EPICS Architecture for Instrument Control at the European Spallation Source

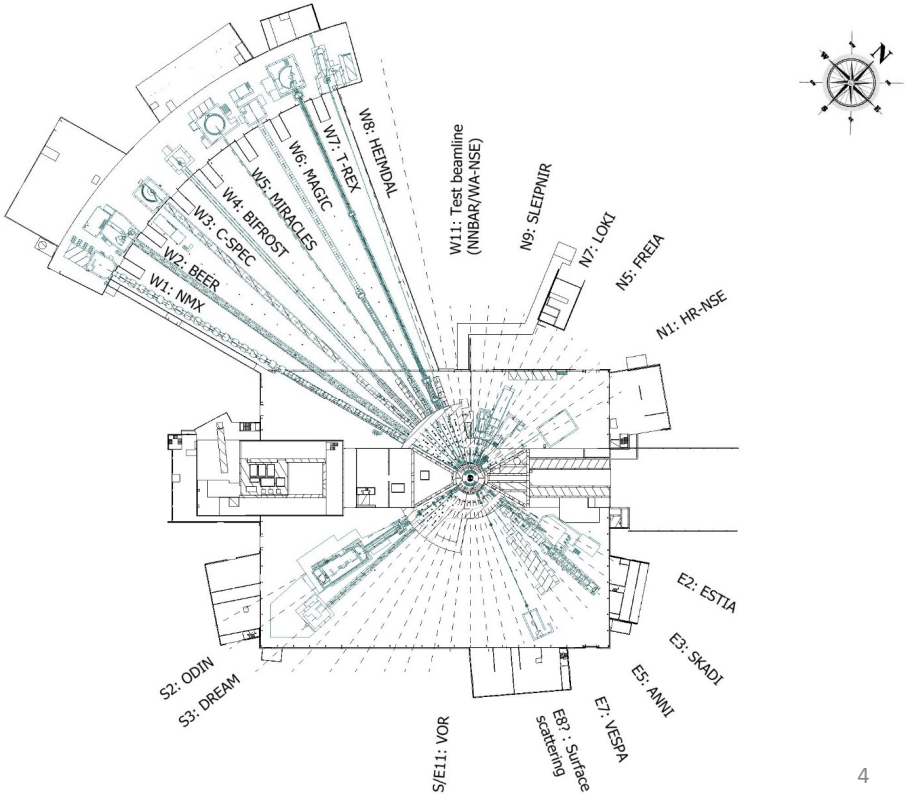
John Sparger
Control Systems Engineer

ESS Instruments

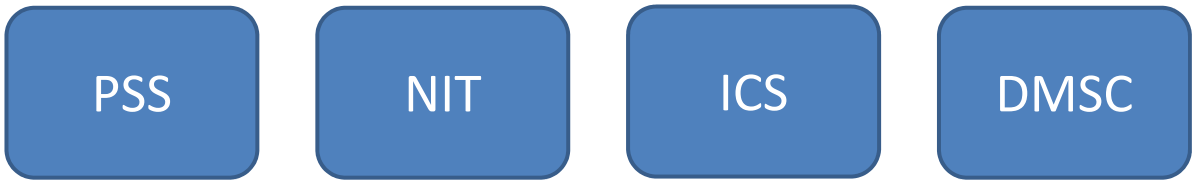
- ESS Instruments:
  - 22 instruments originally planned
  - 15 instruments are currently funded
  - 8 instruments will be ready for routine scientific use by 2023
- The instrument suite is being developed across the ESS member nations

ESS Instruments

ESS Instruments

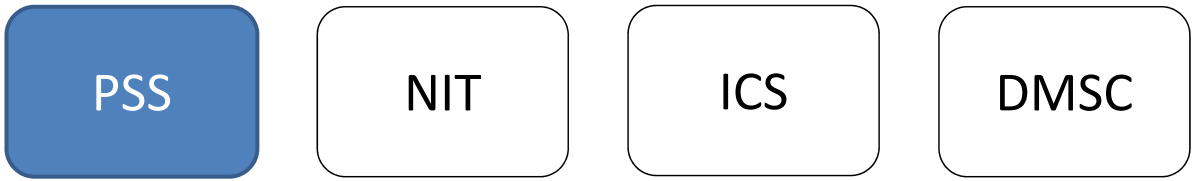


Instrument Controls



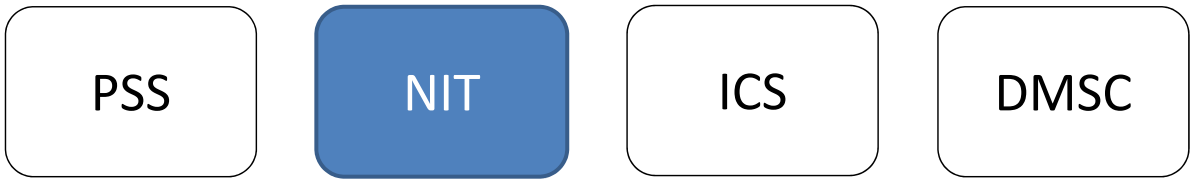
Personnel Safety System

- Responsible for mitigating safety hazards at ESS
  - Radiation
  - Oxygen depletion
  - Hazards from fixed equipment
- Developed according to IEC 61508



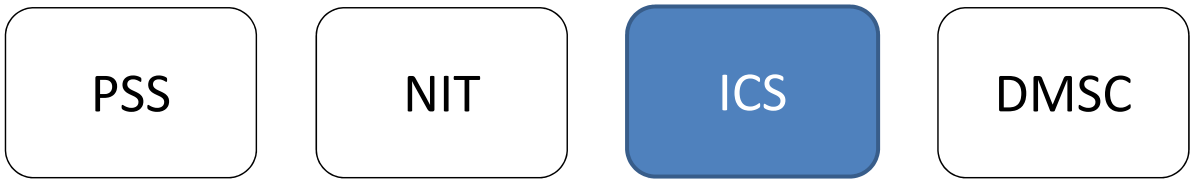
Neutron Instrument Technologies

- ESS staff are working to define standard components and interfaces:
  - Motion control interface
  - Chopper control interface
  - Detector readout system
  - Sample environment equipment



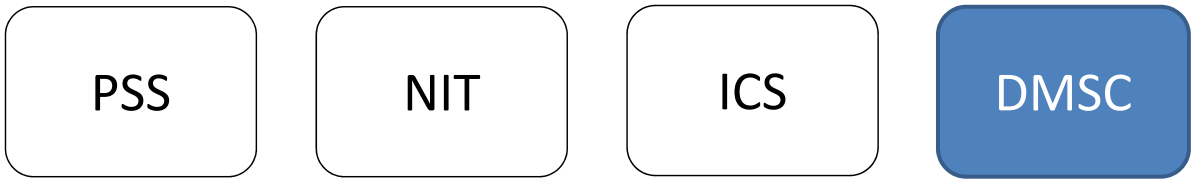
Integrated Control System

- Define and develop standard hardware platforms for control system use
- Deploy the EPICS controls for ESS instruments

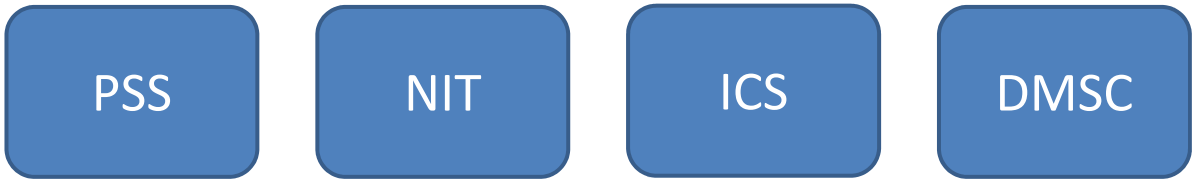


Data Management and Software Center

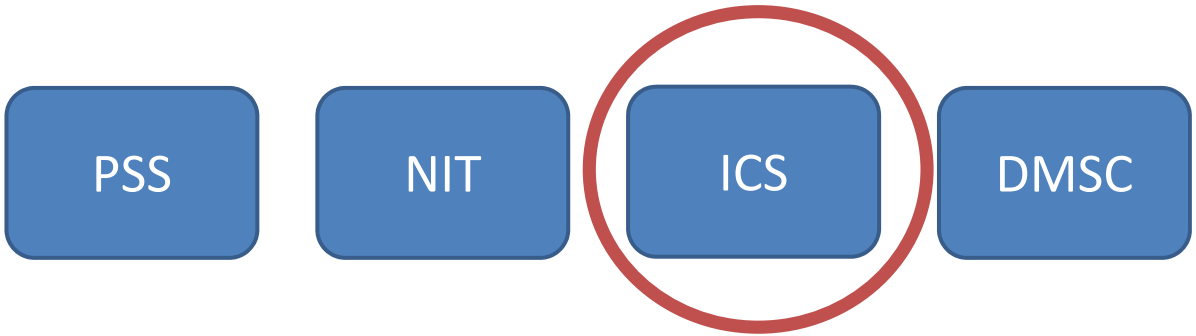
- Acquisition and analysis of scientific data from instruments
- High level control of ESS instruments



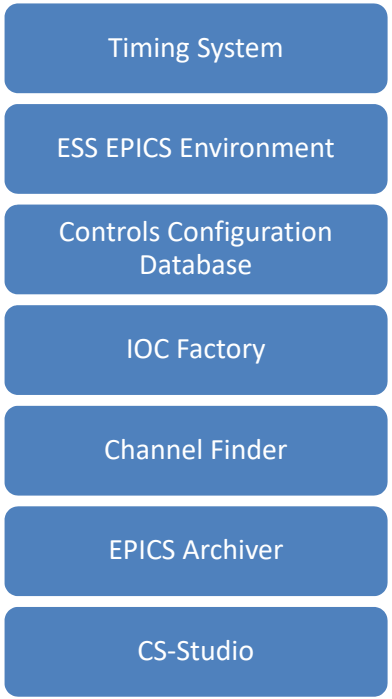
Instrument Controls



Instrument Controls



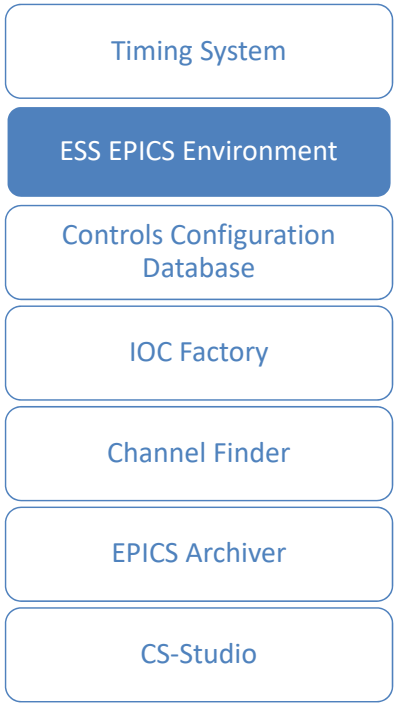
ICS Infrastructure and Workflows



MRF Timing System

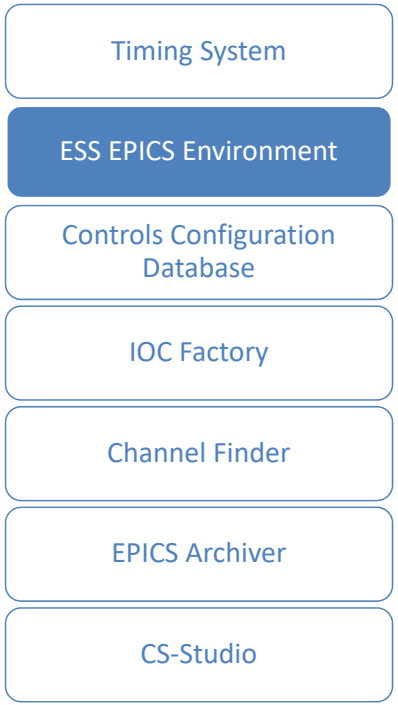
- Micro-Research Finland
- Used to synchronize the entire facility
  - Accelerator
  - Target
  - Instruments
- Critical for instrument components like choppers which must be precisely synchronized with pulse

ESS EPICS Environment (EEE)



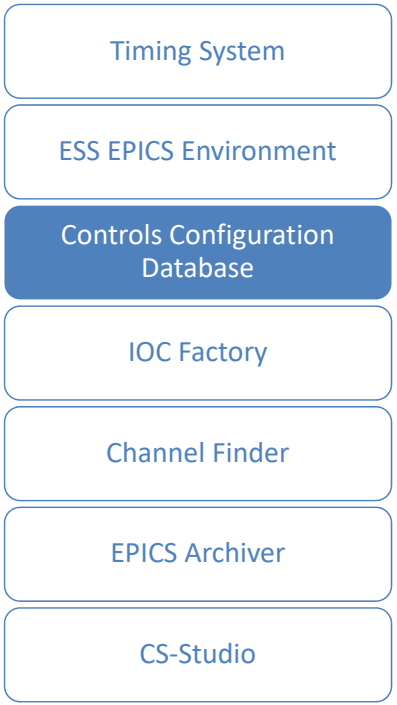
- Build system for EPICS at ESS
- Modules
  - Single Makefile
    - Project inspection
    - Cross compilation
- IOCs
  - List required modules in startup script
  - Dependencies loaded at runtime
    - Switch between versions of modules or EPICS Base without recompilation

ESS EPICS Environment (EEE)



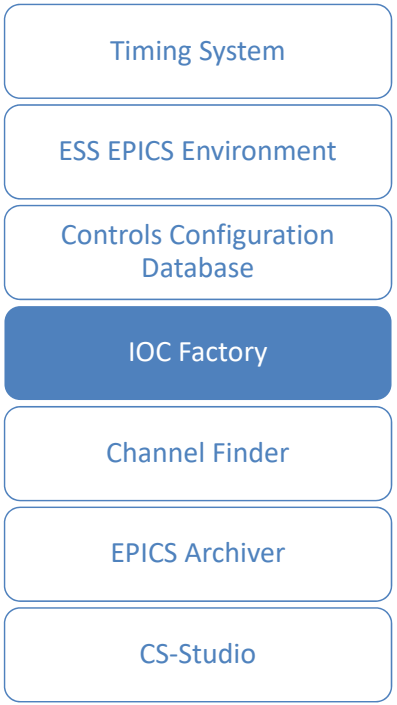
- Also a deployment system
- Synchronized repository of EPICS modules
  - NFS on-site
  - Rsync for in-kind partners off-site
- Continuous integration
  - Jenkins builds on ESS Bitbucket
  - Tagged releases deployed to file system
- IOC startup scripts deployed based on host name

Controls Configuration Database (CCDB)



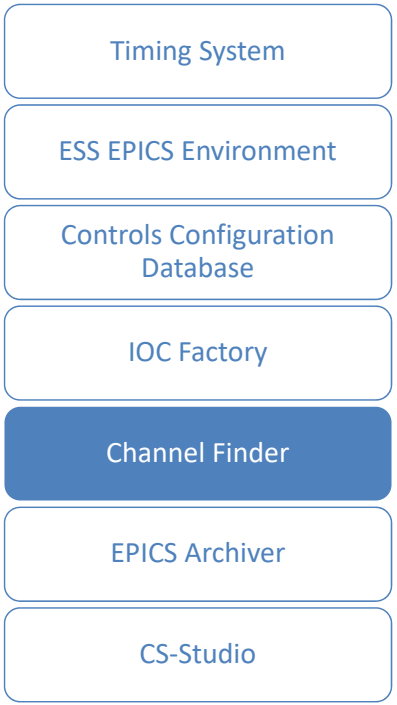
- Used to model ESS control system
- Relationships:
  - Contains
  - Controls
  - Powers
- High level models:
  - Software dependencies
  - Applicable device types
- Low level models:
  - Specific computer running IOC
  - Specific hardware being controlled
- Several tools consume this data to generate code and automate configuration/deployment of controls

IOC Factory



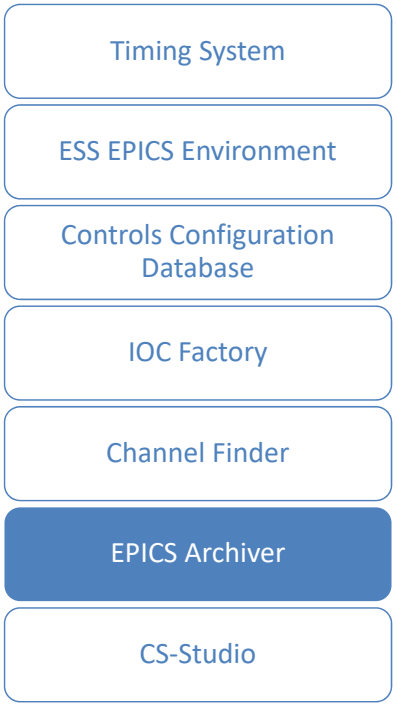
- A tool to manage EPICS IOCs at ESS
  - Configure
  - Deploy
  - Browse
  - Audit
- Consumes EPICS modules and devices from CCDB to generate startup scripts
- Deploys IOC to appropriate server through EEE
- IOC versioning

Channel Finder



- Directory service for EPICS PVs
- Recsync:
  - Automatically upload list of PVs to Channel Finder on startup
  - Allow Channel Finder to determine if PVs are disconnected
- Control System Studio integration
- Metadata as Key-Value pairs
- Will be used as component in Sample Environment “plug and play” with NICOS experiment control

EPICS Archiver Appliance



- An EPICS client which continuously records PV values
- Historical values and trends
- Web interface and HTTP API
  - Configure
  - Query
- Data retention and decimation policies

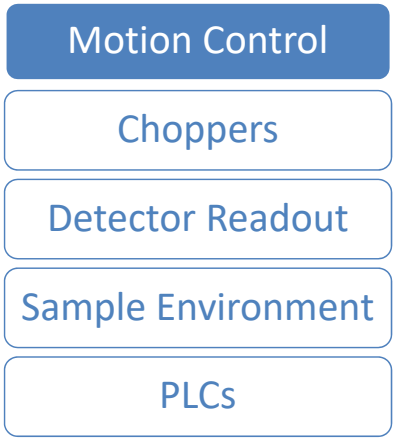
Control System Studio

- GUI which can help users interact with EPICS and related software
  - Tools to construct custom Operator Interfaces
  - View historical data from archiver
  - Search for PVs listed in Channel Finder
- Will be used for all expert engineering screens at ESS
  - (NICOSII will be used for experimental control)

Instrument Components

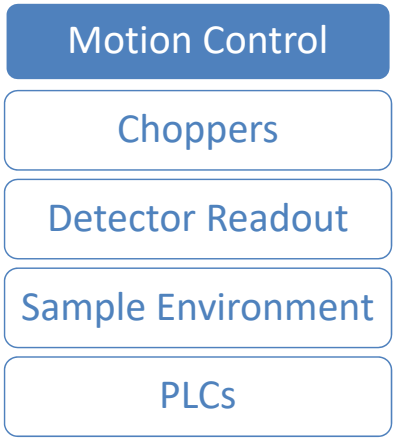
- Motion Control
- Choppers
- Detector Readout
- Sample Environment
- PLCs

Motion Control



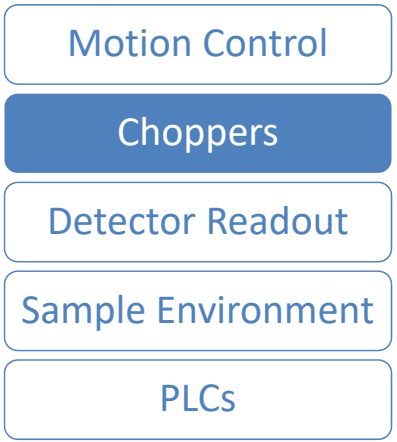
- Motion axes are common components of neutron instruments
  - Slit systems
  - Shutters
  - Positioning systems
- Standard motion control unit (MCU)
- Standard actuators and other motion components

Motion Control



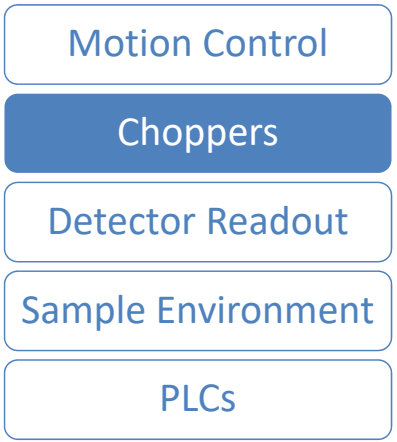
- Most devices:
  - Generic axes through EPICS
  - High level device controls in NICOSII
- Special cases will move logic to lower levels
  - Machine protection
  - Fast response times
- MCU clock can be synchronized to timing system if necessary.

Choppers



- Neutron choppers are rotating discs coated with neutron absorbing material
- Select neutrons of particular energies or introduce time structures
- Fastest ESS choppers will operate at around 400Hz

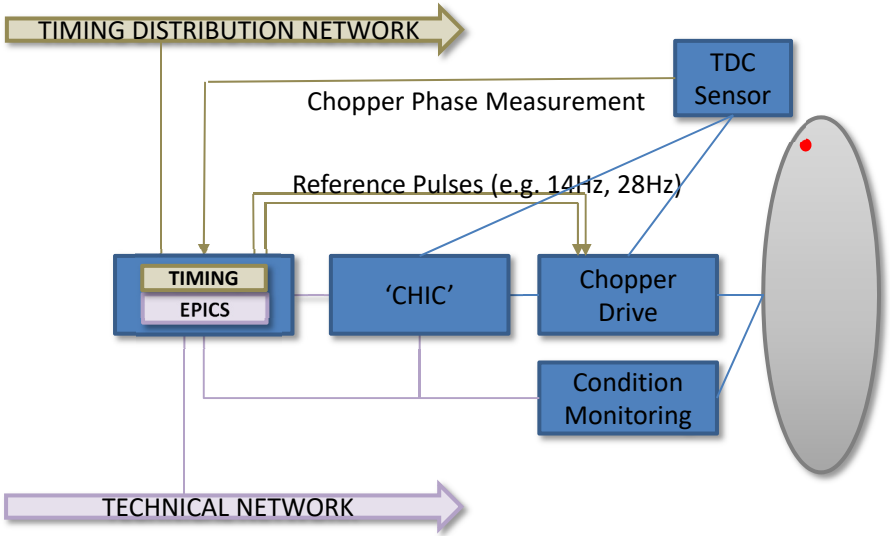
Choppers



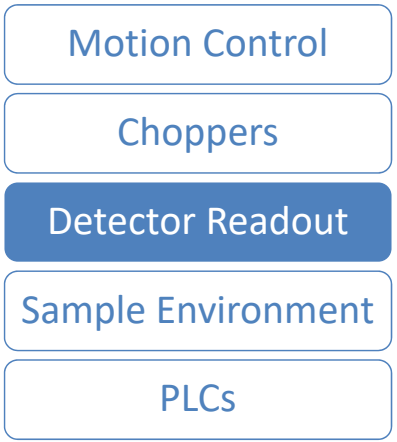
- Choppers from several manufacturers will be used at ESS instruments
- ESS is developing the Chopper Integrated Controller (CHIC) to abstract chopper drive control.
- The timing system and EPICS play an important roll
  - Phase control of choppers
  - Timestamping of chopper rotations
  - Condition monitoring

Choppers

- Motion Control
- **Choppers**
- Detector Readout
- Sample Environment
- PLCs



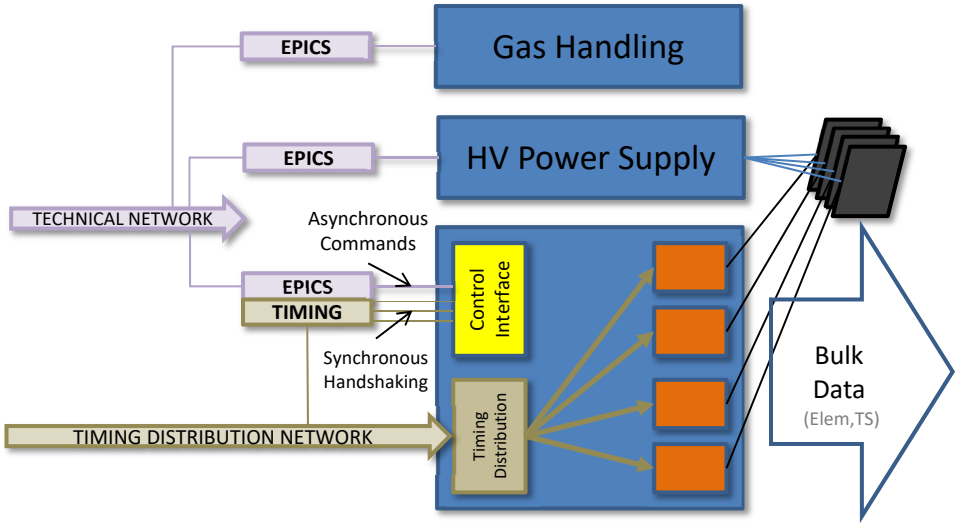
Detector Readout



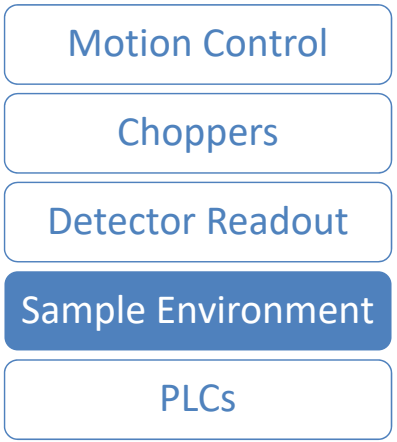
- ESS Detector Group developing standard readout system
- Slow controls through EPICS
- Compatible with a range of analog front-ends and detector technologies
- Responsible for streaming raw data to DMSC for event formation
- Interface to timing system

Detector Readout

- Motion Control
- Choppers
- **Detector Readout**
- Sample Environment
- PLCs



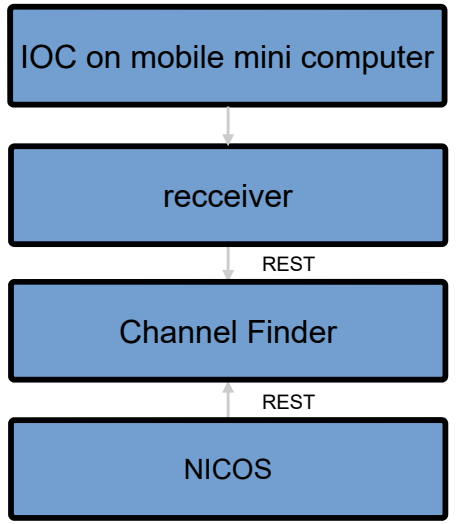
Sample Environment



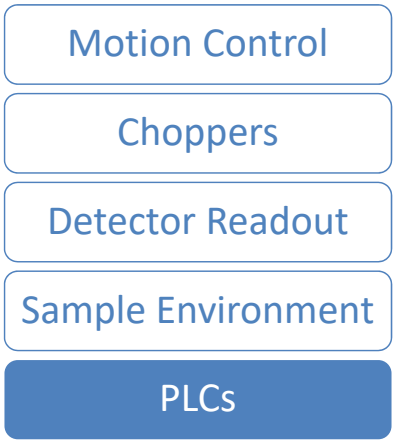
- Used to regulate conditions of sample during measurement
  - Temperature
  - Pressure
  - Magnetic field
- Some instruments have specific sample environment equipment
- Most equipment will be part of a pool
  - Individual control computers
  - Self identifying equipment

Sample Environment “plug and play”

- Motion Control
- Choppers
- Detector Readout
- **Sample Environment**
- PLCs

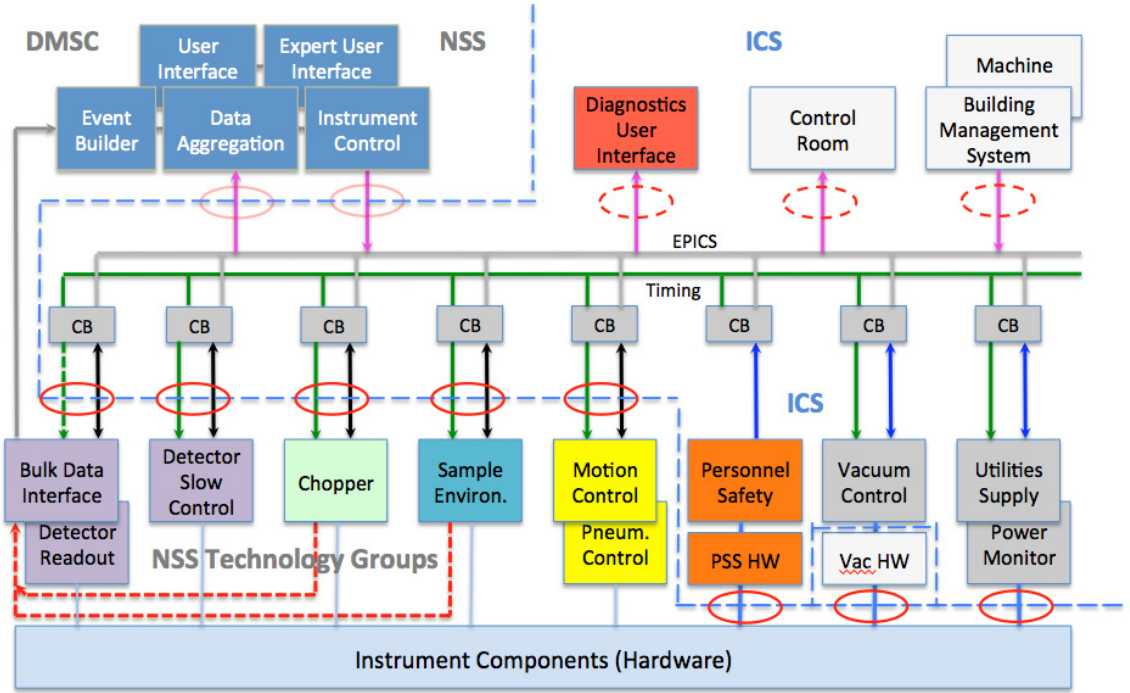


PLCs



- Programmable Logic Controllers
- Instruments will use PLCs for:
  - Vacuum systems
  - Utilities (e.g. cooling water)
  - Detector gases
- PLC programming done by ICS
- Controls/monitoring exposed through EPICS

ICS Interfaces



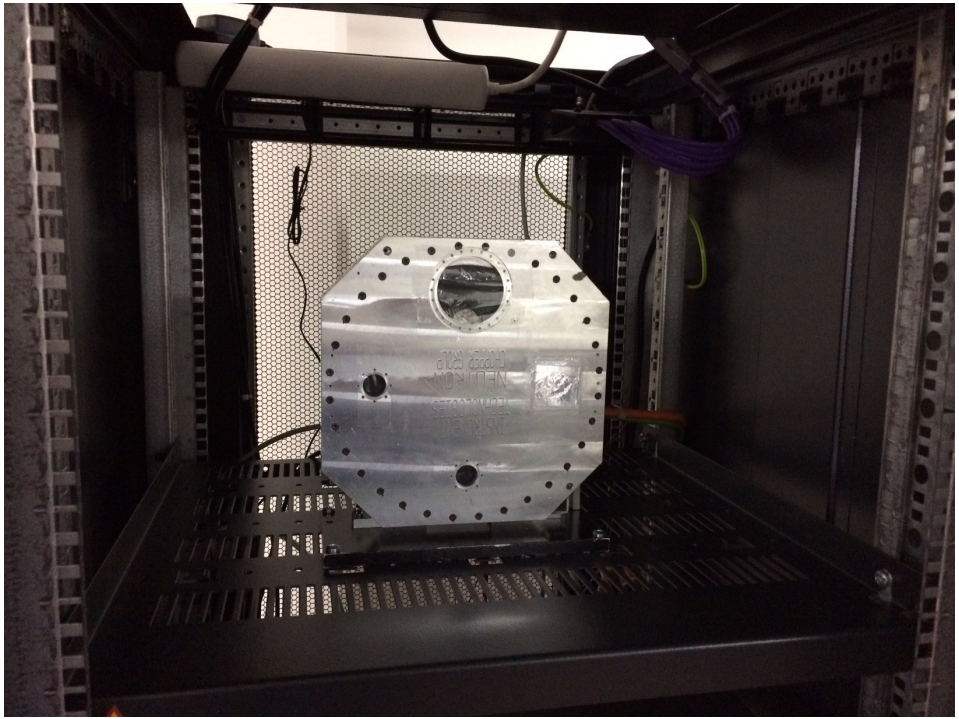
Prototyping: ESS Instrument Integration Project

ESSIIP: ICS Hardware

ESSIIP: Motion Control

ESSIIP: Chopper Drives

ESSIIP: Mini Chopper



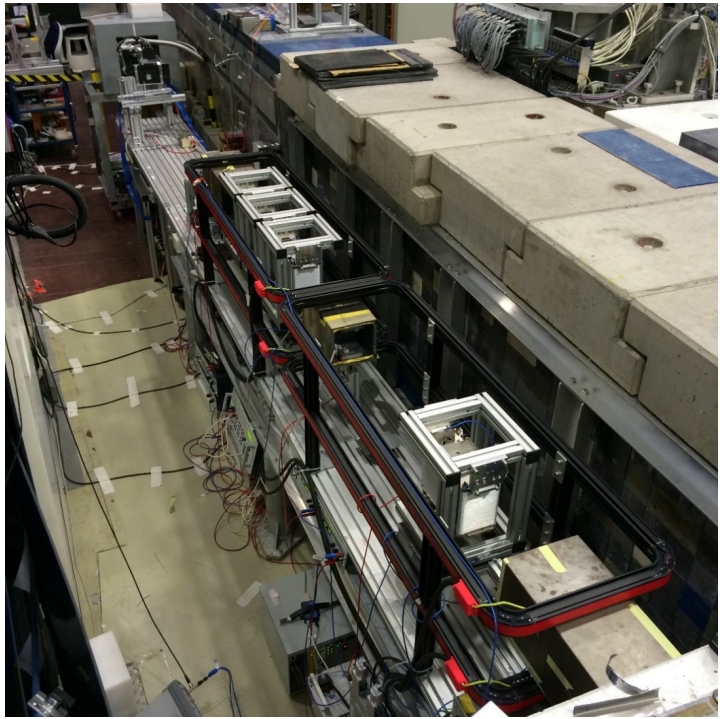
ESSIIP: Sample Environment

ESSIIP: DMSC Servers

ESSIIP: Detector Readout

HZB V20 Beamline

HZB Helmholtz Zentrum Berlin



HZB V20 Beamline

- Beamline at the BER-II reactor at Helmholtz-Zentrum Berlin used to develop ESS technology
- ESS has approved the use of the V20 beamline as a controls integration platform
- DMSC has deployed NICOSII and plans to deploy local data ingest servers.
- ICS has deployed the EEE environment and timing system
  - V20 choppers are already using the ESS timing system to phase lock
- Active users will help troubleshoot the instrument controls architecture

Conclusions

- ESS is building a large suite of scientific instruments which must be controlled
- A high level software infrastructure has been developed which provides a basis for the instrument control system
- ESS is investing effort to reduce the inhomogeneity of the instrument hardware and control systems
- Prototyping efforts are underway to ensure the control system has reached a high level of maturity prior to the first instrument commissioning.

Questions