Modular SCADA:

CERN **JCOP** & **UNICOS** Frameworks and Simatic **WinCC Open Architecture**

Piotr Golonka
CERN BE/ICS-STF

ENTSO-E R&D Meeting
13 September 2024

https://indico.cern.ch/event/1415872/

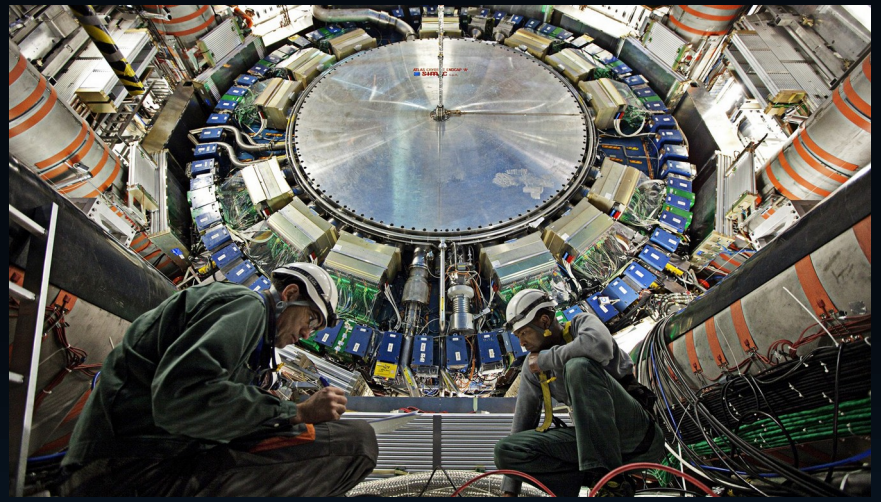
About...

- CERN BE-ICS group: Central support for industrial technologies
  - WinCC OA: de-facto standard SCADA at CERN
    - Central support, collaboration with vendor, distribution, licensing, ...
  - Middleware & PLC
  - Frameworks: JCOP and UNICOS → standardized technology stacks
    - Central teams for development and maintenance
  - Applications
    - Engineering/Development
    - Lifetime maintenance and support (SCADA App Service)
- Me
  - Software Engineer, PhD in physics, 20 years in the group
  - CERN-ETM liaison, responsible for CERN WinCC OA service
  - Project leader for the JCOP Framework
  - Piotr.Golonka@CERN.CH

CERN Industrial Controls: Goal

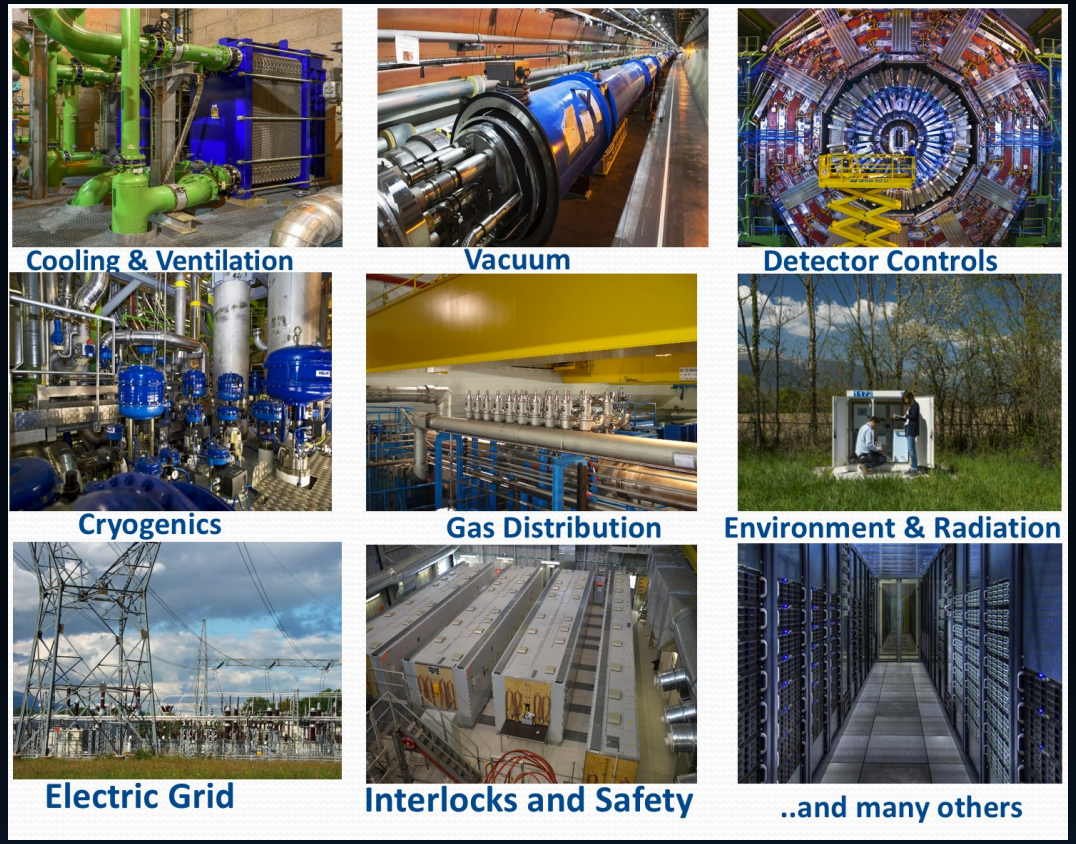
Optimize physics data taking by maximizing uptime and optimal operation of Detectors, Accelerators and Technical Infrastructure

- Implies: maximum availability, optimal operation of all auxiliary systems
  - cryogenics, gas, interlocks, cooling, HVAC, alignment, powering,…
  - detector/experiment control systems
- Additional specific requirements:
  - Environment:
    - radiation areas, strong magnetic field up to 4T
  - Unprecedented number of I/O
    - (3 M h/w channels in ATLAS)
  - Data volumes and rates
    - (e.g. QPS 200.000 changes/s)
  - Large distributed and interconnected systems
  - Complexity (control logic, multiple technologies
  - Highly de-centralized instrumentation (>27 km)



WinCC OA SCADA is the key element in standardization of CERN Industrial Control Systems

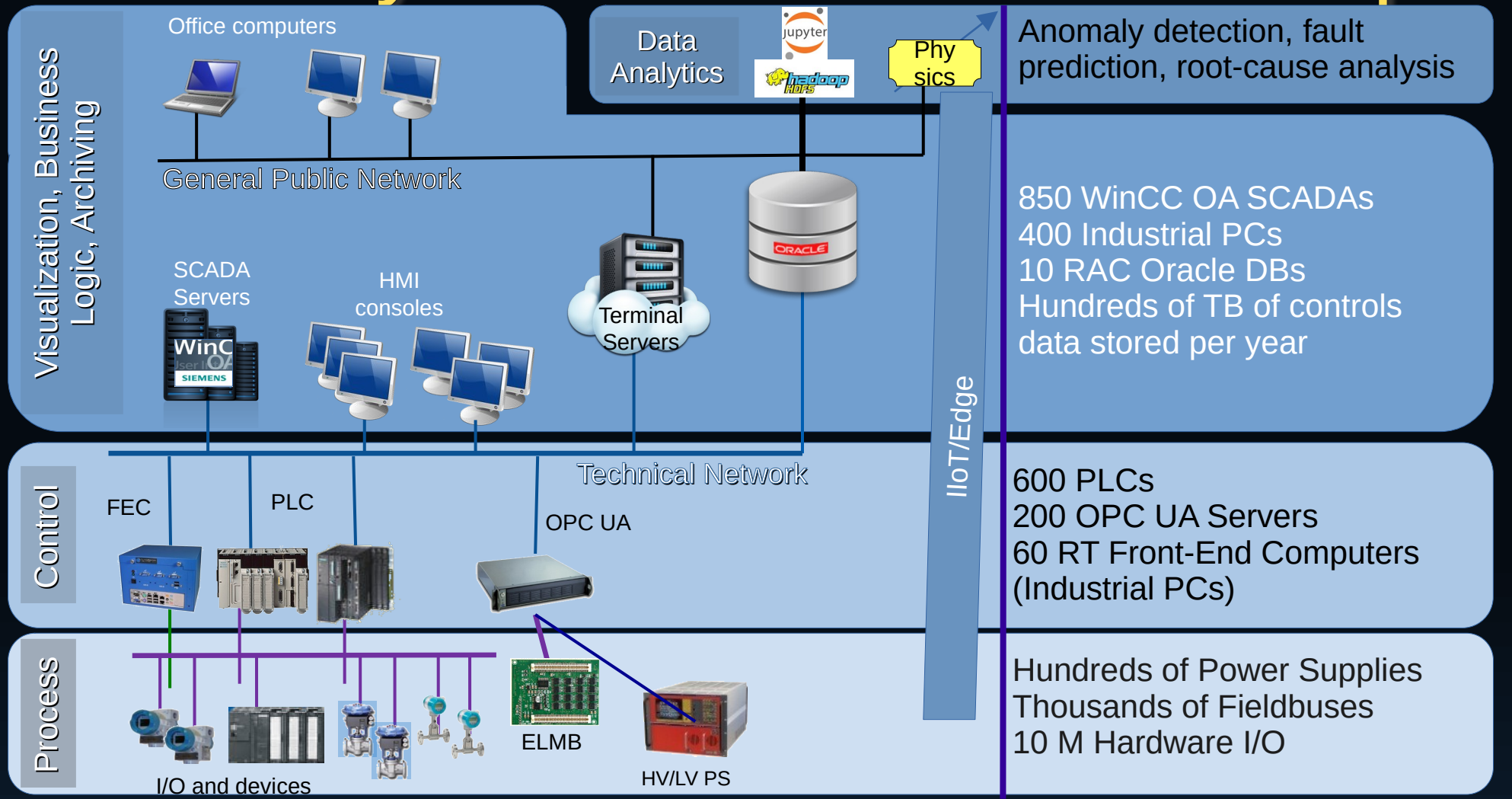
WinCC OA SCADA at CERN



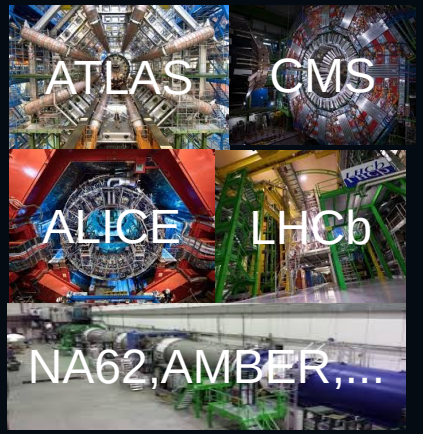
- De-facto standard for the "slow controls" applications
  - Coupled with COTS/industrial as well as custom h/w and s/w
- ~850 production systems →
  - ATLAS: 130 sys, 12M DPEs
  - PSEN: ~1M DPEs in a single system
- Large developer base
  - 500 developers,
  - 150 collaborating institutes,
  - 30 countries
  - 150 training courses,
  - 1100 students

Most important systems are in production since ~2008 yet still evolving
New ones implemented all the time (e.g. consolidation of Cooling&Ventilation)

Control system architecture: example

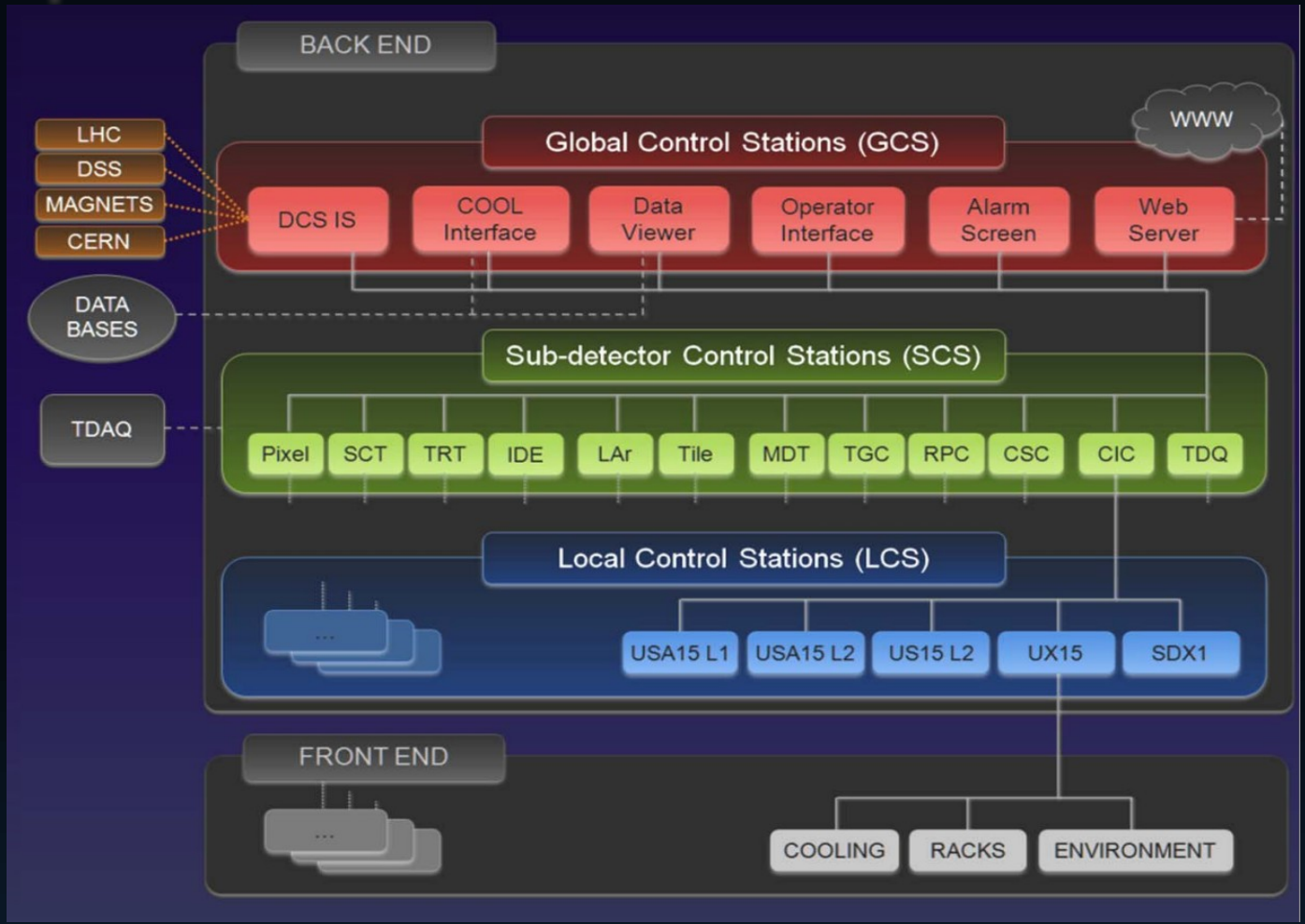


Experiments, Detectors, Collaborations...



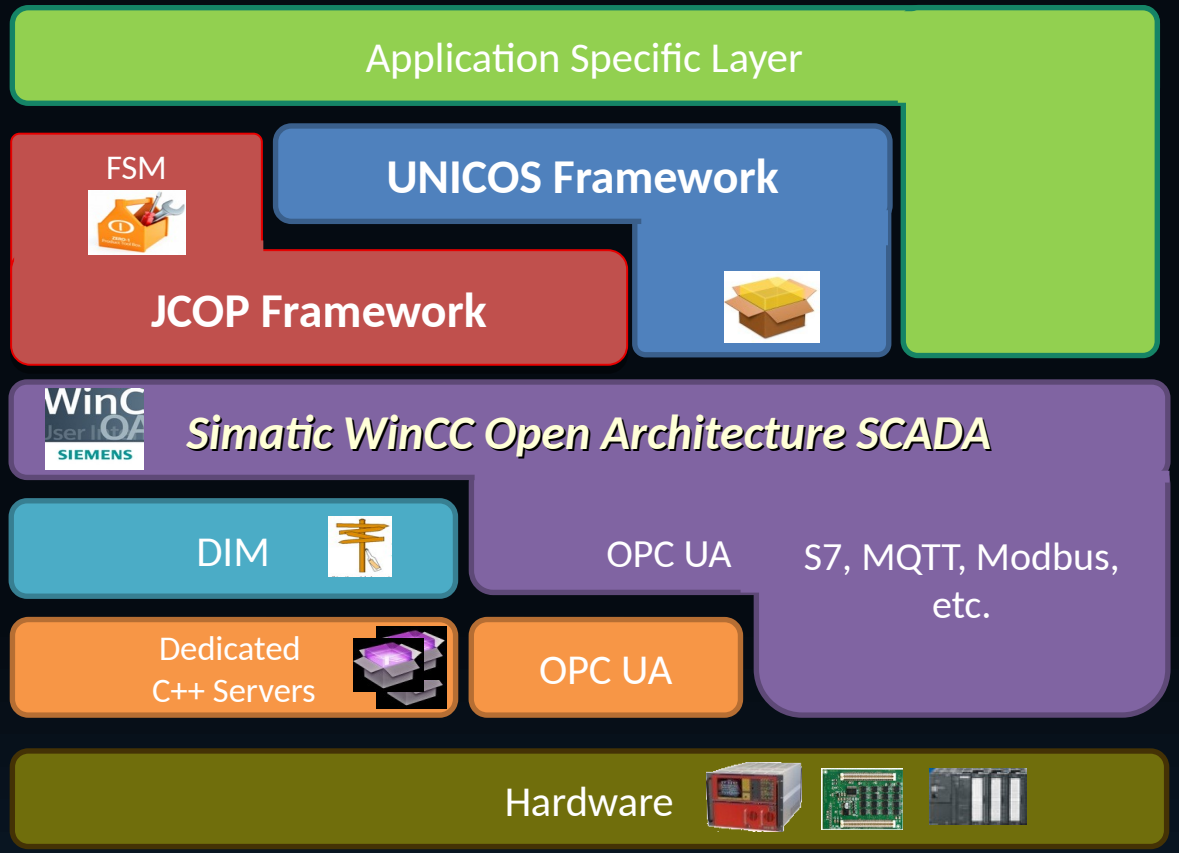
- **CERN**: the Laboratory
  - Delivers colliding beams of high-energy particles + infrastructure
- International research Collaborations
  - conduct Experiments at CERN
  - ATLAS, CMS, ALICE, LHCb, NA62,…
  - 1000s of engineers and physicists in 100s of institutes
- They build large and complex Particle Detectors
  - Genuine parts and subsystems (subdetectors) developed in-house in collaborating research institutes, *all over the world*
  - Assembled and integrated at CERN
- Control Systems
  - **Detector** Control Systems: large and complex, SCADA-centric
    - 10M IOs, distributed, partitioned onto 150 SCADAs
    - Development and maintained scattered in research institutes
      - Local control of subsystems needed while subdetectors built/tested
  - **Accelerator Infrastructure**: Cryogenics, Vacuum, Protection
  - **Technical infrastructure** (Gas, Safety, CV, Electricity)

Example: Dist architecture in ATLAS

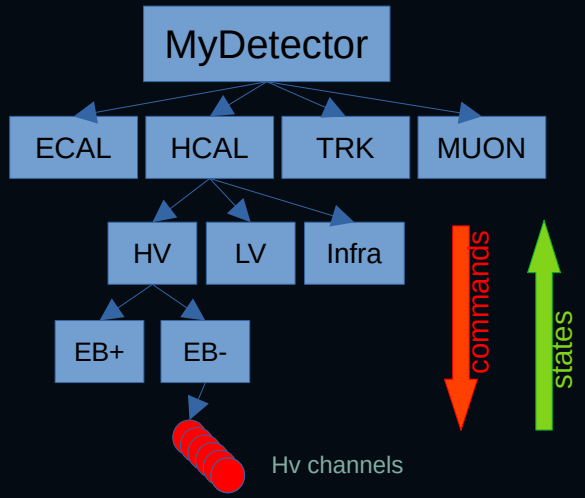


Standardisation and frameworks

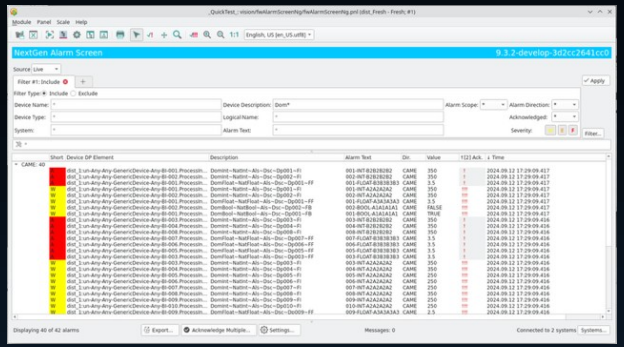
- Essential for integration and homogeneity
- *Component-based frameworks* encapsulate technologies into generic, reusable building block
  - Tools (trending, ConfigurationDB, LDAP)
  - Device integration (OPC-UA, PLCs)
  - Libraries for custom development, ref-panels
  - Conventions and guidelines
- **UNICOS**: unified way to build control systems
  - Automatic generation/configuration of SCADA
  - Synoptic panels drawn by advanced operators
  - PLC-centric **UNICOS-CPC**:
    complete engineering from specs to deployment
- **JCOP**: homogeneous way to integrate very complex distributed control systems
  - Need for tailor-made applications
  - Use of custom hardware and external systems
  - *SCADA-centric business logic*: **FSM**
- Millions of lines of (CTRL) code
  - Going opensource soon...



Detector Control Systems: Integration



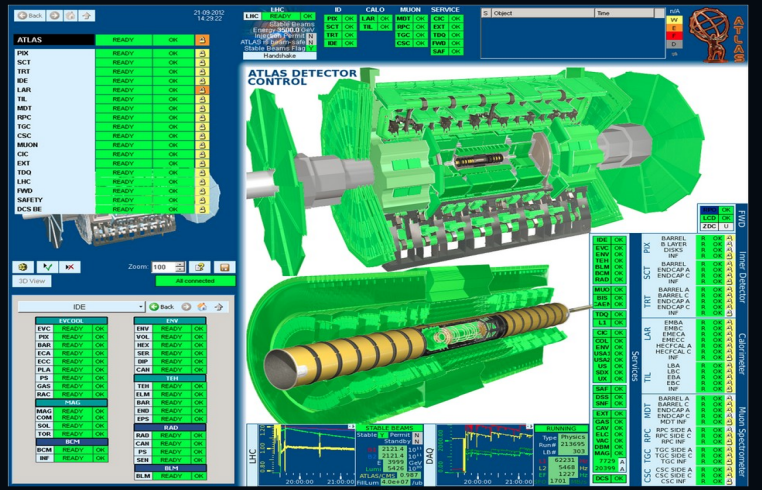
- Hierarchical distributed control systems
  - ***distribution*** feature of SCADA (federation of systems)
  - ***FSM*** hierarchical control toolbox
    - Abstraction: States, Commands, Summarization Logic
    - Propagated through the tree structure
    - Centralised (integrated) operation by shifters
      - at any level (→ of abstraction) in the tree
    - Dynamically partitioned operation
      - Hand-over of subsystems for local operation by experts
      - Central operation with some systems excluded/not present
    - Tree nodes linked with synoptic panels



- **Alarm Screen**: integrate/filter alarms from all subsystems
- **Central DCS Team**: responsible for integration/operation
  - One in each experiment
- **Central Support Team**: technology, framework, expertise

Joint **CO**ntrols **P**roject (JCOP)

- Collaboration to develop detector control systems of the LHC experiments (1998)
  - Promote reuse, COTS to reduce development and maintenance costs
    - Unprecedented complexity/scale of the projects at that time
  - Central team (development, support)
  - Local teams (in the experiments)

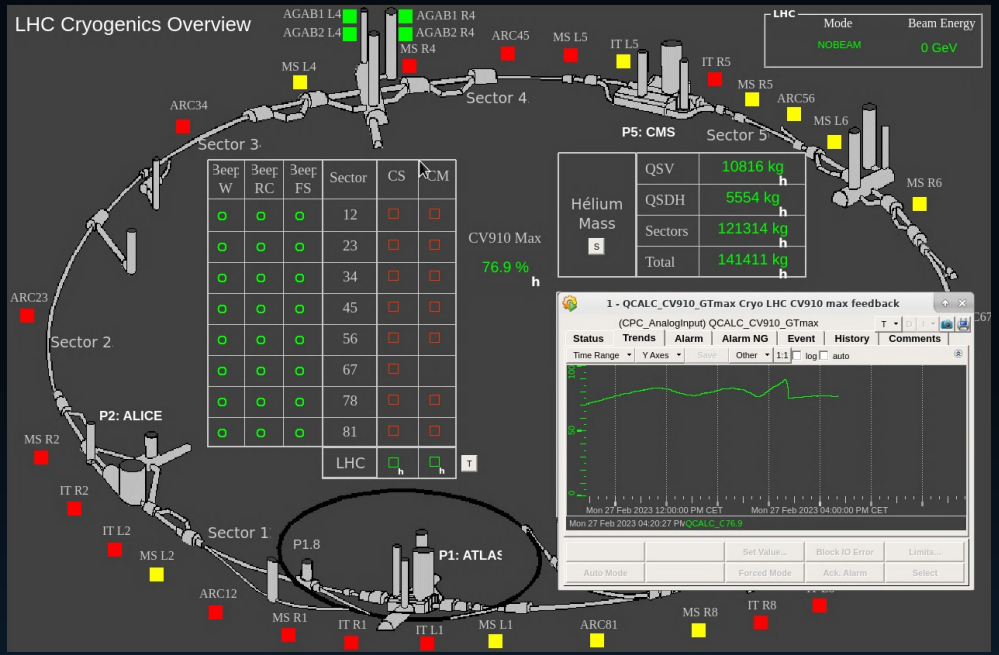


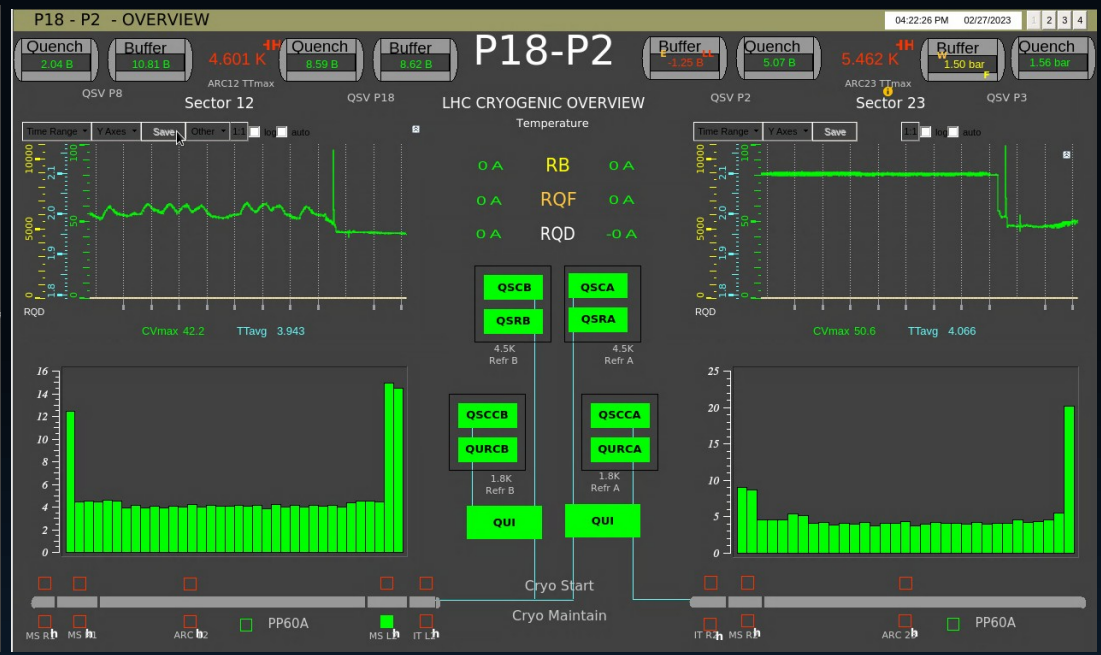
- Objectives
  - Selection of common SCADA
    - Market survey, evaluation: 10 person-year, long list of criterias
    - WinCC OA selected in year 2000 for its openness, multi-platform and potential to develop partnership with company
      → essential, solidified through CERN Openlab
  - The Framework
    - Conventions, guidelines allowing to integrate numerous developments into a large, homogeneous system
    - Components to be mixed and matched as needed to develop numerous control applications
      - common libraries and tools on top of WinCC OA, Integration of standardized set of devices
      - Lifetime management: releases/versions, upgrades, compatibility, upgrade/migration steps taken care of
  - Applications (DSS, GCS, RackControl)

Possible model to draw inspiration for a project with long-term collaboration

UNICOS Project

- Started around the same time as JCOP
- Initially: ISO-compliant industrial control system for the LHC Cryogenics
- Rapidly gained popularity for numerous other use cases in the ACC/TI sector →~220 SCADAs
- Framework developed/maintained centrally by BE/ICS group; application engineers at CERN
- UNICOS/CPC: complete approach for engineering the PLC-centric applications
- Unprecedented homogeneity and integrability: TIP

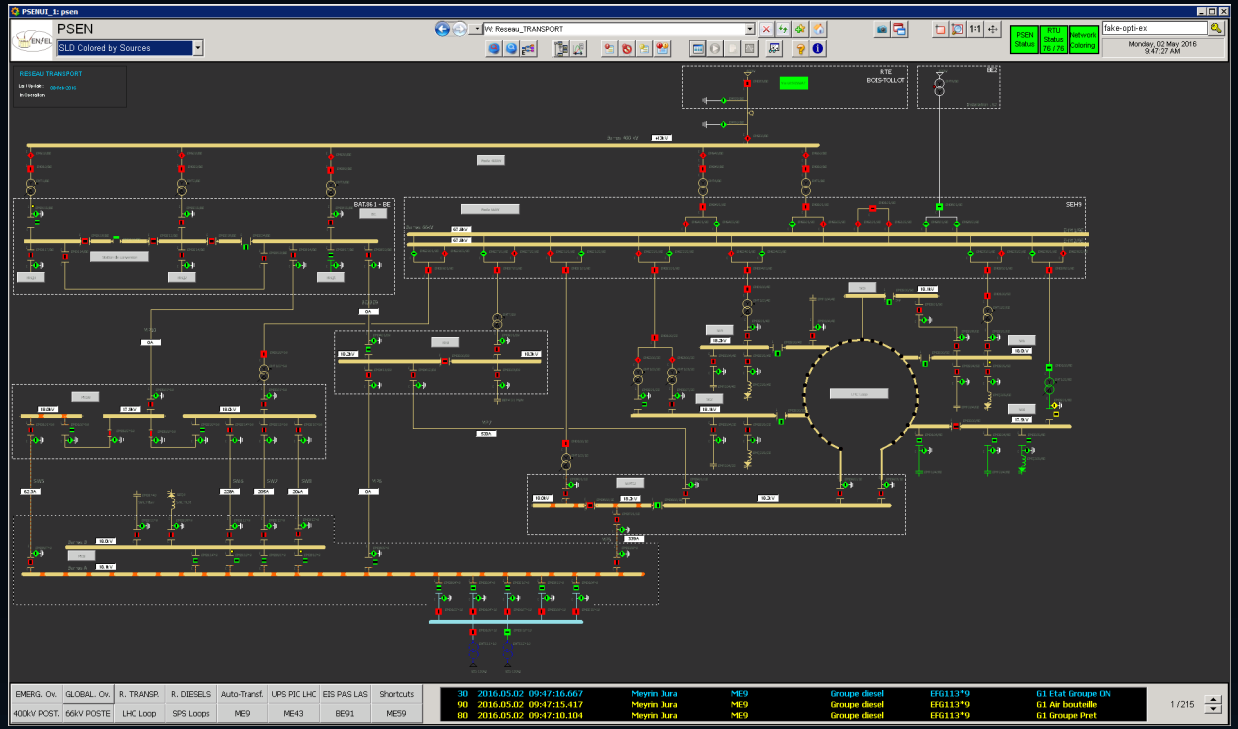




Frameworks: availability, support

- Very strong dependency on WinCC OA (commercial SCADA from ETM/Siemens)
- Frameworks developed/maintained following CERN needs, by local teams
  - Local project management structures: coordination boards, meetings with stakeholders
  - Yearly releases of the complete framework
  - Independent releases of components: bugfixes, urgent features
  - Porting to new version of SCADA, validation, upgrade procedures, etc
- Support to developers/users community
  - Training, on-site assistance, coaching, consultancy for new projects
  - Central provisioning of WinCC OA licenses and downloads for production and development
  - Follow-up of issues with the SCADA vendor (ETM/Siemens)
- Interest in using the frameworks beyond CERN
  - GSI, ITER, Neutrino platform,
- Open source licensing initiative
  - Main challenge: identify IP ownership and dependencies in the project not developed as Open Source from their beginning
  - Expected release this year
  - Shaping a community of external users not yet clear

Electricity SCADA (PSEN)

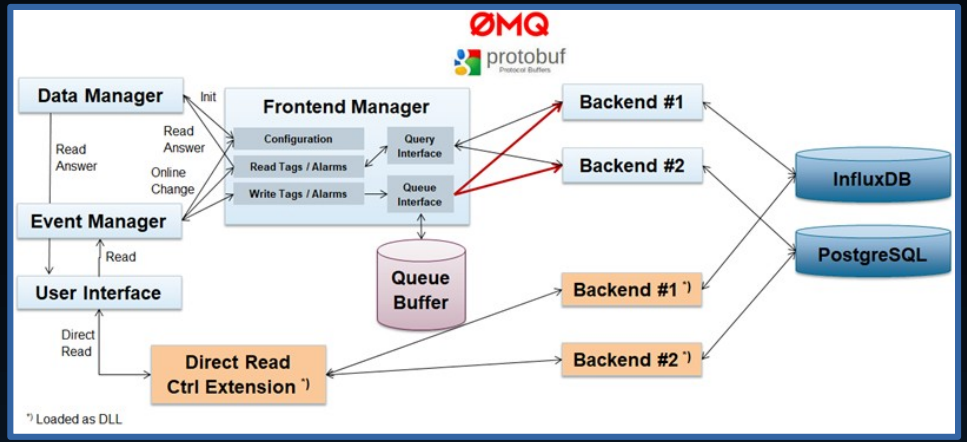


- Largest single WinCC OA application
- Hot-standby redundant WinCC OA system
  - 1 server in Prevessin site
  - 1 server in Meyrin site
  - A pair of “Disaster Recovery” servers
- ~70 RTUs
- ~20k primary/secondary devices
- ~300k field measurements
- ~4M DPEs
- ~10M records archived per day
- ~100M value changes per day
- CERN Energy use: similar to Geneva canton
- Complex, dynamically changing
- Weekly engineering

Custom-tailored to CERN needs
Built using framework components and numerous enhancements and specific solutions

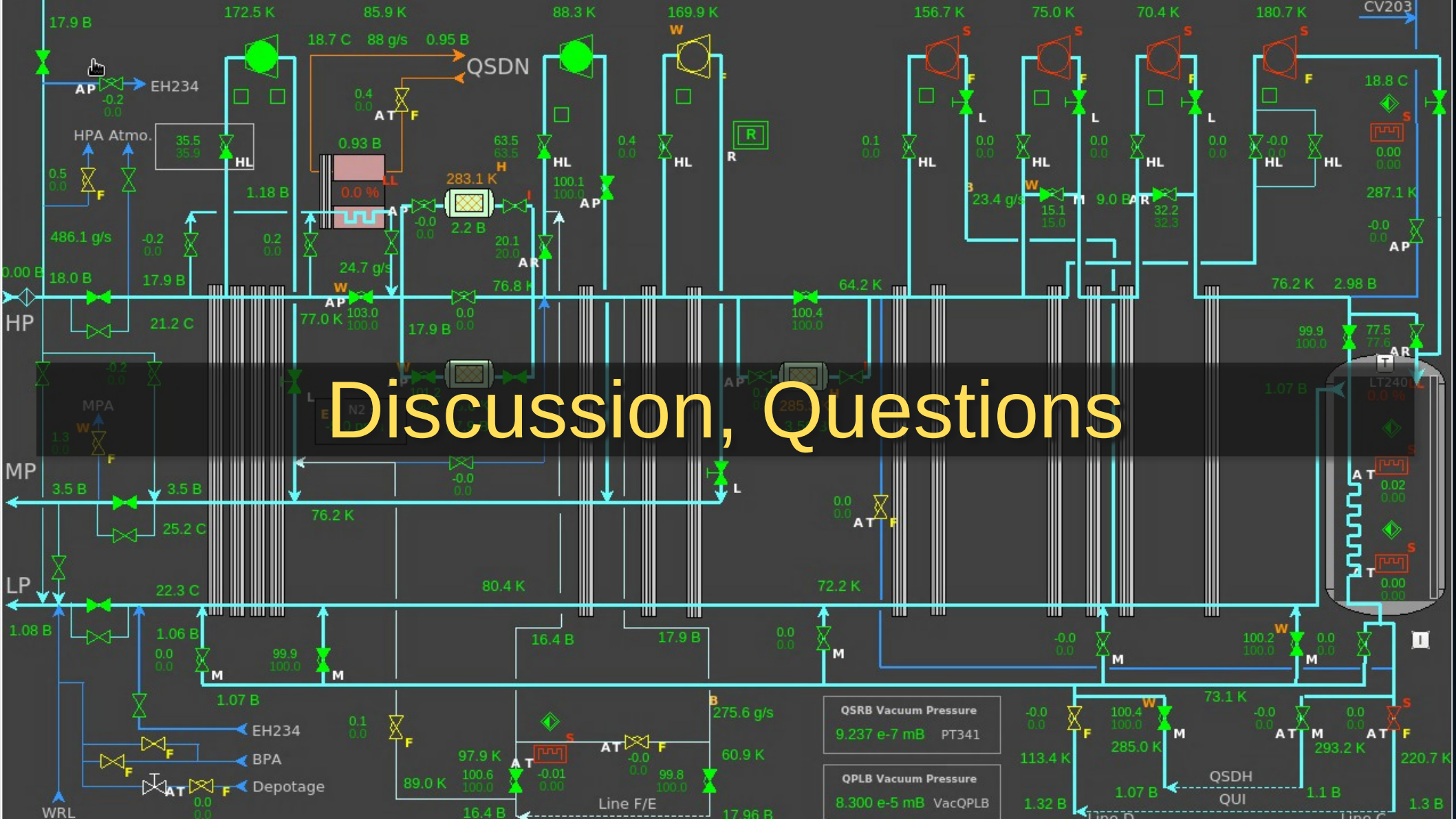
Archiving: source of BigData

- Different systems, needs, sizes, data rates...
  - PSEN: 300k signals, 10M evens per day
  - QPS: 130k signals, 17B events per day (200k/s)
  - 850 systems writing to 350 schemas on 5 Oracle databases, hundreds of GB per day
- Long-standing CERN-ETM collaboration topic (since 2005)
- WinCC OA NextGen Archiver
  - Modular, extendable
  - CERN Oracle backend
  - Prototype TimescaleDB backend
- “Offline” databases for physics
- ALICE O²: physics data streaming
- NXCALS for long-term storage and data analysis (Hadoop)



Handling large-scale and long-lifetime

- Uncharted territory 25 years ago...
- Modularization, components as deployment units, release/version management
- Centralized, automated deployment and monitoring tools
- Databases with billions of records
  - A few, large central databases (Oracle)
  - Maintained, tuned, monitored by central group of experts in the IT department
- Maintaining/evolving software projects with 40-year life-span
  - Keep up with accelerating evolution of technologies
    - S/W upgrade campaigns every 3-5 years
    - Component maintainers assure compatibility, migrations, upgrade paths
  - New needs, upgrades (eg. HL-LHC), unhandled corner cases, unexpected use scenarios
  - Backward-compatibility is essential
  - Need for consolidation, architecture evolution
  - Maintaining adequate level of experience/knowledge/context vs high personnel turnover


Discussion, Questions
HP
MP
LP
QSDN
EH234
HPA Atmo.
MPA
BPA
Depotage
WRL
QSRB Vacuum Pressure
9.237 e-7 mB PT341
QPLB Vacuum Pressure
8.300 e-5 mB VacQPLB
Line F/E
QSDH
QUI
CV203