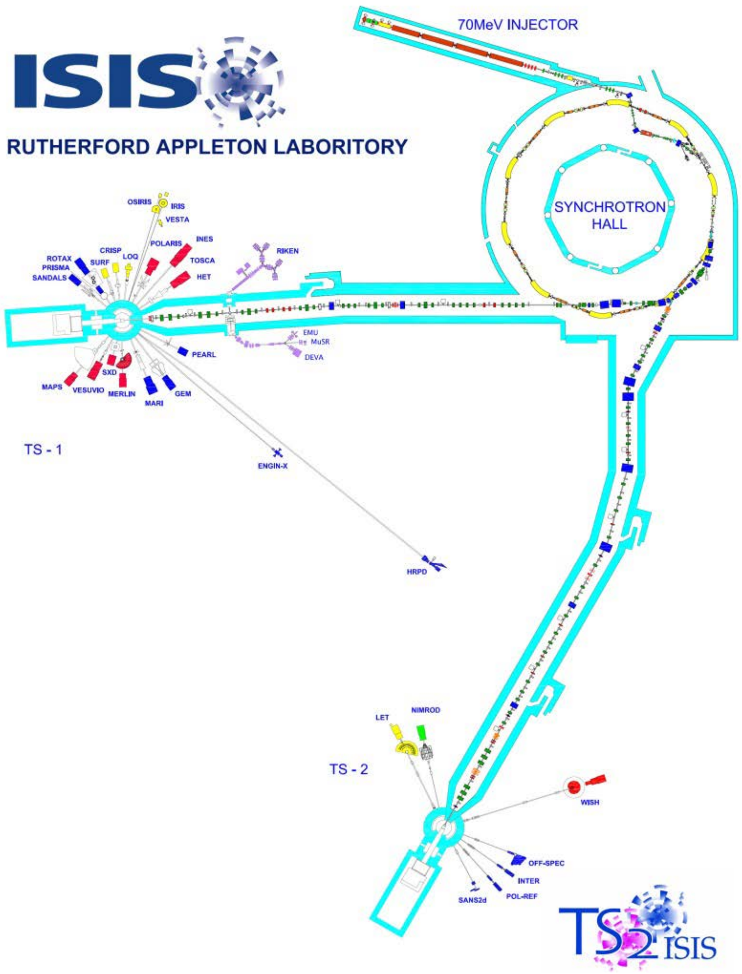
Motion Control at ISIS

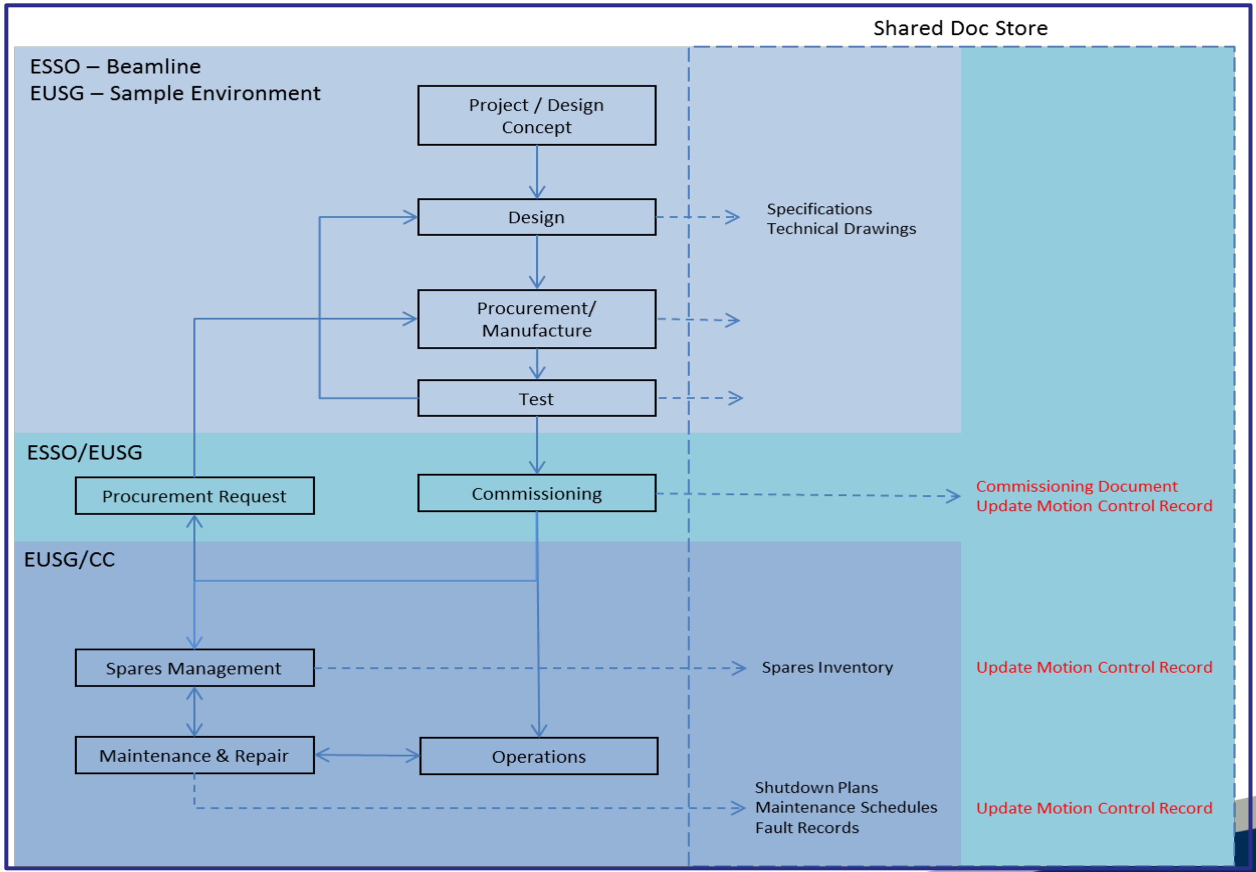


Galil Controller
Commercial Amps
In house Diagnostic Cards

600+ Axes in total
Predominantly Stepper
Piezo for non-mag & vac
Minimal Servo

Motion Control Responsibilities

3 Divisions, 4 Groups – ESSO, EUSG, Computing Controls & Mechanical



Operational Challenges

Engaging with project managers, designers & scientists

- Design in ease of maintenance
- Standardise solutions – But we also want to develop!
- Managing project handovers.

Providing a robust approach to support

- Support requirements ↑ whilst budgets↓
- Know your critical equipment & have a plan.
- Scheduled equipment maintenance – Be proactive.
- Feedback to design groups.

Technical Challenges

Sample Environment

- Rotating samples in dilution fridges at ~25mK.
- Cryogenic goniometers ~4K.
- Can we increase automation with robotics?

Beamline Motion & Computing Control

- Ageing controller vs. next gen. requirements.
- Component longevity in high-rad environments.
- ‘Scan in motion’
  - Multi-Axis coordinated moves linked to neutron data.
  - EPICS driver development.
  - Interface to existing DAE.
  - Manage collision detection.

Science & Technology Facilities Council ISIS

Thank You

Steve Cox
Beamline Motion Design
stephen.cox@stfc.ac.uk

Matt North
Operational Support
matt.north@stfc.ac.uk

Freddie Akeroyd
Computing Controls
freddie.akeroyd@stfc.ac.uk

'A Distributed Remote Monitoring System for ISIS Sample Environment'

Tuesdays Poster Session

EUROPEAN SPALLATION SOURCE

Motion Control at the ESS-Project

Miha Reščič, ICS
*Thomas Gahl, Electrical Engineering Group

ICALEPCS2013-MOCRAF Workshop, 2013-10-06

ESS Overview

- The European Spallation Source (ESS) will house the most powerful proton linac ever built.
  - The average beam power will be 5 MW
  - The peak beam power will be 125 MW
- Built in Lund, Sweden with first neutrons in 2019
- End of construction in 2025 with 22 instruments
- **What is the aim of the institute / vendor?** (from http://europeanspallationsource.se):

The European Spallation Source (ESS) is a multi-disciplinary research centre based on the world's most powerful neutron source. This new facility will be around 30 times brighter than today's leading facilities, enabling new opportunities for researchers in the fields of life sciences, energy, environmental technology, cultural heritage and fundamental physics.

ESS – Motion needs

- Many motion users
  - Accelerator
    Beam diagnostics, LLRF
  - Neutron instruments
  - Others
- Strategy
  - Use a standardized solution for 80% of cases
  - Specialized solution for the remaining 20%
- **How is motion control integrated into the activities of your institute?**
  - Responsibility for control: Integrated Control System (ICS)
  - Biggest stakeholder: Electrical Engineering
  - Considered as users: Accelerator, Others ...

Important Motion Control Features

- **What are your current technical challenges or concerns in the motion control area?**
  - The time stamping issue
  - The components for harsh environment (radiation, magnetic field, high/low temperature etc.)
- Also important
  - EPICS support (!)
  - Control linear piezo-motors (slip-stick) = magnetic fields
  - DC-brushless, AC motors, Linear Motors = speed, torque
  - Resolver, LVDT, but might be adapted externally = radiation
  - BISS-C (high resolution absolute linear encoders)
  - Multi-axes functionality
  - Parametric trajectories

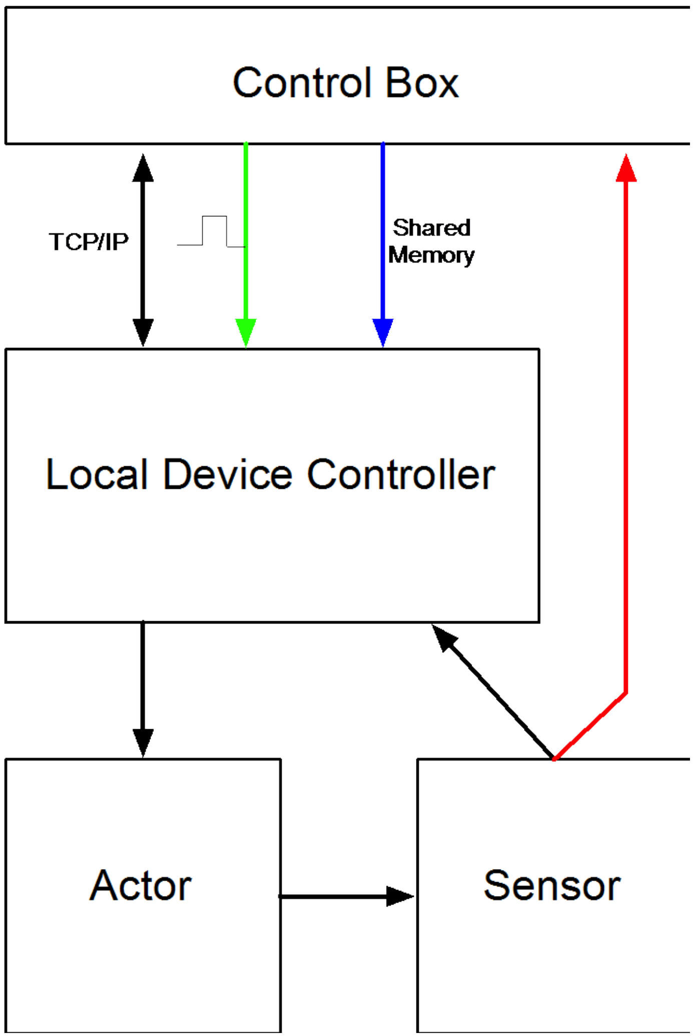
Goals for the workshop

- **What do you expect to hear from other attendees and what questions do you have for them?**

- Expectations from the workshop: get an overview of the motion control situation / position / status at other facilities

- Questions: no specific questions (will have them as we go into more discussion)

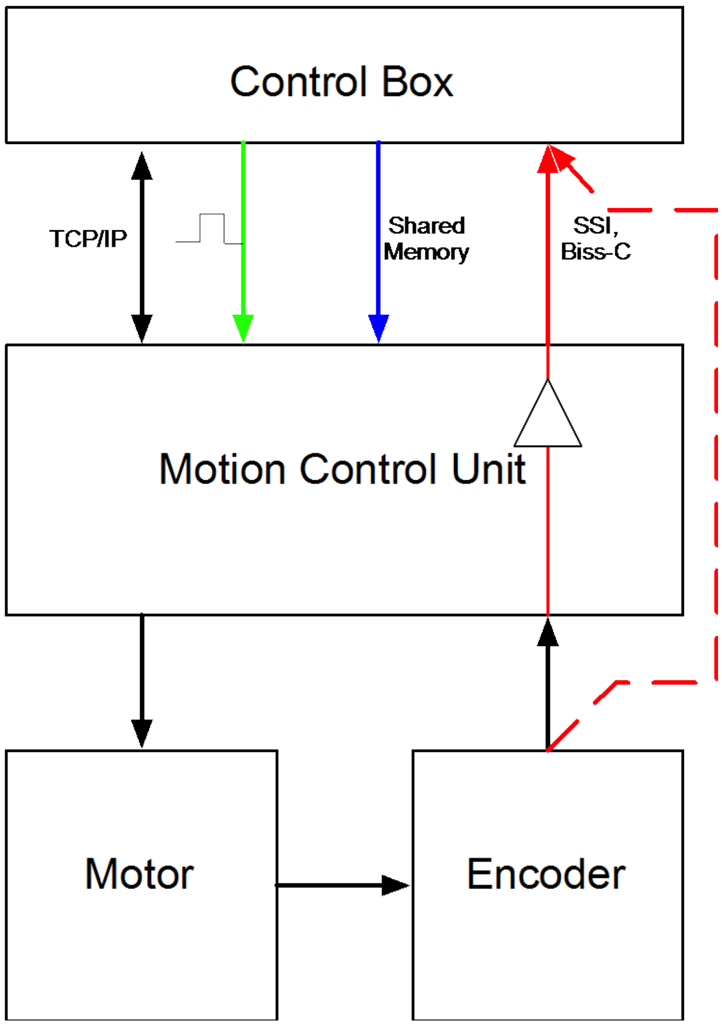
Time stamping



- On the control of local devices 4 different types of time stamping are possible according to the latency requirements
- T1: read out metadata through TCP/IP or RS232, time stamped in the control box (latency few hundreds of msec)
- T2: Synchronizing the periodical reading of metadata in the controller with a pulse from the timing system (latency few msec)
- T3: Importing absolute time to Controller and time stamping there (latency well below 1 msec)
- T4: Direct reading of metadata (from sensor) into the control box and time stamping there (latency well below 1 msec)

EUROPEAN
SPALLATION
SOURCE

Motion Control



- Motion Control Unit is connected to the Control box through TCP/IP for commands and readings
- On motion control all 4 different types of time stamping might be applicable to fulfill the latency requirements derived from the required precision and the used speed
- Read out of positions through TCP/IP, time stamped T1 in the control box
- Synchronizing a periodically reading of positions with a pulse from the timing system, time stamping T2
- Importing absolute time to Motion Control Unit with time stamping T3
- Direct reading of encoder position into the control box with time stamping T4

Motion Control for Rinsing Machines of Superconducting RF Cavities

Paulo GOMES

on behalf of Aleksander SKALA & Henrik VESTERGARD

CERN Vacuum Controls

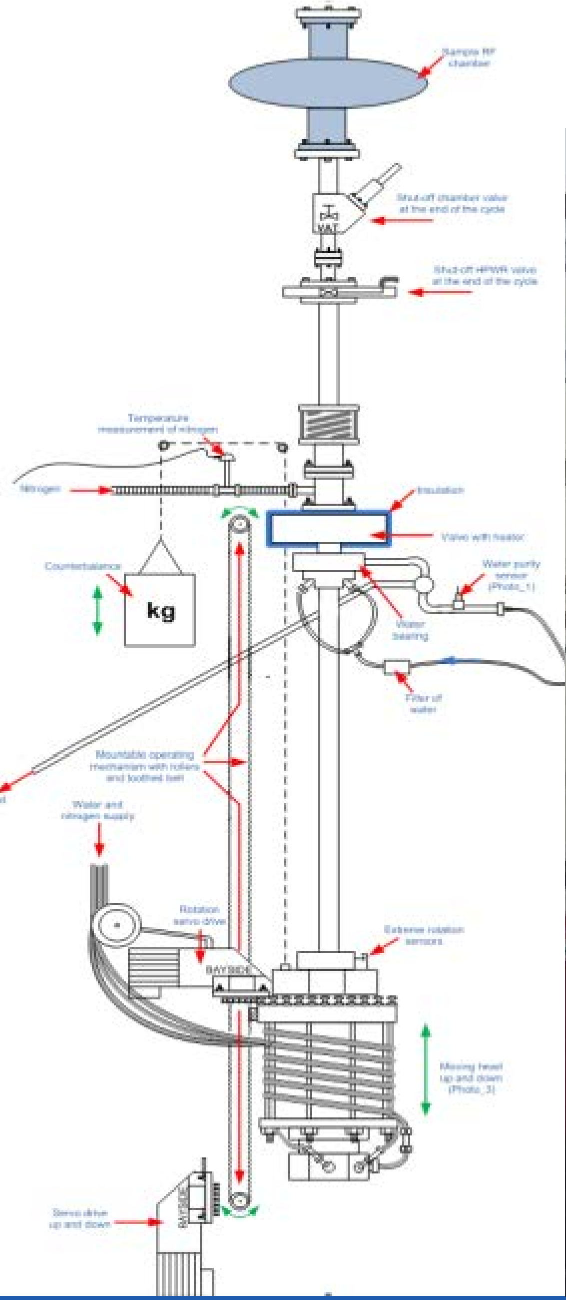
CERN TE / VSC / ICM

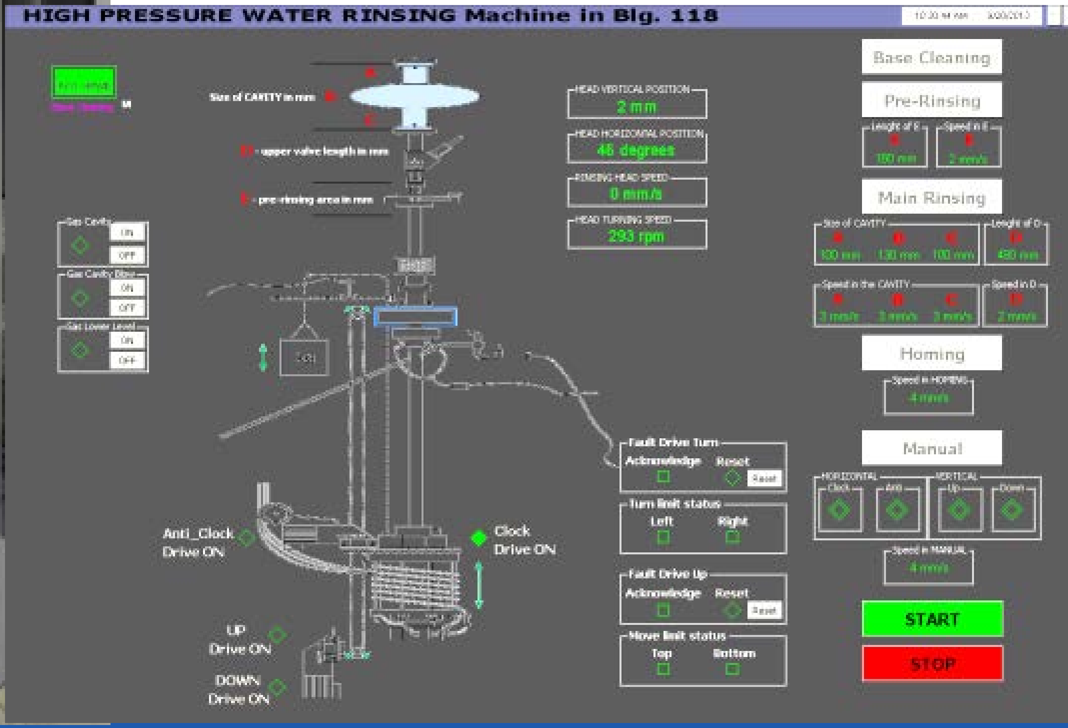
Technology Department (TE)
technologies specific to existing particle accelerators, facilities and future projects

Vacuum Surfaces &Coatings Group (VSC)
design, construction, operation, maintenance &upgrade of
high & ultra-high vacuum systems for Accelerators and Detectors

Interlocks, Controls and Monitoring Section (ICM)
design, maintenance & consolidation of the
vacuum control systems of all Accelerators and Detectors.

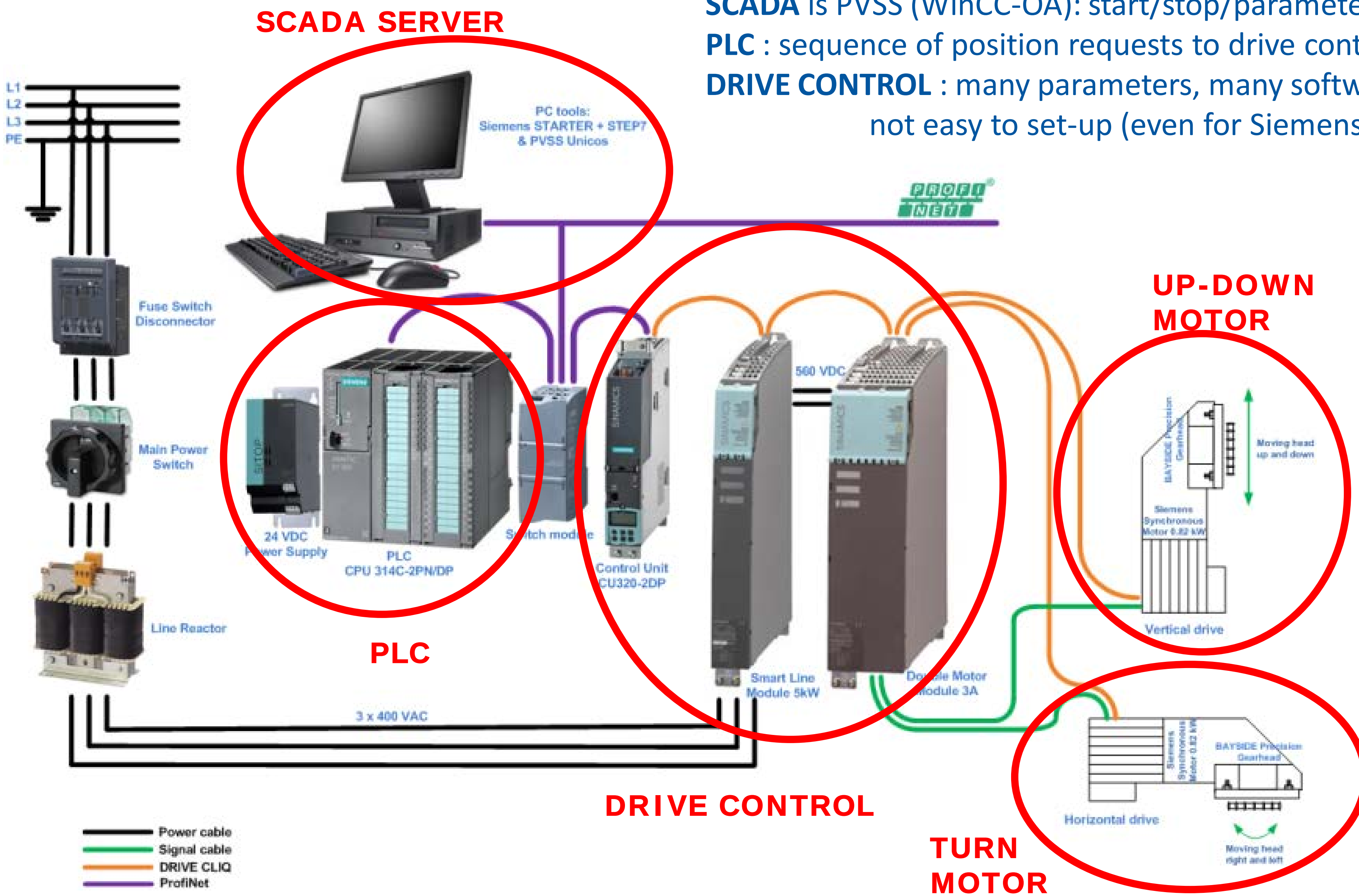
LHC Cavities





Architecture

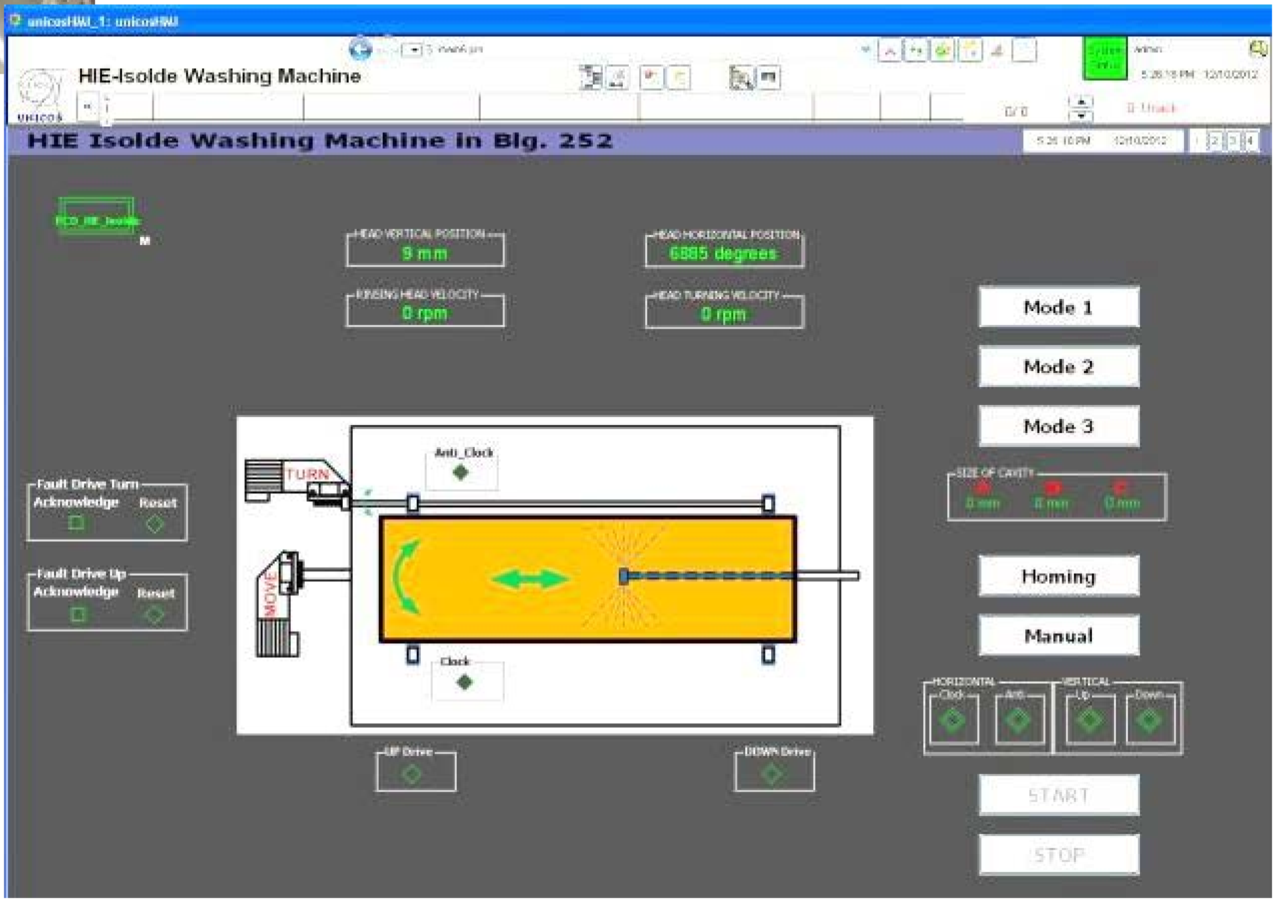
Profinet communication, distributed by a switch
SCADA, PLC, Drive Controller
SCADA is PVSS (WinCC-OA): start/stop/parameters
PLC : sequence of position requests to drive controller
DRIVE CONTROL : many parameters, many softw versions,
not easy to set-up (even for Siemens support)



HIE-ISOLDE Cavities







CERN

MOCRAF 09 2013 – Round Table Session Introduction – ESRF

Presented by N Janvier

MOCRAF 09 2013 – Round Table Session Introduction – ESRF

Presented by N Janvier

ESRF at a glance

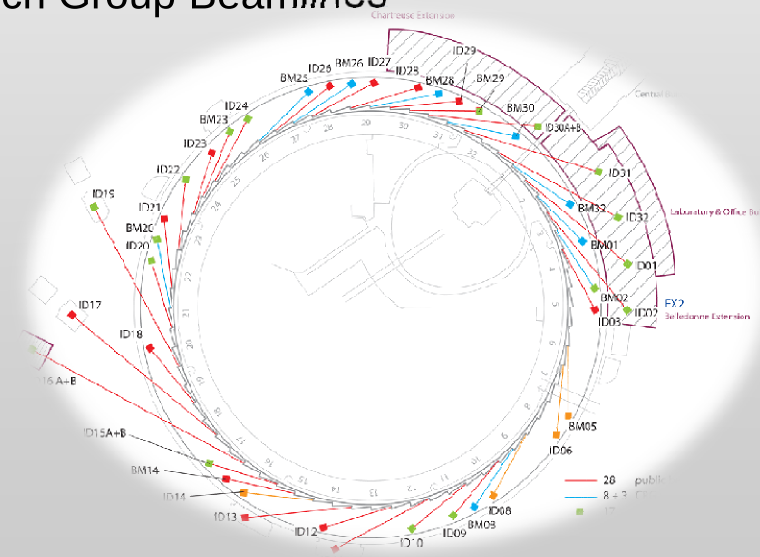
- The **E**uropean **S**ynchrotron **R**adiation **F**acility is an international research institute for cutting-edge science with photons (X-rays)

- ~ 600 people [scientists, technical staff, administrative staff, PhD students]
- ~ 1500 experimental sessions per year / ~ 1800 publications

- 28 public Beamlines – 11 Collaborating Research Group Beamlines

- Upgrade First phase from 2009 to 2015
  - 17 refurbished or upgraded beamlines

  - Improvement in performances depending on innovative and successful X-ray instrumentation programs.



Motion control at ESRF

- ISDD: a division dedicated to Instrumentation support and development > 100 people

- The ESRF "motion" ecosystem:
  - Around 5000 stepper motorised axes; ~ 150 axes / beamline
  - Other actuators: brushless, DC, Piezo-electric, piezo-motors
  - Different position sensors: Incremental encoders (95%), Absolute encoders, Capacitive sensors…
  - Specific needs: synchronization of motion with the Beamline components (detectors, …)

- Strategy and challenge: to offer high performance and adapted solutions while optimizing the cost and the support effort.

- A Motor Controller developed in-house Icepap
- As of today ~ 3000 axes controlled with IcePAP @ ESRF

- Please refer to the presentation "Hardware Solutions For Motion Control At The ESRF"

Expectations

- Hear about solutions and progress in motion control at facilities and vendors

- Present, discuss and compare answers to the (common?) challenges

Thank you for your attention !

Motion at ALBA

Motion Workshop

6^{th} October – ICALEPCS 2013

San Francisco

Guifré Cuní – on behalf of ALBA's Controls Section

ALBA Synchrotron

Third generation 3-GeV **Synchrotron Light Source**, composed by a Machine (**Accelerators**) and several (7) **Beamlines**, each providing **Photon Beam** that scientists use to perform a wide variety of experiments with different techniques like: **Spectroscopy**, **Scattering** or **Imaging**.

The main actuator **(Positioning)** at ALBA is the 2-phase hybrid stepper:

- ~ 100 axes in the accelerators (50 in 8 Front Ends, ~50 in RF, DI, ID)
- ~ 500 axes distributed in the beamlines

Around **50%** of them have an associated **Encoder** (incremental, SSI, or analog) and can work in **Closed Loop** mode when needed.

99% driven with same hardware controller: IcePAP [ICALEPCS 2013]

- Advantage: Same **software interface**
- Advantage: Same axis **configuration**, **test** and **operation**
- Advantage: Simpler hardware **maintenance**, spare control and cabling

Apart from steppers, some specific equipments require brushless DC motors (**PMAC** and **ETEL**), or piezo actuators (**Jena** or **PI**)

Motion examples at ALBA

Machine – **Diagnostics**

Machine – **Radio Frequency**

Machine – **Insertion Devices**

Machine/Beamines – **Front Ends**

Beamlines – **Monochromators**

Beamlines – **Mirrors**

Beamlines – **Diffractometers**

Some motion features

Forwarding of position information by means of encoder-like signals to **counter cards** or **external amplifiers** in slave mode (non-standard motors)

Integration with Safety Systems with “per axis” or “per rack” input **enable/disable signals**

Slave mode: **external signals** as **position source**

Front panel **customizable digital outputs** (e.g. axis’ **breaks** control)

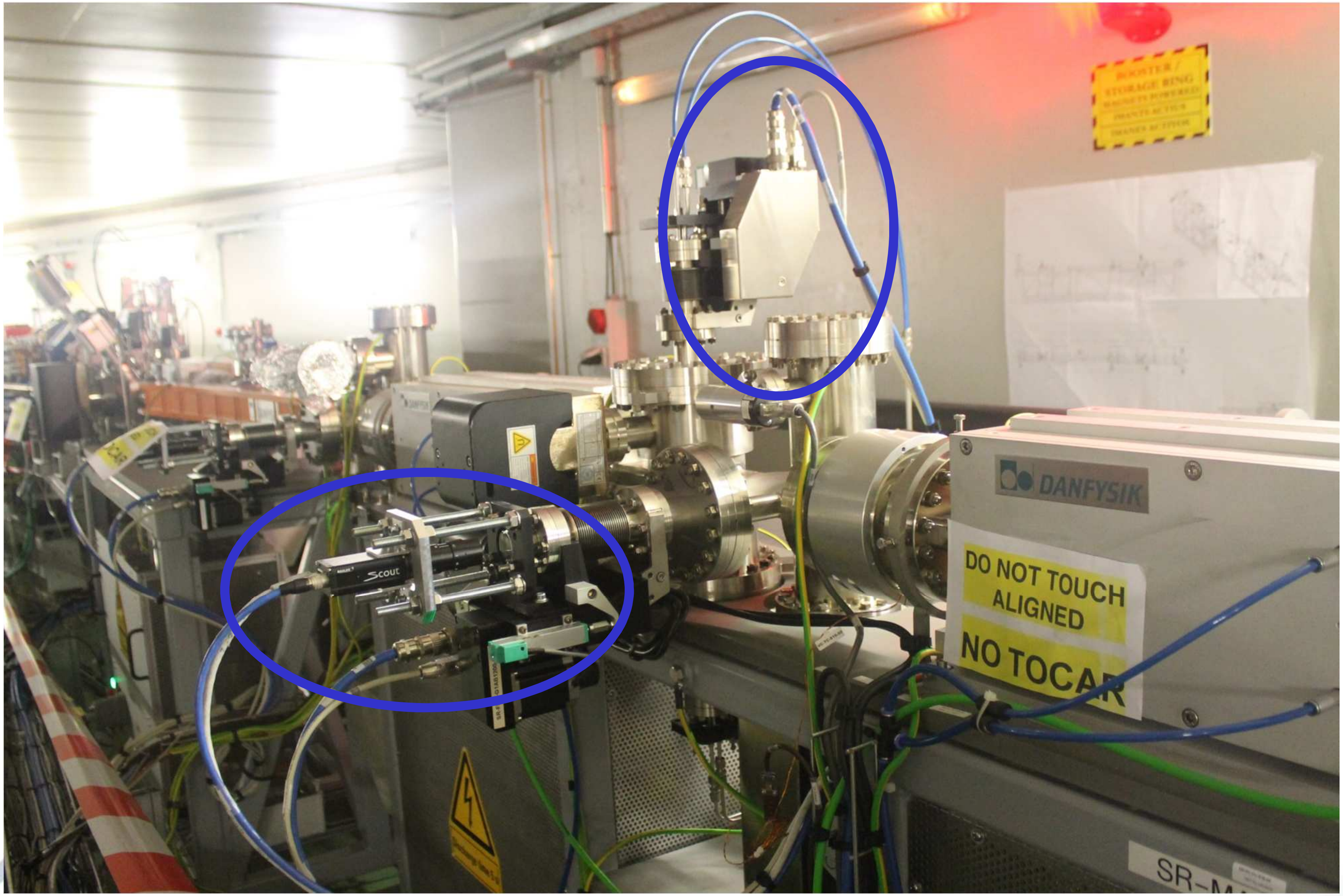
Coordinated motion of **multiple axes**

Trigger by **position** for shutters and detectors

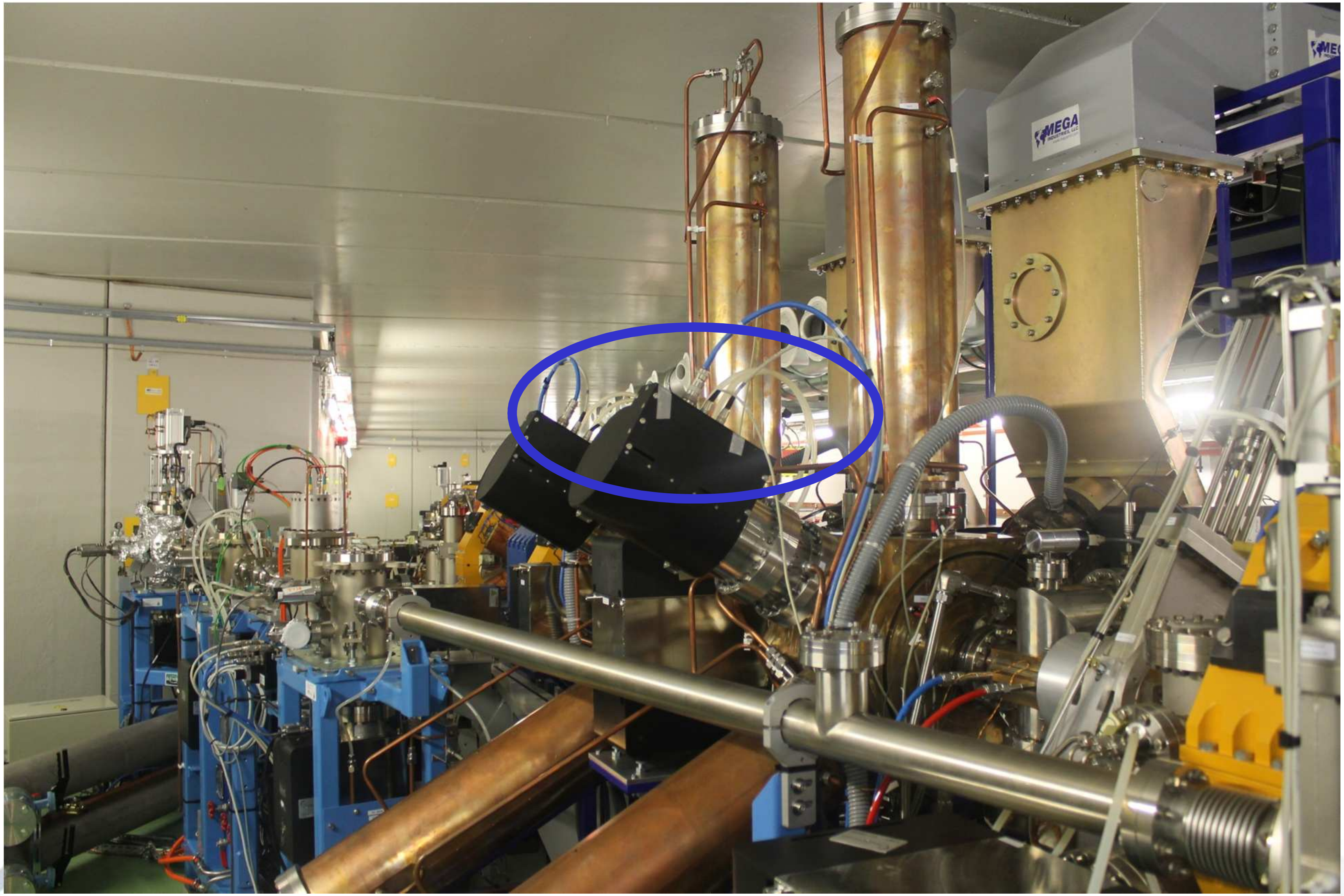
Expectations

- Discover other facilities
- Compare different solutions to similar problems
- Prepare for new setups that may arise
- Identify risks and future challenges
- Get in touch with people

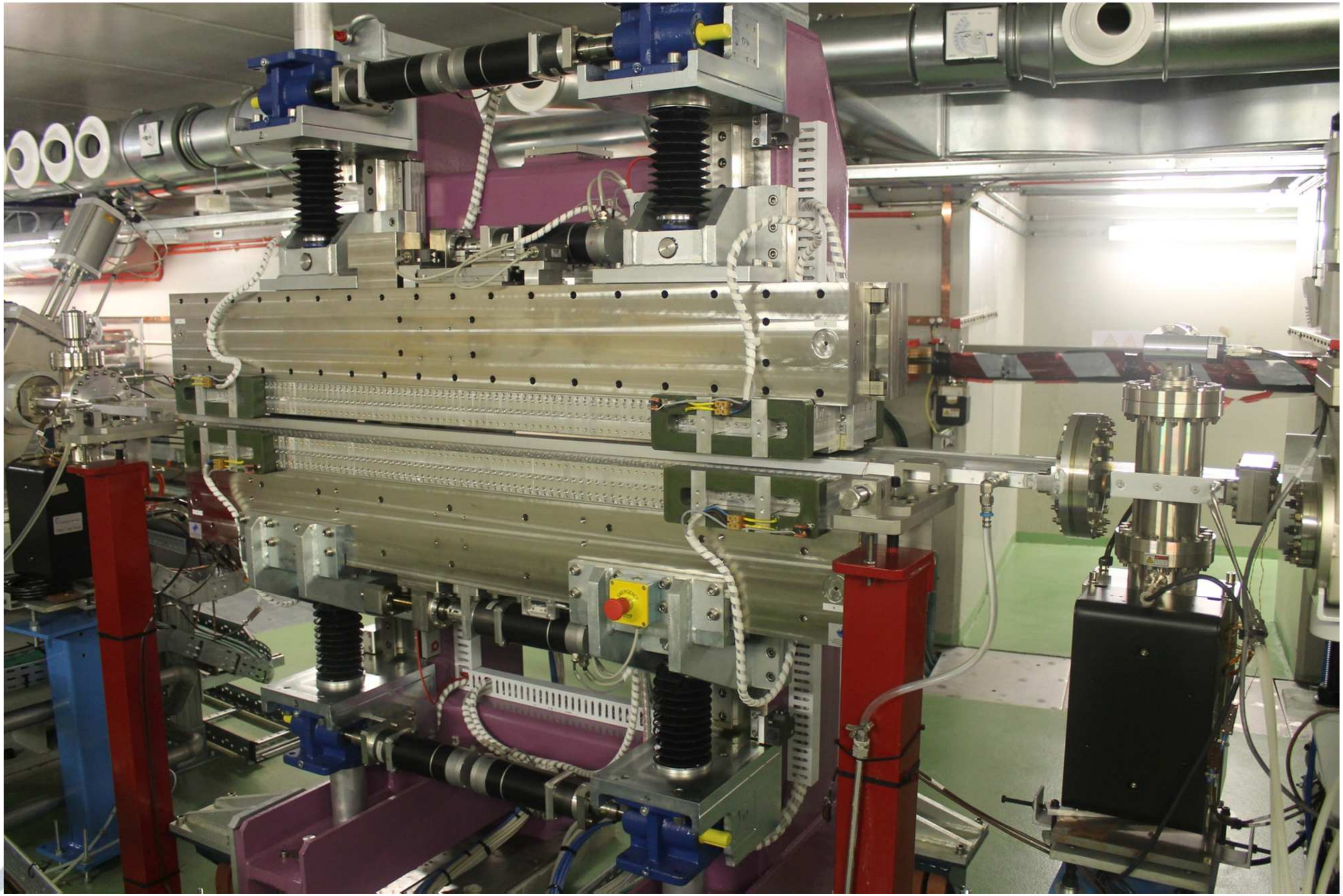
Machine - Diagnostics



Machine – Radio Frequency

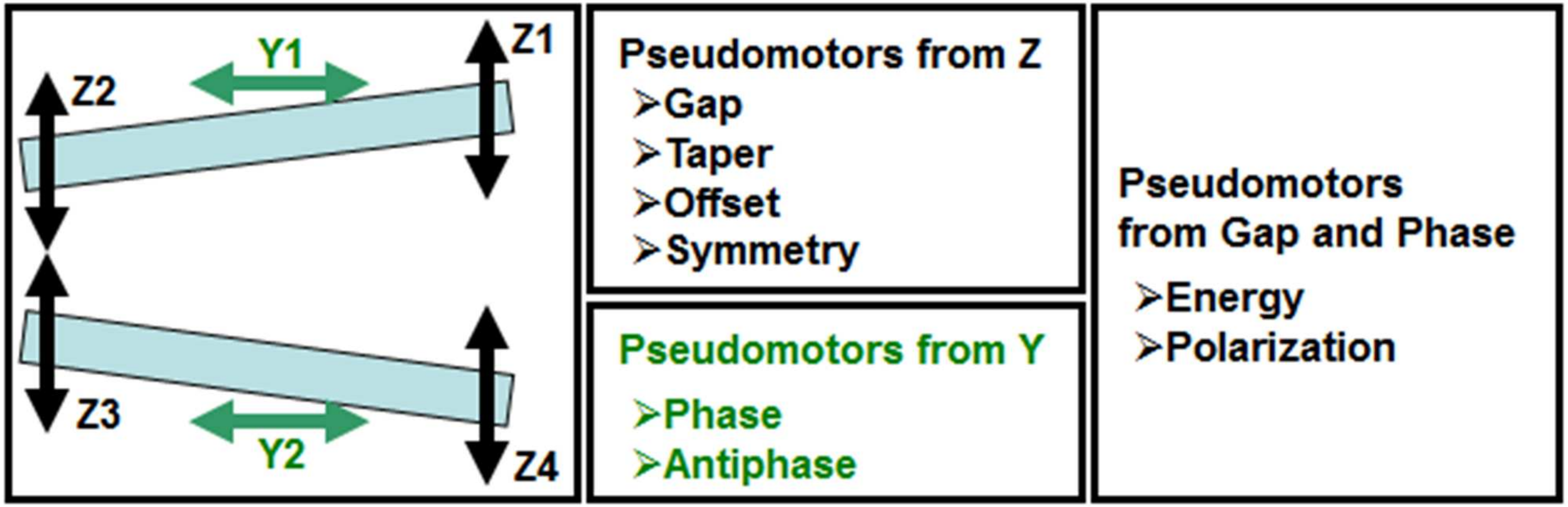


Machine – Insertion Devices (I)



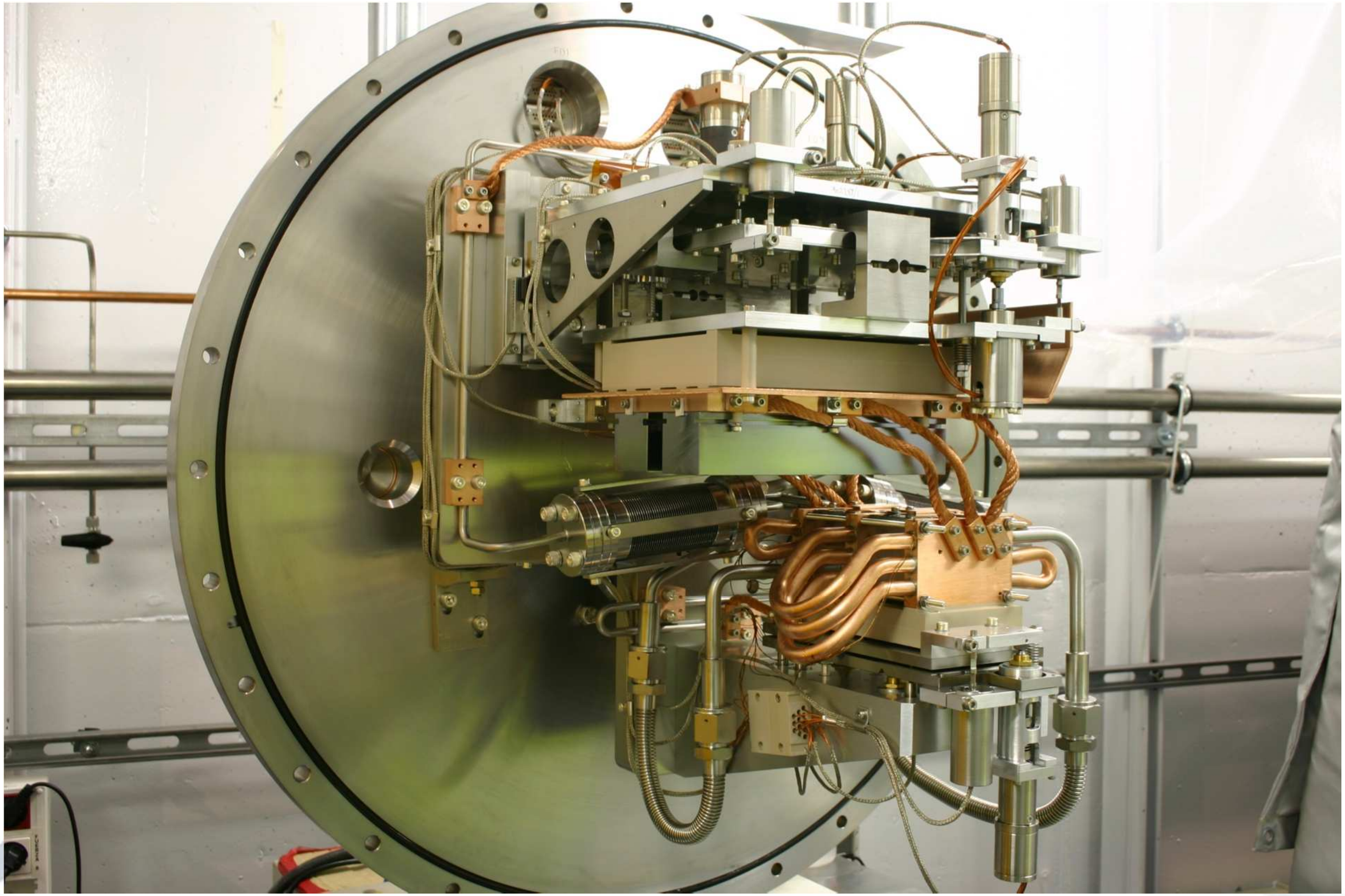
Machine – Insertion Devices (II)

AppleII pseudo motor architecture

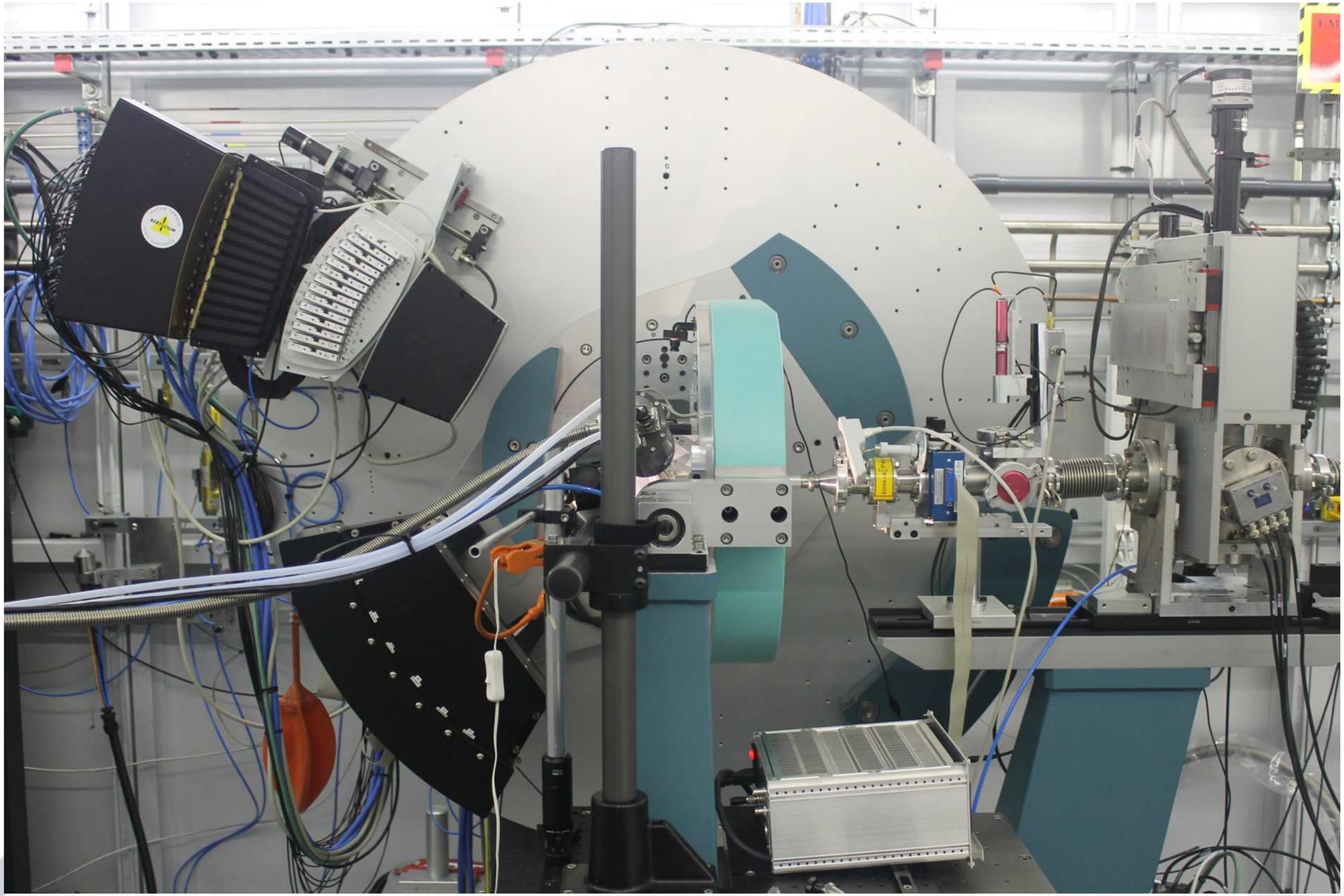


Breaks, Tilt interlocks, Absolute encoders, Pseudo motor architecture

Beamlines – Monochromators



Beamlines – Diffractometers



Motion Control at the Advanced Photon Source Argonne National Laboratory

Mark Rivers
University of Chicago

7 GeV synchrotron x-ray light source, the largest in the U.S.

User facility with over 5700 unique users per year

66 simultaneously operating beamlines

Wide range of science: protein crystallography, physics, chemistry, earth science

Wide range of techniques: diffraction, imaging, spectroscopy

~50% of beamlines run by the APS, use their software controls group

~50% run by external organizations (e.g. University of Chicago), each does its own software controls

Motion Control at APS

Most motion control is on APS experimental beamlines

Small amount on the accelerator side, mostly to control undulator gaps

Recent survey of beamline stepper motor controls (done for safety evaluation after a shock incident)

- 5,137 stepper motors
- 86 different models of motor drivers
- Most popular:
  - Advanced Control Systems Step-Pak (Unipolar, bipolar, mini-stepping bipolar)

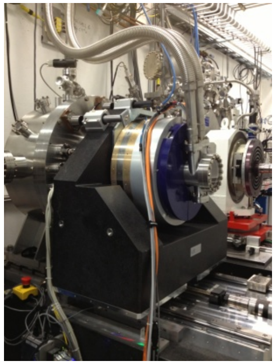
- >25 different kinds of motor controllers (?)
- Most popular:
  - Pro-Dex OMS-58, MaxV (VME)
  - Delta-Tau Turbo-PMAC (Ethernet, VME)
  - Newport XPS (Ethernet)

APS Motor Software Support

- Most (but not all) APS beamlines run the EPICS control system
- Top-level object is the EPICS **motor record**
  - Lots of code has been written to this object:
    - spec, Python and IDL classes, etc.
  - "Least common denominator" support (acceleration, velocity, limits, etc.) but no advanced features
- 3 models of lower-level device and driver support have developed over time
- Original (Model 1)
  - Device-dependent device support and driver support for each controller type
  - Communication between device support and driver is custom for motor code and very limited
  - Cannot use other records to talk to driver, only motor record
  - Cannot take advantage of controller-specific features not supported by motor record
  - No provision for multi-axis coordination
  - Most EPICS drivers are written this way for historical reasons
- Model 2
  - Uses standard *asyn* interfaces to communicate between device support and driver
  - *Can* use other records to talk to driver via asyn interfaces
  - Not as easy as it should be to do so
  - No implementation of multi-axis coordination

APS Motor Software Support

- Model 3
  - Two C++ base classes, asynMotorController and asynMotorAxis.
  - Base classes provide much functionality, only need to write device-specific implementations.
  - Easy to support controller-specific features
  - Don’t have to use motor record.
  - Direct support for non-linear multi-axis coordinated “profile moves” in the driver API.
- Challenges
  - Improve efficiency of data collection by using only on-the-fly scanning
    - Upgrade drivers
    - Ancillary hardware (multi-channel scalers, detector trigger timing)
    - Higher-level software support
  - Coordinate undulator motion with monochromators for on-the fly spectroscopy



Australian Government

ansto

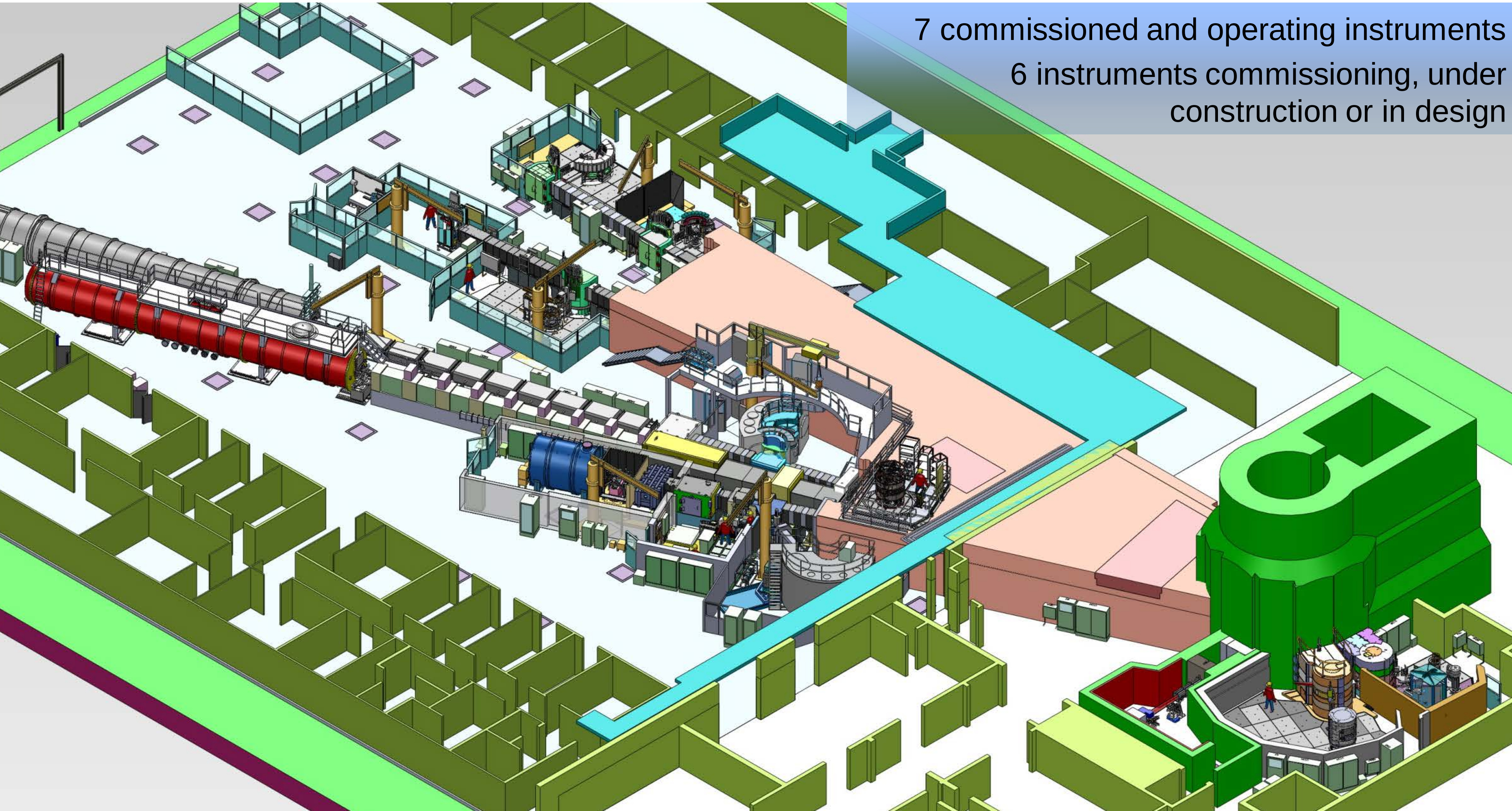
The Bragg Institute

Paul Barron – ICALEPCS 2013

Neutron Scattering Facility

7 commissioned and operating instruments

6 instruments commissioning, under construction or in design



Electrical Engineering Team

- Motion control cabinets – build, design, test, deploy
- PLC control of vacuum and pneumatic systems
- Safety interlock systems
- Clean earthing for detectors

Barry Lewis	Laurence Heffernan	Dan Bartlett	Dave Federici	Macleay Stephenson	John Affleck	Frank Darmann	Paul Barron

Electrical draftsmen		Electrical technicians			Contractor	Lead engineer	Mechatronic engineer

Motion Control Systems

- Built in house
- Based on the Galil 2280 motion controller
- Motors are all 2 phase stepper motors (Stögra, Empire Magnetics, PRECIstep)
- Encoders: 99% are multi-turn absolute SSI (Heidenhain, Kübler, Gurley)
- Resolvers are used in high radiation areas in conjunction with SSI conversion cards (AMCI, Vega)
- Independent drivers for each axis (Parker Computmotor, Parker EDC, PRECIstep)
- Filters on all drives and controllers and dual redundant power supplies
- Integrated air pad control and interlocking
- E-stops from Safety Interlock System decelerate all motion

Challenges Faced

- Technical Challenges
  - High precision encoding in radiation environments
  - Synchronising multiple motion axes
  - Third party verification of what the motion systems are really doing (e.g. laser tracker, theodolite, tilt meter, touch probe, accelerometer)
  - Conveying best practice to contractors building equipment
- Non-technical challenges
  - Maintaining standards and an extensive spares inventory
  - Understanding failures and faults; remedying and pursuing them for the long term not just the short term
  - Trying to practice great engineering within a scientific centric organisation
  - Balancing standard components with unique requirements

Expectations for Workshop/Conference

- Identify best practice methods for common motion control applications
- Compare solutions for similar problems faced in motion control of scientific instruments
- Learn about new challenges that will likely arise in our future
- Networking

Australian Government

ansto

Questions?

Mitglied der Helmholtz-Gemeinschaft

JÜLICH
FORSCHUNGSZENTRUM

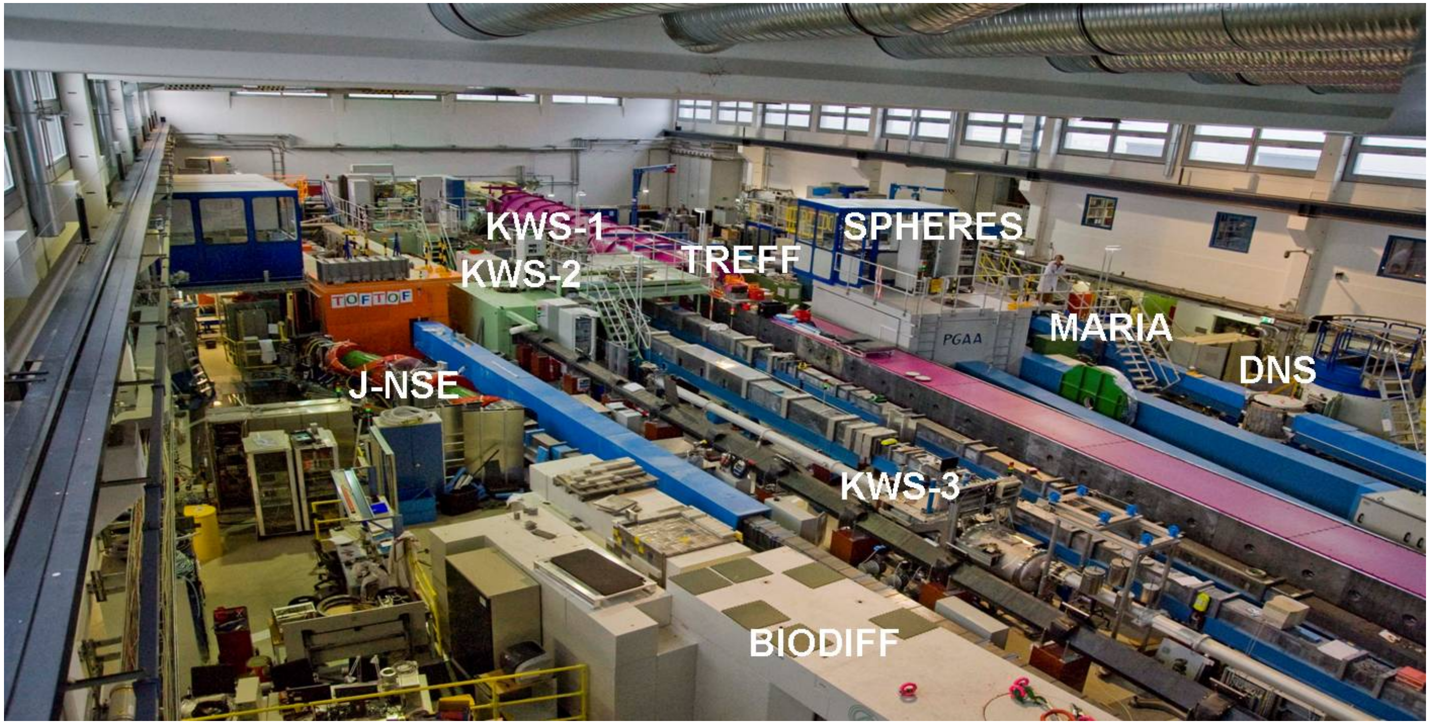
Motion control in Neutron Scattering at Forschungszentrum Jülich

6. Oktober 2013

Harald Kleines, Forschungszentrum Jülich, ZEA-2: Electronic Systems

JÜLICH FORSCHUNGSZENTRUM

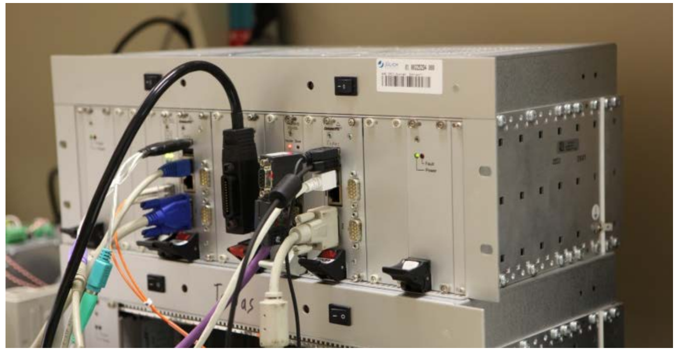
Neutron scattering - JCNS



- ZEA-2 is repsonsible for the control and data acquisition systems of all Neutron instruments of the Jülich Centre for Neutron Science (JCNS)
- Outstations at FRM-2 (Garching), ILL (Grenoble) and SNS (Oak Ridge)
- Neutron instruments comparable to synchrotron beamlines
  - About 30 mechanical axes
  - Mostly stepper motors
  - Sometimes synchronized (by PLC software)

PLC technologies for Motor Control

Server Computers



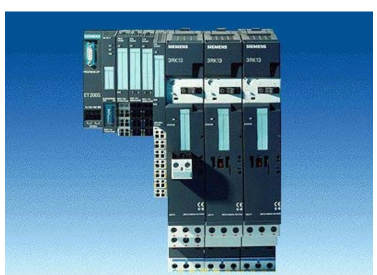
PLC gives homogeneous view on axes, independant of controller type, encoder,..

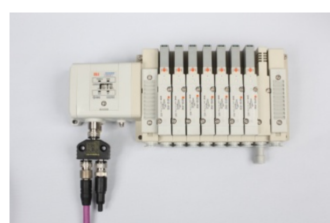
PROFIBUS DP, MPI, PROFINET

PLCs + Op. Panels

PROFIBUS DP, PROFINET, AS-Interface

Decentral Periphery





Used Motion Controllers (mainly from Siemens)

1STEP

1STEP-Drive

- Phytron

FM357

-4 axes controller

FM353

-DIN 66025

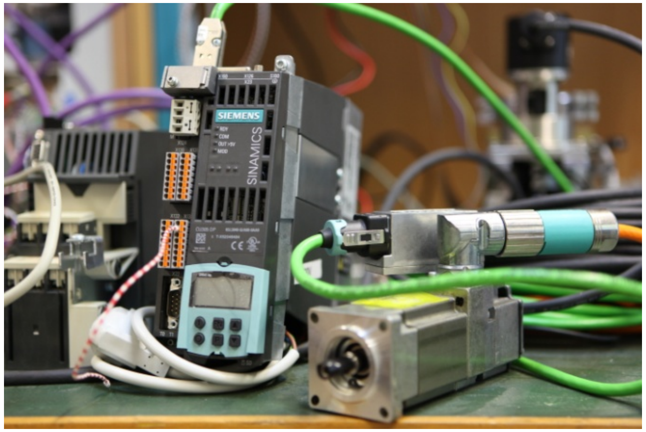
FM351 + 1POS

-Rapid traverse / creep speed drives

DS1-X

-Direct starter

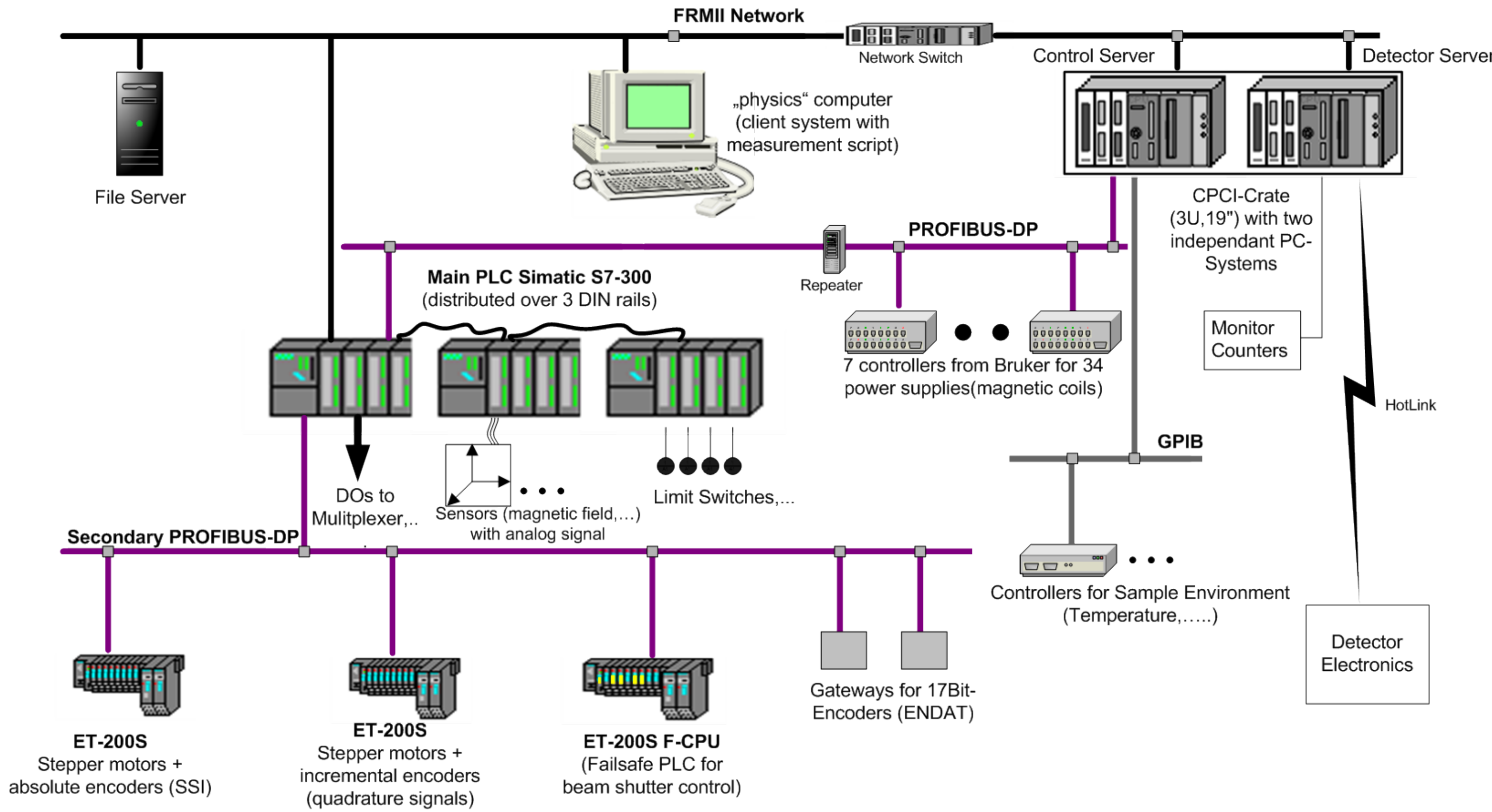
-up to 5,5 kW



Sinamics S

-Frequency converter

Example: Spin Echo Spectrometer at FRM-II



- Main challenges for the future: Frequency converters and synchronized axes (synchronization with other axes and/or with detectors)
- No actual problems: just interested in what the other labs are doing

Founded in 1976 Our Aim is to supply the best motion control systems as defined by our customers.

History:

General ‘76-’81
General + Motion Control ‘81-’85
Motion Control Only ‘85 Onward
Motion Control Systems, N.C. ‘95

Yearly Turnover:

Approx. $30 million

Financing:

Self Financed – Independently Owned

Number of Employees:

Over 200 Worldwide

Facilities:

120,000 sq. ft (approx. 12,000 sq. m.) since ‘99
Excellent Production and R&D Facility

Operation:

ISO-9001-2000 Certified (Dec. ‘06)
Automated Inventory Control (Bar coding)
New SMT Assembly Line (Lead-free, RoHS)
Automated Visual and X-Ray Inspection
Equipment for Automatic In-Circuit Testing
Updated/Semi-Automated Functional Testing
Test Results and Date Code Traceability

Welcome to

DELTA TAU
Data Systems, Inc.

Featuring

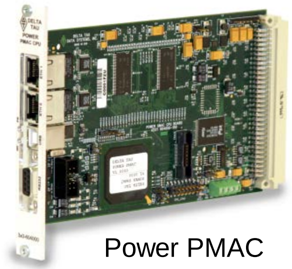
PMAC
Programmable **M**ulti **A**xis **C**ontroller

UMAC
Universal **M**achine and **A**utomation **C**ontroller

and

7th Generation

Power PMAC



Power PMAC 3U CPU

Board Level Controllers

PMAC VME

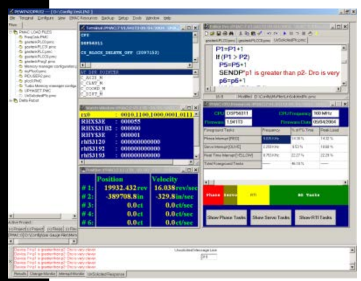
PMAC PCI

PMAC PC/104

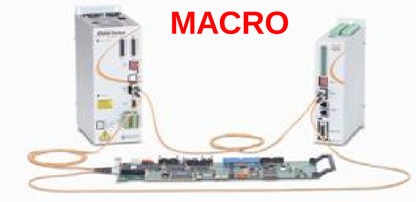
System Level Controllers

UMAC

Software



Facility



Turbo PMAC2 Ultralite
with **MACRO** Peripherals

CNC Systems

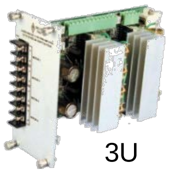
Power Brick LV

Quad Power Supply

Amplifiers

Geo Drives

Quad Amplifier



3U Amplifiers

Founded in 1976 Our Aim is to supply the best motion control systems as defined by our customers.

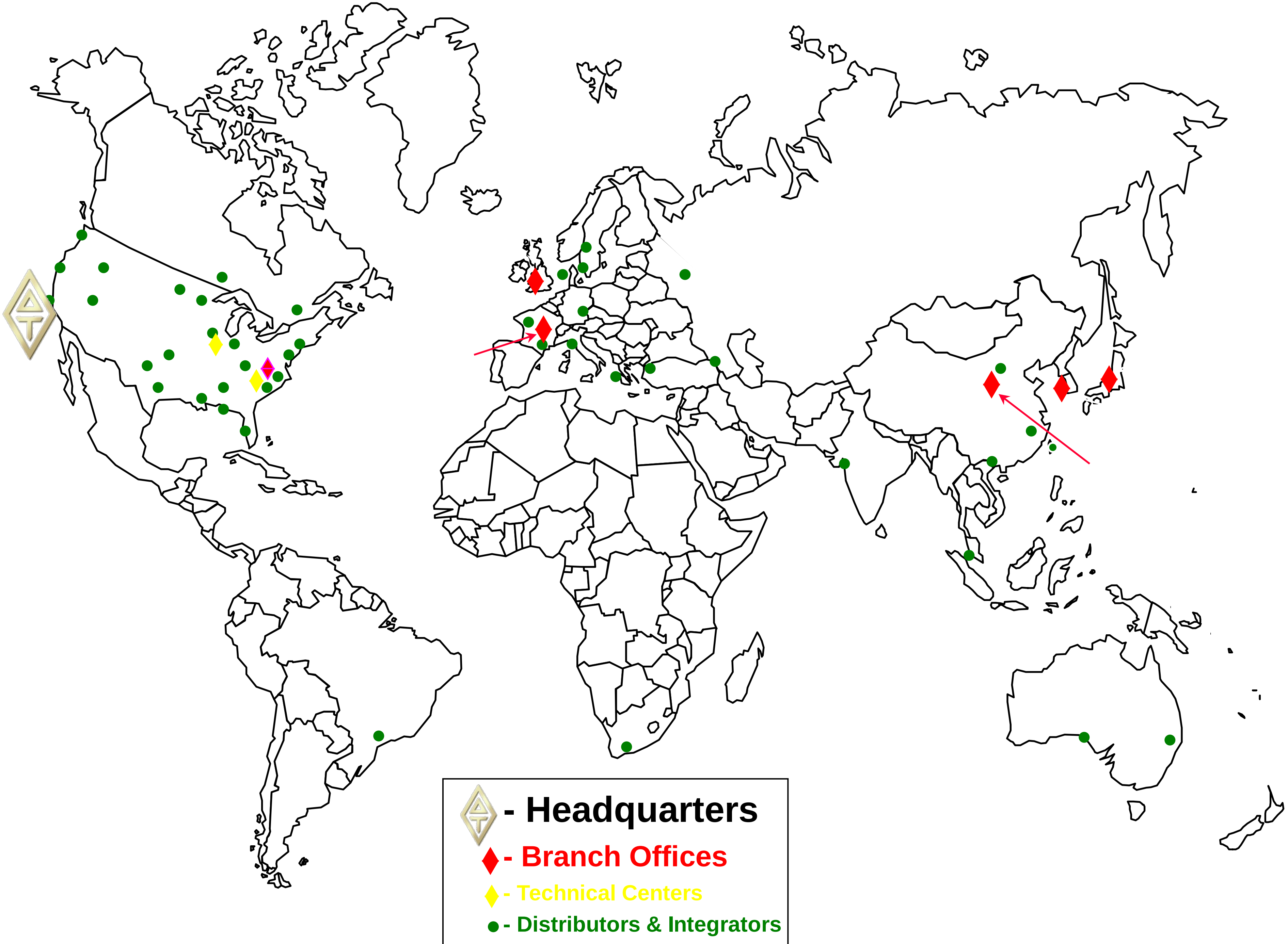
Our current technical challenges and concerns

1. To seamlessly integrate our control philosophy with existing “open source SCADA systems” such as EPICS and Tango
2. Meet the ever increasing requirements for positional accuracy, resolution and speed.
3. Keep up with demand for an increased number of synchronized axes, (now 256 with Power PMAC)

Questions

1. We would like clarity on the requirements for multi axes position control systems as applied to real time scanning applications?
2. Formulate a “standard” encouraging the use of high level functions such as inverse kinematics within the motion control hardware?
3. What demands will the developing science put on the motion controlers of the future?

NEW IDEAS IN MOTION


- Headquarters
- Branch Offices
- Technical Centers
- Distributors & Integrators