FAIR Control System

Discussions on CR

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Outline

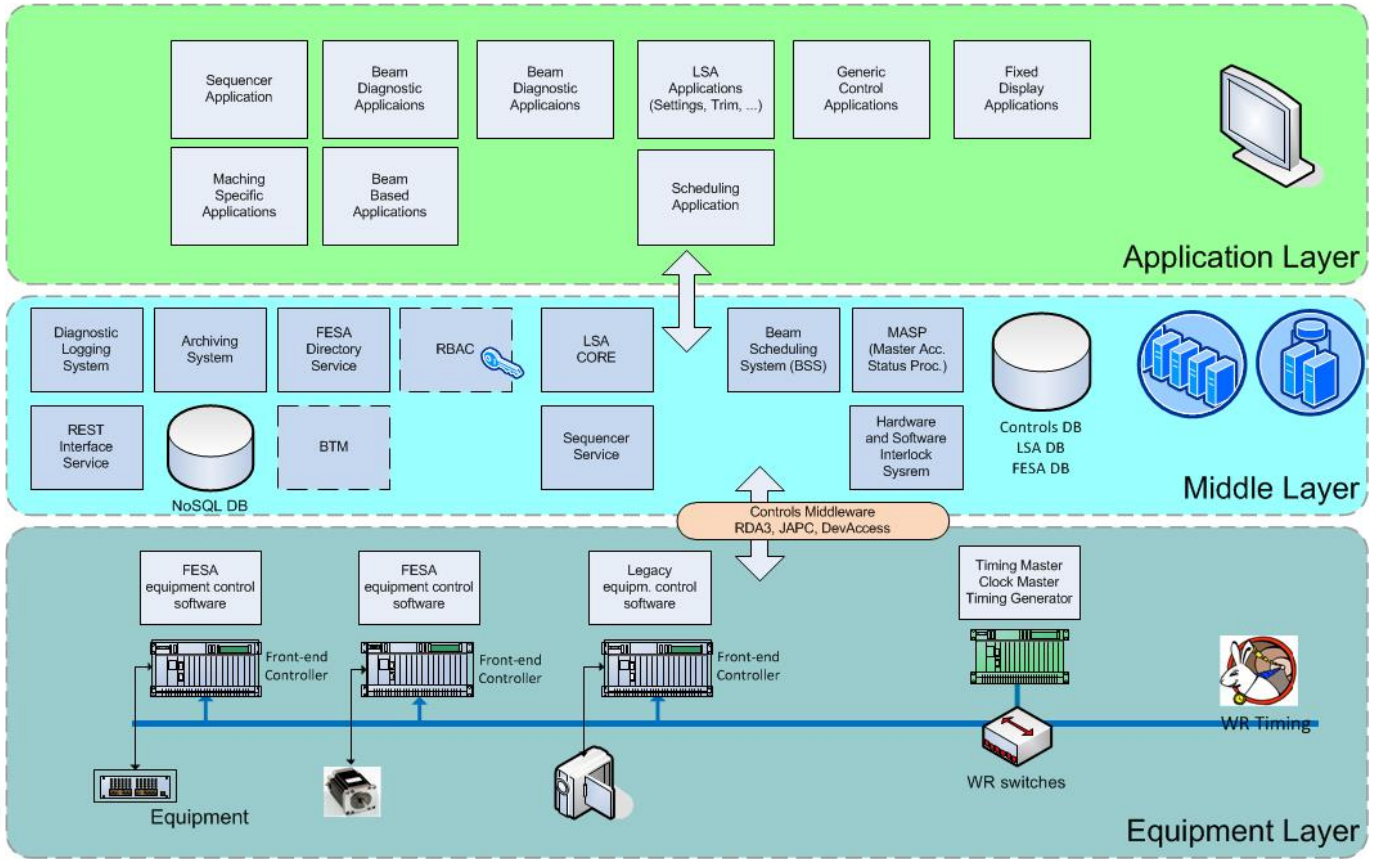
- Control System Overview – System Architecture
- Implementation Status of Major System Building Blocks
- Tools for Hardware and Beam Commissioning
- Outlook & Summary

Recap: Control System Architecture Stack

Presentation Tier

Middle Tier powerful servers

Resource Tier FESA



- Standard 3 tier model; distributed OO system
- Modular design with well defined interfaces

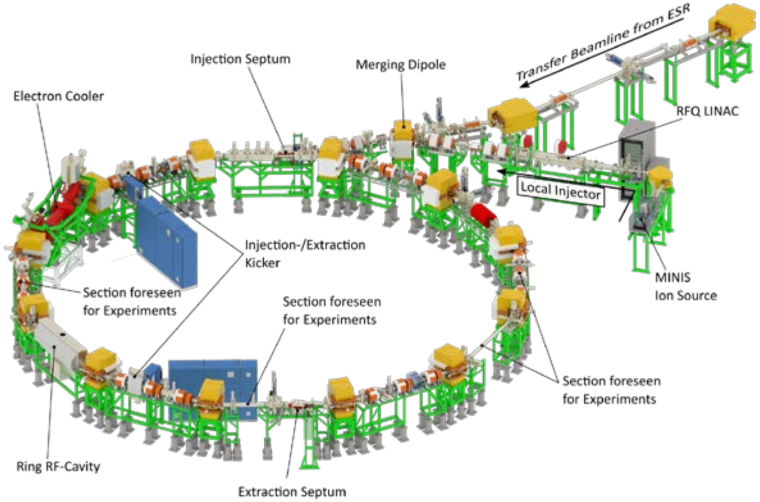
Control System Implementation Strategy

Control System early use at CRYRING

CRYRING @ GSI

➔ used as a continuous testbed for FAIR

➔ good model for CR as well

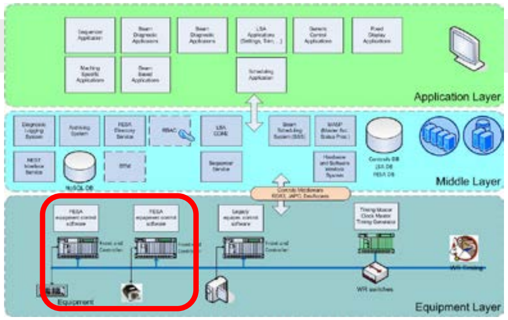


Implement basic functions of the FAIR ACS for validation of concepts, test, debugging, optimizations

„Early-adopter machine“ for new control system releases and functions without interfering with production beam-times

- Gaining experience under real-life conditions
- Check and verify new features and concepts
- Identify possible design limitations, debugging early in the project
- Considered a potent QA measure for the control system
- Allows validating commissioning procedures

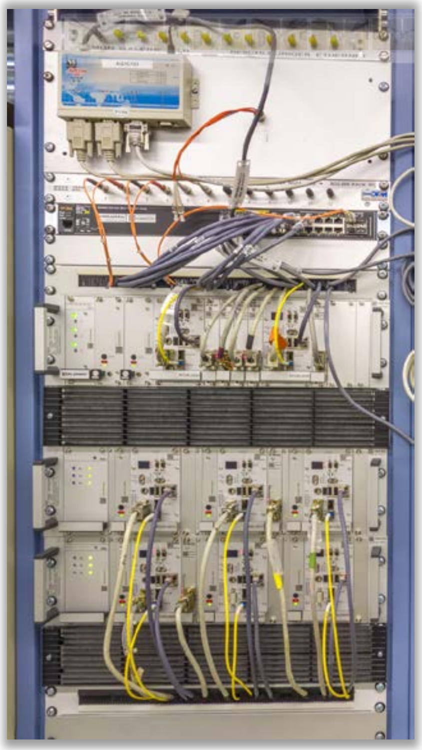
Equipment Control
Front-End Electronic and Software



Hardware status: SCU hardware eco-system
- 250 SCU controllers produced, ~100 installed in operational environment (CRYRING, SIS18/ESR/FRS/HEBT
- Continuous in-house production of 200 units ongoing
- Preliminary analysis of SCU hardware failure rate: 13 units within 3 years (well within the expected and calculated range)
- SCU slave board of multiple types developed and in use (DIO, AIO, I/F, DDS, ...)

Devices controlled by FAIR SCU controllers
- All CRYRING power converters (multiplexed and ramped, using AIO and DIO boards, no FAIR ACU digital controllers)
- All SIS-18 and ESR ramped power converters (using MIL-1553 field-bus interface)
- All GSI HEBT multiplexed magnet power converters (MIL-1553)
- All ring RF systems using direct SCU backplane communication to DDS, AIO, DIO boards; full FAIR-style)

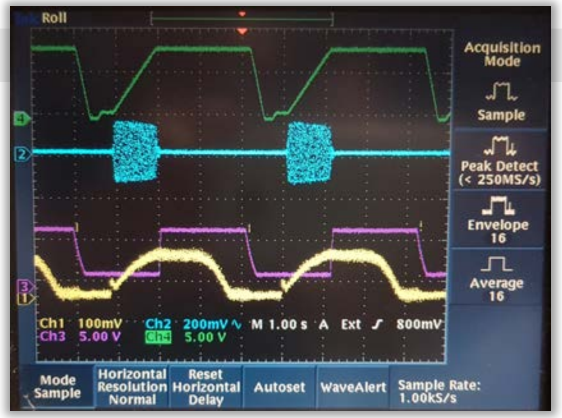
Equipment control software
- FESA framework (real-time equipment control software)
- Several FESA classes developed: CRYRING devices (ion source, multiplexed & ramped power converters, linac and ramped RF cavities, many BI DAQ systems, etc.)



Retrofitted controls rack controlling power supplies

Equipment Control

Front-End Electronic and Software



Function Generator (FG) subsystem

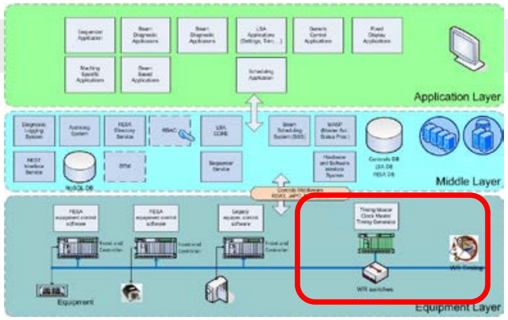
- control of ramped devices
- FPGA/HDL development for Function Generator
- Operational already (production beam time 2019)

Present activities & next steps

- Implementation of DAQ functionality (VHDL & FESA software)
- Roll-out of FAIR analog signal digitization systems
- Improve RT performance of the Timing System Library

Analog signals digitization system (PicoScope based)

General Machine Timing System
Implementation Status



Timing System installed and productive

- CRYRING – tested in 4 beam times (05/2017 to 03/2018)
- SIS-18/ESR/HEBT – producively used in beamtime 2019

Present hardware setup

- Central Timing System installation (WR/BuTiS) done
- 2 Clock Masters installed (grandmaster clock of WR network, GPS as reference clock, phase-locked to BuTiS)
- Data Master operational (PRO, DEV, INT)
- about 80 White Rabbit Switches installed
- DM orchestrates ~300 SCU controllers (timing receivers)
- and several more in other form factors (PCIe, VME, AMC, PMC)

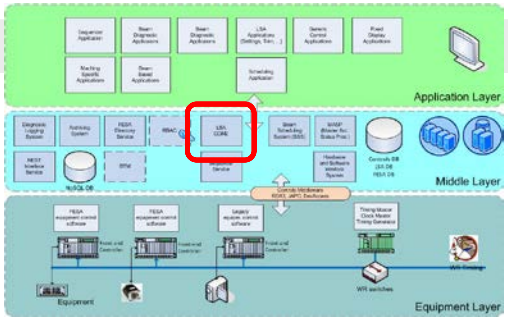
Hardware Situation

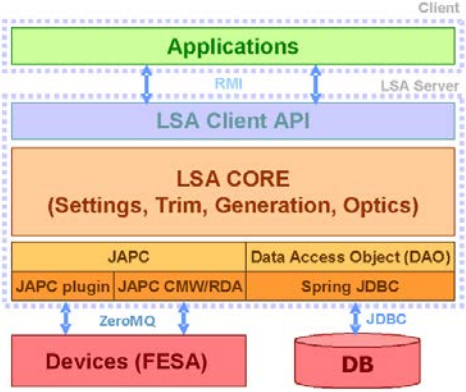
- 170 PCIe have been produced by GSI (→ CO Digitizers, BI)
- AMC and PMC in production (SLO in-kind)
- Procurement process for all WRS needed started: Delivery in 2019 and 2020 (full scope)

Setting Generation and Management
Status

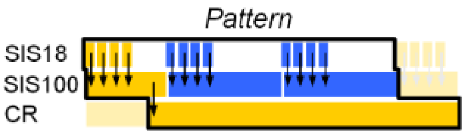
LSA status

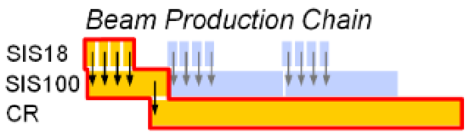
- LSA is ***the*** core component of the FAIR Control System, used for settings generation and management
- Well developed framework for CERN and FAIR accelerators (maintained in collaboration)
- Provides consistent settings on all levels, contains optics, accelerator model(s) and parameters (hierarchy from physics to devices)

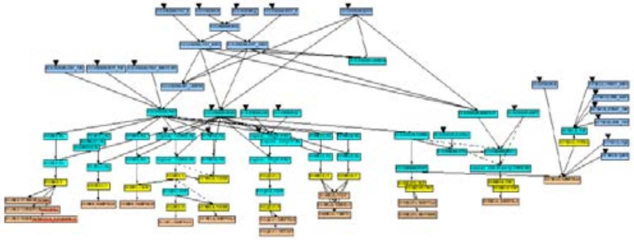




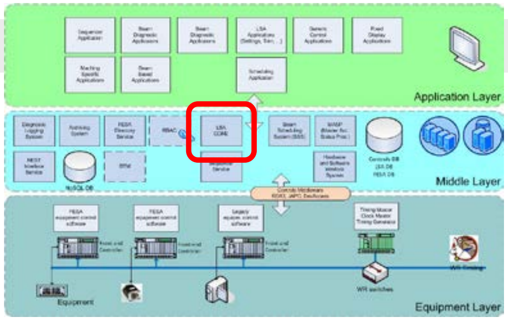
- To control the GSI/FAIR accelerator complex, new fundamental concepts have been defined and successfully integrated in the LSA core code base: Pattern, PBC (beam production chain).







LSA: Setting Generation and Management
Next Steps & Outlook

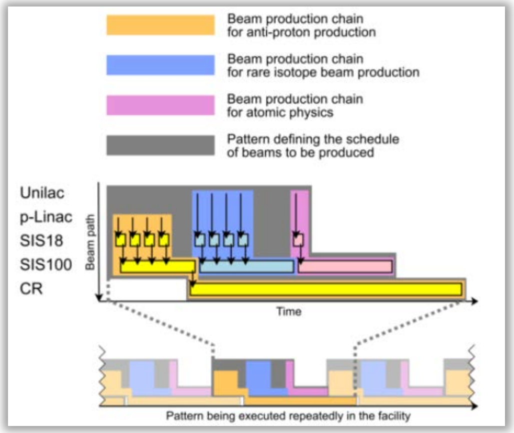


Status and operational experience

- All accelerators (CRYRING injector & ring, SIS-18, HEBT, ESR (in work)) have successfully been modelled in LSA and operated
- LSA core was extended by several components for the beam scheduling system (pattern management, beam requester, MASP status processor)
- LSA core was extended for full setting supply for the FAIR Timing System Data Master (Schedule supply fully implemented)
- Central system architecture and new concepts have proven to be adequate for facility operation, no showstoppers identified.
- LSA is a reliable system component

Next steps

- Continue implementation roadmap Storage → esp. Storage ring functionality (interactive manipulation mode for 2019, partially if possible for 2018)
- Code clean-up and refactoring necessary (2020/21)



Accelerator Status Monitor

Hardware Interlocks & Beam Interlocks

Status of Accelerator equipment and devices is monitored by hardware and software interlock system

Hardware Interlock System

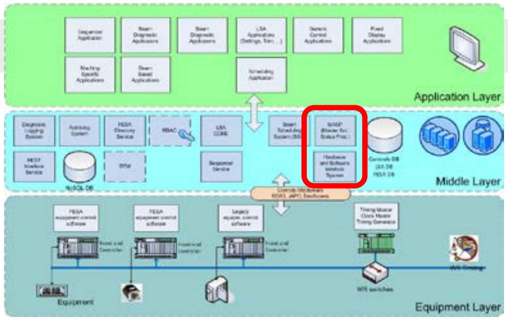
- in-kind delivery of Slovenian FAIR partner
- PLC based aggregation of hardware interlock signals
- Implemented for several HW signals

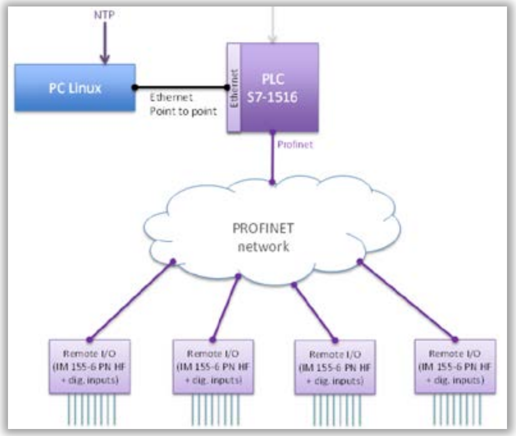
Software Interlock System

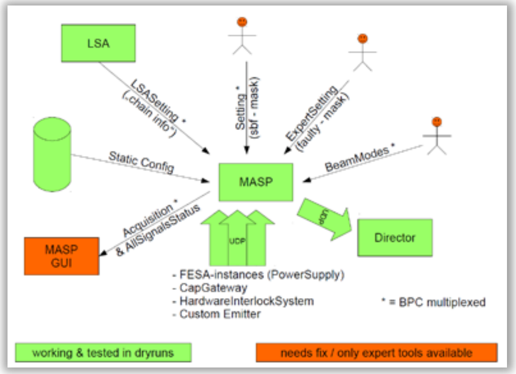
- MASP (Master Accelerator Status Processor)
- Receives and aggregates about 2000 signals from devices & components
- Prototype (mini-MASP) developed for BT 2018 operation (rapid prototype)
- Includes Gateways to monitor legacy FEC status messages
- Sends execution permit to BSS (beam scheduling system)
- Already prepared to manage Beam Modes (presently only NO_BEAM and PILOT_BEAM used)
- No real operational experience yet, just turned operational

Next steps

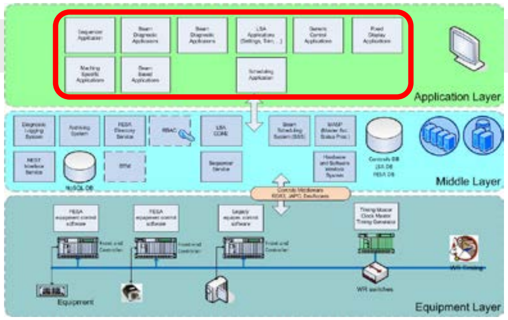
- Overall hierarchical status concept needs to be revised and extended for BPC-specifig beam interlocks
- Refinement of functional specification of the full FAIR Status Processor system and implementation in the next years





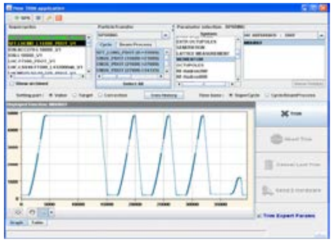


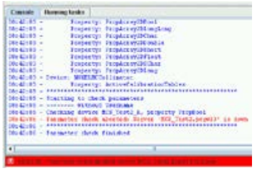
Control Room Applications

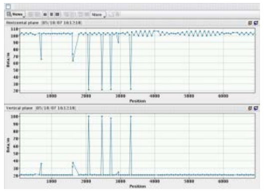


A complete new set of control room applications has been developed for CRYRING and beamtime operation in 2018.

- Implemented in Java (changed from Swing to JavaFX GUI framework)
- Present focus is on implementation of generic type applications to provide basic functionality
- Applications
  - LSA applications (Settings, Trim, ...)
  - Beam Scheduling Applications, Beam Requester
  - Equipment and Timing monitor & control, Interlock and Status monitoring
  - Set of Beam instrumentation (expert applications)

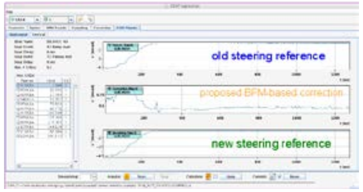


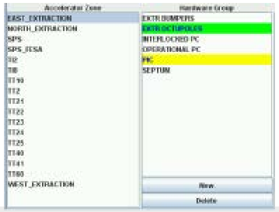




Operational experience and know issues

- Feedback from operator team required – present set of applications are first rudimental versions, unhandy and inefficient to use
- Just porting popular applications from the old control system is no effective strategy, control paradigms changed
- Still very much effort to provide control room applications with operational quality
- Presently insufficient manpower to support machine-specific and beam- and measurement-based applications (is addressed to PL/Management)
- New development: Oracle announced their intention to stop shipping JavaFX with JDK 11 and later → observe community, stay mainstream





Control Room Environment

Prototype for the FAIR Control Centre

Control system consoles

- Prototype operator consoles for FCC have been installed in present main control room for operation with new control system
- Operator consoles consist of a 3x2 TFT screen array with 2 console computers installed in the console corpus
- Fixed displays as foreseen for FCC are already wall-mounted, first overview applications are online

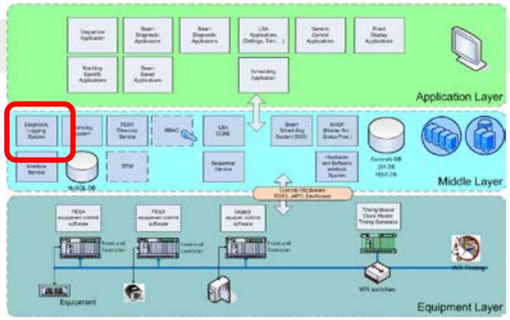
Fixed display prototype (SIS-18)

Central control room with new FAIR console environment (June 2018)

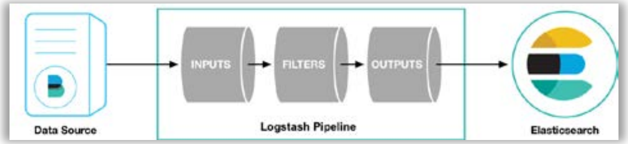
Diagnostic Logging System

Powerful System Diagnostic Tool

Diagnostic Logging: System to receive and store diagnostic logging messages in the control system

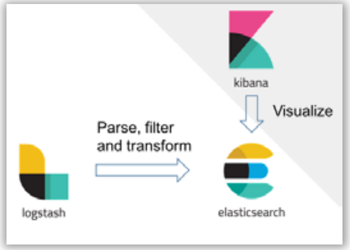


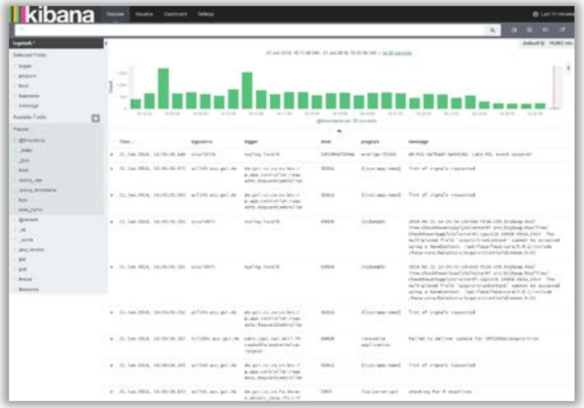
- The system focuses on system messages, not on accelerator measurement data (→ Archiving System)
- The system is implemented as a cluster of *logstash* servers



Logstash?

- Light-weight open-source, server-side data processing pipeline for diagnostic data
- Data pipelined and persisted in *elasticsearch* nSQL DB and popular analytics and search engine
- System emitters for syslog and log4j prepared
- *Kibana* Web-client (open source data visualization plugin) provides comfortable access as well as powerful filter capabilities



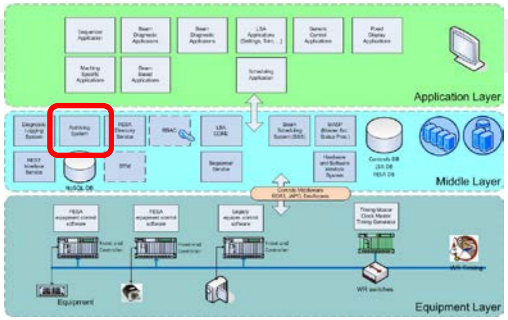


Status and operational experience

- Extremely valuable tool, a “must-have” for debugging, commissioning and operation
- All FEC and system services send diagnostic logging messages

Archiving System

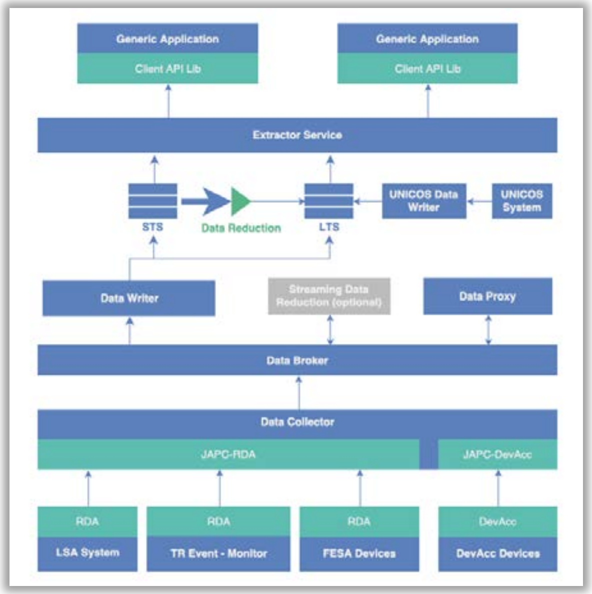
The FAIR Measurement Database



Archiving System is a central building block of the FAIR control system

→ Very important tool for HW/beam commissioning and operation

- Store historical data by FECs and controls processes permanently
- Stores data from automated sequencer tasks
- Allows storing data on configurable base (time resolution, triggered by timing events, on-change, push data)
- Functionality to query, correlate and display historic data
- Includes services that allow smart data reduction or aggregation over time
- Key parameters (FAIR final): ~100 TB storage, ~10 MB/s continuous input data stream
- Design decision: AS will receive and store future PM data (no separate system planned any more)



Some implementation details

- Consists of several components, amongst them...
- Apache Kafka (Data Broker, high performance system)
- Elastic Search (nSQL DB for Data Writer component)

Archiving System

Status and Outlook

Present status

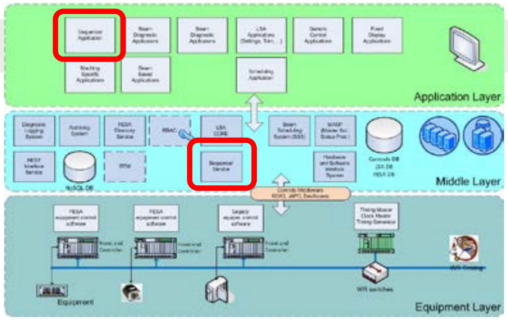
- Presently under development as SLO in-kind contribution (xlab/Tehnodrom)
- First prototype version installed on virtual server environment
- Procurement of IT hardware for test system started (20 TB disk space)
- About 100 FEC are configured to send measurement data to Archive
- Sequencer sends reports to AS
- First GUI program to retrieve, display and analyse data from AS under development
- AS is defined to receive and store PM data (no separate system planned any more)

Outlook & next steps

- Complete implementation until mid of 2019
- Performance tests with beam (2 months on real hardware)
- Gain first experience (store/retrieve) with interested users (Operation/Physics)
- Operational use for Beamtime 2020

Sequencer Framework

Semi-automated Tests for HW and Beam Commissioning



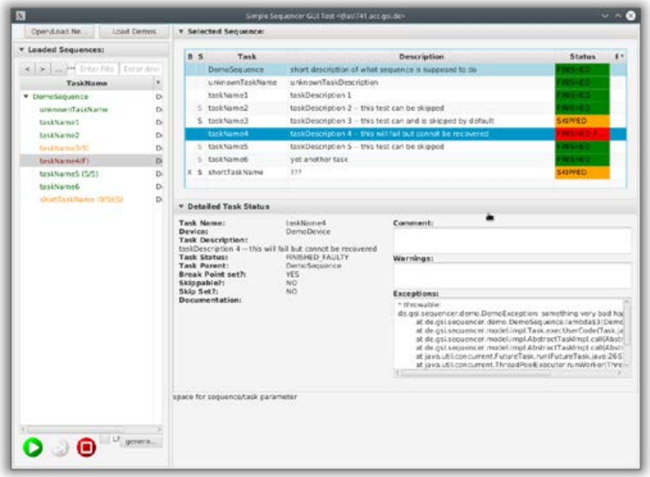
HW and beam commissioning require efficient tools for testing

- Perform initial and acceptance tests, early detection of non-conformities and faults
- Perform QA and regular re-validation tests
- Considering size and complexity of FAIR, and limited resources: efficient and reliable execution and documentation of tests

→ Development of a Java-based **Sequencer framework** started, as a core part of the FAIR control system to aid semi-automated testing

Architecture: Sequencer framework conceptually divided in three parts

- Middle-tier *sequencer service* (run sequences, generate automated reports)
- The *sequences* with a subset of *tasks* (testing steps)
- Graphical user interface (GUI) program



Sequencer GUI impression
(courtesy Ralph Steinhagen)

Operational experience so far:

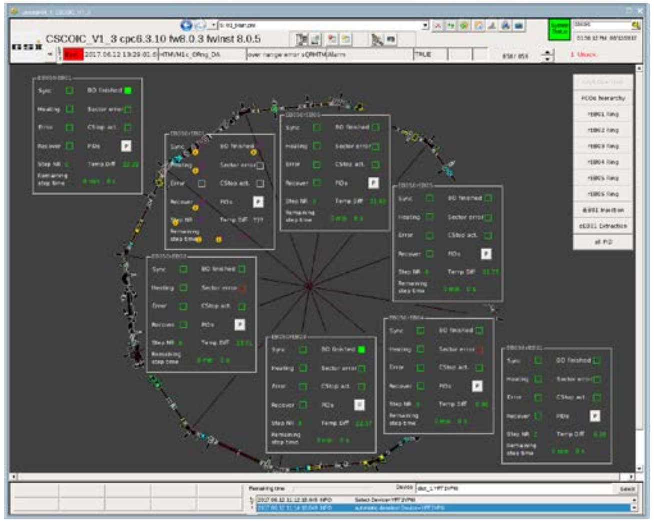
- Was tested and used already during Dry-runs in 2017
- However, new development. Not yet adopted by FESA class and system service developers
- Establish process of writing Sequencer tasks parallel to development (in progress)

Controls Project Status

Vacuum Control System (Controls WP-6)

FAIR Vacuum control system is Slovenian in-kind contribution

- Decision taken to use CRYRING for vacuum controls test bench (including bake-out)
- Implementation done by Tehnodrom and supported by CO
- System almost fully implemented, commissioned and already in use (to be completed until 08/2017)
- Technical evaluation ongoing, some problems and scaling limits identified, to be addressed.



Synoptic displays from CRYRING vacuum control system

- Detailed specification for FAIR vacuum system prepared, needs to be refined by testing results
- FAIR implementation project can only be started with equipment type and BOM vacuum list

General Status & Problems

- No technical problems
- Extended project length (up to 2025) proves to be a problem for in-kind consortium (under clarification)

Summary

- Fundamental building blocks of the FAIR control system have already been developed and are in use (Equipment controllers, frameworks FESA, LSA, UNICOS, Timing, ...), roughly a million lines of code has been developed so far
- CRYRING has been adopted as test bench for FAIR control system vertical test, 4 runs with beam have been executed
- Control system stack was already rolled out to SIS-18, ESR and HEBT and is presently already used in production (successful beam time 2019) → FAIR version 0 control system is already in use today, years ahead of FAIR start
- Architecture, basic concepts and general system design have shown no fundamental problems, showstoppers or technical risks so far → detailed design is continuously refined
- Some technical limits/bottlenecks have been already identified → still early enough to fix in the next years
- Efficient tools for diagnostics, testing and measurement data acquisition for FAIR hardware and beam commissioning have already been developed or are under development (Diagnostic logging, Archiving, Sequencer, Digitization System)
- Control System is far from being feature-complete, presently limited to basic functions. Many important functions and features still need to be developed and iteratively rolled out in the next years until FAIR start
- Operational experience will be gained during beam times in the next years

Next Steps for CR

- CR equipment - Consolidate CR “equipment type list”
  - Compilation of a list of all equipment type for control/monitoring, define rough numbers
  - If needed, discuss on equipment control interfaces (if specified solutions are not adequate)
  - Discuss and agree on equipment functionality
  - needed to work out implementation plan (hardware production, software development, test sequence developments, support for FAT/SAT, ...)

- Consider a visit to the next CRYRING beam time
  - get hands-on experience and better impression on the capacity of the system

thank you!