Programmable Logic Controllers (PLC) @ CERN

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Industrial Controls Group (Engineering Department)

Outline

- PLC-based control
  - Process Control, Interlocks, safety instrumented systems (Vacuum system, Cryogenics, Detector safety systems)
- Application standardization
  - UNICOS
- PLC experience
  - Experience with PLC from different vendors
  - Future trends for PLCs

Objectives

- Show that there is not a single solution but different automation solutions may be applied depending on different factors
- Emphasize the importance of :
  - Standards
  - A control framework
- Share our experience
  - PLC suppliers
  - PLC market evolution
- In summary just some more food for thinking!

Introduction

Process Control

Interlocks

Safety Instrumented Systems

PLC-BASED CONTROL

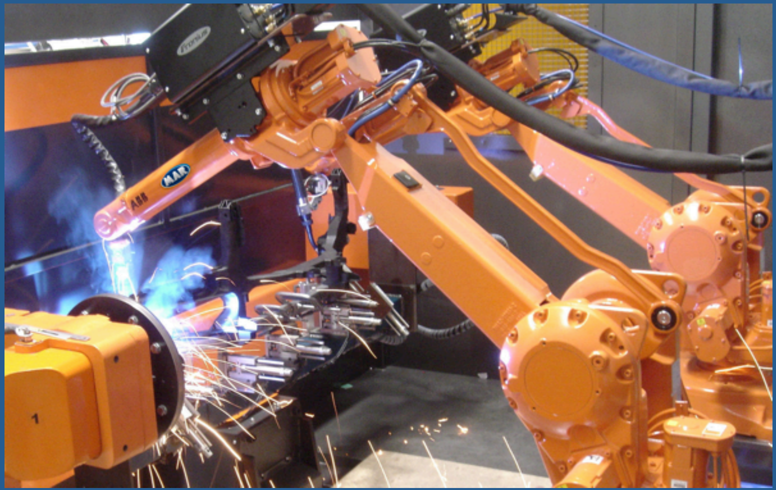
PLC @ Automation: what for?

- One of the CERN goals: maximize uptime of the instruments (accelerators, detectors,…) in order to optimize **physics data** availability

- This objective implies the maximum availability and optimal operation of all the auxiliary/utilities systems (e.g. cryogenics, cooling, HVAC, gas, motion, interlocks,…)

  the correspondent **control systems** must ensure this.

- What is challenging at CERN?
  - Environment (radiation areas)
  - Large systems (highly distributed)
  - Complexity (control logic)
  - Precision (measurements)
  - Performance (regulation)

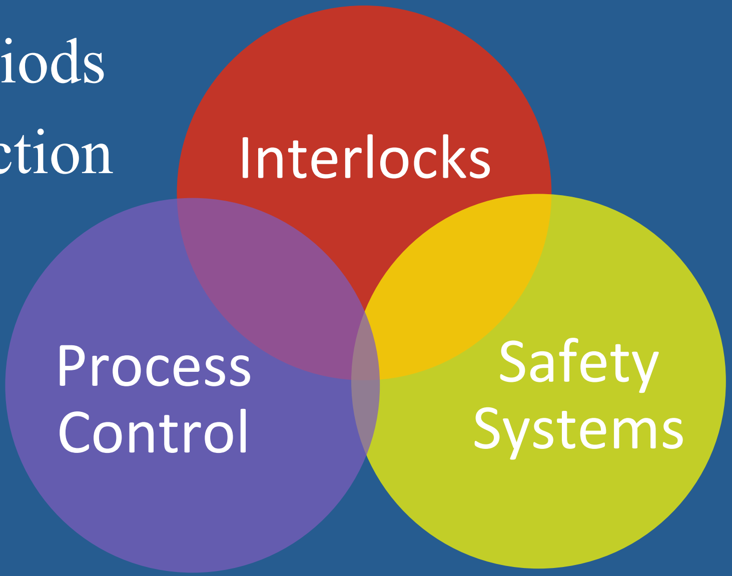


PLC-based control systems

- Process Control vs. Safety Control
  - **Process Control** systems are ACTIVE or DYNAMIC
  - Failures are inherently self-revealing
  - Flexible systems: allow frequent changes

  - **Safety Systems** are PASSIVE or DORMANT
  - Operate without notice for long periods
  - Design to allow little human interaction

Separation of control and safety??



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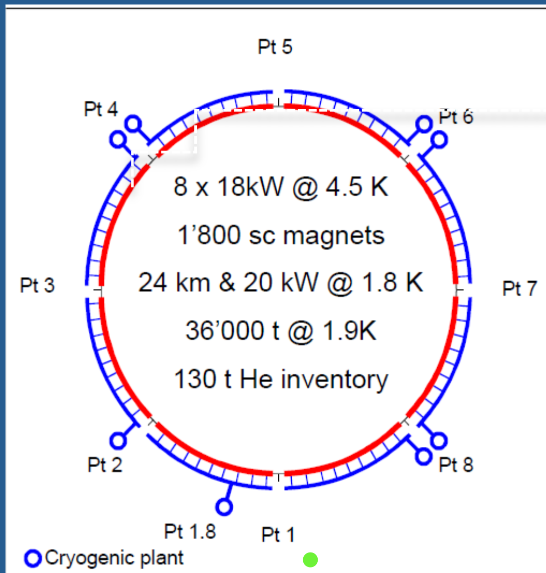
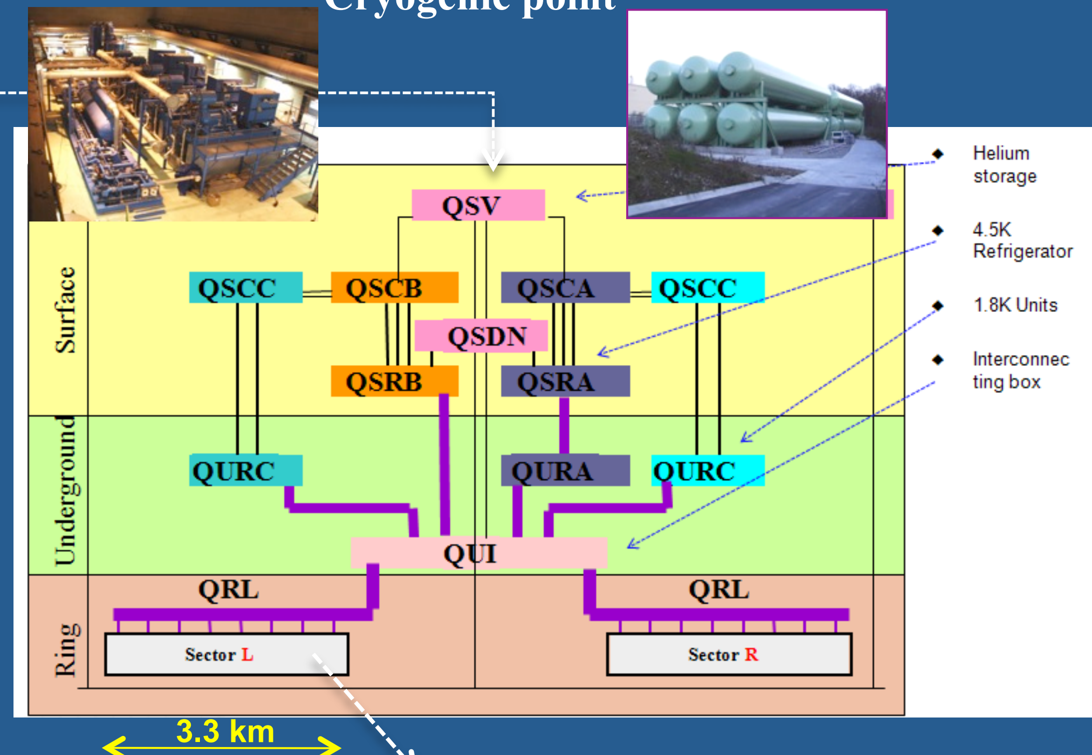
Safety Instrumented Systems

PLC-BASED CONTROL

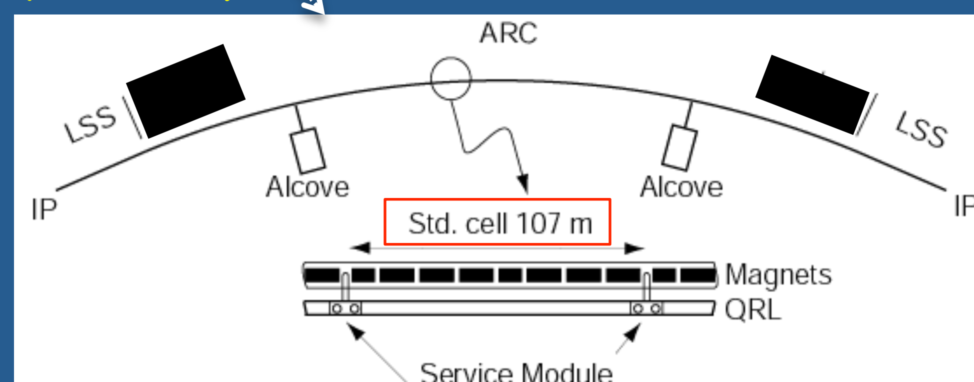
Use Case: LHC Cryogenics Control



Cryogenic point



LHC tunnel (27 km)



Use case: LHC cryogenics control

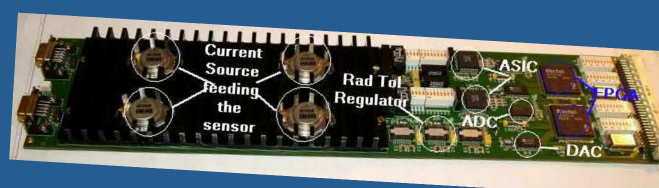
- 27 km of decentralized instrumentation and control
- 50.000 I/O, 11.000 actuators, ~100 PLCs, ~40 IPCs
- 26 SCADA servers : 1.5 million TAGS

WinCC OA HMI in the CCC

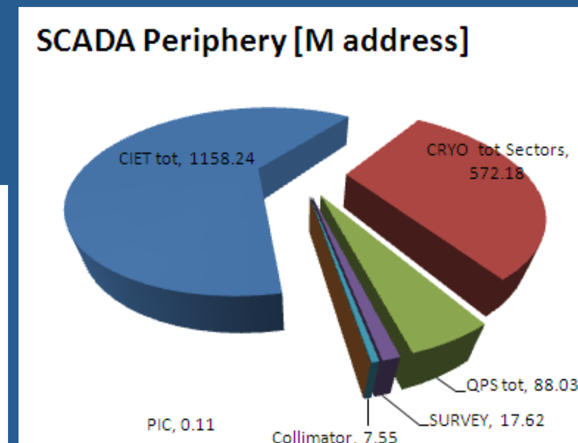
Electro-pneumatic positioner, SIPART PS2

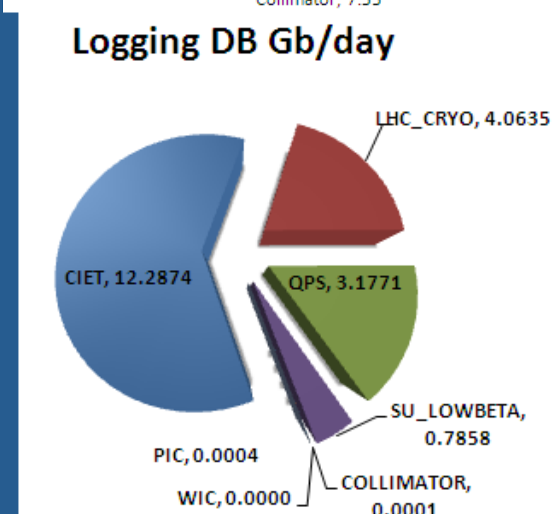
Instruments	Range	Total
TT (temperature)	1.6- 300K	9500
PT (pressure)	0-20 bar	2200
LT (level)	Various	540
EH (heaters)	Various	2500
CV (Control Valves)	0 - 100 %	3800
PV/QV (On Off Valves)	--	2000

Tunnel Instrumentation

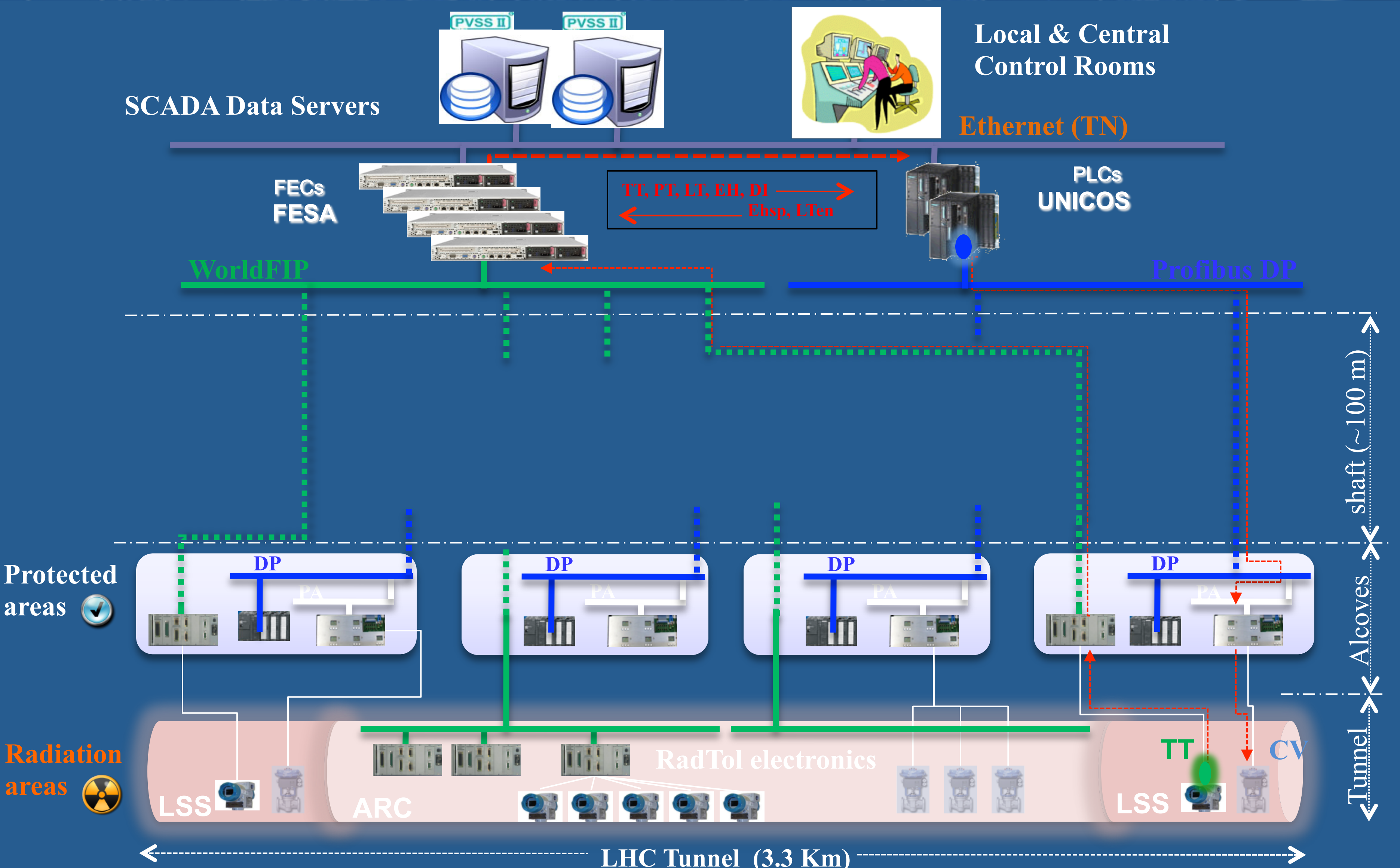


RadTol in-house electronics for signal conditioning and actuation

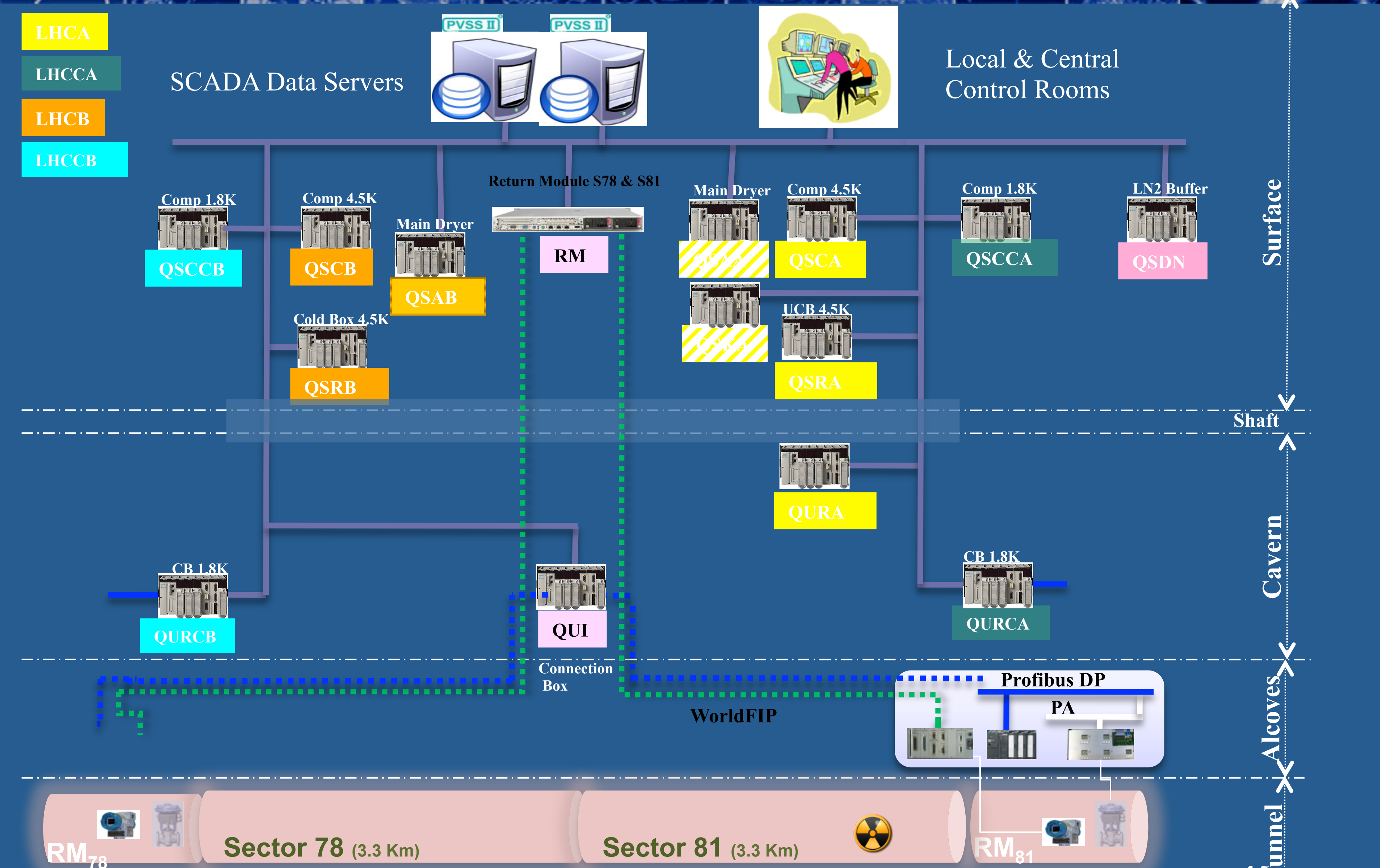




LHC Tunnel cryogenics control

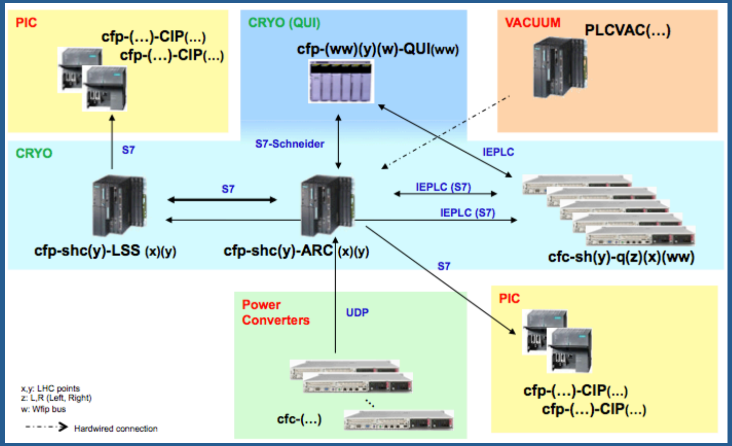


He Production Cryogenics Control

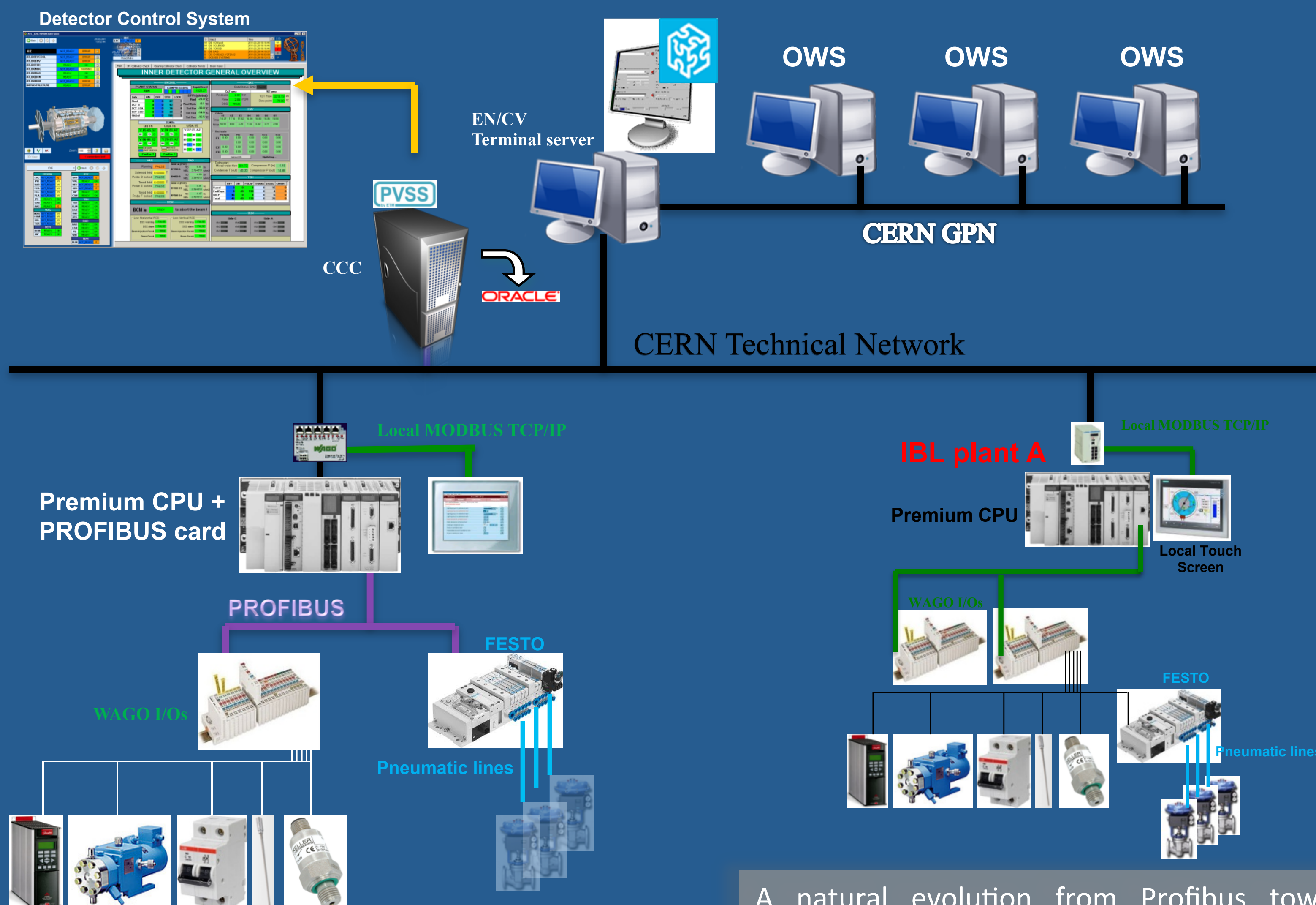


Cryogenics control: Large applications

- Requirements
  - Large systems: thousands of decentralized I/O
  - Extensive feedback control
  - Large connectivity
  - High communications throughput
- PLCs deployed
  - Schneider Premium in He Production
  - Siemens S7-416 in the tunnel
    - >1000 Source files: 250000 lines of SCL code
  - High density of connections
    - Up to 25 in a PLC all together
    - Up to 15 connections on the control layer
- Operational Experience
  - High reliability except some radiation (Single Events) on hot places.
  - Supplier PLC component default identified and corrected



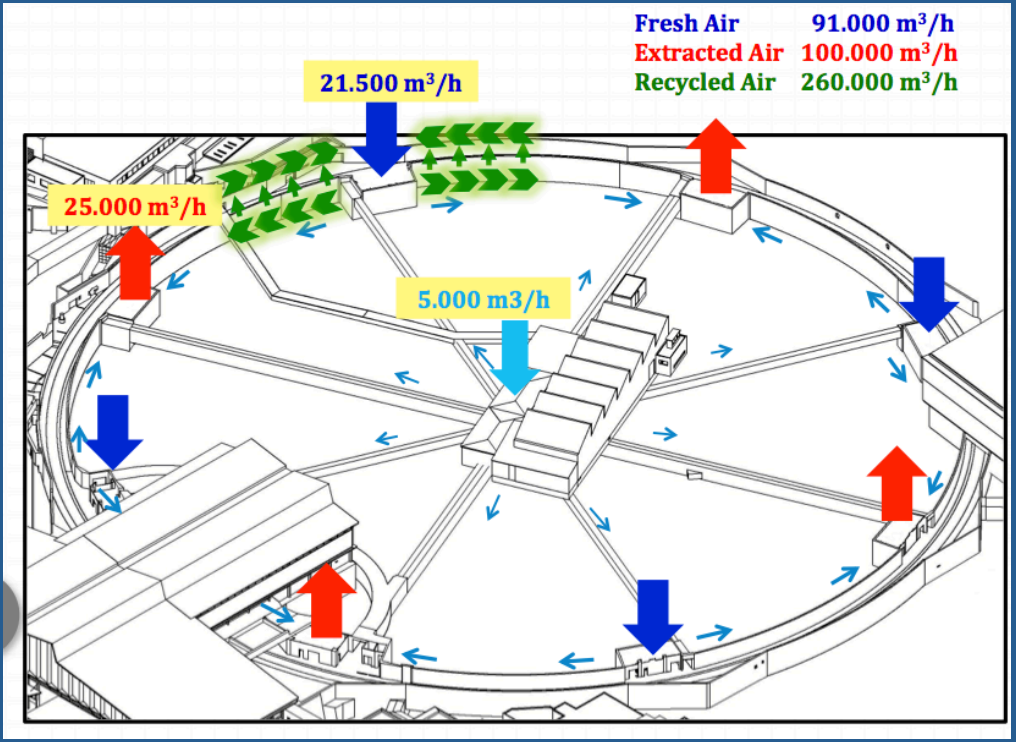
CO_2 Cooling Control



A natural evolution from Profibus towards the Schneider native solution: **Ethernet/IP**

Courtesy of Lukasz Zwalinsky PH/DT

HVAC: Tunnels ventilation



PS ventilation Schema

PS installations

- 628 m with decentralized instrumentation and control (8 technical rooms and 4 galleries)
- 2 PLCs S7-317 PN/DP ensuring the ventilation function be always on
- PROFINET fieldbus (decentralized I/O)
- 1 SCADA server: < 2000 TAGS (in progress)

Requirements
- Mostly S/M plants
- Local operation
- Some critical installations

Solutions
- Small/Medium PLCs
- Decentralized I/O via Profibus
- Sometimes with a backup PLC

ISOLDE Vacuum

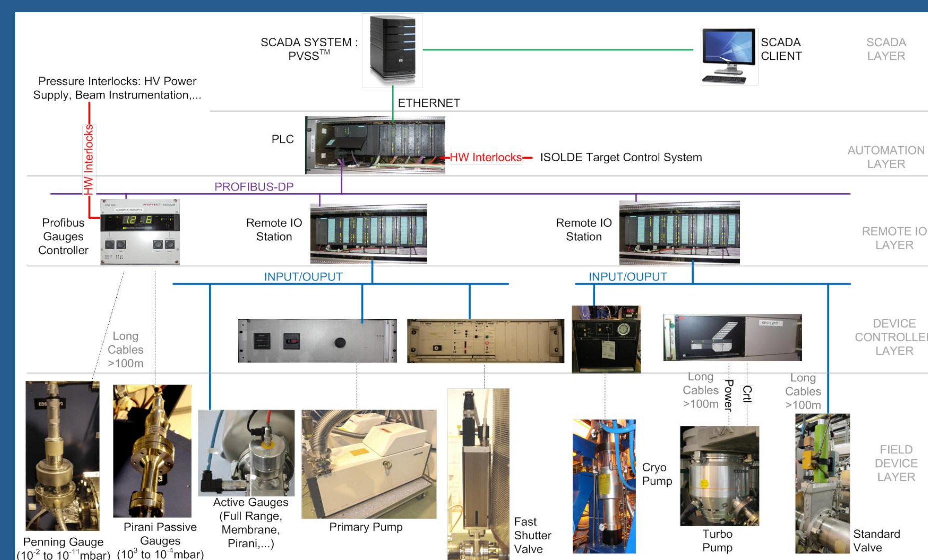
ISOLDE (On-Line Isotope Mass Separator)

CERN facility dedicated to the production of radioactive ion beams for nuclear and atomic physics.

- ISOLDE Vacuum instrumentation
  - Vacuum Pumps, Gauges, Valves
- Vacuum systems
  - Small/medium systems
  - No feedback control
  - Repetitive systems

- ISOLDE Vacuum controls

  Usually Small/Medium PLCs
  - Siemens S7 3xx-PLC
  - WinCC OA SCADA.



Source courtesy of TE/VSC

Introduction

Process Control

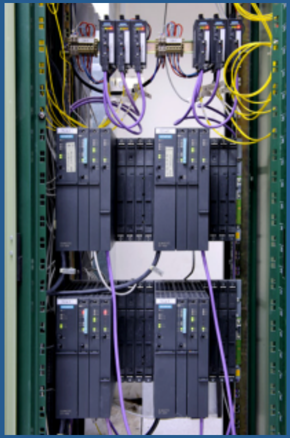
Interlocks

Safety Instrumented Systems

PLC-BASED CONTROL

Detector Safety System

- The **DSS** saves from harm a Particle Detector by executing **protective actions** in response to the detection of user-defined **Alarm Conditions.**
- Sensors, Actuators or **Alarm Conditions** can be added or **re-parameterized** at any time by the user, without stopping the system



Requirements

- Availability
- Flexibility in configuration

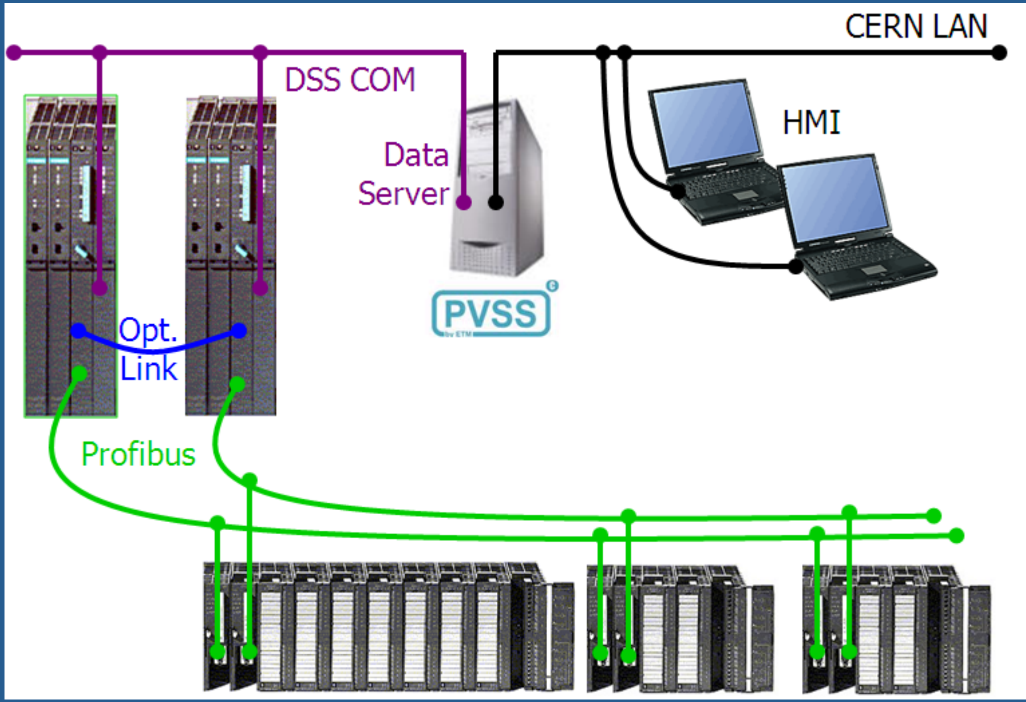
Solutions

SIEMENS PLC S7-**414H**
Redundant Profibus network

Experience (2007 - 2013)

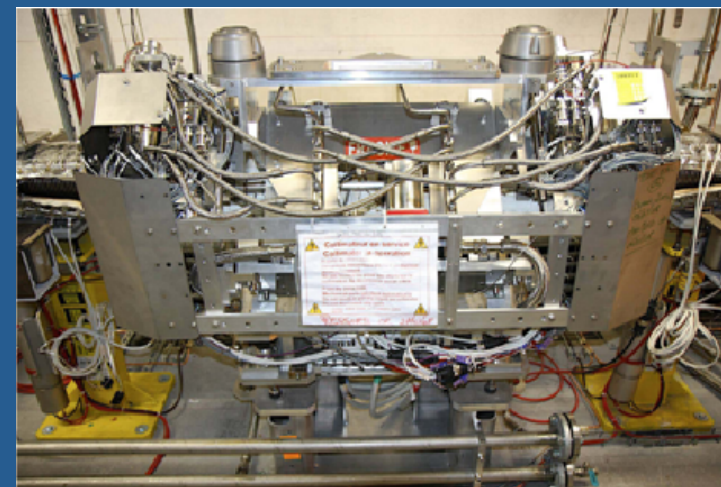
- 1 stop caused by the active backplane
- Some parts (optical links connectors, CPU) covered by redundancy

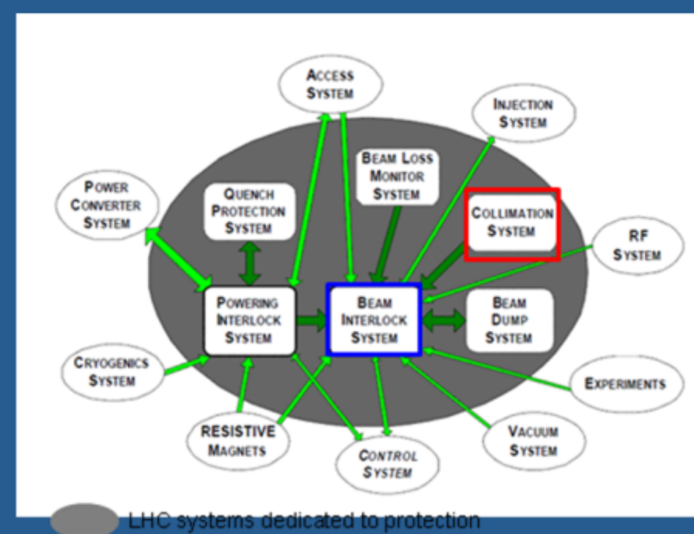
	ALICE	ATLAS	CMS	CMSX	LHCb
DSUs	7	7	6	10	3
Analog Sensors	322	4	6	20	82
Digital Sensors	82	582	431	1540	246
Alarm Conditions	195	581	417	520	297
Alarm->Action links	~220	~2000	~770	~1850	~1150
Actions	223	309	232	513	191



LHC Collimators

- Environmental temperatures
  - 112 collimators (LHC ring and the transfer lines from the SPS to the LHC)
  - Interlocks at jaw and water temperatures
- Requirements
  - Reliable system
  - Interconnection to the Beam Interlock
- Interlock control system
  - Based on S7-315 2PN/DP (15)
  - Double wired output to the BIC
  - WinCC OA as SCADA
- Experience [2010-2013]
  - Only 1 beam dump (caused by PLC failure)
  - Enters in the MTBF expectations





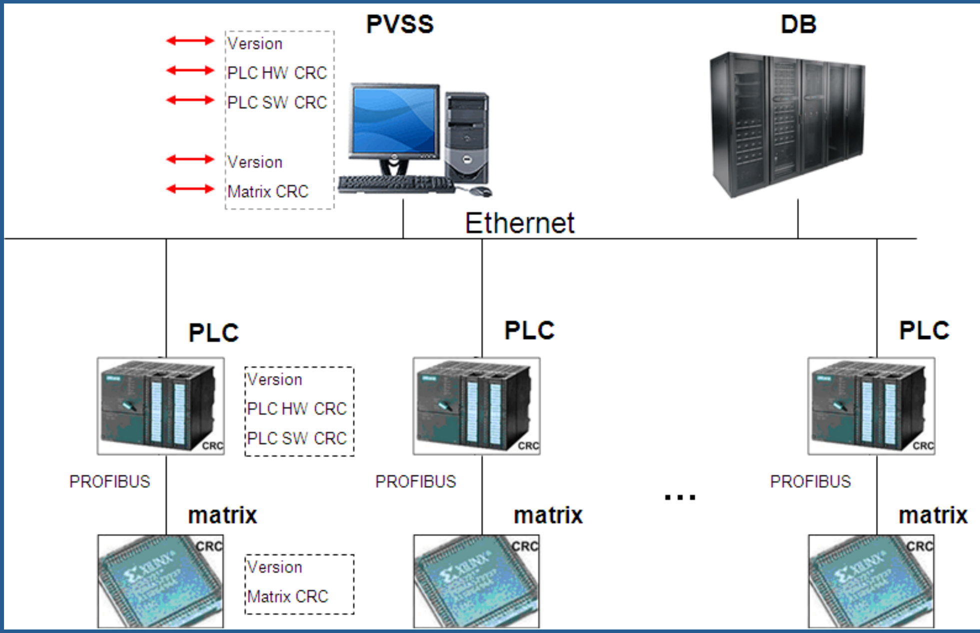
Powering Interlock Controller

- **PICs** ensure that:

  (1) the particle accelerator can only start when all relevant systems have the necessary operational readiness

  (2) the proton beams shut off within a few milliseconds if critical failures occur.

- Underground Distributed system over the whole LHC circumference
- 36 industrial controllers SIEMENS PLC **319-3 PN/DP** (non-safety but optimized for speed: - 1ms cycle time)
- Total of ~500 electronic cards (designed in-house
- Redundant power supplies



Courtesy of Markus Zerlauth TE/MPE

Introduction

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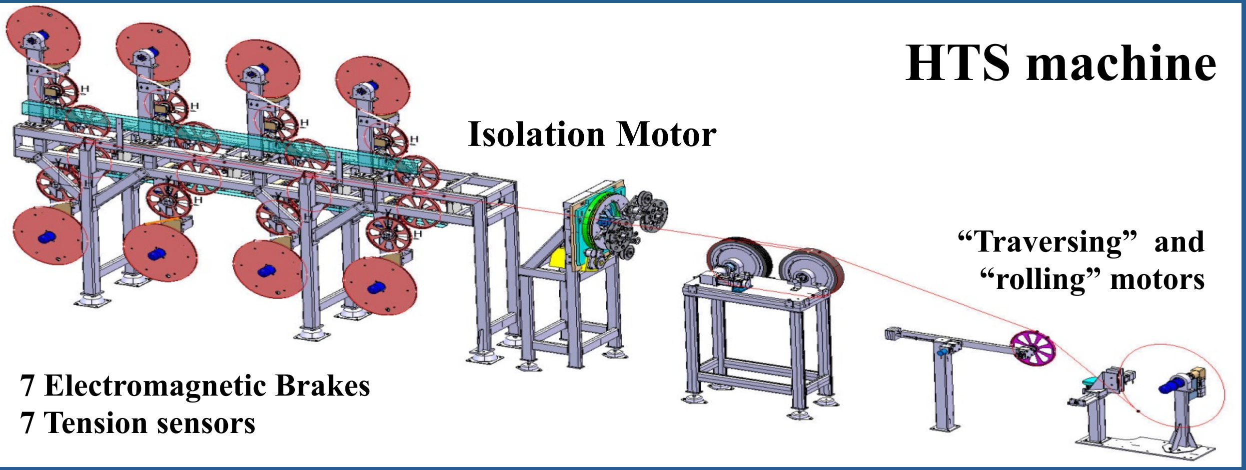
PLC-BASED CONTROL

Safety Instrumented systems

- HTS Winding machine
  - Prototyping HTS 600A main conductor for the LHC magnets (YBCO, BSCCO or MgB2)



- Safety Functions
  - Emergency stop
  - Access
  - Motor cover

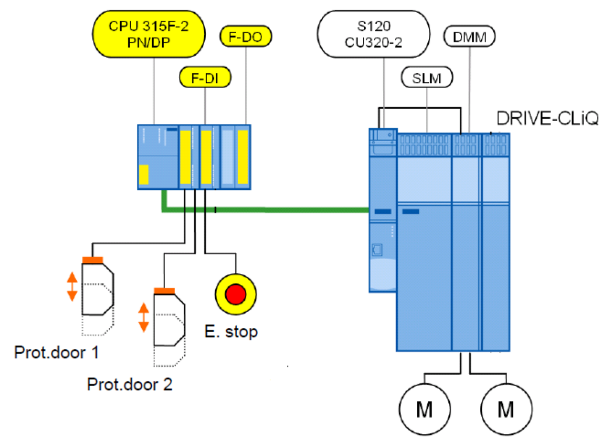
- Equipment

  Safety solution based on:

  Siemens S7-317F PN/DP

  Profisafe on Profinet

  Sinamics Drives



Safety Instrumented Systems: TIM

Train Inspection Monorail (TIM) for the LHC:

TIM is equipped with a **laser scanner** to ensure that the vehicle will always stop immediately if it encounters people still in the tunnel, or an unexpected obstacle.

Solution

The communication with the monitoring computer is performed via **3G** mobile network

- ***Fail-safe*** controller Simatic S7-300 with fast Profinet Siemens CPU **319F-3 PN/DP**

- ***Profisafe*** communication between the individual modules of the vehicle via IWLAN

Source courtesy of EN/HE

UNICOS

APPLICATION STANDARDIZATION

Industrial Control @ CERN

Just the main topics…

GS department
- Access Control Systems
- Building Automation
- Environmental measurements

TE department
- Cryogenics
- Vacuum
- Equipment Protection

EN department
- Electricity
- Cooling and Ventilation
- Handling (Robotics)
- Motion Controls

EN/ICE
Industrial controls

BE department
- RF systems
- Magnet Alignment
- Accelerator Controls

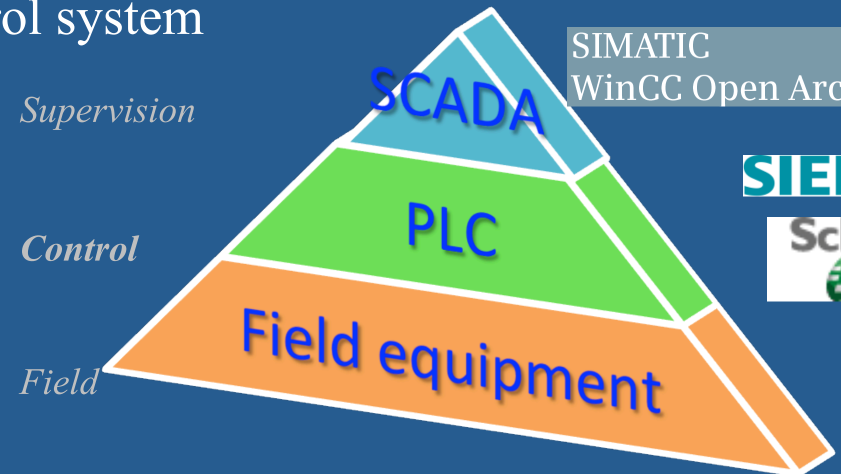
PH department
- Experiment DCS
- Exp. Magnets Control
- Exp. Vacuum
- Other process control: (e. g. CO2 cooling,…)

Creating standards: UNICOS

- **UNICOS** (**UN**ified **I**ndustrial **C**ontrol **S**ystem) was born at CERN as a need to develop the LHC cryogenics control system

- The goal was to create an **industrial control system** covering the upper two layers of the typical automation pyramid.

- Based on industrial standards:
  - ISA-88 / IEC-61512: Batch control
  - IEC-61499 : Distributed systems

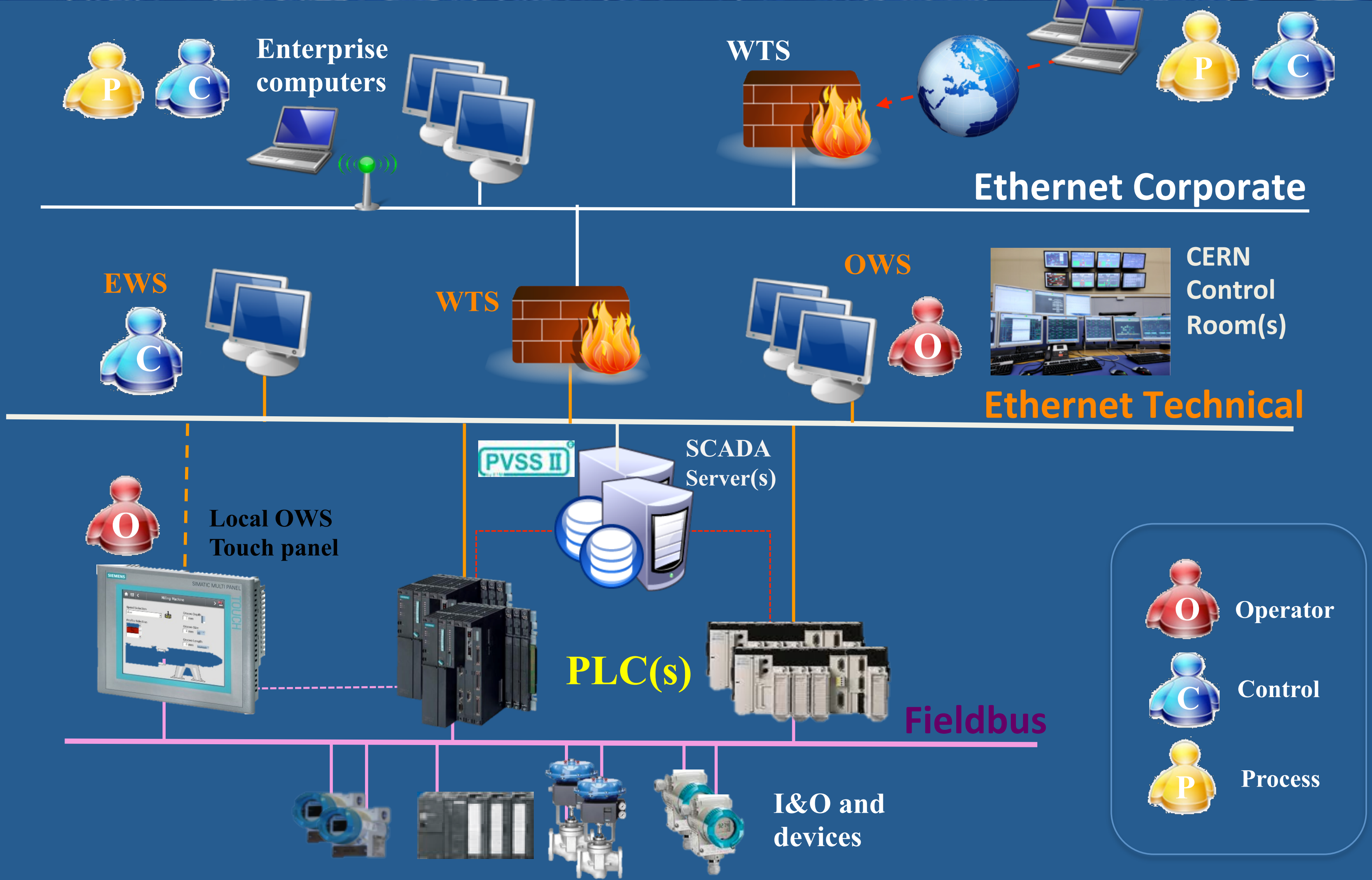


SIMATIC
WinCC Open Architecture

- *Facilitate the task of the automation engineer by allowing him/her in* ***focusing only in the automation duty*** *and not in the software production itself.*

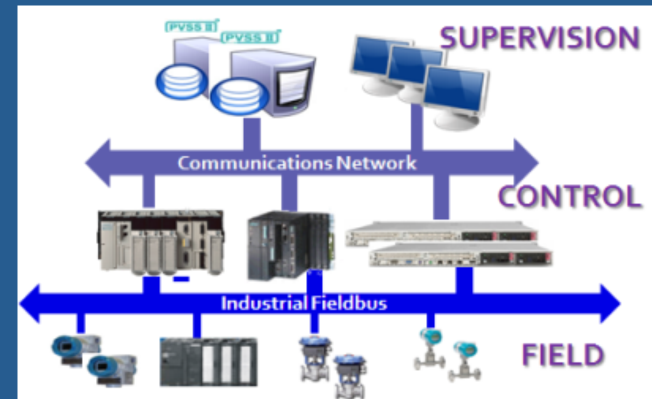
A necessity of specialized **generation tools** to create **automatically** such industrial control systems both in the PLC and the SCADA was identified

Architecture



UNICOS Industrial components

- SUPERVISION, Visualization and programming
  - SIEMENS WinCC OA (PVSS) SCADA (standard)
- CONTROL
  - SIEMENS, Schneider (standards)
  - Industrial PCs: SIEMENS IPC, Codesys
- FIELD LAYER
  - Industrial instrumentation: Sensors, actuators
  - Industrial customized actuators: Profibus PA positioners
  - Home made electronics: ELMB
  - Virtual instrumentation: VFT (flowmeters)
- COMMUNICATIONS
  - Fieldbuses: Profibus, WorldFIP, CAN (CERN standards)
  - Ethernet based: Profinet, Ethernet/IP
  - TSPP: Time Stamp Push Protocol



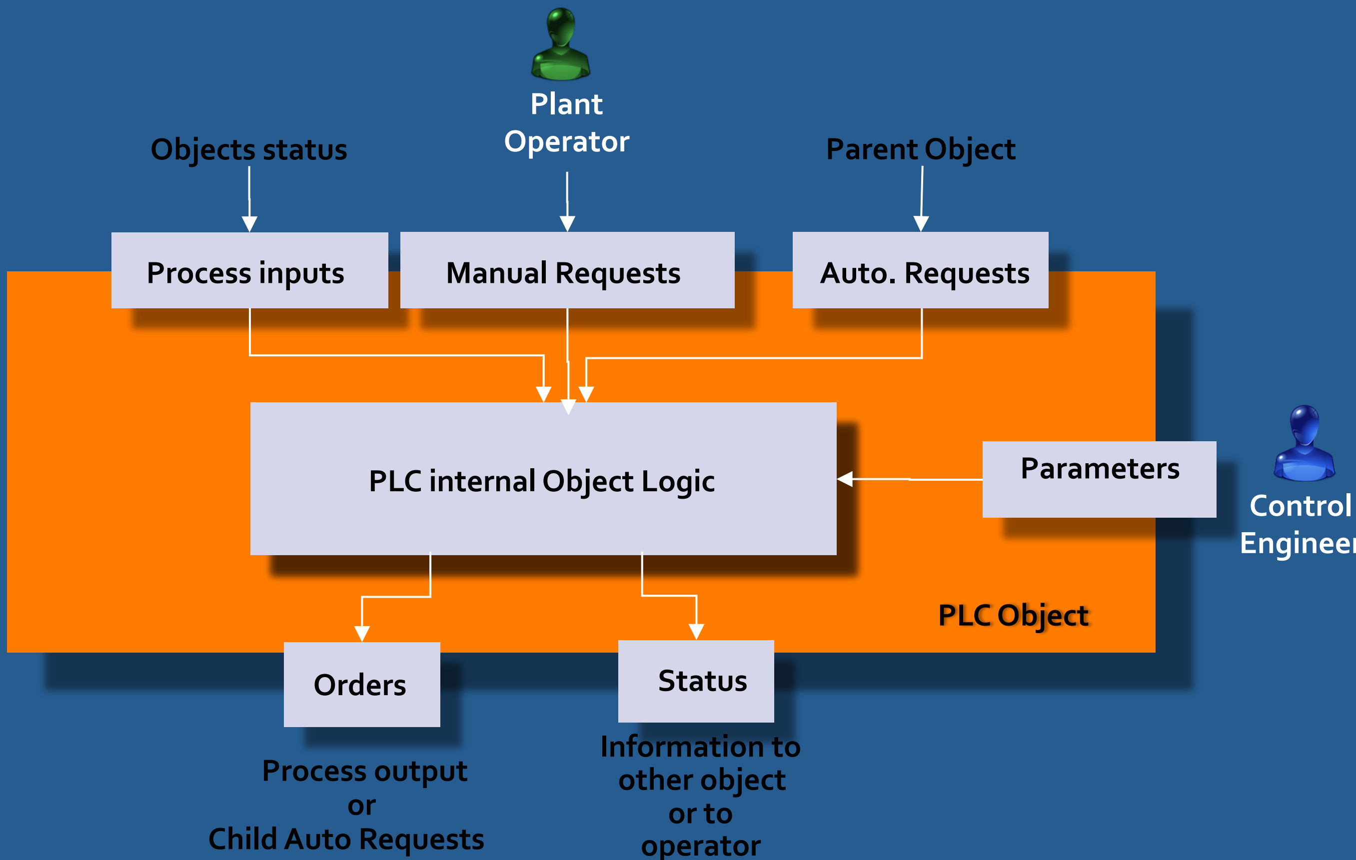
SIMATIC
WinCC Open Architecture

UNICOS Basics I

UNICOS establishes:

- A well defined set of standard objects (device types), both in the control and supervision layers, modeling most of the equipment and needs of continuous processes
  - **I/O Objects**
    - Digital I/O
    - Analog I/O
  - **Field Objects**
    - OnOff
    - Analog
    - AnalogDigital
    - Local
    - AnaDO
  - **Control Objects**
    - Controller
    - Alarms
    - Process Control Object
  - **Interface Objects**
    - Parameter (Digital, Word, Analog)
    - Status (Word, Analog)
- The relationships between them
- A formalized way of :
  - Define the process units of an industrial process (ISA-88)
  - Programming the specific process logic for those units

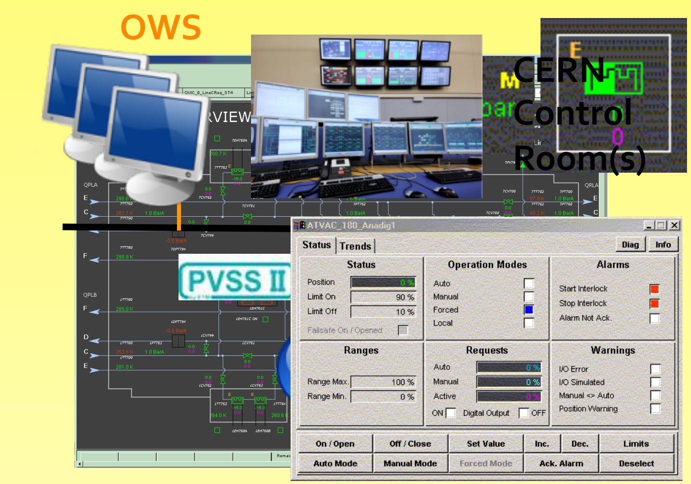
UNICOS CPC Object Model

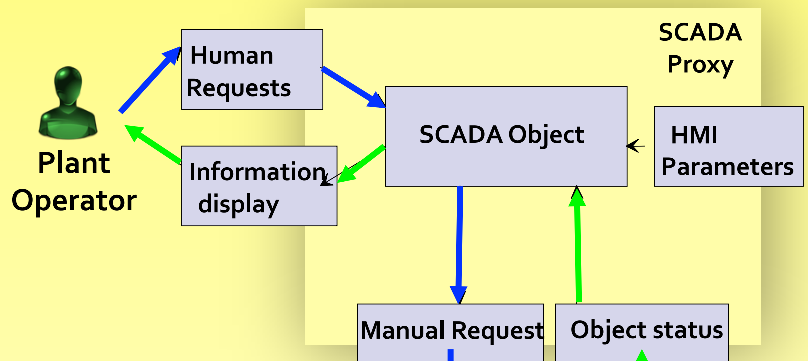


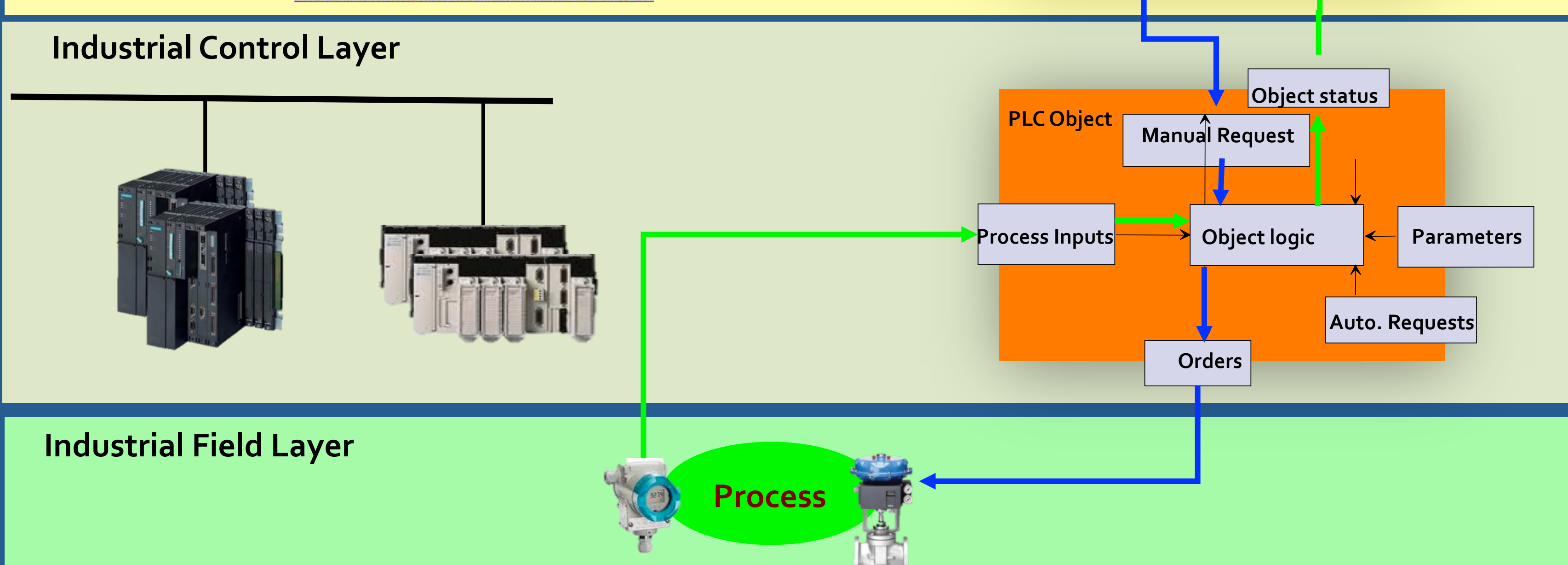
Layers Integration

Industrial Supervision Layer

In the Supervision layer a proxy is associated to each object
This proxy will present the relevant object info to the operator and allow manual commands



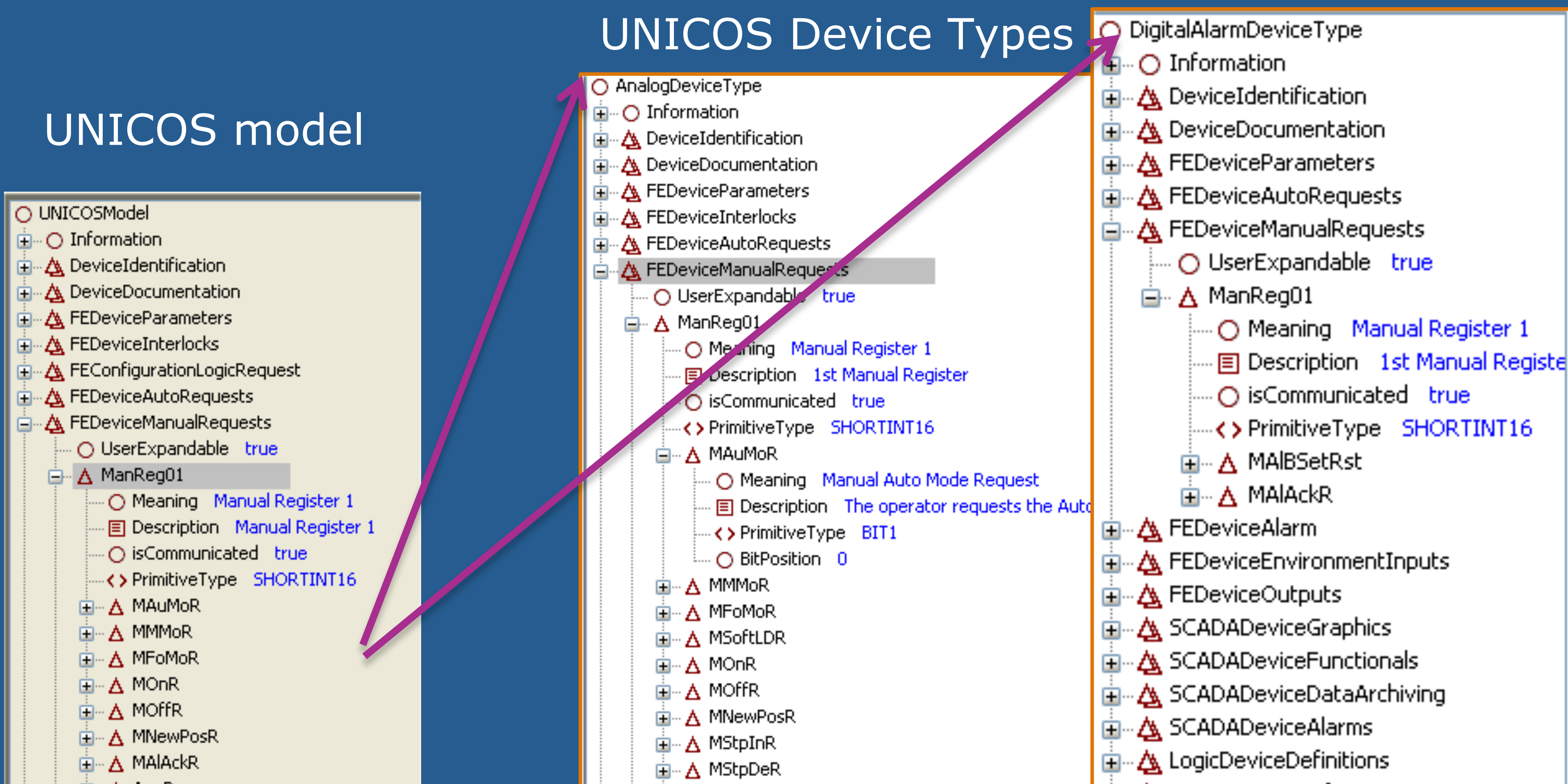




TCT (Type Creation Tool)

UNICOS model

UNICOS Device Types



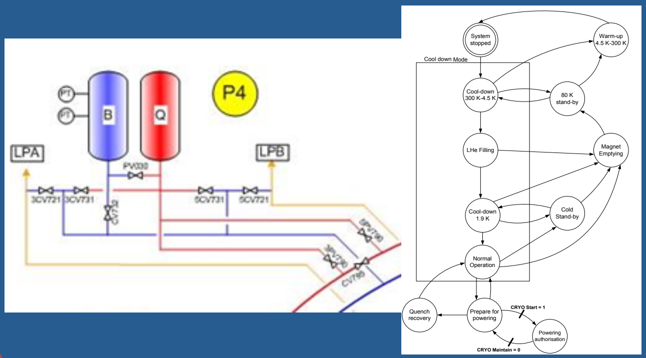
DeviceIdentification	DeviceDocumentation			FEDeviceIOConfig		FE	
					FEChannel		
Name	Description	Electrical Diagram	Remarks	FE encoding type	InterfaceParam1	Range Min	Range Max
QSDN_4_1TT4001	Vessel 1- Heater section1-Temp. control	AI1.0			%IW1.1.0	80	350
QSDN_4_AI1	SPARE	AI1.1			%IW1.1.1	0	100
QSDN_4_1TT4002	Vessel 1- Heater section2-Temp. control	AI1.2			%IW1.1.2	80	350
QSDN_4_1TT4003	Vessel 1- Heater section3-Temp. control	AI1.3			%IW1.1.3	80	350
QSDN_4_1LE400	Vessel 1- LN2 Level	AI1.4			%IW1.1.4	0	1350
QSDN_4_1PT400	Vessel 1- LN2 Vessel Pressure	AI1.5			%IW1.1.5	0	4.0

UNICOS CPC Overview

- I/O Channels
- Field Objects *(Valves, Heaters, …)*
- Process Control Objects *(Compressors, feedbox, …)*

Instances — Specifications — **Logic**

UNICOS CPC package



Instance Generator

PLC and SCADA Baseline

PLC and SCADA Instances

Precise placeholders where the control engineer must write the process logic

Logic Generator

Simplified HMI tool to create process synoptics (drag & drop)

Additional services:
CMW interface
Long-Term archiving
LHC alarm system

Diagnostics tools
System Integrity

- Operators
- Process Engineer
- Control Engineer

UNICOS Methodology

1. **Specifications creation**
   - Instances: data captured by filling EXCEL (XML) worksheets
     - Eventually these specifications may be created also automatically (e.g. DB oriented)
   - Functional Analysis + Logic specification: Word templates

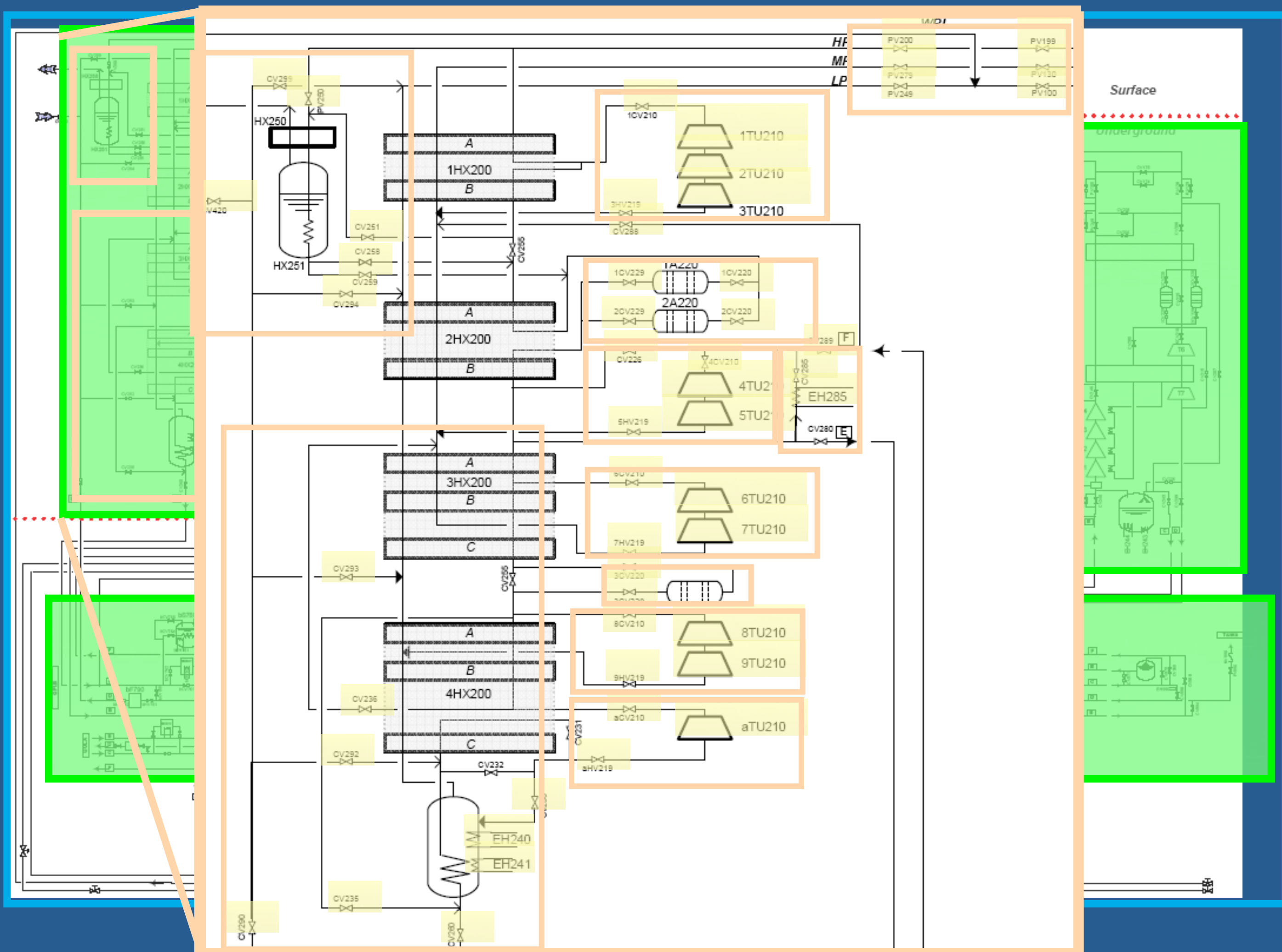
2. **Automatic generation (UAB: UNICOS Application Builder)**
   - Instance generator
   - Standard Logic generation

3. **Manual intervention**
   - Process logic coded by the control engineer in an standardized way. Some applications may create automatically the logic based on templates.
   - Process synoptics: drag & drop

Support

- Documentation, Tutorials
- Online support

Process Analysis: Decomposition



Unit

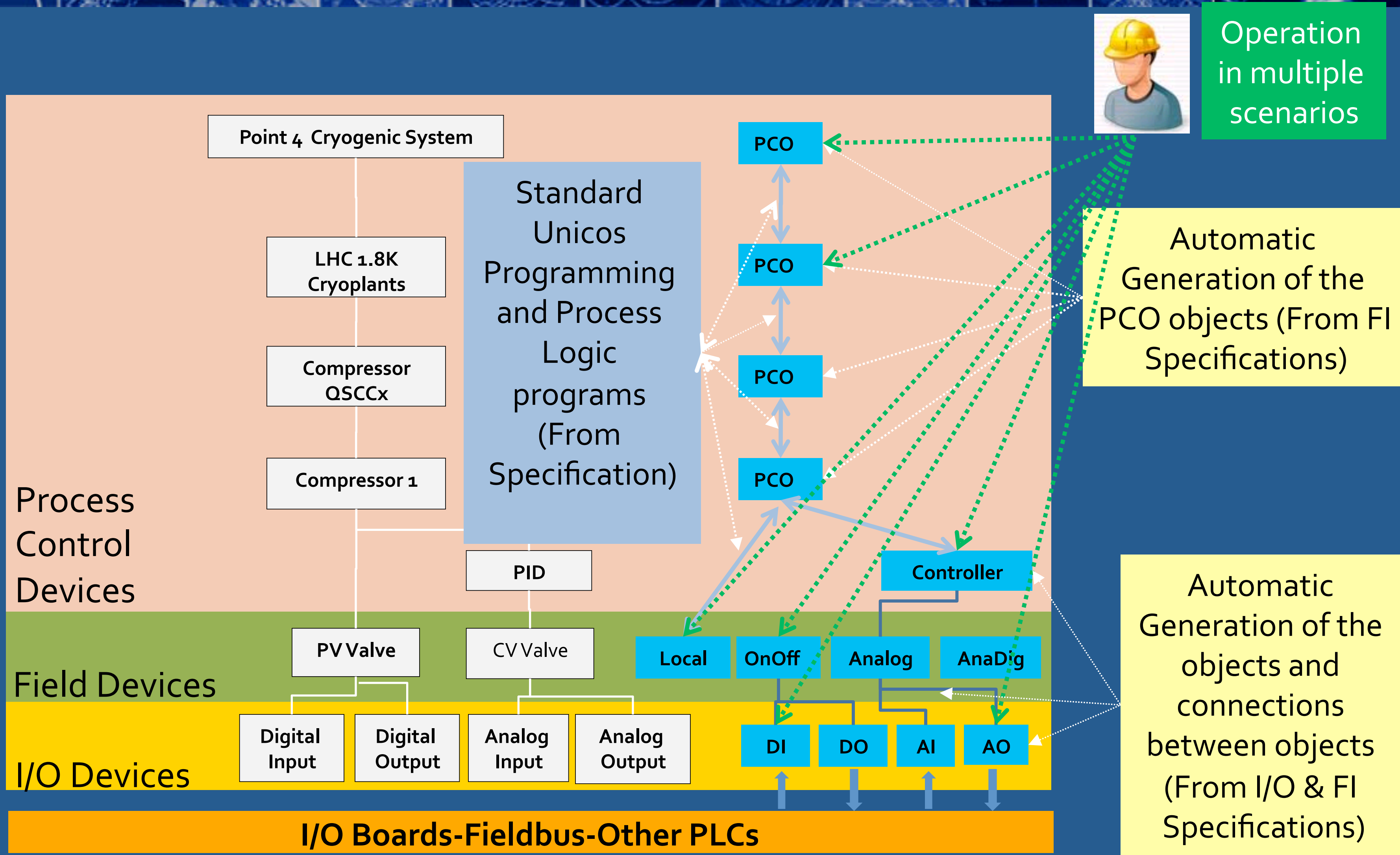
Equipment Modules

Equipment Modules

Control Modules

IEC 61512-1
Physical model

Process vs. control Architecture



(1) Specifications

DeviceIdentification	DeviceDocumentation			FEDeviceIOConfig		FEDeviceParameters				
					FEChannel					
Name	Description	Electrical Diagram	Remarks	FE encoding type	InterfaceParam1	Range Min	Range Max	Raw Min	Raw Max	DeadBand (%)
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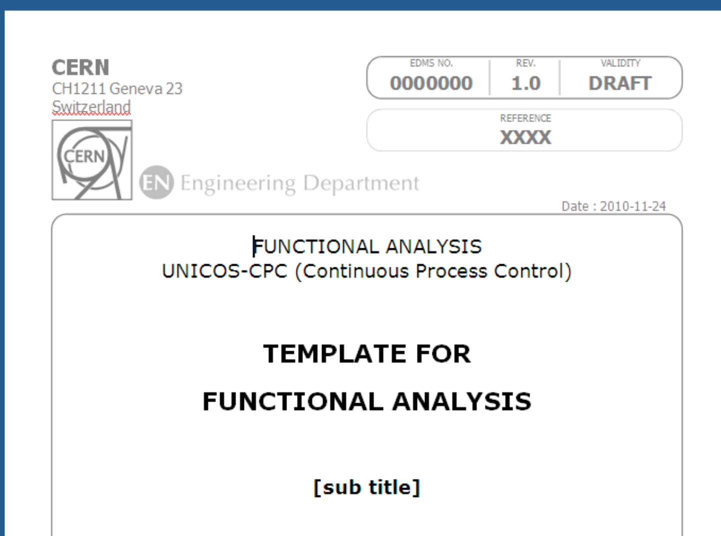
QSDN_4_AI1	SPARE	AI1.1			%IW1.1.1	0	100	0	10000	0.025
QSDN_4_1TT4002	Vessel 1- Heater section2-Temp. control	AI1.2			%IW1.1.2	80	350	0	10000	0.025
QSDN_4_1TT4003	Vessel 1- Heater section3-Temp. control	AI1.3			%IW1.1.3	80	350	0	10000	0.025
QSDN_4_1LE400	Vessel 1- LN2 Level	AI1.4			%IW1.1.4	0	1350	0	10000	0.025
QSDN_4_1PT400	Vessel 1- LN2 Vessel Pressure	AI1.5			%IW1.1.5	0	4.0	0	10000	0.025

UNICOS CPC Specs (xls/xml file)

Functional Analysis + Logic specification (Word templates)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Switzerland

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REFERENCE XXXX

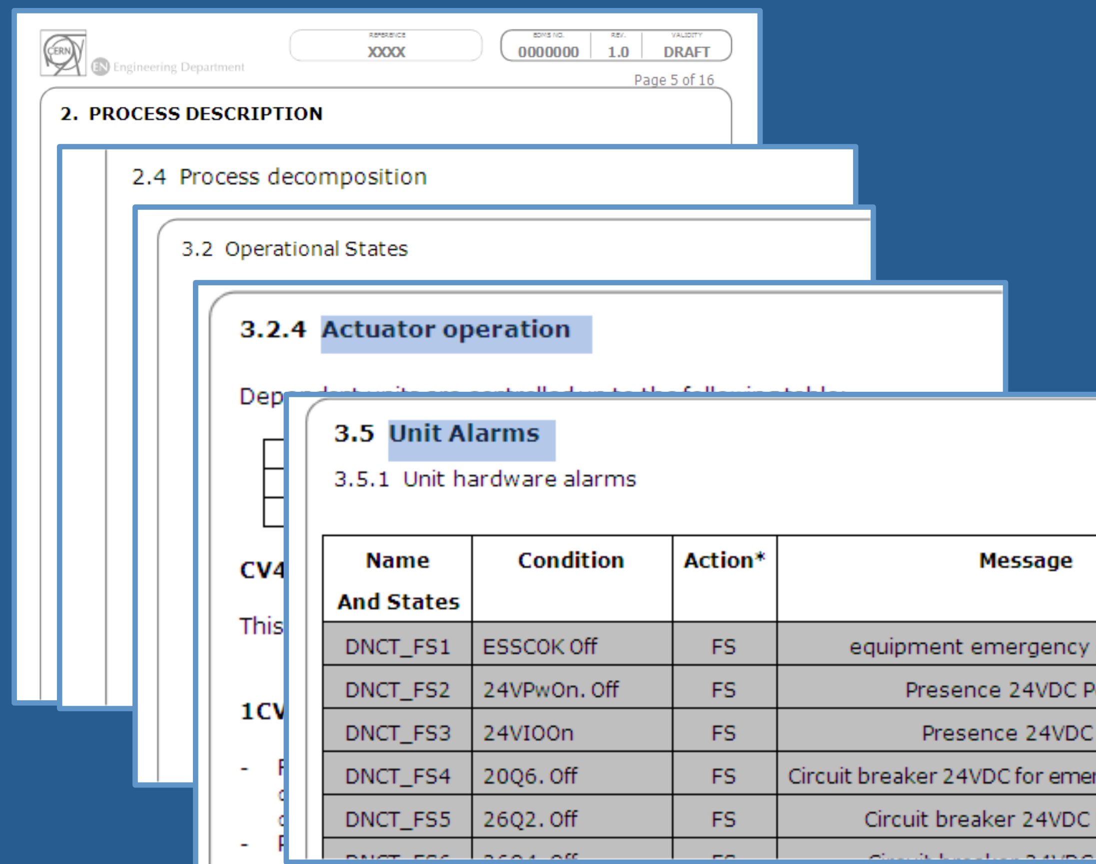
EN Engineering Department

Date : 2010-11-24

FUNCTIONAL ANALYSIS
UNICOS-CPC (Continuous Process Control)

TEMPLATE FOR
FUNCTIONAL ANALYSIS

[sub title]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2. PROCESS DESCRIPTION

2.4 Process decomposition

3.2 Operational States

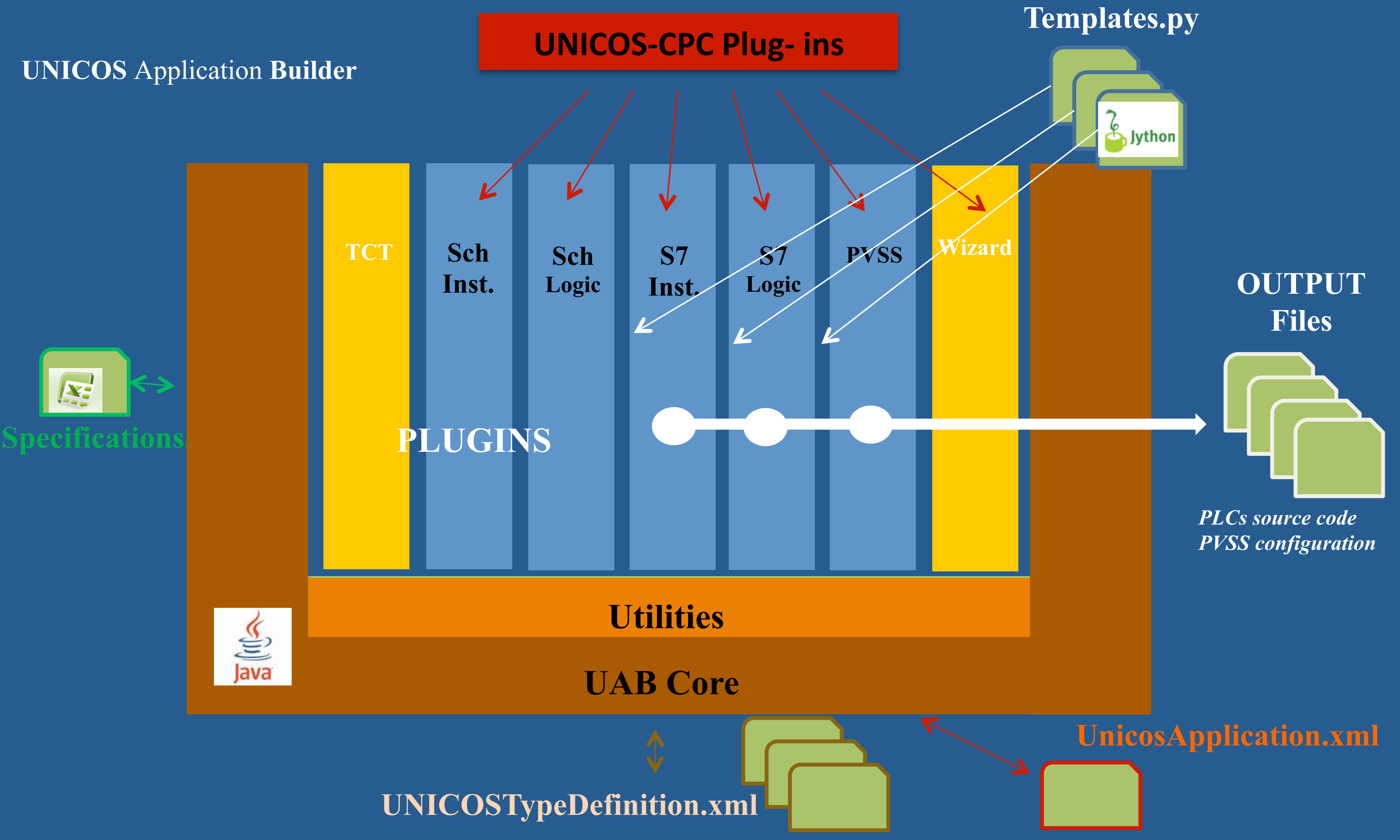
3.2.4 Actuator operation

3.5 Unit Alarms

3.5.1 Unit hardware alarms

Name And States	Condition	Action*	Message
DNCT_FS1	ESSCOK Off	FS	equipment emergency s
DNCT_FS2	24VPwOn. Off	FS	Presence 24VDC Po
DNCT_FS3	24VIOOn	FS	Presence 24VDC I
DNCT_FS4	20Q6. Off	FS	Circuit breaker 24VDC for emerg
DNCT_FS5	26Q2. Off	FS	Circuit breaker 24VDC D

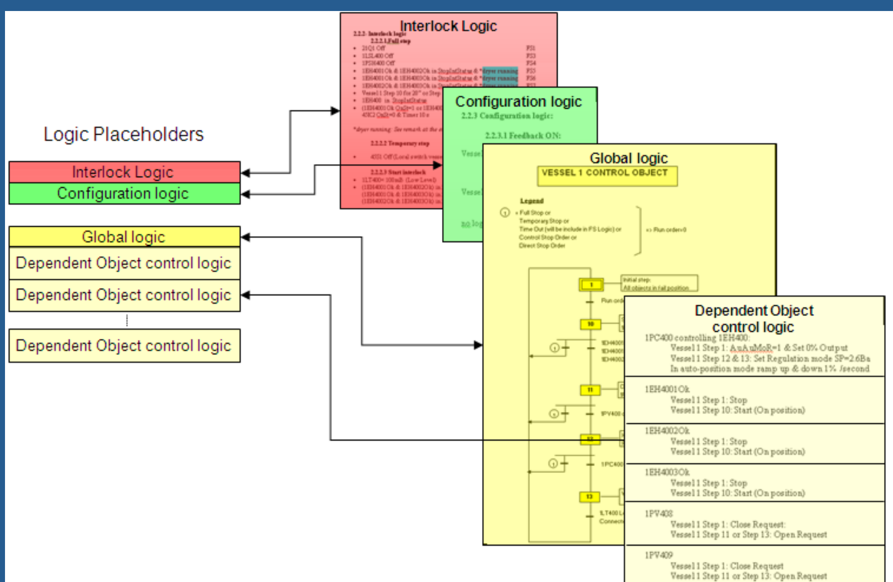
(2) Code Generation (UAB)



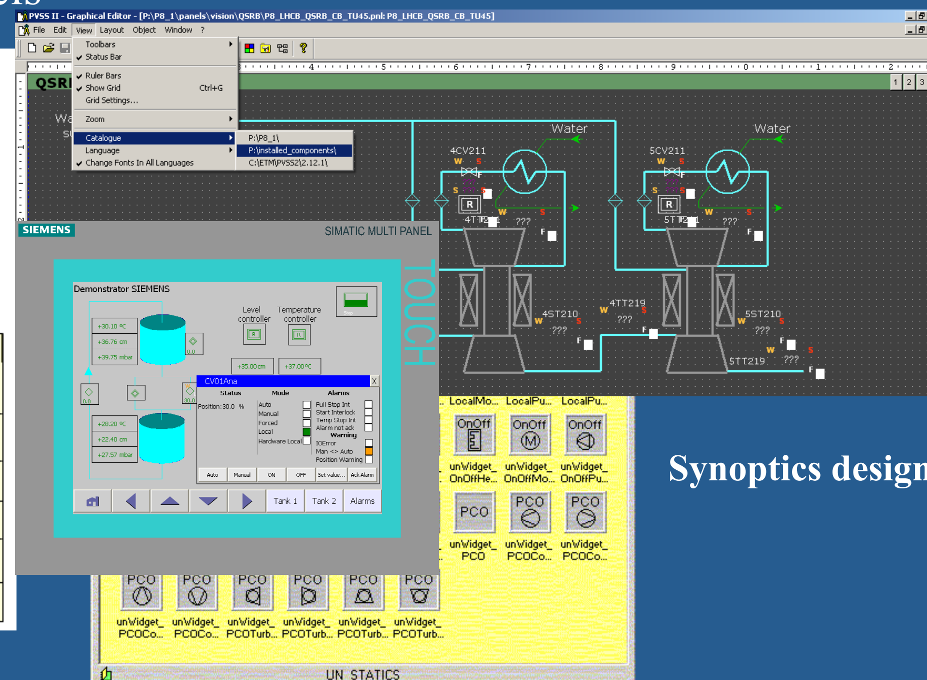
(3) Manual interventions

The goal is to reduce the human intervention:

- Process logic can be either:
  - coded by the control engineer in an standard way.
  - Some applications may create automatically the logic based on templates.
- HMI Process synoptics: drag & drop from a UNICOS-CPC catalog
  - For the SCADA and the Local panels



Logic Placeholders



Synoptics design

Advantages

- Advantages
  - Uniform and maintainable code (IEC 61131-3 languages is not enough)
  - Reduced team of engineers
    - Development (Rapid and Homogenized applications)
    - Commissioning (e.g. PLC & SCADA mapping, no development at SCADA)
    - Maintenance (Original developer is not any more critical)
  - Unified operation in control rooms
  - Centralized monitoring

- Some issues to overcome
  - In case of multiple technologies (e.g. Siemens/Schneider): Baselines maintenance
  - May reduce the developer creativity
  - Special needs may required non standard solutions (fast interlocks?)

Suppliers experience

Present and FUTURE trends

PROGRAMMABLE LOGIC CONTROLLERS (PLC)

PLC WG mandate

- PLC Working Group Mandate [1997]
  - PLC used to control and monitor technical services, accelerators, experiments and to construct the LHC machine.
  - In order to <u>optimize design time, installation time and maintenance effort</u> the <u>number of the PLC</u> families of products must be reduce to a minimum

- WG Actions
  - Market survey to find the optimal **PLC suppliers** to homogenize the CERN inventory
  - Define the **policy** for the next 10 years of usage of PLCs at CERN
  - Take into account the already existing "recommendation on the usage of fieldbuses"

PLC @ CERN, 1998

- *CERN Inventory, June 1998*

PLC INSTALLATIONS at CERN

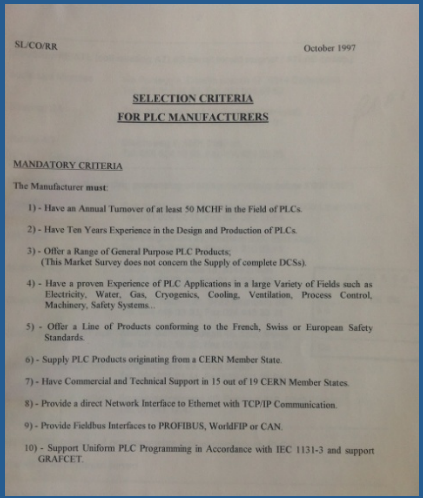
MANUFACTURERS		TYPE of PLC	NUMBER of PLCs	TOTAL
SIEMENS	(1984-97)	S5 S7(New Model)	336 29	365
SCHNEIDER	(1984-97)	EPS SEPAM	23 130	
- TELEMECANIQUE		TSX APRIL	6 9	
- MERLIN-GERIN		PB400	8	
- CEGELEC		C370	1	177
ELTEK	(1993)	SMNSP	40	40
HAZEMEYER	(1992)	CIT	31	31
SACE	(1992)	MEGAMAX	25	25
SAINCO	(1992)	EMS	17	17
TEXAS	(1987-88)	520	16	16
TRANE	(1987)	M-S	16	16
MR	(1992)	TCS	6	6
MANNESMAN	(1996)	HNC	1	1
SILICON	(1996)	SILICON	1	1
PLCs used Individually			GRAND TOTAL =	695

ABB	(1987-97)	AC MP	8 43	51
LANDIS	(1986-97)	various	205	205
PLCs Integrated into DCSs			GRAND TOTAL =	256

PLC selection

- *Selection criteria, October 1997*

MANDATORY CRITERIA FOR PLC MANUFACTURERS


SL/CO/RR October 1997

SELECTION CRITERIA
FOR PLC MANUFACTURERS

MANDATORY CRITERIA

The Manufacturer **must**:

1) - Have an Annual Turnover of at least 50 MCHF in the Field of PLCs.

2) - Have Ten Years Experience in the Design and Production of PLCs.

3) - Offer a Range of General Purpose PLC Products;
(This Market Survey does not concern the Supply of complete DCSs).

4) - Have a proven Experience of PLC Applications in a large Variety of Fields such as Electricity, Water, Gas, Cryogenics, Cooling, Ventilation, Process Control, Machinery, Safety Systems...

5) - Offer a Line of Products conforming to the French, Swiss or European Safety Standards.

6) - Supply PLC Products originating from a CERN Member State.

7) - Have Commercial and Technical Support in 15 out of 19 CERN Member States.

8) - Provide a direct Network Interface to Ethernet with TCP/IP Communication.

9) - Provide Fieldbus Interfaces to PROFIBUS, WorldFIP or CAN.

10) - Support Uniform PLC Programming in Accordance with IEC 1131-3 and support GRAFCET.

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- 8) Provide a direct Network Interface to Ethernet with TCP/IP Communication.
- 9) Provide Fieldbus Interfaces to PROFIBUS, WorldFIP or CAN.
- 10) Support Uniform PLC Programming in Accordance with IEC 61131-3 and support GRAFCET.

PLC Market Survey

QUALIFICATION of MANUFACTURERS

PLC MARKET SURVEY - MS/2547/SL

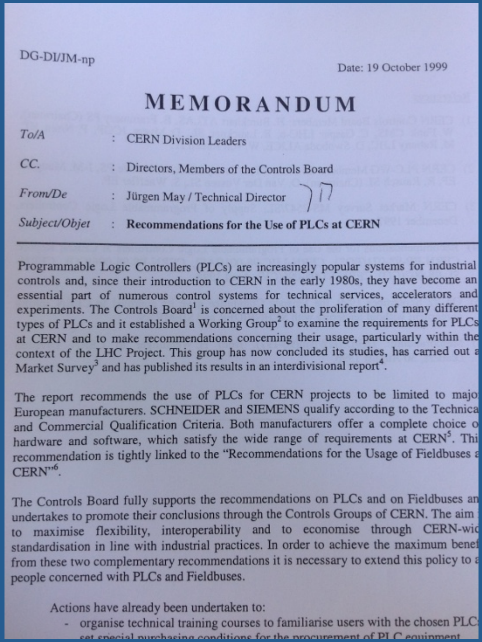
MANUFAC TURERS	QUALIFICATION CRITERIA										QUALIFI CATION
	TurnOver > 50 MCHF	Experien. >10 Years	General Purpose PLC	Safety	Redun dancy	Origine Europe	Support CH & F	TCP/IP Communication	CAN Profibus WorldFIP	IEC 1131-3	
ABB	YES	YES	NO	YES	YES	YES	YES	YES	Profibus Develop.*	YES*	NO
ALFA LAVAL	NO	YES	YES	NO	YES	YES	YES	YES	Profib.*	Partly YES	NO
CEGELEC	YES	YES	YES	NO	YES	Partly YES	YES	YES	Profibus WorldFIP	YES	NO
ELSAG BAILEY	NO	NO	YES	NO	YES	YES	YES	YES	Profibus	YES	NO
GE FANUC	YES	YES	YES	NO	YES	NO	YES	YES	Profibus	NO	NO
INGELEC TRIC-TEAM	NO	YES	YES	YES	YES	YES	NO	YES	CAN Profibus	YES	NO
KLÖCKNER MOELLER	NO	YES	NO	NO	NO	YES	YES	NO	Profibus	YES	NO
PEP MODUL. COMPUTER	NO	NO	NO (VME)	NO	NO	YES	YES	YES	CAN Profibus	YES	NO
ROCKWELL (F) + (UK)	YES	YES	YES	YES	YES	NO	YES	YES	CAN Profibus	YES	NO
SAT	YES	YES	YES	NO	YES	YES	CH	YES	Profib.*	NO	NO
SCHNEIDER (CH) + (F)	YES	YES	YES	YES	YES	YES	YES	YES	Profibus WorldFIP	YES	YES
SELECTRON	NO	YES	YES	NO	NO	YES	F	NO	CAN	YES	NO
SIEMENS	YES	YES	YES	YES	YES	YES	YES	YES	Profibus	YES	YES

* No Detailed Information or Description given in the Technical Documentation Provided

Updated on 29/04/98

Standard PLCs @ CERN

- **Recommendations for the use of PLCs at CERN,** *October 1999*
- The PLC WG recommends the use of both **SCHNEIDER** and **SIEMENS** (qualified according to technical and commercial qualification criteria)
- **Actions**
  - Organize Technical trainings
  - Negotiate special purchasing conditions
  - Produce documents for future technical specifications
  - Organize centralized support : GUAPI : PLC users group



DG-DI/JM-np

Date: 19 October 1999

MEMORANDUM

To/A : CERN Division Leaders

CC. : Directors, Members of the Controls Board

From/De : Jürgen May / Technical Director

Subject/Objet : **Recommendations for the Use of PLCs at CERN**

Programmable Logic Controllers (PLCs) are increasingly popular systems for industrial controls and, since their introduction to CERN in the early 1980s, they have become an essential part of numerous control systems for technical services, accelerators and experiments. The Controls Board[1] is concerned about the proliferation of many different types of PLCs and it established a Working Group[2] to examine the requirements for PLCs at CERN and to make recommendations concerning their usage, particularly within the context of the LHC Project. This group has now concluded its studies, has carried out a Market Survey[3] and has published its results in an interdivisional report[4].

The report recommends the use of PLCs for CERN projects to be limited to majo European manufacturers. SCHNEIDER and SIEMENS qualify according to the Technica and Commercial Qualification Criteria. Both manufacturers offer a complete choice o hardware and software, which satisfy the wide range of requirements at CERN[5]. Thi recommendation is tightly linked to the "Recommendations for the Usage of Fieldbuses a CERN"[6].

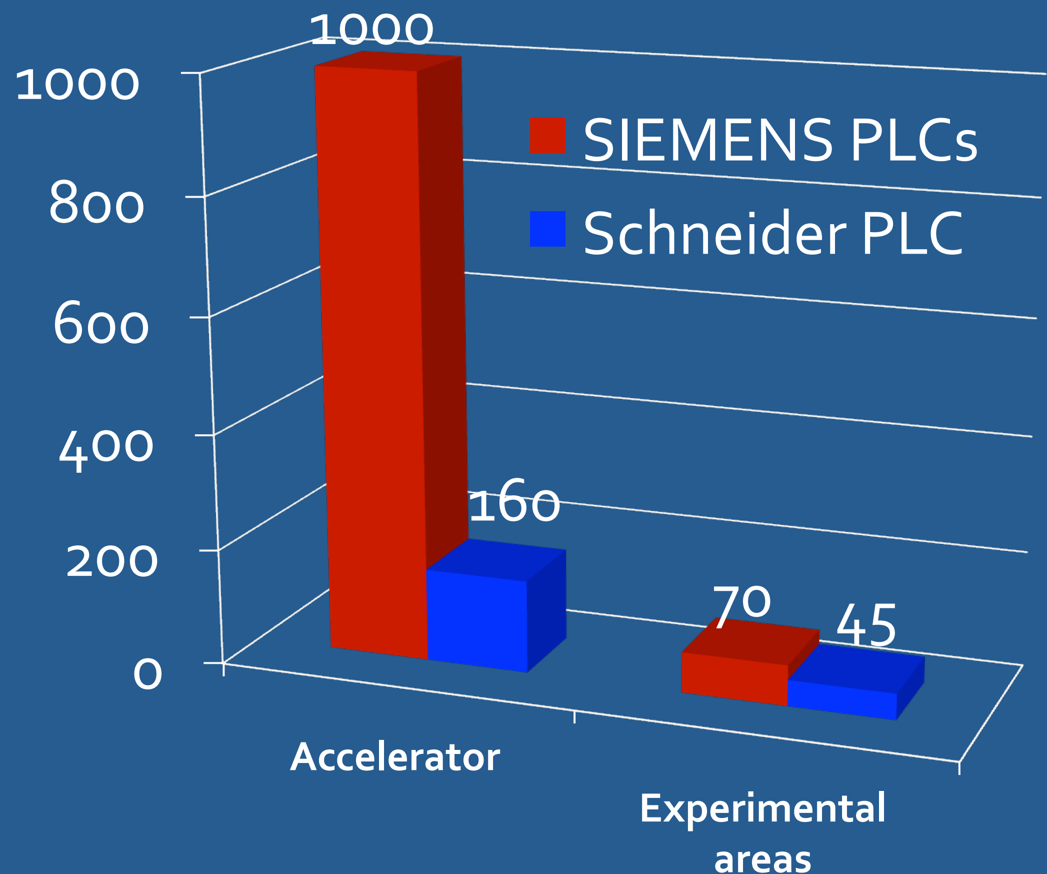
The Controls Board fully supports the recommendations on PLCs and on Fieldbuses an undertakes to promote their conclusions through the Controls Groups of CERN. The aim to maximise flexibility, interoperability and to economise through CERN-wic standardisation in line with industrial practices. In order to achieve the maximum benef from these two complementary recommendations it is necessary to extend this policy to a people concerned with PLCs and Fieldbuses.

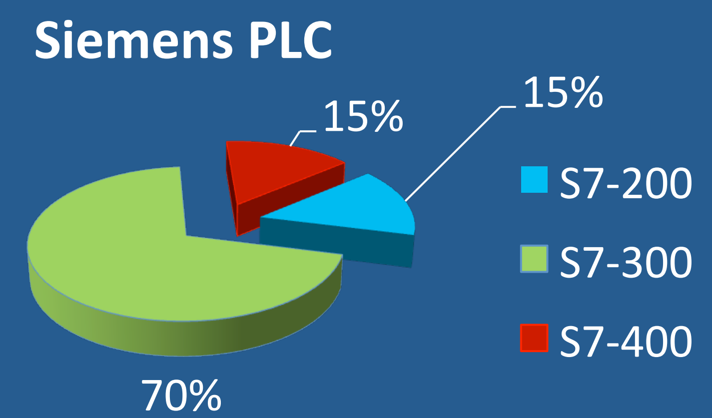
Actions have already been undertaken to:

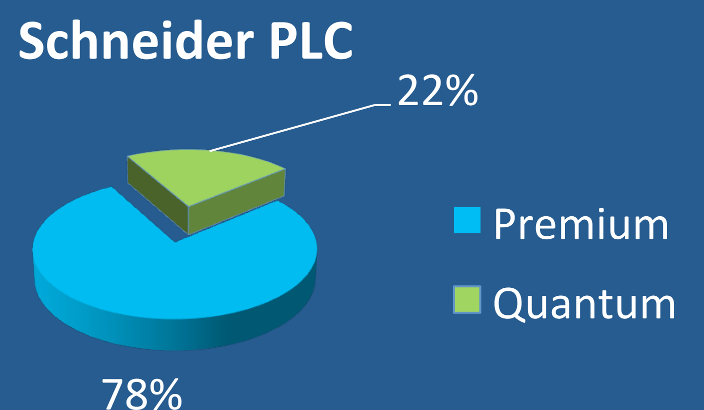
- organise technical training courses to familiarise users with the chosen PLC

CERN management endorses these recommendations and ask CERN designers and developers to base their projects and technical specifications for equipments operated at CERN on the two complementary recommendations for PLCs.

PLCs inventory at CERN







Data collected year 2012

PLCs oriented applications

- **Classic PLCs**
- Cryogenics (Accelerator and experimental areas)
- Gas systems
- Cooling systems
- HVAC
- Motion: servo-motors and Stepping motors
- RF
- Vacuum
- Electrical systems
- Interlocks
  - PIC: Powering Interlocks
  - CIS: SPS Power converters interlocks
  - Collimators Temperature Interlocks
- Monitoring
  - RAMSES

Safety Integrated systems

- Access Control (accelerators and special areas)
- Machine-tools sector:
  - Winding machines: HTS cables
- WIC: Warm magnets interlocks
- Cranes control
- Autonomous Mobile Equipment
  - TIM (Train mono-rail)

Redundant systems

- Protection systems in experimental areas
- Electrical systems

Experience with suppliers

- More than 15 years of experience
  - There is not a perfect supplier but a satisfactory supplier
  - Lack of competition between suppliers is not healthy… as long as you can afford it.
  - Despite being a rather conservative technology segment, the supplier must follow tendencies (desirably without imposing continuous upgrades)
  - A strong and reactive technical team must be behind the curtains (commercials are not enough)
  - Take your time before including in your portfolio a new product
  - Key is not having a supplier but a **partner**

Industrial Partner: SCHENEIDER

Schneider Electric

- Dedicated hotline
- Customized prices (in function of sales turnover)
- Technical support on site
- Not a simply supplier but a partner: Collaboration
  - Bi-annual meetings at CERN and the headquarters
  - Radiation tests
  - Field tests (e.g. M580, Ethernet/IP)

Industrial Partner: SIEMENS

SIEMENS

- Dedicated hotline in Germany
- Customized prices (in function of sales turnover)
- Technical support on site
- Not a simply supplier but a partner: Collaboration
  - Bi-annual meetings at CERN and the SIEMENS headquarters
  - SIEMENS roadmap
  - CERN requirements (technological limitations, missing functionalities,…)
  - Beta testers: e.g. TIA portal
  - Prove new solutions (e.g. Touch panels / UMTS comms)

- Reinforced by the presence of SIEMENS in the Openlab.

Other suppliers…

- Risk of increasing the PLC suppliers at CERN
- Supplier Loyalty: A matter of investment
  - Beckhoff:
    - IPC (Codesys) & EtherCAT
    - XFC: EtherCAT PLC with 12.5 μs cycle time
  - WAGO: BACNet communications
  - Others in the building automation segment

We keep an eye on *Rockwell* PLCs ...

PLC services

- The Organization/Institute must **provide** more than just a brand(s) of PLCs !
  - Provide unified services
  - Promote user knowledge exchange
  - Central support: High expertise level required

CERN wide PLC services

- **Versioning** and software distribution
  - *Versioning systems* usage guidelines for PLC developers. (e.g. SVN)
  - Central Software distribution (CMF)
- **Database** support for PLC users (Layout)
  - CERN equipment catalogue
  - Tools to populate databases for functional components
  - Asset database for component tracking.
- **Availability (machines uptime)**
  - **Diagnostics & monitoring**: (PLC agent)
  - ***PARADIS***: Repository for PLC application distribution.
  - Critical spare stock: Fast intervention ensured 24/7
- Optimize **Knowledge**
  - **GUAPI**: PLC Users Working Group
  - Set of demonstrators and training test-benches
- Hardware
  - Reduced set of hardware (recommended hardware)

CERN wide PLC services

Maintenance

- **Corrective** and **Preventive**
  - Ambient environment and PLC conditions (Temperature, humidity, dust, vibrations,…)
  - Connection conditions (Visual inspection, Terminal screws, Line voltage check,…)
  - Runtime conditions (LEDs status, Cycle time, log messages, memory occupancy,…)

- Full available **documentation**
  - Installation guide
  - Operation manual
  - Maintenance manual
  - Spare list
  - Obsolescence management (How do you ensure your piece is not discontinued?)
  - Layout diagram
  - Troubleshooting questionnaire (Quality Control)
  - Experts contact numbers
  - Back-up program

- **CMMS : Computerized Maintenance Management System**

GUAPI: PLC Users Working Group

A **collaborative service** aiming to optimize:

- EFFICIENCY
  - Identify generic developments which could be created, maintained and supported by users teams
  - Knowledge sharing: Avoid duplication of efforts by identifying existing competence and solutions
- CERN-WIDE COMMON POLICIES:
  - Spare material
  - Technical issues follow-up
  - Upgrade of software, firmware, hardware
- EVOLUTION
  - Identify requirements in terms of new functionalities
- TRAINING
  - Identify needs and organize appropriate trainings
  - Product evolution roadmaps

- *“**Direct line**” with manufactures: Outcome of needs and problems before the regular meetings with manufacturers*

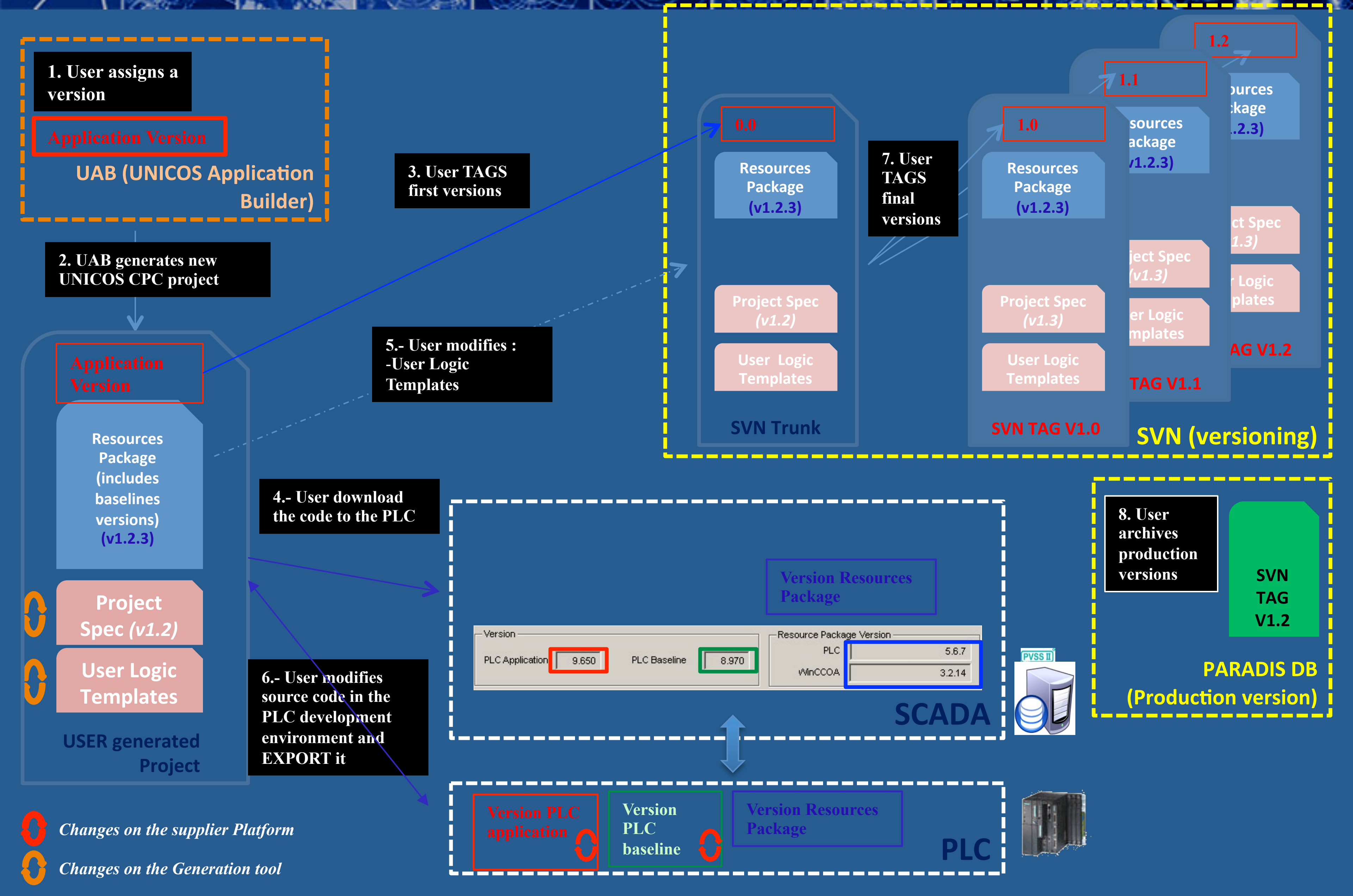
But still a lot to do…

- Some fields to improve
  - Deployment
  - Testing & verification
  - Commissioning

Deployment

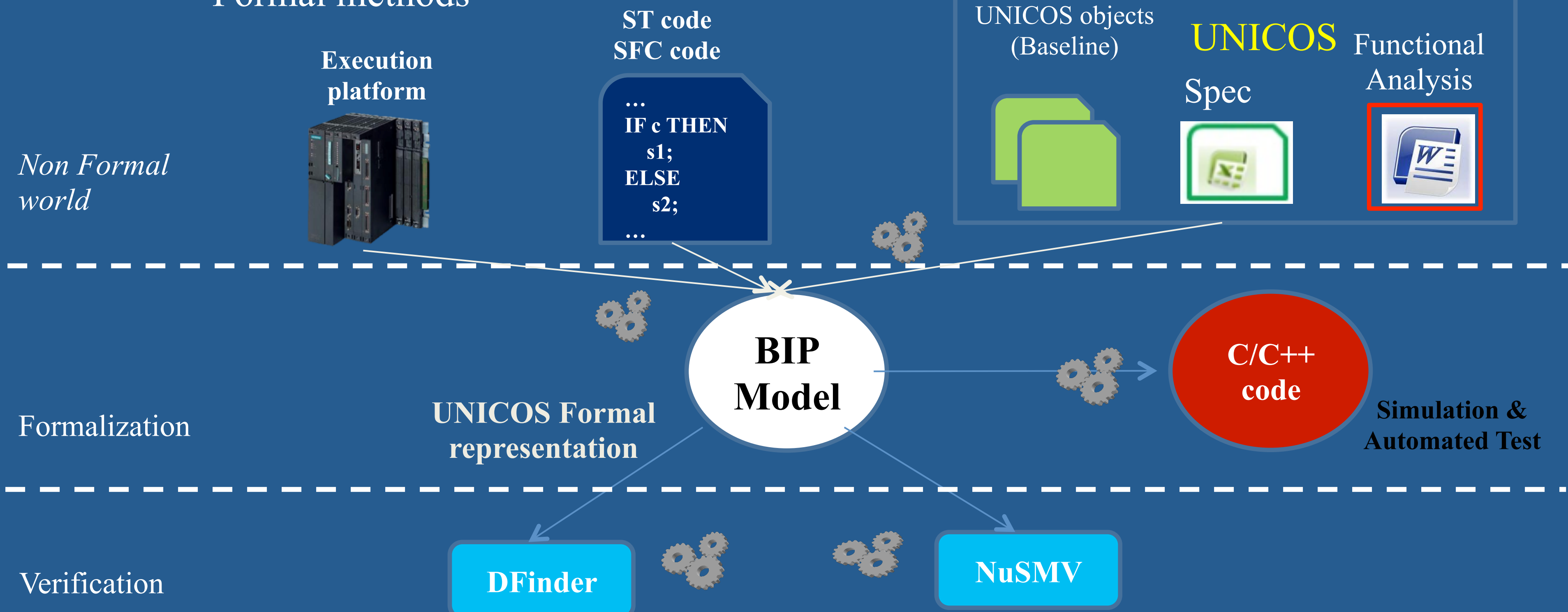
- Questions
  - What details have changed from one archived version of a project to the next version?
  - Which is the version currently deployed in the PLC?
  - Who made the last download?
- Suppliers tools
  - SIEMENS: Simatic Logon , Version Trail and Cross Manager
    - Simatic Logon FDA approval
  - Schneider Electric: Third party solution
  - Third-party: MDT AutoSave Change Management
- In house developments driven by
  - Missing functionalities
  - Internal needs (framework baseline version identification)

UNICOS-CPC versioning



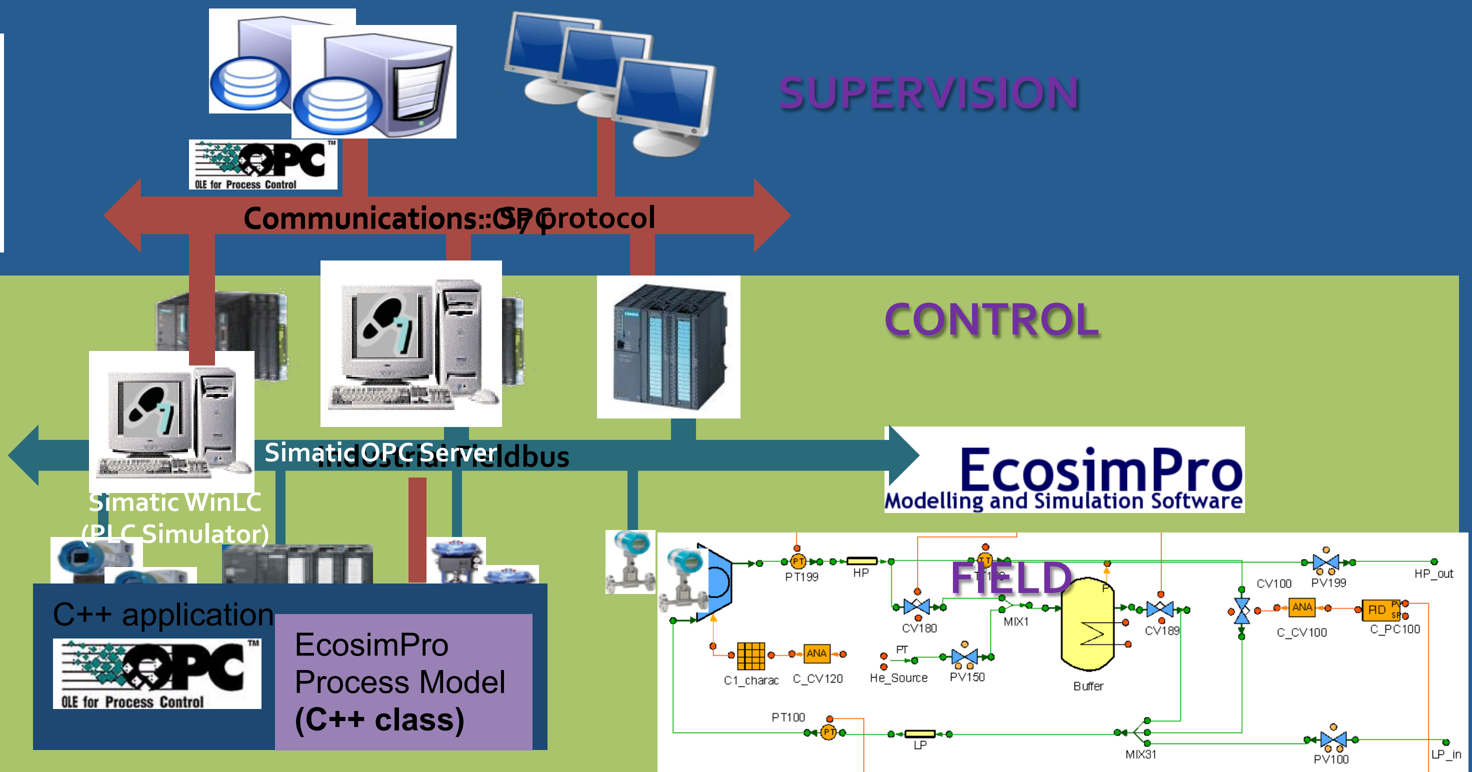
Testing and Verification

- Testing: Standards
  - ANSI/ISA-62381-2011 (IEC 62381 Modified): SAT and FAT activities
  - Automatic tests (unit test-like): Based both in SIMBA box + SCADA scripting
- Verification
  - Formal methods



Testing and Commissioning

- Virtual commissioning
  - Simulation techniques (static and dynamic)



CERN Industrial control architecture vs Simulation

Suppliers experience

Present and FUTURE trends

PROGRAMMABLE LOGIC CONTROLLERS (PLC)

PLC present and future trends

- Some of them may be well known already
- Some of them may be not more than possible roadmaps

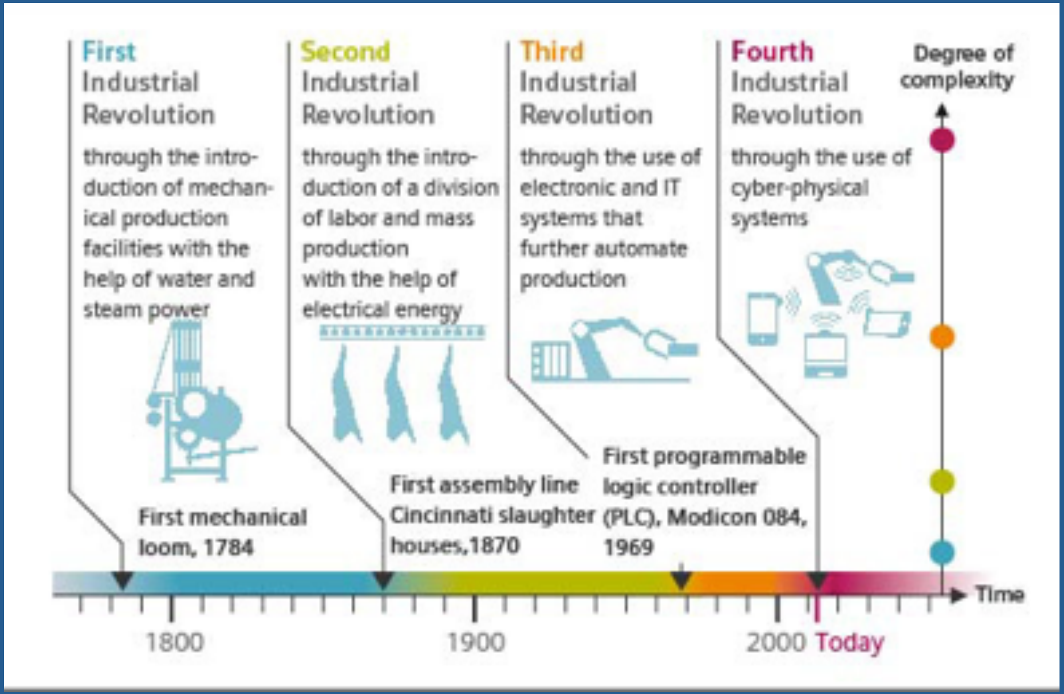
- In any case a summary of:
  – Automation market feelings
  – Experience with suppliers when talking about prospects and concepts…

PLC Automation trends

- **Industry 4.0**

  4th industrial revolution: where IT meets production.

  Some topics:
  - Security
  - Cloud solutions
  - PC-based technology
  - WLAN solutions
  - Open networking
  - General IT concepts



German Research Center for Artificial Intellegence courtesy

PLC Integration

- Further integration: PLC + SCADA
  - Mainly **Overall** and not individual performance
  - Minimize the effort of Engineering
  - Engineering tools for integrated automation

  e.g. Etool (SIEMENS), PlantStruxure™ (SCHNEIDER)

- Integrated engineering
  - Life cycle engineering
  - Plant asset management
  - PI&D, EIC, Controls, Maintenance…

PLC Hardware

- Hardware improvements
  - Speed & Memory
  - On board diagnostics
  - Functional Safety integrated
  - Remotely located systems (I/O)
  - Field devices with embedded intelligence
  - Redundancy until the industrial communicat

  - *Low cost* CPUs (small projects)
- Controllers: PLCs, PACs, IPCs
  - PAC: - Multi-domain functionality (Process control, motion, …)
    - Single development tool
    - Open and flexible architecture
    - Use of many communication standards
  - IPC (e.g. Local logging, complex algorithms: predictive control)

IT integration

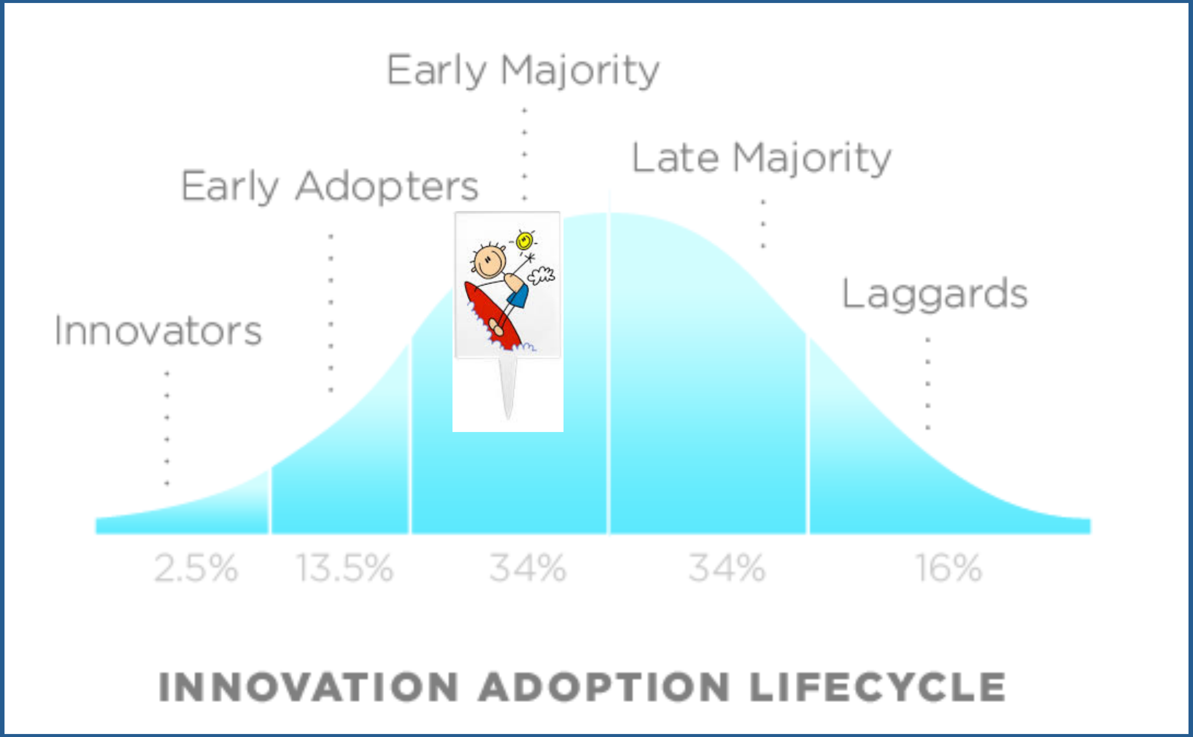
Adoption of new IT paradigms:

- Software management
  - Deployment
  - Versioning
- Interaction
  - Openness
  - Interoperability by ensuring standards
- Development
  - Design (OO Techniques)
  - Multiuser

IT integration (2)

- Not only PRO's!

Time to the market is reduced dangerously and expected quality is effectively compromised



PLC: Cyber Security

- Reinforced Security
    - Standards: ISA-99
    - Certification (e.g. Achilles)
    - Integrity checks on IDEs
    - Secure access (e.g. encrypted passwords…)
    - Defense in depth
    - Secure development

– OpenLab @ CERN : SIEMENS collaboration
    - NDA agreement

Others… not exhaustive

- Industrial communications
  - Interoperability and not just connectivity
  - Not anymore depending of a single supplier! … but still a *sectorization* by suppliers alliances.
  - OPC UA: Interoperability Standard for Industrial Automation
- Embedded IT features
  - WWW servers
  - Simple "supervision" synoptics production: rapid prototyping
  - Enlarged diagnostics
- Local operation
  - Seamless Integration of multi-touch panels

PLC trends: Keywords

Engineering Integration

Security

Standards

Interconnectivity

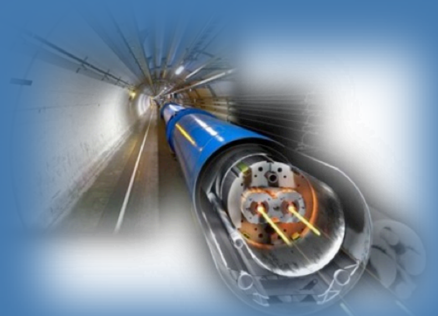
IT

IPCs

All these slides represent the work of many people working at CERN
The PLC future trends is a particular vision of the presenter

CERN

http://www.cern.ch



PLC Selection criteria

- Brand loyalty: A matter of investment

Commercial Issues	Technical Issues
1. Quality of products	1. Quality of tech support
2. Quality of pre-sales service	2. Reusable programming code
3. Local presence	3. Integration with 3rd party devices
4. Wide range of products	4. Uses IEC 61131-3 languages
5. Supplier's reputation	5. Supplier's reputation
6. Discount price	6. Supports open networking standards
7. Willingness to customize products	7. CPU scan time
8. List price	8. Wide range of related products