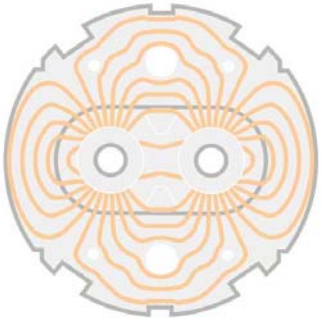
Accelerator Technology Department



Post Mortem Workshop

Session 2 Superconducting circuits: data and analysis

Analysis requirements for the SC magnet systems

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Outline

- Magnet Performance Panel (MPP) and its role during the LHC hardware commissioning
- Tools required for various phases of the magnet system start-up
  - Requirements and challenges of the Global Magnet Post Mortem Analysis System (GMPMA)
    - Main challenges
    - GMPMA scope
    - Architecture of the GMPMA
    - GMPMA functionality
    - Operational requirements
  - Minimum requirements and GMPMA evolution
- Remarks and conclusion

MPP – Main Ring Magnet Performance Panel

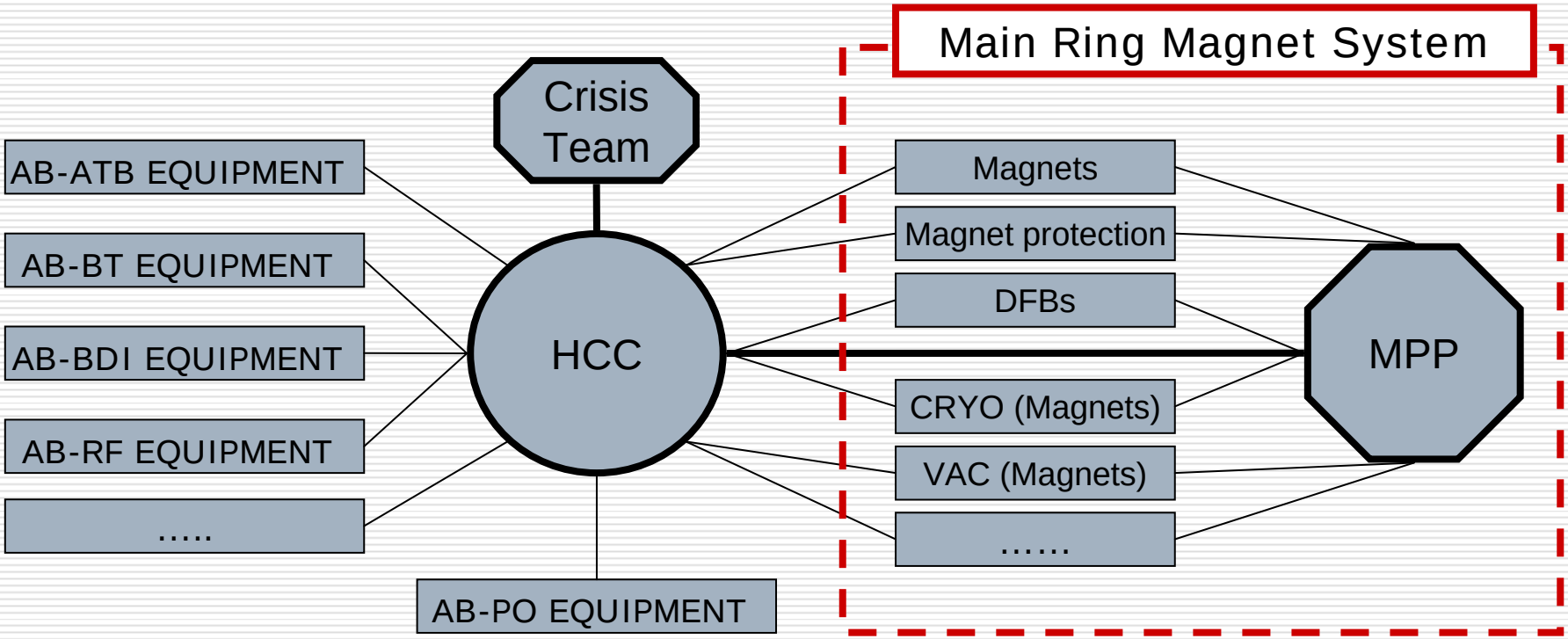
- Mandate
  - Monitor, analyze and manage all aspects of magnet performance including cryogenics and vacuum
  - Detect, diagnose, correct or mitigate problems which could occur in the magnets and the superconducting circuits including the electrical distribution feed boxes
  - Record and track individual magnet performance in relation to their manufacturing, tests, commissioning and operation data
  - Steer the development of the related data bases, analysis and diagnostic tools. Participate to the definition of the needs for analysis tools to be used during routine operation.

MPP Responsibility During Hardware Commissioning

- The MPP is expected to actively contribute to the Hardware Commissioning effort by:
  - participating to the definition of the procedures,
  - analyzing the data gathered,
  - supplying all the information necessary and timely validating the continuation of the commissioning procedures interpreting the data and depending on it allowing/refusing the execution of the following step of the test procedure
  - In case of failure, the MMP is expected to perform in-depth diagnostics to unblock the situation or escalate the problem via Hardware Commissioning Coordination

MPP Responsibility During Hardware Commissioning

- The MPP will integrate AT experts and their expertise to actively contribute to the Hardware Commissioning effort
- The MPP will be integrated into the existing Hardware Commissioning structure



Main Challenges

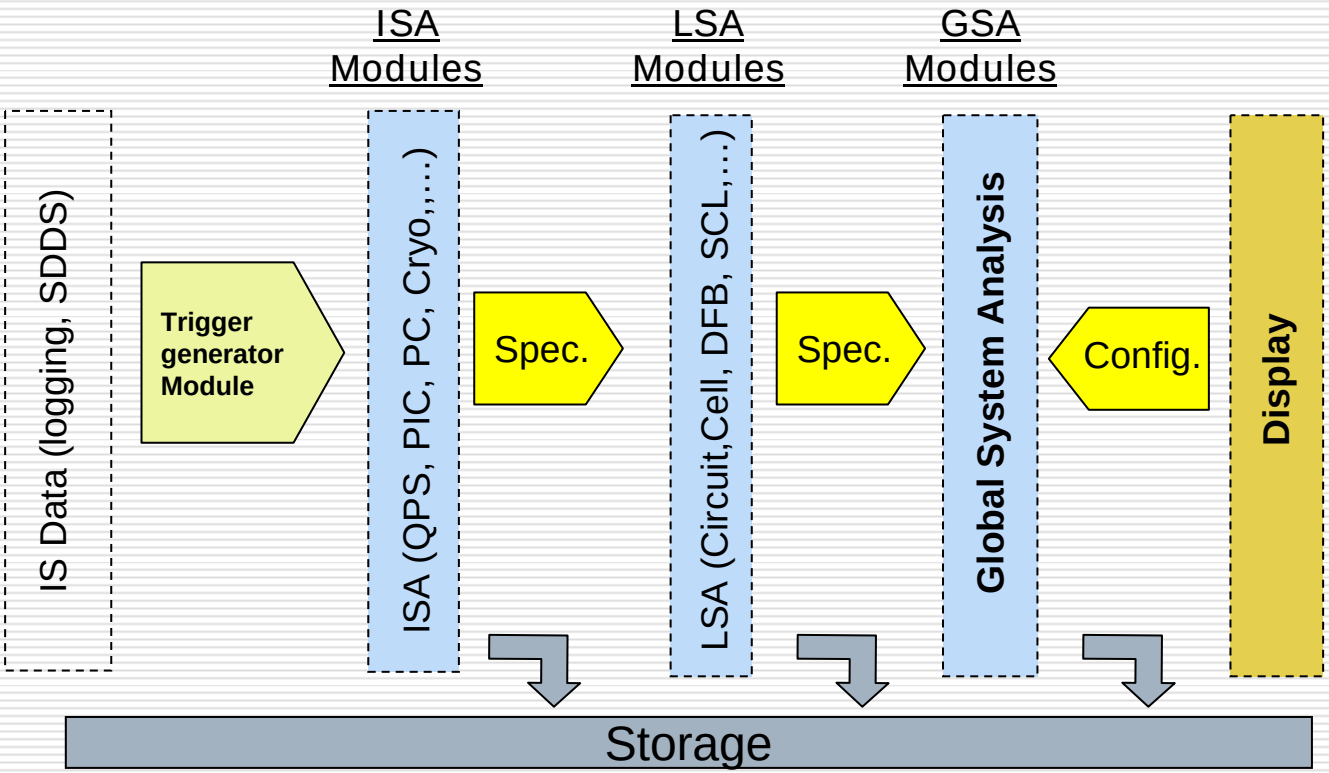
- The LHC Main Ring Magnet System is unprecedented in terms of its complexity, diversity and overall size
- Electrical, quench, magnet protection, vacuum and cryogenic aspects need to be integrated
- A variety of “active” equipment and instrumentation:
  - QPS - ca. 70000 channels (analogue, digital), 2200 field bus couplers, 1732 electric circuits
  - CRYO - ca. 3000 channels (various types: temperature, pressure, He level, etc.)
  - VAC - beam vacuum: 310 sector valves, 900 pressure gauges, 600 ion pumps; insulation vacuum: 720 valves, 850 pressure gauges, 180 turbomolecular pumps
  - …other

GMPMA scope

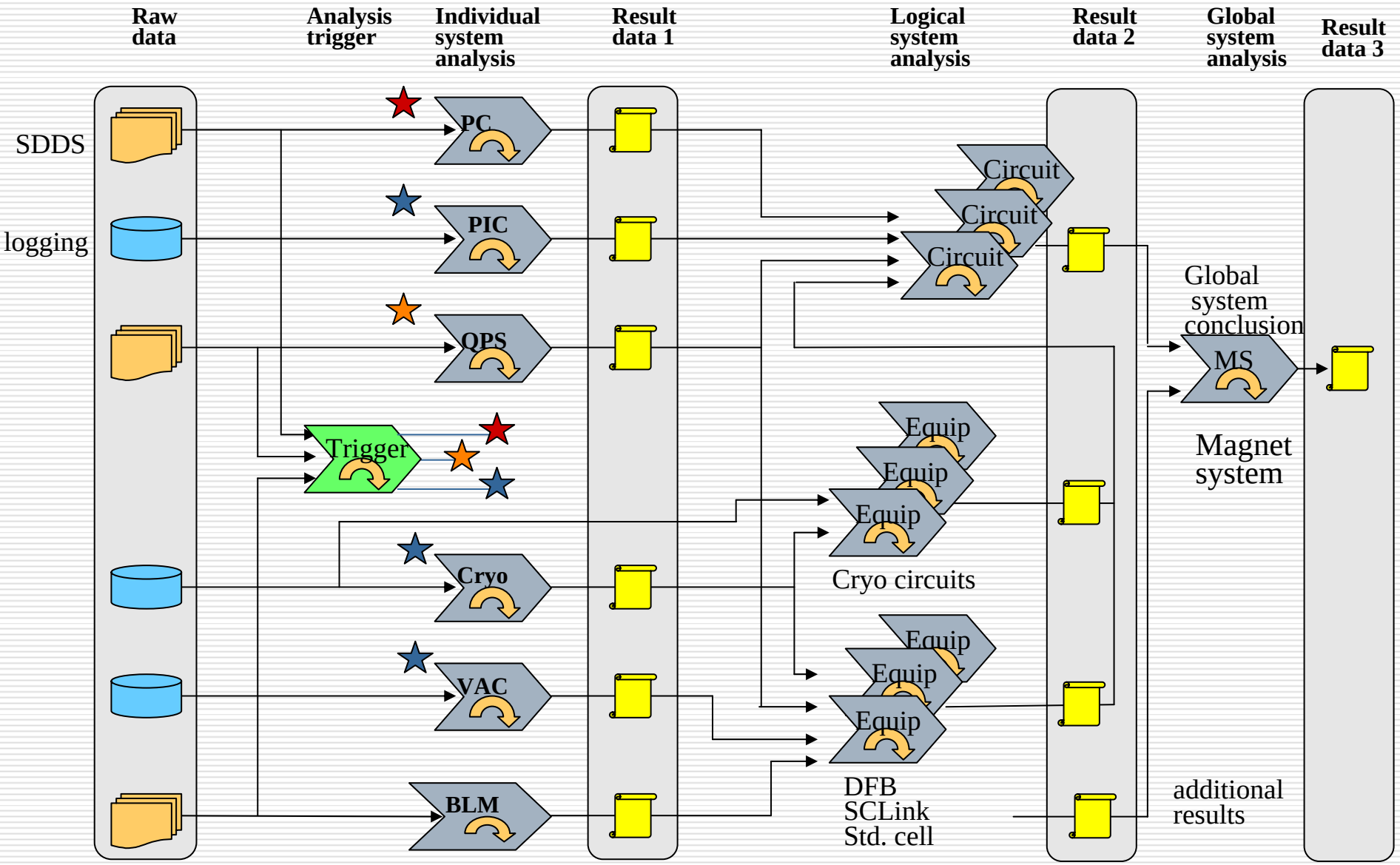
- The GMPMA comprises the main ring magnet system instrumentation and other signals which will come from the logging and Post-Mortem system with checks on and analysis of:
  - Magnets and magnet circuit protection
    - quench detection waveforms
    - voltage waveforms
  - Cryogenics
    - temperature waveforms
    - Flows, valves opening
  - DFB's
  - Vacuum
  - PIC system status
  - Power Converters
  - BLM
  - ...
  - origin of the triggers and dump request

GMPMA general requirements

- Three steps in the analysis process
  - Individual System Analysis (ISA)
  - Logical System Analysis (LSA)
  - Global System Analysis (GSA)



Architecture of the GMPMA system (v4)



GMPMA main functionality (1/2)

- The GMPMA system will be a high-level application which will need to:
  - be triggered after every QPS, PC, Cryo, VAC event or on request e.g. during dedicated tests/diagnostics
  - should run in a server with the hardware
  - acquire the LHC configuration data associated with LHC mode, filling, ramping etc.
  - access equipment data (voltage waveforms, temperatures, flows, pressures, BLM signals, etc.) from the Post-Mortem servers, from the logging DB or from the previous measurement DB;
  - provide facilities for display, browsing and data analysis – complex task: requires data preparation by time, by equipment, historical from DB, etc.

GMPMA main functionality (2/2)

- build a ‘model’ of quench process, in particular for the main magnet circuits, identify the origin the cause etc.
- test the measured equipment data against the model where applicable, and against references in other cases
- display a summary of the comparison results and allow a diagnostic of the identified problem

- give the power permit via a software interlock channel
- withhold the power permit and generate an alarm if the quench process was not as expected and failed the comparison to reference tests

- monitor equipment and equipment state change: all states changes to be recorded
- provide suitable summary data to the LHC logging and Post-Mortem DB where required.

Operational Requirements

- Link to LHC sequencer
- Triggered automatically by QPS, PC, Cryo or VAC events
- As automatic as possible process in the LHC controls environment
  - All known today faults must be captured
  - Detection of onset of equipment hazard and hazard mitigation (alarms or warnings and control within safe operating limits)
- Response time within ca. 15 minutes
  - Retrieving archived data and generating hardware status must not have any operational impact, both during the hardware commissioning and operation with beams

Minimum requirements and GMPMA evolution

- The GMPMA System Architecture is structured, including modularity and allowing partial use of the system during its development

- Modularity and minimum requirements
  - Standard facilities for display, browsing and manual analysis of the Individual System signals are mandatory
  - ISA modules are also essential in terms of the capture of the incidents and faults signatures and thus are important for the equipment safety
  - LSA and GSA modules providing an automated data reduction, building a ‘model’ of quench process, testing the measured equipment data against the model or against references are essential for the HWC and operational efficiency

- **Some of the building blocks of the GMPMA System can wait – but not a lot**

GMPMA development milestones

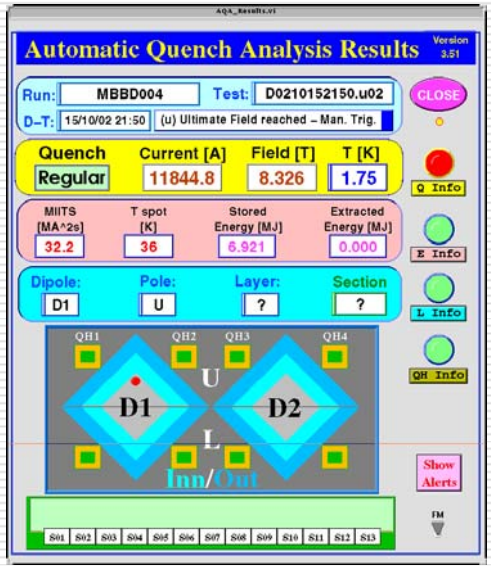
- Minimum requirements

	Initial HWC in Sector 7-8	Parallel HWC in 2 Sectors	HWC with beams	LHC Operation
Individual System Modules				
QPS	X	X	X	X
PIC	X	X	X	X
PC	X	X	X	X
CRYO	logging	X	X	X
VAC	logging	logging	X	X
BLM				X
Logical System Modules				
Electrical Circuits		X	X	X
Std. cells		X	X	X
Magnets		X	X	X
DFB's		X	X	X
SCL's		X	X	X
Cryo circuits		X	X	X
VAC sectors			X	X
BLM				X
…				
New Modules				X
Global System Module			X	X

Remarks

- Energy stored in the magnets is very high (much higher than the beam energy) and can be very destructive
- In superconducting circuits certain critical electrical faulty states can be concealed at operational condition due to equipotentiality of the superconductors.
- The quality and damage-free commissioning of the main ring magnet system will depend not only on the time allocated to the commissioning, but also on the availability of the high level software analysis tools.

There are two BASICALLY DIFFERENT types of the POST MORTEM ANALYSIS



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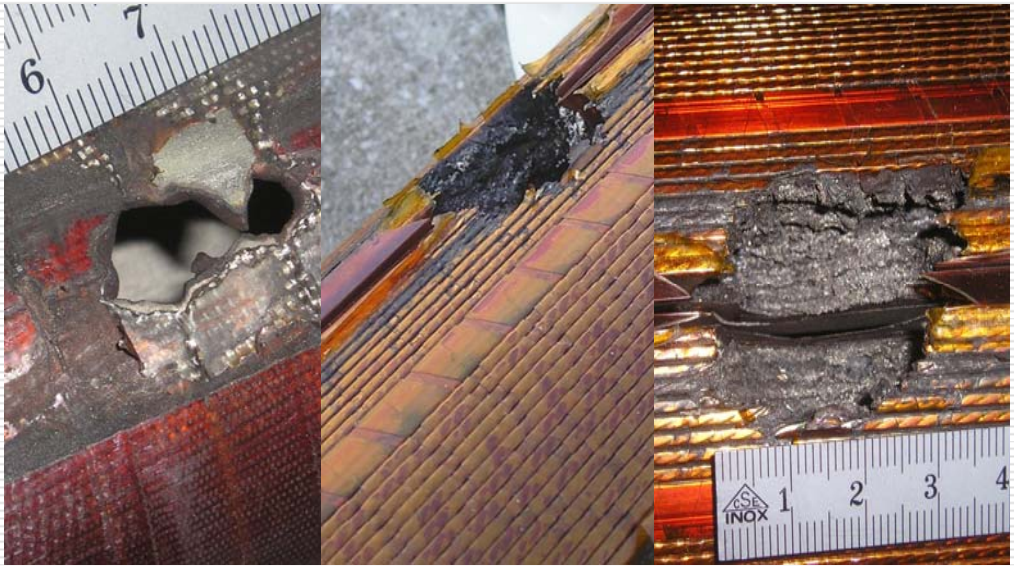

The right choice seems to be obvious!

Conclusion

- The GMPMA System, which is under development by AB/CO is a highly complex, high level application, integrating variety of the equipment, instrumentation and subsystems
- The GMPMA is an essential tool for"
  - Efficient HWC
  - Safe HWC and machine operation
- Job is far from being finished
  - Remaining ISA and LSA modules need to be developed before starting parallel HWC in two sectors!
- Very limited number of experts, capable to specify the GMPMA modules and algorithms exist at present
  - Resources for the GMPMA development were not originally anticipated
  - Existing experts are either installing their equipment or , due to expiration of their CERN contracts, are looking after new jobs
- Further integration of the LHC GPMA System development effort seems to be needed to avoid separate development of tools with similar functions.