Motion Control for Instruments

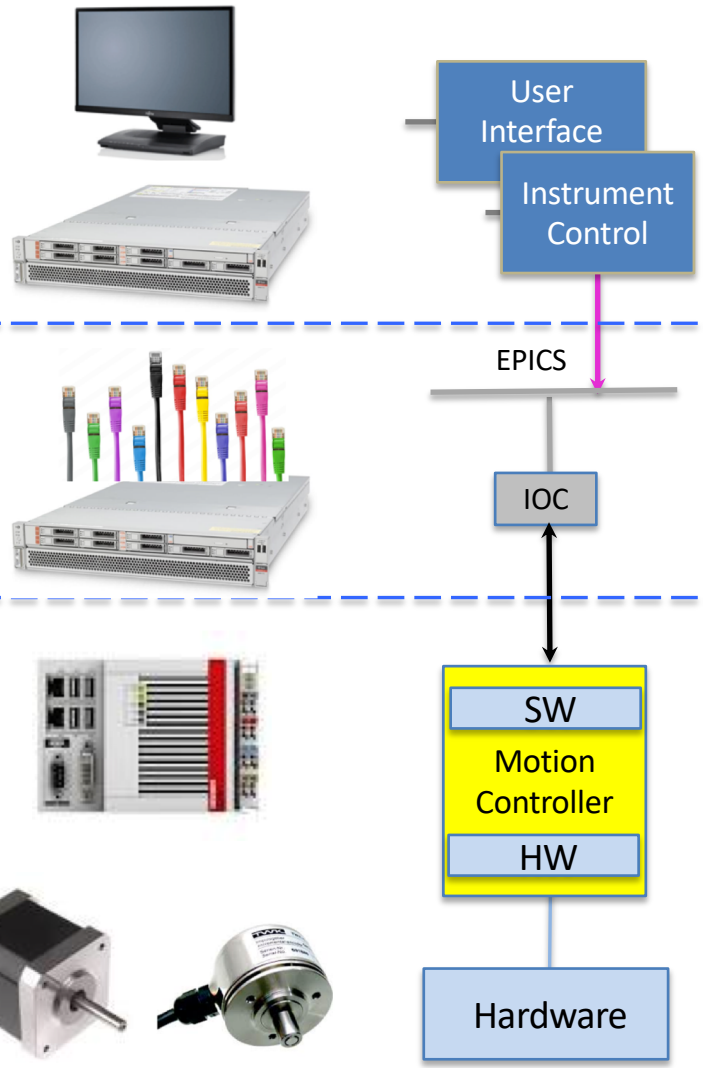
- Status of standardisation, collaboration and implementation -

IKON 16

12th February 2019

Thomas Gahl, Paul Barron, Federico Rojas, Torsten Bögershausen, Matt Clarke

Motion Control Concept



User Interface

Data Stream & Instrument Control

Instrument Representation Layer

EPICS network

EPICS IOC

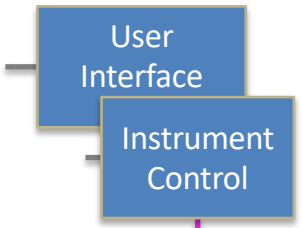
Abstraction & Integration Layer

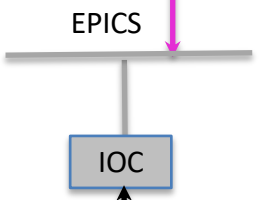
Local Controller

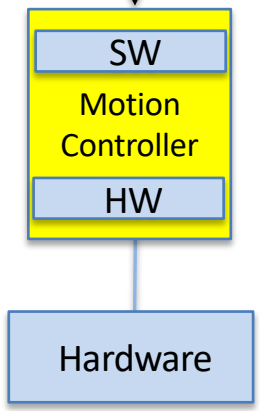
MC Components

Hardware & Hardware Representation Layer

Motion Control Concept







User Interface

Data Stream & Instrument Control

Instrument Representation Layer

EPICS network

EPICS IOC

Abstraction & Integration Layer

MC Software

MC Electronics

MC Components

MCA Work Package

Hardware & Hardware Representation Layer

Technical Advisory Panel (TAP) + MC Workshops

- Frank Darmann, ANSTO (Chair)
- Julio Lidon-Simon, Max IV
- Brian Nutter, Diamond Light Source
- Claude Pradervand, PSI

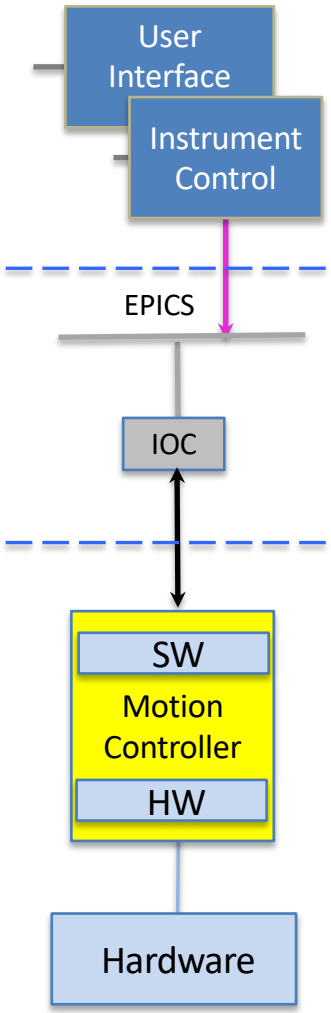
- Charge:
- Support actively Motion Control Workshops
- Give advice on
  - Standardisation
  - Review of instruments projects
  - Prioritisation of tasks
- Contribute with practical knowledge and experience
- Follow the whole project until commissioning

- 4 Workshops since April 2016
- The last in November 2018
- More details in Pauls talk

Overview of talks







User Interface

Data Stream & Instrument Control

EPICS network

EPICS IOC

MC Software

MC Electronics

MC Components

4: Matt Clarke: KAFKA & NICOS for Motion Control

3. Torsten Bögershausen: EPICS integration

2. Federico Rojas: TwinCAT MC software

1. Paul Barron: Update from 4th Motion Control WS

5. Paul Barron: Motion Control Project at V20 in Berlin

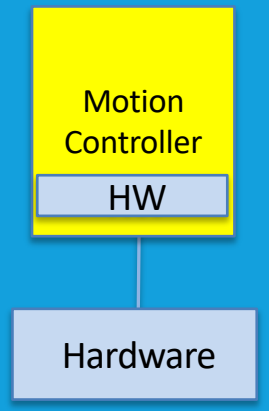
Instrument Representation Layer

Abstraction & Integration Layer

Hardware & Hardware Representation Layer

Update from 4th Instruments Motion Control Workshop

Paul Barron (MCAG)



Summary

- November 6th – 8th 2018
- ~30 participants from in-kind partners, MCAG and ICS
- 4 person TAP
- 2 days total working time
- 1 day TwinCAT workshop run prior to main workshop with participants from ISIS, Jülich and ESS, organised by Federico Rojas

Aim of the workshop

- To create a coherent and high quality suite of instruments at ESS with regards to MCA.
- Inform partners and give updates on the ESS project and motion control standards.
- Share challenges faced on neutron instruments and and experiences from other institutes.
- Get feedback on what MCAG should prioritise; especially from the TAP.
- Build and foster the motion control community within neutron scattering.

Participants

Attendees from	
ANSTO, PSI, Diamond, MaxIV	Technical Advisory Panel (TAP)
FZJ Juelich, Germany	DREAM, SKADI, T-REX, MAGIC
HZG Geesthacht, Germany	BEER
ISIS, UK	LOKI, FREIA, VESPA
AU, Denmark	HEIMDAL
ICS	ESS
MCAG	NMX, BIFROST

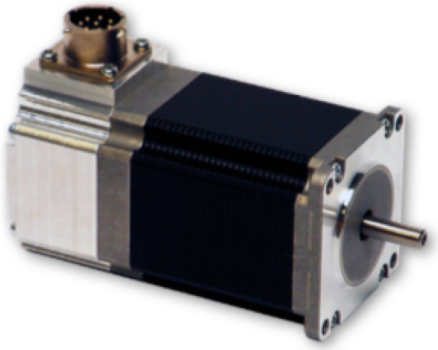
No representitives	
ESS Bilbao, Spain	MIRACLES
LLB Saclay, France	MAGIC, C-SPEC, SKADI, DREAM, BIFROST
PSI, Switzerland	ESTIA, ODIN, BIFROST, HEIMDAL, MAGIC
CNR-ISC, Italy	VESPA
Perugia Univ., Italy	T-REX
Wigner Institute, Hungary	NMX
TUM, Munich, Germany	ODIN, C-SPEC
IFE, Norway	HEIMDAL, BIFROST

Schedule – Day 1

ESS MCA Hardware Standards

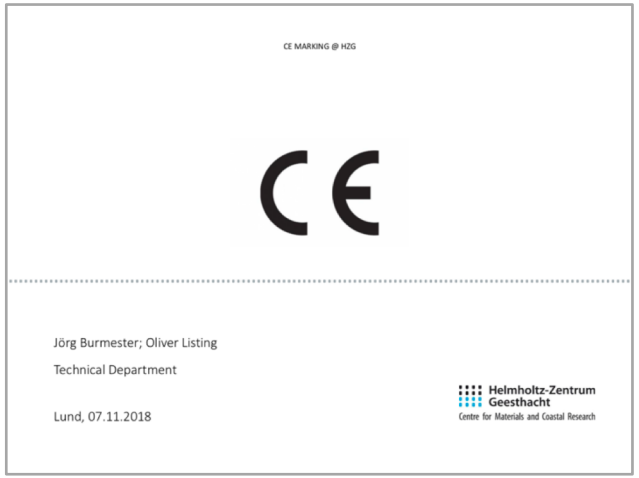
- Motion Control Electronics
  - EtherCAT terminal standards given by Federico Rojas: Includes CPUs, motor drive modules, encoder modules, digital I/O modules etc.
  - Currently chosen CPU is the Beckhoff CX5130

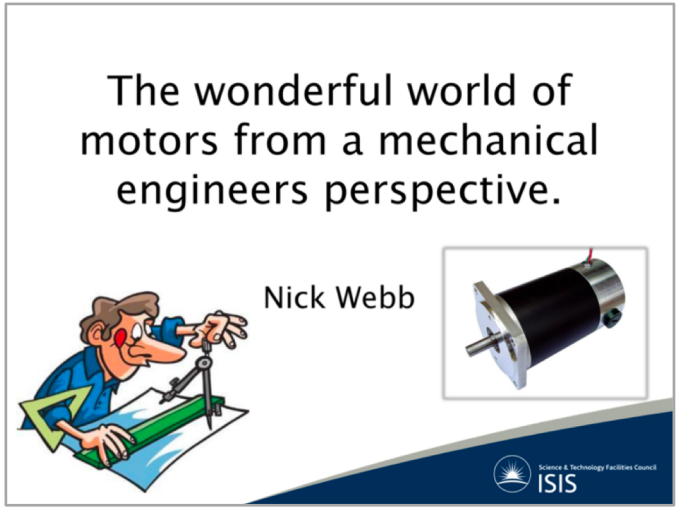
- Motion Control Components
  - Motion Control Hardware standards given by Kristina Jurisic: Includes motors, encoders, limit switch and connectors.



Schedule – Day 2

- ESS In-kind Projects and instrument applications – Jon Elmer (ISIS) talked about fast slits prototyping for FREIA & Michael Klein talked bout linear actuator in-kind project (Jülich)
- CE Markings and Safety – invited talk by Joerg Burmester (HZG)
- Design of motion mechanics – invited talk by Nick Webb (ISIS)
- Group exercise/tutorial session on applying ESS standards and component selection

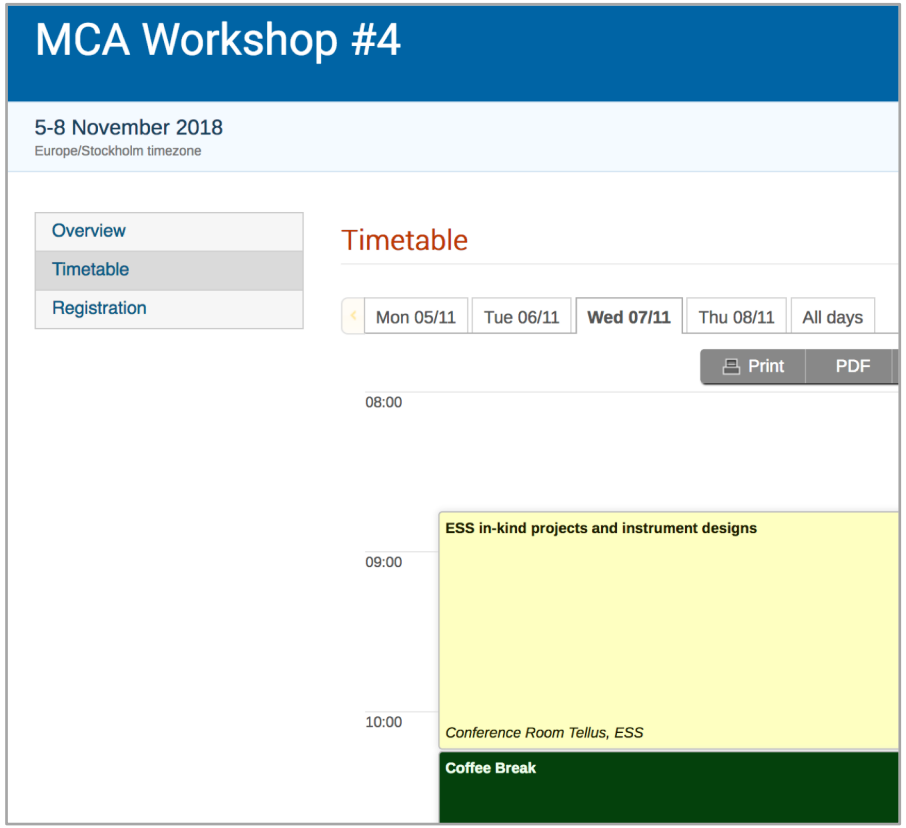




Schedule – Day 3

- Tollgate 3 Process relating to MCA – Paul Barron
- ePlan – Markus Larsson
- Wrap up and conclusions

- https://indico.esss.lu.se/event/1123/timetable/



Reports on Confluence

https://confluence.esss.lu.se/display/MCAG/MCA+Workshops

SPACE SHORTCUTS

- Home Page
- Hardware Standards
- Motion Control Test Crates
- TwinCAT Commissioning Workflow
- GIT Bitbucket Workflow
- Lectures and Seminars
- MCAG Meetings

- Motion Control & Automation Group Home
  - Events and Seminars
    - MCA Lectures and Seminars
    - MCA Workshops
      - 1. ESS MCA Workshop 2016.04
      - 2. ESS MCA Workshop 2016.11
      - **3. ESS MCA Workshop 2017.05**
        - Plenary Presentations
        - Topic1: Hardware Components Standard
        - Topic 2: Motion Controller Standards
        - Topic 3: Cable and Connector Standards
        - Topic 4: Electrical Layout Proposal
      - 4. ESS MCA Workshop 2018.11
    - MCAG Meetings
    - MCAG Info Presentations
  - Instrument Projects
  - Non-instrument Projects
  - Technical Standards & Guides
  - Technical and Engineering Information
  - Discussion Forum
  - Meeting notes
  - Travel

Dashboard / ... / MCA Workshops

Edit

3. ESS MCA Workshop 2017.05

Created by Paul Barron, last modified on Aug 23, 2018

The ESS MCA Workshop #3 will take place May 30 – June 1 2017. Once again it will begin around lunch time on Tuesday and end just before lunch on Thursday. Please register at the indigo page to confirm your attendance: https://indico.esss.lu.se/event/802/.

Agenda

Participants

Report

Important MCA Documents

- Relevant MCA document numbers:

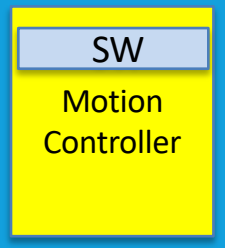
- ESS-0439471 MCA Components Standard (previously ESS-0037290 <- Obsolete)
- ESS-0365855 ESS MCAG Motion Control Electronics
- ESS-0240219 MCA TG3 Review Process for Instrument Projects

Conclusions & Advices

- Advice to finish and publish hardware standards soon as possible
- Focus on the standard applications and refine those e.g. slits
- Need to put some work into the ePlan drawings and templates
- Advice to link and focus on communications with instrument teams
- Next workshop to be planned for mid year

TwinCAT v3 as Motion Control Software for Instruments

Federico Rochas (MCAG)



Low level motion control software package

- TwinCAT is the motion control software package from Beckhoff supposed to run on their EtherCAT CPUs
- TwinCAT 3 is chosen as MC software for ESS Neutron Instruments:
  - Commercial product with wide distribution in Industry but also in Science (European X-FEL etc.)
  - Local support for in-kind partners in all countries available
  - Constant development of new features and performance by the supplier
- TwinCAT base project in Git

https://confluence.esss.lu.se/display/MCAG/GIT+Bitbucket+Workflow

  - Bitbucket (Git) used as distribution, version control and support platform
  - Generic structure for all instruments
  - Library containing all needed motion FB's
  - Regularly updated and maintained by MCAG
  - Training provided by ESS MCAG if needed (by request or MC workshops)

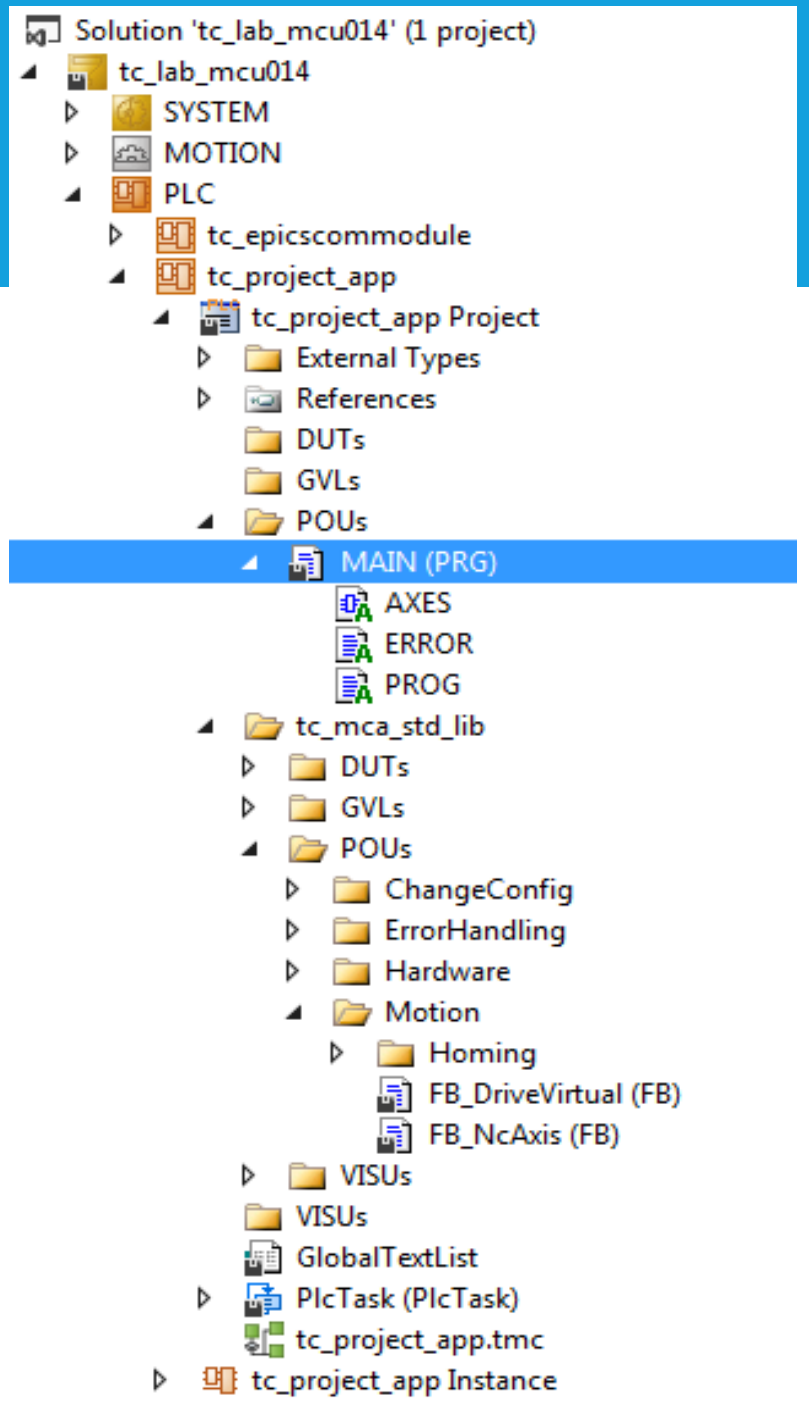
Current TwinCAT structure

Repository

Repository	Last updated
BeckhoffCCAT	2017-09-22
MCAG_Base_Project	2018-05-25
tc_ads_example	2018-03-12
TC_EpicsComModule	2018-07-09
tc_estia_selene_guide_rnd	2018-04-19
tc_generic_structure	2018-07-09
tc_lab_mcu005	2018-03-16
tc_lab_mcu007	2018-03-14
tc_lab_mcu010	2018-04-12
tc_lab_mcu011	2018-05-04
tc_lab_mcu014	2018-10-05
tc_lab_mcu016	2018-10-04
tc_lab_mcu018	2018-04-13
tc_library_documentation	2018-10-11
TC_MCA_Module	2018-03-02
tc_mca_std_lib	2018-10-11
tc_project_app	2017-12-08
tc_se_crate001	2017-11-07

Our folder structure

- tc_epicscommodule
  - MAIN
  - AXES
  - ERROR
  - PROG
- tc_mca_std_lib
  - ChangeConfig
  - ErrorHandling
  - Hardware
  - Motion
    - Homing
  - VISUs



MAIN variables

- Motion variables

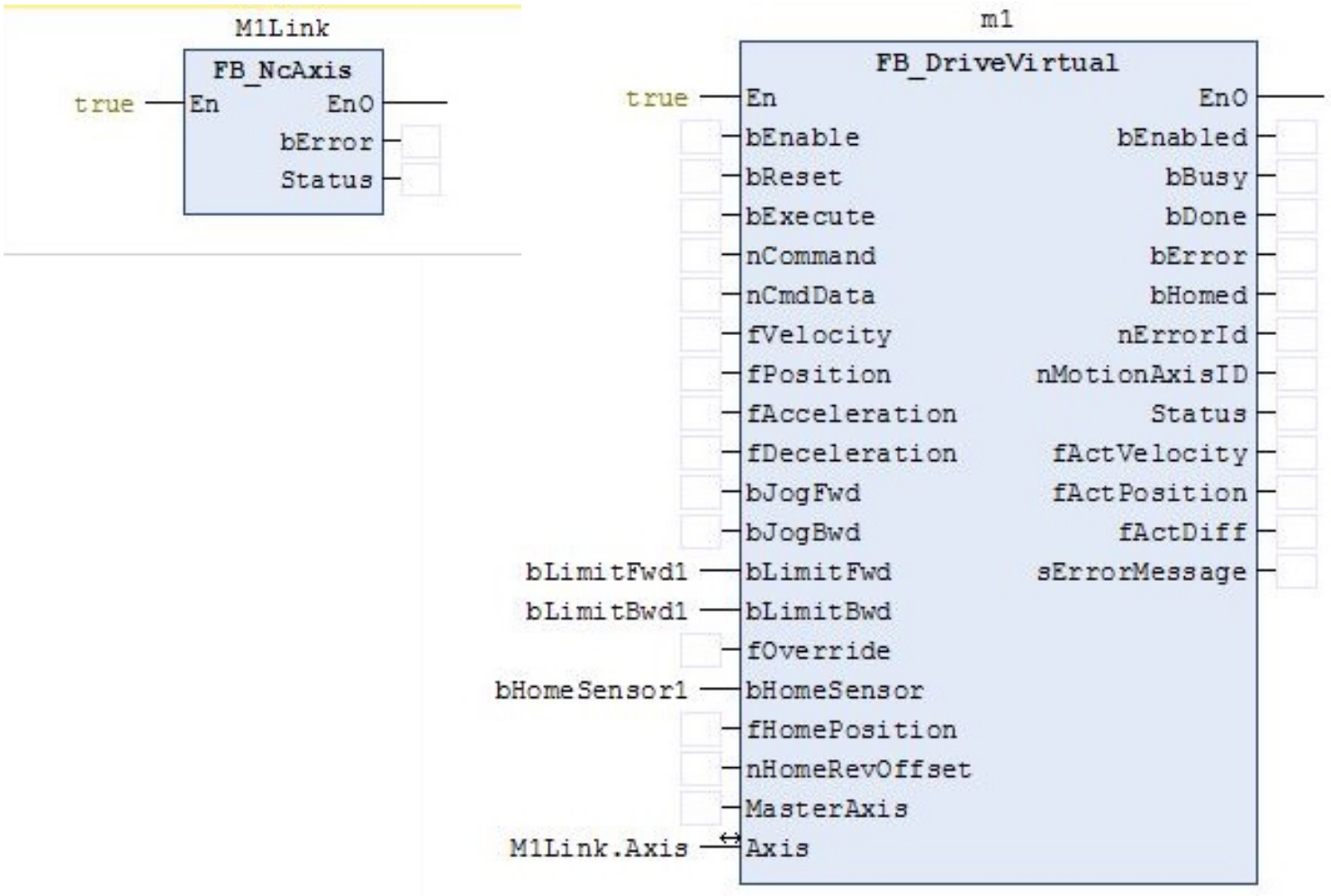
```
PROGRAM MAIN
VAR
    sVersion: STRING:='1.0.0';

(******FB_NcAxis Motor Links********)
    M1Link:FB_NcAxis;
    M2Link:FB_NcAxis;
    //M3Link:FB_NcAxis;
    //M4Link:FB_NcAxis;
    //M5Link:FB_NcAxis;
    //M6Link:FB_NcAxis;
    //M7Link:FB_NcAxis;
    //M8Link:FB_NcAxis;

(******FB_DriveVirtual Motors function blocks********)
    M1:FB_DriveVirtual;
    M2:FB_DriveVirtual;
    //M3:FB_DriveVirtual;
    //M4:FB_DriveVirtual;
    //M5:FB_DriveVirtual;
    //M6:FB_DriveVirtual;
    //M7:FB_DriveVirtual;
    //M8:FB_DriveVirtual;
```

- I/O's variables

```
(******Inputs (Limit switches and Home Sensors********)
    bLimitFwd1 AT %I*: BOOL;
    bLimitBwd1 AT %I*: BOOL;
    bHomeSensor1 AT %I*: BOOL;
    bLimitFwd2 AT %I*: BOOL;
    bLimitBwd2 AT %I*: BOOL;
    bHomeSensor2 AT %I*: BOOL;
    //bLimitFwd3 AT %I*: BOOL;
    //bLimitBwd3 AT %I*: BOOL;
    //bHomeSensor3 AT %I*: BOOL;
    //bLimitFwd4 AT %I*: BOOL;
    //bLimitBwd4 AT %I*: BOOL;
    //bHomeSensor4 AT %I*: BOOL;
    //bLimitFwd5 AT %I*: BOOL;
    //bLimitBwd5 AT %I*: BOOL;
    //bHomeSensor5 AT %I*: BOOL;
    //bLimitFwd6 AT %I*: BOOL;
    //bLimitBwd6 AT %I*: BOOL;
    //bHomeSensor6 AT %I*: BOOL;
    //bLimitFwd7 AT %I*: BOOL;
    //bLimitBwd7 AT %I*: BOOL;
    //bHomeSensor7 AT %I*: BOOL;
    //bLimitFwd8 AT %I*: BOOL;
    //bLimitBwd8 AT %I*: BOOL;
    //bHomeSensor8 AT %I*: BOOL;
```

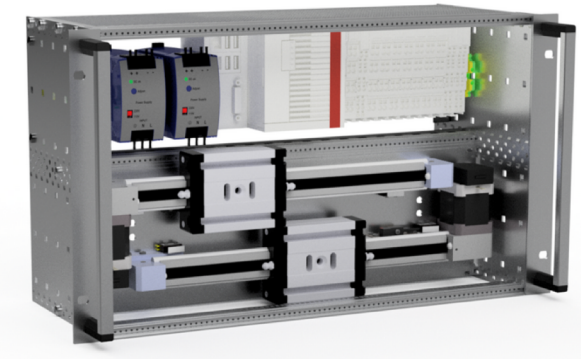
AXES( )

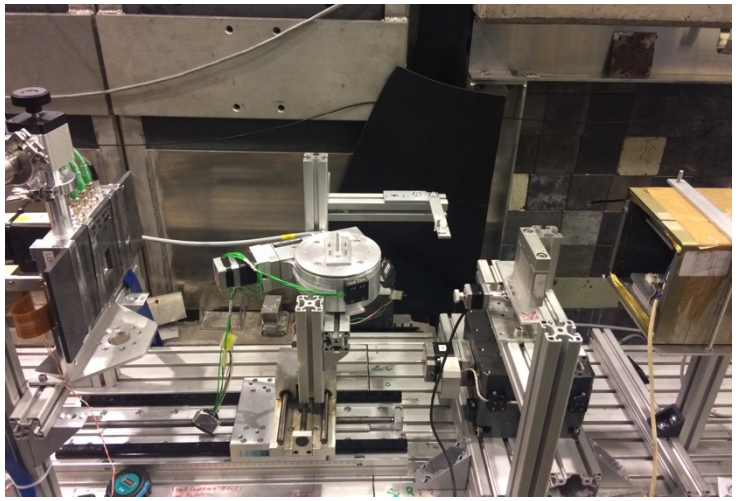
- In FBD language
- NC communication
- FB for driving an axis

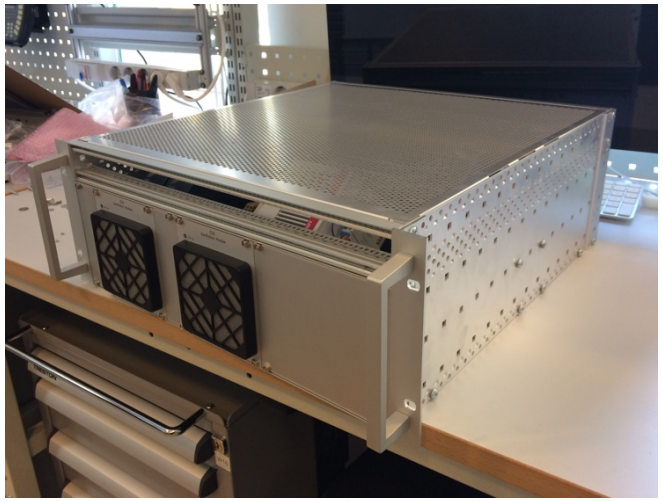


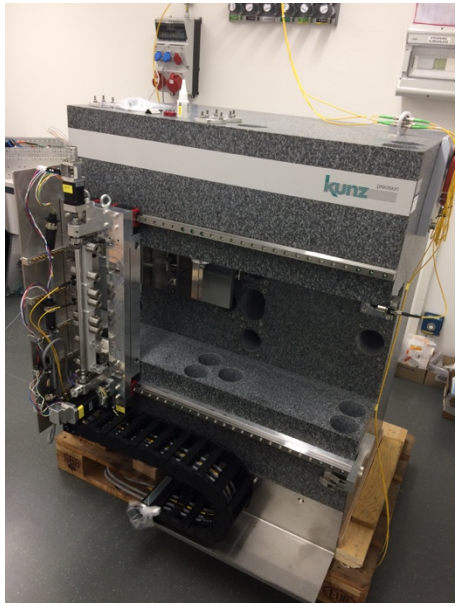
Where are these implementations ?

- Working and running in Berlin test beamline V20
- ESTIA Selene guide prototype at PSI
- Test crates distributed around ESS and partners
- Test beamline at Wigner Budapest
- Flexiprobe collaboration in Bielefeld/FRM-II









The TwinCAT Day

5th - 6th November 2018

EUROPEAN SPALLATION SOURCE

- Pre-motion control workshop
- Participants from ISIS, JCNS and ESS

- Same solution for all instruments at ESS
- Simplifying the handover and maintenance
- Feedback and experience from our in-kind partners
- What was missing or what could be done better?

TwinCAT day
Outcome

ISIS, JCNS and ESS are using the same hardware

+

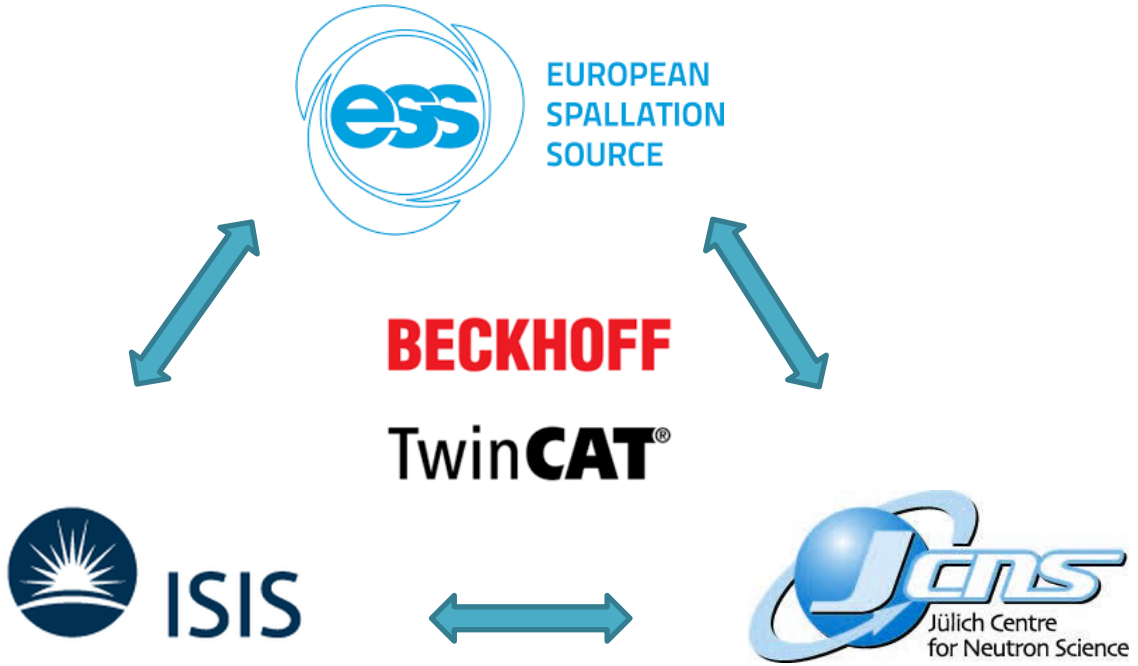
ISIS and JCNS experience

+

ISIS, JCNS and ESS common TwinCAT structure

=

TwinCAT Collaboration!!!



TwinCAT collaboration
Objectives

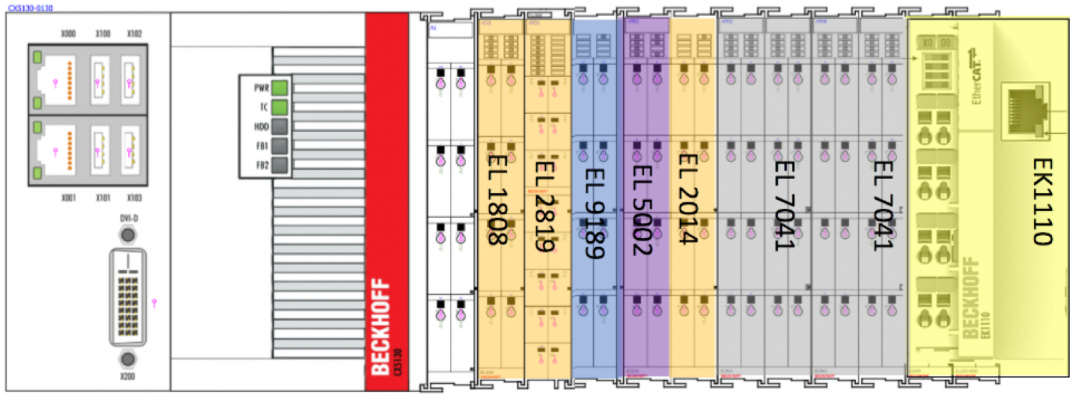
- Work together for a basic TwinCAT structure
- Basic functions
  - P2P movements
  - Simple gearing Master-slave
  - Multi-gearing FB
  - Global variable structure (variables, I/O's, status, etc.)
  - Communication layer between EPICS and the NC (motion)
- Gathering requirements from scientists and instrument teams !!

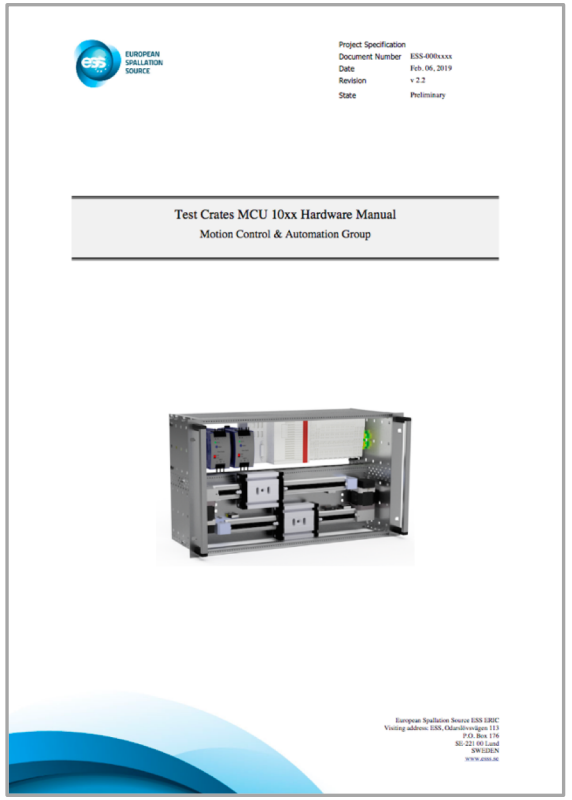
TwinCAT collaboration

Common test hardware MCU 1024

- Compact 19”crate with all components “on board”
  - Power supplies, CPU and EtherCAT components incl. EtherCAT end coupler to connect external components
  - 2 Linear units with stepper motor, SSI encoder, reference and end switches
  - Mechanics to emulate a one-dimensional slit system
- 6 units will be built and distributed

More details + HW manual:
https://confluence.esss.lu.se/display/MCAG/Motion+Control+Test+Crates





TwinCAT collaboration

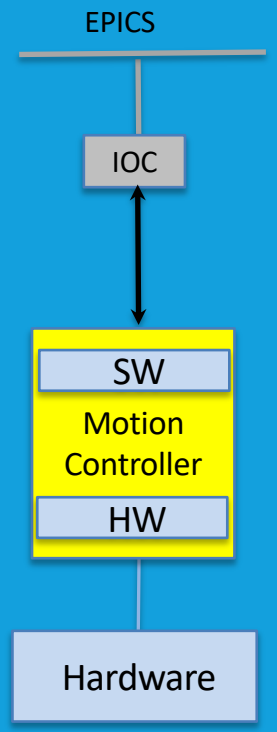
Next steps

- **What**
- Implement communication layer that works for everyone and ICS as basis
- Define the collaboration goals, borderlines and interfaces
- Distribute work load
- Build and distribute test hardware MCU1024
- Refine and review implementation workflow

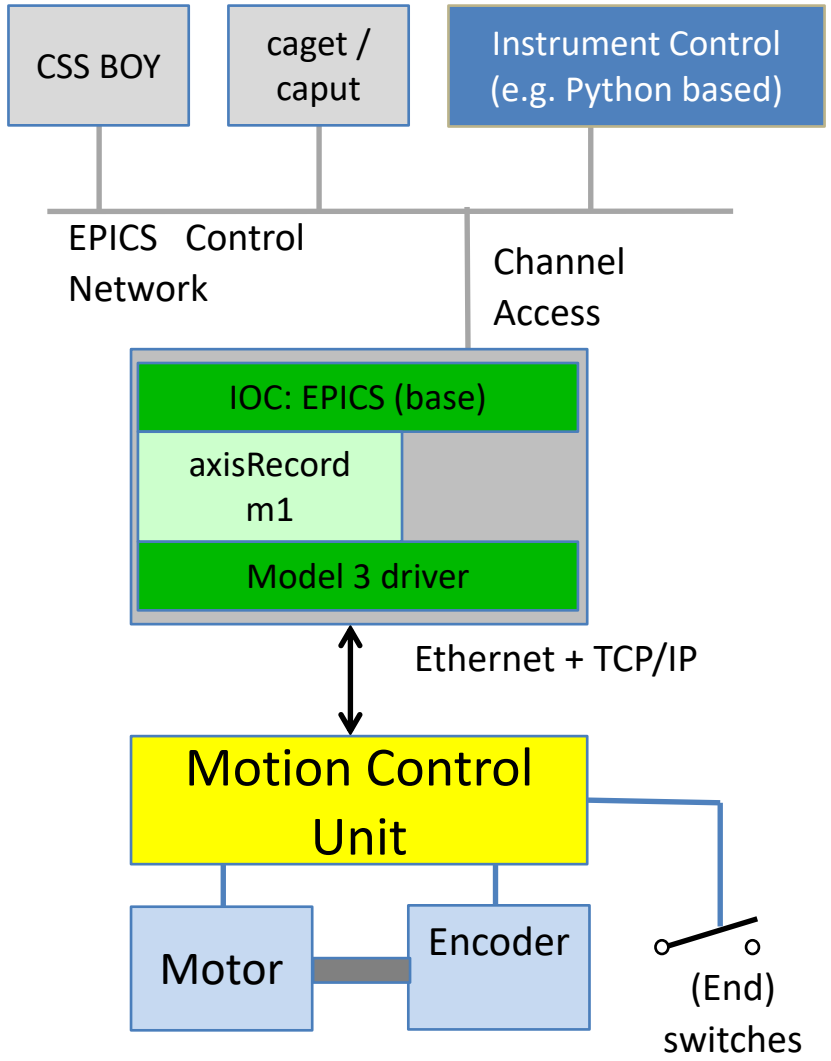
- **How**
- Monthly video conferences
- Code camp
- Collaborating and communicating!

EPICS integration

Torsten Bögershausen (MCAG, ICS)



EPICS Integration
Axis record (motor record)



- Current status:
- 3 layers in control box:
  - EPICS IOC
  - Axis record (single axis)
  - Model 3 driver for TwinCAT
- Basic functionalities for point-to-point movements
- Can also drive “virual” axes in the motion control unit
- Future extensions in additional records:
  - I/Os (temperature etc.)
  - Arrays of recorded positions
  - …

MCA integration I

ESSIIP at Utgård

- Vertical integration at Utgård:
  - NICOS (DMSC, experiment control)
  - EPICS (ICS, abstraction in SW)
  - Motion controller (MCAG)
  - HW (motor + linear stage)

MCA integration I

Inside the rack

- Currently installed Hardware
- Single axis crate with
  - Linear stage
  - Motor, encoder
  - Limit + reference switches
  - Power supply, CPU, terminals
- Double axis crate with 2 linear stages
- Third crate MCU 1024 with absolute encoders will follow

MCA integration I

Movements from e.g. Copenhagen

- As EPICS is network based, a motor can be moved from Utgård, from our offices or even from Copenhagen.
- Physical access needed to be restricted.
  - Door with a warning sign
  - Plexiglas cover inside

MCA Integration II

FLEXIPROBE In-situ Dynamic Light Scattering (DLS)

Universität Bielefeld — Physical and Biophysical Chemistry

In-situ DLS & SANS Sample Environment

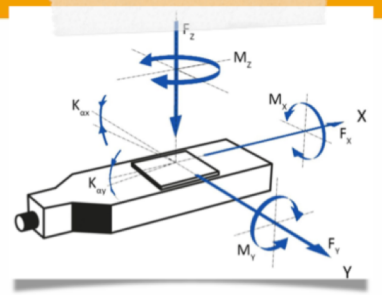
Design - x,z-Translation Unit for Sample Holder

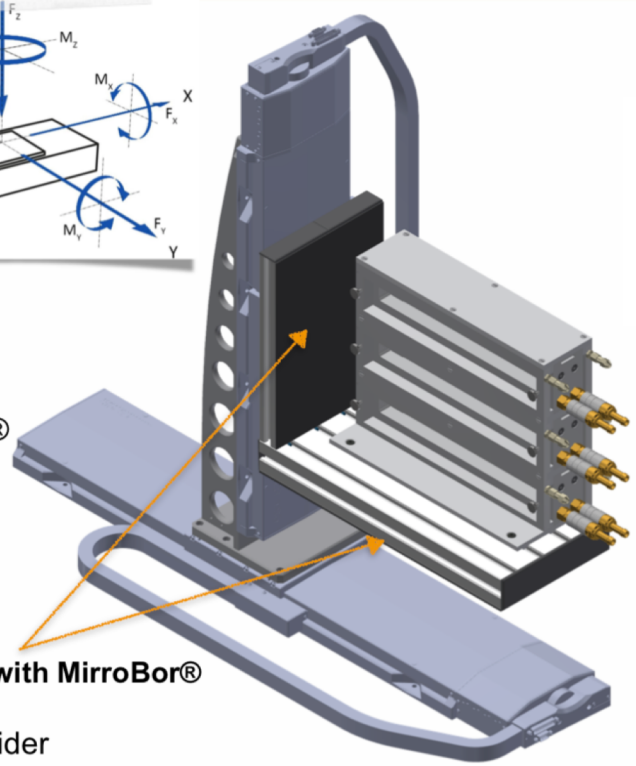
Linear Stages

- LS 180 (PI®)
  - Horizontal
    - 508 mm translation range
  - Vertical
    - 305 mm translation range
    - 5:1 gear box
    - Currentless holding force: 500 N
    - Permissible torque M_y = 132 Nm
  - 2-phase stepper motors
  - A/B quadrature (RS422) linear encoder
- Steel cover plates: ⟶ shielding with MirroBor®

Bracket

- BLOCAN® (Rose+Krieger®) aluminium profiles
- Very low amounts of steel parts necessary
  - Horizontal: F50x200
    - high rigidity
    - almost no deflection
  - Vertical: 2x F30x100
    - lower mass
    - Nut distance suitable for grid pattern of slider



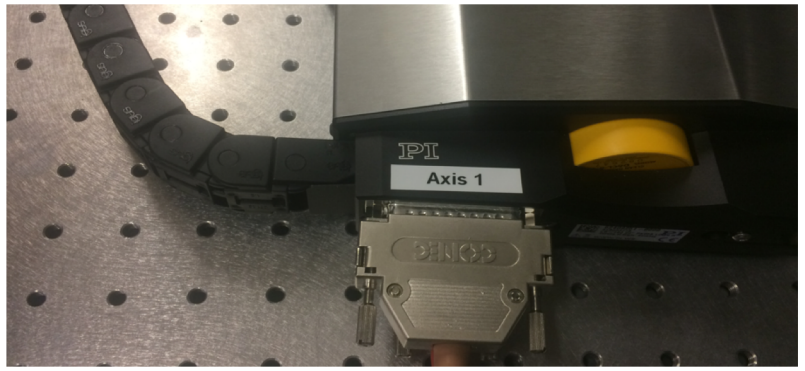


Lund May 29, 2018 — Andreas Schmid | *In-situ* DLS & SANS

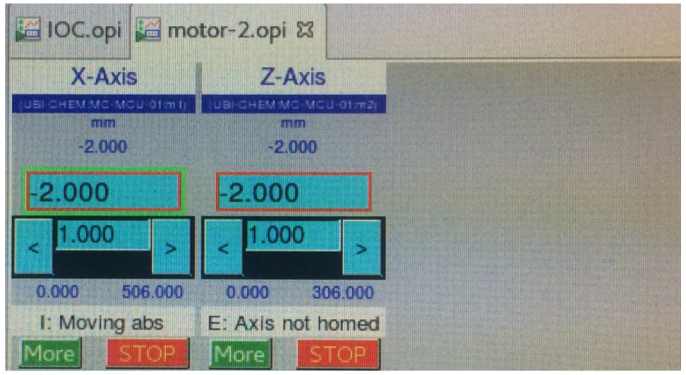
- Collaboration of ESS and German Universities on Sample Environment
- Support of EPICS integration for the in-situ DLS at University in Bielefeld
- Used last week for an experiment at FRM-II

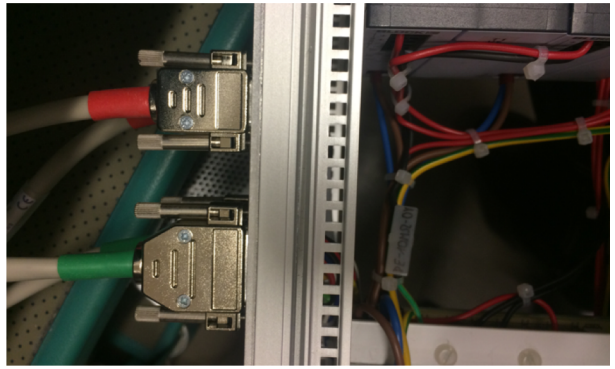
MCA Integration II

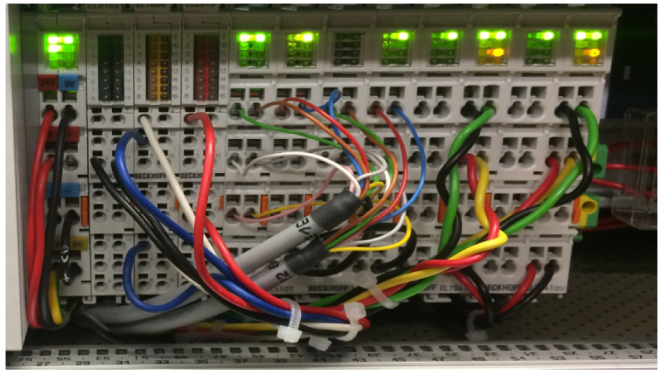
The integration chain (…follow the cable)



- From Motor to EPICS user screen
- Implemented in Jan 2019



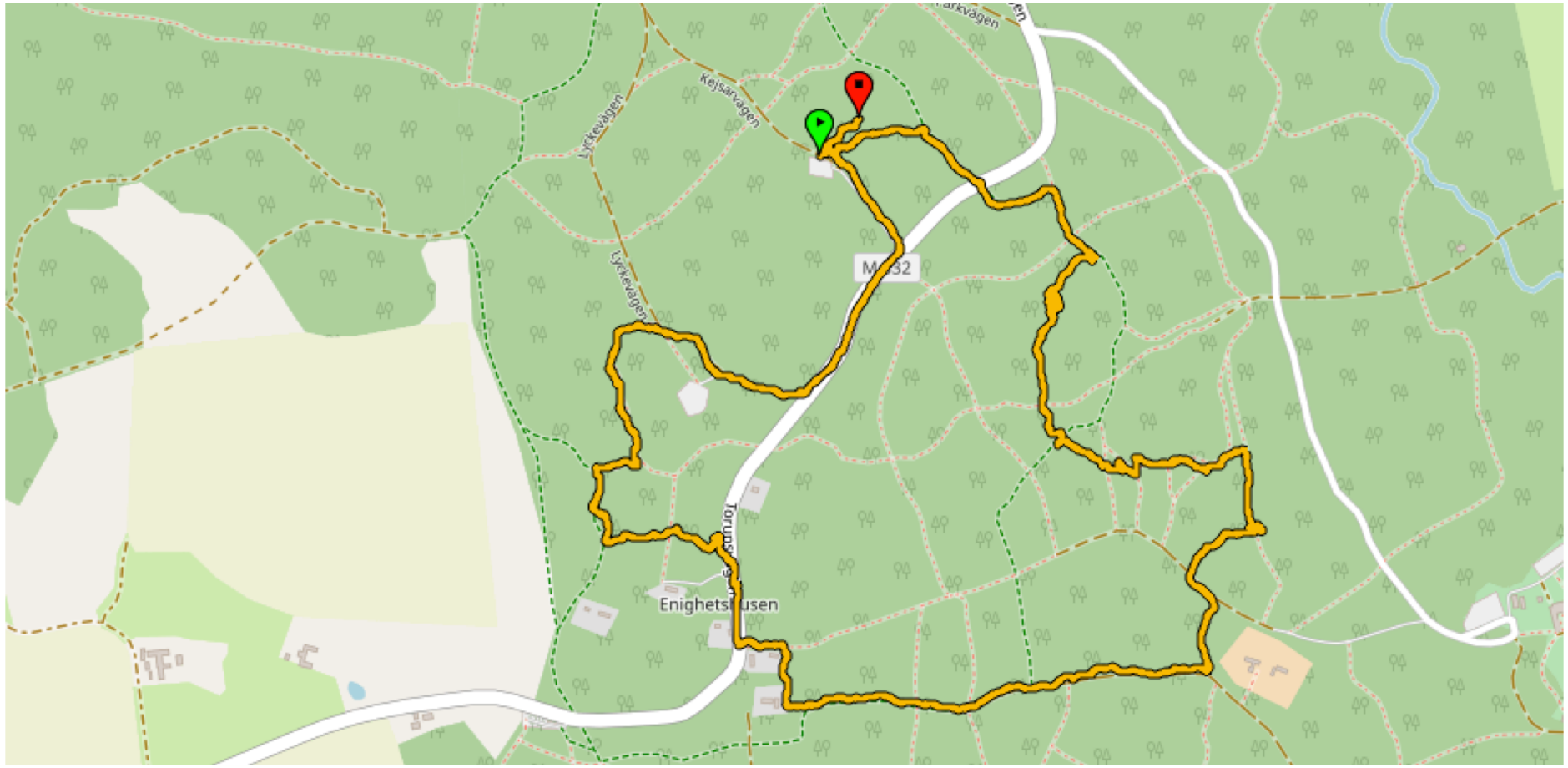




The way forward

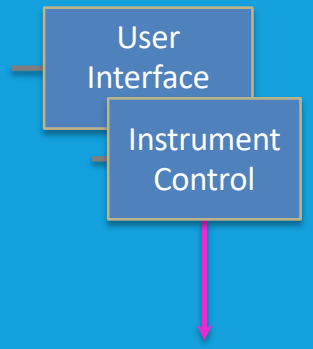
The way forward

Need to search for …



…the box with requirements

- And that should be in the box:
  - Instruments applications
  - Use-cases
  - Requirements
- Box should be filled in the tollgate 3 processes
- The earlier we know about requirements, the better !

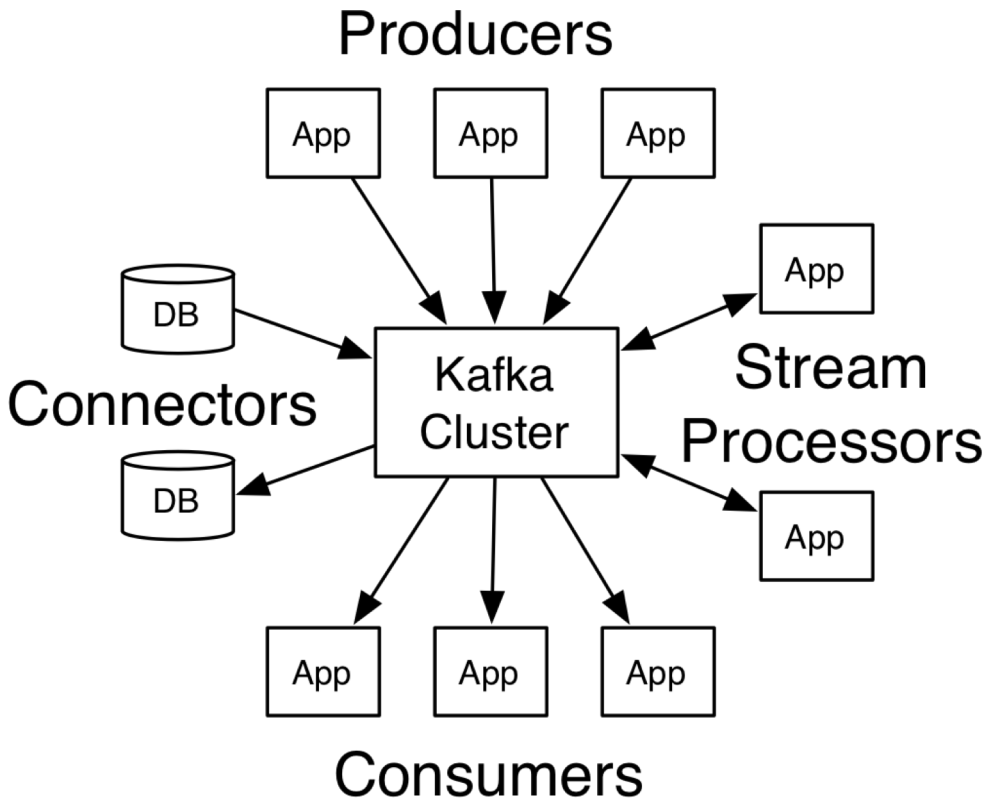


Kafka and NICOS for Motion Control

Matt Clarke (DMSC)

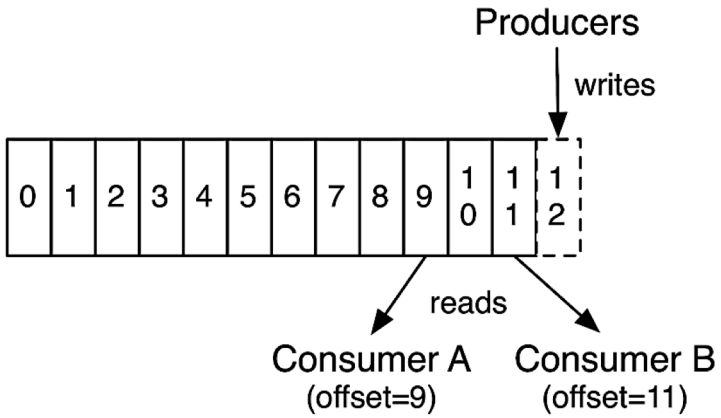
Apache Kafka

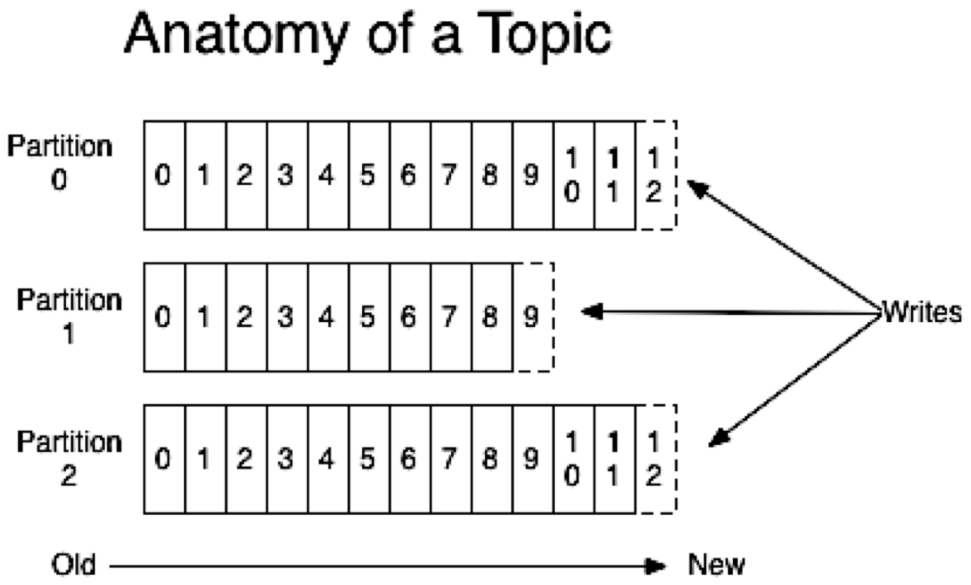
“used for building real-time data pipelines and streaming apps.
It is horizontally scalable, fault-tolerant and wicked fast”



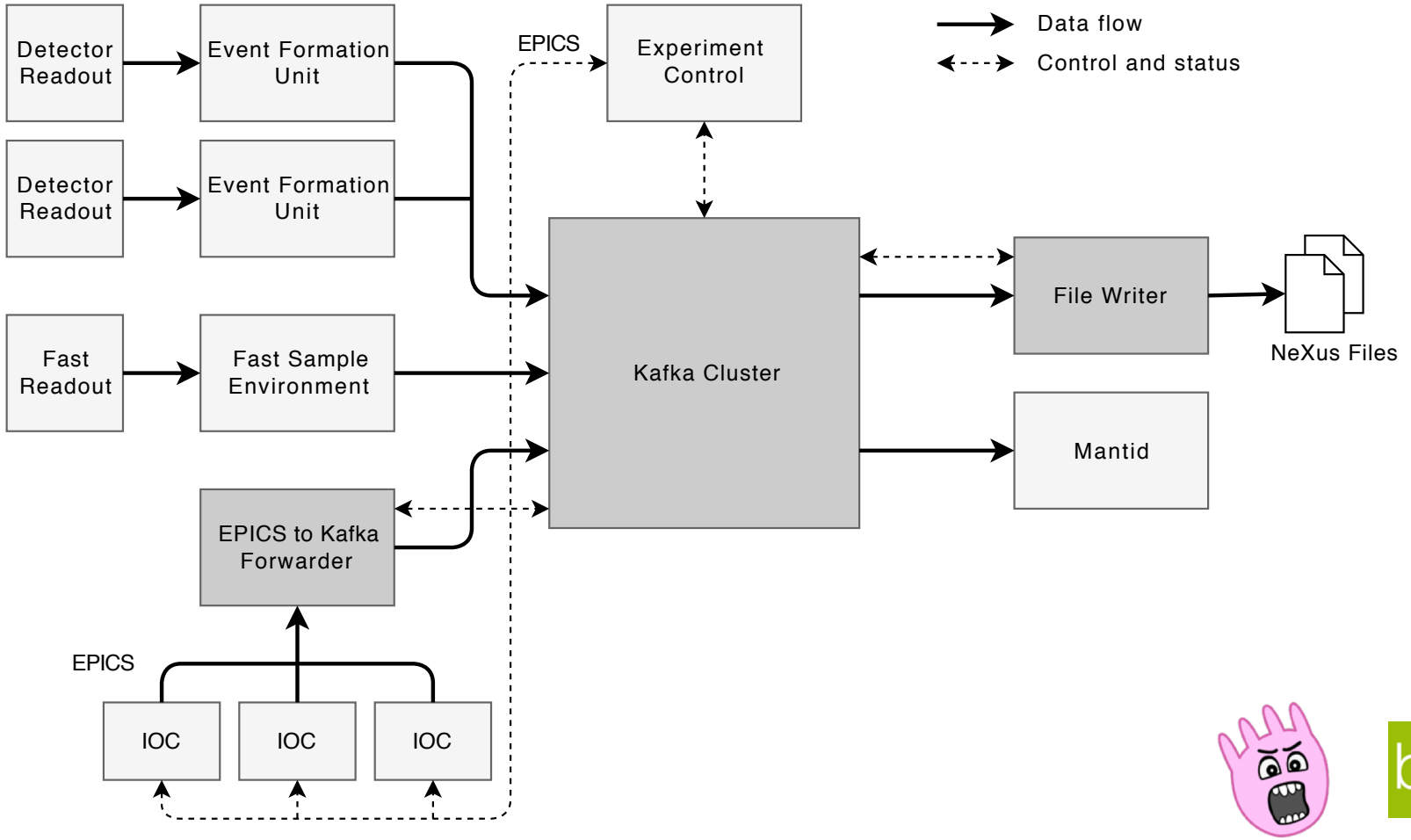
Apache Kafka

- Topics
  - Uniquely named
  - Offset controlled by the consumer
  - Divided into partitions



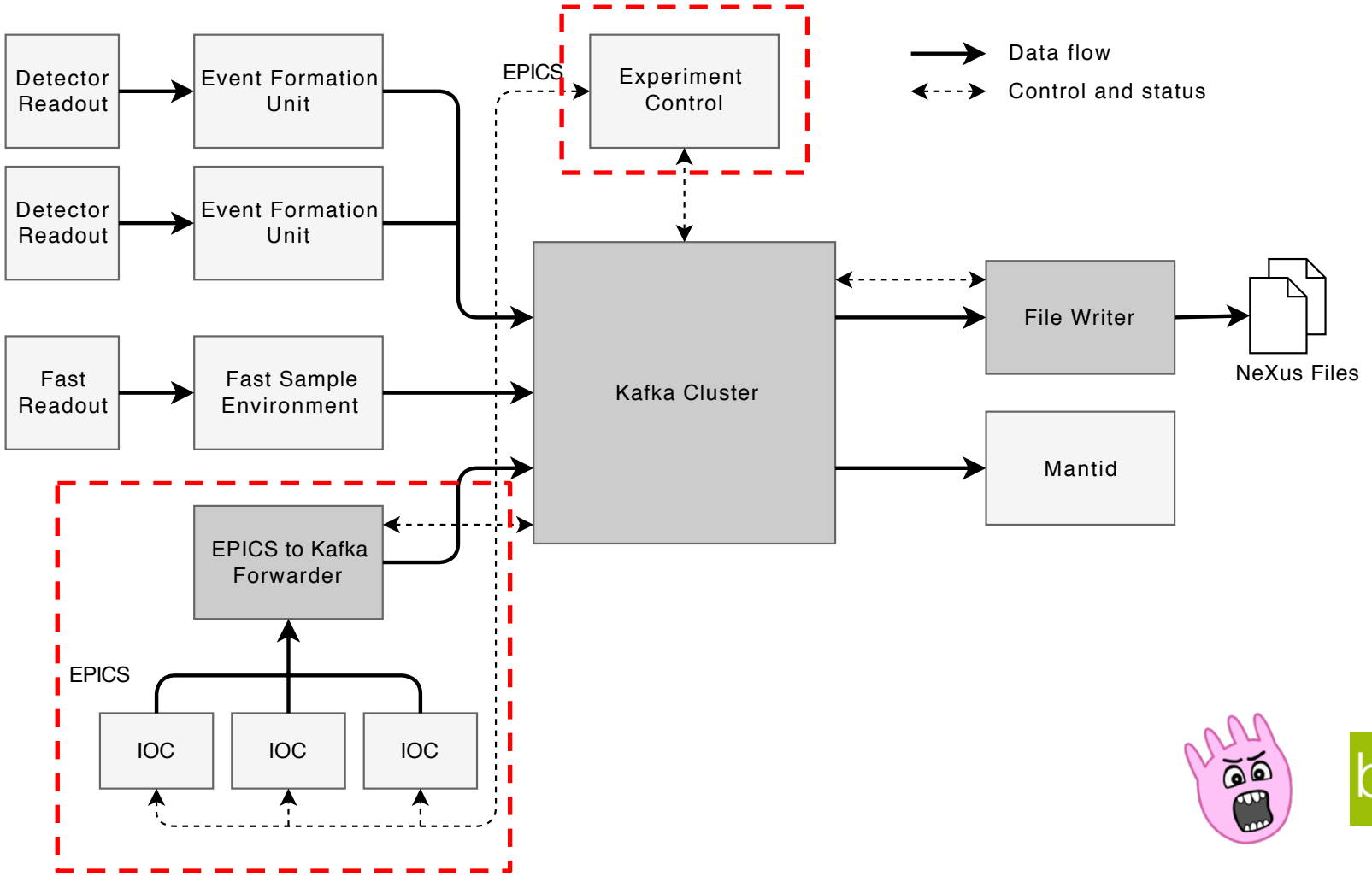


Data streaming architecture



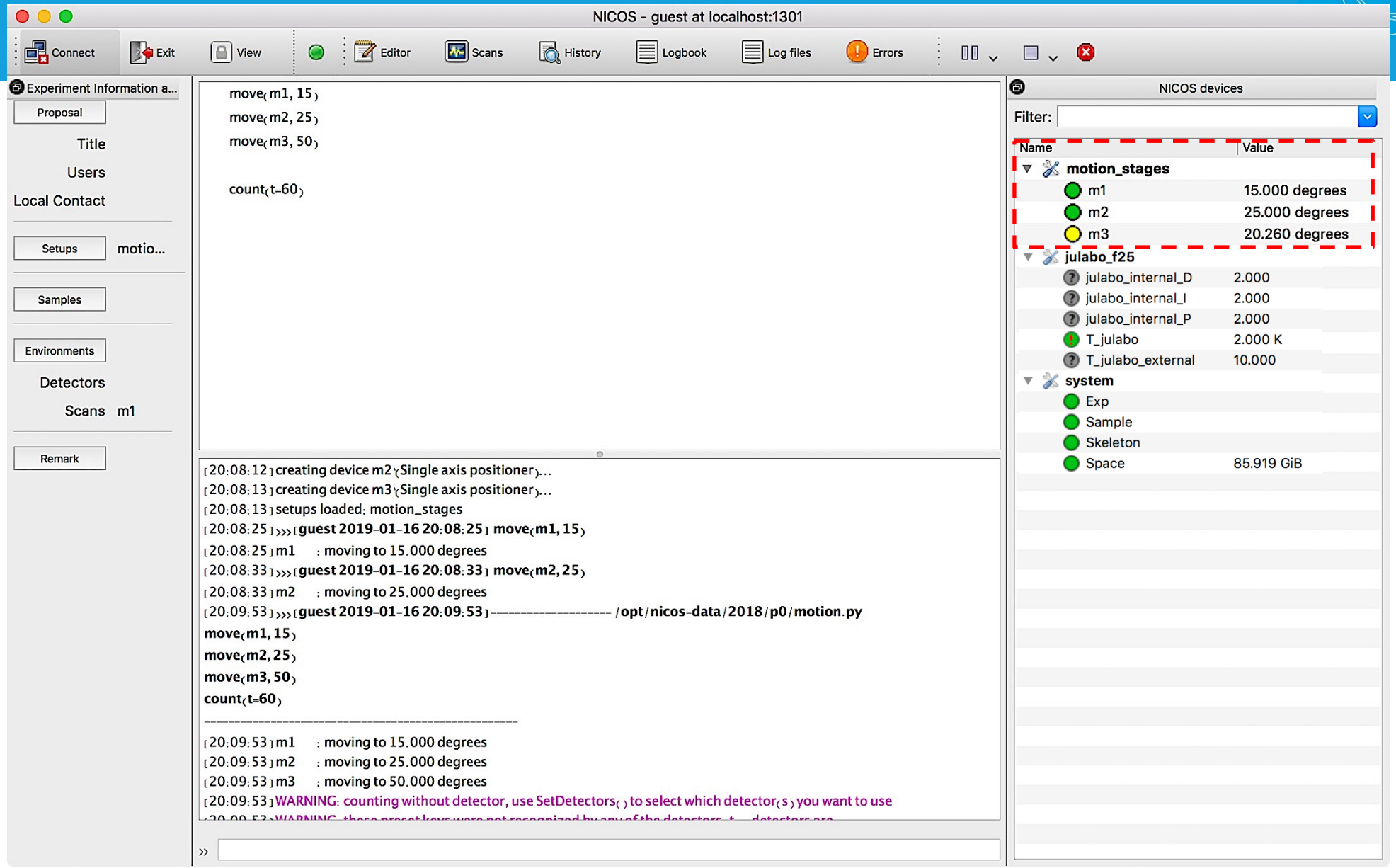
brightness

Data streaming architecture



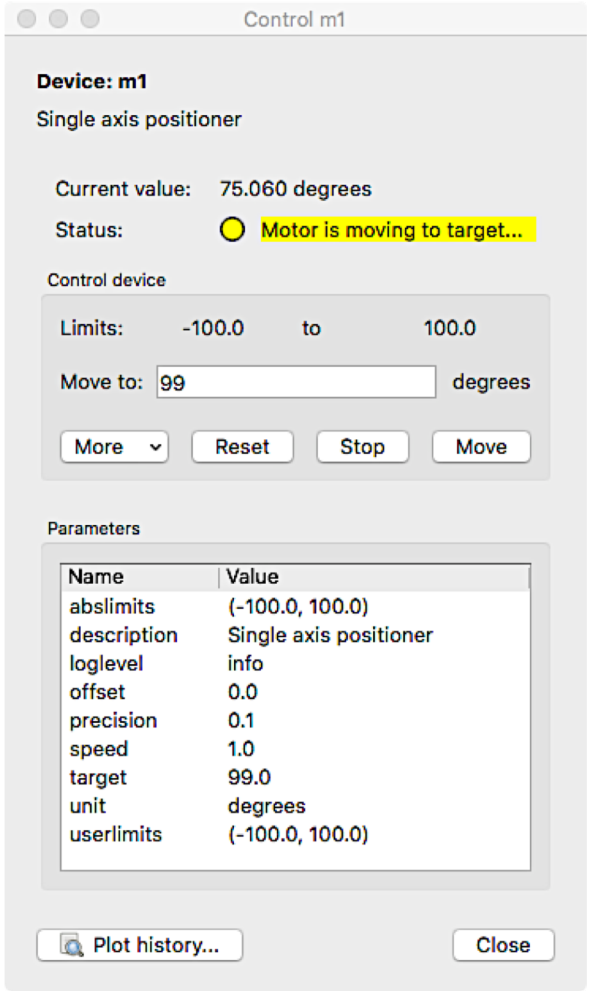
brightness

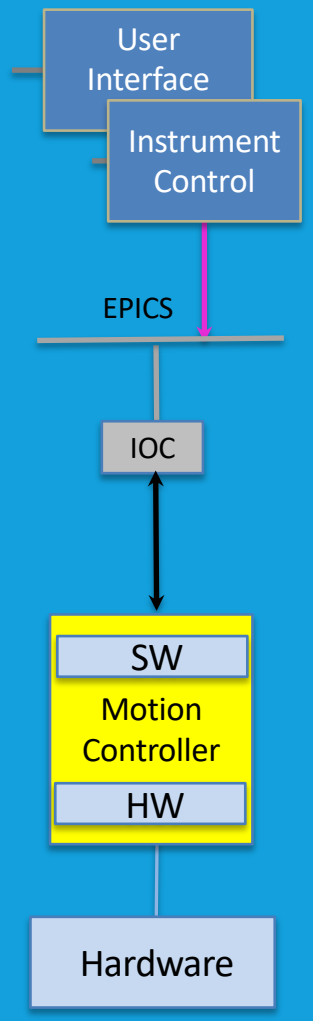
NICOS


NICOS - guest at localhost:1301
Connect
Exit
View
Editor
Scans
History
Logbook
Log files
Errors
Experiment Information a...
Proposal
Title
Users
Local Contact
Setups
motio...
Samples
Environments
Detectors
Scans m1
Remark
move(m1, 15)
move(m2, 25)
move(m3, 50)
count(t=60)
[20:08:12] creating device m2 (Single axis positioner)...
[20:08:13] creating device m3 (Single axis positioner)...
[20:08:13] setups loaded: motion_stages
[20:08:25] >>> [guest 2019-01-16 20:08:25] move(m1, 15)
[20:08:25] m1 : moving to 15.000 degrees
[20:08:33] >>> [guest 2019-01-16 20:08:33] move(m2, 25)
[20:08:33] m2 : moving to 25.000 degrees
[20:09:53] >>> [guest 2019-01-16 20:09:53] ---------- /opt/nicos-data/2018/p0/motion.py
move(m1, 15)
move(m2, 25)
move(m3, 50)
count(t=60)
[20:09:53] m1 : moving to 15.000 degrees
[20:09:53] m2 : moving to 25.000 degrees
[20:09:53] m3 : moving to 50.000 degrees
[20:09:53] WARNING: counting without detector, use SetDetectors() to select which detector(s) you want to use
NICOS devices
Filter:
Name
Value
motion_stages
m1 15.000 degrees
m2 25.000 degrees
m3 20.260 degrees
julabo_f25
julabo_internal_D 2.000
julabo_internal_I 2.000
julabo_internal_P 2.000
T_julabo 2.000 K
T_julabo_external 10.000
system
Exp
Sample
Skeleton
Space 85.919 GiB

NICOS and motion

- We have added support for the EPICS motor record
  - move, maw
  - Used at V20 and Utgård
- NICOS already has support for scans:
  - Step scan
  - Continuous scan (fly-scan?)
  - Sweep scan
  - …
- Logical motors (virtual motors/axes?)
  - Do we need these?
- Coordinating motor statuses with NICOS display
- …





Berlin V20 integration

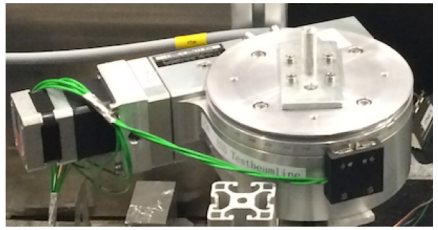
Paul Barron (MCAG)

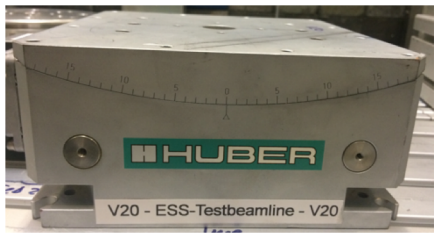
Aim and Scope

- **Aim**
  - Apply and test ESS MCA technologies and principles to a real beamline.
  - Upgrade existing motion control system for ease of beam line use.
  - Work as a team with different groups within ESS.
- **Scope**
  - Construct motion control system to control 8 axes.
  - Axes 1-4: Slit system, axes 5-8: Removable motion stages.
  - Control from EPICS and NICOS (vertical integration).
  - Investigation of virtual axes at MCU level and evaluate the benefits of logic at different control levels.
  - Commission the MCU in Berlin.

Axes

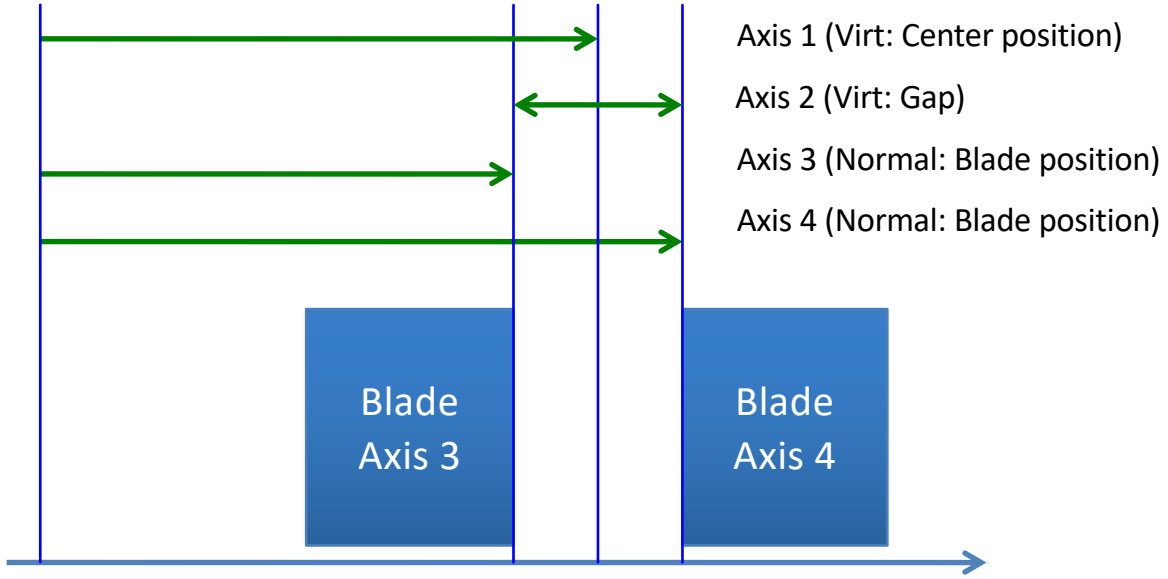
Axis #	Axis Name	Device	Motor	Encoder
1	Slit Y+ Left Blade	Slit System	VEXTA PK224PDB 2-phase stepper, max. 1.5A, 200 steps/rev	Trelectronic CMV36M Absolute SSI - 4096 cts/rev
2	Slit Y- Right Blade	Slit System	VEXTA PK224PDB 2-phase stepper, max. 1.5A, 200 steps/rev	Trelectronic CMV36M Absolute SSI - 4096 cts/rev
3	Slit Z+ Upper Blade	Slit System	VEXTA PK224PDB 2-phase stepper, max. 1.5A, 200 steps/rev	Trelectronic CMV36M Absolute SSI - 4096 cts/rev
4	Sit Z- Lower Blade	Slit System	VEXTA PK224PDB 2-phase stepper, max. 1.5A, 200 steps/rev	Trelectronic CMV36M Absolute SSI - 4096 cts/rev
5	Motion Stage Height (height1)	Sample Positioning	VEXTA PK266-03A 2-phase stepper, max. 3.5A, 200 steps/rev	None - Open loop
6	Motion Stage Omega Rotation (omega2)	Sample Positioning	VEXTA PK266-03A 2-phase stepper, max. 3.5A, 200 steps/rev	None - Open loop
7	Motion Stage Goniometer (beta)	Sample Positioning	VEXTA PK266-03A 2-phase stepper, max. 3.5A, 200 steps/rev	None - Open loop
8	Motion Stage Linear stage (lin1)	Sample Positioning	VEXTA PK266-03A 2-phase stepper, max. 3.5A, 200 steps/rev	None - Open loop





Slit control

- Slit axes were non standard. The blades can collide -> machine protection.
- Scientists prefer to specify gap and gap centre using virtual axes which fed into our requirements. This is often done in higher levels but in our case we wanted to try it at the motion controller level.



Software Layers

Bottom up

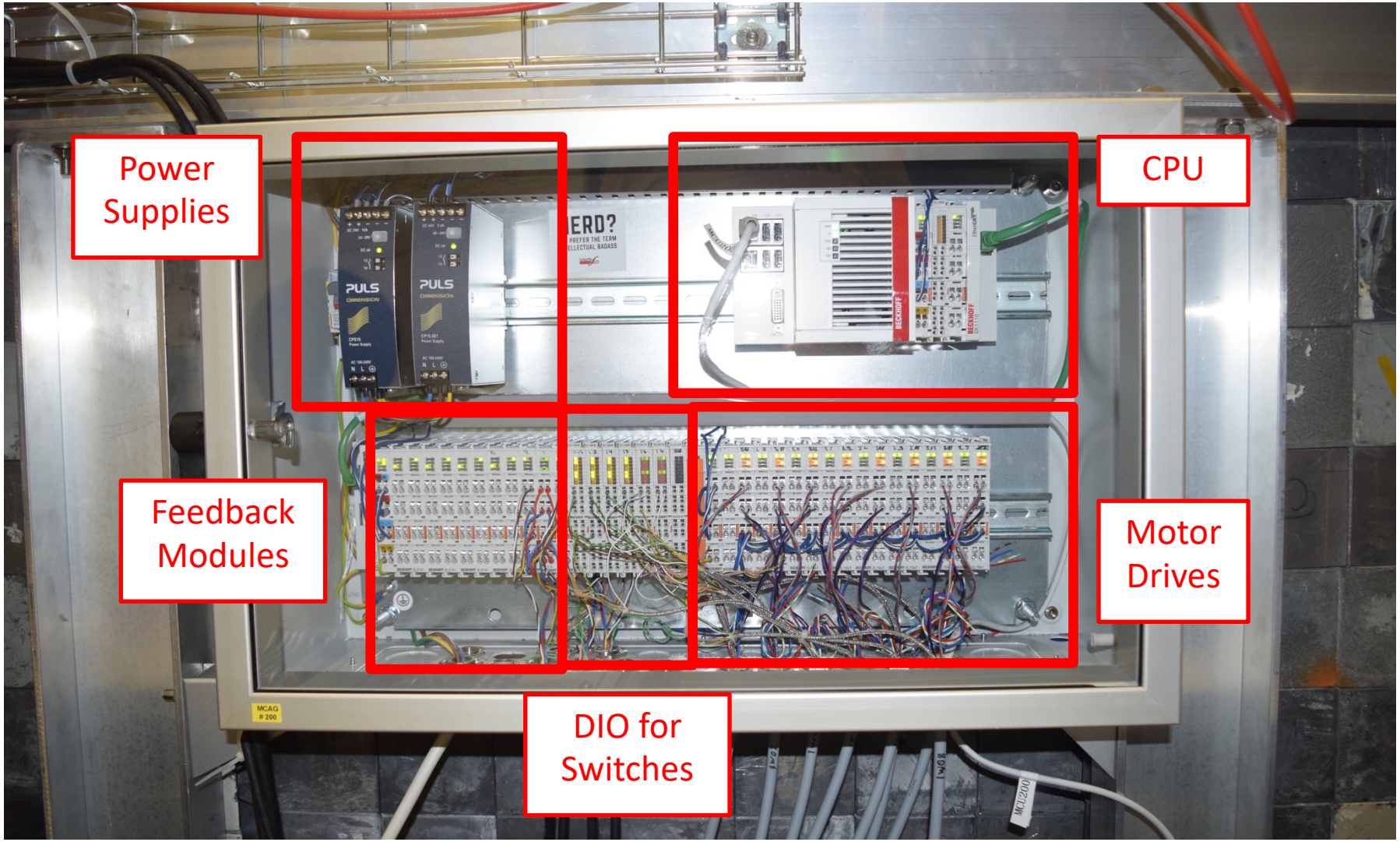
1. TwinCAT: Utilising function blocks from the ESS MCA standard library (tc_mca_std_lib). Standard way of controlling axes.

2. EPICS TwinCAT driver developed over a 2-3 year period within MCA Group to talk to TwinCAT. Included expert GUI as EPICS client.

3. NICOS implemented during commissioning but not too much testing before commissioning. Included User Interface for scientist.

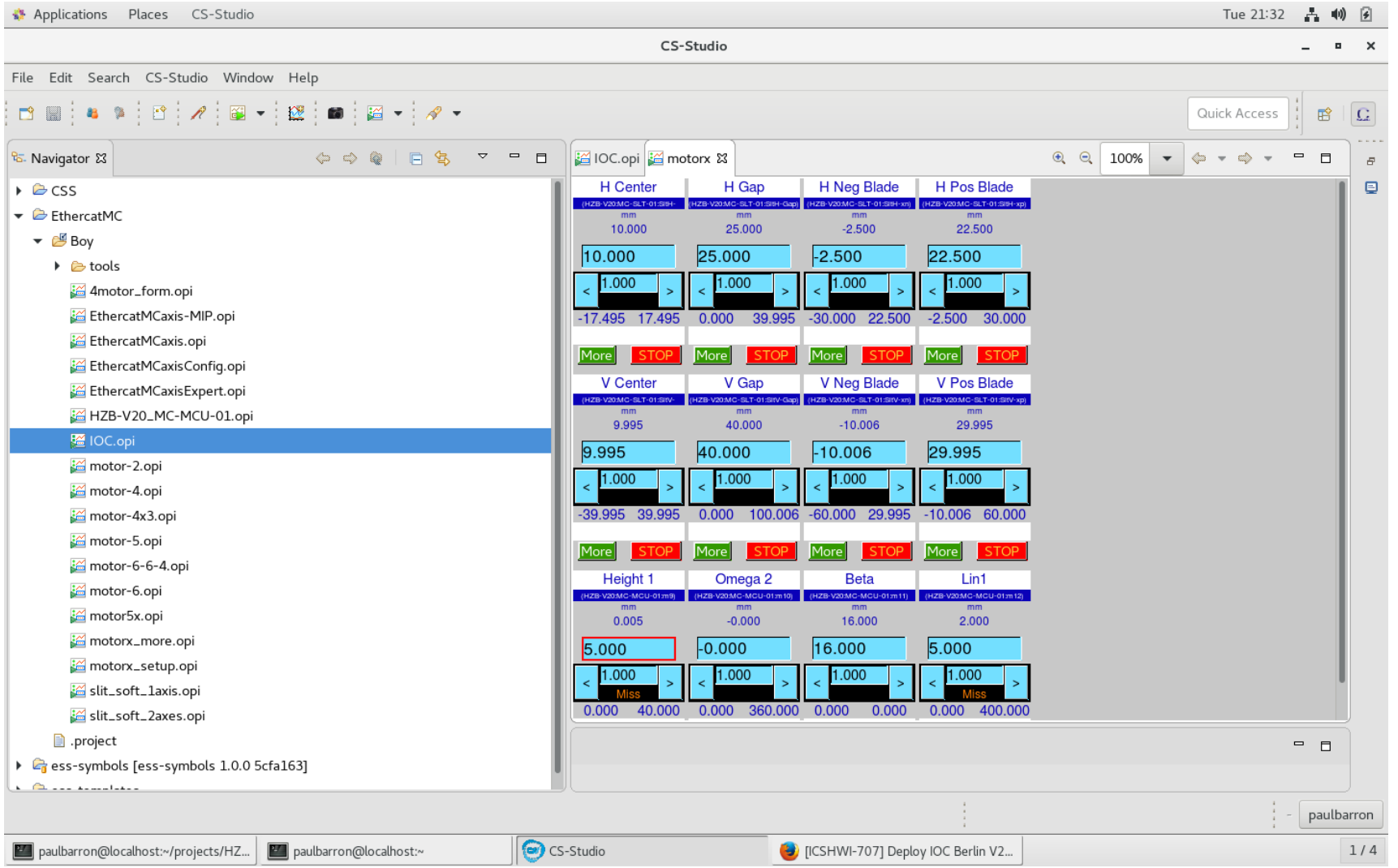
Motion Control Electronics

Wall mounted cabinet at V20



CSS Experts GUI

EPICS client

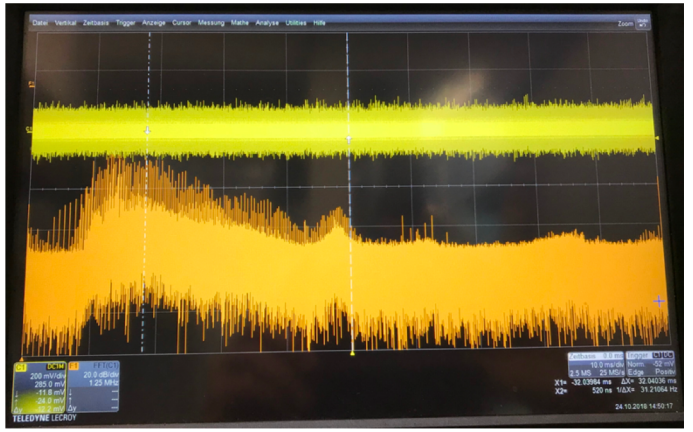


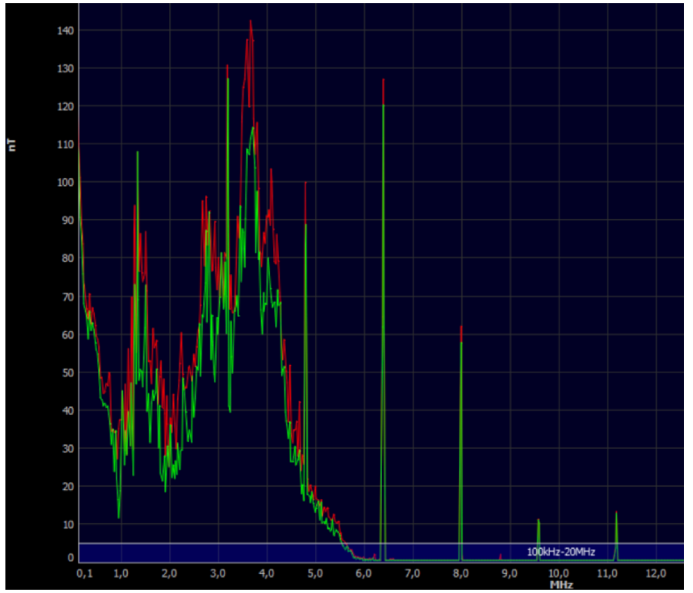
Outcomes

- Motion stages commissioned in TwinCAT.
- Slit functionality currently at the TwinCAT level. Can control either real slit axes or virtual axes from all three software layers.
- Experience gained on using virtual axes/slit systems in TwinCAT.
- EPICS working well with a few small bugs to do with displaying virtual axis parameters.
- NICOS working but lacking a few features available from the engineering screen.

Problems

- Noise picked up by the neutron detector electronics when motor drives turned on; measured later with EMC probe for frequency analysis.
- Problem with one stepper motor module going into error, hard to diagnose remotely.
- Problems when disconnecting a removable motion stage (can’t switch off power to an amplifier from NICOS).
- Scientist not able to easily home an axis directly in NICOS.
- Scientist not able to easily reset an error on an axis in NICOS.





Future work

- Troubleshoot noise coming from motor drives. EMC tests of Beckhoff components in cabinets and 19”crates scheduled at HZG in Geesthacht for April.
- Make additional functionalities available in NICOS software for instrument scientists.
- Synchronization bugs with some parameters not updating after a move on virtual axes.
- Potential hardware upgrades to removable motion stages (encoders and limits).

Any other questions

No?

- Thanks