IFMIF-DONES Control Systems

General Architecture

CELIA CARVAJAL (IFMIF-DONES Control Systems Section Leader)

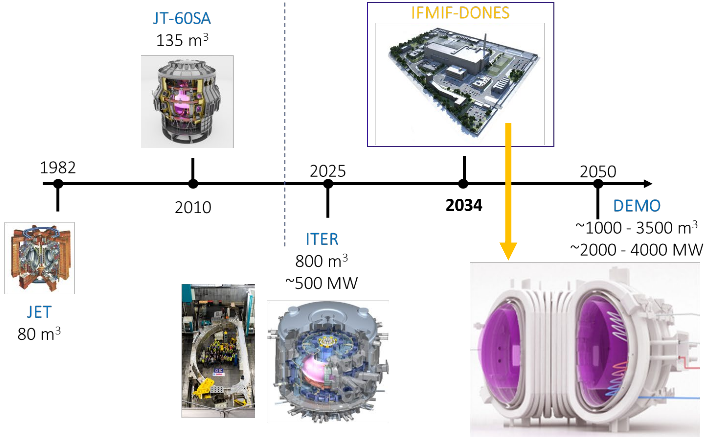
EPICS Collaboration Meeting, April 9th 2025

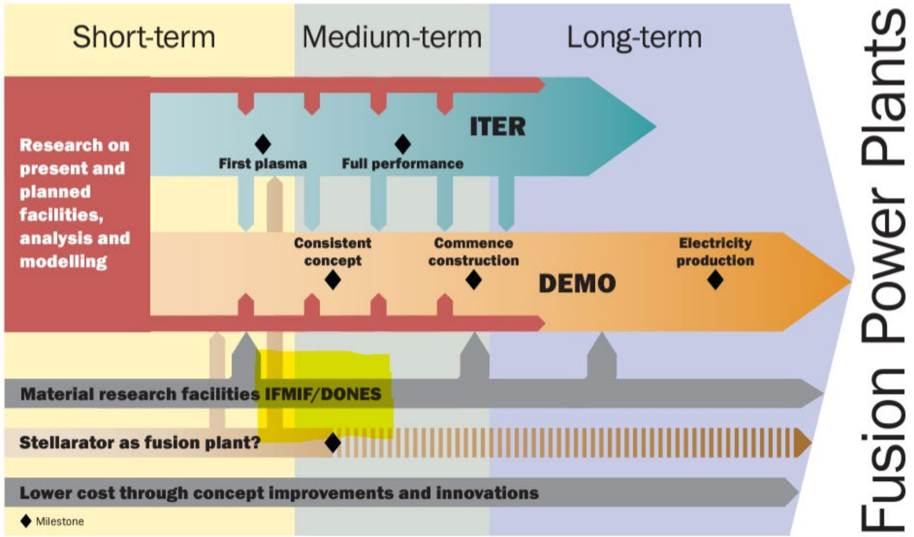
Agenda

1. IFMIF-DONES Context
2. IFMIF-DONES Control Systems overview and goals
3. Achievements and current work
4. Key Challenges
5. DONES Control Systems preliminary architecture
6. Conclusions

NOTE: Please be aware that some images in this presentation are still under construction

1. IFMIF-DONES Context

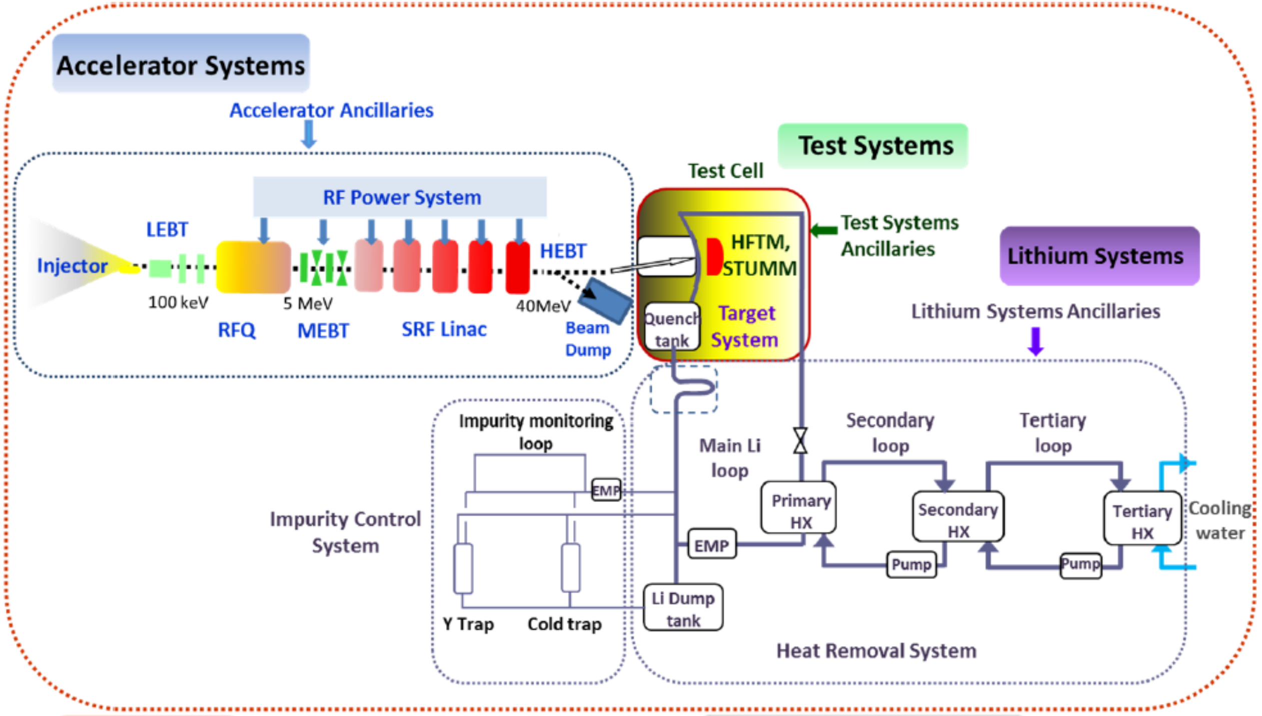




International **F**usion **M**aterials **I**rradiation **F**acility – **D**emo **O**riented **NE**utron **S**ource (IFMIF-DONES)

Main goal: testing, validation and qualification of the materials to be used in future fusion power plants

1. IFMIF-DONES Context



D⁺
- 40 MeV
- 125 mA, CW
- 5 MW output power

Li
- Liquid Li 15 m/s
- 15 m^3 Li inventory
- 100 l/s Flow
- Impurity control system

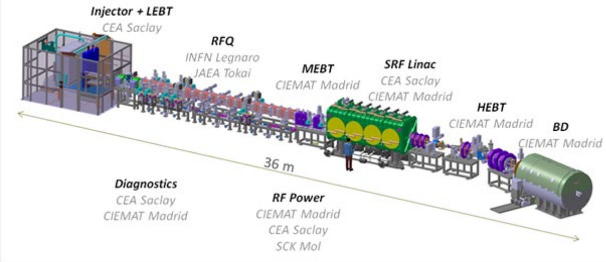
HFTM
- Neutron flux of ~ 5e18 n/m2-s
- 20 dpa/fpy to 100 cm^3
- Irradiation Controlled T [250, 550ºC]

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

1. IFMIF-DONES Context

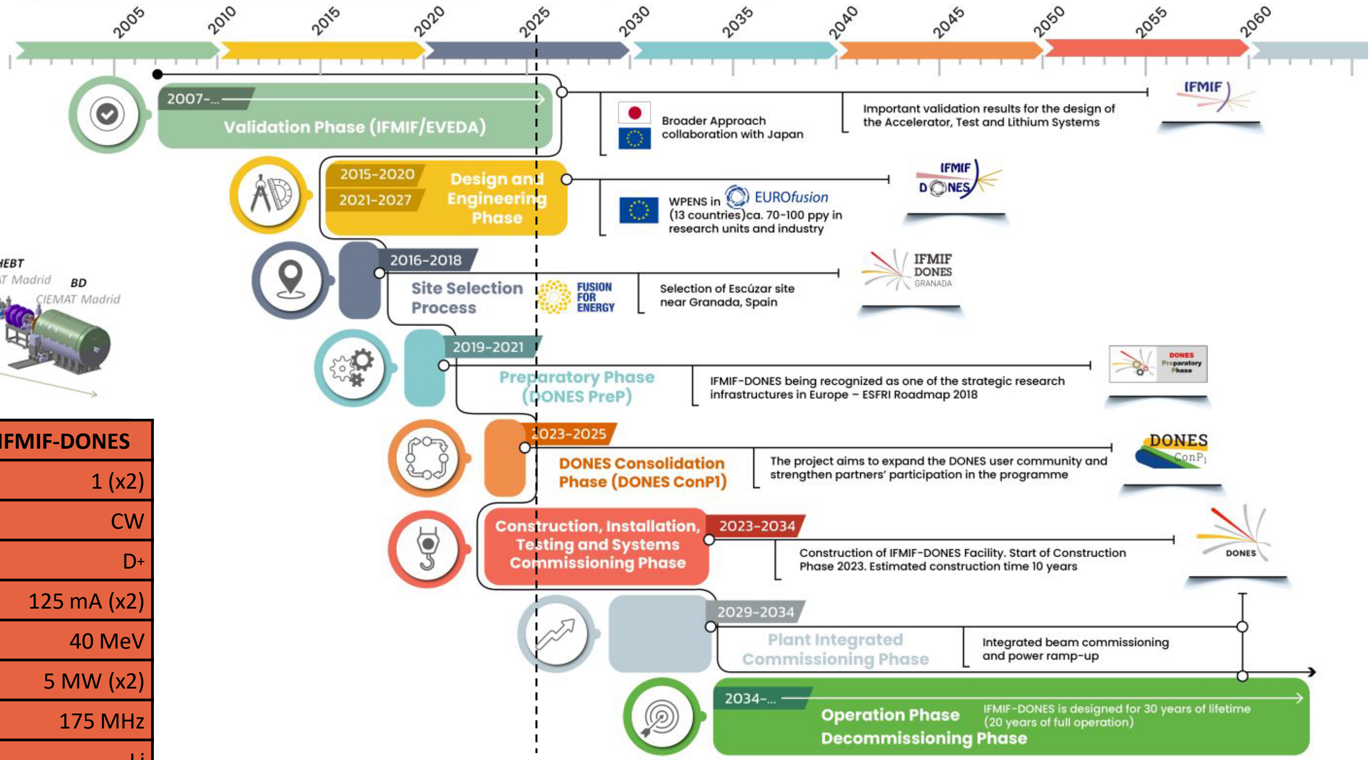
IFMIF-DONES builds upon the experience and technological developments of **LIPAc**:



Primary Parameters	LIPAc	IFMIF-DONES
Number of Linacs	1	1 (x2)
Duty factor	CW	CW
Ion type	D+	D+
Beam intensity on target	125 mA	125 mA (x2)
Beam kinetic energy on target	9 MeV	40 MeV
Beam Power on target	1.125 MW	5 MW (x2)
RF Frequency	175 MHz	175 MHz
Target material	Cu	Li
Total length	34.0 m	84.7 m

DONES Programme Phases

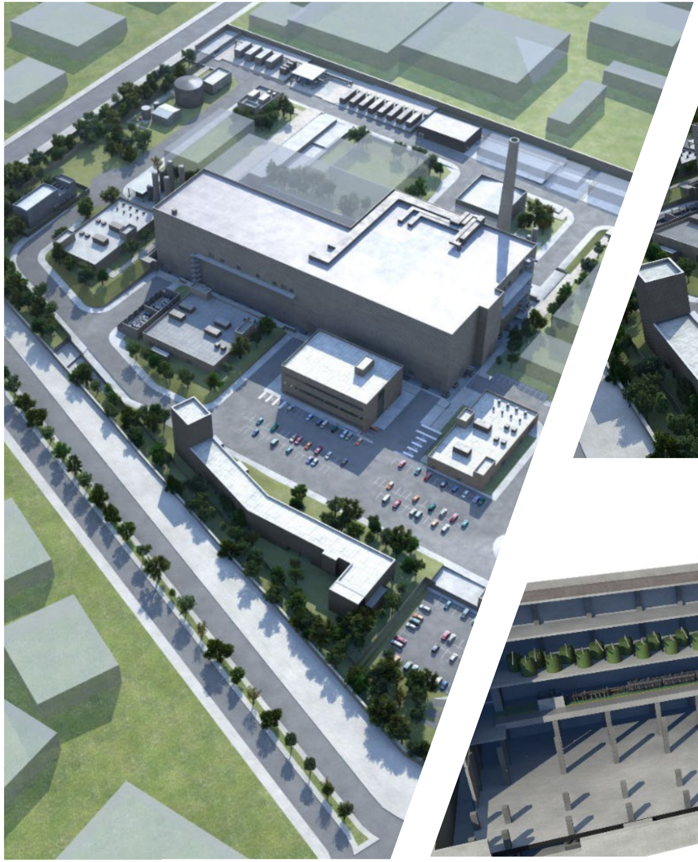
The objective of the DONES Programme is not only for building the IFMIF Facility… but also to operate and to exploit it!!

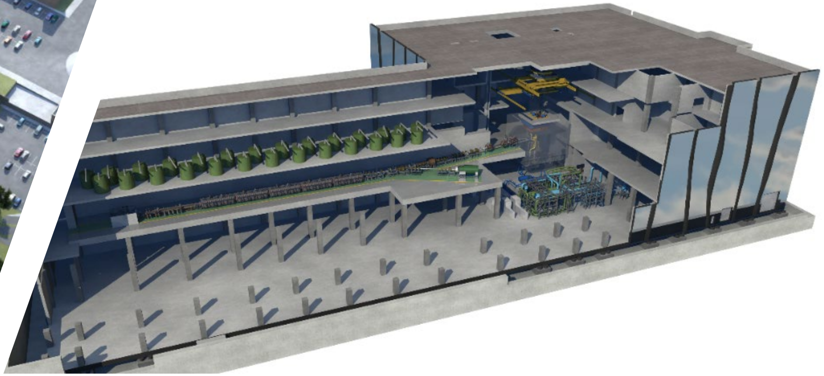


1. IFMIF-DONES Context

Escúzar, Granada, Spain

GOBIERNO DE ESPAÑA | MINISTERIO DE CIENCIA E INNOVACIÓN + Junta de Andalucía → IFMIF-DONES ESPAÑA





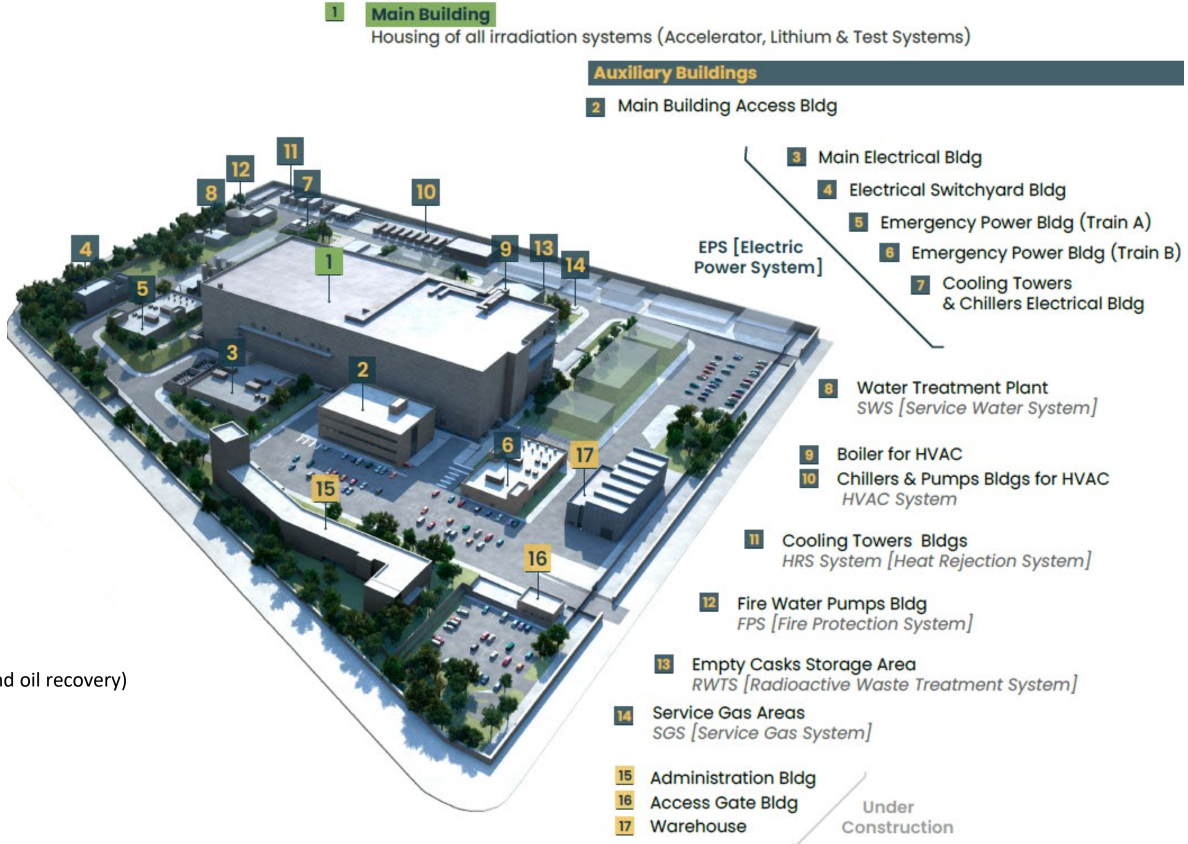
1. IFMIF-DONES Context

Plant Systems:
- HVAC
- Electric Power System
- Heat Rejection System
- Service Water System
- Service Gas System
- Solid Radioactive Material Treatment System
- Liquid Radioactive Waste Treatment System
- Gas Radioactive Waste Treatment System
- Fire Protection System
- Maintenance and handling equipment
- Remote Handling

Accelerator Systems:
- Injector
- RFQ
- MEBT
- SRF Linac
- HEBT and Beam Dump
- RF Power Systems
- AS Ancillaries (power, vacuum, water, gas, cryoplant)

Li Systems:
- Target System
- Heat Removal System
- Impurity Control System
- LS Ancillaries (power, vacuum, gas, heating and insulation, Li and oil recovery)

Test Systems:
- Test Cell
- High Flux Test Module
- Start-Up Monitoring Module
- Other irradiation Modules
- TS Ancillaries (power, water, gas, He cooling)
- Facilities for Complementary Experiments



2. DONES Control Systems overview and goals

CODAC
(Control, Data Access & Communication System):

It implements the orchestrated conventional control functions of all system of the facility.

It also includes “common services”:
- Synchronization
- Centralized alarms and events management
- Centralized data archiving + analysis + ML
- System and network self-diagnosis supervision
- Users Administration
- Software Management
- Common networks:
  - Data Transfer Network
  - Audio-Video Network
  - Management Network
- Control Rooms
- Remote access

MPS
(Machine Protection System):

It implements the machine protection functions against:
- failures of the facilities, system/component,
- failures of CODAC system,
- possible incorrect operation.

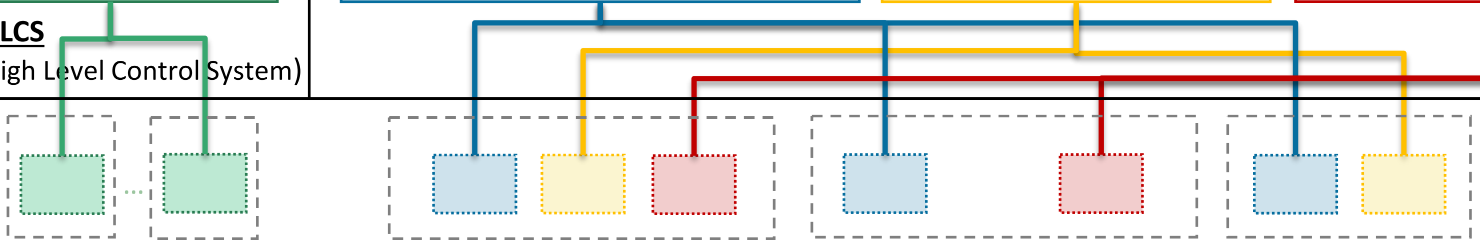
SCS
(Safety Control System):

It implements the safety functions regarding personnel or environment.

Subsystems:
- Plant Safety Subsystem (**PSS**)
- Occupational Safety Subsystem (**OSS**)
- Personal Access Safety Subsystem (**PASS**)
- Radiation Monitoring System for the Environment and Safety (**RAMSES**)

RH-HLCS
It implements specific orchestrated conventional control functions of RH system.

RH-HLCS
(**RH** High Level Control System)



CICS
(**Central** I&C System)

LICS x40
(**Local** I&C System)

2. DONES Control Systems overview and goals

Strategy for Control Systems design based on:

- Standardization
- Leverage experience and feedback from LIPAc project
- Simple architecture
- Instrumentation out of the LICS scope
- Minimise obsolescence impacts
- Improve maintainability
- CI/CD + SW quality control since early development
- Rigorous and representative FAT
- Flexible integration and commissioning process
- Configuration Management [Doc + HW + SW]

Plant requirements

Applicable codes & standards

MAIN GOALS FOR DESIGN PHASE (CICS + LICS)

- Design Description Documents
- Requirements
- Interfaces
- Control Systems guidelines:
  - NETWORKS
  - CATALOGUE
  - CUBICLES
  - LICS ARCHITECTURE
  - LICS SOFTWARE
  - LICS VALIDATION
  - …

Prototypes and labs:

- **LIPAc**
- MuVaCas
- LITEC
- STUMM-PROTO
- VATIAC
- VATIST
- …

In-Kind contributors

3. Achievements and current work

- **Functional analysis:**
  - Conventional control and monitoring (CODAC) ← Operational and Maintenance Procedures (flow diagrams)
  - Protection functions (MPS)
  - Safety functions (SCS)
  - Common functions (required for CODAC, MPS, PSS, OSS, PASS, RAMSES)
    - Synchronization
    - Near-real time monitoring
    - Central control (manual & automatic commands/procedures)
    - Alarms and events management
    - Data and logs archiving
    - Archived data analysis + ML
    - System and network self-diagnosis supervision
    - Users Administration (role permission)
    - Software Management (edition, verification, storage, deployment, version check)
    - Remote access
    - Control Room equipment
- **Components identification (Product Breakdown Structure)**

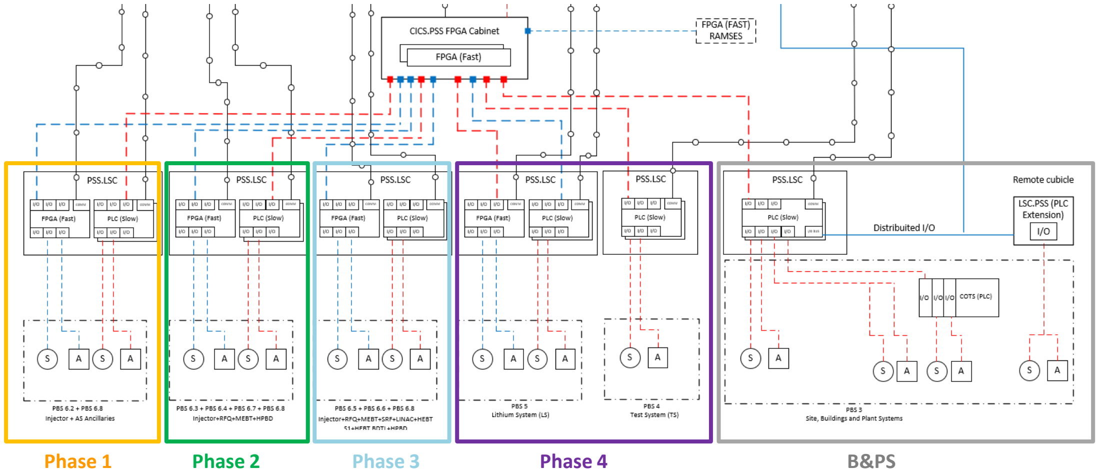
3. Achievements and current work

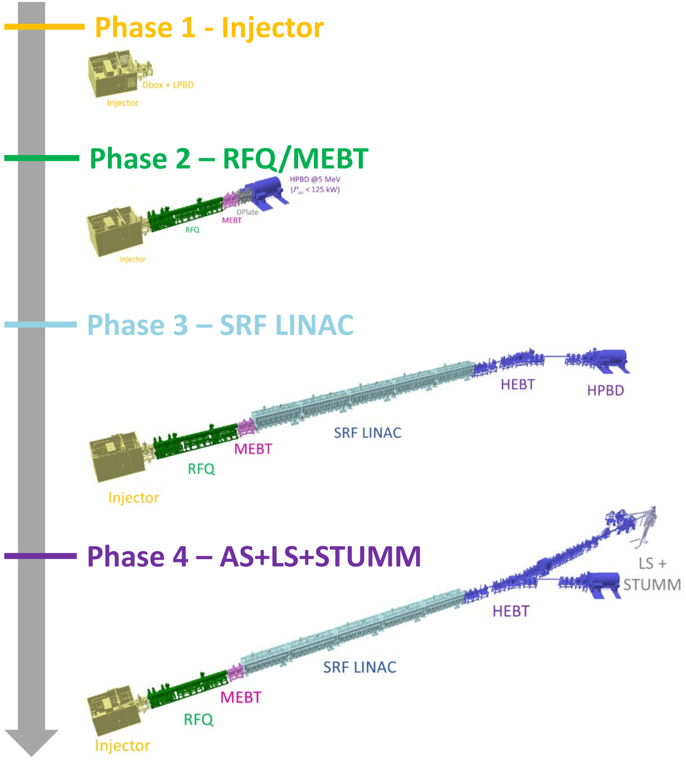
- **Key technology selection:**
  - ➢ Evaluation of EPICS as CODAC and MPS control framework:
    1. SCS Architecture Context:
       - Likely to adopt a control framework already used in a reference facility → typically WinCC OA
       - This suggests a potential unification of SCADA systems across all three control systems
    2. Technical Considerations:
       - Reusable code already developed for LIPAc → potential for reuse in IFMIF-DONES
    3. Vendor Lock-in Concern:
       - WinCC OA implies reliance on a single supplier → increased risk
    4. Community Support:
       - EPICS has strong support through an active and experienced international community

    → *EPICS selected as CODAC and MPS control framework*
  - ➢ Evaluation of OS (Ubuntu?, Debian12?, RockyLinux?, AlmaLinux?)
  - ➢ Evaluation of containers and orchestrator (Docker/Podman?, Kubernetes?)
  - ➢ Evaluation of MTCA for embedded control systems
  - ➢ Evaluation of WR for Timing System
  - ➢ Evaluation of tools for common services (CSS/Phoebus?, Archiver Engine?, InfluxDB?, Gitlab?,…)

4. Key Challenges

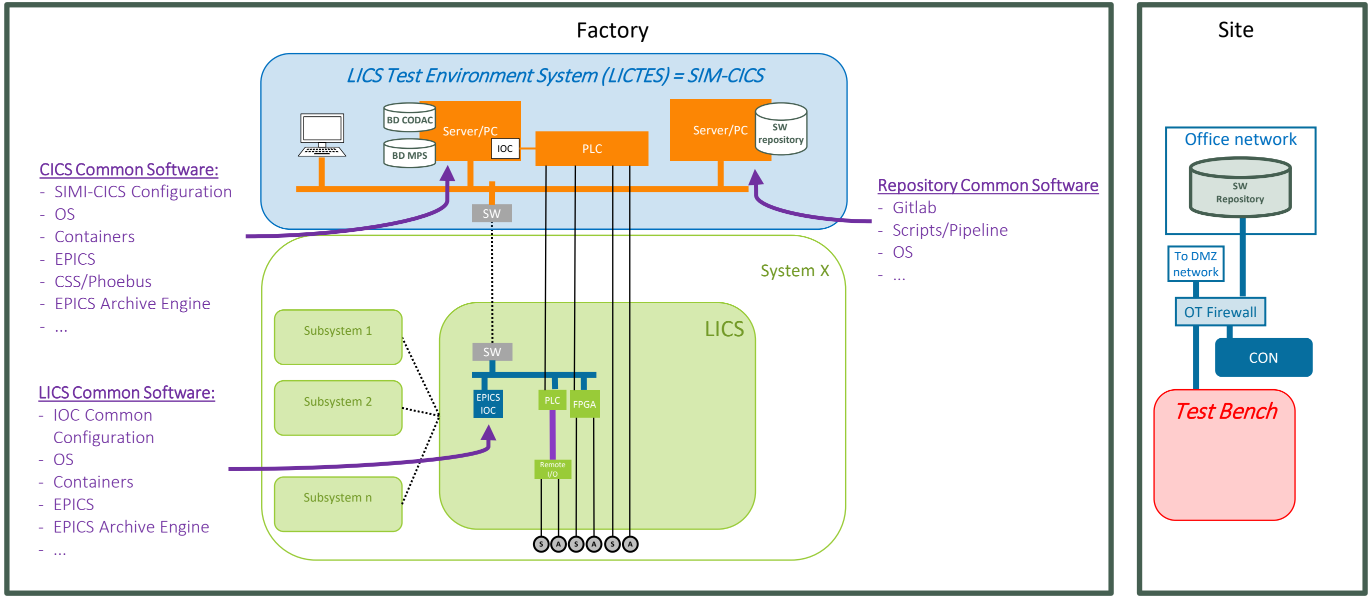
- **Adapt CICS and LICS development, integration and validation process** to make it compatible with:
  - In-kind contribution strategy
  - 4 integrated commissioning phases





4. Key Challenges

- **Specify *process* and *platforms* for LICS development, internal validation, FAT, HW installation, integration and SAT**

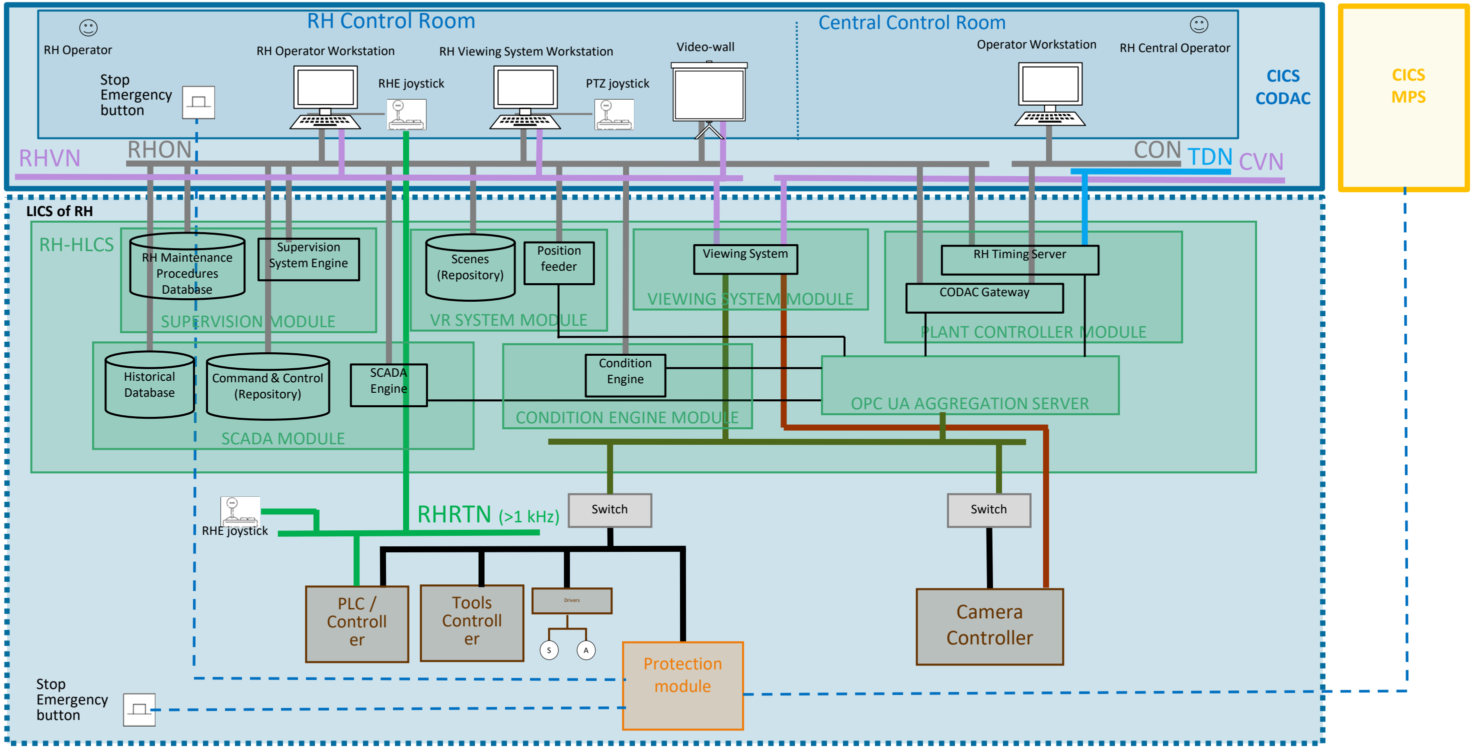


FAT and SAT:

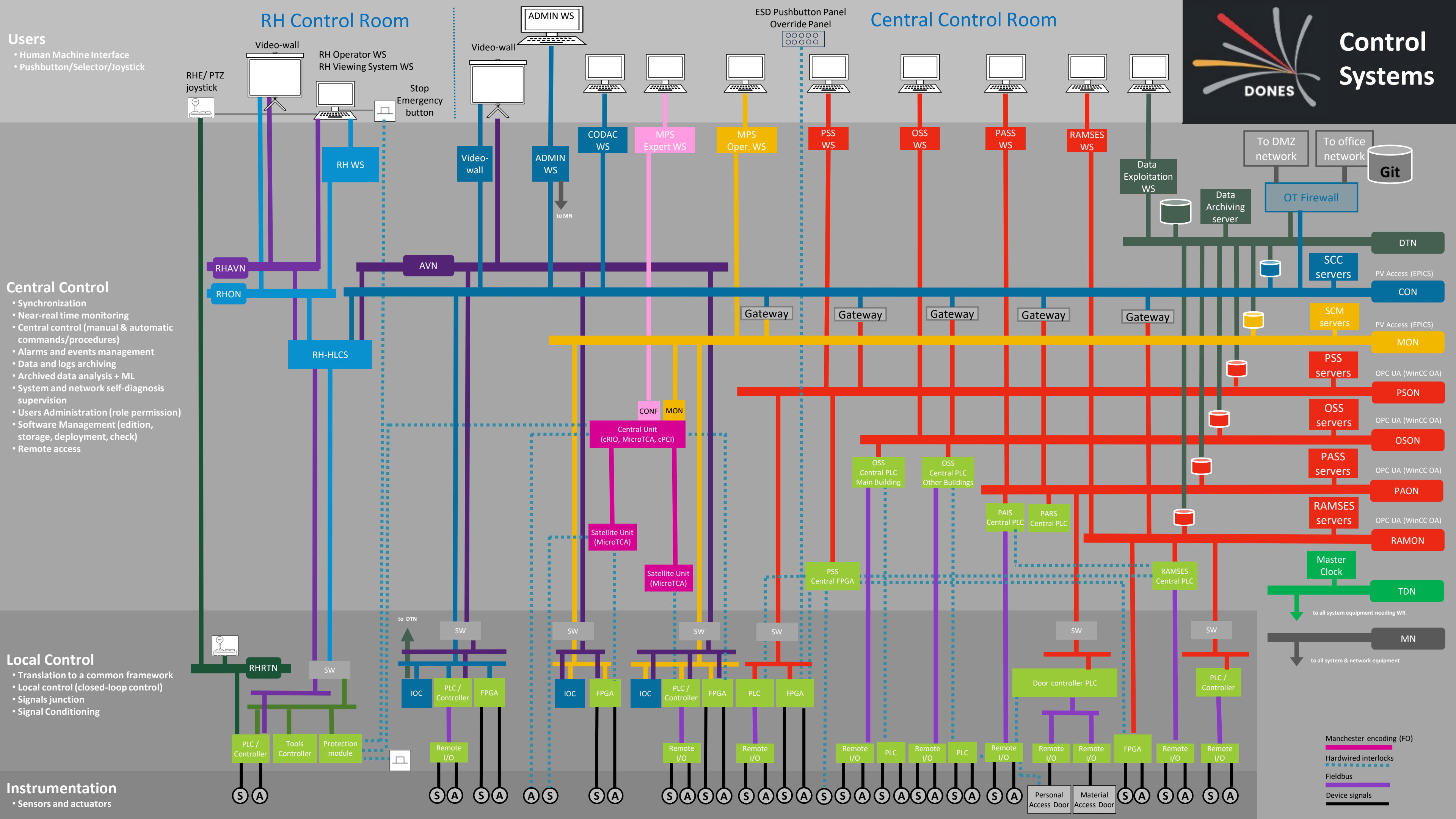
- Representativeness → Evaluate the need for a LICTES and a Test Bench
- Traceability matrix between test procedures and requirements
- Software quality requirements

4. Key Challenges

- Refinement of a detailed design of Remote Handling - High Level Control System



5. DONES Control Systems preliminary architecture



Users
• Human Machine Interface
• Pushbutton/Selector/Joystick
RH Control Room
Central Control Room
Control Systems
DONES
RHE/ PTZ joystick
Video-wall
RH Operator WS
RH Viewing System WS
Stop Emergency button
Video-wall
ADMIN WS
ESD Pushbutton Panel Override Panel
RH WS
Video-wall
ADMIN WS
to MN
CODAC WS
MPS Expert WS
MPS Oper. WS
PSS WS
OSS WS
PASS WS
RAMSES WS
Data Exploitation WS
Data Archiving server
To DMZ network
To office network
OT Firewall
Git
DTN
SCC servers
PV Access (EPICS)
CON
SCM servers
PV Access (EPICS)
MON
PSS servers
OPC UA (WinCC OA)
PSON
OSS servers
OPC UA (WinCC OA)
OSON
PASS servers
OPC UA (WinCC OA)
PAON
RAMSES servers
OPC UA (WinCC OA)
RAMON
Master Clock
TDN
to all system equipment needing WR
MN
to all system & network equipment
Central Control
• Synchronization
• Near-real time monitoring
• Central control (manual & automatic commands/procedures)
• Alarms and events management
• Data and logs archiving
• Archived data analysis + ML
• System and network self-diagnosis supervision
• Users Administration (role permission)
• Software Management (edition, storage, deployment, check)
• Remote access
RHAVN
AVN
RHON
RH-HLCS
Gateway
Gateway
Gateway
Gateway
Gateway
CONF
MON
Central Unit (cRIO, MicroTCA, cPCI)
Satellite Unit (MicroTCA)
Satellite Unit (MicroTCA)
OSS Central PLC Main Building
OSS Central PLC Other Buildings
PAIS Central PLC
PARS Central PLC
PSS Central FPGA
RAMSES Central PLC
Local Control
• Translation to a common framework
• Local control (closed-loop control)
• Signals junction
• Signal Conditioning
RHRTN
SW
to DTN
SW
SW
SW
SW
SW
SW
PLC / Controller
Tools Controller
Protection module
IOC
PLC / Controller
FPGA
IOC
FPGA
IOC
PLC / Controller
FPGA
PLC
FPGA
Door controller PLC
PLC / Controller
Remote I/O
Remote I/O
Remote I/O
Remote I/O
PLC
Remote I/O
PLC
Remote I/O
Remote I/O
Remote I/O
FPGA
Remote I/O
Remote I/O
Personal Access Door
Material Access Door
Instrumentation
• Sensors and actuators
S A
Manchester encoding (FO)
Hardwired interlocks
Fieldbus
Device signals

6. Conclusions

- We aim to build a control system that **meets the specific needs** of each of our system clients while fully adhering to all applicable **codes and standards**.

- Our strategy focuses on maximizing **standardization** and employing a modular architecture to **minimize obsolescence risks**, utilizing cutting-edge technology to enhance system **availability** and **maintainability**.

- We are not starting from scratch; we have a **substantial foundation** of valuable resources to guide us. We also seek to incorporate as much feedback as possible from similar facilities, staying informed on advances and lessons learned by their development and operations teams.

- In recent months, IFMIF-DONES Control Systems teams has establishes new working methodologies and made significant progress in defining architectures, specifying requirements and identifying interfaces, thanks to the dedicated efforts of our team and valuable **collaborations with other projects, research communities, industry partners, and reference facilities**.

- We are excited to deepen our participation within EPICS community. The **expertise of this community** is an invaluable knowledge source, crucial for the development of IFMIF-DONES Control Systems. We are sure that close **collaboration** will help us **overcome current and future technical challenges**.


Thank you