EUROPEAN SPALLATION SOURCE

Motion Control & Automation

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www.europeanspallationsource.se

June 02, 2015

Outline

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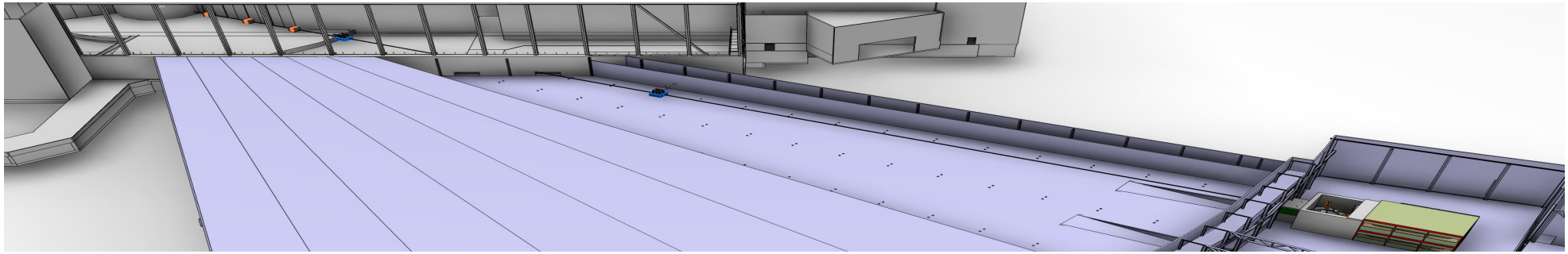
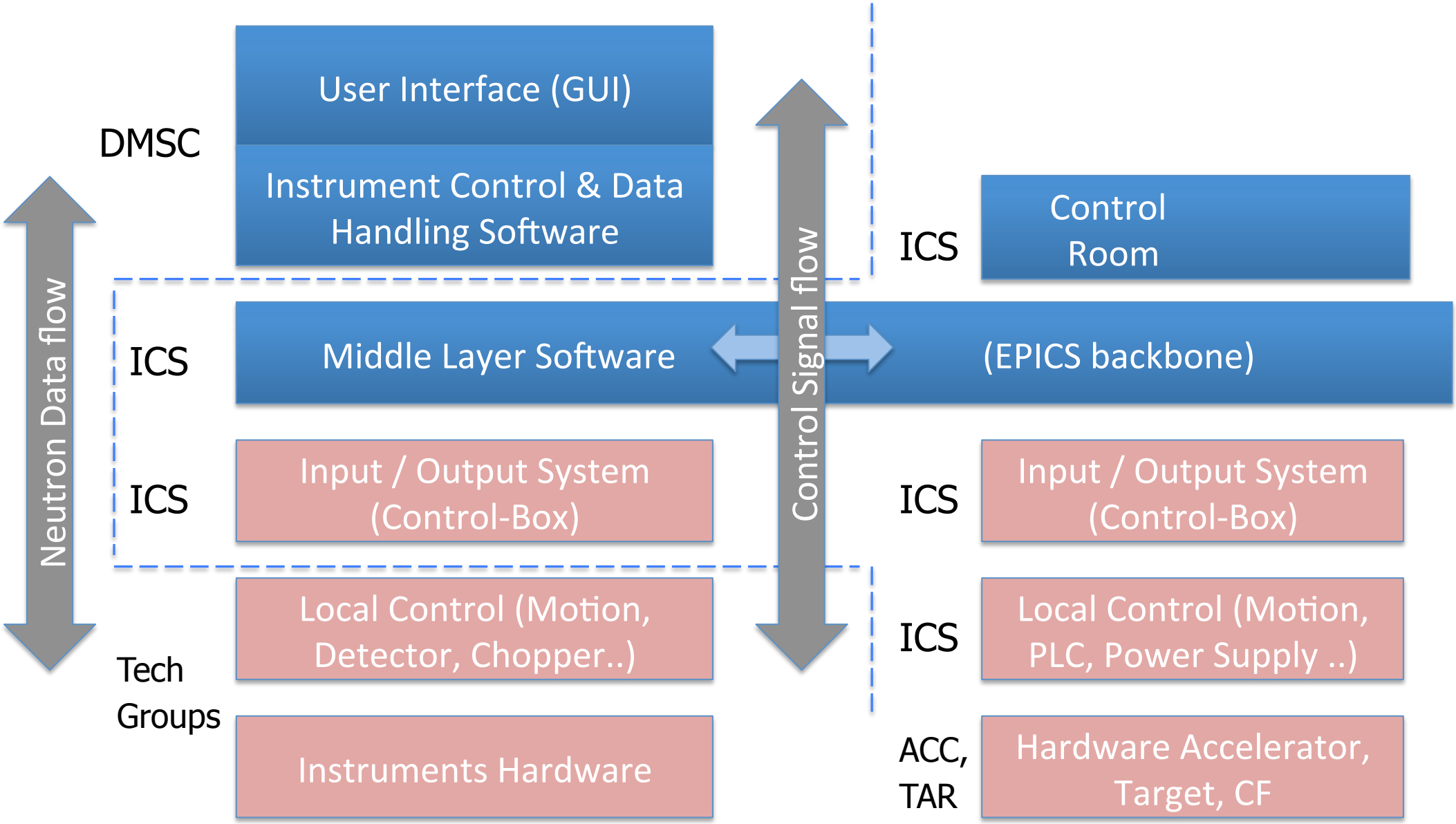
- ESS requirements for Control System
- Modular Instrument Control Concept
- Interfaces NSS - ICS
- ICS Standards (EPICS, Control Box, Timing)
- MCA Standards (Components, Control Unit)
- General Electrical Standards
- General Control Standards
- In-kind contributions
- Motion Control Group

Requirements for Hardware Concept



- Technical: Need to be compatible with the EPICS and Timing infrastructure
- Technical: Large instruments = Need to separate (ESS grounding concept)
- Organisational: in-kind = Need for modularity and clear interface definitions
- Operational: Complex instruments = Need for advanced diagnostics tools

ESS Control System Layers



Power Distribution and Zoning - Overview

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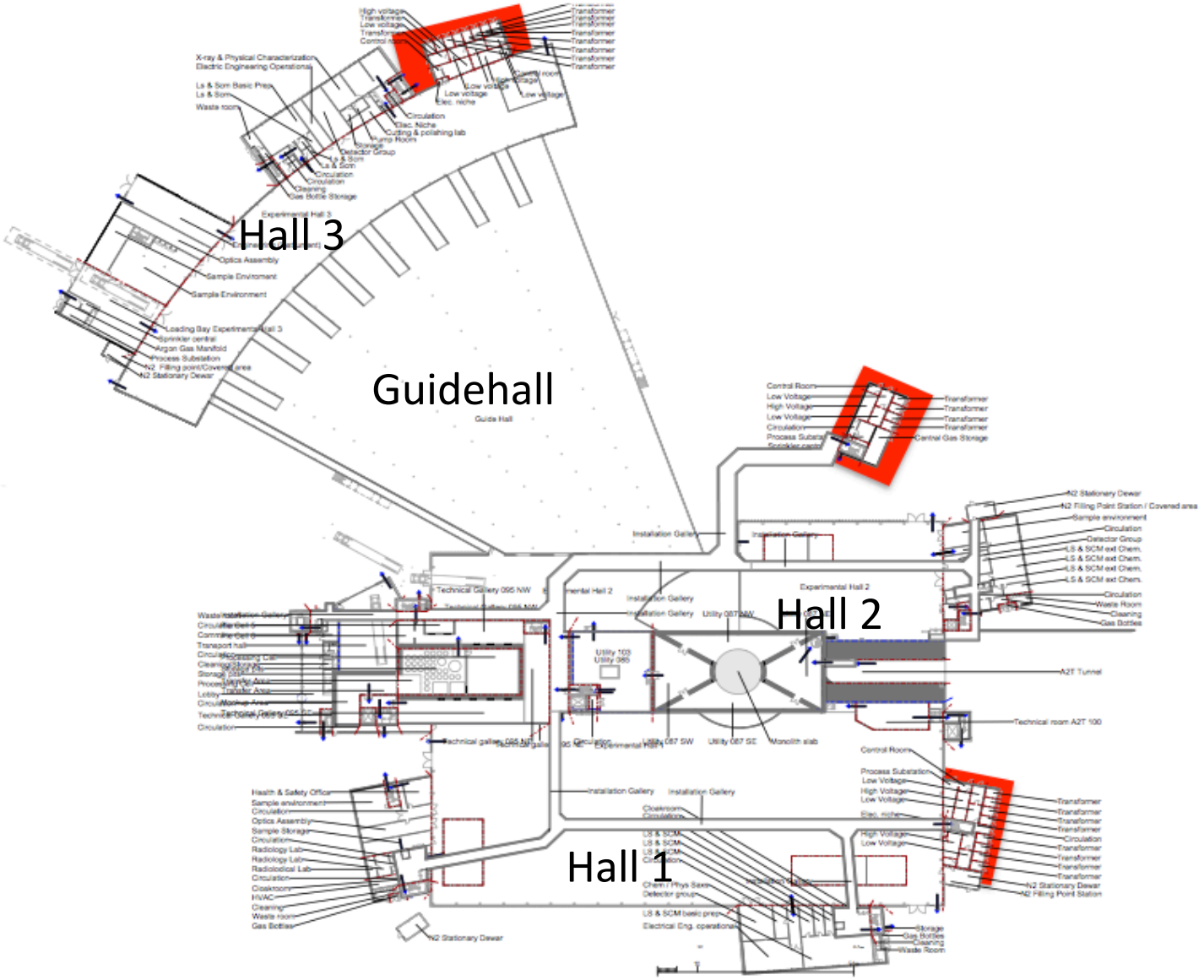

Power Distribution and Zoning - Overview

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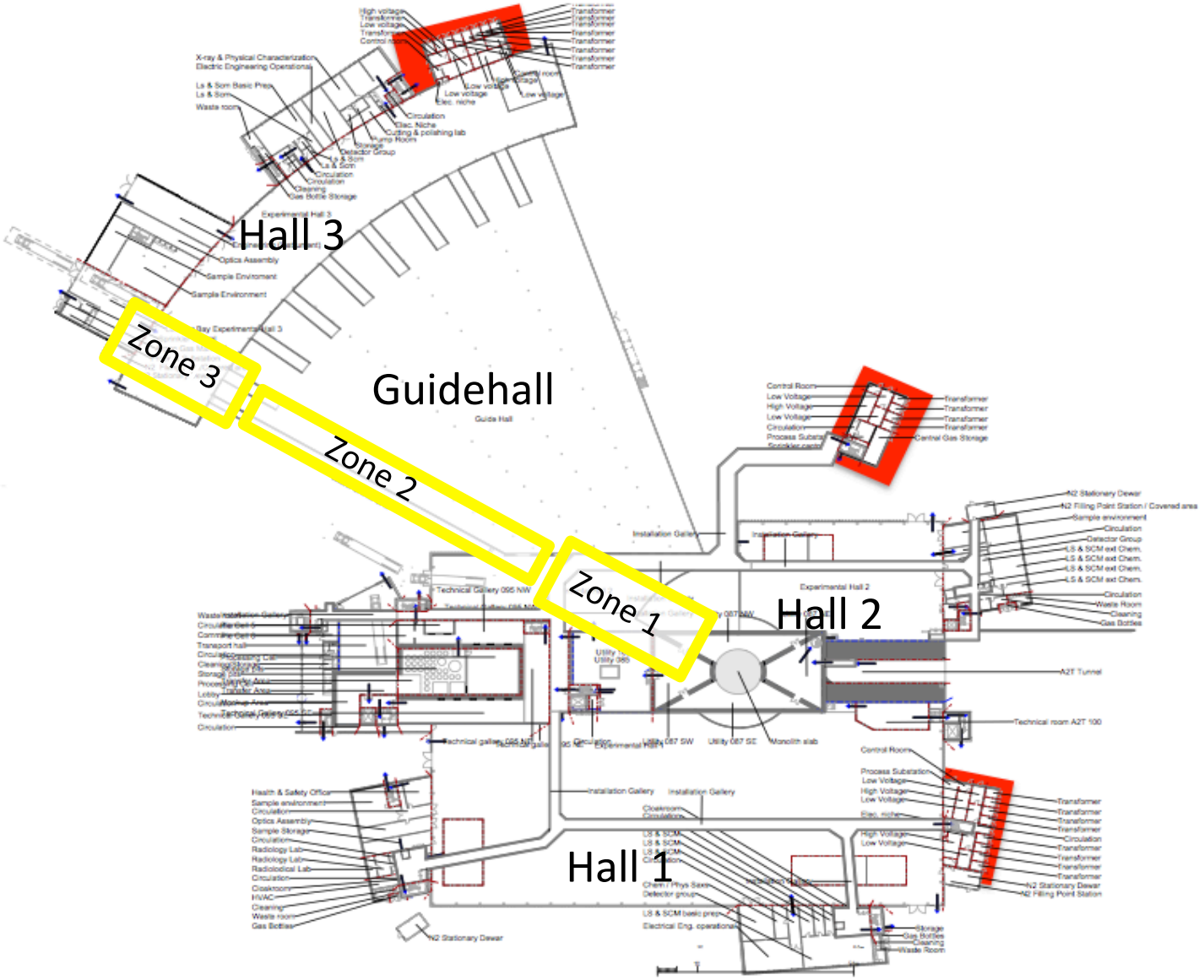
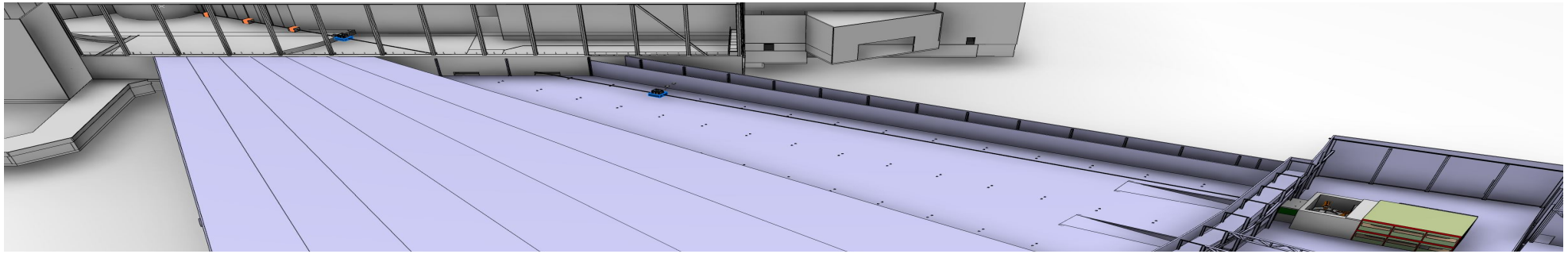


Organisational Challenges

- 17 European partner countries
- Nearly 100 % Neutron Instrumentation is in-kind
- Ranges from whole instruments to single modules
- Strong standardisation necessary (hardware list)

  + good definition of functionality and interfaces
- Support of partners in testing their modules
- Connecting partners to ESS infrastructure

Modular Instrument Control Concept



160m

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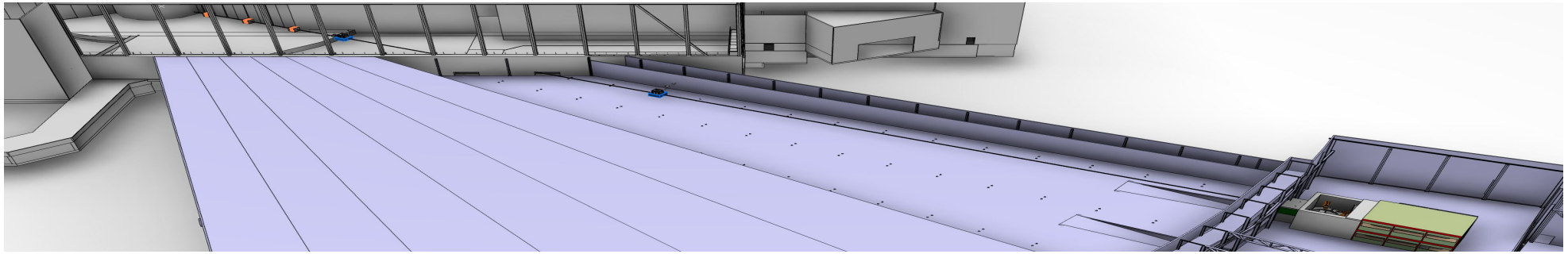
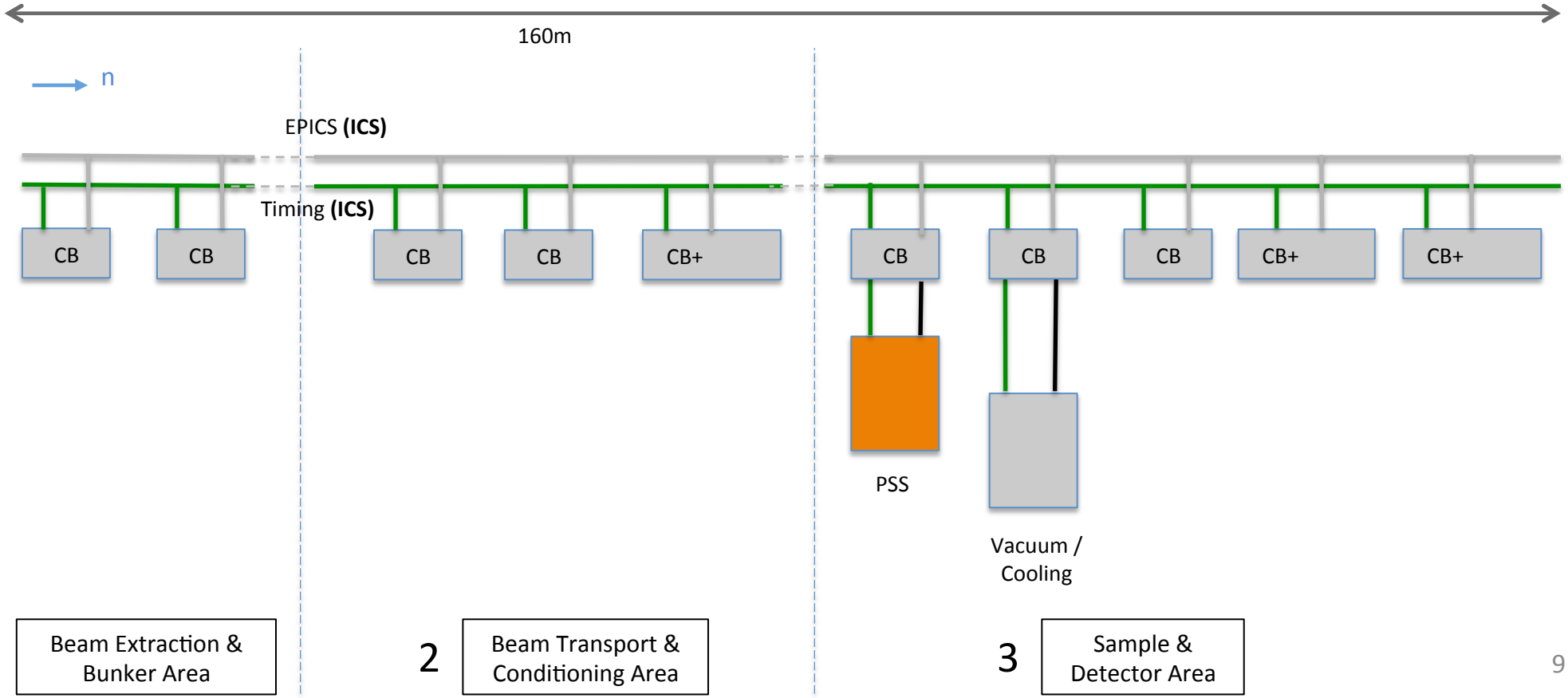
1 Beam Extraction & Bunker Area

2 Beam Transport & Conditioning Area

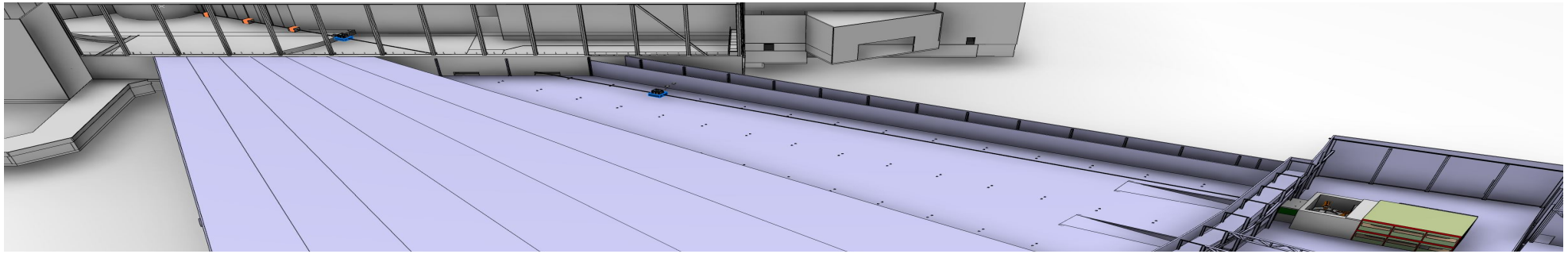
3 Sample & Detector Area

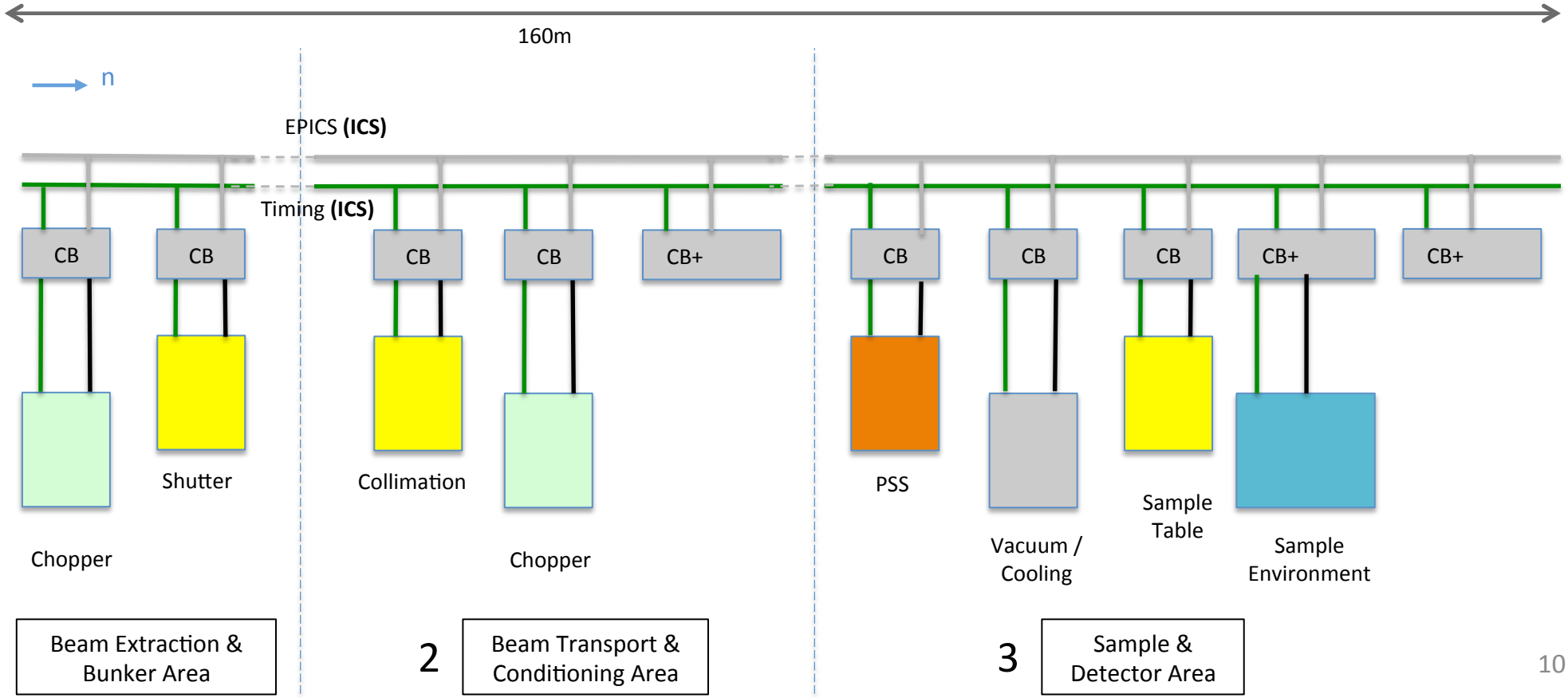
Modular Instrument Control Concept



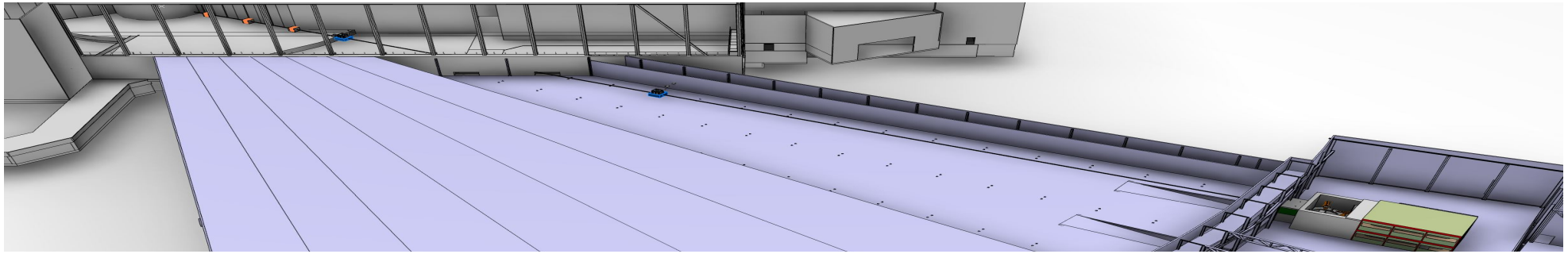


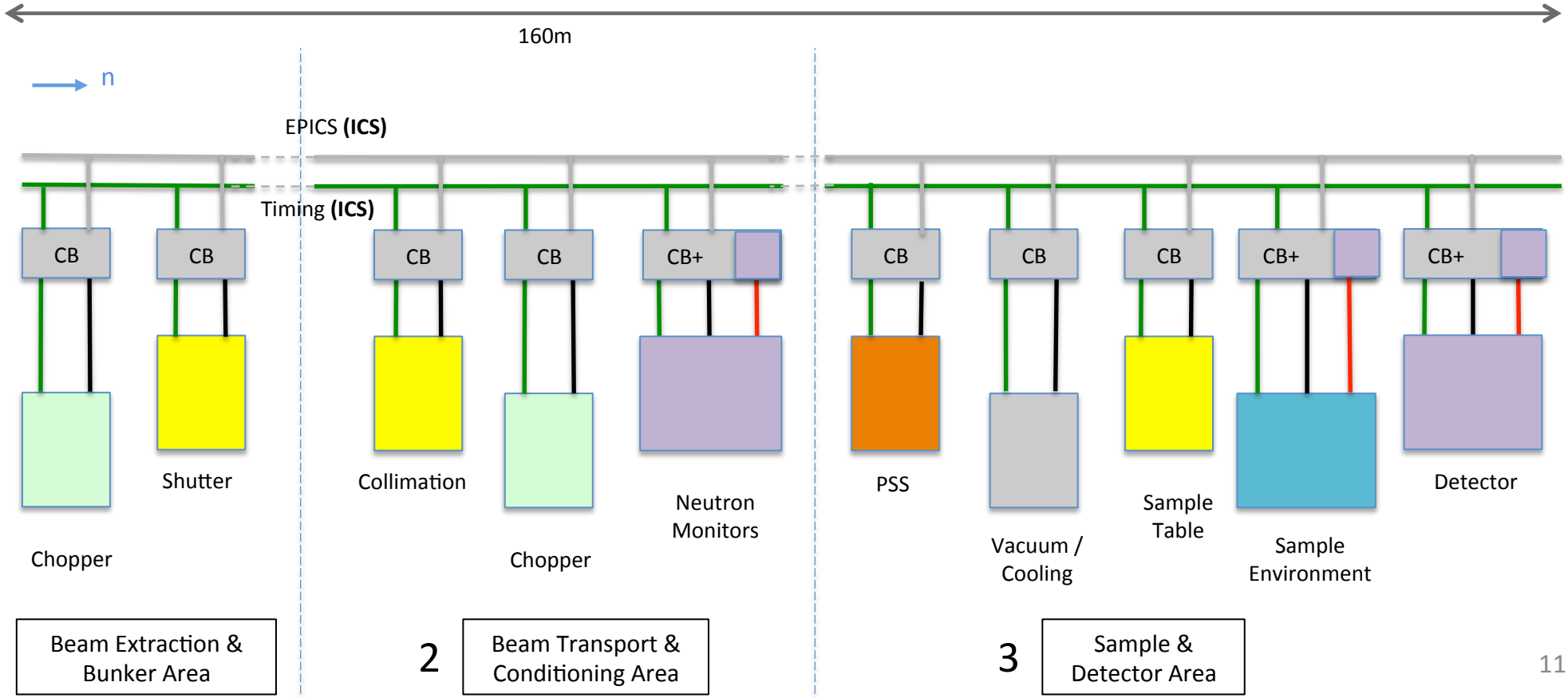
Modular Instrument Control Concept



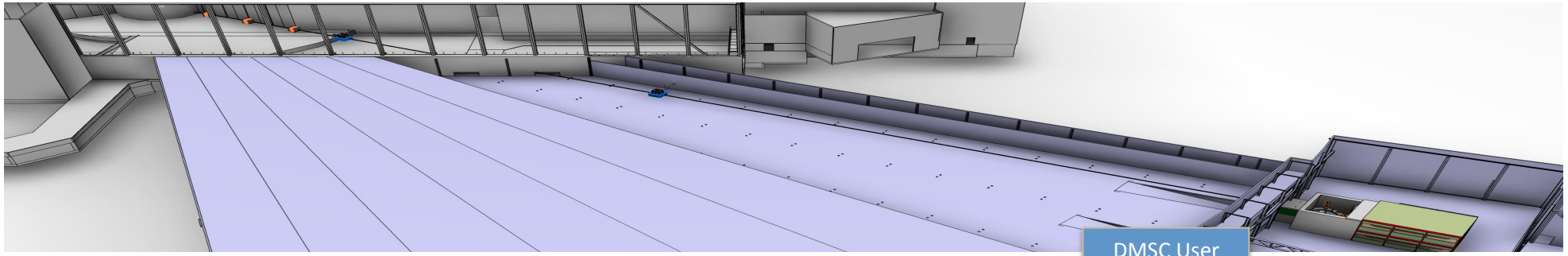


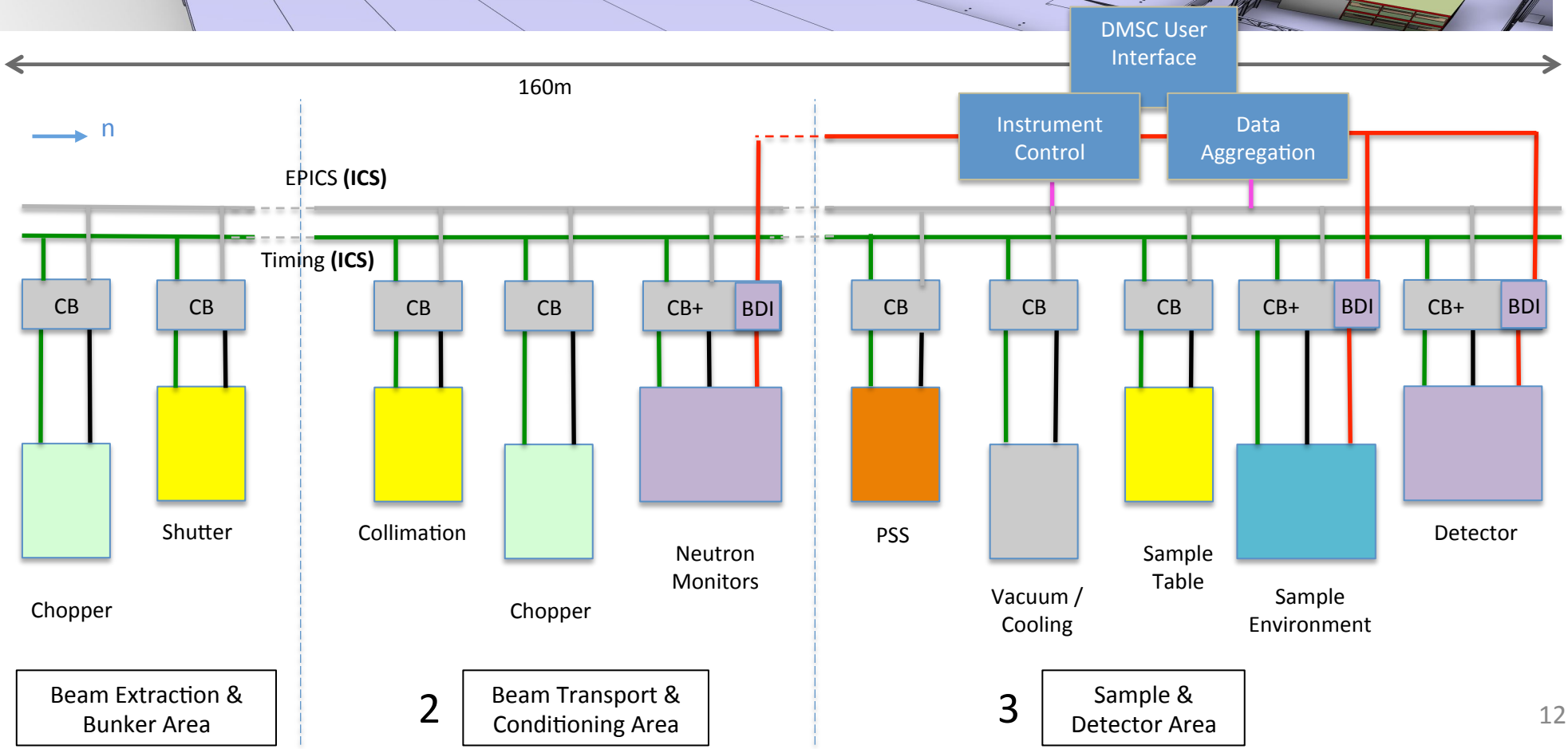
Modular Instrument Control Concept





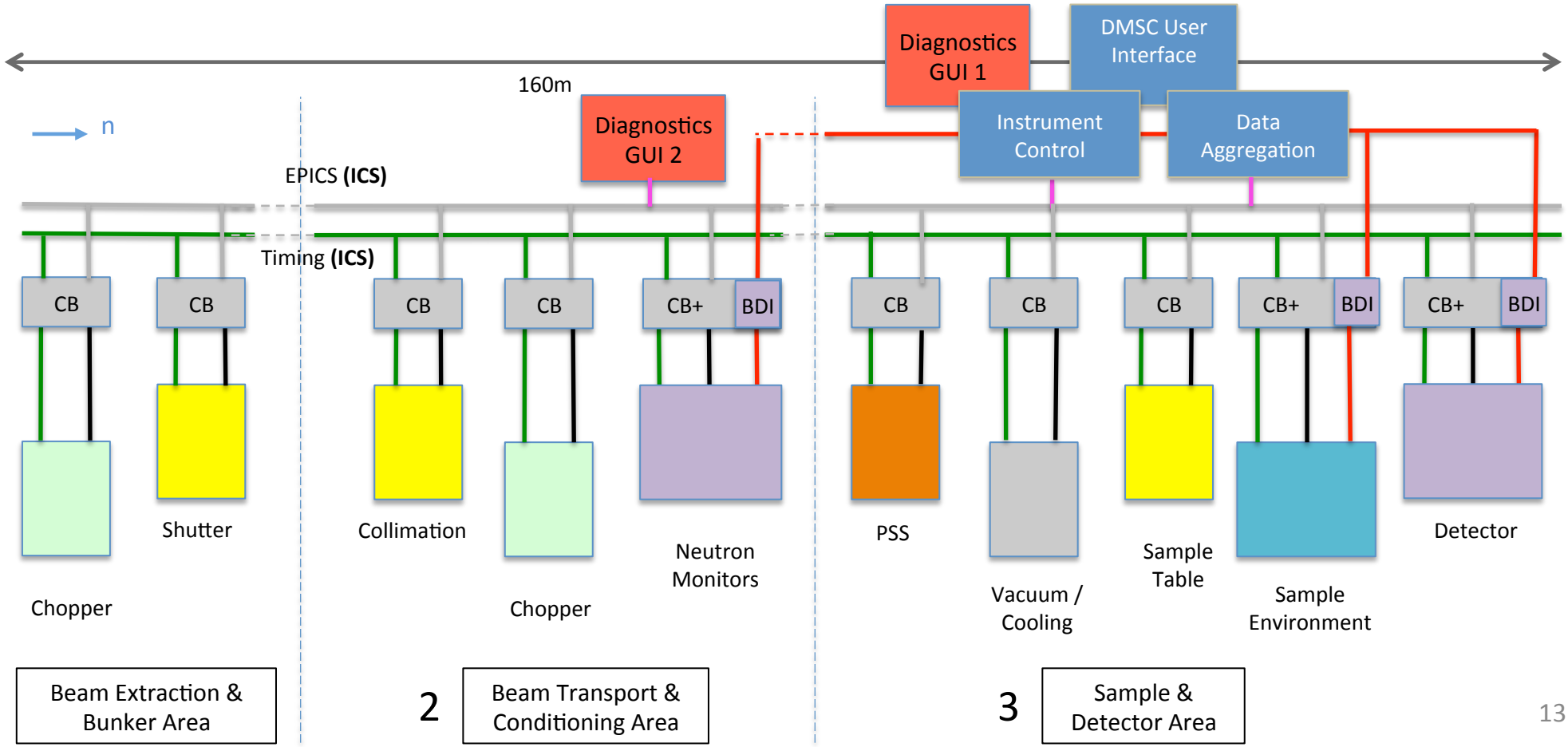
Modular Instrument Control Concept



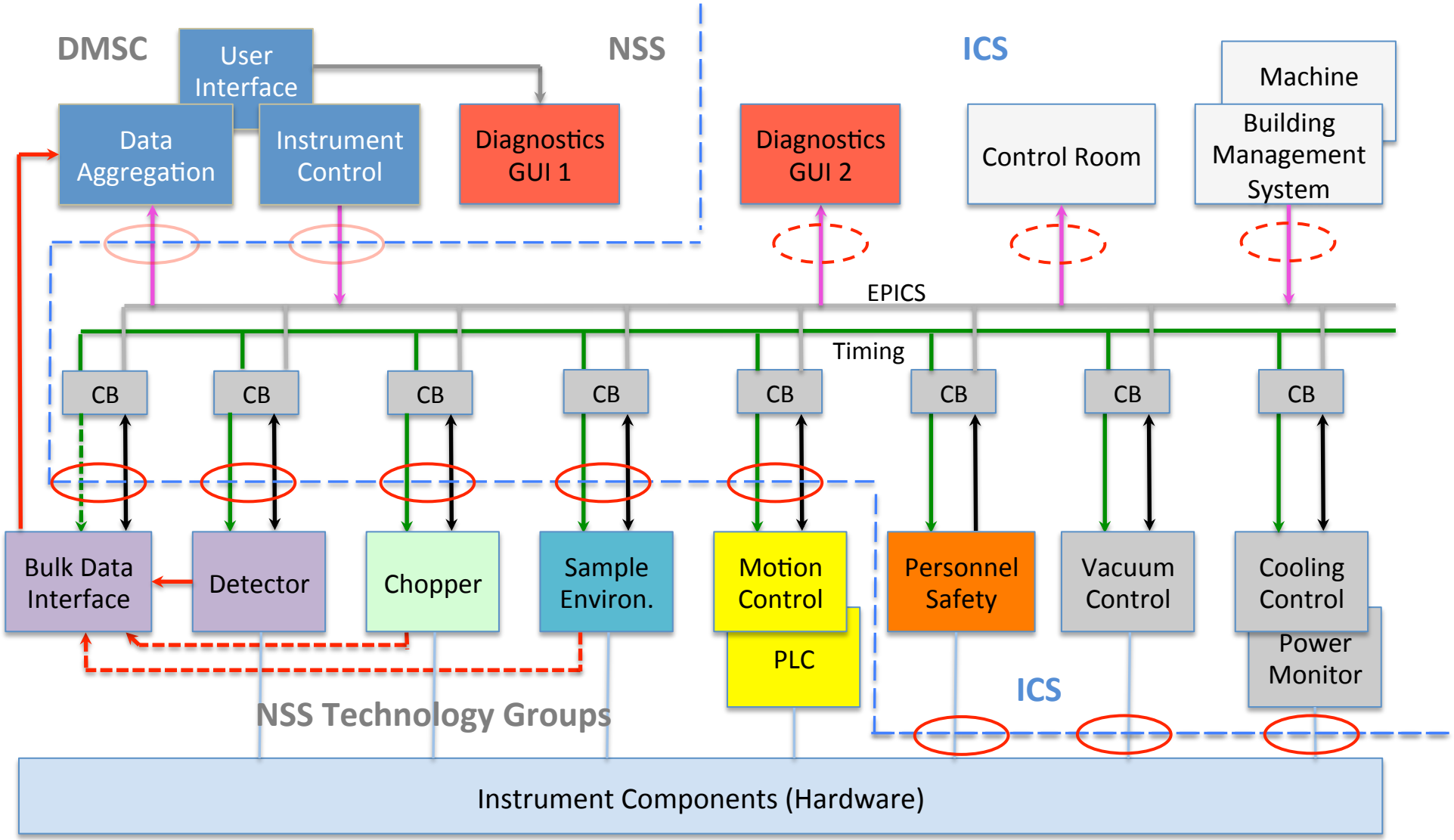


Modular Instrument Control Concept

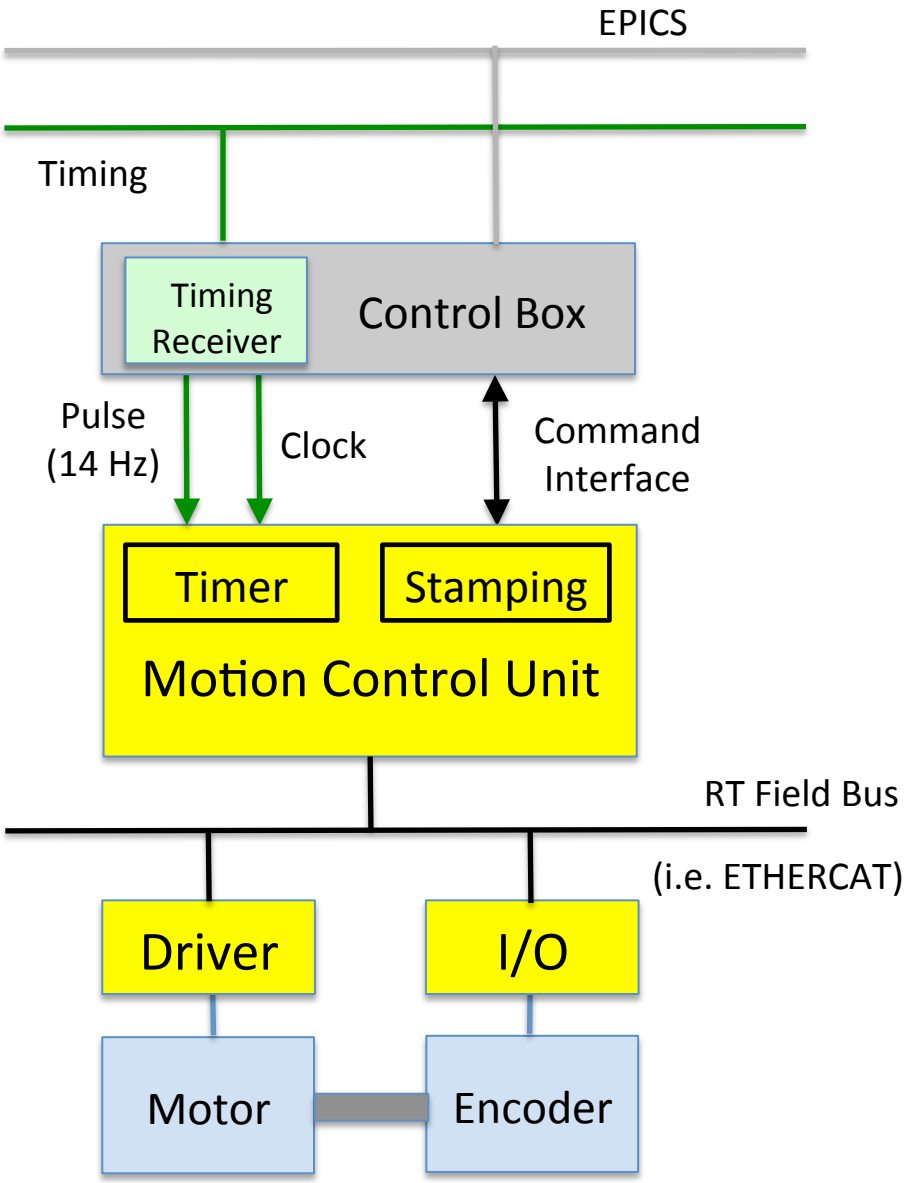
- What can (or has to) be done locally will be done locally
- Clear functionalities and interfaces for a single box
- Linked together by an already existing facility wide network infrastructure



Interfaces NSS - ICS



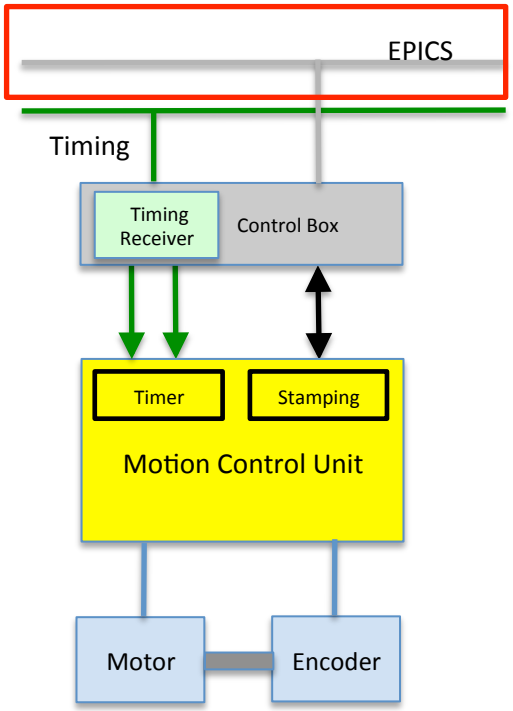
Motion Control Concept



- Transfer absolute timing information from Control Box to the local HW control unit:
- Synchronise a timer on the control unit
- Timestamp in the control unit direct readings of the sensor with minimal latencies
- Transfer the sensor readings through the Control Box into EPICS
- Synchronously vs. asynchronously
- Local distribution of control unit functionalities with real time field busses

ICS Standard: EPICS

- Provides connectivity over the whole ESS facility
- Implementation: One sub-net for each instrument
- Gateways to DMSC
- Hardware connection through Control Boxes
- Functionality not yet fully defined
- Minimum:
  - Data and command transfer
- Possible:
  - Logging / Archiving
  - Parameter / version storage
  - GUI



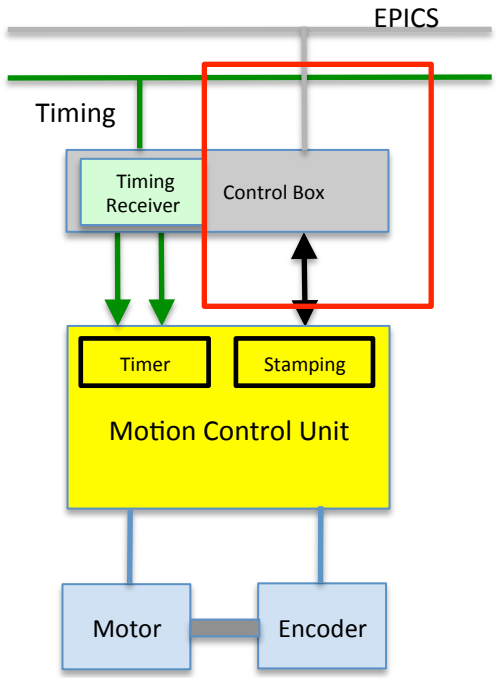
Responsibilities

Technology: ICS

Integration: ICS

ICS Standard: Control Box

- Provides standardised connection to the EPICS network
- Hold and connects a timing receiver
- 3 possible hardware platforms
  - uTCA for Physics
  - Linux PC with PCIe timing receiver card
  - Embedded FPGA/uCPU solution
- Without timing card also soft IOC possible



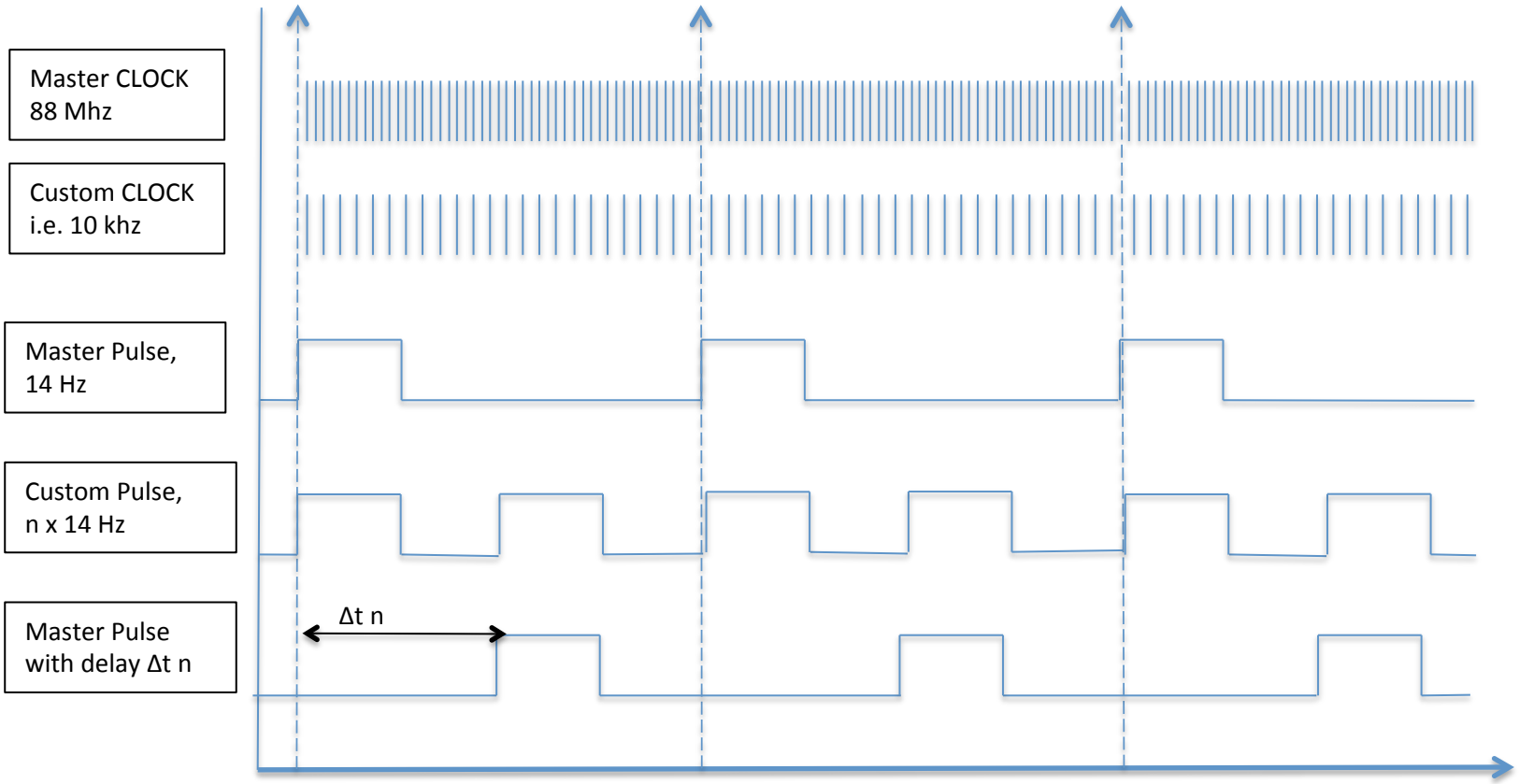
Responsibilities

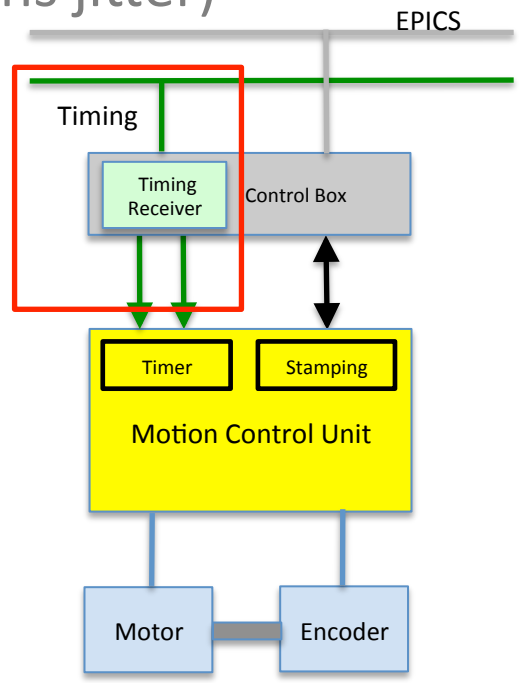
Technology: ICS

Integration: ICS

ICS Standard: Timing System

- Coupling of all timing to one single source – high precision (1ns jitter)
- Everywhere available in the facility
- (time-) compensated cable lengths





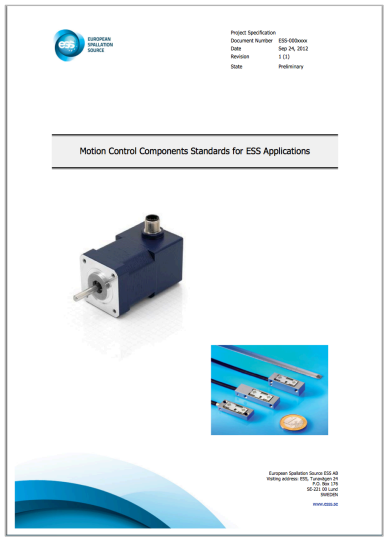
Responsibilities

Technology: ICS

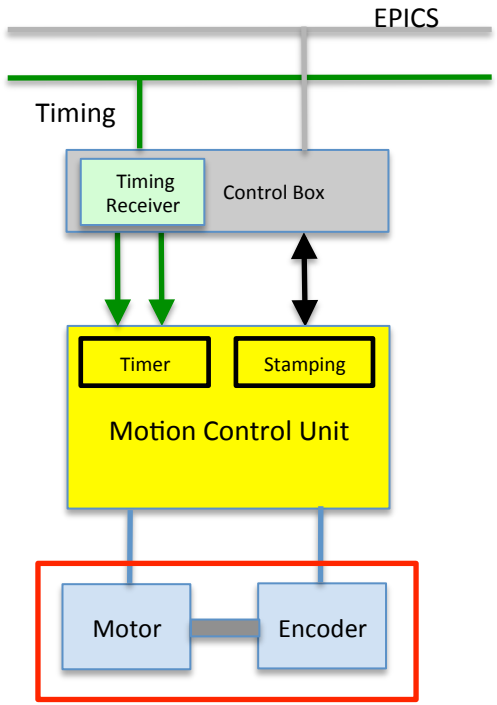
Integration: ICS

MCA Standard: Motion Control Components I

(Motor, Encoder, End Switches)



- Standard passes Harmonisation Committee this week
- Issued with CHESS-Nr. End June 2015
- Actual Range
  - 2Ph. Hybrid Stepper Motors, 24/48V, max. 5A_{rms}, 1/64 Micro stepping
  - Incremental Encoders, digital quadrature (A,B + R), RS-422 output
  - SSI absolute Encoder, max 32 Bit, 1 Mhz clock
  - Resolver, LVDT (not yet specified)
- Will be extended after final decision on Motion Control Unit



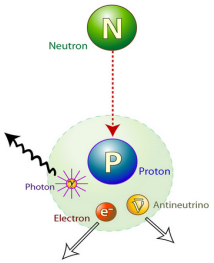
<u>Responsibilities</u>

Technology: MCA

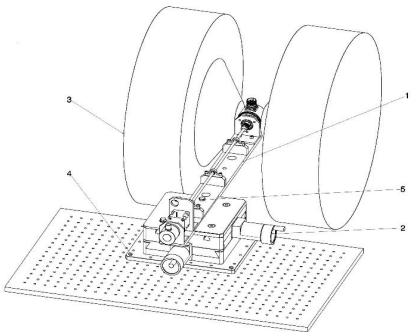
Integration: MCA

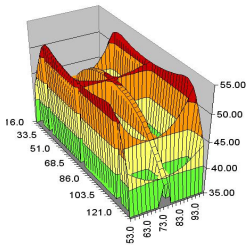
MCA Standard: Motion Control Components II
(Harsh Environment)

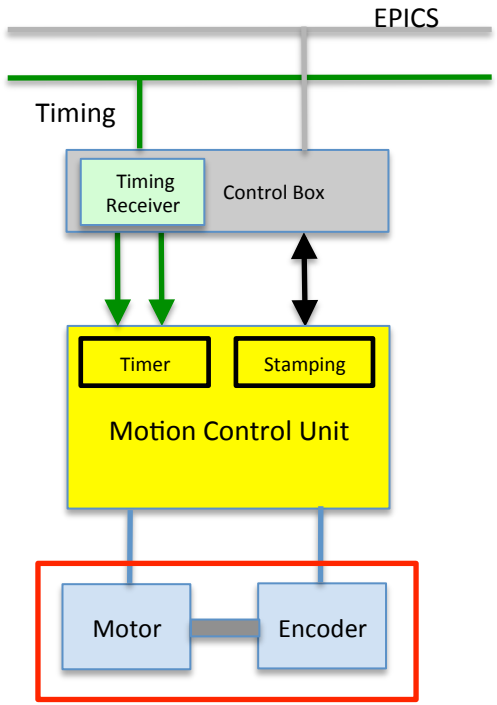
- Radiation Environment (Gamma, Neutrons)
  - Identify and evaluate motors and encoders
  - Integrate components into motion control unit
  - Test in radiation environment if necessary



- High Magnetic Field (DC)
  - Identify and evaluate motors and encoders
  - Integrate components into motion control unit
  - Single components test in magnetic field (1,5T)







Responsibilities

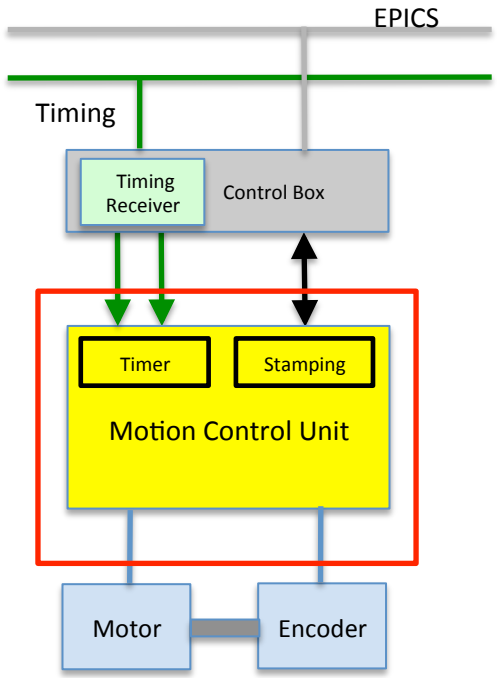
Technology: MCA

Integration: MCA

- Will be issued end 2016

MCA Standard: Generic Motion Control Unit

- Standardised Motion Control Unit for most of the ESS applications
- Scope of standardisation:
  - Control Hardware (controller, driver, I/O, power supply, control panel etc.)
  - Control Software (controller firmware, EPICS IOC)
  - Cables, connectors, distribution boxes, field busses
  - Prototypes for different mechanical and electrical format factors (19”box, DIN-rail, 8-axes, 2-axes etc.)
  - Test environments (Control unit + EPICS)
  - Integration workflow
- Workshop 2nd half 2015, decision end 2015
- Deployment of fully tested system mid 2016



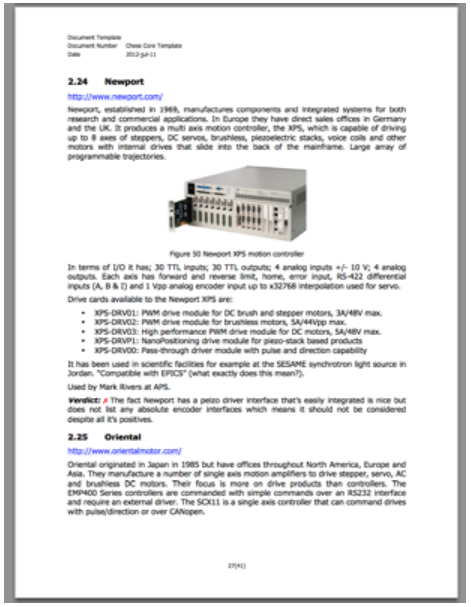
Responsibilities

Technology: MCA

Integration: MCA/ICS

Status Evaluation Process

- Market survey
- Started working group with Harmonisation Committee
- Collecting requirements from accelerator, target and instruments
- Compiling requirements catalog



Document Template
Document Number Chess Core Template
Date 2012-Jul-11

2.24 Newport

http://www.newport.com/

Newport, established in 1969, manufactures components and integrated systems for both research and commercial applications. In Europe they have direct sales offices in Germany and the UK. It produces a multi axis motion controller, the XPS, which is capable of driving up to 8 axes of steppers, DC servos, brushless, piezoelectric stacks, voice coils and other motors with internal drives that slide into the back of the mainframe. Large array of programmable trajectories.

Figure 50 Newport XPS motion controller

In terms of I/O it has; 30 TTL inputs; 30 TTL outputs; 4 analog inputs +/- 10 V; 4 analog outputs. Each axis has forward and reverse limit, home, error input, RS-422 differential inputs (A, B & I) and 1 Vpp analog encoder input up to x32768 interpolation used for servo.

Drive cards available to the Newport XPS are:

- XPS-DRV01: PWM drive module for DC brush and stepper motors, 3A/48V max.
- XPS-DRV02: PWM drive module for brushless motors, 5A/44Vpp max.
- XPS-DRV03: High performance PWM drive module for DC motors, 5A/48V max.
- XPS-DRVP1: NanoPositioning drive module for piezo-stack based products
- XPS-DRV00: Pass-through driver module with pulse and direction capability

It has been used in scientific facilities for example at the SESAME synchrotron light source in Jordan. "Compatible with EPICS" (what exactly does this mean?).

Used by Mark Rivers at APS.

Verdict: ✗ The fact Newport has a peizo driver interface that's easily integrated is nice but does not list any absolute encoder interfaces which means it should not be considered despite all it's positives.

2.25 Oriental

http://www.orientalmotor.com/

Oriental originated in Japan in 1985 but have offices throughout North America, Europe and Asia. They manufacture a number of single axis motion amplifiers to drive stepper, servo, AC and brushless DC motors. Their focus is more on drive products than controllers. The EMP400 Series controllers are commanded with simple commands over an RS232 interface and require an external driver. The SCX11 is a single axis controller that can command drives with pulse/direction or over CANopen.

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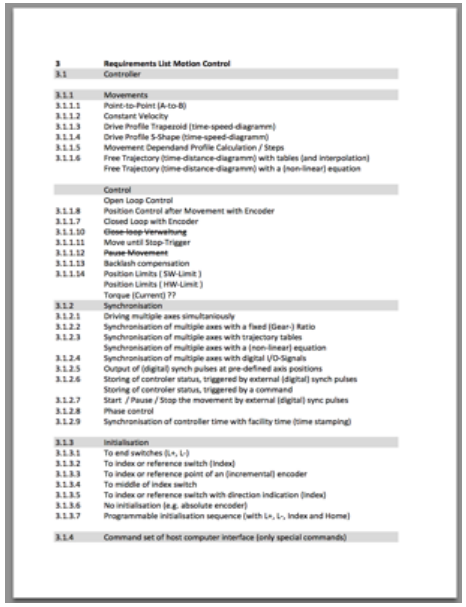
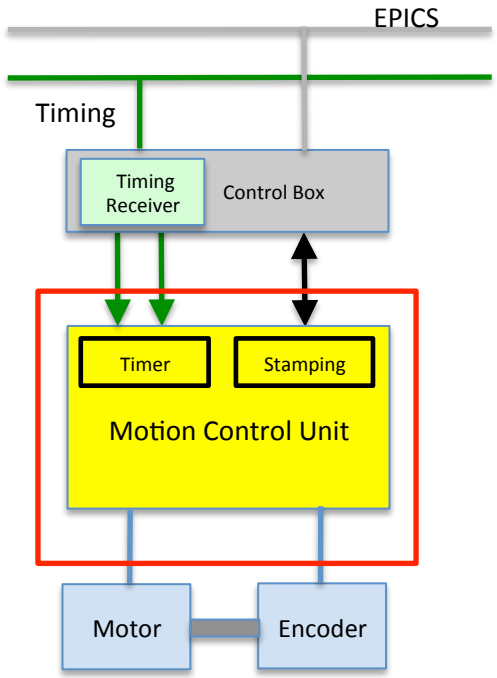


3	**Requirements List Motion Control**
3.1	Controller
3.1.1	Movements
3.1.1.1	Point-to-Point (A-to-B)
3.1.1.2	Constant Velocity
3.1.1.3	Drive Profile Trapezoid (time-speed-diagramm)
3.1.1.4	Drive Profile S-Shape (time-speed-diagramm)
3.1.1.5	Movement Dependand Profile Calculation / Steps
3.1.1.6	Free Trajectory (time-distance-diagramm) with tables (and interpolation)
	Free Trajectory (time-distance-diagramm) with a (non-linear) equation
	Control
	Open Loop Control
3.1.1.8	Position Control after Movement with Encoder
3.1.1.7	Closed Loop with Encoder
3.1.1.10	~~Close loop Verweilzug~~
3.1.1.11	Move until Stop-Trigger
3.1.1.12	~~Pause Movement~~
3.1.1.13	Backlash compensation
3.1.1.14	Position Limits (SW-Limit)
	Position Limits (HW-Limit)
	Torque (Current) ??
3.1.2	Synchronisation
3.1.2.1	Driving multiple axes simultaniously
3.1.2.2	Synchronisation of multiple axes with a fixed (Gear-) Ratio
3.1.2.3	Synchronisation of multiple axes with trajectory tables
	Synchronisation of multiple axes with a (non-linear) equation
3.1.2.4	Synchronisation of multiple axes with digital I/O-Signals
3.1.2.5	Output of (digital) synch pulses at pre-defined axis positions
3.1.2.6	Storing of controler status, triggered by external (digital) synch pulses
	Storing of controler status, triggered by a command
3.1.2.7	Start / Pause / Stop the movement by external (digital) sync pulses
3.1.2.8	Phase control
3.1.2.9	Synchronisation of controller time with facility time (time stamping)
3.1.3	Initialisation
3.1.3.1	To end switches (L+, L-)
3.1.3.2	To index or reference switch (Index)
3.1.3.3	To index or reference point of an (incremental) encoder
3.1.3.4	To middle of index switch
3.1.3.5	To index or reference switch with direction indication (Index)
3.1.3.6	No initialisation (e.g. absolute encoder)
3.1.3.7	Programmable initialisation sequence (with L+, L-, Index and Home)
3.1.4	Command set of host computer interface (only special commands)



Responsibilities

Technology: MCA

Integration: MCA/ICS

Top Requirements

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- Multi-axes synchronisation
- Free configurable trajectories
- Decentralisation through field bus with real-time capabilities
- Modular and scalable (in terms of performance and price)
- Diagnostics (preemptive maintenance)

- Components for high radiation environment
- Components for high magnetic fields
- Stepper motors, DC, DC brushless, piezo
- Encoder inc. quad., abs. SSI, resolver, (analog), (BiSS-C)

Preliminary Standard: Delta Tau Power Brick

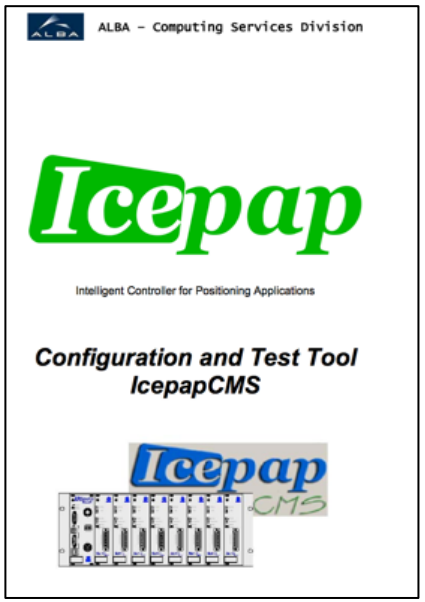
- Well introduced at Diamond, NSLS-II and Australian Synchrotron
- Covers actual requirements for test stands, prototypes
- Will be replaced by final standard start 2016 onwards

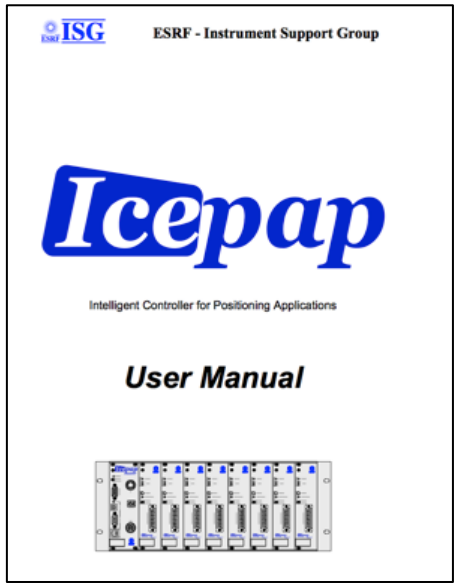
Evaluation 1: Delta Tau Power Brick

- Very good hardware performance (potential)
- Poor soft-/ firmware and IDE
- System is not yet mature!

Evaluation 2: IcePAP

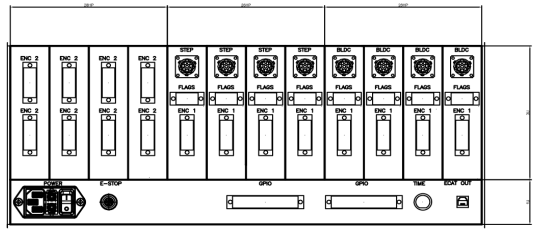
- Custom Motion Control system developed by ESRF
- More than 3000 axes installed at ESRF, ALBA, MaxIV
- ESRF will deliver test unit for evaluation purposes Q1 2015

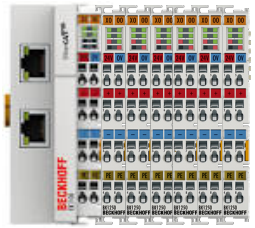


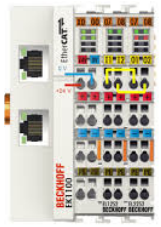


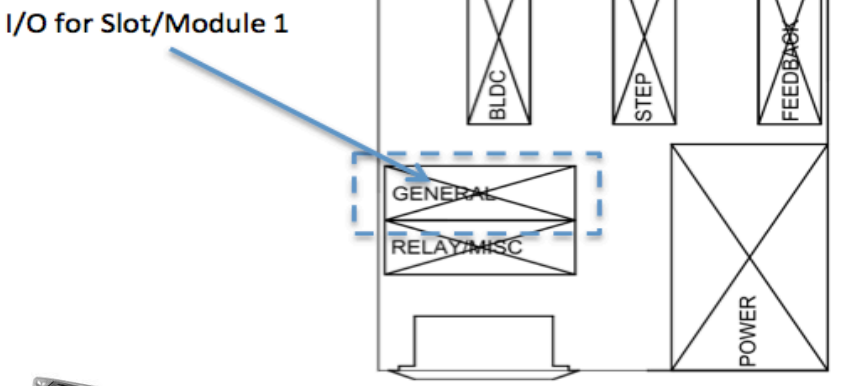
Evaluation 3: Beckhoff

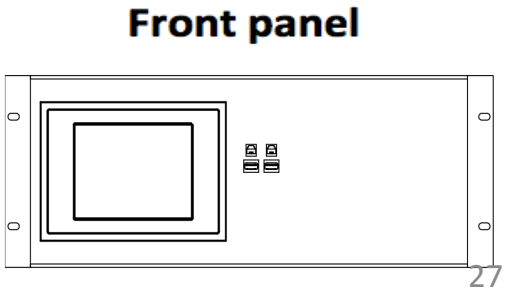
- Flexible and user friendly system
- Real-time bus for timing and synchronisation
- High modularity, further evaluation will follow
- 3rd party Ethercat modules available











Evaluation 4: Siemens

- Flexible, reliable and proven system
- Integrated into Siemens PLC system
- Limited in control of stepper motors (3rd party driver necessary)
- Evaluation is ongoing

1STEP

1STEP-Drive

- Phytron

FM357

-4 axes controller

FM353

-DIN 66025

First application: Chopper Control Demo

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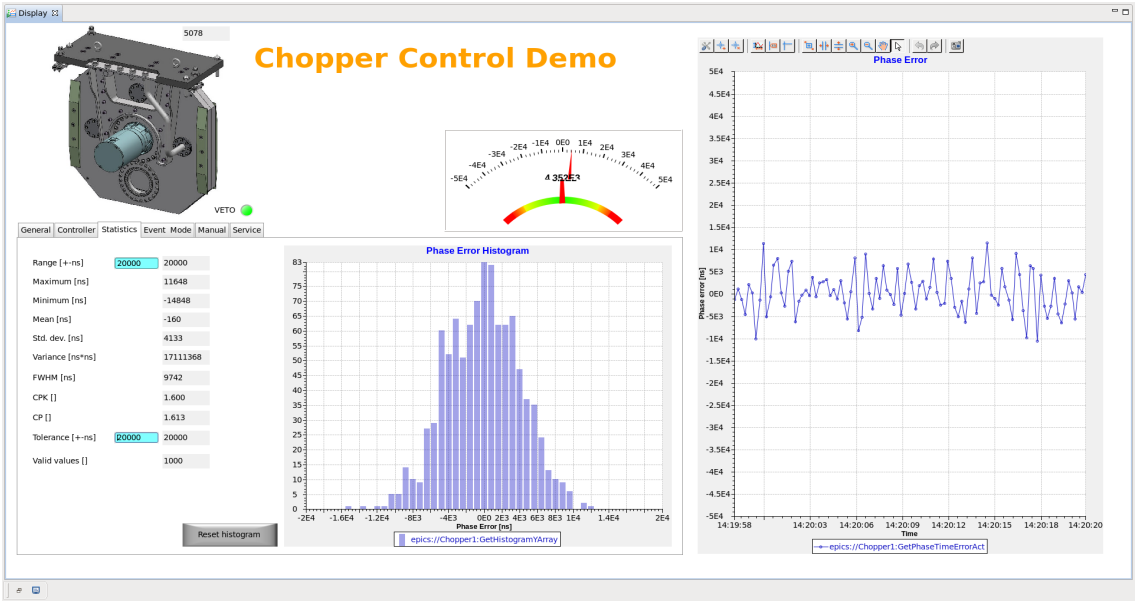
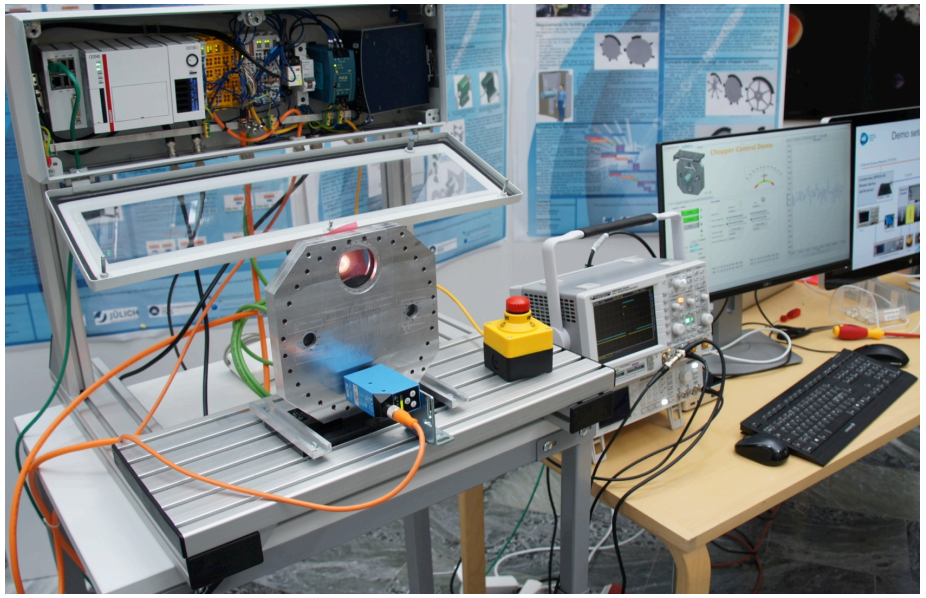
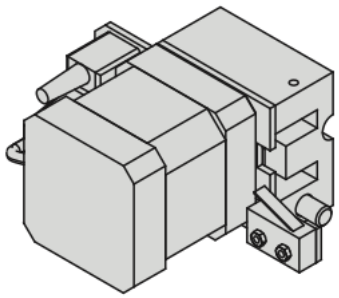
- Development of a motion control for a ¼ scale chopper model and integration in EPICS; interfaces and functionality according to ESS standards
- Demonstration model at IKON8+9 and DENIM 2014 conference in Munich, Germany
- Basis for chopper setup at beam line at IFE Norway (detector tests)



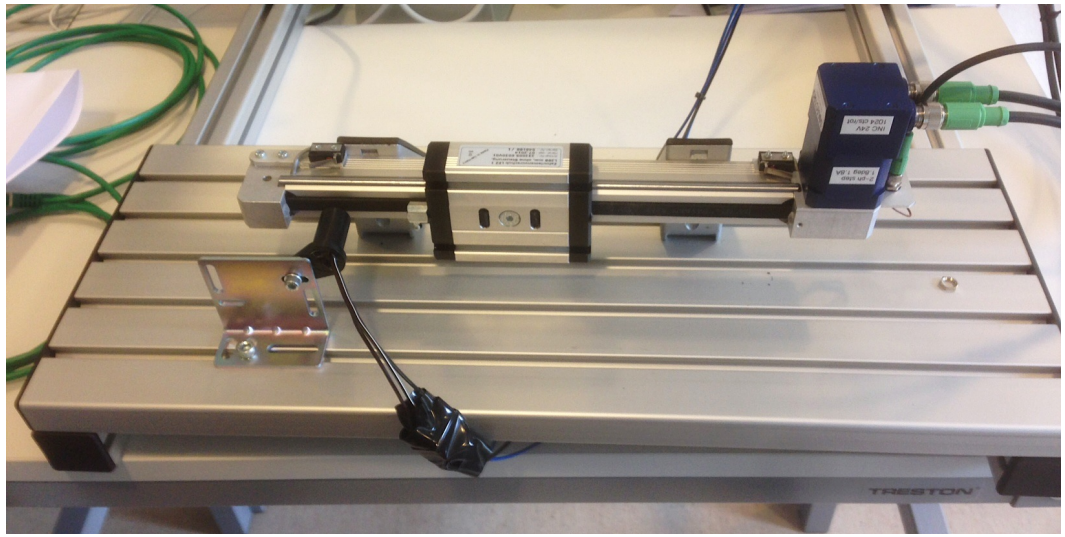


Second application: Linear test bench

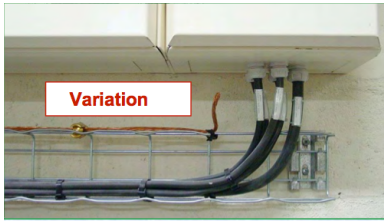
- Linear test bench to control all components of a positioning axis
- Basic mechanical setup for all evaluated motion control units
- Basis for motion control through the motor record of the EPICS IOC
- Further performance tests of single components will follow

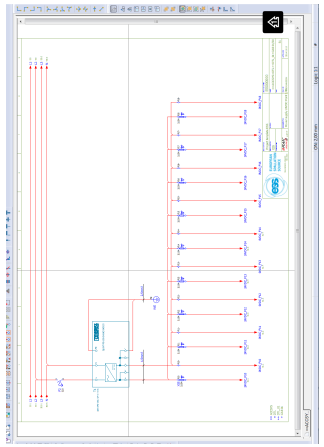


- ISEL LEZ 1
- stepper motor Nanotec AS4118L1804
- incremental encoder Nanotec 500 Inc
- end switches (mechanical, n.c.)

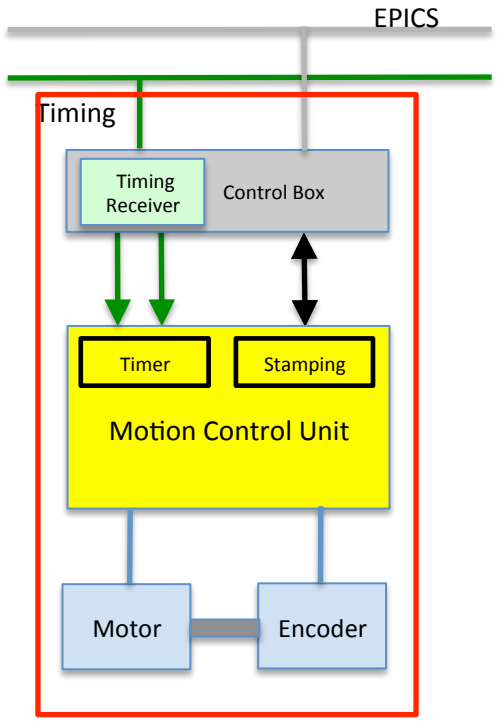


General Electrical Standards





- Power Distribution
  - Following CF standard
- Electrical Installation
  - Cable routing, cable naming etc.
  - Following ESS standard, adapted to NSS needs
- ECAD
- Racks, Electrical Cabinets
  - 19”racks (cooling, UPS, EMC, power)
  - Electrical cabinets
- EMC, Earthing, Grounding
  - Scott’s talk tomorrow

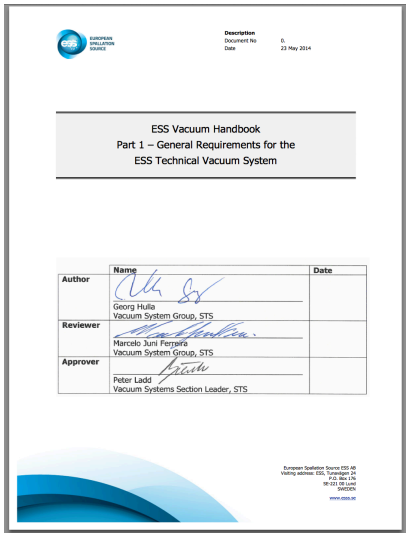


Responsibilities

Technology: MCA/E&IS

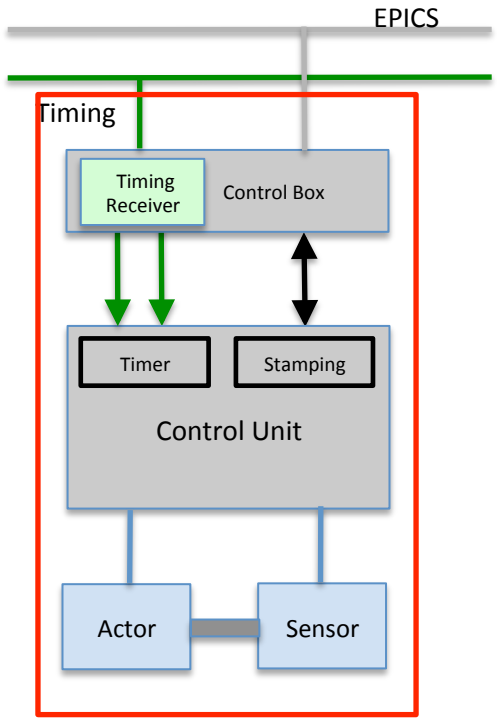
Integration: NSS

General control standards


ESS Vacuum Handbook
Part 1 – General Requirements for the
ESS Technical Vacuum System

	Name	Date
Author	Georg Hula Vacuum System Group, STS	
Reviewer	Marcelo Juni Ferreira Vacuum System Group, STS	
Approver	Peter Ladd Vacuum Systems Section Leader, STS	

- Vacuum
  - Vaccum handbook by Vacuum Group
  - PLC control by ICS
- Cooling
  - PLC control by ICS
- Power Monitoring
  - Monitoring by CF
  - Integration into EPICS by ICS
- Personnel Safety Systems
  - Done by ICS

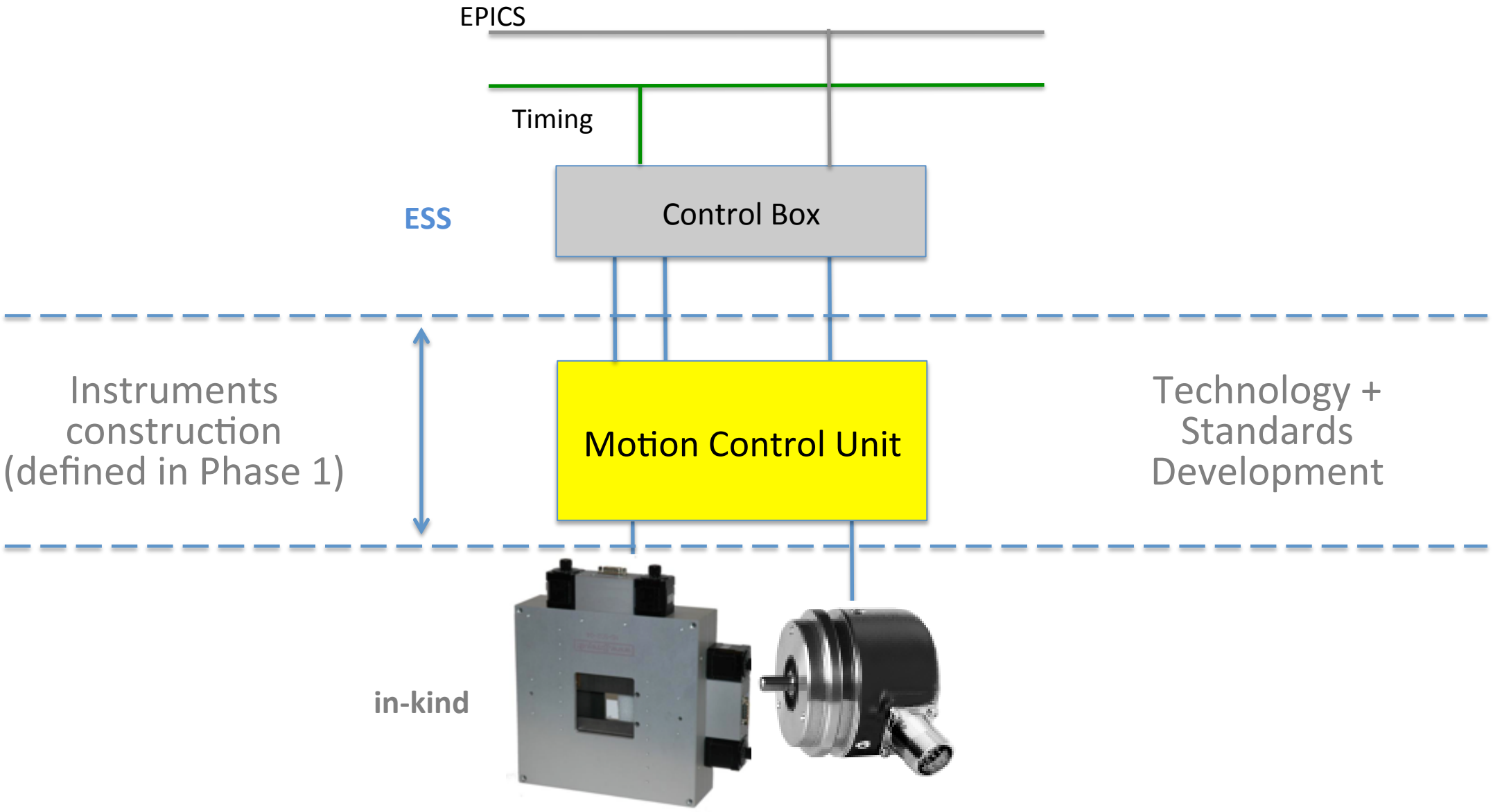


Responsibilities

Technology: ICS

Integration: ICS

Flexibility in providing in-kind



Motion Control & Automation Group

EUROPEAN SPALLATION SOURCE

- Coordination and Integration (“horizontal” overview)
- Leads standards development
- Links the engineering groups of the in-kind partners for exchange of experience and information
- Supports in-kind partner in their instruments projects to the desired level (buffer)
- Provides hard- and software and knowledge to the in-kind partners to test instruments modules
- Key contact partner for the central technical groups at ESS (ICS, vacuum group, design office etc.)

Motion Control & Automation Group

- **Key Contact for Instruments Projects**

1.	LOKI	Anders Sandström
2.	NMX	Paul Barron
3.	ODIN	David Fitzgerald
4.	BEER	Paul Barron
5.	DREAM	Anders Sandström
6.	SKADI	Anders Sandström
7.	C-SPEC	David Fitzgerald
8.	ESTIA	David Fitzgerald

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Thanks

EUROPEAN SPALLATION SOURCE

Any questions?

EUROPEAN SPALLATION SOURCE

ESS Instrument Control

- Summary Use cases-

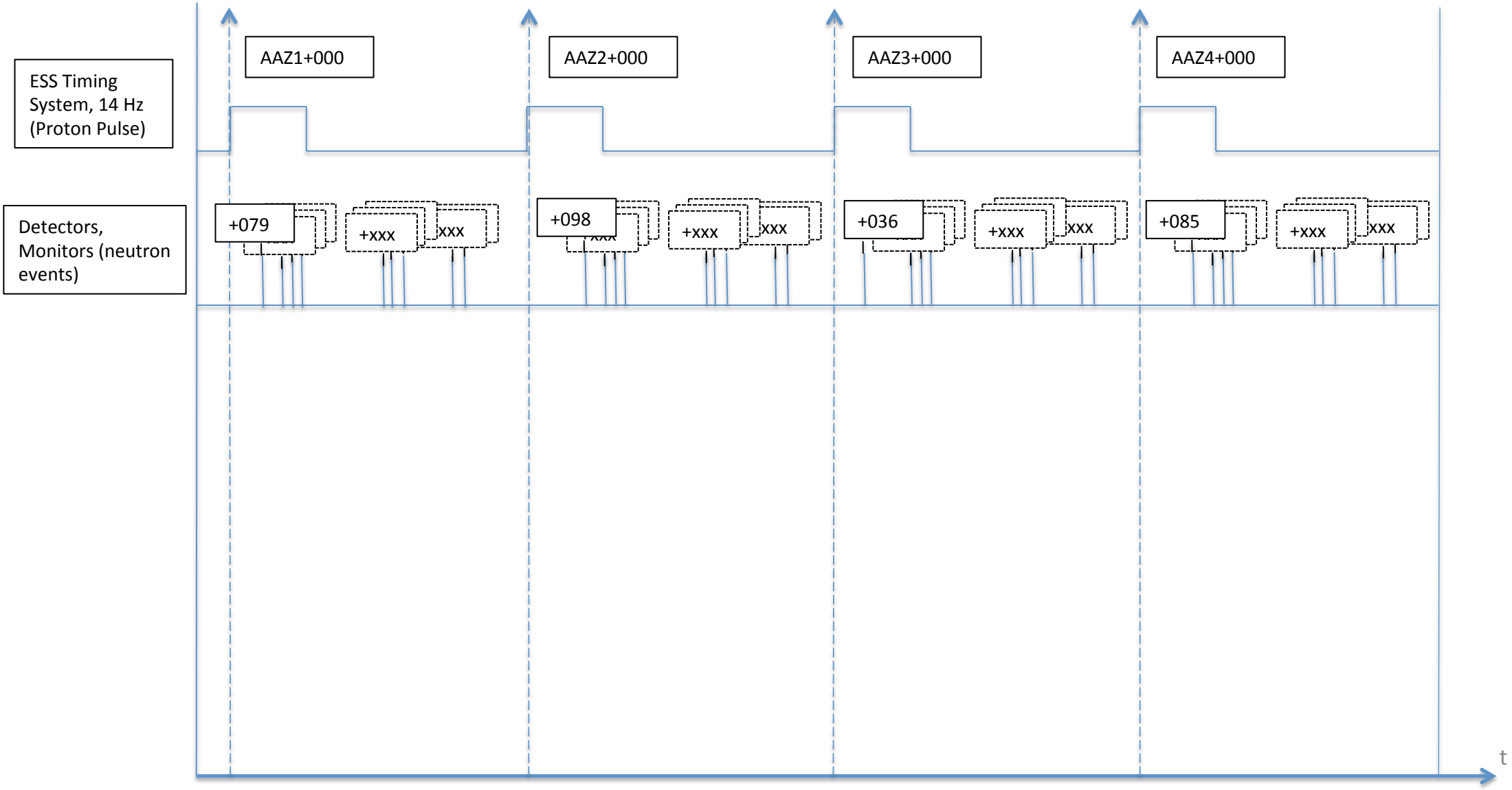
Thomas Gahl

Group Leader Motion Control & Automation

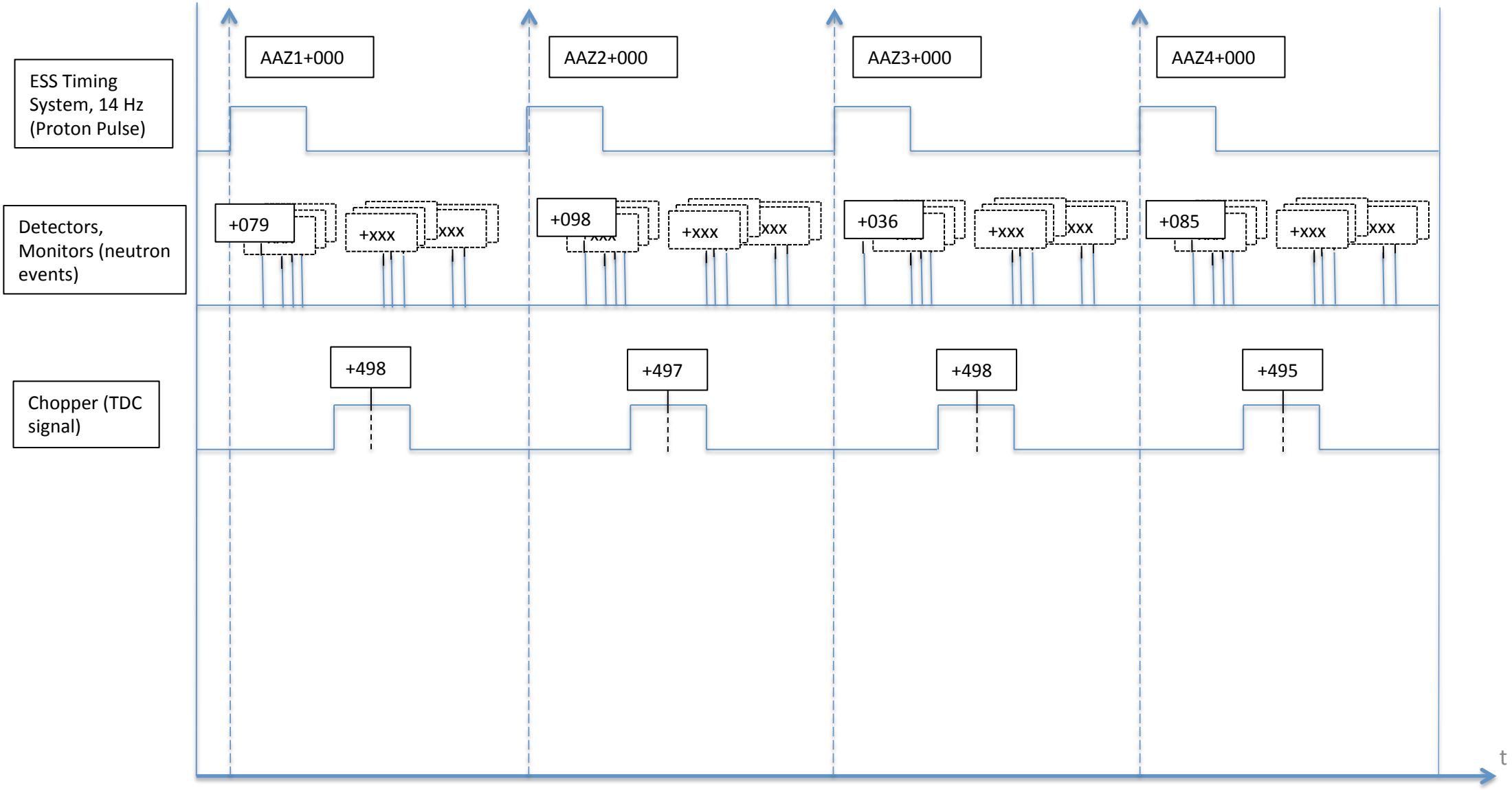
www.europeanspallationsource.se

September 16, 2014

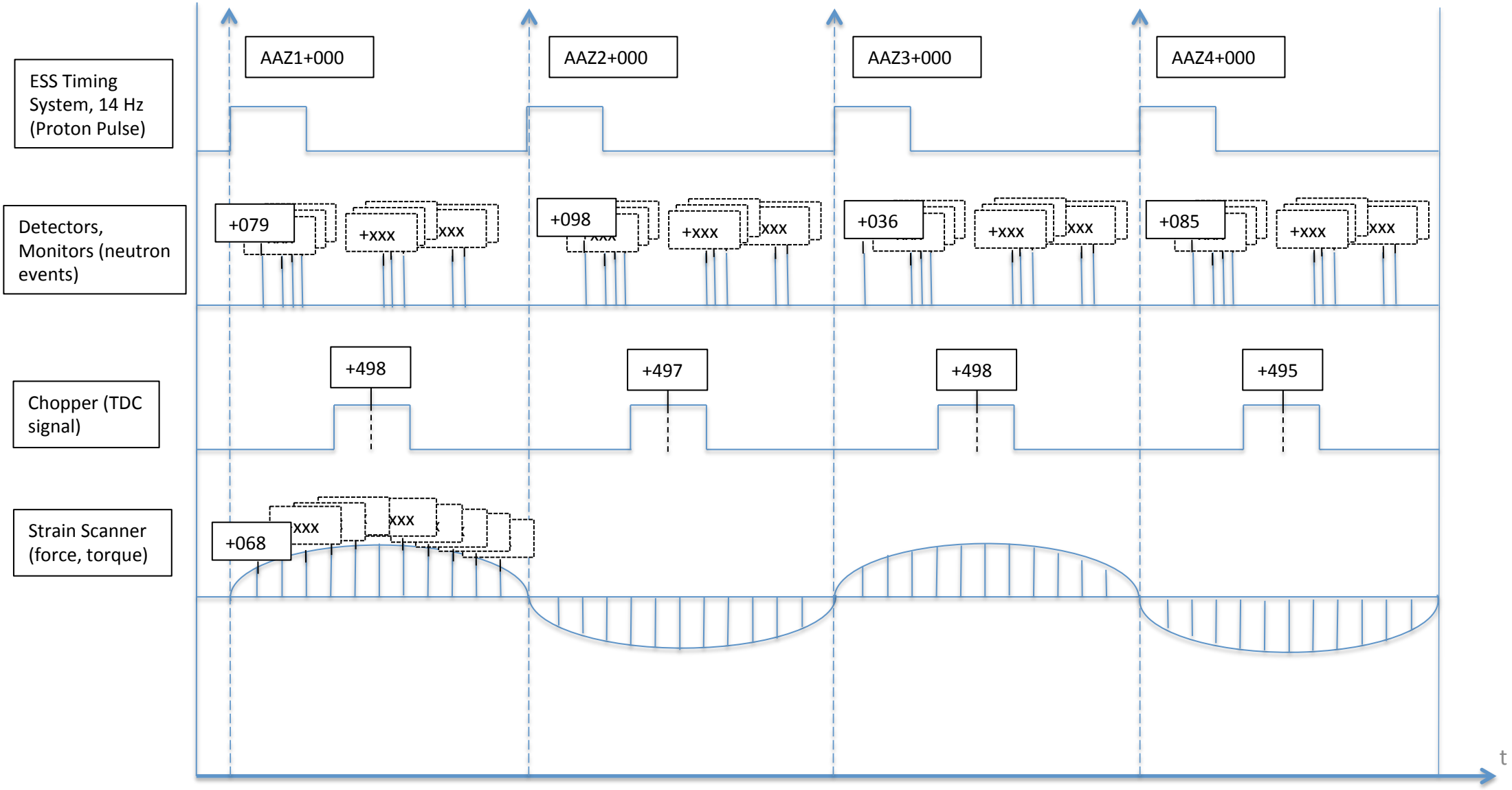
Time Stamping (Event Mode)



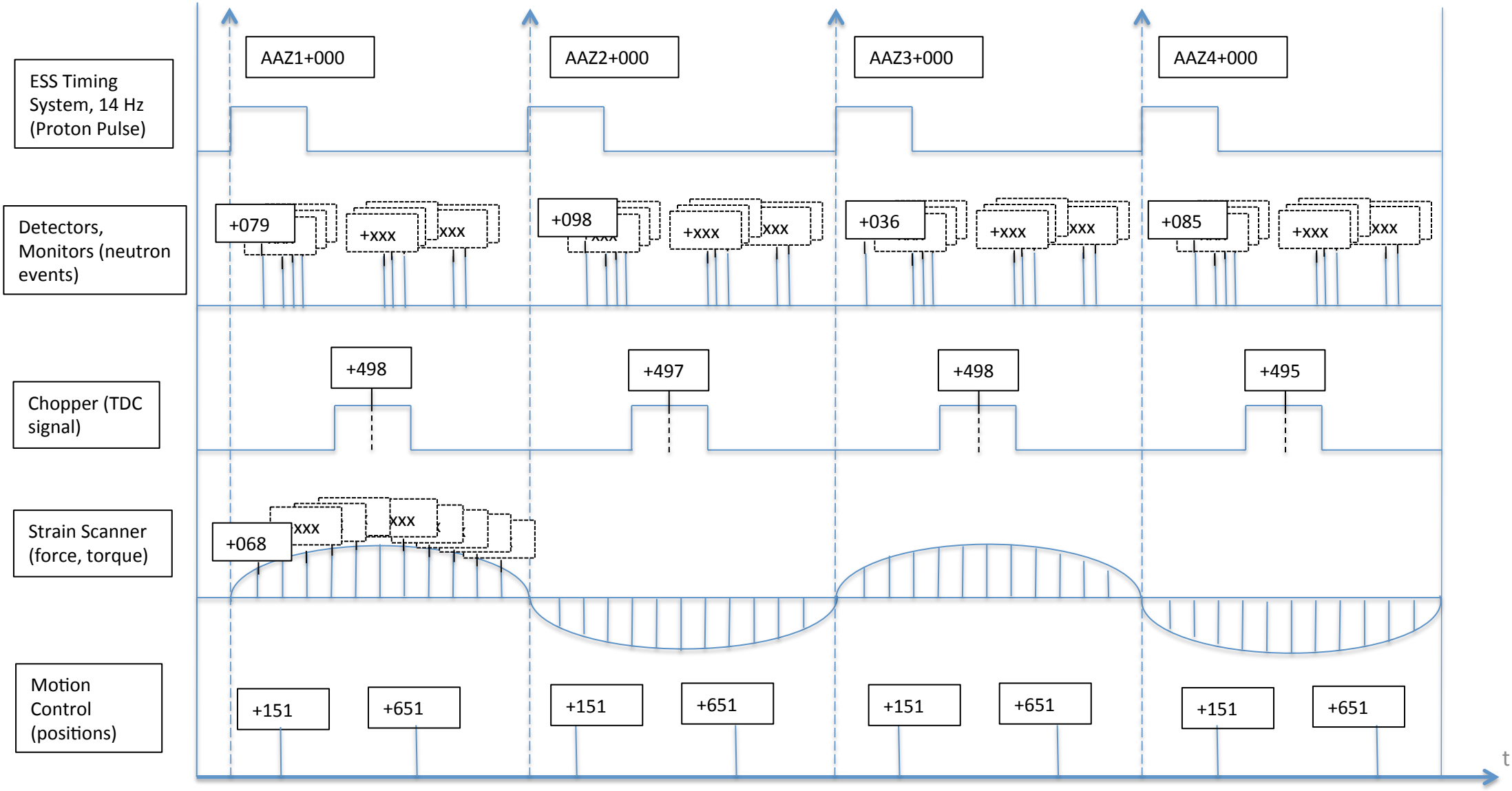
Time Stamping (Event Mode)



Time Stamping (Event Mode)



Time Stamping (Event Mode)



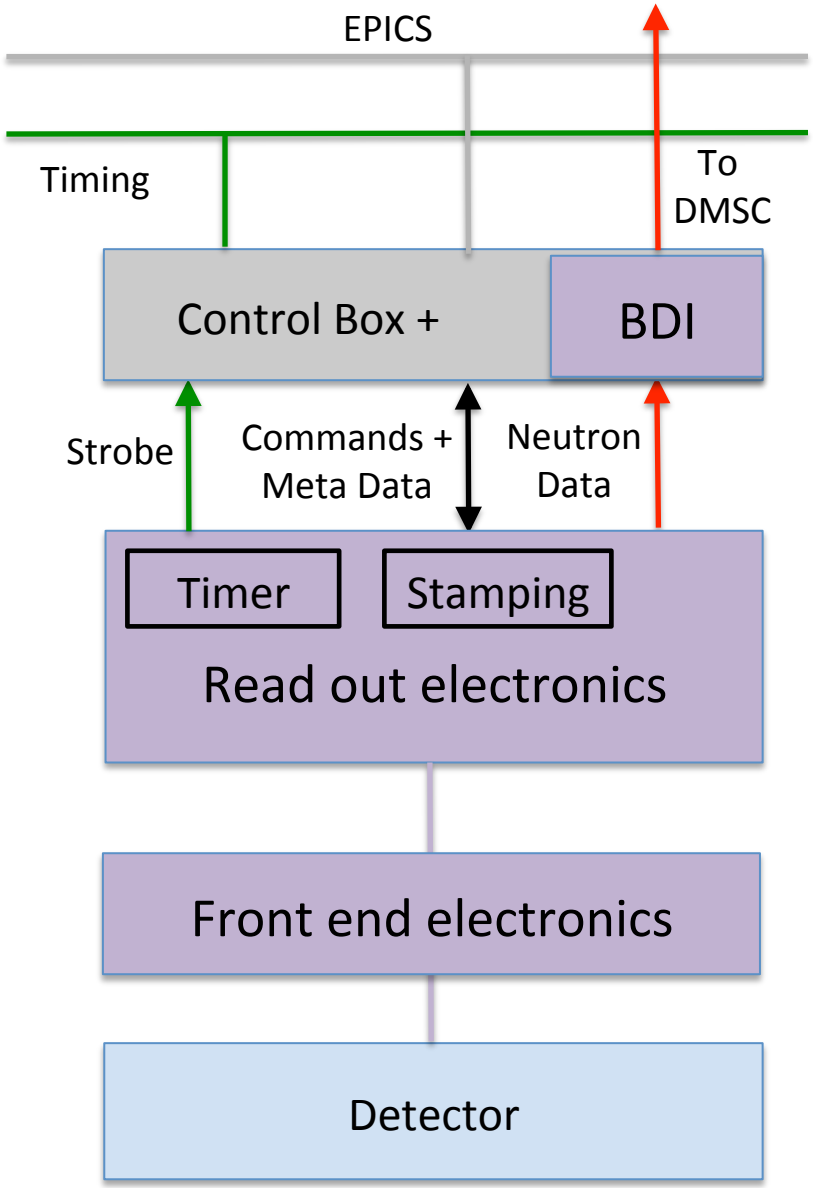
EUROPEAN SPALLATION SOURCE

Control Concepts

12th March 2015

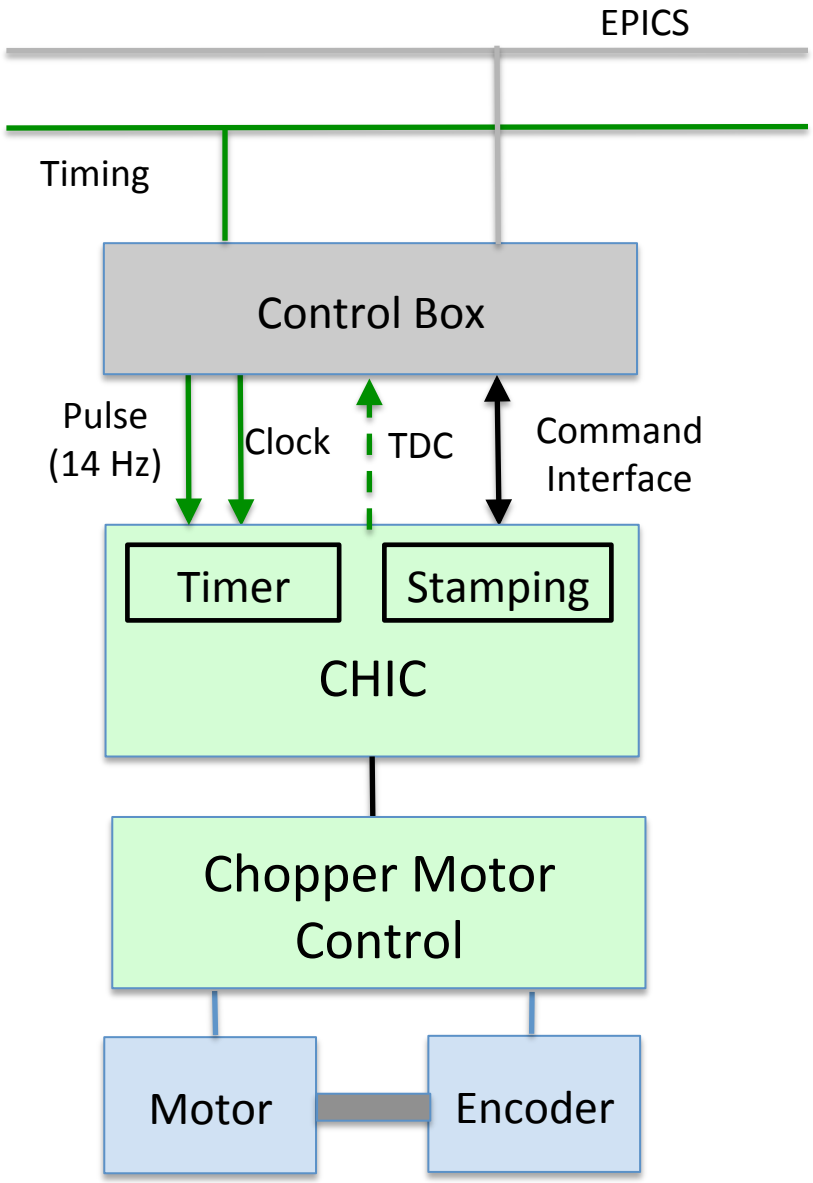
Thomas Gahl

Timing system (Detector electronics)



- Transfer absolute timing information from Control Box to the local HW control unit (read out electronics):
- Synchronise a timer on the electronics
- Timestamp Neutron data and meta data in the read out electronics with minimal latencies
- Transfer Neutron data (large volumes) through the Bulk Data Interface (BDI) to the DMSC data aggregator
- Transfer the meta data (small volumes) through the Control Box into EPICS
- Synchronously vs. asynchronously

Timing system (Chopper)



- Transfer absolute timing information from Control Box to the local HW control unit:
- Synchronise a timer on the control unit
- Timestamp in the control unit direct readings of the sensor with minimal latencies
- Transfer the TDC readings through the Control Box into EPICS
- Alternative: Time stamp in Control Box (needs digital input in CB)

EUROPEAN SPALLATION SOURCE

Motion Control for LOKI

12th March 2015

Thomas Gahl

- Aperture changer
- Collimation changer
- 4-axes slit system
- 6-axes sample stage
- Detector and/or detector vessel

Generic motion control

- Gate valves -- pneumatic motion control

- Secondary shutter -- safety motion control

LoKI Table of Motion Axes

Axis Number	Part Description	PBS Element	Axis description		Linear / Rotation	Range	Load	Accuracy
1	Aperture 1	13.6.3.1.4.3.1	X	xx	Rot	180°	≈10 kg	±0.1°
2	Collimation Guide 1 Movement	13.6.3.1.4.1.1	X	XX	Rot	180°	≈200Kg	±0.1°
3	Aperture 2	13.6.3.1.4.3.2	X	xx	Rot	180°	≈10 kg	±0.1°
4	Collimation Guide 2 Movement	13.6.3.1.4.1.2	X	XX	Rot	180°	≈300Kg	±0.1°
5	Aperture 3	13.6.3.1.4.3.3	X	xx	Rot	180°	≈10 kg	±0.1°
6	Collimation Guide 3 Movement	13.6.3.1.4.1.3	X	XX	Rot	180°	≈300Kg	±0.1°
7	Aperture 4	13.6.3.1.4.3.4	X	xx	Rot	180°	≈10 kg	±0.1°
8	Collimation Gate Valve	13.6.3.1.9.3	Y	XX	Lin	200mm (stroke)	≈10kg	±0.5mm
9	Slit 5	13.6.3.1.4.2.1	Y port	20m	Lin	35mm	≈1Kg	±0.01mm
10			Y starb.	20m	Lin	35mm	≈1Kg	±0.01mm
11			Z upper	20m	Lin	35mm	≈1Kg	±0.01mm
12			Z lower	20m	Lin	35mm	≈1Kg	±0.01mm
13	Sample Stage Linear		X	XX	Lin	2m	≈1t	±1mm
14			Y	XX	Lin	1m	≈1t	±0.5mm
15			Z	XX	Lin	1m	≈1t	±0.5mm

- Support + review mechanical design, procurement, tests, info + signal list to DMSC
- Deliver motion control standards
- Control electronics in a cabinet (design / custom programming / electrical drawing / procurement / FAT / integrate ICS control box)
- Electrical drawings for external cabling
- Commissioning / EPICS integration
- Documentation