Big Science Business Forum 2022

CERN

BEAMS

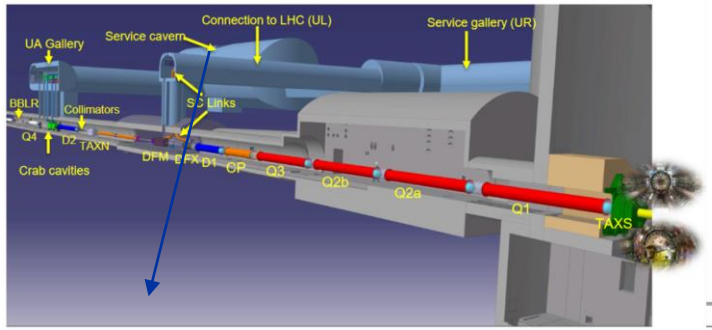
Future procurements at CERN in mechatronics and electronics

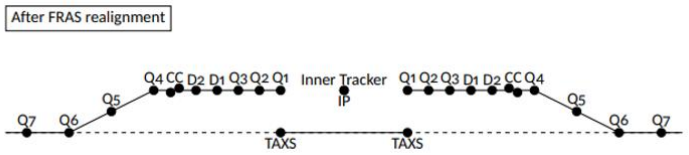
Alessandro Masi, CERN

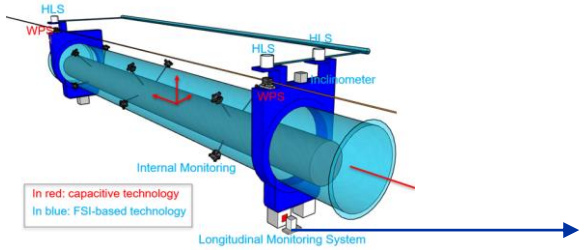
Full Remote Alignment System (FRAS) project

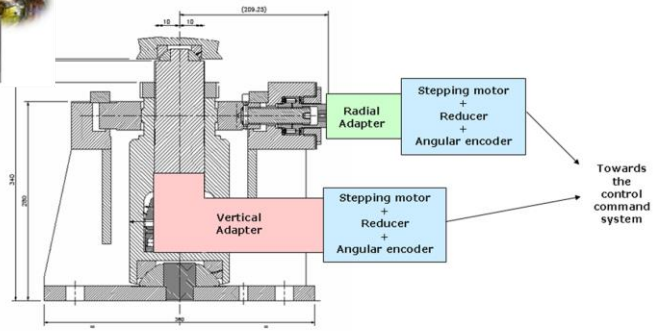
https://indico.cern.ch/event/1079026/contributions/4544748/attachments/2330326/3972436/FRAS_HL_LHC_collaboration_meeting.pptx

- It consists of **alignment systems** (alignment sensors, motorized adapters, their acquisition and control/command systems, associated software) allowing **to determine the position of components and readjust them remotely** within a range of **± 2.5 mm**
- All components from Q1 to Q5 (i.e. quadrupoles and dipoles magnets, collimators) in the LHC interaction points
- Installation and commissioning deadline: LS3 (end 2028)

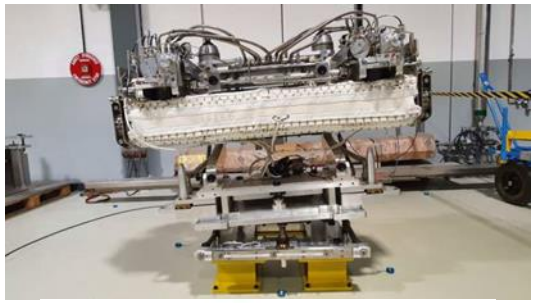


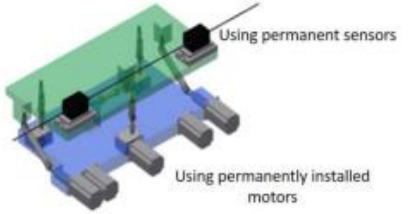






Motorized jacks for quadrupole and dipoles equipped with 2 stepping motors (type 1)



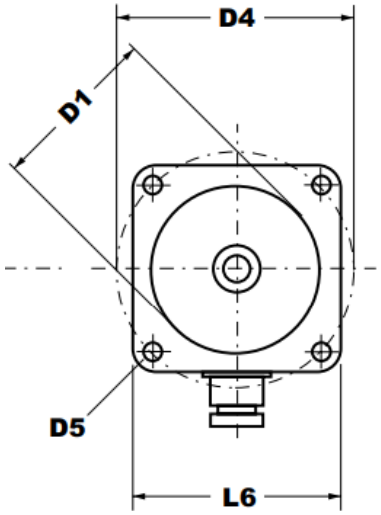


Universal alignment platform to adjust remotely pitch, roll and yaw of the component on top – It is equipped with 5 stepping motors (type 2)

FRAS project: future tenders

- Rad-hard stepper motors (TID 2 MGy) need for FRAS, ~200 full steps per revolution

Motor type	Quantity needed	Inductance/ phase [mH]	Current / phase unipolar [A]	Current / phase bipolar [A]	Holding torque [Nm]	Detent torque [Nm]	Rotor inertia [kgcm^2]	Weight [kg]	Length [mm]	D1, D4, L6 in picture [mm]	Other
Type1	~210	~3	~3.5	~5	~ 3.5	~0.15	~ 1.3	<5	~ 150	~ 40, 70, 60	Single shaft with keway
Type2	~300	~9	~1.5	~2	~1	~0.1	~0.25	<3	~200	~ 75, 100, 90	Single shaft with keway



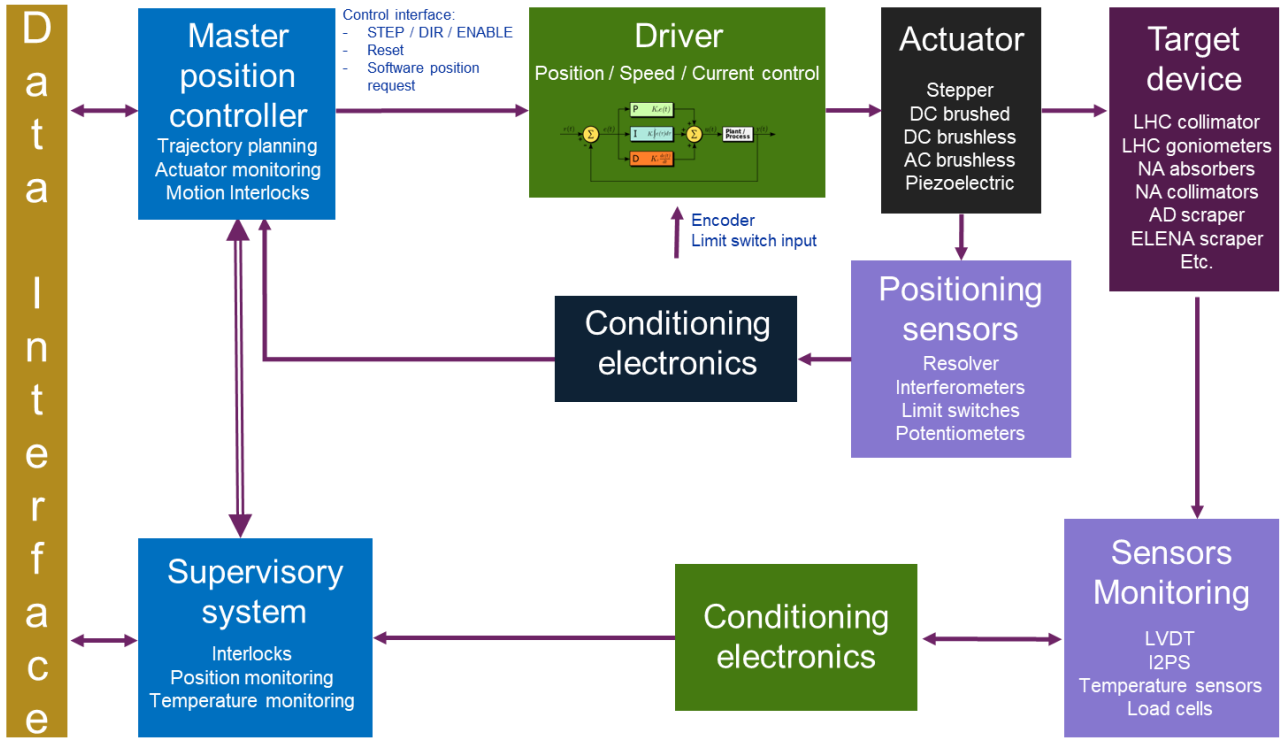
Quantity	Item	Estimated Budget Range	Market survey by
210 300	Stepping Motor Type 1 Stepping Motor Type 2	>750kCHF, <5 MCHF	Q3 2023

Technical responsible: Mario Di Castro
mario.di.castro@cern.ch

Sensors Acquisition & Motion Control (SAMbuCa)

- Flexible and modular low-level control solution for mechatronics devices to provide a standard mechatronics control solution (i.e. standard HW building blocks & API) for the Accelerator Technology Sector

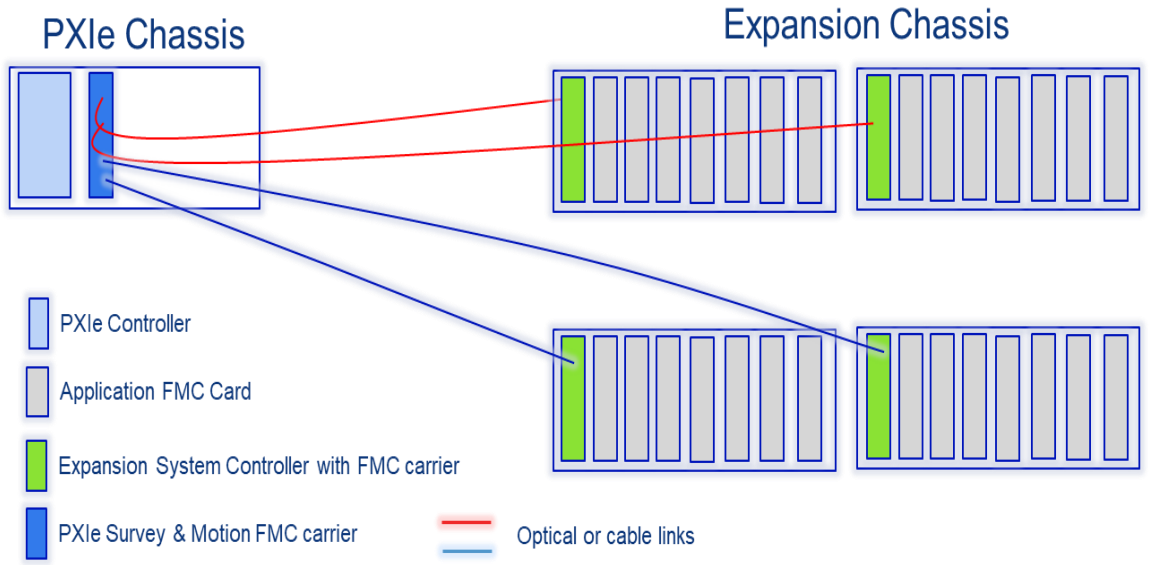
- Low level:
  - ✓ Hard RT constraints → FPGA-based controllers
    - ❑ timing synchronization (i.e. White Rabbit)
    - ❑ µs response time
- User friendly API to profit of all the hardware features



SAMbuCa architecture

Sensors Acquisition & Motion Control (SAMbuCa)

We are looking for industrial partners !

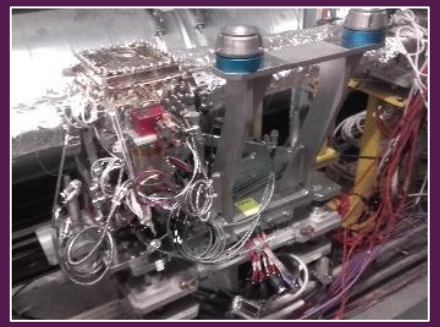


- ✓ **PXIe front-ends**
- ✓ **PXIe carrier card**:
  - ✓ equipped with a large FPGA for data processing and RT control
  - ✓ can host one FPGA Mezzanine Cards (FMC) to ensure the interface with the field instrumentation, sensors and actuators
- ✓ **Set of FPGA Mezzanine Cards (FMC)** to cope with the various field control and instrumentation applications (LVDT, resolvers, IOs, strain gauges, interferometer reading, motor drivers)
- ✓ **Expansion chassis** ensures modularity. It is equipped with a system controller linked and synchronized to the PXIe carriers via White Rabbit

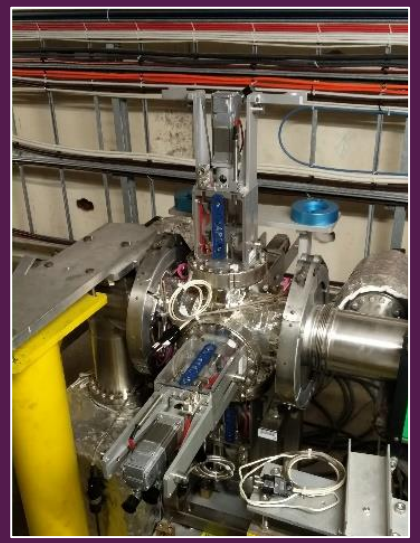
SAMbuCa: CERN Scope

LHC Collimator

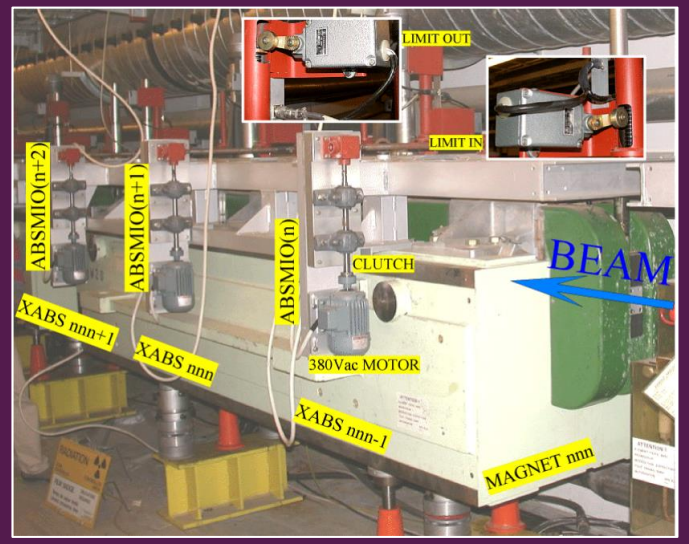
LHC crystal goniometer



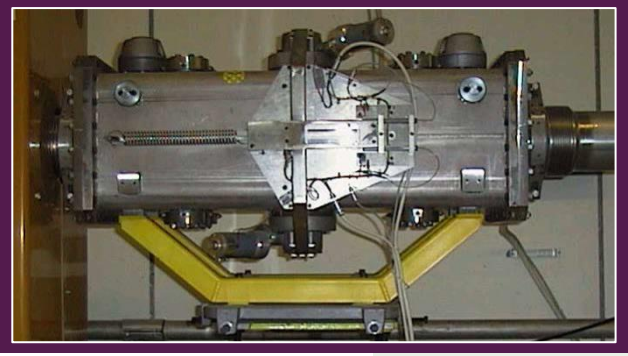
ELENA & AD scrapers



NA absorbers



NA collimators



Actuator

Stepper
DC brushed
DC brushless
AC brushless
Piezoelectric

Target device

LHC collimator
LHC goniometers
NA absorbers
NA collimators
AD scraper
ELENA scraper
Etc.

Positioning sensors

Resolver
Interferometers
Limit switches
Potentiometers

Monitoring sensors

LVDT
I2PS
Temperature sensors
Load cells

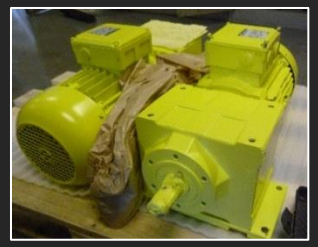
SAMbuCa: Actuators compatibility

Rad Hard Motors / Actuators up to 30 MGy

Stepper

DC brushless

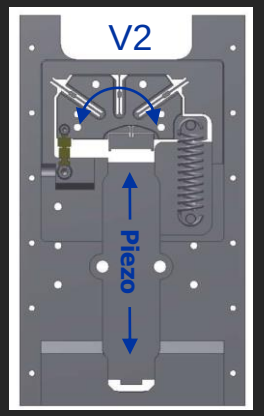
AC brushless



DC brushed

Flexural-hinge based rotational stage
Piezo linear movement
No backlash, hysteresis and creep
→ closed loop control

Piezo actuator



Developed Piezoactuators UHV, HT and Rad Hard

Actuator

Stepper
DC brushed
DC brushless
AC brushless
Piezoelectric

Target device

LHC collimator
LHC goniometers
NA absorbers
NA collimators
AD scraper
ELENA scraper
Etc.

Positioning sensors

Resolver
Interferometers
Limit switches
Potentiometers

Monitoring sensors

LVDT
I2PS
Temperature sensors
Load cells

SAMbuCa: Power Driver

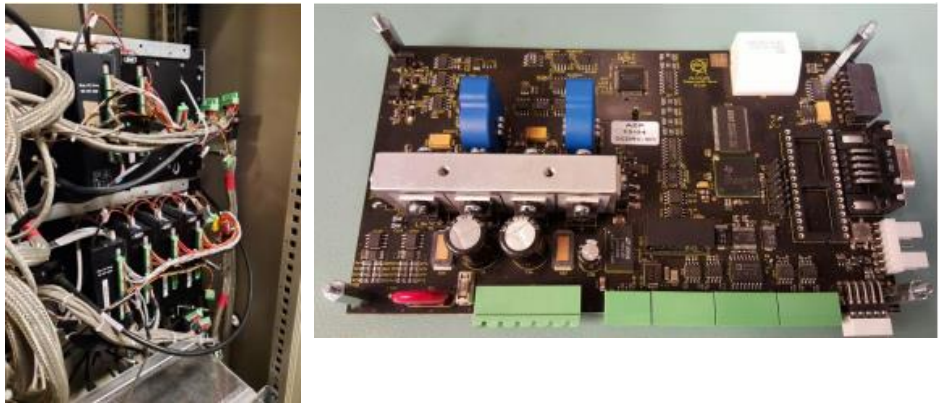
https://indico.cern.ch/event/1115112/contributions/4688938/attachments/2376100/4058940/2022-01-20%20Motor%20Driver%20Overview%20SAMbuCa.pdf

Main features

- Robust and accurate control of stepper and DC brushed motors in constant current or speed control (including also AC and DC Brushless)
- Use over long distances with cable length compensation up to 1km
- standard stepping (open loop) or FOC (closed loop) control via the same interface and hot swappable
- Kalman Filter for position and torque estimation

Main specifications

- ✓ Control of 1 stepper motor or 2 DC brushed motors or 1 DC brushless
- ✓ Maximum current per phase: 10 A (rms)
- ✓ Maximum DC voltage: 170 V
- ✓ Communication interface: MODBUS over RS485, PROFINET, Standard stepper interface (STEP, DIRECTION, ENABLE)
- ✓ Supports up to 2 encoders
- ✓ Current loop bandwidth up to 1 KHz

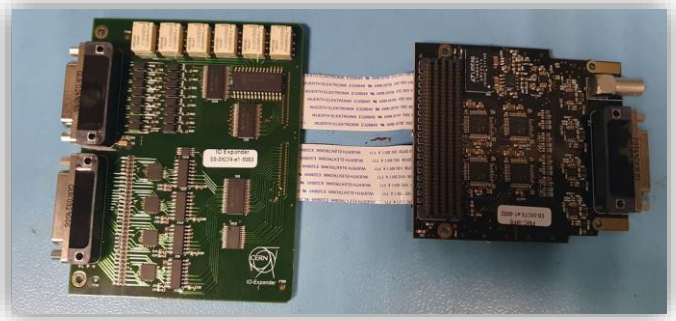


Previous driver version in operation

SAMbuCa: other building blocks

For detailed information: Home · Wiki · Projects / SAMbuCa · Open Hardware Repository (ohwr.org)

PXIe standard High Availability Chassis



- FMC cards for step motion control: gateware grbl interpreter based
  - General purpose DI/DO/AI/AO
  - Resolvers, LVDTs, potentiometer front end module

https://ohwr.org/project/fmc-mfe/wikis

- COM Express CPU

- PXIe carrier card for FPGA Mezzanine Card (FMC) standard

https://ohwr.org/project/spexi7u/wikis/home

- COM Express-PXIe adapter

https://ohwr.org/project/pxie-ctl-comexpress/wikis

SAMbuCa: procurement numbers

Item	Tot. Number
PXIe Carrier	**400**
AF Motion Control FMC Card	**400**
COMe – PXIe	**400**
COMe CPU	**400**
Stepping Motor Driver	**1200**

Item	Estimated Budget Range	Market survey by
Stepping Motor Drivers	200k<c<750k	Q2 2024
FMC cards for Motion Control	50k<c<200k	Q1 2024
PXIe-COMe adapter	200k<c<750k	Q1 2024
COMe CPU	200k<c<750k	Q4 2023
PXIe Carrier	200k<c<750k	Q1 2024

Technical responsible: Javier Serrano
Javier.Serrano@cern.ch

Quench Heater Power Supplies (Superconducting Magnet Protection)

- Quench heater power supplies are an essential part of the quench protection system for the new HL-LHC magnets
- The systems have been designed by CERN and will have to be built to print

Front panel


Back panel


Capacitors

Quantity	Estimated Budget Range	Market survey by
270	>750kCHF, <5 MCHF	Q4 2022

Technical responsible: Mirko Pojer
Mirko.Pojer@cern.ch
David Carrillo
d.carrillo@cern.ch

Quench Heater Power Supplies: Main parameters

- ✓ Max. stored energy: 3.5 kJ +10%
- ✓ Nominal storage energy bank capacitance: 7.05 mF ± 20 %
- ✓ Operational peak current: 200 A
- ✓ Max. peak current: 300 A
- ✓ Rated voltage: 940 V DC (expected range 920-960 V DC assuming ± 2 % of the 230 V AC input power variation)
- ✓ Max (continuous) rated voltage: 1000 V DC
- ✓ Total weight of the unit < 25.5 kg
- ✓ Rack dimensions: Height 5 U x Width 19 inches x maximum length: < 600 mm

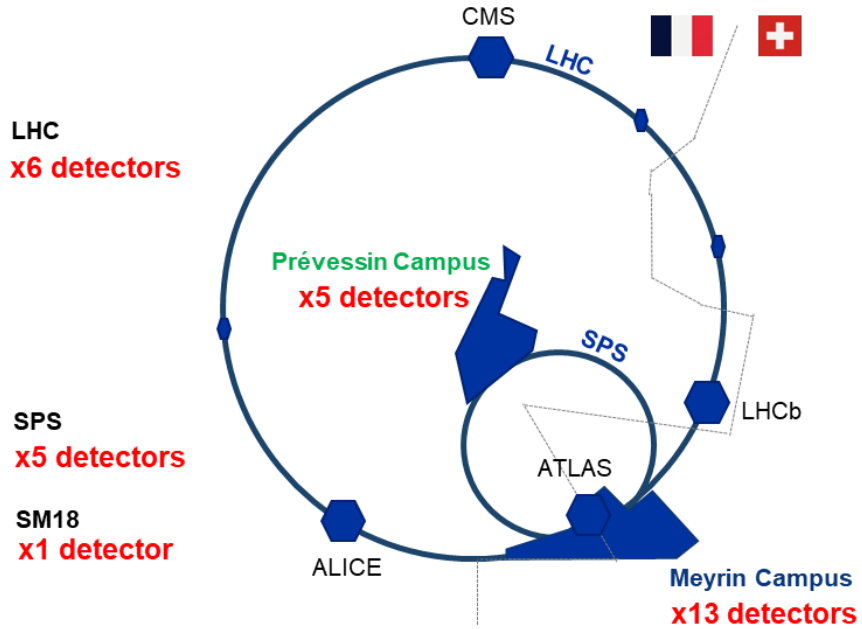
Technical responsible: Mirko Pojer
Mirko.Pojer@cern.ch
David Carrillo
d.carrillo@cern.ch

Site Gate Monitors

Overall Objective: Prevent Harm to the Environment

1. Reliable and fast detection of radioactive objects aboard vehicles and originating from CERN activities
2. Intercept and identify those vehicles through the site exit control system

- **Complete renewal of CERN car gates RP monitoring systems by LS3 (i.e. 2028)**
- **The procurement strategy is not yet decided. Two possible alternatives:**
  - **Full externalization → engineering and manufacturing (open to collaboration)**
  - **Partial externalization → Only manufacturing and assembly (engineering in house)**



Quantity	Item	Estimated Budget Range	Market survey by
30	Site Gate Monitoring System	>750kCHF, <5 MCHF	Q3 2023

Technical responsible: Hamza Boukabache
hamza.boukabache@cern.ch

Site Gate Monitoring

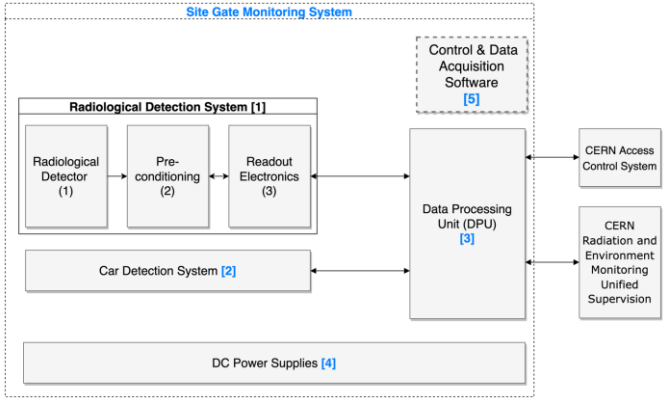
Detection and interception of radioactive objects at CERNs site exits

Current system

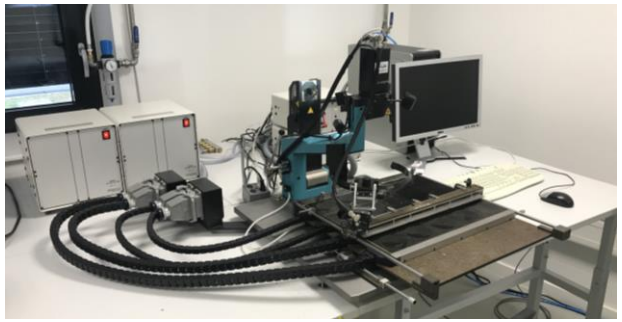
Main Challenges :

- **False detection rate less than 0.001% (>2.4M cars/year)**
- **Detection performances**
- **Live control on vehicles flow without traffic disruption**
- **integration into CERN SCADA systems and CERN access system**

- **The site gate monitor system is based on:**
  - ✓ **Radiology detection system**
  - ✓ **Car detection system**
  - ✓ **Processing and control unit**



Electronics Workshop machines renewal



BGA repair station:

Infra-red based process, embedded mini-stencil station, live process control (temp+camera), max PCB dimension to be determined, semi-automated at least

Item	Estimated Budget Range	Market survey by
BGA repair station	<200k	Q1 2023
Reflow oven	200k<c<750k	Q1 2024

Reflow oven:

Vapor phase process, real time temperature control, PCB dimension up to 650x650mm, batch equipment

Technical responsible: Raphael Berberat
Raphael.Berberat@cern.ch

Robotics related possible future procurements

- ROV with robotic arm
  - ✓ Minimum 6DoF
  - ✓ ~ 100 kg payload
  - ✓ Minimum speed 2km/h
  - ✓ Battery autonomy > 4hours
- ROV base only
  - ✓ Minimum speed 2km/h
  - ✓ Battery autonomy > 4hours

- Versatile legged and wheeled solutions to reach complicated zoned with robotic arm
  - ✓ ~ 5 kg payload
  - ✓ Minimum speed 2km/h
  - ✓ Battery autonomy > 2 hours

- Motion capture system
  - ✓ Area to cover ~ 5 x 5 meters
  - ✓ Sub mm precision
  - ✓ Up to 20 objects to track
  - ✓ > 200 Hz of acquisition rate

www.telerob.com

www.hawe.com/it-it/

www.bostondynamics.com

www.anybotics.com

https://optitrack.com/systems/

Robotics related possible future procurements

Item	Estimated Budget Range	Market survey by
ROV with robotic arm	200k<c<750k	Q3 2023
ROV base only	<200k	Q1 2023
Versatile legged and wheeled solutions	200k<c<750k	Q2 2023
Motion capture system	<200k	Q1 2023

Technical responsible: Mario Di Castro
mario.di.castro@cern.ch

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