LHC Installation

S. Chemli – Alignment, Coordination and Engineering Group

Acknowledgements to : P. Bonnal, J. Coupard, D. Duret, L. Evans, P. Faugeras, K. Foraz, C. Hauviller, P. Proudlock, R. Saban, R. Schmidt

CERN | EN ENGINEERING DEPARTMENT

Main topics exposed

- Some words of introduction
- The LHC installation from the inside
  - Organization
  - Installation phases
  - Lessons learned on the installation
- Behind the scenes
  - Methodology
  - Lessons learned on project management

Main topics exposed

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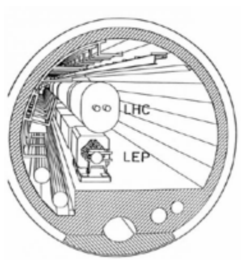
The LHC Project timeline

84: First studies of the LHC project



94: Approval of the project by the CERN Council

98: DUP & Start of civil engineering

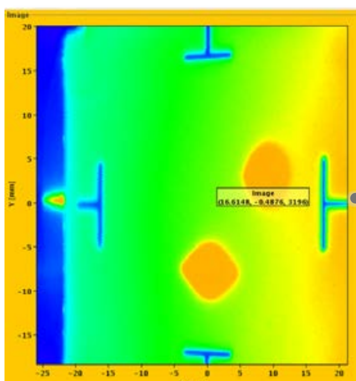
08: 1st beam

09: Start of Physics

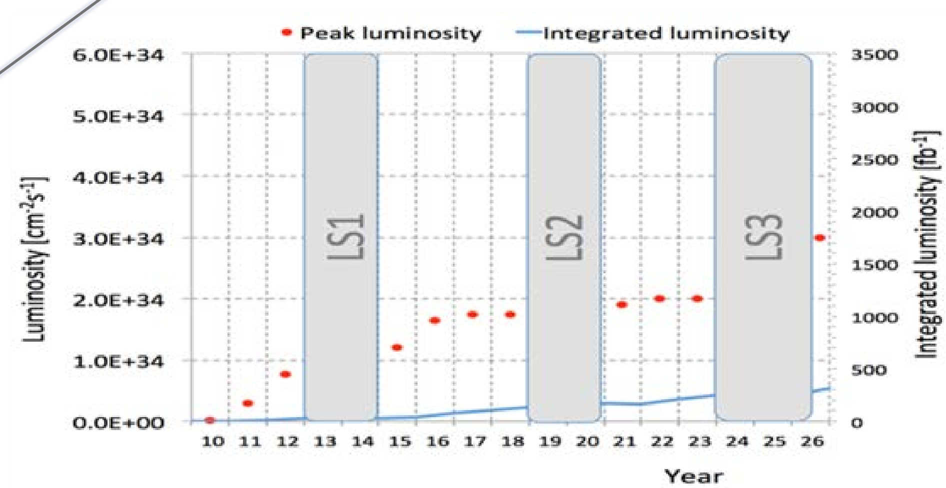
13-14: Long shutdown 1

19-20 : Long shutdown 2

24-25 : Long shutdown 3



First LHC beams



LHC Project as a Mega Project

Mega Project factors	Impact on the project
Time Horizon • Multi-year • Multi-phase	**Risks** had to be properly analysed
Chain of Command • Multi-layer organization • Matrix Structure	**Responsibilities** had to be clear
High-degree of Specialisation • Subject Matter Expertise • Cutting-Edge Technology	**Coordination** was crucial
Dispersed Teams • Virtual teams in multiple locations • Outsourcing to other countries	As well as clear and transparent **communication**

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LHC Project Organization (2004)

Project Management & PL's office

Supporting Departments

- AB — *Accelerator Beams*
- AT — *Accelerator Technology*
- FI — *Finance*
- IT — *Information Technology*
- SG — *Secretary General*
- TS — *Technical Support*
- IC — *Installation Coordination*

Committees

- SC
- TCC
- MARIC
- LEMIC
- LCC
- PLC

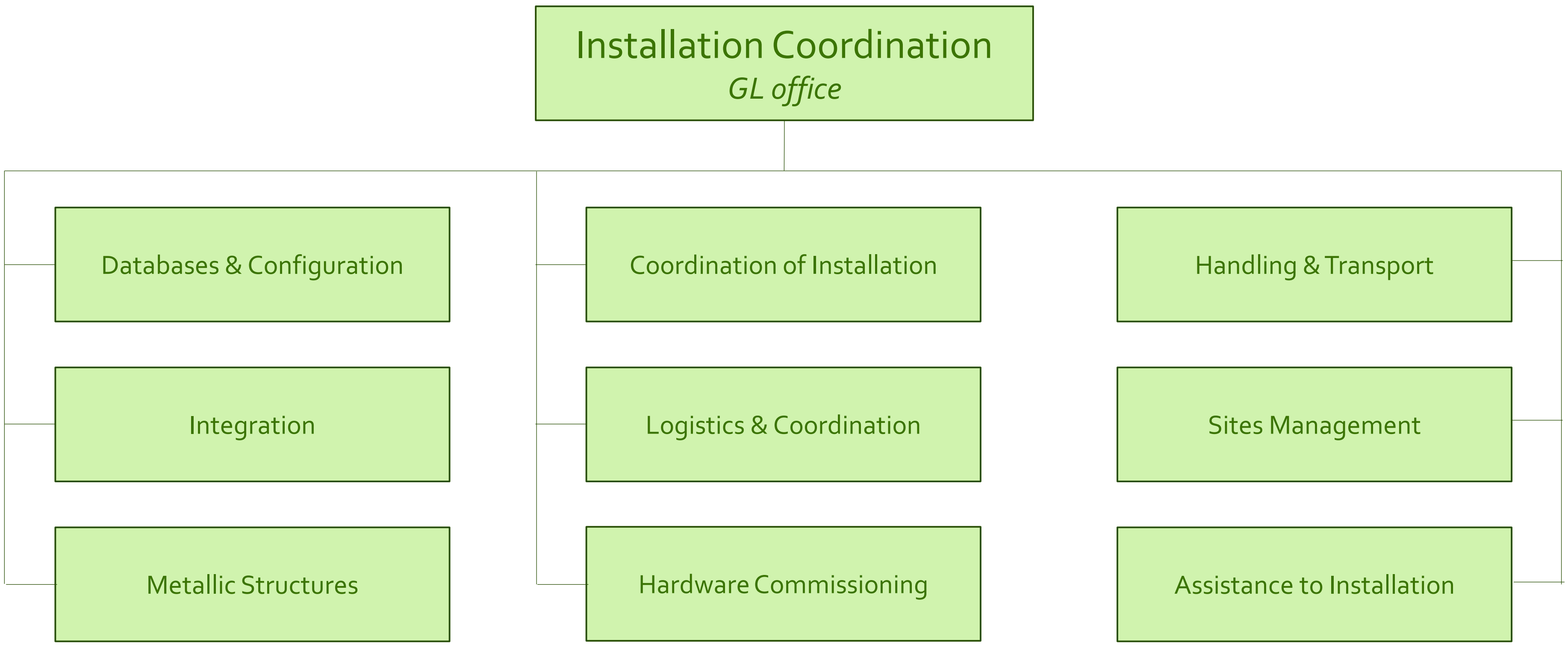
Working Groups / sub-projects

Collaborations

- Canada
- Host states
- India
- Japan
- Russia
- USA

LEMIC	Experiments Machine Interface Committee
LCC	LHC Commissioning Committee
MARIC	Main Ring Committee
PLC	Parameters & Layouts Committee
SC	LHC Specification Committee
TCC	Installation & Commissioning Committee

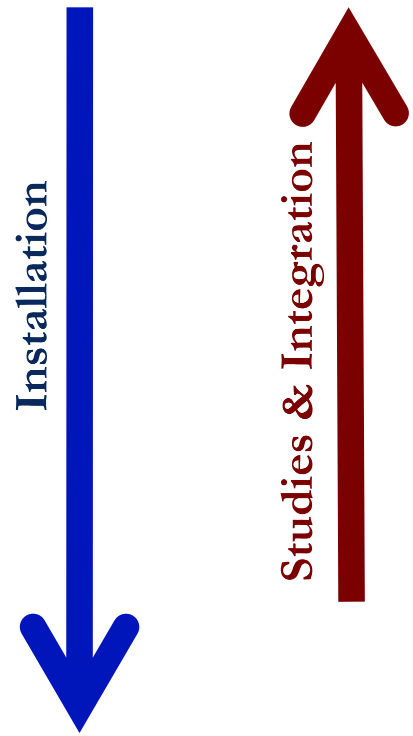
IC group organization



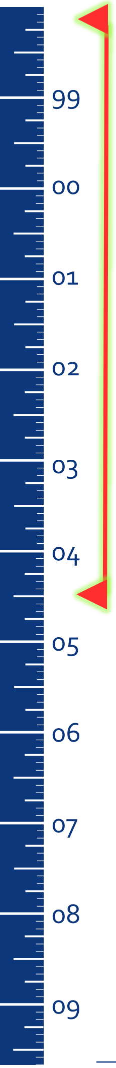
LHC installation history

8 sectors considered as 8 machines

- Civil engineering and LEP dismantling
- General Services
- Cryogenics
- Machine
- Hardware Commissioning

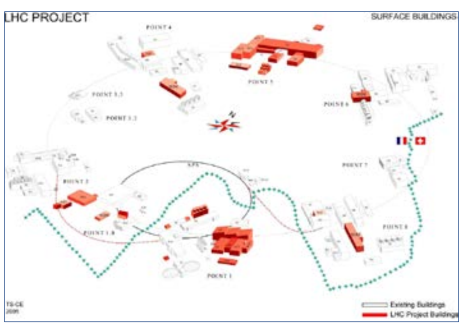


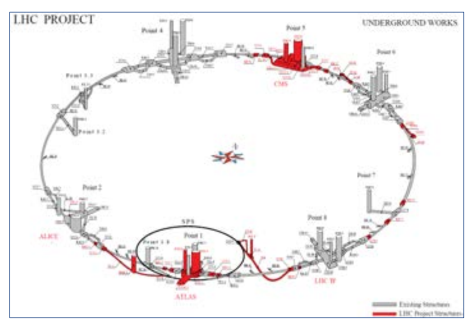
Civil Engineering phase



- 4 main contracts to build:
  - Surface buildings: modification & construction
  - Underground
    - 2 injection tunnels ~5km
    - 2 ejection tunnels ~2km
    - 2 new experimental areas
    - Modification & consolidation of existing areas

240’000 m3





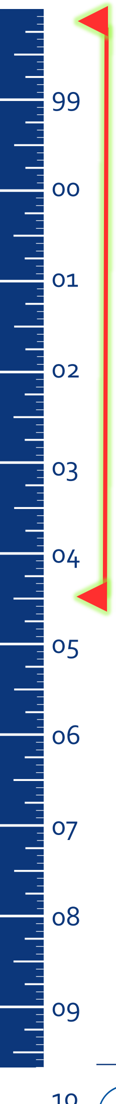
TI2

DUMP

CMS

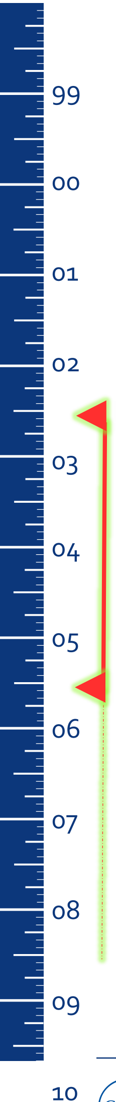
ATLAS

Civil Engineering phase



- Main issues encountered
  - From the Civil Engineering side
    - Modification of the contract envelop
    - Introduction of the 35 hours/week law in France
      - ➢ Impact on resources and schedule
    - Long discussions leading to the introduction of a fixed cost mechanism
    - First time CERN had outsourced the design and the work supervision to external consultant firms
  - From the Coordination side
    - Dust
    - Endless end !

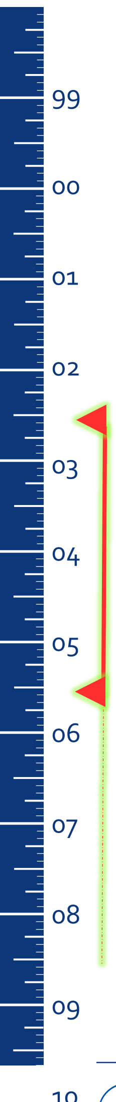
General Services installation



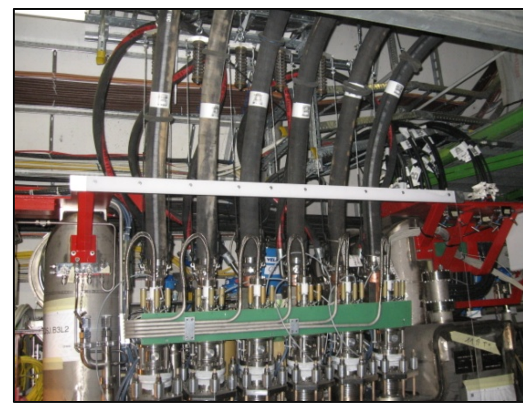
- Cabling & general electrical devices
  - More than 4’500 km of installed cables
  - 2 Industrial services contracts

- Main problems encountered
  - On the Electrical Service side
    - 3D integration not complete before the start of the installation, and late requests from end-users
    - Availability of cables (another contract)
  - On the Coordination side
    - Lots of delays
    - Non-Conformities at the end of the works

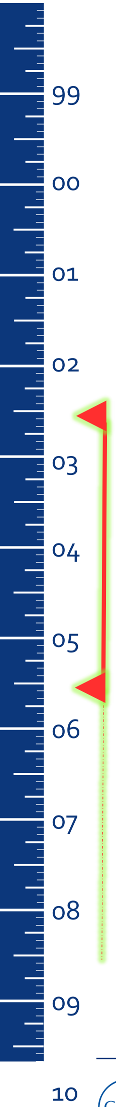
General Services installation



- Optical fibres
  - Qualified contractor, very good follow-up
  - Fast installation
- Water cooled-cables
  - Unreliable schedule
  - Technical problems
    - Mechanical aspects under-estimated
    - A technical CERN «rescue» team set in place to solve the issues



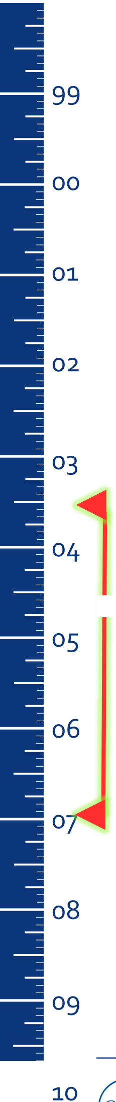
General Services installation



- Cooling & Ventilation
  - 160km primary cooling pipes & ~8km of flexibles
  - Systems installed
    - in surface buildings & experimental areas,
    - in electrical alcoves,
    - modification of the control system

- Main problems encountered
    - Nominal progress rate achieved from the 4th sector (/8)
    - Installation drawing not verified by the 3D integration team

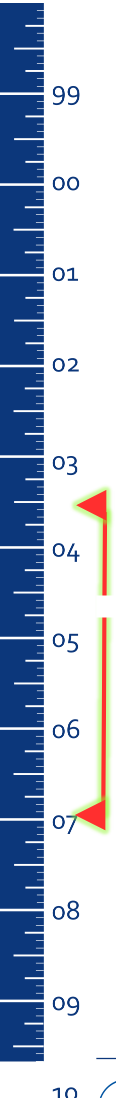
Cryogenic installation



- Cryogenic islands
  - Several contracts
  - 5 islands for the 8 sectors
  - Modification and new installation
  - «Isolated» works – went smoothly

- Cryogenic line installation
  - 1 contract for the 27km
  - Started in June 03
  - After several months of serious technical and schedule problems, works were stopped by the enterprise on July 04
  - In order to progress with the installation , CERN set up another technical «rescue» team to repair and reinstall the faulty equipment already at CERN
  - Works resumed on November 04, ended in December 06

Impact of the delay of the cryogenic line



- Risks
  - QRL systematic tests at cold cancelled
  - Pilot sector on Beam 2 Injection cancelled
- Logistics
  - Cryo-magnets storage
- Coordination
  - Sequence of sectors changed
  - Time-window dedicated to the machine installation reduced
  - Time-window dedicated to the test phase reduced by a factor 2
    - ➢ Search for additional human resources for the Hardware Commissioning

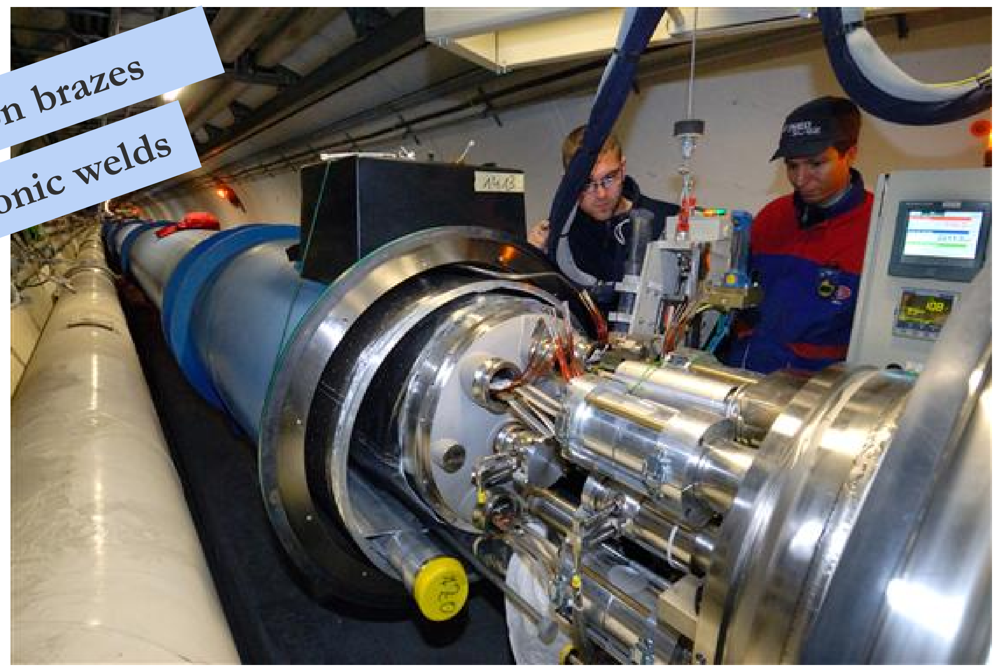
Cryo-magnet transport

- 95% of the total number of cryo-magnets lowered down through one single pit
  - Weight (34t) / load capacity of the crane
  - Dimensions: length ~17m
- More than 1’700 cryo-magnets transported at a speed of 3km/h max
- Huge scheduling constraint
- Main problems encountered
  - Crossing other worksites in narrow areas

Cryo-magnet interconnections

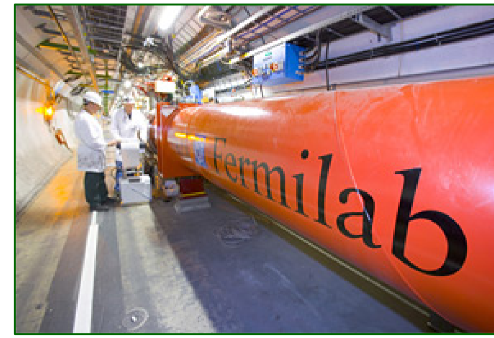
99 00 01 02 03 04 05 06 07 08 09 10

- Including more than 1’900 interconnections, vacuum tests, electrical tests
- Slow start due to missing adjacent magnets and co-activities
- Cruising speed reached at the 3rd sector

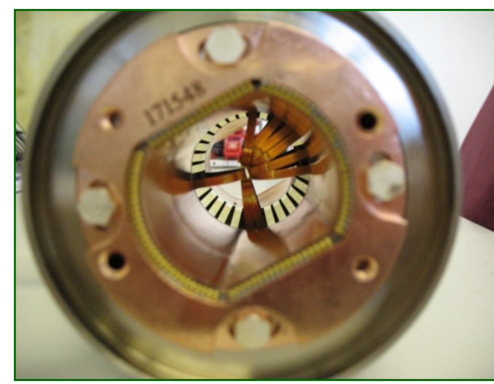


Cryo-magnet interconnections

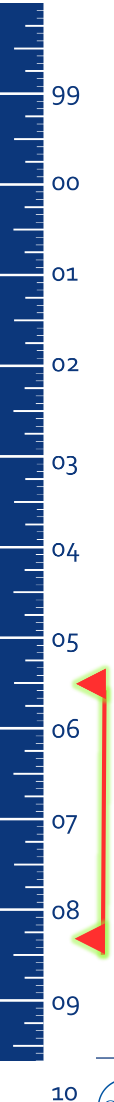
- Main problems encountered
  - Nov. 06- the inner triplets crisis: defect on the exchanger tube
  - Few weeks after their repair: the spiders broke
  - «Task Force» set up to repair and analyse the design
    - ➢First sector cool-down without Inner Triplets in order to gain experience for the following phases



  - Sept. 07: during the warm-up of the 1st sector for the IT connection, a certain number of PIMs (Plug-In Modules) were broken
    - ➢«RF balls» built to diagnose the number of faulty PIMs



Individual system tests



- Each system was individually tested
  - Power converters and associated equipment
  - Pressure and leak tests of the cryogenic line
  - Collimator tests
  - Interlock system tests
  - Extraction energy system tests
  - Beam Instrumentation tests
  - Ejection and dump systems tests
  - Leak and pressure tests of the continuous cryostat
  - ….
- Electrical Quality Assurance testing for the arcs and the individually powered magnets

Cool-down

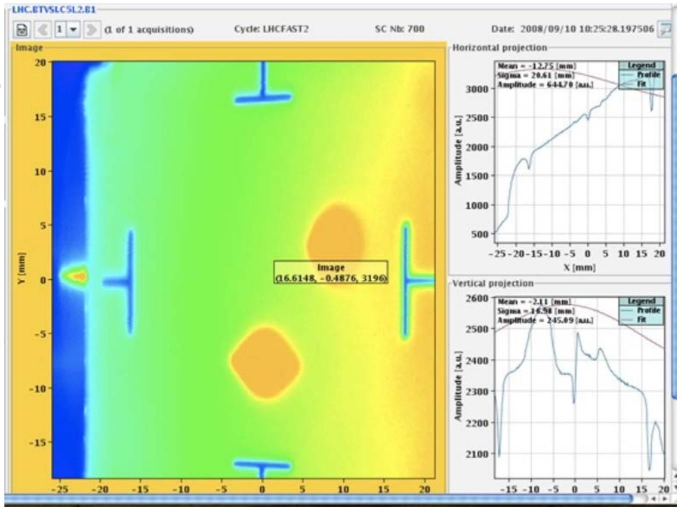
- January 07: difficult start, but weak points quickly identified and compensatory measures set up:
  - On Cryogenics side
    - tuning of Cold compressors
    - tuning of magnets instrumentation
    - condensation and frost on the Current Leads
  - On General Services side
    - electrical cuts
    - network issues
    - tuning of the primary cooling

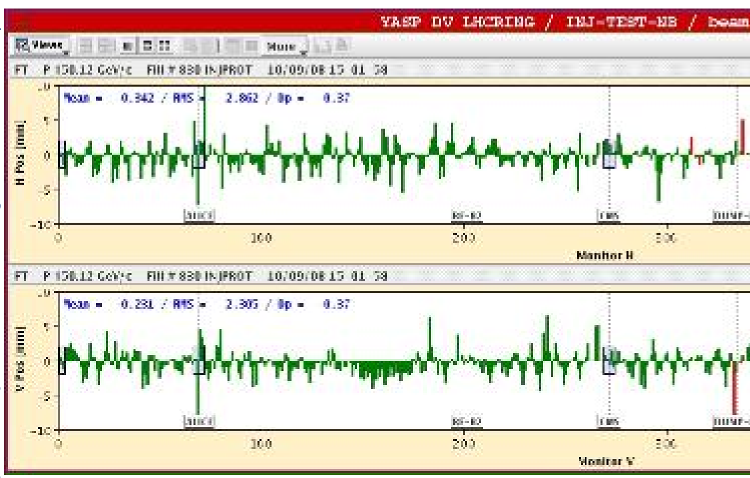
Hardware Commissioning & Powering tests

- Started in March 2007, difficult start due to a low «Mean Time Before Failure» and a high «Mean Time Before Recovery» !

- March 2008: with respect to the last delays and in order to comply with our commitments to have beam before summer, decision was taken to qualify all circuits to 5TeV (7TeV nominal)

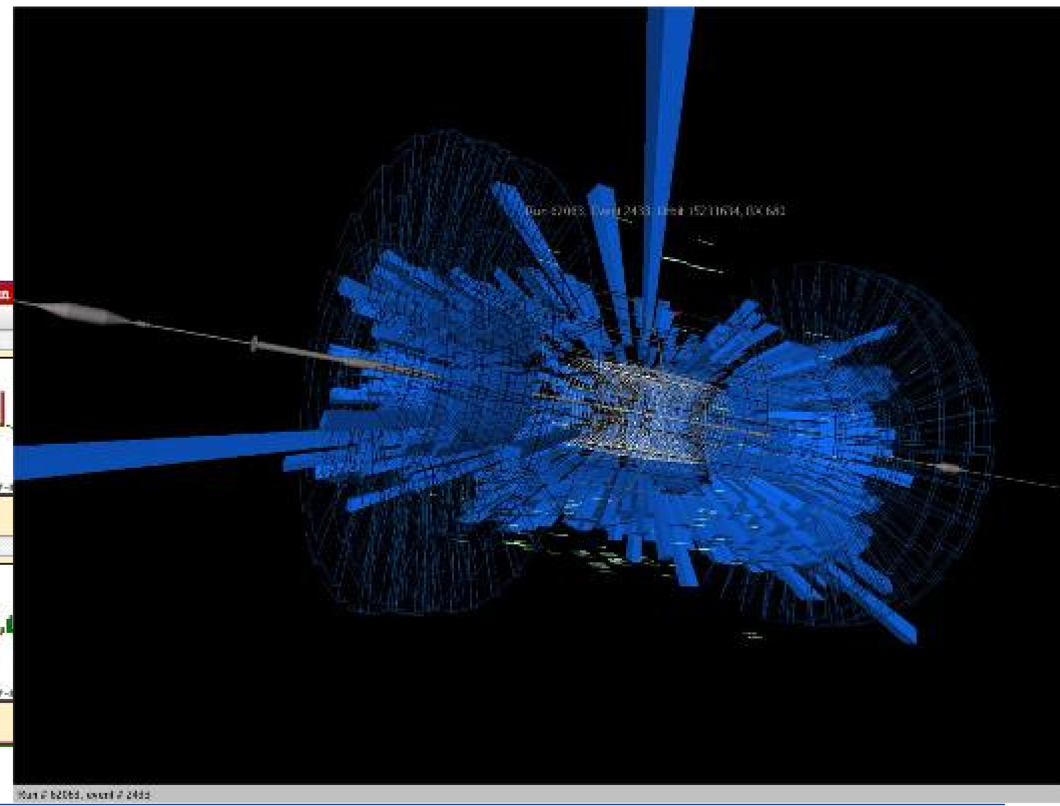
2008, September 10th





First beams

- Beam 1 threaded around the machine in 1h
- Beam 2 threaded around the machine in 1h30



2008 incident

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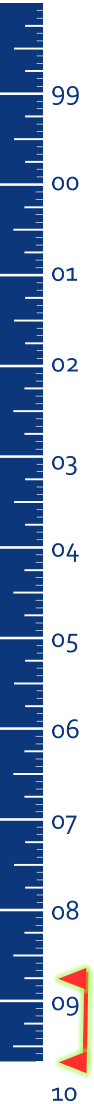
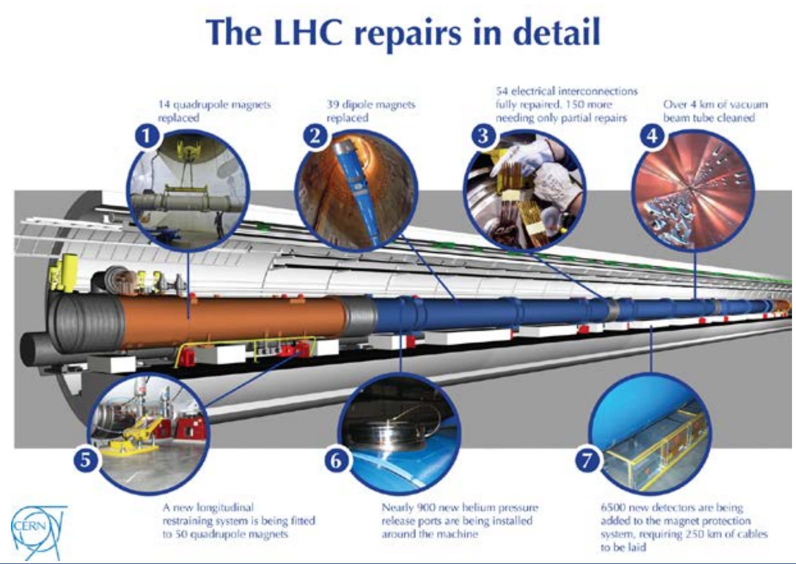
- On 19 September 2008, during powering tests, an electrical fault occurred producing an electrical arc and resulting in mechanical and electrical damage, release of helium from the magnet cold mass and contamination of the insulation and beam vacuum enclosures.

2008 incident



- In the days following the incident which occurred in sector 3-4 of the LHC, a Task Force was set up using experts from the relevant LHC systems to:
  - establish the sequence of facts, based on experimental observations and measurements
  - analyse and explain the development of events, in relation to design assumptions, manufacturing and test data and risk analyses performed
  - recommend preventive and corrective actions for Sector 3-4 and others.

- A fantastic and massive support CERN-wide!



Lessons learned – on installation

- Maintaining sufficient resources in the home laboratory is necessary to cope with
  - tasks outside the interest and capabilities of industry
  - unexpected technical or commercial difficulties

Nota Bene
Hardware only
No Software
No Controls

- The flexibility and the commitment of our colleagues were the key competencies leading to success

- But freeze the layout of the machine as soon as you can, it will help a lot…

- Balance risks: lack of competition for contracts can increase project costs and affect deadlines
  - 2 firms at least for a single adjudication on large/main contracts
  - the only times it was not done, it led to problems (2 out of 3)

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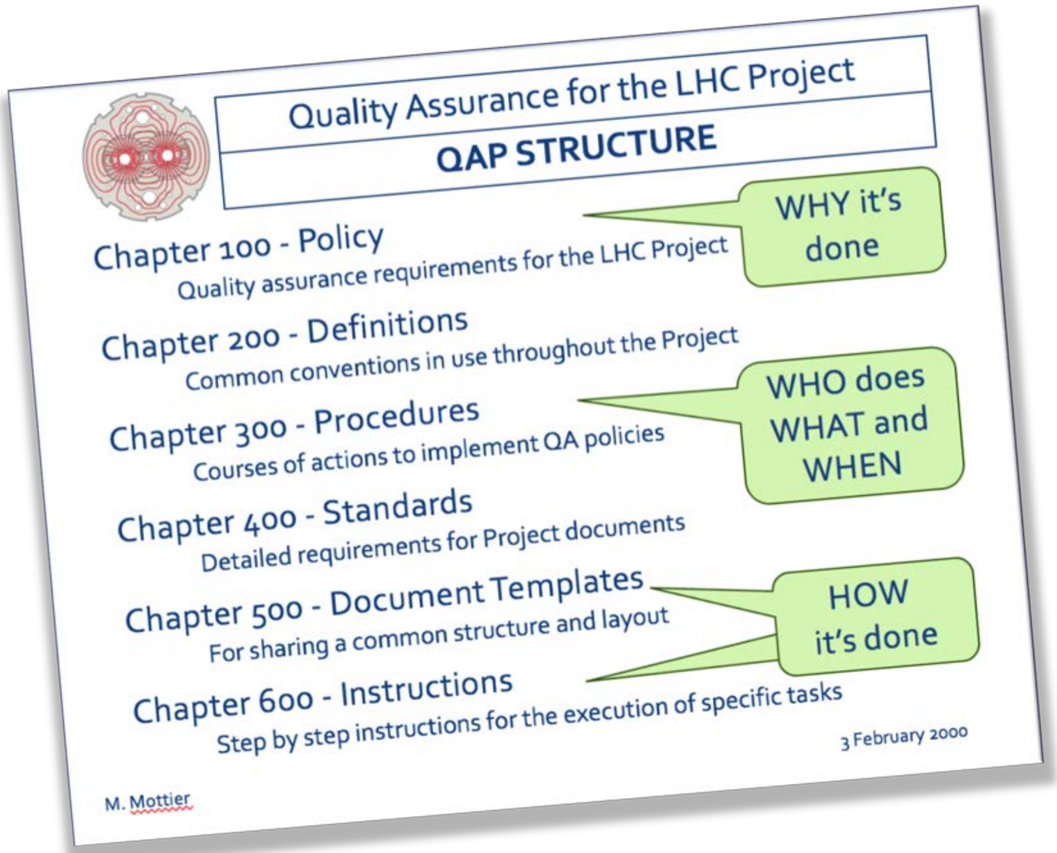
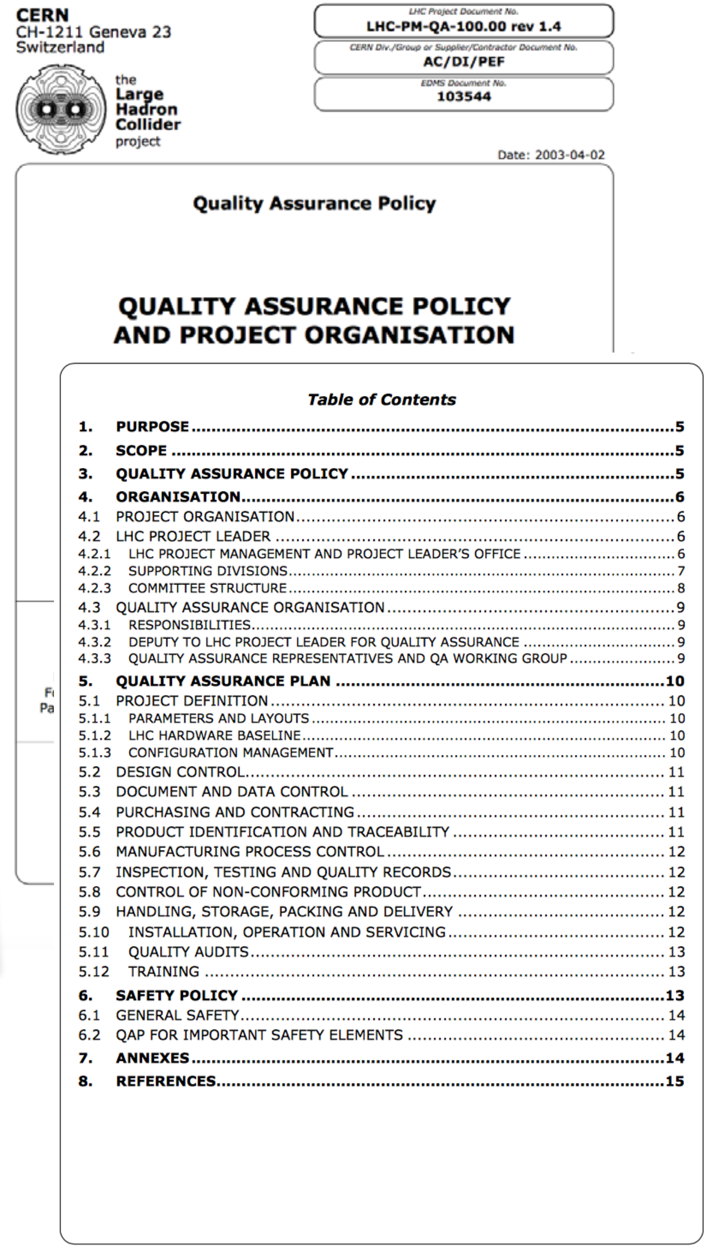
Methodology (1/3)

- Quality Assurance Plan

  Covers documentation and processes over the lifecycle

Quality Assurance





CERN
CH-1211 Geneva 23
Switzerland

the Large Hadron Collider project

LHC Project Document No.
LHC-PM-QA-100.00 rev 1.4

CERN Div./Group or Supplier/Contractor Document No.
AC/DI/PEF

EDMS Document No.
103544

Date: 2003-04-02

Quality Assurance Policy

QUALITY ASSURANCE POLICY
AND PROJECT ORGANISATION

Table of Contents

'I say what I'll do and I do what I said'

Methodology (1/3)

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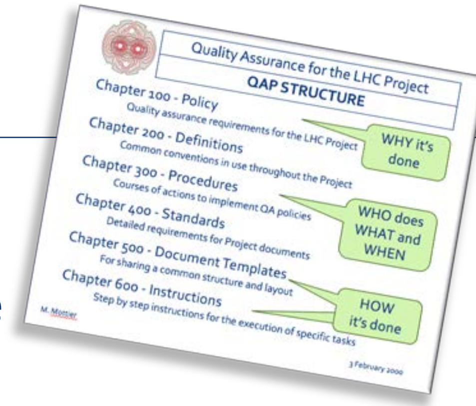
  to ensure that all stakeholders are
  using the same processes



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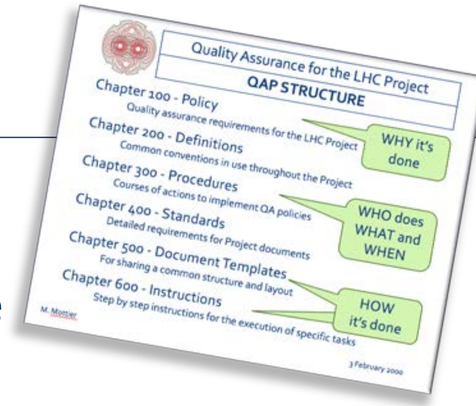

- Quality Assurance Plan

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- Configuration Management & 3D Integration

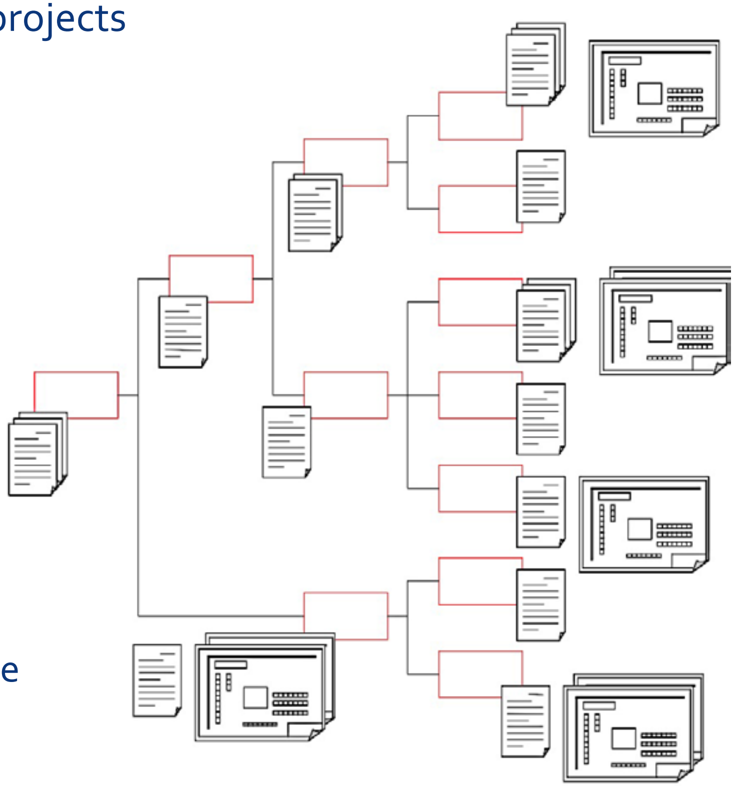
what | Hardware Baseline (aka Product Breakdown Structure)

where | Layout Database for Functional Positions – fully developed during the project times
3D Integration fed with the Digital Mock-Up – from Layout DB to 3D-CAD systems

Project/Product Breakdown

The responsibility of the Project Engineers is reflected by the organization in subprojects

A set of approved and released documents that represents the definition of a product at a specific point in time



The LHC – understood as a project or a facility – is decomposed in terms of <u>functions</u>

- systems
- sub-systems
- main type units to be manufactured

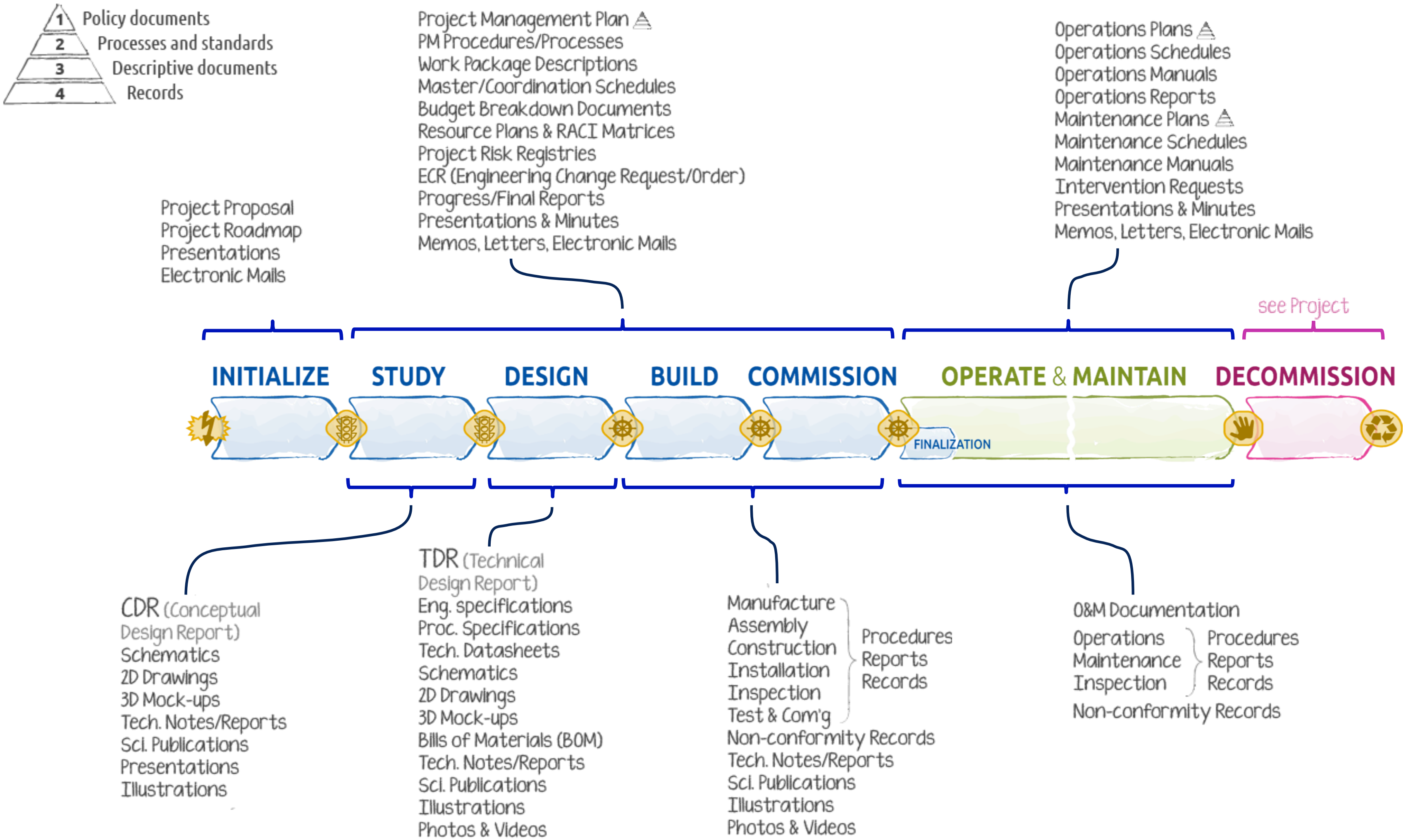
The configuration is mirrored in a tree structure where all the documentation is contained

Configuration Items fully under the control of the configuration management and on which the impact of the changes is analysed

Courtesy R. Saban

All of theses documents are stored in EDMS and/or CAD PDM

With the exception of mails and scientific publications



Courtesy P. Bonnal – see openSE.web.cern.ch

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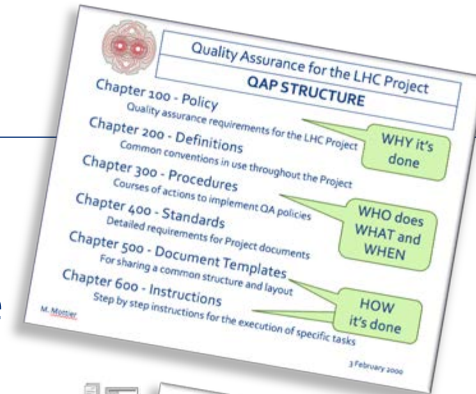

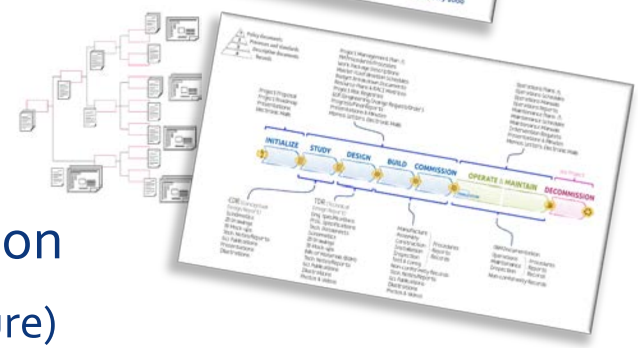

- Configuration Management & 3D Integration

  Hardware Baseline (aka Product Breakdown Structure)
  Layout Database for Functional Positions – fully developed during the project times
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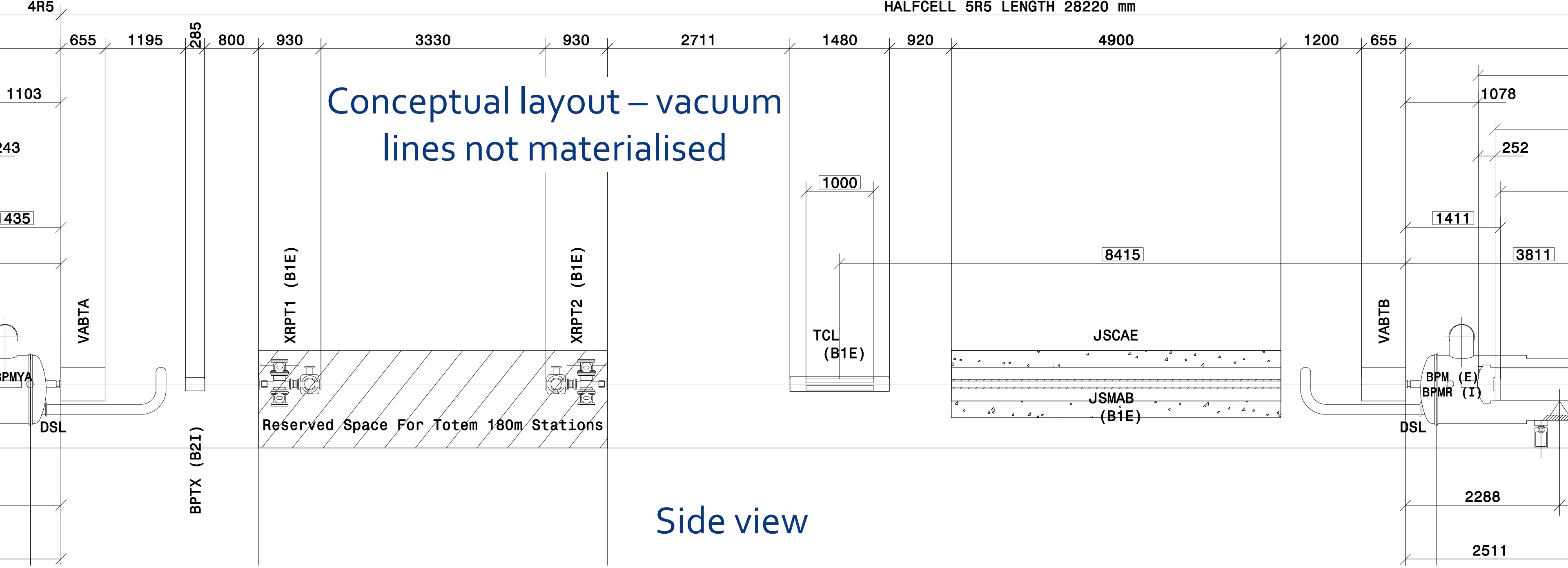
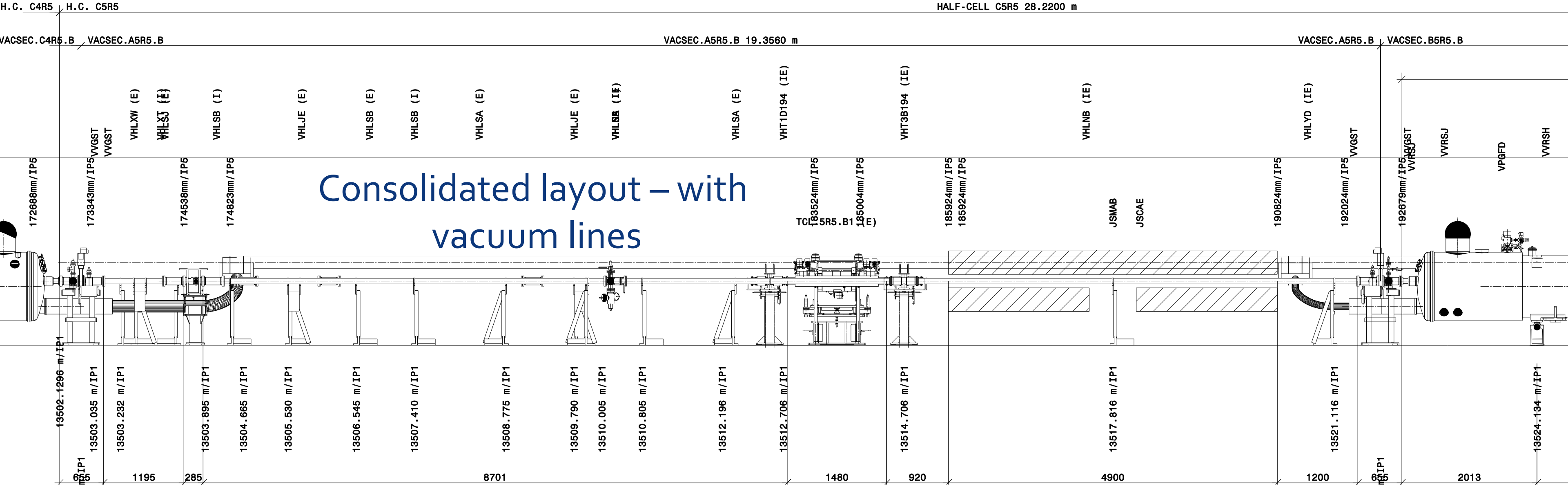
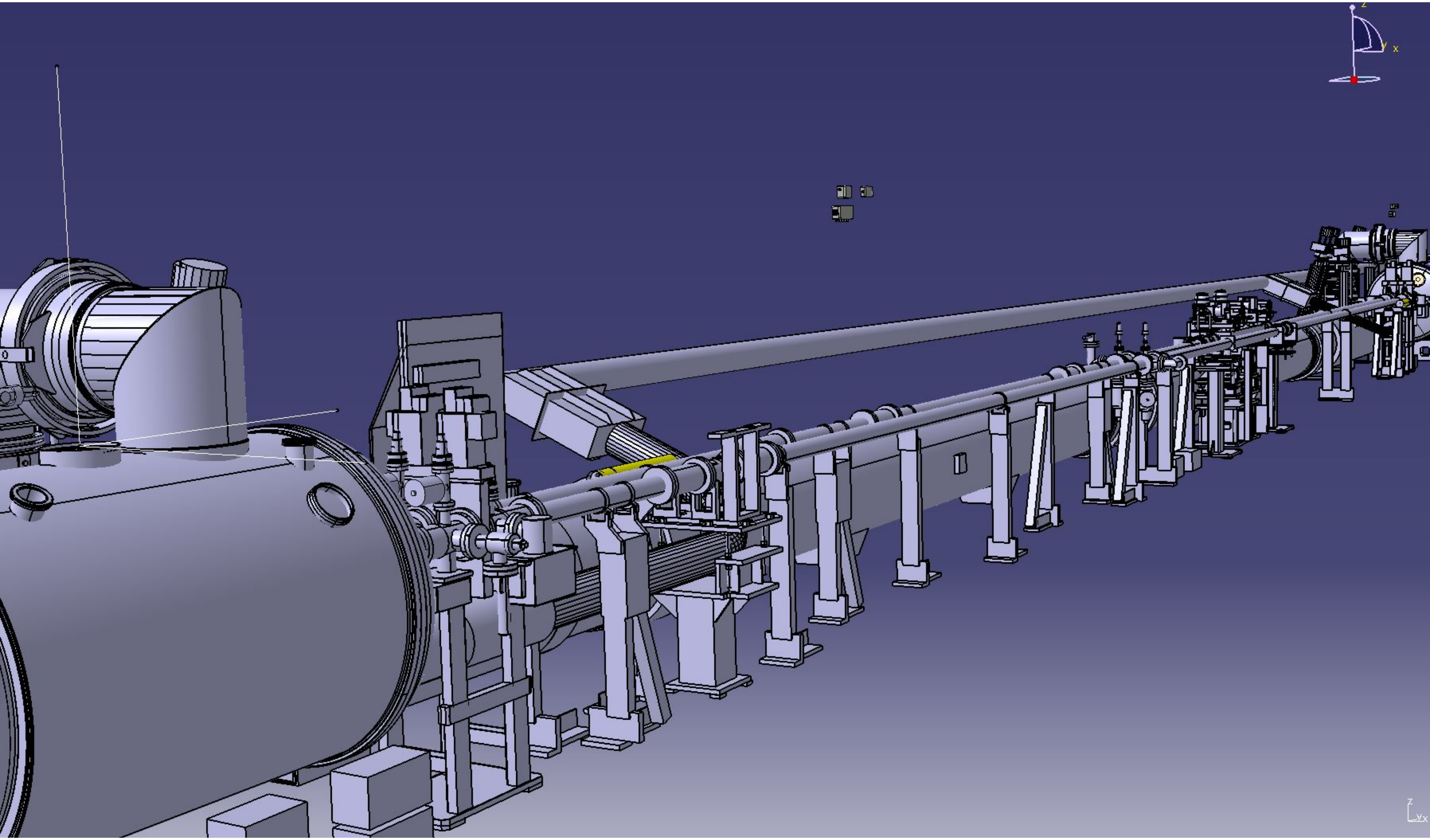
Conceptual layout – vacuum lines not materialised

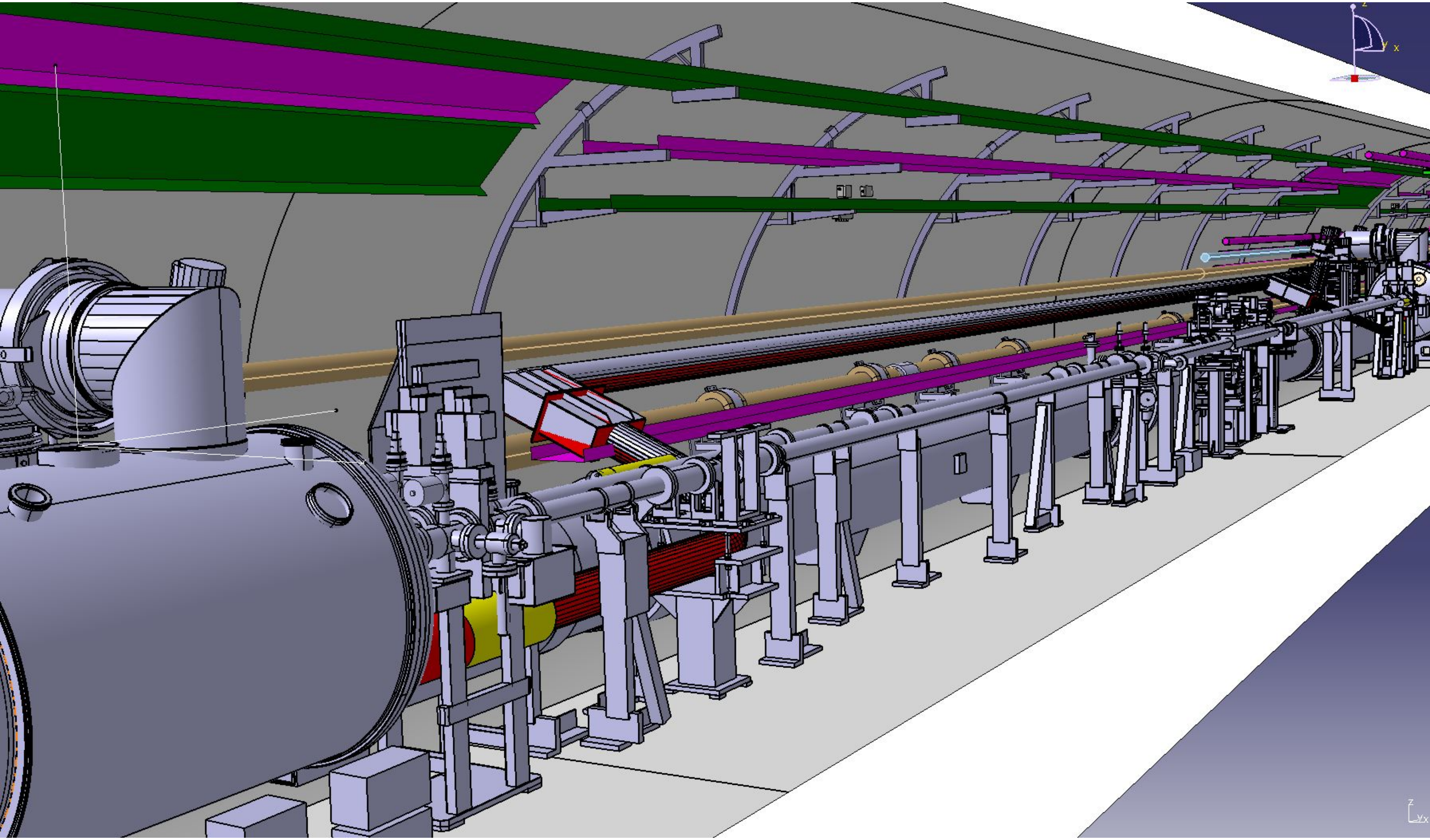
Side view

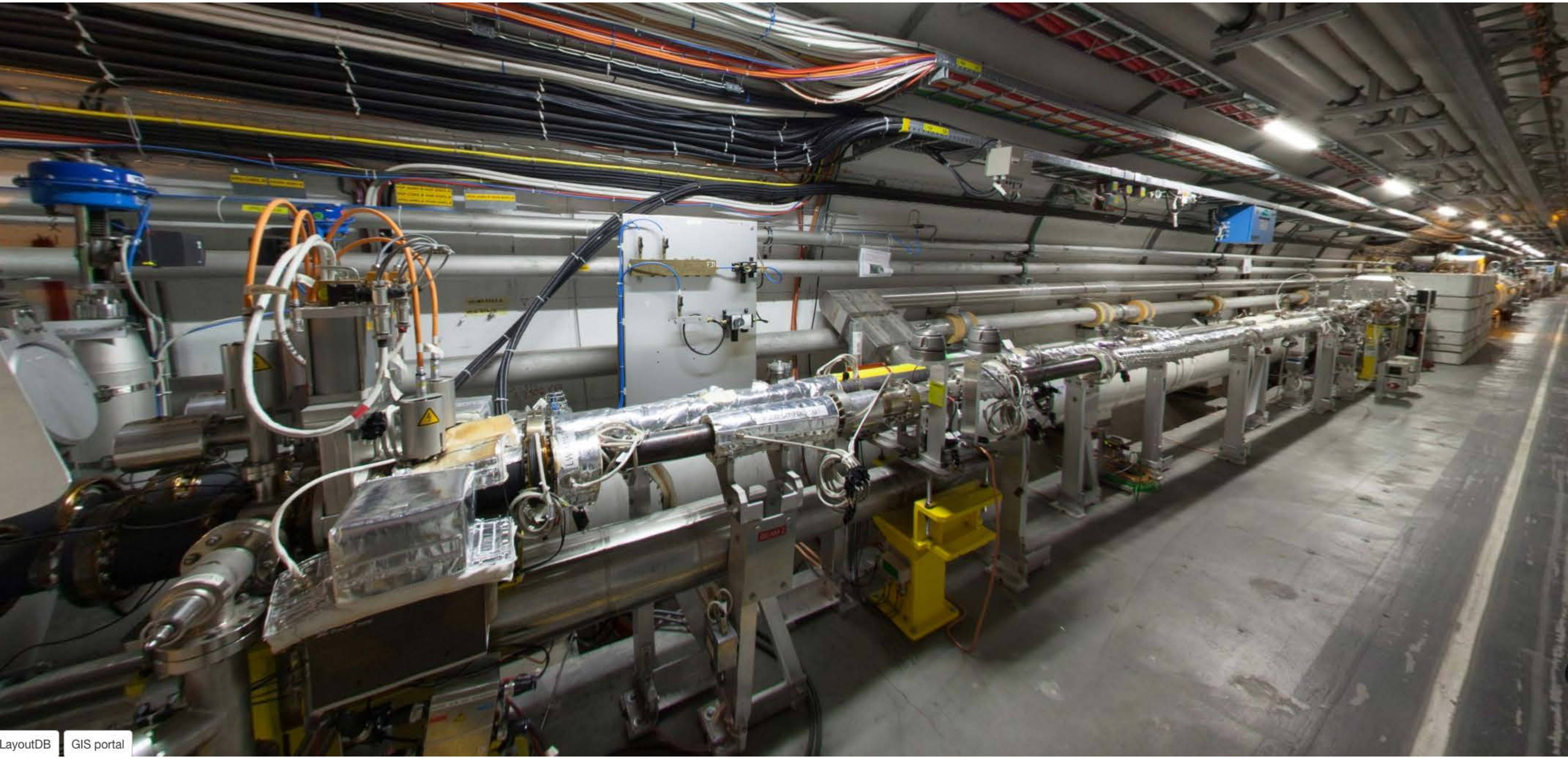


Consolidated layout – with vacuum lines

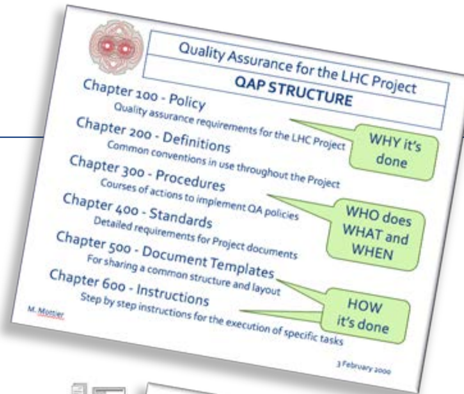







LayoutDB
GIS portal

Methodology (1/3)



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  Covers documentation and processes over the lifecycle

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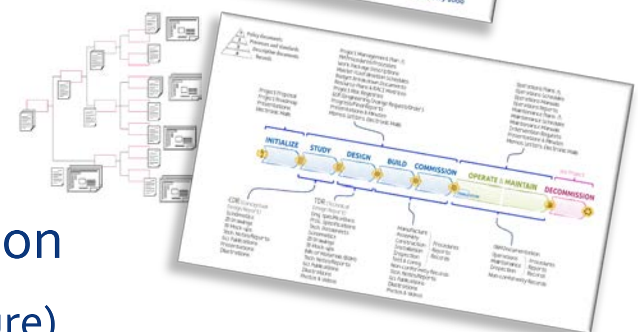
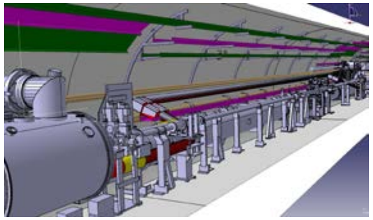
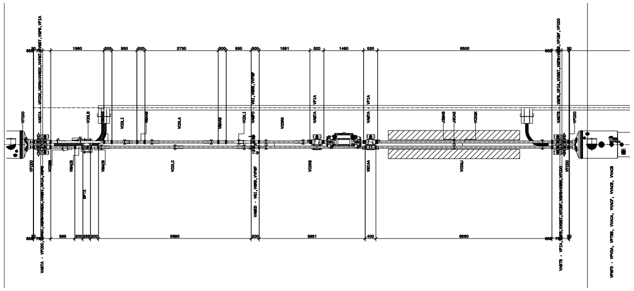


- Configuration Management & 3D Integration

  Hardware Baseline (aka Product Breakdown Structure)
  Layout Database for Functional Positions – fully developed during the project times
  3D Integration fed with the Digital Mock-Up – from Layout DB to 3D-CAD systems

  to ensure that all stakeholders are working on the same version of the specifications
  to represent the accelerator in 3D in an automated way

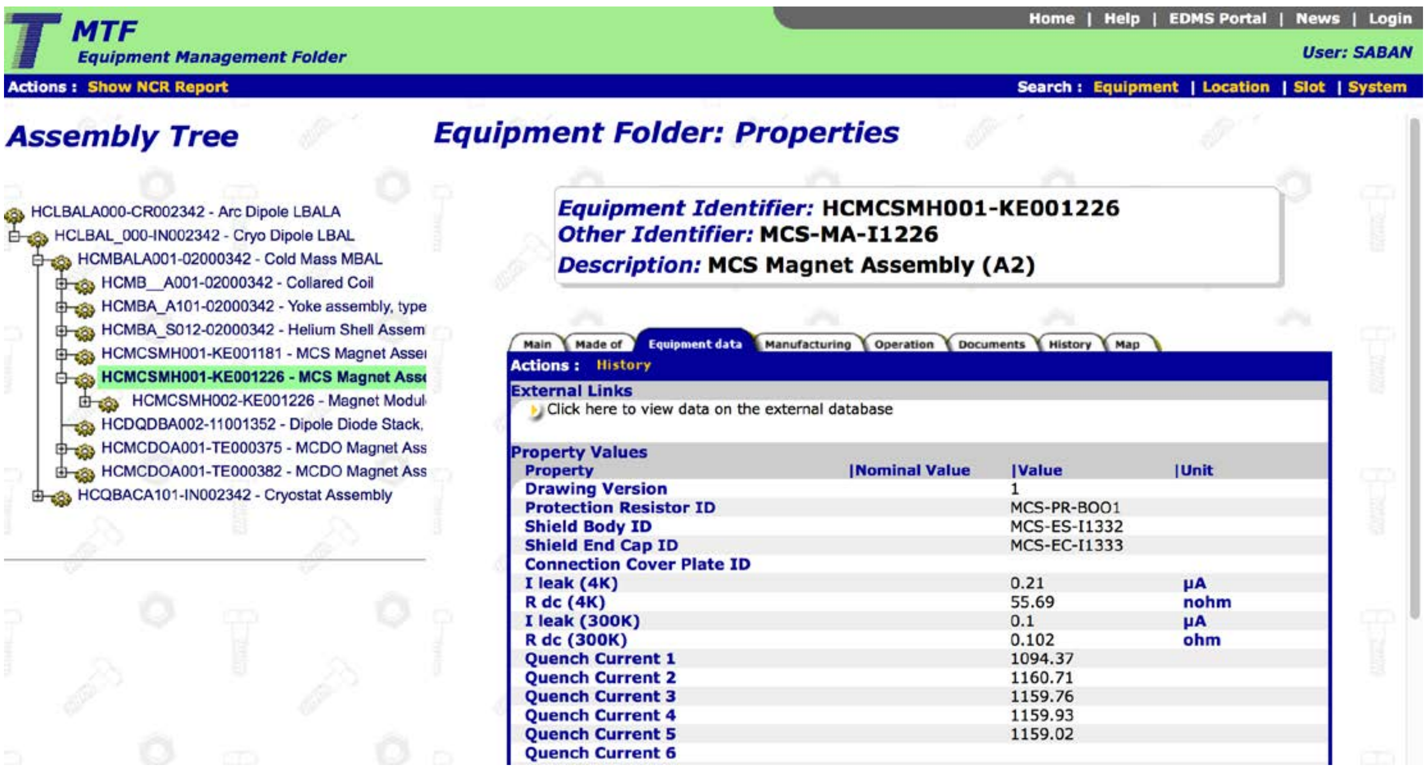




Methodology (2/3)

- Manufacturing and Installation

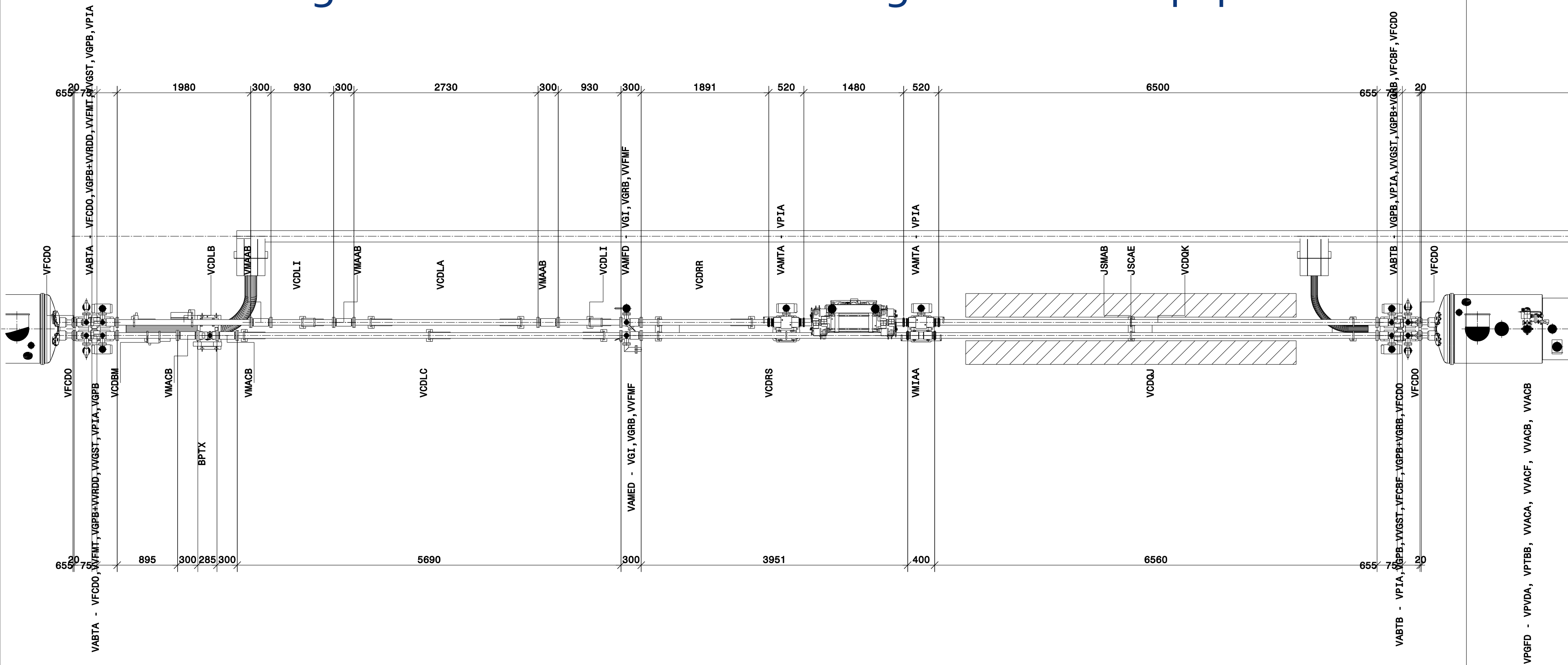
  Manufacturing follow-up from the early stages
  Equipment delivery dates monitoring in the LSS –
  Design Office and Central Manufacturing facility scheduling



Courtesy S. Mallón – R. Saban

Monitoring of delivery dates in the LSS

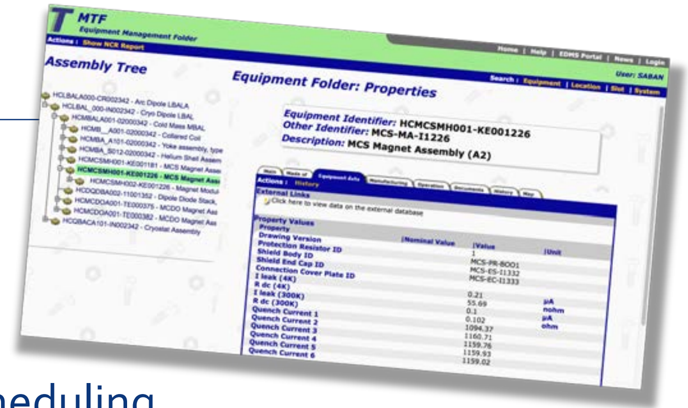
- Late design – hence late manufacturing – on some equipment



- Clear influence on the order of the sectors to close and to bake-out
- Manufacturing of replacement chambers in some cases

Methodology (2/3)

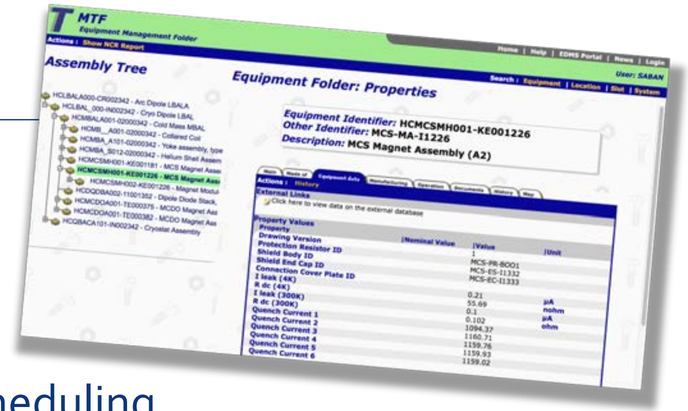
- Manufacturing and Installation



Manufacturing follow-up from the early stages
Equipment delivery dates monitoring in the LSS –
Design Office and Central Manufacturing facility scheduling

to trace all the important assets with their test results
to organise the order of vacuum sub-sectors to close and the bake-out activities

Methodology (2/3)



- Manufacturing and Installation

  Manufacturing follow-up from the early stages
  Equipment delivery dates monitoring in the LSS –
  Design Office and Central Manufacturing facility scheduling

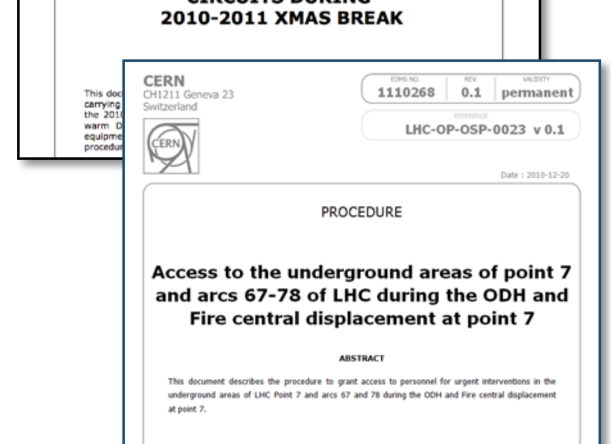
  to trace all the important assets with their test results
  to organise the order of vacuum sub-sectors to close and the bake-out activities

- Coordination meetings

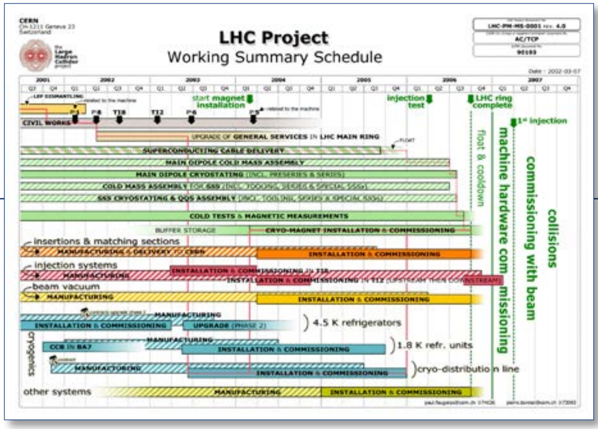
  Configuration, Integration, Planning,
  Worksite follow-up & logistics – Hundreds of ad-hoc meetings
  Analysis of co-activities and worksite safety organisation

Safety

- Safety is **1st** priority
- Delicate balance between host states & European & internal rules
- Description of the frame work of any worksite is mandatory
  - "Plan de Coordination des Travaux et de la Sécurité" applicable organizational measures in matter of work planning and coordination, of general safety and radiation protection
- Additional procedures are edited to take into account our specific risks



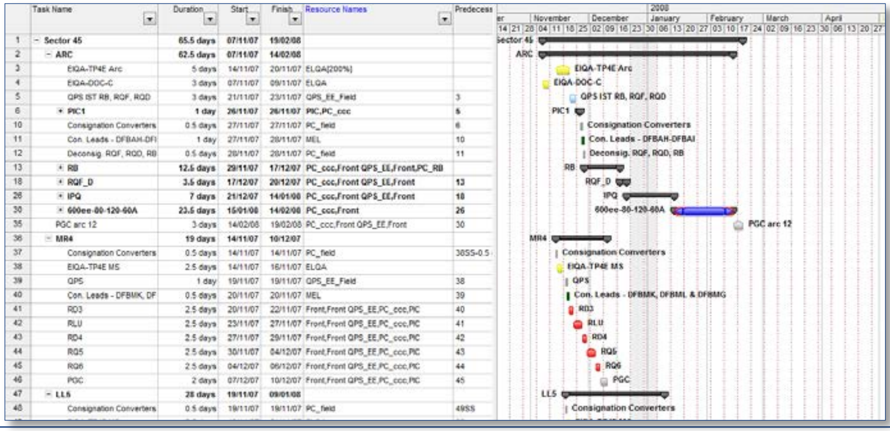
3 levels of schedule



- Strategic schedule
  - Strategic goals and major milestones of the project

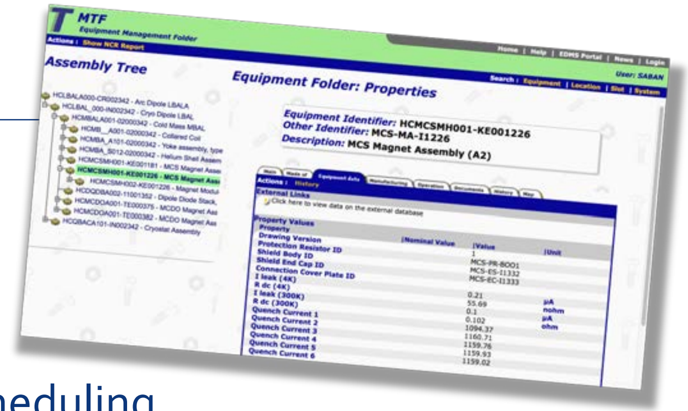
- Tactical schedule
  - Flow of installation following the main milestones of the master schedule
  - Logistics

- Operational schedules



	Task Name	Duration	Start	Finish	Resource Names	Predecess
1	− Sector 45	65.5 days	07/11/07	15/02/08		
2	− ARC	62.5 days	07/11/07	14/02/08		
3	EIQA-TP4E Arc	5 days	14/11/07	20/11/07	ELQA[200%]	
4	EIQA-DOC-C	3 days	07/11/07	09/11/07	ELQA	
5	QPS IST RB, RQF, RQD	3 days	21/11/07	23/11/07	QPS_EE_Field	3
6	+ PIC1	1 day	26/11/07	26/11/07	PIC,PC_ccc	5
10	Consignation Converters	0.5 days	27/11/07	27/11/07	PC_field	6
11	Con. Leads - DFBAH-DFI	1 day	27/11/07	28/11/07	MEL	10
12	Deconsig. RQF, RQD, RB	0.5 days	28/11/07	28/11/07	PC_field	11
13	+ RB	12.5 days	29/11/07	17/12/07	PC_ccc,Front QPS_EE,Front,PC_RB	
18	+ RQF_D	3.5 days	17/12/07	20/12/07	PC_ccc,Front QPS_EE,Front	13
26	+ IPQ	7 days	21/12/07	14/01/08	PC_ccc,Front QPS_EE,Front	18
30	+ 600ee-80-120-60A	23.5 days	15/01/08	14/02/08	PC_ccc,Front	26
35	PGC arc 12	3 days	14/02/08	19/02/08	PC_ccc,Front QPS_EE,Front	30
36	− MR4	19 days	14/11/07	10/12/07		
37	Consignation Converters	0.5 days	14/11/07	14/11/07	PC_field	38SS-0.5
38	EIQA-TP4E MS	2.5 days	14/11/07	16/11/07	ELQA	
39	QPS	1 day	19/11/07	19/11/07	QPS_EE_Field	38
40	Con. Leads - DFBMK, DF	0.5 days	20/11/07	20/11/07	MEL	39
41	RD3	2.5 days	20/11/07	22/11/07	Front,Front QPS_EE,PC_ccc,PIC	40
42	RLU	2.5 days	23/11/07	27/11/07	Front,Front QPS_EE,PC_ccc,PIC	41
43	RD4	2.5 days	27/11/07	29/11/07	Front,Front QPS_EE,PC_ccc,PIC	42
44	RQ5	2.5 days	30/11/07	04/12/07	Front,Front QPS_EE,PC_ccc,PIC	43
45	RQ6	2.5 days	04/12/07	06/12/07	Front,Front QPS_EE,PC_ccc,PIC	44
46	PGC	2 days	07/12/07	10/12/07	Front,Front QPS_EE,PC_ccc,PIC	45
47	− LL5	28 days	19/11/07	09/01/08		
48	Consignation Converters	0.5 days	19/11/07	19/11/07	PC_field	49SS

Methodology (2/3)



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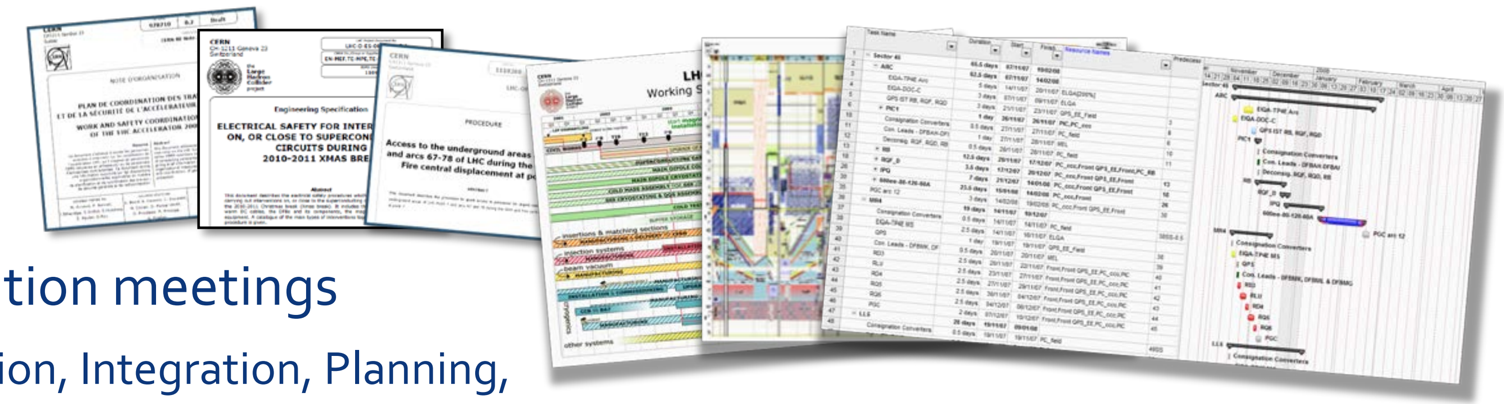


- Coordination meetings

  Configuration, Integration, Planning,
  Worksite follow-up & logistics – Hundreds of ad-hoc meetings
  Analysis of co-activities and worksite safety organisation

  to keep all stakeholders on the same page and to reduce risk due to co-activities

Methodology (3/3)

- Deviation Handling

    Changes are reported and approved – or not – by the Committees
    Non-conformity reports on equipment and installation

Change Control

- Configuration baselines are established whenever it is necessary to define a reference configuration during the lifecycle of the product.
  - during project times, this was mainly driven by optics modifications or by heavy changes in the project (RF modifications, collimation project major review, etc.)
  - the baseline is used as a starting point for further activities until it is revised in a controlled way.
- All changes are reported to the Committees handling the project or the facility as soon as they get circulated
  - approval of Change Requests is done by the Committees,
  - other technical documents are mentioned at the start of the approval cycle and when released
- Between two baselines, all of the impacted documents are listed in Release Notes (also in EDMS)

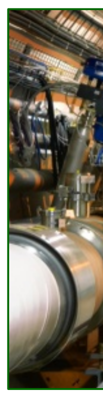
Deviations handling

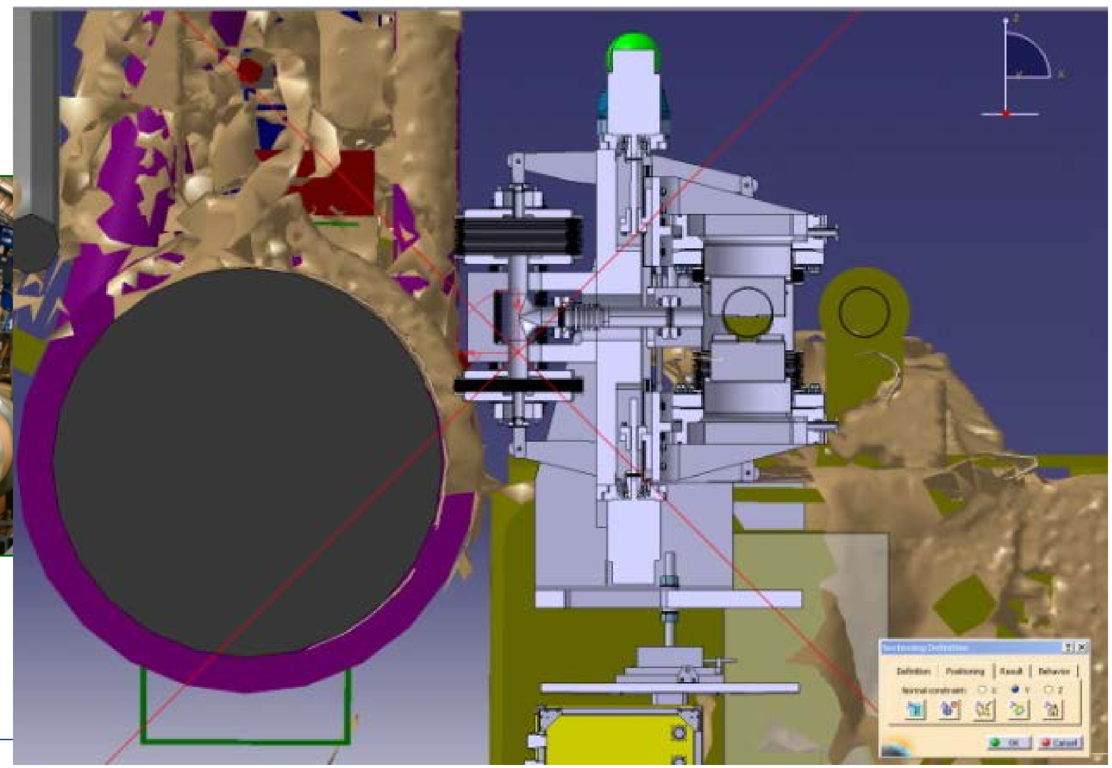
- From the nominal definition, deviations are treated in terms of documentation by
  - a simple update of the Engineering Specification of a product as long as there is no impact outside (e.g. updates on the list of cryo-dipoles types due to a new set of interconnections)
  - an Engineering Change Request issued by any of the stakeholders of the project (and having an impact on the Form-Fit-Function of a product) if some parameters/design need to be modified
  - or a Non-Conformity Report on an equipment or its installation (deviation from nominal positioning) – that forces the update of the Engineering Specification of the product
    - equipment non-conformities are traced within the Manufacturing and Testing Folder (MTF – Infor EAM). If the non-conformity is impacting other equipment an ECR could be generated.
    - installation non-conformities are often detected by 3D scans superimposed to the 3D-intregration model

All stored in EDMS

Installation non-conformities

- Is there enough space left after each installation stage?
  - 3D geo-referenced scans on the top of the 3D mock-up scenes
  - Installation non-conformities (~500 in total) treated by the Integration team and consequent modifications – if needed – done by the responsible teams



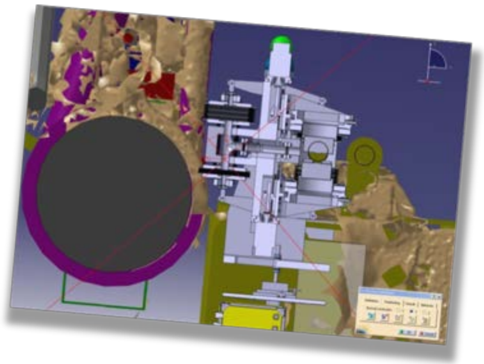


Methodology (3/3)

- Deviation Handling

    Changes are reported and approved – or not – by the Committees
    Non-conformity reports on equipment and installation

to trace the nominal machine and deviations
to trace the space left for the coming equipment installation



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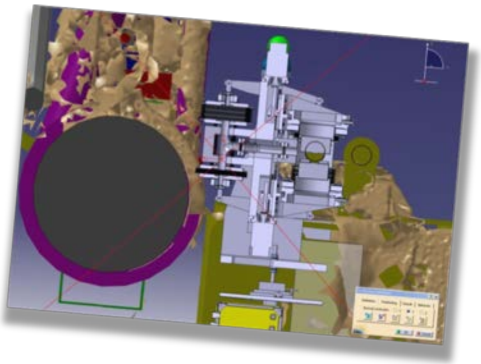
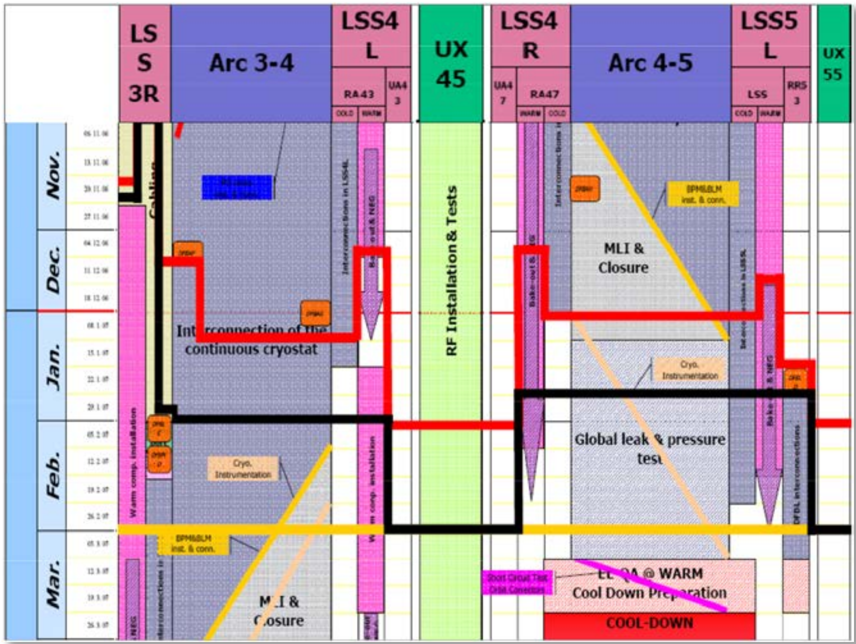


- Reports

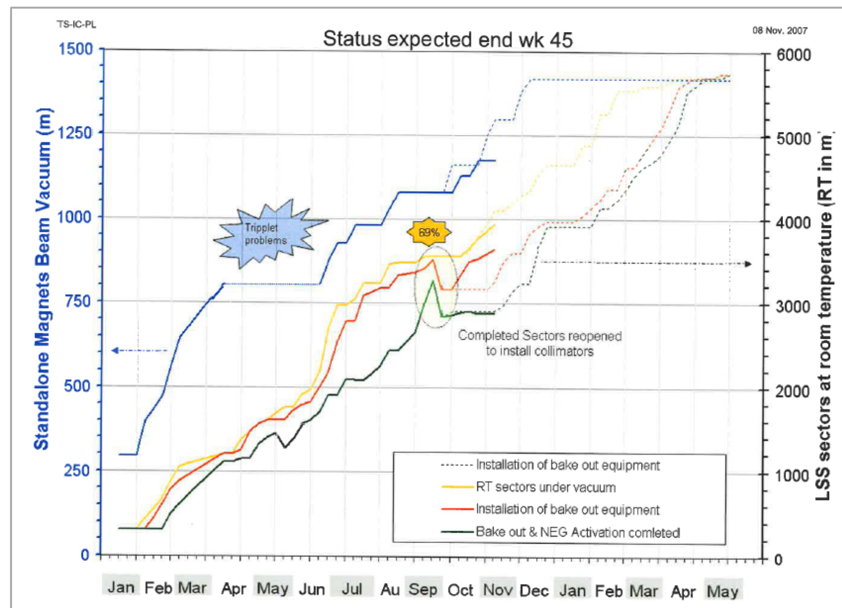
  Earned Value Management set up – see back-up slides
  Periodic reports to the Top Management, the Project Leader Office, the Committees

Scheduling reporting



Broken line

Yellow line is today
Black line is "today's broken line"
Red line is "last month's broken line"



Example of IC-group direct reporting to the DG

on a every month basis

Methodology (3/3)

- Deviation Handling

  Changes are reported and approved – or not – by the Committees
  Non-conformity reports on equipment and installation

to trace the nominal machine and deviations
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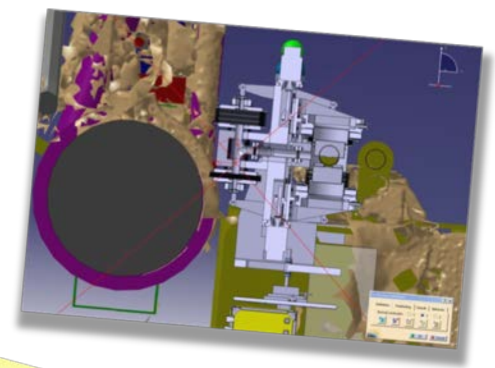
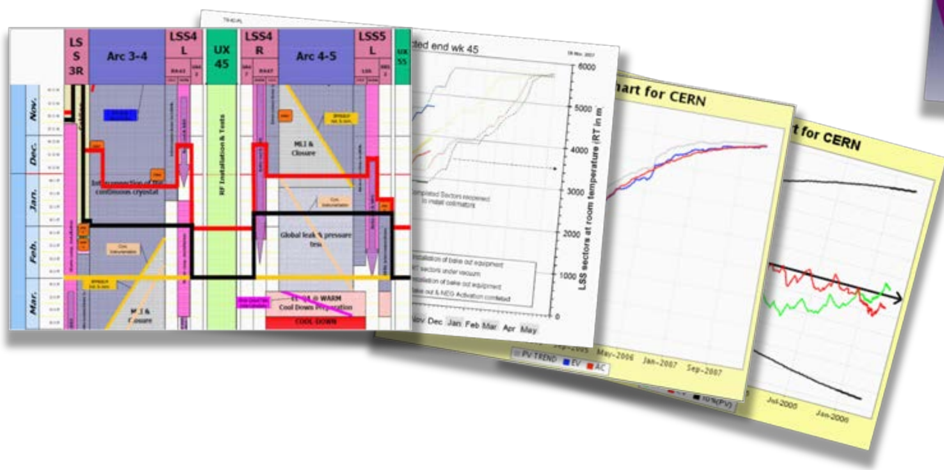




- Reports

  Earned Value Management set up
  Periodic reports to the Top Management, the Project Leader Office, the Committees

to trace deviations on schedule/cost and to take corrective actions to keep the project on tracks

Lessons learned – on project management

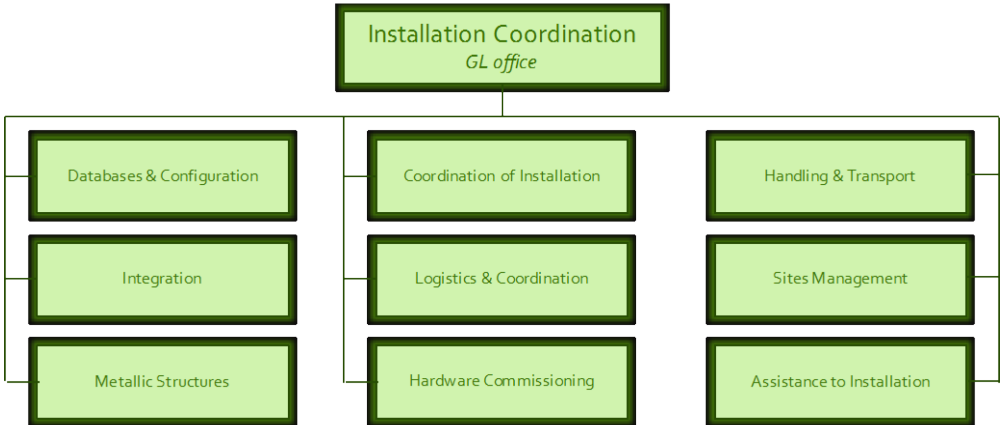
- Achieving quality throughout the project involves the establishment and enforcement of a comprehensive and solid QAP
  - all stakeholders adhered to the message 'I say what I'll do and I do what I said'
  - the weak point was the Interface Specification between two Work Packages
- Unique methodology and common Project Management culture
  - methodology now in place for all new CERN projects (Elena, HIE-Isolde, LIU, HL-LHC, Awake, Physics Beyond Colliders,…) – scalability
  - 150 Project Engineers in the Accelerator Sector now trained with OpenSE
- Granularity on information and expectation levels was properly set
  - at the crossing points of different points of view, installation oriented
- Project investment on people and tools – learning curve
- EVM should be carefully introduced, supported and assisted.
  - done in the middle of the project, but allowed to restore member states confidence

Lessons learned – on project management

- Central organisation: A dedicated group was put in place gathering the key organisers

integration, configuration, coordination and scheduling, logistics, operational safety, hardware commissioning

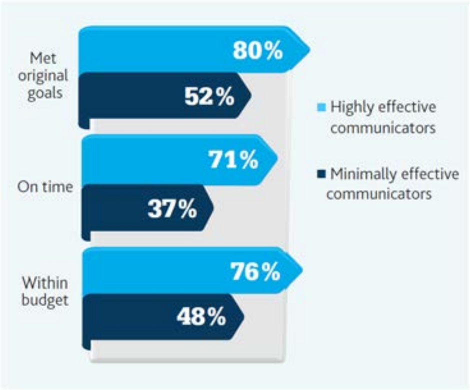
- Small teams per topic
  - configuration – 6
  - integration – 6
  - scheduling – 3
  - logistics – 1
  - operational safety – 4+2
  - hardware commissioning – 2+10
  - site management – 8
  - transport – 10+30
  - assistance to installation – 3+10



Corresponding tools and services were handled centrally for all the groups (equipment and service groups)

Conclusions

- A solid & common methodology of project management is crucial
  - openSE is becoming CERN-internals standard in the Accelerator Sector
- Our best resources are human resources: in addition to a strong expertise, flexibility, accountability and communication shall not be forgotten



Source: ©2013 Project Management Institute, Inc. *Pulse of the Profession In-Depth Report: The High Cost of Low Performance: The Essential Role of Communications*, May 2013. PMI.org/Pulse

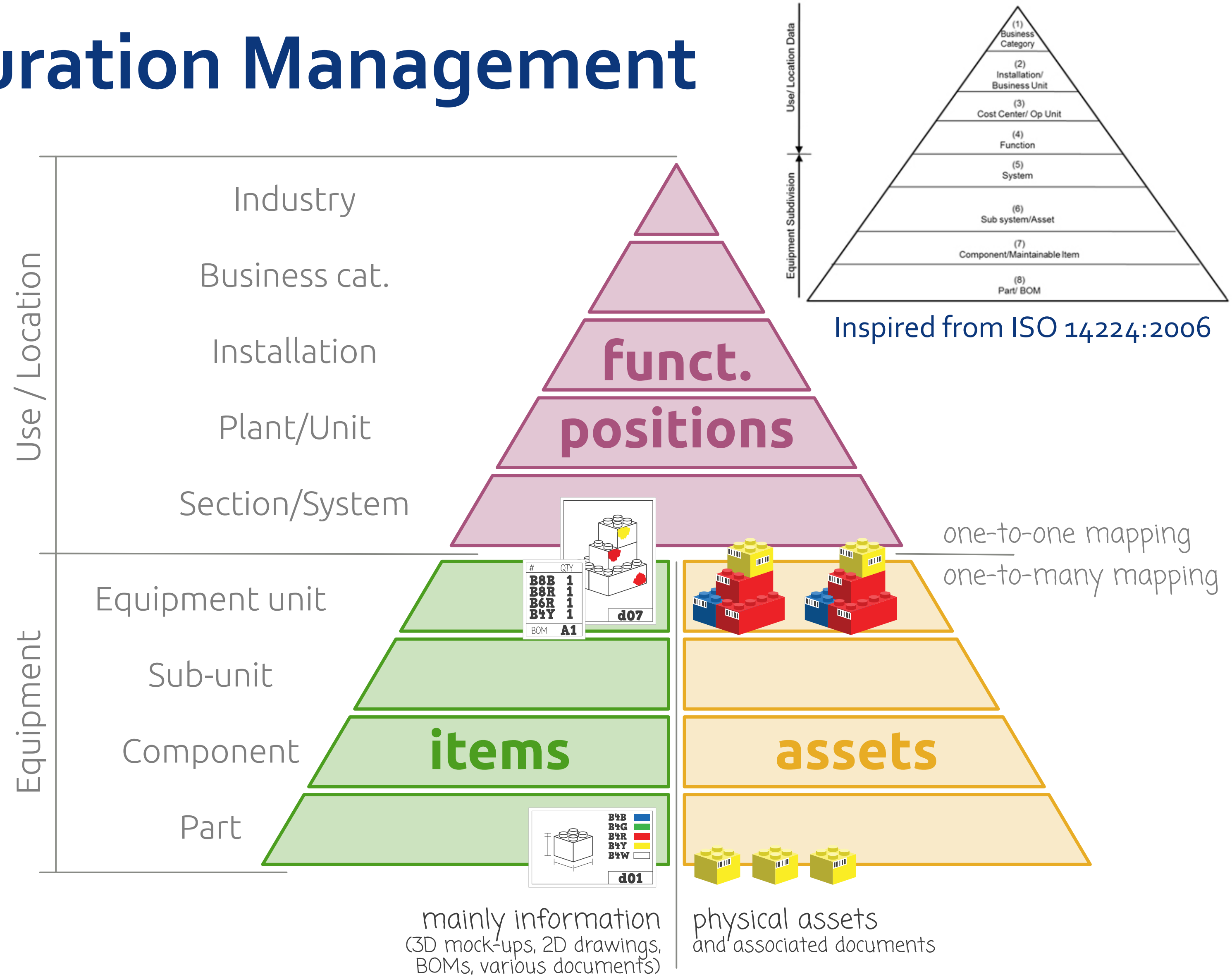
Back-Up slides

Personal Lessons Learned
Configuration Management,
From Project to Programmed Stops,
Parallel configuration of facilities (LHC – Injectors) and projects (LIU – HL)
IMPACT
PLAN
openSE

Lessons learned - personal

- To get documents of high quality means to invest time and effort in reading/correcting/suggesting to authors
  - essential to keep 100% control on the baseline documents and not delegate
  - added value is to identify impacted stakeholders not mentioned by authors
- Mid-term/long-term personnel to handle the configuration and integration data is essential
  - the learning curve is long – diversity of document types, equipment groups, needs, … - current exercice is over 2 years
  - interactions with Digital Mock-Up, Integration and Scheduling are important to master
- Better 3D reviewing sessions with all players
- Flexibility and human interactions are essential ingredients of success
- Non-conformity checking is better accepted in team-work mode

Configuration Management



Configuration Management

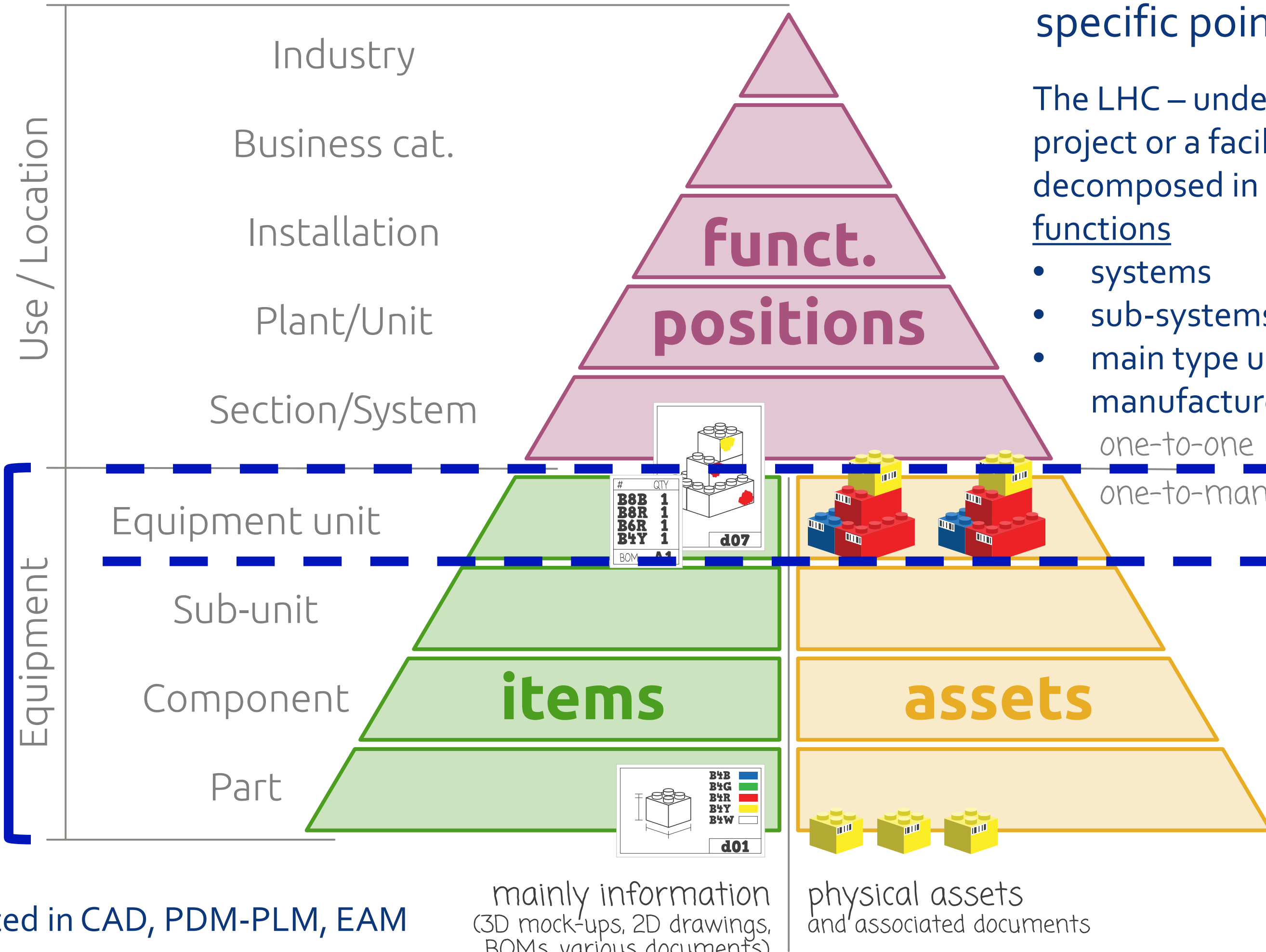
A set of approved and released documents that represents the definition of a product at a specific point in time

The LHC – understood as a project or a facility – is decomposed in terms of <u>functions</u>

- systems
- sub-systems
- main type units to be manufactured

one-to-one mapping

one-to-many mapping



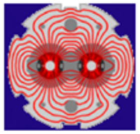
BOM management

- assemblies
- sub-assemblies
- parts

This is mainly how reflected in CAD, PDM-PLM, EAM systems. Breakdown of <u>types</u>

Purchasing documentation in PBS

PURCHASING-CONTRACTING



GENERAL CONDITIONS

CERN/FC/5164-I	General Conditions Governing Invitations to Tender and Tenders	FC5164-I.pdf
CERN/FC/5164-II	General Conditions of CERN Contracts	FC5164-II.pdf

OTHER PURCHASING DOCUMENTS

---	Certificate of property	CertProp.pdf
CERN/FI-A/2753	Bank Guarantee	FI2753.pdf

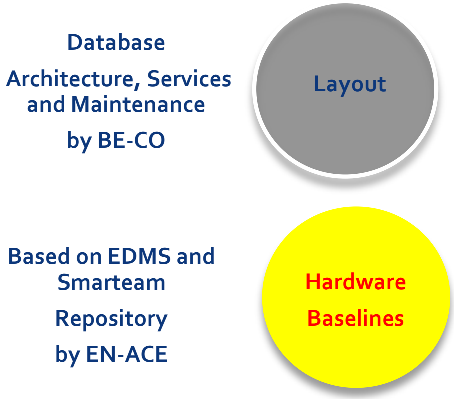
WORK OF CONTRACTORS ON THE CERN SITES

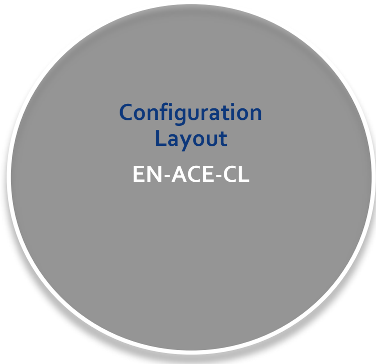
CERN/ FI/ 120	Special conditions for the operation and/ or maintenance of CERN equipment and installations	FI120.pdf
CERN/ FI /98	Special Conditions for the provision of temporary labour to CERN	FI98.pdf
CERN/DSU-DO/RH/9335	Relations between CERN, the competent bodies of the Host States and contractors concerning occupational health and safety on the Organization's site	DSU9335.pdf
TIS/ES/MD/rb/89-423	Special Health and Safety Committee	TIS89-423.pdf
DSU-DO/RH/1845	Contractors & their staff: Access to & activities on the CERN site	DSU1845.pdf
CERN/DSU-DO/RH/8200	The Tunnel linking the CERN sites - Rules for use	DSU8200.pdf
DSU-DO/RH/6833	Conditions governing the use of vehicles belonging to or hired by CERN by the personnel of CERN contractors	DSU6833.pdf
DIR/ADM/MI-RH/660	Regulations for use of storage areas in the CERN site for contractor's equipment	ADM660.pdf
---	Position of non- French firms setting up an establishment in France and of their staff	FR001.pdf
---	Position of Non-French firms seconding staff to France without setting up an establishment there	FR002.pdf
CERN/DSU-DO/RH/8917/Rev.1	Information concerning residence and work permits for employees of CERN contractors	DSU8917.pdf
---	Procédure de demandes d'autorisation de travail pour frontalier applicable aux employés d'entreprises établies en Suisse, liées au CERN par un contrat	G010425.pdf
---	Memorandum relating to conditions governing the provision of services in France by firms established abroad (extract)	DSU11048.pdf
---	Letter from French Inspector of Labour (referenced in above memorandum)	F020731.pdf

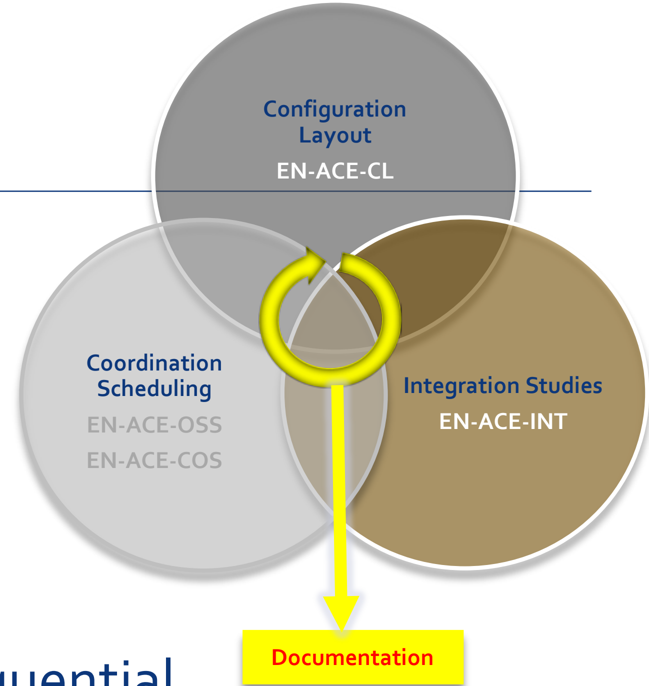
USE OF CERN FACILITIES

Operational Circular N° 5	Use of CERN Computing Facilities	OC5.pdf

Introduction

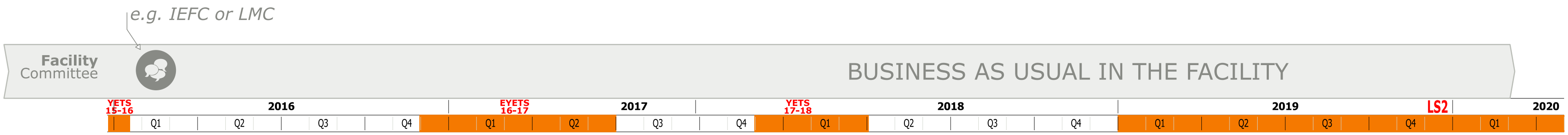






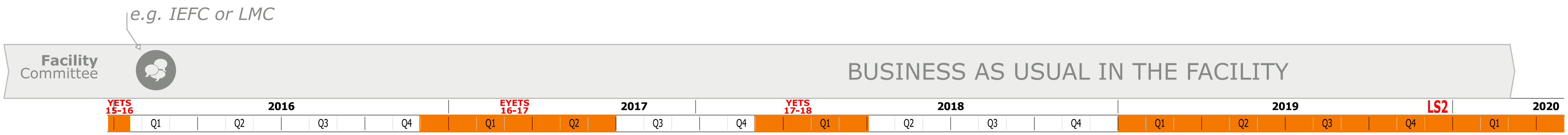
- Versioning of Accelerators in Operation is sequential
  - Based on TS/(e)YETS/LS
  - One snapshot in the timeline for each TS to freeze the configuration
- Preparing projects in advance requires forking the configuration on
  - Hardware Baselines – time-dependent and forked
  - Layout data – time-dependent and forked
  - Integration Scenes – with all the services included – time-dependent and forked
  - List of Activities to prepare for the new configuration – naturally time-dependent and forked

Machine Configurations



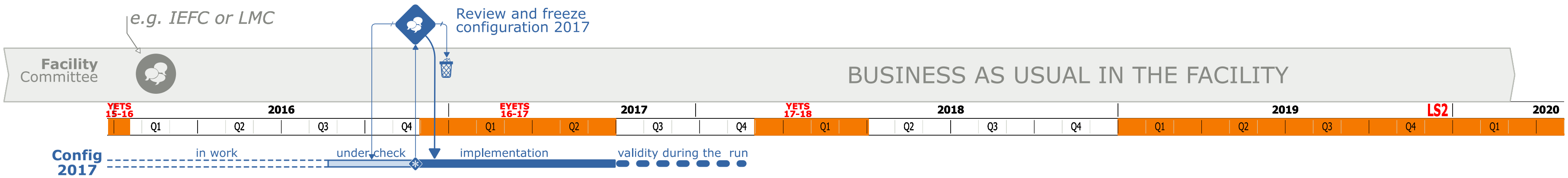
- Configuration of the Facilities in operation are managed by a Committee
  - Based on TS/(e)YETS/LS

Machine Configurations



- Configuration of the Facilities in operation are managed by a Committee
  - Based on TS/(e)YETS/LS
- Machine Configuration is reporting to the Committees
  - Regular presentations on the coordination of the activities
  - Validation of the Change Requests
  - Integration is embedded in the Change Requests
  - Layout is maintained

Machine Configurations



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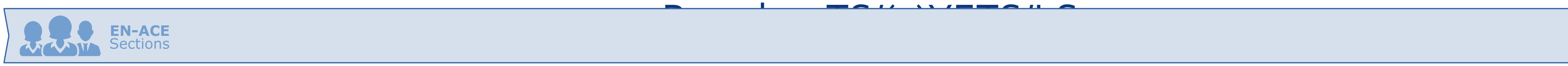

- A given Configuration has
  - A preparation time with Eng. Specifications and Change Requests circulating and getting approved
  - A review and validation time of coherence
  - An implementation time
  - A validity for a Run

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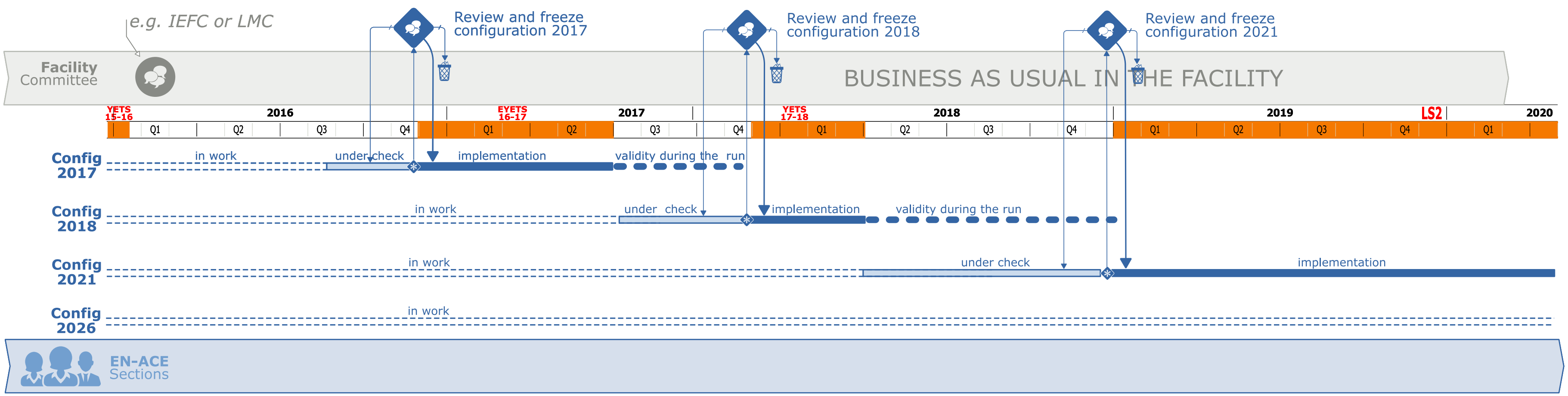
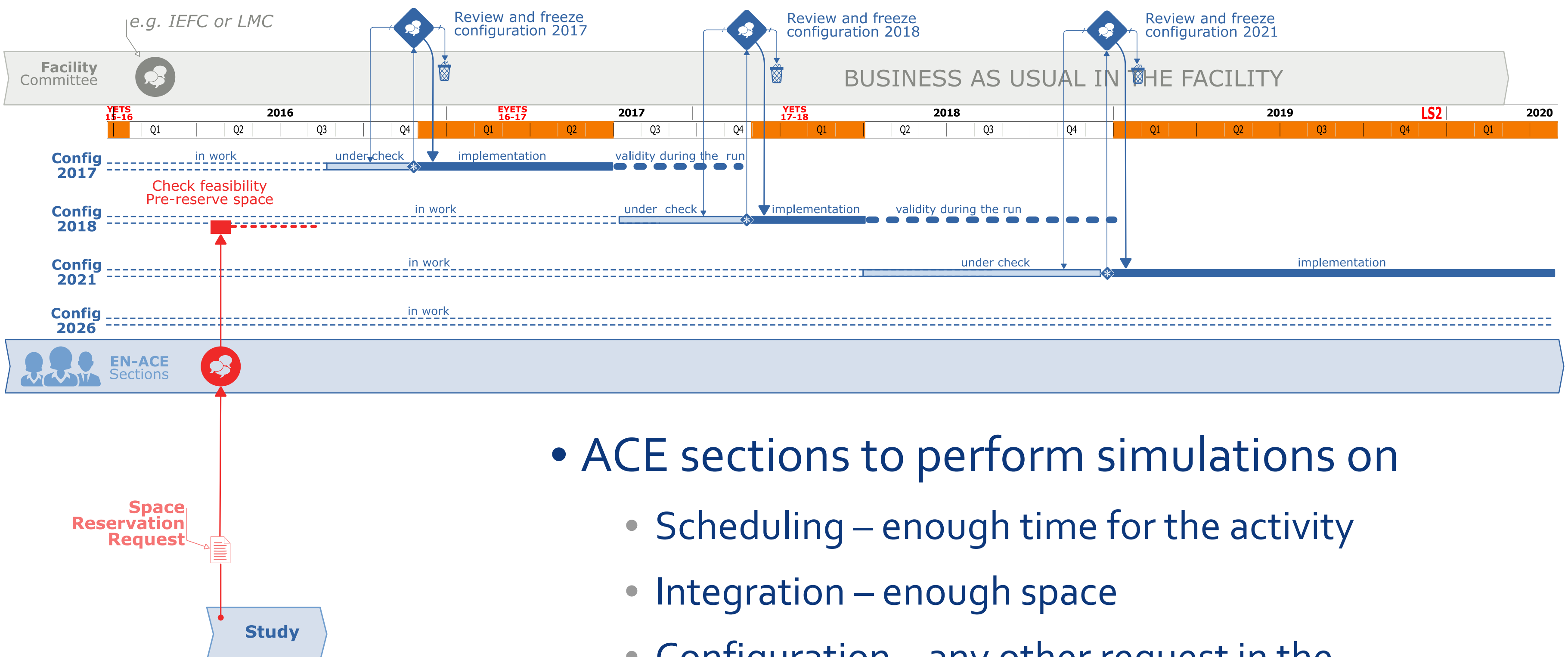


- Machine Configurations sometimes need to be known in advance
  - E.g. activities planned for 2018 and ECR already approved
  - Projects – LIU and HL-LHC – need their configuration stored and handled

- A given Configuration has
  - A preparation time with Eng. Specifications and Change Requests circulating and getting approved
  - A review and validation time of coherence
  - An implementation time
  - A validity for a Run

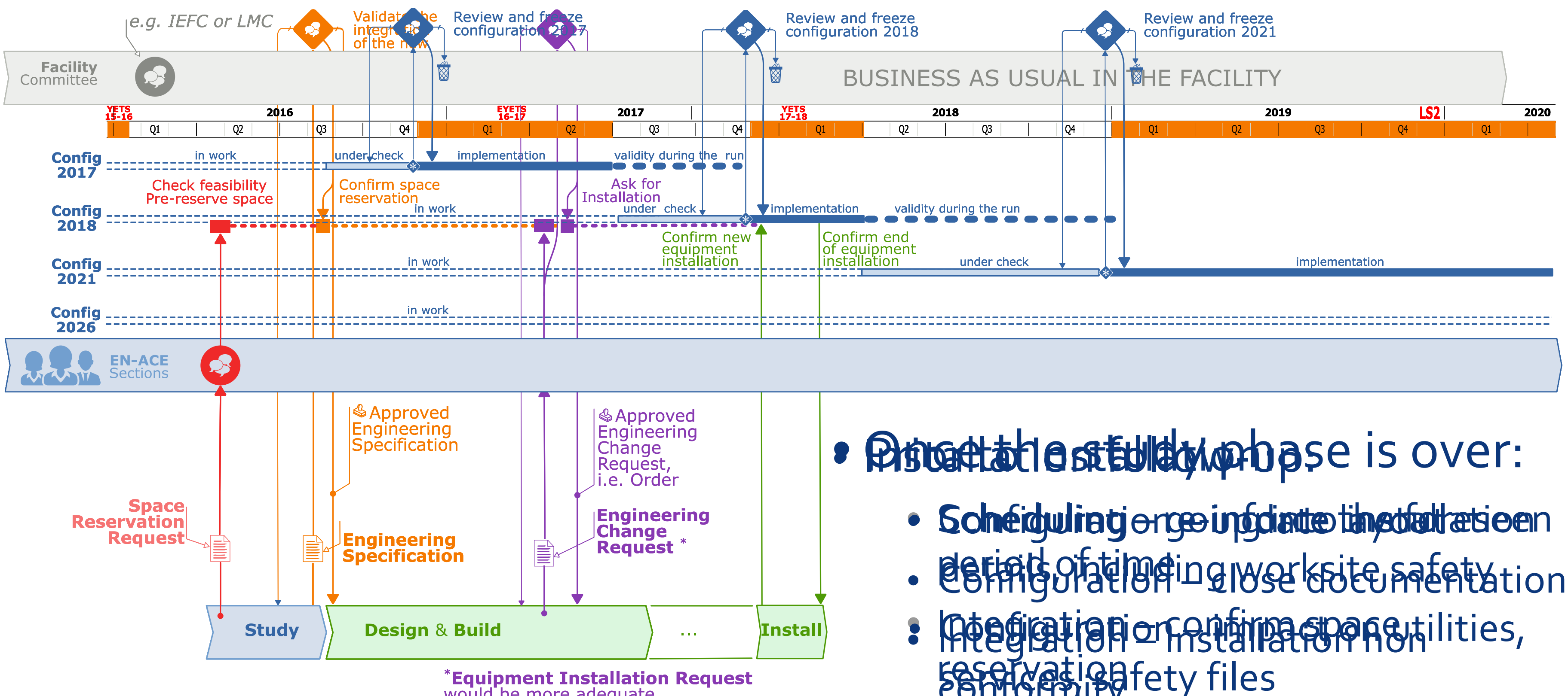
Preparing configuration is heavily linked to the equipment lifecycle

Equipment Lifecycle



- ACE sections to perform simulations on
  - Scheduling – enough time for the activity
  - Integration – enough space
  - Configuration – any other request in the neighborhood

Equipment Lifecycle



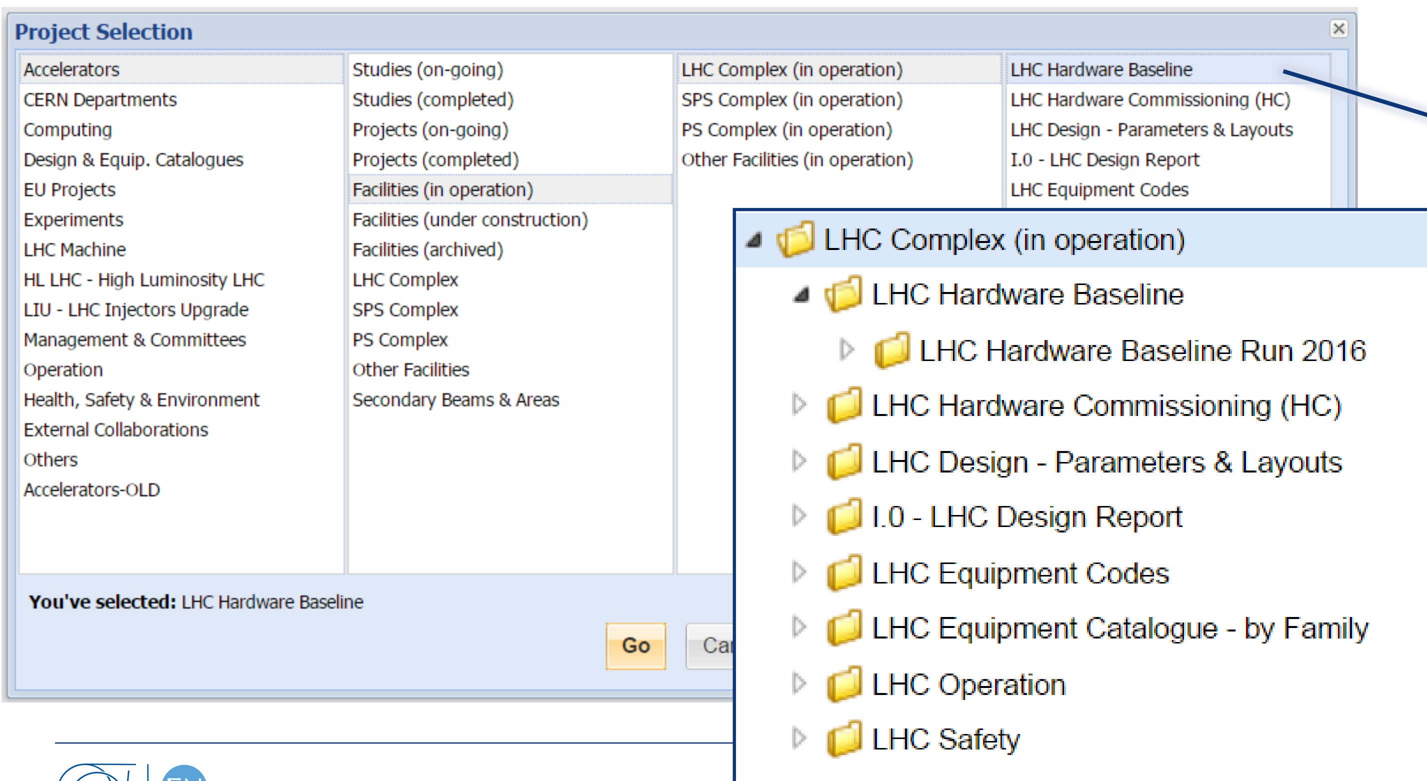
- Once the study phase is over:
  - Scheduling – confirm the installation period of time
  - Configuration – update layout details including worksite safety
  - Integration – confirm space reservation
  - Configuration – impact on utilities, services, safety files
  - Configuration – documentation follow-up
  - Integration – update machine drawing layouts
- Installation follow-up:
  - Configuration – close documentation
  - Integration – installation non conformity
  - Integration – check equipment remains inside envelope

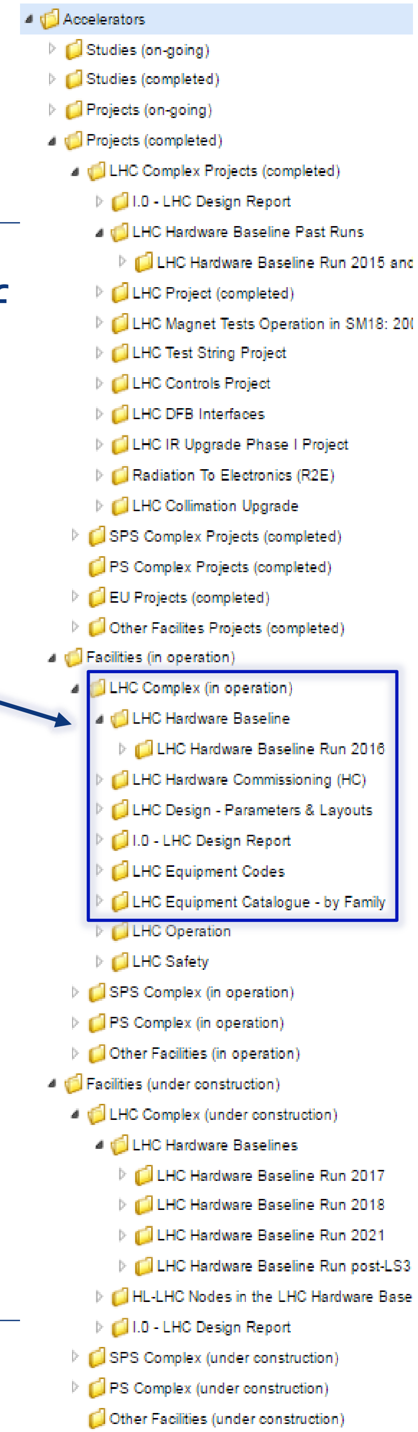
Changes in the tools – EDMS

- Configuration documentation in EDMS needed to be changed to allow an easy forking on structures.
  - Structures needed to be separated
  - Documents need their validity to be re-affirmed for a given configuration
    - E.g. specifications on the QRL sectorisation remaining valid up-to configuration Run 2021 or Run 2022.
    - E.g. removal of the String 2 documentation in current and future baselines.

Changes in the tools – EDMS

- Refurbishment of the EDMS portal to reflect the forking of the structures and to follow the Engineering Lifecycle
  - Studies – Projects – Operation – Dismantling
  - Allows a better view on the baseline forking





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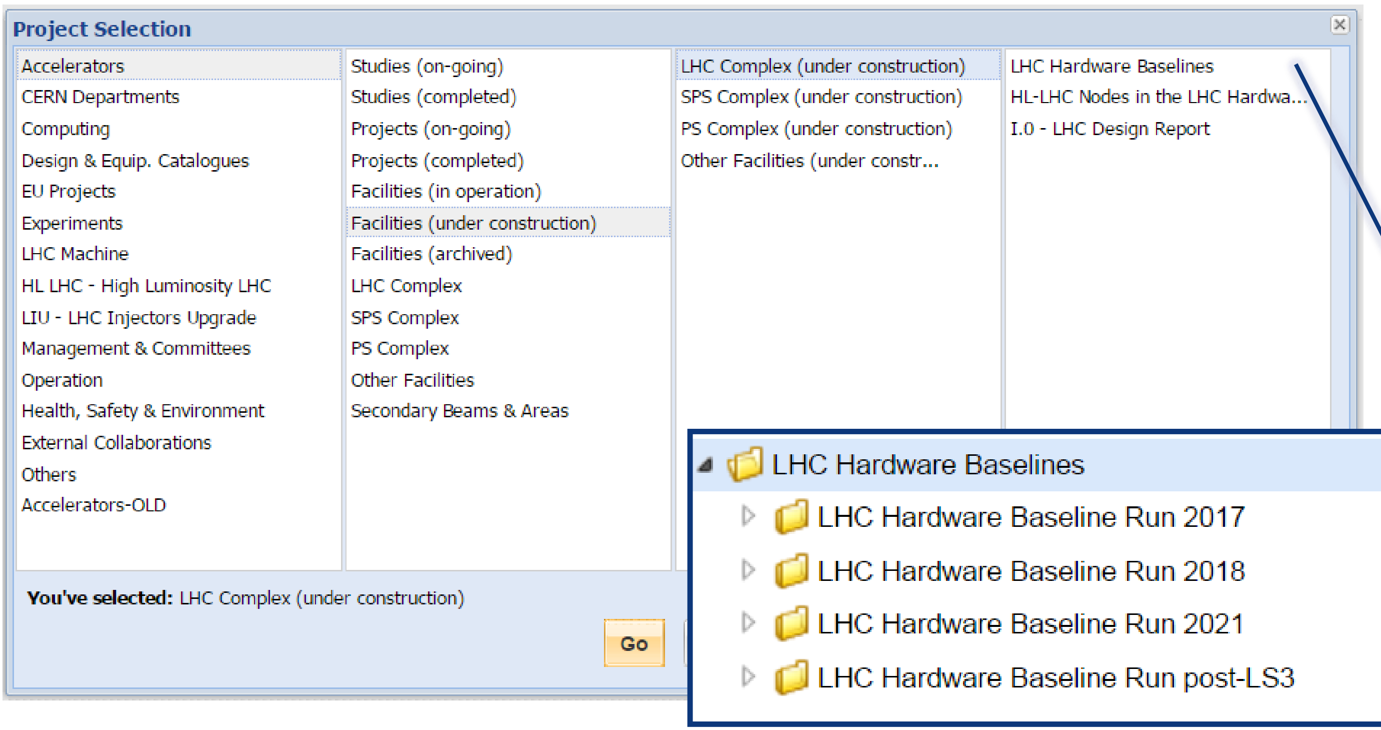
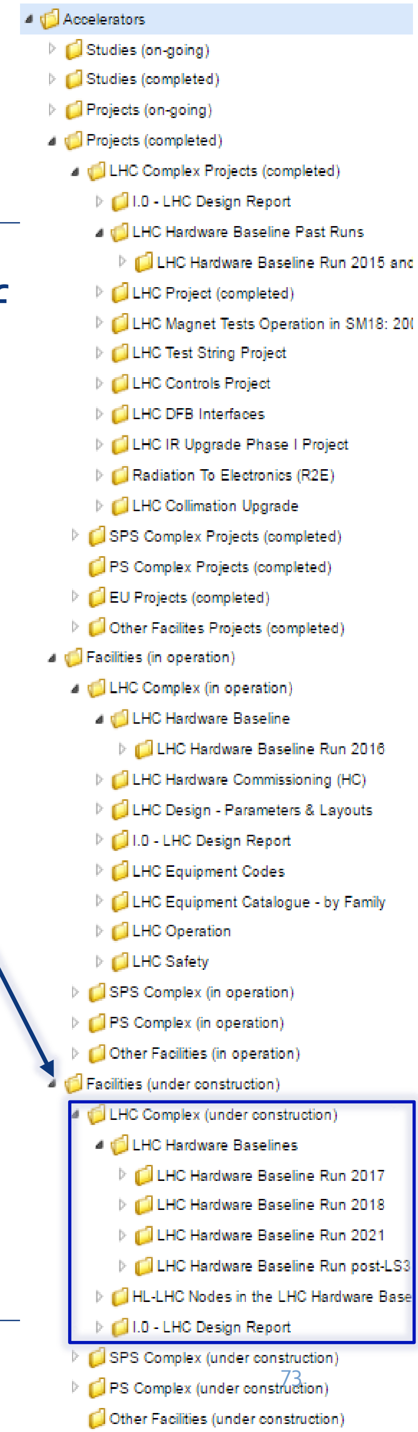


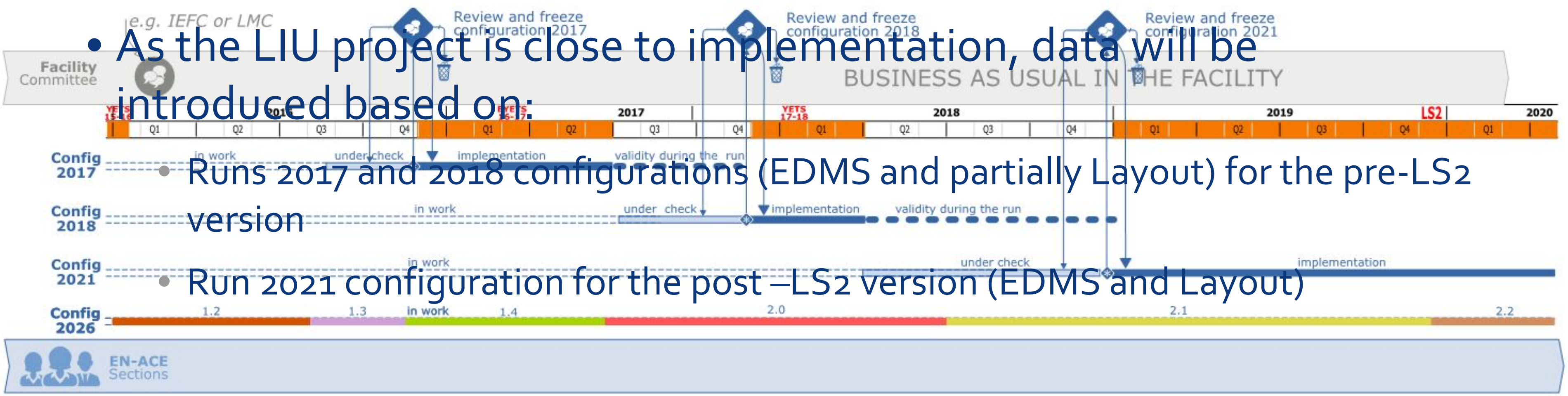


Changes in the tools – Layout Drawings

- There is an on-going campaign by ACE-INT
  - to identify and produce all the missing layout drawings, based on machine regions (period, sector, section)
  - to separate all-in-one (e.g. LT, LTB, LBE, LBS) to individually manage them
  - to clarify any confusion with the assembly drawings produced by EN-MME Design Office which are mechanical and not layout drawings
- This set of drawings will then be used to produce the layout drawings for the post-LS2 period
  - in parallel to the data entering in the layout database
  - knowing that all incremental changes drawings have already been produced for the ECRs.

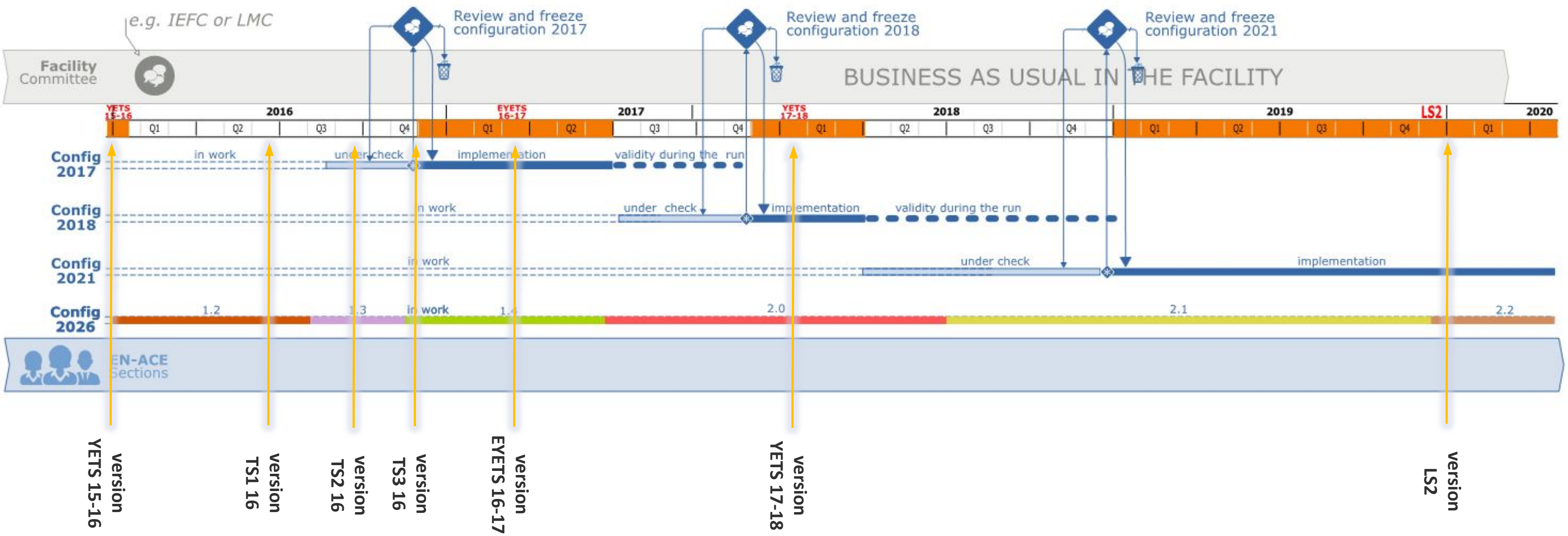
Changes in the tools – Project Versioning

- Sequential versions for the HL-LHC project (optics versions 1.1, 1.2, 1.3, etc.) will have to be tagged in the new layout database on the base of the Configuration for Run 2026.
  - This will allow a coherence check per recorded optics version
  - NB: The current version of the database is unable to do this
- As the LIU project is close to implementation, data will be introduced based on:
  - Runs 2017 and 2018 configurations (EDMS and partially Layout) for the pre-LS2 version
  - Run 2021 configuration for the post –LS2 version (EDMS and Layout)



Changes in the tools – Layout DB

- New layout DB (+ WEB GUI) under development by BE-CO



- What is a version in the new Layout DB ?
  - A version represents an installed layout at the end of a stop period
  - It is valid for the whole following run period

From project to installation

Functional and Engineering Specifications

- to make people describe their requirements, their interfaces, their engineering

Engineering Change Request/Order

- to ensure the information is up-to-date at a given time, and shared with all those participating to the project
- to control changes through validation and update impacted specifications

CDR(Conceptual Design Report), TDR (Technical Design Reports), Schematics, 2D-Drawings, 3D-Mockups, Technical Notes, Technical Reports, Technical Datasheets, various lists, BoMs , Procurement Documents (TD,TQ, QC, TS, TF), Scientific Publications, illustrations, sketches, photos, videos

Courtesy R. Saban

The installed collider

The installed machine evolves

- Components are exchanged
- New components are installed
- The configuration changes

Engineering
Change
Request/Order

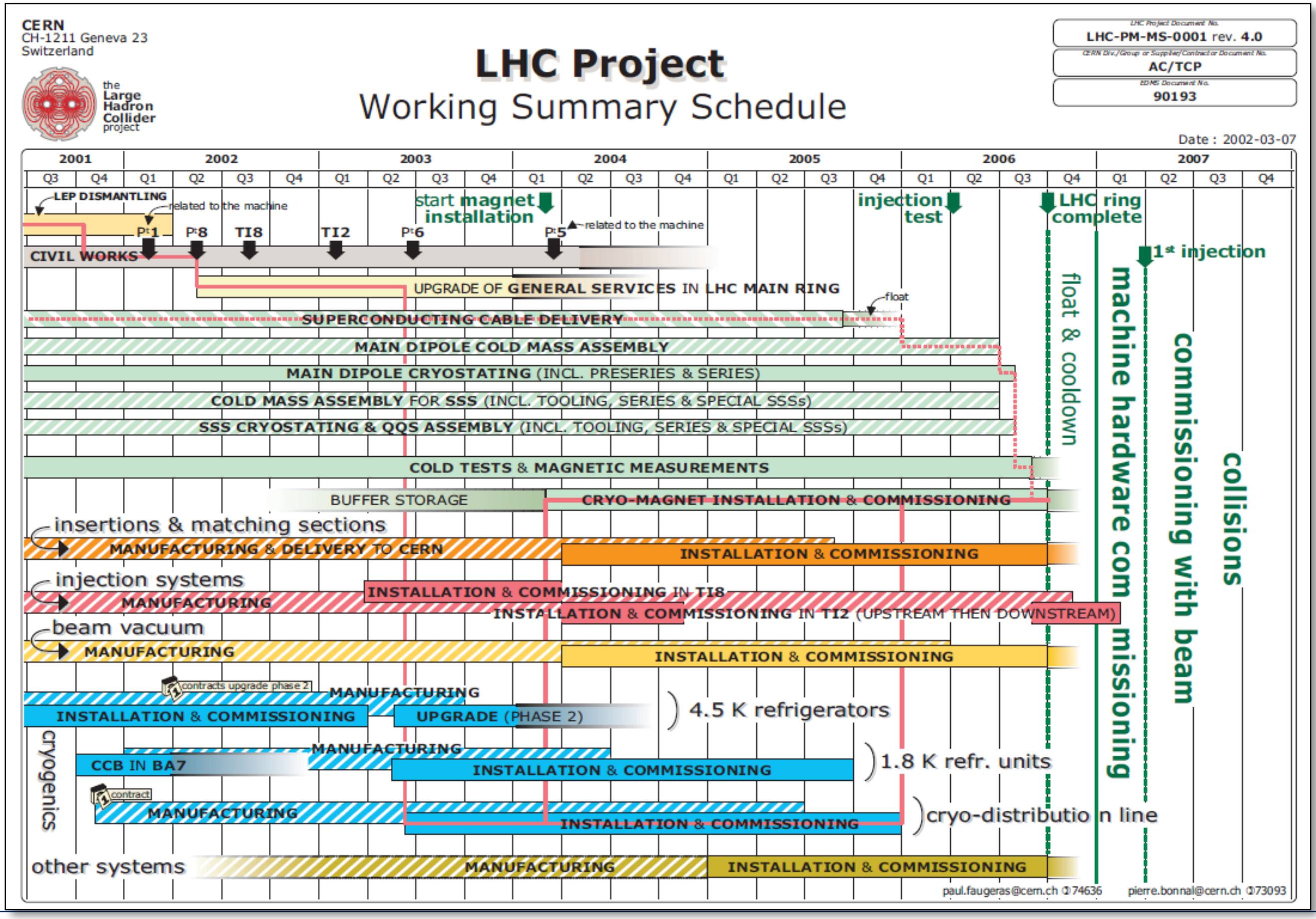
⇨

- Changes are documented
- The impact on safety, infrastructures, on neighboring systems, planning, budget is carefully studied
- The layout is updated to ensure the integration of the next changes is possible

Courtesy R. Saban

The Master Schedule

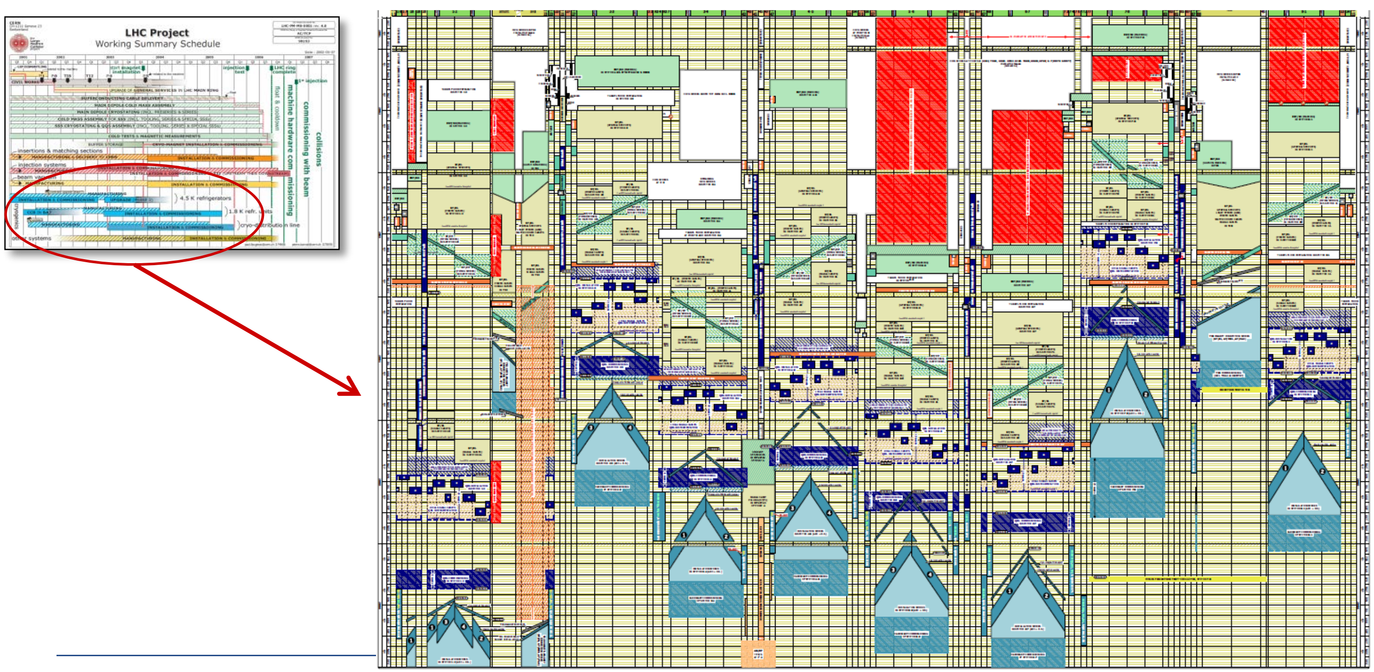
Review of the **strategic** goals and major milestones



LHC construction & installation schedule

From strategy to tactics

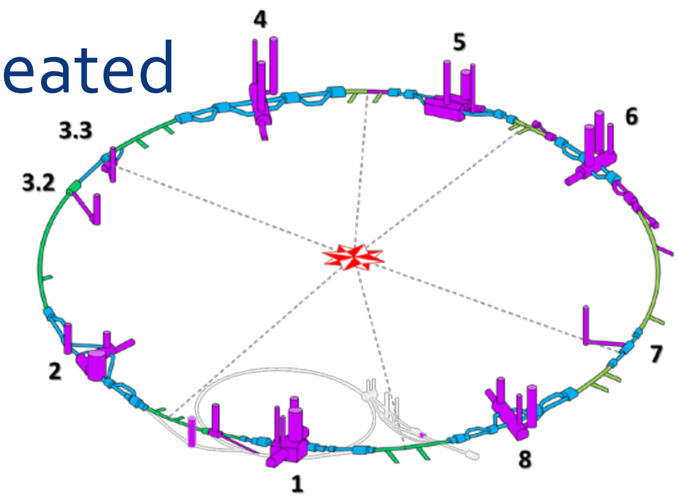
- Aim: implement and control the flow of installation
- Respect the main milestones of the Master Schedule
- Based on the WBS
- Linear schedule



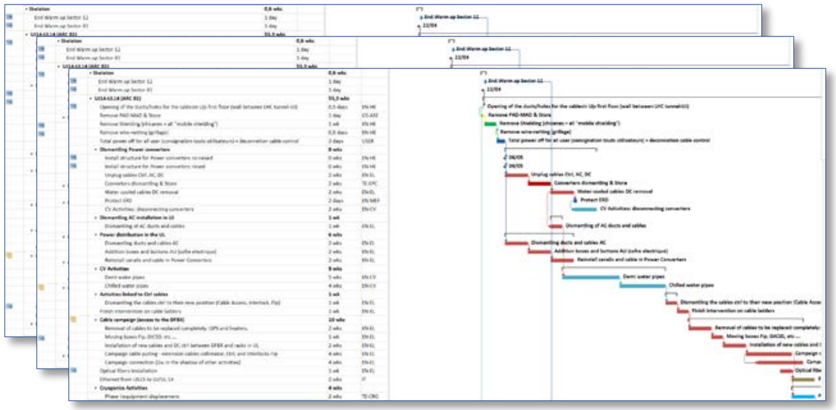
Detailed schedules

From tactics to operation

- The LHC main ring: 8 sectors treated as 8 identical machines
  - Arcs
  - Long Straight Sections
  - Services areas



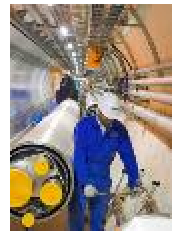
- 3 main MSProject files
- Review of the 3 schedules, and their dependencies on a weekly base



Baseline evolution

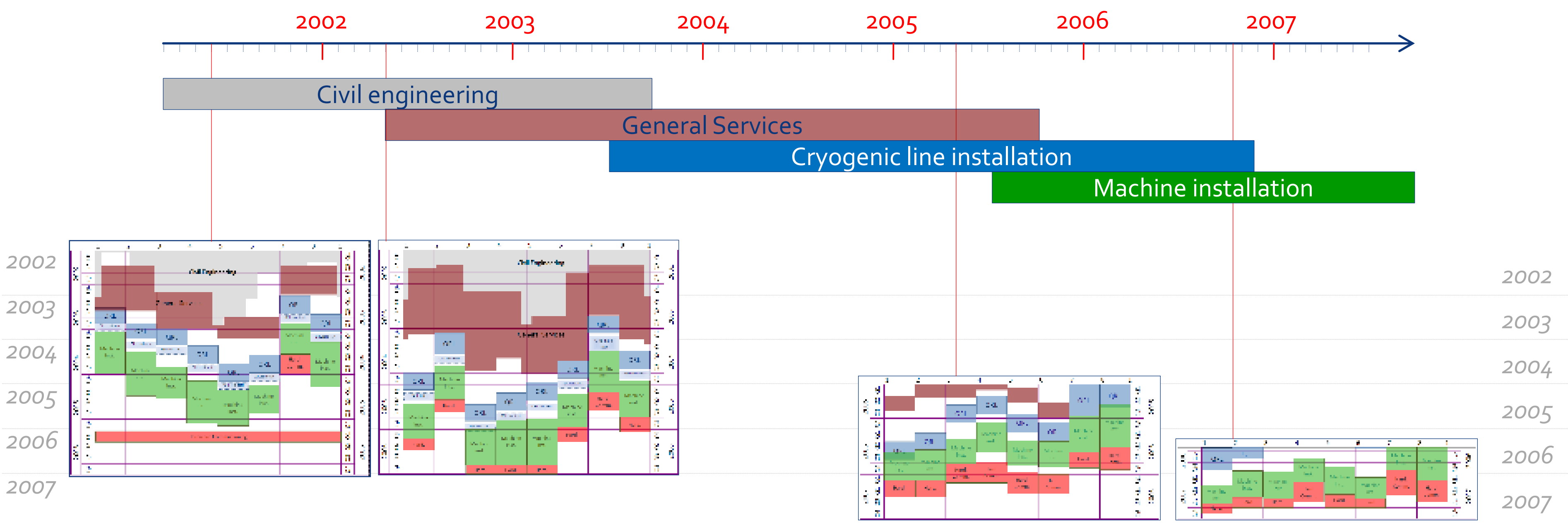

LHC civil engineering work


Water cooled cables

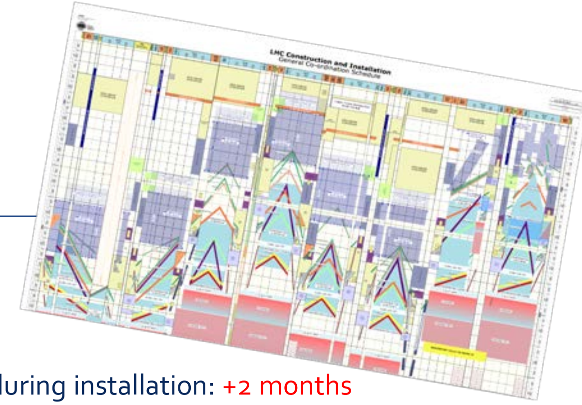

Cryogenic line


1st LHC cryo-magnet lowering


LHC Interconnection work



Baseline schedule



The delay of the QRL imposed the reshuffling of some activities. Additional resources were added for the following phases +3 months

Major non-conformities during installation: +2 months because of the QRL, +4 months because of the interconnections

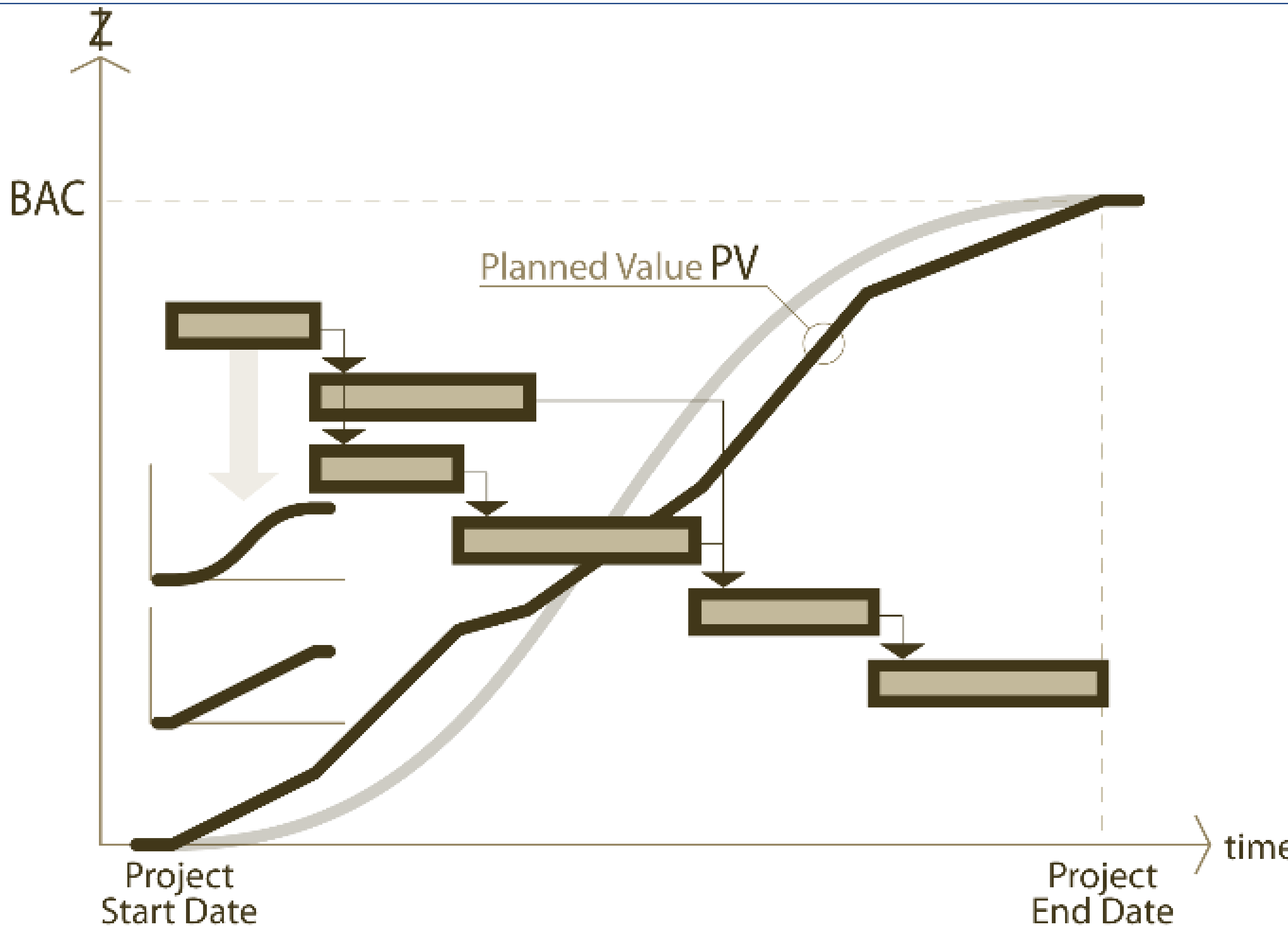
Id	Title	Created on
LHC-PM-MS-0005 v.4.0	LHC Construction/Installation General Coordination Schedule	2007-06-14
LHC-PM-MS-0005 v.3.1	LHC Construction/Installation General Coordination Schedule	2006-10-10
LHC-PM-MS-0005 v.3.0	LHC Construction/Installation General Coordination Schedule	2006-07-07
LHC-PM-MS-0005 v.2.0	LHC Construction/Installation General Coordination Schedule	2005-04-06
LHC-PM-MS-0005 v.1.7	LHC Construction/Installation General Coordination Schedule	2003-03-31
LHC-PM-MS-0005 v.1.6	LHC Construction/Installation General Coordination Schedule	2003-03-18
LHC-PM-MS-0005 v.1.5	LHC Construction/Installation General Coordination Schedule	2003-03-03
LHC-PM-MS-0005 v.1.4	LHC Construction/Installation General Coordination Schedule	2002-04-19
LHC-PM-MS-0005 v.1.3	LHC Construction/Installation General Coordination Schedule	2002-03-27
LHC-PM-MS-0005 v.1	LEP Dismantling and LHC Construction/Installation General Coordination Schedule	1999-04-06

Hardware commissioning was included

Interconnection non conformities + Inner Triplet Crisis +7 months

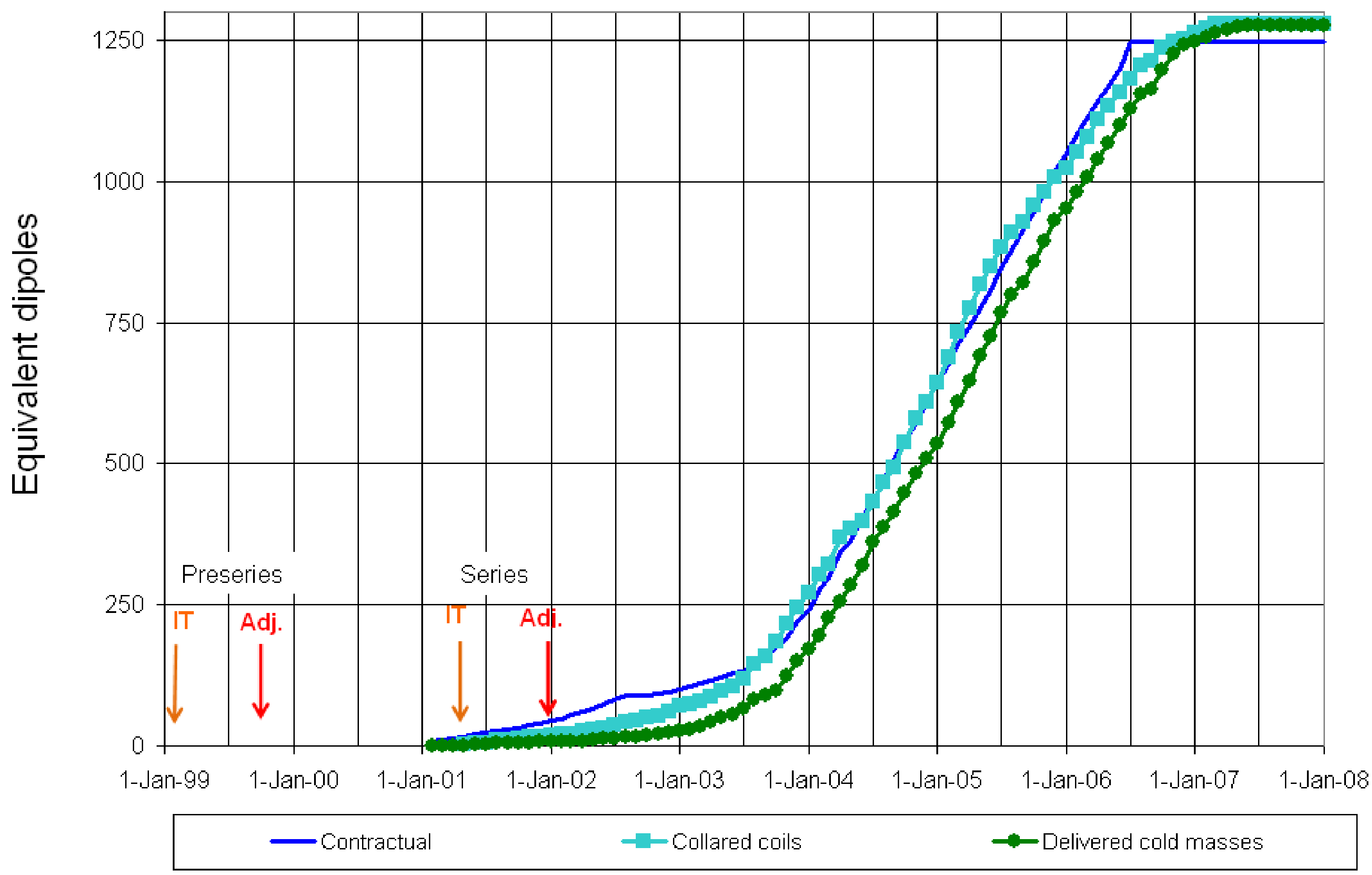
Courtesy R. Saban

EVM Basics

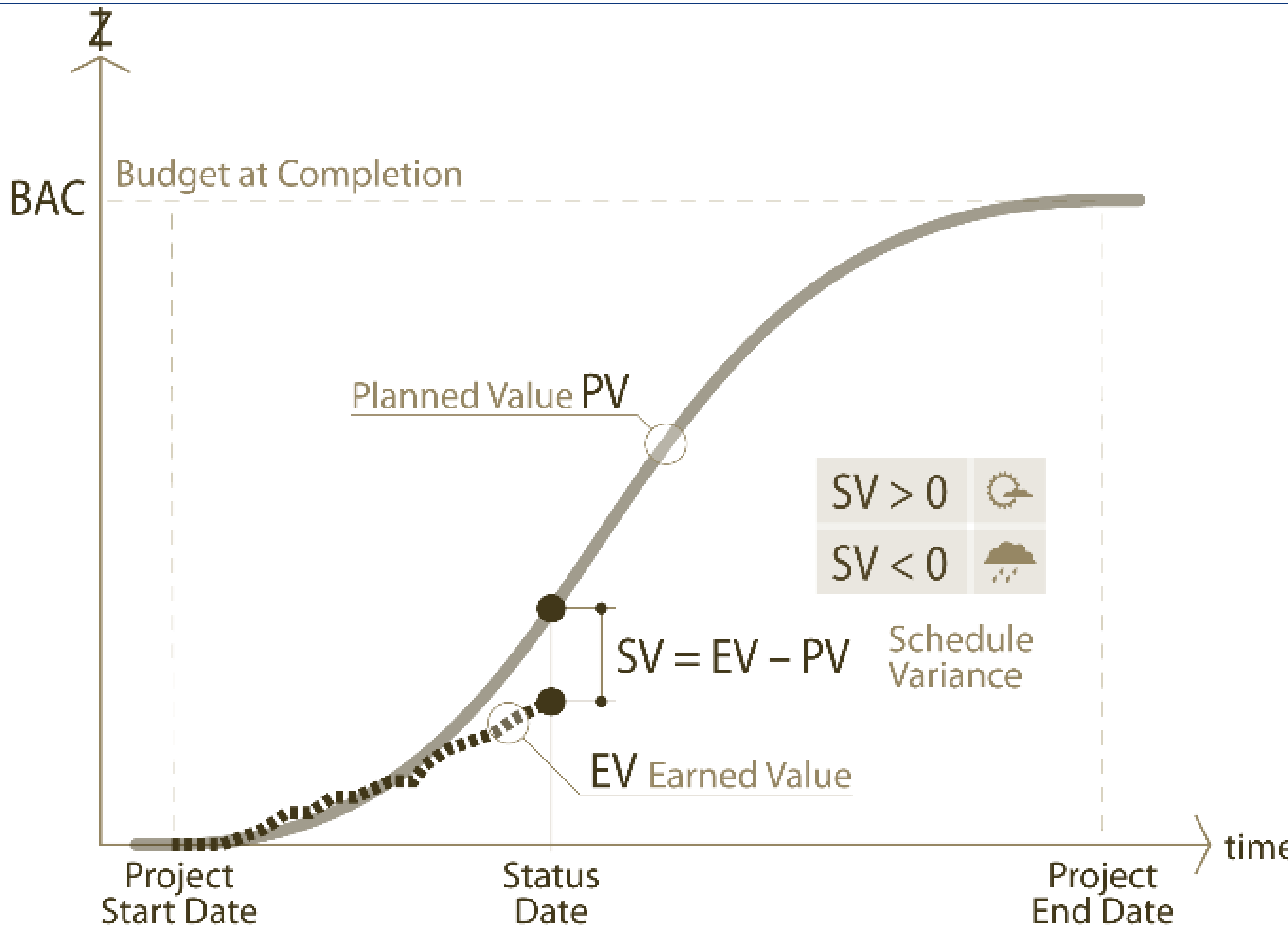


Courtesy P.Bonnal

Industrialization & production ramp-up
LHC superconducting dipole magnets

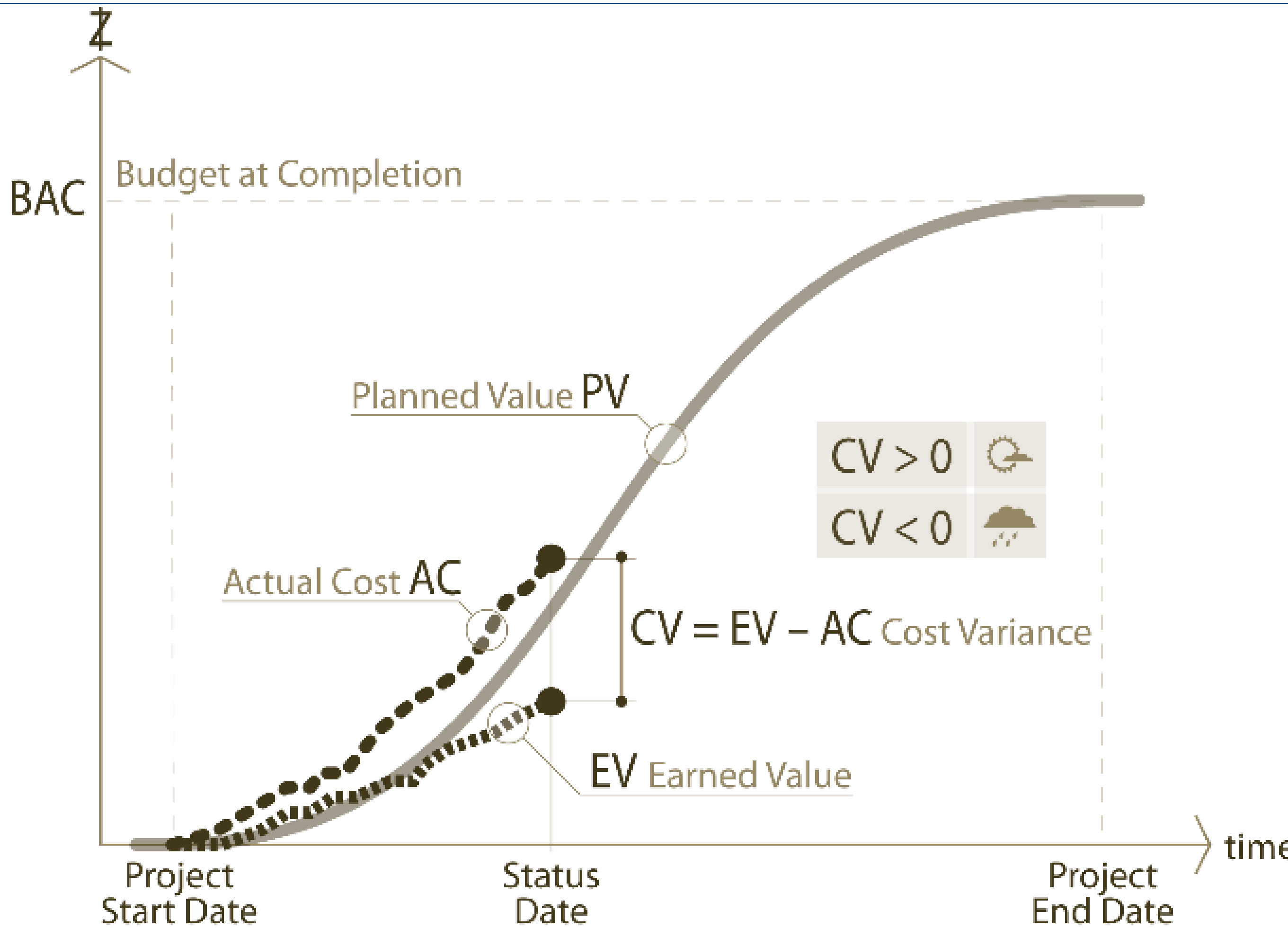


Schedule Variance



Courtesy P.Bonnal

Cost Variance



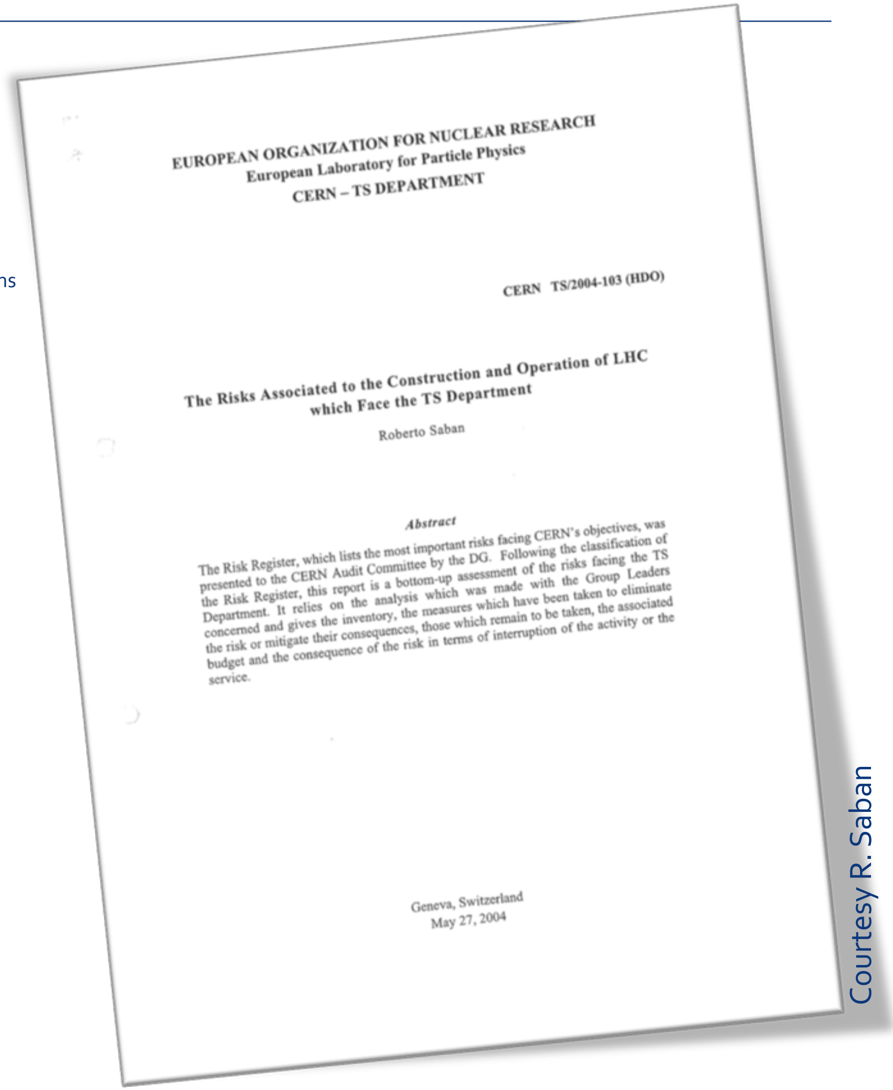
Courtesy P.Bonnal

Risk Analysis

Each risk was assigned a measure for

1. Likelihood rare, possible, likely, frequent, very frequent
2. Impact on CERN's objectives insignificant, moderate, major, catastrophic
3. Impact on the interruption of operation hours, days, weeks, months

from which a score was derived to rank the risks.



EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH
European Laboratory for Particle Physics
CERN – TS DEPARTMENT

CERN TS/2004-103 (HDO)

The Risks Associated to the Construction and Operation of LHC which Face the TS Department

Roberto Saban

Abstract

The Risk Register, which lists the most important risks facing CERN's objectives, was presented to the CERN Audit Committee by the DG. Following the classification of the Risk Register, this report is a bottom-up assessment of the risks facing the TS Department. It relies on the analysis which was made with the Group Leaders concerned and gives the inventory, the measures which have been taken to eliminate the risk or mitigate their consequences, those which remain to be taken, the associated budget and the consequence of the risk in terms of interruption of the activity or the service.

Geneva, Switzerland
May 27, 2004

Courtesy R. Saban

A record was prepared for each risk giving a description, the owner, the measure which could be taken to mitigate it, its cost, its score and the new score if the mitigation measures are taken.

Based on this analysis, the Management took the decision on how to handle each risk. i.e. take mitigation measures or accept it.

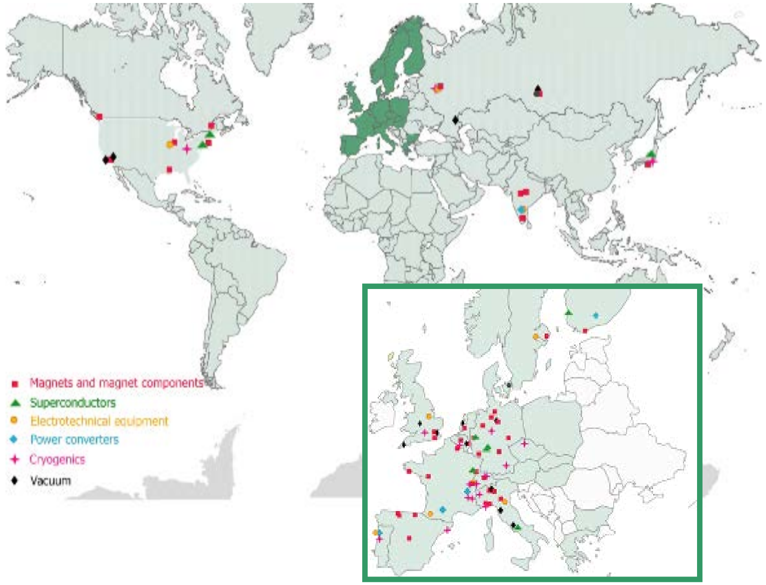
Risk Analysis

[Equipment / System]		Risk Score	
		without consolidation	with consolidation
Probability of failure (P)	Rare (once in 10 to 25 years) = 1 Possible (once in 5 to 10 years) = 2 Likely (once in 2 to 5 years) = 3 Frequent (once a year) = 4	4	2
Impact on CERN's scientific objectives (Io)	Insignificant (loss of 1 day of physics or less) **= 1** Moderate (between 1 day and 1 week of physics lost) **= 2** Major (up to 1 month of physics lost) **= 3** Catastrophic (no more operation, failure to meet scientific objectives for the year) **= 5**	2	1
Impact on CERN's (AB's) reputation (Ir)	Insignificant = 1 Moderate (problem dealt with inside ATS) = 2 Major (problem discussed at Executive Board or Governing bodies) = 3	2	1
Financial Impact of failure (If)	Insignificant (<0.1% of ATS annual operation budget or less than 100 kCHF) = 1 Moderate (between 0.1% and 1% of ATS annual operation budget or 0.1 – 1 MCHF) = 2 Major (additional budget essential for repair i.e. > 1 MCHF) = 3 Catastrophic (report to Council, could jeopardize CERN's future) = 5	3	1
Safety Impact of failure (Is)	Insignificant (i.e. no injury or environmental consequence) = 1 Moderate (i.e. injury requiring medical attention, but no loss of working days) = 2 Major (i.e. serious injury requiring medical attention and loss of working days) = 3 Catastrophic (i.e. loss of life) = 5	1	1
Facilities Concerned (i)	LHC scientific program (i = 0.3) LHC test beams (i = 0.1) SPS fixed target scientific program (i = 0.15) PS fixed target scientific program (including nTOF) (i = 0.15) AD scientific program (i = 0.15) ISOLDE scientific program (i = 0.15)	0.3	0.3
The Risk score (Rs) is calculated as	Rs = P × max(Io;Ir;If;Is)		
The weighted Risk score (Rs') is calculated as	Rs' = Rs×Σi		

Courtesy R. Saban

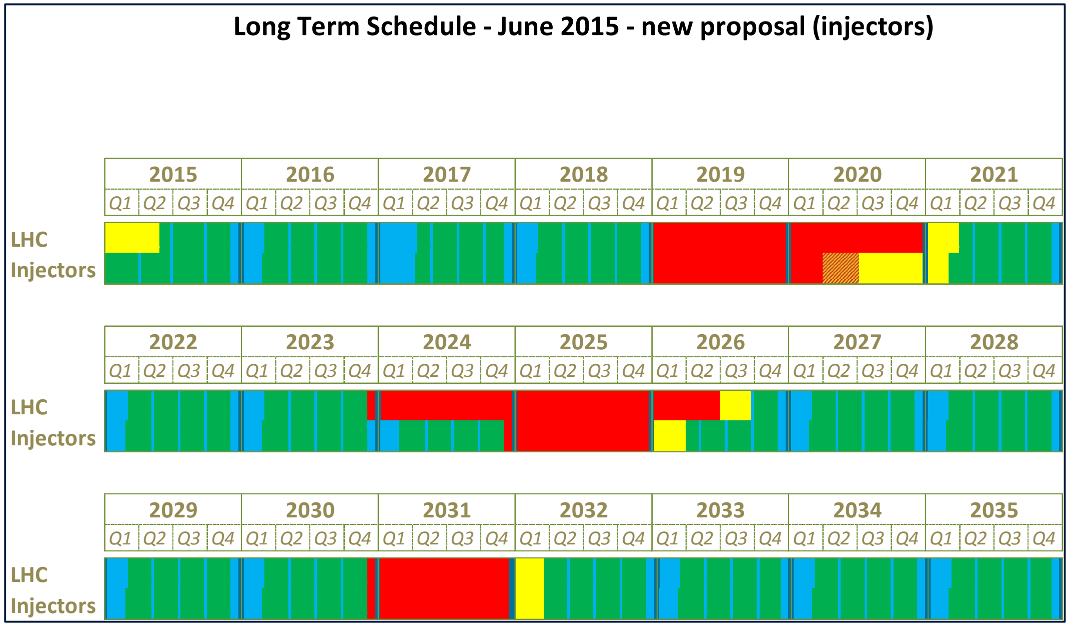
Lessons learned

- Balance risks: lack of competition for contracts can increase project costs and affect deadlines
  - **90 main industrial contracts in the world**
  - 2 firms at least for a single adjudication on large/main contracts



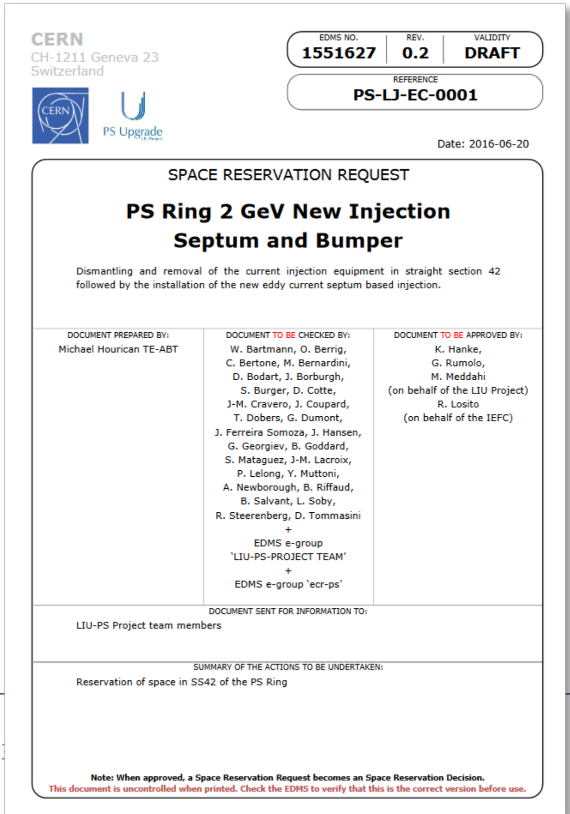
From Project to Operation

- LHC has a cycle of ~ 5 years
  - ~ 3 years of operation (incl. 3 TS & YETS)
  - ~2 years of Long Shut-down to consolidate, upgrade and perform full maintenance of the different systems.



QAP - document evolution

- Configuration Management
  - Exported to the existing beam facilities
  - ECRs : templates evolved- additional chapters concerning the existing situation, schedule, impact on utilities and services, safety aspects, follow-up of actions
  - Space Reservation Requests were introduced



CERN
CH-1211 Geneva 23
Switzerland

PS Upgrade

EDMS NO.	REV.	VALIDITY
1551627	0.2	DRAFT

REFERENCE
PS-LJ-EC-0001

Date: 2016-06-20

SPACE RESERVATION REQUEST

PS Ring 2 GeV New Injection Septum and Bumper

Dismantling and removal of the current injection equipment in straight section 42 followed by the installation of the new eddy current septum based injection.

DOCUMENT PREPARED BY:	DOCUMENT TO BE CHECKED BY:	DOCUMENT TO BE APPROVED BY:
Michael Hourican TE-ABT	W. Bartmann, O. Berrig, C. Bertone, M. Bernardini, D. Bodart, J. Borburgh, S. Burger, D. Cotte, J-M. Cravero, J. Coupard, T. Dobers, G. Dumont, J. Ferreira Somoza, J. Hansen, G. Georgiev, B. Goddard, S. Mataguez, J-M. Lacroix, P. Lelong, Y. Muttoni, A. Newborough, B. Riffaud, B. Salvant, L. Soby, R. Steerenberg, D. Tommasini + EDMS e-group 'LIU-PS-PROJECT TEAM' + EDMS e-group 'ecr-ps'	K. Hanke, G. Rumolo, M. Meddahi (on behalf of the LIU Project) R. Losito (on behalf of the IEFC)

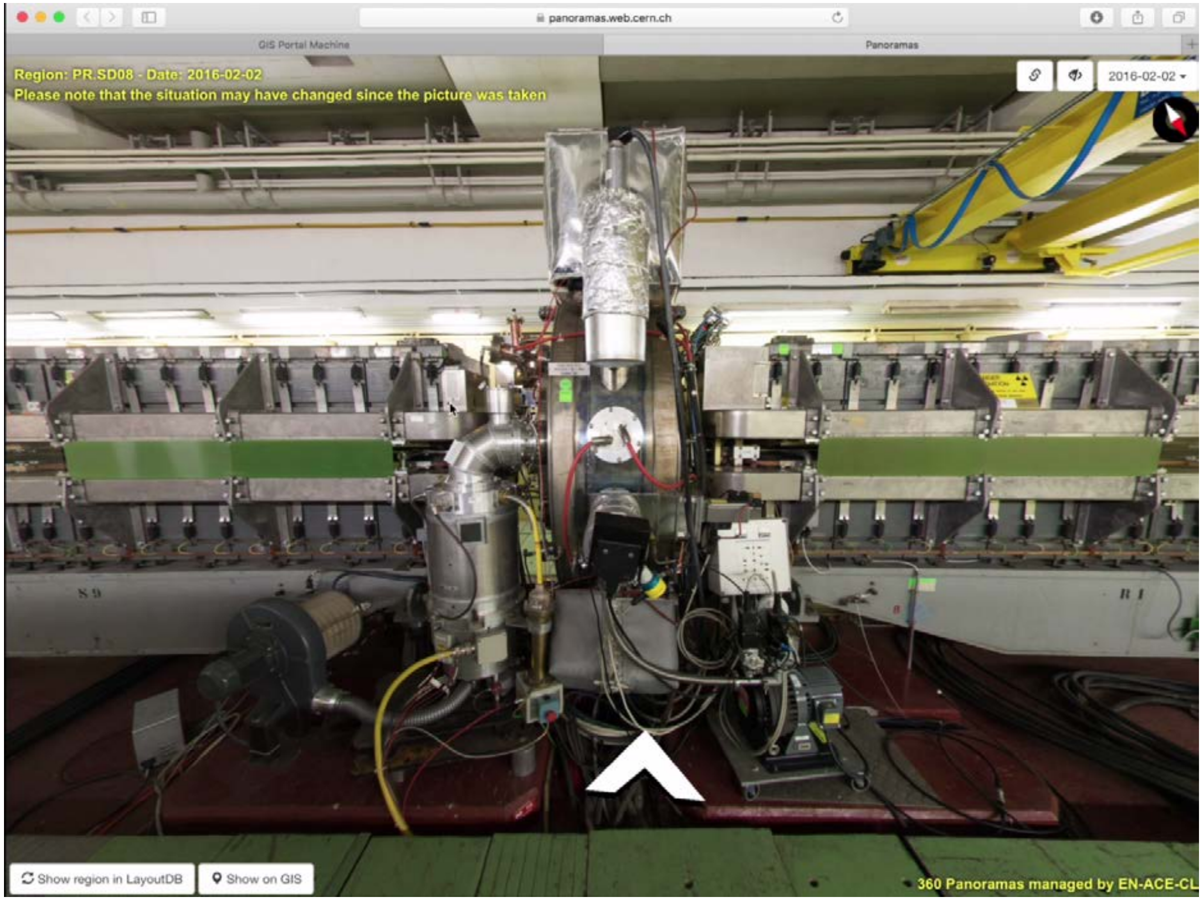
DOCUMENT SENT FOR INFORMATION TO:
LIU-PS Project team members

SUMMARY OF THE ACTIONS TO BE UNDERTAKEN:
Reservation of space in SS42 of the PS Ring

Note: When approved, a Space Reservation Request becomes an Space Reservation Decision.
This document is uncontrolled when printed. Check the EDMS to verify that this is the correct version before use.

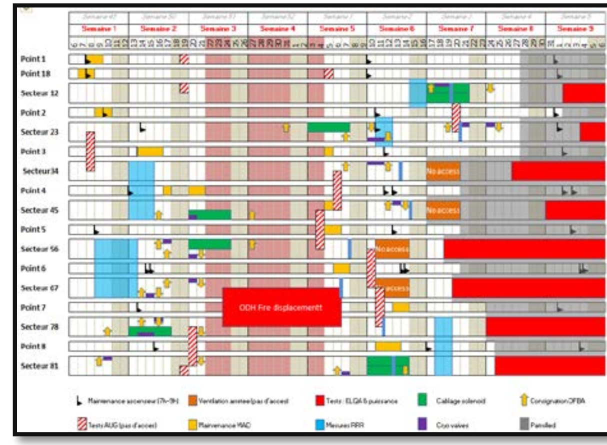
Configuration & Layout db evolution

Integration of 360°pictures in layout database

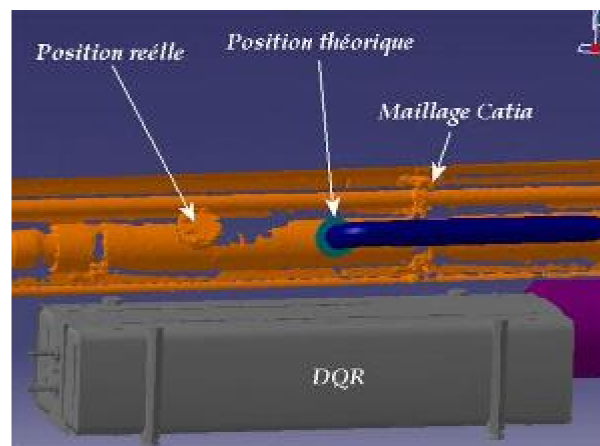


Coordination of Programmed Stops

- Participative approach
  - Integration & work preparation meetings **with stakeholders and experts** WPA: What, where, how, when…safety
  - Skeleton schedule ▶ detailed resource levelled schedule & access constraints schedule
  - ALARA meetings where needed



- Non Conformities detection eased with Scans



The painful 1st year of Operation

- 2010 was not a smooth year
  - Operation and physicists waited many years for beams
  - Programmed stops were mandatory to cure the technical teething problems and perform a regular maintenance (reliability)

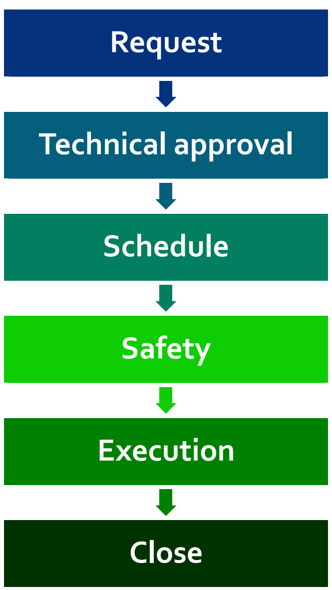
  - Recovery after each programmed stops was long, coming from the fact that we had no means to strictly control the activities (as the access system was linked only to the "training" database!)
  - Moreover, the same information was copy-paste into different forms, and access time to the machine was huge (average of 20 minutes/person - ~ 500 persons wanting to access - 2 operators granting access

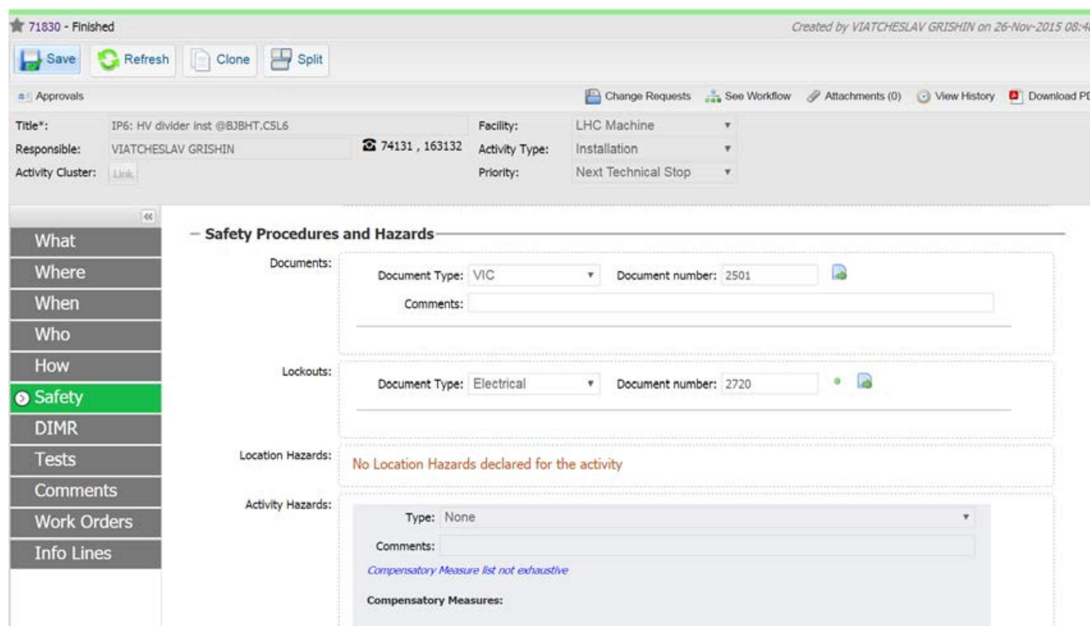
▶ Intervention Management Planning And Coordination Tool

IMPACT

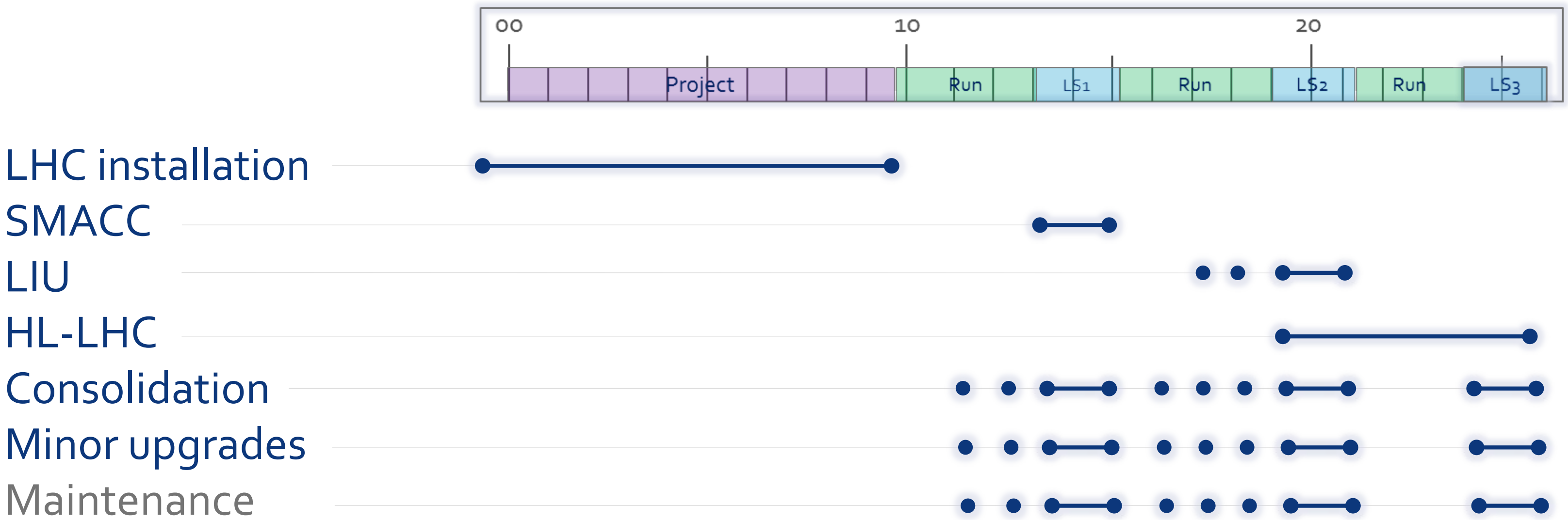
- One database grouping all the interventions in all the accelerator complex
- Approval process through the existing Electronic Document Handling (EDH)
- Linked to the Access Control System database
- Generation of safety forms: fire permit, DIMR…

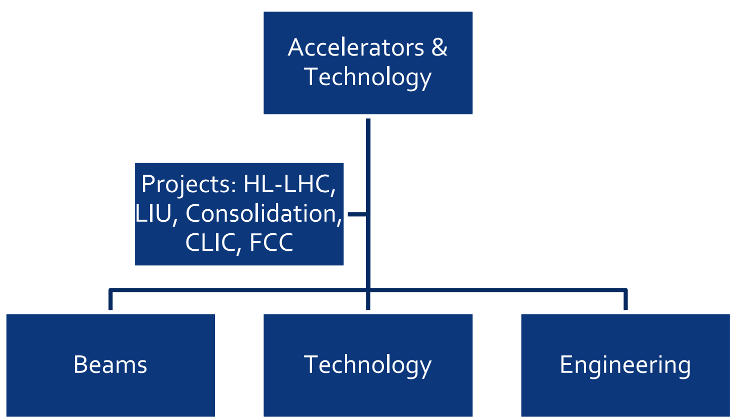
Workflow



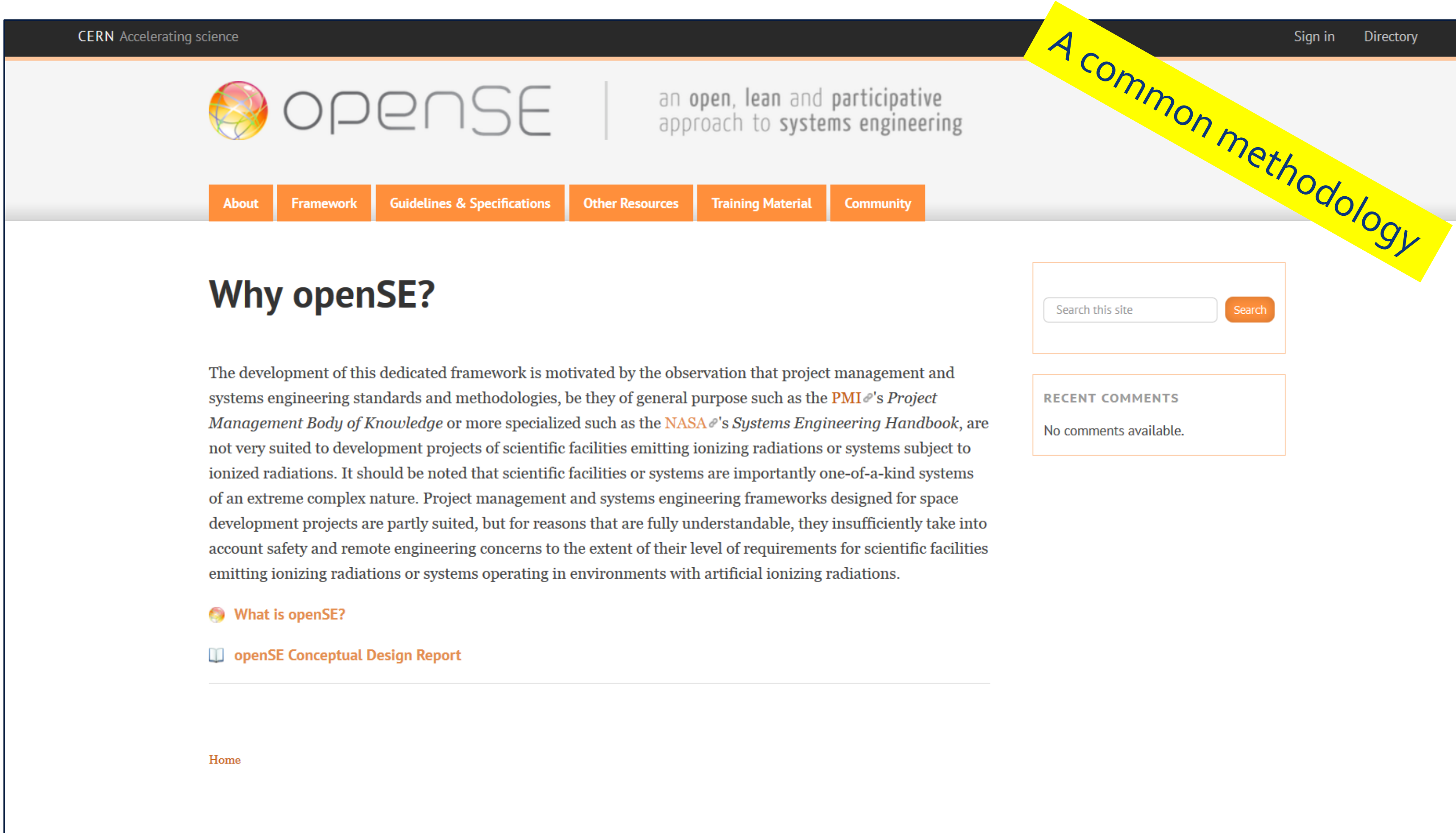


From one project to multi-projects





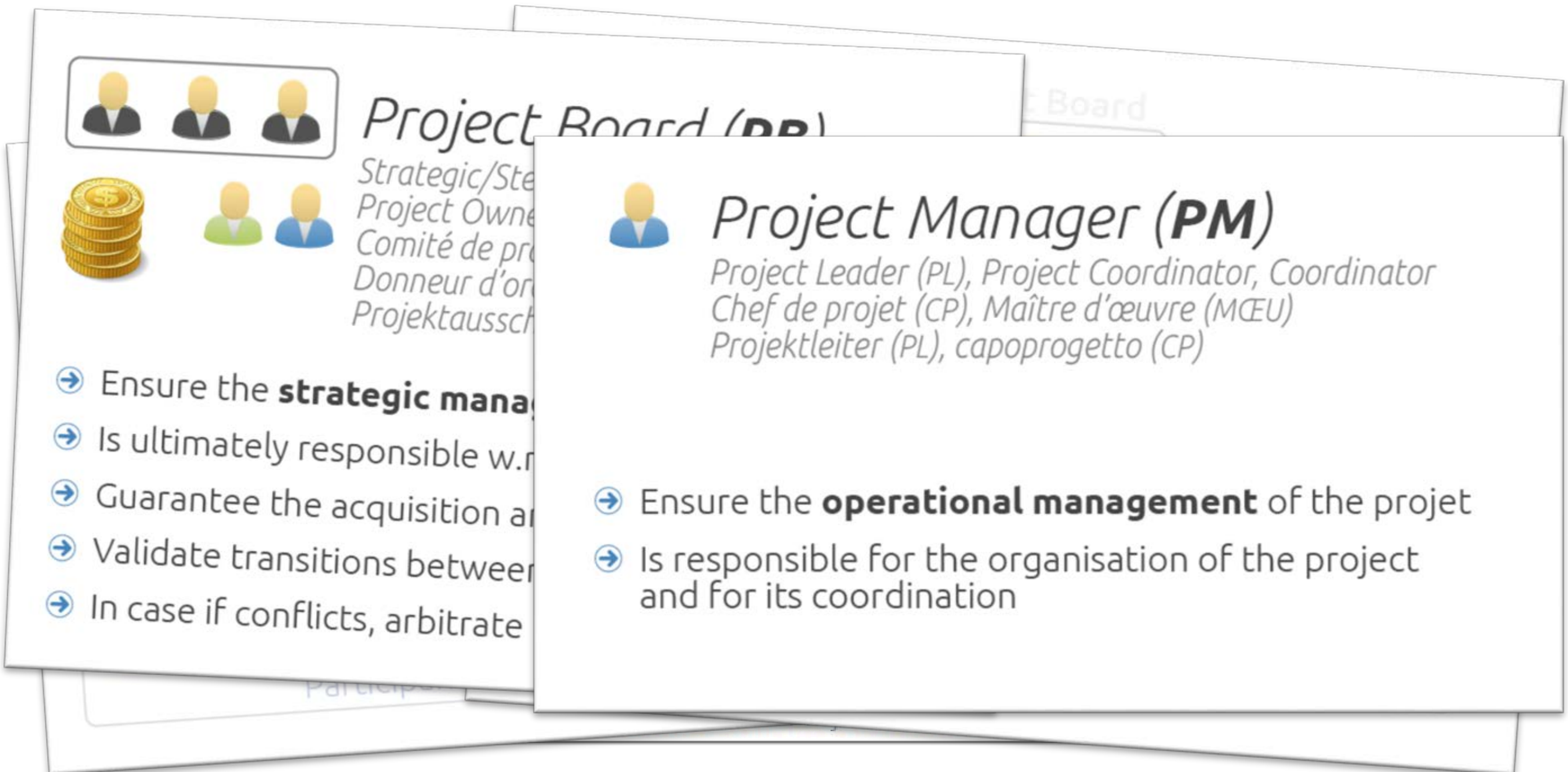
From one project to multi-projects: OPENSE



Courtesy: P. Bonnal

From one project to multi-projects: OPENSE

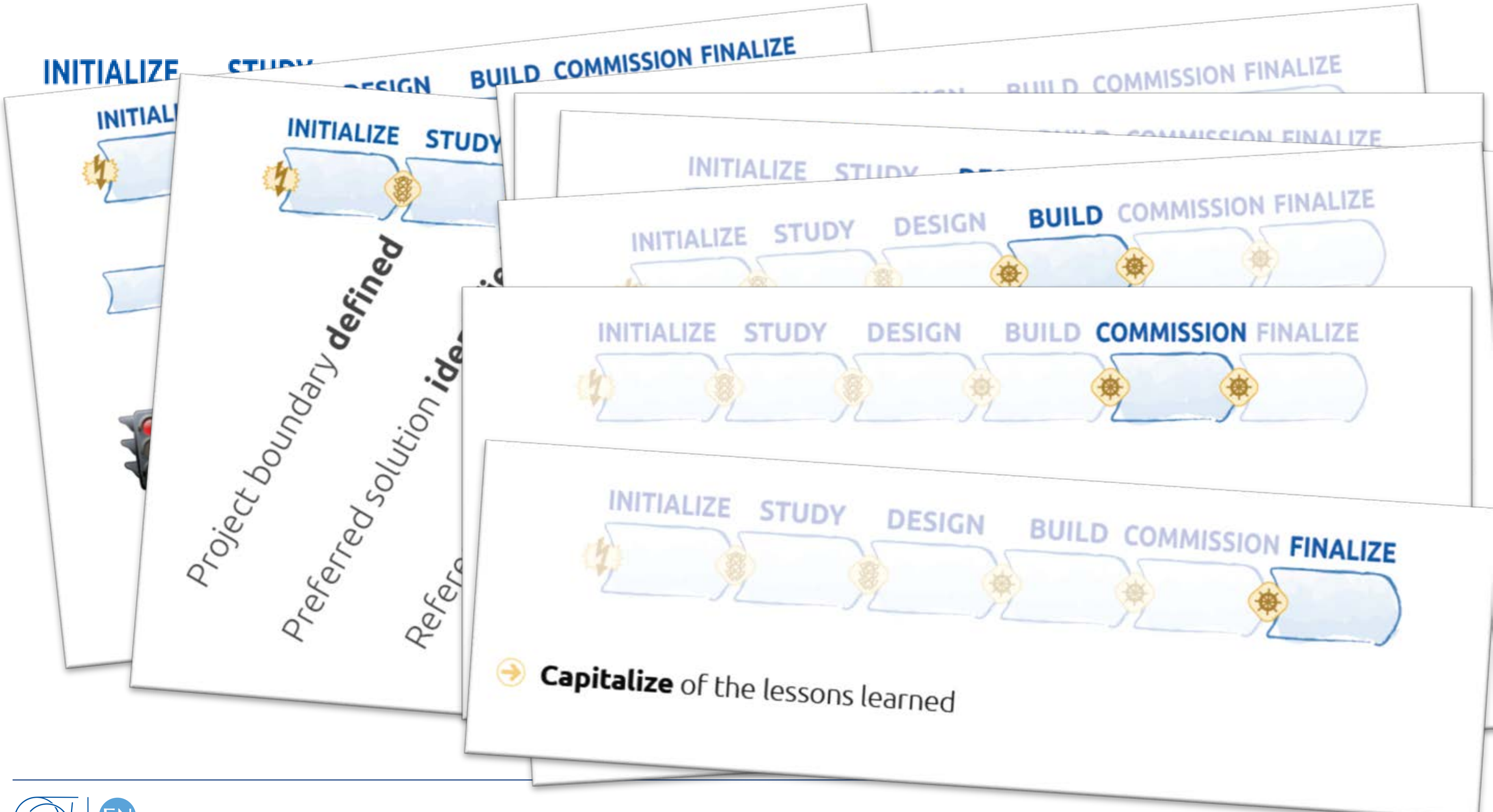
- Common understanding of roles and responsibilities



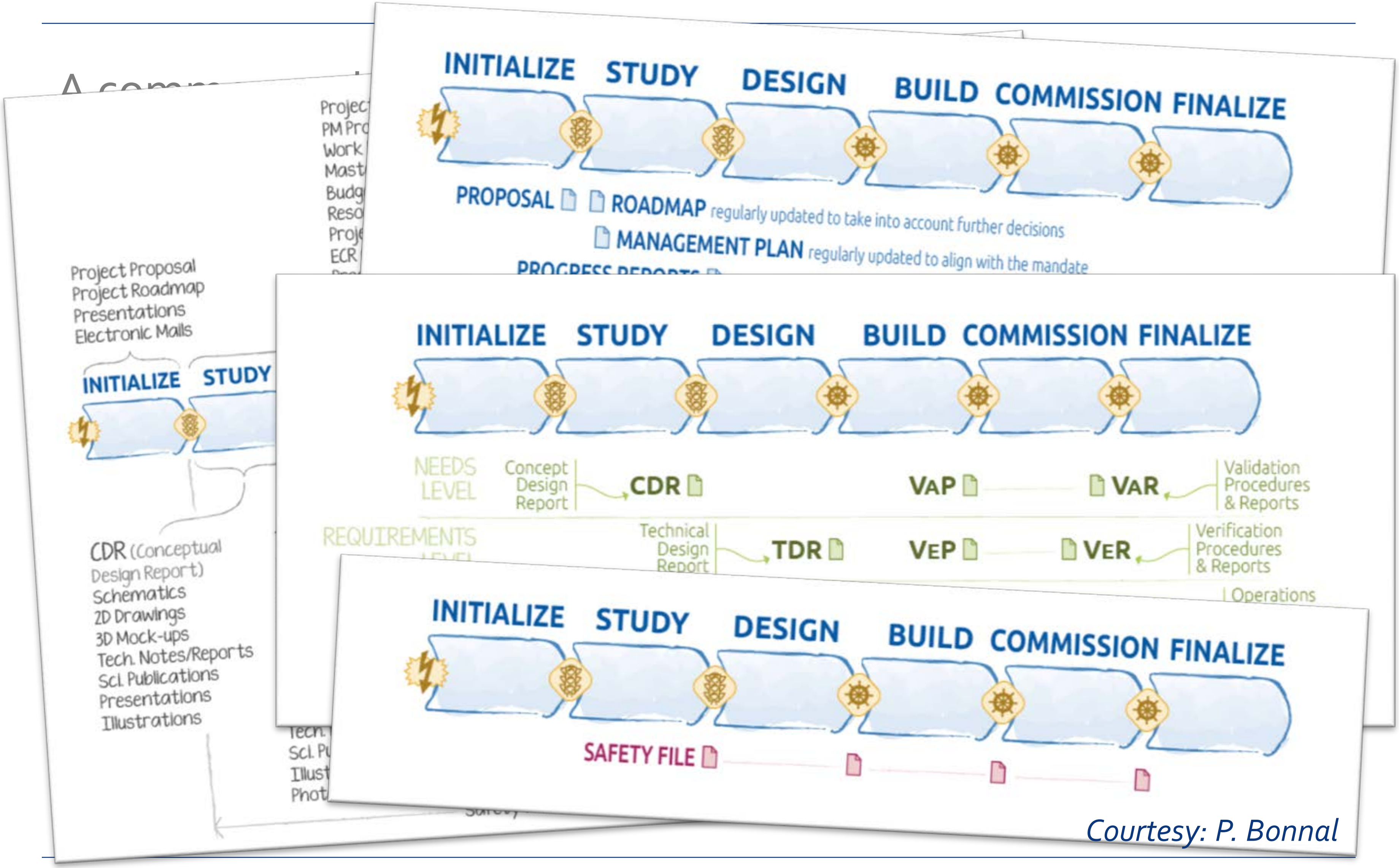
Courtesy: P. Bonnal

From one project to multi-projects: OPENSE

- Common understanding of a facility or system lifecycle



From one project to multi-projects: OPENSE



Courtesy: P. Bonnal

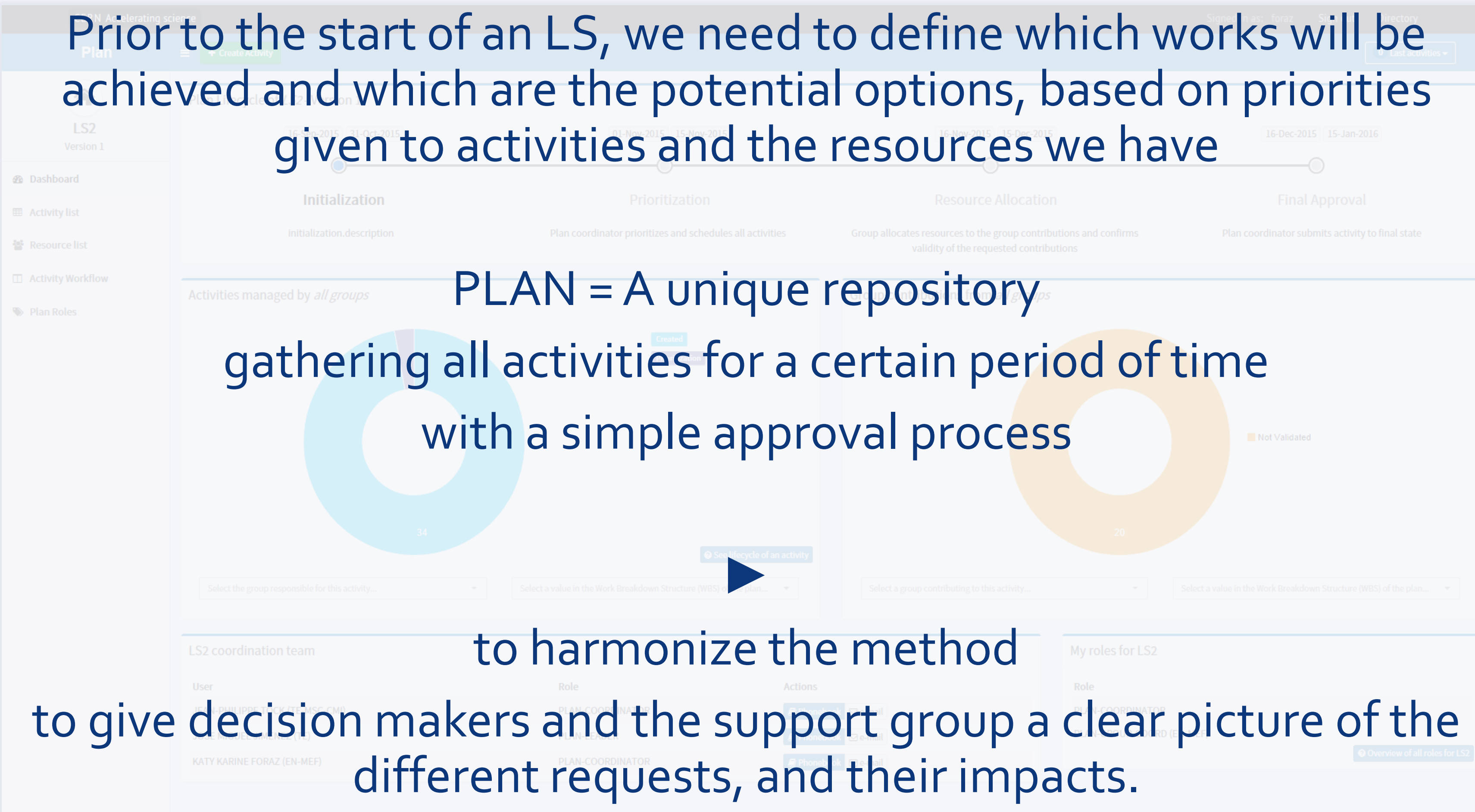
From one project to multi-projects

- Frame of a common methodology in place

- Project and management tools in place to manage each project
  - Project structure, regular reviews of technical aspects, cost & schedule
  - Layout db & configuration management
  - Earned Value Management
  - Activity Planning Tool ▶ short, medium and long term resource planning
  - Schedule & control of activities

- But preparing LS1, we faced to a tricky point:
  - Project engineers were assuming the support resources available
  - Small support requests were coming late
  - Support groups were struggling with the delicate balance between resources and workload

PLAN



Prior to the start of an LS, we need to define which works will be achieved and which are the potential options, based on priorities given to activities and the resources we have

PLAN = A unique repository

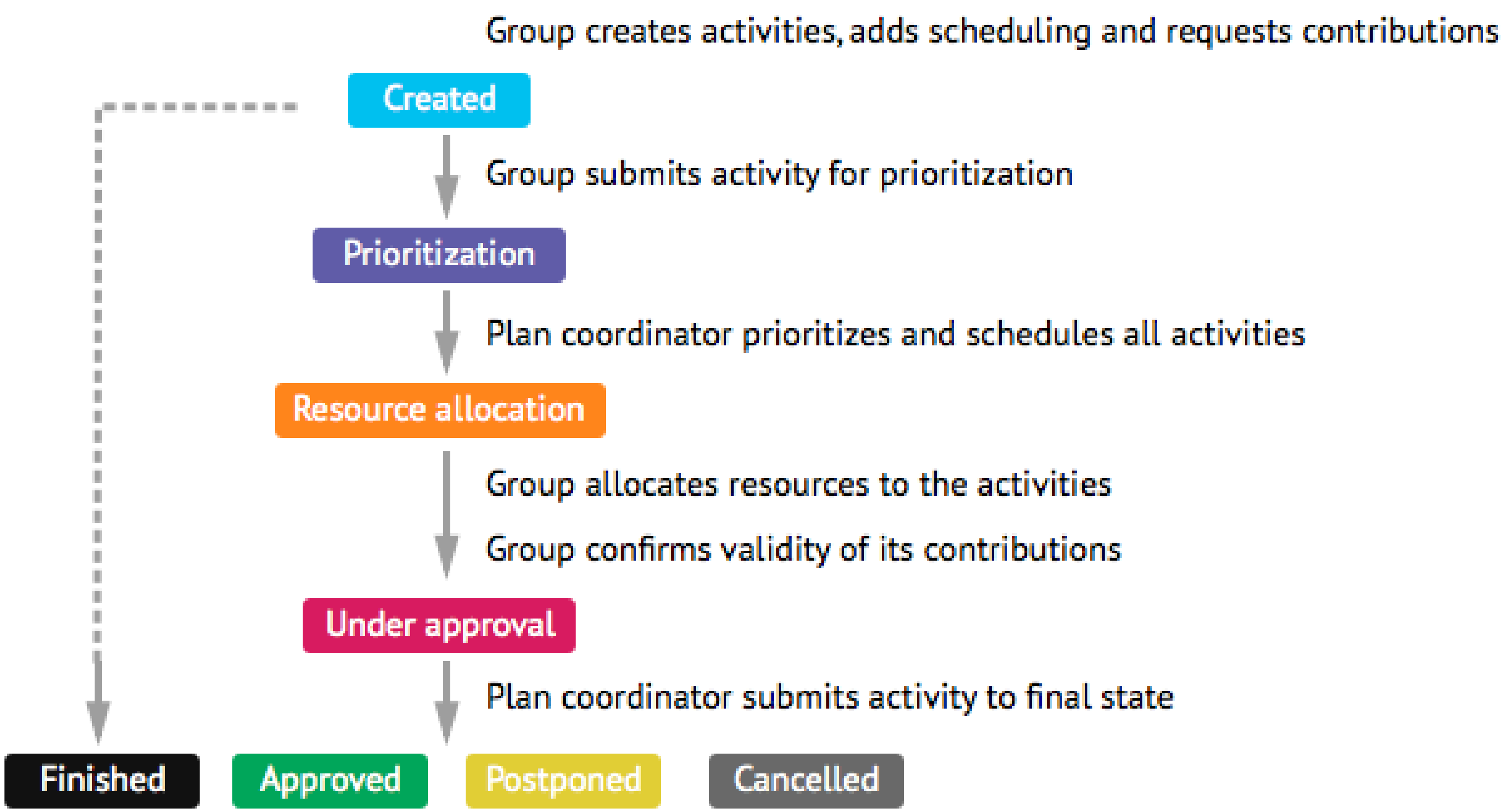
gathering all activities for a certain period of time

with a simple approval process

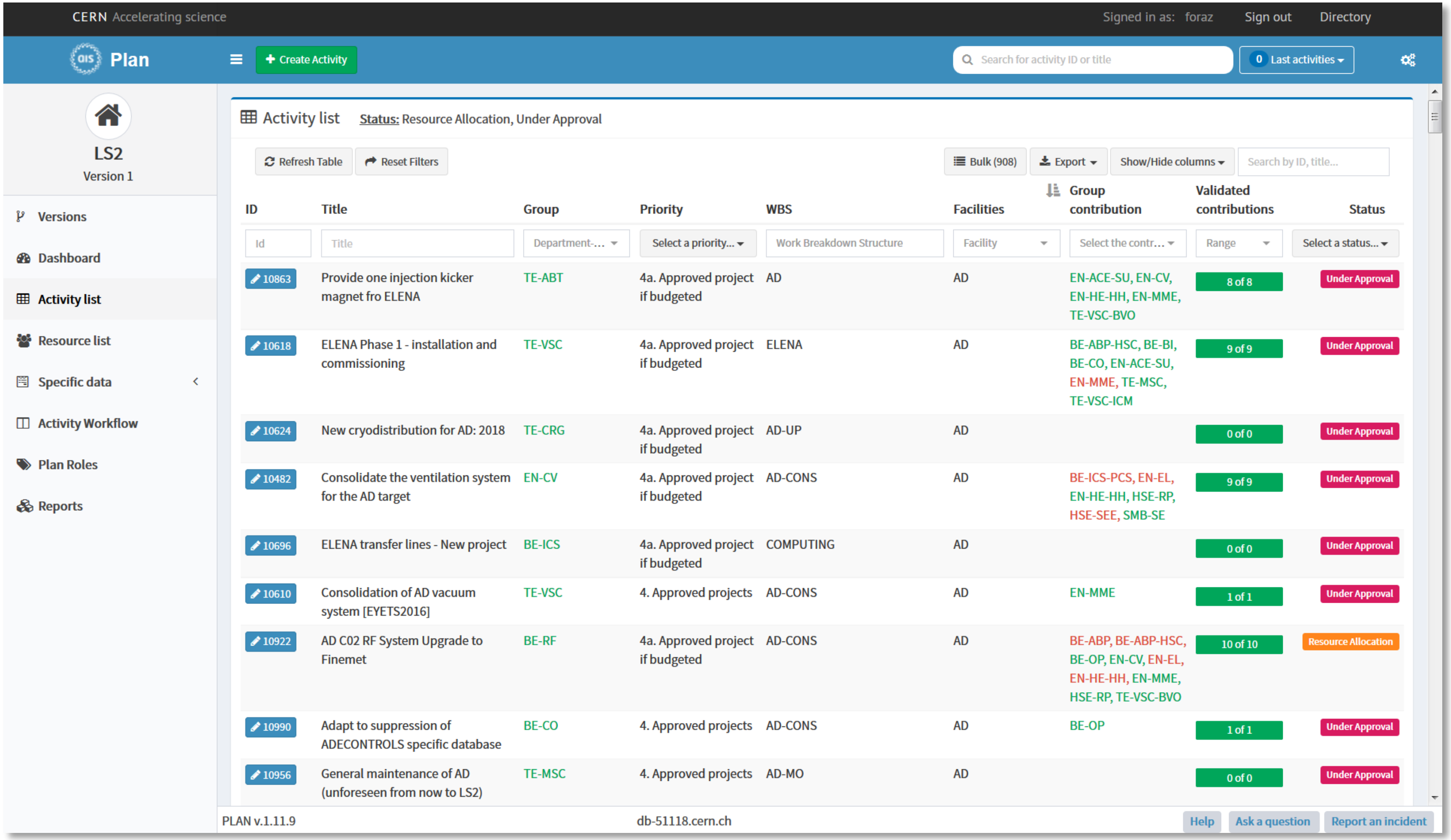
to harmonize the method

to give decision makers and the support group a clear picture of the different requests, and their impacts.

PLAN

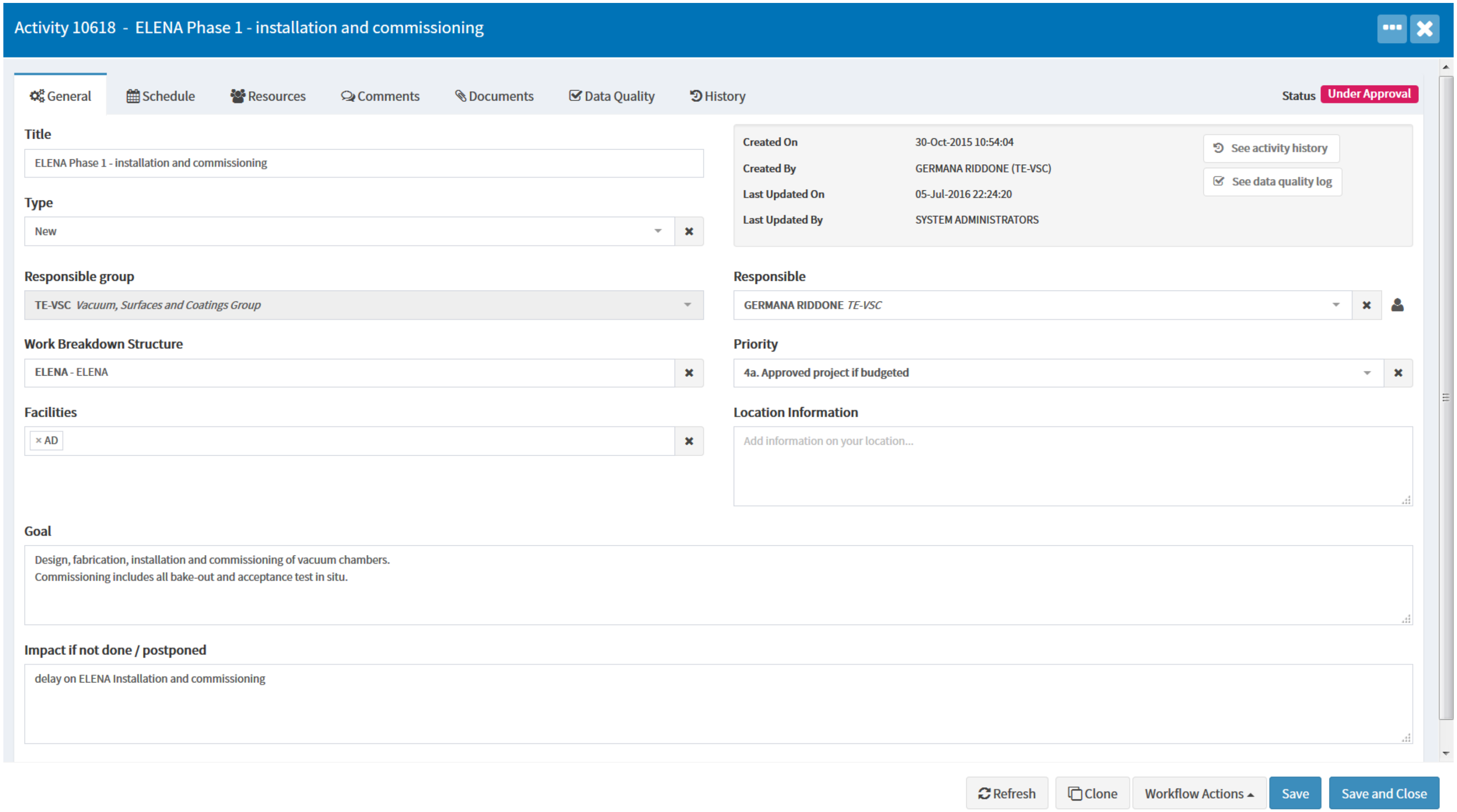

Group creates activities, adds scheduling and requests contributions
Created
Group submits activity for prioritization
Prioritization
Plan coordinator prioritizes and schedules all activities
Resource allocation
Group allocates resources to the activities
Group confirms validity of its contributions
Under approval
Plan coordinator submits activity to final state
Finished
Approved
Postponed
Cancelled

PLAN



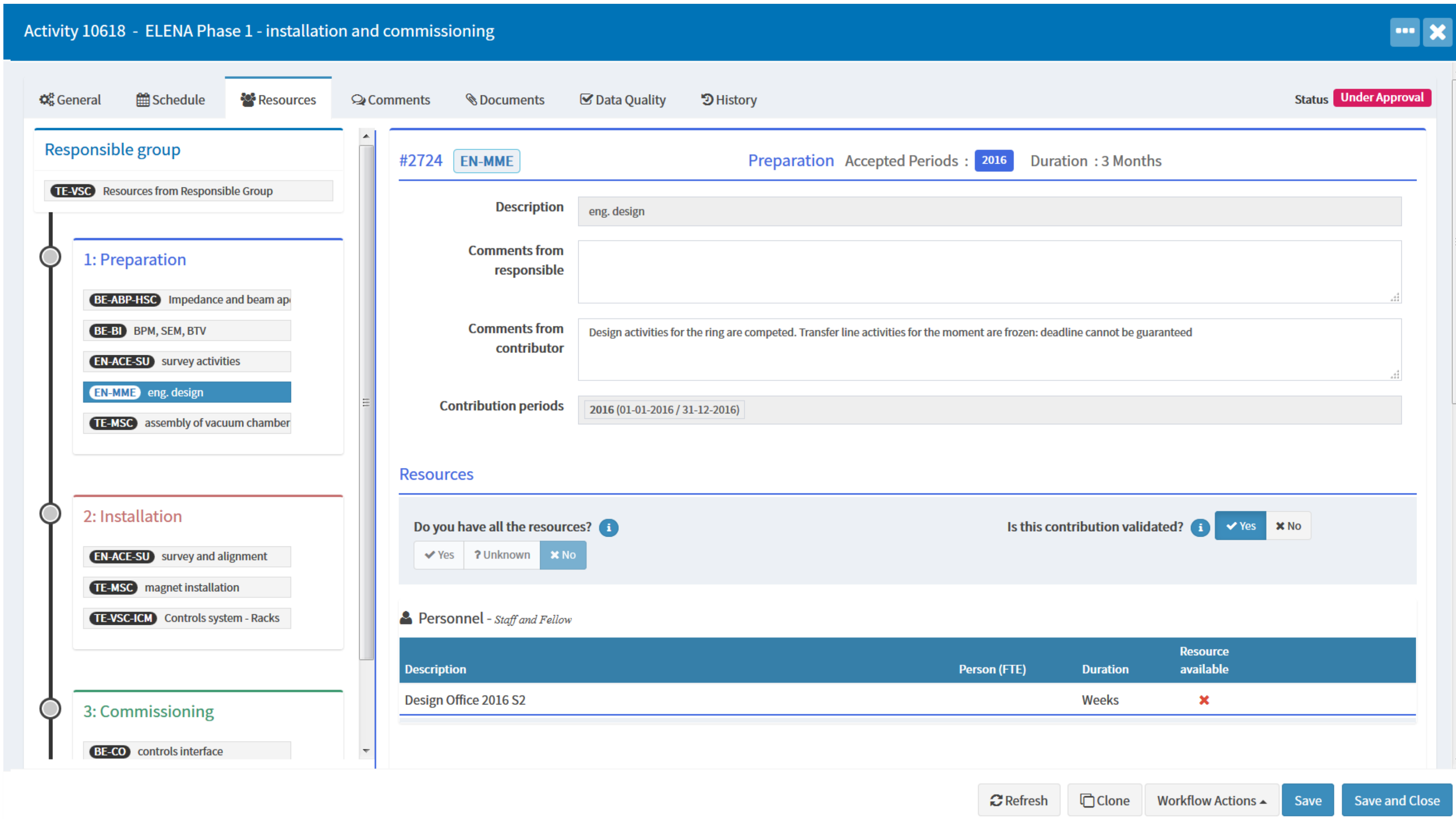
ID	Title	Group	Priority	WBS	Facilities	Group contribution	Validated contributions	Status
Id	Title	Department-...	Select a priority...	Work Breakdown Structure	Facility	Select the contr...	Range	Select a status...
10863	Provide one injection kicker magnet fro ELENA	TE-ABT	4a. Approved project if budgeted	AD	AD	EN-ACE-SU, EN-CV, EN-HE-HH, EN-MME, TE-VSC-BVO	8 of 8	Under Approval
10618	ELENA Phase 1 - installation and commissioning	TE-VSC	4a. Approved project if budgeted	ELENA	AD	BE-ABP-HSC, BE-BI, BE-CO, EN-ACE-SU, EN-MME, TE-MSC, TE-VSC-ICM	9 of 9	Under Approval
10624	New cryodistribution for AD: 2018	TE-CRG	4a. Approved project if budgeted	AD-UP	AD		0 of 0	Under Approval
10482	Consolidate the ventilation system for the AD target	EN-CV	4a. Approved project if budgeted	AD-CONS	AD	BE-ICS-PCS, EN-EL, EN-HE-HH, HSE-RP, HSE-SEE, SMB-SE	9 of 9	Under Approval
10696	ELENA transfer lines - New project	BE-ICS	4a. Approved project if budgeted	COMPUTING	AD		0 of 0	Under Approval
10610	Consolidation of AD vacuum system [EYETS2016]	TE-VSC	4. Approved projects	AD-CONS	AD	EN-MME	1 of 1	Under Approval
10922	AD C02 RF System Upgrade to Finemet	BE-RF	4a. Approved project if budgeted	AD-CONS	AD	BE-ABP, BE-ABP-HSC, BE-OP, EN-CV, EN-EL, EN-HE-HH, EN-MME, HSE-RP, TE-VSC-BVO	10 of 10	Resource Allocation
10990	Adapt to suppression of ADECONTROLS specific database	BE-CO	4. Approved projects	AD-CONS	AD	BE-OP	1 of 1	Under Approval
10956	General maintenance of AD (unforeseen from now to LS2)	TE-MSC	4. Approved projects	AD-MO	AD		0 of 0	Under Approval

PLAN



Activity 10618 - ELENA Phase 1 - installation and commissioning
General
Schedule
Resources
Comments
Documents
Data Quality
History
Status Under Approval
Title
ELENA Phase 1 - installation and commissioning
Type
New
Created On 30-Oct-2015 10:54:04
Created By GERMANA RIDDONE (TE-VSC)
Last Updated On 05-Jul-2016 22:24:20
Last Updated By SYSTEM ADMINISTRATORS
See activity history
See data quality log
Responsible group
TE-VSC Vacuum, Surfaces and Coatings Group
Responsible
GERMANA RIDDONE TE-VSC
Work Breakdown Structure
ELENA - ELENA
Priority
4a. Approved project if budgeted
Facilities
× AD
Location Information
Add information on your location...
Goal
Design, fabrication, installation and commissioning of vacuum chambers.
Commissioning includes all bake-out and acceptance test in situ.
Impact if not done / postponed
delay on ELENA Installation and commissioning
Refresh
Clone
Workflow Actions
Save
Save and Close

PLAN



Activity 10618 - ELENA Phase 1 - installation and commissioning
General
Schedule
Resources
Comments
Documents
Data Quality
History
Status
Under Approval
Responsible group
TE-VSC Resources from Responsible Group
1: Preparation
BE-ABP-HSC Impedance and beam ap
BE-BI BPM, SEM, BTV
EN-ACE-SU survey activities
EN-MME eng. design
TE-MSC assembly of vacuum chamber
2: Installation
EN-ACE-SU survey and alignment
TE-MSC magnet installation
TE-VSC-ICM Controls system - Racks
3: Commissioning
BE-CO controls interface
#2724 EN-MME
Preparation Accepted Periods : 2016 Duration : 3 Months
Description
eng. design
Comments from responsible
Comments from contributor
Design activities for the ring are competed. Transfer line activities for the moment are frozen: deadline cannot be guaranteed
Contribution periods
2016 (01-01-2016 / 31-12-2016)
Resources
Do you have all the resources?
Yes
? Unknown
No
Is this contribution validated?
Yes
No
Personnel - Staff and Fellow
Description
Person (FTE)
Duration
Resource available
Design Office 2016 S2
Weeks
Refresh
Clone
Workflow Actions
Save
Save and Close