



HSE

Occupational Health & Safety
and Environmental Protection unit





REMUS

RADIATION AND ENVIRONMENT MONITORING UNIFIED SUPERVISION



CESP
CERN Entrepreneurship
Student Programme

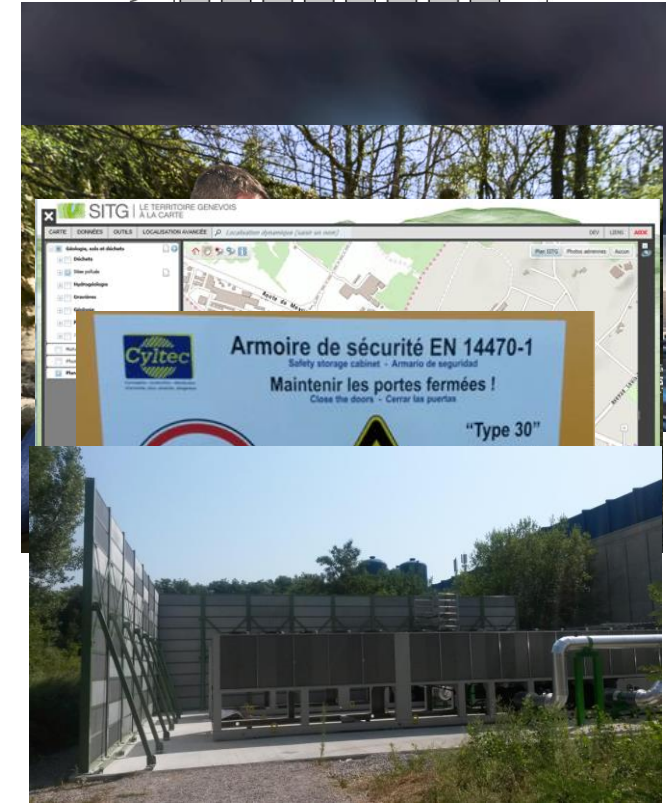
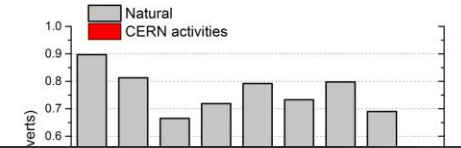
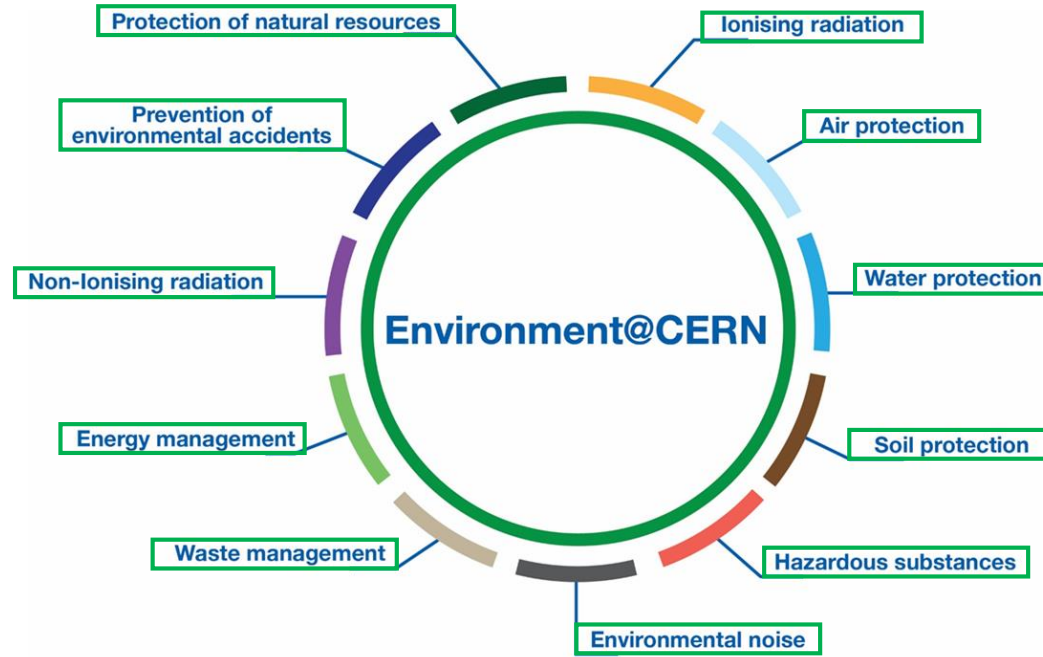
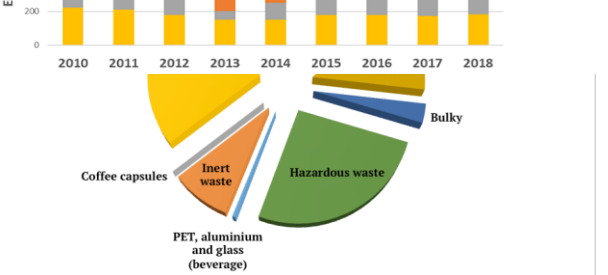
23rd July 2019 - Adrien Ledoul, Gustavo Segura on behalf of REMUS Team



23.07.2019

EDMS no: 2194531

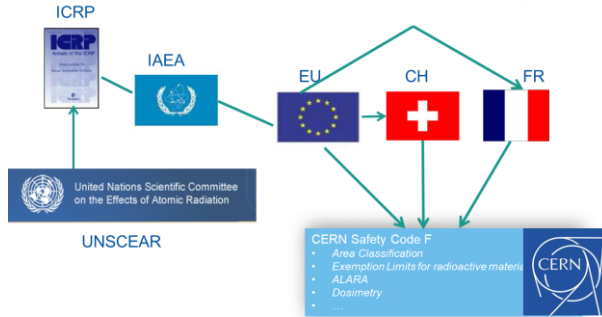
Context: Environmental Protection at CERN



Courtesy of HSE Environmental Protection Section

Context – SCADA Systems – Innovations – REMUS at CERN – Prospects

Context: Radiation Protection at CERN



Operational Radiation Protection

- Risk assessments for personnel and public
- Definition of protective measures, authorization of operation
- Lead in implementation of ALARA principle
- Studies for projects and upgrades
- R&D for tools and methods, operation of shielding benchmark facility

Radioactive Waste Management

- Operation of pre-conditioning and interim storage facility
- Waste disposal towards host states
- Support to departments in radioactive waste minimization and treatment

Individual Dosimetry

- Monitoring of external and internal doses and reporting (CERN dosimetry service carries official accreditation in Switzerland)
- Operation of calibration facility



Services

- Inter/intra-site radioactive transport
- Shipping (import/export) of radioactive goods
- Radiological characterization of material and waste, operation of analytical laboratory
- Radioactive sources service

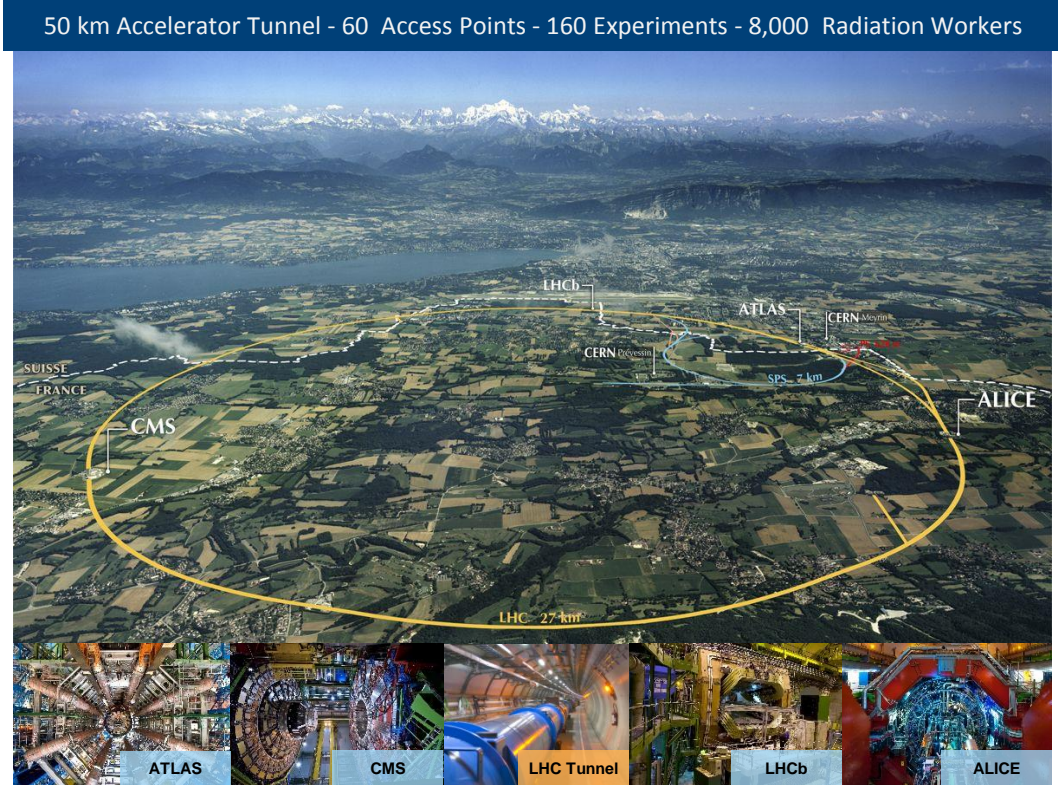
Instrumentation

- Development, Procurement, Installation, Operation and Maintenance of radiation monitoring systems

Courtesy of HSE Radiation Protection Group

Context – SCADA Systems – Innovations – REMUS at CERN – Prospects

Context: Radiation Protection and Environmental Monitoring at CERN



Context – SCADA Systems – Innovations – REMUS at CERN – Prospects



Context: Radiation Protection and Environmental Monitoring at CERN

Water Monitoring



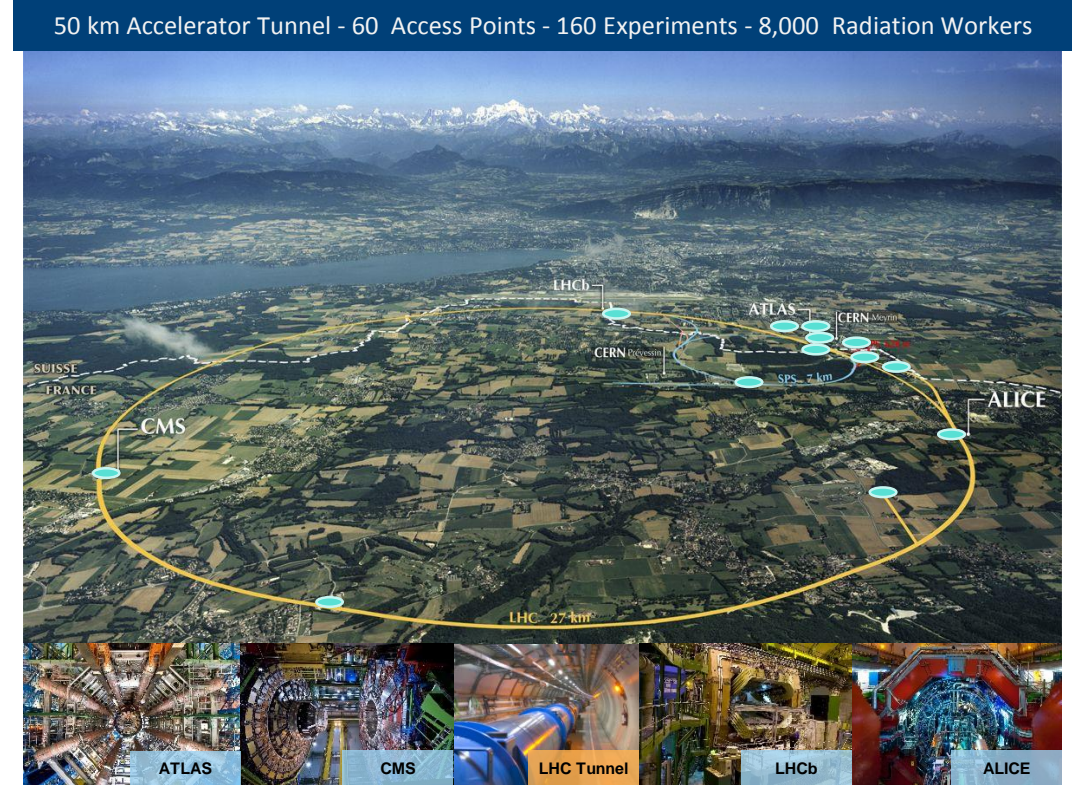
Water Monitoring Station (x7)



SMART Water Monitoring Station (x6)



Release Water Monitor for Radioactivity (x13)



Context – SCADA Systems – Innovations – REMUS at CERN – Prospects

Context: Radiation Protection and Environmental Monitoring at CERN

■ Ventilation Monitoring



Ventilation Monitoring Stations (x10)

50 km Accelerator Tunnel - 60 Access Points - 160 Experiments - 8,000 Radiation Workers



Context – SCADA Systems – Innovations – REMUS at CERN – Prospects

Context: Radiation Protection and Environmental Monitoring at CERN

Air Monitoring



NO, NOx, NO2 Monitor (x5)



O3 Monitor (x5)



Air Alpha/Beta Monitor (x4)



Alpha/Beta Particulate Monitor (x8)



Radon Monitor (x4)



Tritium Monitor (x3)



SMART Aerosol Sampler (x8)



Context – SCADA Systems – Innovations – REMUS at CERN – Prospects

Context: Radiation Protection and Environmental Monitoring at CERN

■ Meteorological Monitoring



Meteorological Monitoring Stations (x10)



Context – SCADA Systems – Innovations – REMUS at CERN – Prospects

Context: Radiation Protection and Environmental Monitoring at CERN

Operational Radiation Protection Monitoring



DA Monitoring Station (x142)



LB112 Monitoring Station (x114)



CROME Monitoring Station (x14)



MinAlarm Monitor (x1)



UNIDOS Dose Meter (x2)



Context – SCADA Systems – Innovations – REMUS at CERN – Prospects

Context: Radiation Protection and Environmental Monitoring at CERN

Contamination Monitoring



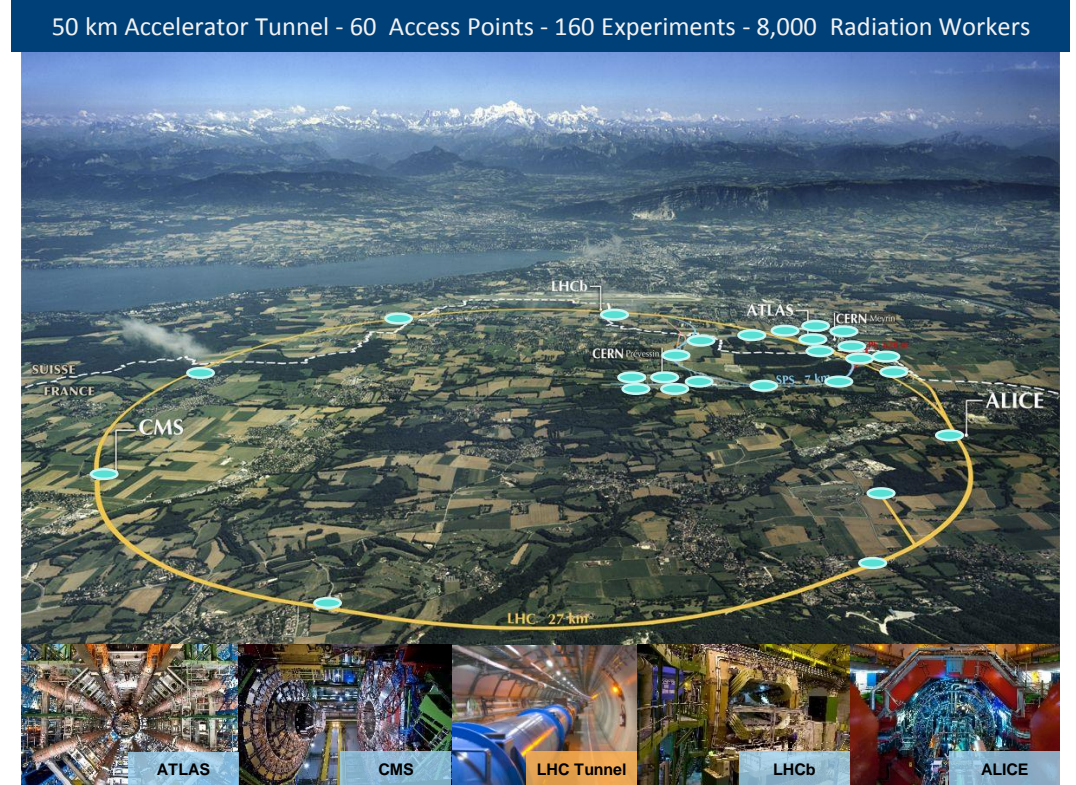
Hand & Foot Contamination Monitor (x18)



LB147 Hand & Foot Contamination Monitor (x49)



Material Control Monitor (x19)



Context – SCADA Systems – Innovations – REMUS at CERN – Prospects

Context: Radiation Protection and Environmental Monitoring at CERN

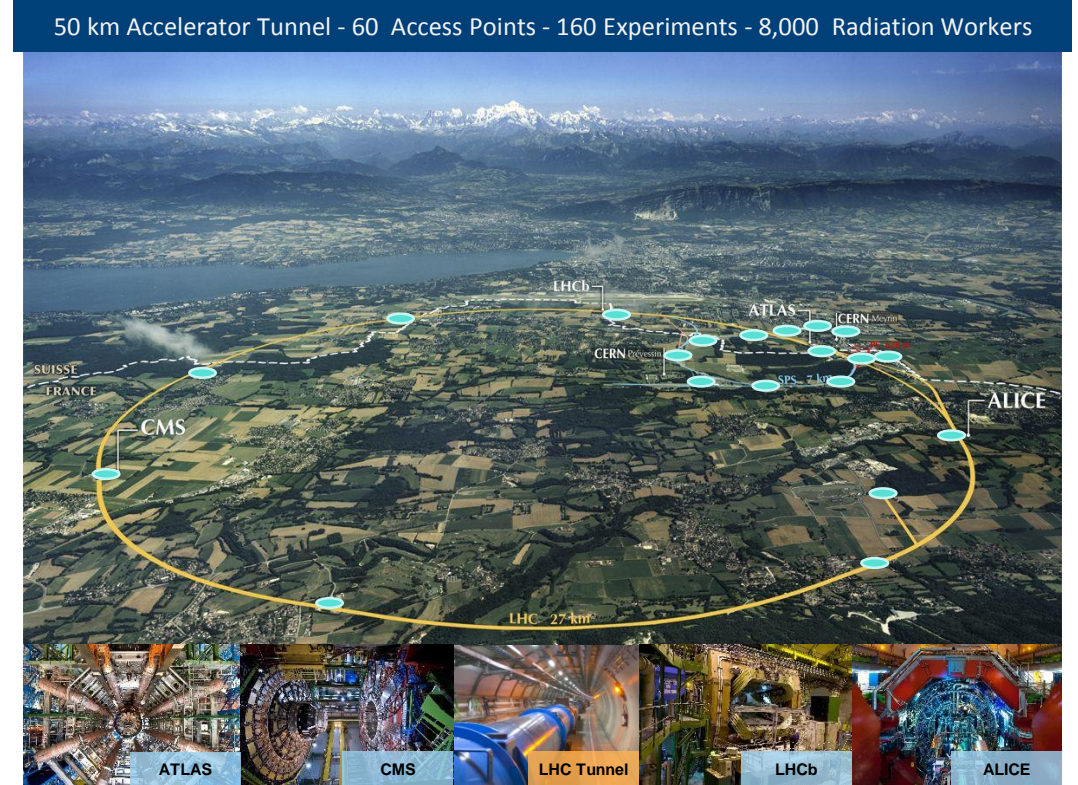
Gate Monitoring



Site Gate Monitor (x22)



Truck Gate Monitor (x2)



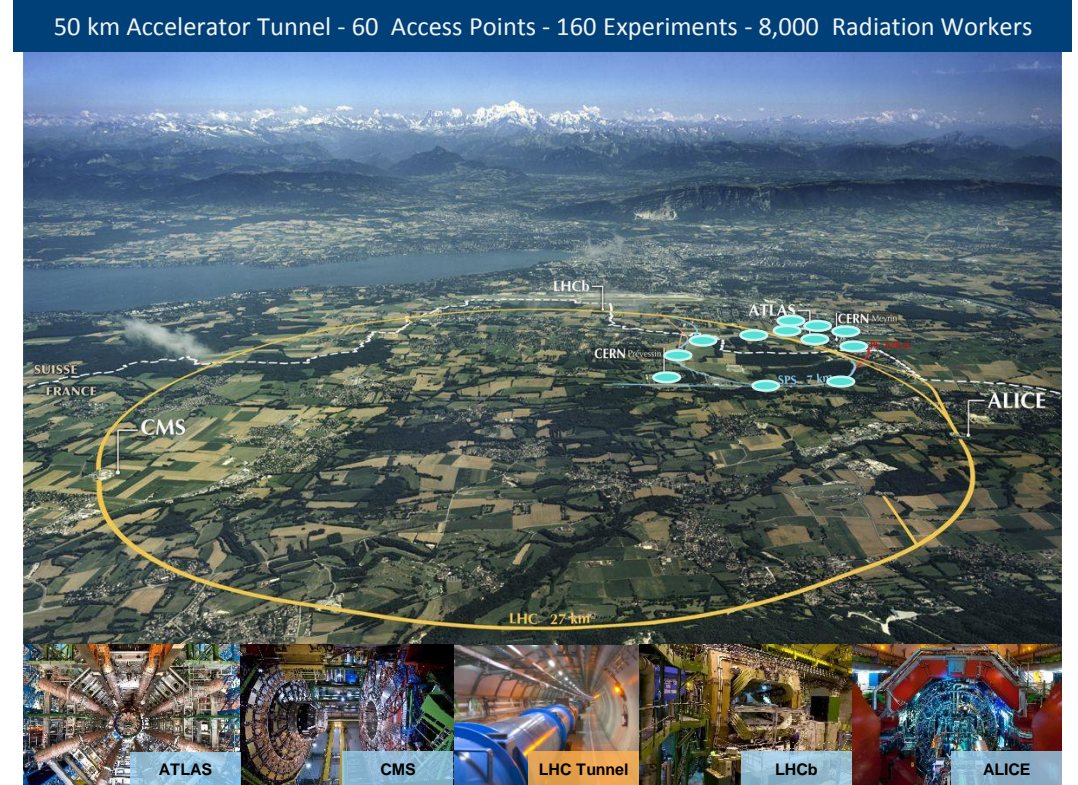
Context – SCADA Systems – Innovations – REMUS at CERN – Prospects

Context: Radiation Protection and Environmental Monitoring at CERN

Signal Repeaters



Alarm repeaters (x28)



Context – SCADA Systems – Innovations – REMUS at CERN – Prospects

Context: Radiation Protection and Environmental Monitoring at CERN

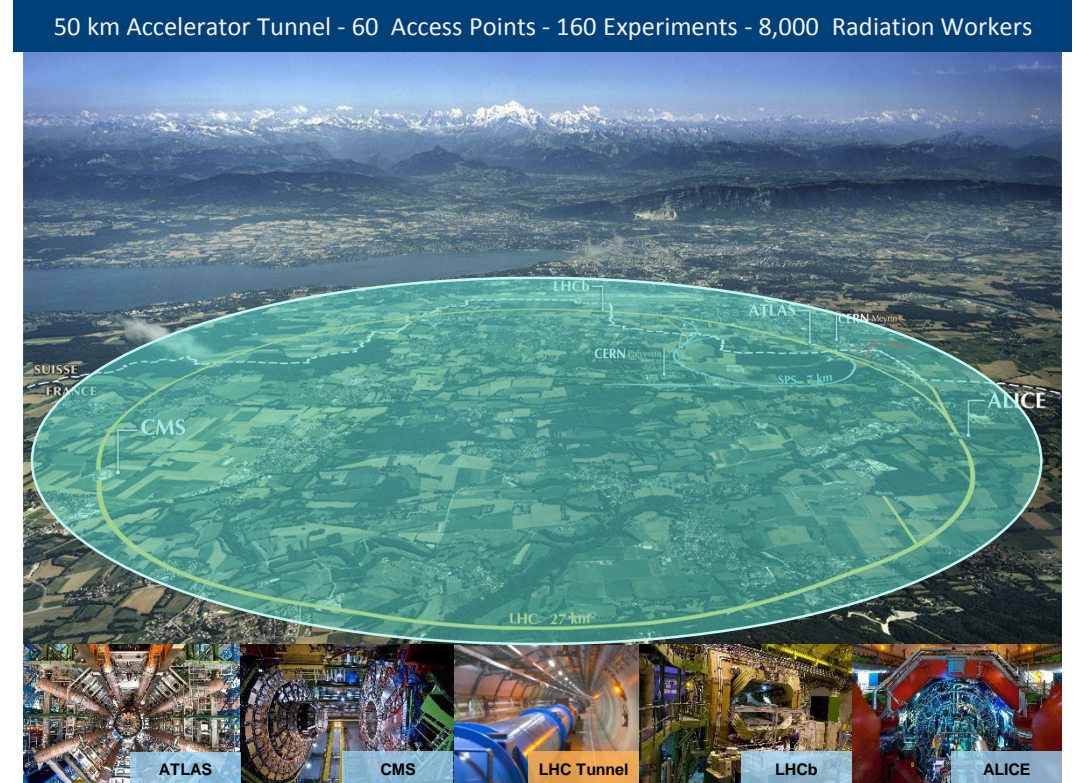
Mobile Monitoring



FHT1100 Mobile Monitor (x4)



AD6 Mobile Monitor (x14)



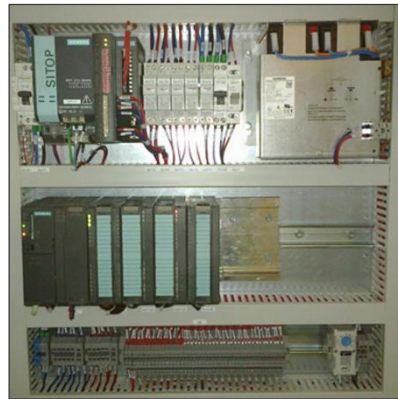
Context – SCADA Systems – Innovations – REMUS at CERN – Prospects

Context: Radiation Protection and Environmental Monitoring at CERN

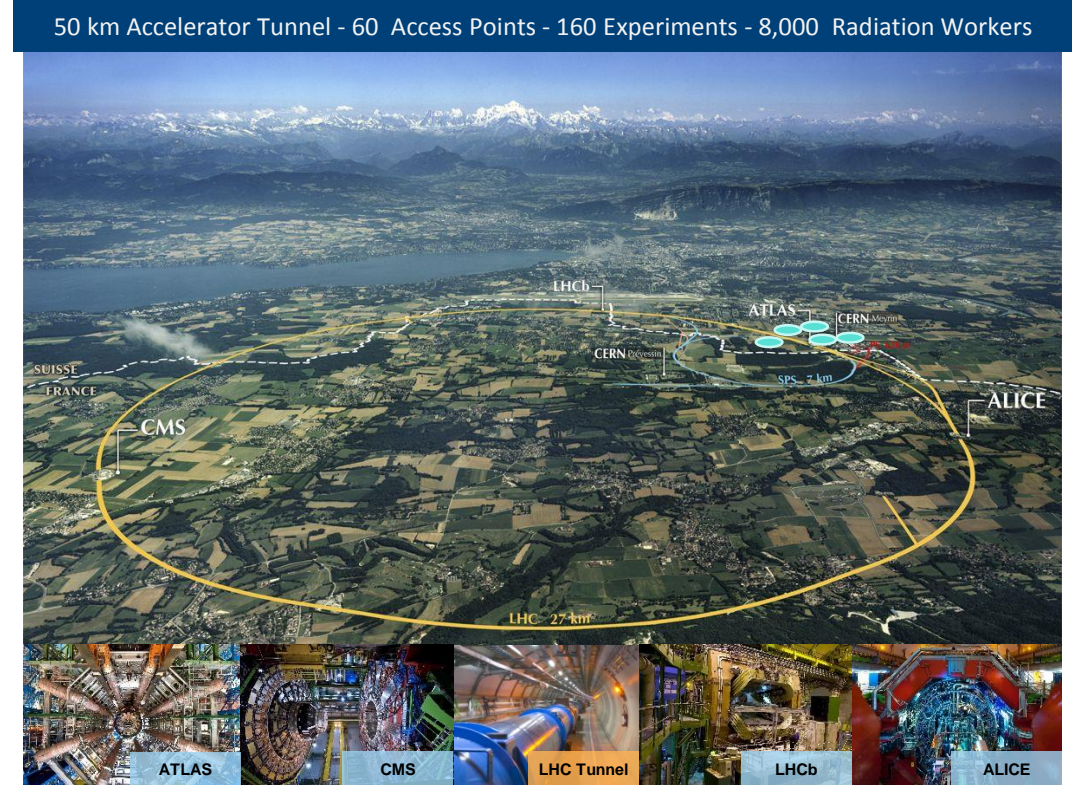
- Multi purpose Controllers



Area Controller (x4)



SMART Controller (x1)



Context – SCADA Systems – Innovations – REMUS at CERN – Prospects

Context: Radiation Protection and Environmental Monitoring at CERN

540 Monitoring Stations:

- 27 different types
- Commercial Off-the-Shelf & Internally Developed Stations
- Surface and Underground areas

3,100 Measurement Channels:

- 1,000 measurements archived / second

Workplace and Environment Safety

Reporting to authorities:

- Nature and quantities of emitted ionizing radiation
- Conventional environmental measured values

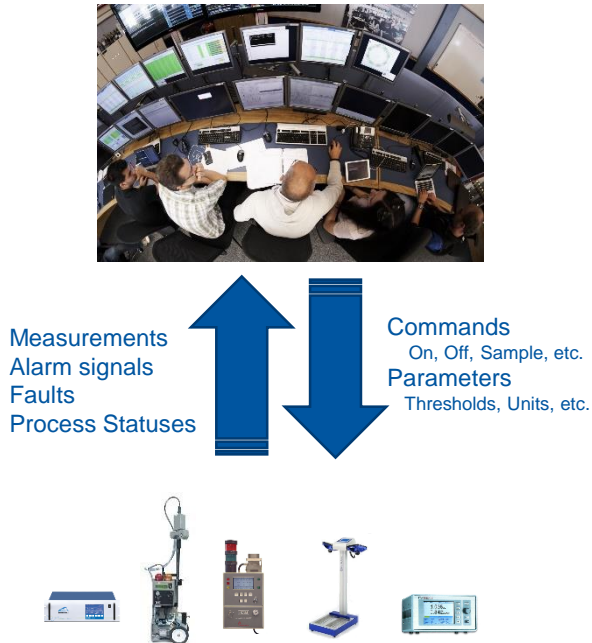
50 km Accelerator Tunnel - 60 Access Points - 160 Experiments - 8,000 Radiation Workers



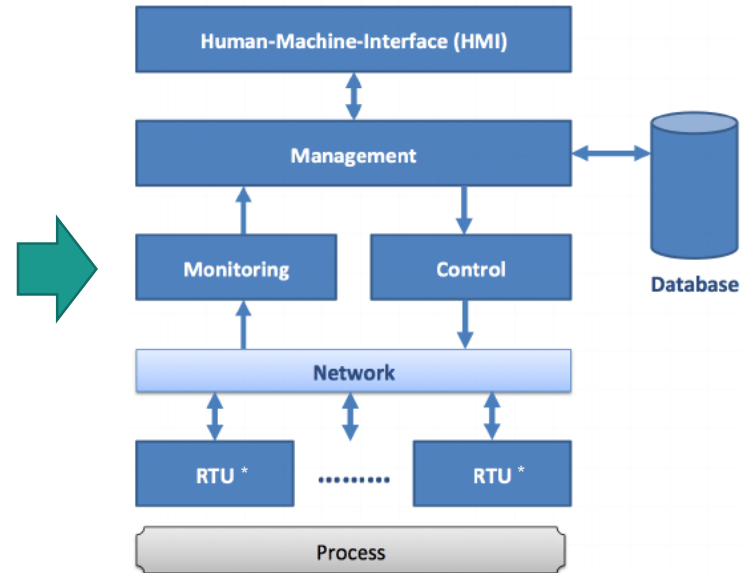
Context – SCADA Systems – Innovations – REMUS at CERN – Prospects

SCADA Systems

- What do we need?
 - A SCADA system: Supervisory Control And Data Acquisition

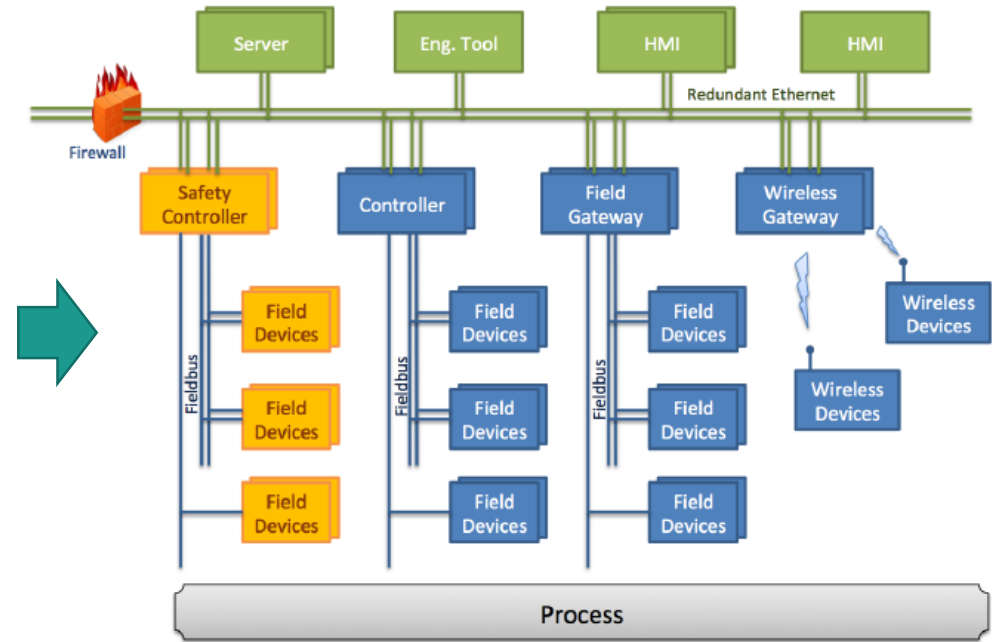


Basic Functionalities of a SCADA system



Source: State of the Art in Industrial Automation, Thomas Bangemann et. al, 2014

Typical Software Architecture for a SCADA System



Source: State of the Art in Industrial Automation, Thomas Bangemann et. al, 2014

State-of-the-art Distributed Control System

Context – SCADA Systems – Innovations – REMUS at CERN – Prospects

*Remote Terminal Unit

SCADA Systems

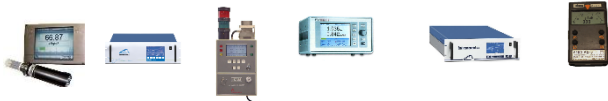
- But we need more than “just” a **Distributed** system! We need a system that is:

Scalable

Absorb **Growing** number of instruments

Versatile

Interface **Heterogeneous** devices (vendors, protocols, networks, etc.)



Extensible

New types of equipment can be easily interfaced

Secured

Tailorable

Users can define their **Own Interface**

Multiplatform



Performant

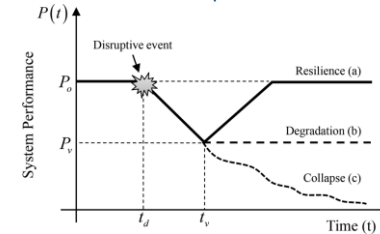
Serve the users in a **Timely Manner**

Reliable

Low failure rate

Resilient

Recover from Disruptive events



Source: *Engineering Resilience Quantification and System Design Implications: A Literature Survey*, Nita Yodo et. Al, 2016

Continuous

Run-time upgrades and maintenance

Context – **SCADA Systems** – Innovations – REMUS at CERN – Prospects

WinCC Open Architecture

- SCADA Technology selected by CERN as standard for Control Systems. Why?
 - Allows:

Distributed

Scalable

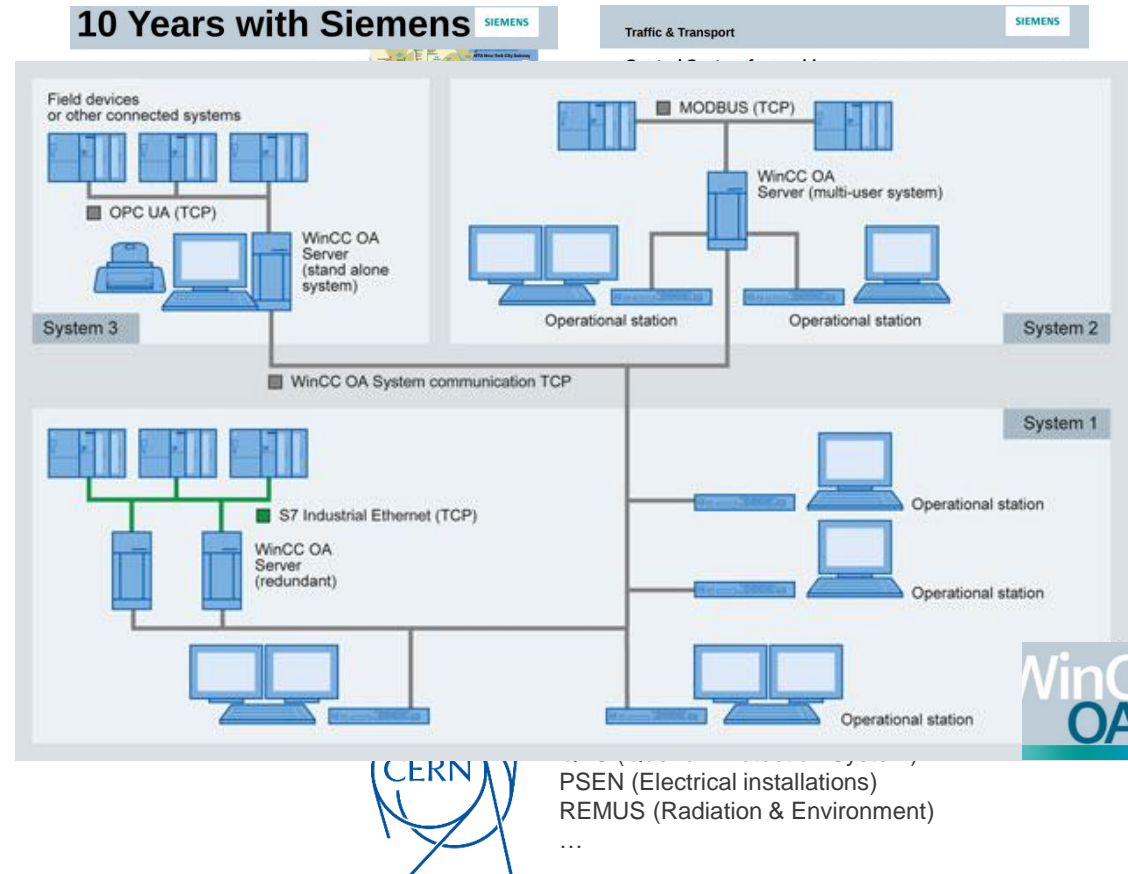
Secured

Multiplatform

Redundant

Reliable

Performant



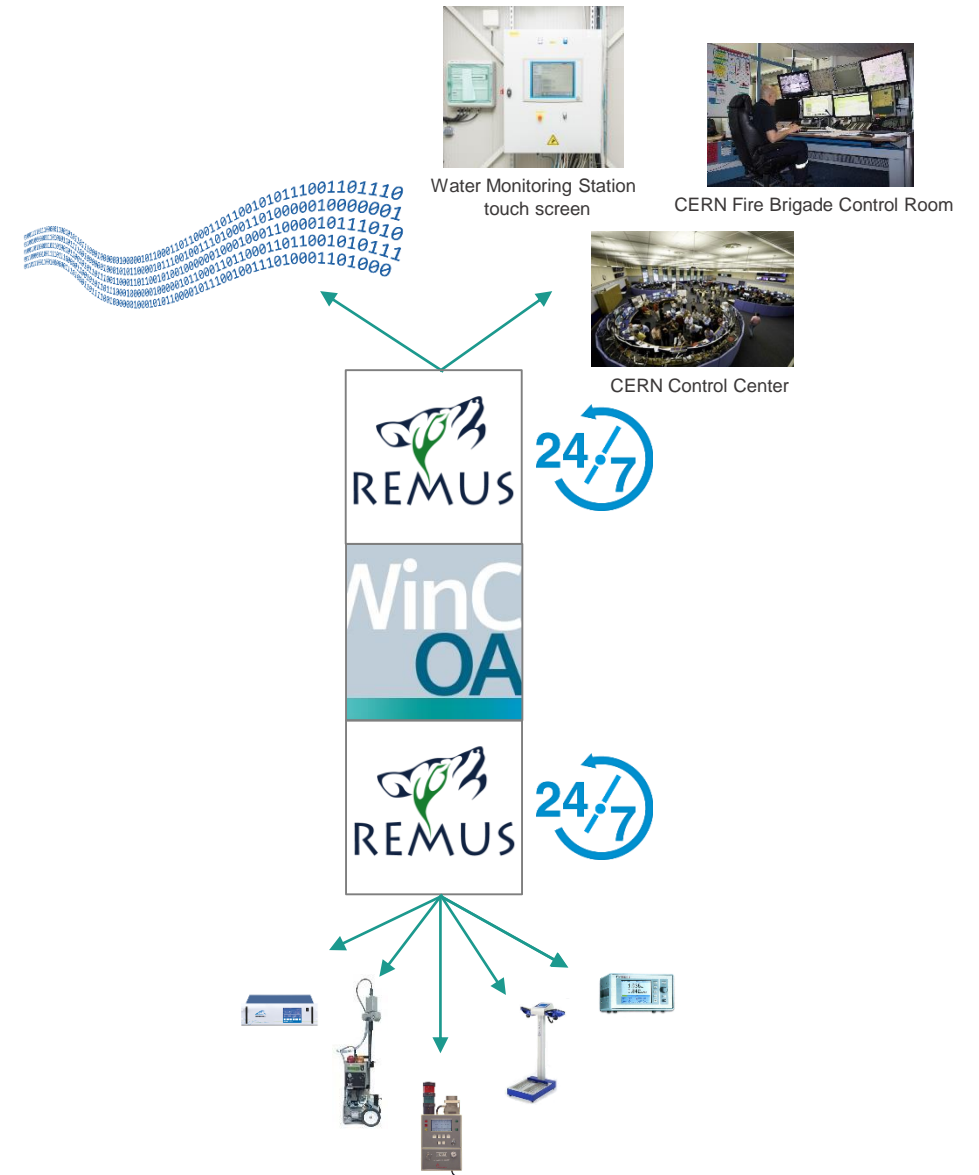
Context – SCADA Systems – Innovations – REMUS at CERN – Prospects

WinCC Open Architecture + REMUS Layer

- WinCC OA is a pertinent choice, but we still need to add some features!

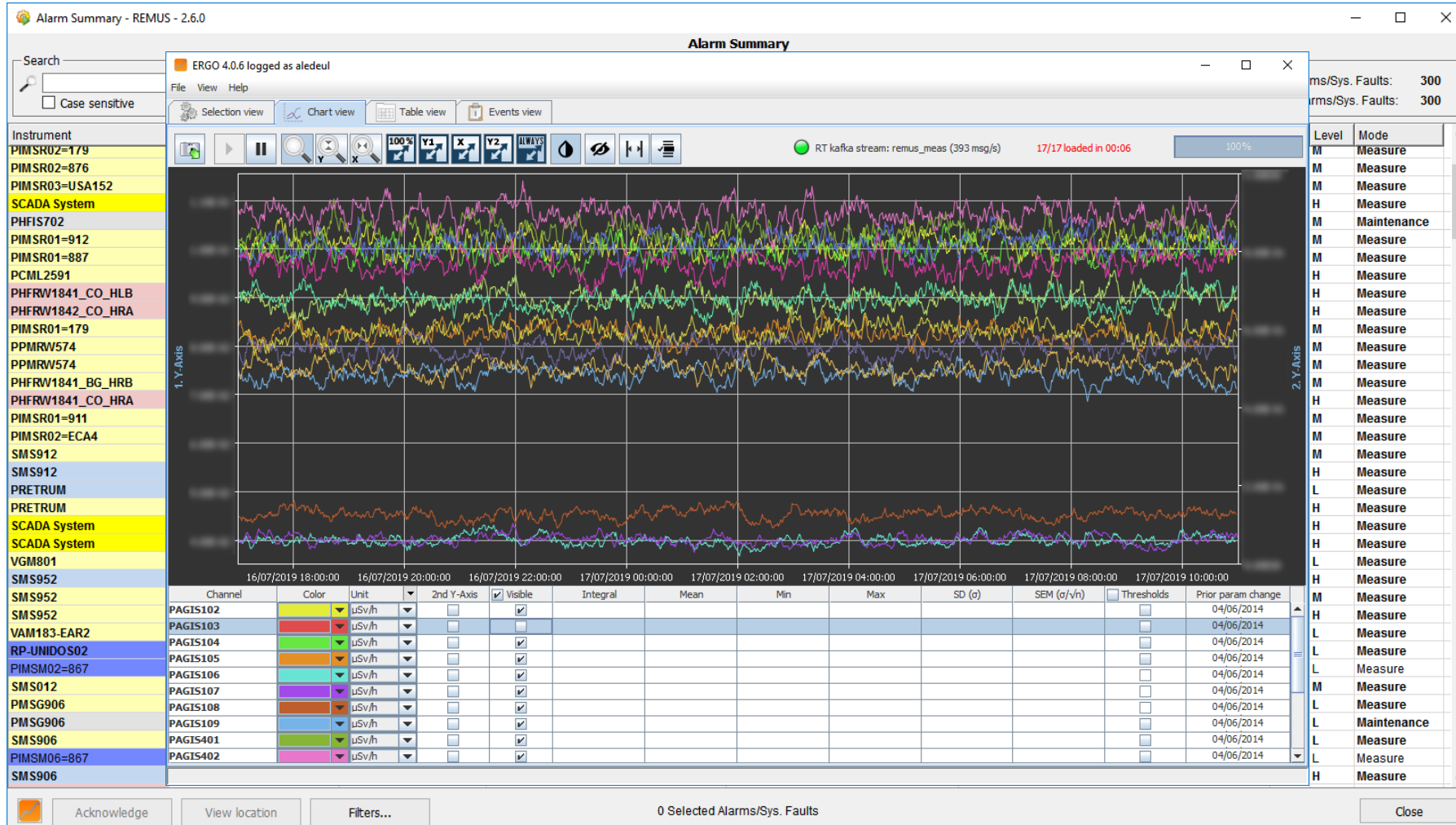
REMUS:

| |
|----------------------------------------|
| WinCC OA features |
| + |
| Handling Heterogeneous Instrumentation |
| Handling Diversity of Users |
| Run-time Updates |
| Secured Data Streaming |



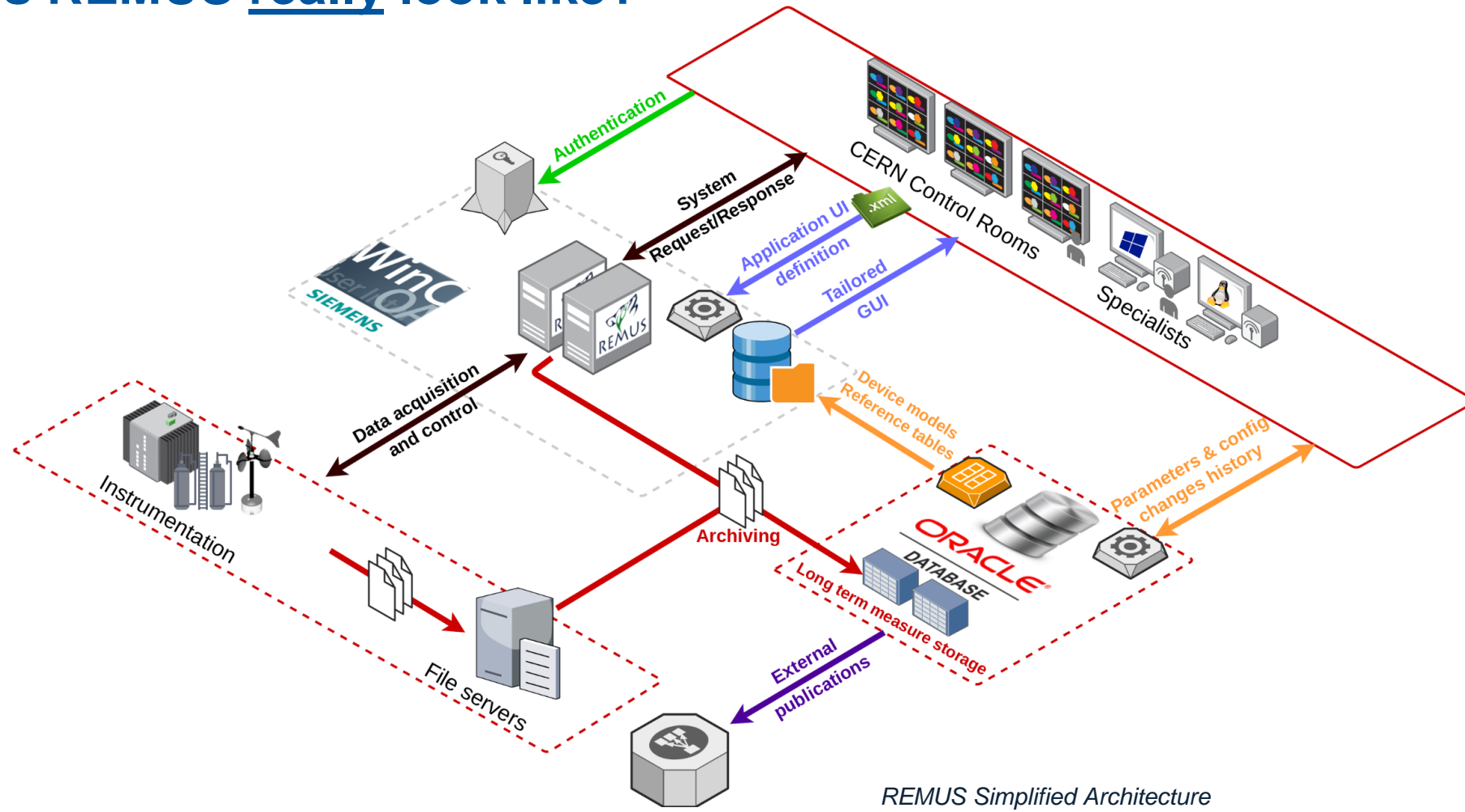
Context – SCADA Systems – Innovations – REMUS at CERN – Prospects

What does REMUS look like?



Context – SCADA Systems – Innovations – REMUS at CERN – Prospects

What does REMUS really look like?



Context – SCADA Systems – Innovations – REMUS at CERN – Prospects

Heterogeneous equipment integration handling

■ Challenges

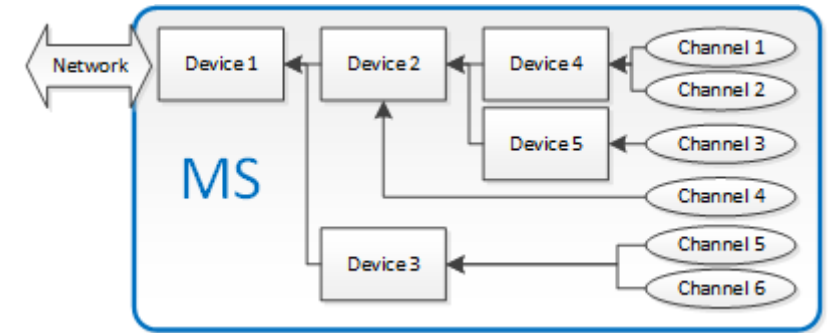
- HSE owns very diverse types of monitoring equipment, for 2 reasons:
 - Wide scope of measurements to acquire
 - Long lifetime of equipment, costly to replace: electronics of different generations overlap
- **This is a common challenge for supervisory systems**

■ Aim

- Uniformity of instrumentation from users' perspective
- Uniformity of instrumentation from developers' perspective (code simplification)

■ REMUS Solution

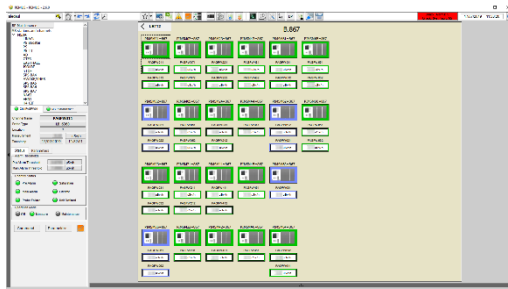
- Abstraction of instrumentation technical specificities by modeling:
 - 3 concepts only: Channel, Device, Monitoring Stations
 - All types of instrumentation are modeled using the same concepts



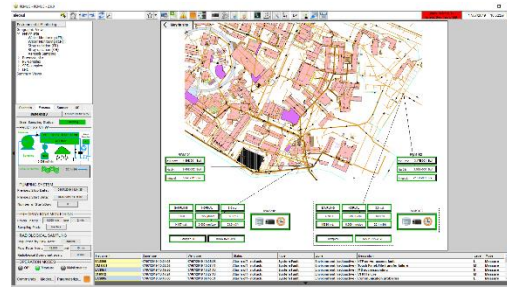
Example of REMUS Device model

REMUS Applications

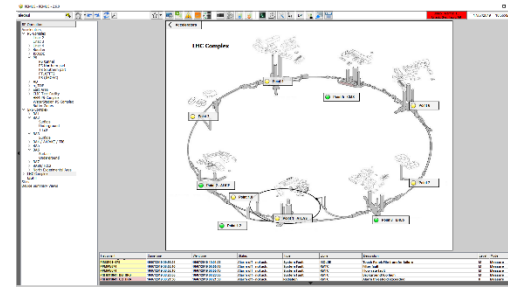
- **Users have different needs**
 - **Many different user profiles** use REMUS (accelerator & experiments operators, radiation protection engineers, environmental engineers, physicists, firefighters, maintenance teams...)
- **Customized User interfaces**
 - REMUS is split into several **Applications** (subsets of REMUS instrumentation), with a customizable layout (synoptic, widgets)



RP Maintenance Application



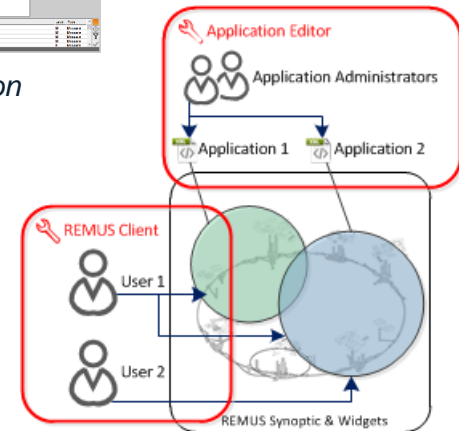
Environmental Monitoring Application



RP Operation Application

- **Advantages**

- Users can focus on the **part of the supervision** they are interested in
- Improved **Performance**
- **Distributed maintenance effort**



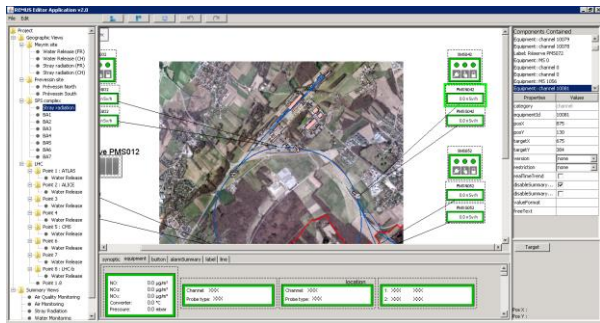
Context – SCADA Systems – *Innovations* – REMUS at CERN – Prospects

REMUS Applications

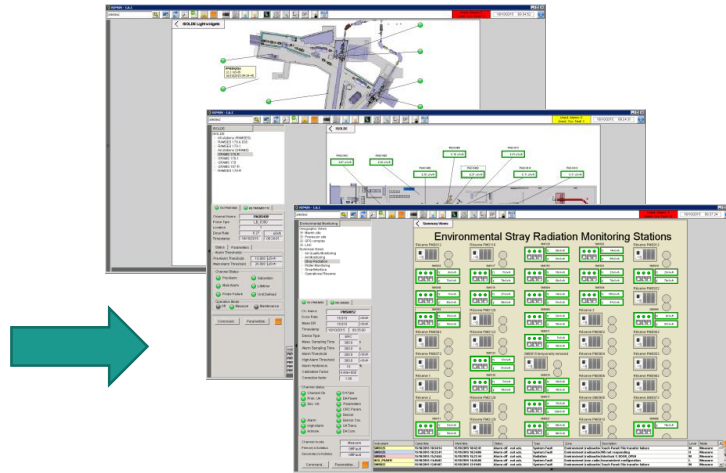
Tailored User Interfaces

- **REMUS final users can build their own user interfaces (Application)**

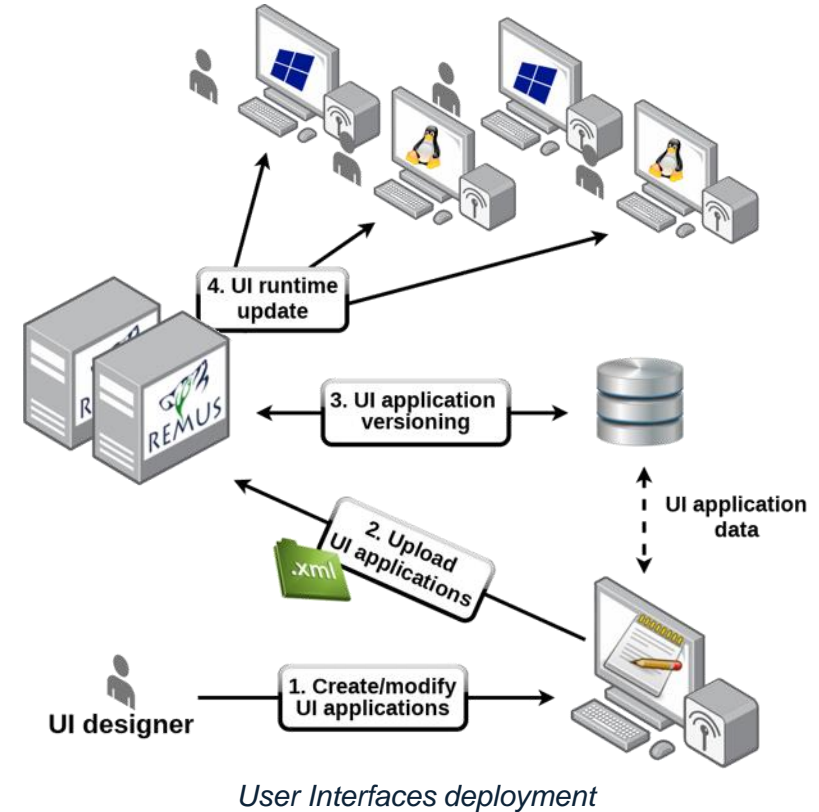
- REMUS provides users with a tool to build their own tailor-made user interface
- Graphical tool to draw user interfaces with “drag and drop”
- No knowledge of programming languages necessary
- User interface can be modified in minutes
- New user interfaces can be deployed at run-time



User Interfaces Editor



Tailored User Interfaces



Context – SCADA Systems – *Innovations* – REMUS at CERN – Prospects

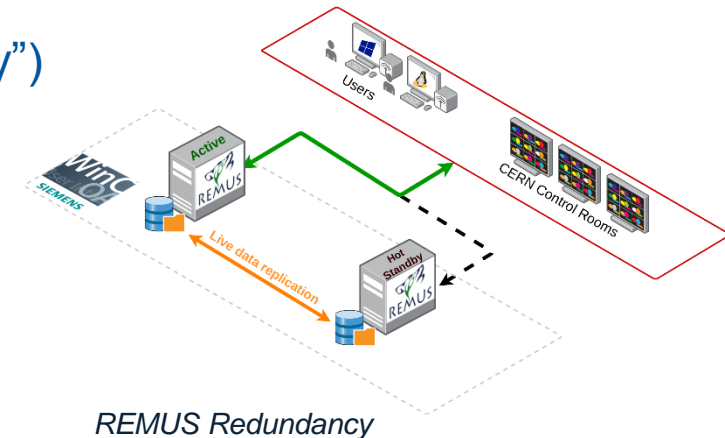
Continuous Operation

■ Challenges

- HSE needs to operate its supervisory system 24/7, 365 days a year:
 - Monitoring is necessary during accelerator runs AND shutdowns

■ Solution implemented in REMUS

- Redundancy of the Servers and all sub-systems
- All software components are designed to be resilient
- Maintenance and support operations designed to be executable at Run-Time:
 - Deployment of new User Interfaces
 - Declaration and connection of new equipment in the system (“plug-and-play”)
 - Framework upgrades
 - Operating System upgrades



REMUS average down time 2013-2018: 7mn / year

Context – SCADA Systems – *Innovations* – REMUS at CERN – Prospects

Data Streaming

Apache Kafka®: an open-source distributed streaming platform

Challenges

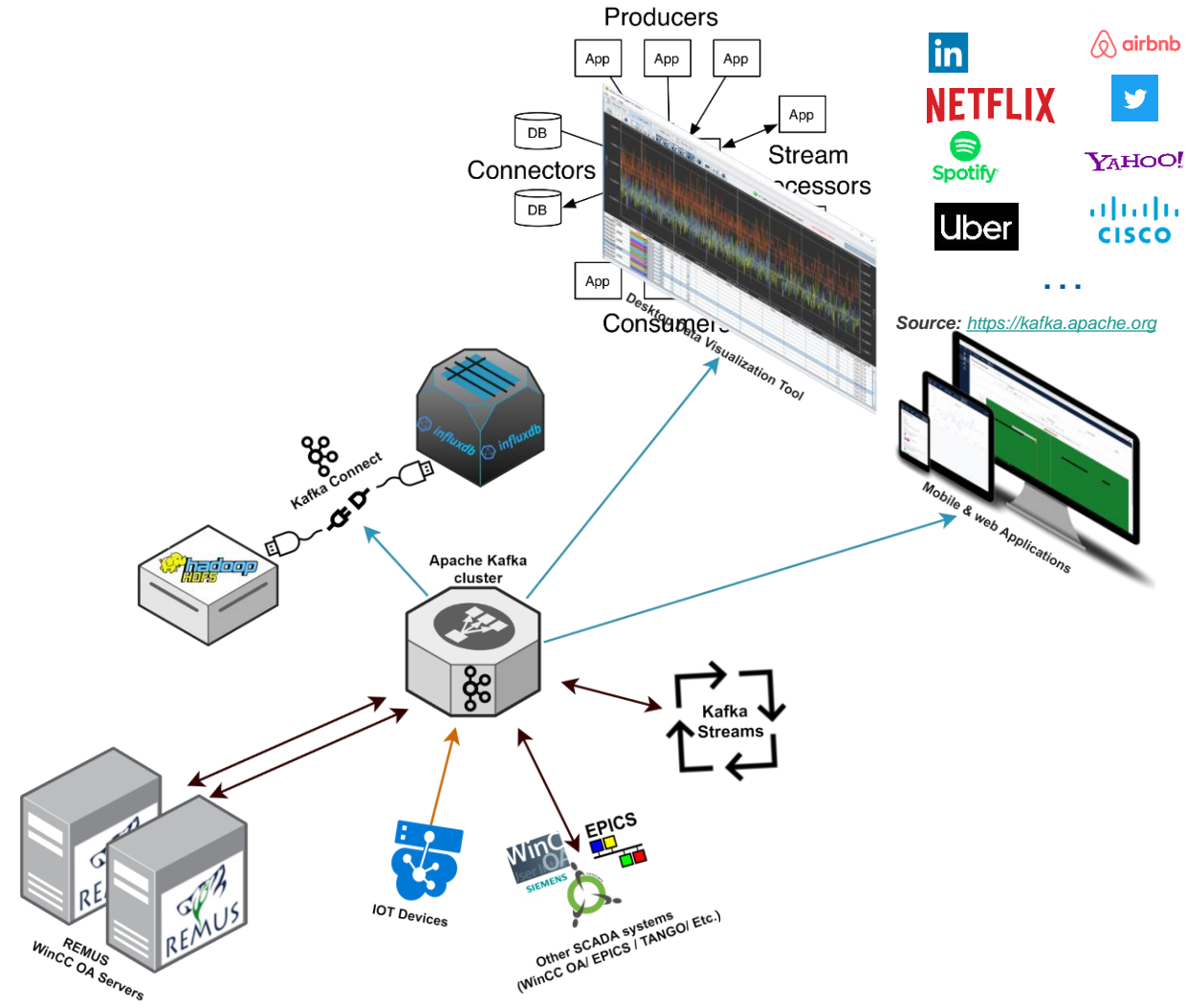
- REMUS needs to exchange data with external systems (In and Out)

Solution implemented in REMUS

- Implementation of a Driver allowing data exchange between WinCC OA and Apache Kafka

Benefits

- Easy Integration of IoT Devices
- De-coupled and secured exchange with other SCADA (WinCC OA, EPICS, TANGO, ...)
- Stream Processing, Data Enrichment capabilities
- Archiving (Hadoop, InfluxDB, Elasticsearch, ...)
- Near real-time data visualization (Desktop, Mobile, Web)



Context – SCADA Systems – Innovations – REMUS at CERN – Prospects

Data Streaming: Application: REMUS Web (under development)

- Provides real time visualization of REMUS processes and measurements from a **Web** browser
- Provides **Statistics** on REMUS (Users, I/O, etc.)
- Provides **Configuration** tools (i.e. Notifications)

- Highly demanded:
 - **Maintenance** entry point
 - **Reports** generation
 - **On-site** intervention (mobile)

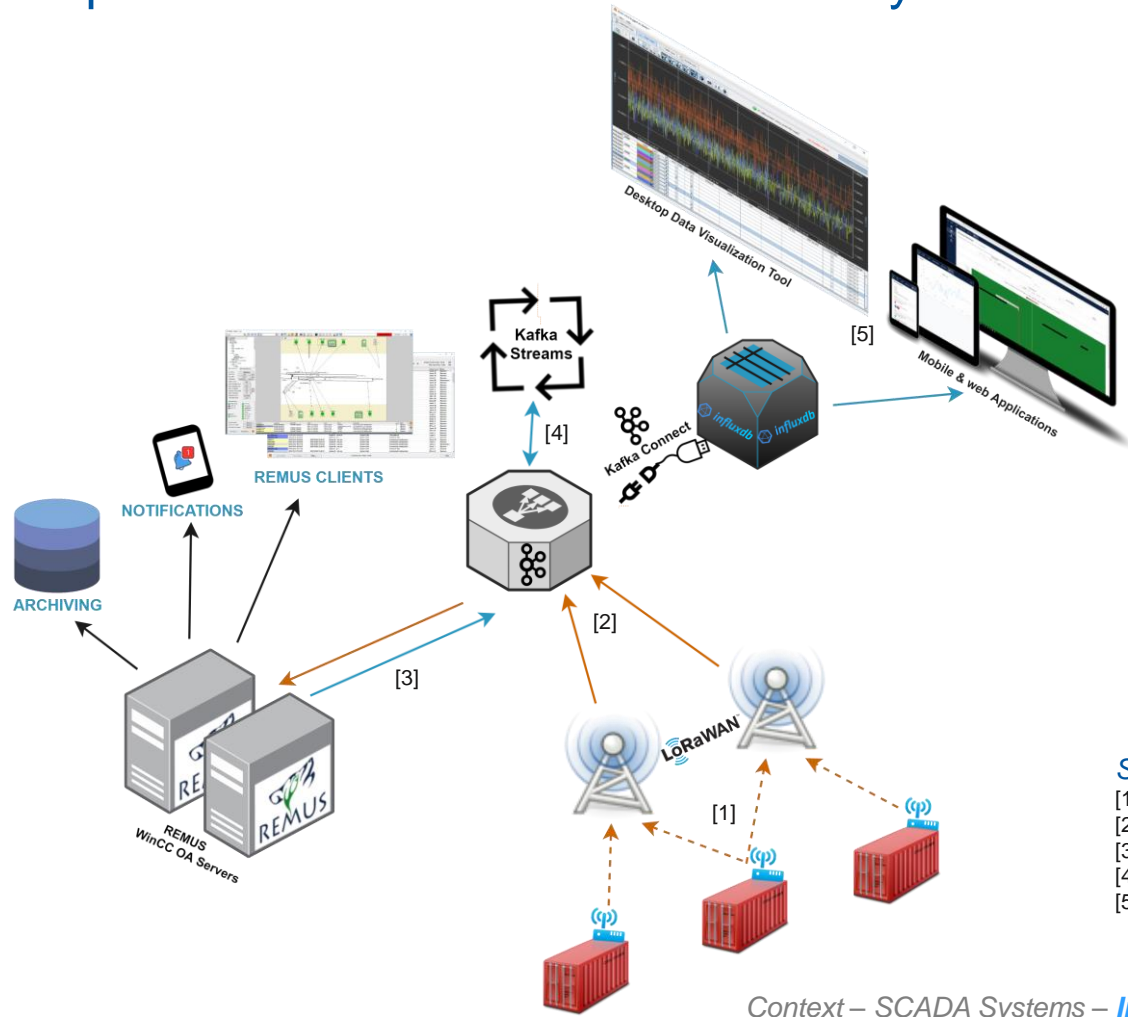
- Can be used by **ANY** Control System!
 - Utilizes generic JSON messages for Near Real-Time data visualization



Context – SCADA Systems – *Innovations* – REMUS at CERN – Prospects

Data Streaming: Application: Waste-Monitoring IoT Pipeline (project)

- Replace manual containers checks by **automated Waste Monitoring**



Single measurement data format:

- [1]: 2019-07-23 09h30;5.2356;110110
- [2]: {"date": "2019-07-23 09h30", "meas": 5.2356, "tags": "110110"}
- [3]: {"id": "1165", "timestamp": 1563867000000, "value": 5.2356, "flags": {"unit": 23, "mode": 1}}
- [4]: {"id": "1165", "timestamp": 1563867000000, "value": 5.2356, "flags_unit": 23, "flags_unit_enr": "ct/s", "flags_mode": 1, "flags_mode_enr": "measure"}
- [5]: [x,y]

Context – SCADA Systems – *Innovations* – REMUS at CERN – Prospects

REMUS at CERN: Project

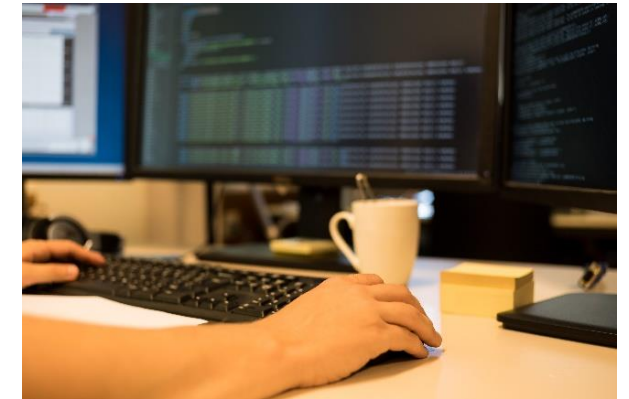
- **REMUS Project** Started in 2012. Goal:
 - **Unify** all CERN Radiation and Environment supervisory systems
 - **Reduce delay** and the **cost of adding new devices** to the supervision
 - Provide **light and fast clients, customized** for each user's requirements
 - **Reduce overall maintenance** needs for operation
 - Take advantage of **30 years of experience** providing Safety Systems to CERN

- **Core Project Team**
 - **G. Segura, A. Ledeul, B. Styczen, A. Savulescu**
 - **K. Szkudlarek, R. Silvola, D. Vazquez, L. Leone, L. Sienko** (former members)

- **Domain Experts representatives**
 - **J. Regnard** (Environment), **M. Witorski** (Radiation Protection)

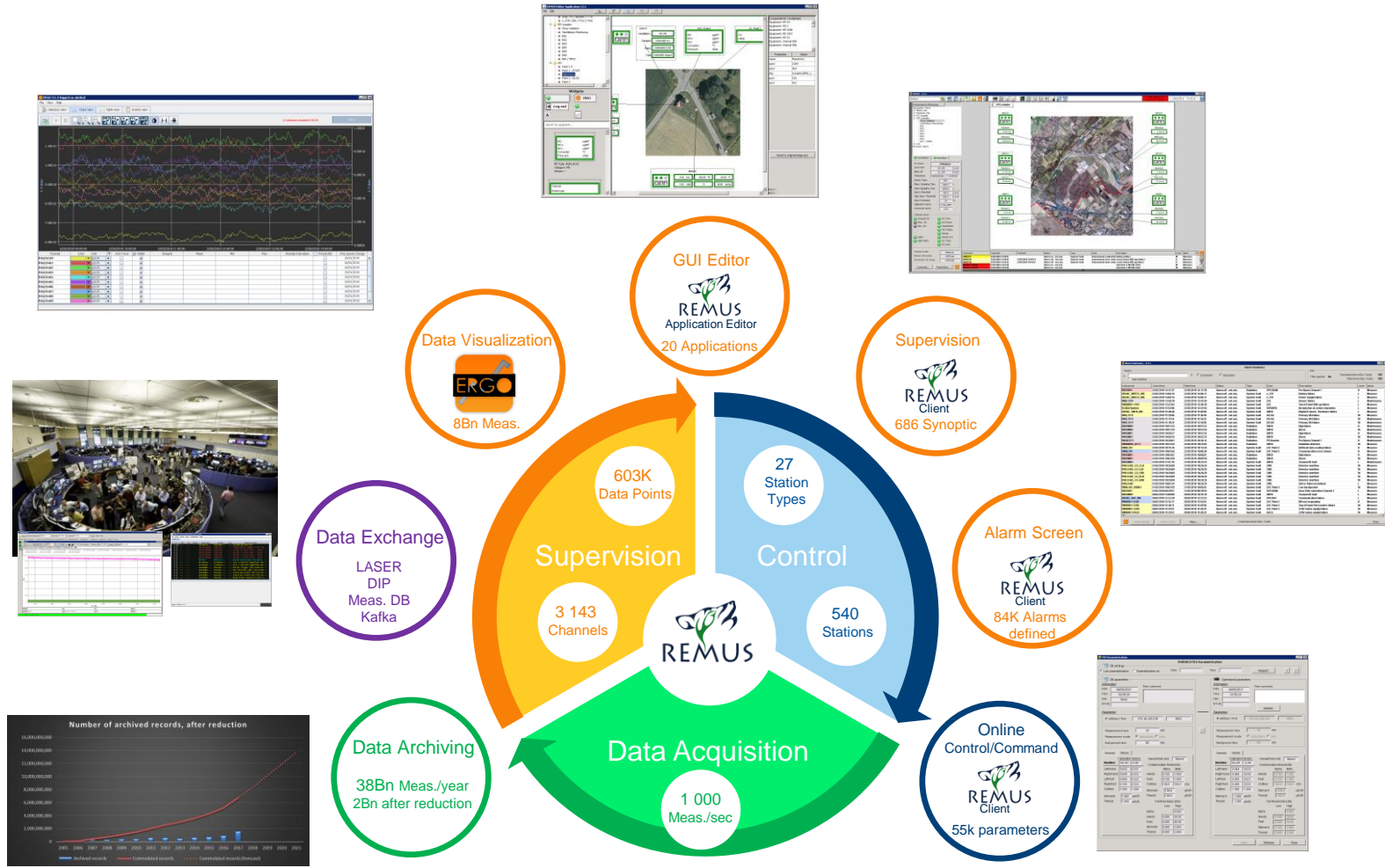


RADIATION AND ENVIRONMENT MONITORING UNIFIED SUPERVISION



*Context – SCADA Systems – Innovations – **REMUS at CERN** – Prospects*

REMUS at CERN: Main Functionalities



REMUS Functional Diagram

Context – SCADA Systems – Innovations – REMUS at CERN – Prospects

Prospects: Deployment outside CERN: Technical Requirements

■ Hardware

- 1-2 WinCC OA Servers (Windows or Linux, REMUS uses CentOS 7)
- 1 Oracle Database Server (PostgreSQL can be used instead, spending ~70 man-days)

■ Software Licenses

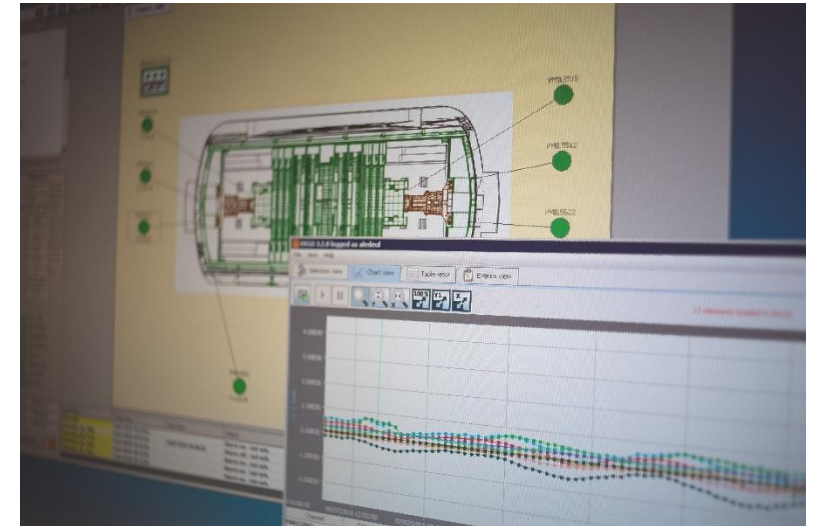
- 1-2 WinCC OA Licences
- 1 Oracle licences (if Oracle used)

■ Support Services

- Administration and support for: OS, DB and Network infrastructure

■ Installation/Set-up/Tests

- ~15 man-days assuming Databases, Servers and Network infrastructure are ready

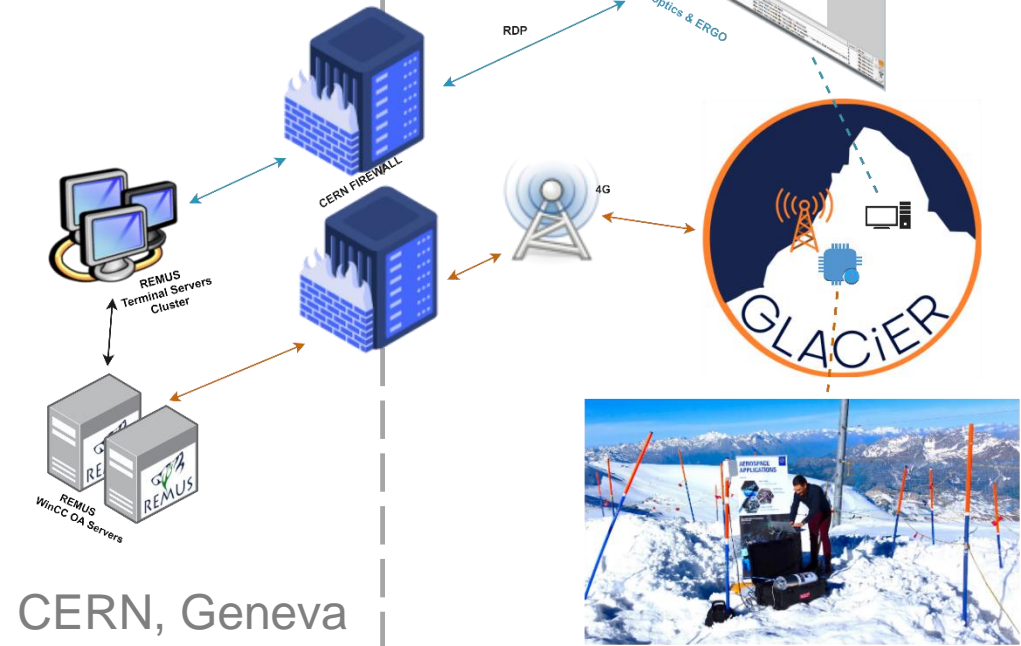


REMUS is essentially non-CERN dependant
Can be used for other processes than RP/Environment Monitoring

Context – SCADA Systems – Innovations – REMUS at CERN – Prospects

Prospects: “Cloud” service

- All operations of the systems can be done **without any SCADA or IT expertise**
- The system can be hosted **remotely (“SaaS” Windows/Linux)**
- Real example: **IGLUNA** Installation (June 2019):
 - CERN RP Expert set up two CROME (Radiation Monitors) on Zermatt Glacier
 - A 4G modem is installed to send the data to CERN
 - From Zermatt, a Remote Desktop connected to a dedicated REMUS Synoptic allowed the Configuration, Control and Supervision of the monitors
 - No SCADA infrastructure nor service was necessary on site
 - No intervention of the SCADA team was necessary



Context – SCADA Systems – Innovations – REMUS at CERN – Prospects

Prospects: Collaborations

▪ Possible Clients:

- Devices manufacturers
- Laboratories, Research Institutes
- Plants, Governmental Environmental Monitoring Programs
- Clients of supported devices
- ...

▪ Possible Models:

- Open Source / Proprietary
- Cloud / On-premise
- License / Partnership / Subscription / Support / Sponsored functionalities (e.g. extension of supported instrumentation catalog)

▪ REMUS Web can be distributed **separately**

Context – SCADA Systems – Innovations – REMUS at CERN – Prospects



www.cern.ch

List of instrumentation supported by REMUS (1-14/27)

- GROAC (CERN) General Purpose (counting cards)
- MSDA (CERN+) Radioactivity
- MMS (CERN+) Meteorological Monitoring Station
- VMS (CERN+) Ventilation Monitoring Station
- RWM (*Bertin*) Release Water Monitor for Radioactivity
- HFM (*Nuvia Instrument*) Hand & Foot contamination Monitor
- PCM (*Bertin*) Material Control Monitor for Radioactivity
- SGM (*Bertin*) Site Gate Monitors for Radioactivity
- WMS (CERN+) Water Monitoring Station
- AC32 (*Environnement S.A.*) NO, NO_x,NO₂ Monitoring
- O342 (*Environnement S.A.*) O₃ Monitoring
- LB112 (*Berthold*) Gamma Radiation Monitor
- FHT1100 (*Thermo*) Rate-meter (mobile)
- AD6 (*Automess*) Radioactivity (mobile)

COTS (Commercial Off-The-Shelf) instrumentation

CERN developed instrumentation

“CERN+”: CERN & COTS instrumentation

List of instrumentation supported by REMUS (15-27/27)

- ICAM (*Canberra*) Air Alpha/Beta Monitor
- SMART (CERN) General Purpose (PLC)
- LB147 (*Berthold*) Hand & Foot contamination Monitor
- iWMS (CERN+) Water Monitoring Station
- RADHOME (*Algade*) Radon Monitoring
- ABPM (*Mirion*) Alpha/Beta Particulate Monitor (mobile)
- DTionix (*Premium Analyze*) Tritium Monitoring
- MinAlarm (*Thermo*) Radioactivity
- UNIDOS (*PTW*) Dosemeter
- iAS (CERN+) Aerosol Sampler
- Alarm Repeater (CERN) Alarm Signals
- FHT1388 (*Thermo*) Truck Gate Monitor for Radioactivity
- CROME (CERN) Radioactivity

COTS (Commercial Off-The-Shelf) instrumentation

CERN developed instrumentation

“CERN+”: CERN & COTS instrumentation

Use Case : Continuous Operation

■ Situation

- Expert plugs in a new monitor
- Declares the MS, Devices, Channels in REMUS
- Downloads the Application he needs to update
- Updates the Application with the Editor
- Uploads the Application back on REMUS
- Defines, Configures & Parameterizes the Station
- Visualizes the Real-Time Data

■ What happened, in the Backend

- New instance of existing model created in DB
- New online variables added to WinCC OA
- New alarms/faults added to WinCC OA
- New connection added in the selected Driver
- Application versioned
- Run-time update of all clients using this App.
- Parameters & Configuration set-up
- Data Archiving & Streaming set-up

