WPENS/DONES
General overview on
Central Instrumentation and Control Systems (CICS)

WIP FUSPHY

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VC

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Outline

1. Introduction to the DONES Project

2. Central Instrumentation and Control Systems

3. Further works in FP9 (2022-2025)

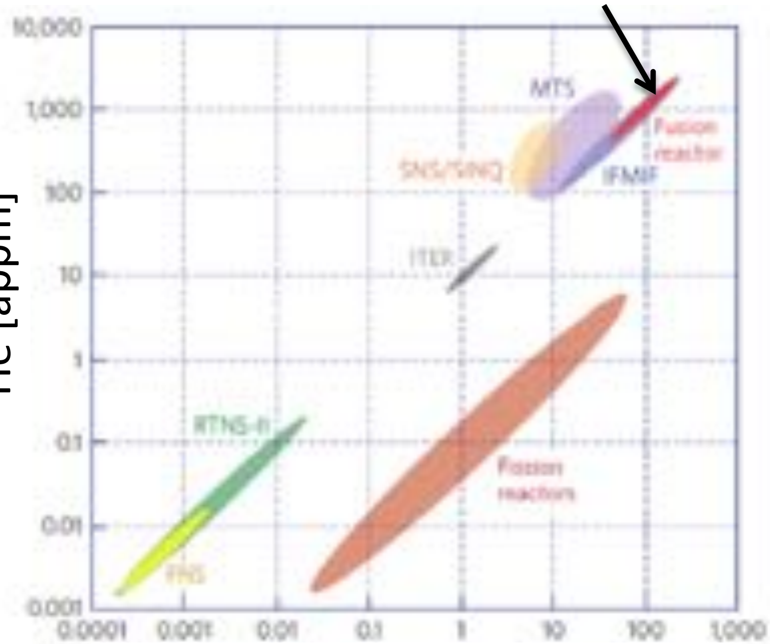
Introduction to the DONES Project

Why a neutron source for fusion?

The first wall will be exposed to high heat fluxes, radiation damage from 14.1 MeV neutrons and He injection from the plasma as well as He production from (n,α) reactions.

In DEMO: **~10-12 appm He/dpa**

He [appm]



Dispacement damage [dpa]

Presently available n sources are not adequate to reproduce fusion-like environment

- **Fission reactors:**

  0.3 appm He/dpa

- **Spallation sources:**

  50-70 appm He/dpa, pulsed, light ions,…

International consensus was reached on developing accelerator-based neutron sources exploiting **D-Li stripping reactions**:

Li(d,xn)

as the optimal choice to provide **suitable n flux and spectrum** to reproduce the irradiation conditions of fusion reactors

A 40-years long history…

In the '80s
FMIT (Fusion Materials Irradiation Test) in the US
deuterons at 100 mA in CW and 35 MeV for a 0.01 l volume

In the '90s
ESNIT (Energy Selective Neutron Irradiation Test) in Japan
deuterons at 50 mA and 40 MeV for a 0.125 l volume

Since 1994
IFMIF (International Fusion Materials Irradiation Facility)
RF, US, **JA, EU** joined efforts and generated a baseline

Since 2007
IFMIF/EVEDA project included in the EU-JA Broader Approach Agreement
JA, EU joined efforts

IFMIF Intermediate Engineering Design report (2013)

…and the current scenario in EU fusion roadmap

The staged approach

Stage	Objective	Accumulated damage
DEMO Phase-I	Start-up and feasibility evaluation	< 20 dpa (Fe)
DEMO Phase-II	Availability improvement and lifetime	< 50 dpa (Fe)
Power Plant	Commercial operation	> 100 dpa (Fe)

Demo-Oriented early NEutron Source (DONES)

Upgrade to full IFMIF

IFMIF-DONES top-level requirements

Requirement	Value	Remarks
Accumulated damage / irradiation volume	• 20-30 dpa_{NRT} (Fe) in < 2.5 years over 300 cm^3 • 50 dpa_{NRT} (Fe) in < 3 years over 100 cm^3	> 8-12 dpa/fpy in 0.3 l > 16 dpa/fpy in 0.1 l
Irradiation Temperature	250-550 °C	Actively controlled
Plant lifetime	30 years	
PIE	External lab	

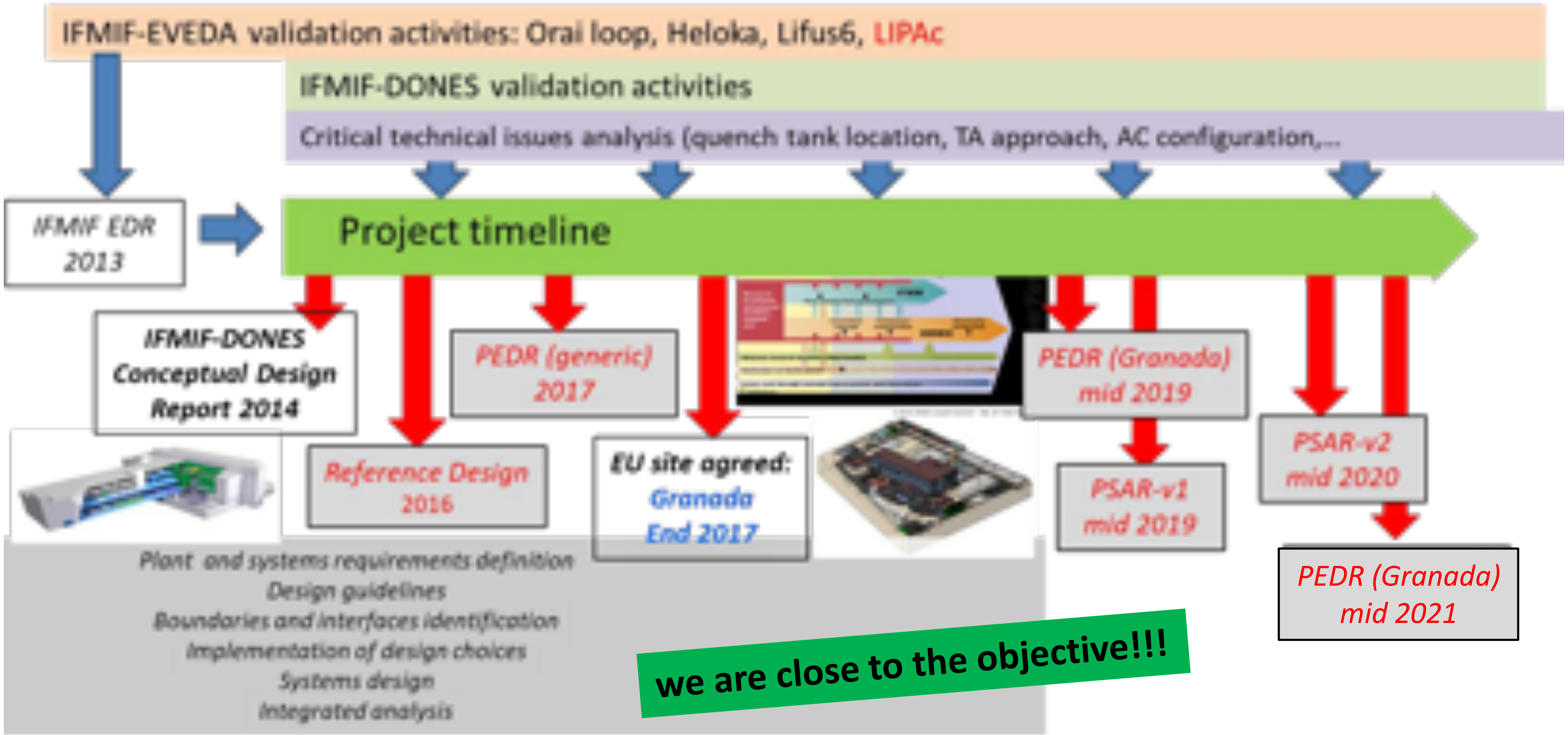
The DONES Project

DONES-related activities at the EU level are presently running in different frameworks:

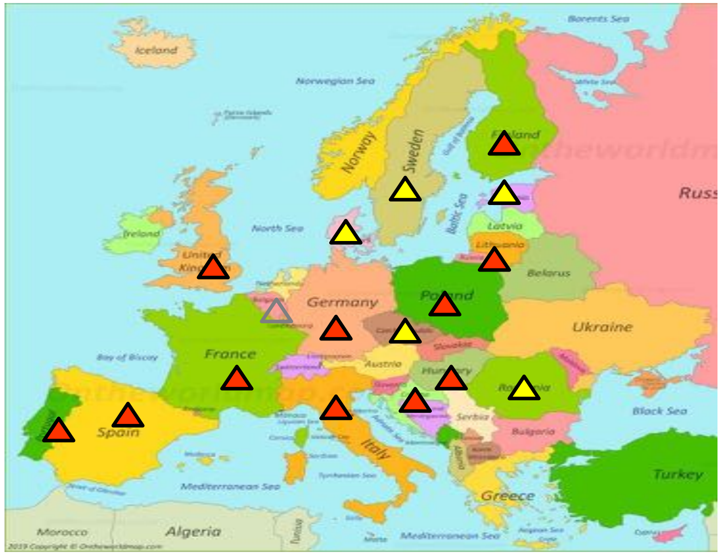
- **IFMIF/EVEDA** (included in the BA)
- **WPENS** –including specific Industry contract- (EUROfusion WP)
- **DONES-PreP** (ESFRI preparatory phase, EURATOM CSA)
- **DONES-PRIME** and **DONES-UGR** (Spanish funded projects)

DONES-PRIME
DONES-UGR

The DONES Project: FP8

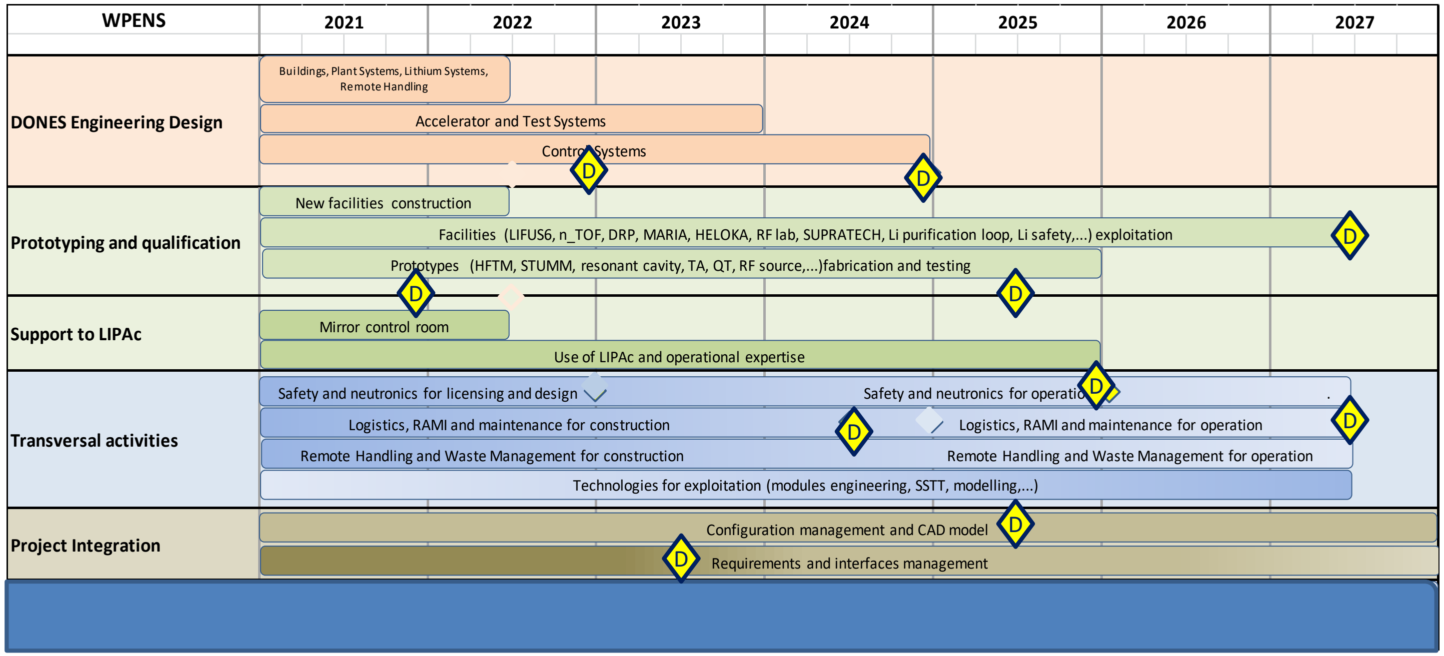


The DONES Project: FP9

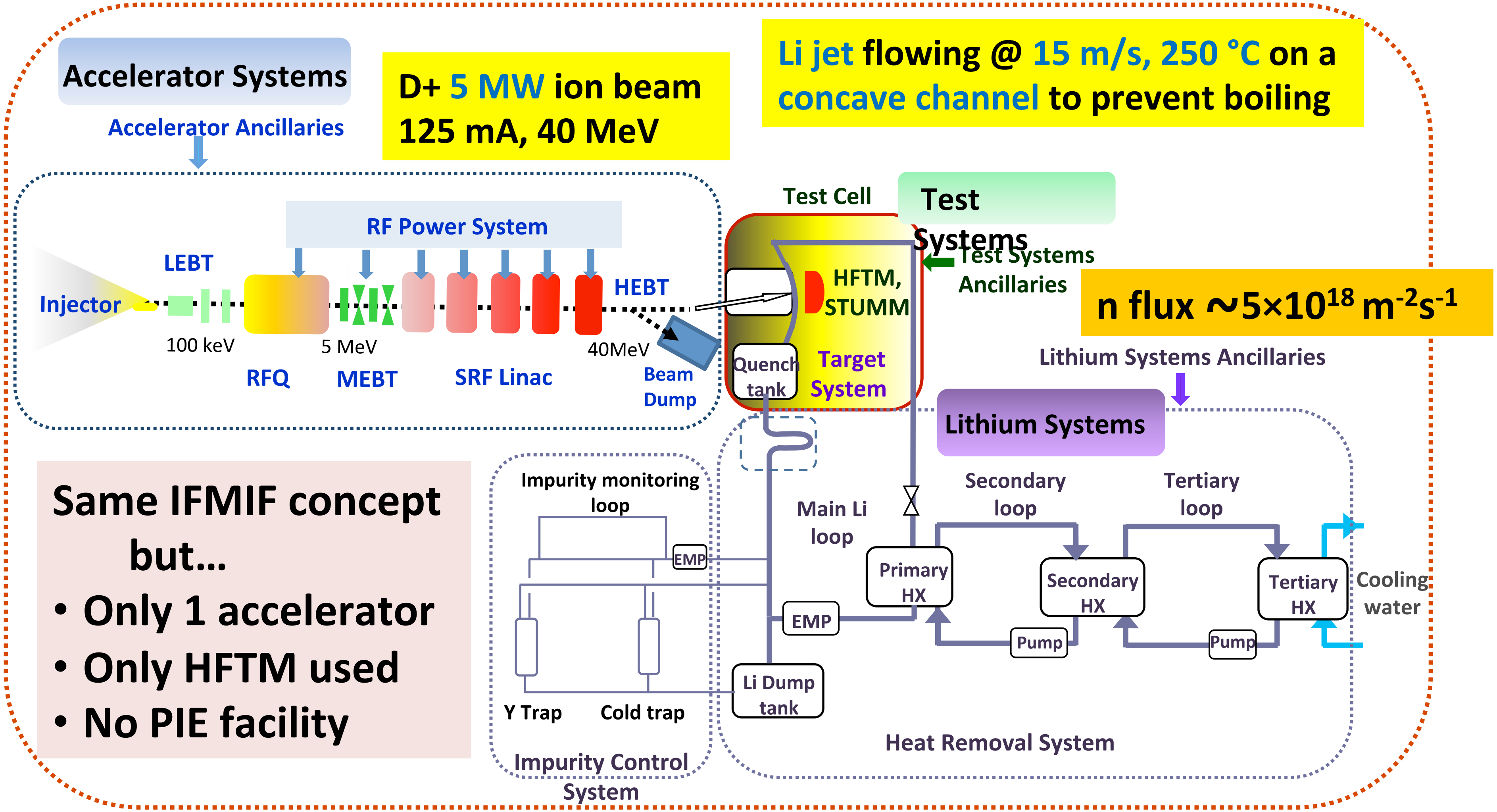


Up to 16 RUs (in some cases involving also several Associated Entities –research institutions or companies- in the country)

NEW PHASE!



IFMIF-DONES Plant configuration



Site, Buildings & Plant Systems

- Layout & Site Infrastructures
- Buildings
- HVAC, Electrical Power Supply, HRS, etc.
- Remote Handling System

Central Instrumentation and Control Systems

- CODAC System
- Machine Protection System
- Safety Control System

Introduction to the Central Instrumentation and Control Systems (CICS)

DONES CICS Current Team

ENEA
Mauro Cappelli (Coordinator)

CIEMAT
Joaquin Molla
Victor Gutierrez

Ansaldo Nucleare
Andrea Bagnasco (SR)
Francesca Ambi (SR)
Enrico Botta (SR)

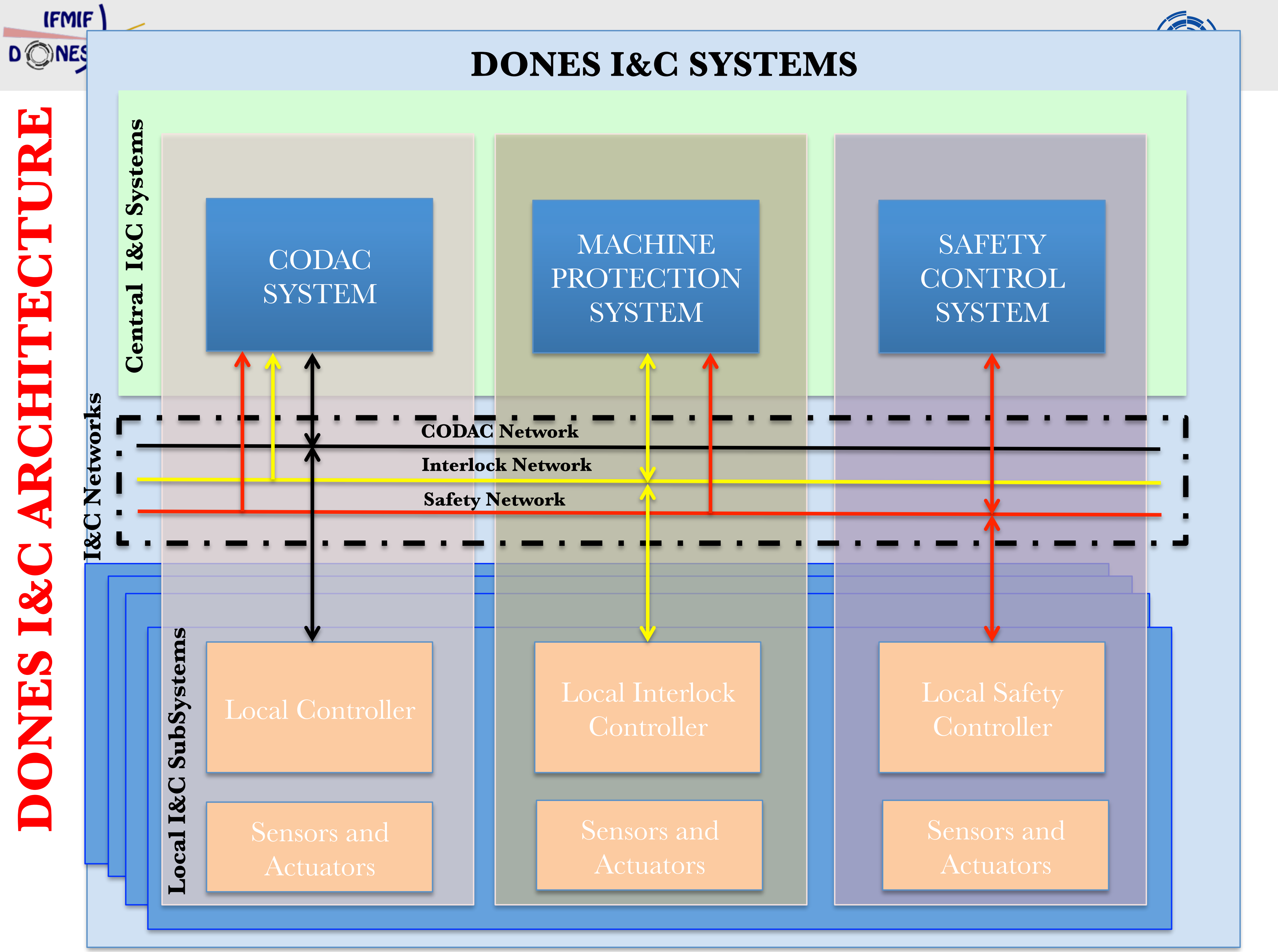
University of Granada
Javier Diaz

IPFN
Jorge Sousa

S2 Innovation (New Comer 2021)
Wojciech Soroka
Piotr Goryl

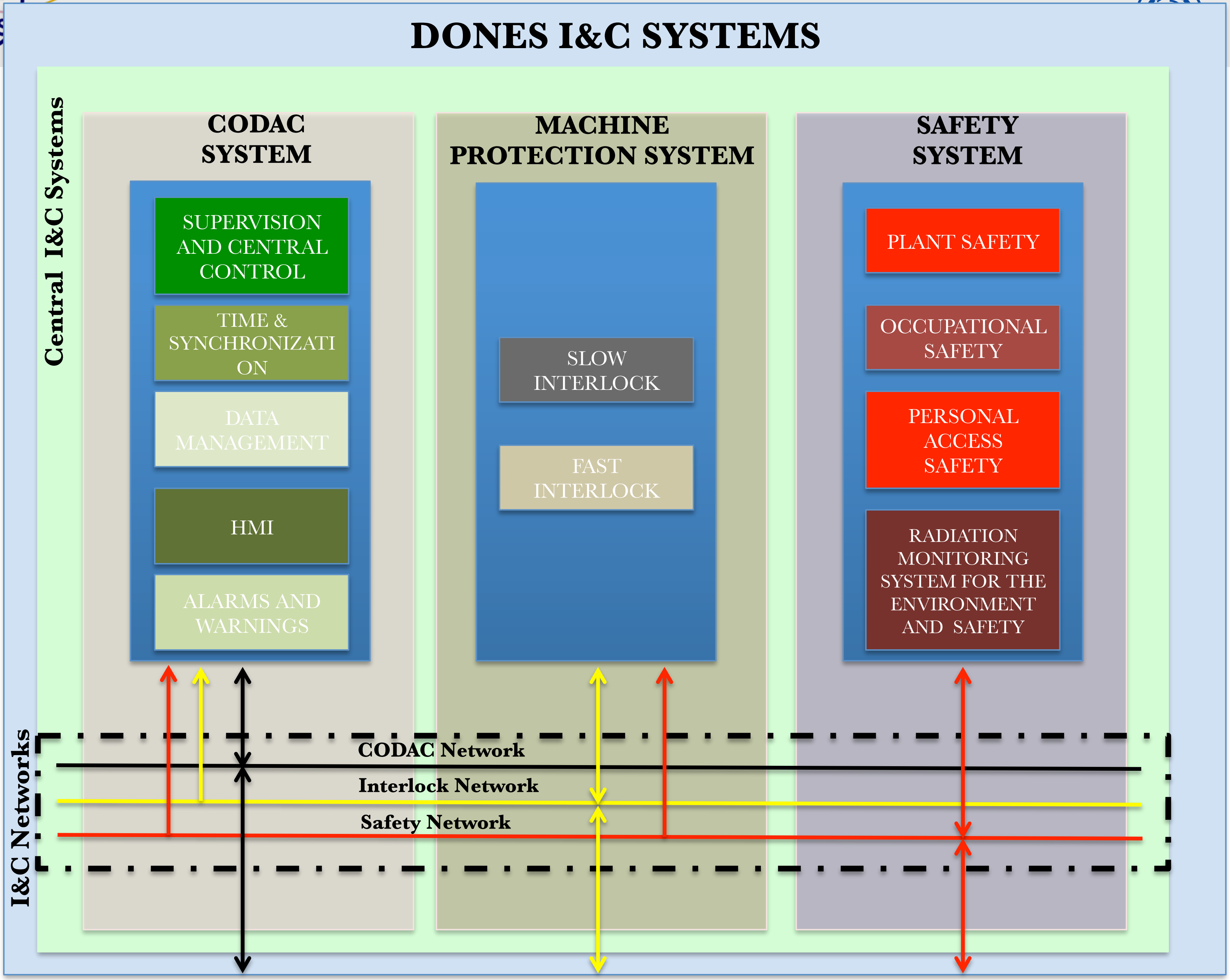
University of Aalborg (New Comer 2021)
Zhe Chen

General architecture

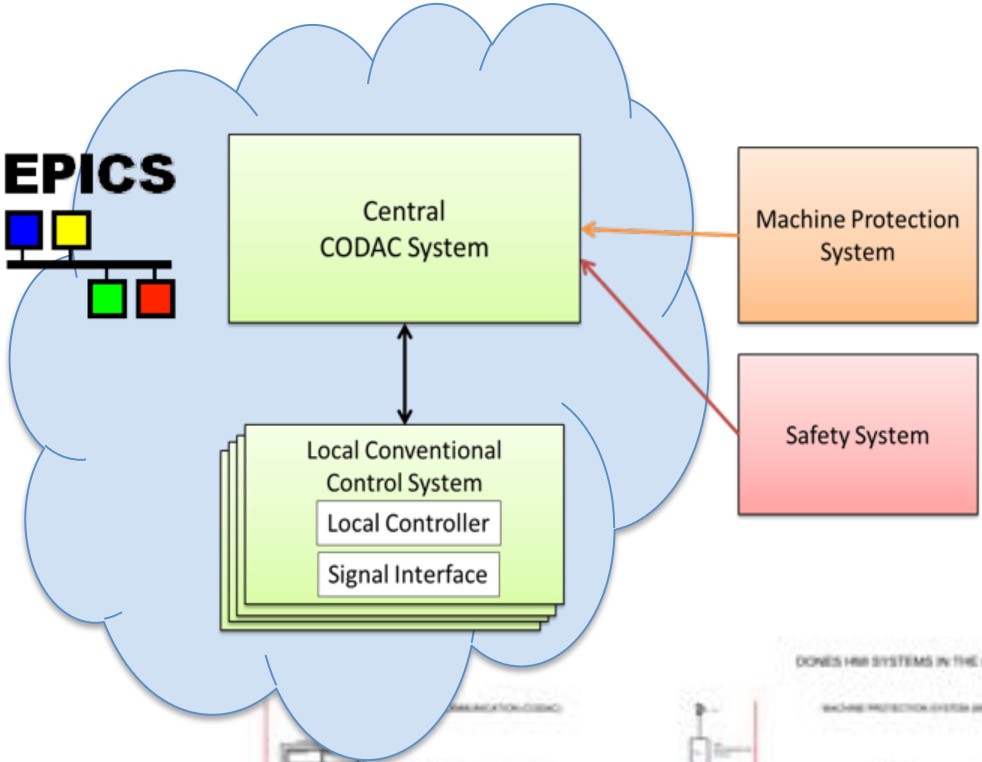


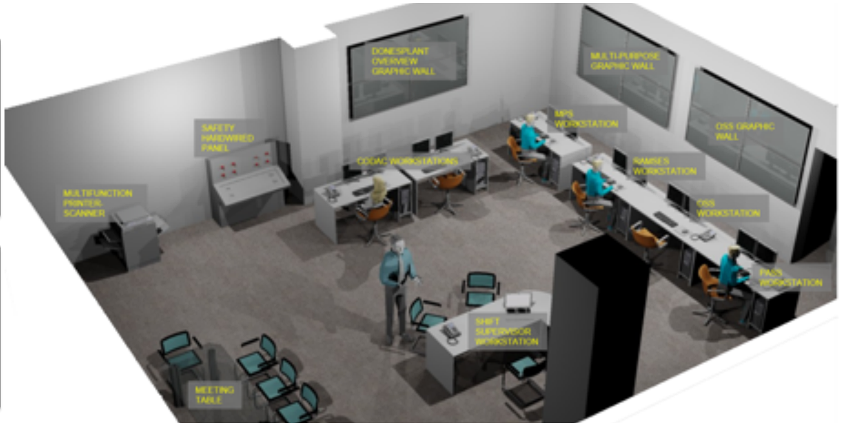
DONES I&C ARCHITECTURE
DONES I&C SYSTEMS
Central I&C Systems
CODAC SYSTEM
MACHINE PROTECTION SYSTEM
SAFETY CONTROL SYSTEM
I&C Networks
CODAC Network
Interlock Network
Safety Network
Local I&C SubSystems
Local Controller
Local Interlock Controller
Local Safety Controller
Sensors and Actuators
Sensors and Actuators
Sensors and Actuators

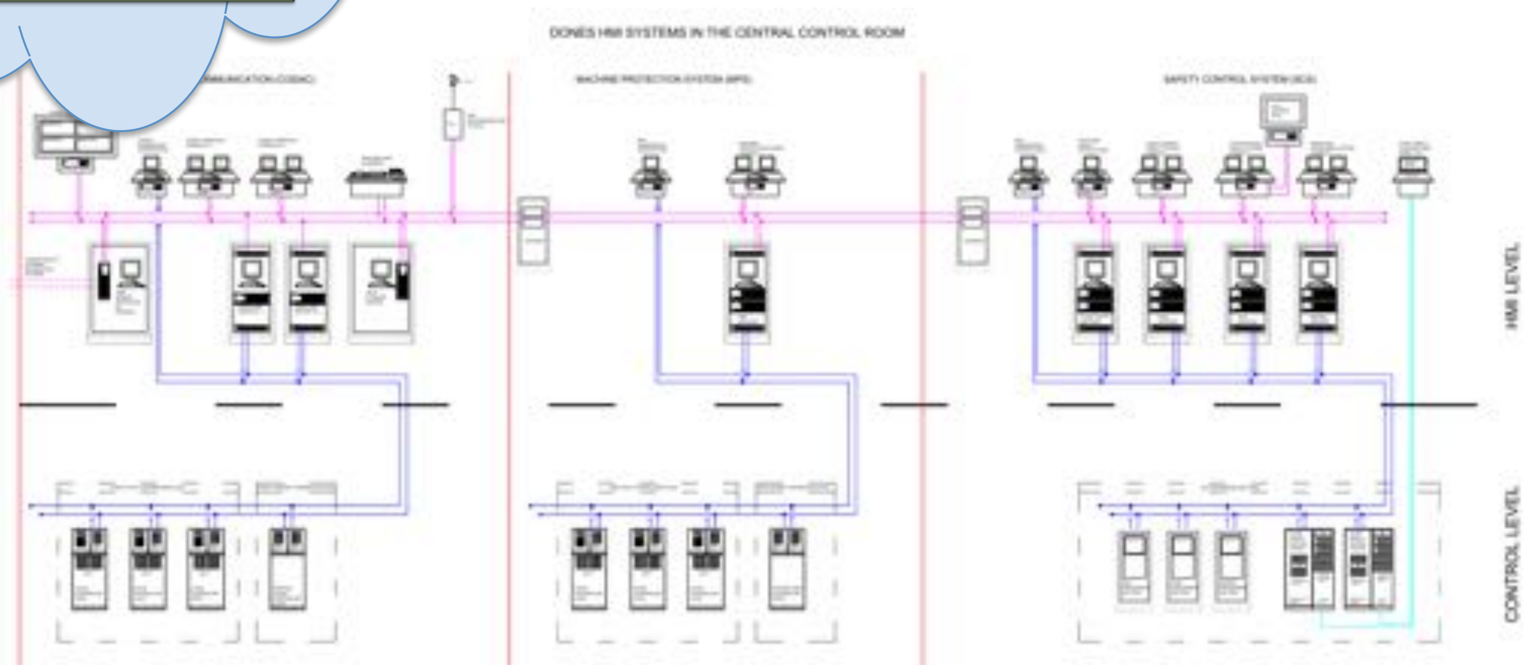
DONES I&C ARCHITECTURE



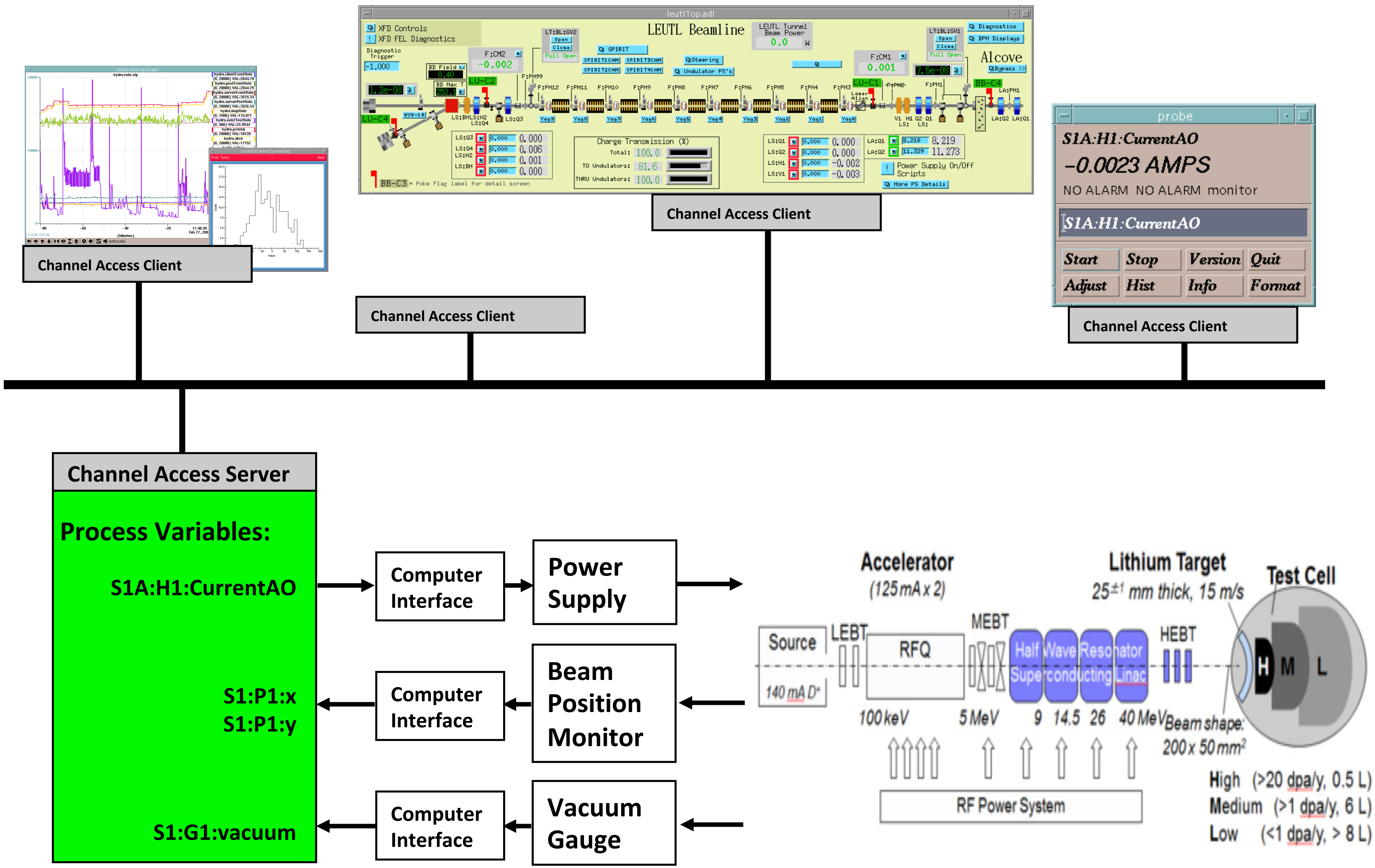
Relations among Control Systems



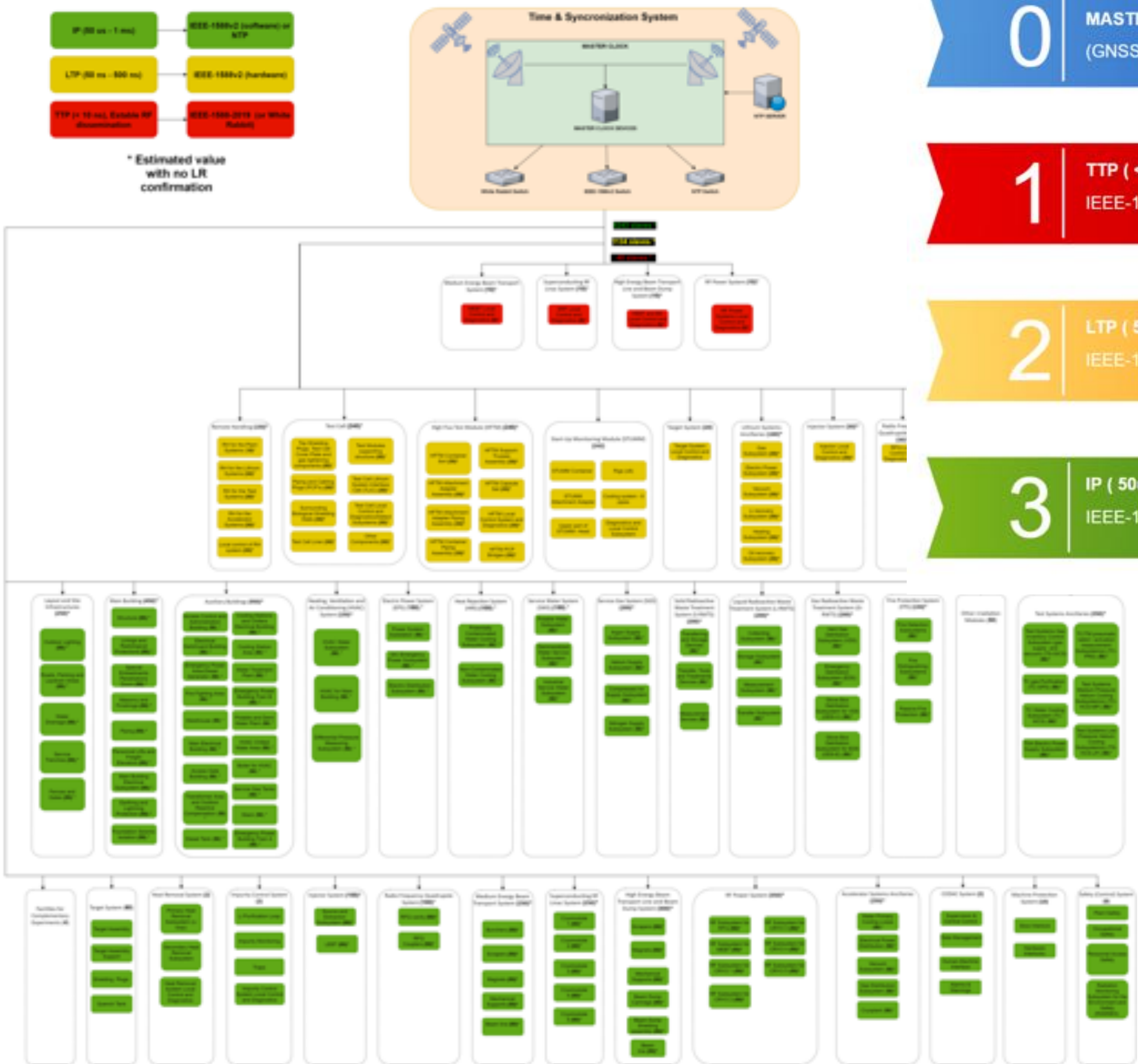




EPICS7 ARCHITECTURE



TIMING SYSTEM: Network Architecture



Time generation

0 MASTER CLOCK
(GNSS + OSCILLATOR + STEPPER)

1 TTP (< 10ns) Estable RF dissemination
IEEE-1588-2019 (or White Rabbit)

2 LTP (50ns - 500ns)
IEEE-1588-2019 (hardware)

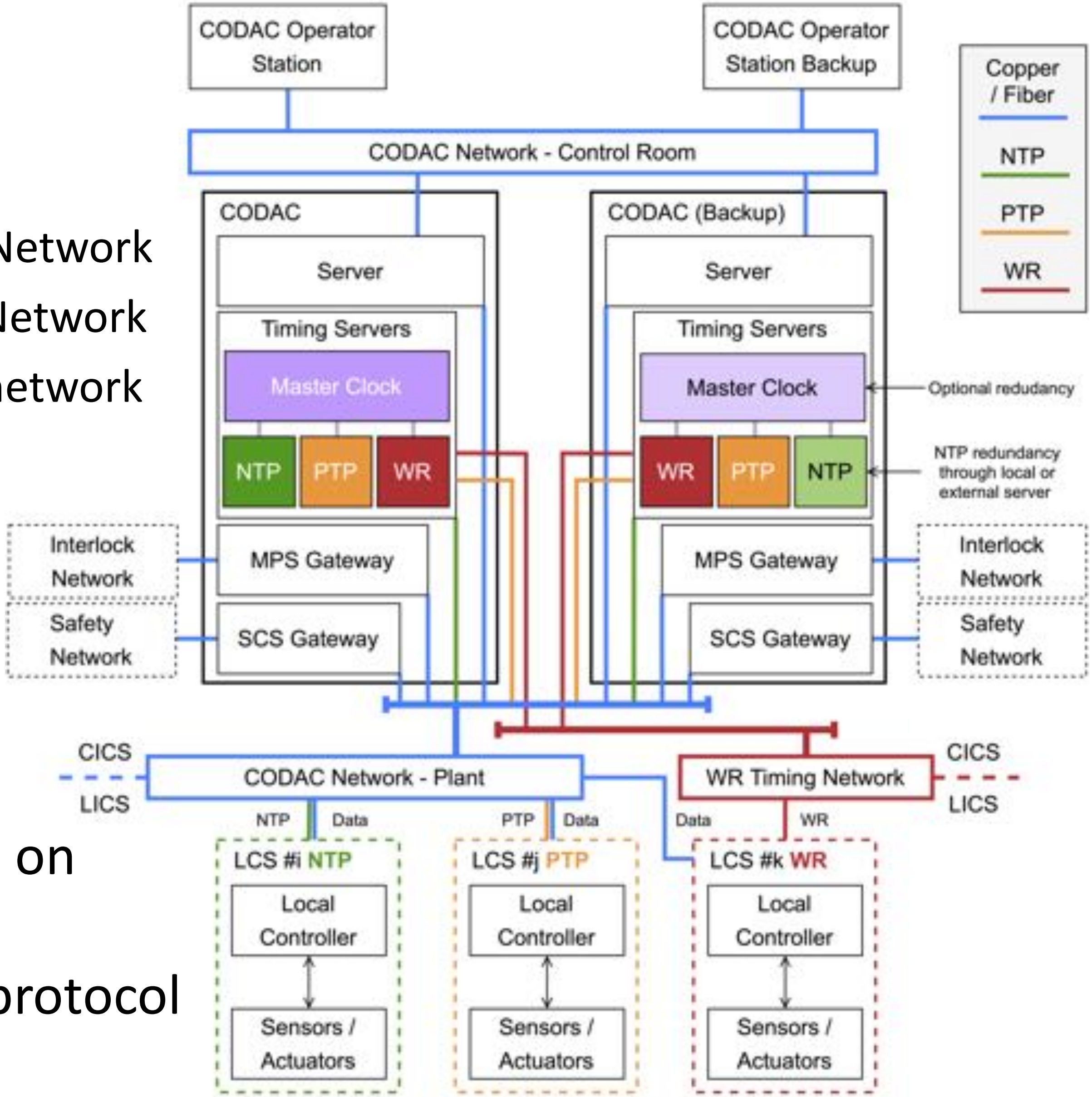
3 IP (50us - 1ms)
IEEE-1588-2019 (software) or NTP

Time transfer based on Ethernet protocols

Timing System and Network

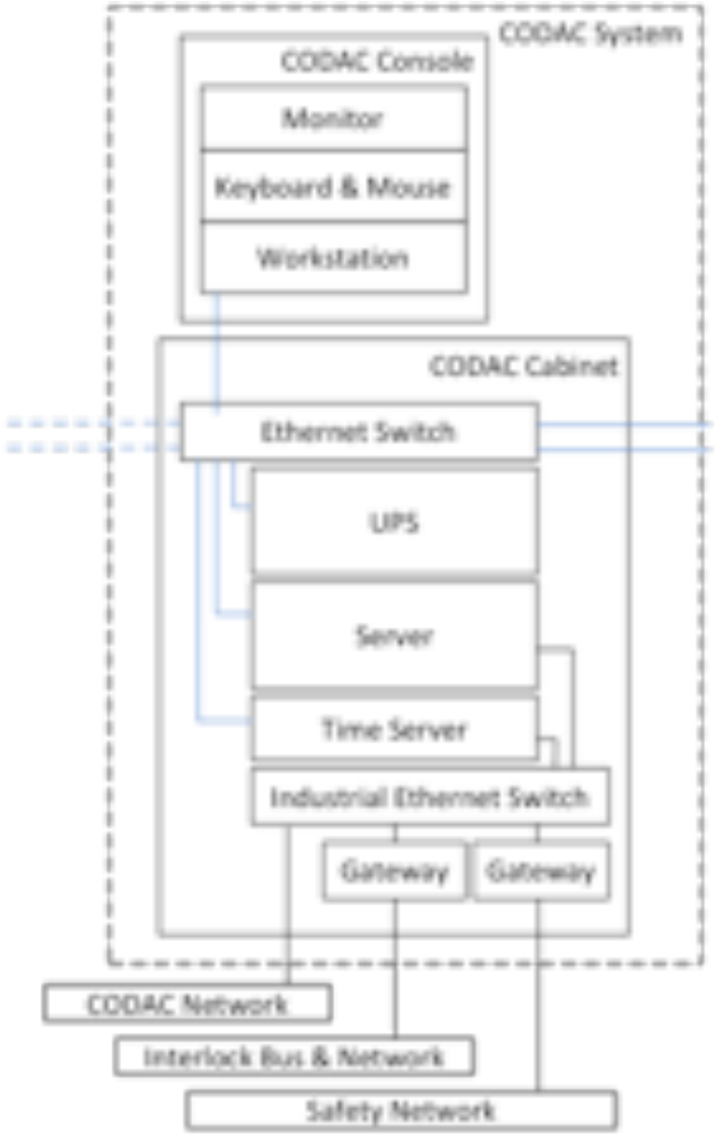
Integration

- 3 Timing Servers
  - **NTP**: to CODAC Network
  - **PTP**: to CODAC Network
  - **WR**: additional network
- **Master Clock**
- Backup side
  - Master Clock
  - Time Servers
- LICS may depend on more than one synchronization protocol

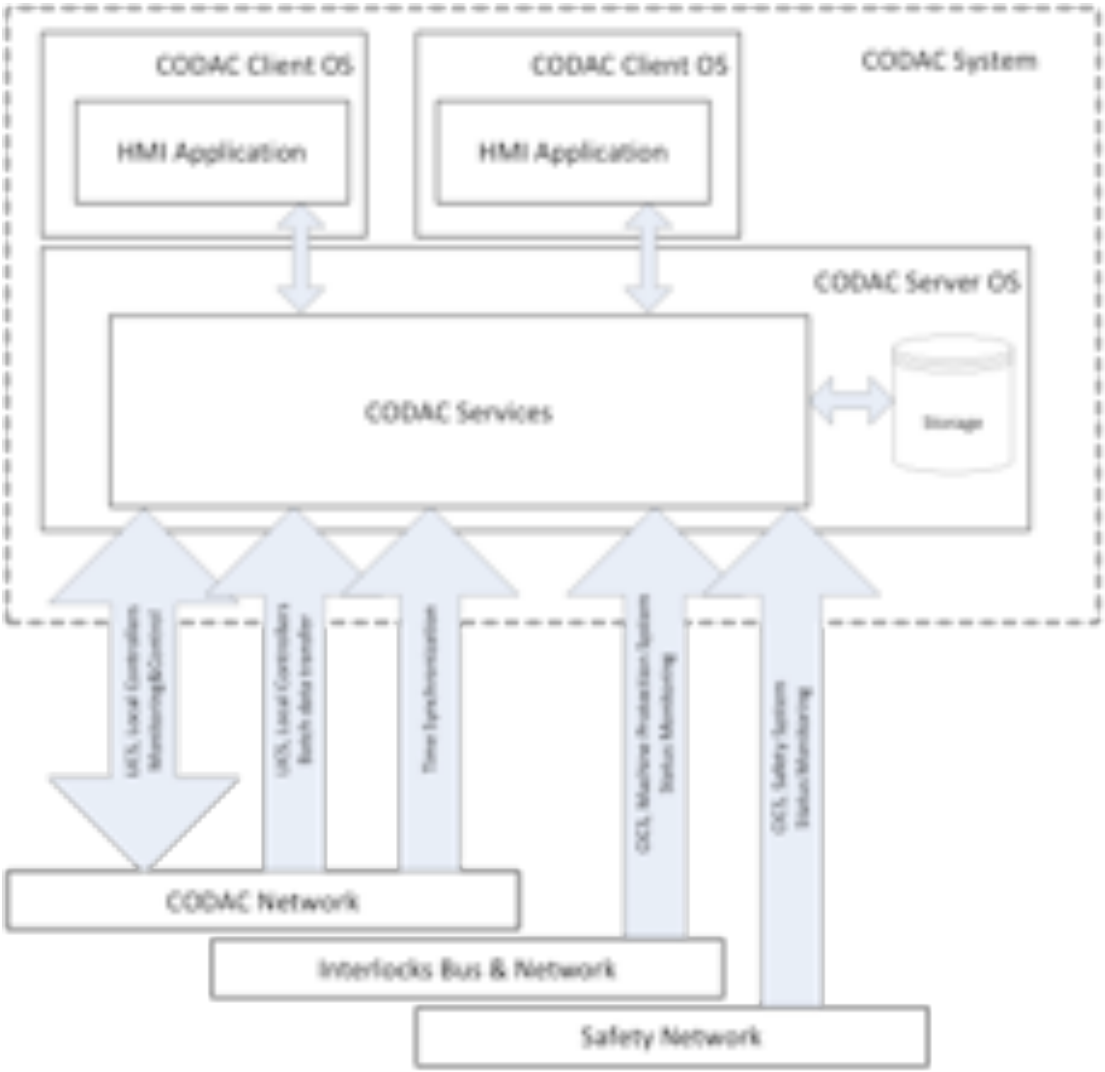


CODAC - Main components identification

Physical Architecture

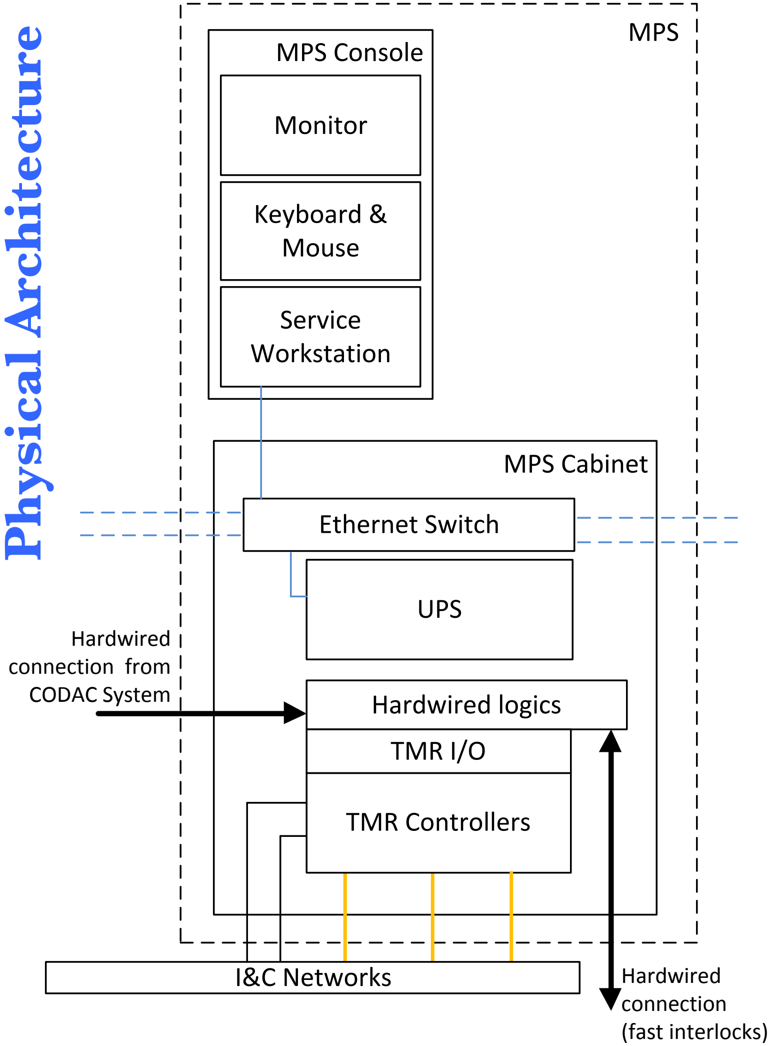


Software Architecture



MPS: Main Components Identification

Physical Architecture

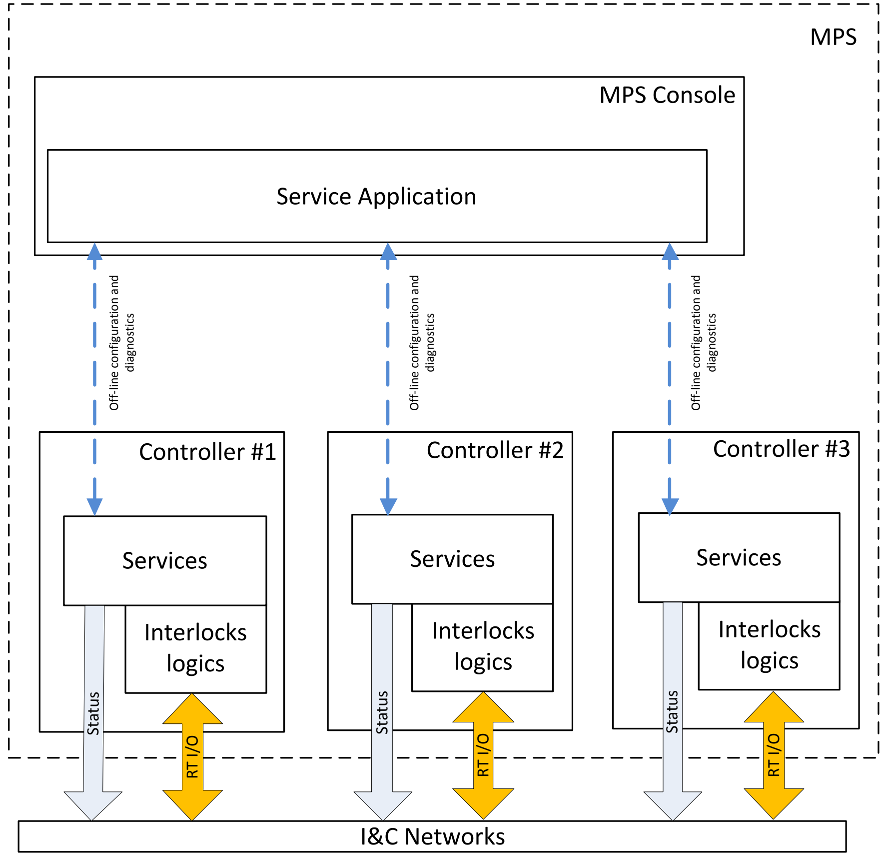


Three Modular Redundant (TMR) controller for slow interlocks

Hardwired logics for fast interlocks

Service workstation for configuration and management

Software Architecture



Three identical control logics running in parallel

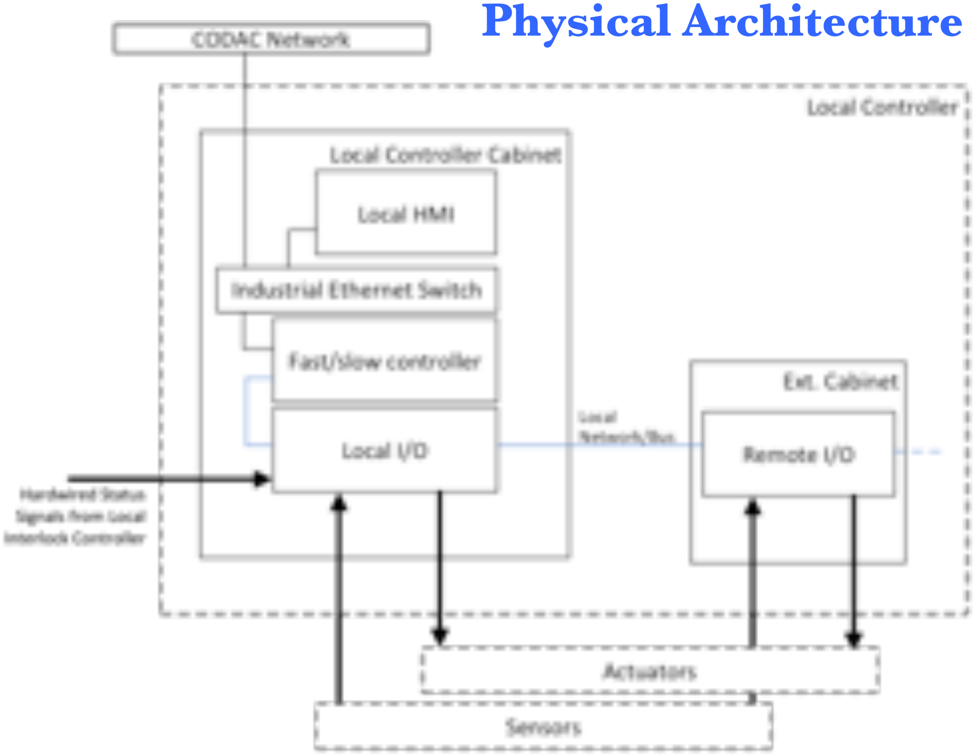
Voting system: logics 2oo3

LICS – LOCAL CONTROLLER

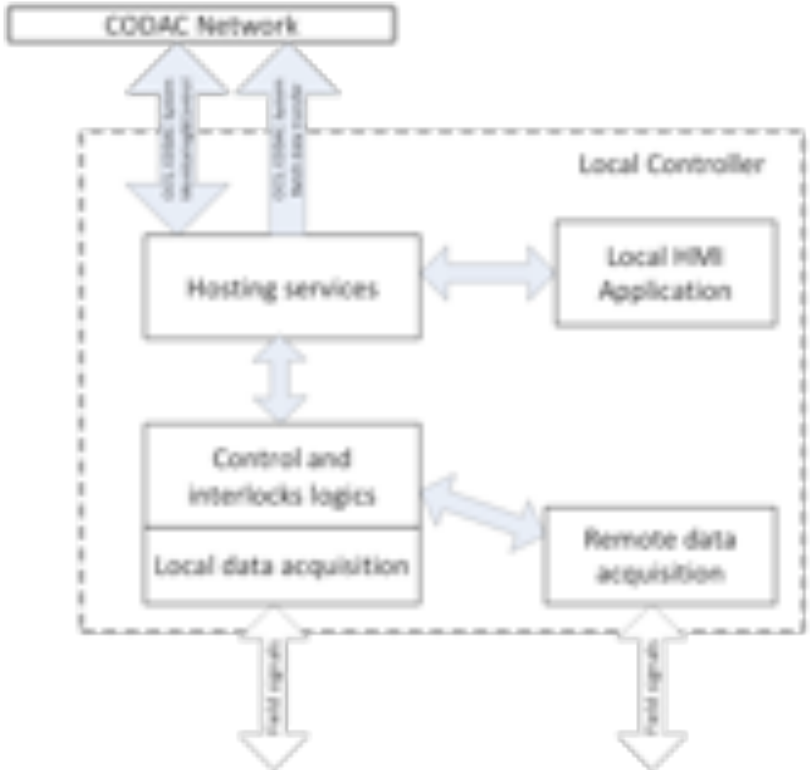
The typical Local Controller system consists of one Local Controller Cabinet and a set Extension Cabinets.

The Local Controller software have to provide the following operation:
Field data acquisition and generation;
Field data processing, control loops and soft interlocks execution;
Data exchange with the CODAC Server;
Local HMI.

Physical Architecture



Software Architecture

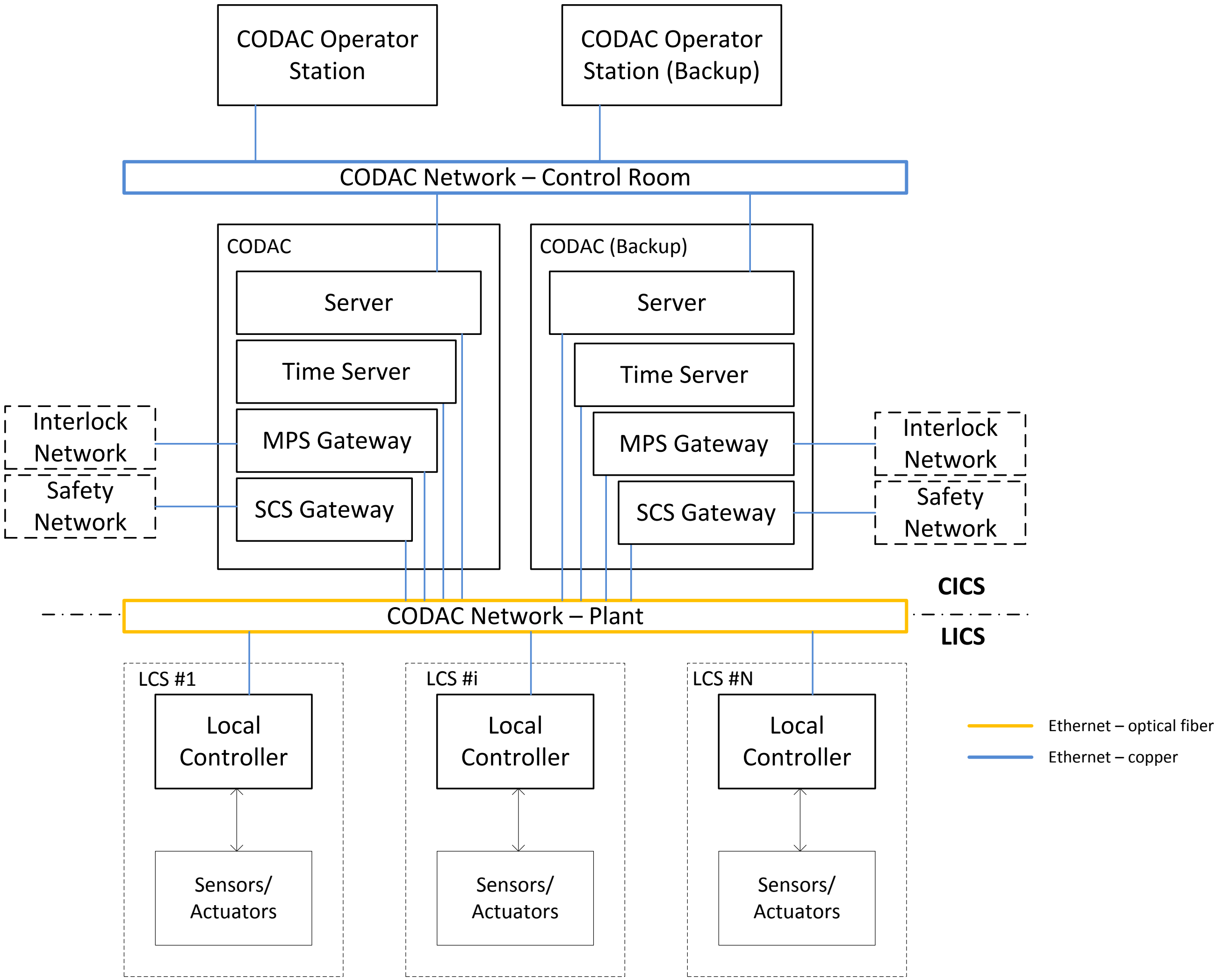


CODAC Network - Architecture

Two layers for logical and physical segregation

Main requirements

- Gigabit Ethernet (10/100/1000)
- Ring-based redundant architecture
- Optical connection for plant section
- Copper for Control Room section



Interlock Networks - Architecture

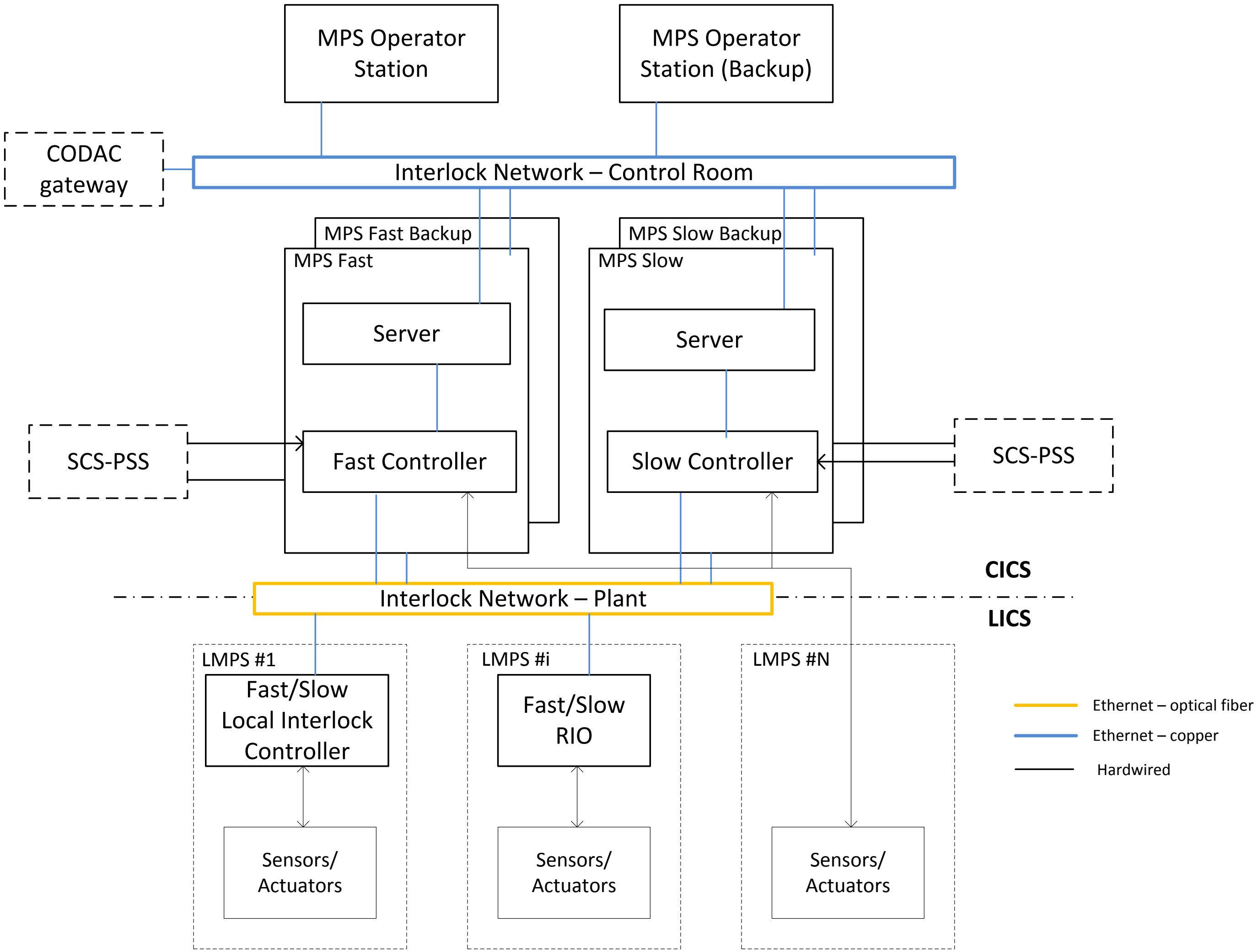
Main requirements

- Gigabit Ethernet (10/100/1000)
- ring-based redundant architecture
- Optical connection for plant section
- Copper for Control Room section
- Virtualization for sharing plant section beetwen slow and fast data, assigning different QoS

Hardwired connections

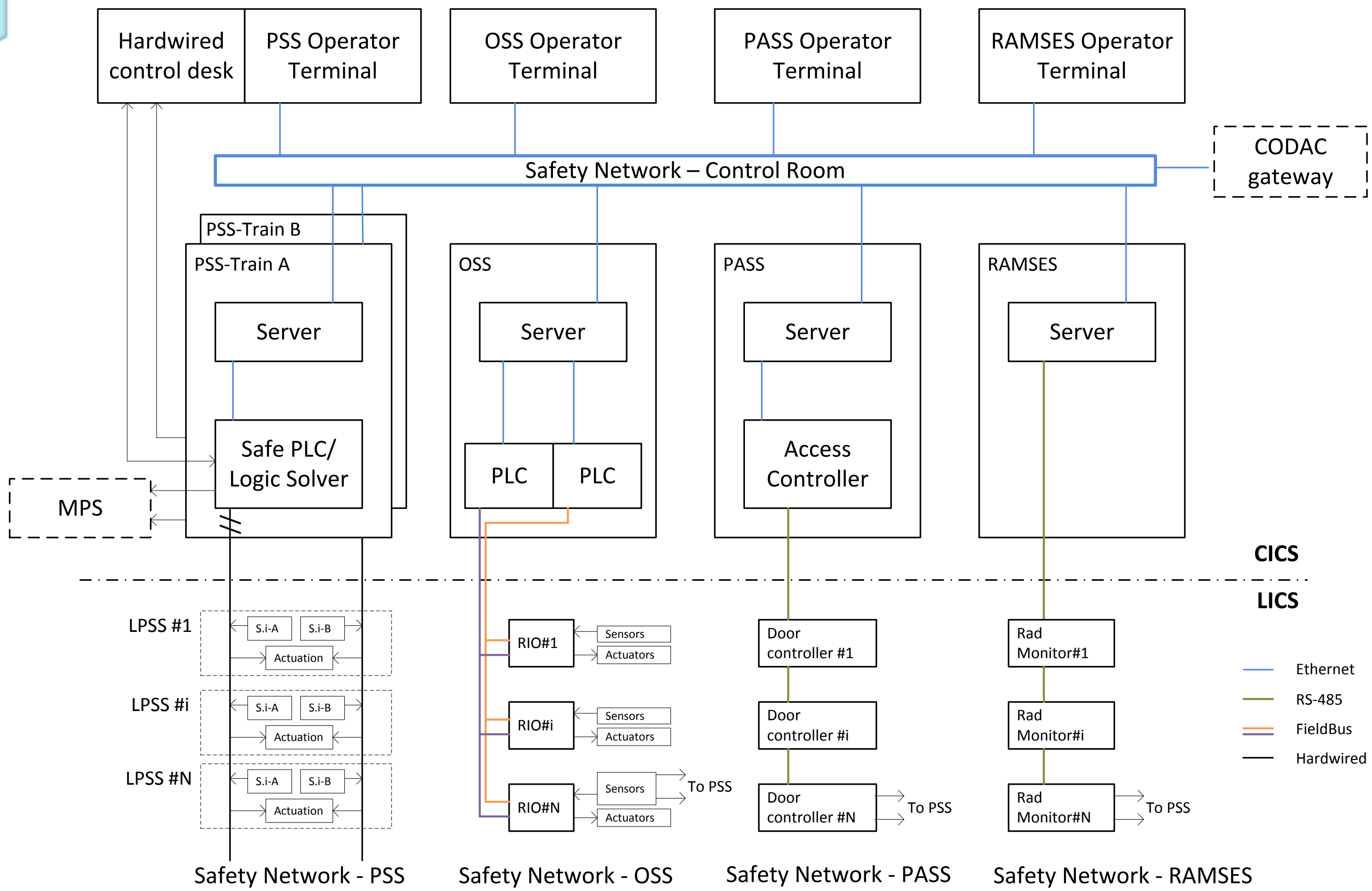
- LMPS and central fast controllers
- SCS and central fast controllers
- Central slow controller and central fast controller

Two layers for logical and physical segregation



SCS Networks - Architecture

SEPARATION VS INTEGRATION



Different SIC classification, but **access as a whole** from the operators:

- lower part: four separate "legs" (different for performance, configuration and physics).

- upper part: provides the seamless integration of the safety data to be accessed by the operator and by the CODAC gateway.

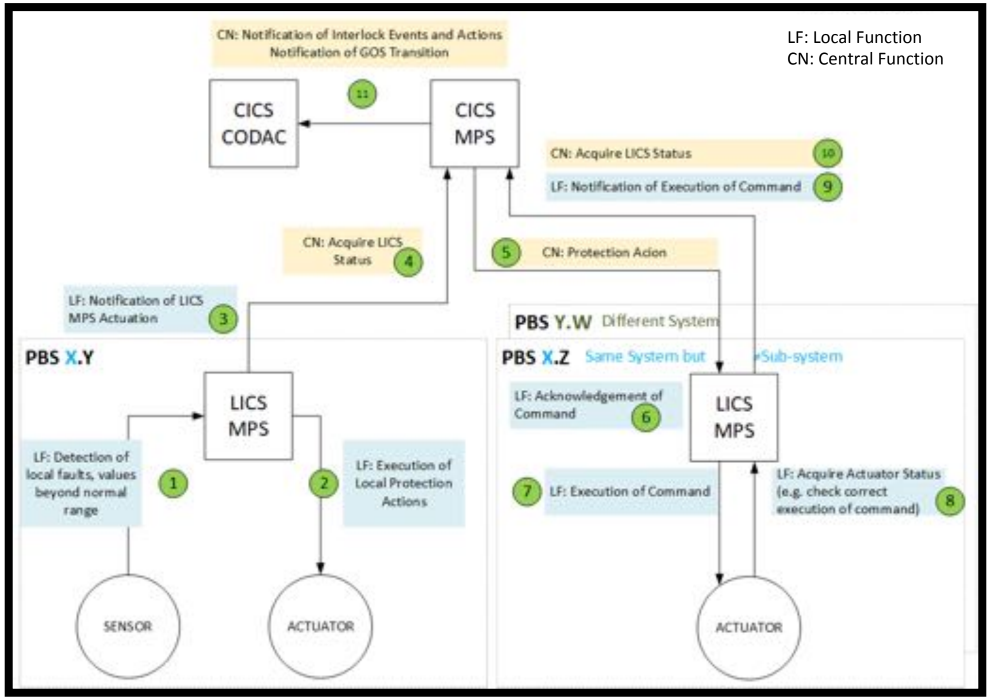
The **separation** between the different levels of the networks is always mediated by **servers** (separation layer between the operators and the safety controllers).

An **additional degree of separation** is created toward the interfacing CODAC system (not safety-classified), by means of the CODAC gateway.

MPS

MPS: Main requirements

- Inhibits Dangerous Actions
- Management of GOS transitions
- Checks the state and availability of the connected LICS
- Cross-system interlock management.
- Enables or disables the functionalities of the LICS
- Protection against the execution of incorrect operation.

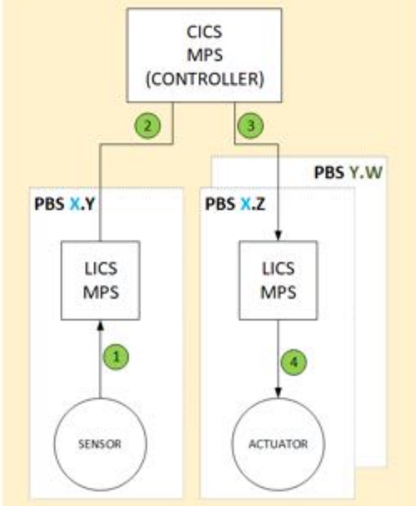


Timing Requirements of Interlocks:

- > 300 ms → Slow Architecture
- **From few ms to 300 ms** → Fast Architecture
- < 30 µs → Hardwired

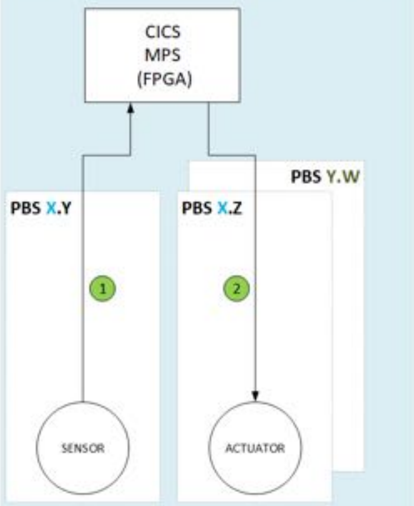
FAST ARCHITECTURE

- 4 Steps
- 3 Controllers (safety response time of certified I/O module ~ hundreds of µs)



HARDWIRED ARCHITECTURE

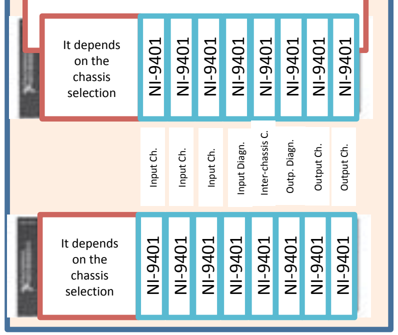
- 2 Steps
- 0 Controllers
- FPGA + I/O Modules (response time of 5-20 µs)



Config. 1 (faster than option 2)

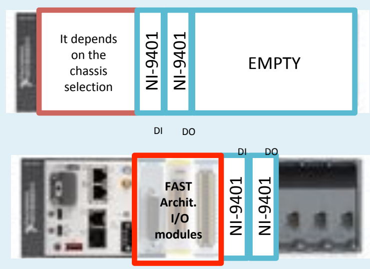
1) **cRIO-9118**, on board reconfigurable Virtex-5 LX 110 (same FPGA used @ ITER in SIL3 configuration but different model of chassis). It needs an external controller (TBD).

2) **cRIO-9048**, FPGA 160T. Same integrated controller of the fast architecture. FPGA ≠ from the one tested by ITER.



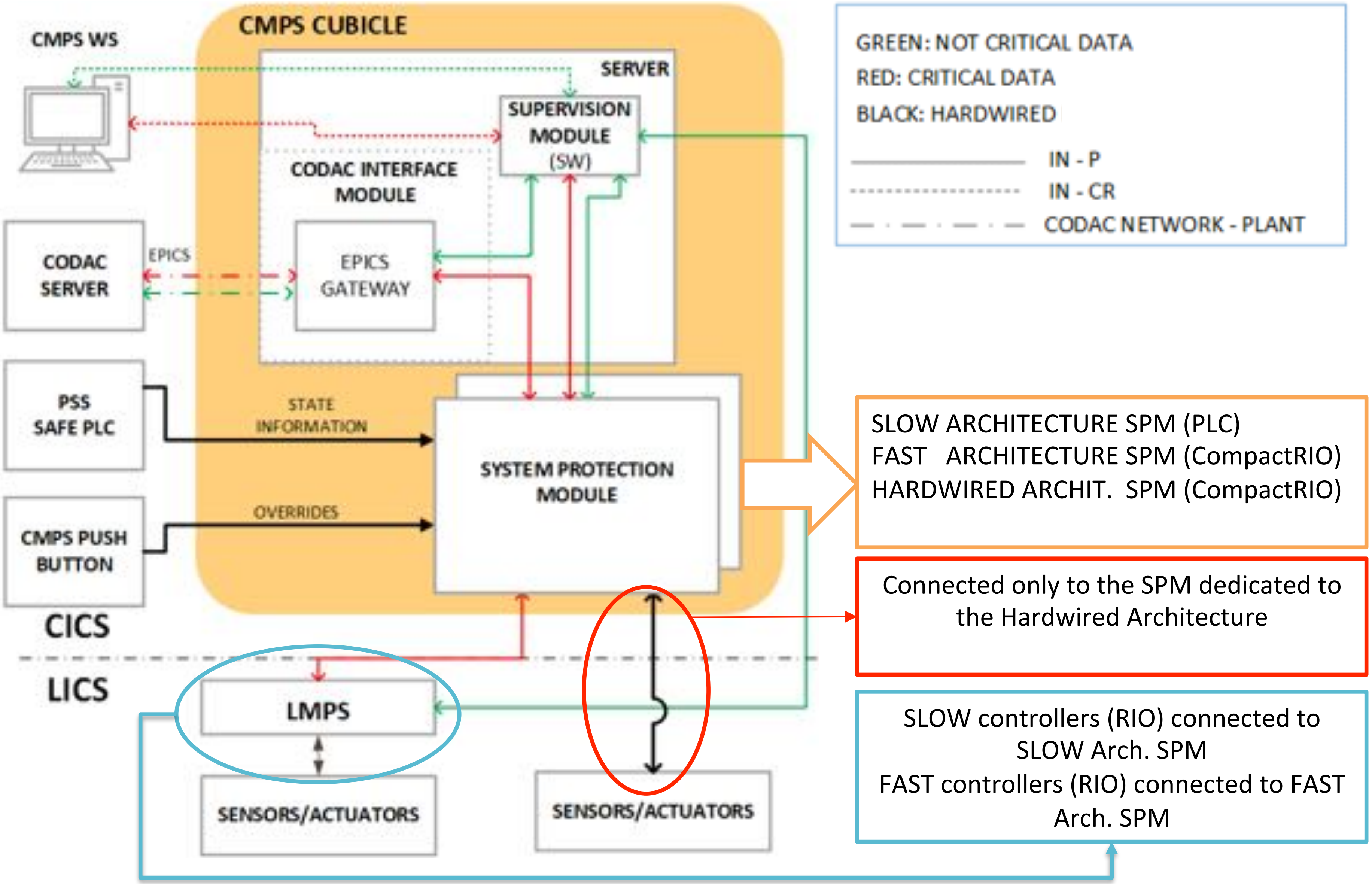
Config. 2 (response time ~ 100 µs)

Option A: if hardware components of Hardwired Architecture need to be separated from those of the fast architecture

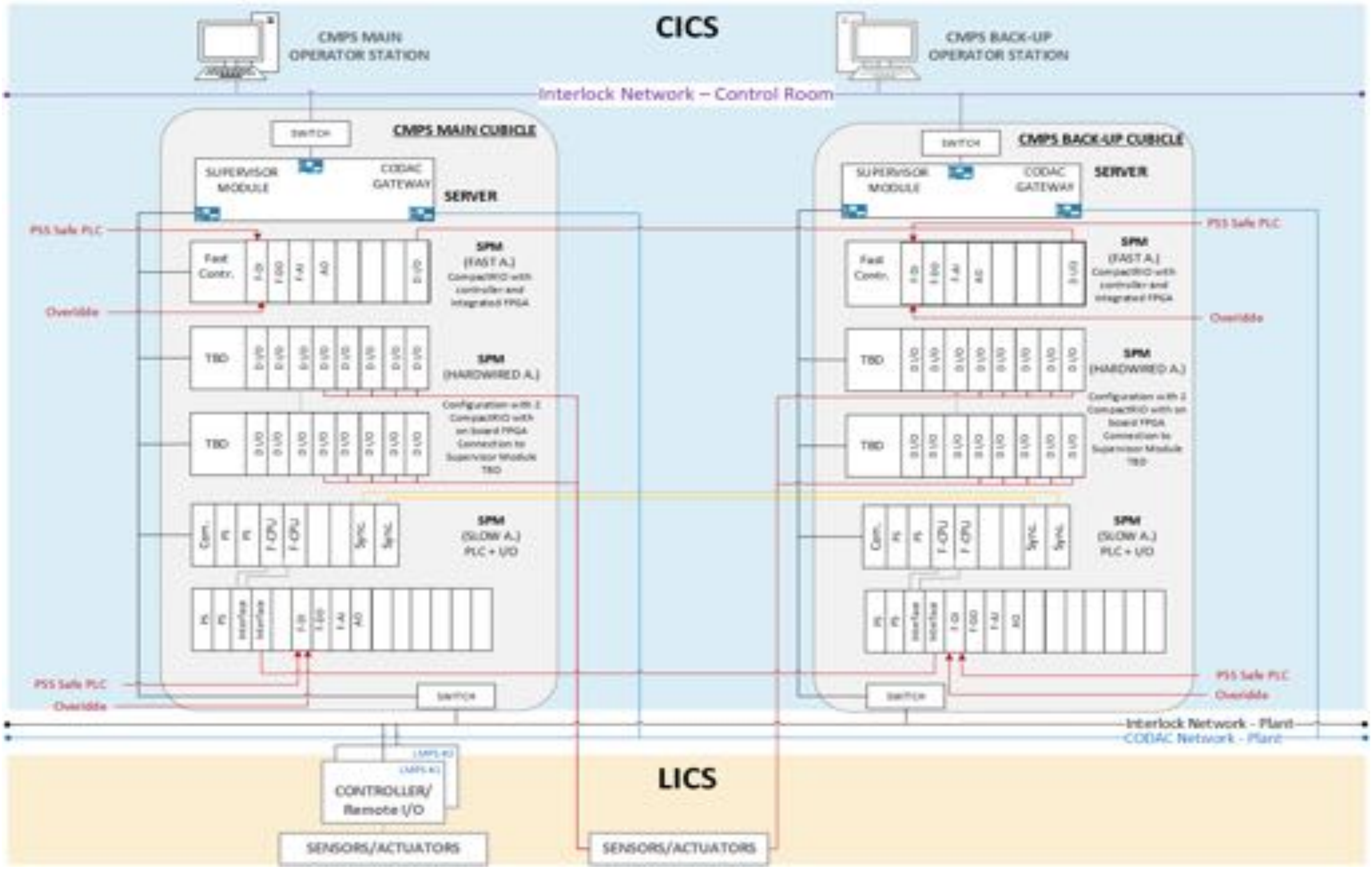


Option B: integrating the hardware components of Hardwired Architectures can be integrated in the fast controller chassis.

MPS – Modules & Data Flow



Central MPS Overall Architecture



SCS

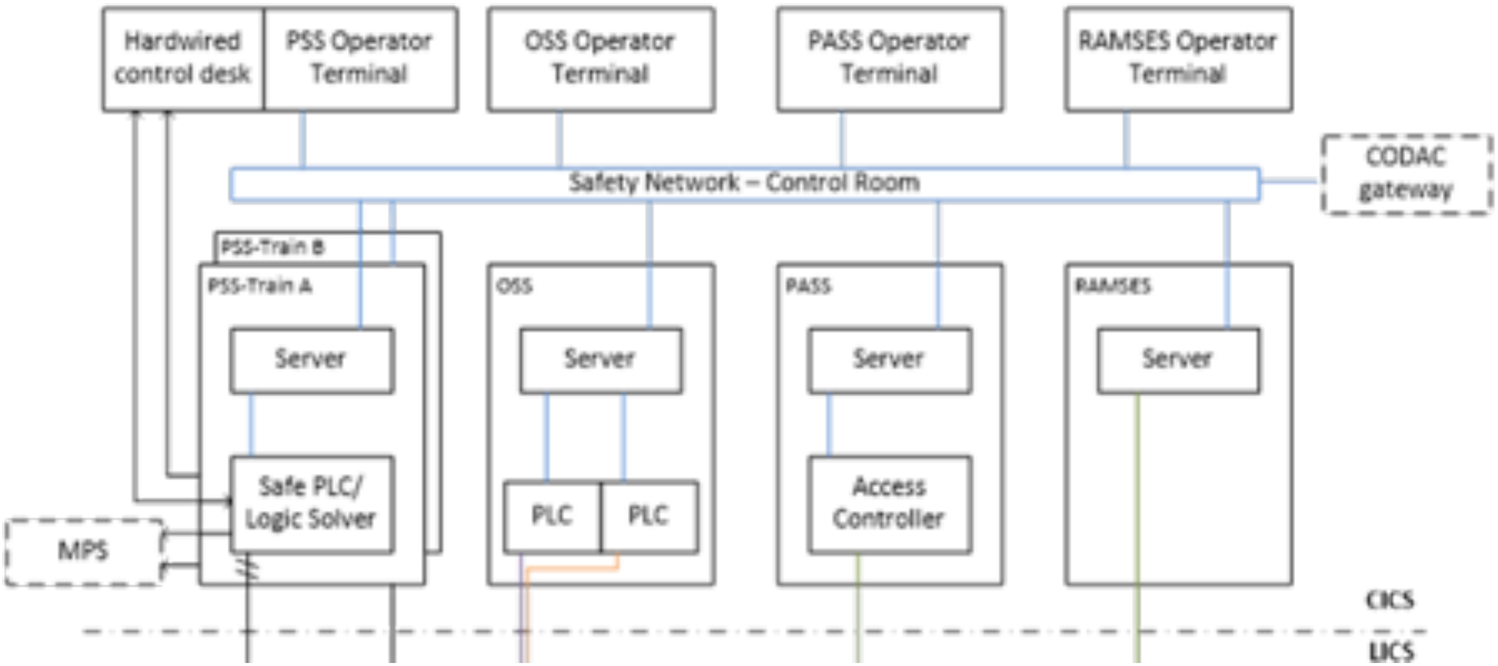
SCS: Main Functions

SCS-PSS acts in protecting the plant function also when people & environment are not exposed to any potential hazards

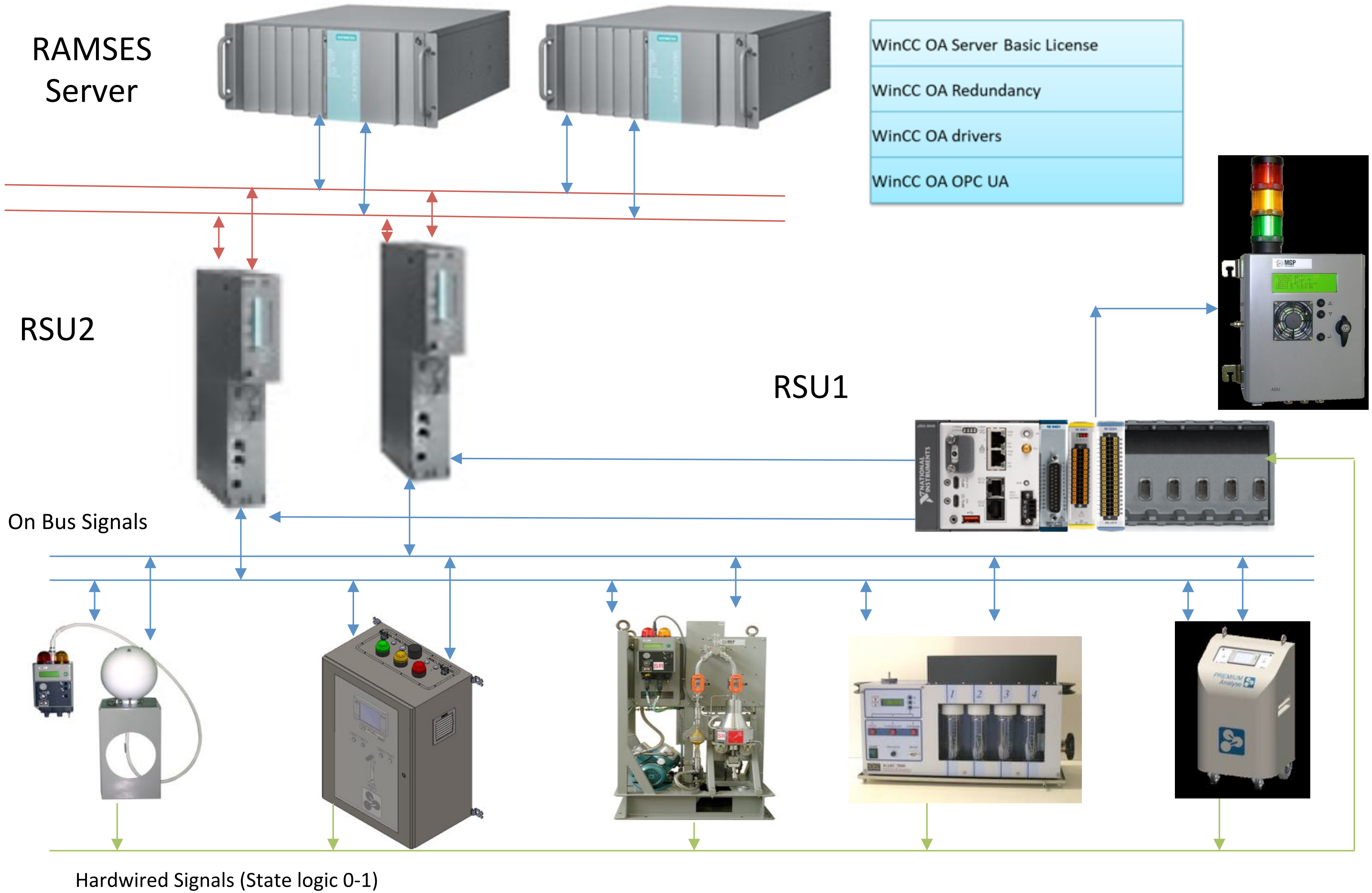
SCS-OSS : safety functions to protect people and the environment against all possible hazards which may be produced inside the plant in normal and abnormal circumstances

SCS-PASS has the objective to implement all the actions oriented to the safety of the people in some specific areas that generate safety risks.

SCS-RAMSES contributes to the protection of people by permanent monitoring of dose rates in areas with risk of exposure to ionizing radiation



SCSIE RAMSES Data Networking



Conclusion

What am I doing here?

ASSESSED

- Design of the **Central** Instrumentation and Control Systems and interfaces with **Local** Instrumentation and Control Systems at a **Definition Design phase.**
- **Main components for Networks, Timing System, HMI, Data Management, Control Room, Alarms/Warnings** have been characterized
- Basis of the **control framework (EPICS) implementation**
- Main control logics defined, need verification and completion.

ONGOING

A step forward…

- Improvement of control **logics** in operational and emergency conditions
- Detailed design of the **control frameworks** (EPICS, ….)
- Detailed Safety Control System design for the following subsystems :
  - **Occupational Safety (OSS)**
  - **Personnel Access (PASS)**
  - **Environment Radiation Monitoring System (RAMSES)**
- **Safety** signals identification **(PSS)** and **SIC** components design
- Evaluation of **Power Quality** and EMI
- Project **integration activities**

PLANNING

The near future…

- Completion and integration of control and operation activities
- Improvement of **CICS-LICS integration: use-cases**
- Overall control system (software and hardware) **integration**
- **Activation of the FWC in 2022**