

## ORGANIZATION

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### Abstract

The organization and the structure put in place for the machine preparation for beam (Hardware Commissioning, Dry Runs over the last 3 years & Machine Check-Out), and for the Injection Tests and Beam Commissioning have been instrumental for the rapid progress of the commissioning of the LHC Machine. After a review of the 2008 experience, the organization for 2009 will be sketched with the expected commissioning steps and the roles of the different actors.

### ORGANIZATION IN 2008

The LHC Commissioning in 2008 consisted of the following phases:

- Hardware Commissioning
- Dry Runs
- Machine Check-Out

- Injection Tests
  - Beam Commissioning
- which run in parallel for a large fraction of the commissioning.

### HARDWARE COMMISSIONING

The Hardware Commissioning phase was mainly dedicated to powering tests (including powering interlock verification) of the magnet circuits after qualification for operation the individual systems (vacuum, cryogenics, quench protection, interlocks, powering, etc.).

The impressive organization and amount of work done are described in [1][2][3].

The Hardware Commissioning organization chart is presented in Figure 1.

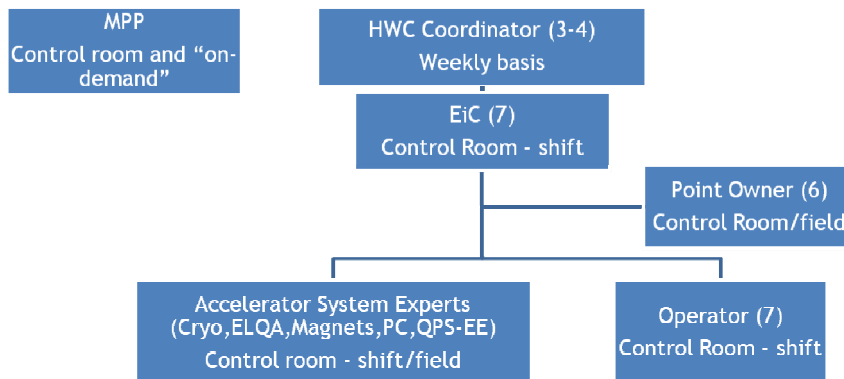


Figure 1: Organization chart for the Hardware Commissioning in 2008.

The following roles can be identified:

**Hardware Commissioning Coordinator:** an engineer/physicist with experience in superconducting circuits. He prepares the conditions for the commissioning: procedures, safety, environment, infrastructure, Quality Assurance assisted by the Point Owners. He defines the commissioning programme and procedures with System Experts. He reports progress and problems to the Project Management and wider community.

**Point Owner:** an engineer/physicist with the knowledge of the “field” (2 sectors at least). He assists the Hardware Commissioning Coordinator in the preparation of the commissioning and the Hardware Commissioning Coordinator and the Engineer in Charge in the definition of the commissioning plan contributing to identify and to solve potential conflicts (e.g. access/safety/installation).

**Engineer in Charge (EiC) on shift:** an accelerator Engineer/Physicist with approximately 2 years experience in the operation of CERN accelerators. He is the

responsible for the safety during the shift, he makes sure that the plan is executed, and he contributes to its execution. He documents the tests and the progress and he coordinates the access in collaboration with the Point Owners.

**Operator on shift:** an accelerator technician with experience in the operation of the LHC Injectors or in the operation of the Magnet Test Facility in SM18. He executes the test plan and he assists the Engineer in Charge in handling the accesses.

**System Expert:** an engineer, physicist or technician with experience in one of the systems involved in the powering tests (cryogenics, electrical quality assurance, quench protection, superconducting magnets, power converters, etc.). He executes the steps required for the preparation of the Hardware Commissioning on the field (electrical quality assurance, quench protection system preparation, cryogenics tuning) or in the CERN Control Centre (CCC) on shift. He monitors, analyses and manages the

performance of his system during the Hardware Commissioning.

The powering tests and their results were closely monitored by a team of superconducting magnet, magnet protection and cryogenics experts composing the Main Ring Magnet Performance Panel (MPP) acting as “control” body with the task of defining/revising the procedures for the tests, monitoring, analyzing and managing all aspects of magnet performance, detecting, diagnosing, correcting or mitigating problems on magnets and superconducting circuits. MPP experts were working on shift in CCC for the on-line analysis of the results of the powering tests or they were working “off-line” for the analysis of detected non-conformities with the aim of understanding their implications for the operation of the machine and of identifying the required modifications or mitigation measures. Finally the MPP had the charge of defining the operational envelope for a circuit taking into account the results of the powering tests.

### MACHINE PREPARATION FOR BEAM

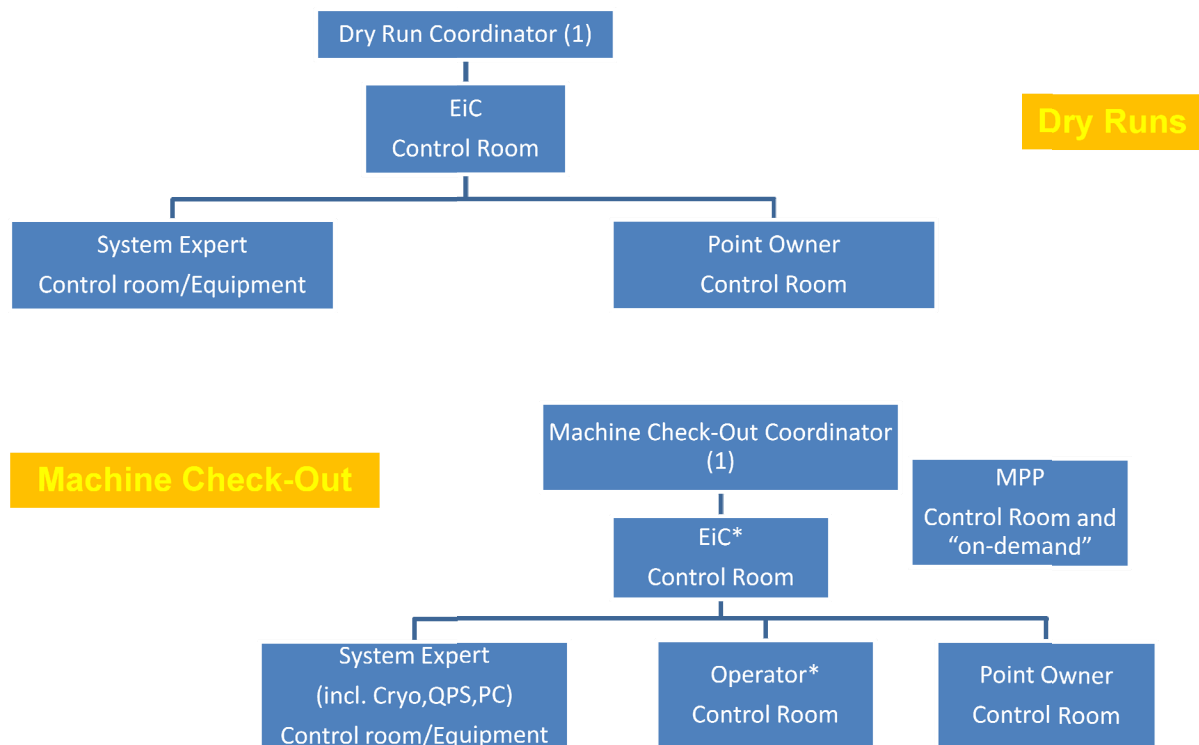
The preparation of the machine as a whole for Beam Commissioning was organized in the form of Dry Runs & Machine Check-Out tests aiming at verifying the operation of several systems mimicking different

operational phases (e.g. injection, ramp, squeeze, beam dump, interlocks tests, etc.).

*Dry Runs* (as those for the injection transfer lines, injection and beam abort system) started in 2003 with the tests of the TT40 extraction from the SPS to the TI8 line. Dry Runs follow individual system tests conducted by the equipment experts and are organized in blocks each spanning over a few days and spaced by few weeks to analyze and correct any problem encountered during the test. Dry Runs take place in CCC using operational software and aim at debugging the systems and their controls. System Experts, System Commissioners and Engineers in Charge conduct the Dry Runs.

*Machine Check-Out* tests (e.g. tracking among circuits and systems, beam interlock & alarm verification) are performed to test the different circuits/sectors in unison and in operational conditions (ramp rates, acceleration rates, settings) once released by Hardware Commissioning and are aimed at integrating an increasing number of accelerator systems (injection, beam dump, RF, collimators, beam interlocks, alarms, etc.) once debugged in Dry Runs. They are designed and conducted by the ‘users’ (Engineers in Charge and operators) from the CCC using operational software.

The organization during Dry Runs and Machine Check-Out is schematically represented in Fig. 2.



**\*On shift approximately one month before beam commissioning start**

Figure 2: Organization chart for the Dry Runs and Machine Check-Out in 2008.

The following roles can be identified:

Dry Run and Machine Check-Out Coordinators. They are accelerator physicists with at least 10 year experience in accelerator operation (LEP, LHC injectors) and machine

supervision. The coordinator defines the test programme with the Accelerator System Experts and Commissioners taking into account the constraints imposed by parallel activities like Hardware Commissioning, installation,

Machine Check-Out, Dry Runs. He makes sure that tests procedures exist, they are updated and available for the people executing the tests. The coordinator reports on the progress of the Dry Runs and Machine Check-Out and on the issues arising to wider community (management, experiments, equipment experts, etc.).

An Engineer in Charge and/or an Operator assist the System Commissioner or System Expert in executing the tests. He updates the procedures and the sequences for the tests and their results. The Engineer in Charge is responsible for the safety when on shift. An Engineer in Charge or an Operator were on shift (2 shifts/day during working days) for the Machine Check-Out starting approximately 40 days before the start of the commissioning with circulating beam. Two weeks before the start of the Beam Commissioning full coverage (7/7 – 24/24) was available. When two Engineers in Charge were on shift the Engineer in Charge for the Hardware Commissioning was taking the role of responsible for the safety.

The System Commissioner or Expert is a physicist or engineer with experience in accelerators or accelerator equipment. He is not necessarily the “provider” of the system (in particular during Machine Check-Out) so that the verification of the functionalities of the systems is conducted by experienced potential users of the systems. The System commissioner makes sure that the system under his/her responsibility is tested from the CCC and ready for Beam Commissioning. The System

Commissioner or Expert defines the tests procedures, implement them in collaboration with the Coordinators and the Engineers in Charge and finally documents the results of the tests.

The Point Owner assists the Coordinator/Engineer in Charge in identifying and solving potential conflicts between the Hardware Commissioning and Machine Preparation activities in particular with respect to powering, access and safety.

### BEAM COMMISSIONING [4][5]

The LHC commissioning with beam has been preceded by Injection Tests occurring in the last part of the Hardware Commissioning and Machine Check-Out phases as soon as the sectors passed the Hardware Commissioning tests.

Injection Tests proved to be invaluable to [6]:

- debug fine timing and synchronization,
- debug instrumentation with beam for the first time,
- conduct a final verification of the machine configuration (polarities, settings),
- test tools for threading and optics measurements,
- speed-up the commissioning with circulating beam by correcting all the issues found during the Injection Test.

The organization during the Beam Commissioning phase is schematically represented in Fig. 3.

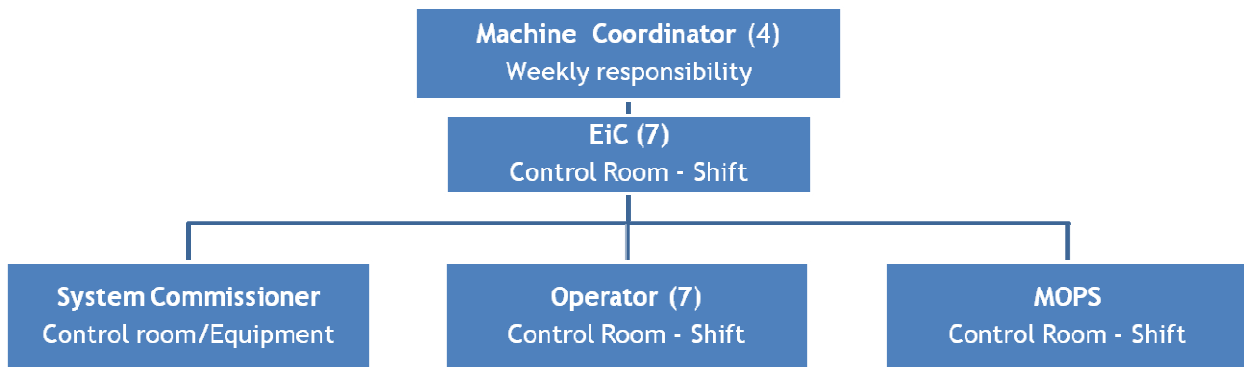


Figure 3: Organization chart for the Beam Commissioning in 2008.

In this organization the Machine Coordinator is an experienced accelerator physicist with the overall responsibility for the LHC machine on a weekly basis. He implements the LHC commissioning program according to the procedures established by the LHC Commissioning Working Group [7][8]. He supervises and directs the shift crews and he coordinates the contributions of the Commissioner/Experts in the different phases of the commissioning. He ensures that the necessary follow up is done for issues arising during the commissioning. He reports on progress and potential problems to the wider community (Experiments, Management, etc.).

The System Commissioner who, in the Dry Run or Machine Check-Out phases, has contributed to the commissioning of a system (e.g. RF controls tests) or to the preparation of a phase (e.g. tests of the squeeze sequence without beam) defines and conduct the necessary beam measurements (e.g. those needed for the RF capture or for the setting up with beam of the squeeze) and implements corrections in collaboration with the Engineers in Charge according to his expertise in an accelerator or accelerator physics system. He has a hands-on experience on the controls of the machine developed during the Dry Run and/or Machine Check-Out phases. The System Commissioner passes on information to the Engineers in Charge for incorporation into routine

operation concerning the procedures developed and tested during the commissioning with beam.

During this phase the Engineer in Charge works on shift (7/7 – 24/24) under the direction of the Machine Coordinator and he takes the overall responsibility of the LHC during the shift. He drives the machine through the operation cycle, he establishes procedures for future operation and he assists the System Commissioner during the Commissioning of a system or of part of the operational machine cycle.

The Operator on shift (7/7 – 24/24) assists the Engineer in Charge and the System Commissioner.

The MOPS (Magnet Operation and Performance Support) Expert [9] is Engineer or Physicist with experience in superconducting magnets and magnet protection. He monitors, analyses and manages the superconducting circuits performance (including the electrical feed and protection systems) in relation to their impact on machine availability and performance. He authorizes powering of the magnets integrating all relevant conditions, including quench protection, cryogenics and vacuum. He contributes to the understanding and refinement of the LHC magnetic model.

## EXPERIENCE IN 2008

The success of the Beam Commissioning in 2008 is to a large extent the result of the careful preparation through Hardware Commissioning, System Integration tests & Dry Runs, piece-wise Machine Check-Out and Injection Tests. Installation, Hardware Commissioning and Machine Check-Out have overlapped in time significantly. This cohabitation worked thanks to the good will of all the parties involved and in spite of:

- the interferences in the last part of the commissioning due to the increasing number of fronts opened both for Hardware Commissioning and Machine Check-Out
- the sharing of limited resources in terms of experts (MPP, QPS), Engineers in Charge, Point Owners, Operators.
- The problems encountered in the operation of the Access System.

The time pressure for the Beam Commissioning on one side and the problems encountered during the Hardware Commissioning on the other almost zeroed the amount of time with the complete machine closed and conditions for operation. As a result of that the machine protection could be tested in its minimal configuration, only sufficient to allow operation at pilot intensity and injection energy (e.g. Beam dump tracking could not be tested thoroughly) [10]. This implies postponing part of the machine protection tests in the Beam Commissioning phase but also the definition of envelopes (intensity, energy, emittance) for safe operation of the machine [11].

Contribution from the early phases of the commissioning is a key ingredient to achieve a proper training of all the actors participating to the Beam

Commissioning and Operation phase. This should be encouraged in order to have a sufficient number of people to avoid “burn-out” and increase further their effectiveness during Beam Commissioning. In that respect the involvement of the System Commissioners to the Commissioning has been concentrated in most cases (with few exceptions) during the Injection Tests and Beam Commissioning. The involvement of the System Commissioners should be therefore extended to Dry Runs and Machine Check-Out.

The participation to the Machine Preparation for beam has served as training for the Engineers in Charge and operators in the operation of the various machine systems and their controls but it needs to be complemented with training sessions during the shut-down when the workload due to the powering and test activities is still moderate.

## PROSPECTS FOR 2009 AND POSSIBLE IMPROVEMENTS

Realistically an important overlap among the different phases and components of the commissioning is to be expected also in 2009. Dedicated periods of a few days with machine closed and all systems available need to be scheduled (and maintained) to test machine protection either during Machine Check-Out or during the very early phase of the Beam Commissioning.

Important modifications are taking place with respect to the original design of the magnet protection and new test procedures needs to be envisaged with the contribution of the magnet and magnet protection experts [2].

As a result of the Sector 3-4 incident and the corresponding safety risk analysis tighter rules are expected for the access in the tunnel and experimental caverns during powering. These need to be defined soon in order to evaluate the impact on the cohabitation of Shut-Down, Hardware Commissioning, Machine Check-Out and Experiments activities. A tighter coordination among them will be certainly required.

Some of the Coordinators, Equipment Experts, Point Owners have left and therefore the team in charge of the Hardware Commissioning and of the preparation for beam needs to be strengthened.

It must be noted that the attachment of the Point Owners to BE/OP will result in a larger synergy and an exposure of the different actors to a larger number of phases of the commissioning with different roles, although it will imply a longer effort for the same group of people. In that respect contributions from a larger pool of people (in particular the System Commissioners) should be encouraged.

The creation of a team of Machine Coordinators responsible of the coordination of the Commissioning in its different phases from HWC to Beam Commissioning would help in:

- strengthening the Hardware Commissioning team,
- making more transparent the line of command for all the actors involved,

- minimizing conflicts in the assignment of resources for the different phases,
- providing a clear interface for the experiments, management and wider community,
- the overall planning of concurrent commissioning activities.

The larger spectrum of activities that the Machine Coordinator is requested to cover is likely compensated by the experience gained in 2008 and by the availability of procedures (although some of them might need to be modified). Furthermore the effort to be provided by the Machine Coordinators will extend over a longer period and for that reason their number should be increased to more than four.

Involvement of all the System Commissioners, Engineers in Charge and Operators is essential from the beginning of the commissioning as training for effective operation of the machine during beam commissioning and later.

The exact organizational structure would then adapt to the different phases but with some roles present all along the duration of the commissioning and during the operational phase (e.g. Machine Coordinators, Engineers in Charge). A possible scheme is shown in fig. 4.

The availability of Machine Protection Experts will be important from the early phases of the commissioning [11] to:

- help in defining the conditions for safe operation of the LHC within the envelope of the Machine Protection System during the staged commissioning (intensity and energy increase);
- provide support to the Machine Coordinator and the Engineer in Charge in defining the mode of operation of the machine in case of abnormal operation of any element of the Machine Protection System.

Equally important will be presence of magnet and magnet protection experts in the control room in particular in the Commissioning and Early Physics phases.

The expert coverage (shift vs. on-call) should be reviewed and might vary according to the phases.

## SUMMARY AND CONCLUSIONS

The organization and the structure put in place for the piece-wise machine commissioning (Hardware Commissioning, System Integration tests & Dry Runs over the last 3 years, Machine Check-Out, Injection Tests) and for the Beam Commissioning have been instrumental for the rapid progress.

The overall strategy for the commissioning and its phase will remain mostly unchanged. The proposed modifications to the organization are mainly aimed at:

- distributing the load of the commissioning and (potentially long) operation over a larger team from the early phases of the commissioning,
- simplifying the line of command and minimizing the potential conflicts,
- favouring training of the actors contributing to the commissioning of the machine at an early stage talk.

## ACKNOWLEDGEMENTS

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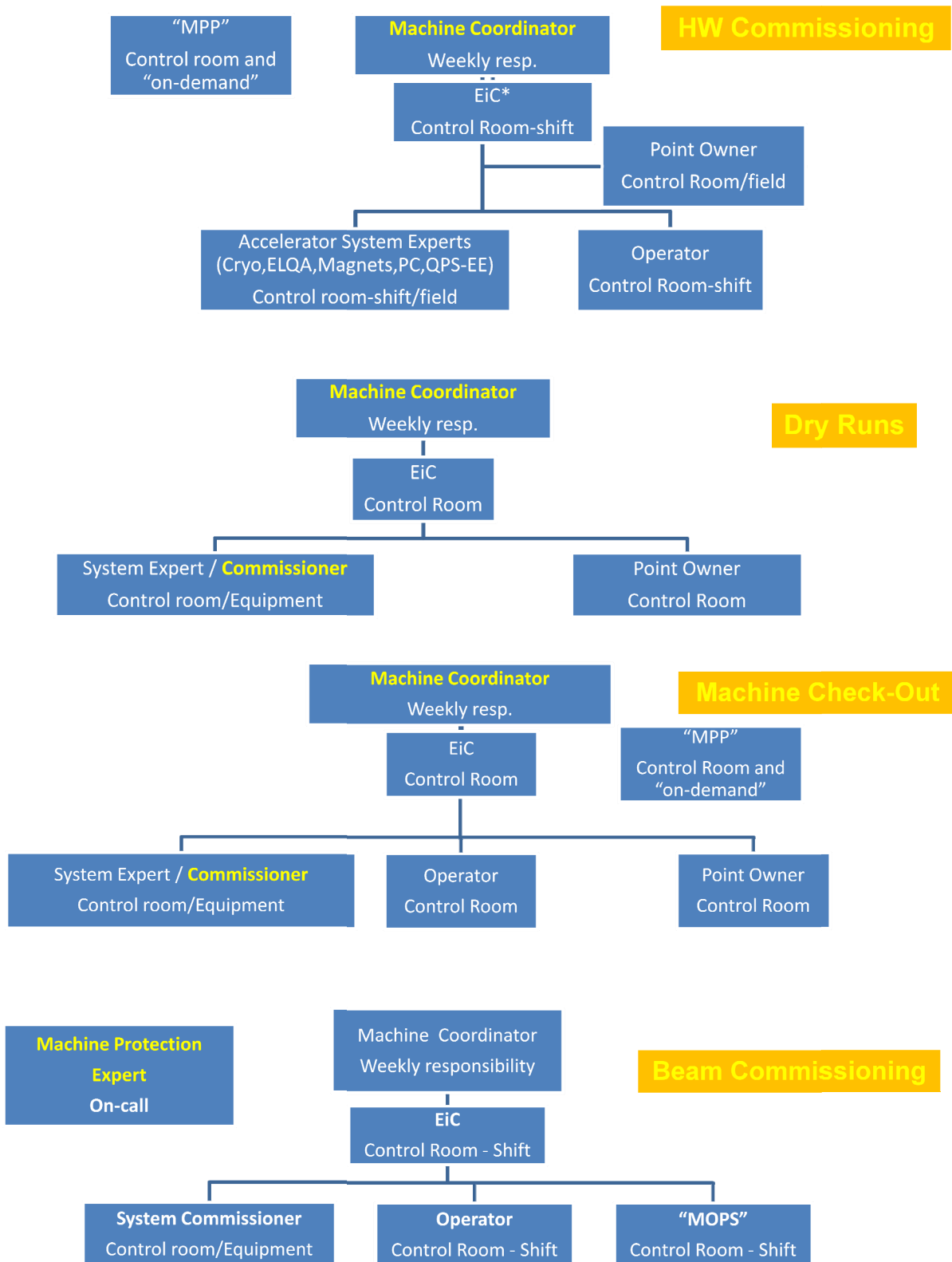


Figure 4: Possible organization charts for the different phases of the commissioning in 2009. In yellow the differences with respect to the 2008 organization are highlighted.