CRYOGENICS OPERATIONS 2008

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Organized by CERN

The LHC Control System

Philippe Gayet

On behalf of AB-CO-IS

LHC Cryogenics Architecture

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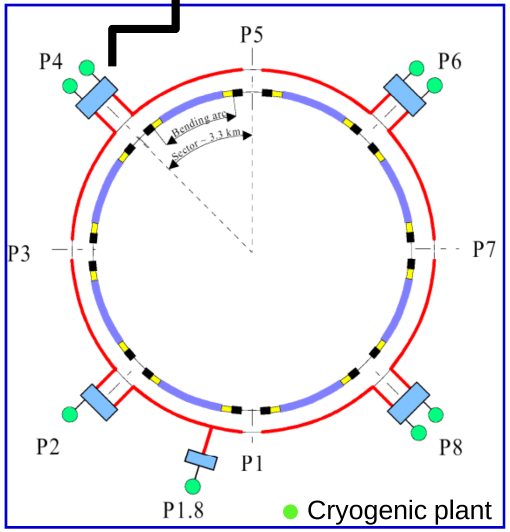
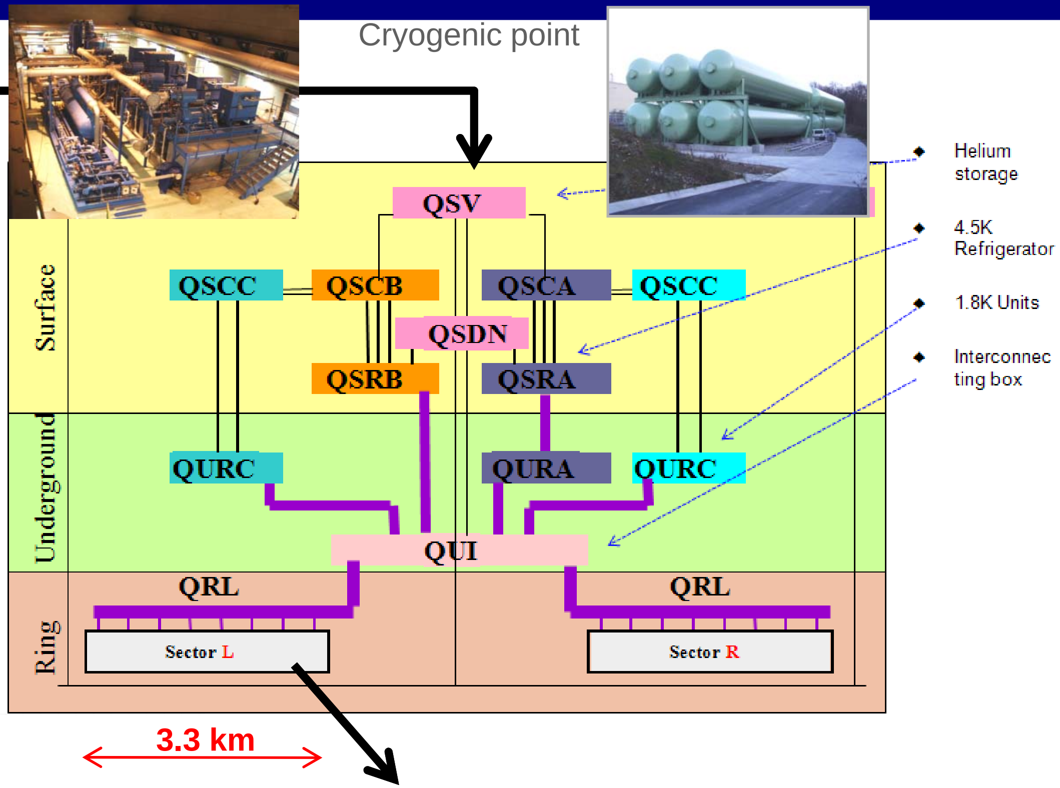
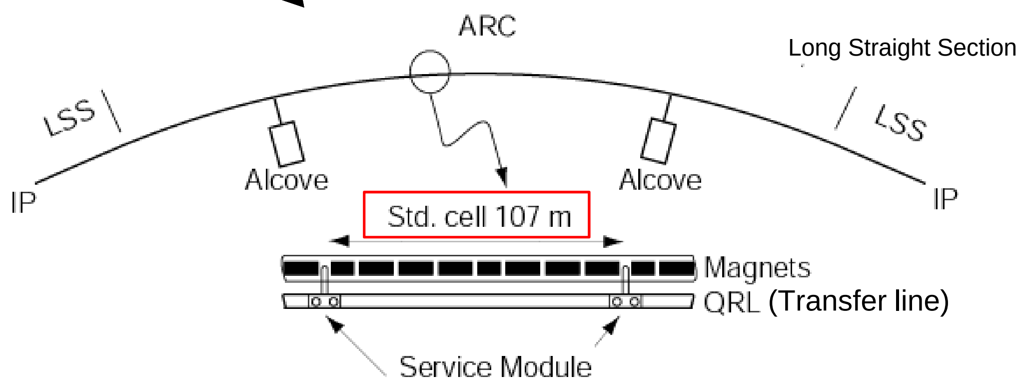
LHC cryogenics overview





LHC tunnel (27 km)



Deployment constraints

- **Application production by various team**
  - » CERN internal
  - » External company (initial tight schedule)
  - » Produced by external collaboration
- **Staged commissioning**
  - » Commission a new cryogenics component without stopping the already running ones
- **8 years of deployment with evolving technology and requirements**
  - » Evolution Radiation environment prevision
  - » Increased number or channels from 30000 to 60000

Operational contraints for CS

- **Reliability**
  - » Avoid Cryogenic downtime
- **Efficiency**
  - » The complexity of the controlled process is such that the operator duty shall be alleviate by a very high level of automation and efficient diagnostics facilities
- **Ergonomic**
  - » Compatible with former operation practices
  - » Homogeneous, intuitive, adapted to a large system
  - » Seamless integration of various control hardware components

HARDWARE

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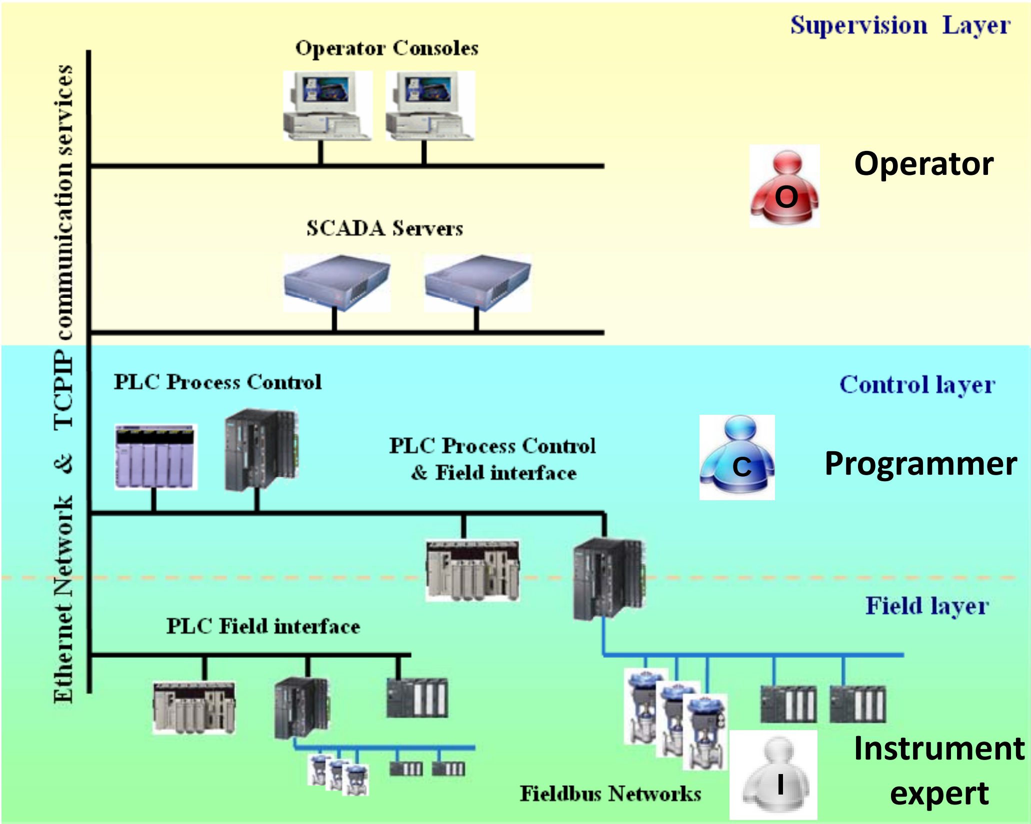
LHC control a BIG step forward

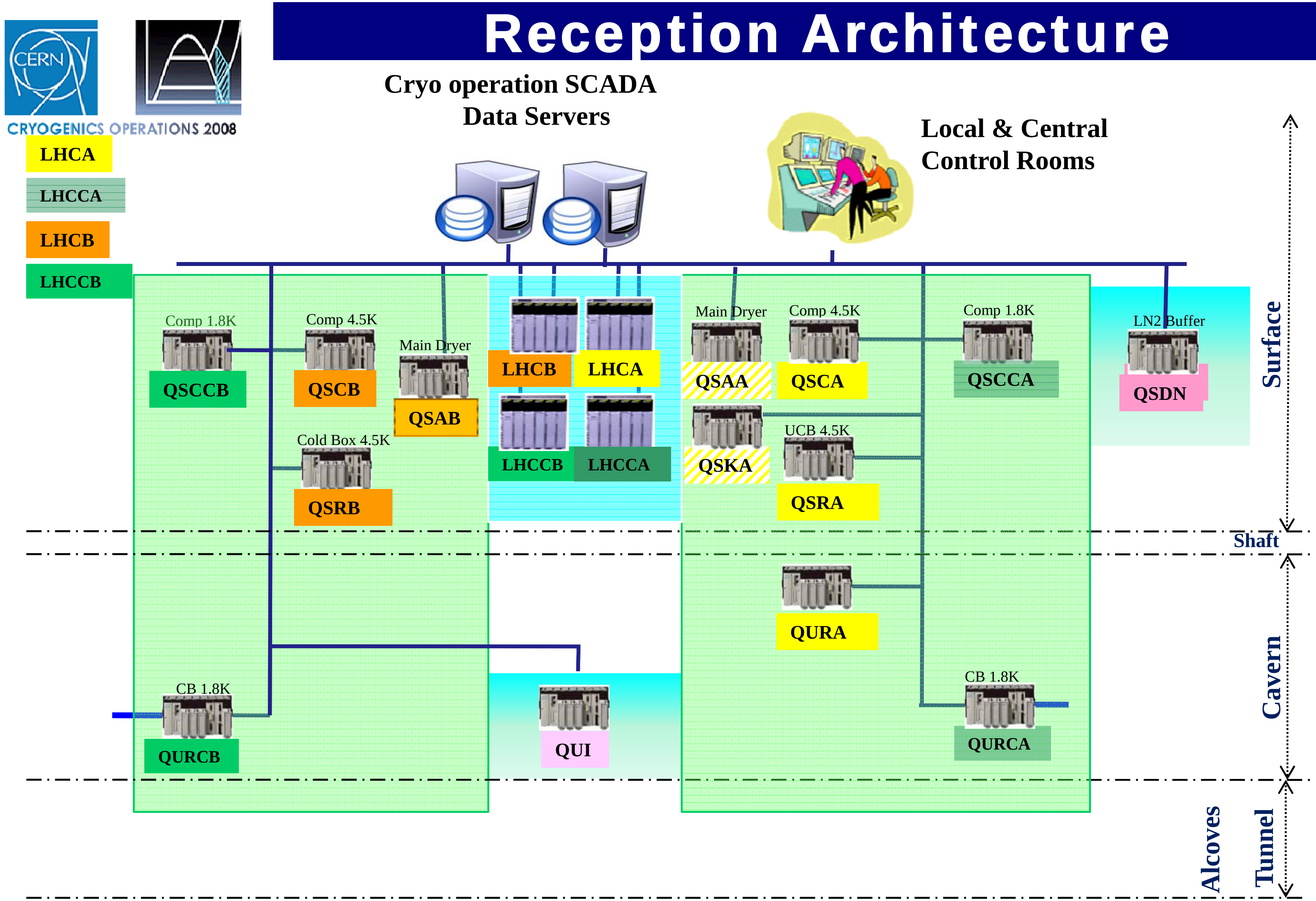
- **LEP 2 (1992-2000) (2 layers solution)**
  - » 11 Supervision servers Used Operator workstations
  - » 20 PCU directly connected to process I/O
  - » 8000 I/O
- **LHC SPECIFIED (1999) (3 layers solution)**
  - » 20 OWS connected to 5 supervision servers
  - » 29 PCU connected to process I/O throught 421 Field interfaces (remote I/O board or fieldbuses)
  - » 30000 I/O

Specification Architecture



- Supervision layer
  - Interface for operation Team
  - All operators action are taken from this level
- Process control layer
  - PLC : the control logic is performed at that level
  - Programmers act on that Level
- Field layer
  - Interface to process direct I/O Boards, Fieldbuses

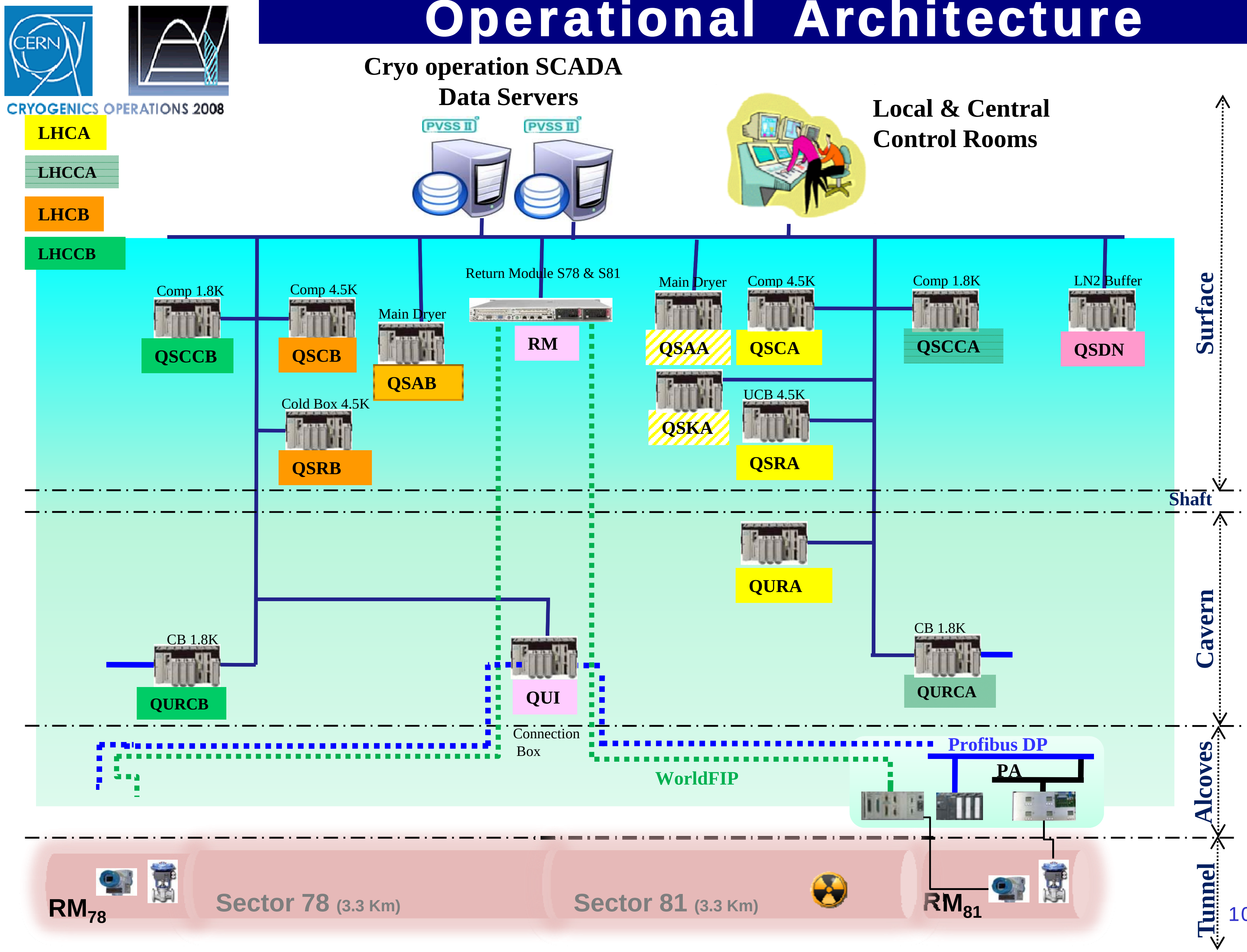
Reception Architecture



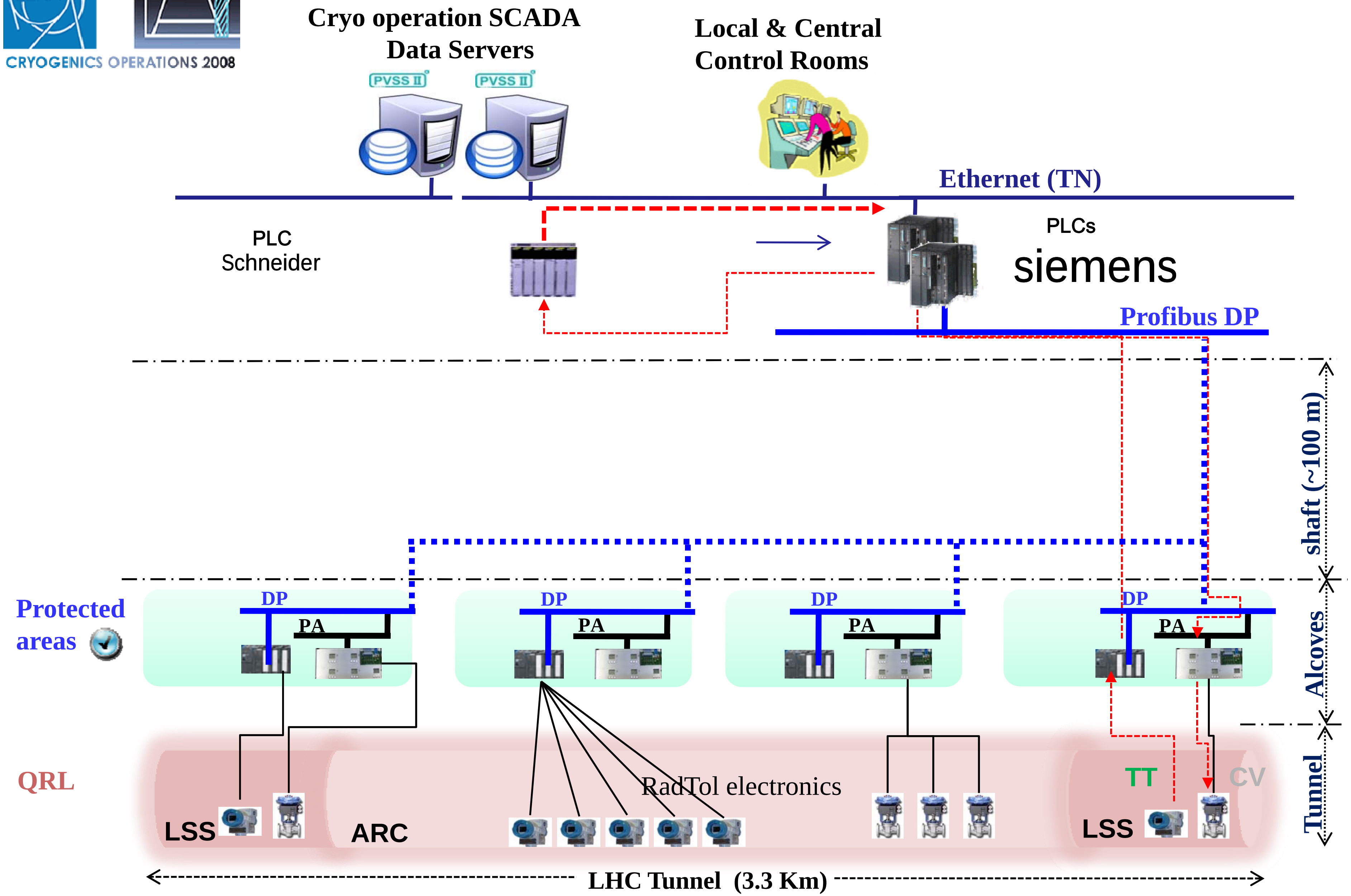
Adaptation during project

- **Control Layer and Field layer**
  - » Dependency of closed loop to the network led o the suppression of Quantum PLC (2007)
  - » Introduction of FIP for instrument under  Environment
  - » Doubling of I/0 numbers compared to Specification
  - » Migration from PL7 and concept to UNITY (2001)

Operational Architecture



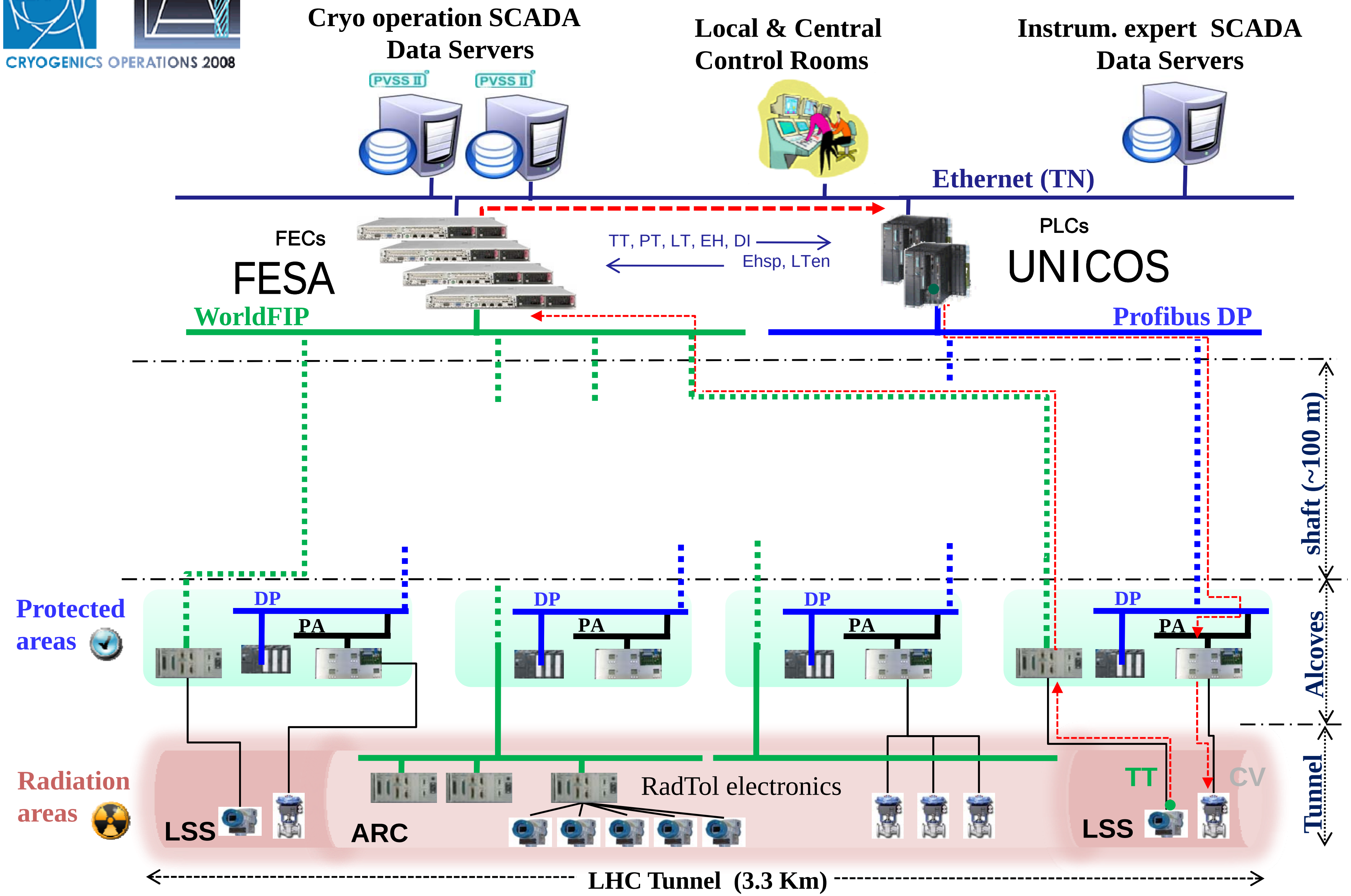
QRL Architecture



Adaptation during project

- **Control Layer and Field layer evolution**
  - » Introduction Of FESA FEC for FIP (2004) to take profit of the AB-CO support on that hardware type
  - » Development of UNICOS on Siemens PLC (2004) and use of them for Tunnel control (2004) To reduce the number of components improve the reliability and allow the use of intrumentation maintenance software for cryogenic valves

Tunnel Architecture

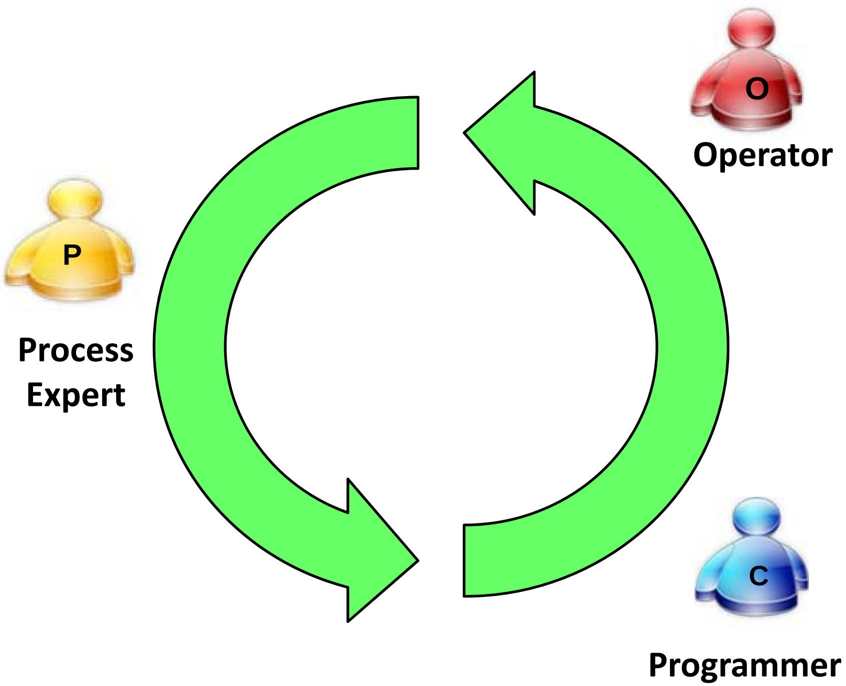


Learned lesson

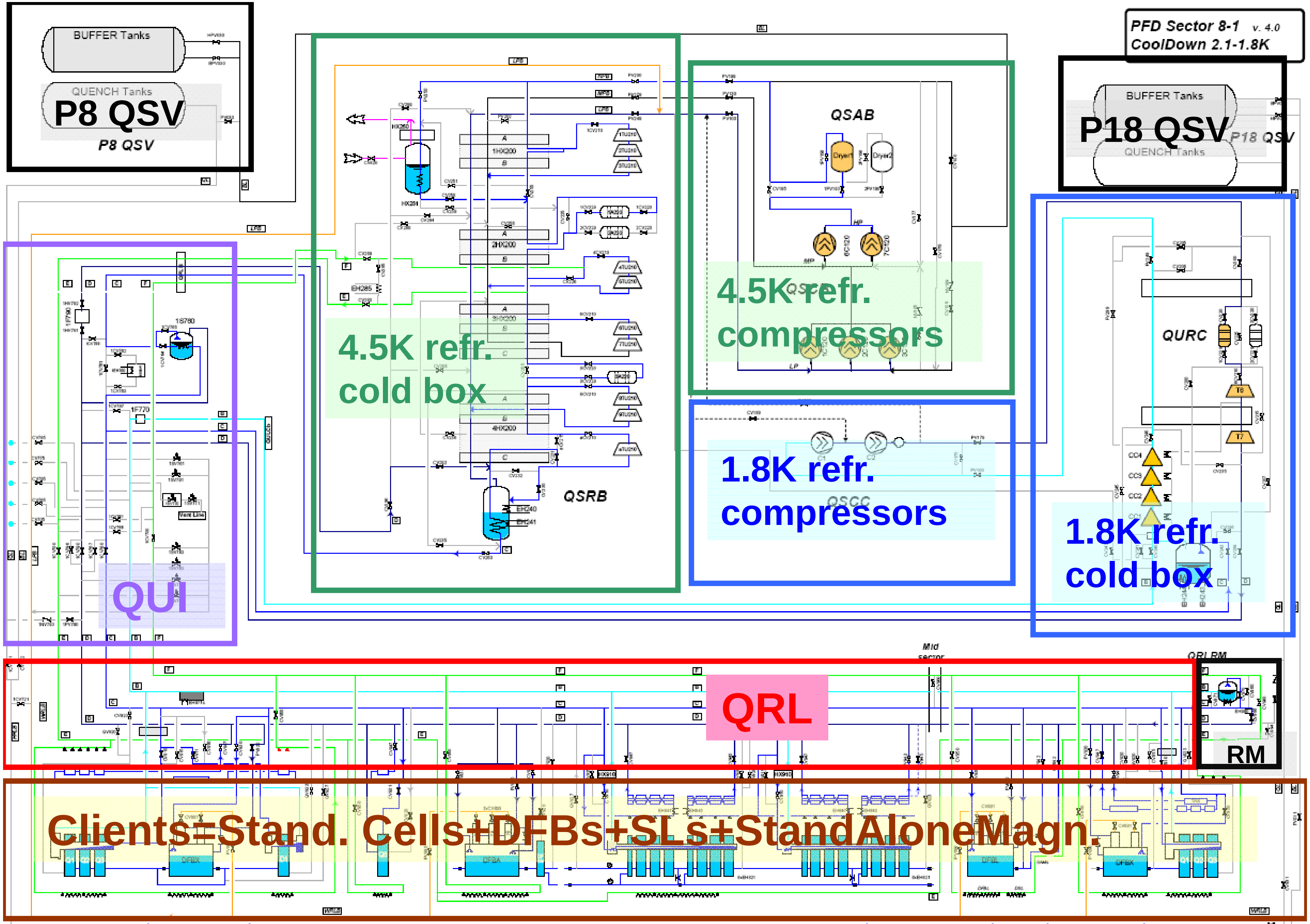
- Absolute necessity of Layer Independence
- Choose always scalable solutions
- In house mastering of the technology allow the proper adaptation to the user requirement evolution

SOFTWARE

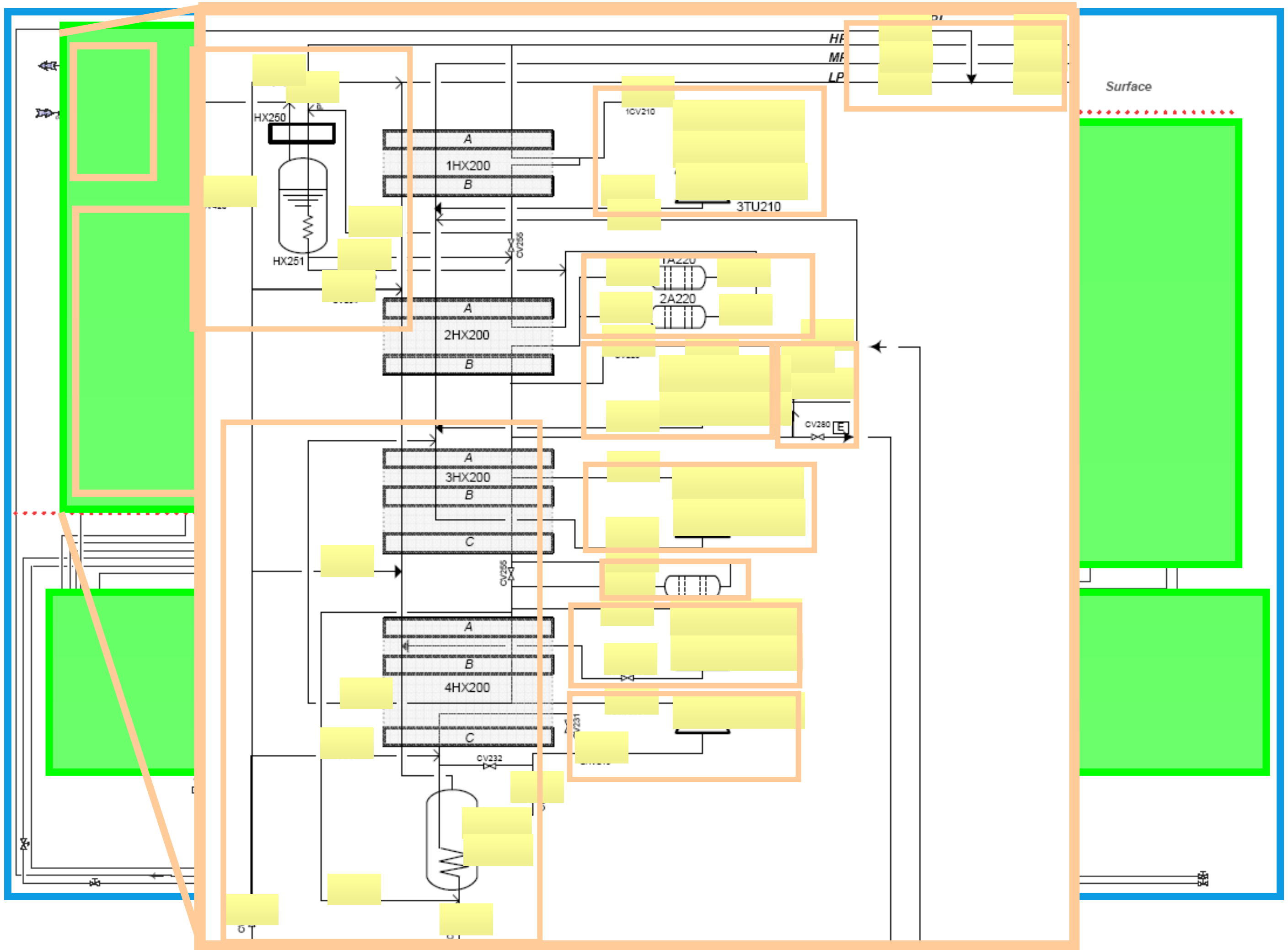
SOFTWARE CYCLE

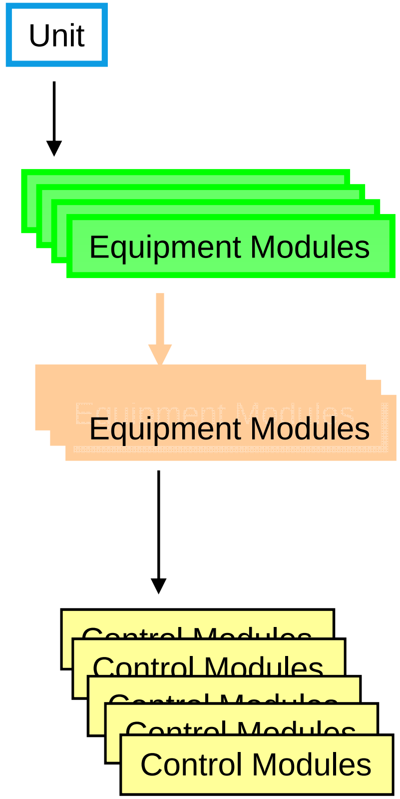


- This iterative cycle implies a good communication between the actors.
- All partner shall have a common understanding without knowing the details of the other specialties
- The cycle will perform several loops and the more you approach the operation the shortest it is.
- The quality shall no be forgotten but must remain manageable
- No regression or side effect must be generated by control logic modifications.


PFD Sector 8-1 v. 4.0
CoolDown 2.1-1.8K
BUFFER Tanks
QUENCH Tanks
P8 QSV
P8 QSV
P18 QSV
P18 QSV
QSAB
QSRB
QURC
4.5K refr. cold box
4.5K refr. compressors
1.8K refr. compressors
QSCC
1.8K refr. cold box
QUI
QRL
RM
Clients=Stand. Cells+DFBs+SLs+StandAloneMagn.

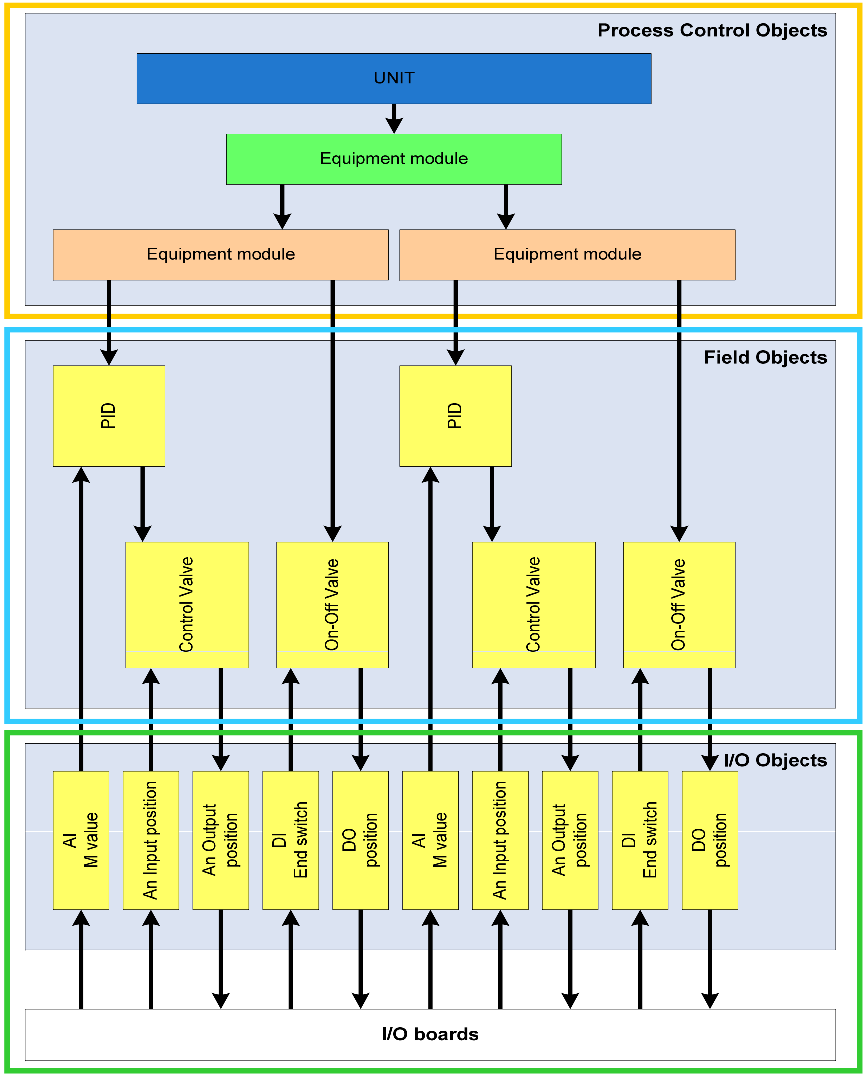
Hierarchical Process Functional Analysis





IEC 61512-1
Physical model

Control system breakdown

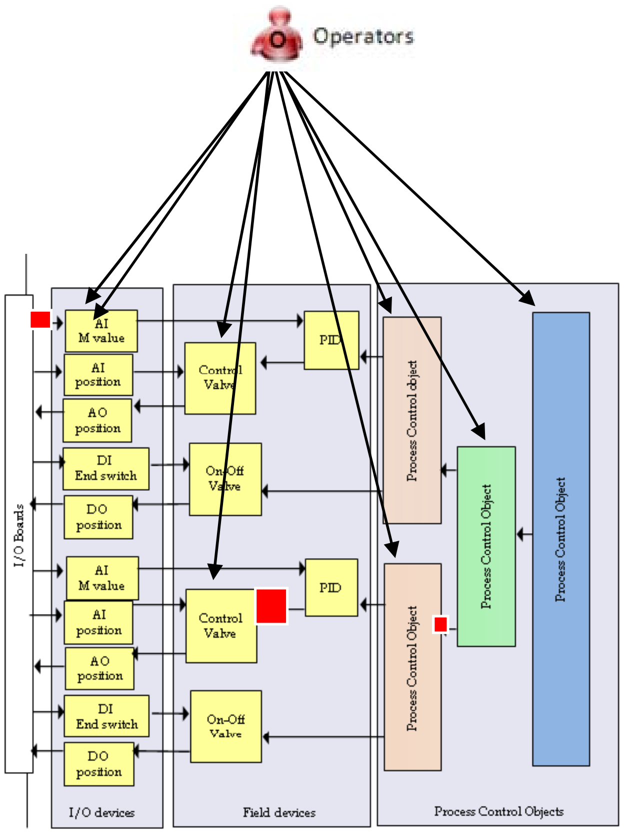


Process Control Objects: automation of a group of dependent device

Field Objects: image of the real devices : valves, motors, pumps..

I/O Objects: Interface the process

Control and Operation principles



- **Automation duties are performed in PLC**
  - » Automatic startup/stop sequences
  - » Closed loop control
  - » Interlock action and automatic recovery

- **But Operation team must be able to :**
  - » Take manual control of any individual control device to overcome automatic request :
    - Online tune the close loop
    - Simulate Input in case of sensor failures
    - Brake the closed loop
    - Put part of the controlled system in special condition to face degraded environment.
    - Test new control strategy manually before implementation

Learned lesson

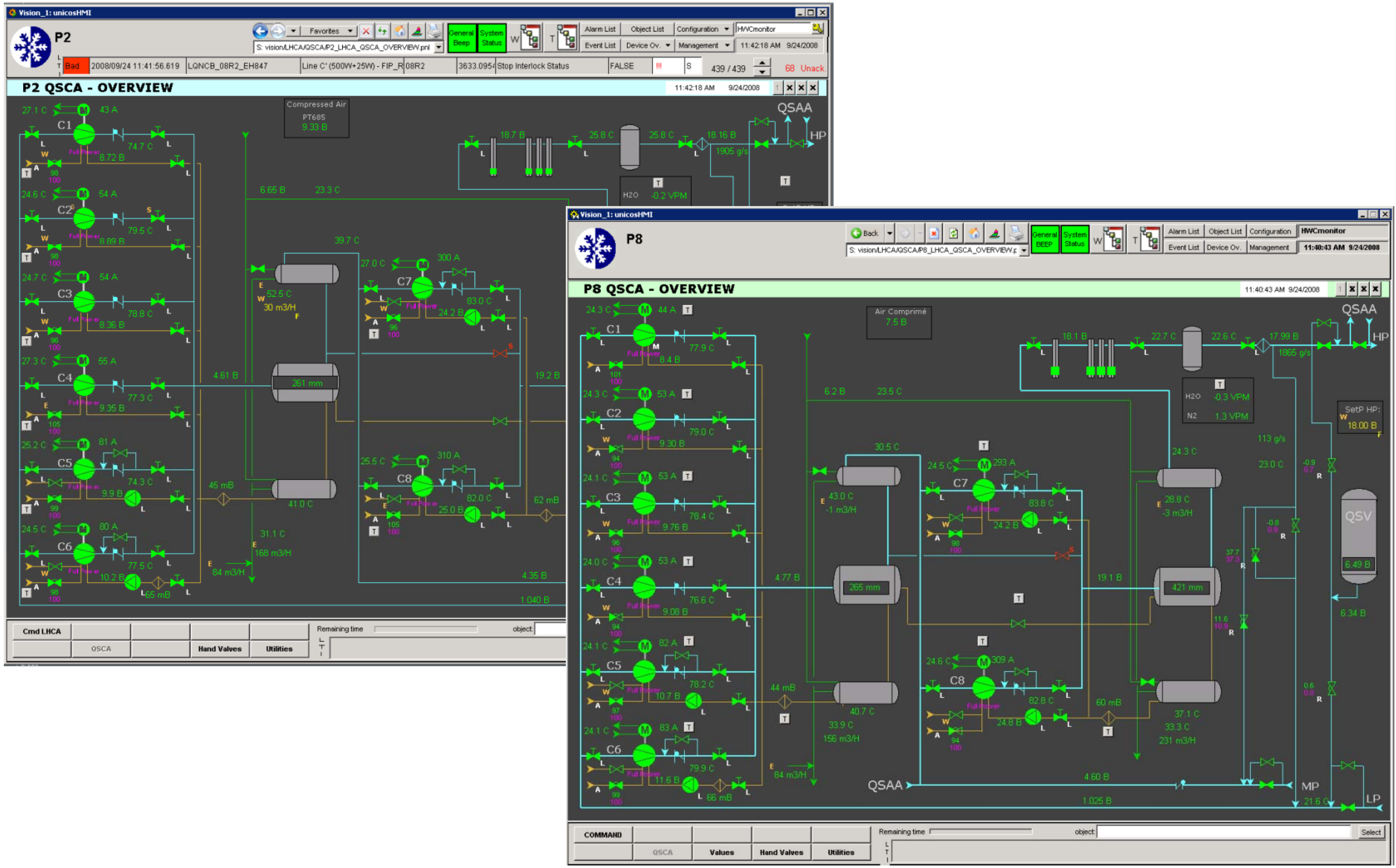
- Chosen breakdown analysis and control implementation is successful and adapted to all cryogenics systems, the software cycle was efficient, we have experienced regression but now the processus is mastered
- Possibility of online modification was mandatory for commissioning period but the modifications will be reduced and even suppressed during the operation to avoid downtime as these actions weaken the control system
- The capabilities to overcome implemented logic given to Operators have been extensively used and was necessary

Operator user interface

Principles & Functionality

- **Homogeneous user interface**
  - » Panels with identified roles
  - » Enforced rules to present the information
  - » Common interaction to devices
  - » Access to all information related to one device by one click
- **Access right to distinguish between users**
- **Post mortem tools and integrated diagnostics**
- **Monitoring on the control system itself**

Homogeneous layout



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rules of information presentation

Data quality	Letter	Color	Priority
Invalid	N	Cyan	Highest
IO Error	E	Orange	Highest
IO Simulated	S	Orange	High
Forced <> Auto	W	Orange	Normal
Manual <> Auto	W	Orange	Normal
Position Warning	W	Orange	Normal
…	W	Orange	Normal

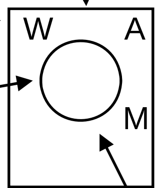
Alarm	Letter	Color	Priority
Full Stop Interlock	F	Red	Highest
Stop Interlock	S	Red	High
Start Interlock	I	Red	Normal
Position Alarm	P	Red	Normal

Mask	Letter	Color	Priority
Alarm Blocked (in PLC)	B	Yellow	Highest
Alarm Masked (in PVSS)	M	Yellow	High
Event Masked	e	Yellow	High

Body	Color	Priority
Invalid	Cyan	Highest
Alarm Unack.	Red Blinking	High
Alarm	Red	Normal
Forced Mode	Yellow	Low
Auto Mode	Green	Lowest

Frame selection state

Data quality



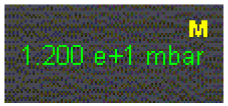
Alarm nature

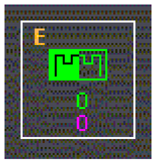
Body
Color :alarm state
Filling : state

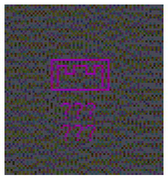
Mode

Feedback
&
orders or option mode

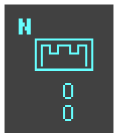
Mode	Letter	Color
Auto	None	None
Manual	M	White
Local	L	White
Forced	F	Yellow
Regulation	R	White
Tracking	T	White



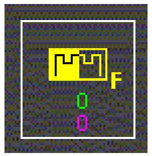




Data not connected



Data invalid



Homogeneous interaction

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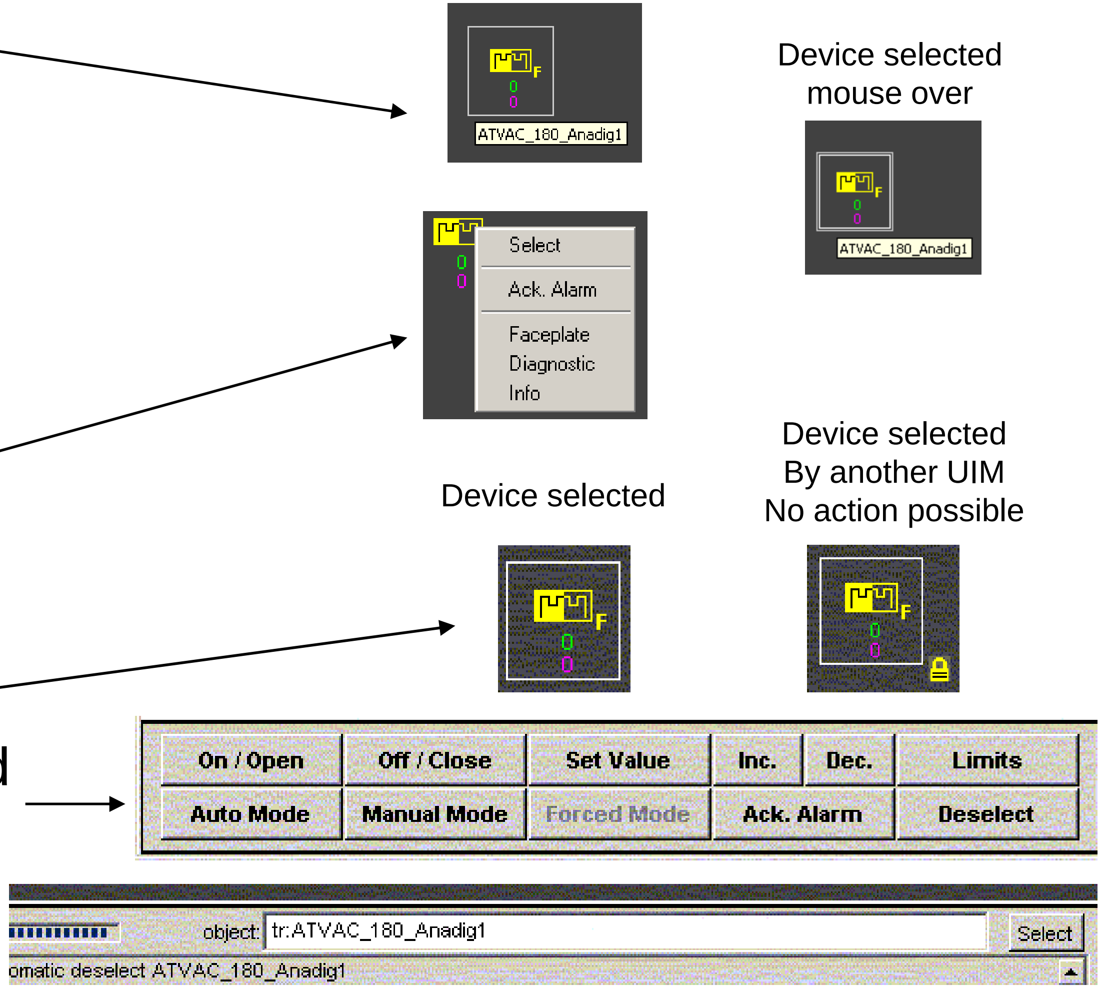
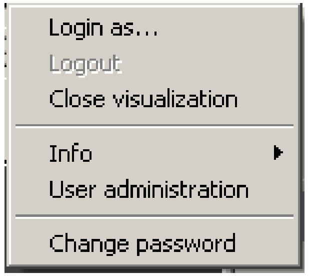
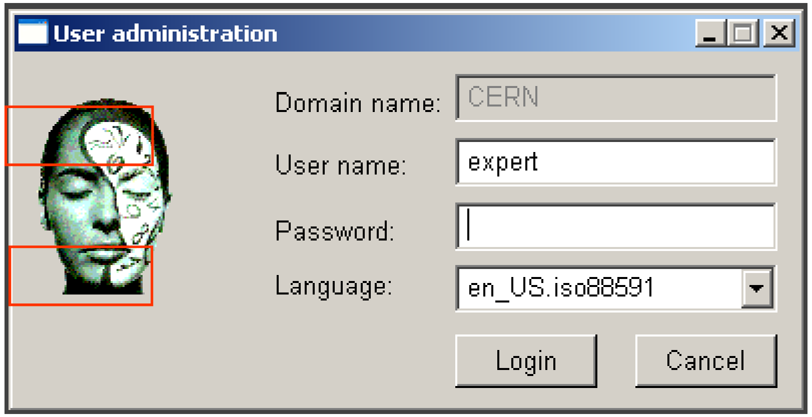
- Mouse over
- Mouse click
  - ✓ Select if user authorized: operator minimum
- Mouse double click
  - ✓ Select, open faceplate
- Mouse right click
  - ✓ Menu
- Device selected:
  - ✓ White box around
  - ✓ Contextual button opened in context area
  - ✓ Device name set in the footer of the graphicalFrame



Access and privilege rigth





Users:

root
admin
expert
operator
monitor

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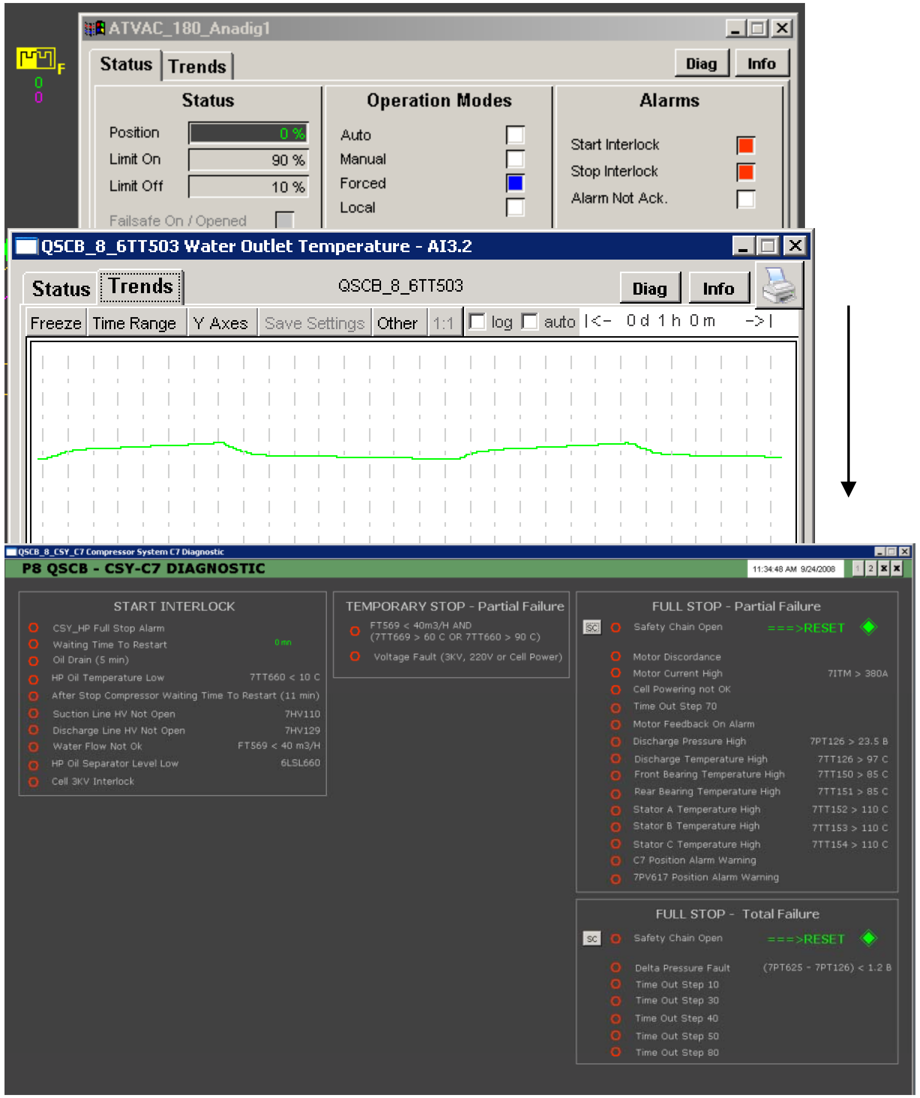
Device analysis

- Data area
- Trend area
- Diagnostic: PVSS panel



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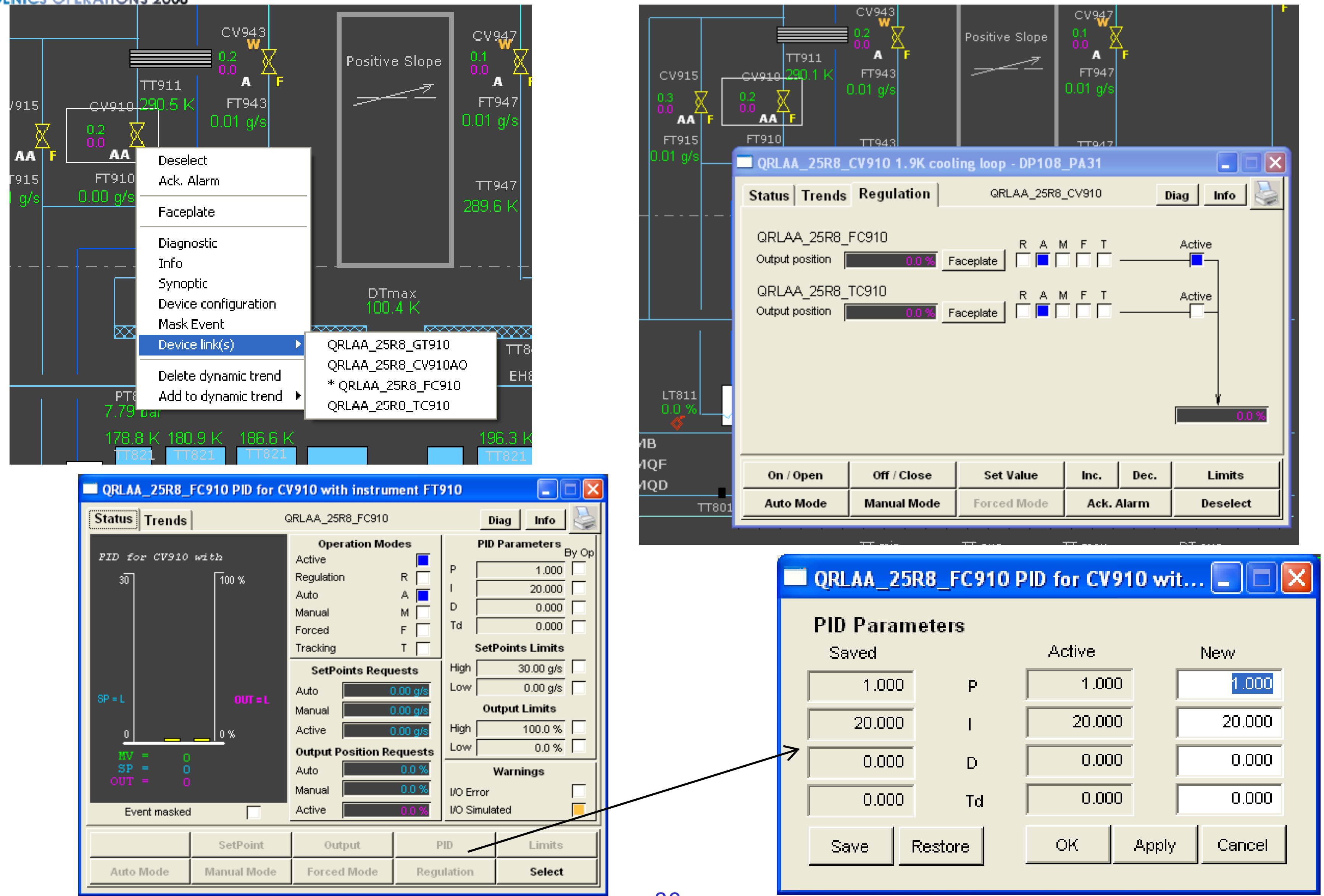
Easy navigation between devices



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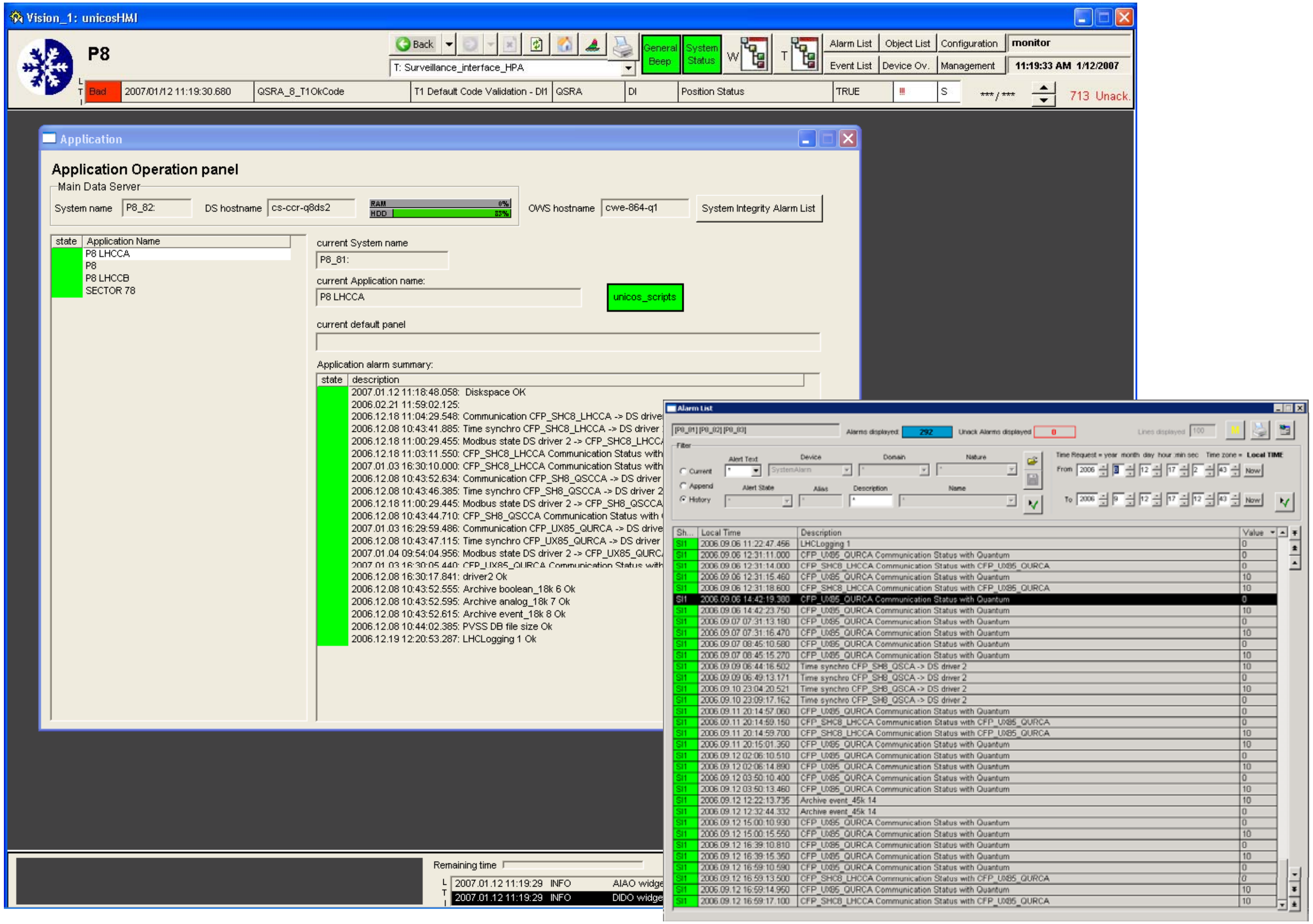
Integrated system diagnostics



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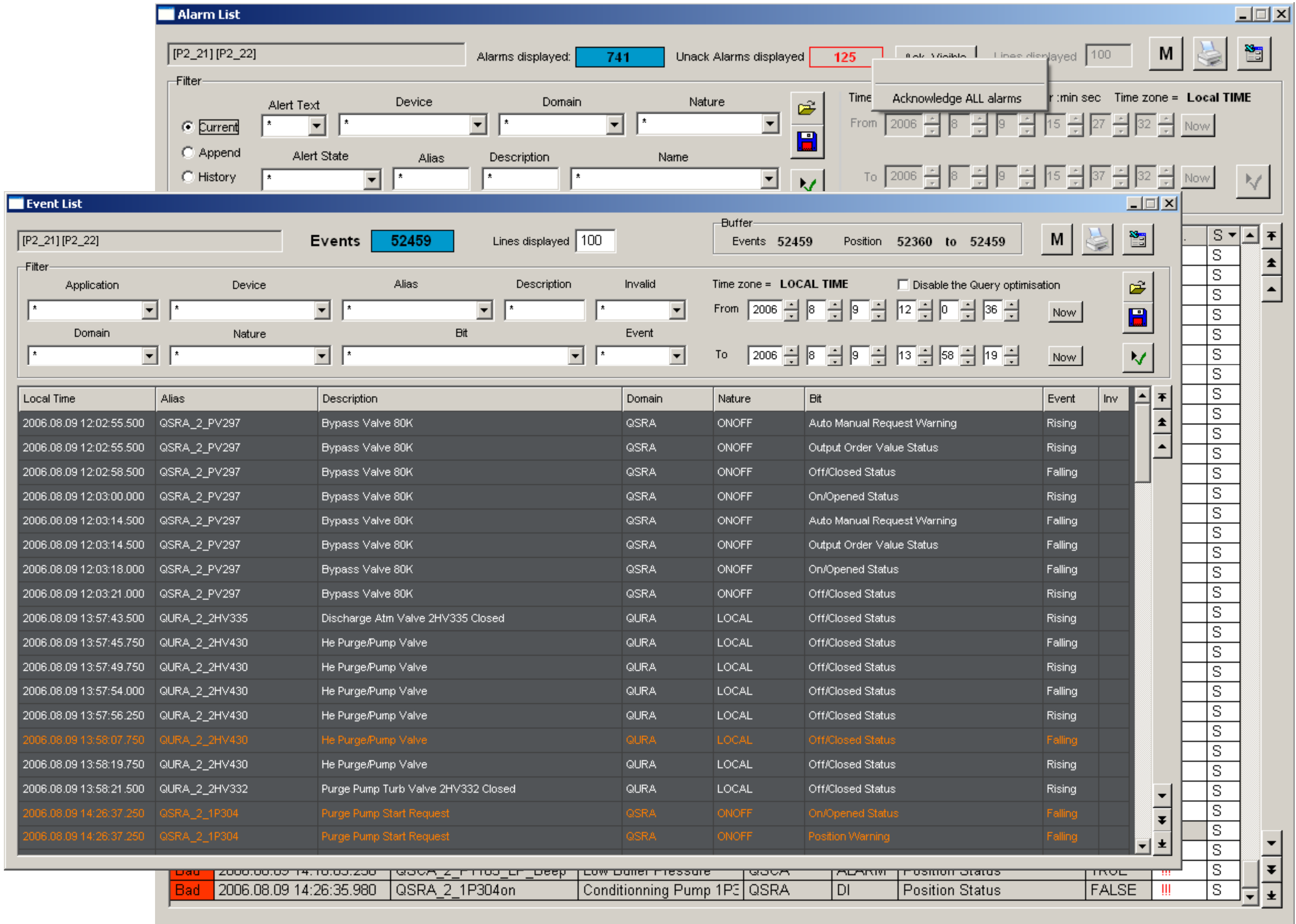
Post mortem tools

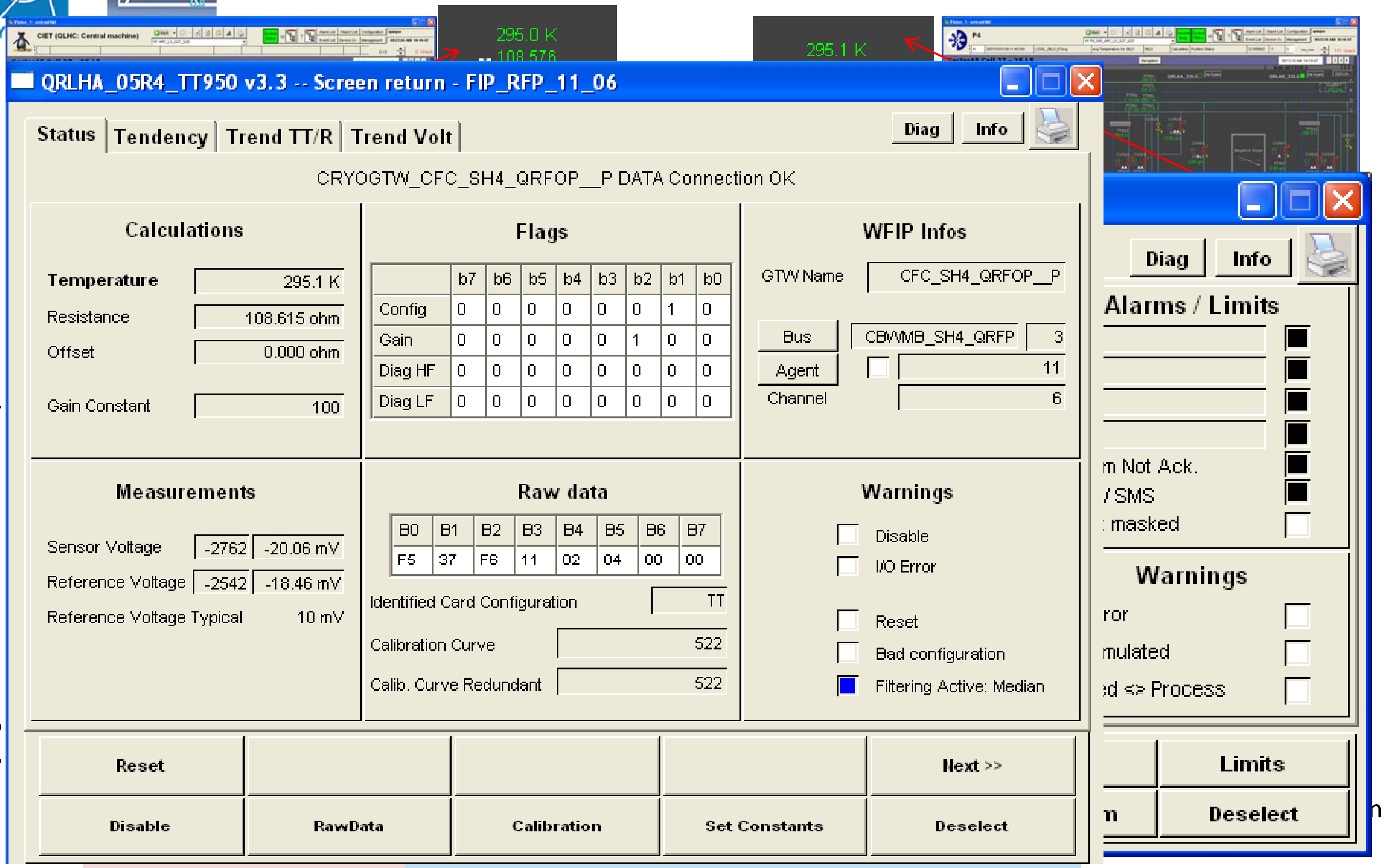


Adaptation during project

- **Supervision layer**
  - » scalability and performance during first commissioning and political decision pushed us to migrate from PCVUE to PVSS (2002) to solve
  - » performances and commissioning constraints lead to increase the number of server from 5 to 15
  - » Number of task to be performed and the complexity of the duty imposed to increased number of operator consoles from 12 to 30
  - » Safety issues and early diagnostics Implied the necessity to access/operate from remote location (20 clients per sites)
  - » Necessity to develop a dedicated application for instrumentation experts

Adapted supervision tools

CIET: Cryogenics Instrumentation Expert Tool



Learned lesson

- **For such a large project scalability of the supervision system is absolute necessity**
- **“When you give your hand to the operator they want your arm”**
  - » Many additional functionalities had to be added (xy diagrams, bar-graph, device links,....)
- **Supervision tools must be adapted to the User needs :**
  - » Instrument expert requirements are far from the cryogenic operator ones and the tools shall be separated.

Conclusion

- **Despite of the evolution of the project requirements and planning the control system for LHC has (almost) always be delivered in time and fulfilled the Users needs.**
  - » Chosen 3 independent layers architecture
  - » Choice of scalable components
  - » Decision to use an enforced control methodology
  - » In house mastering of the technology even for parts that had to be subcontracted.
  - » Excellent cooperation and mutual understanding of the control and cryogenic teams