CRYOGENIC CONTROLS TODAY AND TOMORROW

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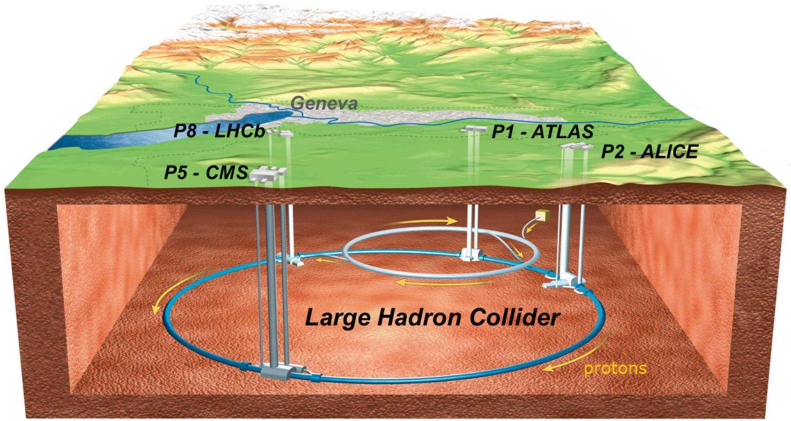
outline

- Introduction CERN LHC Cryogenic infrastructure
- Cryogenic Control System TODAY
- Cryogenic Control System evolution in the NEAR FUTURE
- Cryogenic Control System TOMORROW
- Conclusion

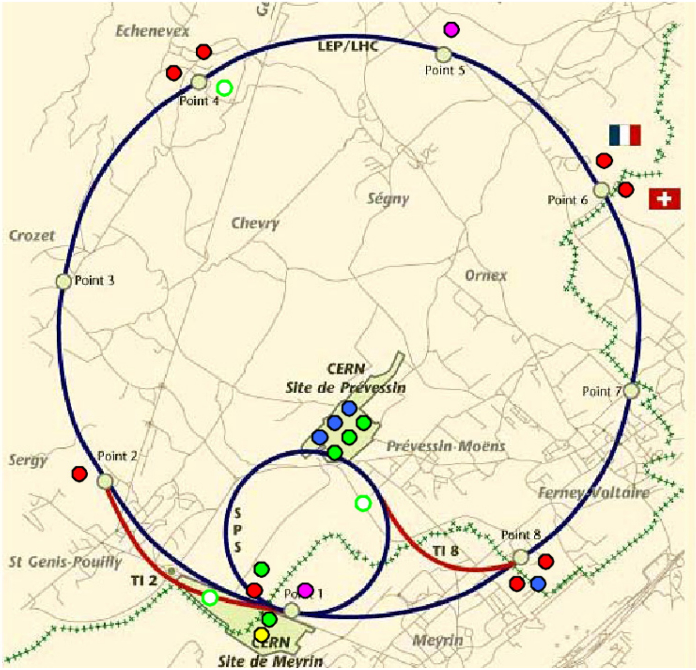
CERN LHC Cryogenic Infrastructure



CERN LHC circumference ~ 27 km.

Situated at ~ 100 m underground.

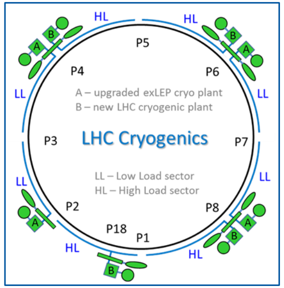
CERN LHC Cryogenic Infrastructure



- LHC accelerator
- LHC detectors
- Other detectors
- Test areas
- Central services
- Standby

<u>Total for 8 sectors:</u>

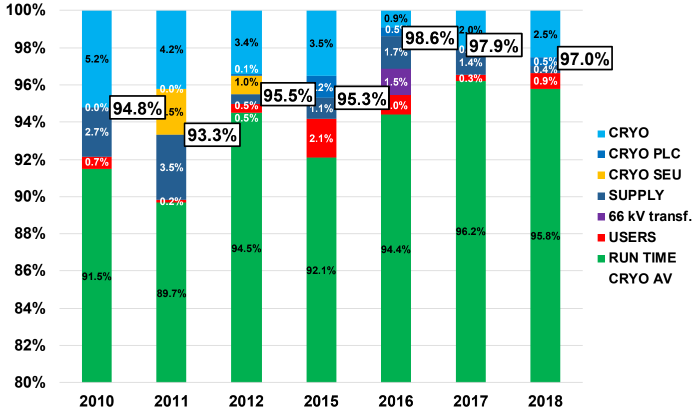
Compressors: 64
Turbines: 74
Cold Comp.: 28
Leads: 1’200
I/O signals: ~120’000
PID loops: ~7’000
PLC: ~150 cpu in production



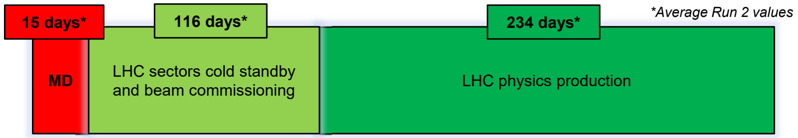
- Compressor station
- 4.5 K refrigerator
- Interconnection box
- 1.8 K pumping unit (cold compressor)

CERN LHC Machine Availability

Cryogenic Availability Evolution



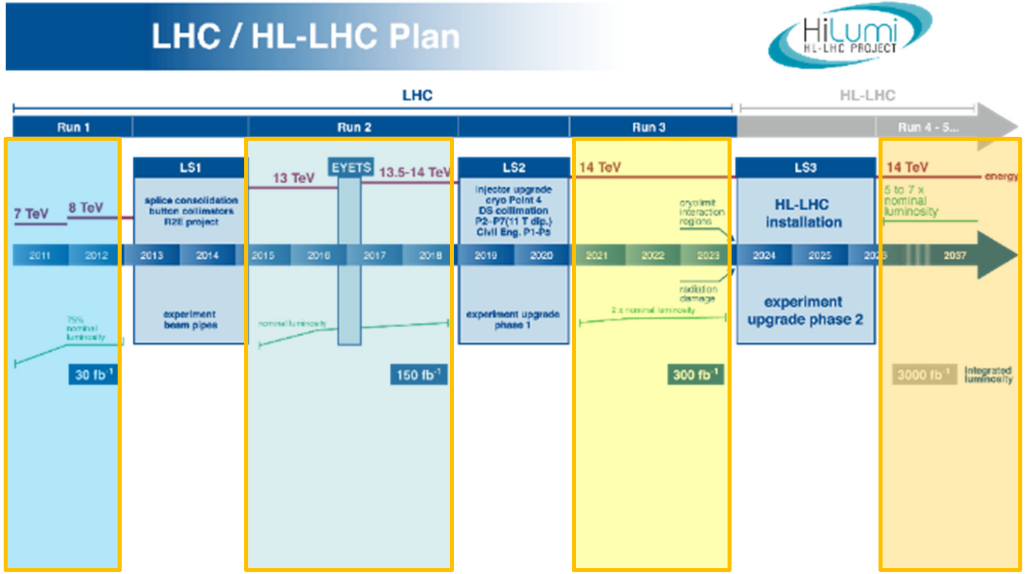
Typical yearly Physic Run campaign for LHC



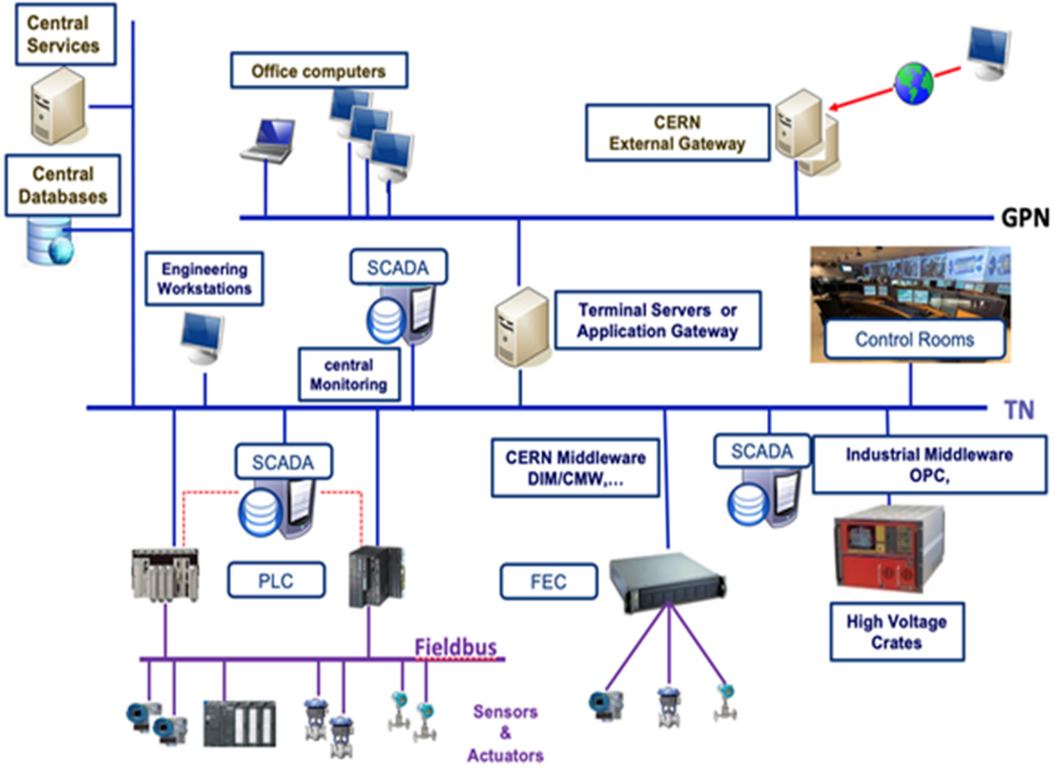
*Cryo availability : **97.0%** for 8 independent sectors*
*⇔**99.6%** for each cryoplant !!*

⇔99.99% for Cryo Control System

Day to day technical challenges : availability / optimisation



Present Cryogenic Control System Implementation



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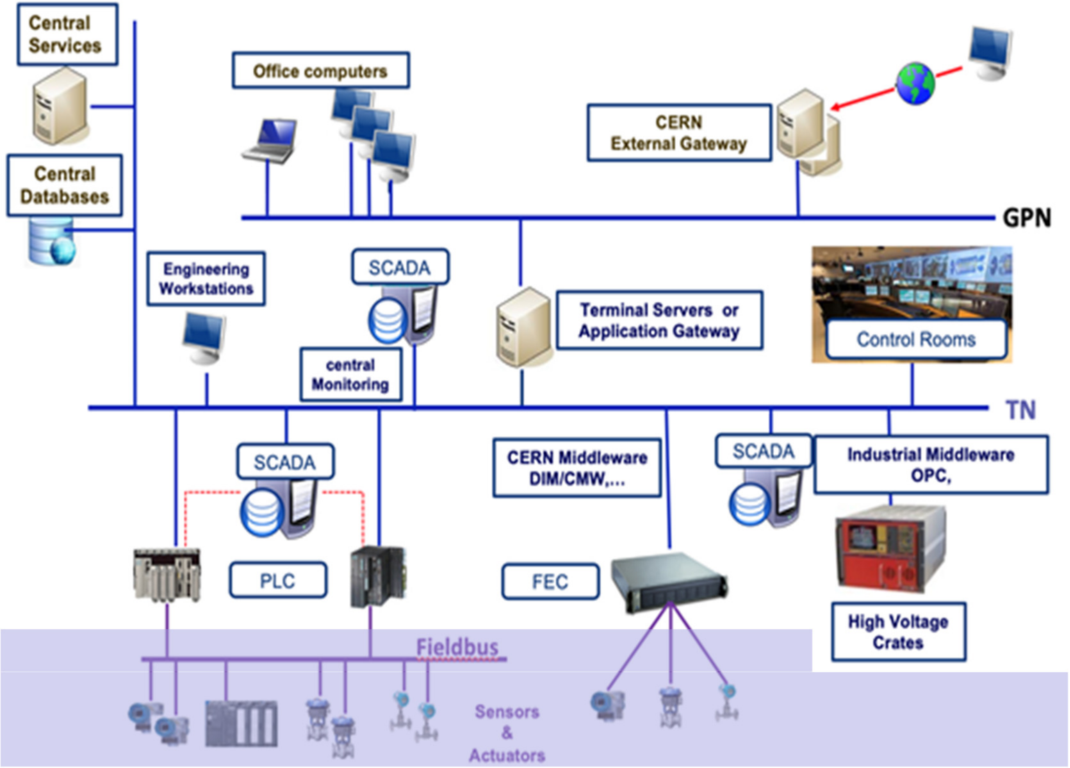

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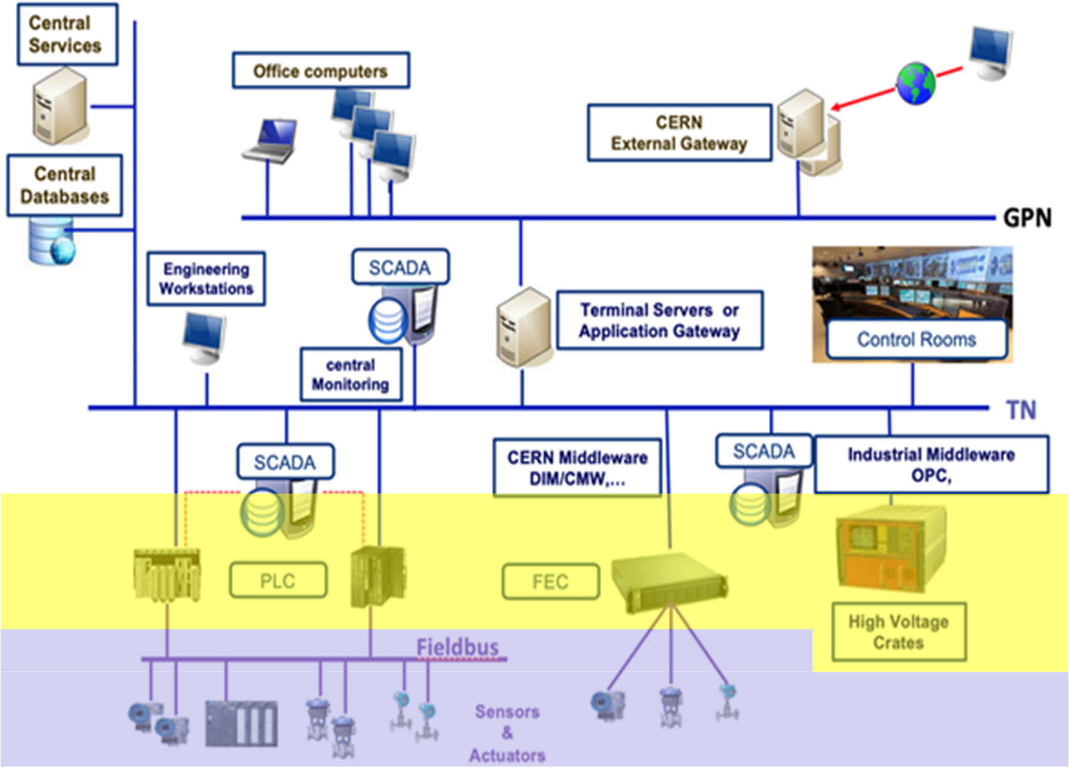

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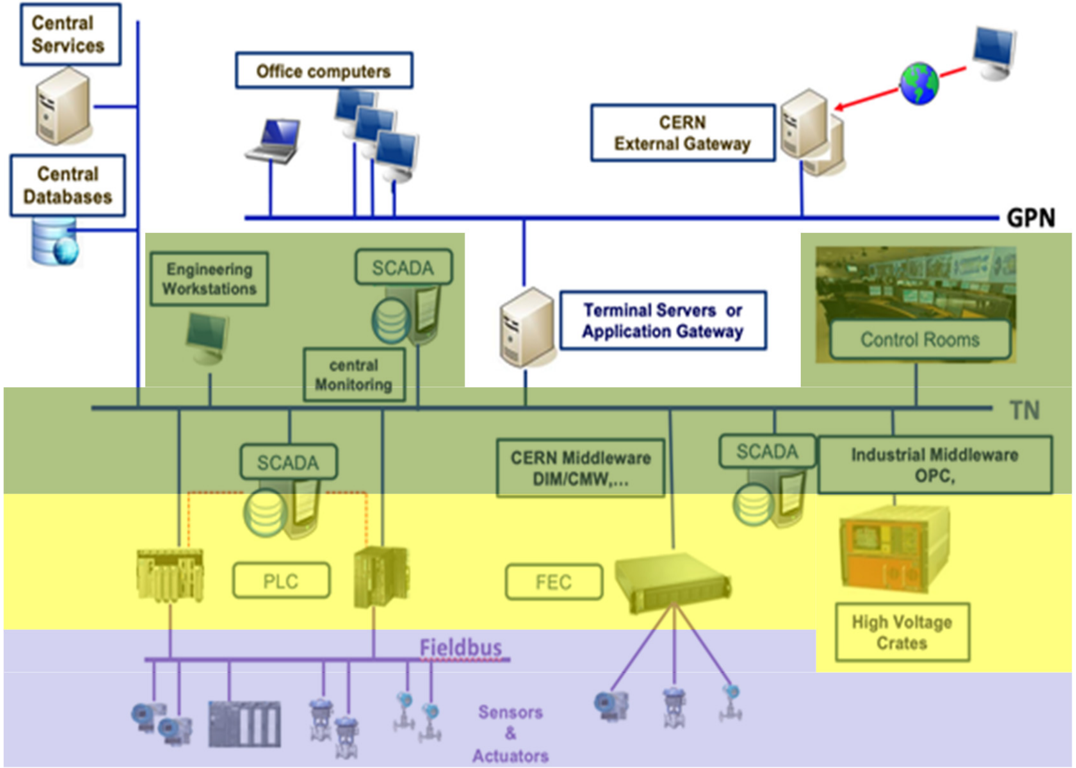

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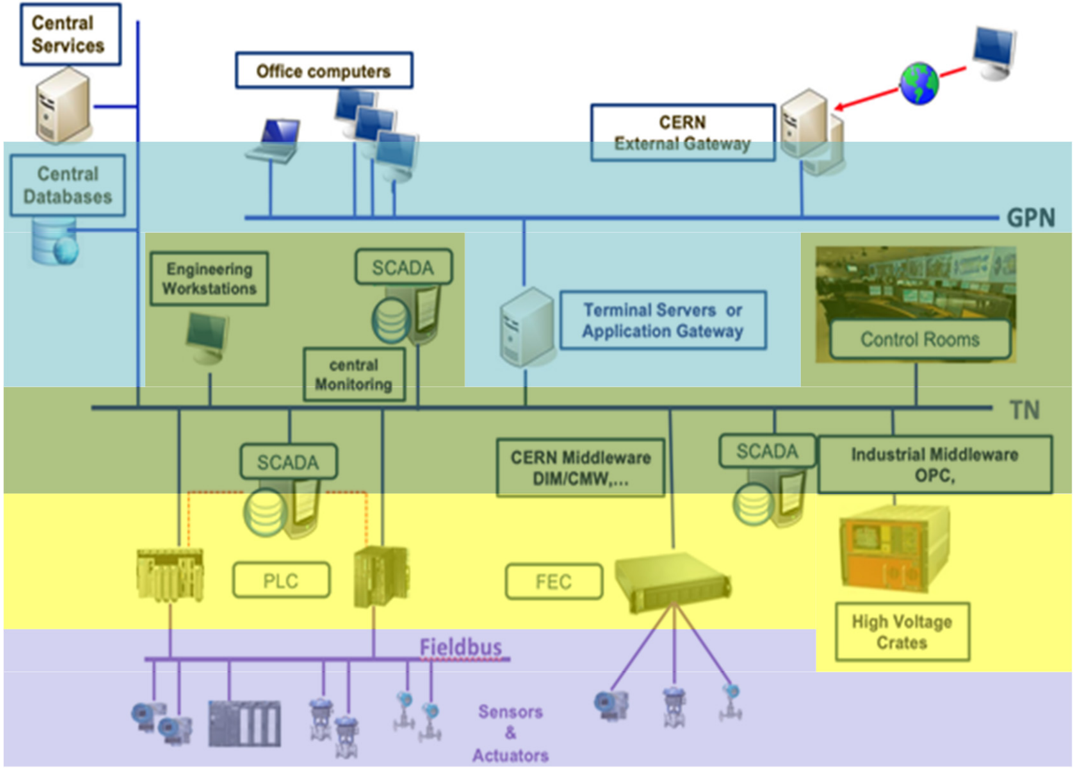

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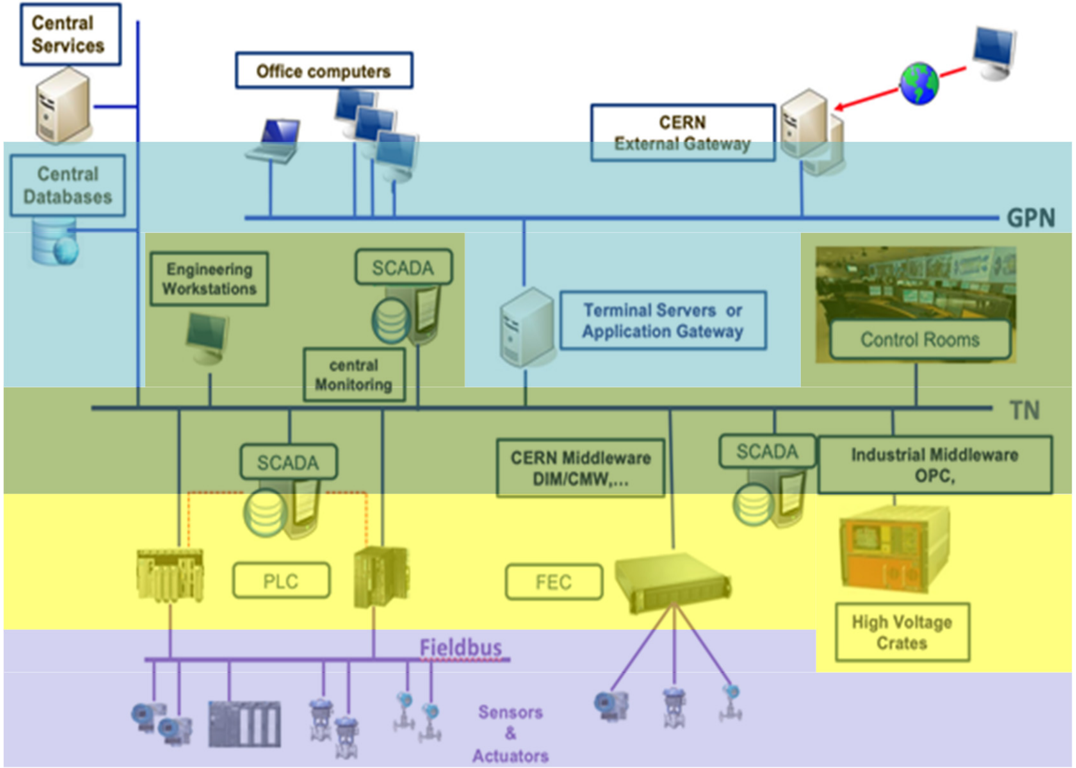

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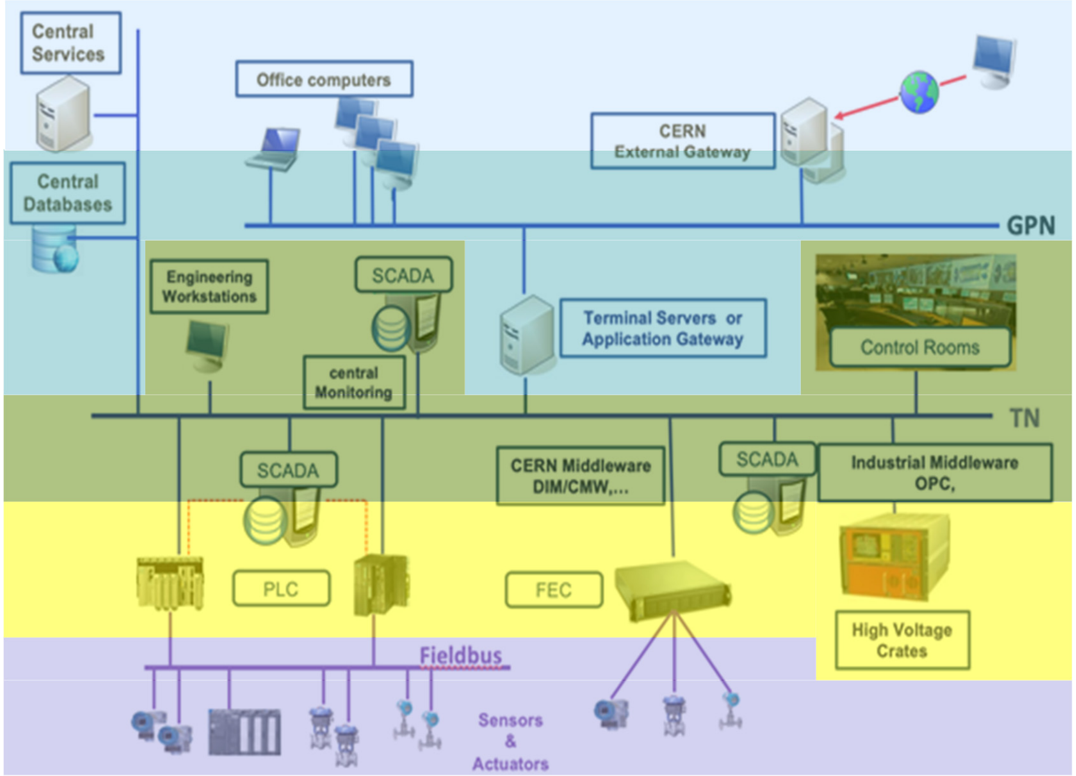

Company Layer (CL) : At this level, this level is filled with Administrative Information Services (AIS) applications. Up to now there are only few ad-hoc integrations

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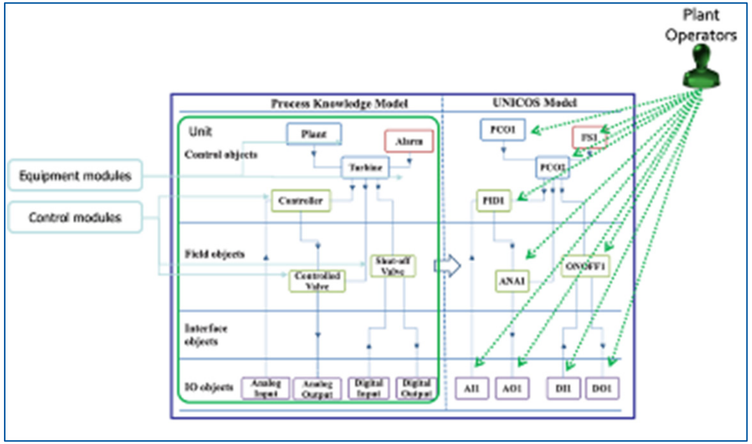
Cryogenic Control Applications



To develop a cryogenic control application CERN engineers decompose a facility in a hierarchy of building blocks from the complete facility in EM down to the actuators CM and for each EM a control logic is specified and completed by interlocks for CM

The operation teams have access to classical SCADA tools (e.g., process synoptics, time stamped alarms, events lists, trend curves) and also to the **visualisation of** the **process hierarchy**, the **interlocks** per devices, the control loop auto tuning, and the device documentation.

Thus CERN UNICOS with Continuous Process Control package (UCPC) applications **ease the operator's ability** to follow the evolution of the process, understand the dynamics of a situation, the role of each physical component, identify the origin of a failure, and predict what could happen in the near future.

Cryogenic Application Generation

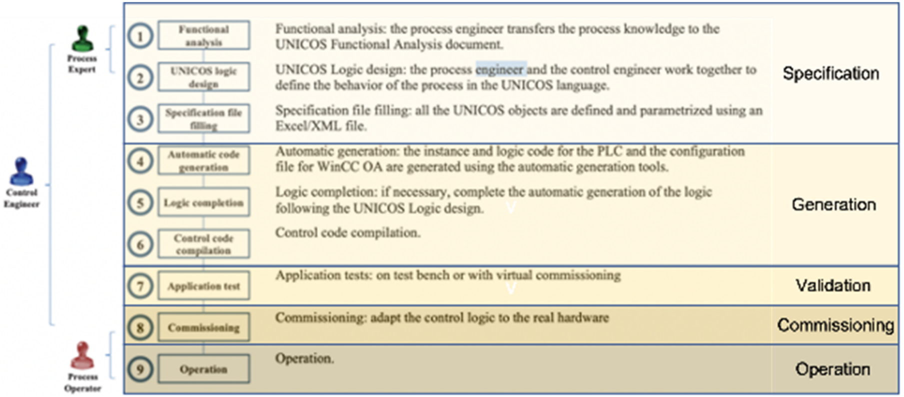
Specification: The process and the control engineers prepare the XML inputs files and the templates for the automatic generator : UNICOS Application Builder (UAB)

Generation: The UAB generator combines the XML inputs files and the templates for PLC codes and SCADA panel, to produce the ready to import applications

Validation: Applications are tested either on a test bench or using a simulator

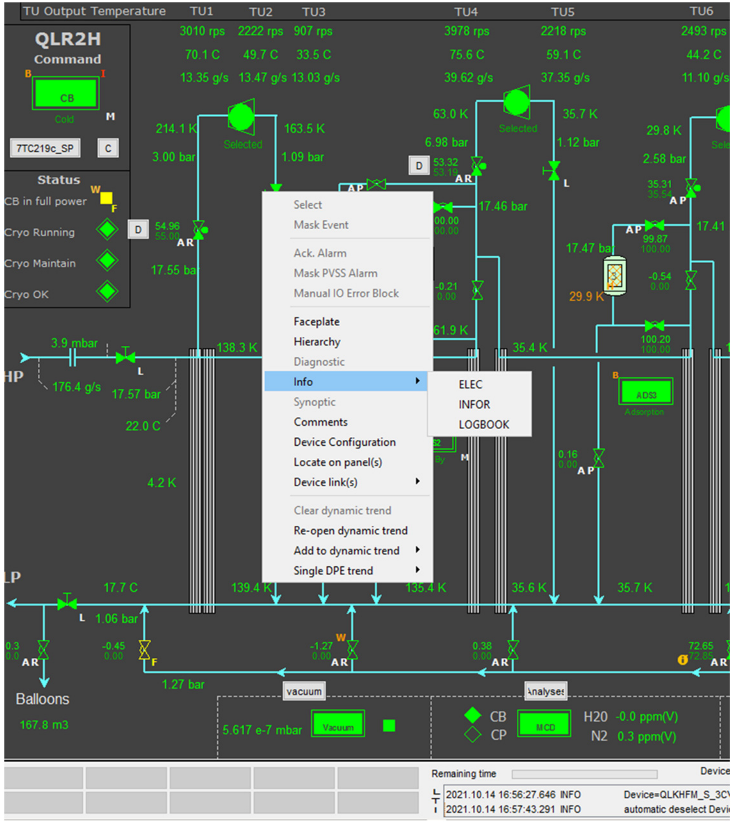
Commissioning: Applications are imported in CL & SL adapted and optimized if necessary

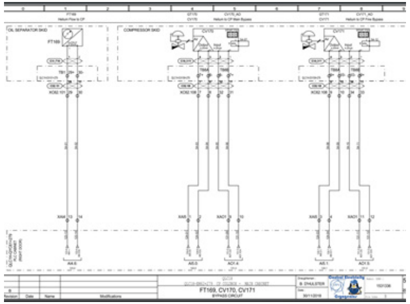
Operation: Applications enter in production



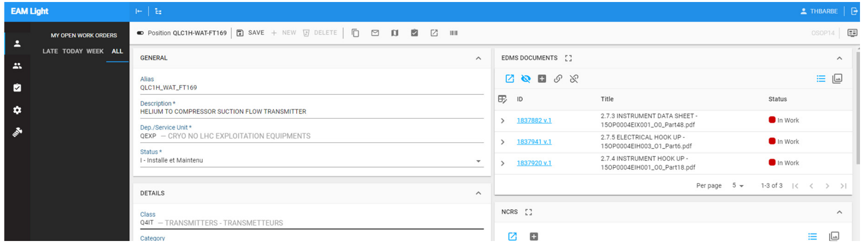
CRYOGENIC CONTROL SYSTEM EVOLUTION IN THE NEAR FUTURE

Supervision Level evolution to facilitate the operator's duties

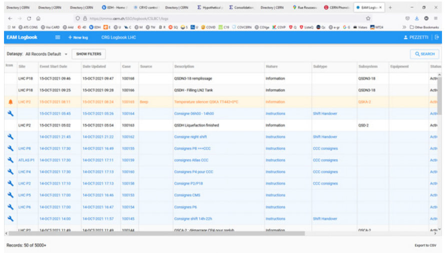




"Operation oriented" Electrical schemas

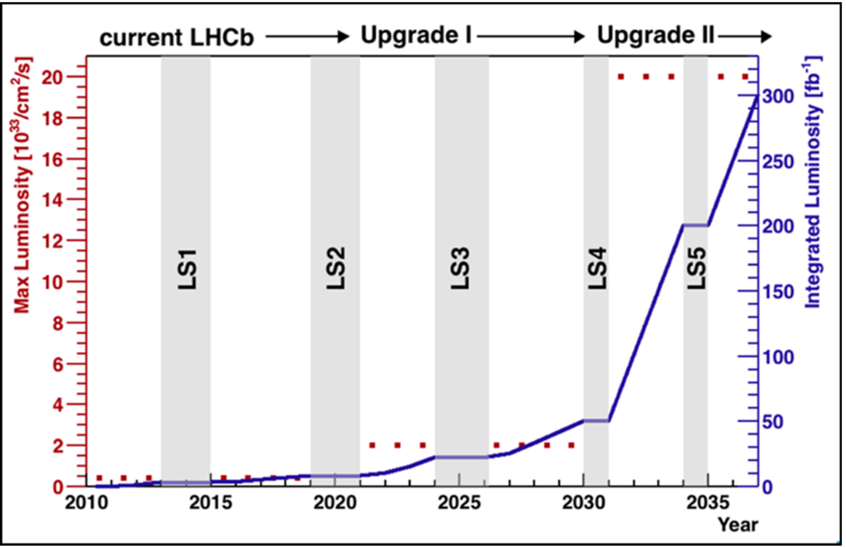


"Maintenance oriented" DB asset management



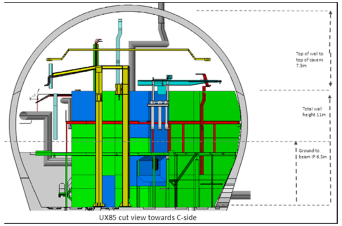
Smart & connected Logbook

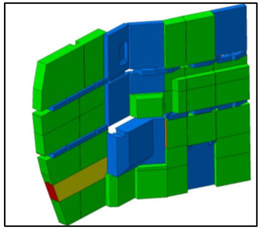
CRYOGENIC CONTROL SYSTEM EVOLUTION IN THE NEAR FUTURE



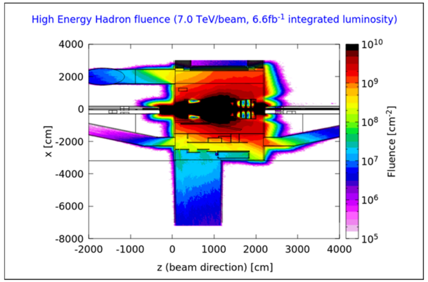
CERN LHC Pt8 LHCb Detector

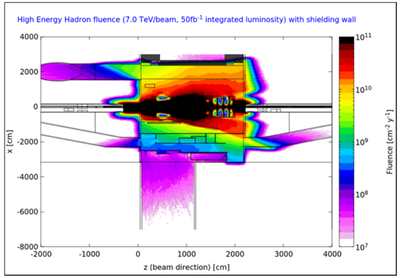
Proposed wall constitution (concrete in green, iron in blue).





HEH fluence averaged at beam height.



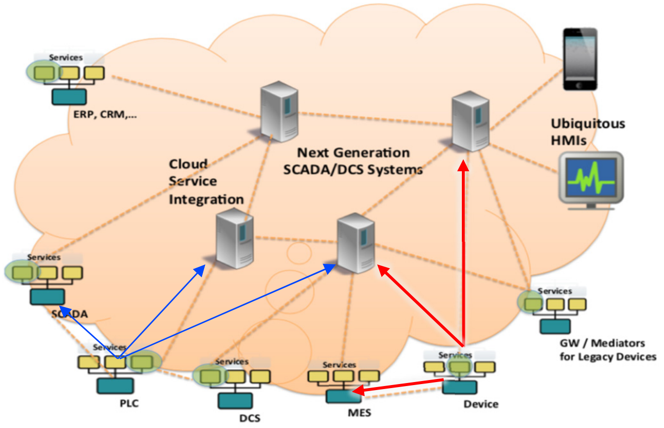


Radiation tolerance consolidation both in “hard” solution and in a serious investment in more radtol electronic…

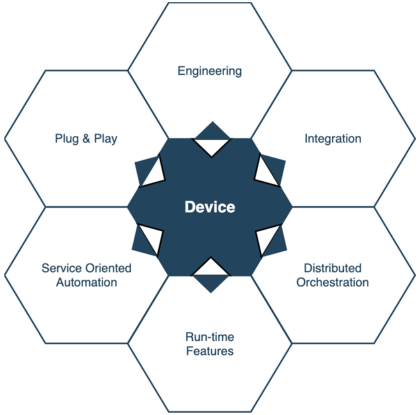
CRYOGENIC CONTROL SYSTEM TOMORROW

Future Cryogenic Control system shall be based on a
Cyber Physical Cloud based Control (CPSC) architecture system using :

Service Oriented Architecture (SOA) implemented in a cloud.



Internet of Things Devices (IoT).

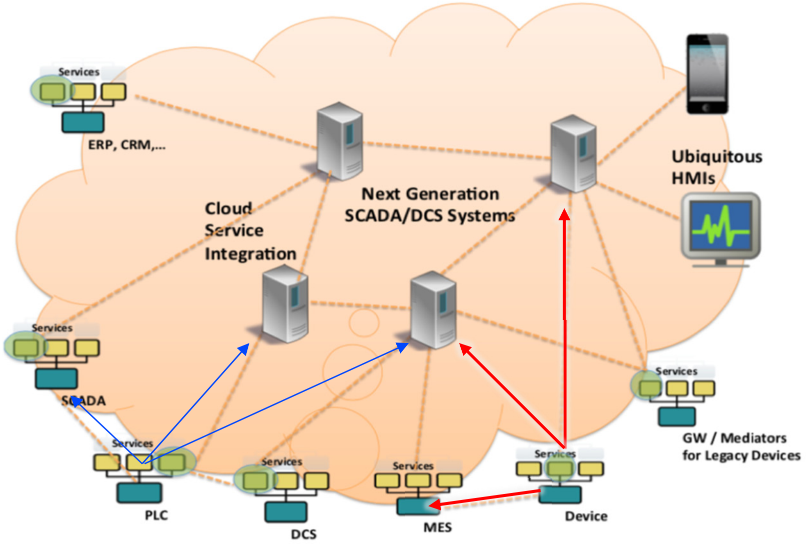


Challenges and Solutions: FUTURE

SOA - Service Oriented Architecture

PLC comm
Device comm

SOA replace the hierarchical communication existing in the classical IEC layered architecture in a flat exchange of information adapted to the need of the various components of the control system within a Cloud.



Supports cross layer integration to make large distributed systems more interoperable and make available the services needed for the IOT devices.

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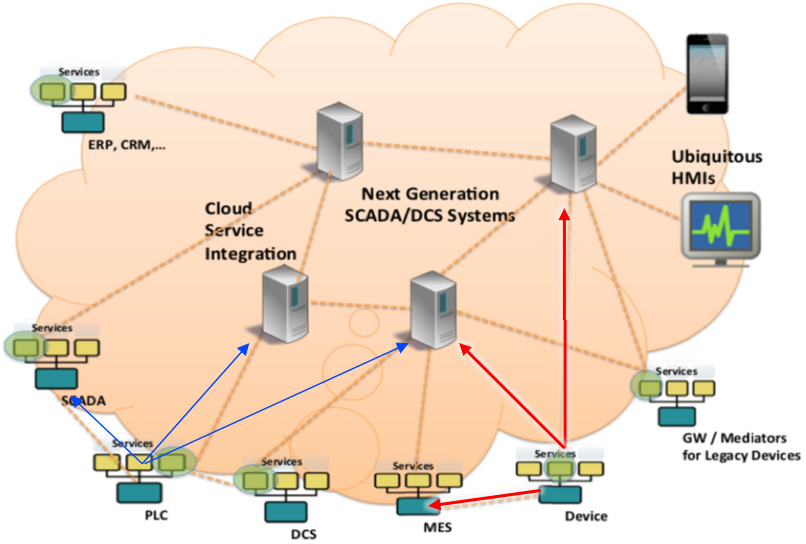


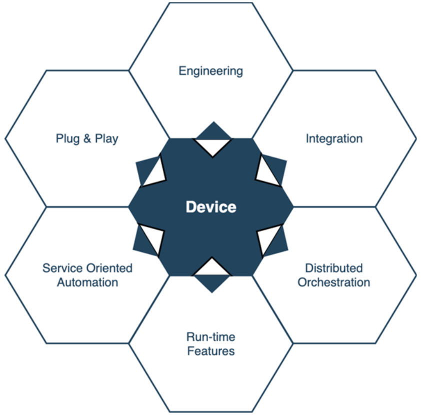
Supports cross layer integration to make large distributed systems more interoperable and make available the services needed for the IOT devices.

The services embedded in the system are loosely coupled. They operate independently from each other. Their interactions are stateless, asynchronous and not context-related.

Challenges and Solutions for FUTURE

IOT Device Specificities

With IOT the control systems devices are no longer at the lowest level of the control pyramid but they are the node of interactions with several services across the levels.



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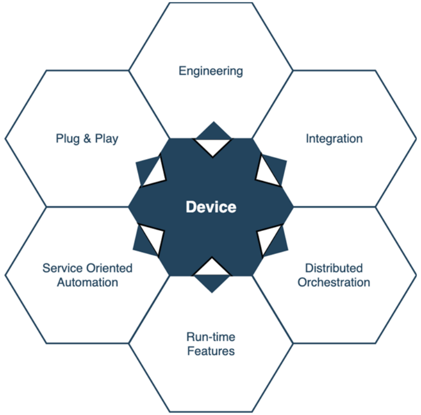

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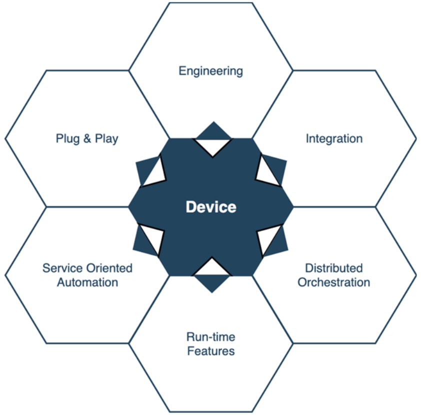

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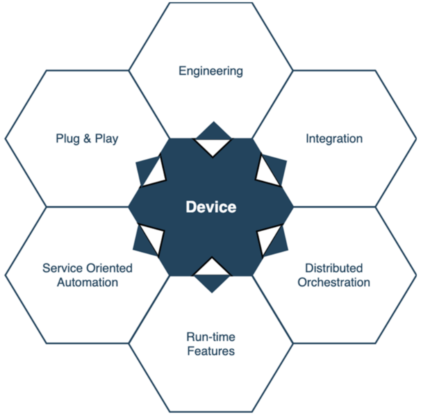

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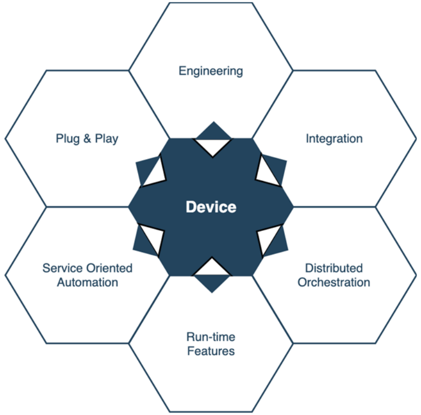

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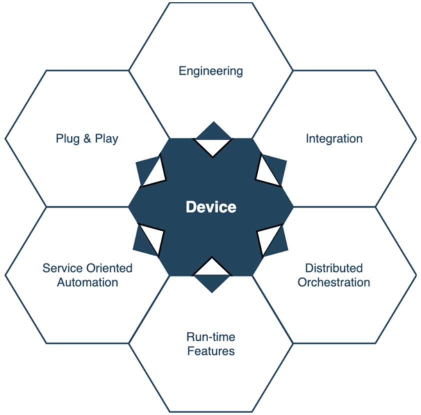

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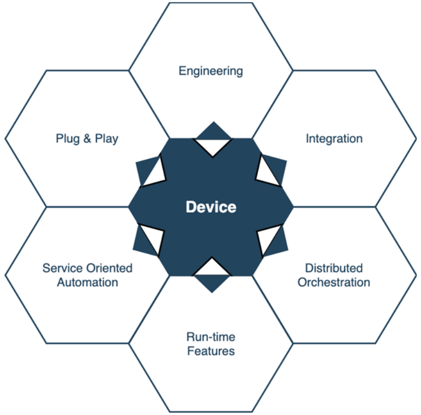

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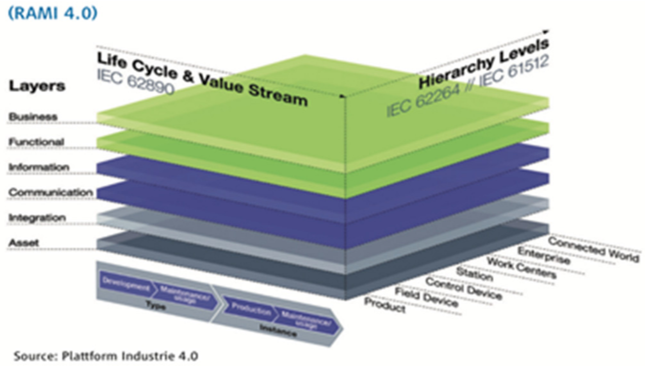
Run-time features are necessary when the system is in operation. Here, the high-level features considered are re-configurability, adaptability, intelligence, auto-sustainability…

Challenges and Solutions for FUTURE

Rami 4.0 Method in CERN Cryo control system



AXIS 1 – Hierarchy : The Factory

At CERN the hierarchy level axis, it`s necessary to integrate accelerators and detectors equipment (Field devices) with the system levels (control devices, Controlled system, CERN campus, Physics community, Connected world).

AXIS 2 – Product Life Cycle

The development process shall use a lifecycle management framework that spans from concept (requirements, design, procurement implementation, transition to operation, operation, maintenance/repair upgrade) to decommissioning.

AXIS 3 - Architecture

Services, interfaces and guidelines shall be conceived to allow the Hierarchy and life cycle components to interact with the different functional levels

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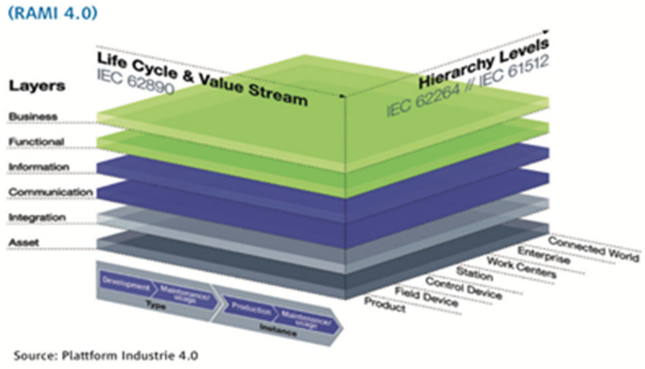

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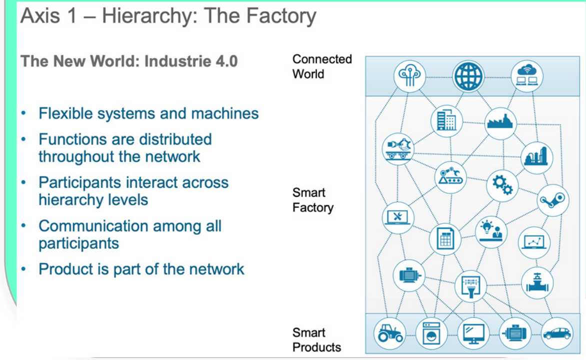

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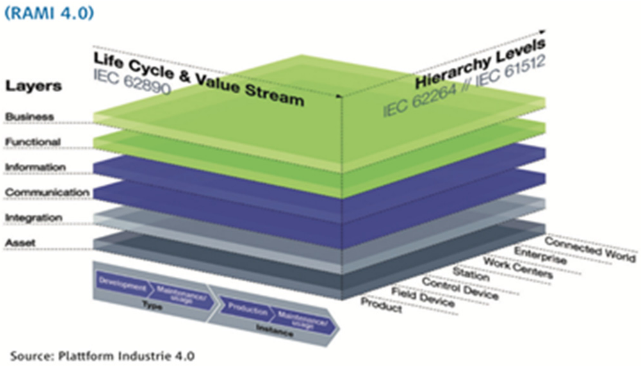

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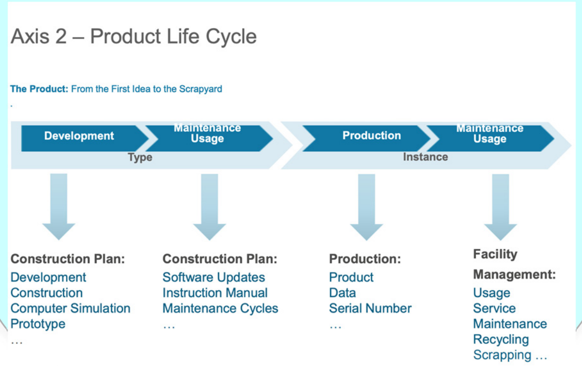
At CERN the hierarchy level axis, it`s necessary to integrate accelerators and detectors equipment (Field devices) with the system levels (control devices, Controlled system, CERN campus, Physics community, Connected world).

AXIS 2 – Product Life Cycle

The development process shall use a lifecycle management framework that spans from concept (requirements, design, procurement implementation, transition to operation, operation, maintenance/repair upgrade) to decommissioning.

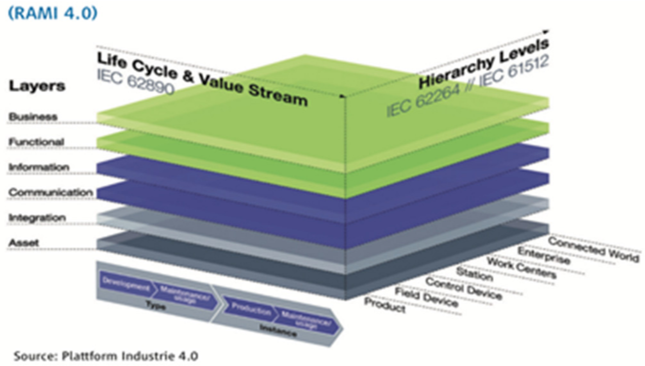


AXIS 3 - Architecture

Services, interfaces and guidelines shall be conceived to allow the Hierarchy and life cycle components to interact with the different functional levels

Challenges and Solutions for FUTURE

Rami 4.0 Method in CERN Cryo control system



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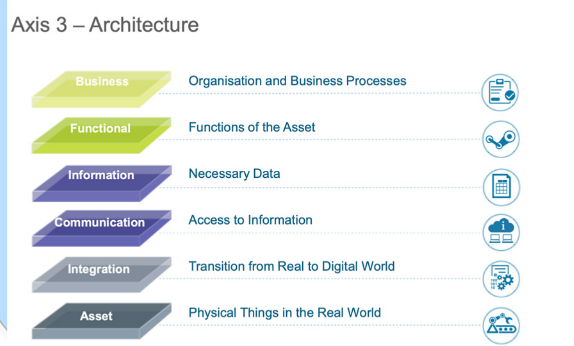
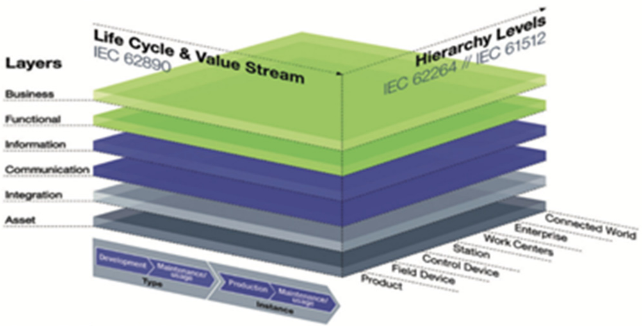


Challenges and Solutions for FUTURE

(RAMI 4.0)



Source: Plattform Industrie 4.0

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With a model inspired from RAMI 4.0 CERN shall develop a new "opensource" CERN CPSC (SOA and IOT integrated control system)

CRYOGENIC CONTROL SYSTEM TOMORROW

- Evolution of the present hardware solution adapted to the above concepts;

And specifically for HEP

- Radiation environment specific evolutions for electronics in accelerator tunnel or experiments;
- Reducing cabling cost on HEP.

Challenges and Solutions for FUTURE

Evolution of the low level device functionalities

Low-level devices used in our systems does not yet integrate complex capabilities such as dynamic discovery, configuration adaption with process conditions , etc. typical from IoT devices.

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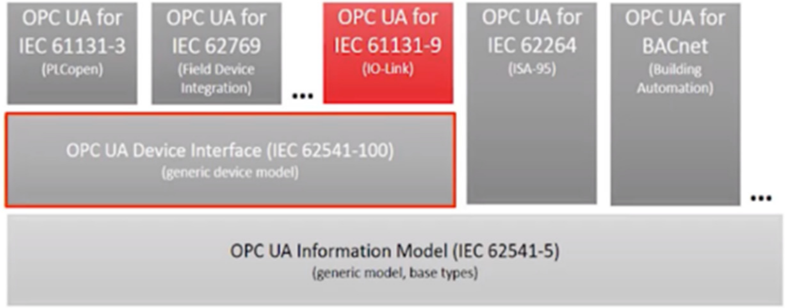

However, of the shelves Industrial Control Middleware such as OPC-UA propose IoT compatible devices services (such as IO-link compatible devices) and mediator to interconnect services (configuration, maintenance data exchange, Etc…)

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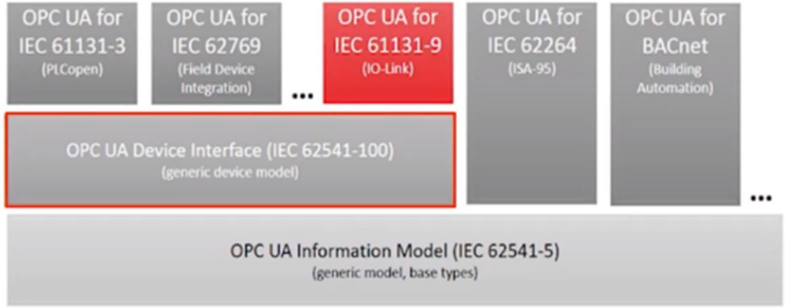

Challenge: Find/develop the middleware compatible with IoT integration

pose IoT compatible devices services (such as IO-link compatible devices) and mediator to interconnect services (configuration, maintenance data exchange, Etc…)

Challenges and Solutions for FUTURE

Evolution of Control Layer Controllers

Challenges and Solutions for FUTURE

Evolution of Control Layer Controllers

The LHC PLC have always been the best choice for systems such as Cryogenics, Cooling and Ventilation, Vacuum, thanks to their simple and efficient programming languages (IEC 61131), their high level of availability and reliability. However:

- The present generation is not really compatible with the SOA or with IOT concepts.
- High level programming capabilities to perform parallel equation solving algorithms are missing

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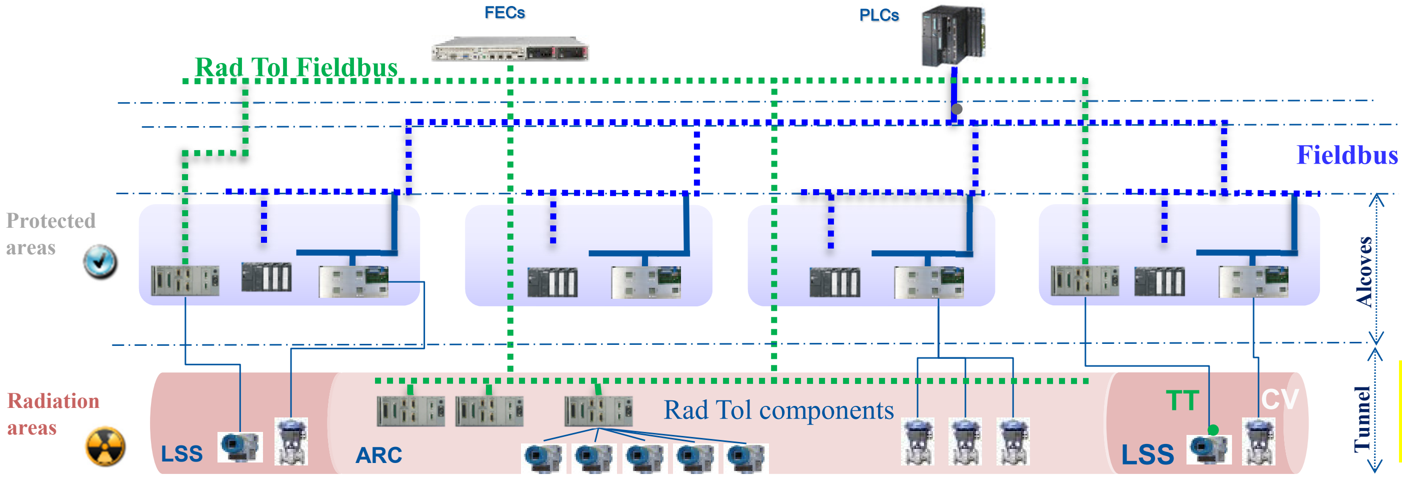
Challenge: new controller platform compatible with SOA and IOT, which must be easy to program and as reliable as PLC.

Challenges and Solutions for FUTURE

Communication with Process Components submitted to radiation

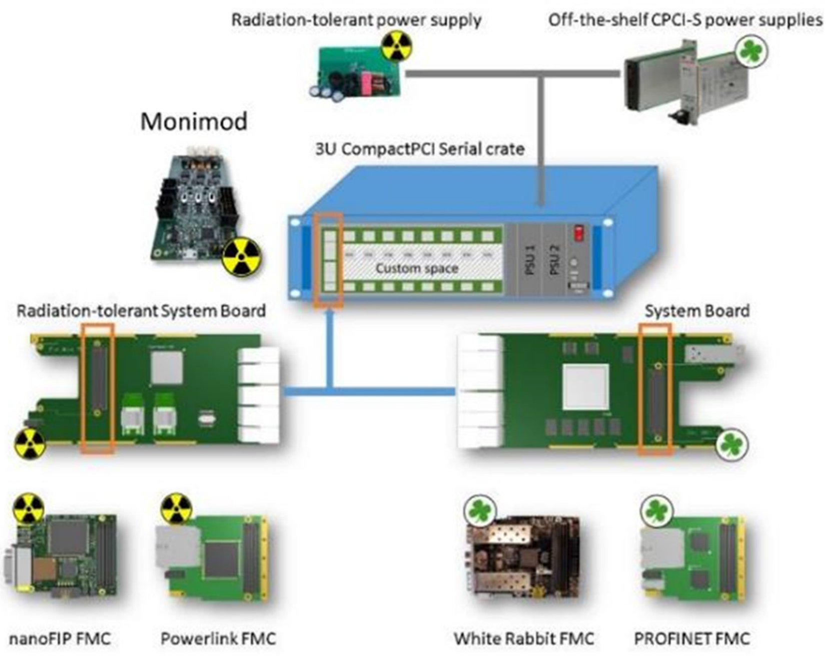
In future colliders, many control components located within the accelerator and experiment tunnel will be submitted to radiation at a harsh level i.e., for FCC an increase by factors of **500** and **200** for the stochastic and the cumulative effect are expected



FCC radiation factors
Compatible with
Off the shelves electronics

Expected increase Radiation factors
500 for stochastic
200 for cumulative

Challenges and Solutions for FUTURE



CERN DIOT Modular solution project:

-For both radiation and free radiation areas
-Low Cost (if mass scale use..)
-Extended EoL
-Universal
-Several Communication Protocols implemented
-Different Voltage power supply implemented

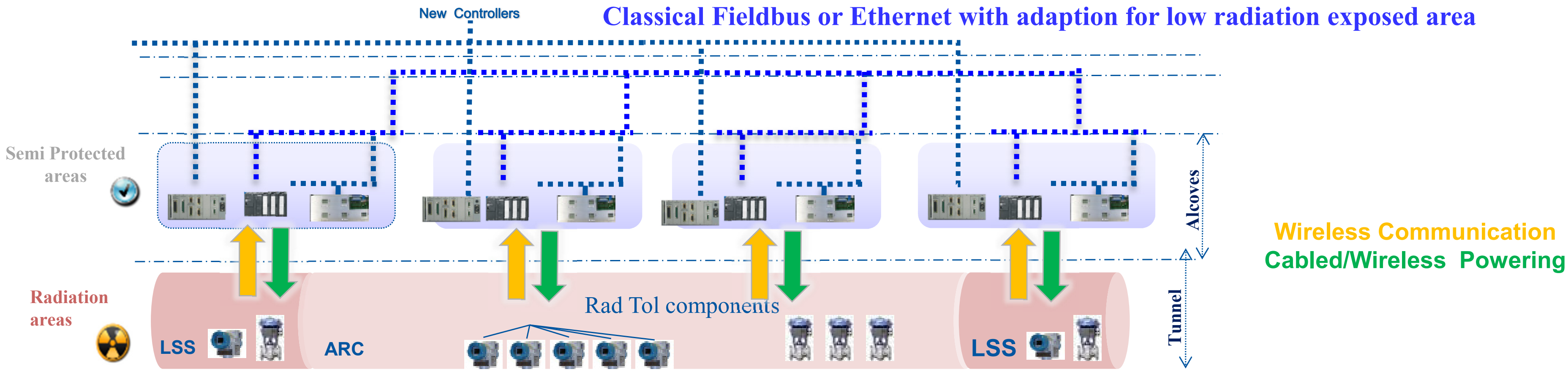
Common platform for design of dedicated (or not) end user card! ☺

Challenges and Solutions for FUTURE

Communication with Process Components submitted to radiation

Wireless communication and powering from the alcoves to the sensors/actuators.

same type of proposal based on 60GHz wireless CMOS Chips.



Conclusion

According to the rupture inducted by the **Cyber Physical Cloud based Control (CPSC)** control paradigms, the development needs to be organised at the laboratory level. CERN control community must be able to address the challenges proposed by the evolution of technologies with strength.

- Profit of the past experiences in our labs or within successful control collaborations;
- Cover all level of the ancient control pyramid but offers all necessary services included in the SOA/IOT approaches;
- Include the CERN infrastructures, accelerators, experimental physic control community and industry to :
  - Federate the efforts to include the technological breakthrough;
  - Not miss any technological rupture that will inevitably happen;
  - Take profit of the fast pace progress observed in the industry;
  - Create condition for trustful and win/win collaboration for all partners.
  - Find the right balance between Open solutions, Solution based on open standards, Off the shelf's components and proprietary solution.

CERN will need to:

- ➢ to keep under control the strategical domains,
- ➢ avoid vendor lock-in issues
- ➢ allow a fair knowledge transfer between partners.

These collaboration frameworks need to start soon in particular for the radiation components and will request a strong management support (and of course the technical team).

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SYNERGY

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CERN