FRAS Motorized Axes Control System

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Review of HL-LHC Alignment and Internal Metrology (WP15.4)

Outline

- The control system requirements
- Solution proposed: SAMbuCa
- Development Timeline
- Conclusions

FRAS Motorized axes IP5 summary

Racks location	Racks names	Cable length up to the sensors / actuators (m)	Axes type	Axes number	Axes` groups to be synchronized
UL557	GYPOS_01 ÷ GYPOS_04	100	Motion (stepping motor + resolver)	60	30 +30
			Load cells(TBC)	36 ÷ 60	0
			Position sensors (TBC)	60	0
UR55	GYPOS_01_R ÷ GYPOS_06_R	300	Motion (stepping motor + resolver)	71	24+16+10+10+10
			Load cells(TBC)	31	0
			Position sensors (TBC)	31	0
UR55	GYPOS_01_L ÷ GYPOS_06_L	300	Motion (stepping motor + resolver)	71	24+16+10+10+10
			Load cells(TBC)	31	0
			Position sensors (TBC)	31	0

FRAS Motorized axes IP1 summary

Racks location	Racks names	Cable length up to the sensors / actuators (m)	Axes type	Axes number	Axes` groups to be synchronized
UR15	GYPOS_01 ÷ GYPOS_04	100	Motion (stepping motor + resolver)	60	30 +30
			Load cells(TBC)	36 ÷ 60	0
			Position sensors (TBC)	60	0
US15	GYPOS_01_R ÷ GYPOS_06_R	300	Motion (stepping motor + resolver)	71	24+16+10+10+10
			Load cells(TBC)	31	0
			Position sensors (TBC)	31	0
US15	GYPOS_01_L ÷ GYPOS_06_L	300	Motion (stepping motor + resolver)	71	24+16+10+10+10
			Load cells(TBC)	31	0
			Position sensors (TBC)	31	0

FRAS Motorized axes summary

Axes type	Total Axes number
Motion (stepping motor + resolver)	400
Load cells (TBC)	194 ÷ 244
Position sensors (TBC)	244
Limits switches	1044

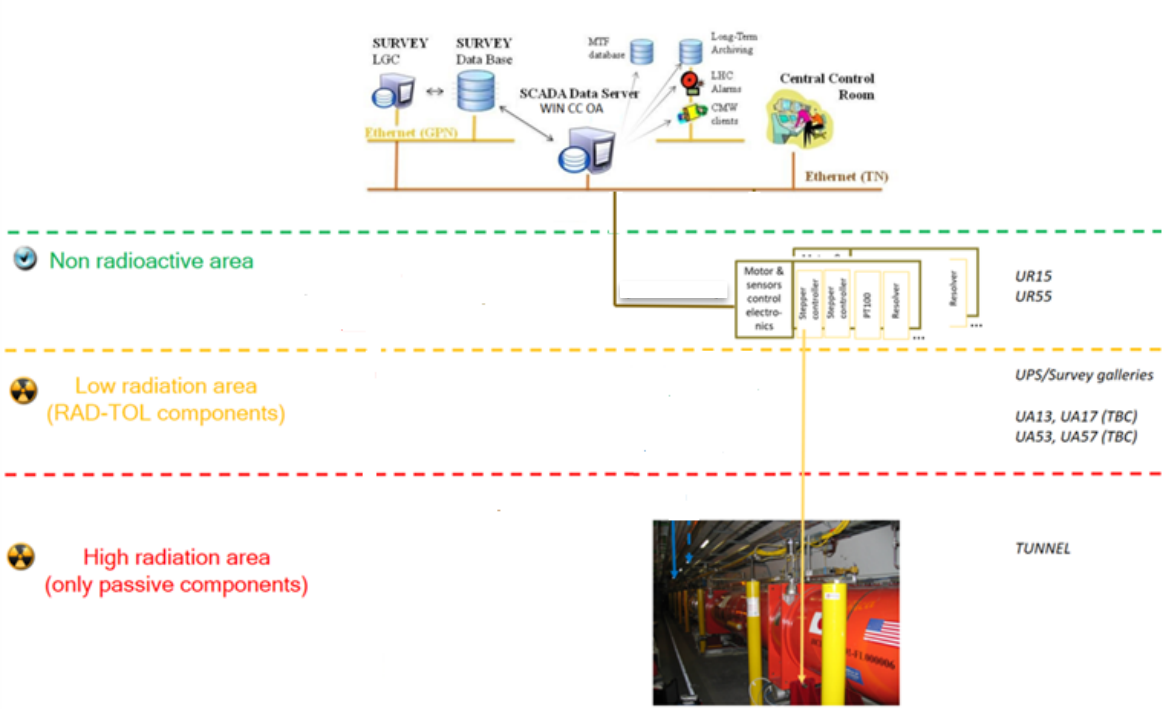
Control System Requirements

Sensors / Actuators	
Sensors / Actuators Total Integrated Dose (TID)	< 2 MGray
Sensors / Actuators cable length from the electronics	300 m
Maintenance	free
Life time	Min 10 years
Operation time	86 h

Control System Requirements

Control system architecture & components	
Axes positioning resolution	few µm
Axes motion synchronization	1s per axes` groups (system can achieve 1 ms)
Motion start trigger	Software trigger
Modularity	Architecture scalable with number and axes` groups position in the racks
Flexibility	Conditioning electronics proper designed for the project actuators / sensors
Fields I/O connectivity	High Density / High robustness to avoid false contacts and oxidation
Maintainability	Mean Time To Repair < 10min
Long term investment	Full control of hw and sw for future upgrades / improvements

Control system architecture



Maximum distance to the control / command system	300 m
Control/command system located in a non-radioactive area	

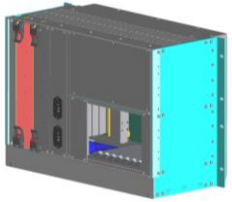
Low-level control: SAMbuCa (Sensors Acquisition & Motion Control system)

Complete In-house solution (i.e. hw and sw)

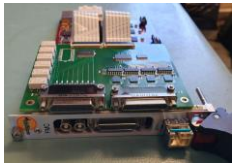
Architecture :

- **PXIe Front-ends in High Availability chassis**

  PXIe chosen as successor of the PXI standard that is getting obsolete - Platform fully standardized at CERN with BE-CO (i.e. Cent OS 7 and C++)



- **a PXIe FPGA Carrier and a set of FMC cards to cover the interfacing requirements with the field sensors and actuators**



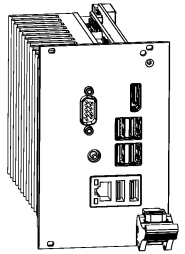
- **EN-SMM step driver (long cables, open/closed loop)**

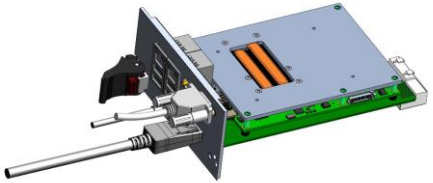
- **Focus on connection reliability and re-configurability**

Same control system solution to be adopted for the LHC Collimators low level control upgrade (HL-LHC – Collimation System International Review Feb2019)

Low-level control: SAMbuCa (Sensors Acquisition & Motion Control system)

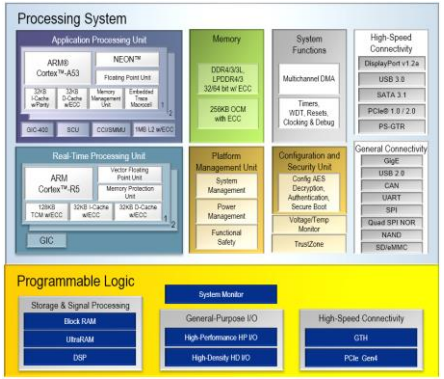
- PXIe Controller
  - Based on COM-Express CPU modules
  - Computing power chosen according to user needs
- Will run Be/CO Linux and FESA class
- Software framework and Linux drivers to configure and control the peripheral cards
- Collaboration with BE/CO to ensure the compatibility with their ecosystem– Open Hardware
- Design in progress – Outsourced to external company



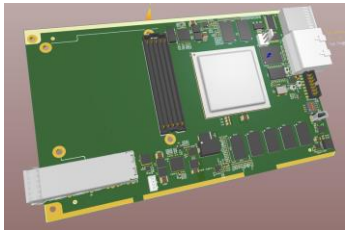


Low-level control: SAMbuCa (Sensors Acquisition & Motion Control system)

- PXIe FMC Carrier
  - Based on Xilinx Zynq UltrasScale+
  - PCIe Gen2x4
  - 4GB DDR4 memory with ECC for processor
  - 2GB DDR4 memory for programmable logic
  - 64GB eMMC flash
  - Remotely reconfigurable from PXIe controller
  - White-Rabbit support for synchronization
  - HPC FMC connector fully wired to FPGA
  - Board layout in progress, prototype expected by Q4 2019

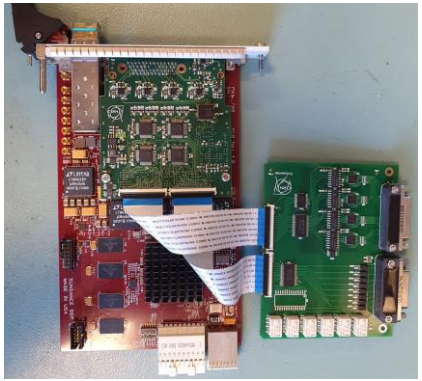


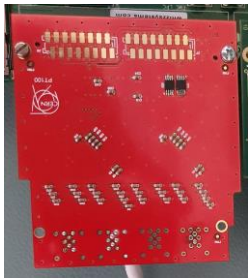
- Control algorithms executed either by ARM cores or programmable logic



Low-level control: SAMbuCa (Sensors Acquisition & Motion Control system)

- Set of FMC cards
  - 8-ch LVDT/Resolver/Potentiometer analog front-end
  - 12-ch Thermocouple/PT100
  - Digital IOs (limit switch, interlock, motor driver, …)
  - Strain gauge
  - Force sensor
  - Optical fiber card to connect an expansion chassis (CompactPCI serial from BE/CO)



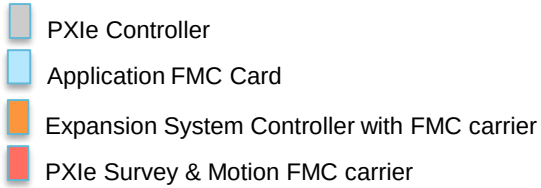


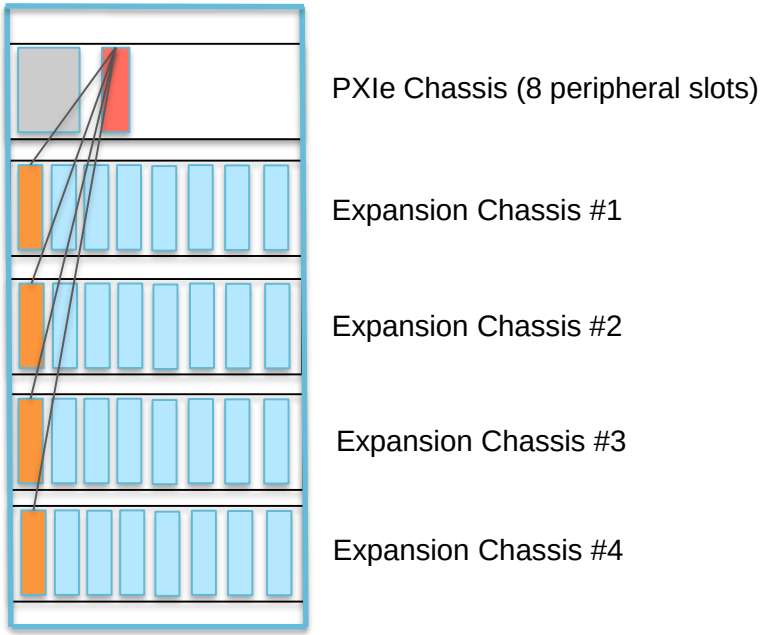
Low-level control: SAMbuCa (Sensors Acquisition & Motion Control system)

- Expansion chassis with DIOT (WP18 HL-LHC)
  - https://wikis.cern.ch/display/DIOT/Distributed+IO+Tier+chassis
  - Possibility to connect up to 4x chassis to PXIe FMC carrier
  - Can be an option for slow application

Low-level control: SAMbuCa (Sensors Acquisition & Motion Control system)

- Rack layout example
  - 4 expansion chassis connected to PXIe FMC carrier via optical links





Development Timeline

- Proof of concept 2020
- FRAS control system validation on string tests
- Mass production and validation 2022-2023
- Operational software 2024
- Deployment and commissioning 2025-2026

Conclusions

- Design study shared with LHC collimator control system
- Building blocks profit of BE/CO developments foreseen in WP18 HL-LHC (expansion chassis)
- SAMBUCA will ensure with respect to commercial solutions
  - Full control on hardware and software components
  - High-availability ensured by 15-years past experience on motion control for critical missions (e.g. LHC collimator control system)

Thank you