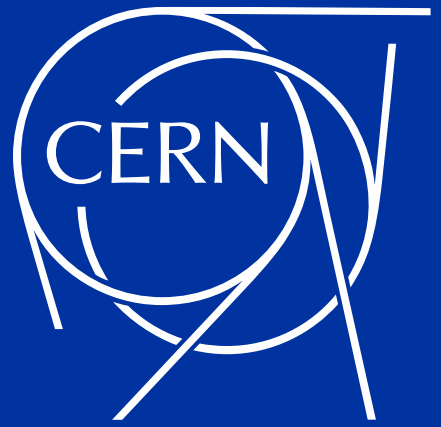


Automation of equipment commissioning, setting up and recovery

JAP Workshop 2024

Raul Murillo-Garcia
December 12th, 2024

Why automation?

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN-ISR-CO/80-29

TOWARDS FULL AUTOMATION OF ACCELERATORS THROUGH COMPUTER CONTROL

by

J. Gamble, J.-Y. Hemery, D. Kemp, R. Keyser, J.-P. Koutchouk,
P. Martucci, L. Tausch, L. Vos

Paper presented at the XIth International Conference on High-Energy Accelerators, CERN, Geneva, 7-11 July 1980.

Geneva, July 1980

TOWARDS FULL AUTOMATION OF ACCELERATORS THROUGH COMPUTER CONTROL

J. Gamble, J.-Y. Hemery, D. Kemp, R. Keyser, J.-P. Koutchouk, P. Martucci, L. Tausch, L. Vos

CERN, 1211 Geneva 23, Switzerland.

ABSTRACT

The computer control system of the Intersecting Storage Rings (ISR) at CERN has always laid emphasis on two particular operational aspects, the first being the reproducibility of machine conditions and the second that of giving the operators the possibility to work in terms of machine parameters such as the tune. Already certain phases of the operation are optimized by the control system, whilst others are automated with a minimum of manual intervention. The paper describes this present control system with emphasis on the existing automated facilities and the features of the control system which make it possible. It then discusses the steps needed to completely automate the operational procedure of accelerators.

https://cds.cern.ch/record/1023439/files/CM-P00065164.pdf

Why automation?

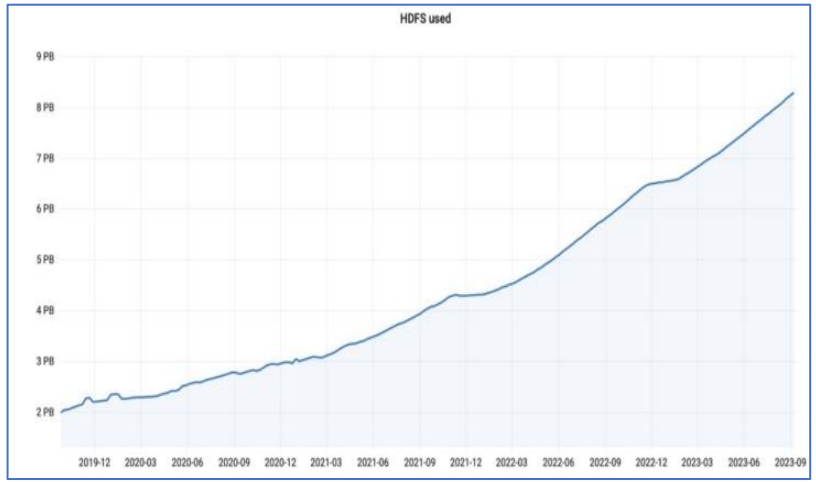
Automation evolves

- Efficient LHC operation relies on advanced tools such as orbit and tune feedback, luminosity leveling, sequencers, and automatic collimator alignments, and many more.

Settings management – status and plans (15'+10')	*Michi Hostettler*	
Royal Plaza Montreux & Spa	16:45 - 17:10	
Dynamic beam scheduling and automated LHC filling (20'+10')	*Amaury Beeckman*	
Royal Plaza Montreux & Spa	17:10 - 17:40	
Results and plans for integration of automation and optimization in operation (20'+10')	*Georges Trad*	
Royal Plaza Montreux & Spa	17:40 - 18:10	
OP feedback and recommendations as we move towards automation (15'+10')	*Denis Gerard Cotte*	
Royal Plaza Montreux & Spa	18:10 - 18:35	

- Auto-pilot, auto-start of PS HF cavities, auto-reset of PS RF cavities, auto-steering in TT2, FGC notification, automatic optimizers, etc.

Why automation?

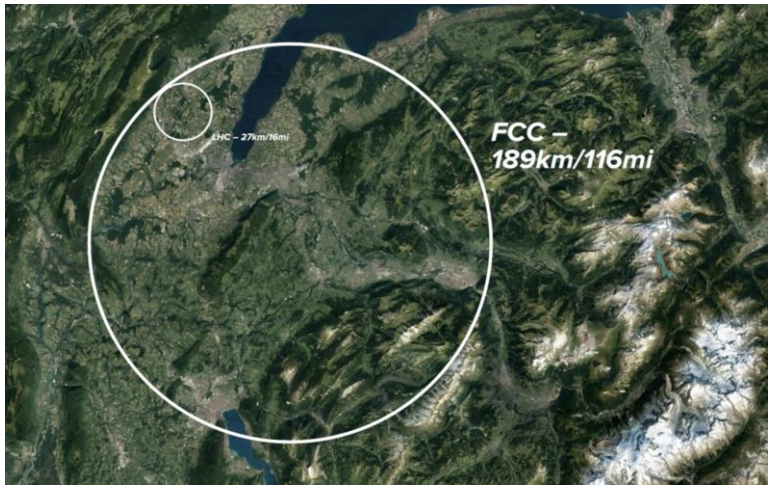


Lots of data produced by equipment devices.

Are we exploiting this data at its fullest?

Automation is everywhere: powerful processing units have facilitated AI, ML, etc.

Automation within a system and across systems, commission, analysis, recovery, etc.



Remote experiments, accessibility is not easy.

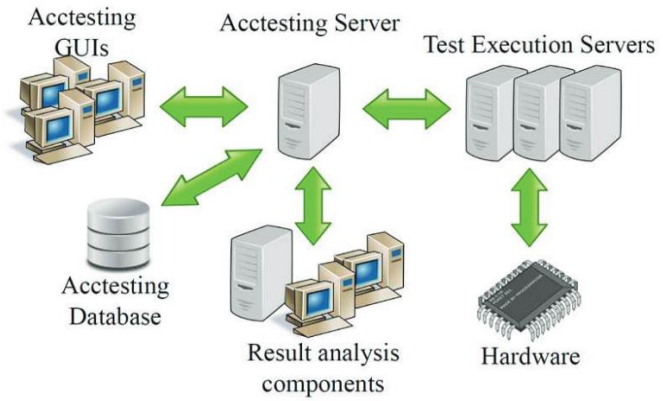
Redundancy, robotics, prognosis.

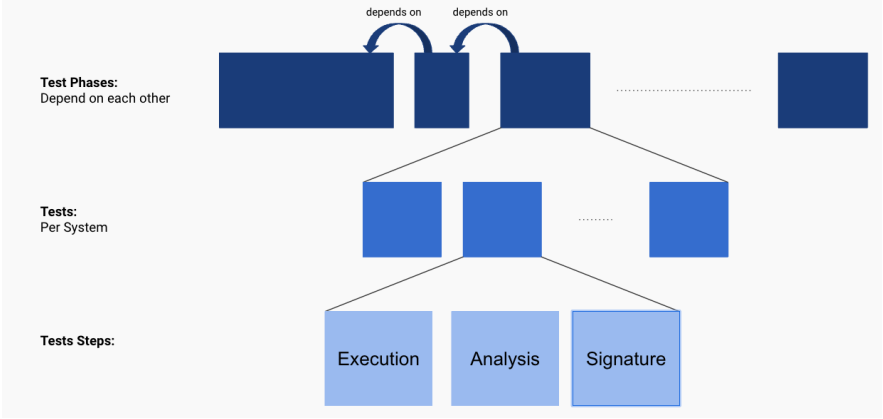
Why not to automate

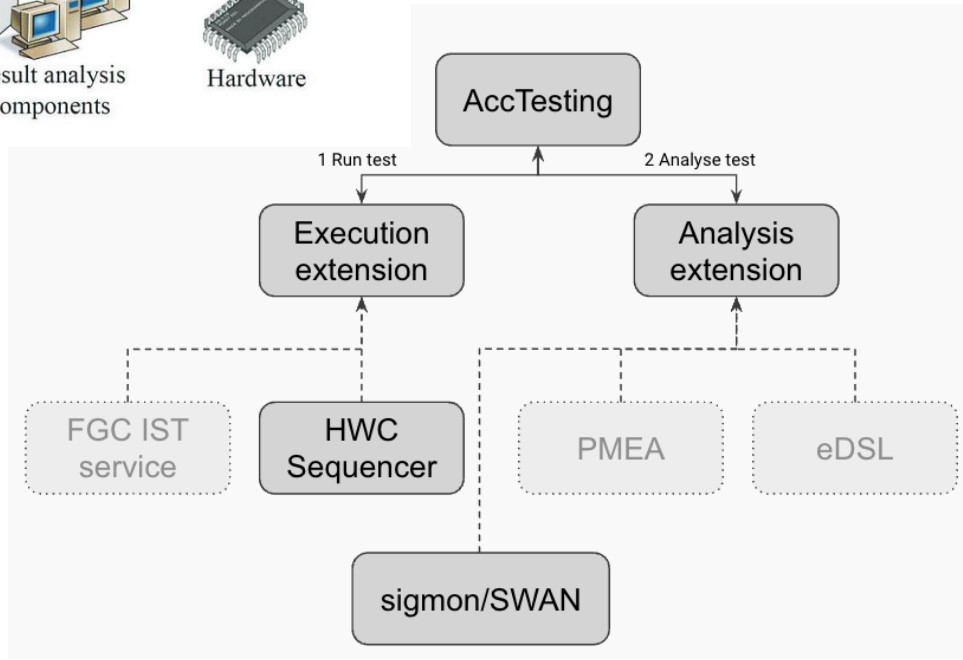
- Automation remains limited due to several key challenges:
  - A trade-off exists between the required investment and the expected output.
  - Resource constraints hinder progress.
  - Existing hardware is not designed to support automation.
  - Users ‘loose control’.
  - Certain processes still require visual inspection (after beam stop check collimators, water leaks, etc.).
  - Available tools and solutions are often not widely known or utilized.

AccTesting

- AccTesting is an extensible framework for orchestration and tracking tests executions, analysis and/or signatures.
- GUI, server and Oracle DB.
- Delegates to third party services (extensions) the execution and analysis.

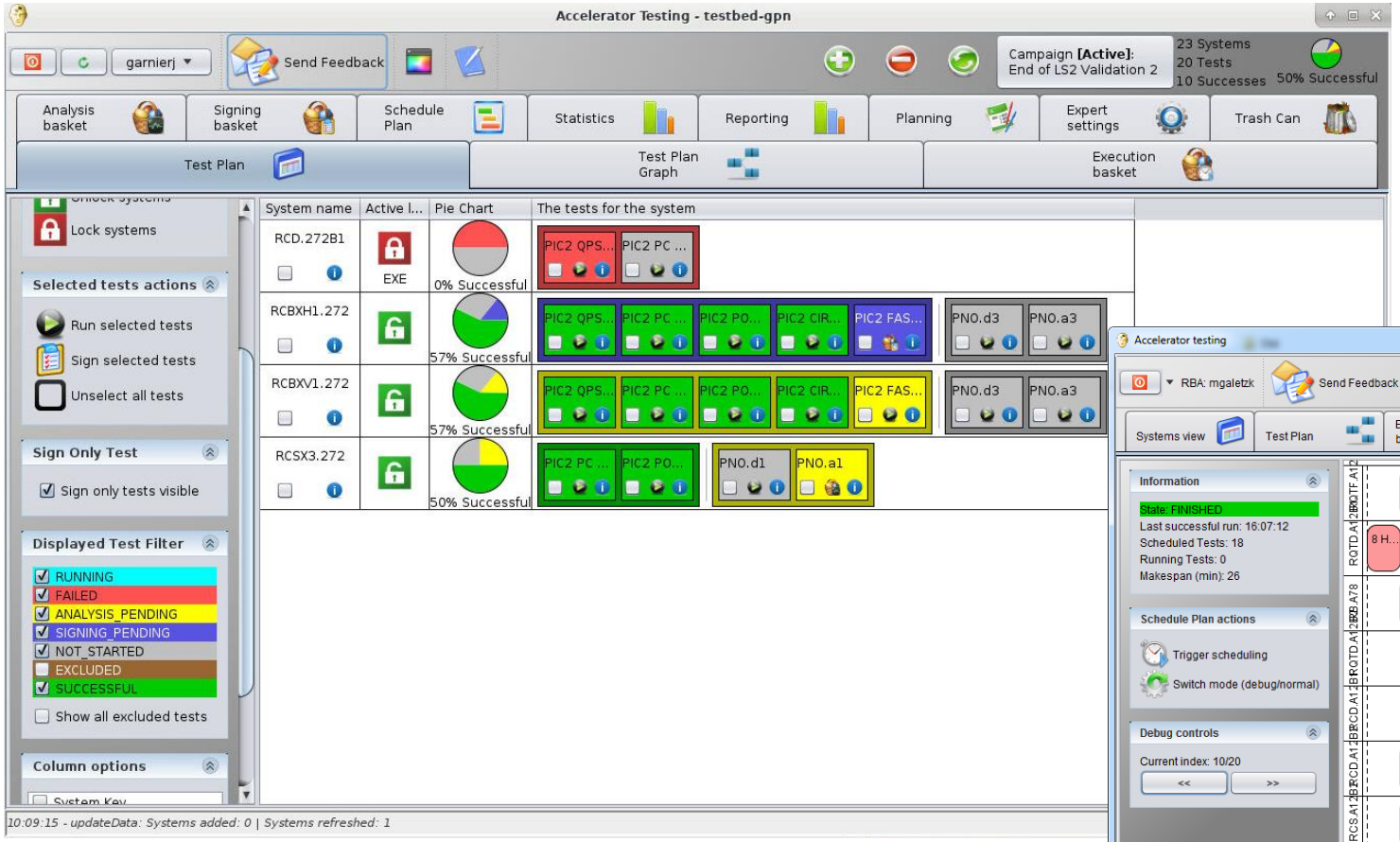


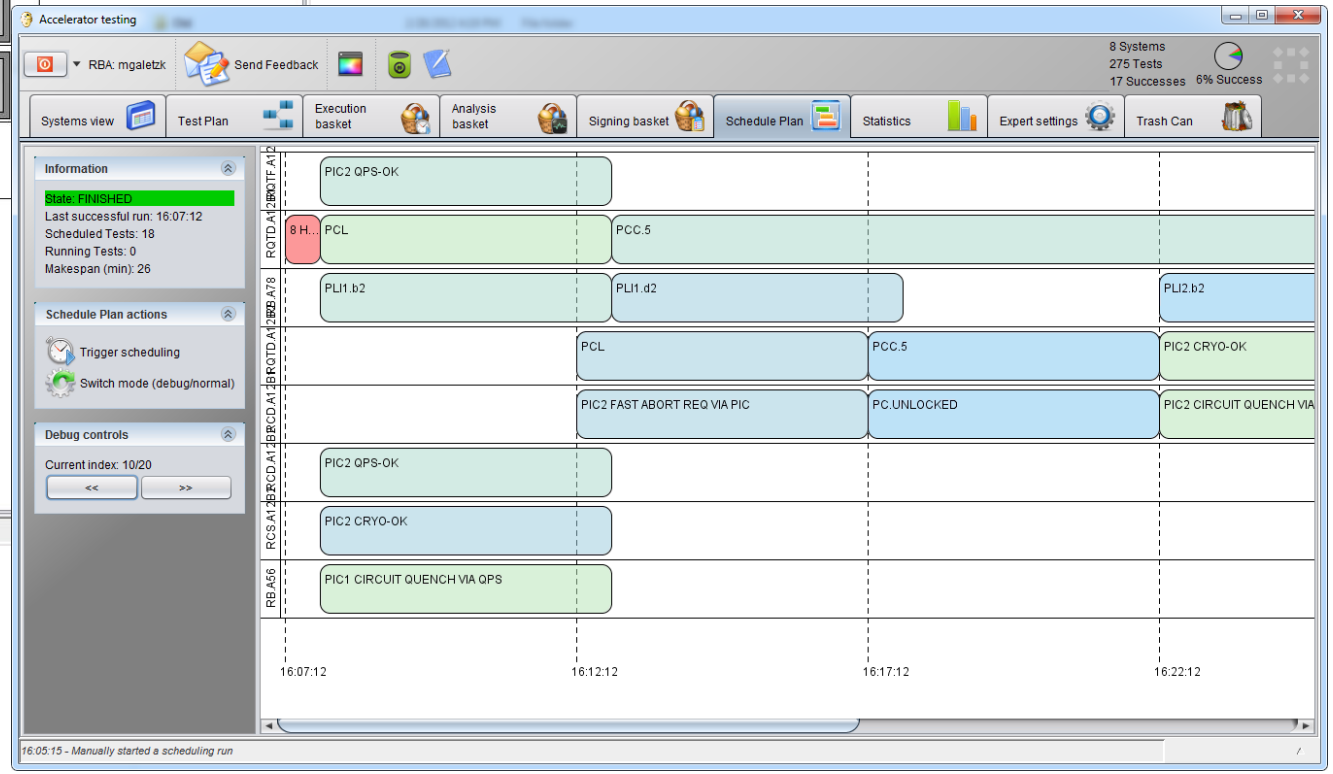




AccTesting status and plans 2023 by JC Garnier

AccTesting


Accelerator Testing - testbed-gpn
garnierj
Send Feedback
Campaign [Active]: End of LS2 Validation 2
23 Systems
20 Tests
10 Successes
50% Successful
Analysis basket
Signing basket
Schedule Plan
Statistics
Reporting
Planning
Expert settings
Trash Can
Test Plan
Test Plan Graph
Execution basket
Lock systems
Selected tests actions
Run selected tests
Sign selected tests
Unselect all tests
Sign Only Test
Sign only tests visible
Displayed Test Filter
RUNNING
FAILED
ANALYSIS_PENDING
SIGNING_PENDING
NOT_STARTED
EXCLUDED
SUCCESSFUL
Show all excluded tests
Column options
System name
Active l...
Pie Chart
The tests for the system
RCD.272B1
EXE
0% Successful
PIC2 QPS...
PIC2 PC ...
RCBXH1.272
57% Successful
PIC2 PO...
PIC2 CIR...
PIC2 FAS...
PNO.d3
PNO.a3
RCBXV1.272
RCSX3.272
50% Successful
PNO.d1
PNO.a1
10:09:15 - updateData: Systems added: 0 | Systems refreshed: 1

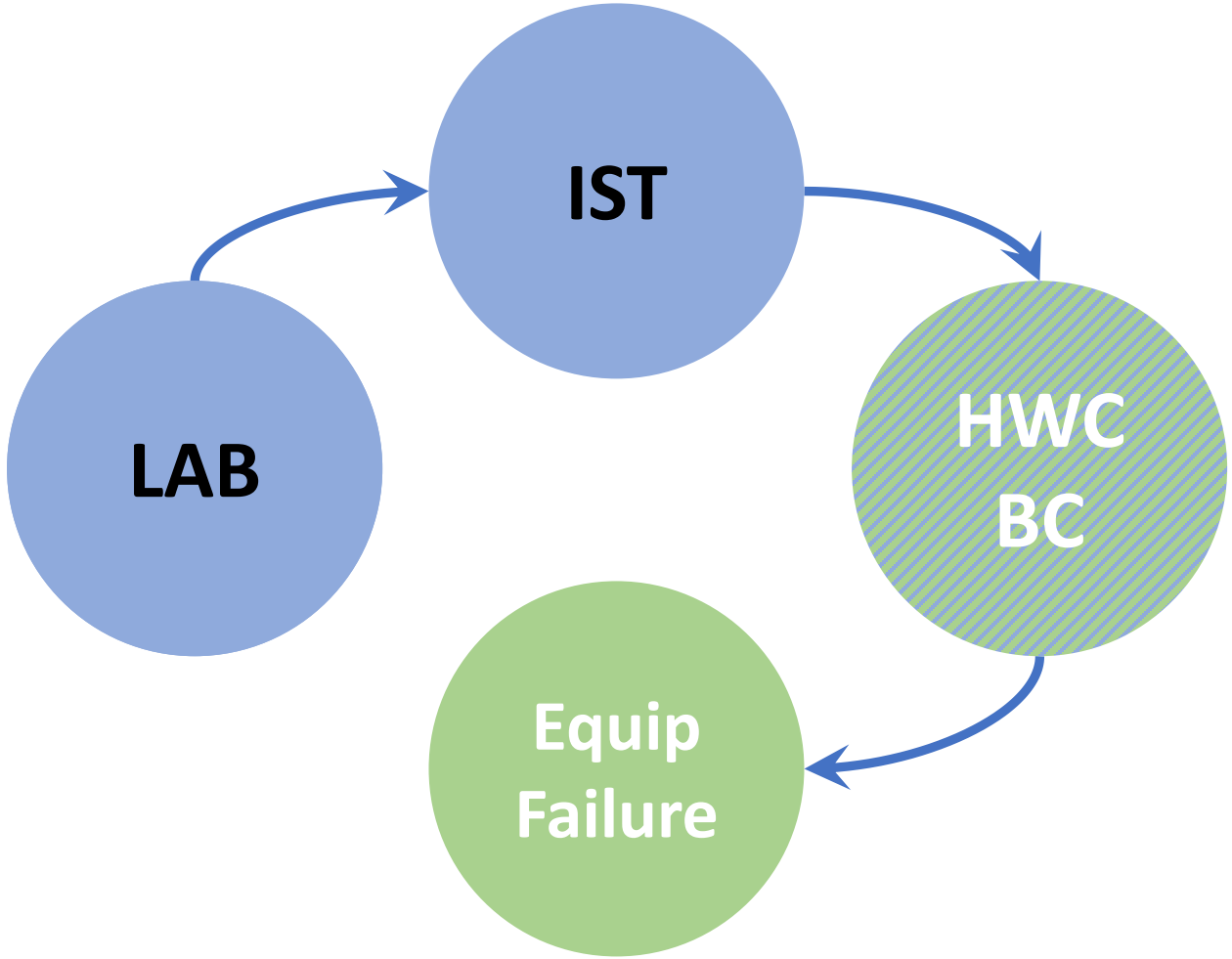

Accelerator testing
RBA: mgaletzk
Send Feedback
8 Systems
275 Tests
17 Successes
6% Success
Systems view
Test Plan
Execution basket
Analysis basket
Signing basket
Schedule Plan
Statistics
Expert settings
Trash Can
Information
State: FINISHED
Last successful run: 16:07:12
Scheduled Tests: 18
Running Tests: 0
Makespan (min): 26
Schedule Plan actions
Trigger scheduling
Switch mode (debug/normal)
Debug controls
Current index: 10/20
PIC2 QPS-OK
8 H..
PCL
PCC.5
PLI1.b2
PLI1.d2
PLI2.b2
PIC2 CRYO-OK
PIC2 FAST ABORT REQ VIA PIC
PC.UNLOCKED
PIC2 CIRCUIT QUENCH VIA
PIC1 CIRCUIT QUENCH VIA QPS
16:07:12
16:12:12
16:17:12
16:22:12
16:05:15 - Manually started a scheduling run

AccTesting

- AccTesting is used during the LHC hardware commissioning.
- First tests using AccTesting in the injectors for PS power converter commissioning during HWC 2025
- For more information or to evaluate how AccTesting could meet your needs, contact Jean-Christophe Garnier (MPE) or Andrea Calia (OP).
- As part of EPA WP7:
  - An upcoming collaboration between equipment experts and OP to assess AccTesting's potential as a tool to further optimize machine and equipment commissioning.
  - AccTesting is being restructured to leverage its features for use in other machines and campaigns, such as IST.

AccTesting status and plans 2023 by JC Garnier

Four phases of automation: QA, efficiency and reliability



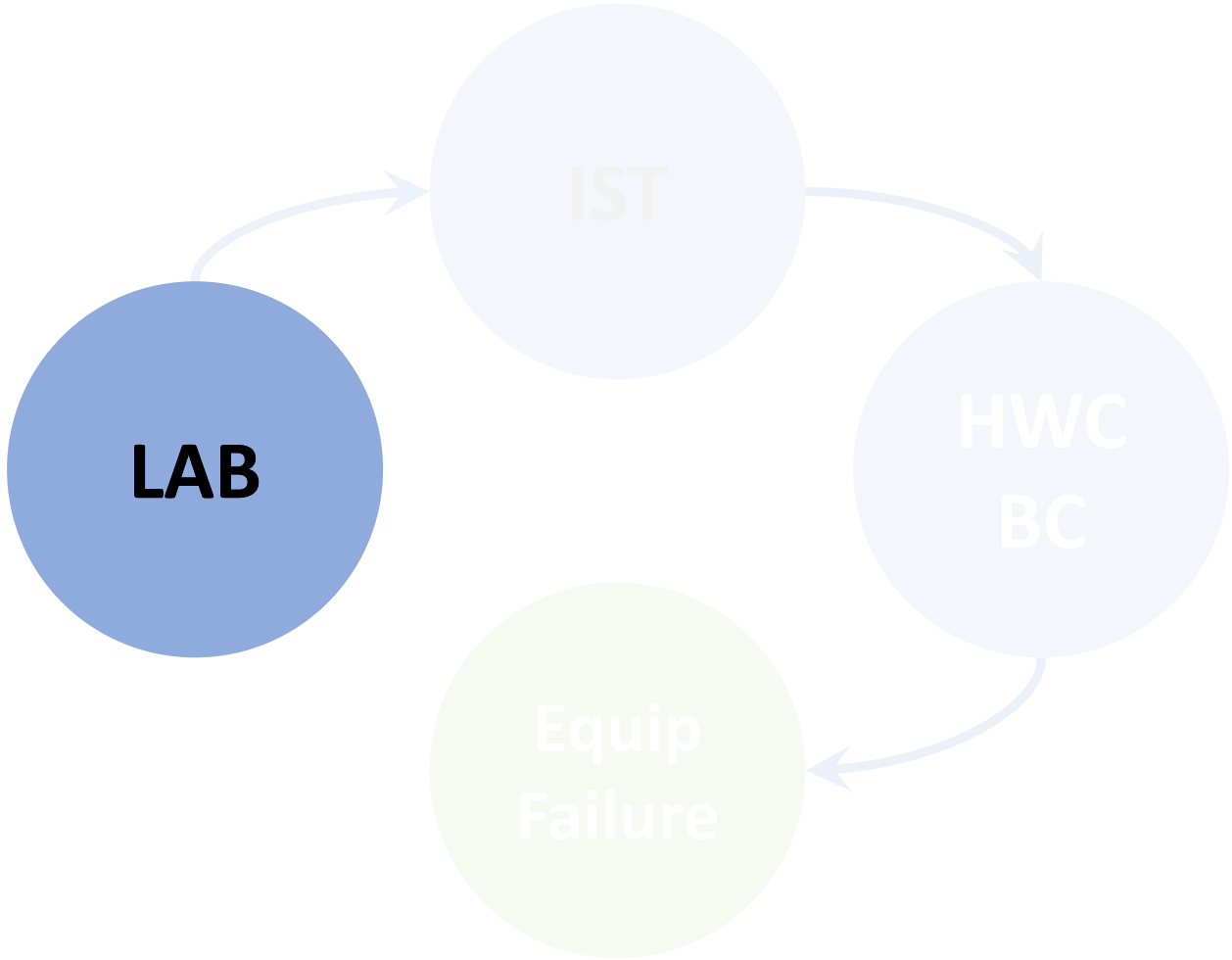
Beam agnostic

Beam present

Equip experts

Operators

Four phases of automation: QA, efficiency and reliability



Beam agnostic

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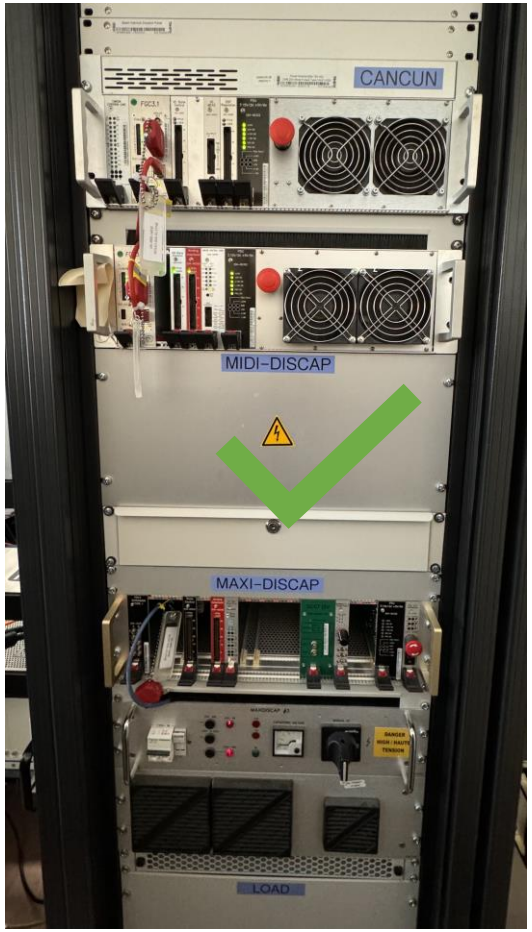
Equip experts

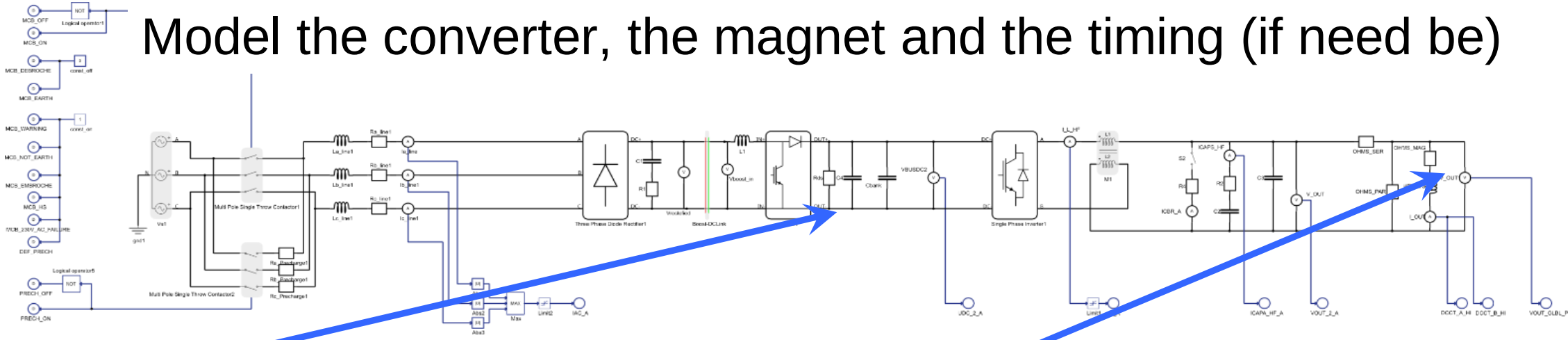
Operators

Automation in equipment labs: EPC

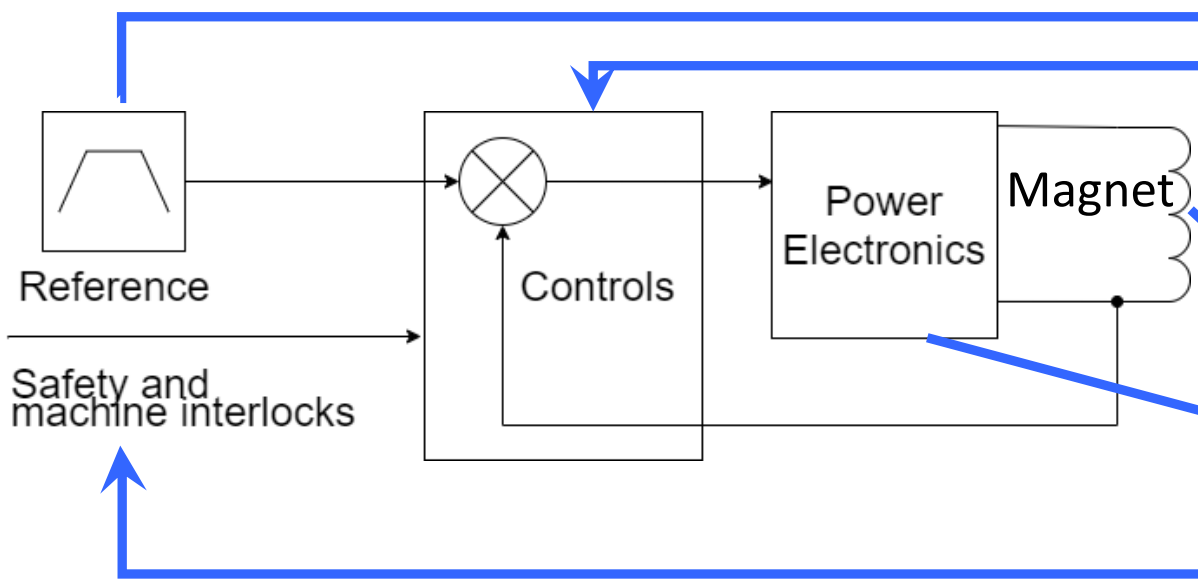


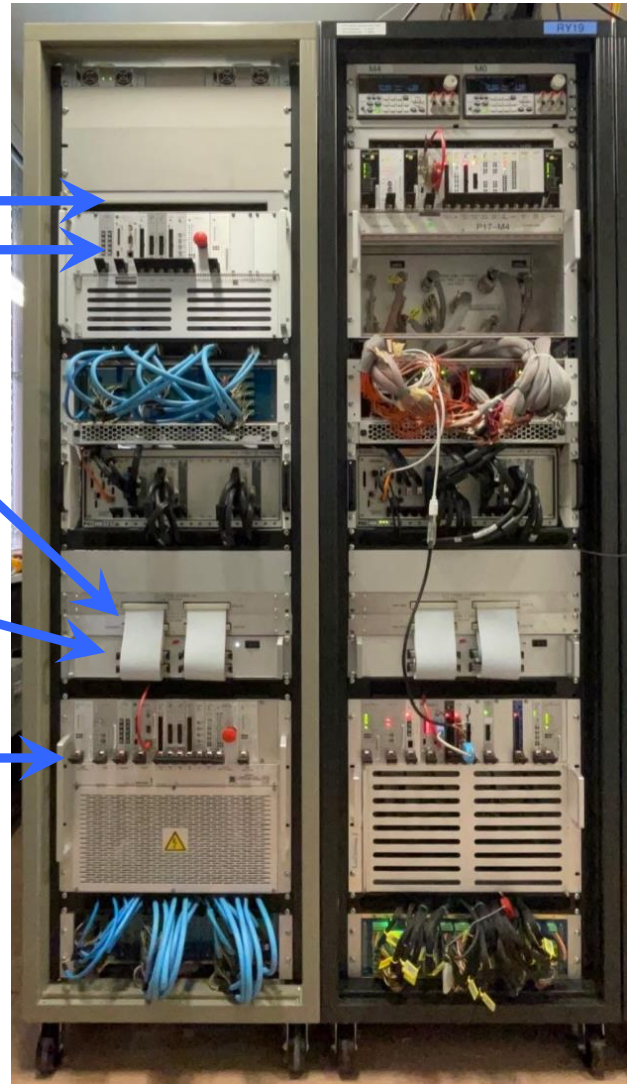
Automation in equipment labs: EPC

Model the converter, the magnet and the timing (if need be)



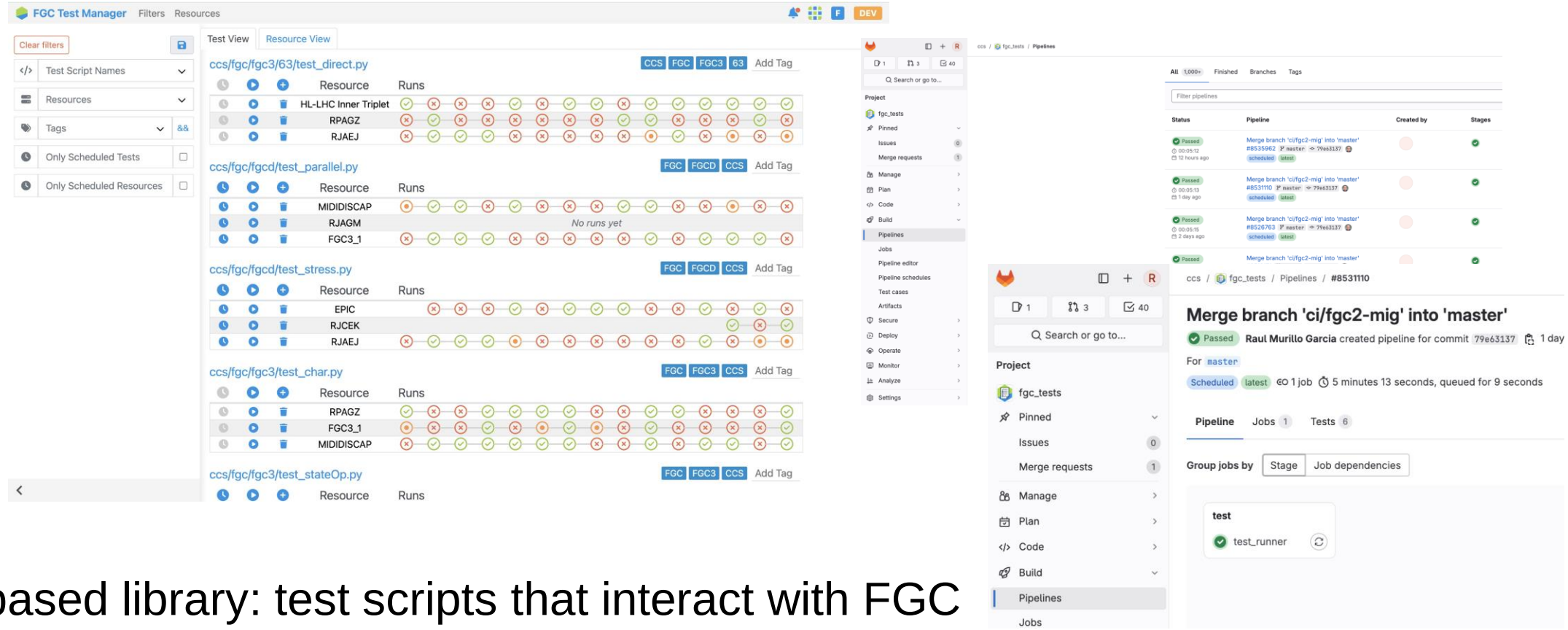
Automation in equipment labs: EPC





- Hardware In the Loop (Typhoon & SpeedGoat)
- One system can emulate different types of converters by loading different models.

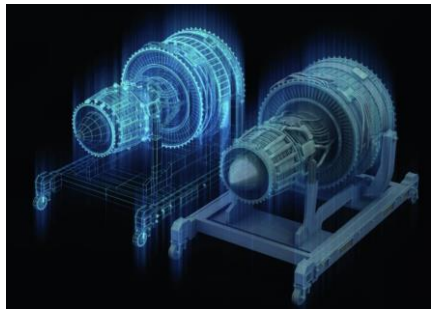
Automation in equipment labs: EPC



- Python based library: test scripts that interact with FGC devices.
- Test Manager GUI to associate tests to resources.
- CI/CD with Gitlab to run test nightly or on demand.

Automation in equipment labs

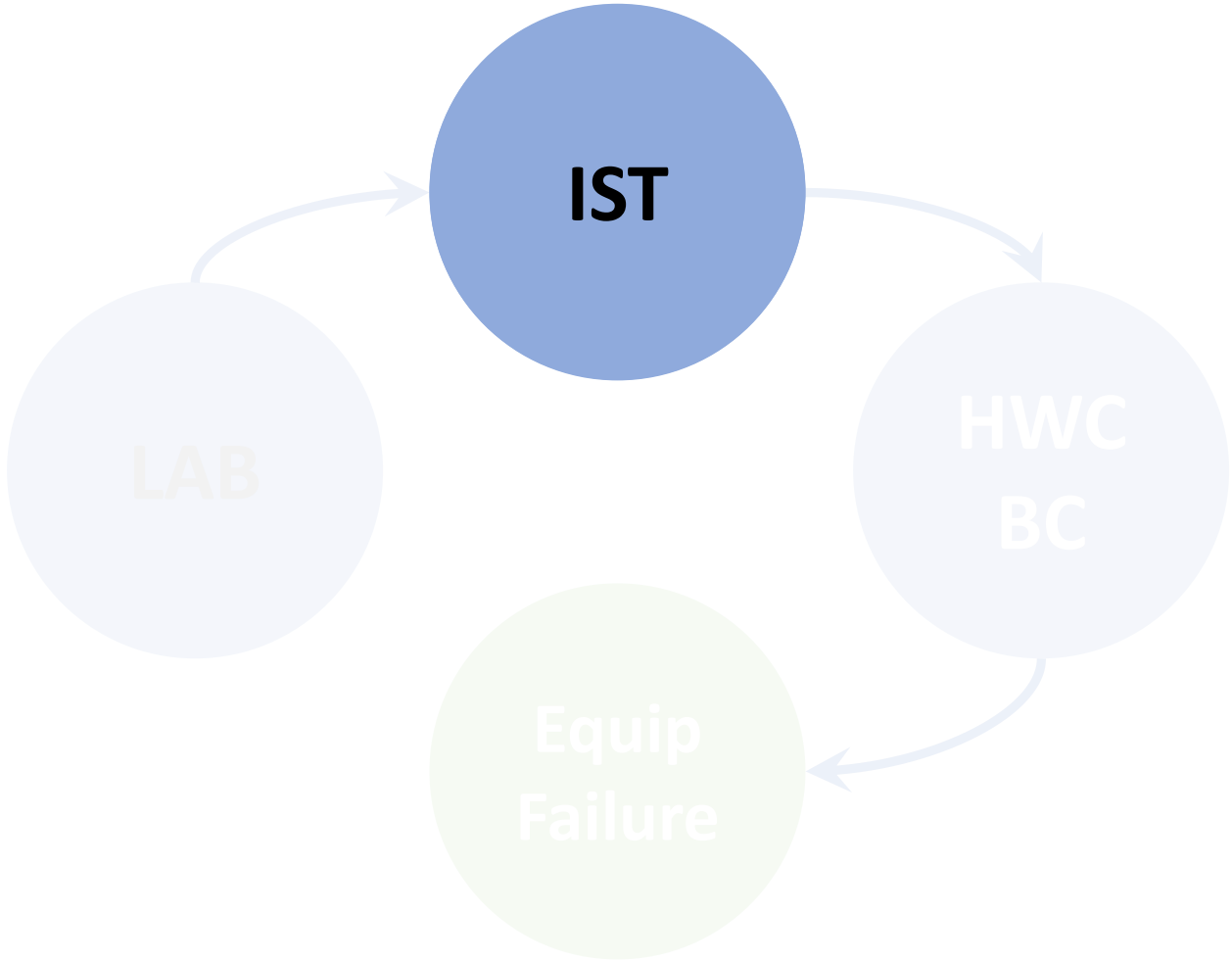
- GitLab CI/CD is widely used across the lab to automate various processes, including VHDL functional tests, unit tests (Python, C++), builds, and releases.
- Teams not yet using GitLab have expressed strong interest in adopting it.



- Real hardware setups.
- Testbenches for ABT mission-critical projects.
- Vertical slices (detector-to-interlock) for BI systems.
- Mock-ups or real hardware for STI systems.
- BE-CEM use digital twins to simulate equipment behaviour.
- Virtual and simulated hardware environments.

- Some tests are performed manually, while others leverage automation with expert tools.
- Certain upgrades, such as low-level RF systems that require a beam, can only be fully tested in the machine. This necessitates system integration tests during beam commissioning.

Four phases of automation: QA, efficiency and reliability



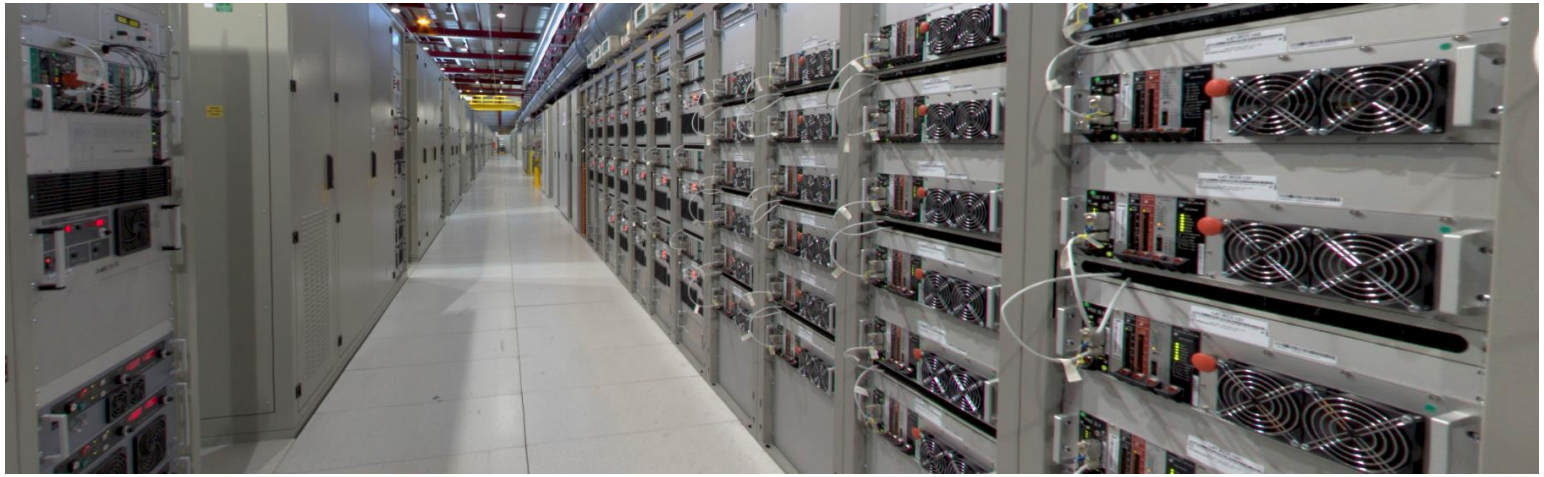
Beam agnostic

Beam present

Equip experts

Operators

EPC upgrade deployment



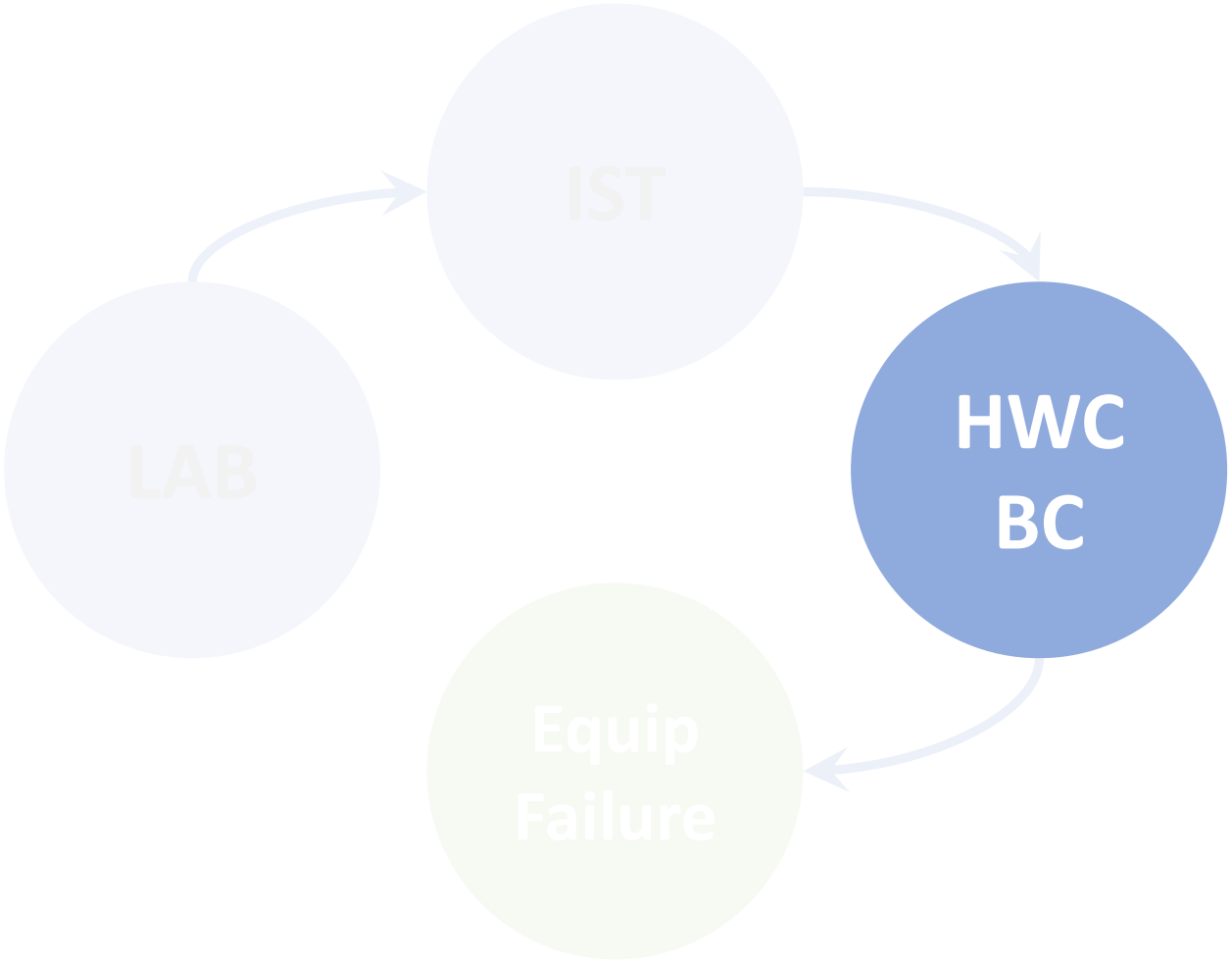
EPC upgrade deployment

- Upgrade deployed on thousand of devices during the IST period.
- Converter experts validate the release manually: low coverage, no tracking.
- Evaluate the use of AccTesting to automatize the validation of upgrades and increase test coverage.
- Discuss with OP if the same tests can be run during hardware commissioning or further system integration tests are needed.

Deployment

- Upgrades are deployed during IST or throughout YETS, depending on equipment availability.
- Testing is primarily conducted manually by experts.
- In some cases, validation is automated using the sequencer and/or specialized expert tools.
- The validation of LHC/SPS RF systems is automated due to their design, but the process still takes approximately two weeks. For legacy systems, such as those in the PS, validation remains a manual process.

Four phases of automation: QA, efficiency and reliability



Beam agnostic

Beam present

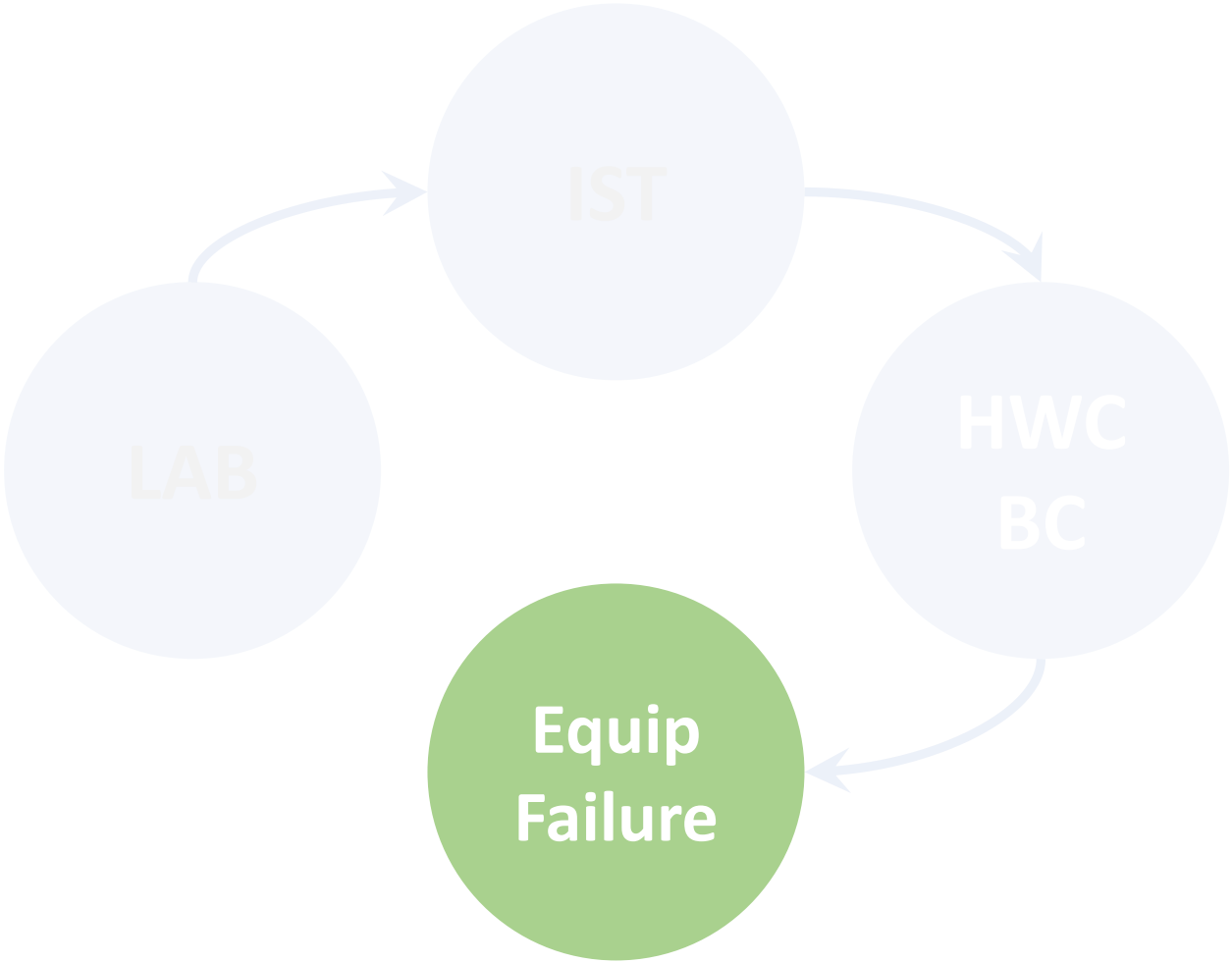
Equip experts

Operators

Hardware and beam Commissioning

- Hardware and beam commissioning processes are complex and vary depending on the machine.
- Checklists are validated by equipment groups, experts, OP, or a combination
- The level of automation differs across machines: LHC HW commissioning using AccTesting; in other machines, tests are automated using the Sequencer, but there is room for improvement; certain checks still require manual execution.
- AccTesting is being evaluated as part of an effort to gradually automate processes. As part of the EPA project, a dialogue will be initiated between OP and equipment experts to support this effort.
- Reducing HW or beam commissioning makes a difference if the other machines can start HW or beam commissioning earlier.

Four phases of automation: QA, efficiency and reliability



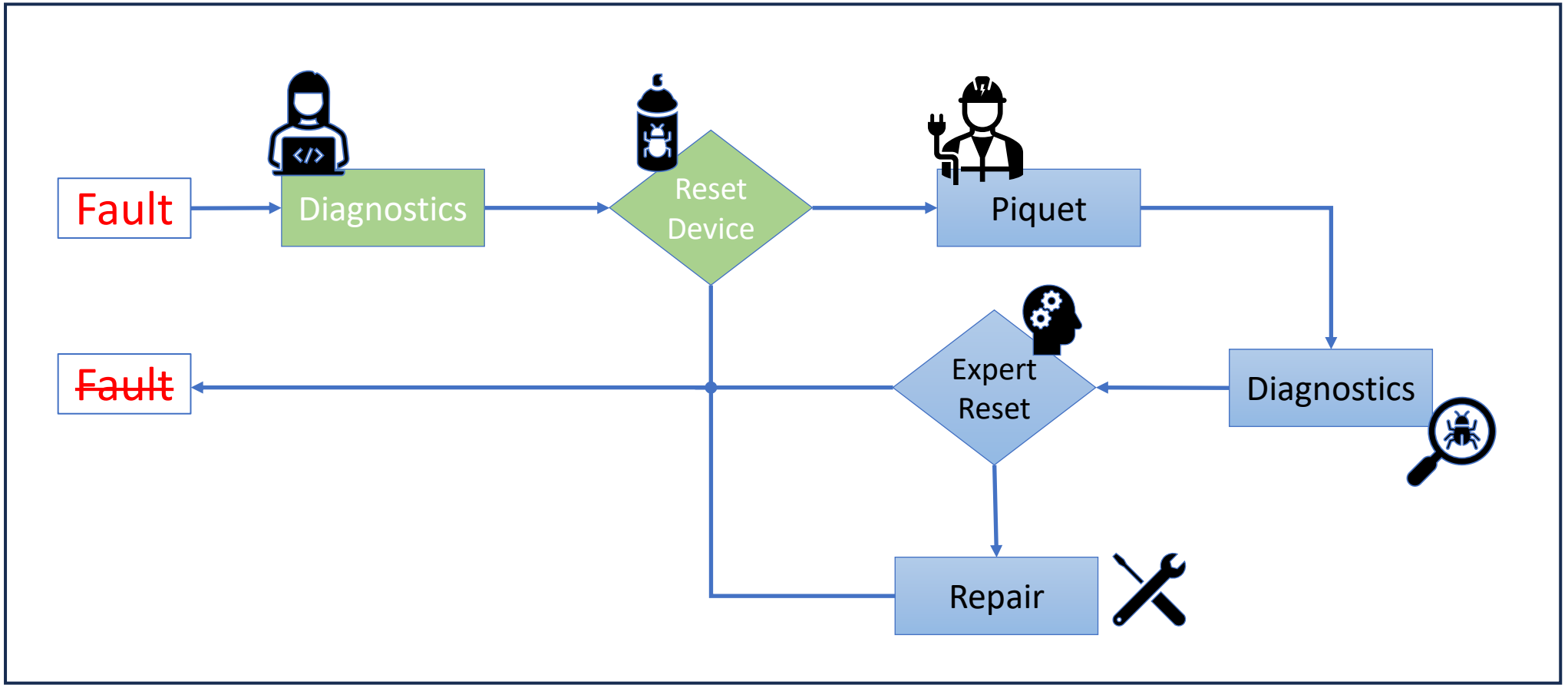
Beam agnostic

Beam present

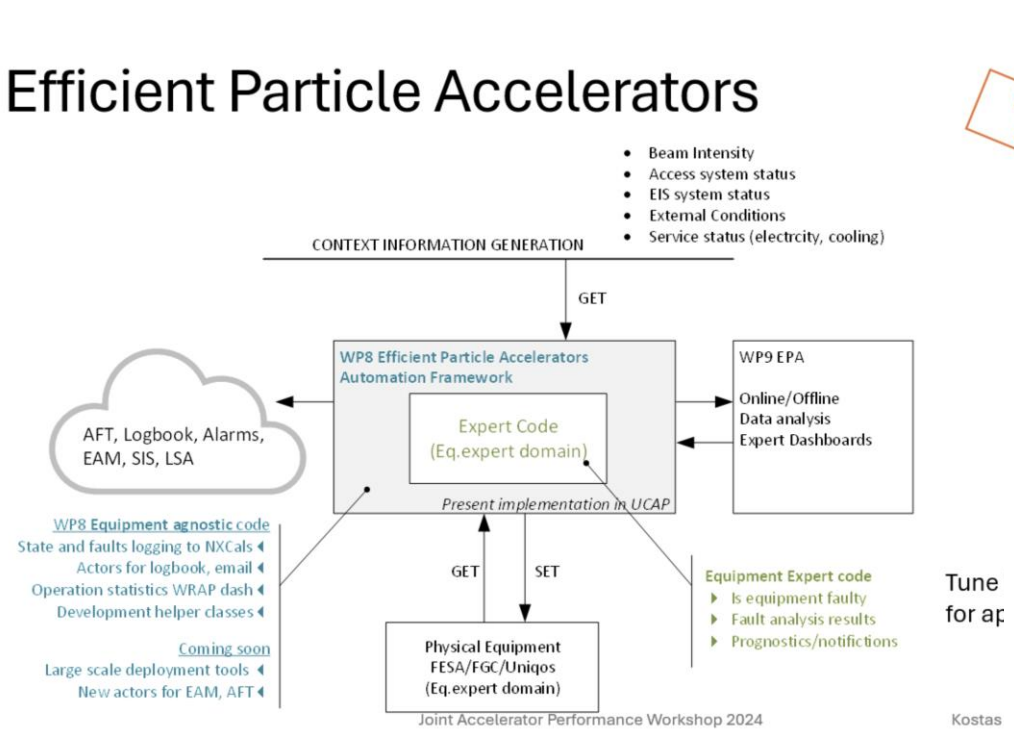
Equip experts

Operators

Equipment failure



Automation framework: EPA WP8 & WP9

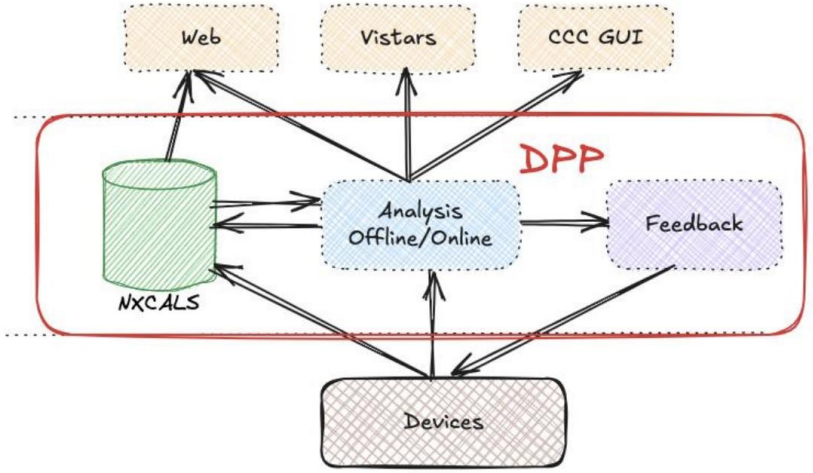


TO REQUEST CCTB ENDORSEMENT

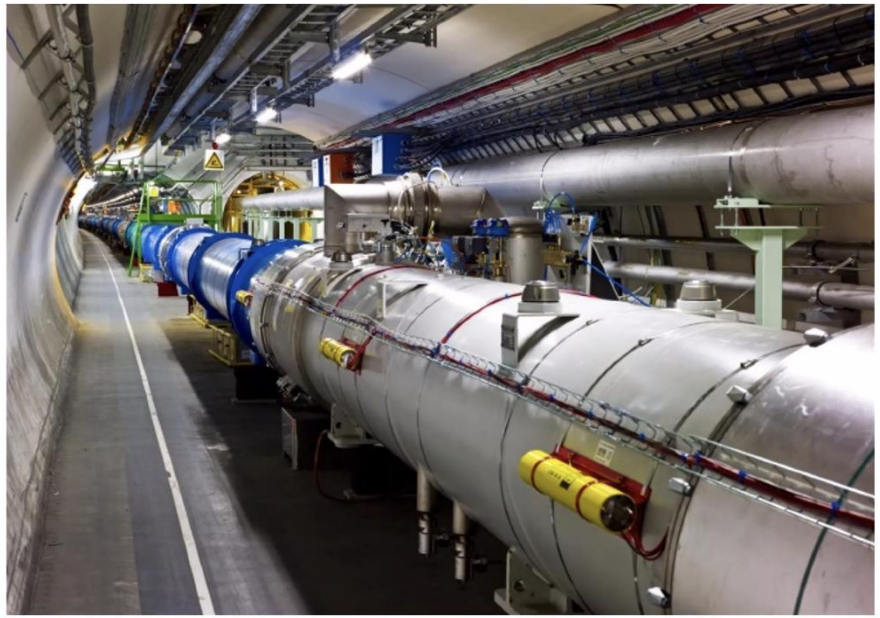
Tune
for ap

Data Processing Platform

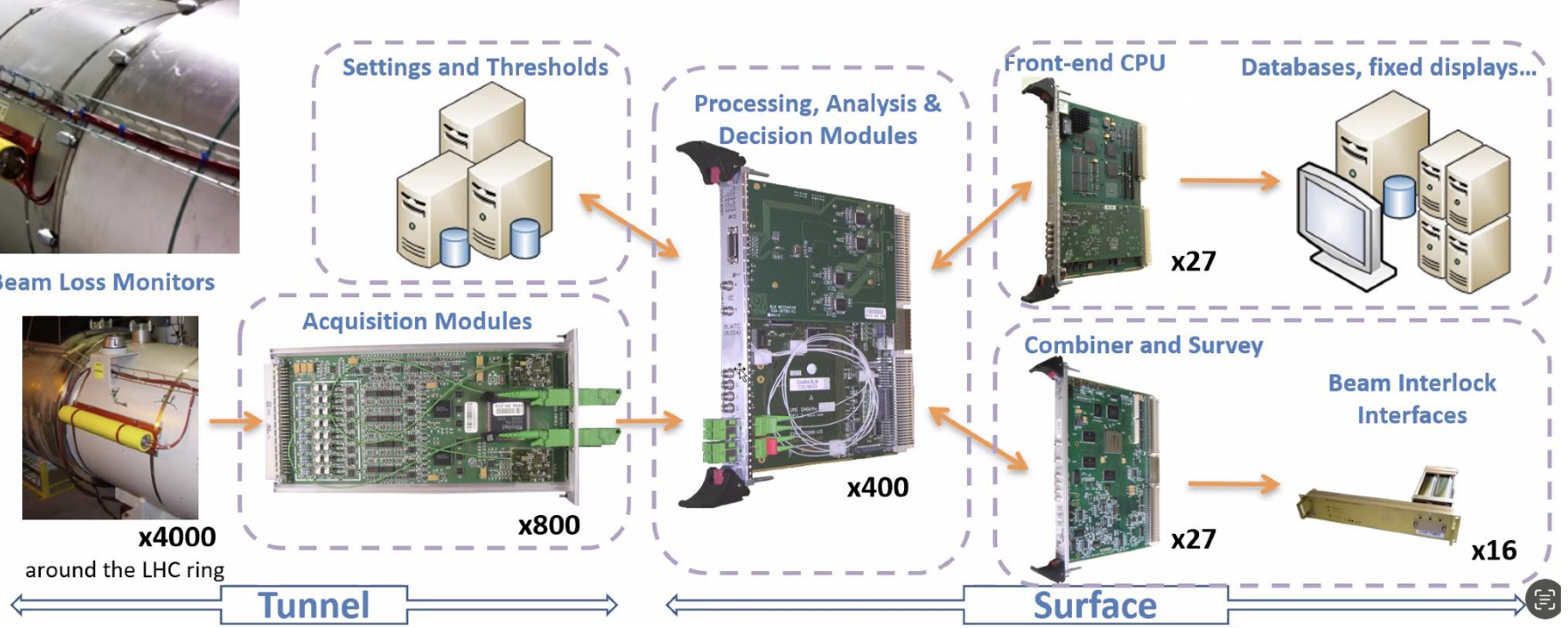
One tool for Online and Offline Analysis adopting the UCAP philosophy: focus on solving your problems and performing your analysis – we'll take care of the rest



Automation framework: BLM monitoring

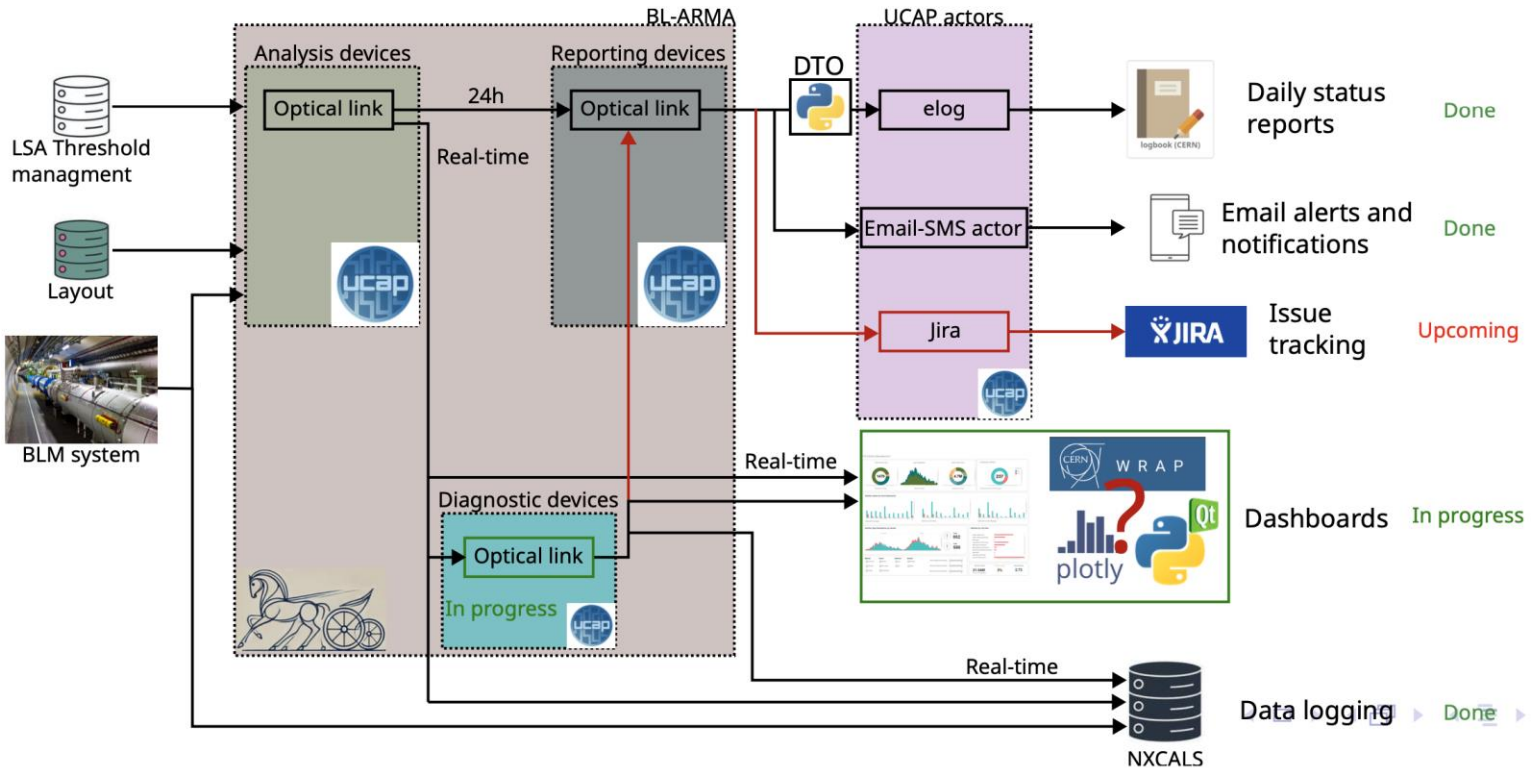


- Monitoring the connection status between the BLM acquisition boards and the processing modules.



Automation framework: BLM monitoring

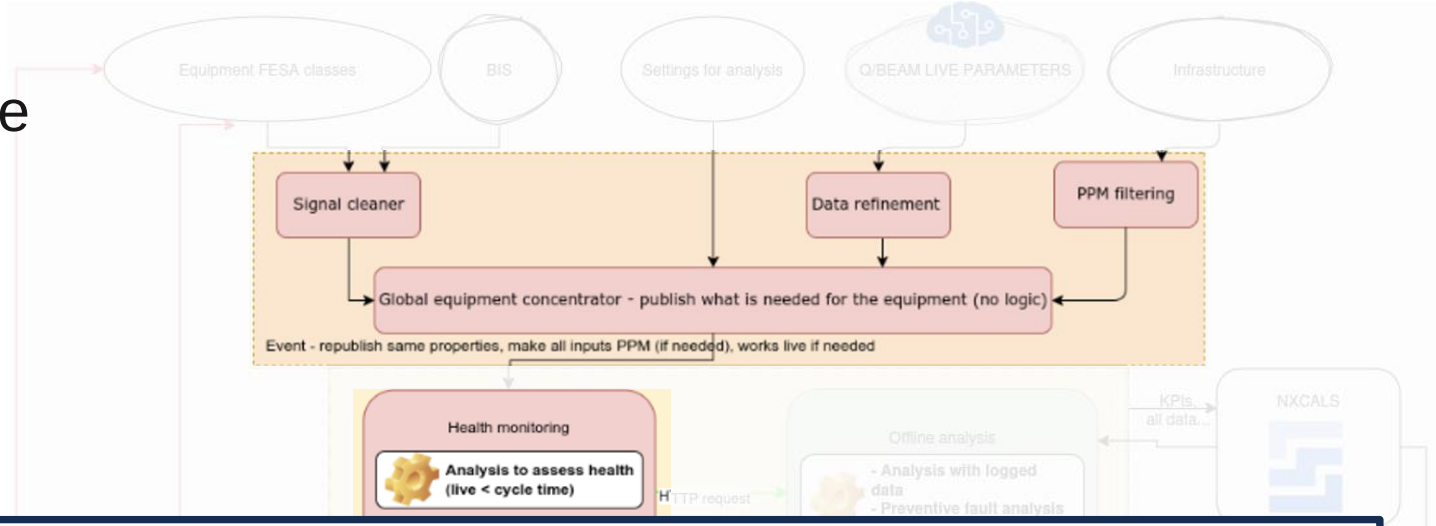
- Connection status of 4,000 BLMs.
- Diagnostic produce real-time data logged in NXCALS, WRAP dashboards…
- Every 24 hours, reporting to emails, logbook, Jira issues, notify the piquet directly.
- Equipment already auto-reset, so auto-recovery not meaningful.
- Human intervention is required for fault resolution.

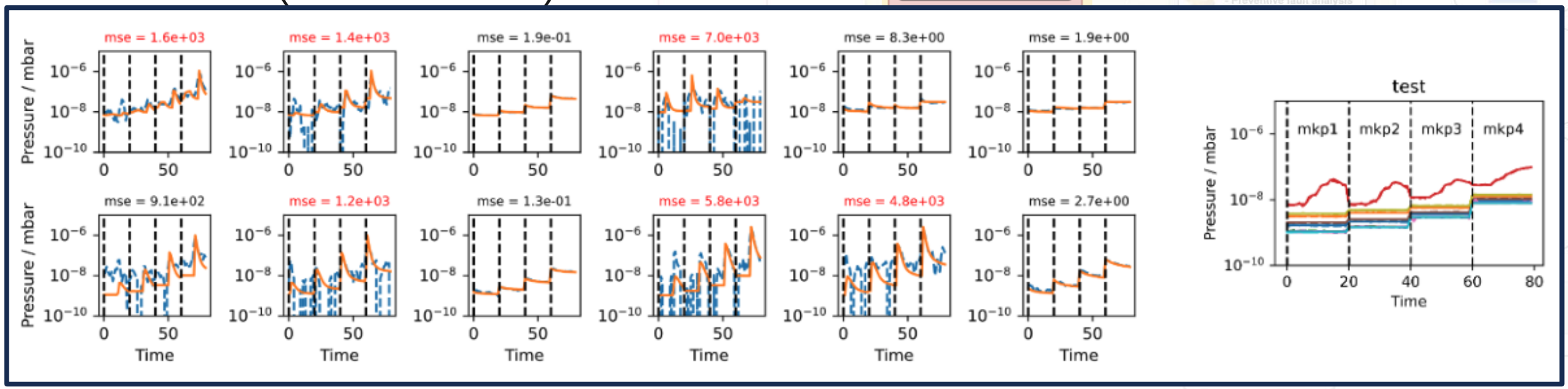


Automation framework: BLM monitoring

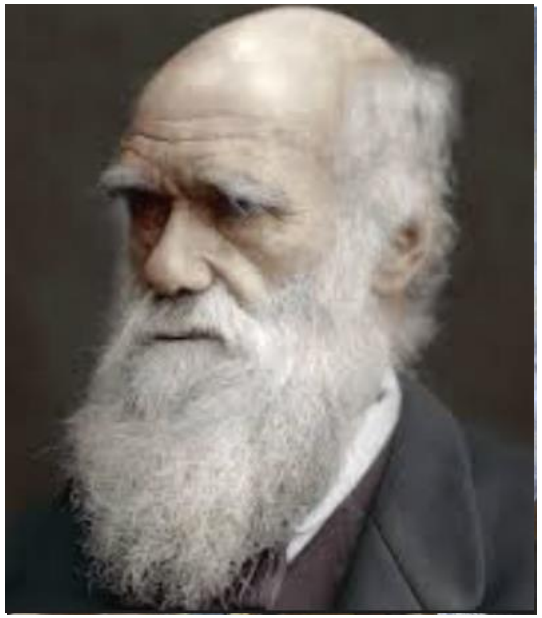
Automation framework: kicker spark detection

- MKP faults are reported through the standardized UCAP.
- When a fault occurs, the analysis monitoring logic retrieves vacuum pressure data and inputs it into an autoencoder (neural network).





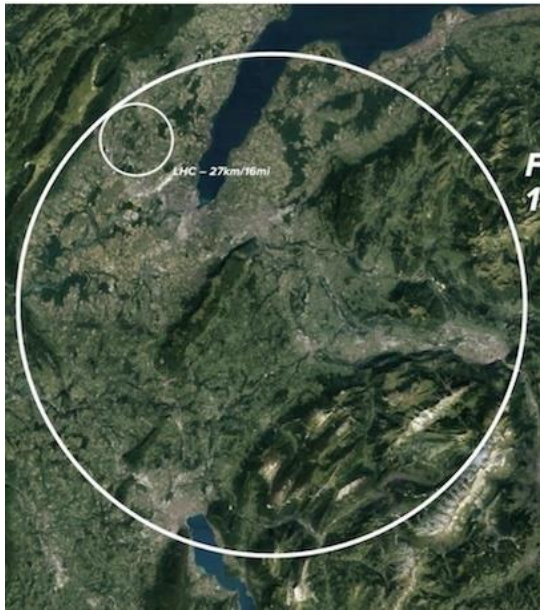
Conclusion



Evolution

Collaboration

Forum



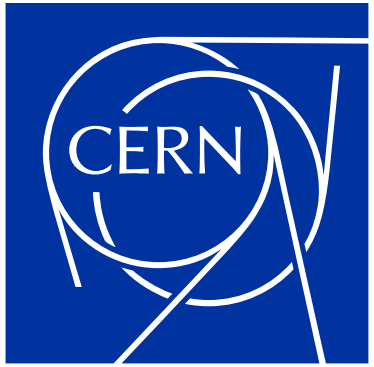
Foundation for Future

Conclusion

“So far, we've automated as much as we can … with the resources we have. The next step would be a big investment in time… that of course, would outweigh the benefits in the long term, but the fact is that today we just don't have these resources, sadly enough.”

There is a strong collective desire to improve processes.

But allocation of resources is essential to drive this effort forward.



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EPA organigram

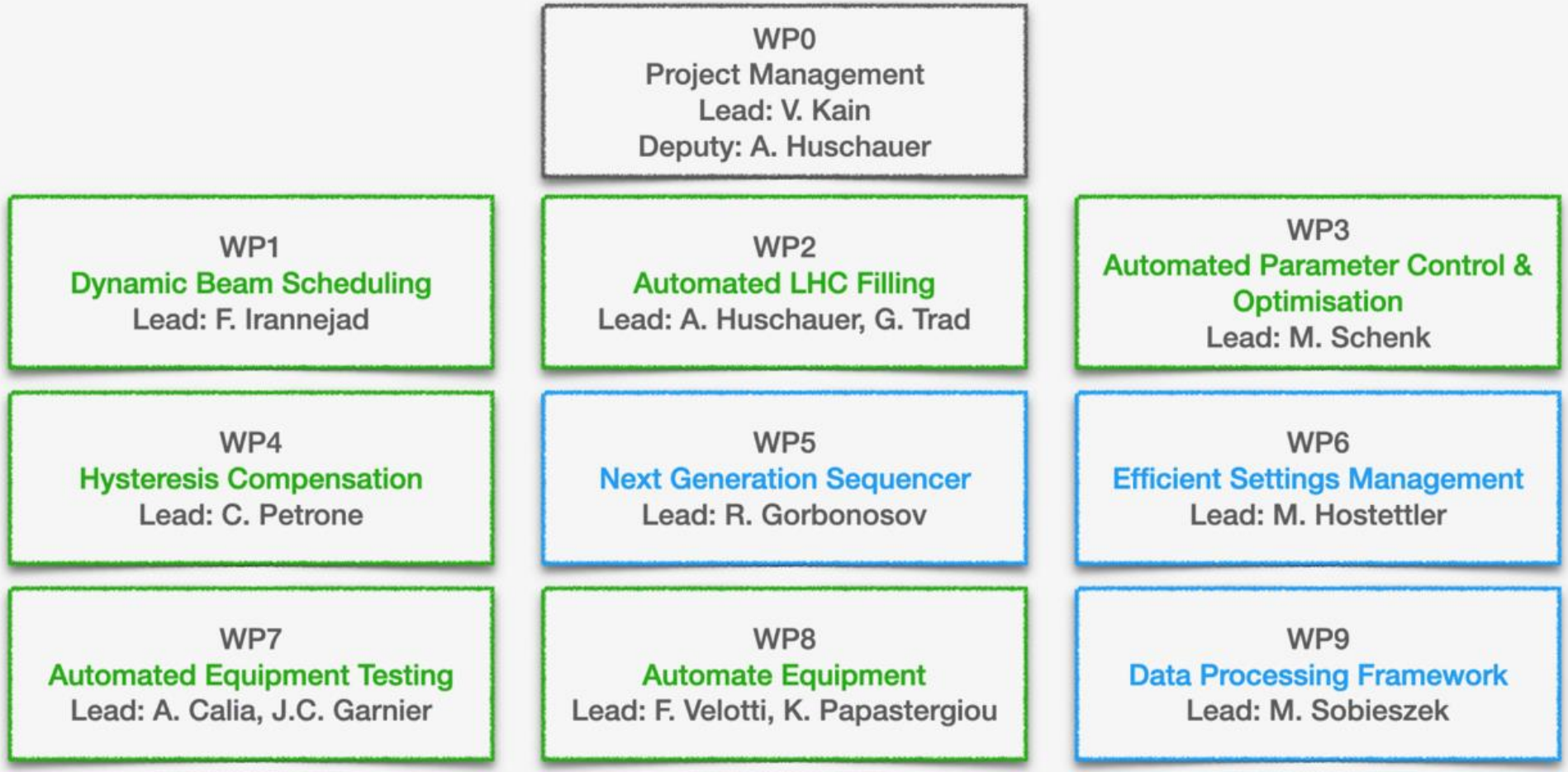

Figure 2.1: Project structure and work packages. The green color highlights the WPs directly inferred from the ETT recommendations, whereas the WPs in blue address the controls infrastructure evolution.