
CERN
HSE
Occupational Health & Safety
and Environmental Protection unit

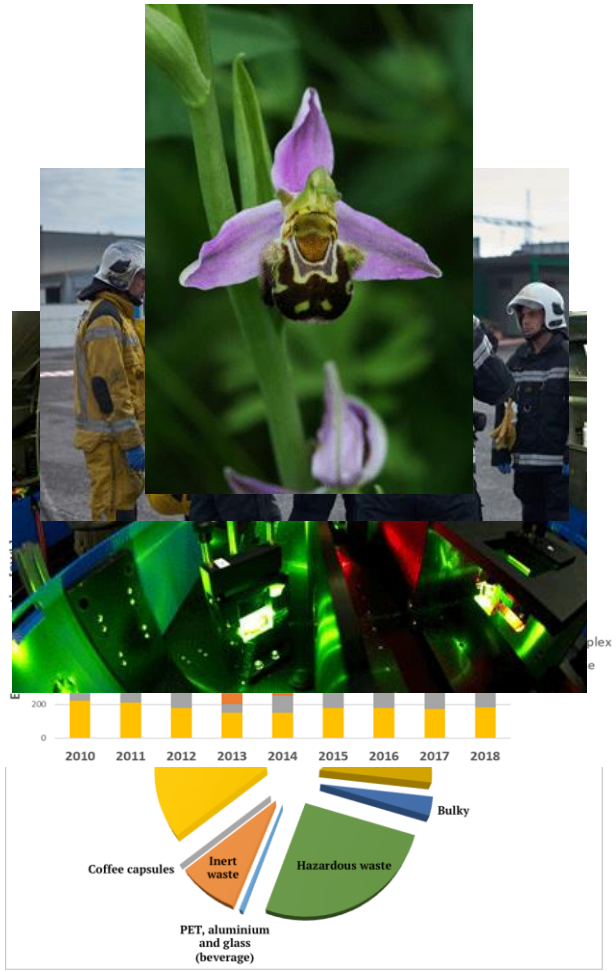
# REMUS

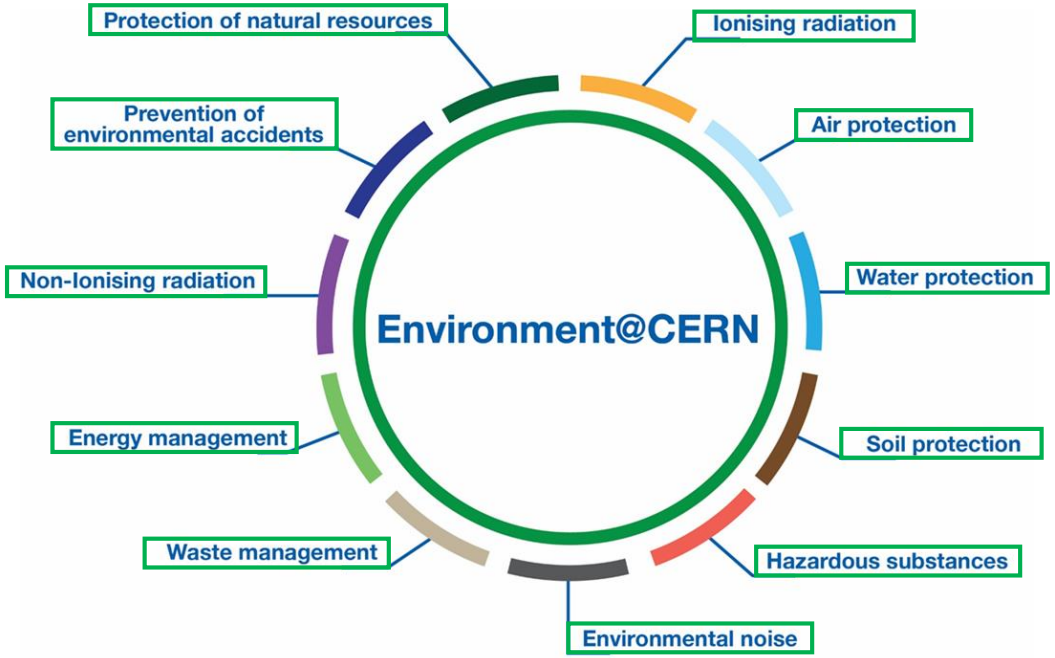
RADIATION AND ENVIRONMENT MONITORING UNIFIED SUPERVISION

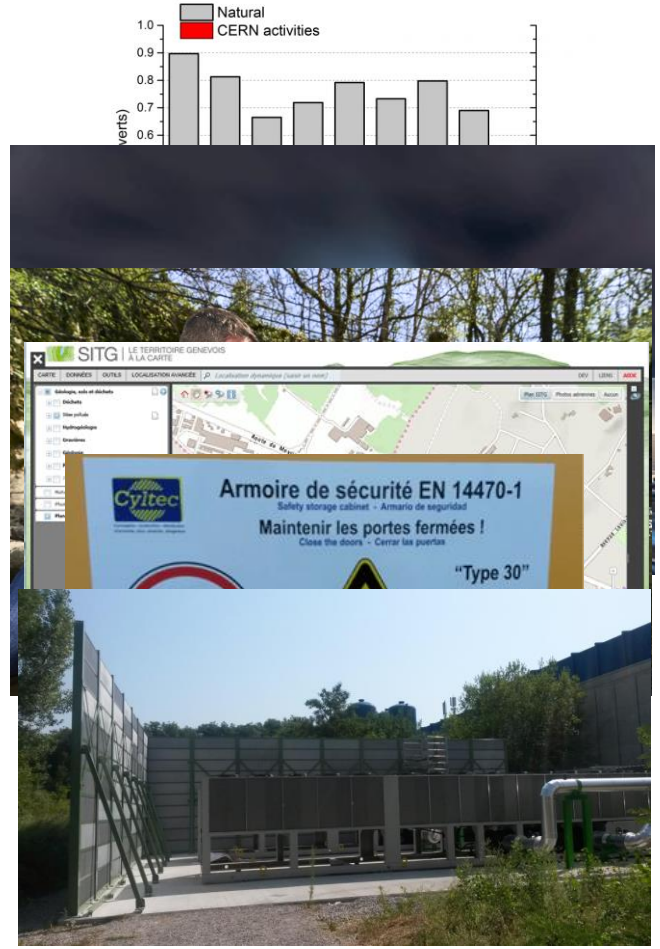
CESP
CERN Entrepreneurship Student Programme

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

# Context: Environmental Protection at CERN

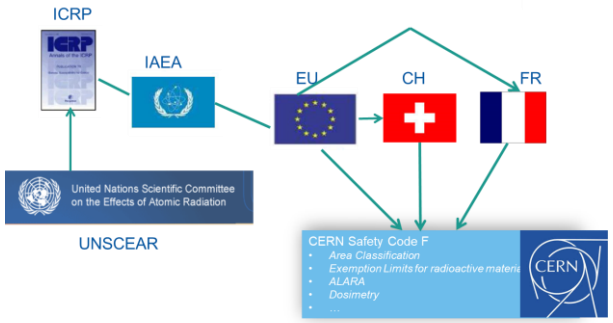



*Curtesy of HSE Environmental Protection Section*

# 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

*Curtesy of HSE Radiation Protection Group*

# Context: Radiation Protection and Environmental Monitoring at CERN

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

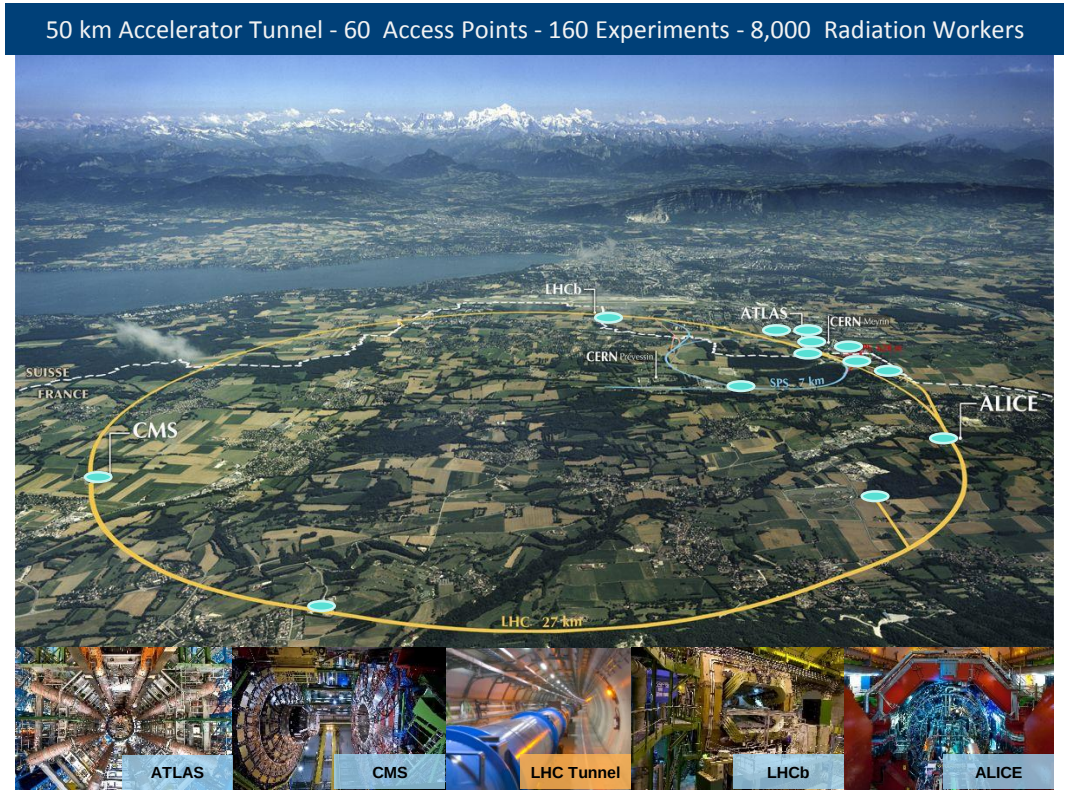
# Context: Radiation Protection and Environmental Monitoring at CERN

- **Water Monitoring**

Water Monitoring Station (x7)

SMART Water Monitoring Station (x6)

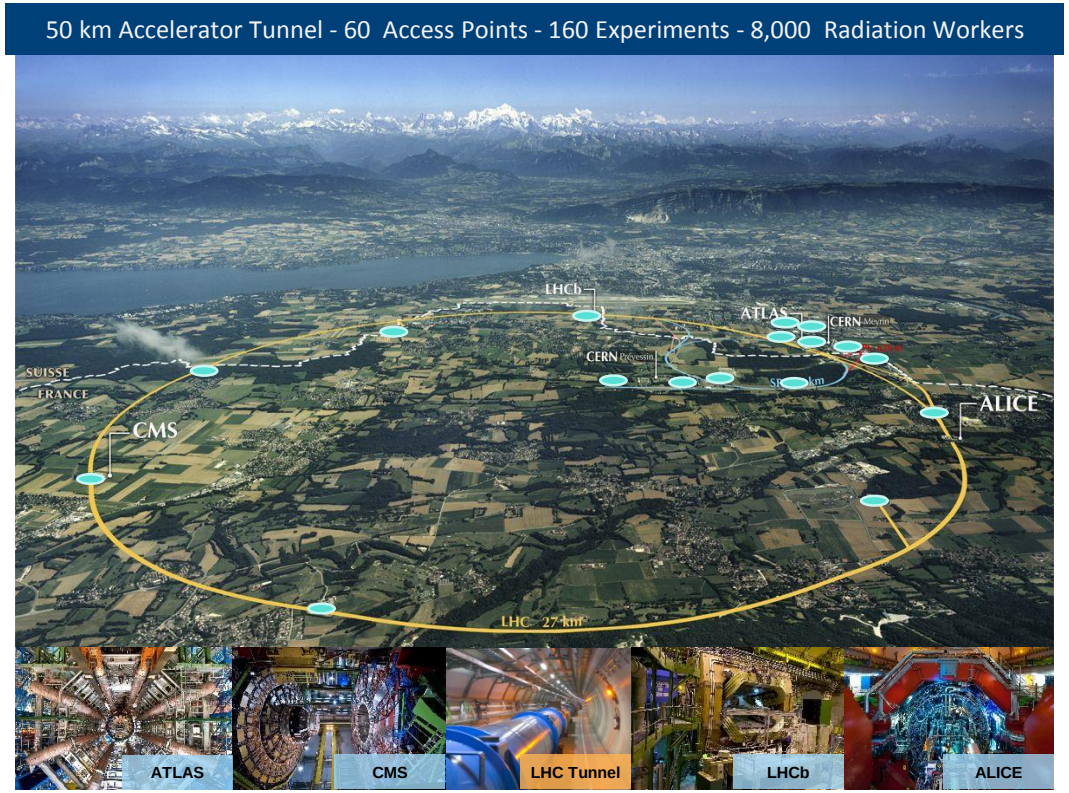
Release Water Monitor for Radioactivity (x13)



# Context: Radiation Protection and Environmental Monitoring at CERN

- **Ventilation Monitoring**

Ventilation Monitoring Stations (x10)



# Context: Radiation Protection and Environmental Monitoring at CERN

- **Air Monitoring**

NO, NOx,NO2 Monitor (x5)


O3 Monitor (x5)

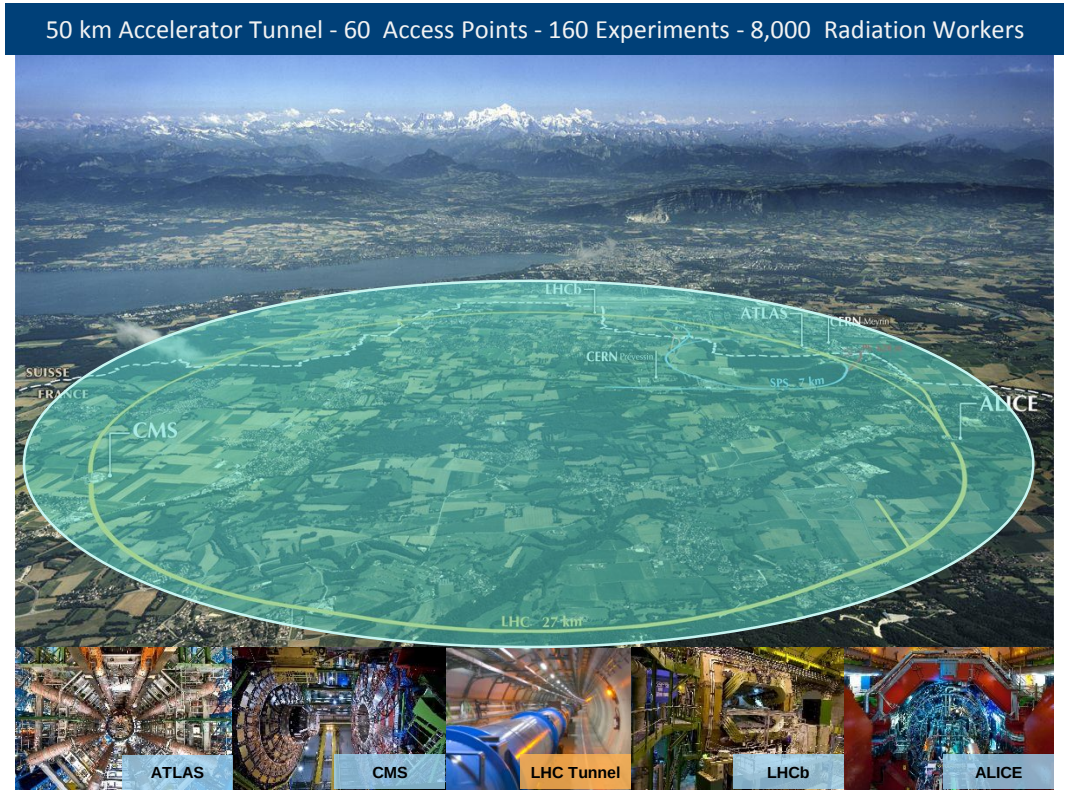
Air Alpha/Beta Monitor (x4)

Alpha/Beta Particulate Monitor (x8)

Radon Monitor (x4)


Tritium Monitor (x3)

SMART Aerosol Sampler (x8)



# Context: Radiation Protection and Environmental Monitoring at CERN

- **Meteorological Monitoring**

Meteorological Monitoring Stations (x10)

# Context: Radiation Protection and Environmental Monitoring at CERN

- **Operational Radiation Protection Monitoring**

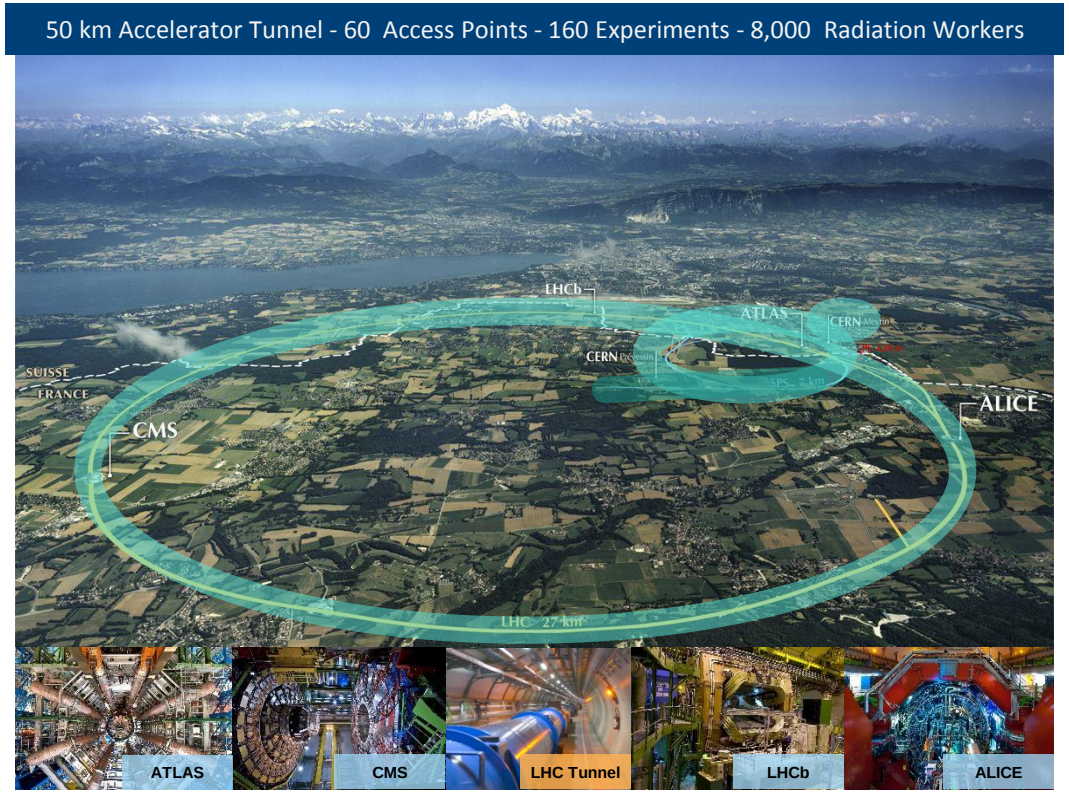
DA Monitoring Station (x142)

LB112 Monitoring Station (x114)

CROME Monitoring Station (x14)

MinAlarm Monitor (x1)


UNIDOS Dose Meter (x2)



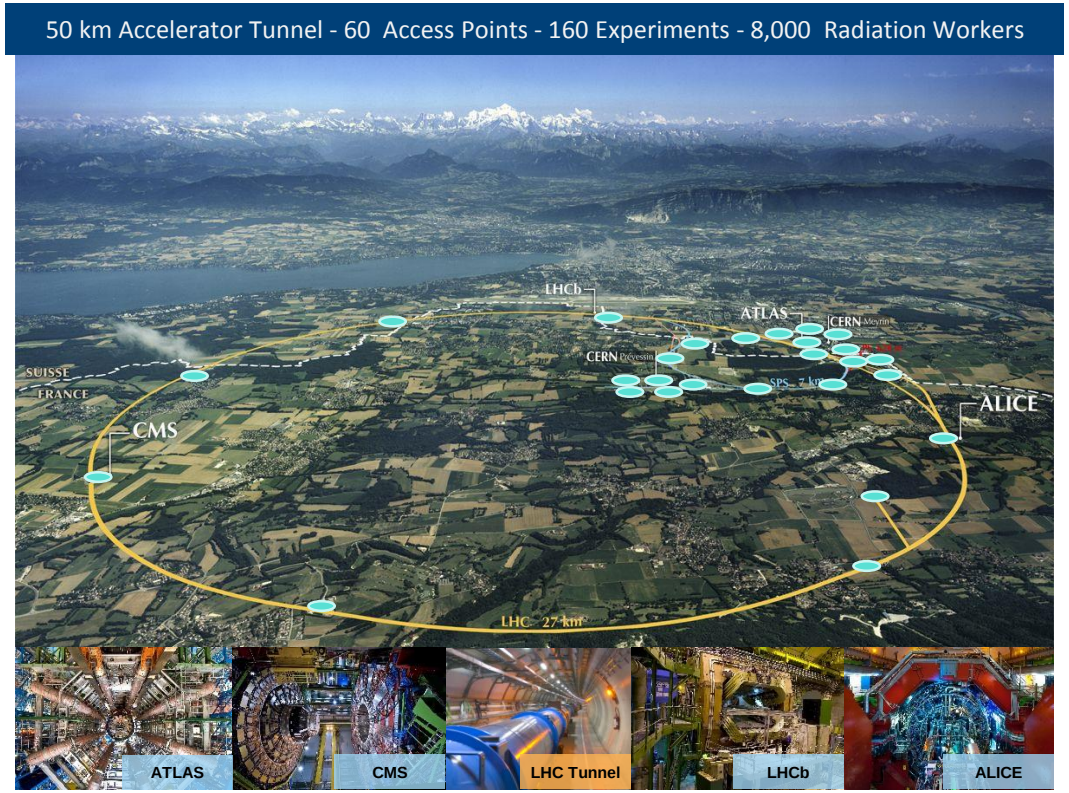
# Context: Radiation Protection and Environmental Monitoring at CERN

- **Contamination Monitoring**

Hand & Foot Contamination Monitor (x18)

LB147 Hand & Foot Contamination Monitor (x49)

Material Control Monitor (x19)

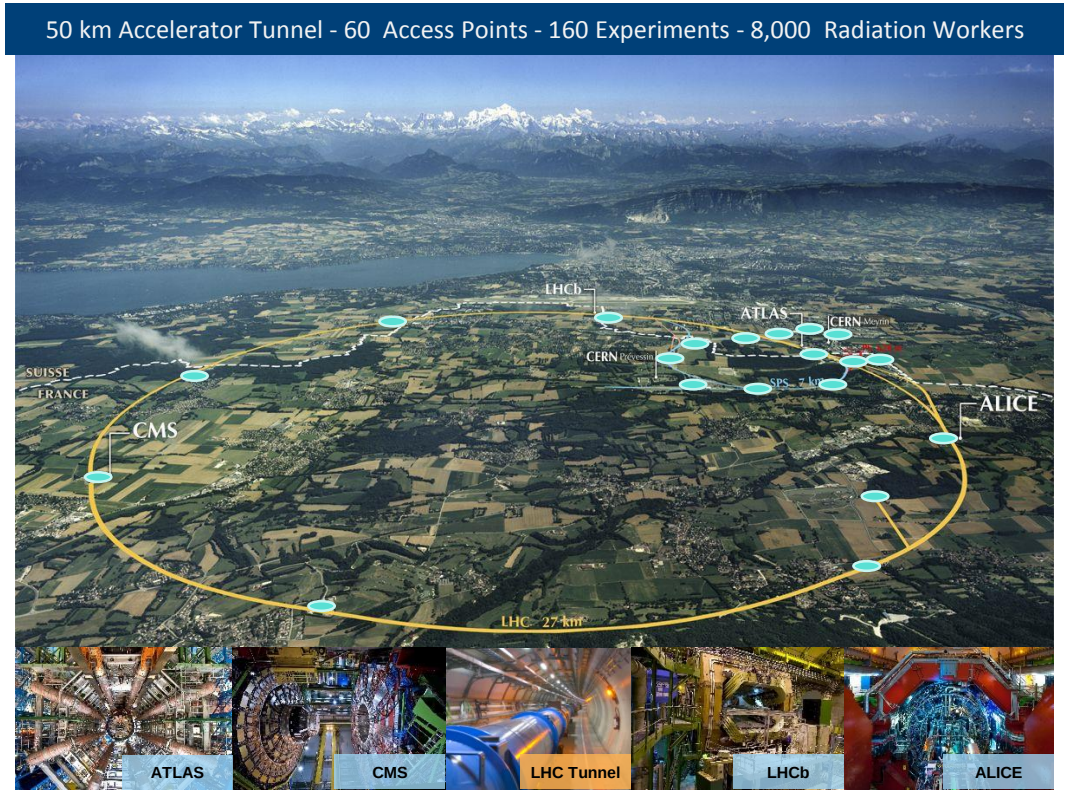


# Context: Radiation Protection and Environmental Monitoring at CERN

- **Gate Monitoring**

Site Gate Monitor (x22)

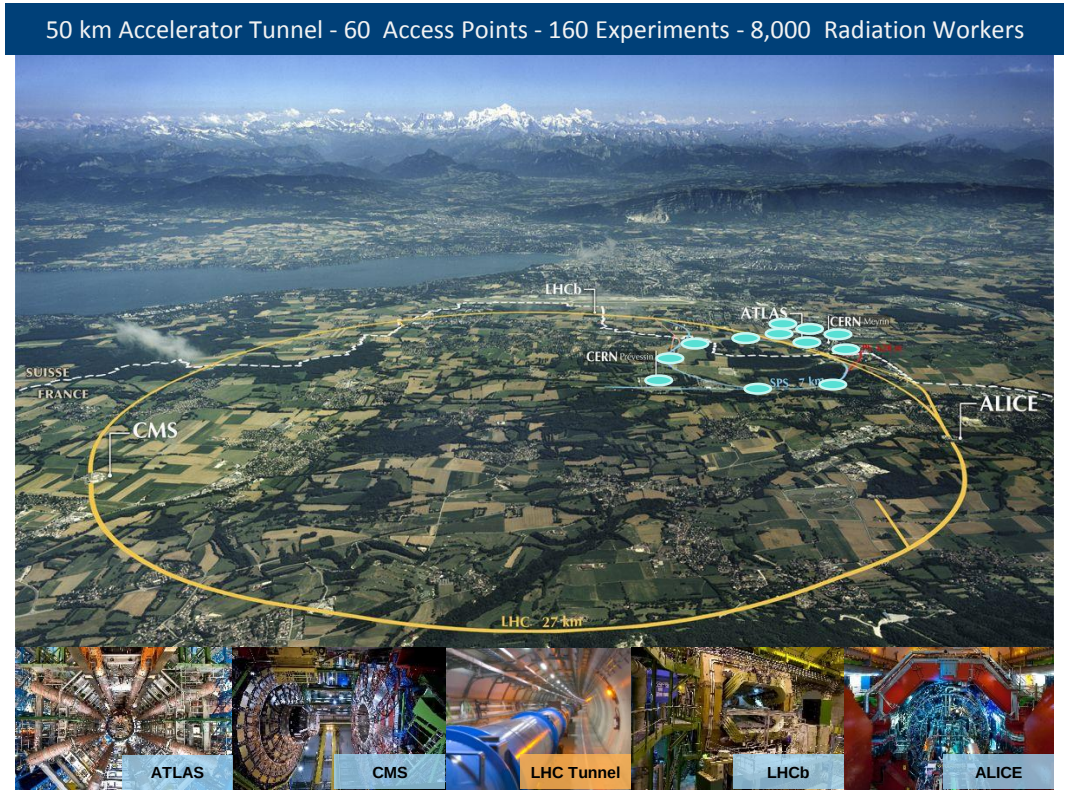
Truck Gate Monitor (x2)



# Context: Radiation Protection and Environmental Monitoring at CERN

- **Signal Repeaters**


Alarm repeaters (x28)

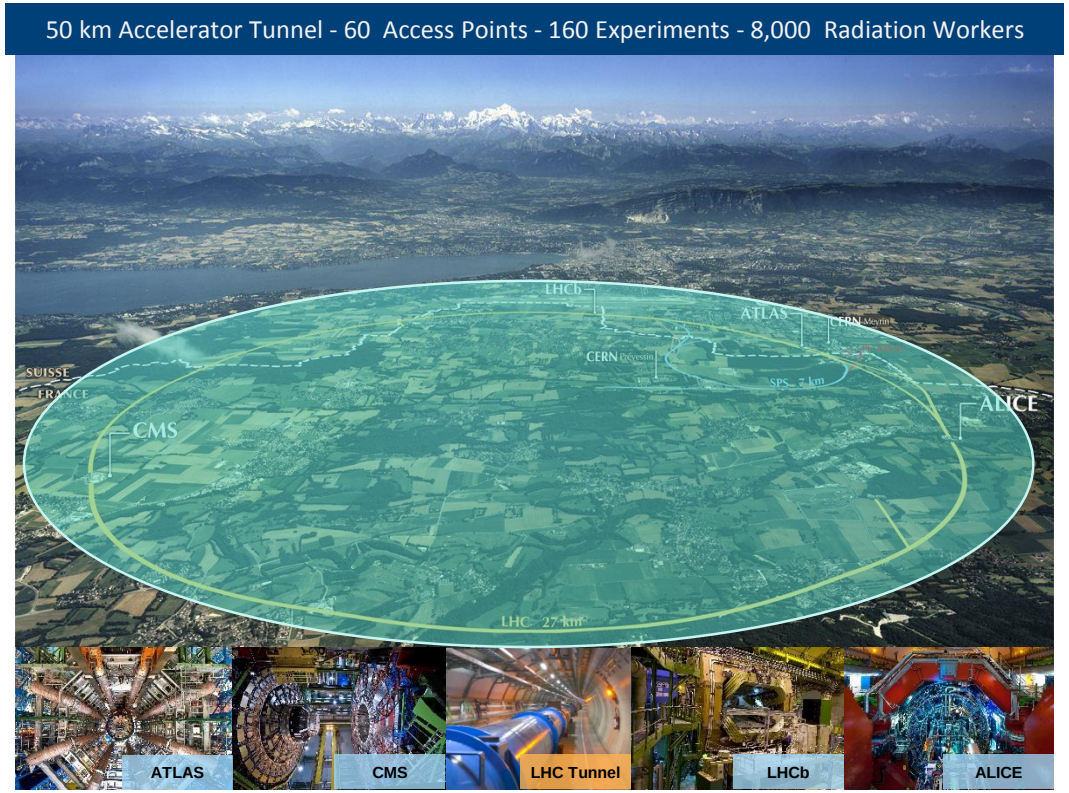


# Context: Radiation Protection and Environmental Monitoring at CERN

- **Mobile Monitoring**

FHT1100 Mobile Monitor (x4)

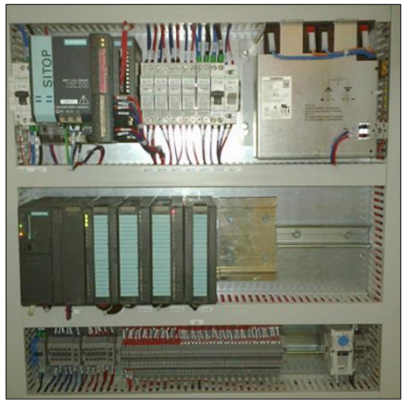

AD6 Mobile Monitor (x14)



# Context: Radiation Protection and Environmental Monitoring at CERN

- **Multi purpose Controllers**

Area Controller (x4)



SMART Controller (x1)

# 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

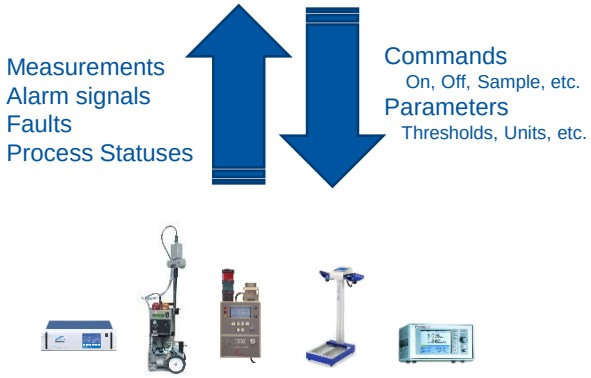
**Workplace and Environment Safety**

**Reporting to authorities:**

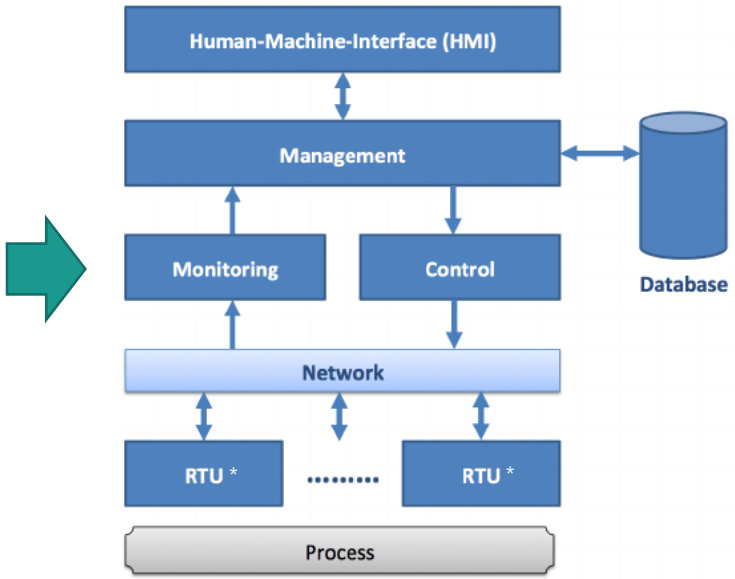
- **Nature and quantities of emitted ionizing radiation**
- **Conventional environmental measured values**

# SCADA Systems

- **What do we need?**
  - A **SCADA** system: **S**upervisory **C**ontrol **A**nd **D**ata **A**cquisition

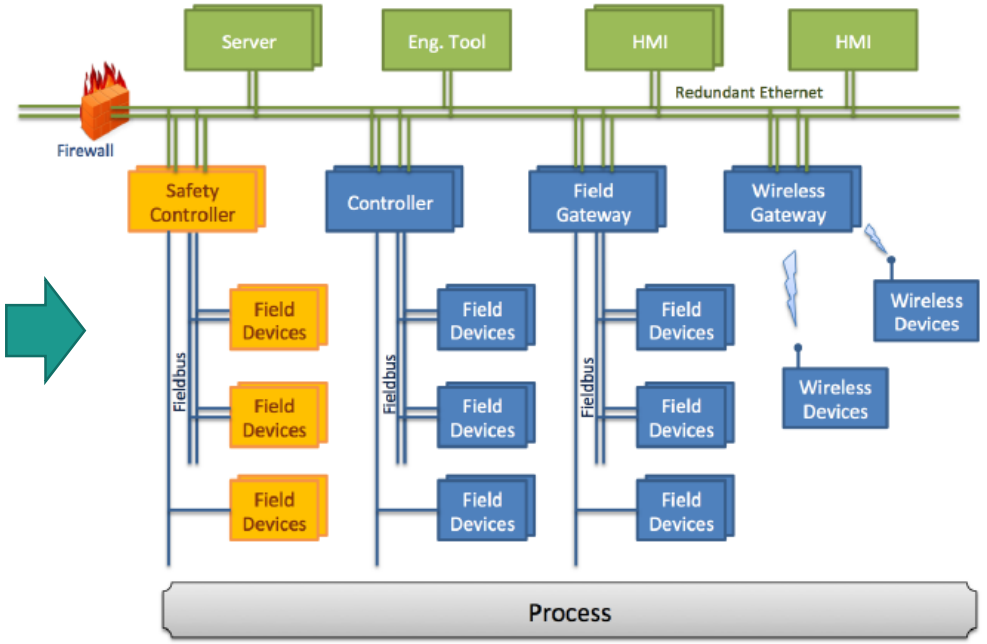



*Basic Functionalities of a SCADA system*




*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*

# SCADA Systems

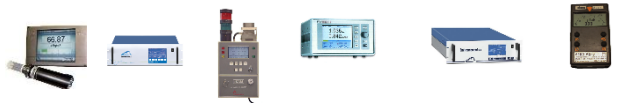
- But we need more than “just” a **Distributed** system! We need a system that is:

## 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

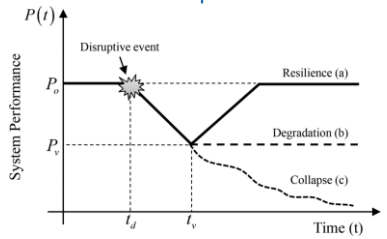
Serve the users in a **Timely Manner**

## 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

# WinCC Open Architecture

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

**Distributed**

**Scalable**

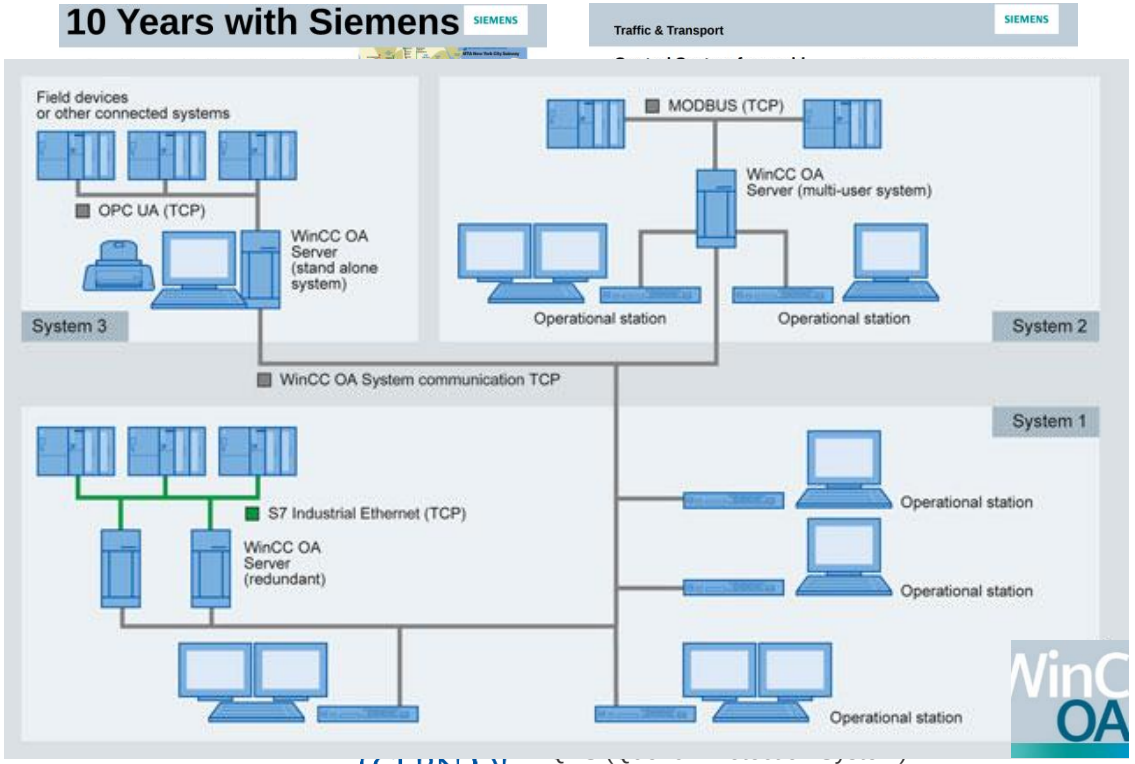
**Secured**

**Multiplatform**

**Redundant**

**Reliable**

**Performant**




PSEN (Electrical installations)
REMUS (Radiation & Environment)
…

# WinCC Open Architecture + REMUS Layer

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

**REMUS:**

**WinCC OA features**

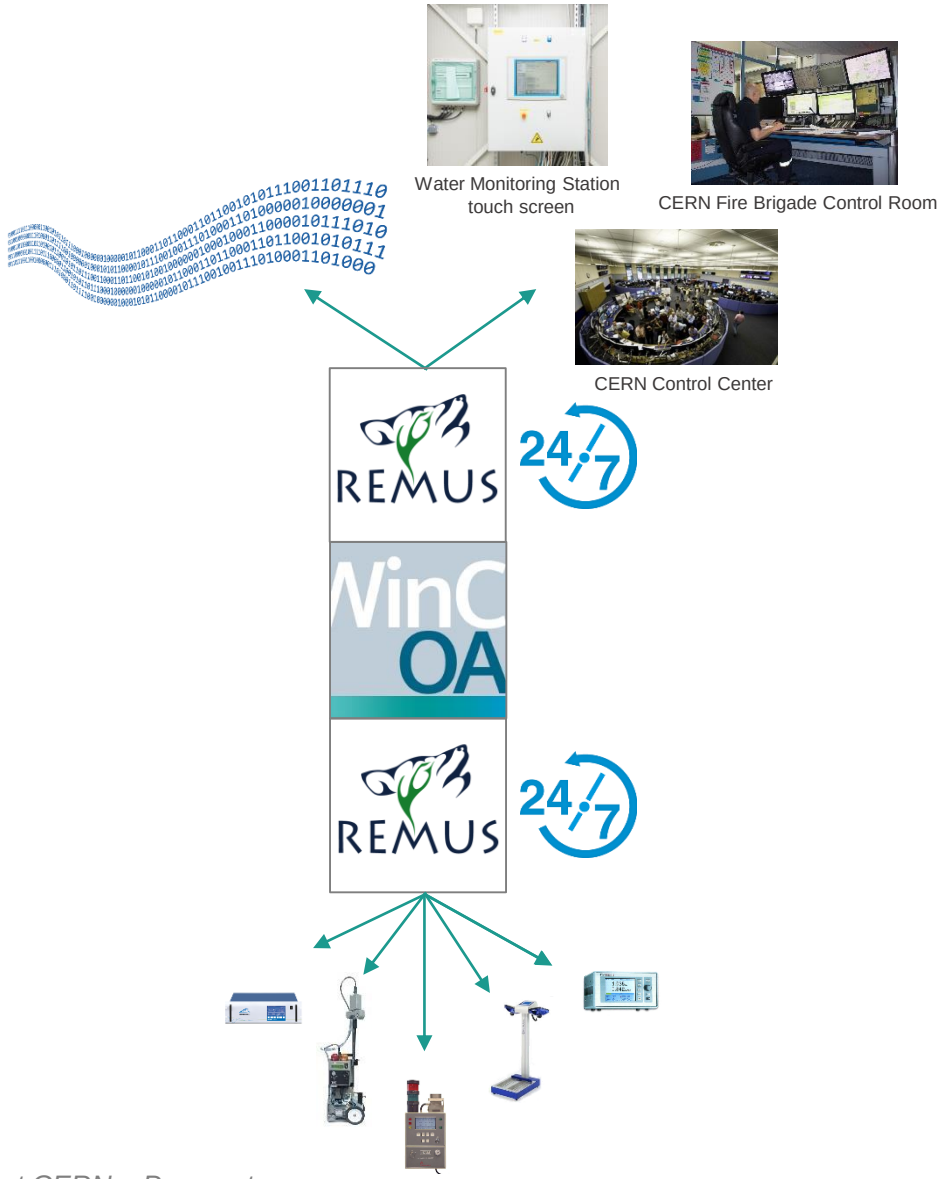
**+**

**Handling Heterogeneous Instrumentation**

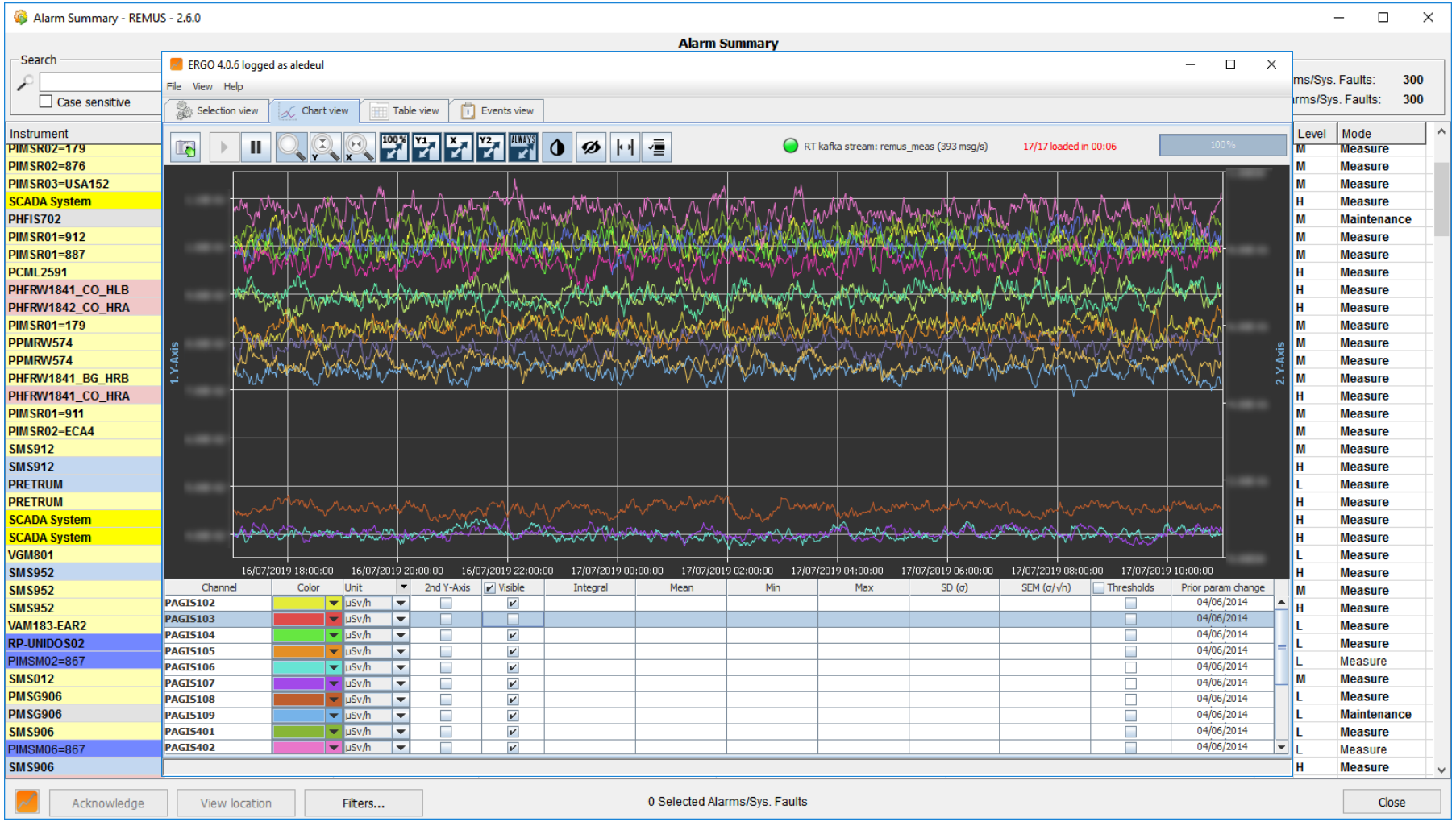
**Handling Diversity of Users**

**Run-time Updates**

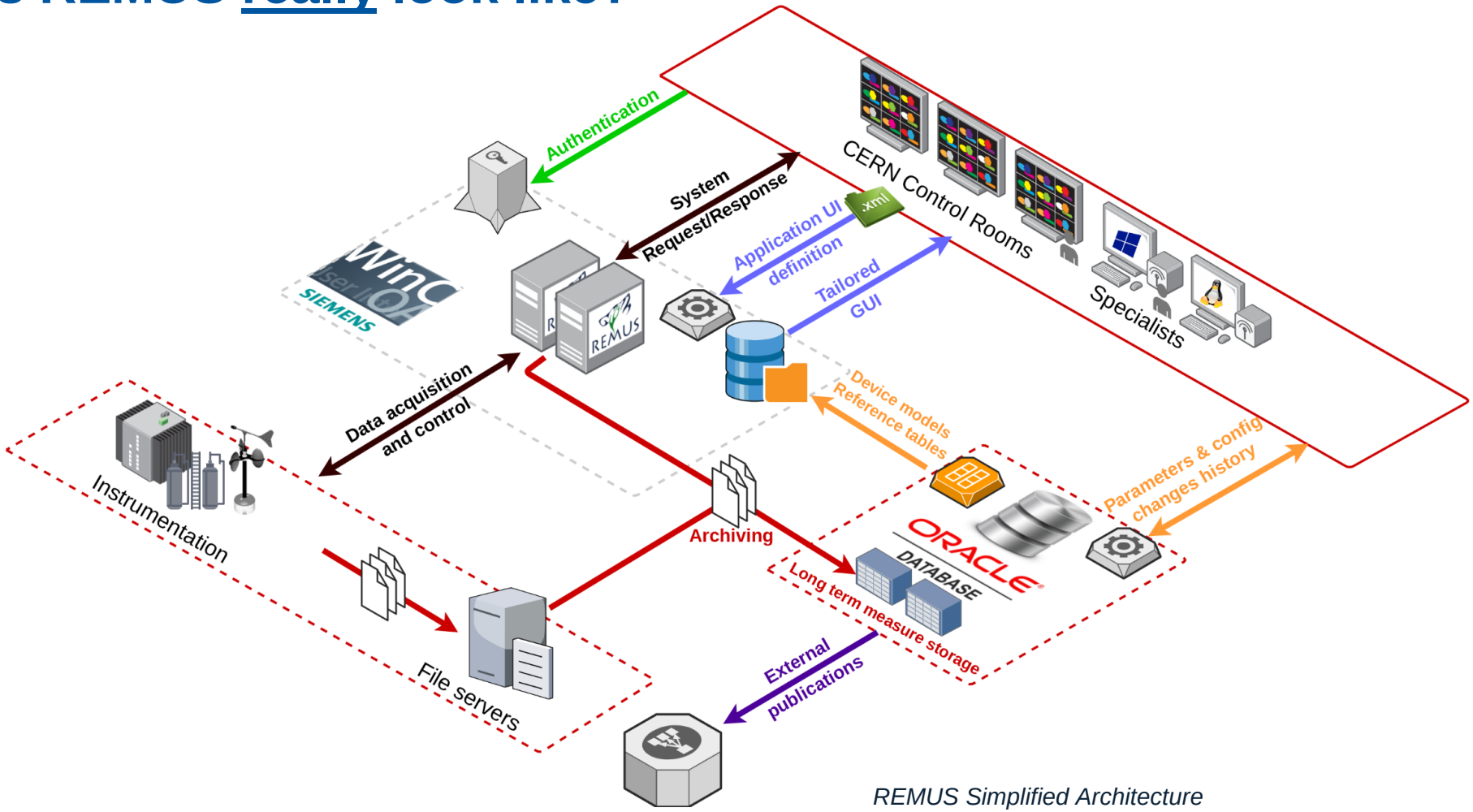
**Secured Data Streaming**



# What does REMUS look like?



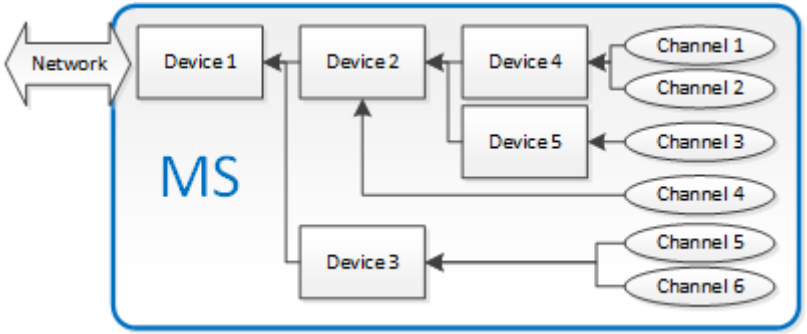
# What does REMUS really look like?




*REMUS Simplified Architecture*

# Heterogeneous equipment integration handling

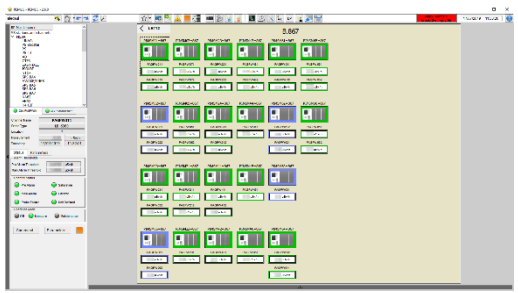
- **Challenges**
  - HSE owns very diverse types of monitoring equipment, for 2 reasons:
    - Wide scope of measurements to acquire
    - Long lifetime of equipment, costly to replace: electronics of different generations overlap
  - **This is a common challenge for supervisory systems**
- **Aim**
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



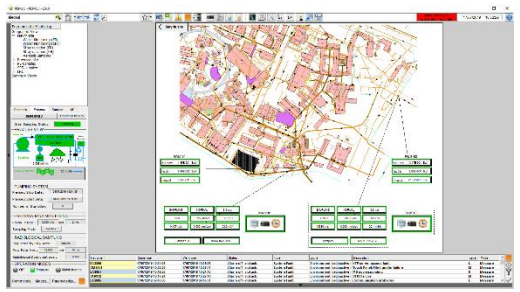

*Example of REMUS Device model*

# REMUS Applications

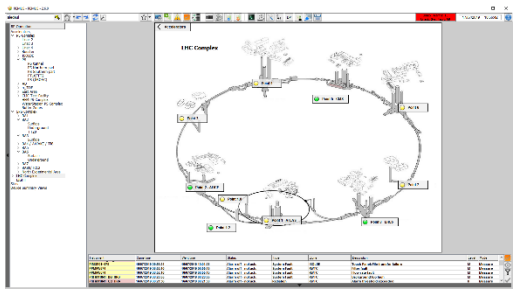
- **Users have different needs**
  - **Many different user profiles** use REMUS (accelerator & experiments operators, radiation protection engineers, environmental engineers, physicists, firefighters, maintenance teams…)
- **Customized User interfaces**
  - REMUS is split into several **Applications**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



*RP Maintenance Application*

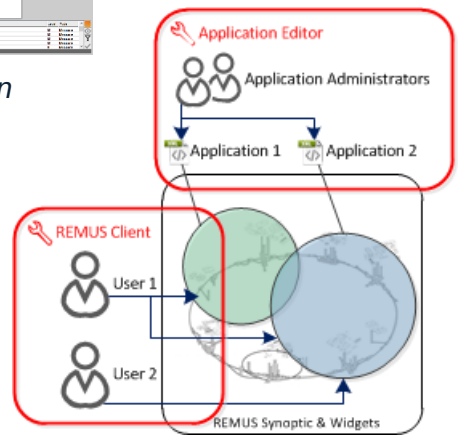


*Environmental Monitoring Application*



*RP Operation Application*

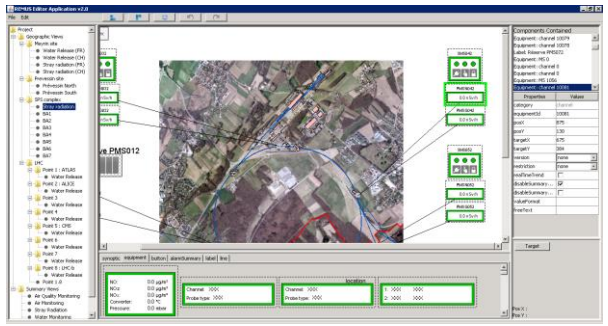
- **Advantages**
  - Users can focus on the **part of the supervision** they are interested in
  - Improved **Performance**
  - **Distributed maintenance** effort



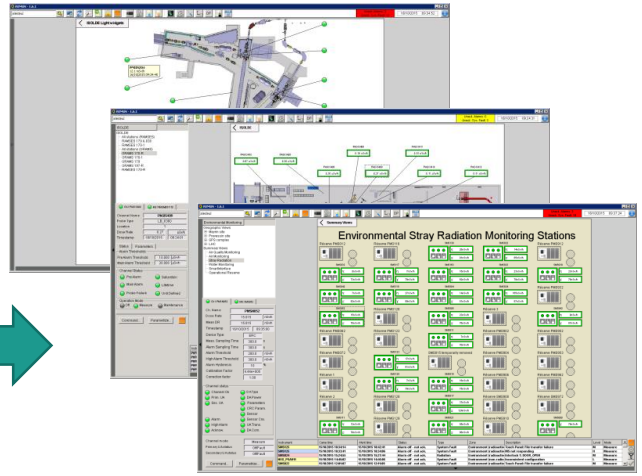

*REMUS Applications*

# Tailored User Interfaces

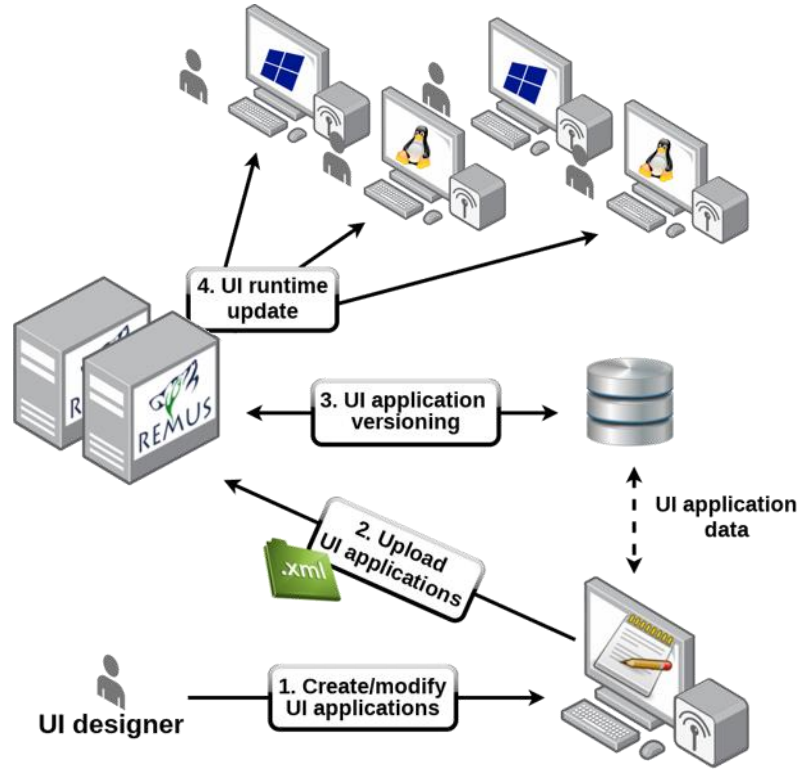
- **REMUS final users can build their own user interfaces (Application)**
  - REMUS provides users with a tool to build their own tailor-made user interface
  - Graphical tool to draw user interfaces with “drag and drop”
  - No knowledge of programming languages necessary
  - User interface can be modified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



*User Interfaces Editor*




*Tailored User Interfaces*




*User Interfaces deployment*

# Continuous Operation

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

REMUS
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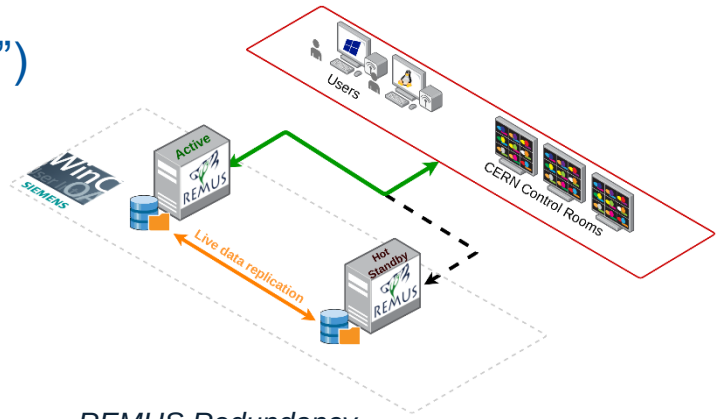
24/7

- **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**




*REMUS Redundancy*

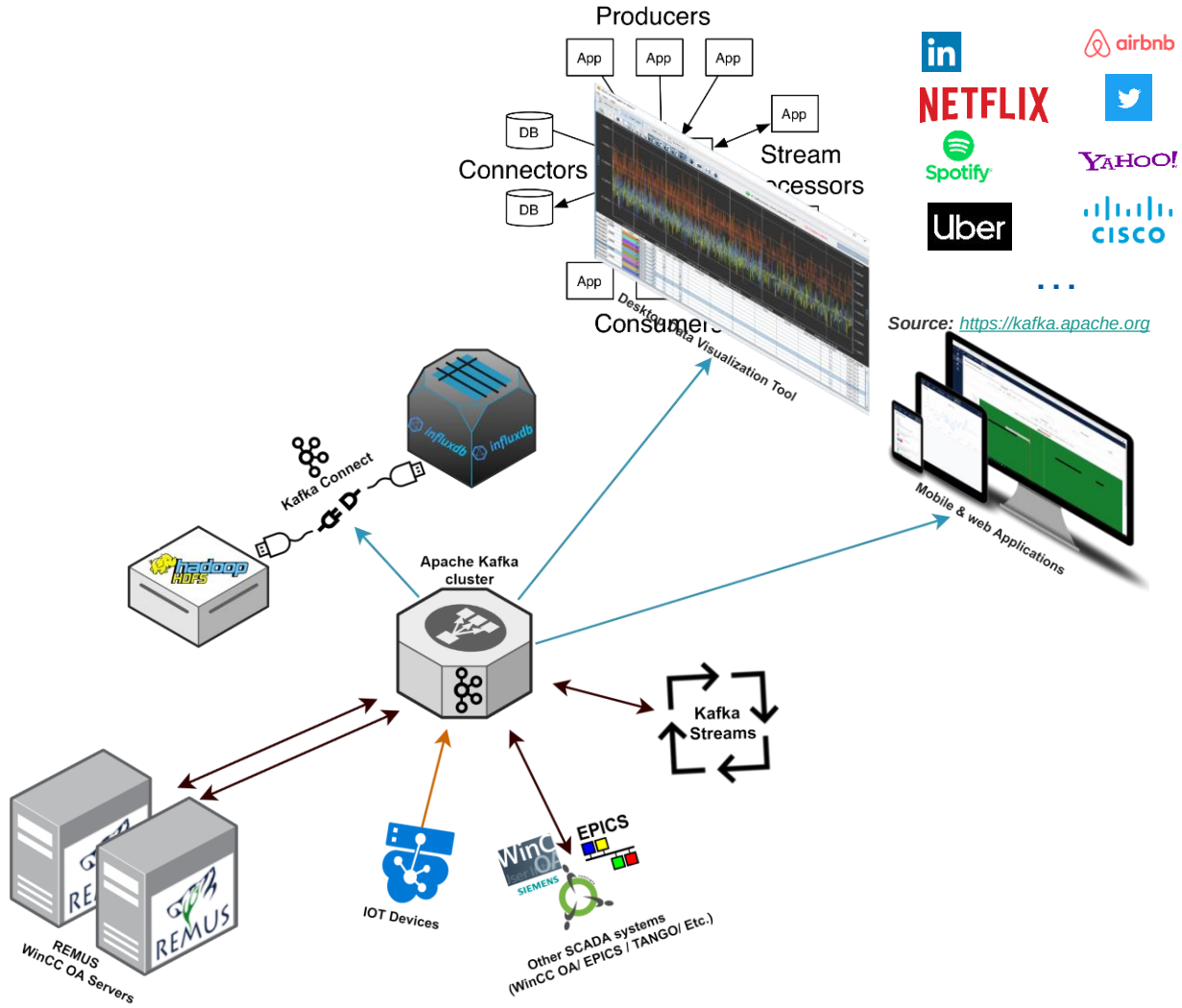
# Data Streaming

- **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)

**Apache Kafka®:** ***an open-source distributed streaming platform***



# Data Streaming: Application: REMUS Web (under development)

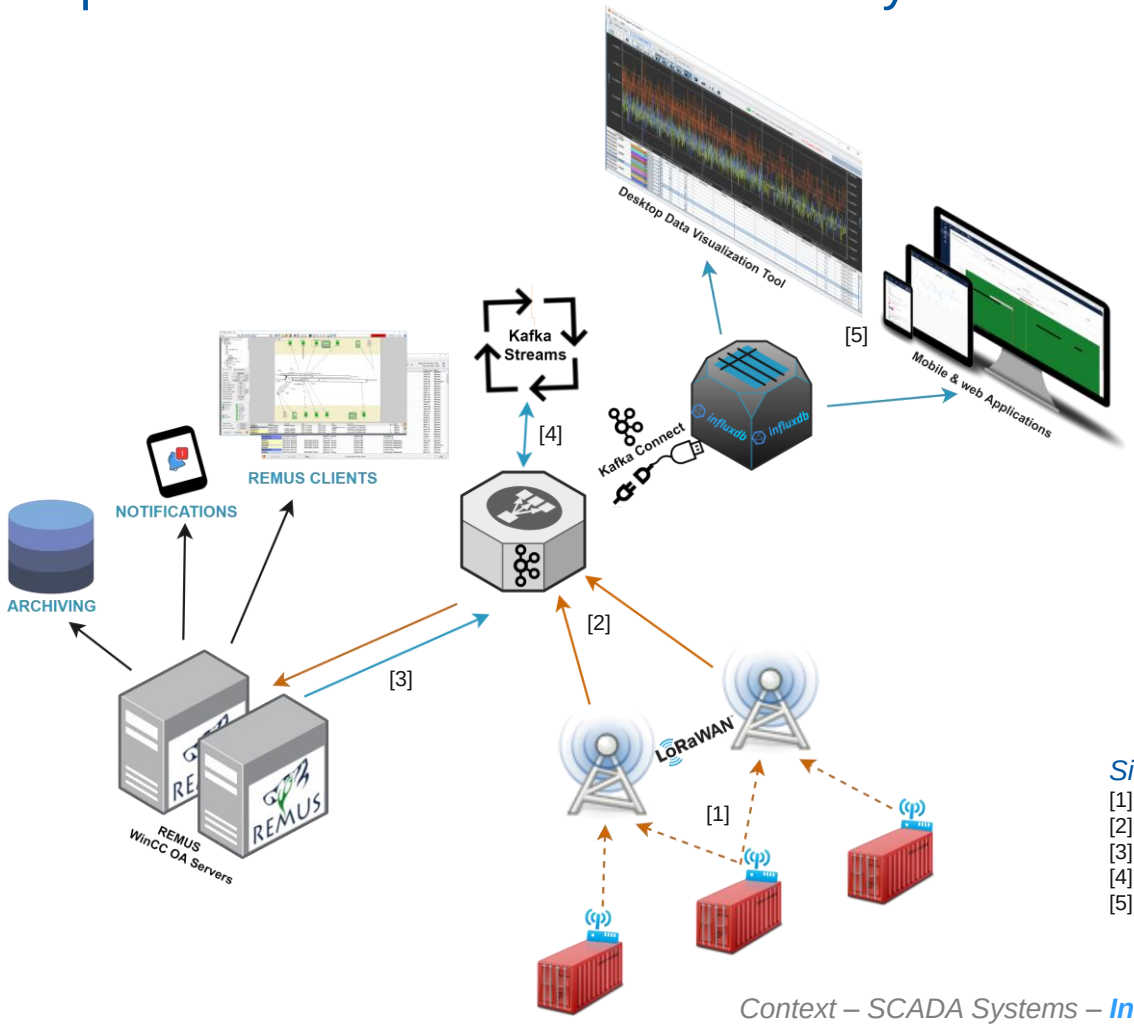
- Provides real time visualization of REMUS processes and measurements from a **Web** browser
- Provides **Statistics** on REMUS (Users, I/O, etc.)
- Provides **Configuration** tools (i.e. Notifications)

- 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

# 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]

# REMUS at CERN: Project

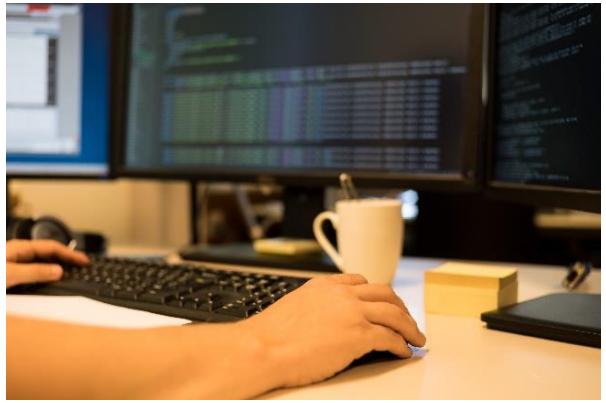
- **REMUS Project** Started in 2012. Goal:
  - **Unify** all CERN Radiation and Environment supervisory systems
  - **Reduce delay** and the **cost** of **adding new devices** to the supervision
  - Provide **light and fast clients**, **customized** for each user's requirements
  - **Reduce overall maintenance**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

REMUS

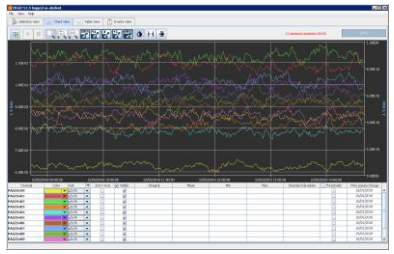
RADIATION AND ENVIRONMENT MONITORING UNIFIED SUPERVISION

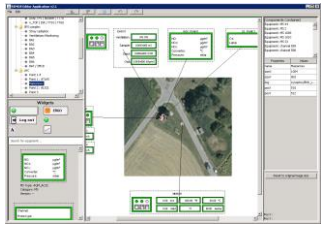
- **Core Project Team**
  - **G. Segura, A. Ledeul, B. Styczen, A. Savulescu**
  - **K. Szkudlarek, R. Silvola, D. Vazquez, L. Leone, L. Sienko** (former members)

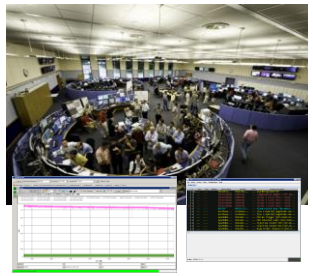
- **Domain Experts representatives**
  - **J. Regnard** (Environment), **M. Widorski** (Radiation Protection)

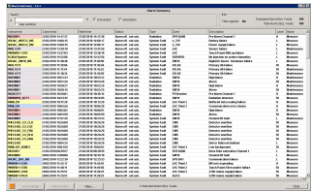


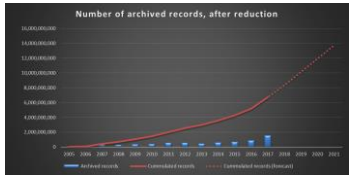
# REMUS at CERN: Main Functionalities

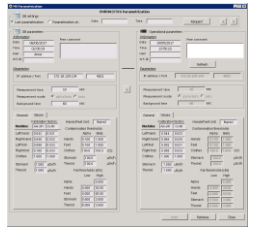


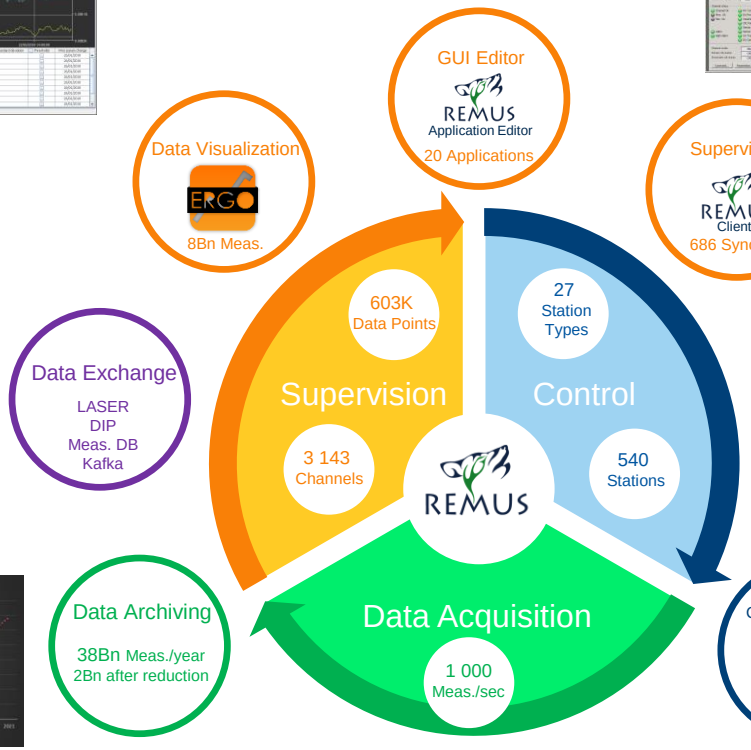








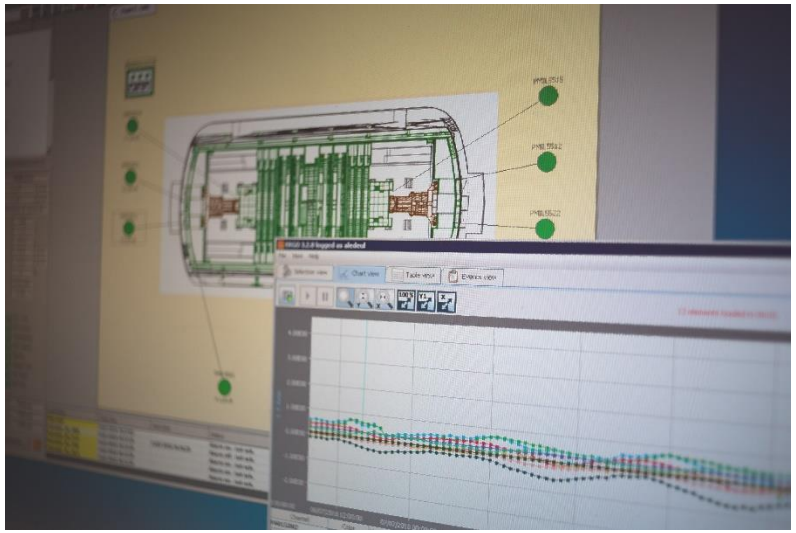



*REMUS Functional Diagram*

# 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)



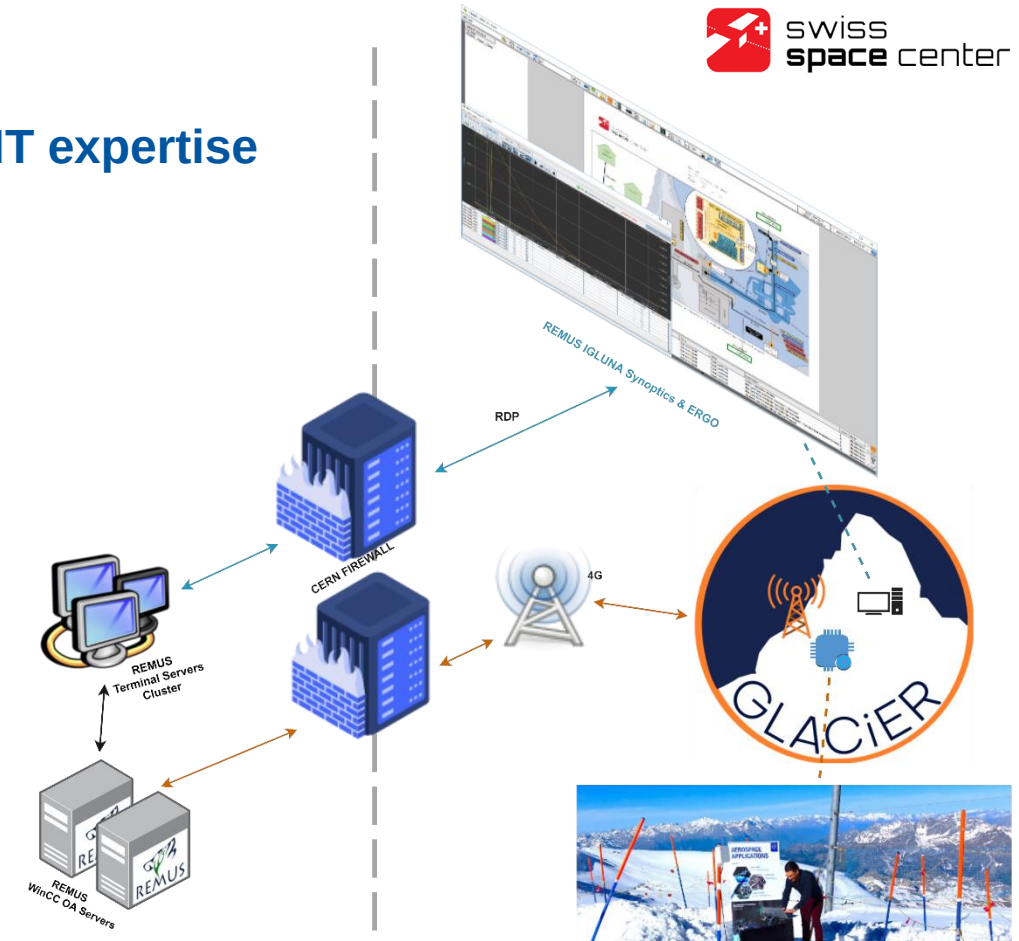
- **Support Services**
  - Administration and support for: OS, DB and Network infrastructure

- **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

# 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




CERN, Geneva

Klein Matterhorn, Zermatt

# 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**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# 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, NOx,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