Hardware commissioning across the injector complex

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• The preparation of the planning of the hardware commissioning periods in the different machines is only starting.

• This talk will therefore mainly focus on strategy
  ▪ Define the various phases and requirements
  ▪ Indicate where clarification of responsibilities or required resources still necessary
  ▪ Describe how we will work to be adequately prepared
→ Very short time for first standalone beam commissioning in schedule

→ PREPARATION IS KEY
How to prepare for efficient beam commissioning

• From the draft beam commissioning plans:
  ▪ Determine what is required to produce all operational beam types and required operational modes (COAST,...)?
  ▪ Prioritise those beams or scenarios that are required first or have greater impact

• Define and prepare the availability of controls interfaces, tools, algorithms for each stage leading up to beam commissioning
  ▪ Dry runs – staged deployment of systems throughout LS2
    - Which additional systems, services or tools are required
  ▪ Individual system tests
    - Which tests, which general services are required, what access conditions
  ▪ Hardware commissioning tests
    - Make sure controls are available and stable in advance of Hardware availability
  ▪ Check-out tests
    - Special conditions and tools (simulated signals, masked interlocks,...)?

• Listing of new equipment and main new functionality

Beginning of LS2
Coming months
How to prepare? – typical plan of attack during LS2

- Define, prepare and test integration of new/upgraded systems
  - Defines FESA readiness dates taking into account high level software adaptation
  - Staged deployment: defines vertical slice tests/dry runs
  - Define IST test requirements

- Synchronise new/LIU testing with “standard” hardware commissioning

- Prepare IST, hardware/beam commissioning and check out
  - Planning, procedures, check lists

Main part of LS2

As an outcome and in parallel to the above
How to prepare? – who is responsible

• The preparation for restart will be overseen by commissioning working groups per machine
  ▪ Membership: OP, re-commissioning coordinators, equipment groups, beam dynamics experts

• In addition: specific integration working groups for various systems
  ▪ Work out in detail integration of larger systems (e.g. RF systems, Beam dump systems…)

• Planning and coordination of the hardware commissioning and check-out phases by re-commissioning coordinators from the CCC
  ▪ Co-responsibility with EN-ACE during IST

• IST responsible: equipment groups
  ▪ Preparation and definition between shutdown coordination meetings and commissioning meetings
Remark: Commissioning ≠ re-commissioning

- Restarting a system or equipment that has not undergone significant modification is not the same as commissioning a new system.
- History, reference and experience will not exist for several systems.
- Commissioning of new systems to be conducted hand in hand with equipment experts.
  - Check lists will have to be completed during testing or procedures re-written for post-LS2 start-ups.
- Commissioning of new systems will run in parallel and will be somewhat independent to recommissioning activities but must be synchronised to general HWC.
  - Full system integration towards end of HWC and start of cold checkout.
- Training will be needed to explain the differences, functionalities and limitations of the new systems.
  - Will partly come through working on the integration.
  - Formal training/information sessions should be organised prior to HWC.
What are Individual System Tests?

- Allows equipment groups to test as extensively as possible the functionality of their systems independently of the wider control system
  - Equipment affected by “Mise hors tension partielle”* to be tested in well defined IST blocks
  - Systems not affected by “Mise hors tension partielle” can be tested at any time prior to HWC, subject to declaration and agreement with EN-ACE and BE-OP. Ideally to be planned outside of main IST blocks

- Coordinated in collaboration by EN-ACE and BE-OP
  - Equipment groups should declare which tests they intend to conduct and discuss any necessary pre-requisites

- Tests take priority. Intervention is secondary
  - Shutdown works should generally be complete prior to IST

- OP strongly encourages the use of the IST by all equipment groups for primary fault finding – objective: to identify and resolve HW issues prior to the start of HWC period
  - We hope not to discover equipment remaining “consigné” or disconnected once into HWC period

- Details of responsibilities and durations of the IST are still to be defined, ideally with a common approach across machines

*Separation de reseau affects: RF, Septa, Kickers, and power supplies
What is Hardware Commissioning?

- Checking that the machine has been reassembled as foreseen
  - All cables connected and to the right equipment
  - Cooling circuits operating correctly, not restricted, leaking etc
  - A correctly executed IST will undoubtedly facilitate HWC

- Any tests which require machine closed
  - Main magnet and power supply tests
  - Testing of interlocked elements
  - Safety systems tests, DSO tests etc

- Heat runs, reliability runs, stability checks, polarity checks

- Initial controls checks – can we remotely control, trim all equipment under operational conditions? Ensure that physics parameters trimmed corresponds to correct hardware trims

- Previous HWC periods were slowed down by outstanding access requests
  - 86 impact requests made during 2018 SPS HWC period (some of which were unavoidable, many of which were avoidable)
  - Coordinating these access requests is a big job in itself
What is a cold checkout?

• To bring accelerator to beam ready conditions
• All foreseen cycles generated with settings and functions verified
  ▪ Comparisons to previous settings where references and history exist
• Verifications to switching of operational configurations timing sequence editing etc. under all operational scenarios e.g. coast, LHC mastership
• Verifications of interdependent systems (see next slide)
• Verification of interlock systems (BIC, SIS, WIC, FEI, FMCM, etc.)
  ▪ Machine in beam ready condition, BIC loop closed (where possible. Mask, bypass and/or simulate where not) Ensure interlocks react as expected
  ▪ Ensure all masks, bypasses and simulations are reverted prior to beam
Typical checkout test: pulse the SPS-to-LHC extraction kickers

- SPS-to-LHC extraction kickers are interlocked with the extraction interlock system and the SPS energy.
- In addition they only pulse if the RF pre-pulse is available and the cycle has the correct dynamic destination.

Goal: pulse extraction kickers from remote

Pre-pulse RF

All interlocks OK

Correct dynamic timing destination

BETS tracking

Mains pulsing
Hardware commissioning time line – SPS example

- LS2
- IST
- TE-EPC main power supply tests

HWC:
- Heat runs, cycle verifications
- Polarity tests
- Etc.

Cold checkout
- Simulated beam conditions:
  - Interlock verifications
  - Etc.

Beam commissioning

“Mise hors tension” removed
Patrol: Access controlled from CCC? TBC
First beam injected

HWC period

Priority for access and intervention
Priority for testing
HWC priority: Access and intervention only upon OP request or breakdown

EN - ACE
BE - OP
IST breakdown – SPS example

Removal of “mise hors tension” point by point (Subject to LS2C approval) Patrol, closure, balisage details TBC

Access and fire safety global commissioning

Period with potential access and testing in parallel - Requires careful coordination

IST details, durations and planning remain to be fully defined

Strong collaboration required between EN-ACE, BE-OP and equipment groups
Summary of main upgrades Affecting HWC*

- **LEIR & LINAC3**
  - Minimal LIU works in ion chain
  - Ventilation renewal
  - Injection line BPM electronics etc.
  - RF low level and amplifiers
  - Controls Change Requests = 2

- **LINAC4**
  - Integration into accelerator chain (timing access, etc)
  - Commissioning of new transfer lines
  - Interlock systems BIS, WIC, SIS FEI, etc
  - New OP control applications
  - Controls Change Requests = 5

- **PSB**
  - Finemet cavities
  - POPSB and AUX power supplies upgrades
  - Interlock and safety systems upgrade
  - Beam instrumentation improvements
  - Controls Change Requests = 16

- **PS**
  - 2GeV injection
  - Main magnet consolidation
  - Cable campaigns
  - TT2 converters & New FGCs
  - Controls Change Requests = 18

- **SPS**
  - 200MHz cavity upgrades
  - Access system renewal
  - RF digital low level
  - Fire safety systems
  - Beam dumping system upgrade
  - Cable campaigns
  - ALPS beam position measurement
  - TE-EPC MACAO controls
  - Controls Change Requests = 21

*Not exhaustive

Pending request for LINAC4
1 week IST

More time may be required for switchyard HWC? Under evaluation TBC
Controls

- **BE-CO LS2 planning managed by Machine Controls Coordinators:**
  - M. Gourber-Pace = LINAC4, CPS, SPS. Also planning officer in BE-CO.
  - E. Fortescue-Beck for PSB
  - A. Dworak for LINAC3, LEIR

- **BE-CO announced end of life deadline for several legacy critical elements: 1 January 2020**

- **BE-CO plans 3 software coordinated releases in LS2 resulting in LS2 baseline release taking us up to LS3**

- **Front end and software freeze dates are still to be defined**
  - *Front ends undergoing significant upgrade MUST consider and allow time for downstream application upgrades and adaptations*
  - *Machine Controls Coordinators and OP Linkpersons should be consulted.*

- **Major CO HW and SW changes (pulse repeaters, sequence manager,…) will require re-qualification time**
  - Either in dedicated time or in background during the systems re-commissioning by EQ and OP groups.
Shutdown to beam timeline – SPS example (precise dates TBC)

DRY RUN: RF cavity control (with cavity model): full LSA integration

DRY RUN: SPS ALPS single sextant test

DRY RUN: Upgraded timing system

DRY RUN: ALPS Global test

DRY RUN: Many more to come … To be followed up by commissioning WG

First beam!
Tools – check lists, ASM planning

- Check list tool available across the complex and evolving since 2017
  - To define tests with procedures
  - To track test results with comments,…
  - To provide statistics
Tools – check lists, ASM planning

• Check list tool has proven to be very useful and allows tracking and follow up that didn’t exist previously

• Check lists have grown – management and linking of tests is to be made easier
  ▪ More than 10’000 tests in the SPS
  ▪ Also integration with logbook and screenshotting to be improved

• Next generation check lists are to evolve and be coordinated through commissioning coordination committee

• Ideally these improvements should be in place for 1st stage LINAC4 HWC starting mid Sept 2019
Tools – check lists, ASM planning

- Historically various tools used for HWC planning
  - Excel, MS Project, Outlook calendars….and even more primitive methods!
- ASM Trialled throughout the injector complex in 2018
- → turned out to be not sufficiently flexible and the layout not adapted for scheduling of tests
- Possible improvements to ASM under discussion to allow task dependencies and rescheduling
  - Should already be available for trial for LBE run preparation
Resources

- **IST: operators on shift during extended days?**
  - Depends on required access mode – remains to be clarified
  - Might have impact on flexibility of OP for commissioning meetings, software development, etc …

- **All piquets available from start of HWC in relevant machine**

- **OP Night and weekend shift from cold checkout period depending upon needs**

- **Will have to plan testing time slots for hardware experts during hardware commissioning**
  - Repartition of hardware experts across machines to be evaluated
  - Priorities to be defined
Hardware commissioning preparation - Status

- Hardware commissioning periods under development for all injectors with the exception of LINAC4 which is already well defined

- Recommissioning coordinators are:
  - Gathering information of what has or will change and what testing is required
  - Understand the consequence of upgrades to HW tests and estimate testing accordingly
  - Better define the allocation of HWC period in conjunction with equipment experts
    - Estimate if allocated time is sufficient or can be optimised
  - Identify potential conflicts and investigate mitigations
  - Aim to have a first solid draft for HWC -10 months
  - Well defined with checklists adapted by HWC -3 months

- End of this year: check whether allocated time in schedule really fits
Risks for schedule?

• As mentioned: HWC planning only beginning \(\rightarrow\) impact on schedule not yet clear

• Challenges will come from
  ▪ Inter-machine conflicts – Both technical and resources
  ▪ Management of Christmas stop 2020/21 to guarantee hot start
    - Part of the machines in beam commissioning
    - SPS in check-out
    - Christmas will effectively reduce the available time (the two Christmas weeks excluded).

• Will be discussed in detail in the commissioning coordination committee
Potential Inter-machine conflicts

Closing of switchyard poses potential conflict with LINAC3 and LEIR HWC

LINAC4 LBE beam commissioning requires switchyard closed: LINAC4 agrees to allow limited and coordinated access where necessary

TI2 and TI8 transfer line commissioning and LHC cool down + SPS access renewal: consequences for LHC??

POPSB and POPS commissioning in parallel: TE-EPC availability??
Summary and conclusions

• Details of IST and HWC periods remain to be clarified
  ▪ Recommissioning coordinators and commissioning working groups working towards this

• Strong collaboration between Equipment experts, BE-OP and EN-ACE is essential to make it work

• HWC periods initially appear challenging but achievable
  ▪ …To be clarified in the coming months
  ▪ A close eye is to be kept on the 2019/2020 Christmas stop and inter machine conflicts

• Several critical systems changing dramatically over all machines
  ▪ Re-commissioning will undoubtedly represent a significant challenge
  ▪ Injector complex has not seen this kind of evolution for >20 years!!

• Careful preparation and thorough testing will be key

• All re-commissioning coordinators are looking forward to see beams back in the complex