Technical coordination of Machines at CERN

Marzia Bernardini *on behalf of Katy Foraz*
Accelerator Coordination and Engineering Group

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
- LHC today
  - Change management
  - Long shutdown 2
- Conclusions

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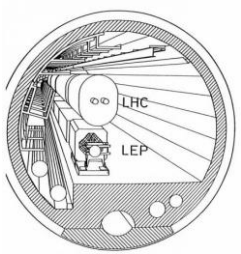
The LHC Project timeline

84: First studies of the LHC project



94: Approval of the project by the CERN Council

98: DUP & Start of civil engineering

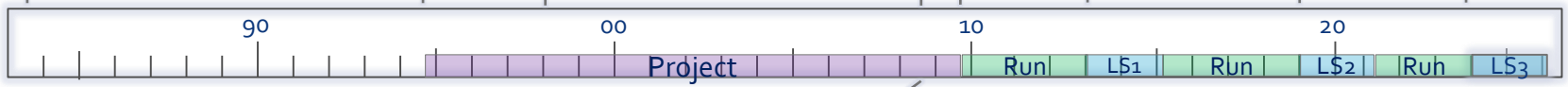
08: 1st beam

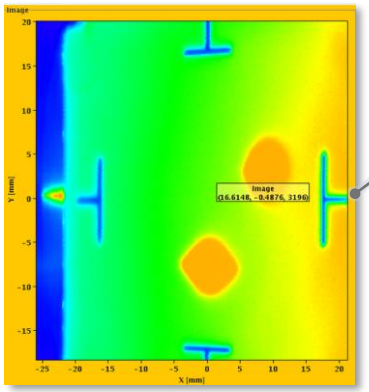
09: Start of Physics

13-14: Long shutdown 1

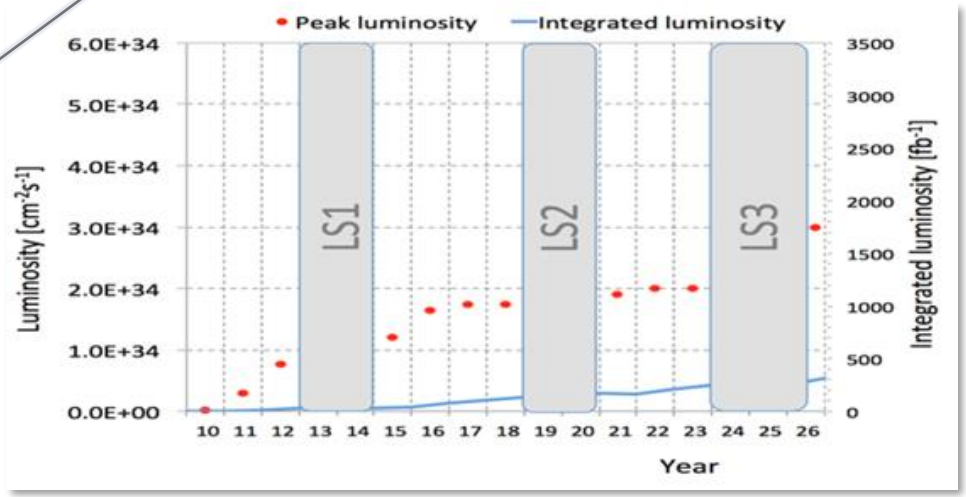
19-20 : Long shutdown 2

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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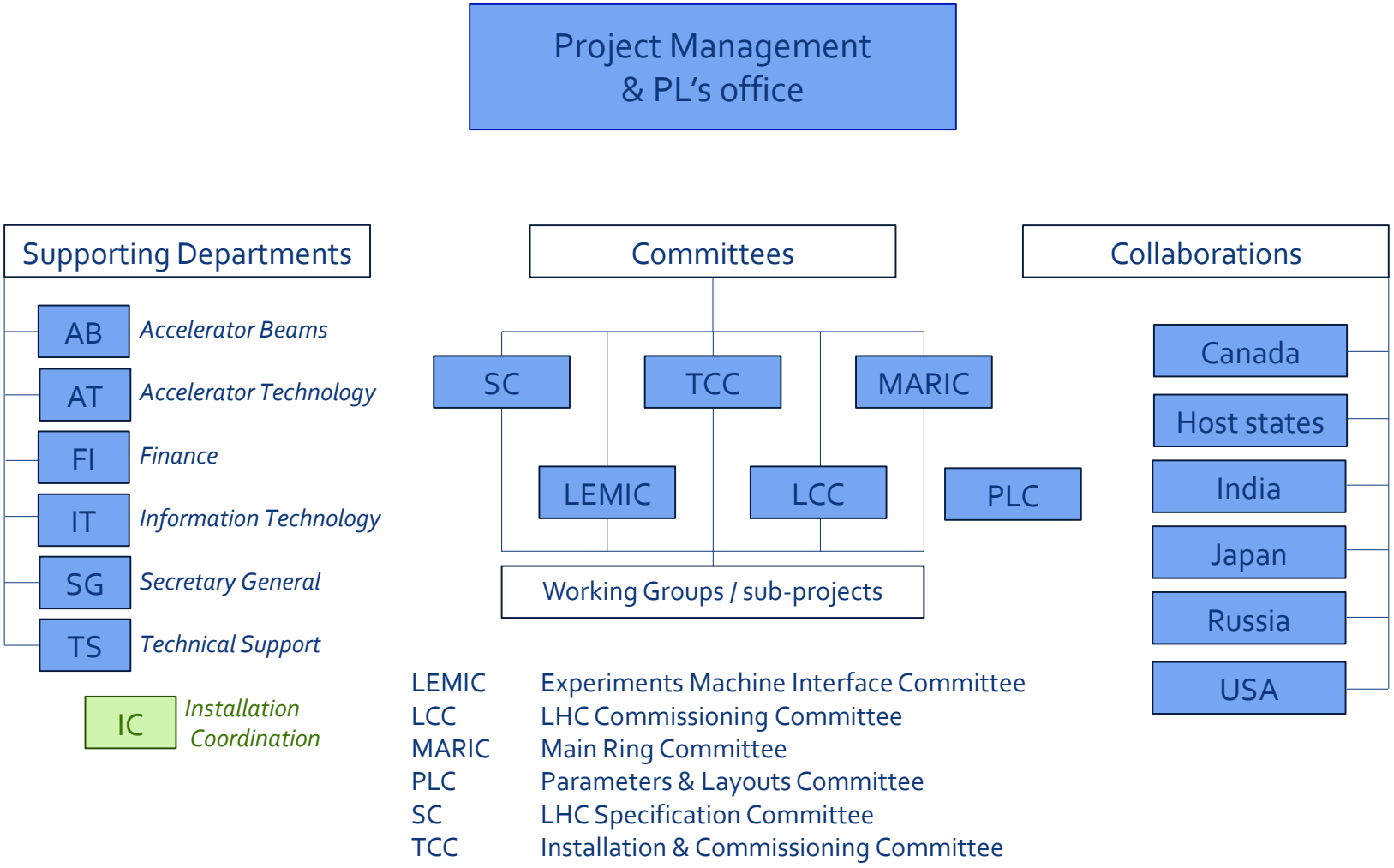
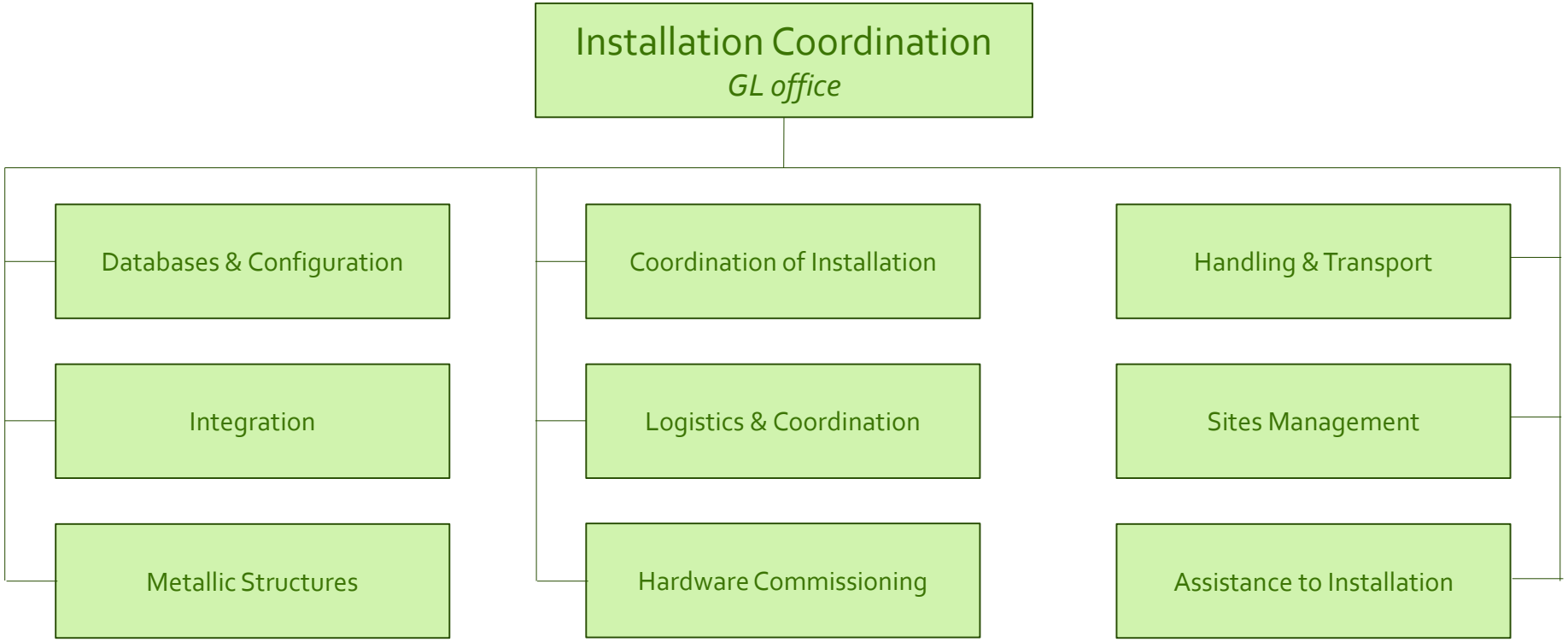
LHC Project Organization (2004)



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

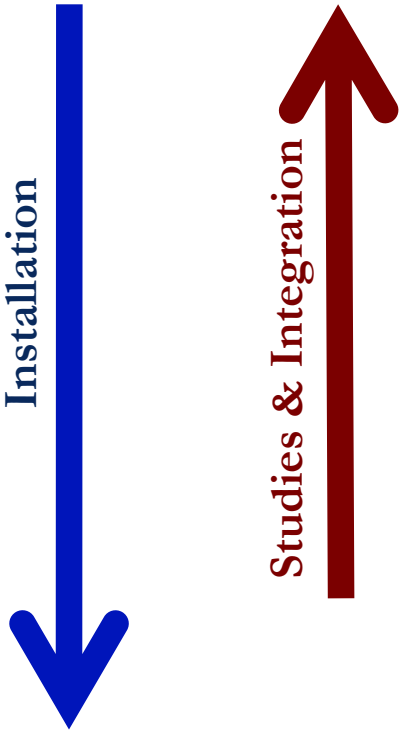
IC group organization



LHC installation history

8 sectors considered as 8 machines

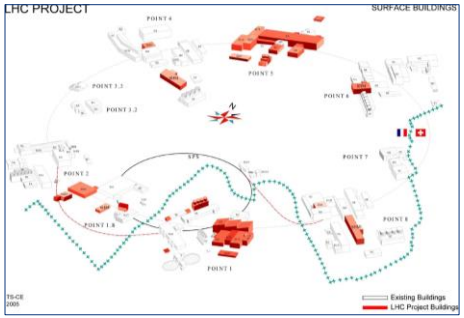
- Civil engineering and LEP dismantling
- General Services
- Cryogenics
- Machine
- Hardware Commissioning

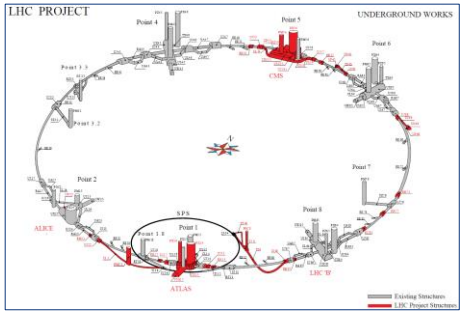


Civil Engineering phase

- 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 hour-week law in France
      - ➢ Impact on resources and schedule

    ➢ Long discussions leading to the introduction of a fixed cost mechanism

  - From the Coordination side
    - Dust
    - Endless end !

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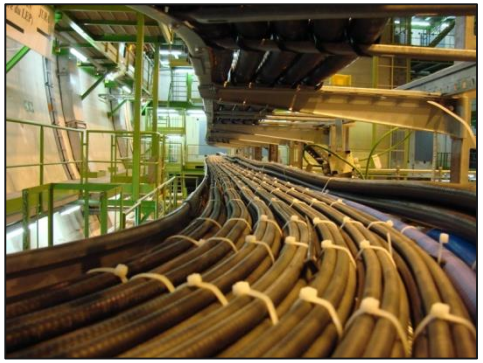
General Services installation

- 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 users
    - Availability of cables (another contract)
  - On the Coordination side
    - Lots of delays
    - Non-Conformities at the end of the works

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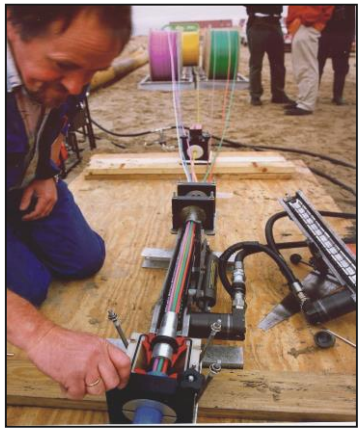
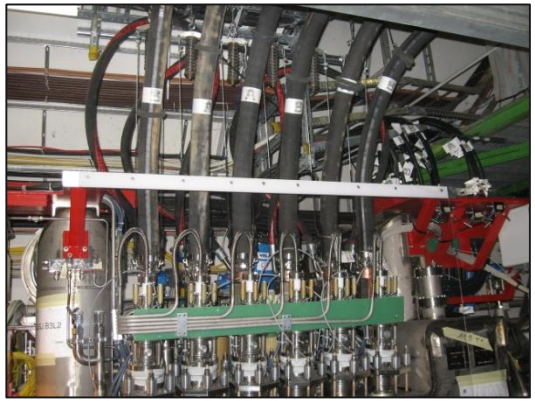
General Services installation

- 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



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General Services installation

- Cooling & Ventilation
  - 160km primary cooling pipes & ~8km of flexibles
    - Cooling and Ventilation systems
      - 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)
      - Size of the supporting devices for the lines
      - Installation drawing not verified by the 3D integration team

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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

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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
  - Underground transport of cryo-magnets in // with other worksites
- 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

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

Cryo-magnet transport

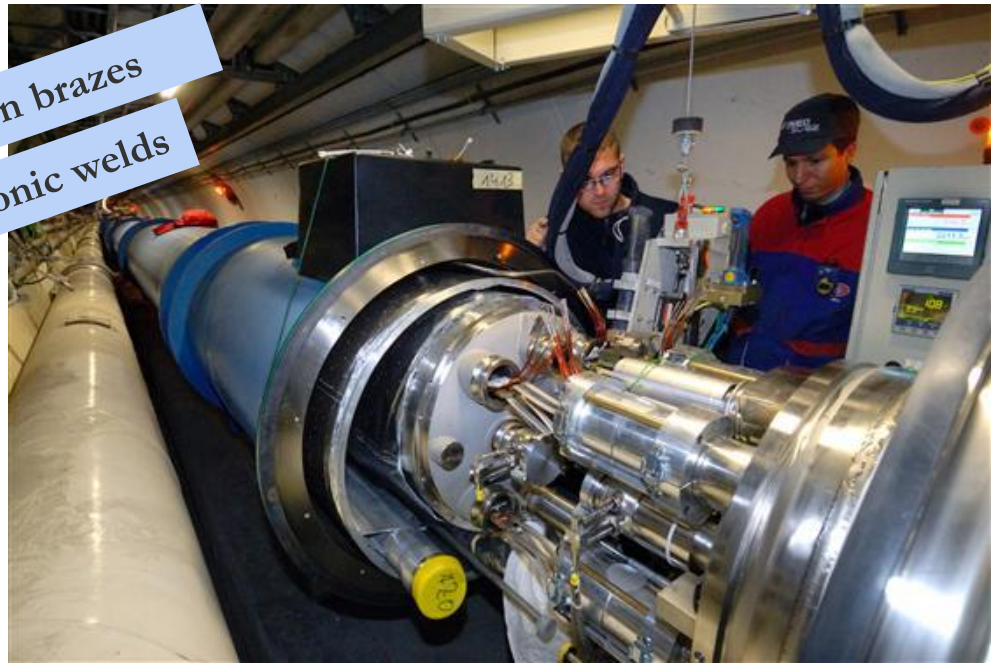
- 95% of the total number of cryo-magnets lowered down through one single pit
  - Weight (34t) / load capacity of the crane
  - Dimensions: length ~17m
- More than 1'700 cryo-magnets transported at a speed of 3km/h max
- Huge scheduling constraint
- Main problems encountered
  - Crossing other worksites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

Cryo-magnet interconnections

- 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

10’000 induction brazes

60’000 ultrasonic welds



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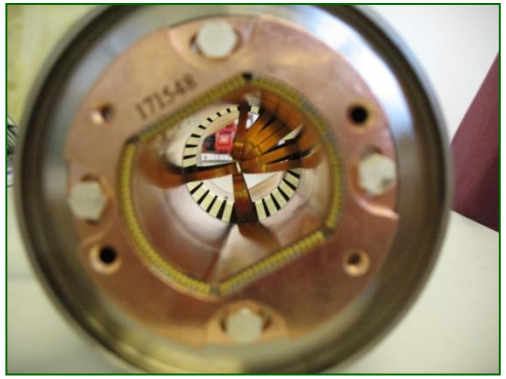
Cryo-magnet interconnections

- 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



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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

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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)

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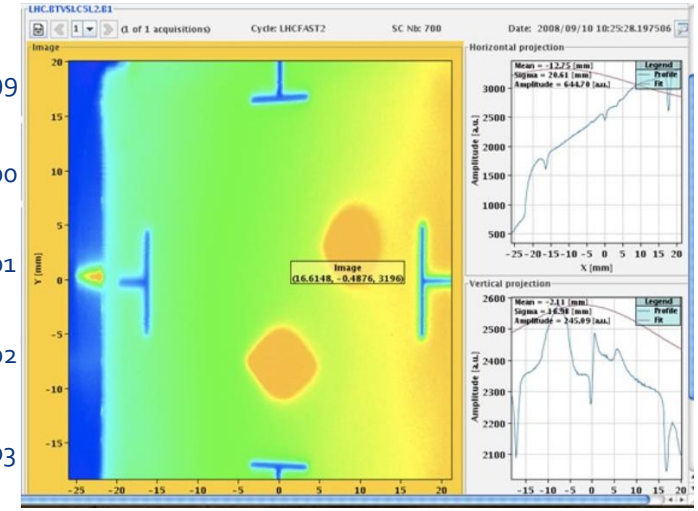
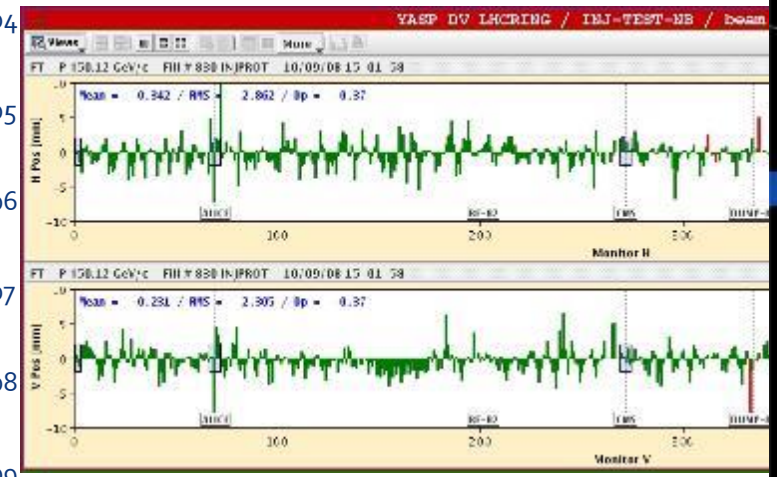
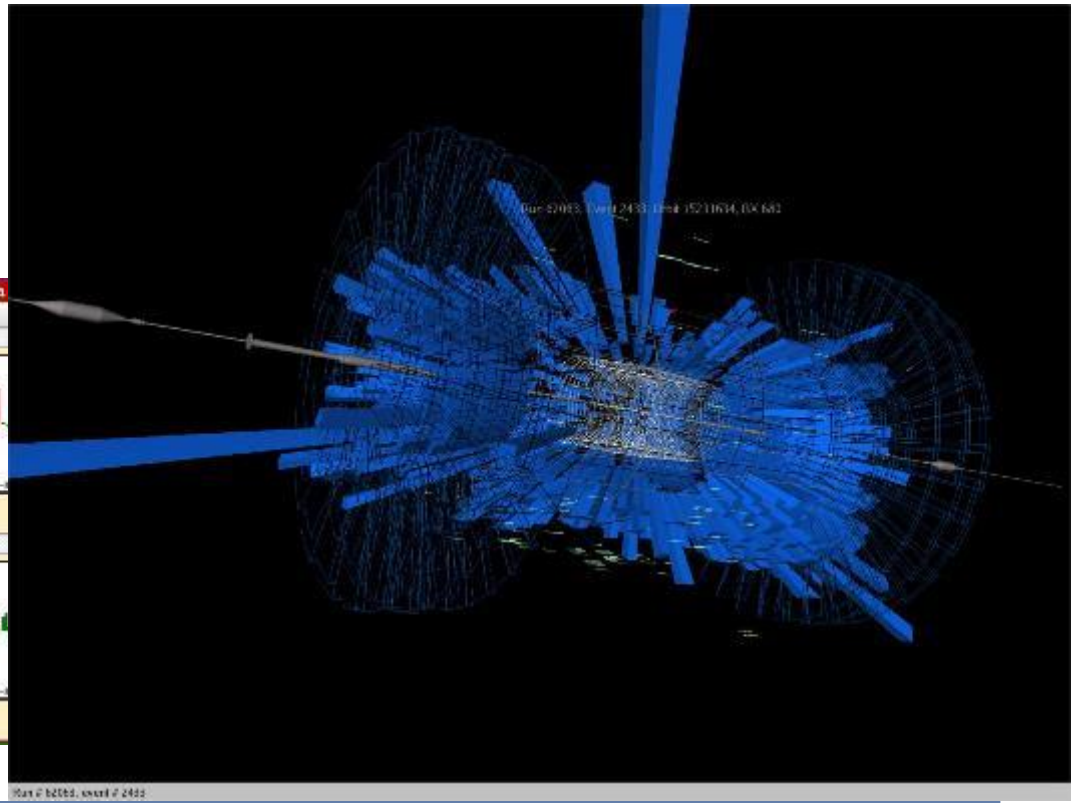
2008, September 10th





First beams

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



2008 incident

- 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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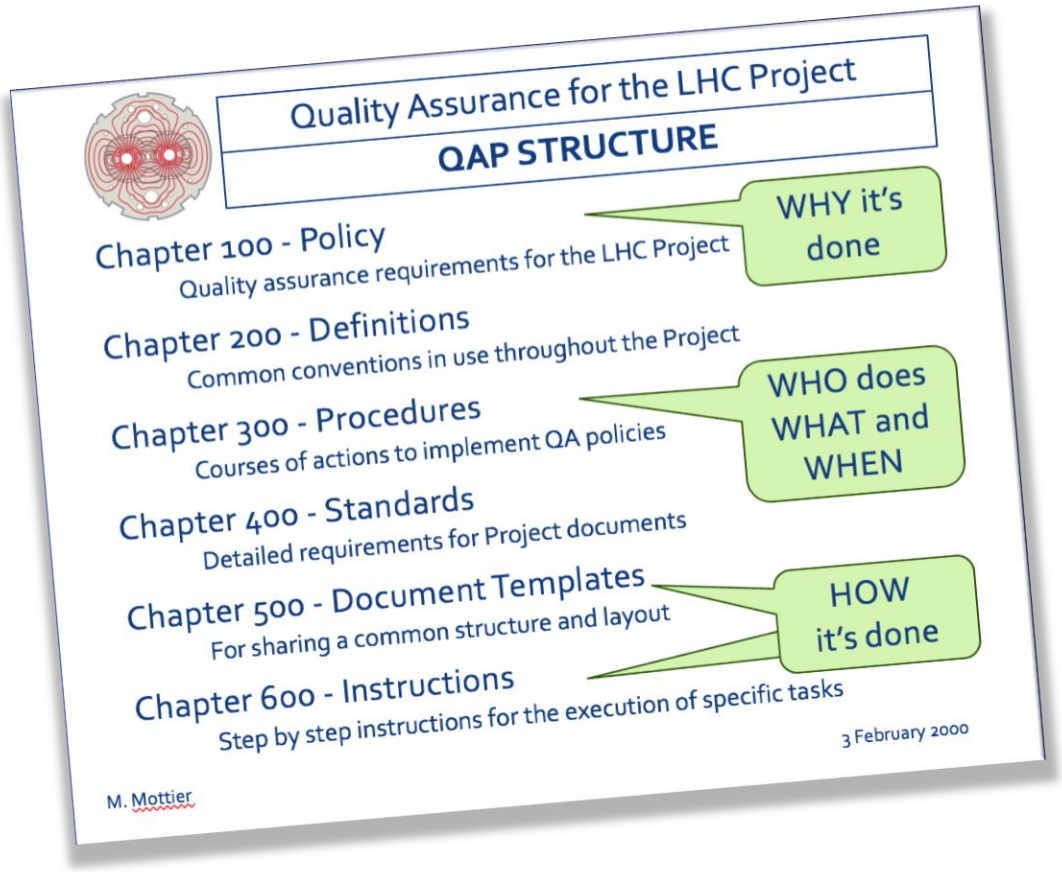
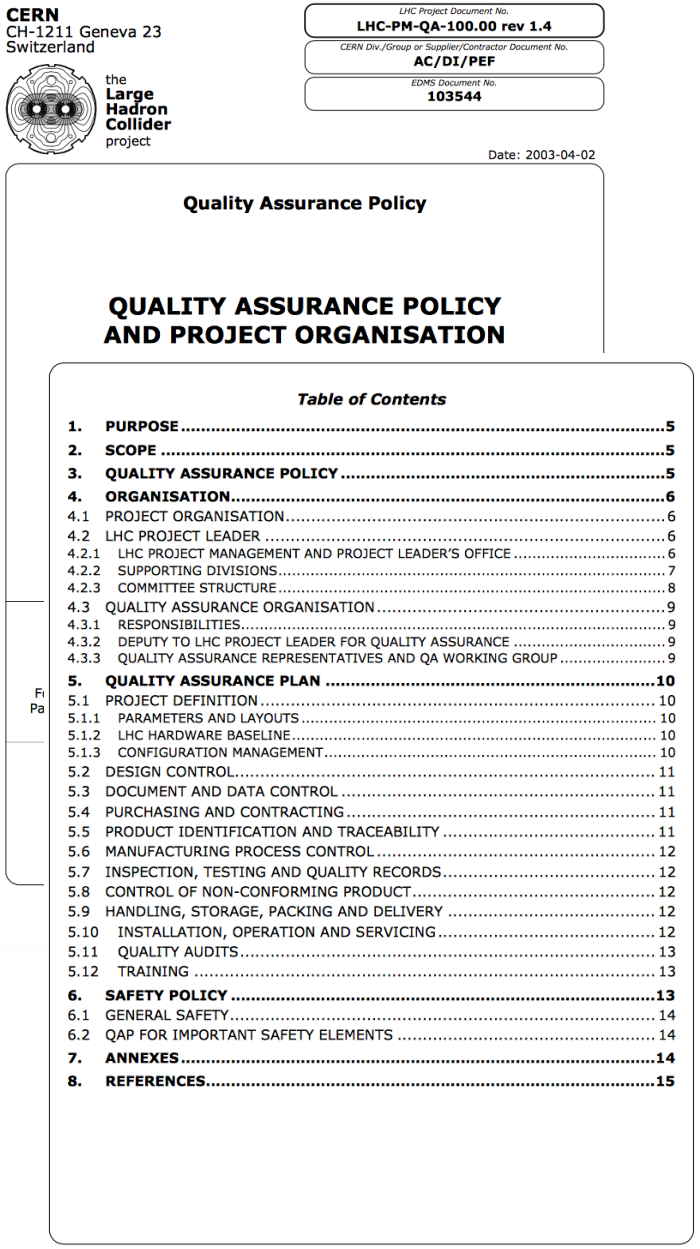
Methodology (1/3)

- 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

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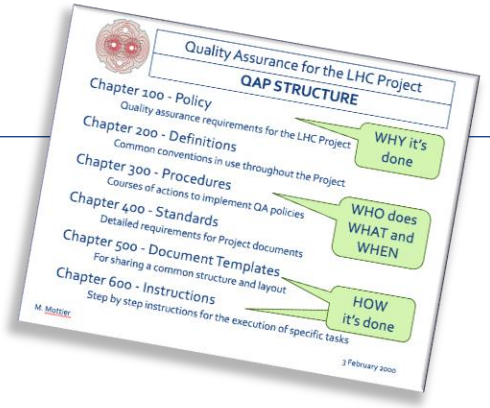
'I say what I'll do and I do what I said'

Methodology (1/3)

- Quality Assurance Plan

  Covers documentation and processes over the lifecycle

  to ensure that all stakeholders are
  using the same processes



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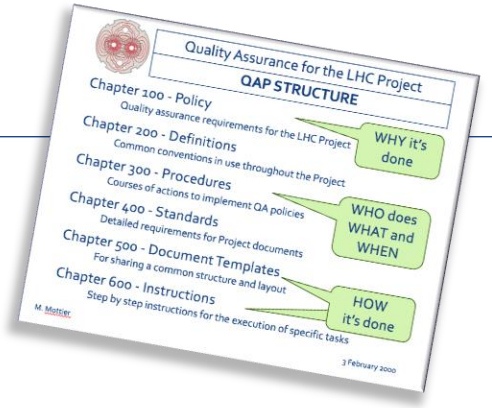

- Quality Assurance Plan

  Covers documentation and processes over the lifecycle

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- Configuration Management & 3D Integration

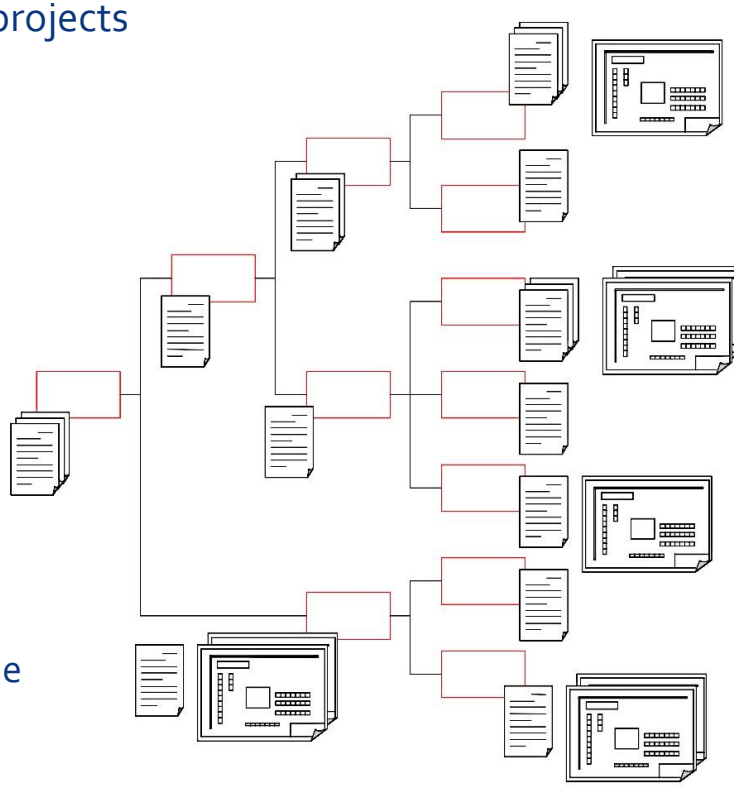
what | Hardware Baseline (aka Product Breakdown Structure)

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



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

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>

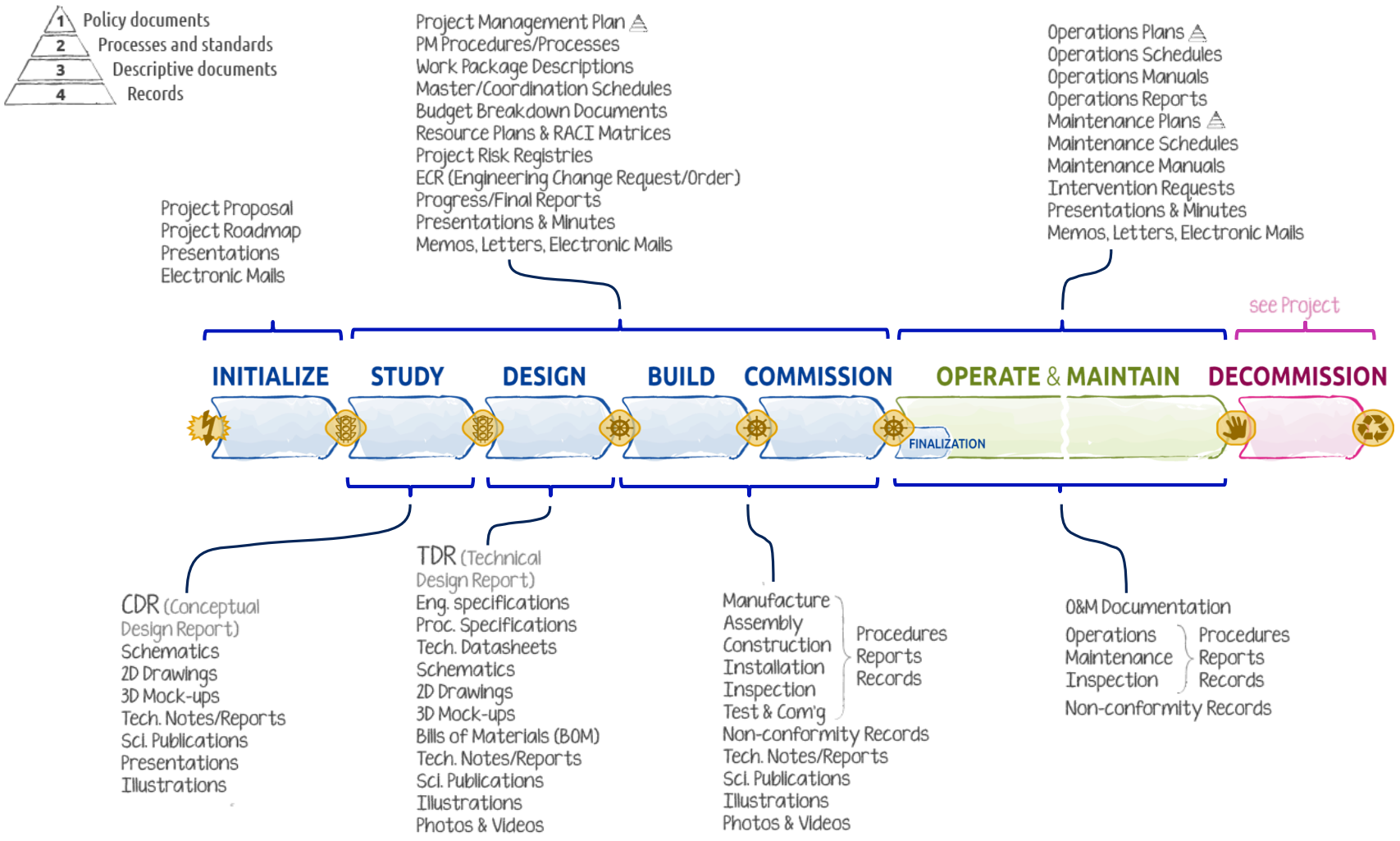
- systems
- sub-systems
- main type units to be manufactured

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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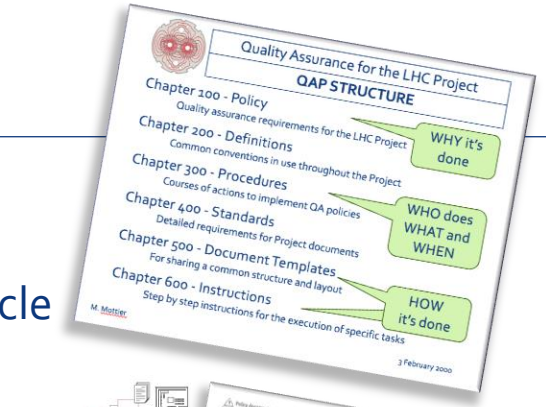
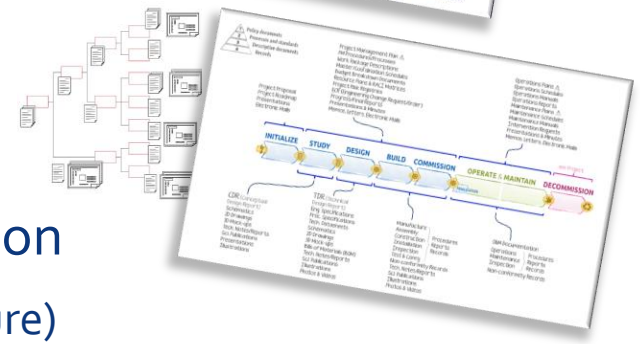
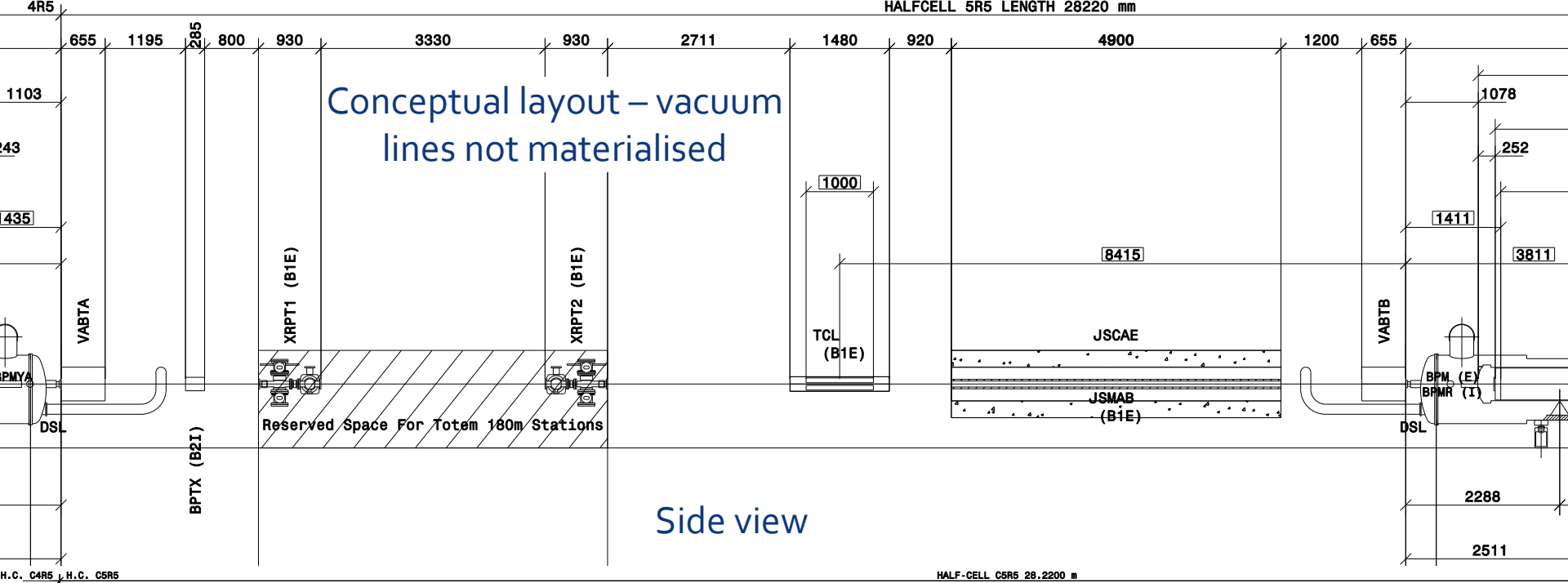
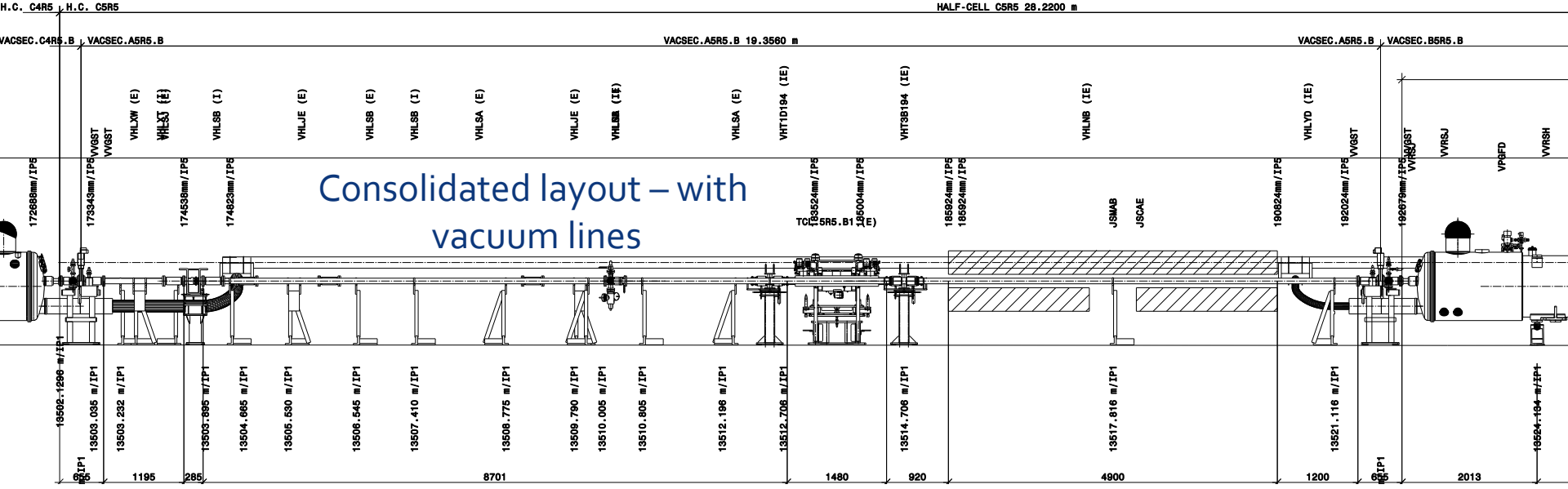




- Configuration Management & 3D Integration

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

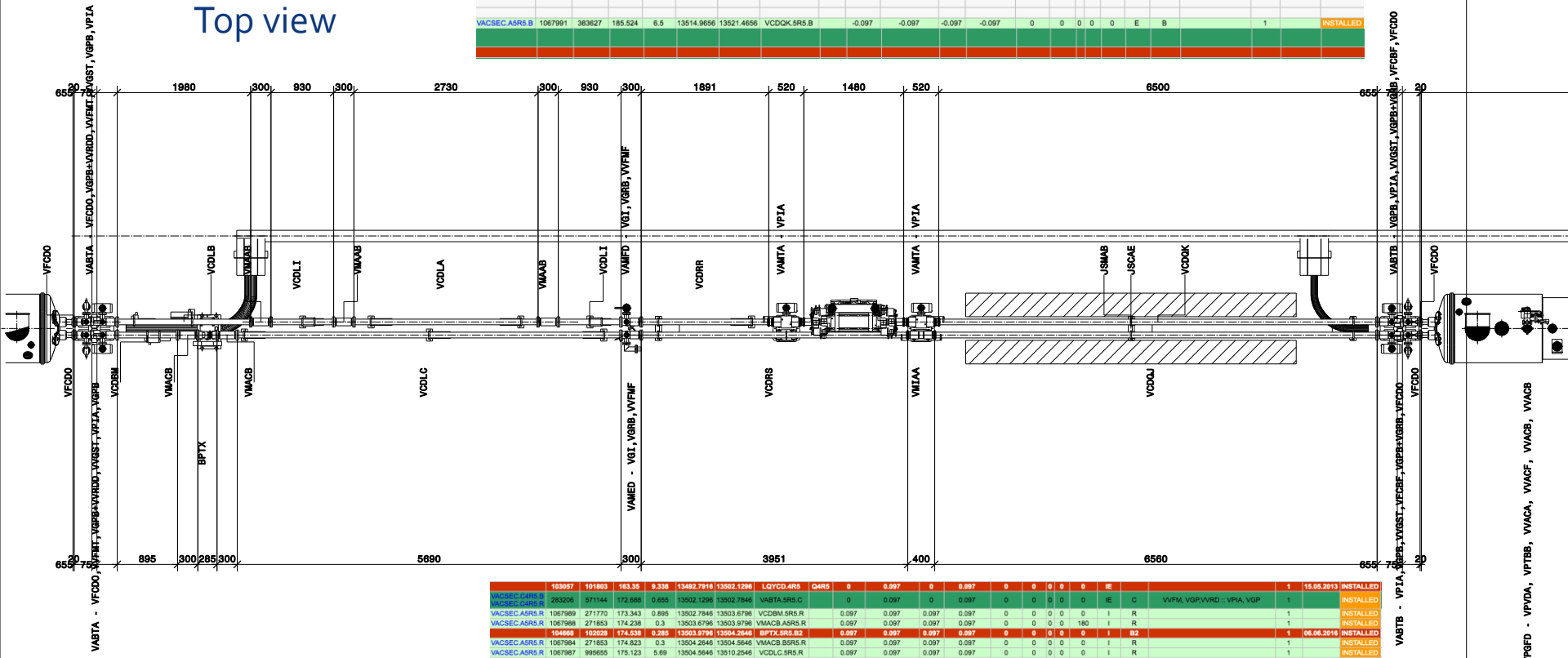

HALFCELL 5R5 LENGTH 28220 mm
Conceptual layout – vacuum lines not materialised
Side view
VABTA
XRPT1 (B1E)
XRPT2 (B1E)
TCL (B1E)
JSCAE
JSMAB (B1E)
VABTB
DSL
BPTX (B2I)
Reserved Space For Totem 180m Stations
BPM (E)
BPMR (I)
H.C. C4R5
H.C. C5R5
HALF-CELL C5R5 28.2200 m


Consolidated layout – with vacuum lines
VACSEC.C4R5.B
VACSEC.A5R5.B
VACSEC.A5R5.B 19.3560 m
VACSEC.B5R5.B
VHLXW (E)
VHLJE (E)
VHLSB (E)
VHLSB (I)
VHLSA (E)
VHLJE (E)
VHLSA (E)
VHT1D194 (IE)
VHT3B194 (IE)
VHLMB (IE)
VHLYD (IE)
VVGST
VRSJ
VPGFD
VVRSH
JSMAB
JSCAE
TCL.5R5.B1 (IE)

Sequence of functional positions on the external beam

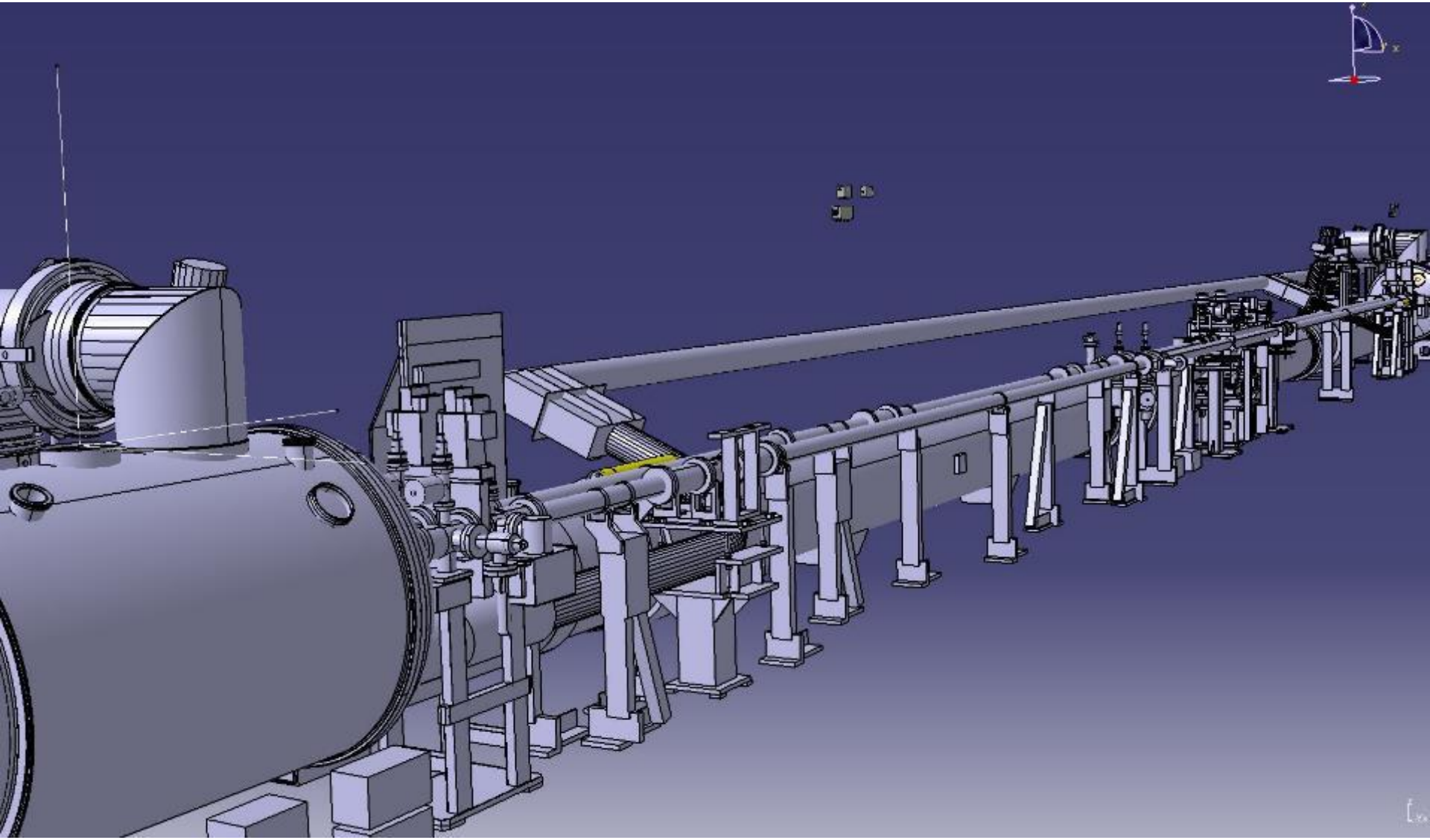
VACSEC.A5R5.B	1067990	995641	173.343	1.98	13502.7846	13504.7646	VCDLB.5R5.B		-0.097	-0.097	-0.097	-0.097	0	0	0	0	E	B		1		INSTALLED
VACSEC.A5R5.B	1068002	271848	175.323	0.3	13504.7646	13505.0646	VMAAB.A5R5.B		-0.097	-0.097	-0.097	-0.097	0	0	0	0	E	B		1		INSTALLED
VACSEC.A5R5.B	1068001	998042	175.623	0.93	13505.0646	13505.9946	VCDLI.A5R5.B		-0.097	-0.097	-0.097	-0.097	0	0	0	0	E	B		1		INSTALLED
VACSEC.A5R5.B	1068000	271848	176.553	0.3	13505.9946	13506.2946	VMAAB.B5R5.B		-0.097	-0.097	-0.097	-0.097	0	0	0	0	E	B		1		INSTALLED
VACSEC.A5R5.B	1067999	995607	176.853	2.73	13506.2946	13509.0246	VCDLA.5R5.B		-0.097	-0.097	-0.097	-0.097	0	0	0	0	E	B		1		INSTALLED
VACSEC.A5R5.B	1067998	271848	179.583	0.3	13509.0246	13509.3246	VMAAB.C5R5.B		-0.097	-0.097	-0.097	-0.097	0	0	0	0	E	B		1		INSTALLED
VACSEC.A5R5.B	1067997	998042	179.883	0.93	13509.3246	13510.2546	VCDLI.B5R5.B		-0.097	-0.097	-0.097	-0.097	0	0	0	0	E	B		1		INSTALLED
VACSEC.A5R5.B	1067996	606710	180.813	0.3	13510.2546	13510.5546	VAMFD.5R5.B		-0.097	-0.097	-0.097	-0.097	0	0	0	0	E	B	-,VGR,VGI,VVFM	1		INSTALLED
VACSEC.A5R5.B	1067992	998576	181.113	1.891	13510.5546	13512.4456	VCDRR.5R5.B		-0.097	-0.097	-0.097	-0.097	0	0	0	180	E	B		1		INSTALLED
VACSEC.A5R5.B	1067995	606728	183.004	0.52	13512.4456	13512.9656	VAMTA.A5R5.B		-0.097	-0.097	-0.097	-0.097	0	0	0	180	E	B	VPIA	1		INSTALLED
	103059	101837	183.524	1.48	13512.9656	13514.4456	TCL.5R5.B1		-0.097	-0.097	-0.097	-0.097	0	0	0	0	E	B1		1	06.06.2016	INSTALLED
VACSEC.A5R5.B	1067993	606728	185.004	0.52	13514.4456	13514.9656	VAMTA.B5R5.B		-0.097	-0.097	-0.097	-0.097	0	0	0	180	E	B	VPIA	1		INSTALLED
VACSEC.A5R5.B	1067991	383627	185.524	6.5	13514.9656	13521.4656	VCDQK.5R5.B		-0.097	-0.097	-0.097	-0.097	0	0	0	0	E	B		1		INSTALLED

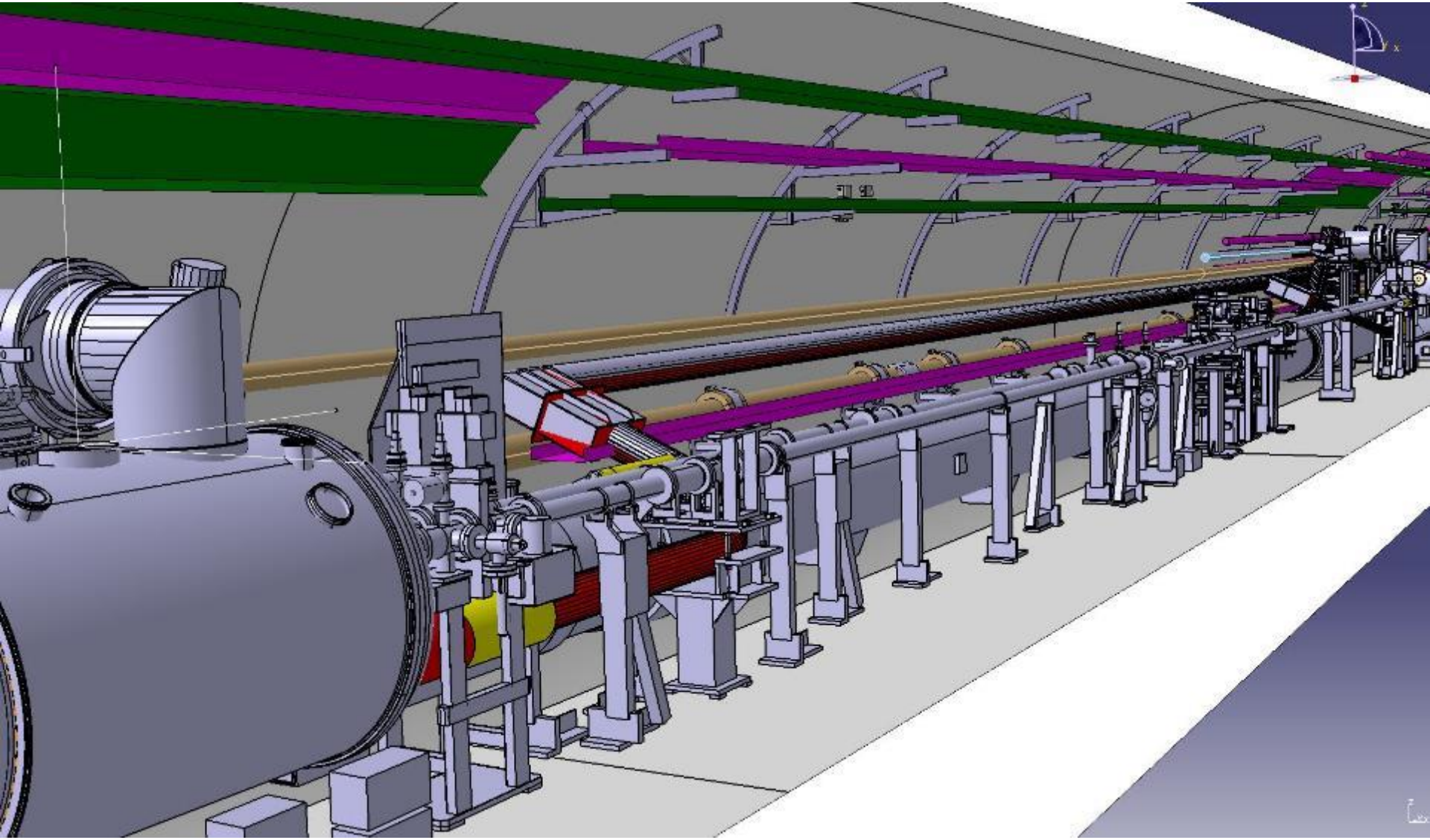
Top view

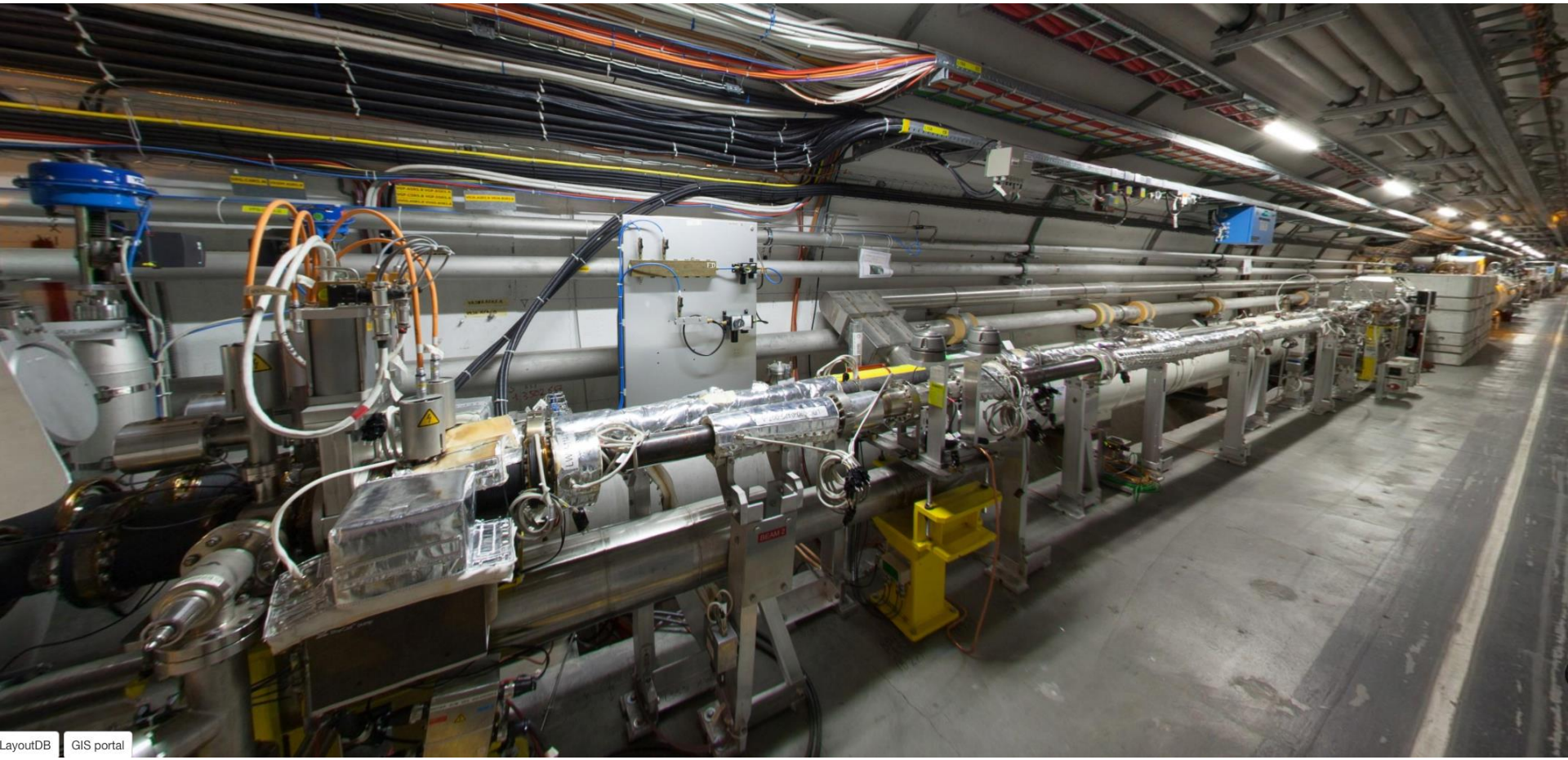


Sequence of functional positions on the internal beam

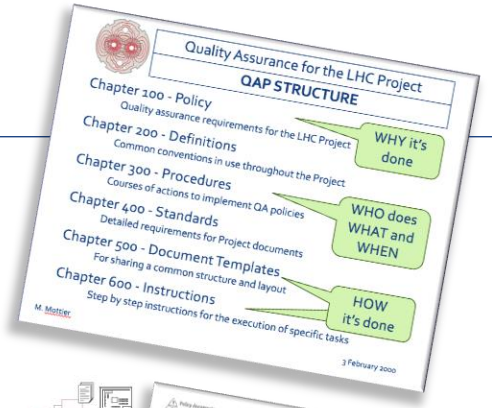
	103057	101803	163.35	9.338	13492.7916	13502.1296	LQYCD.4R5	Q4R5	0	0.097	0	0.097	0	0	0	0	0	IE			1	15.05.2013	INSTALLED
VACSEC.C4R5.R VACSEC.C4R5.R	283206	571144	172.688	0.655	13502.1296	13502.7846	VABTA.5R5.C		0	0.097	0	0.097	0	0	0	0	0	IE	C	VVFM, VGP,VVRD :: VPIA, VGP	1		INSTALLED
VACSEC.A5R5.R	1067989	271770	173.343	0.895	13502.7846	13503.6796	VCDBM.5R5.R		0.097	0.097	0.097	0.097	0	0	0	0	0	I	R		1		INSTALLED
VACSEC.A5R5.R	1067988	271853	174.238	0.3	13503.6796	13503.9796	VMACB.A5R5.R		0.097	0.097	0.097	0.097	0	0	0	0	180	I	R		1		INSTALLED
	104668	102028	174.538	0.285	13503.9796	13504.2646	BPTX.5R5.B2		0.097	0.097	0.097	0.097	0	0	0	0	0	I	B2		1	06.06.2016	INSTALLED
VACSEC.A5R5.R	1067984	271853	174.823	0.3	13504.2646	13504.5646	VMACB.B5R5.R		0.097	0.097	0.097	0.097	0	0	0	0	0	I	R		1		INSTALLED
VACSEC.A5R5.R	1067987	995655	175.123	5.69	13504.5646	13510.2546	VCDLC.5R5.R		0.097	0.097	0.097	0.097	0	0	0	0	0	I	R		1		INSTALLED
VACSEC.A5R5.R	1067986	607170	180.813	0.3	13510.2546	13510.5546	VAMED.5R5.R		0.097	0.097	0.097	0.097	0	0	0	0	0	I	R	VGI,VGR,_,VVFM	1		INSTALLED
VACSEC.A5R5.R	1067983	999018	181.113	3.951	13510.5546	13514.5056	VCDRS.5R5.R		0.097	0.097	0.097	0.097	0	0	0	180	0	I	R		1		INSTALLED
VACSEC.A5R5.R	1067982	382426	185.064	0.4	13514.5056	13514.9056	VMIAA.5R5.R		0.097	0.097	0.097	0.097	0	0	0	0	0	I	R		1		INSTALLED
VACSEC.A5R5.R	1067985	383557	185.464	6.56	13514.9056	13521.4656	VCDQJ.5R5.R		0.097	0.097	0.097	0.097	0	0	0	0	0	I	R		1		INSTALLED
VACSEC.A5R5.R VACSEC.A5R5.R	283212	571145	192.024	0.655	13521.4656	13522.1206	VABTB.5R5.C		0	0.097	0	0.097	0	0	0	0	180	IE	C	VPI,VGP :: VGP, VGR	1		INSTALLED
	103060	101703	192.679	8.229	13522.1206	13530.3496	LQNDA.5R5	Q5R5	0	0.097	0	0.097	0	0	0	0	0	IE			1	15.05.2013	INSTALLED

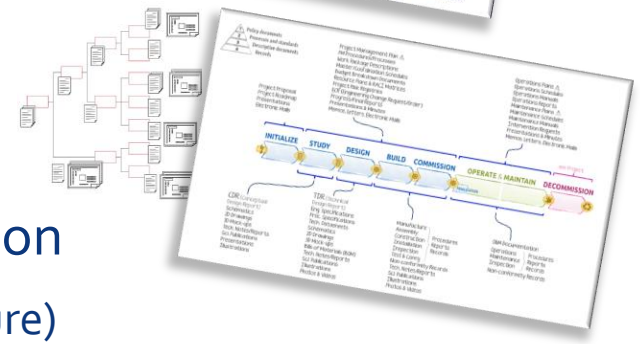





LayoutDB
GIS portal

Methodology (1/3)





- Quality Assurance Plan

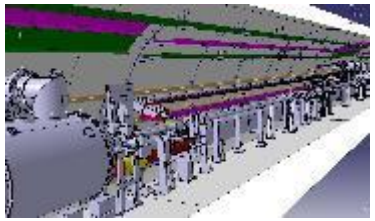
  Covers documentation and processes over the lifecycle

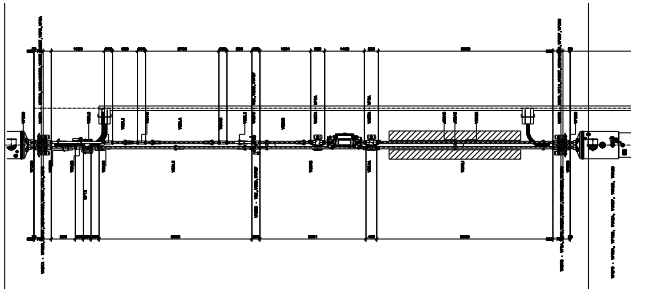
  to ensure that all stakeholders are
  using the same processes

- 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
  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

MTF *Equipment Management Folder*

Home | Help | EDMS Portal | News | Login

User: SABAN

Actions : Show NCR Report

Search : Equipment | Location | Slot | System

Assembly Tree

- HCLBALA000-CR002342 - Arc Dipole LBALA
  - HCLBAL_000-IN002342 - Cryo Dipole LBAL
    - HCMBALA001-02000342 - Cold Mass MBAL
      - HCMB__A001-02000342 - Collared Coil
      - HCMBA_A101-02000342 - Yoke assembly, type
      - HCMBA_S012-02000342 - Helium Shell Assem
      - HCMCSMH001-KE001181 - MCS Magnet Asse
      - **HCMCSMH001-KE001226 - MCS Magnet Ass**
        - HCMCSMH002-KE001226 - Magnet Modul
      - HCDQDBA002-11001352 - Dipole Diode Stack,
      - HCMCDOA001-TE000375 - MCDO Magnet Ass
      - HCMCDOA001-TE000382 - MCDO Magnet Ass
    - HCQBACA101-IN002342 - Cryostat Assembly

Equipment Folder: Properties

Equipment Identifier: **HCMCSMH001-KE001226**
Other Identifier: **MCS-MA-I1226**
Description: **MCS Magnet Assembly (A2)**

Main | Made of | Equipment data | Manufacturing | Operation | Documents | History | Map

Actions : History

External Links

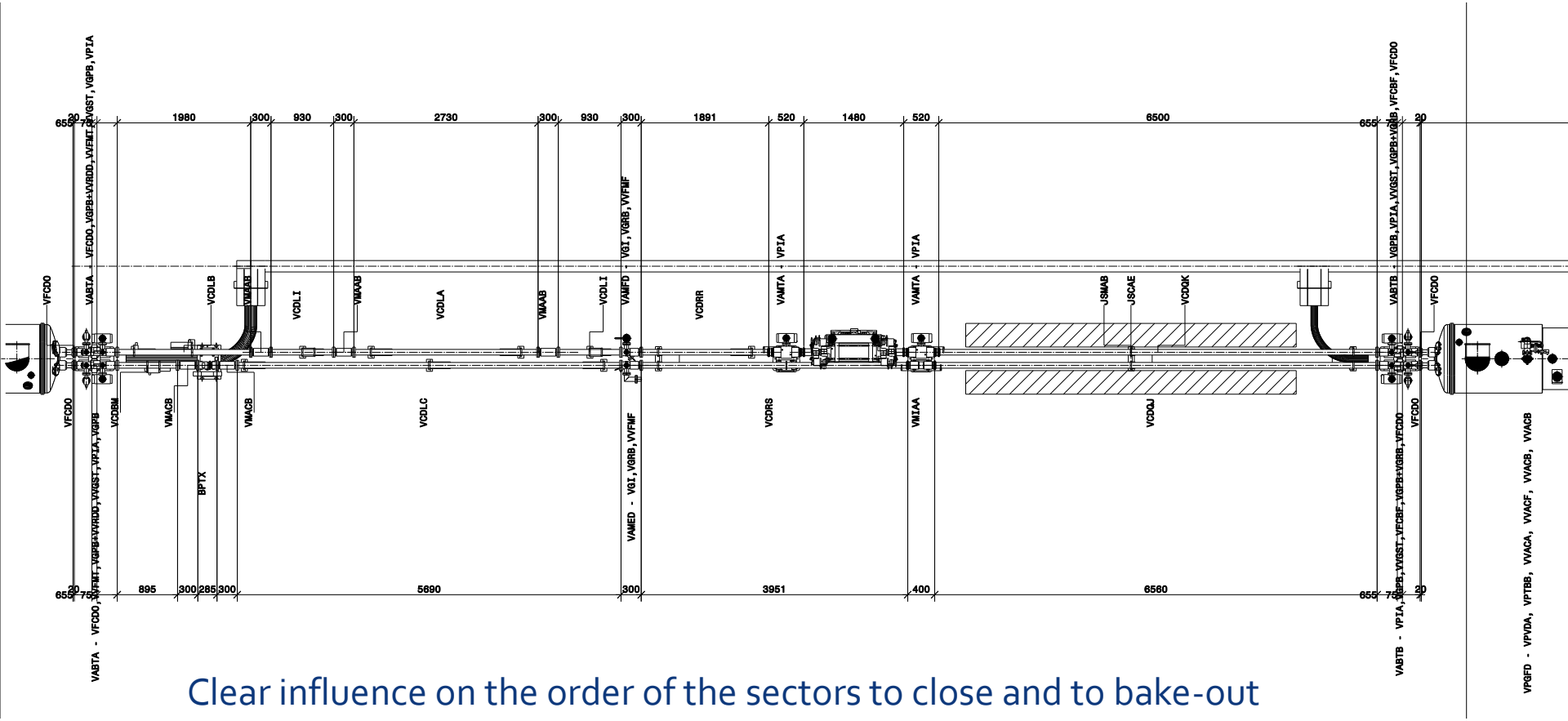
Click here to view data on the external database

Property Values

Property	Nominal Value	Value	Unit
Drawing Version		1	
Protection Resistor ID		MCS-PR-BOO1	
Shield Body ID		MCS-ES-I1332	
Shield End Cap ID		MCS-EC-I1333	
Connection Cover Plate ID			
I leak (4K)		0.21	µA
R dc (4K)		55.69	nohm
I leak (300K)		0.1	µA
R dc (300K)		0.102	ohm
Quench Current 1		1094.37	
Quench Current 2		1160.71	
Quench Current 3		1159.76	
Quench Current 4		1159.93	
Quench Current 5		1159.02	
Quench Current 6			

Courtesy S. Mallón – R. Saban

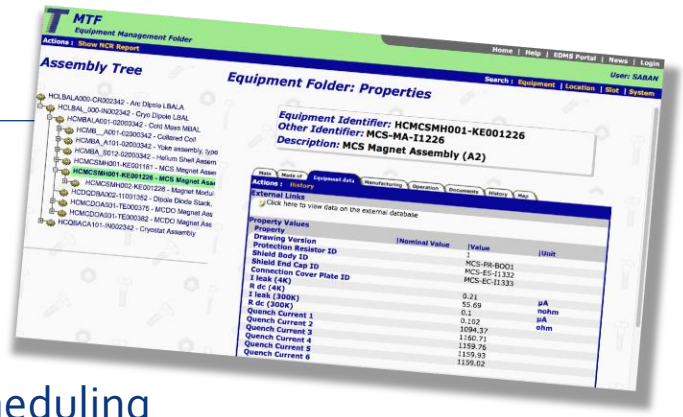
Late design – hence late manufacturing – on some equipment



Clear influence on the order of the sectors to close and to bake-out

Manufacturing of replacement chambers in some cases

Methodology (2/3)

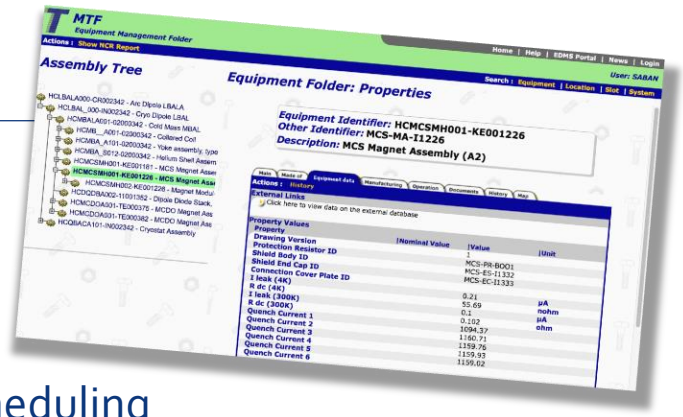


- Manufacturing and Installation

  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)



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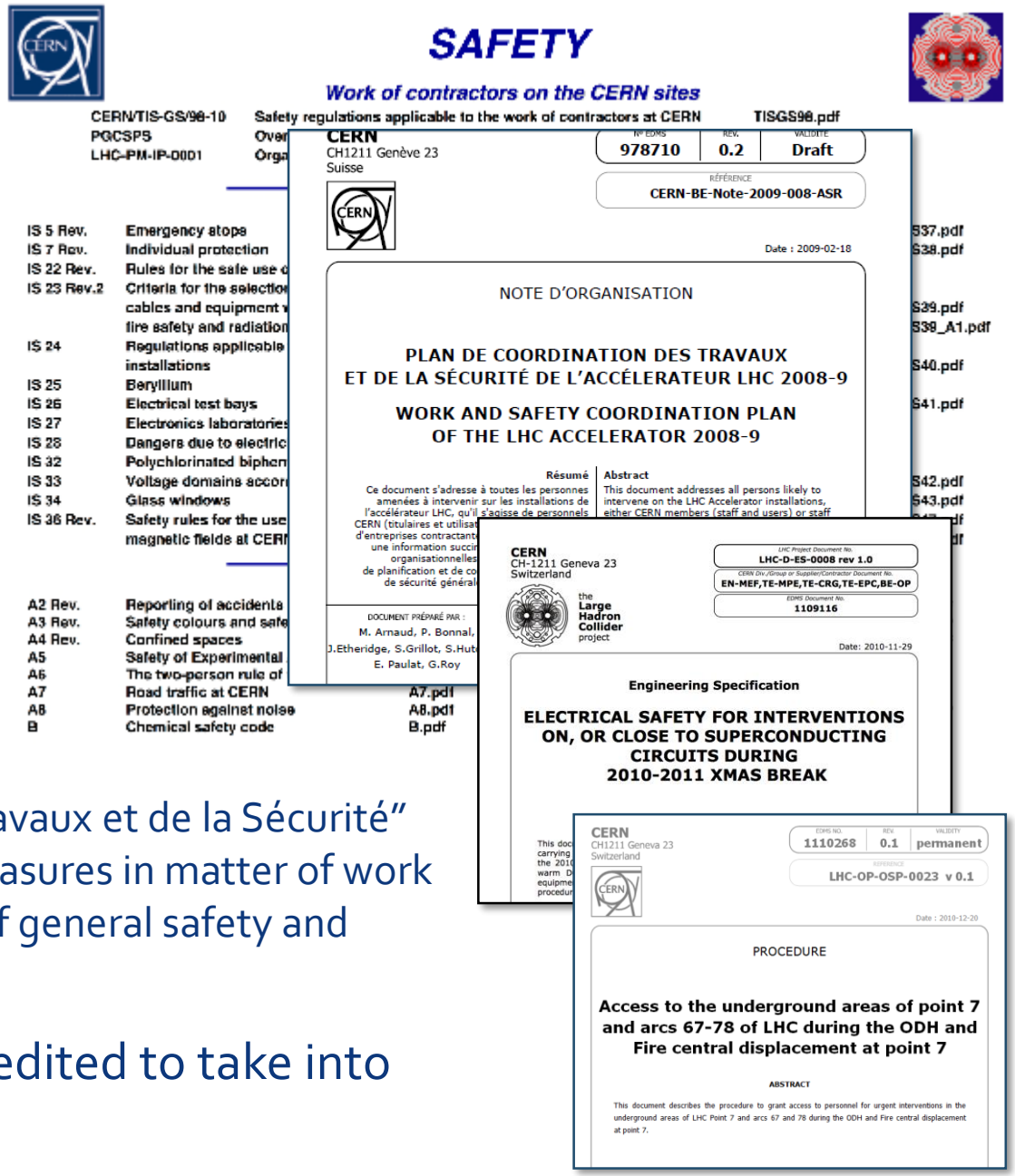
- Coordination meetings

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

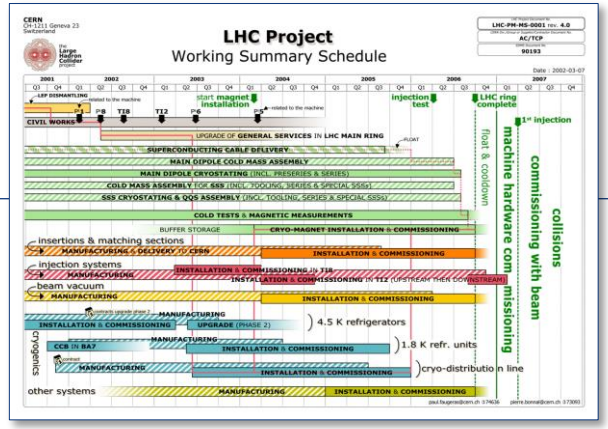
Safety

- 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

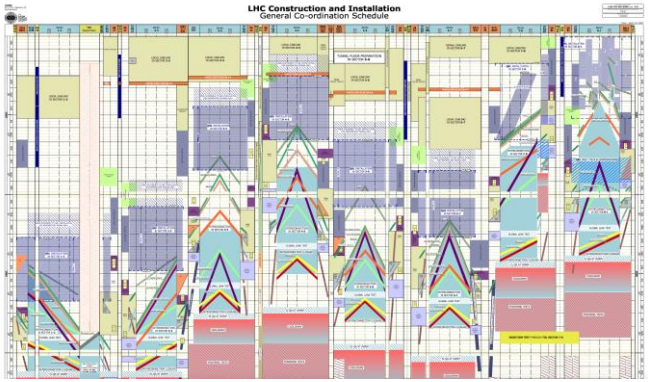


3 levels of schedule

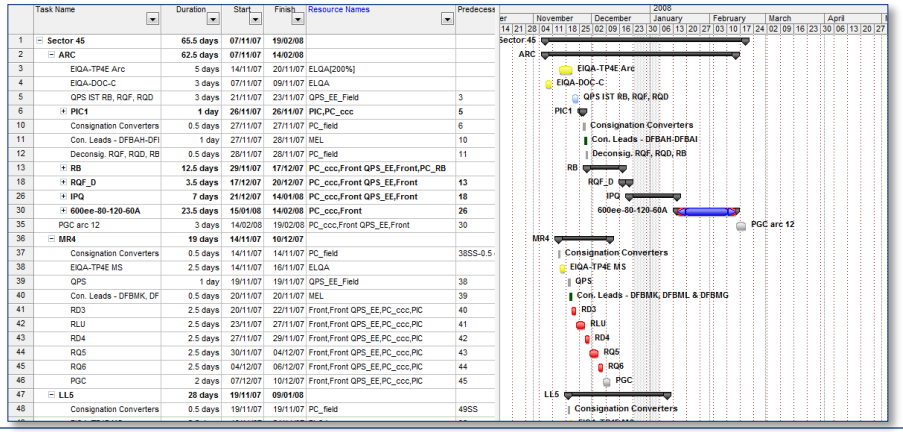
- Strategic schedule
  - Strategic goals and major milestones of the project



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

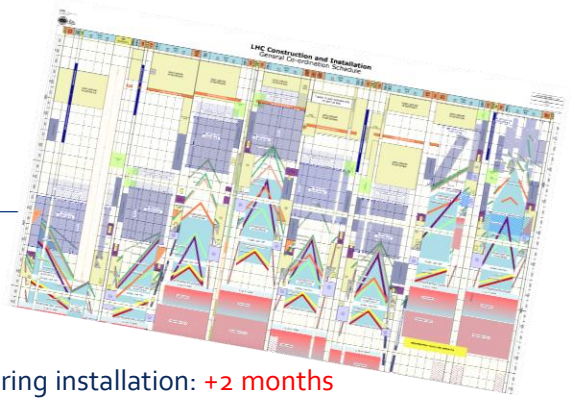


- Operational schedules



	Task Name	Duration	Start	Finish	Resource Names	Predecess
1	Sector 45	65.5 days	07/11/07	19/02/08		
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

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

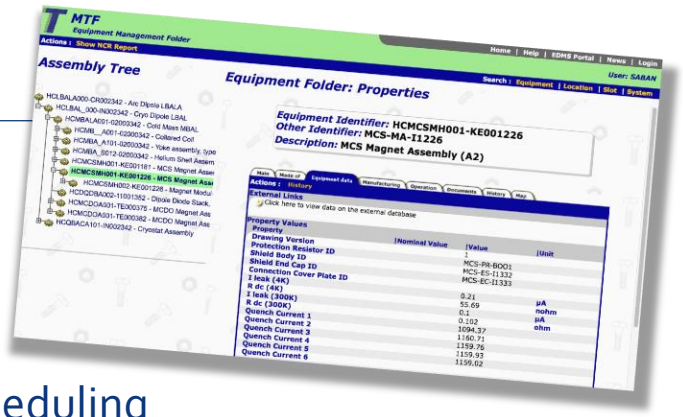
Id	Title	Created on
LHC-PM-MS-0005 v.4.0	LHC Construction/Installation General Coordination Schedule	2007-06-14
LHC-PM-MS-0005 v.3.1	LHC Construction/Installation General Coordination Schedule	2006-10-10
LHC-PM-MS-0005 v.3.0	LHC Construction/Installation General Coordination Schedule	2006-07-07
LHC-PM-MS-0005 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

Courtesy R. Saban

Hardware commissioning was included

Interconnection non conformities + Inner Triplet Crisis +7 months

Methodology (2/3)



- Manufacturing and Installation

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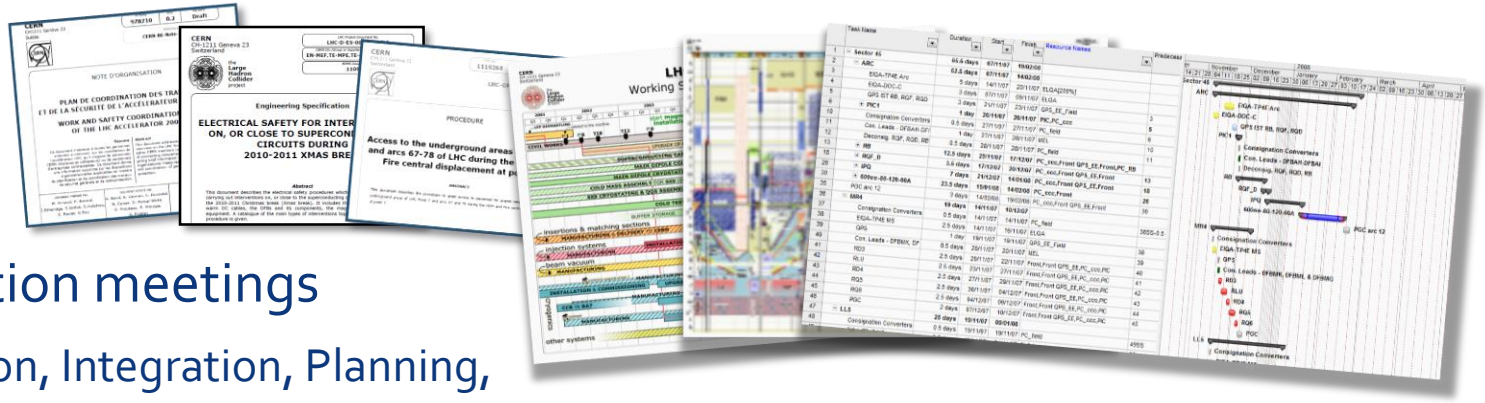


- Coordination meetings

  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

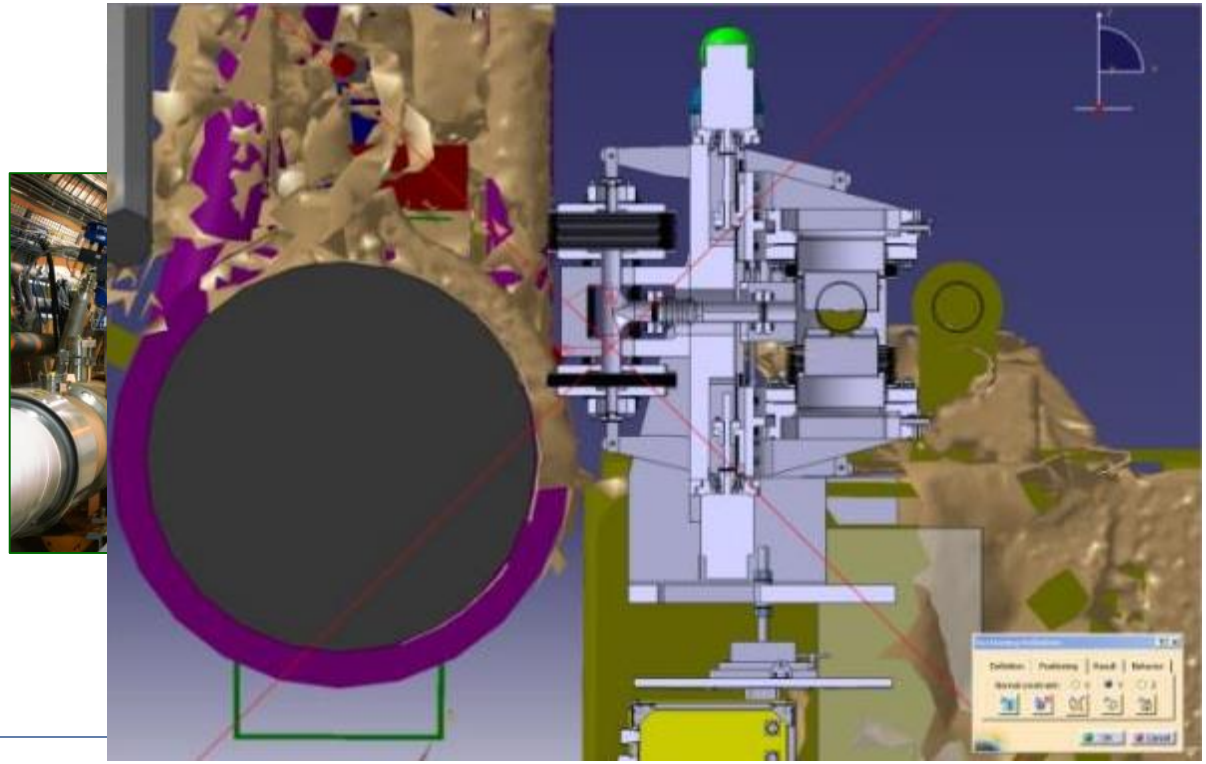
- From the nominal definition, deviations are treated in terms of documentation by

All stored in EDMS

  - 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

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

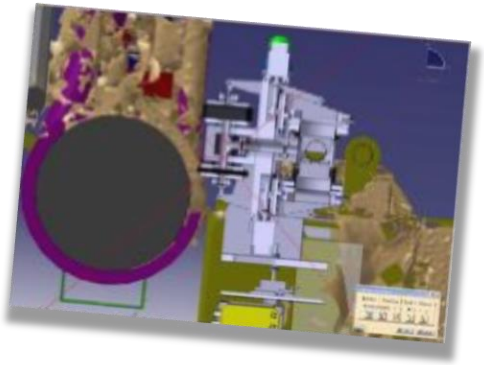


Methodology (3/3)

- 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



Methodology (3/3)

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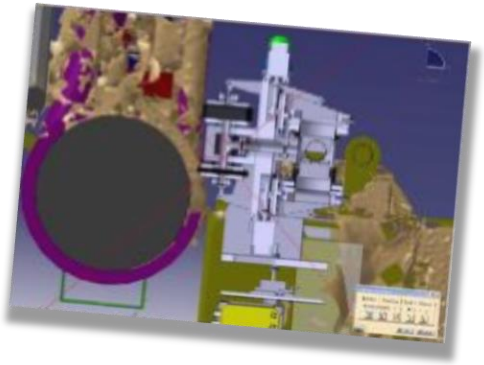
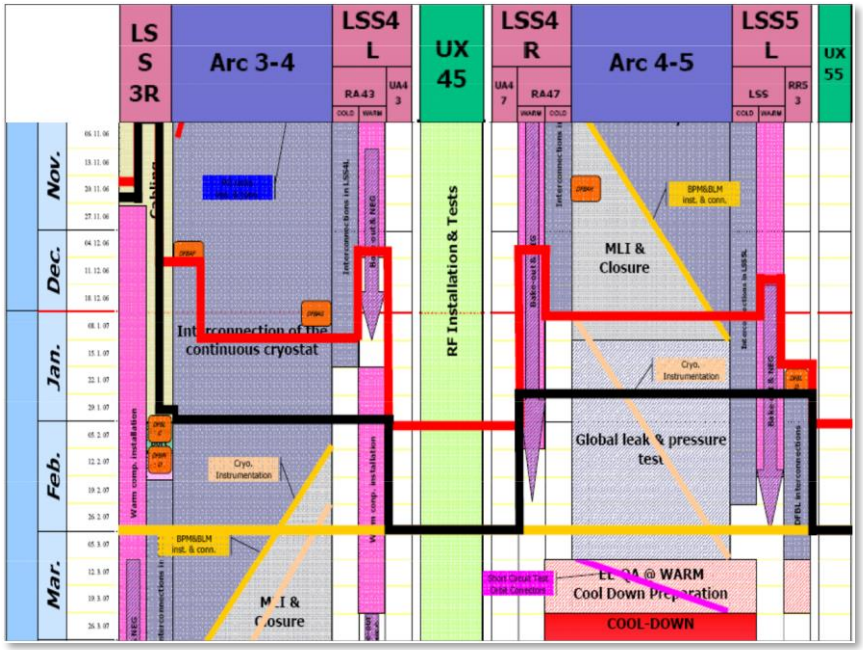


- Reports

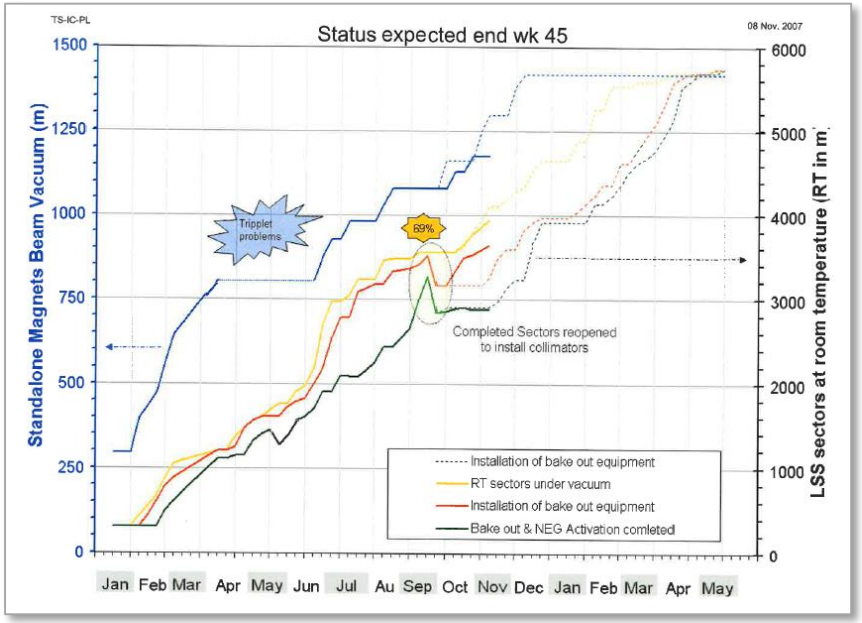
  Earned Value Management set up
  Periodic reports to the Top Management, the Project Leader Office, the Committees

Scheduling reporting



Broken line

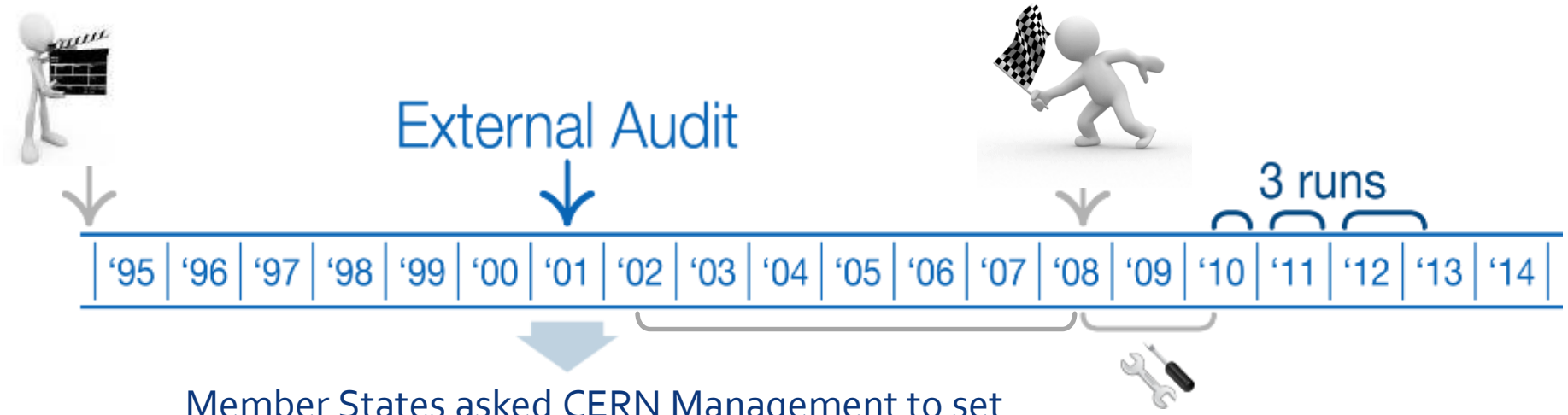
Yellow line is today
Black line is "today's broken line"
Red line is "last month's broken line"



Example of IC-group direct reporting to the DG

on a every month basis

EVM in the LHC project

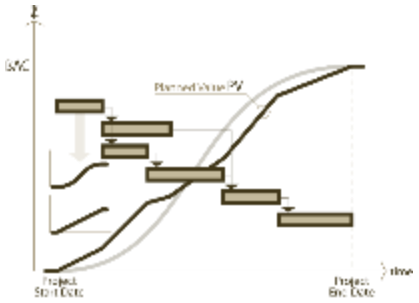


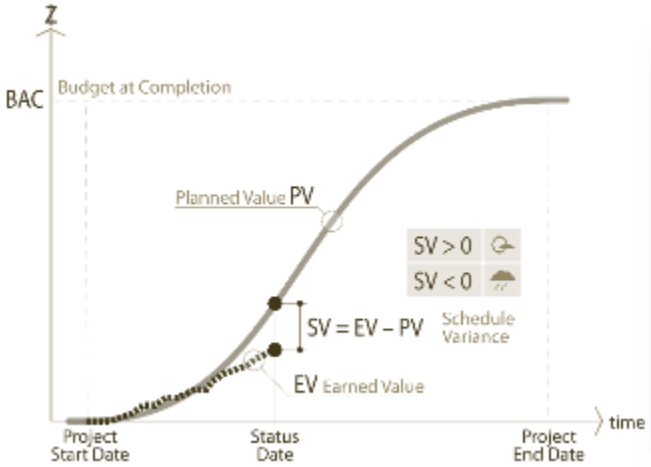
Member States asked CERN Management to set up an appropriate Project Control System

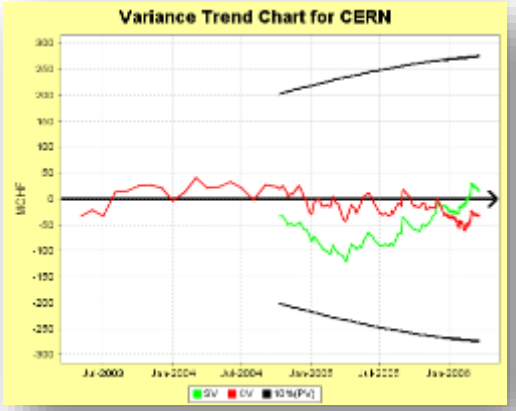
Earned Value Management

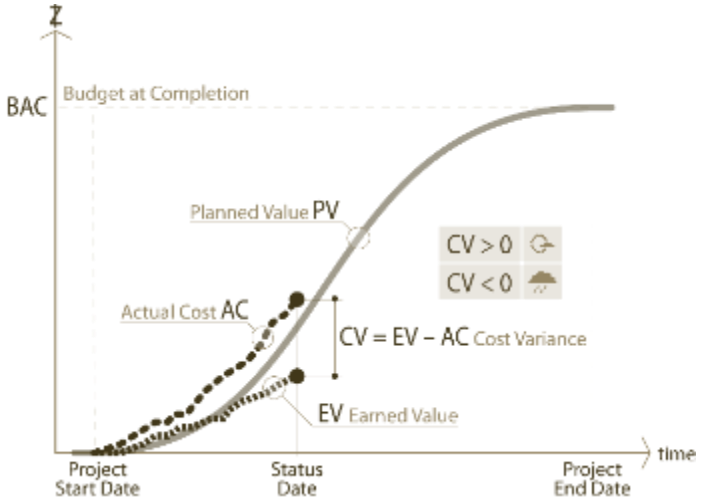
- Interfaced to accounting system → Actual Costs
- Interfaced to contract management system
- Interfaced to human resource management system
- In-kind contributions

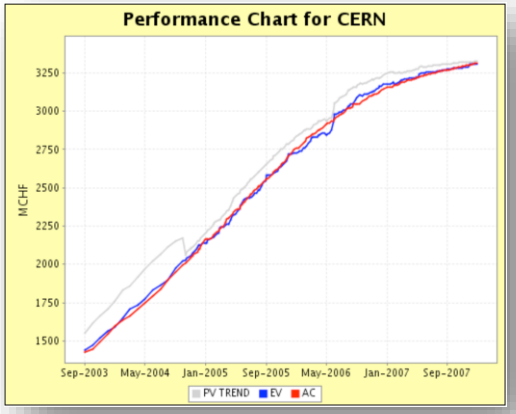
EVM – schedule and cost variance









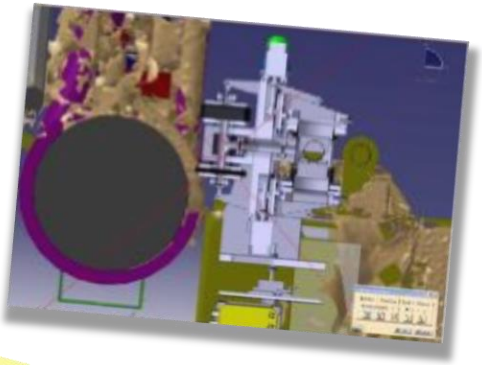


Courtesy P .Bonnal, P. Lebrun

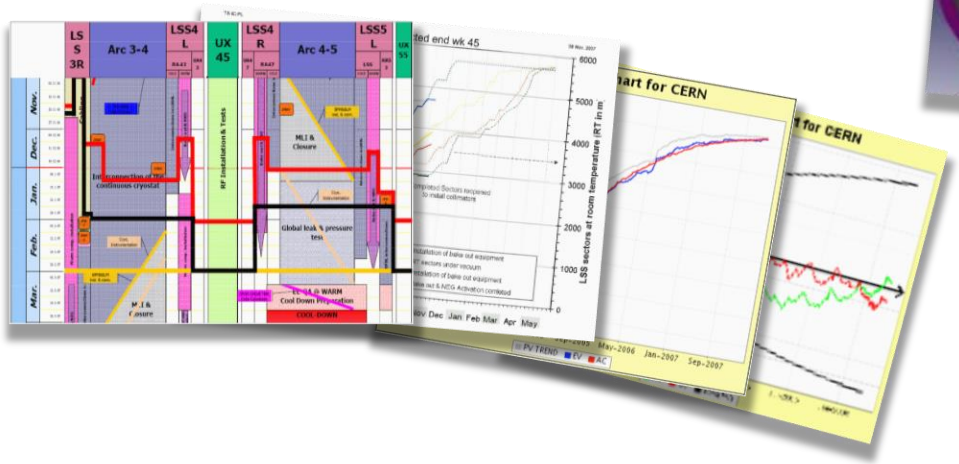
Methodology (3/3)

- 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



- 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

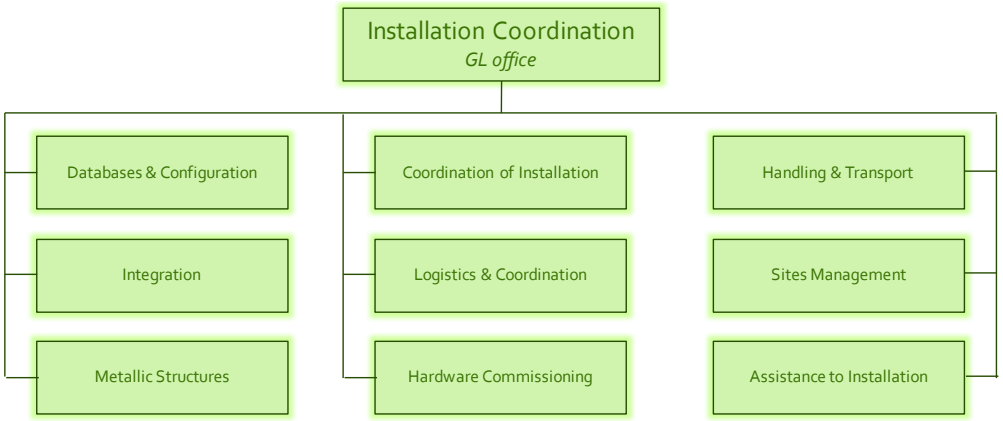
- Achieving quality throughout the project involves the establishment and enforcement of a comprehensive and solid QAP
  - all stakeholders adhered to the message 'I say what I'll do and I do what I said'
  - the weak point was the Interface Specification between two Work Packages
- Unique methodology 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
  - not too deep, not too light, not too heavy, well-balanced, 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 some spotting out

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

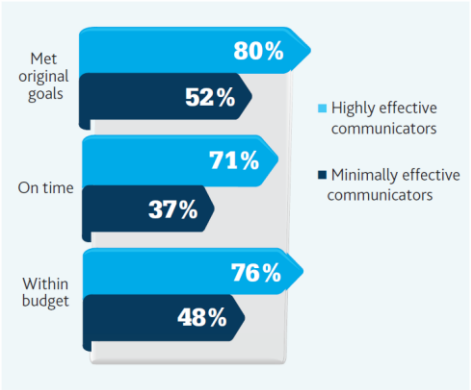
- Small teams per topic
  - configuration – 6
  - integration – 6
  - scheduling – 3
  - logistics – 1
  - operational safety – 5
  - hardware commissioning – 2+6
  - site management – 8
  - transport – 40
  - assistance to installation – 3+10



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

Lessons learned

- Soft skills :
  - Communication is crucial
  - The flexibility and the commitment of our colleagues were the key competencies leading to success

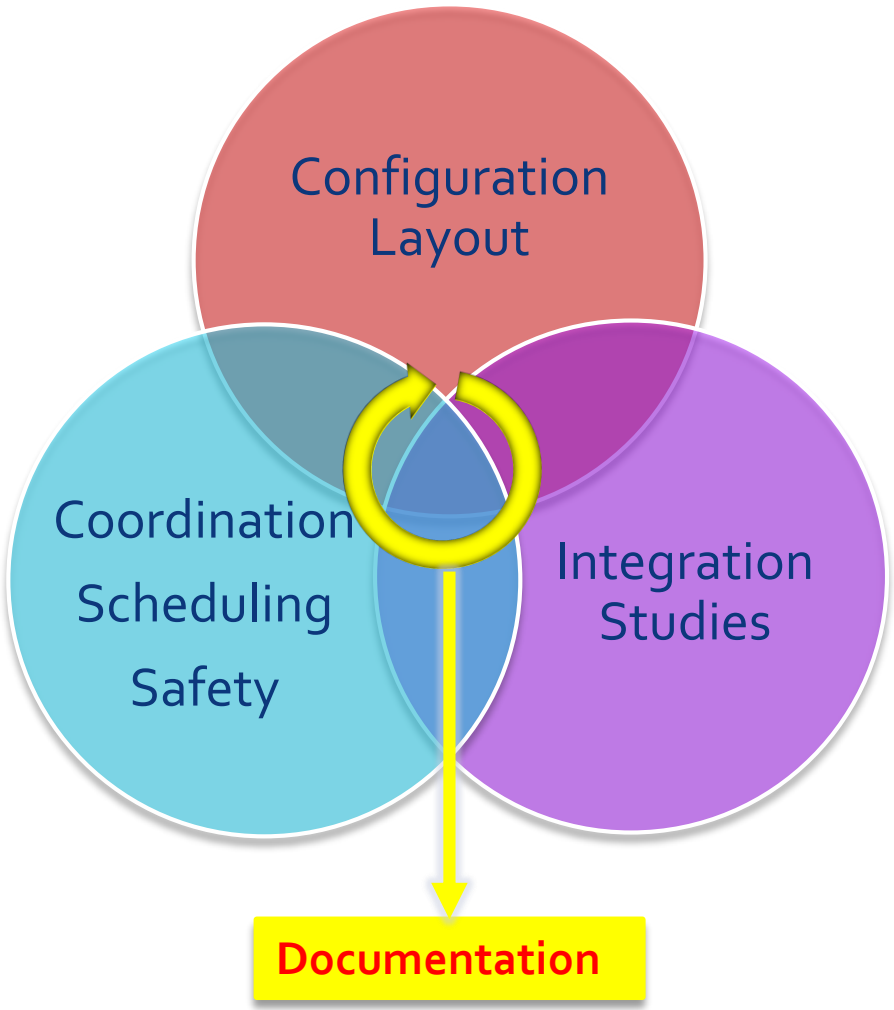


Source: ©2013 Project Management Institute, Inc. *Pulse of the Profession In-Depth Report: The High Cost of Low Performance: The Essential Role of Communications*, May 2013. PMI.org/Pulse

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
- LHC today
  - Change management
  - Long shutdown 2
- Conclusions

Change management

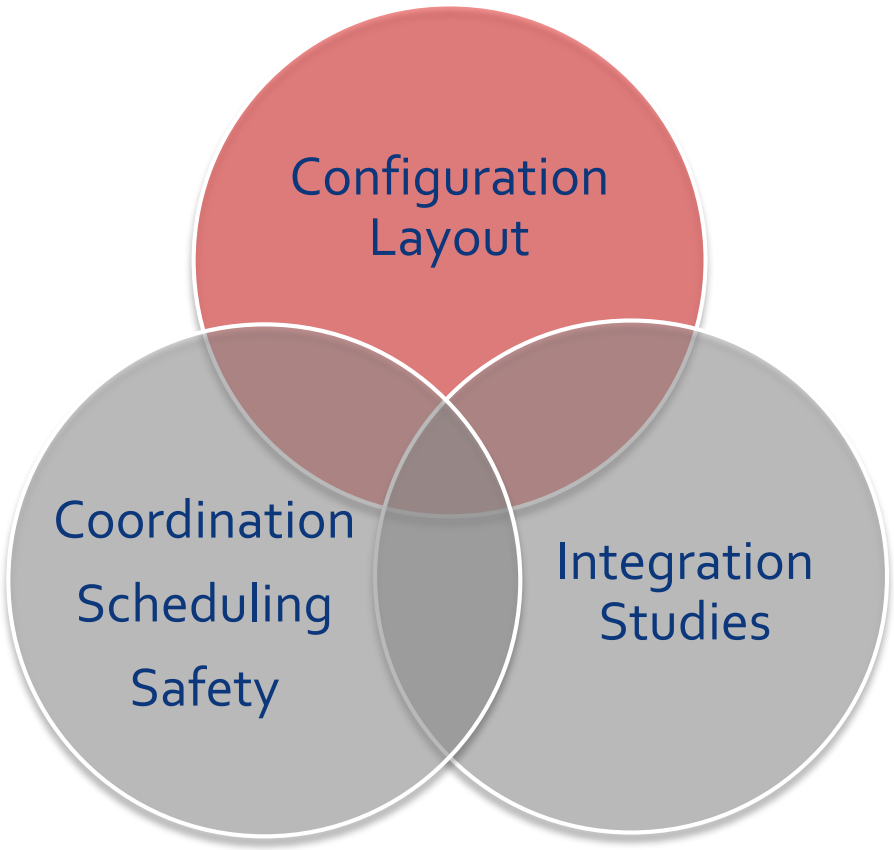


Management of the configuration relative to the machines *(Space reservation, Engineering Change Request, Functional Specification, Engineering Specification, Installation Procedure, Tests Procedure etc…)*
Update of the layout databases

Central information of the 3D models between all design office *(services, mechanical etc…)*
Identification of the interferences
Non-conformities of installation

Central information of the activities to schedule taking into account the logistic and operational safety aspects
Follow-up of the documentation *(Space reservation, Engineering Change Request, Functional Specification, Engineering Specification, Installation Procedure, Tests Procedure etc…)*
Follow-up of the Non-conformities of installation

Change management



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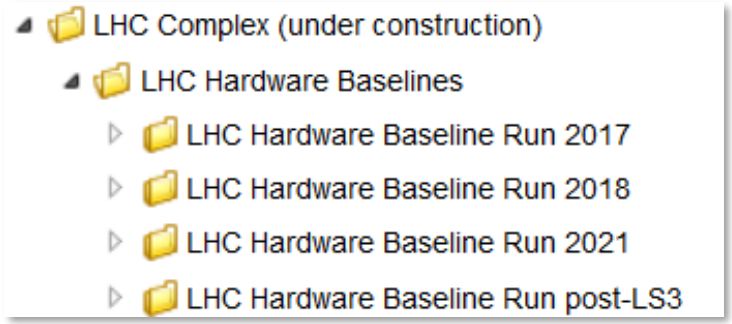
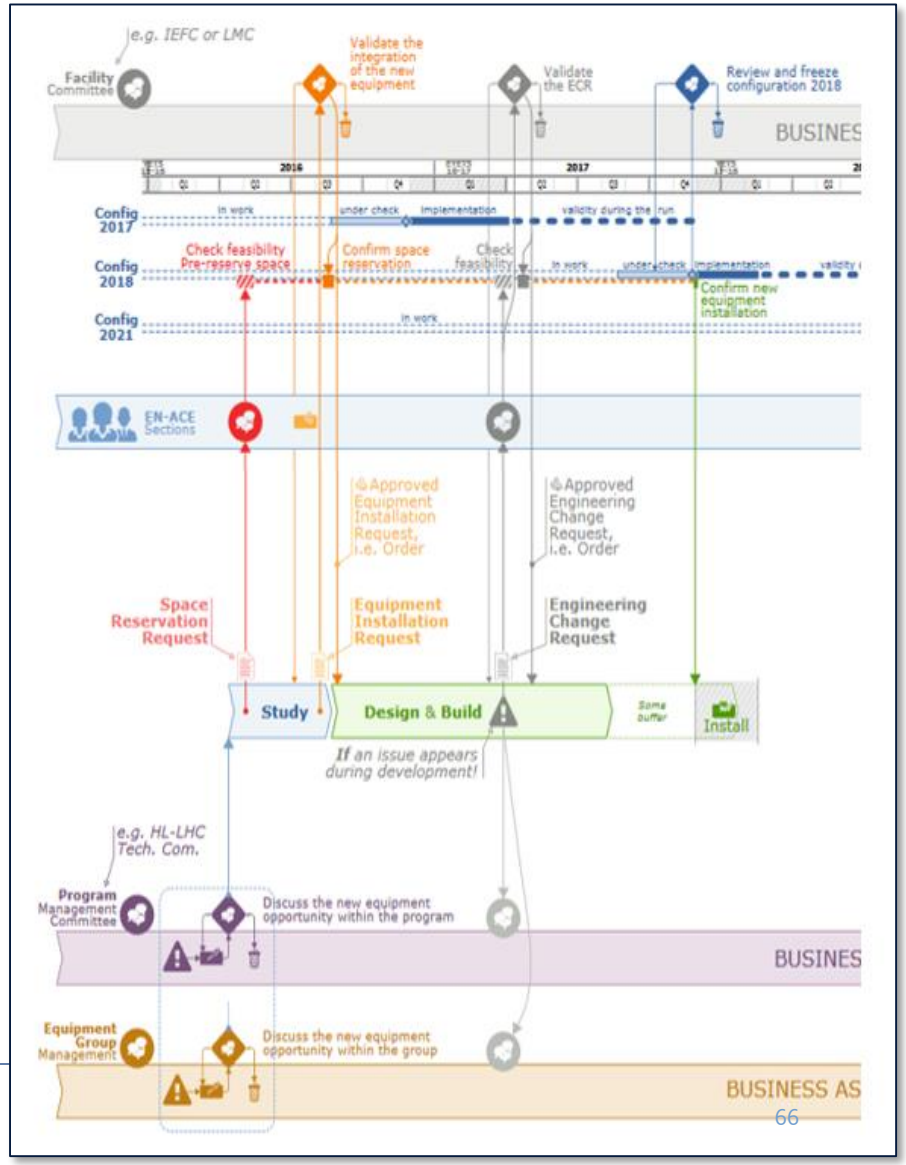
Changes: Layout database evolution

Management of different parallel configuration and layout

▶ a clear view of future runs (space, optics…)

▶ to cope with projects needs



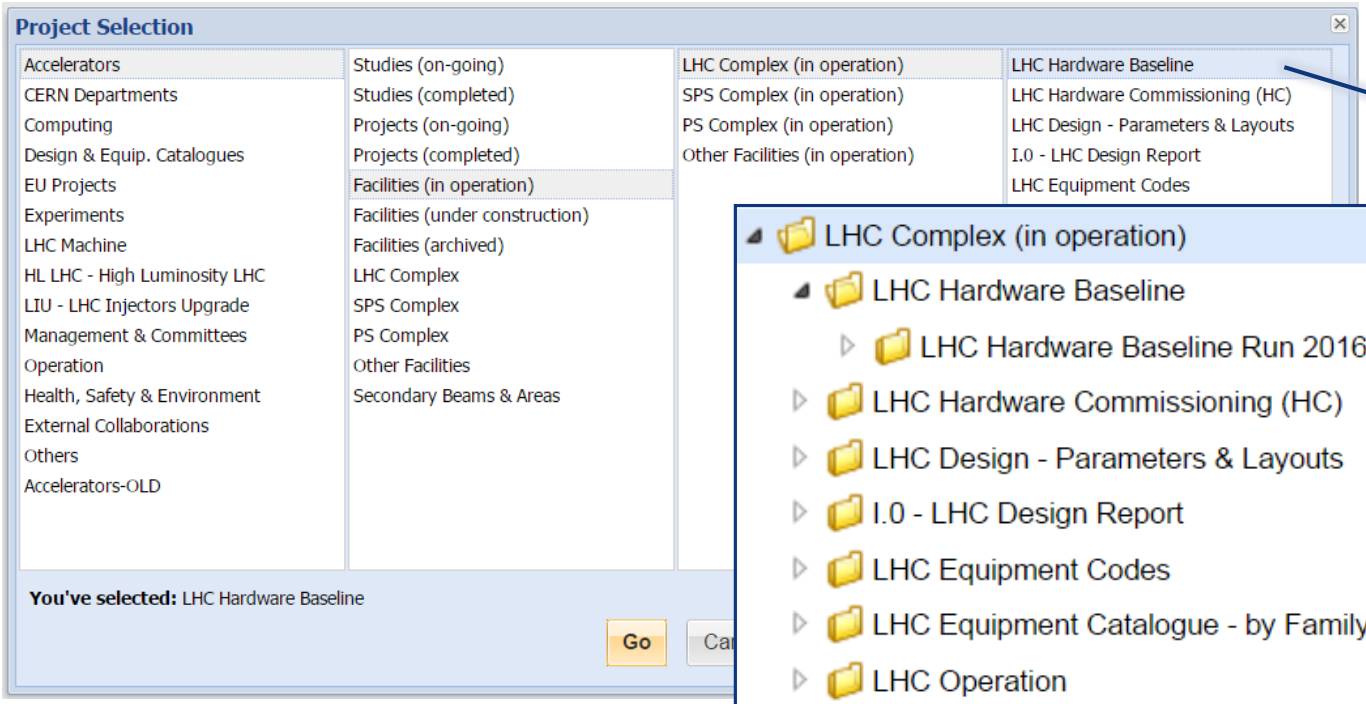


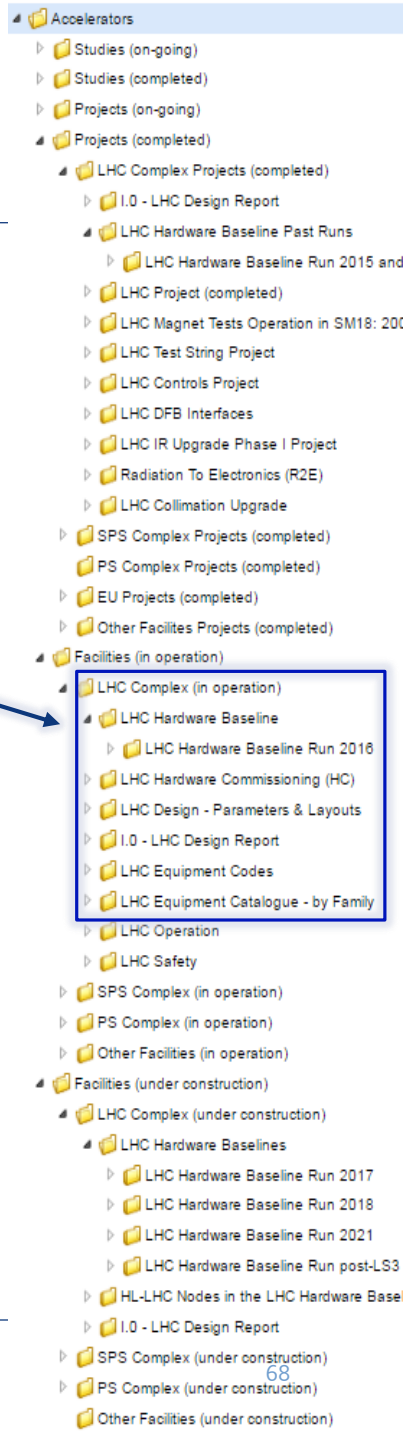
Changes in the tools – EDMS

- 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

Changes in the tools – EDMS

- The EDMS portal reflects the forking of the structures and follows the Engineering Lifecycle
  - Studies – Projects – Operation – Dismantling
  - Allows a better view on the baseline forking





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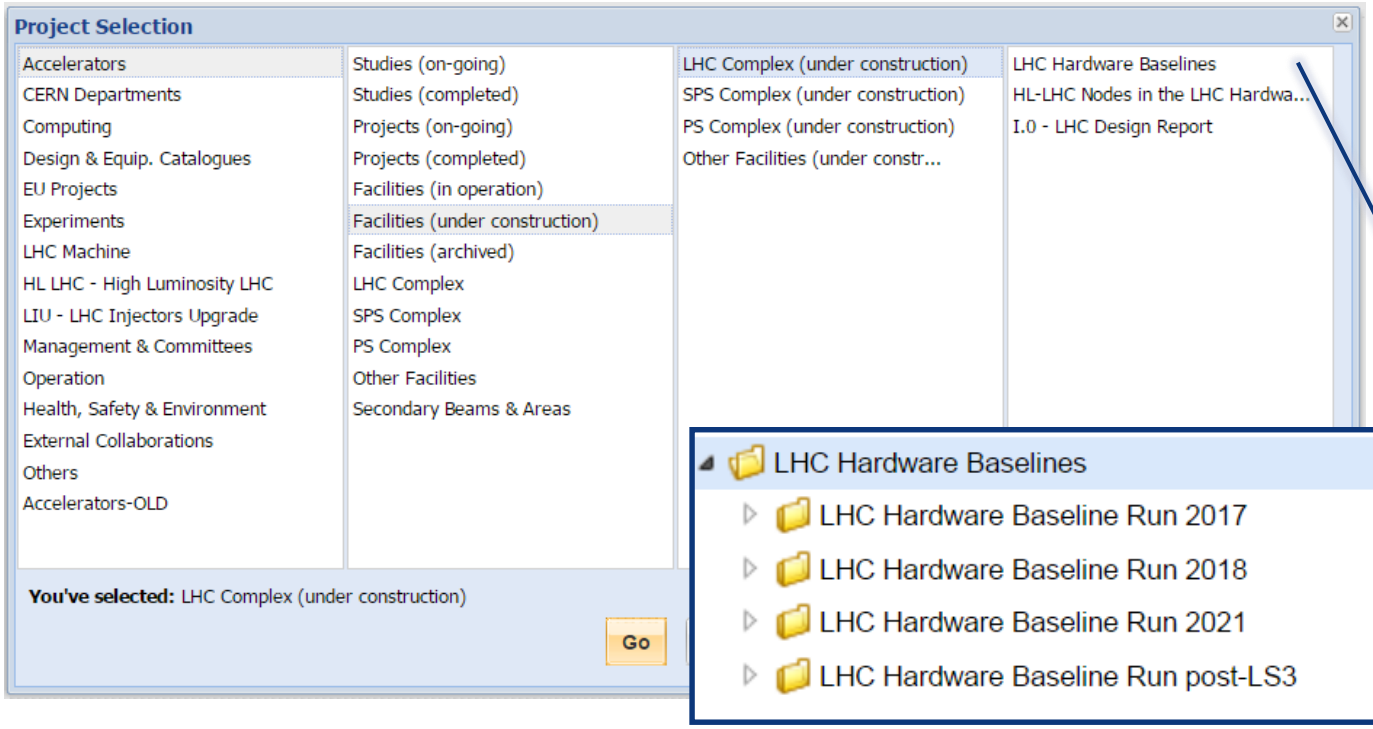
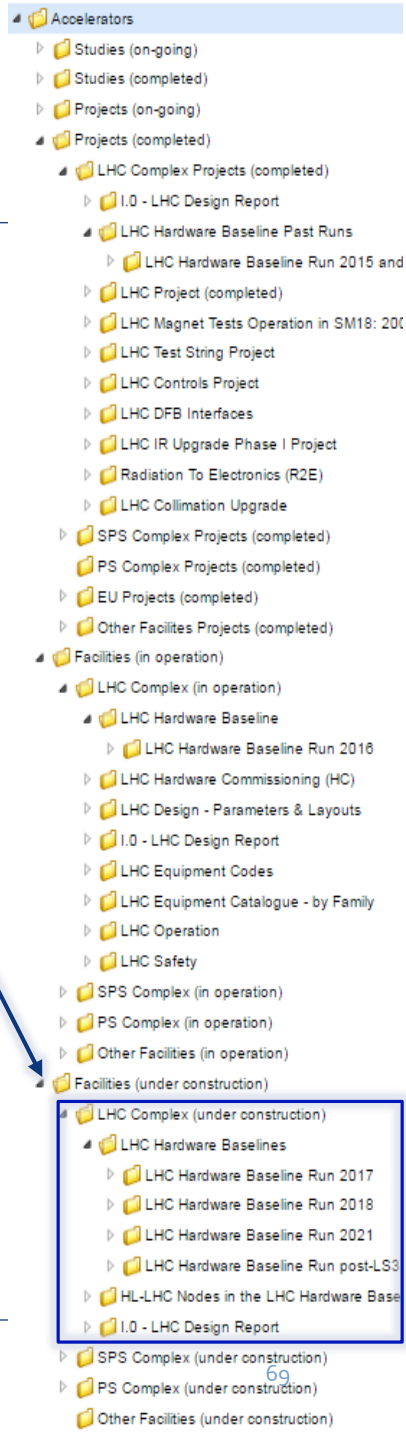
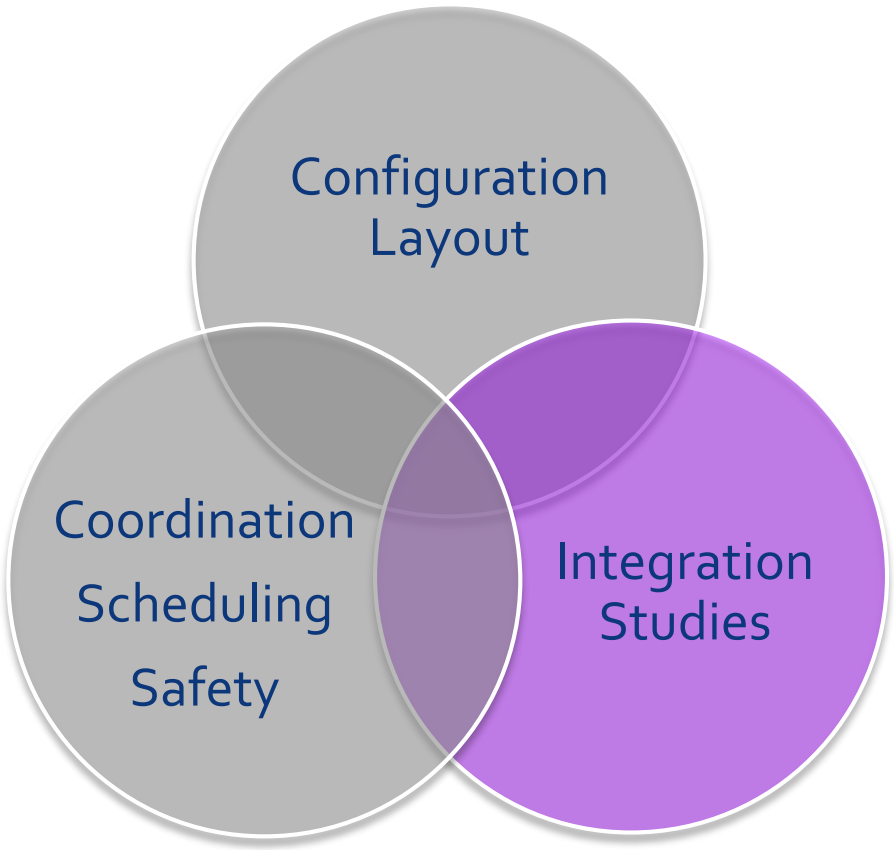




Change management

Refer to Yvon's presentation



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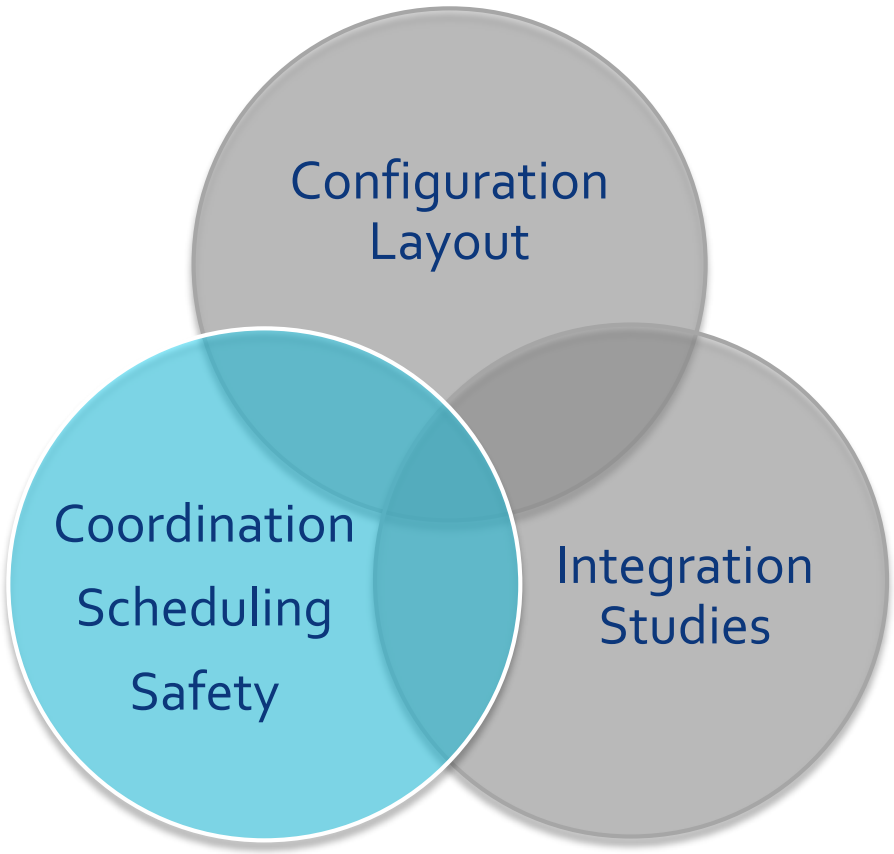
Change management



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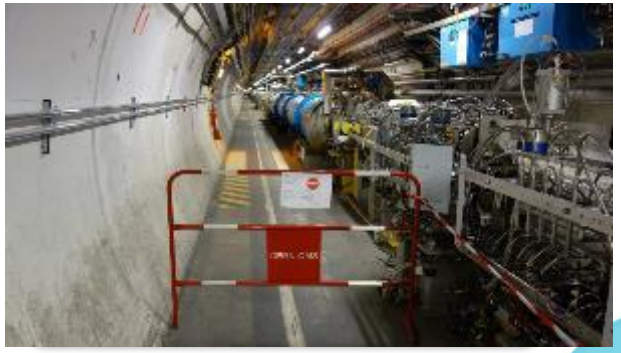
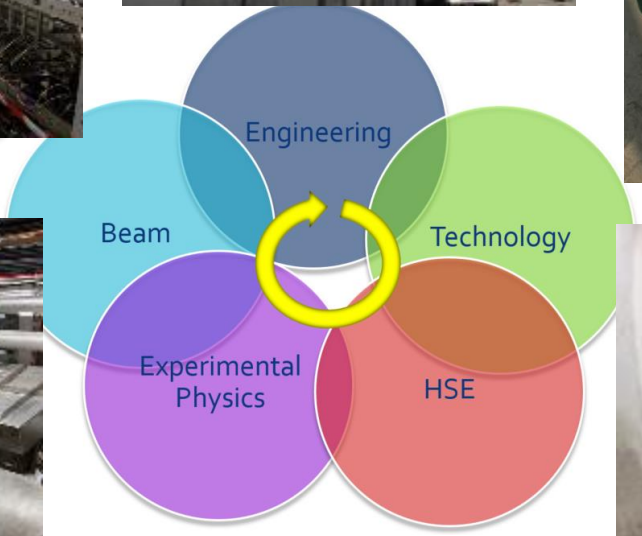
Changes: Coordination & Scheduling

Coordinate and schedule activities in the respect of **Safety and Quality**





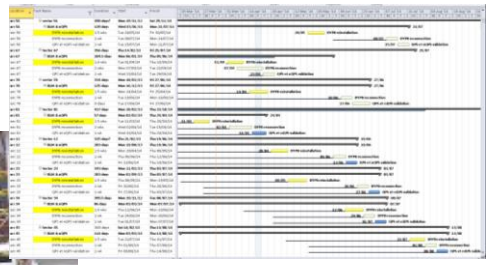
from 1wk to 2years

Changes: Coordination & Scheduling

- Participate from the feasibility studies to the realisation
- Enhance **team spirit** and ease information flow
- **Set and share** priorities across Departments
- Support Groups in the difficult **resource allocation** process
- Anticipate and solve conflicting situations, be **flexible**
- **Propose** solutions to solve issues
- Manage stressful situations
- **Report to management**

  LHC Machine Committee, LS1 Committee, LS2 Committee,

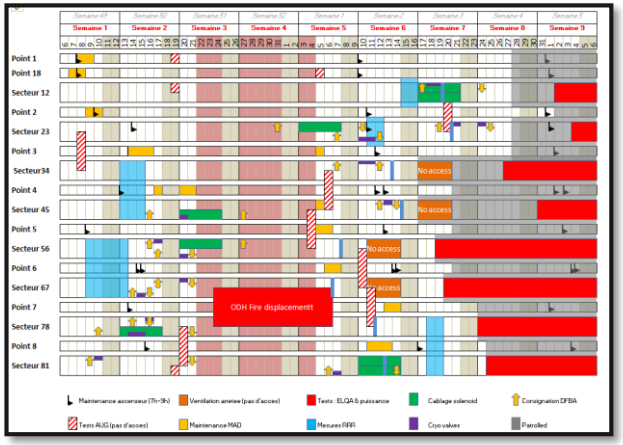
  LHC Injectors & Experimental Facilities Committee, Enlarged Directorate



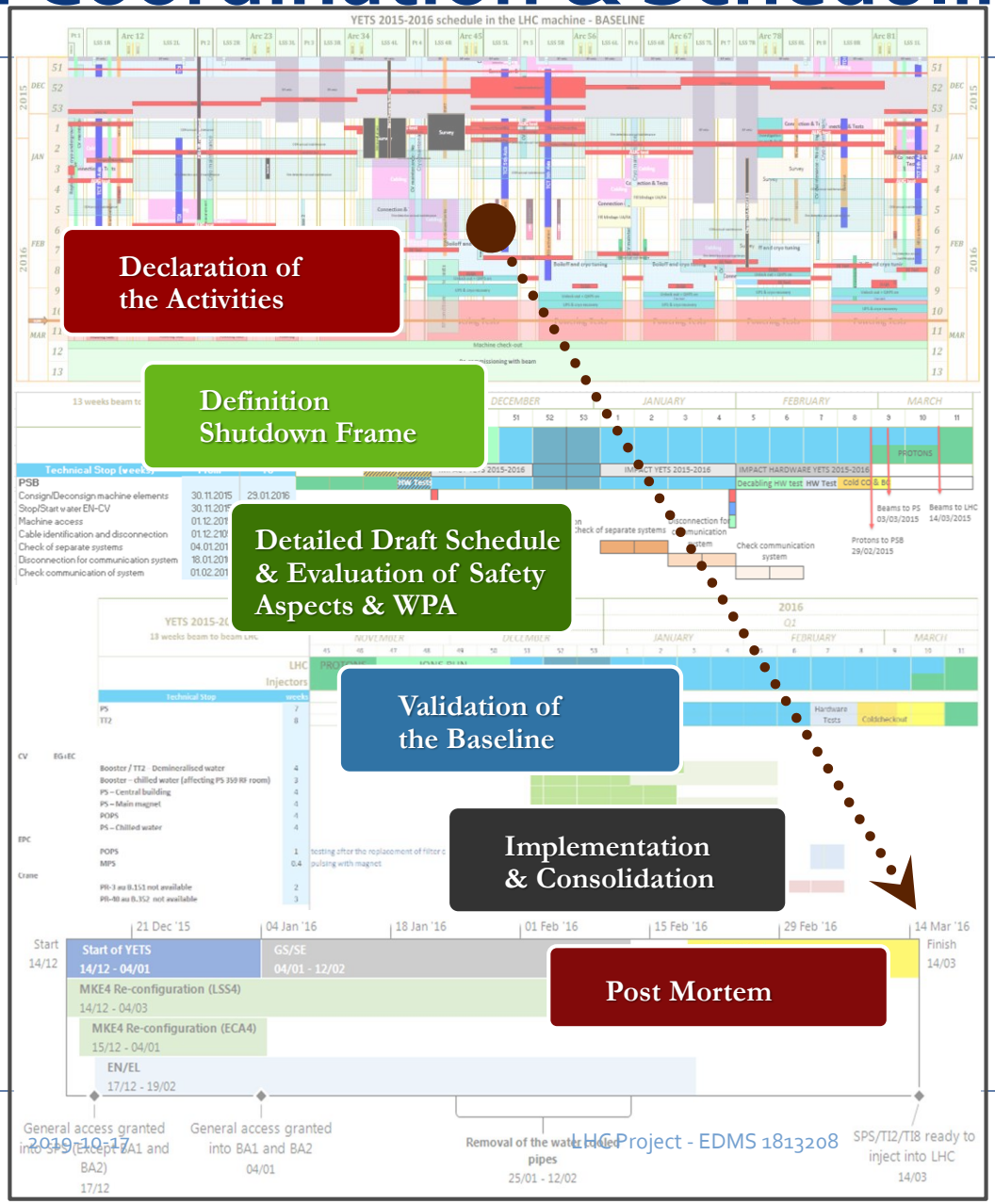
Changes: Coordination & Scheduling

COORDINATION of PROGRAMMED STOPS

- Participative approach
  - Integration & work preparation meetings **with stakeholders and experts**
    Work Package Analysis - WPA:
    What, where, how, when…safety
    Visite d'Inspection Commune - VIC
  - Skeleton schedule ▶
    detailed resource levelled schedule
    & access constraints schedule
  - As Low As Reasonably Achieveble meetings where needed
- Non Conformities detection eased with Scans

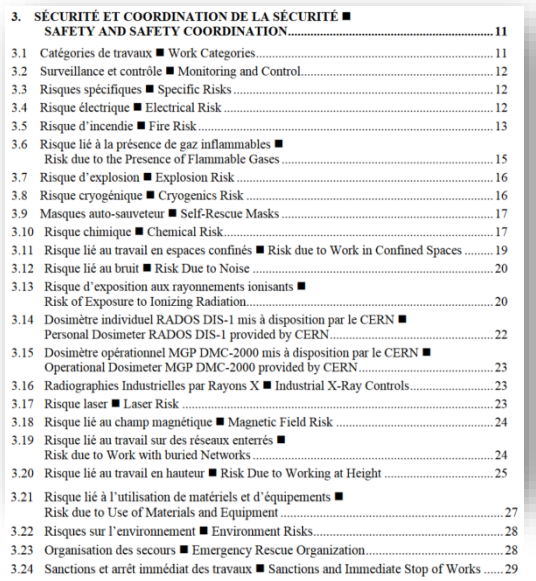


Changes: Coordination & Scheduling



Changes: Safety Coordination

- Anticipate, plan, declare, evaluate
- Safety integrated in different meetings
  Coordination, Work Package Analysis
- Organic unit responsible for the coordination of the stop
- One basic document as a reminder of the key Safety requirements
- Prior declaration (IMPACT) for each intervention
- Safety "evaluation" document per intervening entity
  procedure, task list, or equivalent…
- " Visite d'Inspection Commune" VIC if requested/necessary
- To take into account all the risks, resulting from co-activity and successive activities
- To ensure that the general principles of prevention are implemented and that the "rules and regulations" are respected



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3.23 Organisation des secours ■ Emergency Rescue Organization 28
3.24 Sanctions et arrêt immédiat des travaux ■ Sanctions and Immediate Stop of Works 29

- When risk occurs
  - Dedicated task force: correct expertise and appropriate experts !!
  - Being ready for the unexpected and determining your response to it

Changes: Safety Coordination

- The Safety Coordination should be involved from the conception stage and they should be consulted if there are major modifications to be carried out.
- The objective is to ensure that prevention is built in where ever possible.
- This will improve the working conditions, reduce risks, improve the quality of the work and therefore save time and money
- All work, tests, interventions, must be:
  - Planned
  - Prepared with a procedure and or a "fiche de taches"
  - Authorized including:

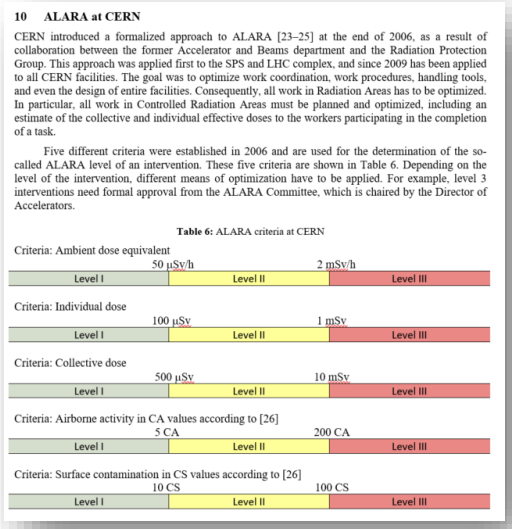
    Visite d'Inspection Commune

    As Low As Reasonably Achievable Principle- ALARA

    Demande d'Intervention en Milieu Radioactive – DIMR

    Lockout, hot work permit, IS 37 etc…
- All documentation respected

Unfortunate mixture of water and electricity



10 ALARA at CERN

CERN introduced a formalized approach to ALARA [23–25] at the end of 2006, as a result of collaboration between the former Accelerator and Beams department and the Radiation Protection Group. This approach was applied first to the SPS and LHC complex, and since 2009 has been applied to all CERN facilities. The goal was to optimize work coordination, work procedures, handling tools, and even the design of entire facilities. Consequently, all work in Radiation Areas has to be optimized. In particular, all work in Controlled Radiation Areas must be planned and optimized, including an estimate of the collective and individual effective doses to the workers participating in the completion of a task.

Five different criteria were established in 2006 and are used for the determination of the so-called ALARA level of an intervention. These five criteria are shown in Table 6. Depending on the level of the intervention, different means of optimization have to be applied. For example, level 3 interventions need formal approval from the ALARA Committee, which is chaired by the Director of Accelerators.

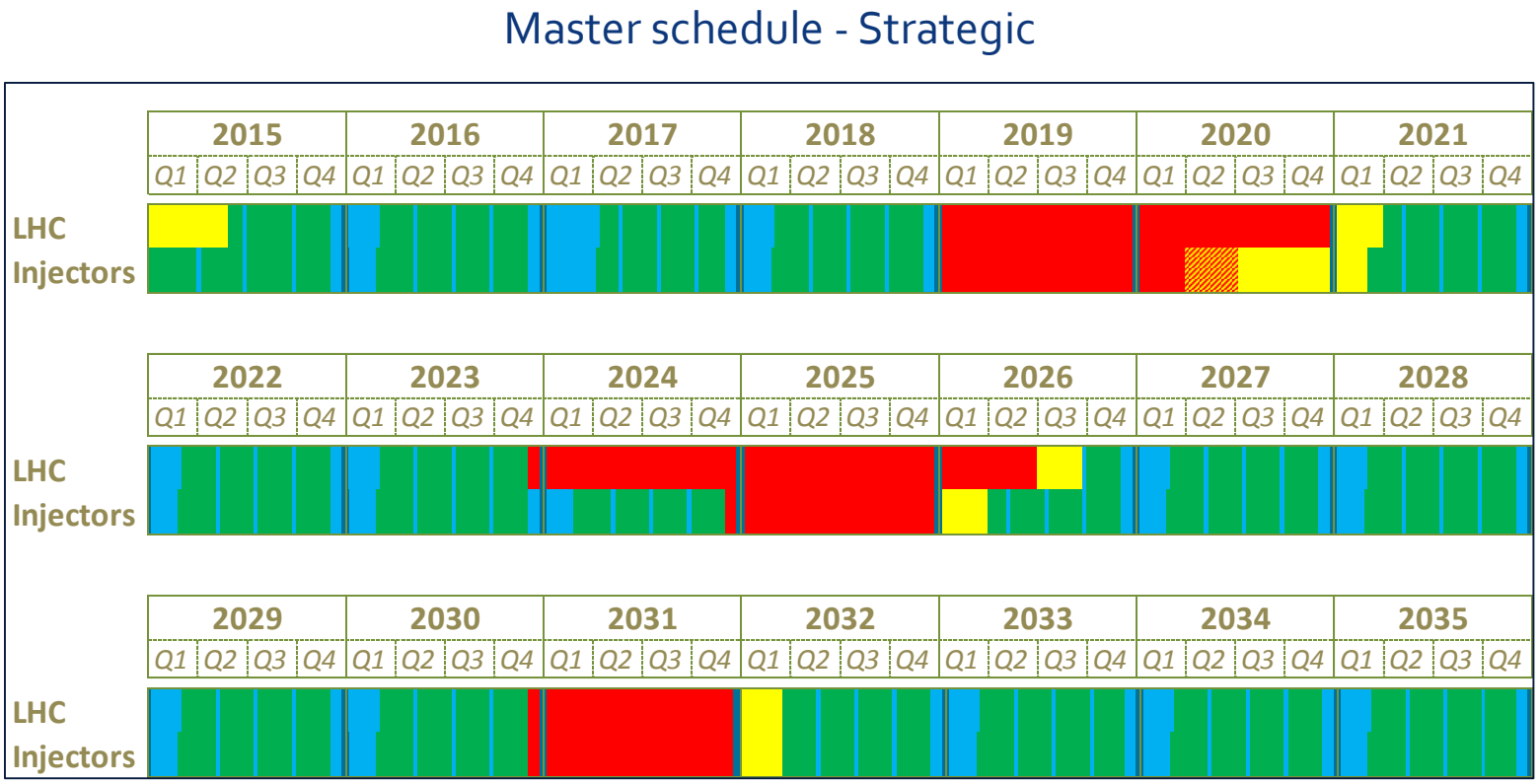
Table 6: ALARA criteria at CERN

Criteria: Ambient dose equivalent		50 μSv/h	2 mSv/h
	Level I	Level II	Level III
Criteria: Individual dose		100 μSv	1 mSv
	Level I	Level II	Level III
Criteria: Collective dose		500 μSv	10 mSv
	Level I	Level II	Level III
Criteria: Airborne activity in CA values according to [26]		5 CA	200 CA
	Level I	Level II	Level III
Criteria: Surface contamination in CS values according to [26]		10 CS	100 CS
	Level I	Level II	Level III

Long shutdown 2: an example

Changes: Scheduling

- Multi level planning:
  from Master Schedule to detailed installation schedule



Changes: Coordination & Scheduling

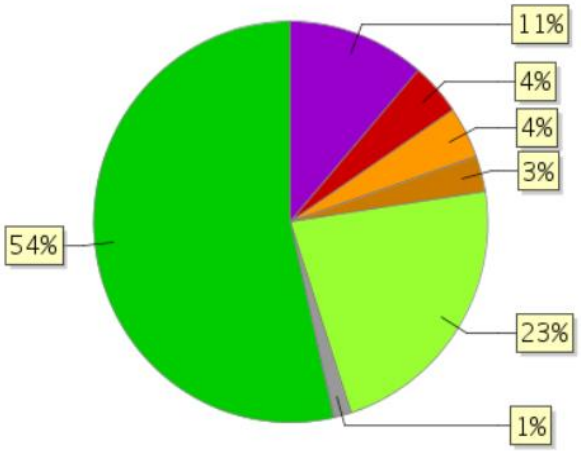
ECR ID	Title	Authors	Status	Location	Group	Track It
LHC-B-EC-0006 v.1.0	HL-LHC ECR - WP13. Modifications to the Scope of WP13. Action PSM	R. Jones	Released	Point 5 and 7	BE-BI	78191
LHC-BGC-EC-0002 v.0.1	Installation of a Beam Gas Curtain (BGC) Demonstrator Instrument Stage 1	Gerhard Schneider	Approval Accepted	LSSL4	BE-BI	77996
LHC-DQDB-EC-0001 v.0.1	Consolidation of the LHC Dipole Diode Insulation System	Christian Scheuerlein	Under Approval		TE-MSC	10539
LHC-EIOF-EC-0001 v.1.0	Distributed Optical Fibre Radiation and Temperature Sensing in parts of LHC	Diego di Francesca, Yacine Kadi	Released	IP1, IP5 and IP7	EN-EA	80054
LHC-G-EC-0005 v.1.0	Triplet Monitoring System Modifications in Points 2 and 8	Andreas Upsy	Released	points 2 and 8	EN-SMM	82241

ECR ID	Title	Authors	Status	Location	Group	Track It
LHC-G-EC-0010 v.1.0						
LHC-G-EC-0011 v.1.0						
LHC-HHAAS-EC-0003 v.0.1						
LHC-HHAAS-EC-0007 v.1.0						
LHC-JS-EC-0001 v.1.1						
LHC-LBH-EC-0001 v.0.2						
LHC-LE-EC-0005 v.0.2						
LHC-LJ-EC-0041 v.1.0						
LHC-LJ-EC-0045 v.2.0						
LHC-LJ-EC-0046 v.1.0						
LHC-MKI-EC-0004 v.1.0						
LHC-MKI-EC-0005 v.0.1						
LHC-MW-EC-0002 v.2.0						
LHC-QI-EC-0009 v.1.0	Additional Cryogenic Instrumentation for Local Diagnostics of Beam-Induced Heat Loads	Benjamin Bradu	Released	S45 and S12 sector 45 & sector 12	TE-CRG	82948 82471
LHC-QIF-EC-0001 v.0.1	Installation of cryogenic global mass flowmeters in the QUI and on the WRL	Krzysztof Brodzinski	Approval Accepted	P18, P2, P6	TE-CRG	82946
LHC-QQBI-EC-0001 v.1.1	Protective Half-Shells for the Vacuum Pumping Lines	Cédric Garion, Christian Duclos	Released		TE-VSC	79283
LHC-QRMP-EC-0001 v.1.0	New working platforms for pumping groups located at height in L2 and R8 of the LHC	Jaime PEREZ ESPINOS	Released	UJ22-UJ88	TE-VSC	77849
LHC-RF-EC-0002 v.1.0	FGClite Deployment - Phase 2 (RRs)	Slawosz Uznanski	Released	RRs	TE-EPC	10707
LHC-RF-EC-0004 v.1.0	Deployment of the RegFGC3 electronics in TI2 (SR2) and TI8 (SR8)	J.M. Fernández García; H. Thiesen	Released		TE-EPC	81899
LHC-RP-EC-0002 v.0.3	Installation of three news COMET 2p power converter for LIU-SPS TCDI	Gilles de Godec, Christophe Mutin	In Work	SR2	TE-EPC	76458
LHC-RPH-EC-0003 v.1.0	Change of LHC4-6-8kA power converters in the LHC RR13/17/53/57 areas	JULIEN FABIEN CHANOIS	Released	RR13/17/53/57	TE-EPC	79739
LHC-RPMBD-EC-0001 v.1.0	Change of RPMB Power Converters in the LHC RR13/17/53/57/73 and 77 areas	Vincente Raul Herrero Gonzalez	Released	RR13, RR17, RR53, RR57, RR73, RR77	TE-EPC	10682
LHC-TANB-EC-0001 v.0.2	Installation of a TANB in A4R8 and A4L8 and Related layout Modifications	Francisco Sanchez Galan	Under Approval	LSS8	EN-EA	10274

ECR ID	Title	Authors	Status	Location	Group	Track It
LHC-TC-EC-0011 v.1.0						
LHC-TC-EC-0012 v.0.1						
LHC-TC-EC-0013 v.0.1						
LHC-TC-EC-0014 v.0.1						
LHC-TC-EC-0015 v.0.1						
LHC-TC-EC-0016 v.0.1						
LHC-TC-EC-0019 v.0.1						
LHC-TCAP-EC-0001 v.0.1						
LHC-TCDI-EC-0002 v.1.1						
LHC-TDIS-EC-0001 v.0.2						
LHC-V-EC-0011 v.1.0						
LHC-V-EC-0012 v.1.0						
LHC-V-EC-0013 v.1.0						
LHC-V-EC-0015 v.1.0						
LHC-V-EC-0016 v.1.0						
LHC-VAZ-EC-0006 v.1.0						
LHC-VC1T-EC-0001 v.0.1	Modification of the VT retractable support system in the ATLAS experiment	Josef Sestak, Piotr Gebolis	Approval Accepted	Point 1	TE-VSC	79284
LHC-VC2-EC-0001 v.0.1	UPGRADE of the LHC Vacuum Sectors A1L2.X, IP2.X and A1R2.X Within the LS2 ALICE Experiment Upgrade	Josef Sestak, Jerome Gilles Chaure	Approval Accepted	A1L2.X, IP2.X and A1R2.X	TE-VSC	78700
LHC-VC5-EC-0002 v.0.1	Upgrade of the IP5.X Beam Vacuum Sector	Josef Sestak	Approval Accepted	IP5	TE-VSC	78698
LHC-VPG-EC-0003 v.1.0	Second Vacuum Upgrade of the Turbo Pumping System on LHC MKB Tanks	J. Finelle, G. Bregliozzi, E. Page, G.Pigny	Released	LSS6 dump lines	TE-VSC	79268
LHC-VSC-EC-0002 v.1.0	Amorphous carbon coating in standalone magnets of the LHC in IR2 and IR8 during LS2 2019-2020	Pedro Costa Pinto, Mauro Taborelli	Released	LSS R2, LSS L8, Q5, Q6	TE-VSC	79734
LHC-XAFP-EC-0005 v.1.0	Maintenance of the AFP Detectors in LS2	Michael Rijsenbeek	Released	LSS1	EP-UAT	82243
LHC-XRP-EC-0018 v.0.1	Removal of the PPS Horizontal Roman Pot 210 near and re-installation at 220 near	Joachim Baechler, Michele Arneodo, Mario Deile, Dmitry Druzhkin, Eris Page	Approval Accepted	LSS1 6R5, 6L5	EP-CMT EP-CMX	82749 79708
LHC-Y-EC-0013 v.1.0	LASS reliability and usability modifications during LS2	Timo Hakulinen	Released		BE-ICS	78620
LHC-Y-EC-0014 v.1.0	LASS radiation veto modification in TI2 and TI8	Timo Hakulinen	Released	TI2 and TI8	BE-ICS	78621
LHC-Y-EC-0015 v.1.0	Access Door Supervision Modifications at PM18, PMI2, SDX1, USA15, PM54, PX56, SZ8	Timo Hakulinen	Released	PM18, PMI2, SDX1, USA15, PM54, PX56, SZ8	BE-ICS	78709
LHC-Y-EC-0016 v.1.0	Replacement of UP25 MAD by an end-of-zone door	Timo Hakulinen	Released	UP25/UL26	BE-ICS	77867
LHC-Y-EC-0017 v.1.0	New Maintenance Doors in PM18, UL55 and UX85	Timo Hakulinen	Released	PM18, UL55, UX85	BE-ICS	78906
LHC-Y-EC-0018 v.1.0	Condemnation LHC Top-of-Pit Elevator Technical Area Trap Doors	Timo Hakulinen	Released	point 3, Point 2, Point 4, Point 6	BE-ICS	78707
LHC-Y-EC-0019 v.1.0	LHC Access Control System upgrade	Timo Hakulinen	Released	All Access Points all points	BE-ICS	78911 78362
LHC-Y-EC-0020 v.1.0	Enlargement of MADs at PZ33, PZ45, PM56, and PM76	Timo Hakulinen	Released	PZ33, PZ45, PM56, PM76	BE-ICS	10596
LHC-Y-EC-0021 v.1.0	LHC Safety System Modifications due to HL-LHC during LS2	Timo Hakulinen	Released	RI132-RI171, UJ53, R571 UPRs galleries in Points 1 and 5 SD5	BE-ICS EN-ACE	10406 78943 78765
LHC-Y-EC-0022 v.1.0	Modification of the Sectorisation of CMS Drainage Gallery (UP542-3529)	Harry SHAKESHAFT	Released	UP542-K3529	EP-CMX	81450

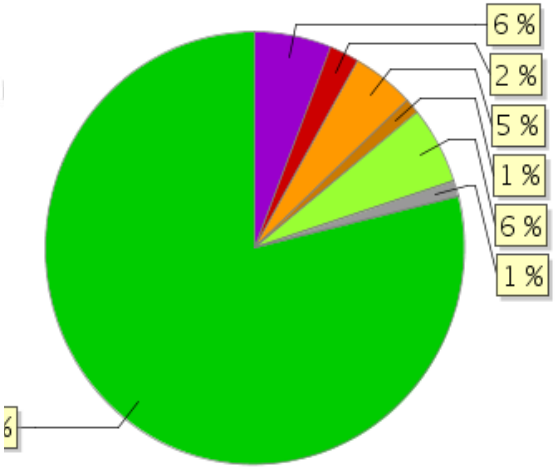
Changes: Coordination & Scheduling

ECRs for LHC - *December 2018*



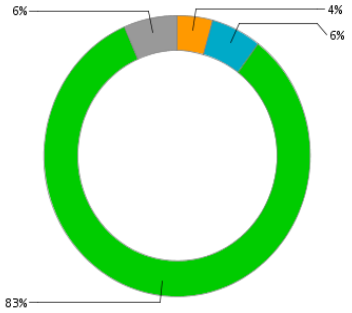
ECRs treated = 62

ECRs for LHC - *October 2019*



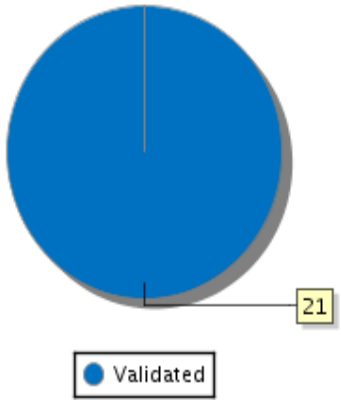
ECRs treated = 80
(5 still needed)

Integration studies for LHC



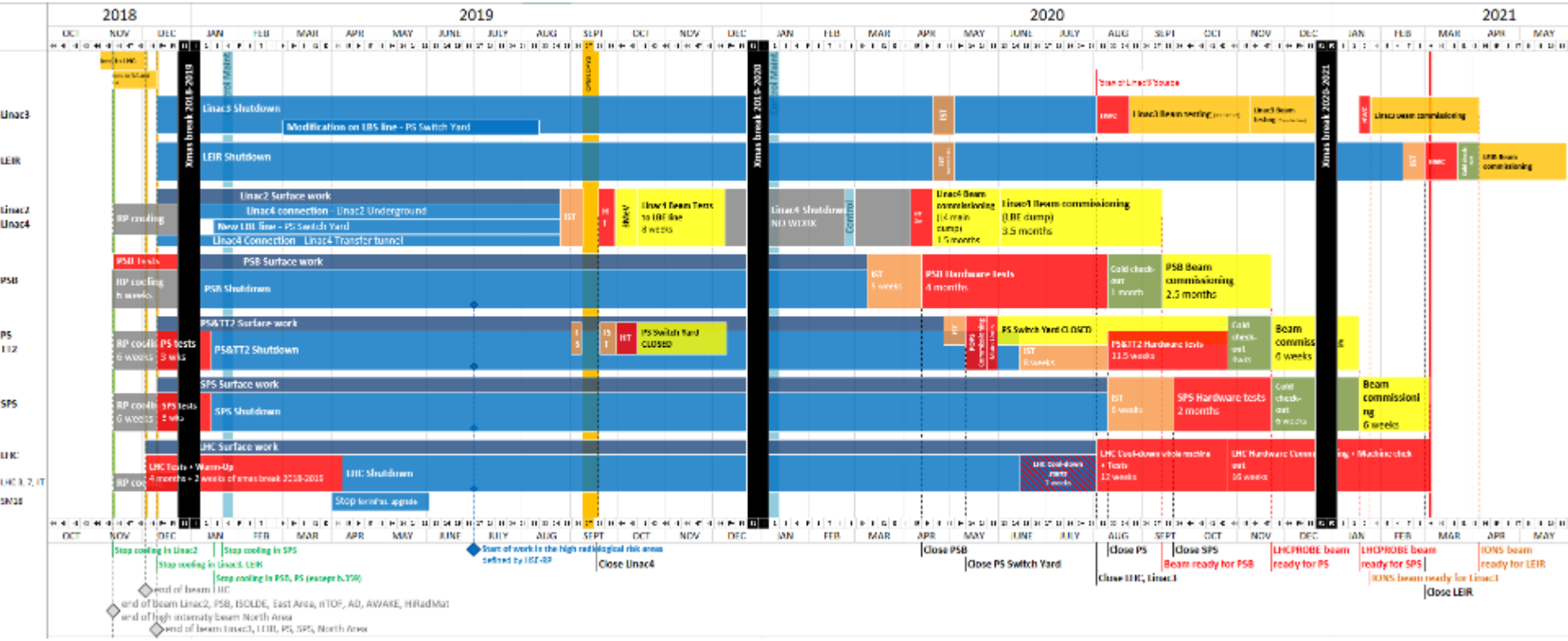
Studies in progress = 5

Differential Layouts



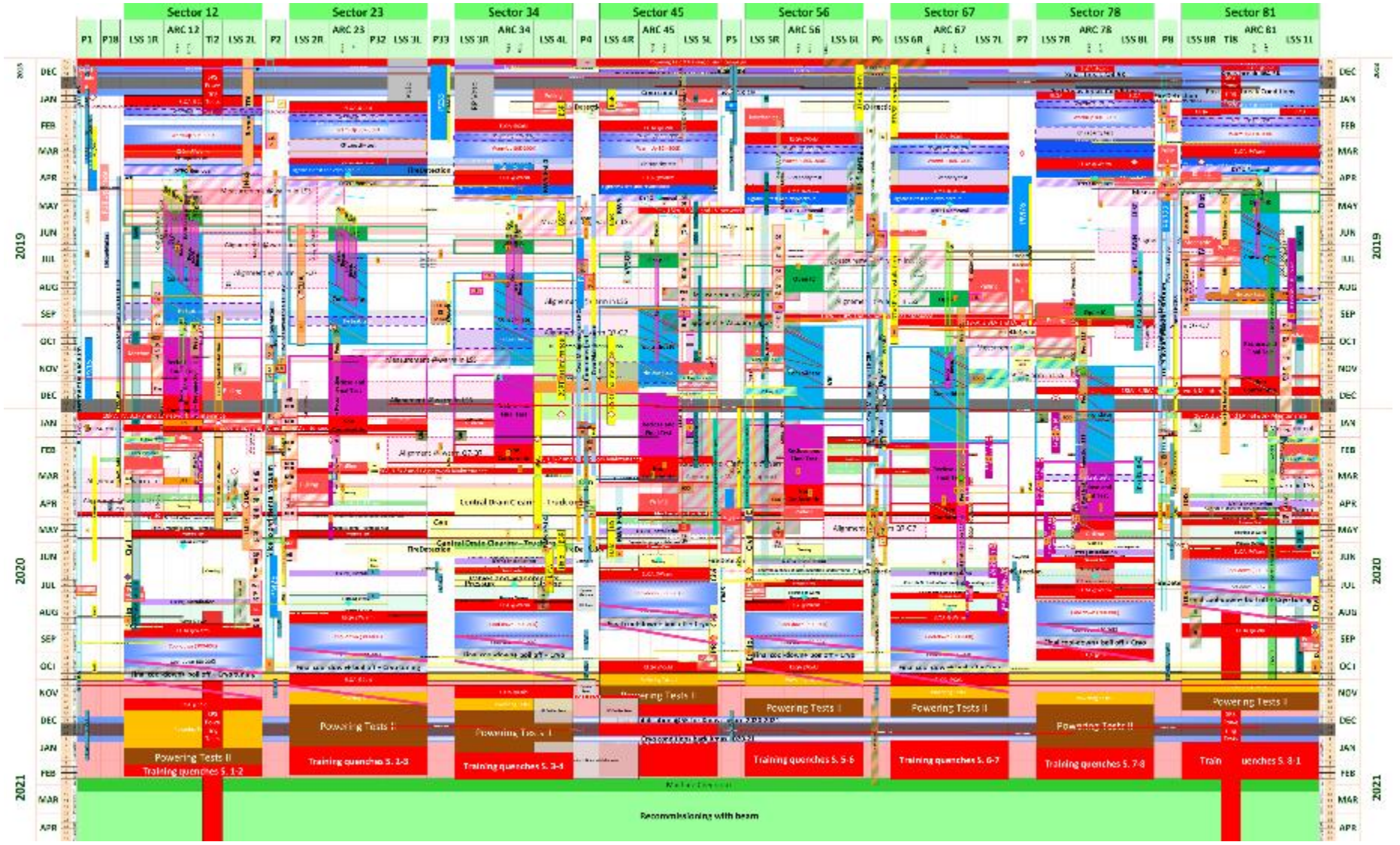
Changes: Scheduling

Master schedule - operational



Coordination & Scheduling

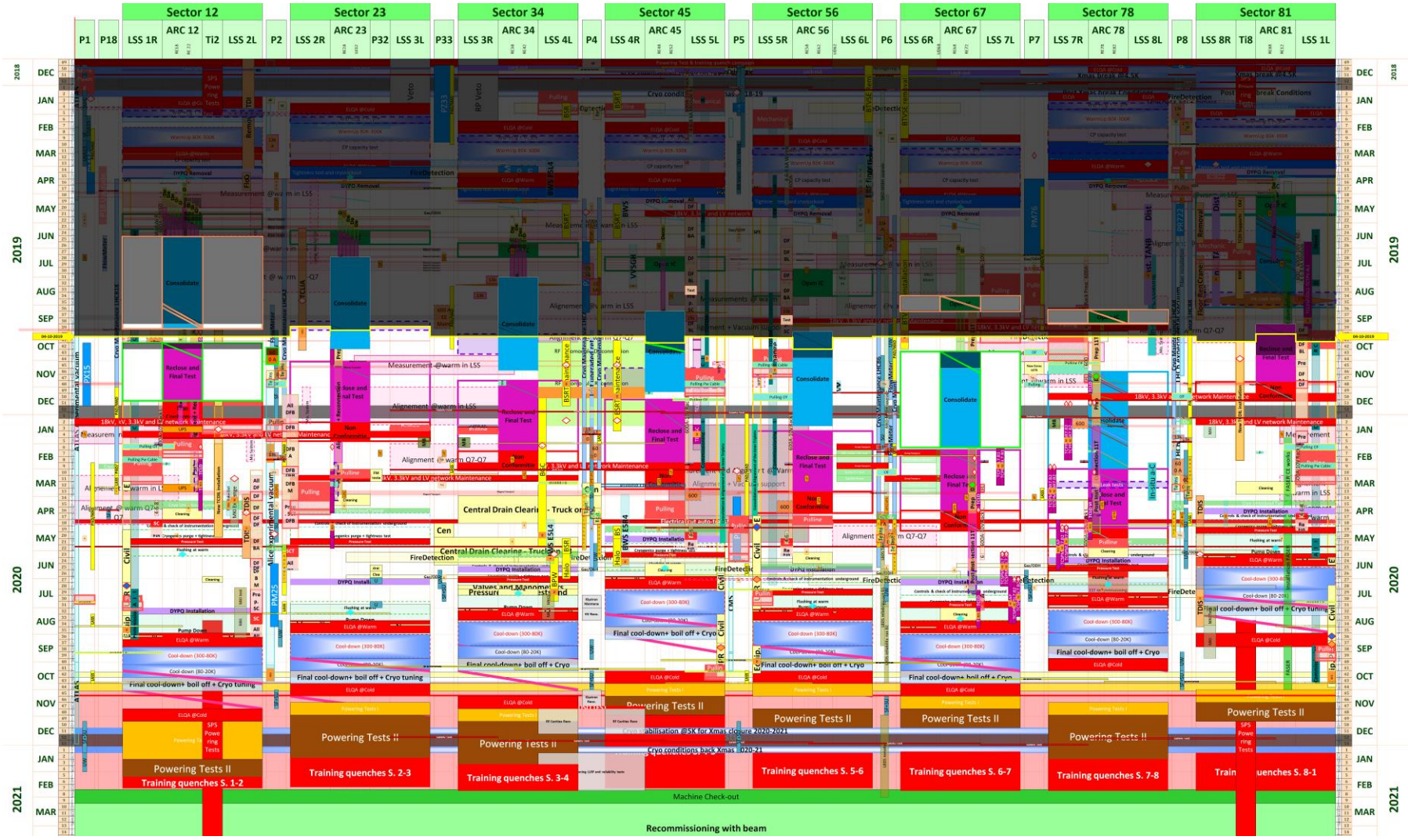
Detailed schedule



Scheduling follow up

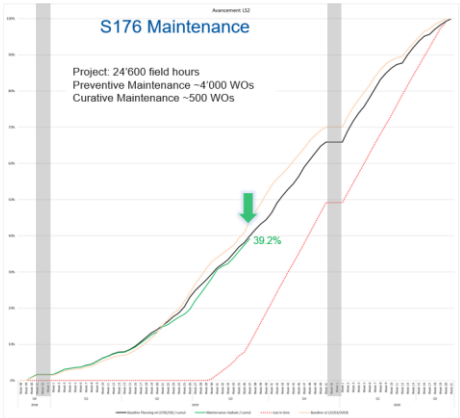
- Specific coordination and follow up for major projects and activities on the critical path
  - Identify and follow up key performance indicators
  - React faster to find out technical solution
  - Ease the delay recovery
- General coordination
  - Global overview
  - Analyse on any deviation on the global schedule
  - Support the groups in ressource allocations and planning processes

LS2: Scheduling follow up



LS2: Scheduling follow up

LS2 Dashboard for CRG maintenance



CERN PLANNING CHANGES
- Maintenance P1 MR + P5 Postponed in 2020
- Mechanical cleaning of exchangers rescheduled
- Replacement of Molecular sieve in dryers P4A & B, P6A
- Reviewed scope for vacuum activities

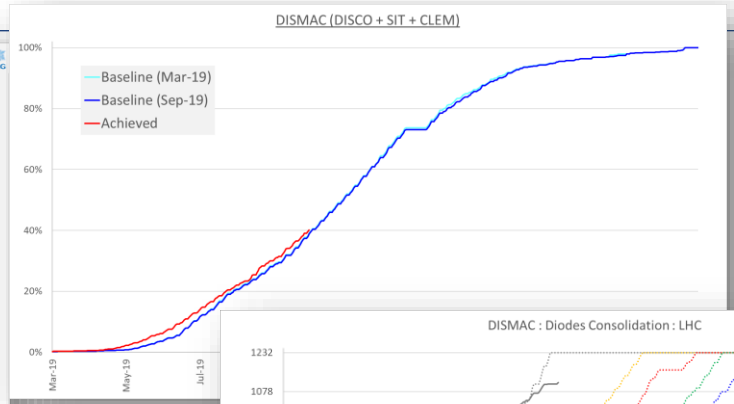
MECHANICAL TEAM - GAP 500h = +1.5 week
- Gap remain stable since mid August
- ACTION PLAN 1 : recover cumulated time loss **PM méca 330h :**
  - Recover the full team + on extra resource effective **beginning of September**
  - Vacuum team mobilized on mechanical tasks **from mid-September till mid-October**
  - Situation to be reviewed beginning of October
- ACTION PLAN 2 : recover cumulated time loss **EX cleaning 170h**
  - Critical EX done, scope of priority 2 will be reviewed end of October

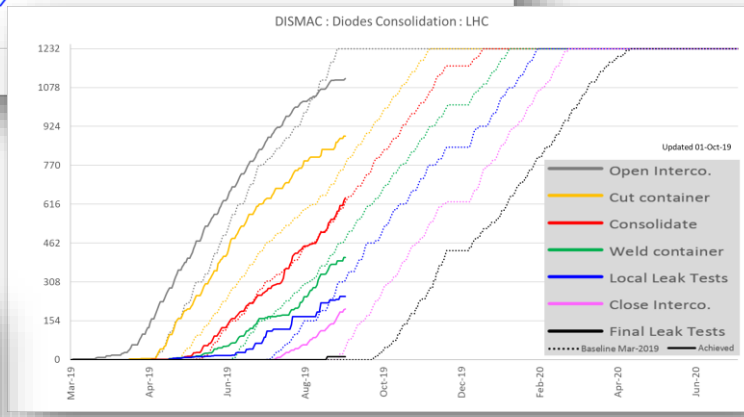
ELEC & INSTRUM TEAM – On time (-200h)
- We get the return on investment on Beamex instrumentation collector

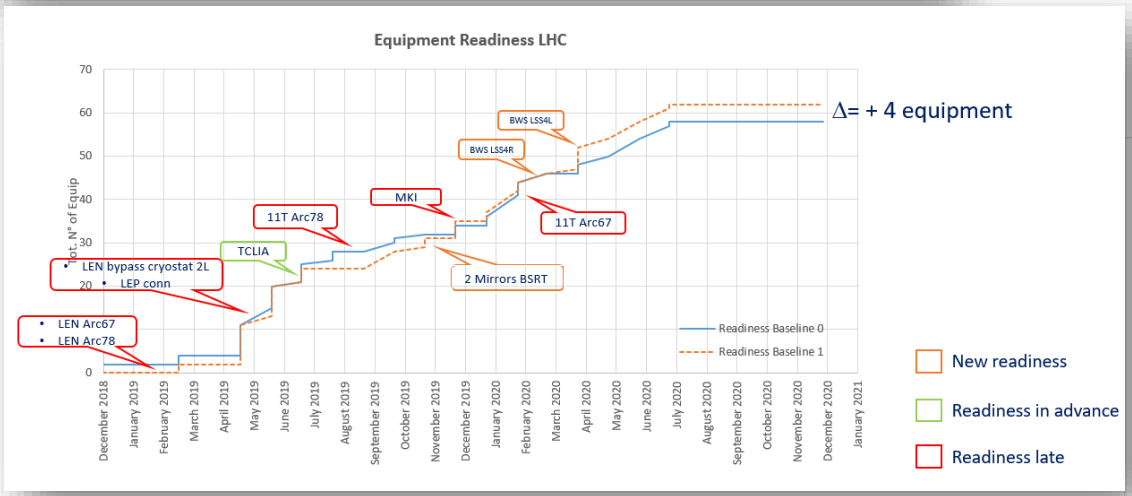
VACUUM – ON TIME – On time (-130h)
- Workload diminishing temporarily in the coming month

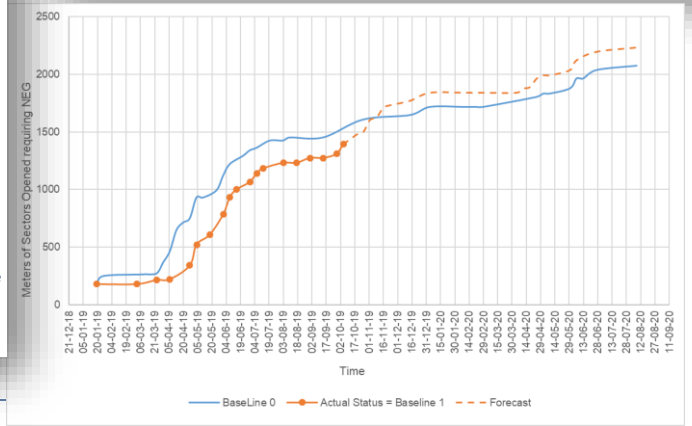
BASELINE Mid-January 2019 | Reference including planning changes | Reported progress | Just in time

5





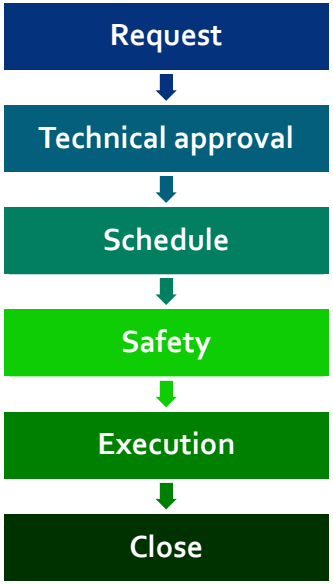


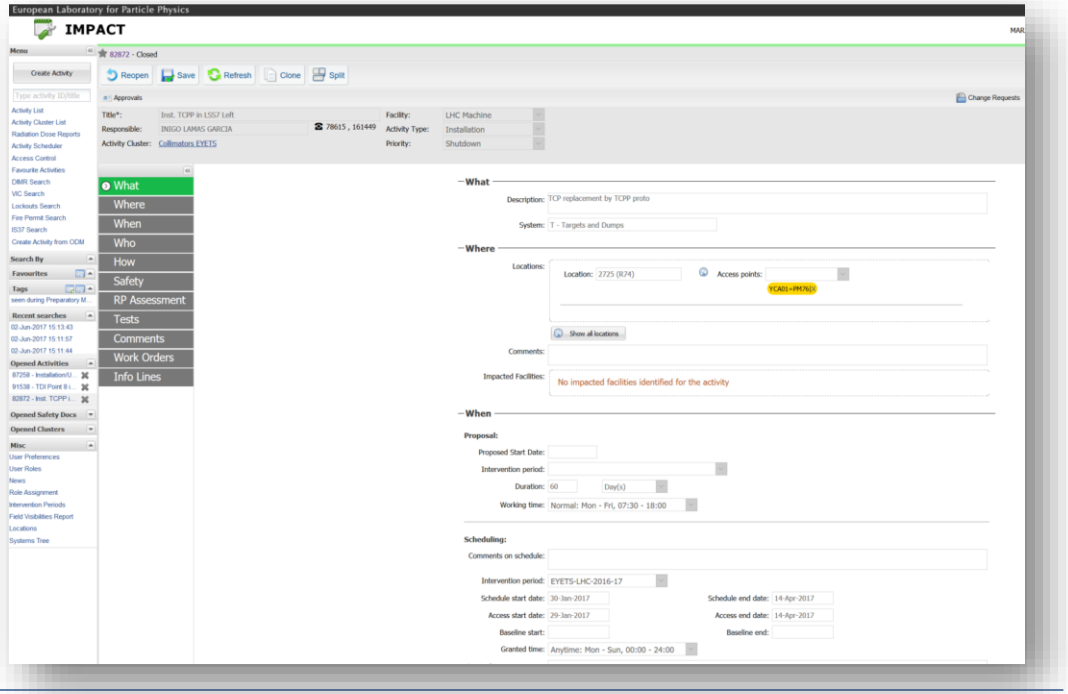


Changes: some tools - IMPACT

- 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





Changes: some tools - 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

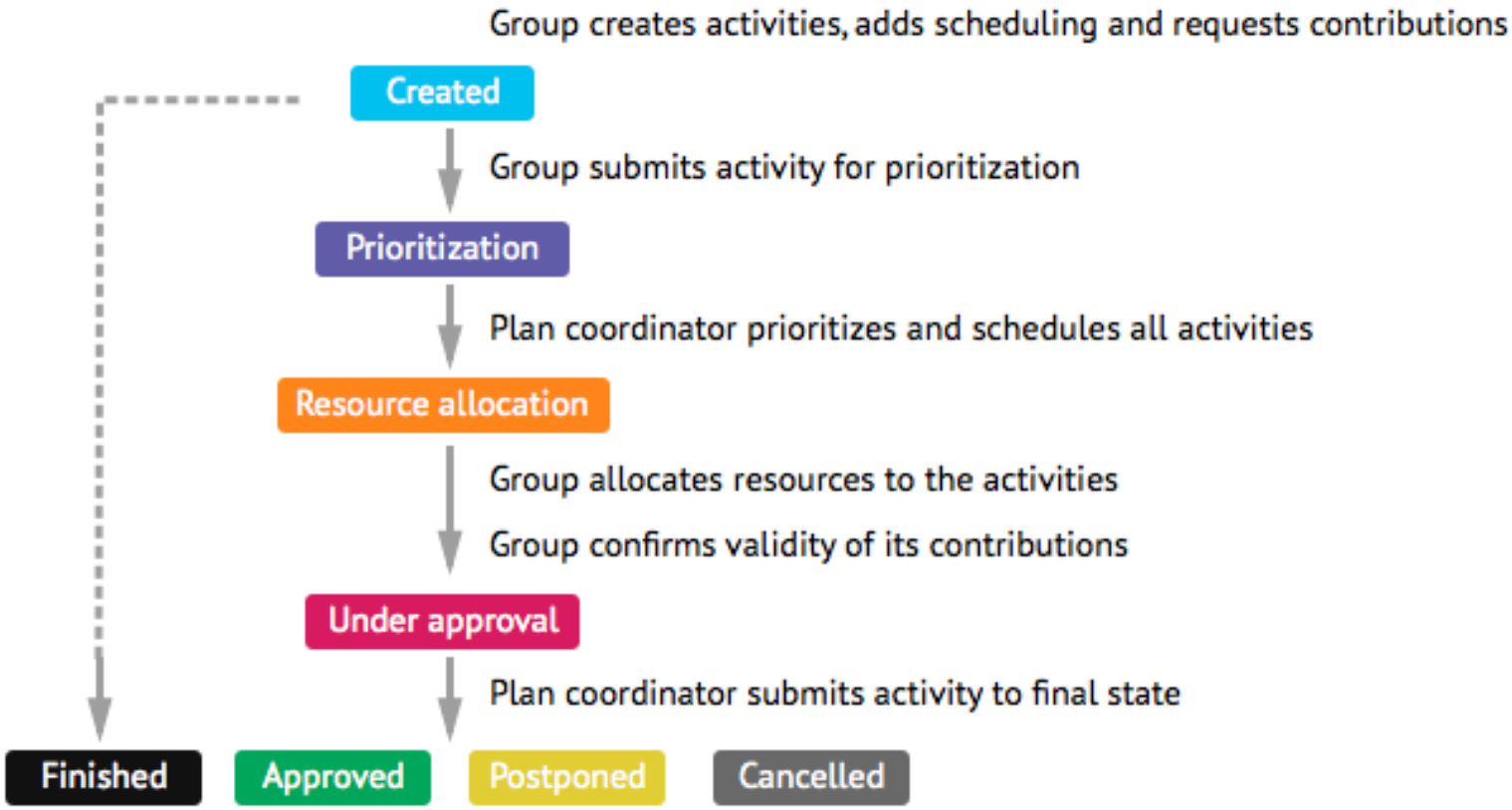
gathering all activities for a certain period of time

with a simple approval process

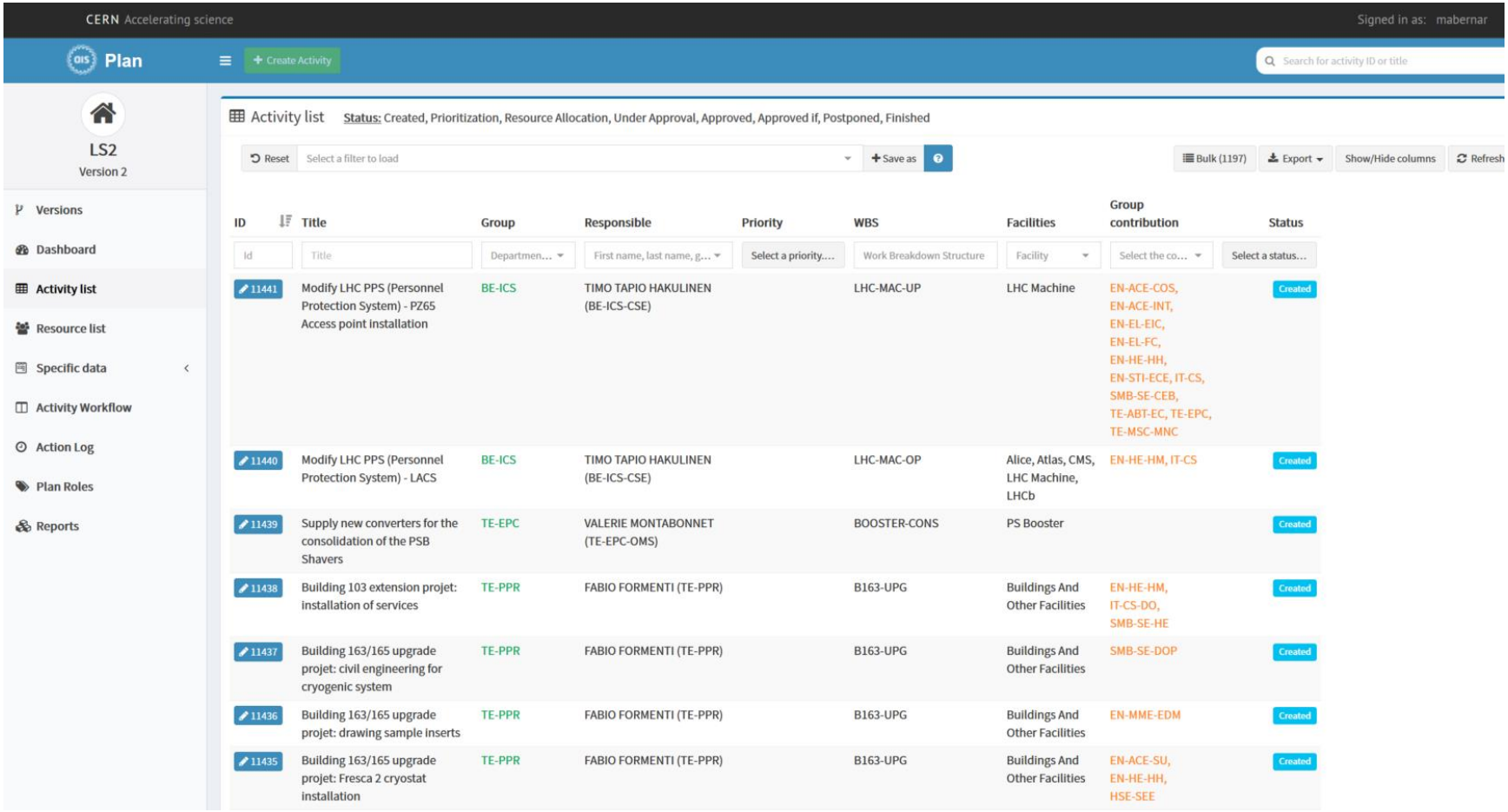
to harmonize the method

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

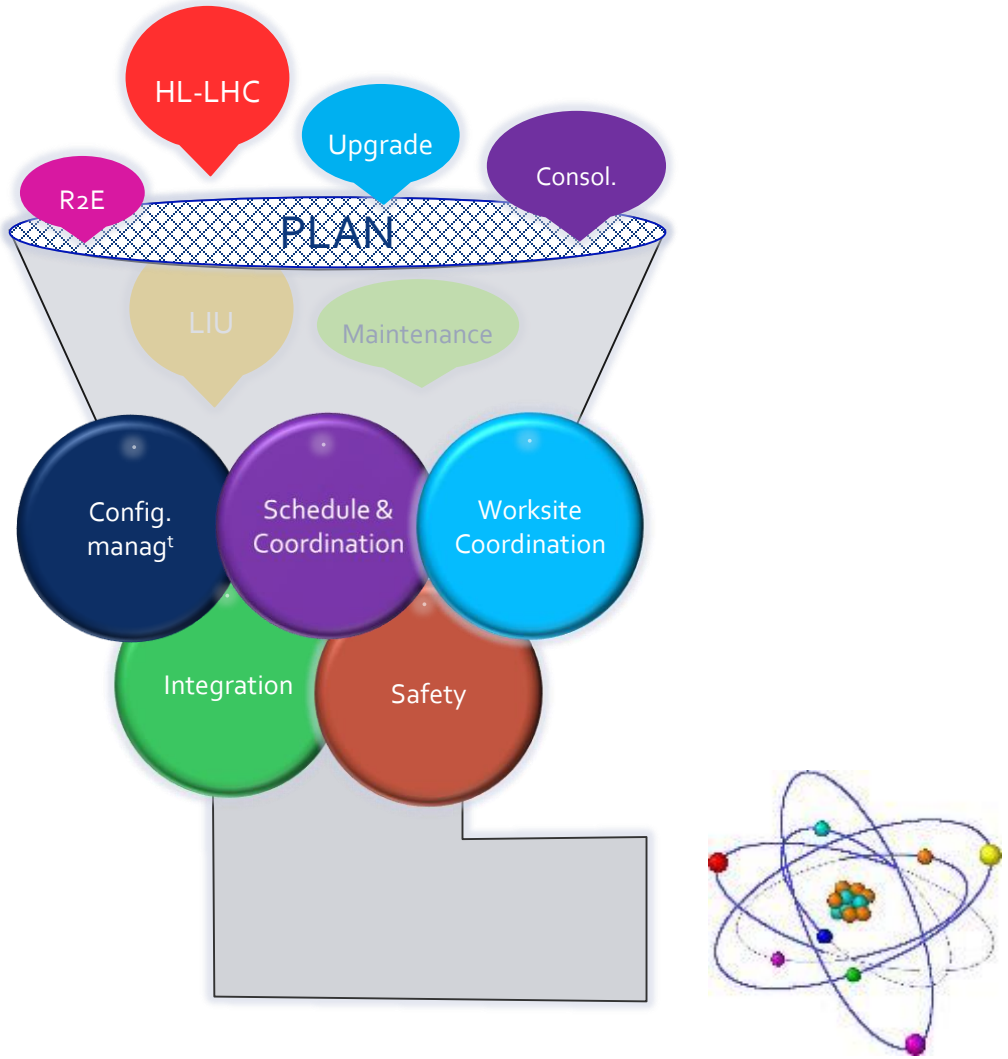
Changes: some tools - PLAN



Changes: some tools - PLAN



Changes: global picture



Conclusions

- A solid & common methodology of project and process management is crucial for a good technical coordination
- The tools must be adapted according to the evolution of the needs during the project, and after
- The on site and safety coordination is a key element
  - Tools to identify deviations must be set
  - Procedures and Work package analysis defined, to anticipate any potential issue
  - Flexibility is a key behavioural competency is our environment
- The bottleneck of technical coordination is often related to expertise and experts availability
  - Anticipate the critical activities to allocate resources accordingly
- In our environment our best resources are human resources
- Expertise, flexibility, accountability and communication are key success factors!

Our best resources are human resources

in addition to a

strong expertise,

flexibility,

accountability and communication !