalities. Terminology. Standardization. Documentation	Quantities and units	1360514										
01.080.30		Graphical symbols	1360510						X				
01.100.01		Technical drawings	Technical drawings in general	1360511									
01.100.20			Mechanical engineering drawings	1360512								X	
01.100.30			Construction drawings	1360513									X
03.120.10	Services. Company organization, management and quality. Administration. Transport. Sociology	Quality	1360523	X				X	X	X		X	
13.240	Environment. Health protection. Safety	Protection against excessive pressure	1360509						X				
13.260		Protection against electric shock. Live working	1360508		X							X	
17.020	Metrology and measurement. Physical phenomena	Metrology and measurement in general	1360520	X									
17.040.20		Linear and angular measurements	Properties of surfaces	1360519	X						X		
17.140.50			Acoustics and acoustic measurements	Electroacoustics	1360518		X						X
17.160		Vibrations, shock and vibration measurements		1360522						v			
17.200.20			Thermodynamics and temperature measurements	Temperature-measuring instruments	1360521								
19.100		Testing	Non-destructive testing	1360502	X		X	X	X			X	
23.020.30	Fluid systems and components for general use	Fluid storage devices	1360482	X	X								
23.020.40		Pipeline components											
23.040.01			Valves										X
23.040.10													
23.040.40		Vacuum technologies											
23.040.60													
23.040.70													
23.060													
25.040.40		Manufacturing engineering	Industrial automation										
25.160.01			Welding, brazing, etc.										
25.160.10													
25.160.20													
25.160.40	Surface treatment												
25.160.50													
25.220.20													
25.220.40													
29.030	Electrical engineering		Magnetic material										
29.035.01			Insulating materials										X
29.035.20													
29.045		Semiconducting materials											
29.050			Superconductivity										
29.060.10			Electrical wires and cables										
29.120.50		Electrical accessories										X	
29.120.70												X	
29.130.20													
29.160			Switchgear and controlgear										
29.160.30	Rotating machinery												
29.180		Transformers, reactors										X	
29.200		Rectifiers, converters, electronic power supply										X	

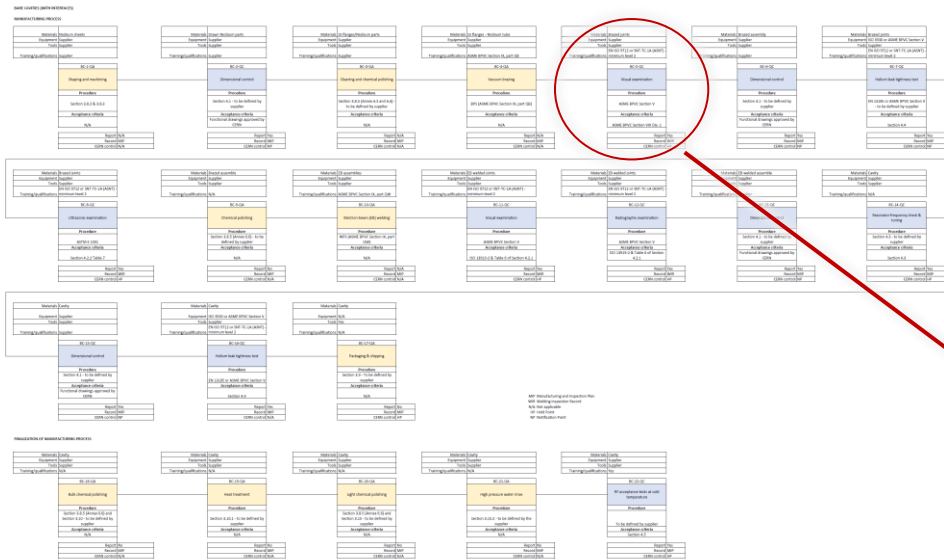
Example

Technical requirements	Standards fields/groups	Selected standards
EB welding	Manufacturing engineering → Welding processes	ASME BPVC Section IX PART- QW
Visual examination of EB welds	Manufacturing engineering → Welded joints	ISO 13919-2
Pressure vessel	Fluid systems and components for general use → Pressure vessels	ASME BPVC
Niobium – Titanium transition pieces	Metallurgy → Other products of non-ferrous metals	ASTM B884-11

To be discussed and validated by the project management

Specification of technical processes (1/2)

Quality assurance and quality controls needed to meet the requirements → **input to MTF**



Quality control step
→ supported by validated technical standards

Materials	EB welded joints	
Equipment	Supplier	
Tools	Supplier	
Training/qualifications	EN ISO 9712 or SNT-TC-1A (ASNT) - minimum level 2	
	BC-11-QC	
	Visual examination	
	Procedure	
	ASME BPVC Section V	
	Acceptance criteria	
	ISO 13919-2 & Table 6 of Section 4.2.1	
	Report	Yes
	Record	WIR
	CERN control	HP

Specification of technical processes (2/2)

Quality assurance steps

→ supported by validated technical standards and/or by **CERN best practices**

Materials	SS flanges - Niobium tube	
Equipment	Supplier	
Tools	Supplier	
Training/qualifications	ASME BPVC Section IX, part QB	
	BC-4-QA	
	Vacuum brazing	
	Procedure	
	Section 3.8.6 & BPS (ASME BPVC Section IX, part QB)	
	Acceptance criteria	
	N/A	
	Report	N/A
	Record	MIP
	CERN control	N/A

Materials	Brazed assembly	
Equipment	Supplier	
Tools	Supplier	
Training/qualifications	N/A	
	BC-9-QA	
	Chemical polishing	
	Procedure	
	Section 3.8.5 (Annex 6.6) - to be defined by supplier	
	Acceptance criteria	
	N/A	
	Report	No
	Record	MIP
	CERN control	N/A

Other CERN best practices used to support the specification (examples):

- Niobium RRR 300 - Material Technical Specification N° 3300
- Cleaning procedure for stainless steel components

Thank you for your attention!

Questions?



Preparation of functional/engineering specifications for HL-LHC

Annex(es)



Interface specifications



1. Identification

External interfaces matrix

	WP1	WP2	WP3	WP4	WP5	WP6	WP7	WP8	WP9	WP10	WP11	WP12	WP13	WP14	WP15	WP16	WP17
WP1																	
WP2			X	X	-	-	X	-	-	-	X	X	X	X	-	-	-
WP3	X			-	-	X	X	-	X	X	-	X	X	X	X	X	X
WP4	X	-			-	?	X	-	X	-	-	X	X	-	X	?	X
WP5	-	-	-			-	X	-	-	-	X	X	X	X	X	X	X
WP6	-	X	?				X	-	X	-	X	X	-	-	X	X	X
WP7	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X
WP8	-	-	-	-	-	-	X		-	-	-	-	?	X	X	X	?
WP9	-	X	X	-	X	X	-		-	X	X	X	X	-	X	?	X
WP10	-	X	-	-	-	-	X	-		-	X	X	X	X	-	-	-
WP11	X	-	-	X	X	X	X	-	X	X		X	X	-	X	X	X
WP12	X	X	X	X	X	X	X	?	X	X	X		X	X	X	?	X
WP13	X	X	X	X	-	X	X	X	X	X	X		X	X	X	-	X
WP14	X	X	-	X	-	X	X	-	X	-	X	X		X	X	X	X
WP15	-	X	X	X	X	X	X	X	-	X	X	X		X	X	-	-
WP16	-	X	?	X	X	X	X	?	?	-	X	?	-	X	-		-
WP17	-	X	X	X	X	X	X	X	-	X	X	X	X	-	-		-

2. Definition

WPs	Data-flow (from-to)	Interface-definitions	Due-date(s)
Accelerator-physics-and-performance-(WP2)			
Magnets-(WP3)			
Radio-Frequency-(WP4)			
Collimation-(WP5)			
Cold-Powering-(WP6)	None		
Machine-Protection-(WP7)			
Experiments-Interface-(WP8)			
Cryogenics-(WP9)			
Energy-Deposition-&-Absorber-Coordination-(WP10)			
11-T-Dipole-Magnets-(WP11)			
Vacuum-(WP12)			

3. Requirements specification



→ EDMS-NO. → 0000000 → REV. → 0.0 → VALIDITY → DRAFT
 REFERENCE: {OTHER-REFERENCES}

INTERFACE-SPECIFICATION

[ENTITY-NAME-WPX]

[HL-LHC-EQCOD-ACCORDING-TO-CONFIGURATION-MANAGEMENT]

Abstract
 Brief description of the purpose.

EDMS #1398340

Can be used for external and/or internal interfaces

- 1 → Purpose
- 2 → Applicable documents
- 3 → External interface requirements
 - 3.1 → Identification
 - 3.2 → Requirements
- 4 → Internal interface requirements
 - 4.1 → Identification
 - 4.2 → Requirements
- 5 → Annex(es)
- 6 → Summary table

How to specify requirements?

- Criteria:
 - Each requirement shall be stated in such a way that an objective verification can be defined for it.
 - Each requirement should be cross-referenced to the associated verification.
 - Only requirements that are necessary, measurable, achievable, and verifiable shall be included.
 - Requirements shall be worded to provide a definitive basis for acceptance or rejection.
 - Requirements shall be described in a manner to encourage competition.
 - Requirements shall be worded such that each paragraph only addresses one requirement or topic.



Degree of detail: include only requirements (i.e., characteristics) of the system, sub-system,..., component that are **conditions for the entity acceptance**