



EUROPEAN
SPALLATION
SOURCE



MicroTCA deployment at the European Spallation Source

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HEAD OF INTEGRATED CONTROL SYSTEMS DIVISION AT ESS

2020-12

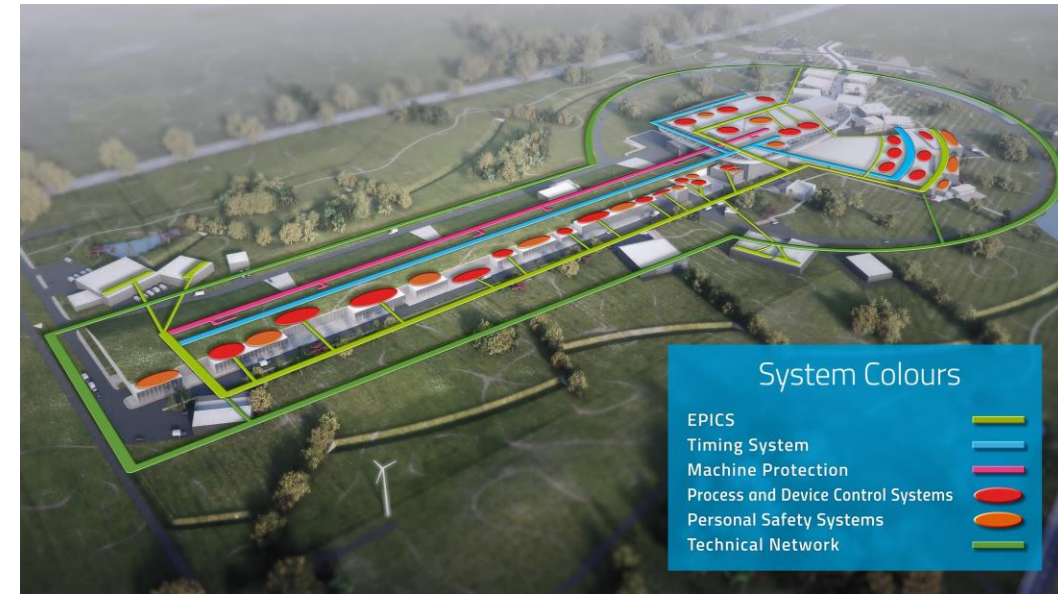
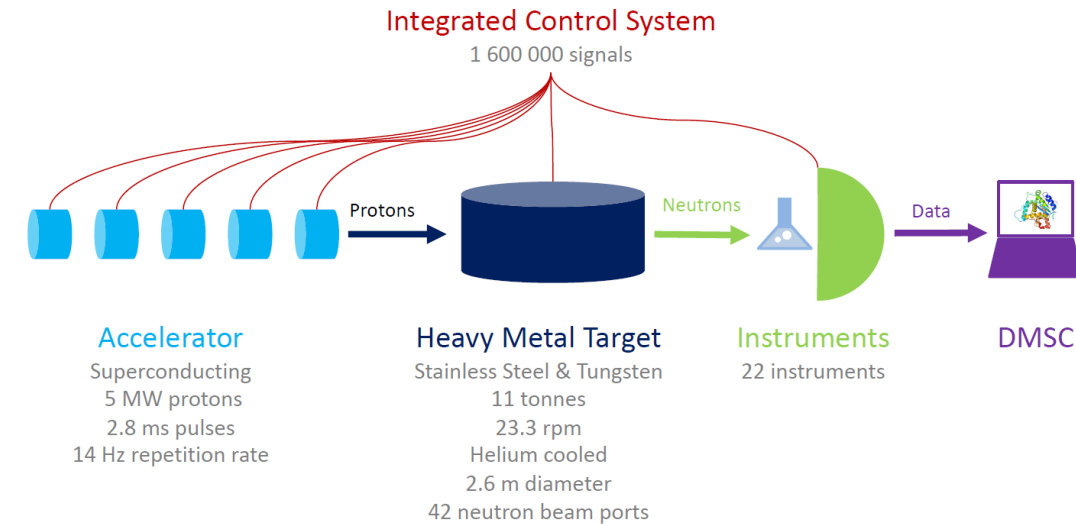
The European spallation source



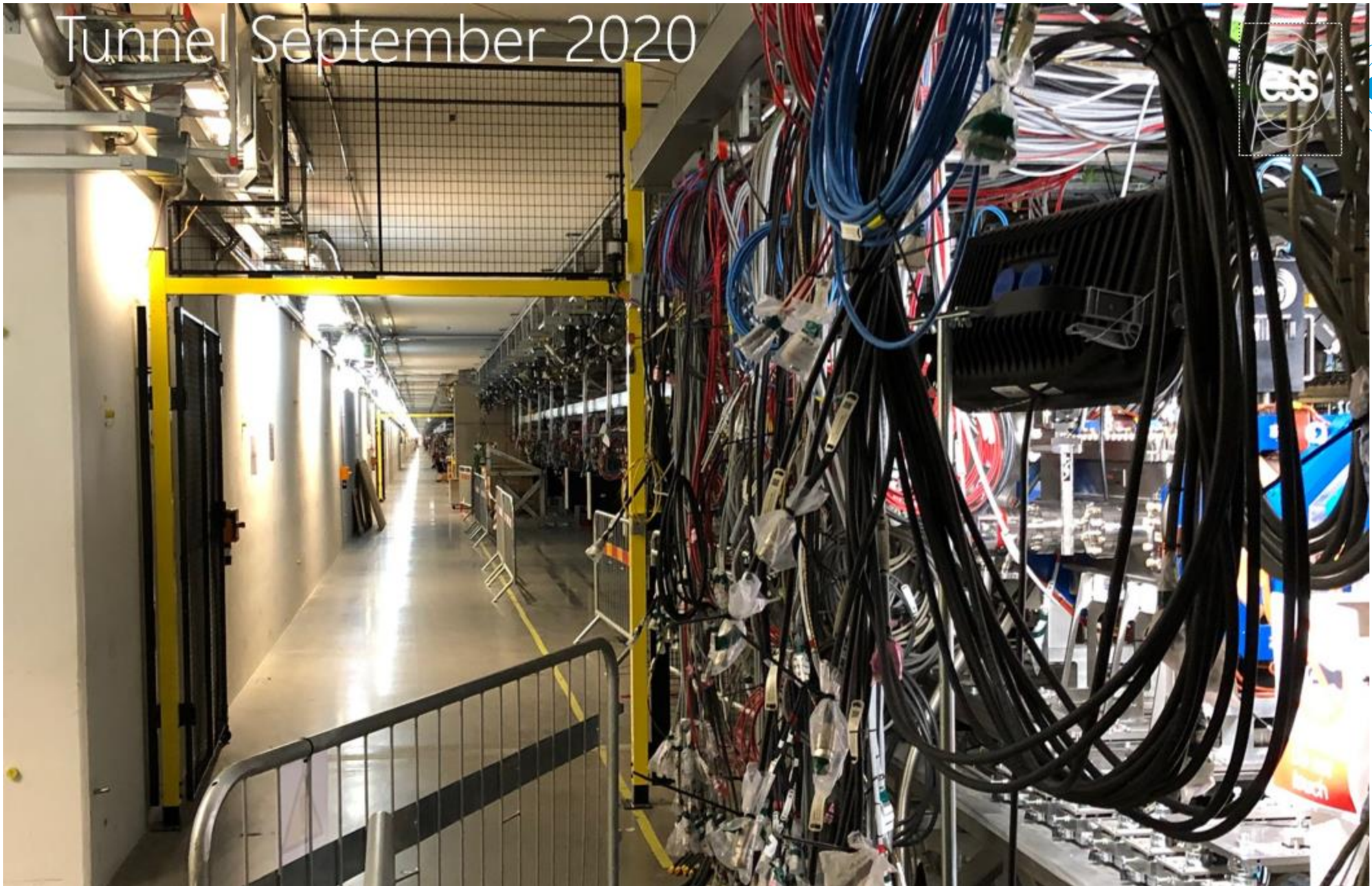
The European Spallation Source is one of the largest science and technology infrastructure projects being built today

The facility design and construction include the most powerful linear proton accelerator ever built, a five-tonne, helium-cooled tungsten target wheel, 22 state-of-the-art neutron instruments, a suite of laboratories, and a supercomputing data management and software development centre.

In the context of its history and future as a scientific organisation, however, it is more than the sum of its parts. It is a brand new Big Science organisation, built from the ground up.



Tunnel September 2020



Elliptical CDS



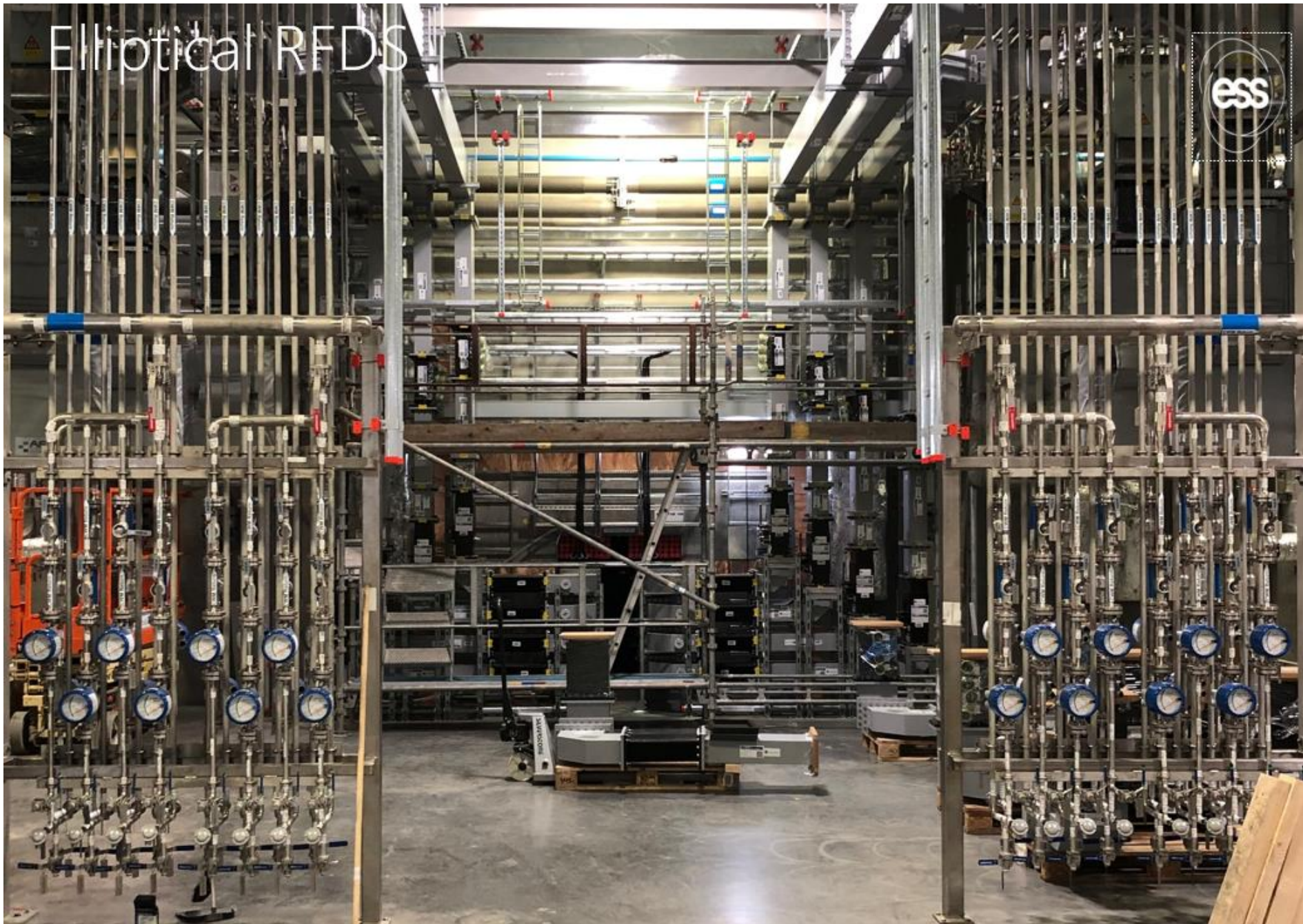
MEBT







Elliptical RFDS



Integrated control system



The ESS facility is a large and complex machine with very much and diverse equipment that needs to work in synchronization and with well-known configurations

The Integrated Control System Division (ICS division) is responsible for the control systems within the ESS facility including controls for

- **Accelerator**
- **Target**
- **Neutron Scattering Systems**
- **Conventional Facilities**

In addition, ICS will implement

- **Machine Protection System**
- **Personnel Safety System**

To build a distributed control system of this size is a major undertaking



The ESS integrated control system



The ESS control system complexity is very high

- About 1 600 000 “process values”
- About 100 000 connected “devices”
- Ambitious approach to automation of control system configuration

Facility availability goals are very high

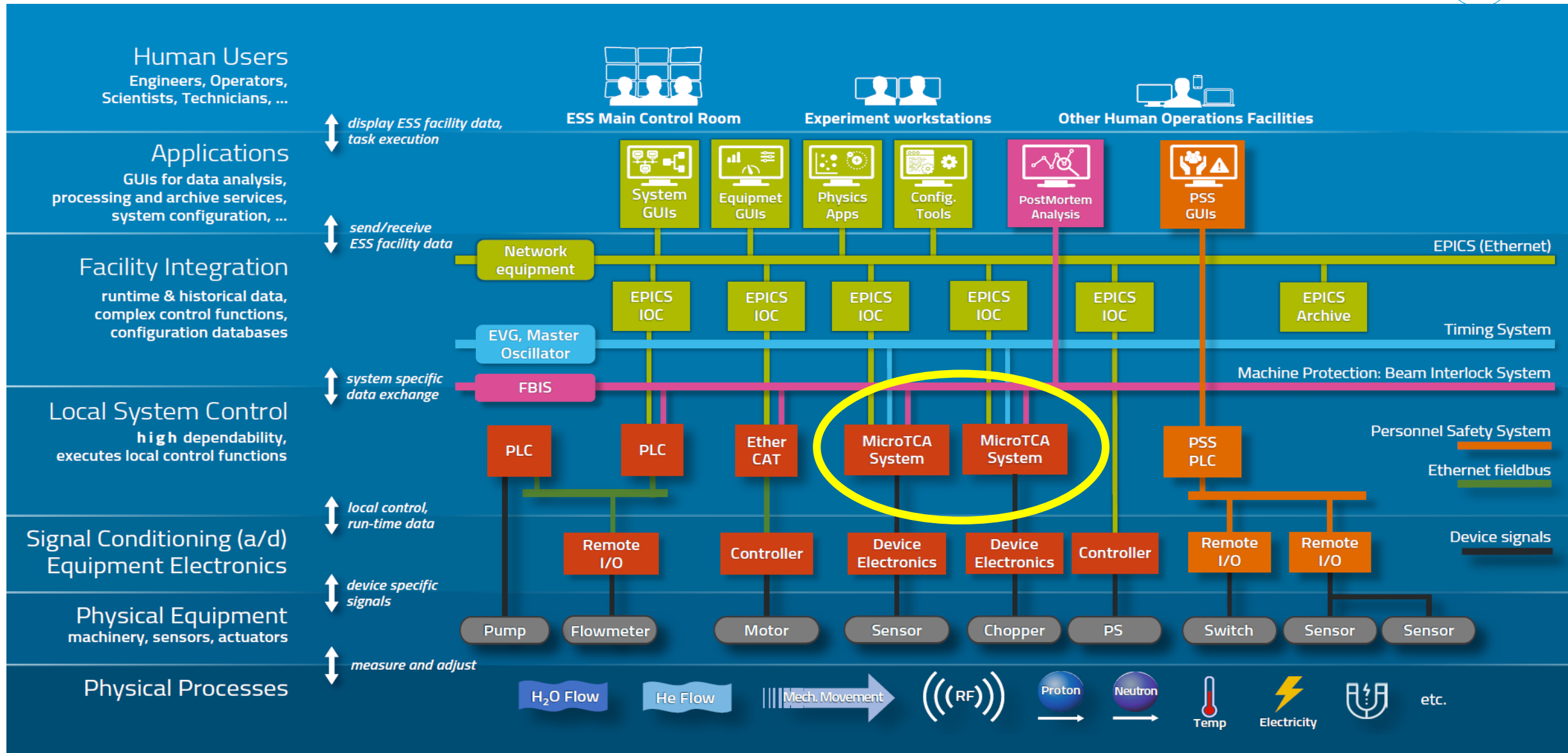
- ICS plays a key role for the availability of the facility
- High performance and availability requirements on equipment used

Some new approaches will be implemented at ESS/ICS

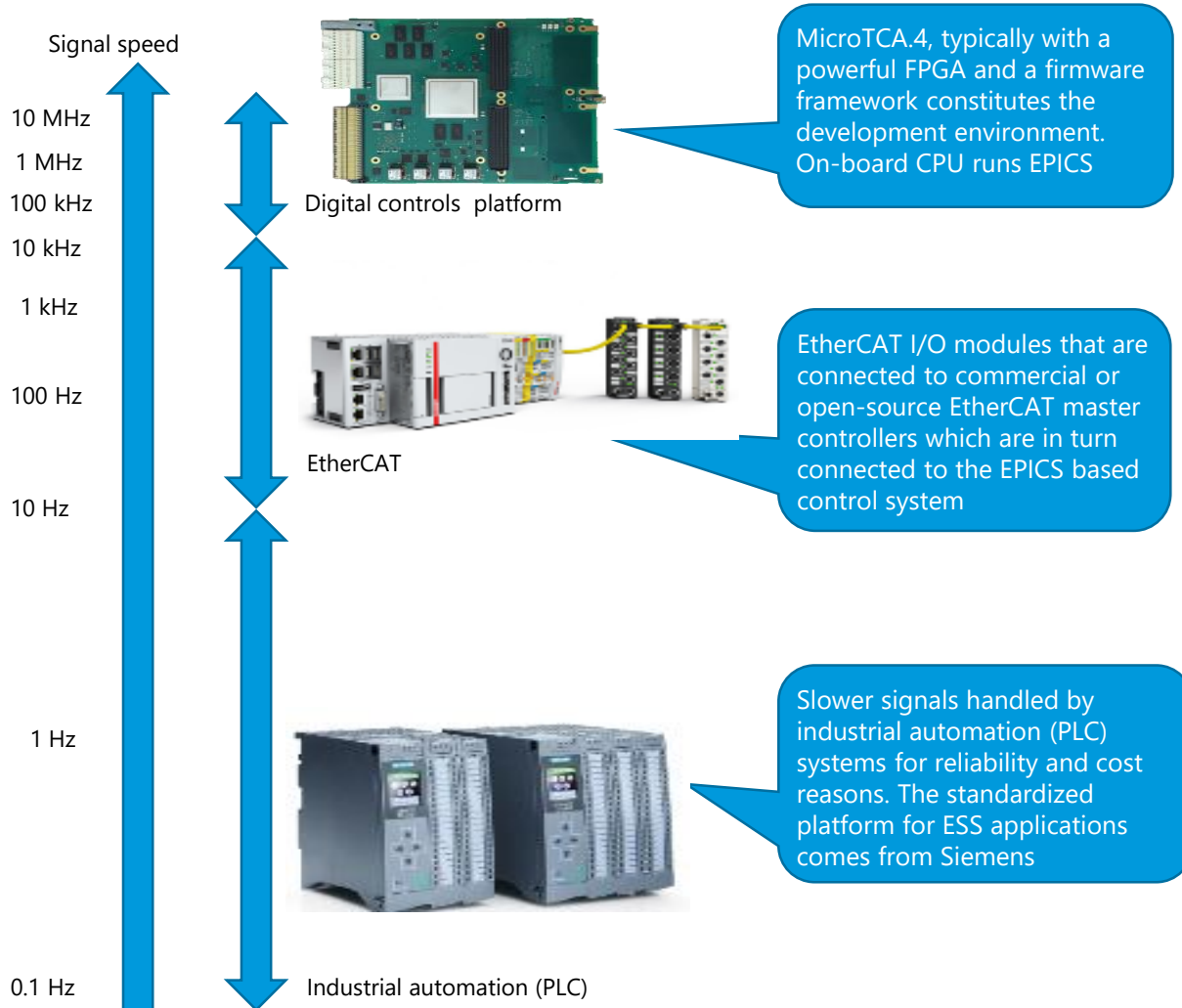
- Full scale deployment of EPICS 7
 - ESS is committed to contributing to the EPICS community
- Full scale deployment of MicroTCA.4
 - ESS is involved in a public procurement for innovation initiative
- Machine learning/Artificial intelligence assisted control system
 - Project started to explore how machine learning technologies can be applied



A layered control system



Three level strategy for control systems at ESS



ICS has adopted a three level strategy for implementing the control system based on signal processing needs

- MicroTCA.4 for applications with data acquisition exceeding few kHz
 - Typically FPGA and custom, high-speed signal processing in system.
-
- For slower signals, EtherCAT is used for good price/performance ratio
 - Synchronization and event information are key for applications where a full custom platform solution would be too costly
-
- Low speed signals are handled with COTS PLC systems
 - This is a cost-effective solution meeting reliability and maintainability
 - The PLCs are integrated with EPICS into the control system

MicroTCA application areas

Four major areas requiring MicroTCA solutions

- Beam Instrumentation

- Beam position monitors
- Beam current monitors
- Beam loss monitors
- etc...

Captures and delivers information used for machine protection, beam diagnostics and operational optimisation of the ESS machine

- Machine Protection System

- Fast beam interlock system

Prevents damage and activation to the ESS machine to optimise uptime

- RF Systems

- Low level RF system
- RF local protection system

Drives and coordinates RF power delivered to accelerate protons

- Timing System

- Components for the central ESS timing system

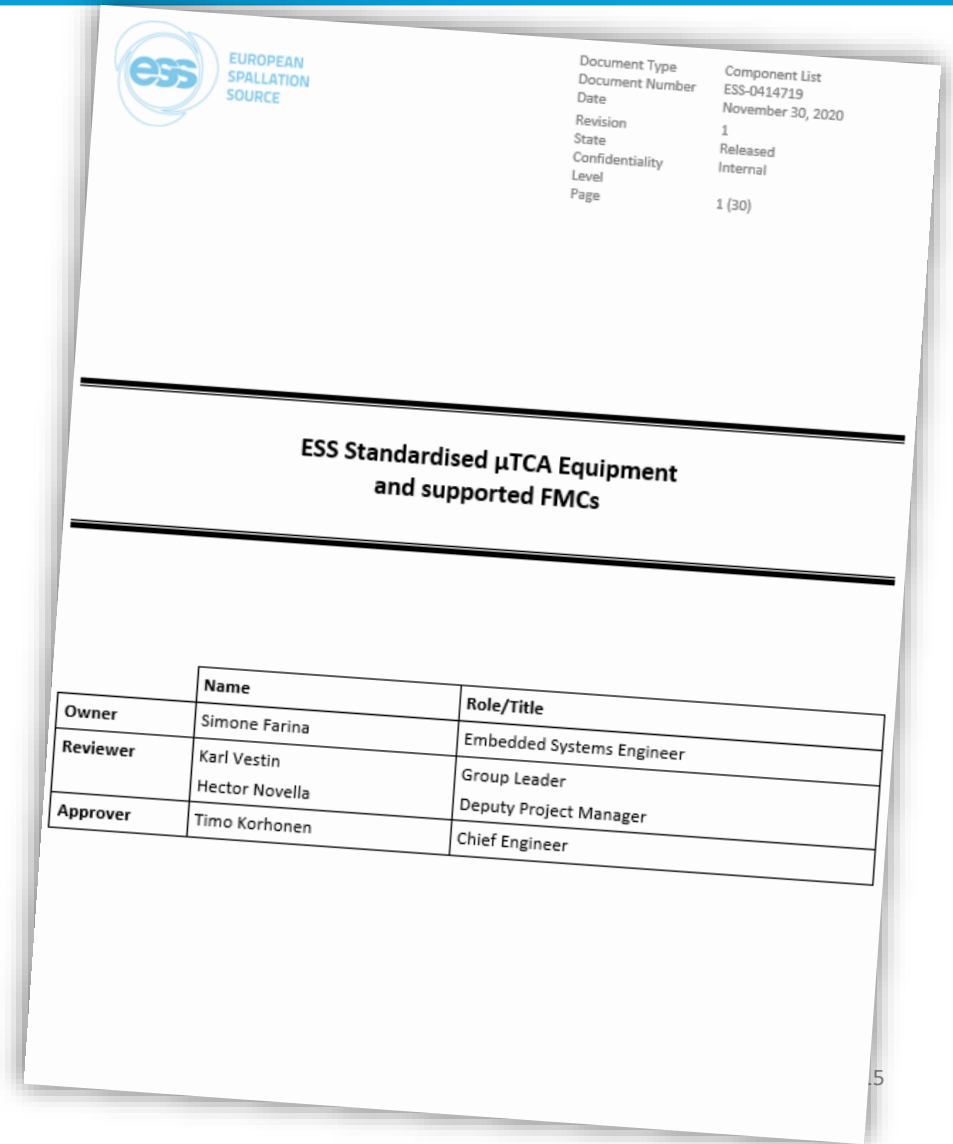
Facility-wide timing and data co-ordination to nanosecond precision



Standardization Process for MicroTCA

To be efficient in managing inventory, ESS has standardised MicroTCA components that can be used at ESS

- Infrastructure components
 - Chassis
 - Power modules
 - MicroTCA Carrier Hubs
 - Chassis replacement parts
- Specialized AMC cards:
 - High performance CPU
 - Data Acquisition
 - Timing synchronization
- Versatile AMC cards
 - FMC carrier
 - RTM support card
- RTM cards
- FMC modules

Document Type
Document Number
Date
Revision
State
Confidentiality
Level
Page

Component List
ESS-0414719
November 30, 2020
1
Released
Internal
1 (30)

ESS Standardised μ TCA Equipment and supported FMCs

	Name	Role/Title
Owner	Simone Farina	Embedded Systems Engineer
Reviewer	Karl Vestin Hector Novella	Group Leader Deputy Project Manager
Approver	Timo Korhonen	Chief Engineer

MicroTCA infrastructure components

- 12 slots 9U for systems requiring more than 6 AMCs and/or more than 4 RTMs or redundant low noise power modules;



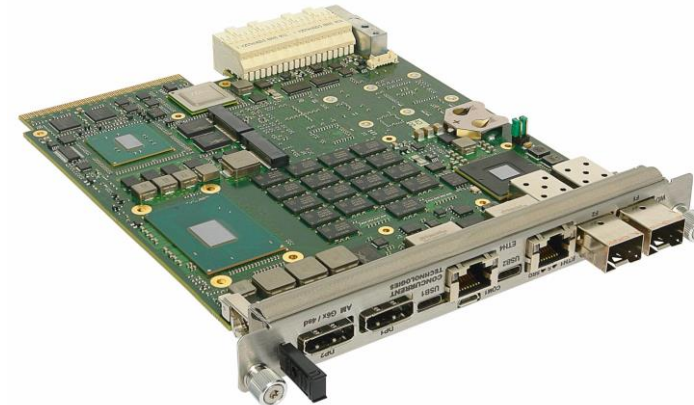
- 6 slots 3U to reduce system space in racks.



Power Modules: Wiener (1KW), N.A.T. (600W)



Concurrent Technologies AM G6x





IOxOS IFC_1410

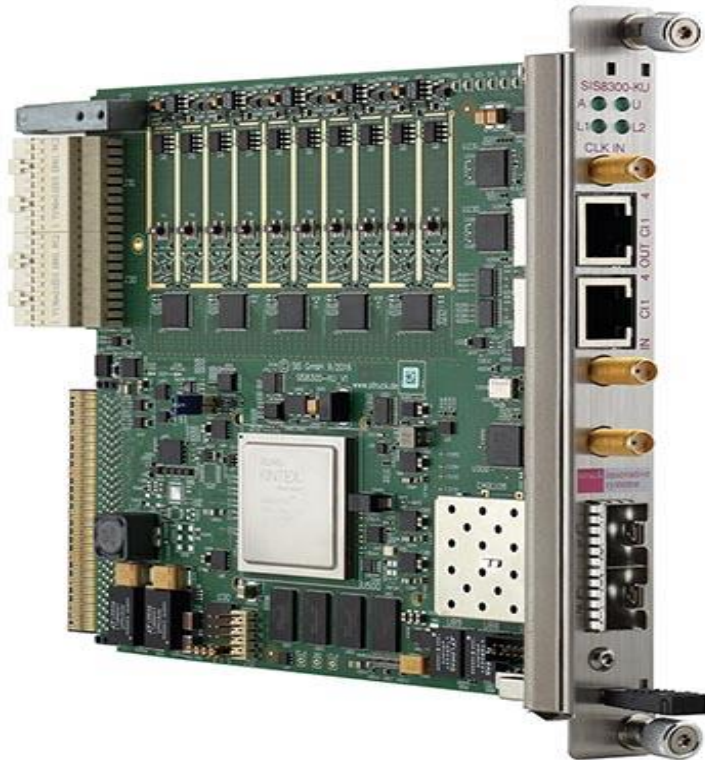
(In-kind contribution from PSI, Switzerland to ESS)

Processing System:

- NXP T2081 PPC running at 1.8GHz
- 2GB DDR3L (upgrade path to 4GB with ECC)
- 64 MB SPI Flash memory
- 512MB NAND Flash
- PCIe x4 gen.3 connection to Programmable Logic (no direct connection to backplane)

Programmable Logic:

- Xilinx Kintex Ultrascale KU040 (vertical migration KU060)
- 2x 512MB DDR3L
- 3 PCIe End Points (x4 gen.3 to backplane)
- 2 HPC FMC support
- Support for custom mezzanine card on AMC side 1 or 2
- Zone3 connector (RTM support) compliant to class D1.4



SIS8300-KU:

COTS AMC card

Programmable Logic:

- Xilinx Kintex Ultrascale KU040
- 2 GB DDR4
- x4 gen.3 PCIe End Point to backplane
- 10 ch ADC 125MSPS 16-bit
- 2 ch DAC 16-bit
- Internal, Front Panel, RTM and Backplane Clock Sources
- Support for up to 2 SFP+ modules for high speed system interconnect
- 2 front panel RJ45 for external I/Os (eg BIS connection)
- Zone3 connector compliant to class A1.1CO



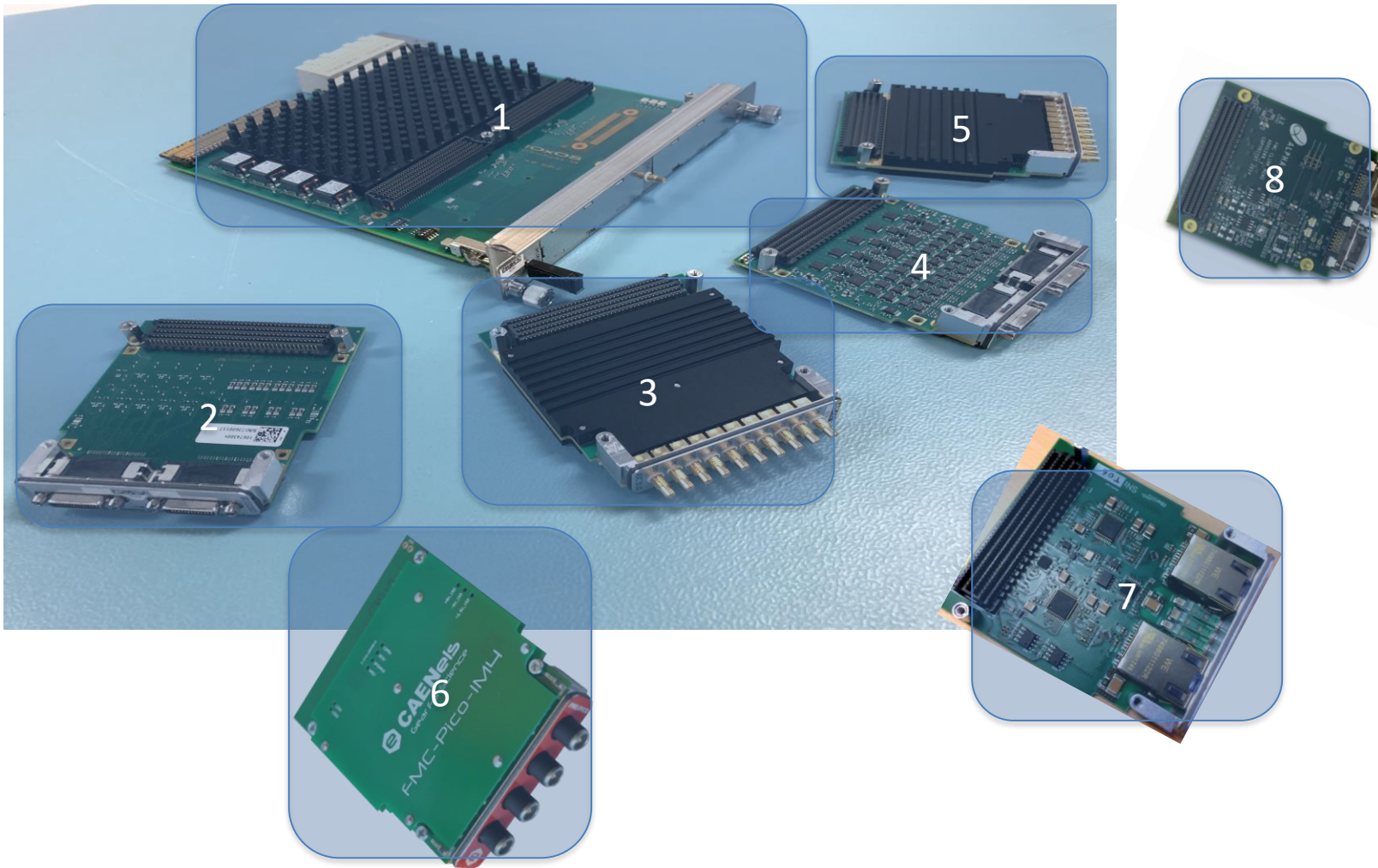
Timing system EVR:

- clocks from/to TCLKA/TCLKB
- driving/receiving differential triggers AMC RX/TX ports 17 to 20 (MLVDS)
- front panel 4 x TTL outputs, 2 x TTL inputs
- front panel 2 Universal I/O modules
- Delay compensation with feedback

Timing system EVM (Event Master: Generator and Fanout)

- Compatible with other 300-series form factors (VME, cPCI)
- Dual functionality: Event Generator or Fanout module
 - 1-to-7 fanout
- Integrates also two Event Receivers
- EPICS integration tests ongoing

FMC I/O cards



I/O interface cards:

1. IFC_1410 AMC
 - Carrier board
2. DIO_3118
 - Digital in/out
3. ADC_3110
 - 250 MSPS ADC, 8 Ch
4. ADC_3117
 - 5 MSPS ADC, 20 Ch
5. ADC_3111
 - Like #3 but DC-coupled
6. PICO-FMC
 - Low current measurements
7. ECATS
 - EtherCAT slave interface
8. FMC-Cameralink
 - Integration of cameras

Other development

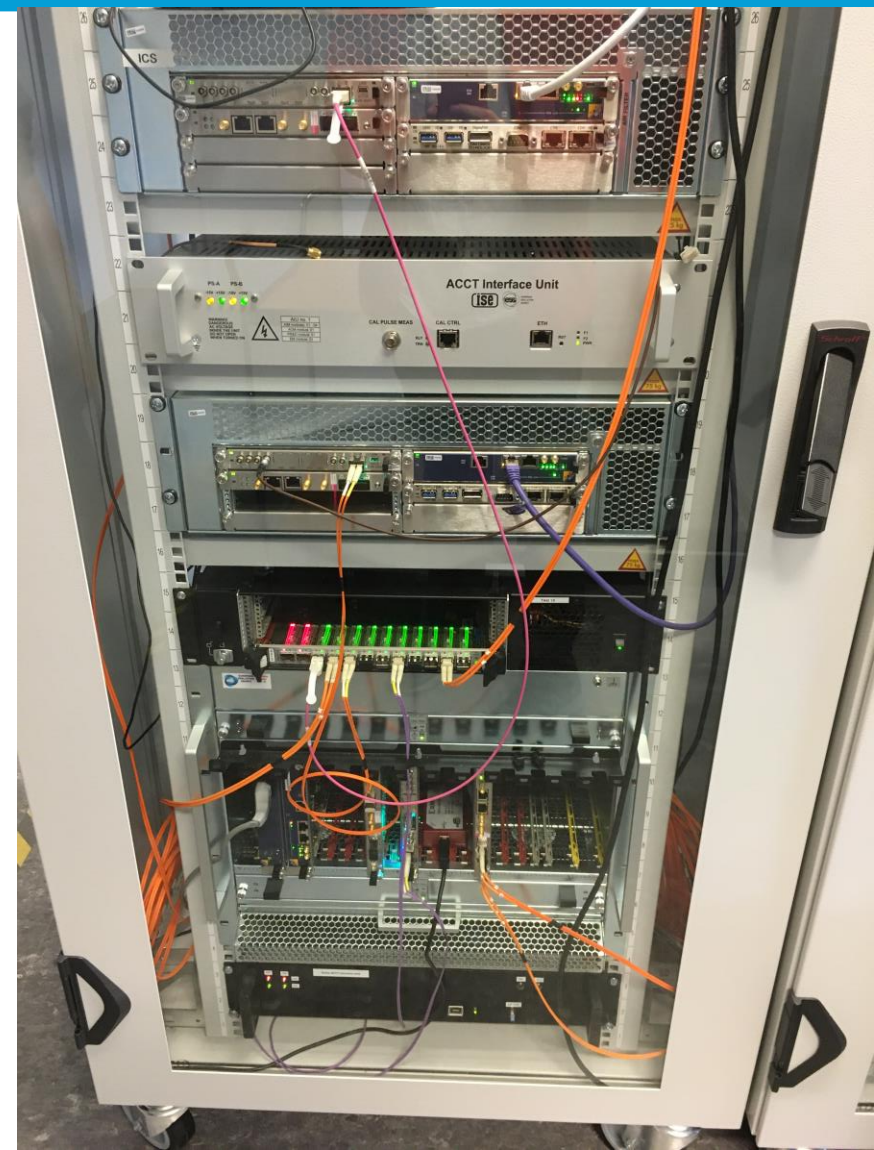
- IPMI project
 - An in-kind contribution from Poland to improve IPMI/EPICS integration
- FPGA framework standardisation
 - Several initiatives ongoing at ESS
- Participation in the next generation standardisation in PICMIG
 - at a low intensity due to focus on installation.
- Automation setup deployment and testing
 - Scripting and test-beds to automate large-scale deployment



Scale of MicroTCA deployment at ESS

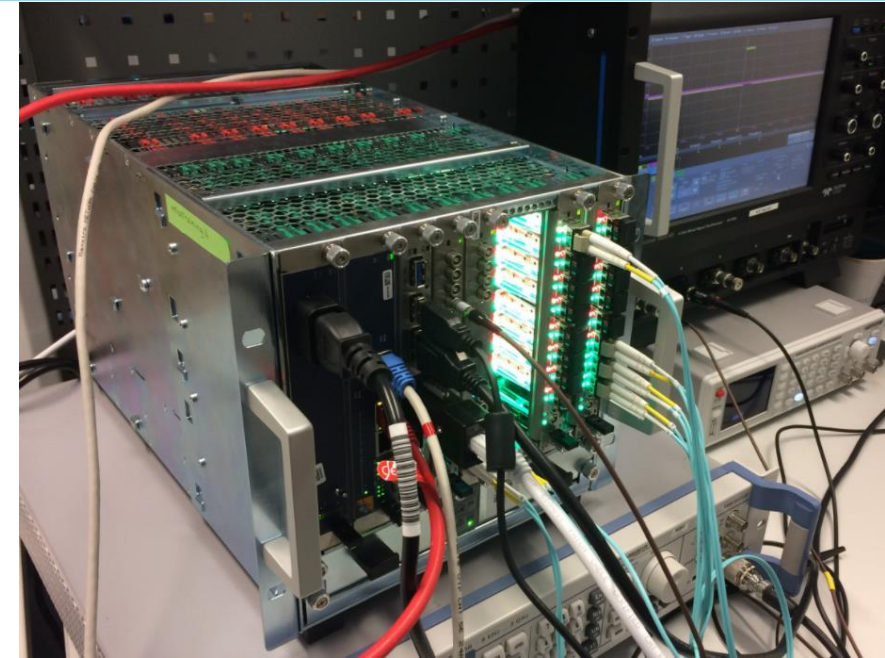
About 200 MicroTCA “systems” will be deployed

- Infrastructure
 - ~70 3U chassis
 - ~130 9U chassis
 - a handful of “tabletop” crates for lab development
 - corresponding number of MCH & CPU
- AMC
 - ~ 500 AMC:s
 - ~ 250 FPGA digitiser boards with built-in CPU:s
 - ~ 250 FPGA digitiser AMC + ~ 60 Processor AMC
 - ~ 300 custom RTM:s
- Timing system
 - ~ 150 AMCs for timing distribution (central master and fanout system)
 - ~ 300 AMC receivers in each MTCA system (and some industrial PCs)



Summary

- ESS uses MicroTCA in several high-speed applications
 - Large-scale, facility-wide deployment with many application areas
 - Hundreds of components connecting thousands of devices
- Standardised selection of components
 - To help and guide the users and to make future support possible
 - Kept up-to-date as technology evolves
- Mostly commercial and in-kind contributed components
 - Limited internal staff to drive in-house (hardware) developments
 - Much effort put into firmware and low-level software support
- Some initial problems found and solved during deployment
 - Good interaction within community and with suppliers





Thank you for your attention!

ICS vision: *"ESS operated efficiently, reliably and safely, with a control system that everyone loves"*