ICS-NSS Controls Integration

TAC 17

John Sparger

Control Systems Engineer

ICS

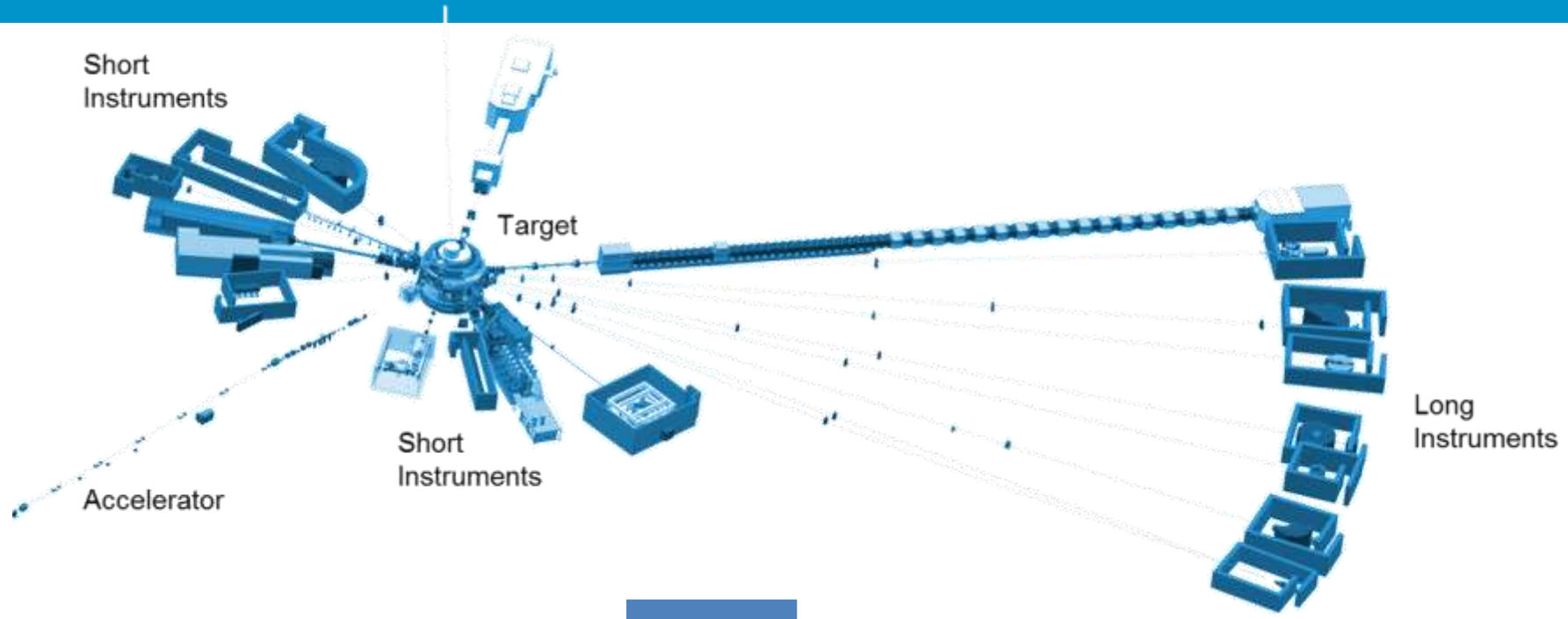
Overview

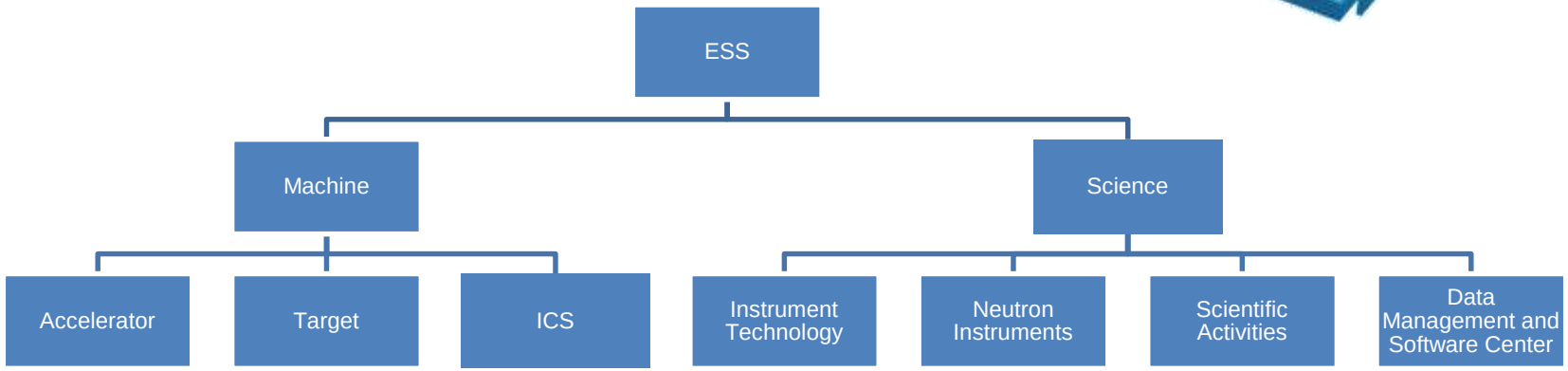
- Introduction
- Instrument Technology Groups
- Neutron Instruments
- ICS
- Timeline, deliverables, and resources
- Proposals
- Conclusions
- Discussion

ICS and NSS

- The Integrated Control System Division (ICS division) is the organizational group responsible for the control systems within ESS for the accelerator, target, neutron scattering systems and conventional facilities, including a machine protection system and a personnel safety system.
- The Science Directorate is the organizational group responsible for developing the neutron instruments and associated generic technology. The neutron instruments and these enabling systems make up the Neutron Scattering System project (NSS).

Organization





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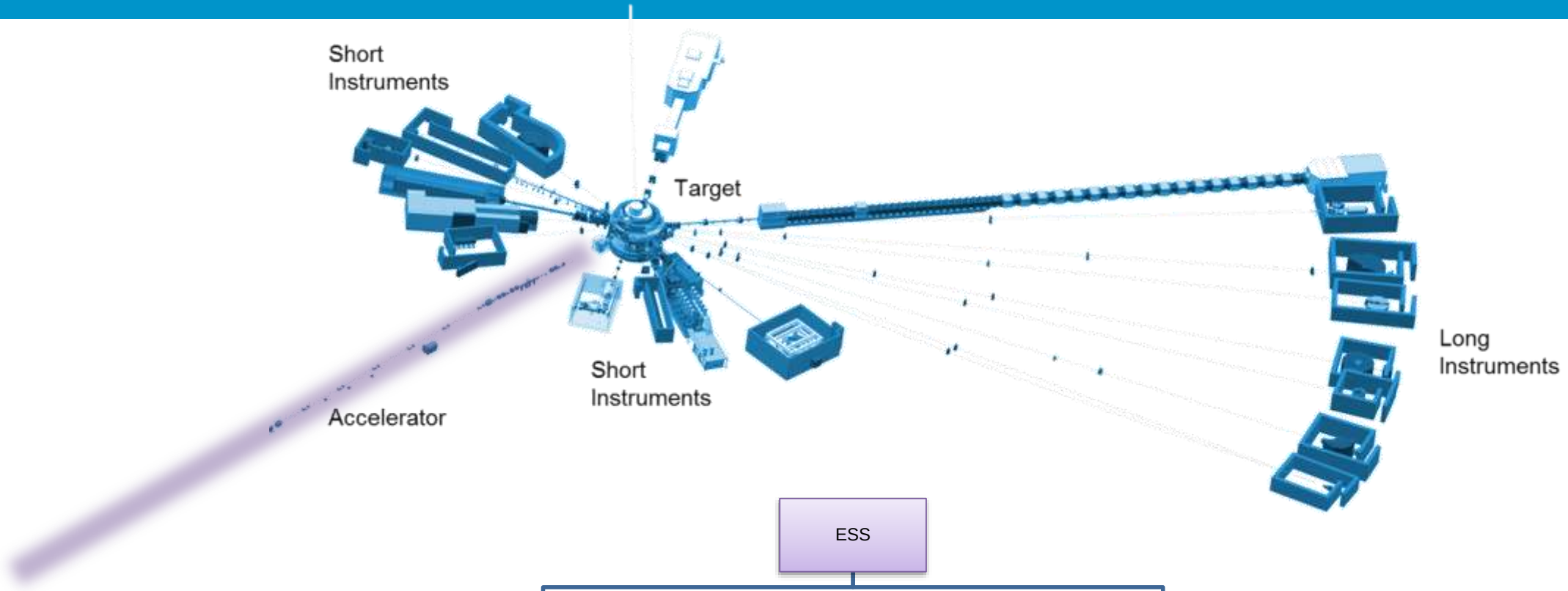

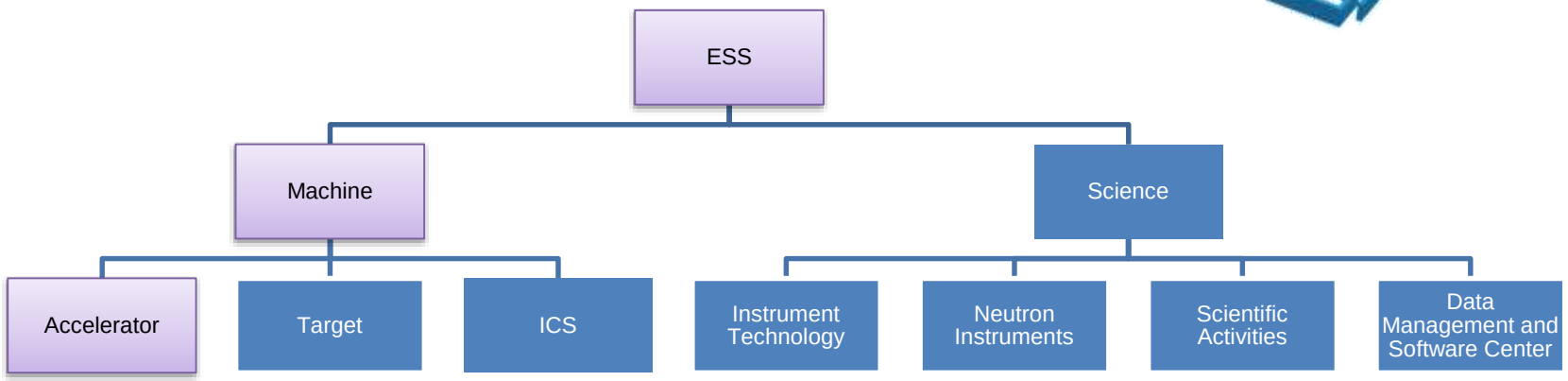

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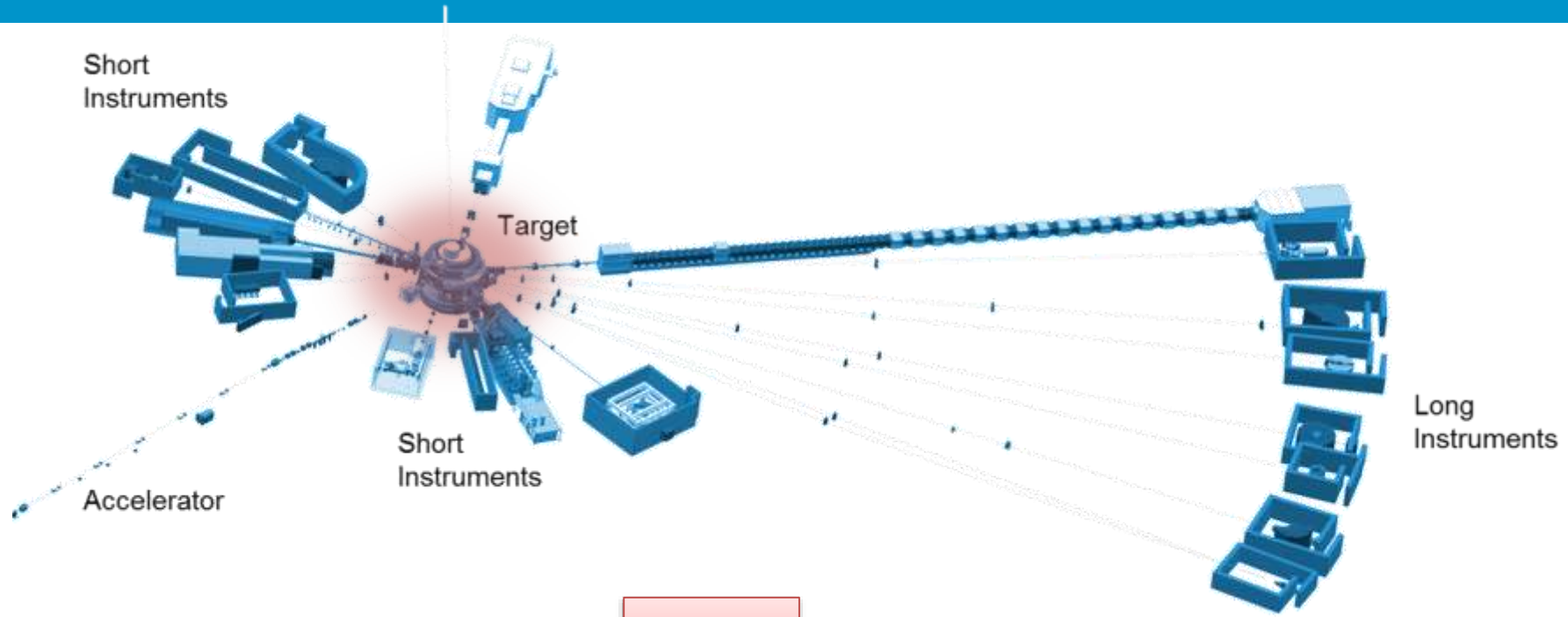

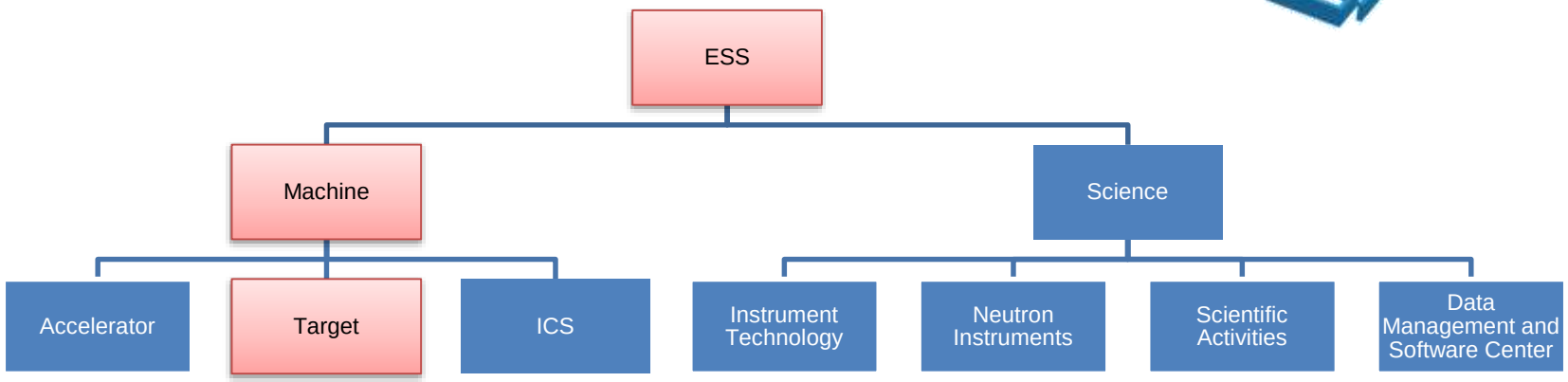

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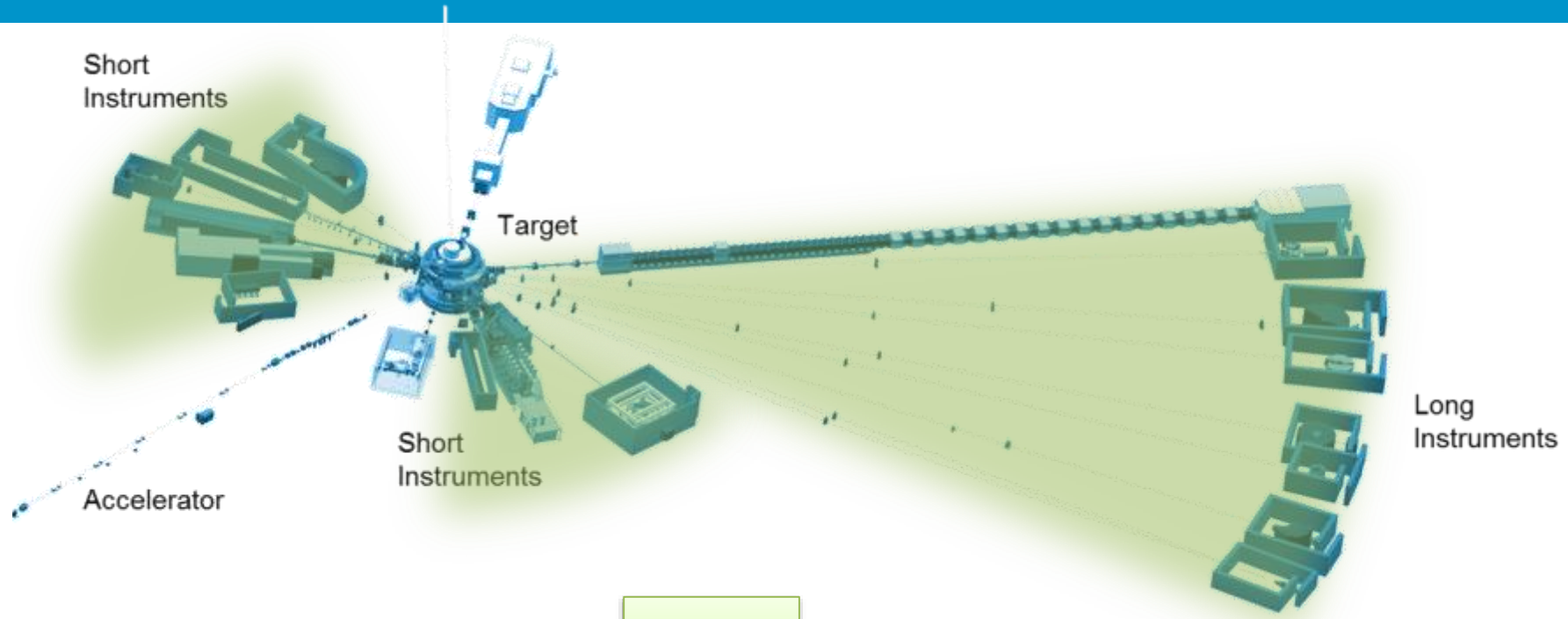

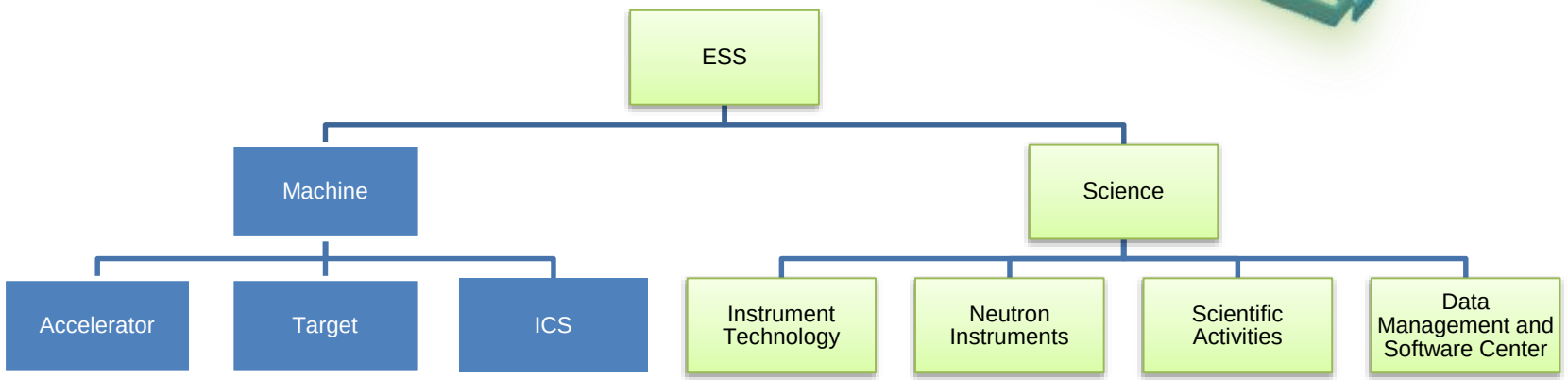

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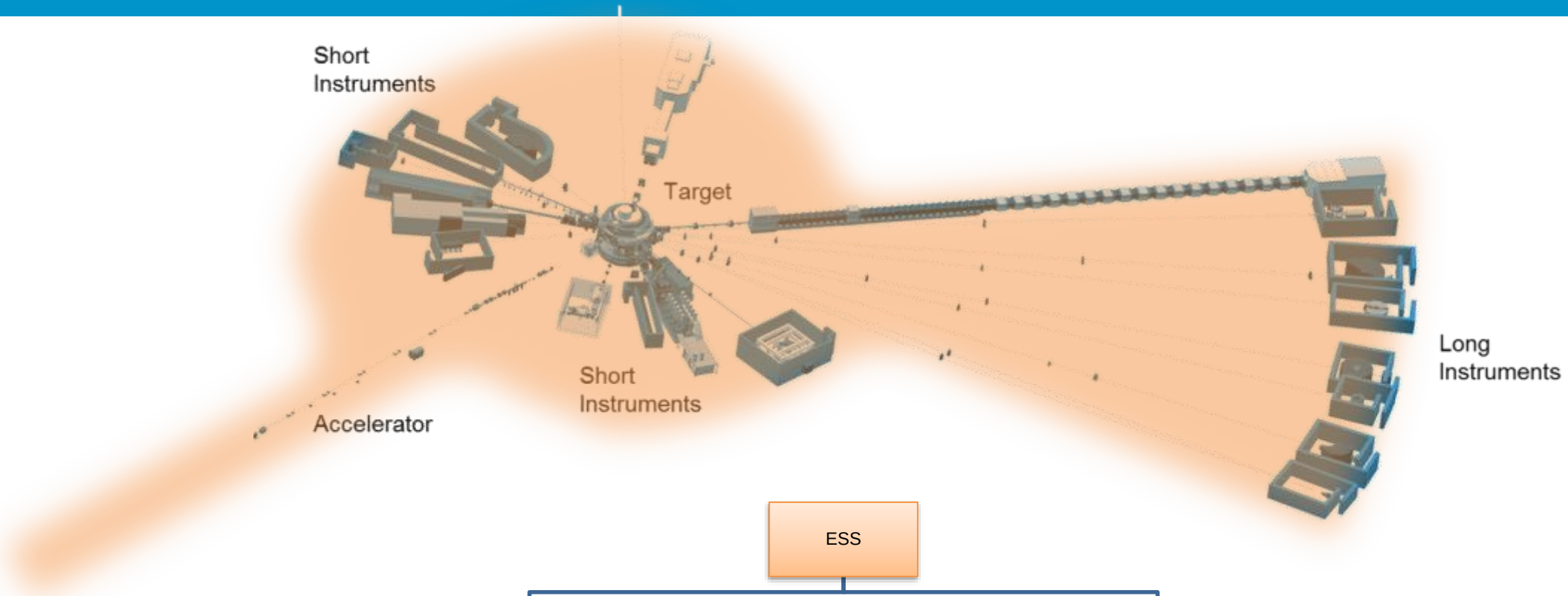
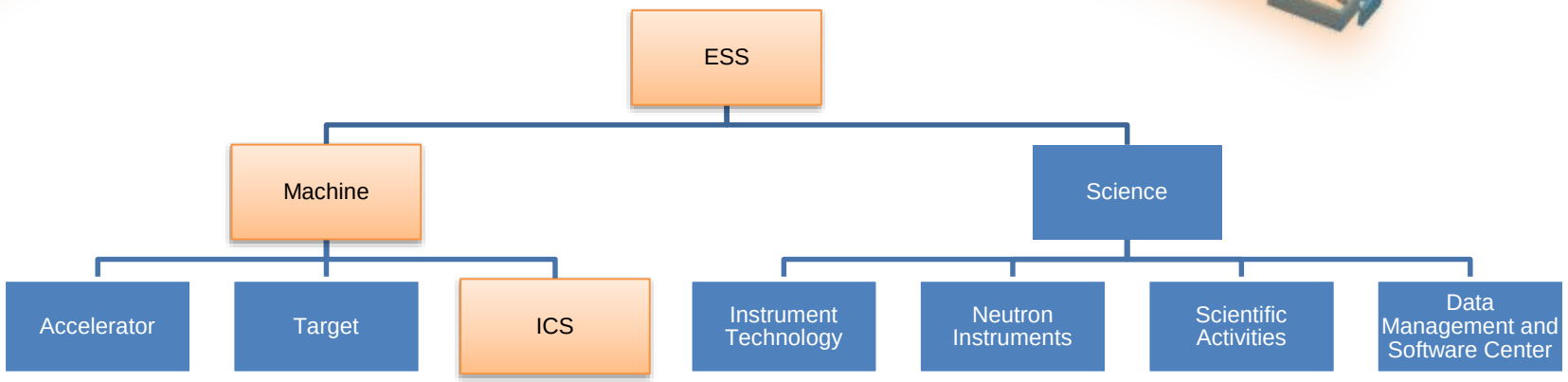
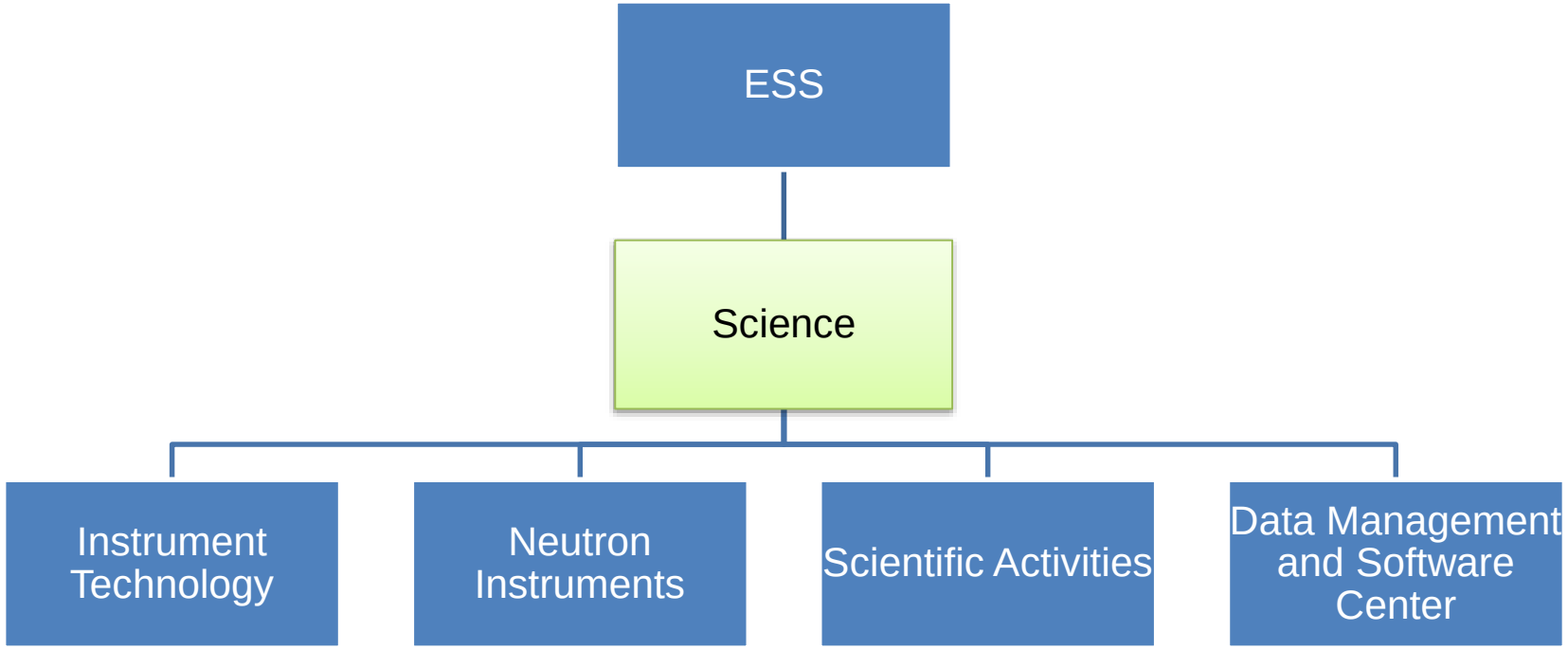
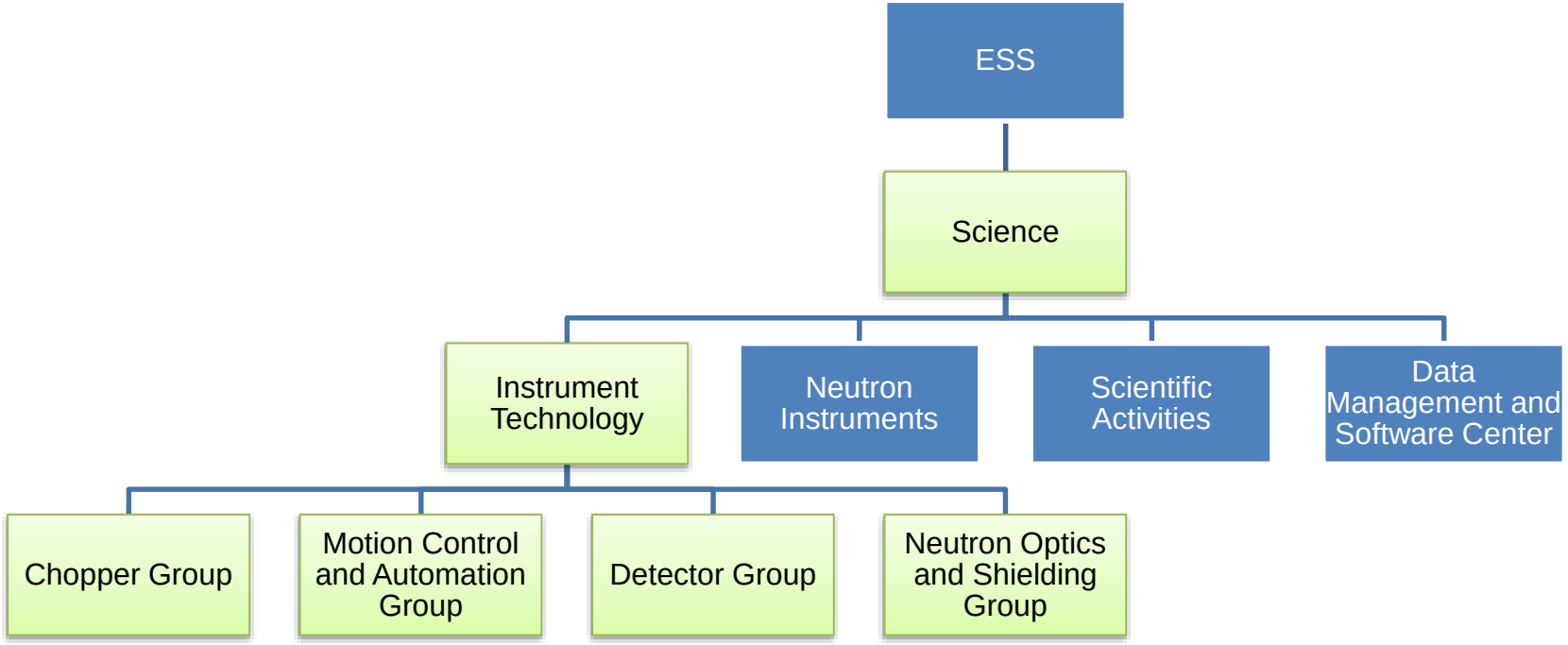




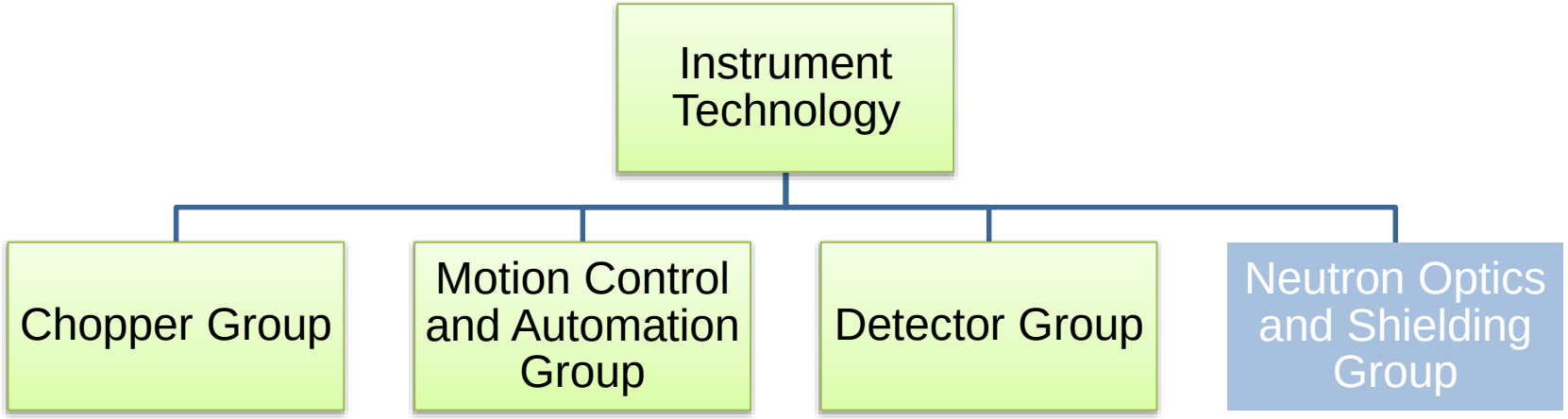
Science


ESS
Science
Instrument Technology
Neutron Instruments
Scientific Activities
Data Management and Software Center

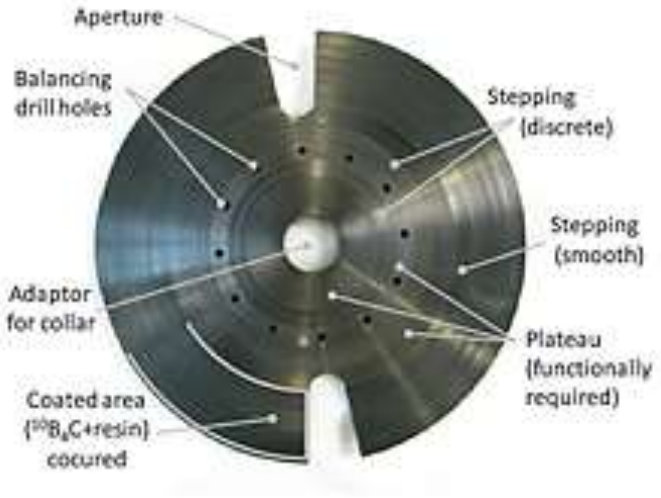
Technology Groups

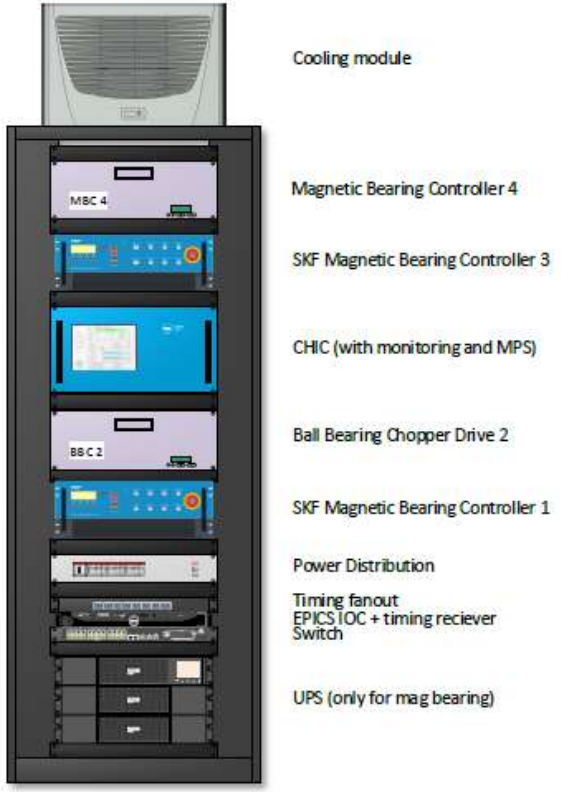


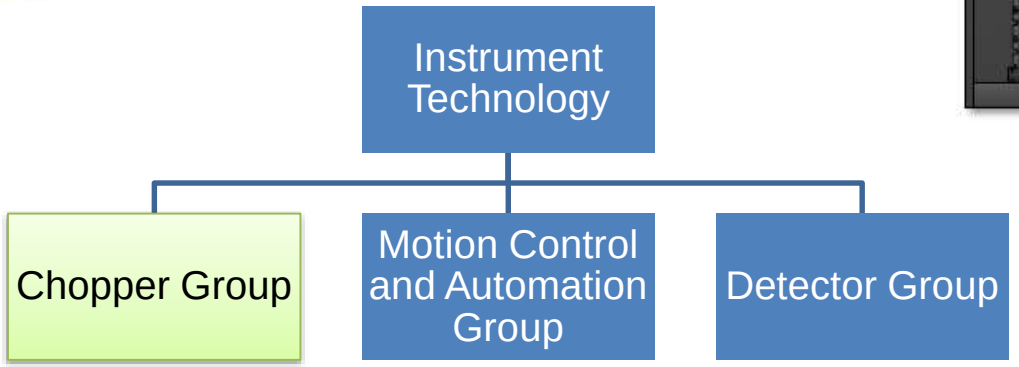
Technology Groups



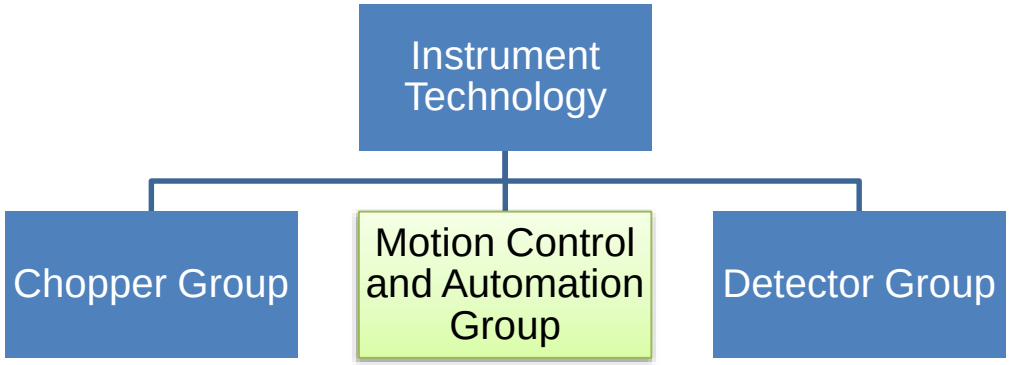
Chopper Group



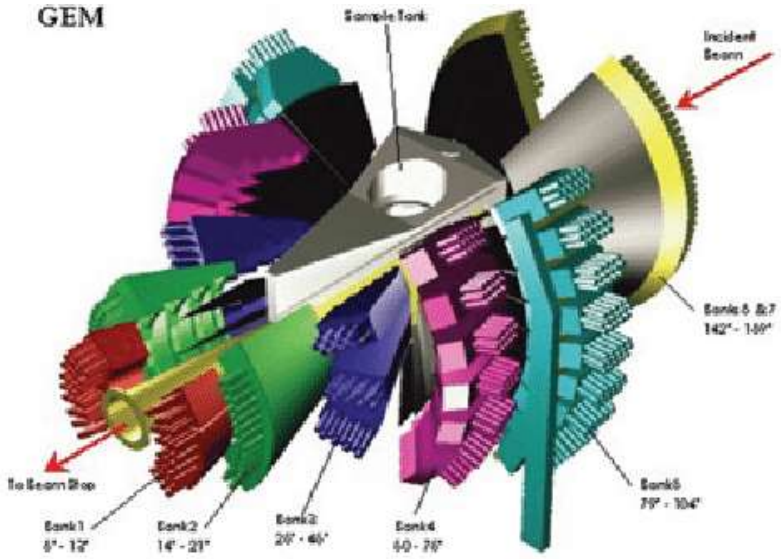


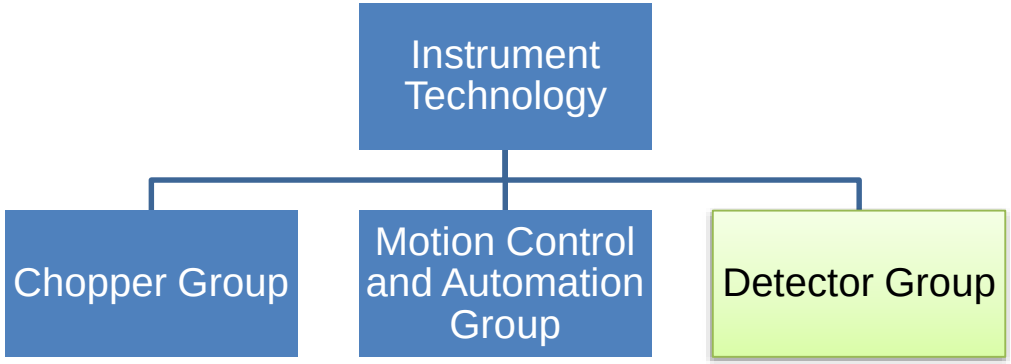


MCAG


Instrument Technology
Chopper Group
Motion Control and Automation Group
Detector Group

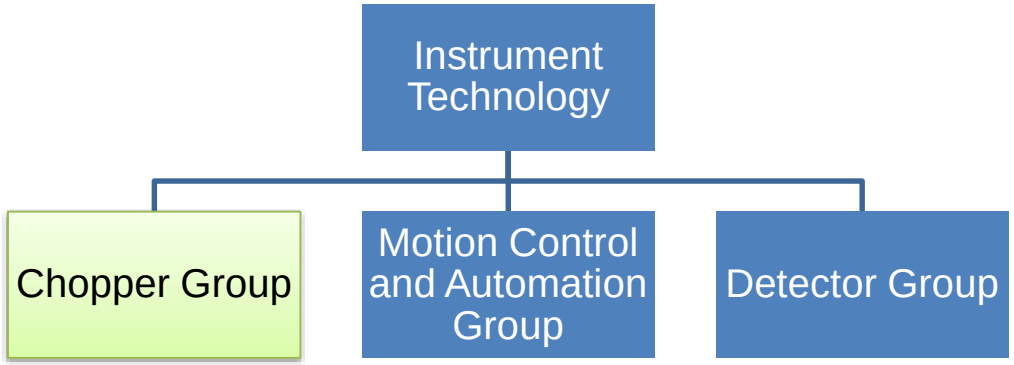
Detector Group





Generic technology

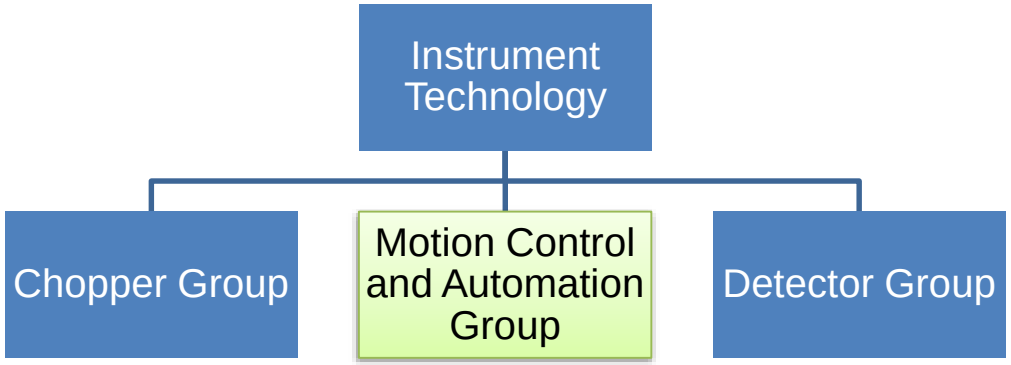
Chopper Integrated Controller (CHIC)



Generic technology

Chopper Integrated Controller (CHIC)

Motion Control Unit (MCU)

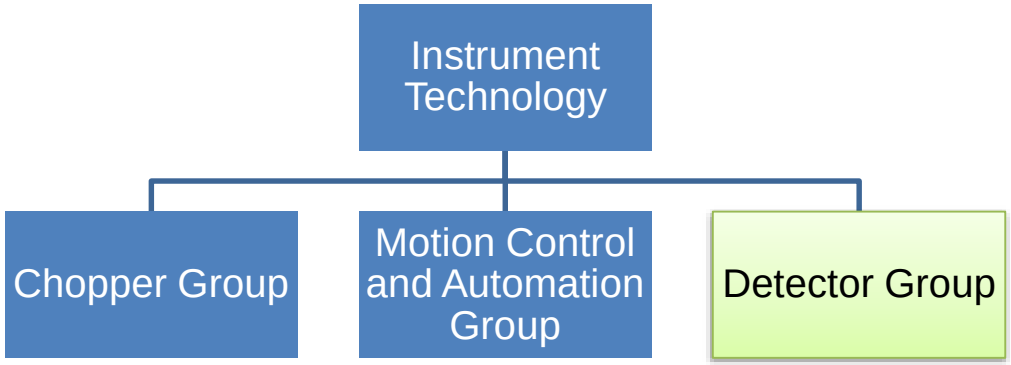


Generic technology

Chopper Integrated Controller (CHIC)

Motion Control Unit (MCU)

Detector Readout System



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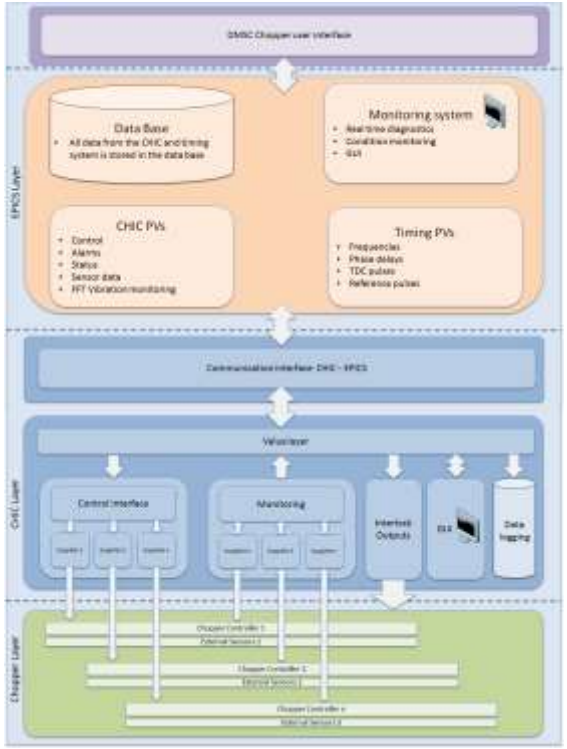
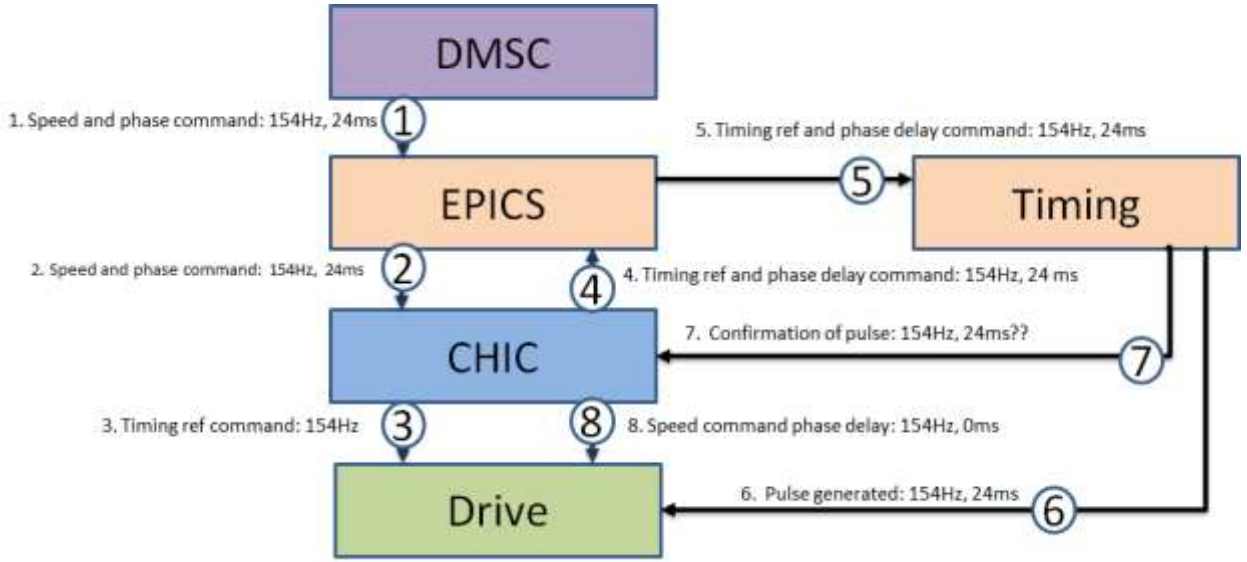
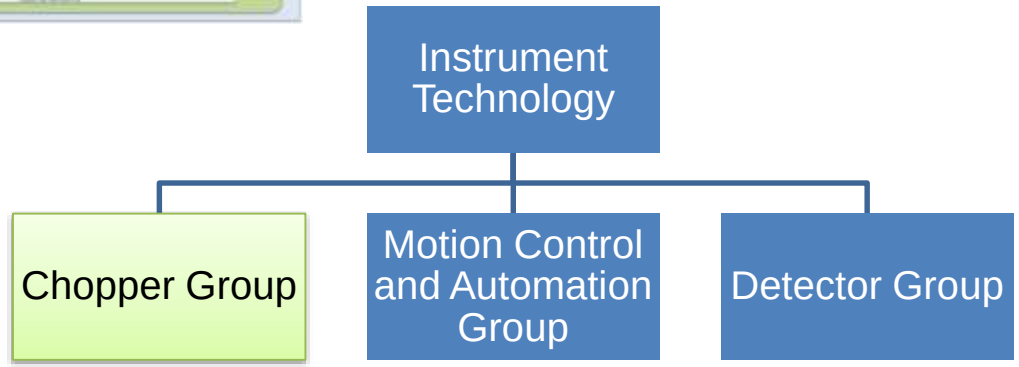
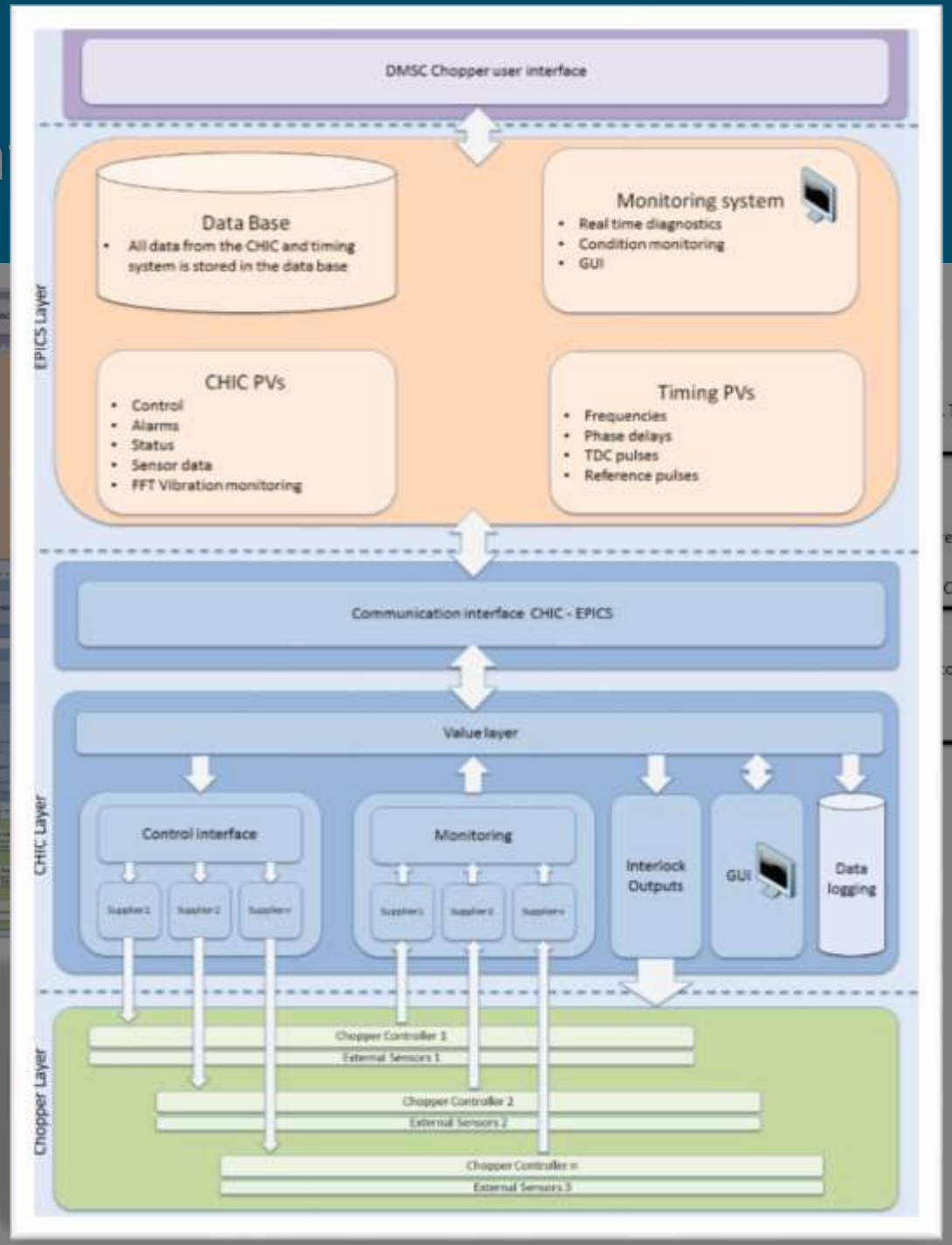
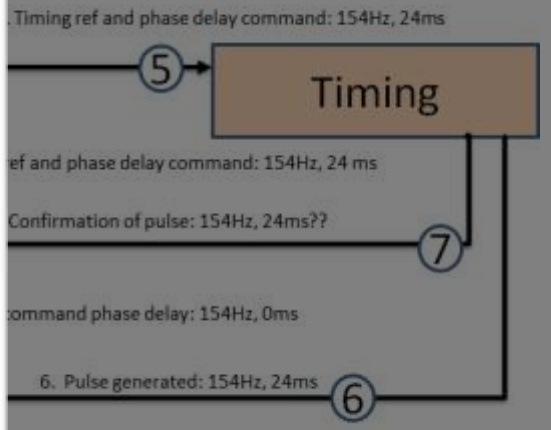




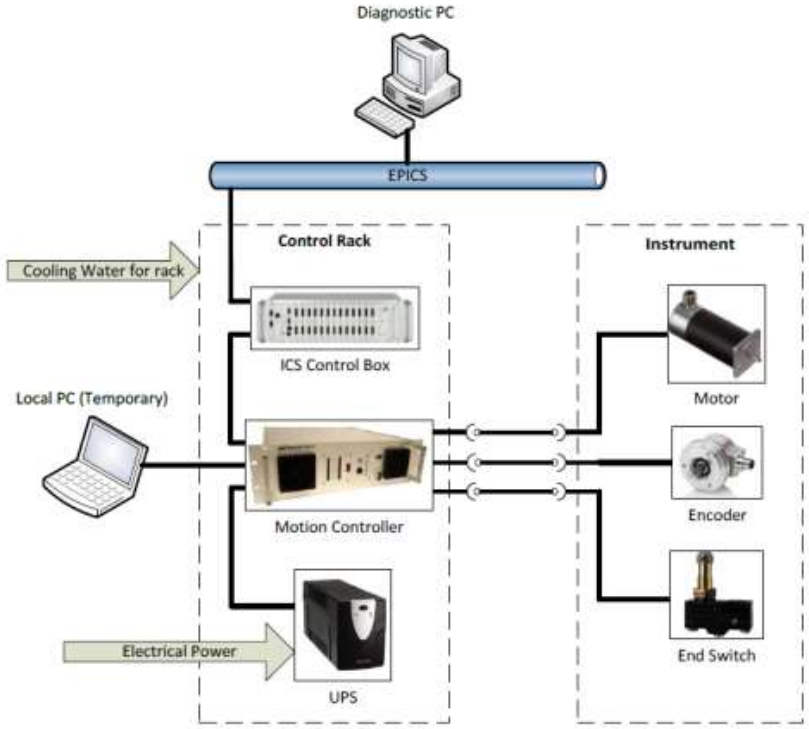


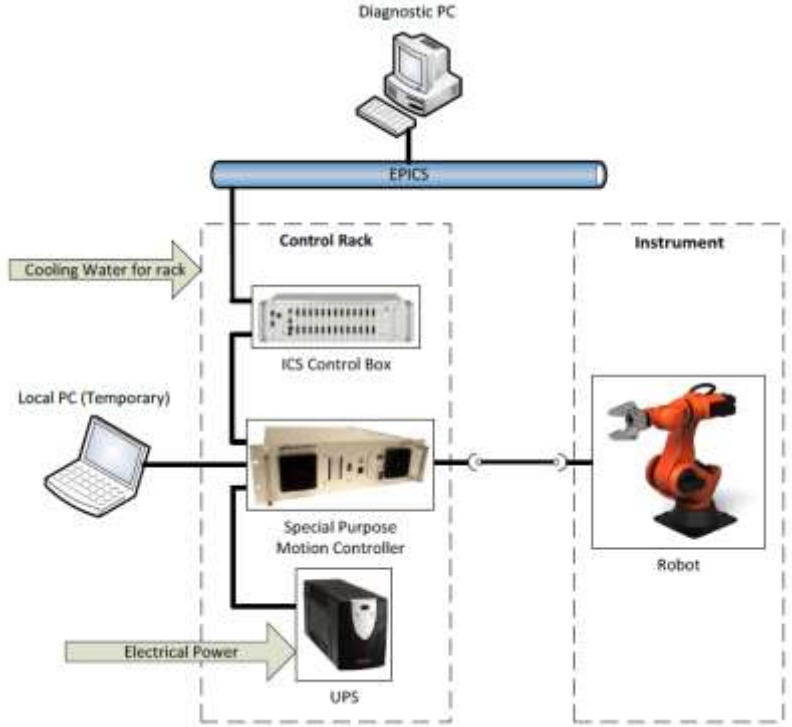
Chopper Integra

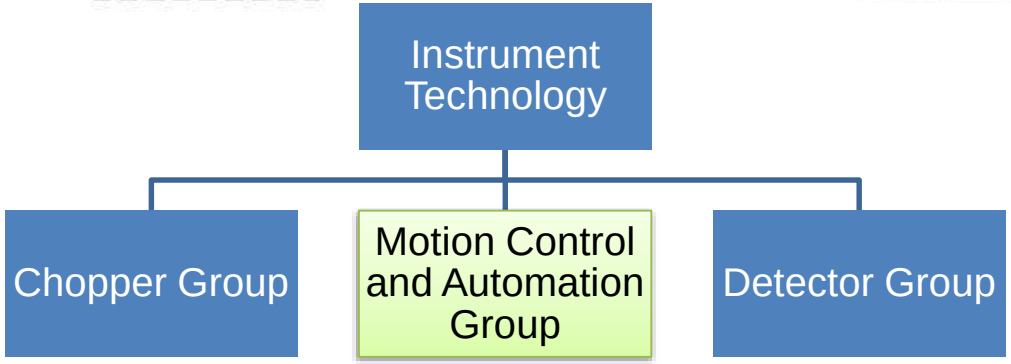




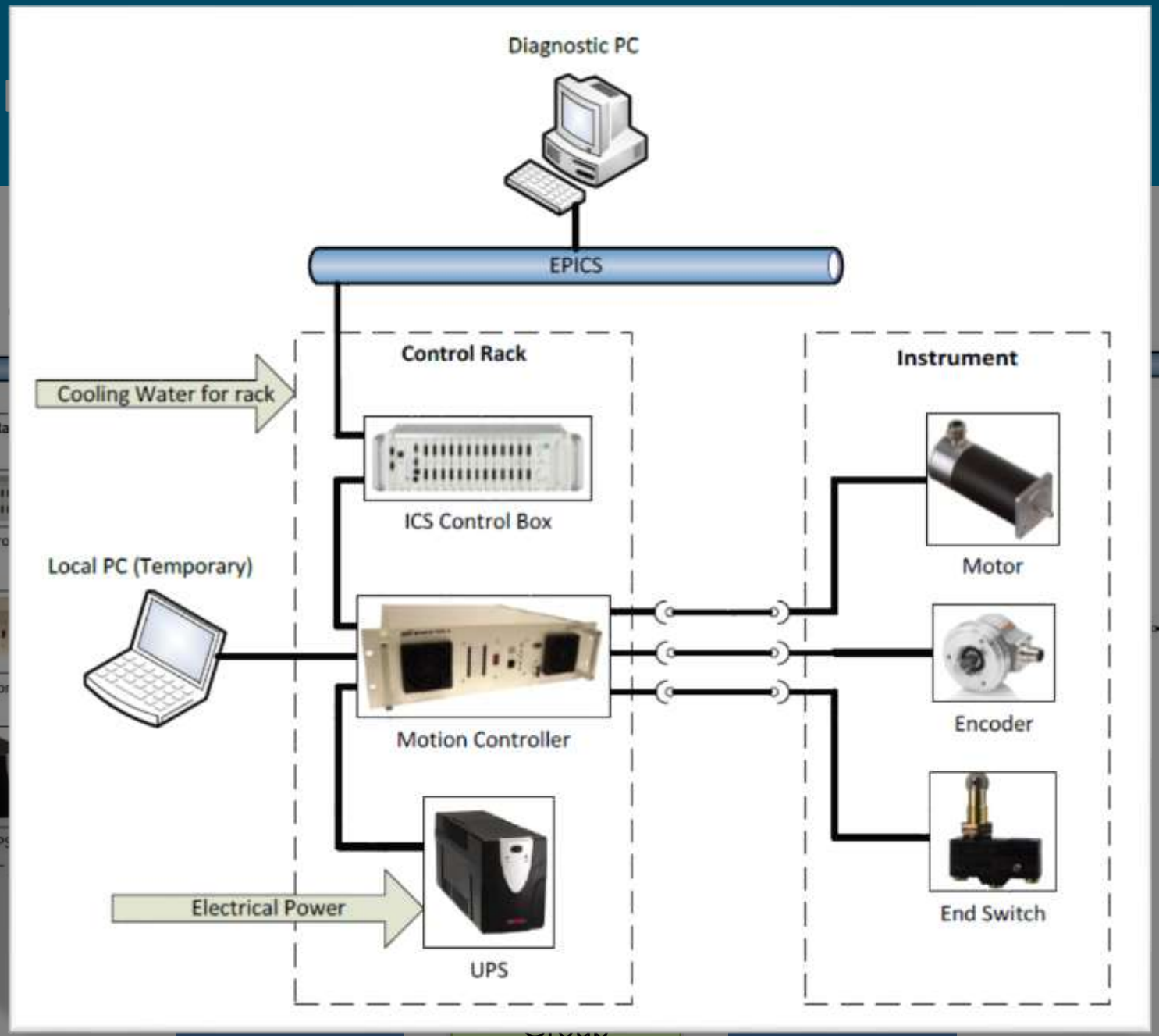
Motion Control Unit



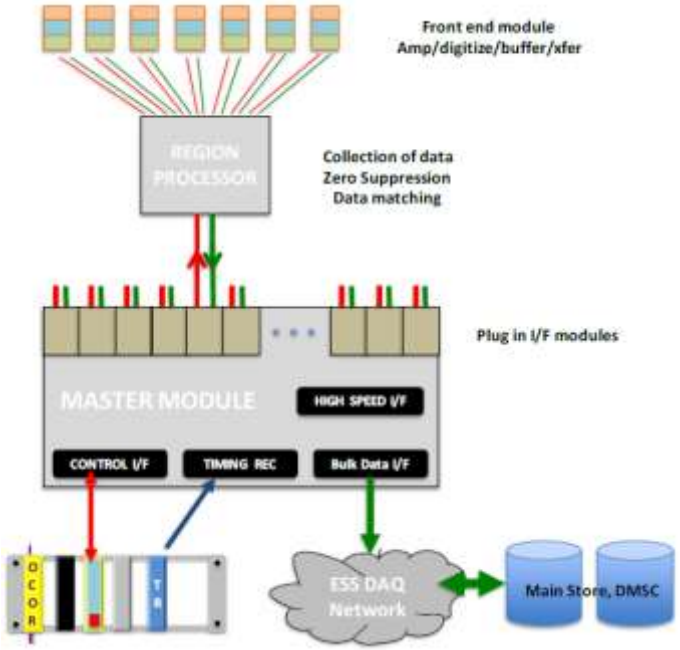


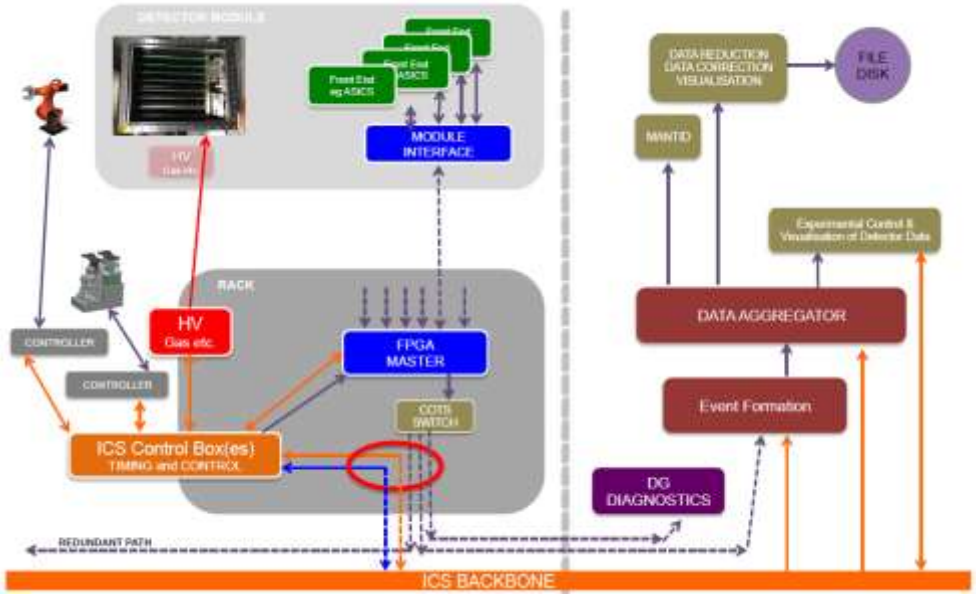


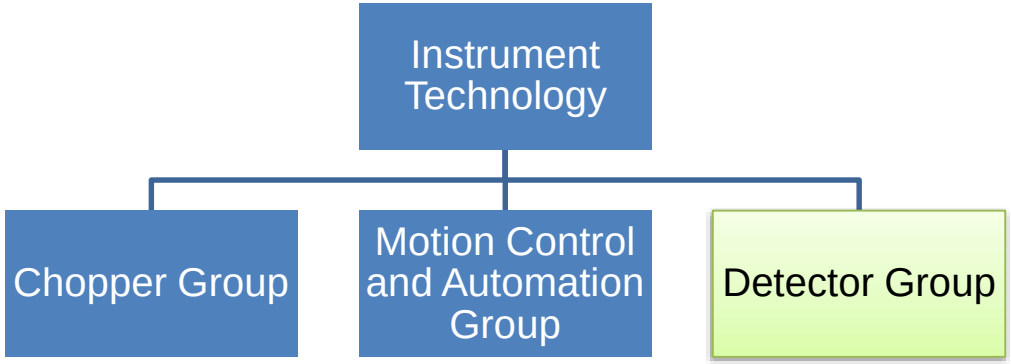
Motion Co


Diagnostic PC
EPICS
Control Rack
Instrument
Cooling Water for rack
ICS Control Box
Local PC (Temporary)
Motor
Motion Controller
Encoder
Electrical Power
End Switch
UPS

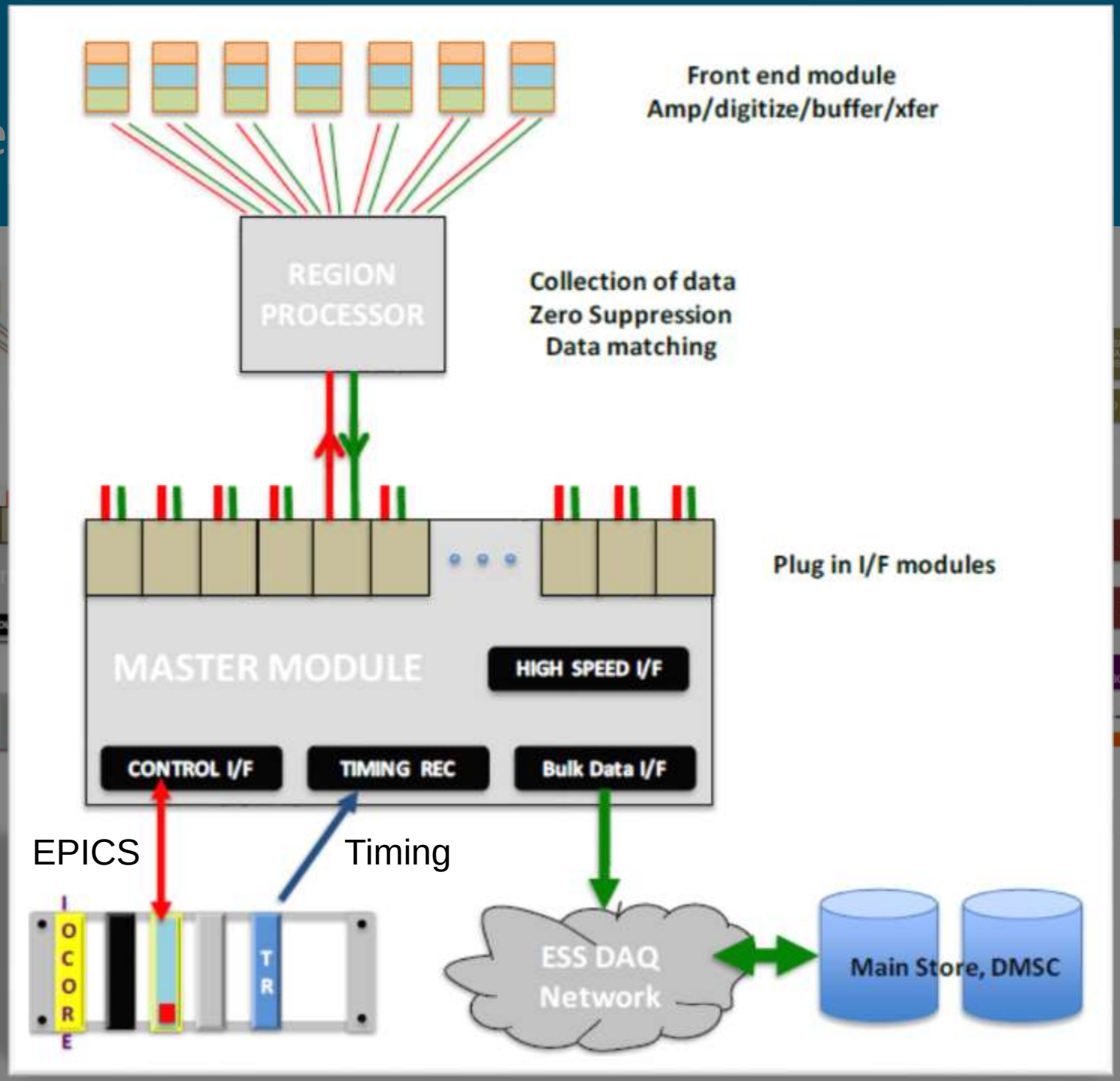
Detector Readout System



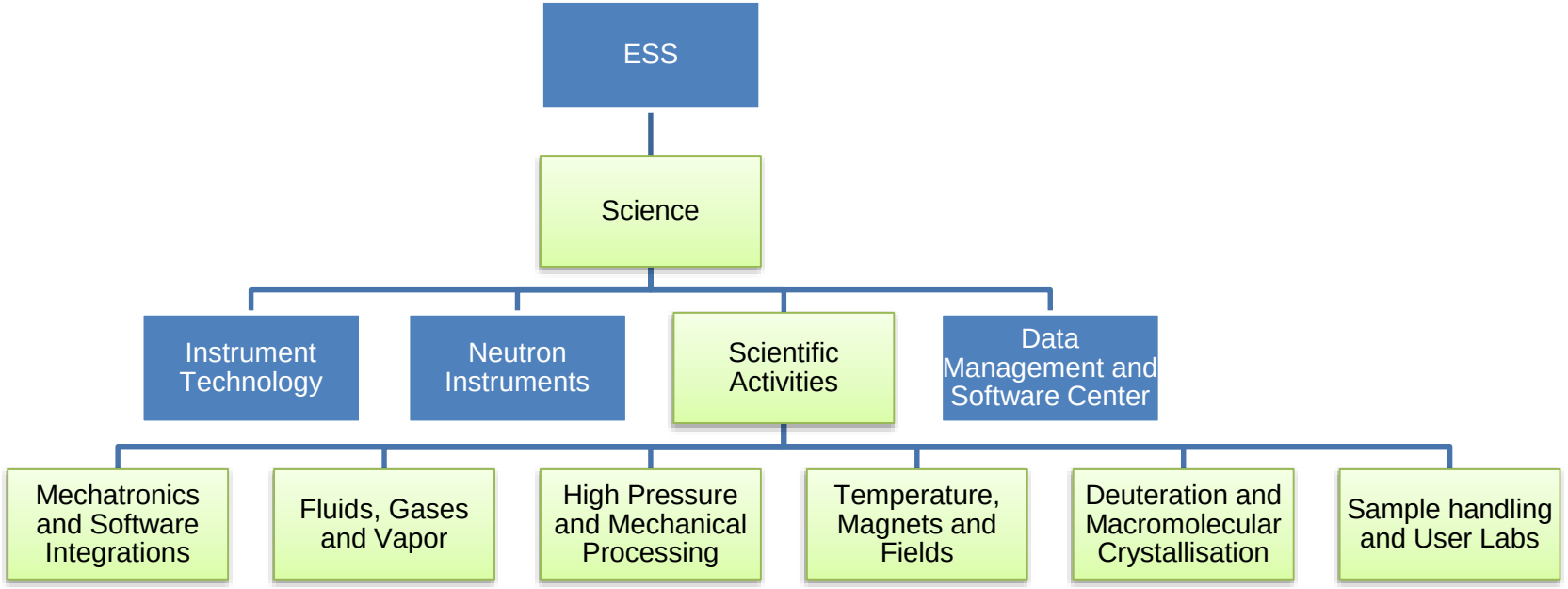




Detector Re

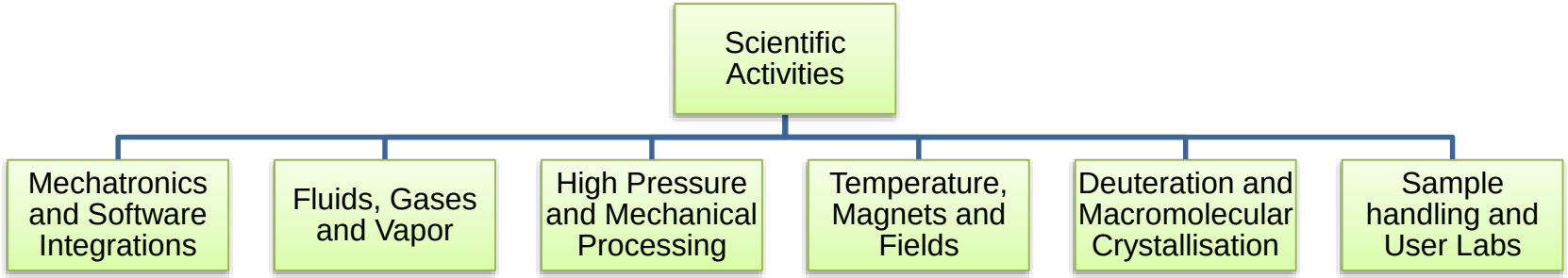

Front end module
Amp/digitize/buffer/xfer
REGION PROCESSOR
Collection of data
Zero Suppression
Data matching
Plug in I/F modules
MASTER MODULE
HIGH SPEED I/F
CONTROL I/F
TIMING REC
Bulk Data I/F
EPICS
Timing
I/O CORE
TR
ESS DAQ Network
Main Store, DMSC

Sample Environment



Sample Environment

- Sample Environment equipment puts samples in conditions where they are of scientific interest to study. This science is the purpose of ESS.



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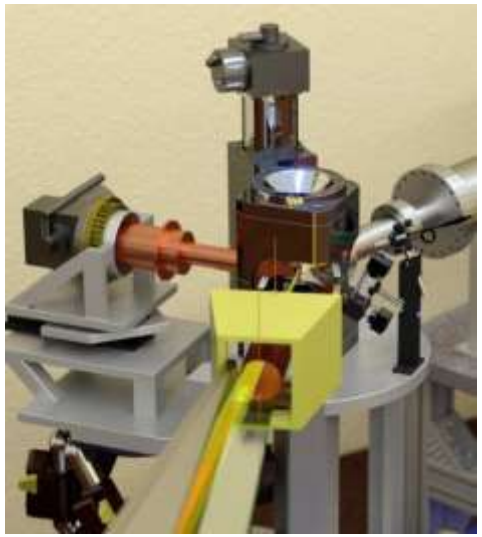
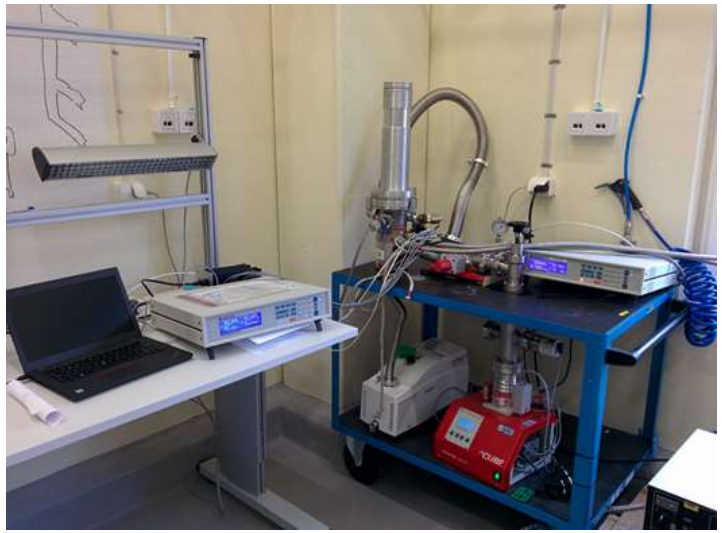
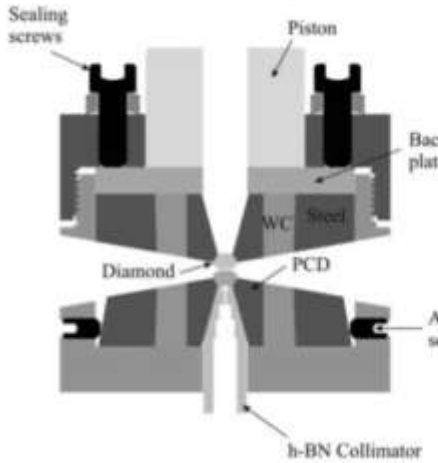
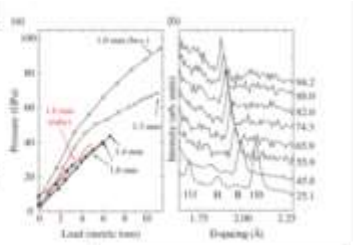
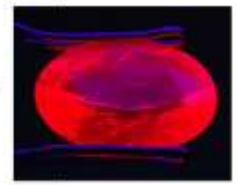








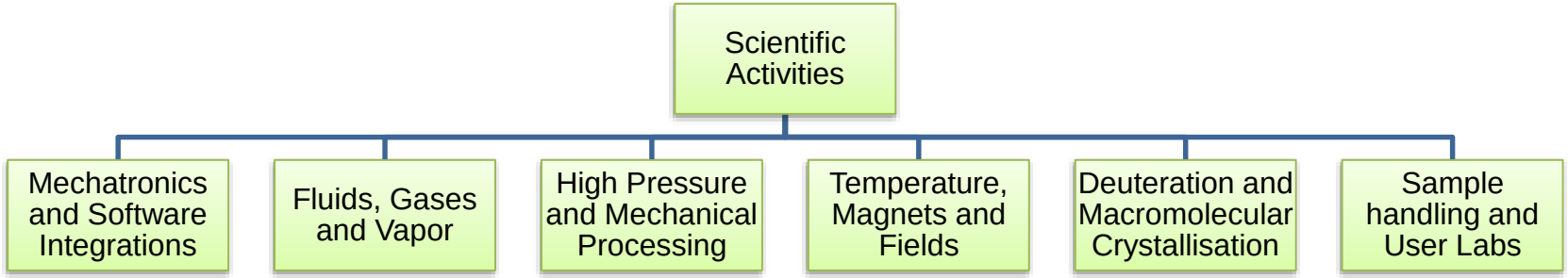


Boehler et al 2013

- Scientific Activities
  - Mechatronics and Software Integrations
  - Fluids, Gases and Vapor
  - High Pressure and Mechanical Processing
  - Temperature, Magnets and Fields
  - Deuteration and Macromolecular Crystallisation
  - Sample handling and User Labs

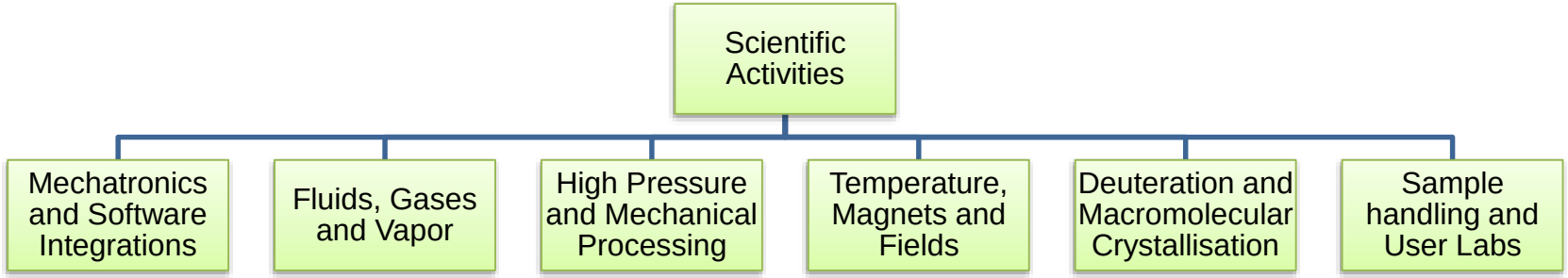
Sample Environment

- As a cost saving measure, most SE equipment has been moved out of the instrument scope and into a shared pool managed by the Scientific Activities Division (SAD).



Sample Environment

- Around 8 Million Euro's in NSS sample environment equipment budget.
- Around 120 pieces of SE equipment need controls development



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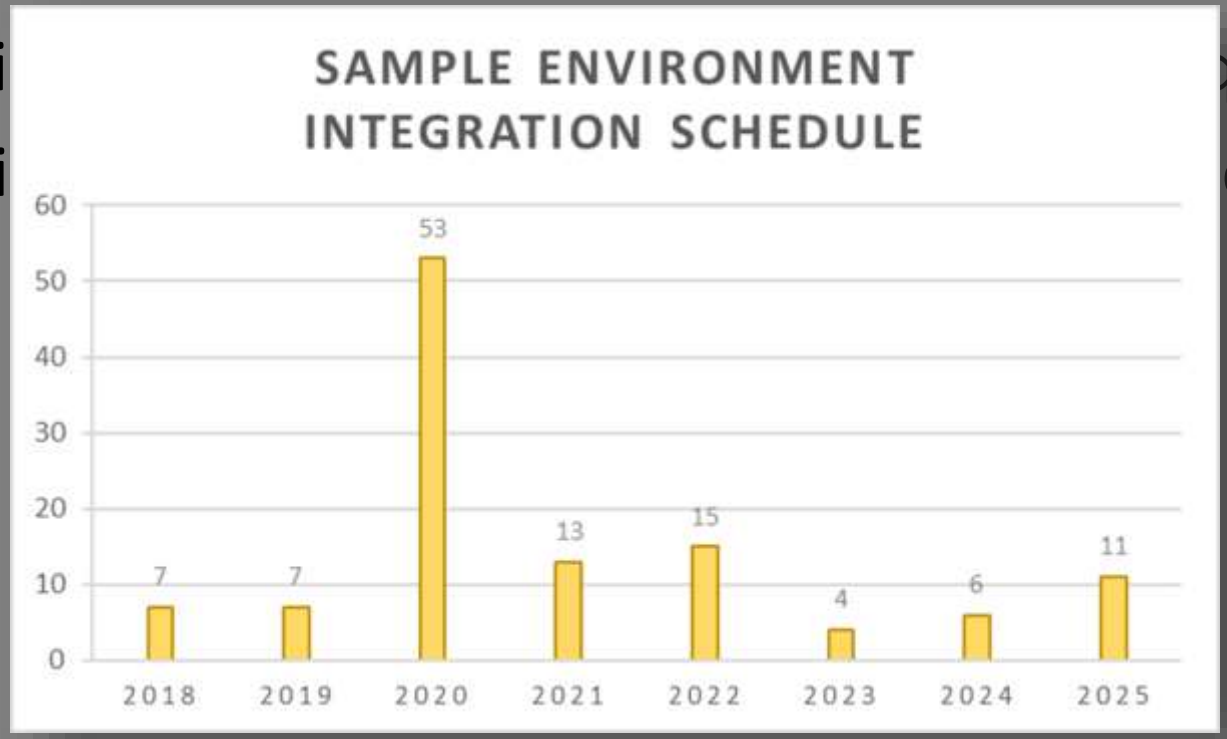
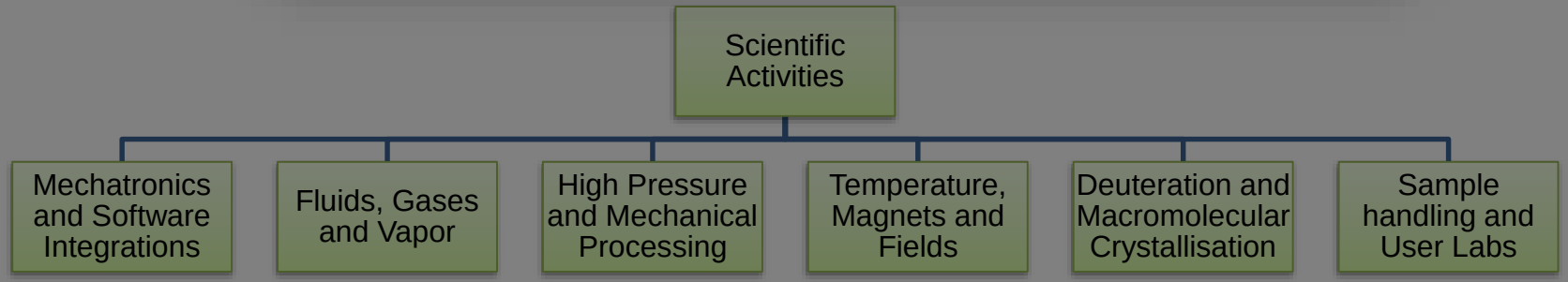
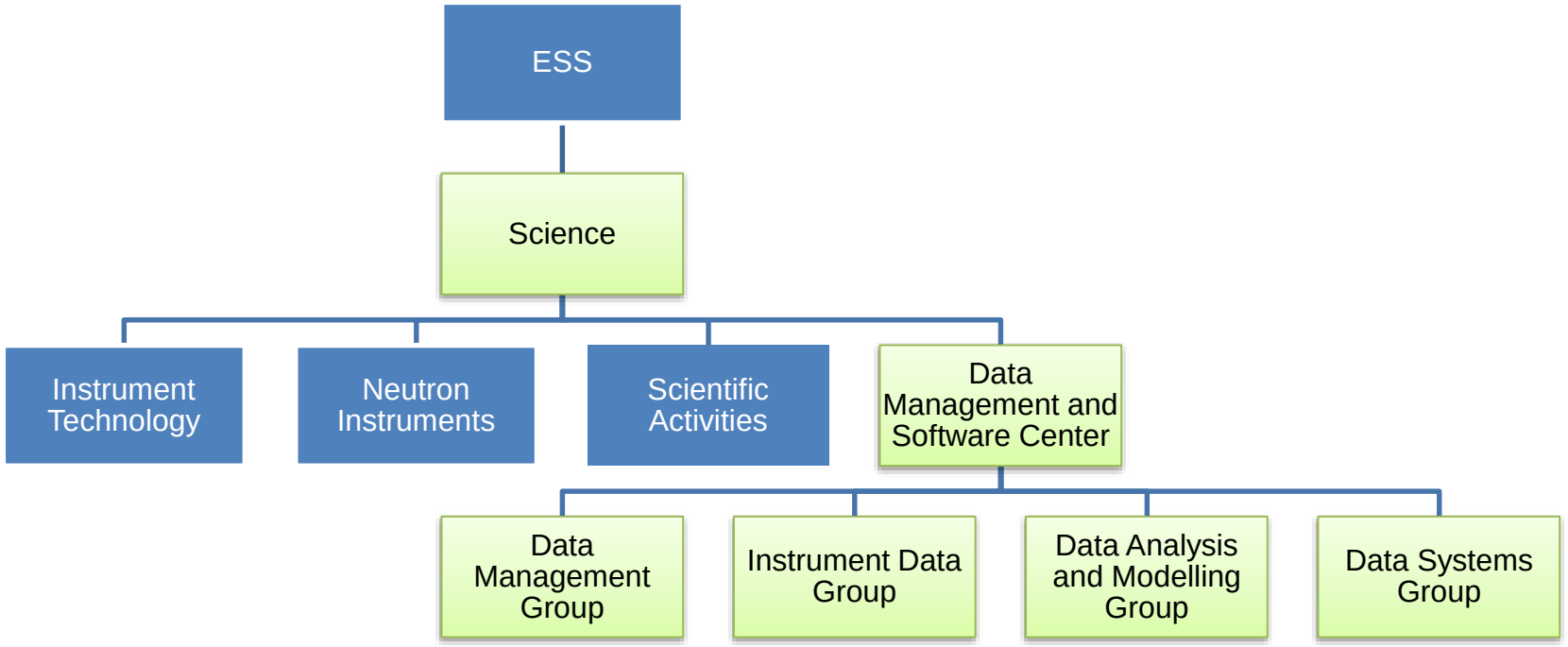
- Around 120 pi elopment

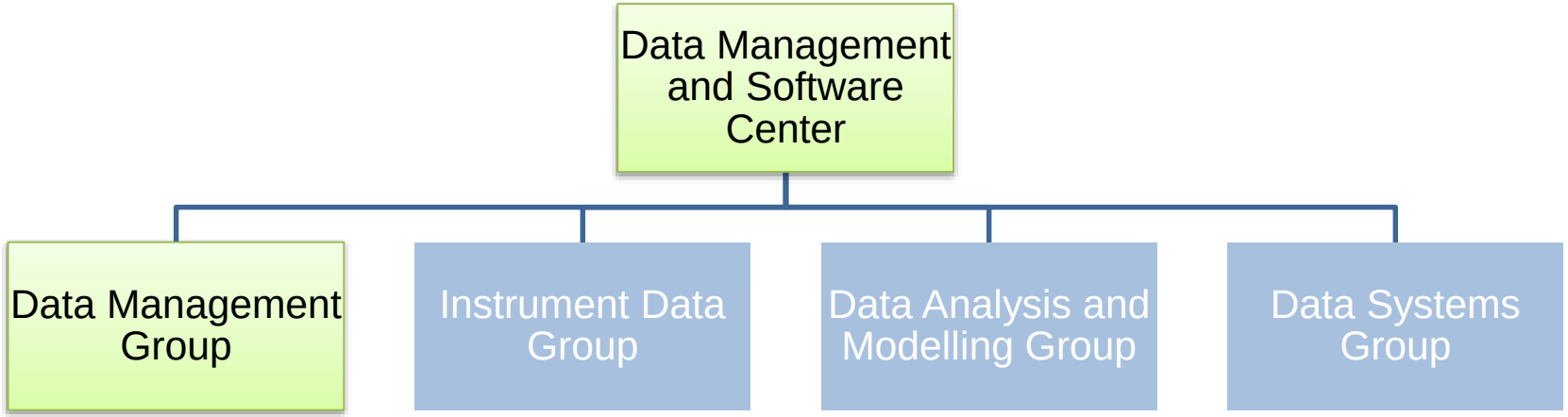




DMSC

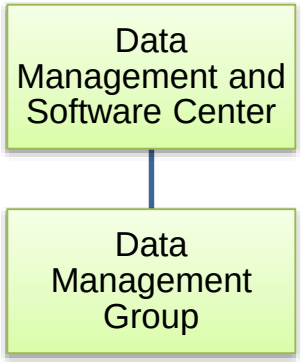

ESS
Science
Instrument Technology
Neutron Instruments
Scientific Activities
Data Management and Software Center
Data Management Group
Instrument Data Group
Data Analysis and Modelling Group
Data Systems Group

DMSC


Data Management and Software Center
Data Management Group
Instrument Data Group
Data Analysis and Modelling Group
Data Systems Group

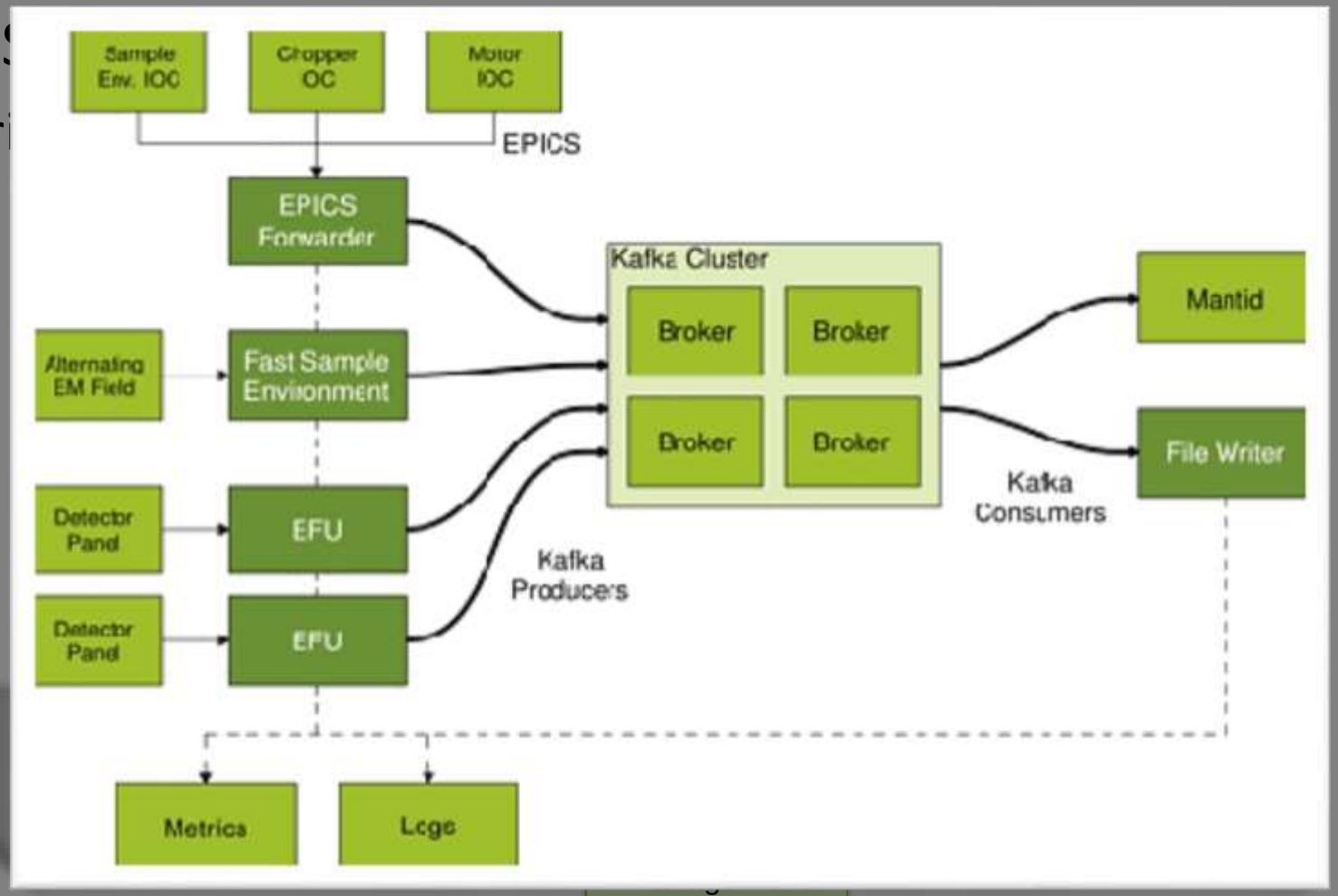
DMSC

- The DMSC is responsible for providing:
  - Experimental data aggregation, streaming, and storage



DMSC

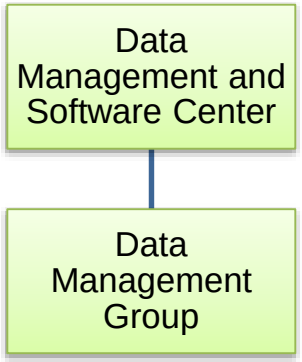
- The DMS
  - Experi



Group

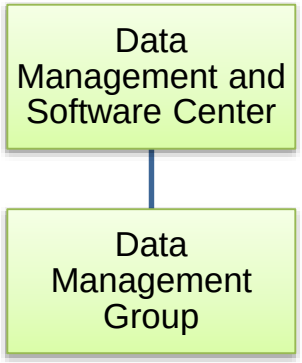
DMSC

- The DMSC is responsible for providing:
  - Experimental data aggregation, streaming, and storage



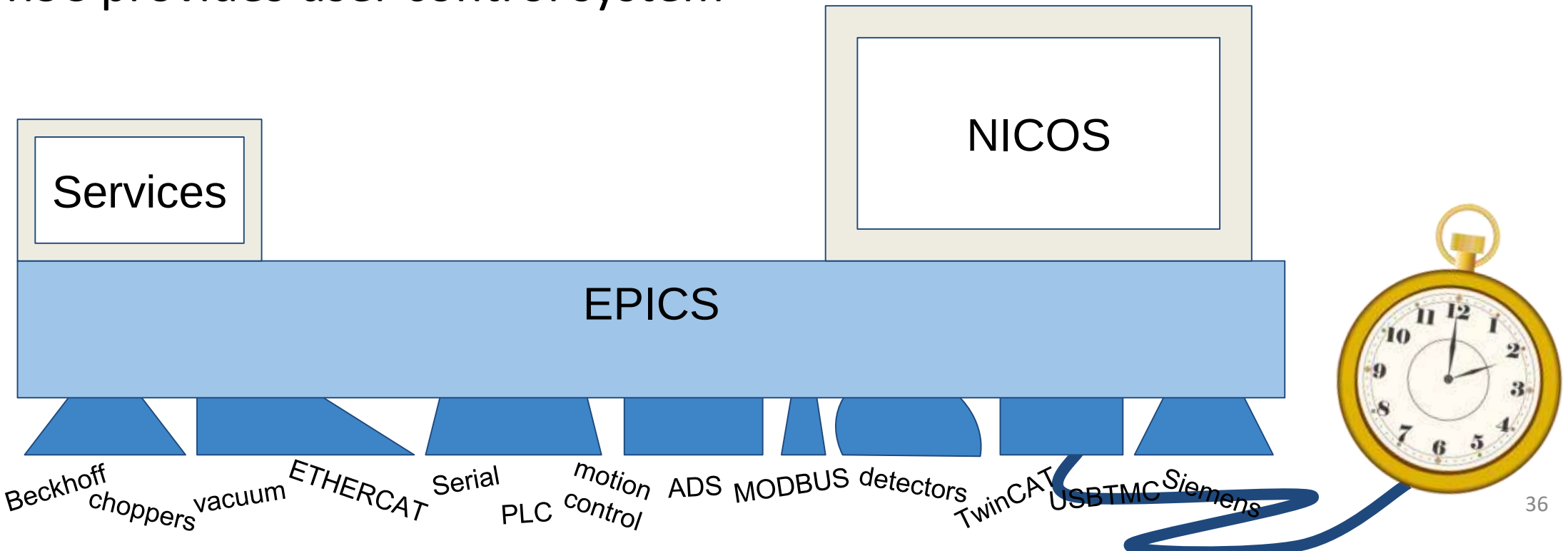
DMSC

- The DMSC is responsible for providing:
  - Experimental data aggregation, streaming, and storage
  - The User Control System (NICOS). This is the experimental scripting layer.

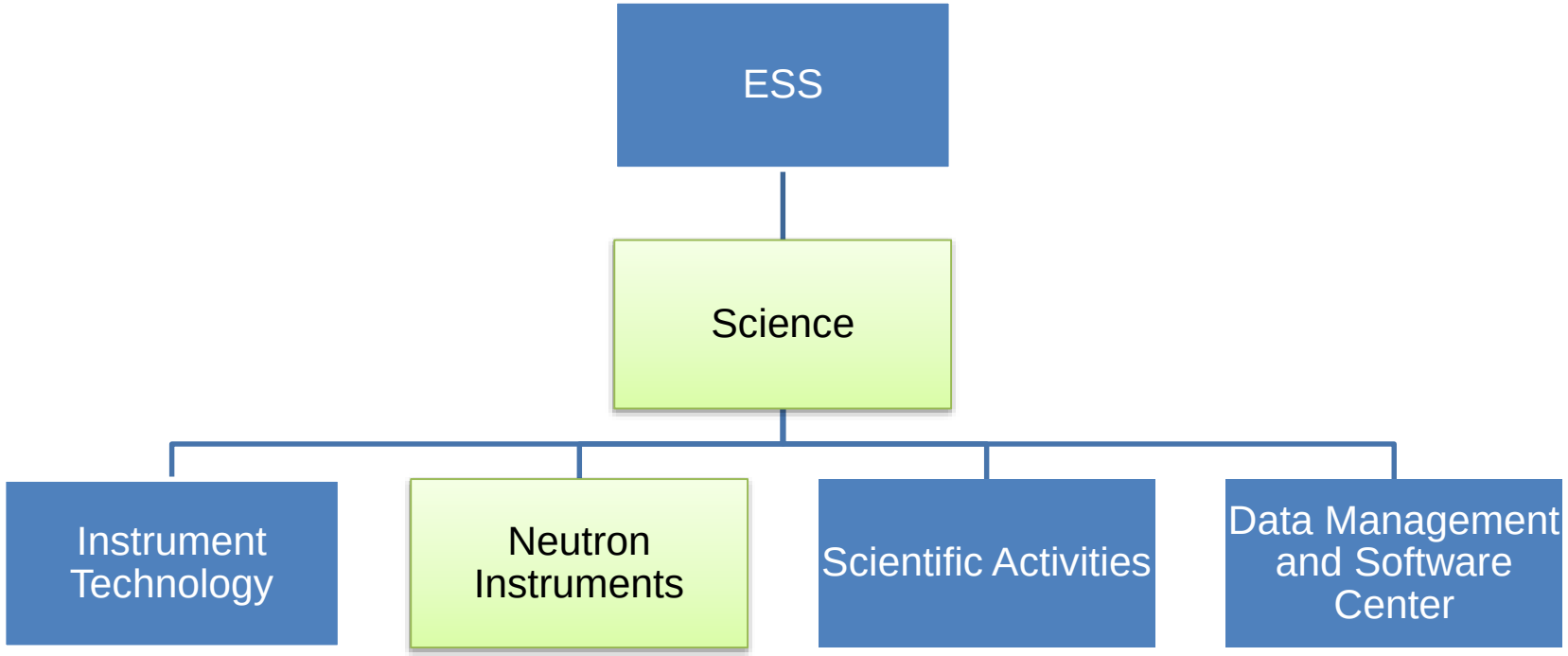


The ESS control system architecture

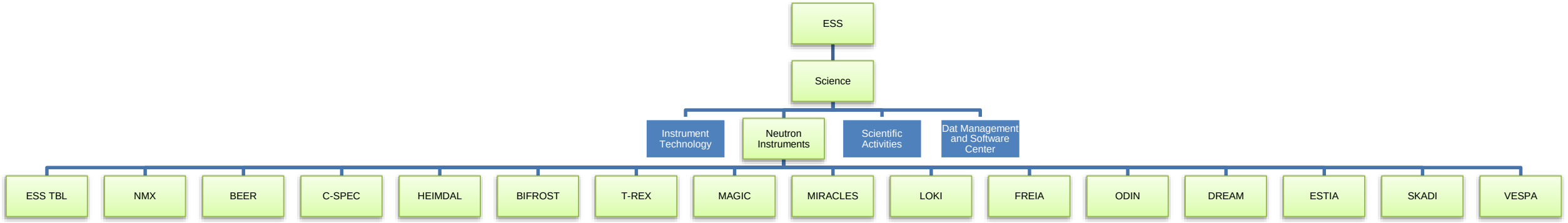
- ICS provides the EPICS Layer
- ICS provides the timing system
- DMSC provides user control system



Neutron Instruments

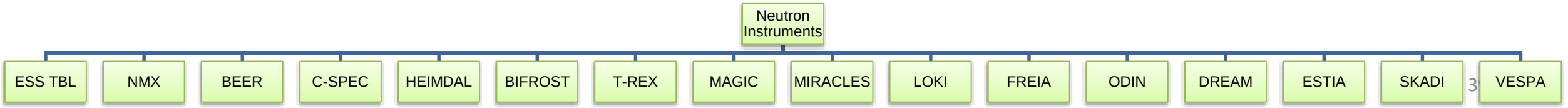


Neutron Instruments

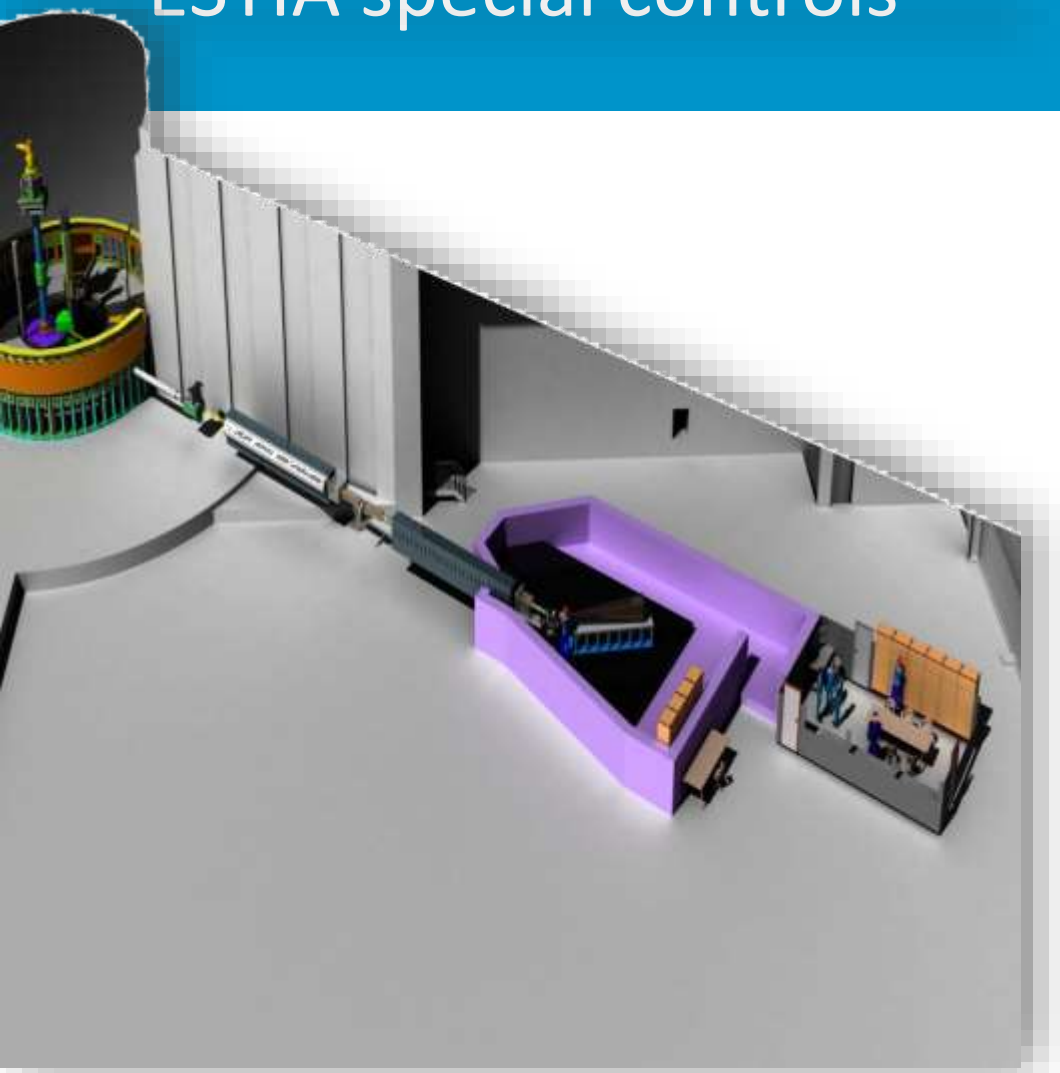


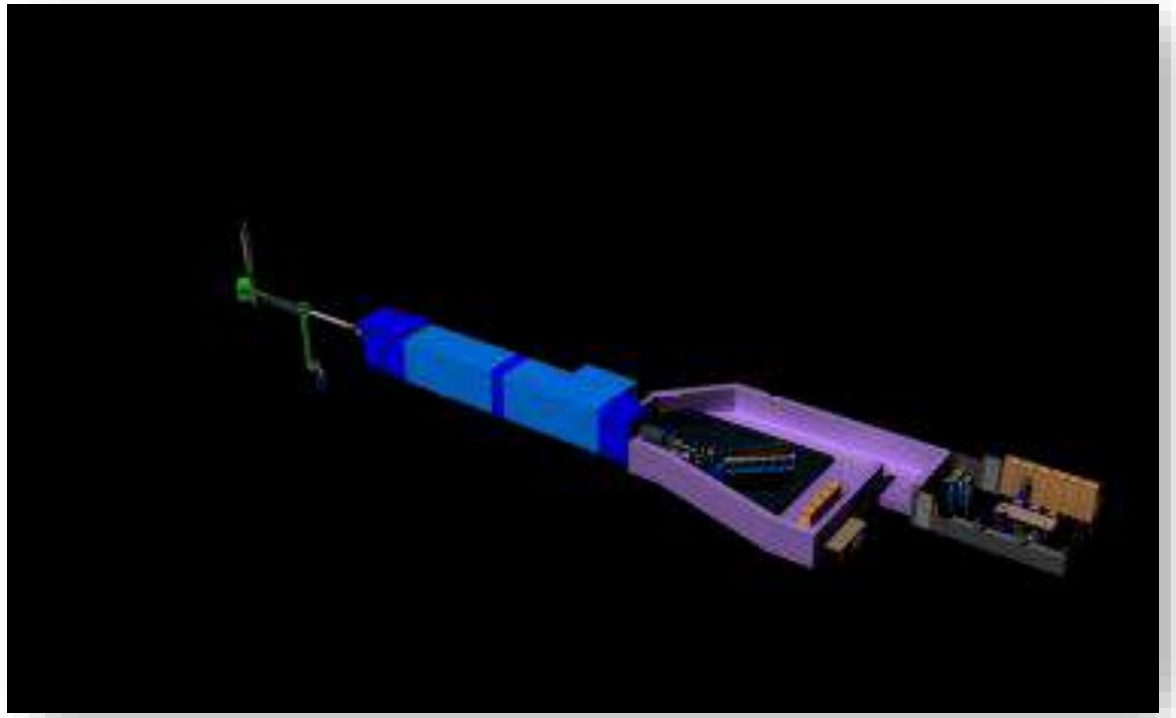
Special vs. Generic Controls

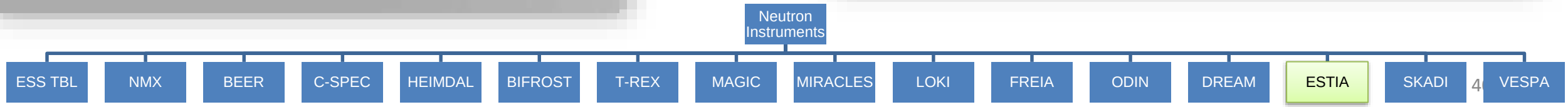
- Generic controls solutions are being developed with the Instrument Technology Groups
  - Chopper Integrated Controller (CHIC)
  - Motion Control Unit
  - Detector readout backend
- Special controls may be needed for components which
  - Do not fall within the scope of the Instrument Technology Groups (e.g. cameras)
  - Are unique to the instrument (e.g. robots)
  - Require specialized timing (e.g. oscillating magnets)



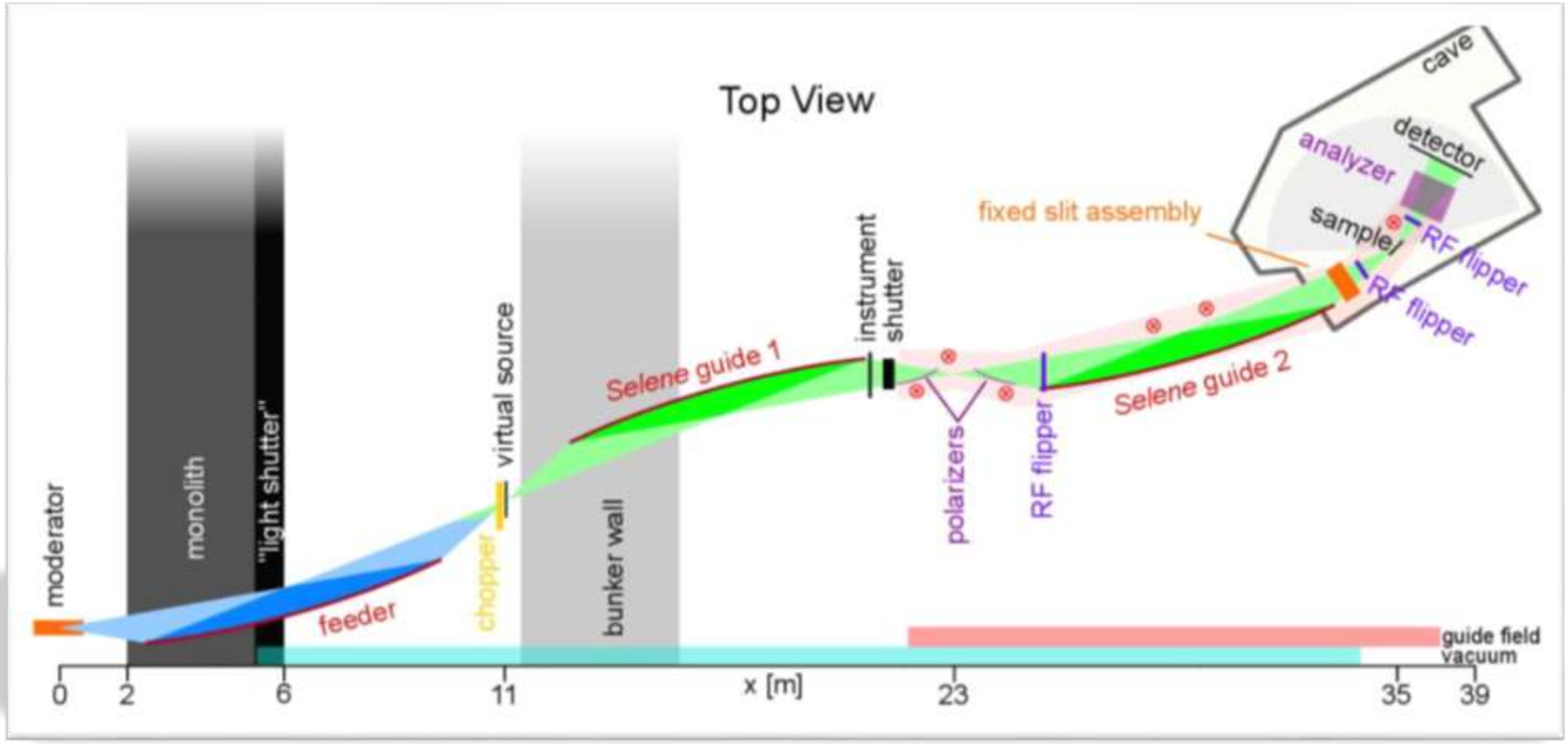
ESTIA special controls







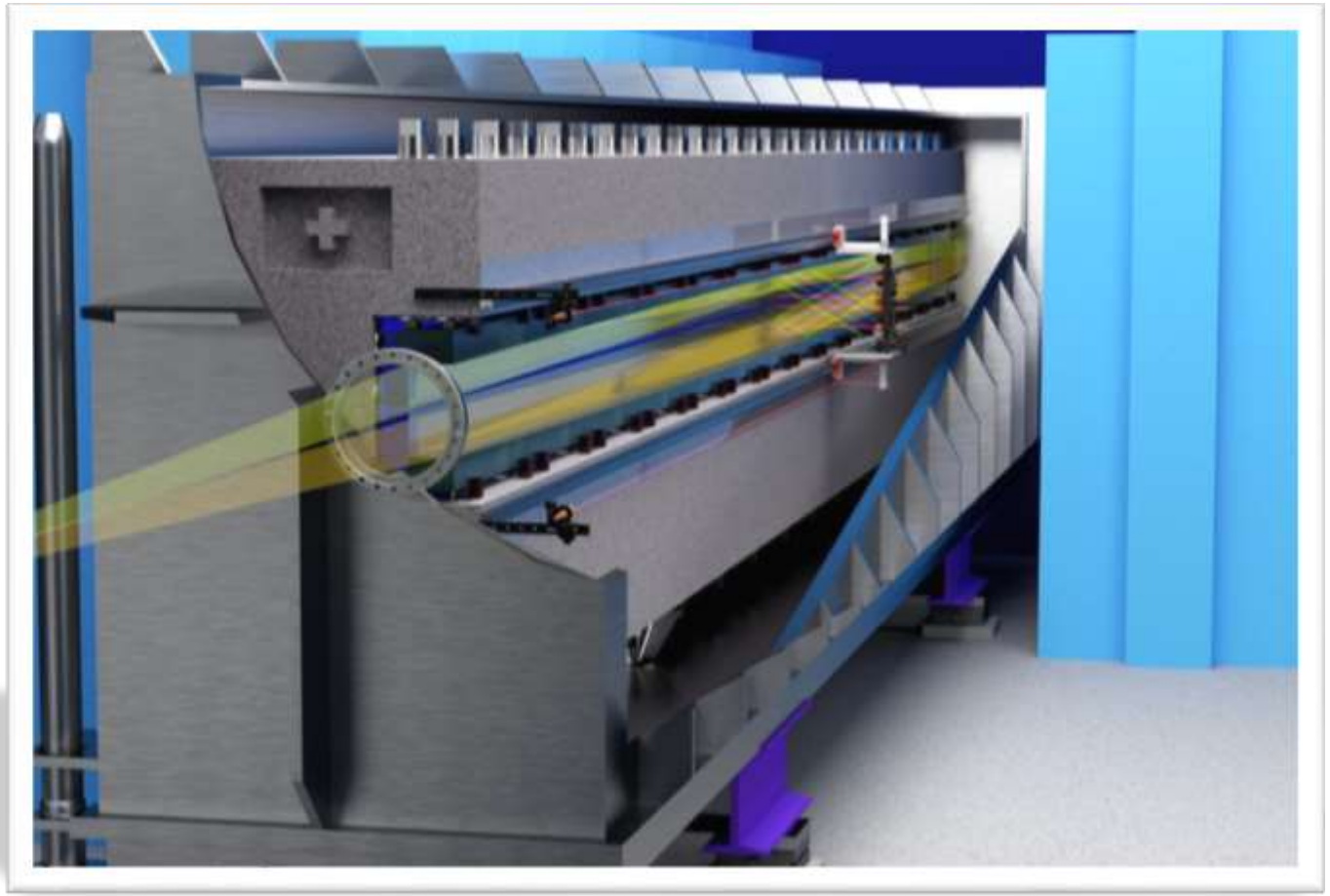
ESTIA – Selene Guide



Neutron Instruments

ESS TBL | NMX | BEER | C-SPEC | HEIMDAL | BIFROST | T-REX | MAGIC | MIRACLES | LOKI | FREIA | ODIN | DREAM | ESTIA | SKADI | VESPA

ESTIA - Selene Guide



Neutron Instruments

ESS TBL | NMX | BEER | C-SPEC | HEIMDAL | BIFROST | T-REX | MAGIC | MIRACLES | LOKI | FREIA | ODIN | DREAM | **ESTIA** | SKADI | VESPA

ODIN – Fast Camera

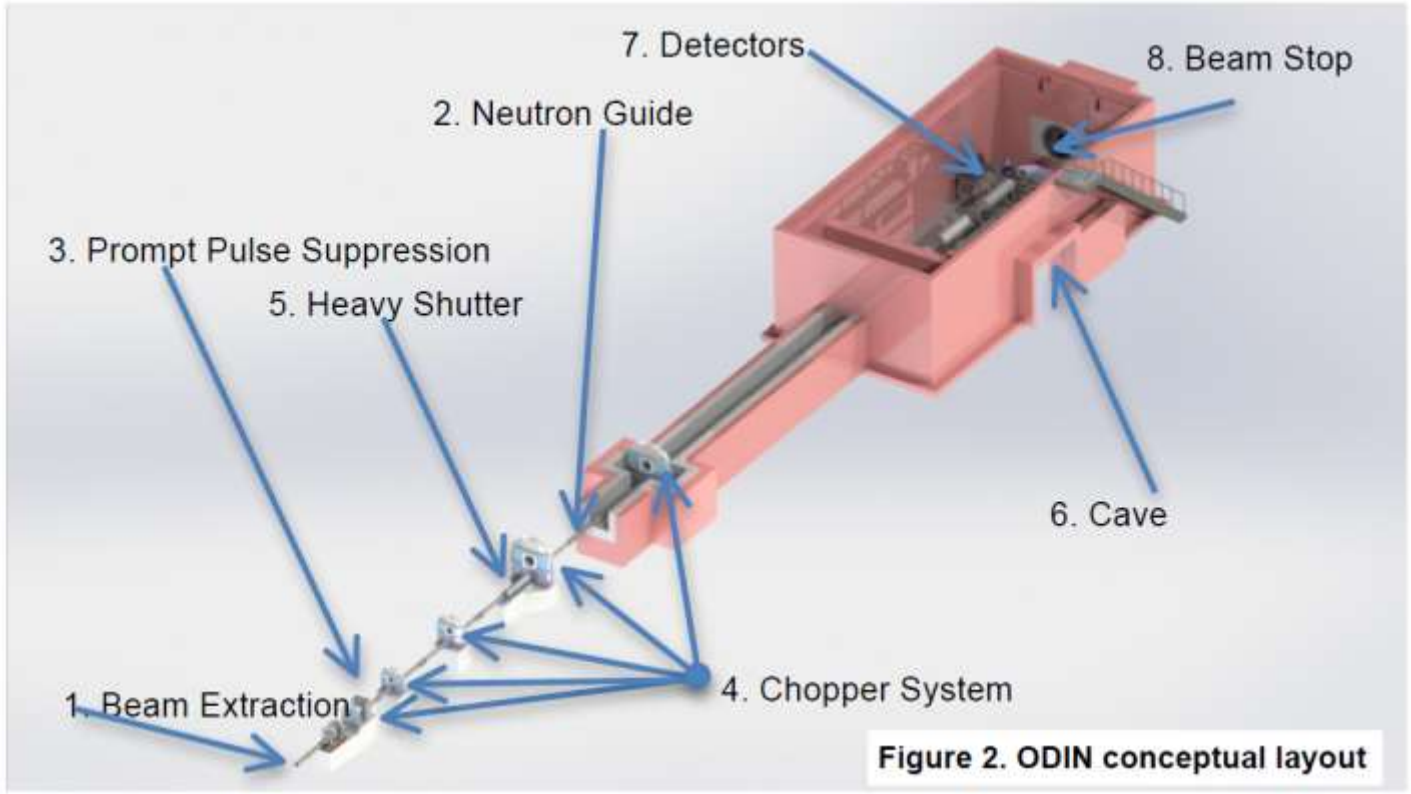
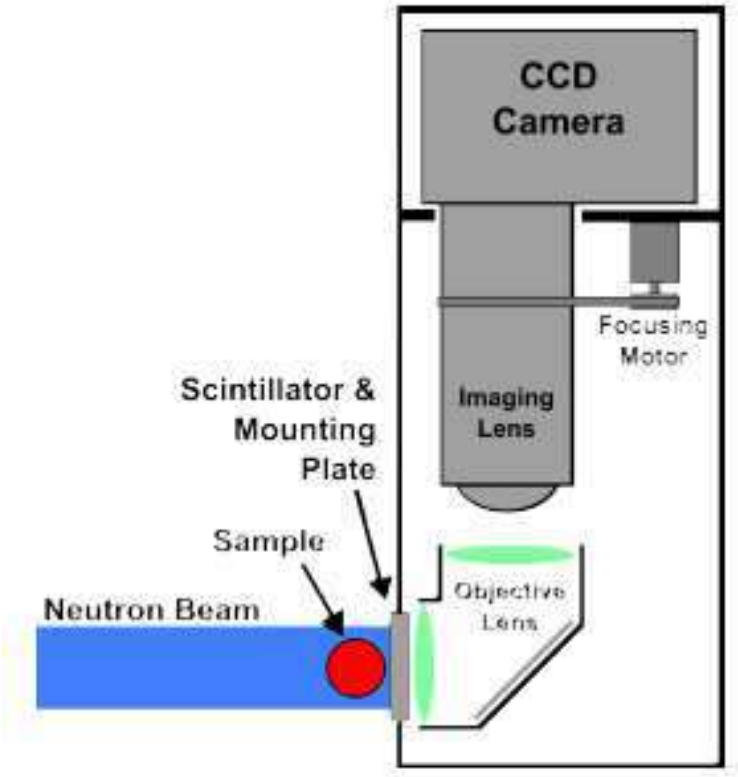
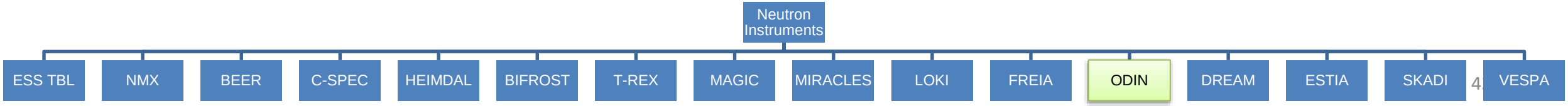
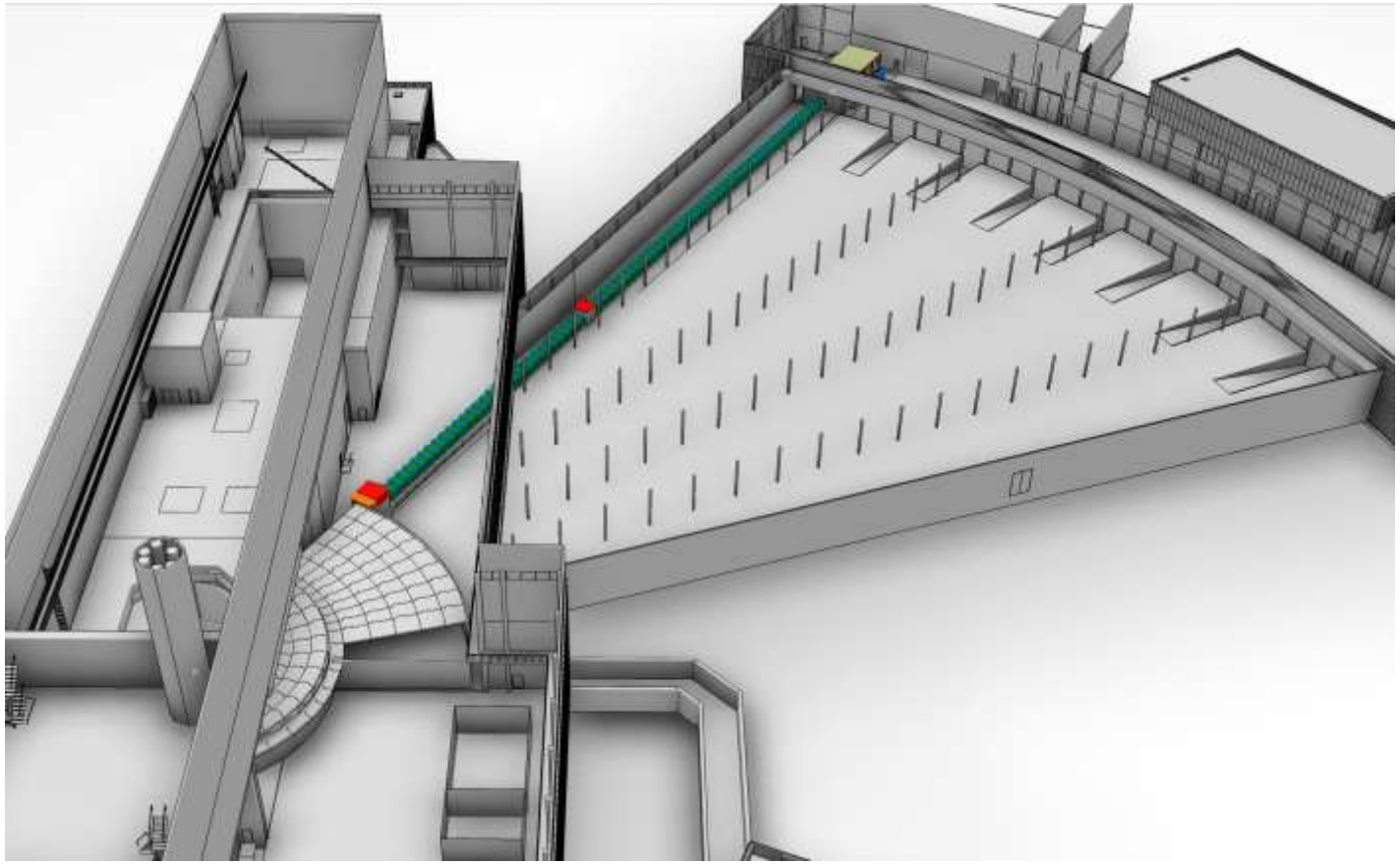


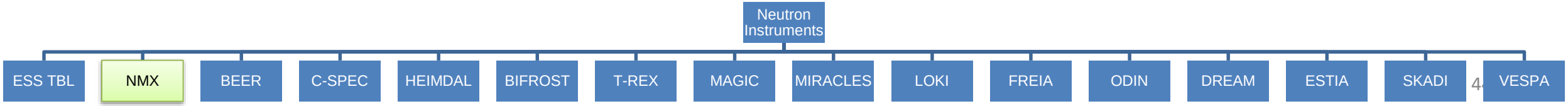
Figure 2. ODIN conceptual layout



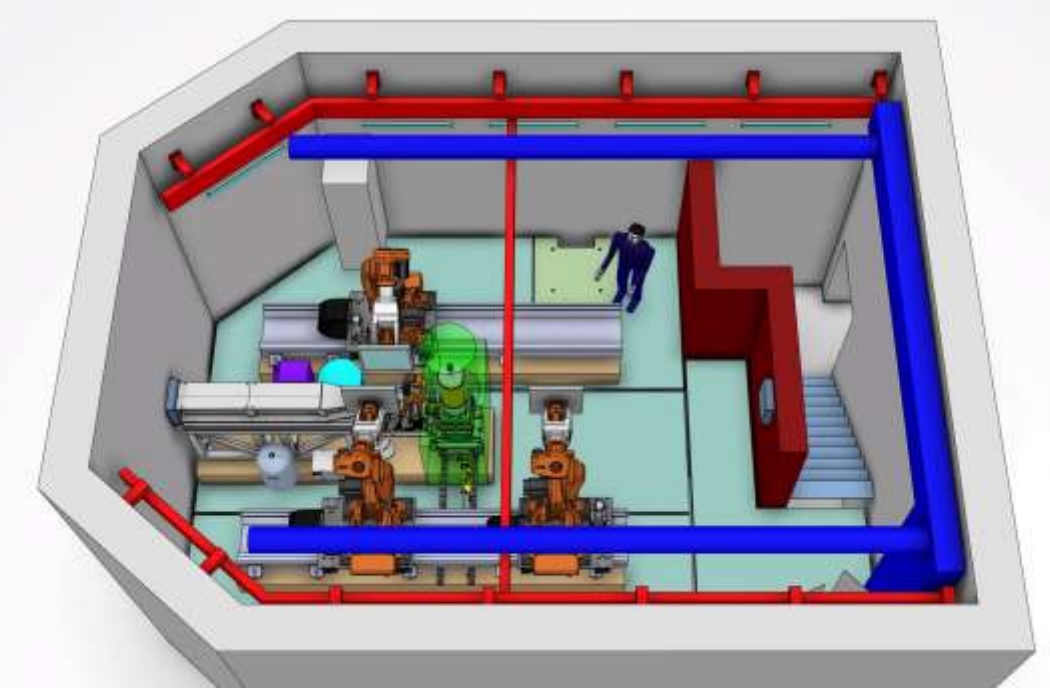


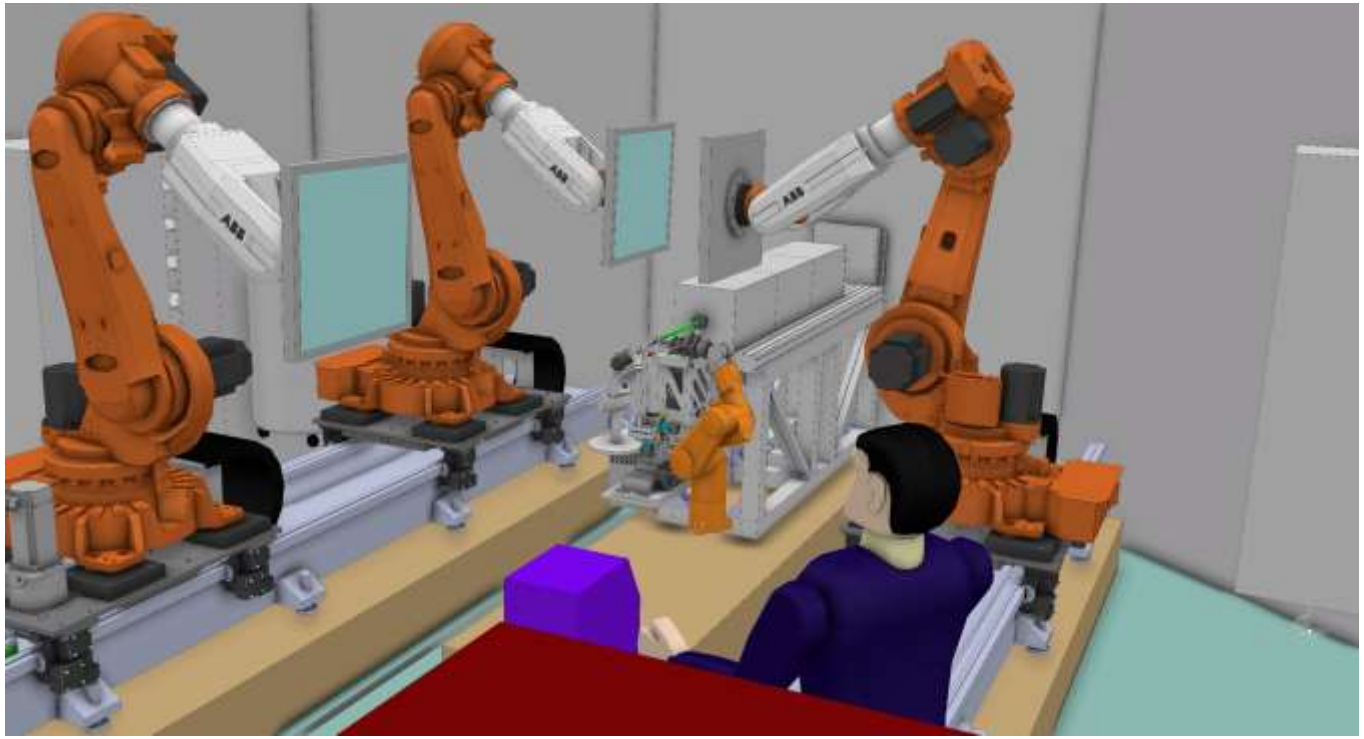
NMX special controls

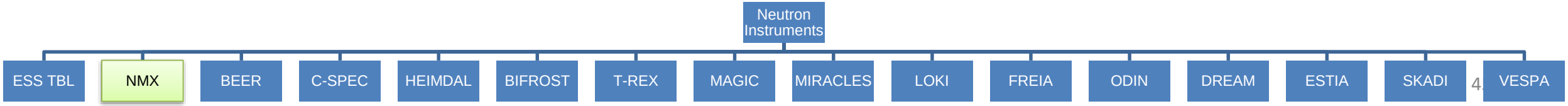




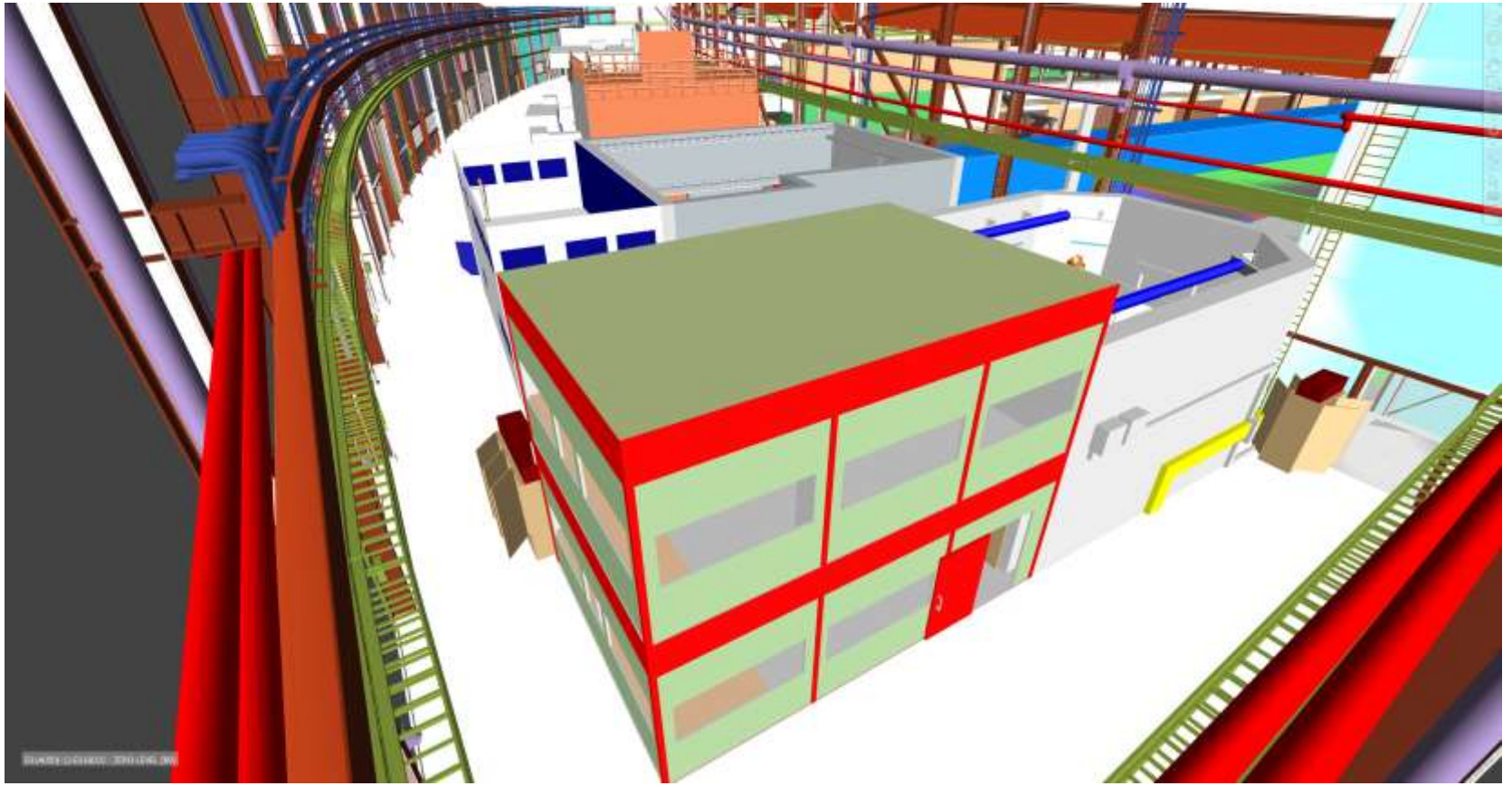
NMX – Robot Arms





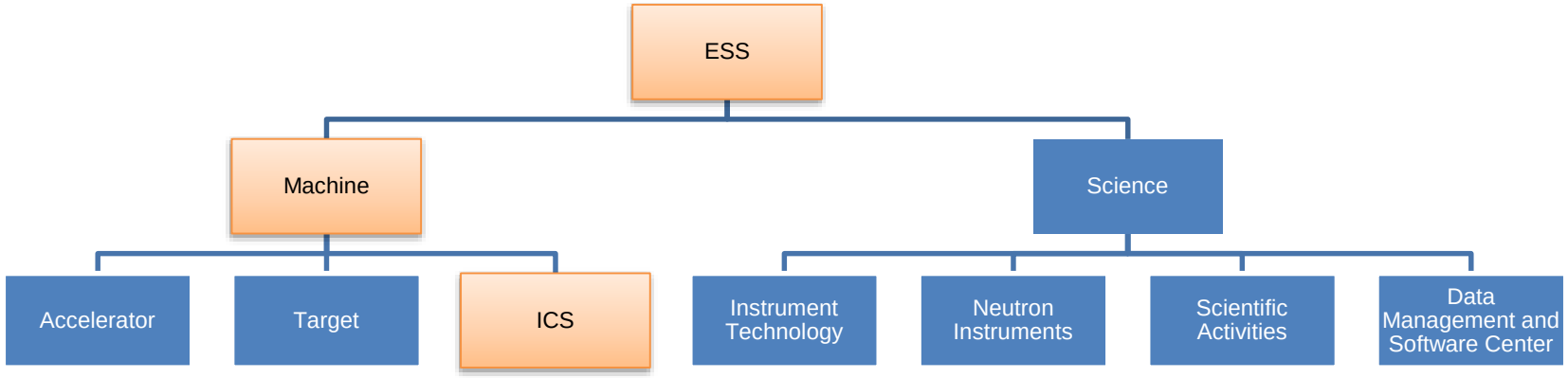


NMX – Sample Preparation Area

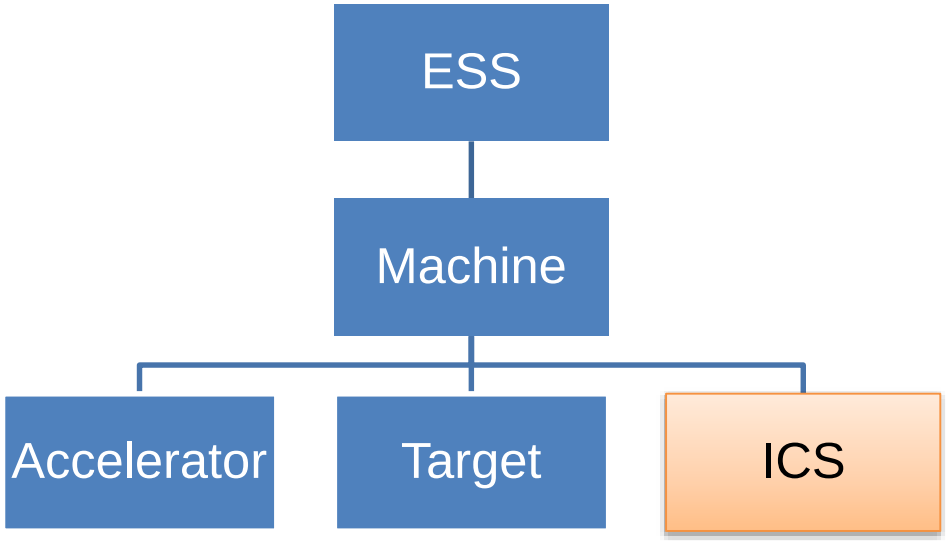


Integrated Control System (ICS)

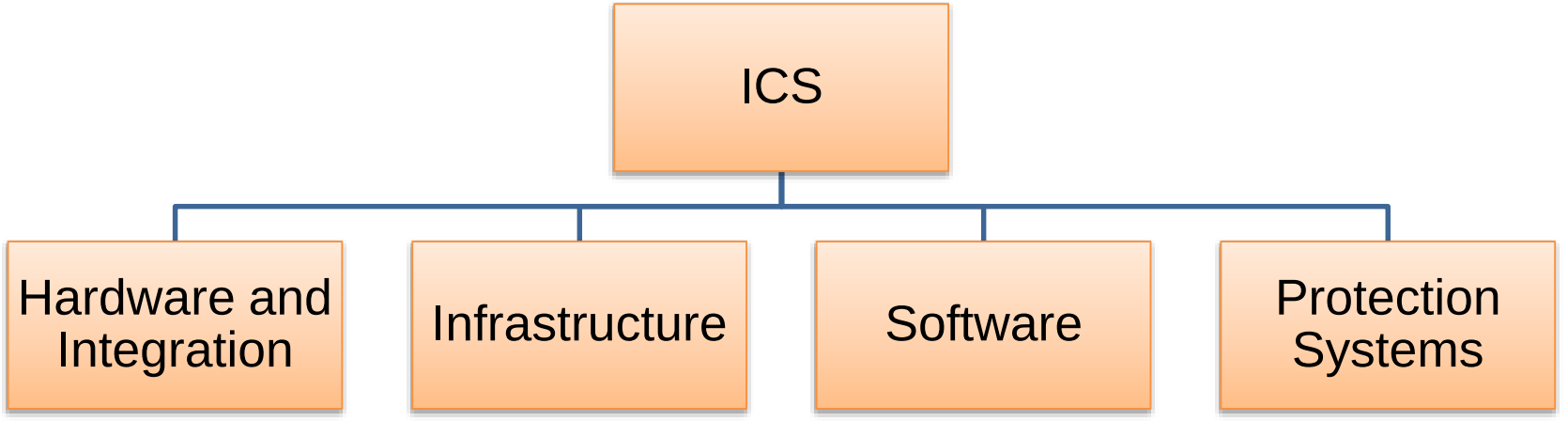
ICS


ESS
Machine
Science
Accelerator
Target
ICS
Instrument Technology
Neutron Instruments
Scientific Activities
Data Management and Software Center

ICS

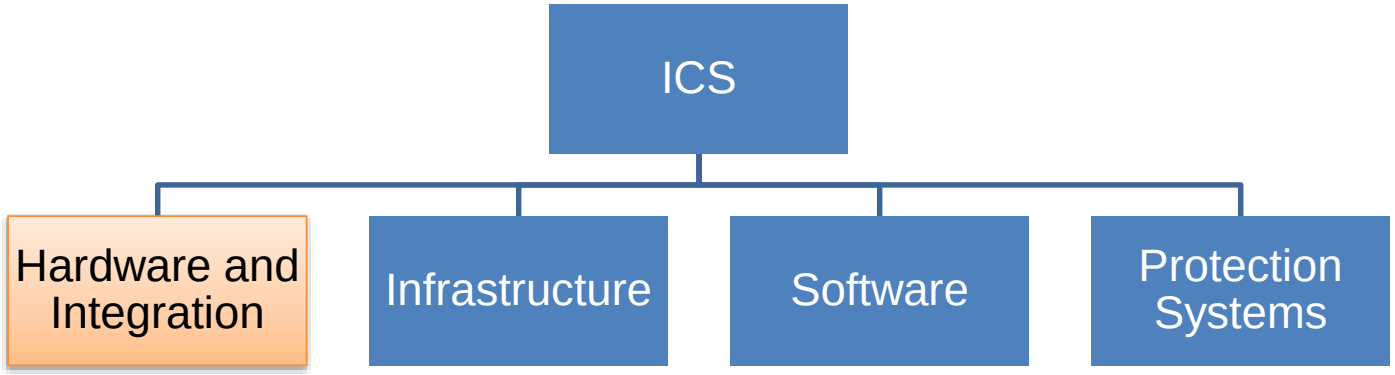


ICS


ICS
Hardware and Integration
Infrastructure
Software
Protection Systems

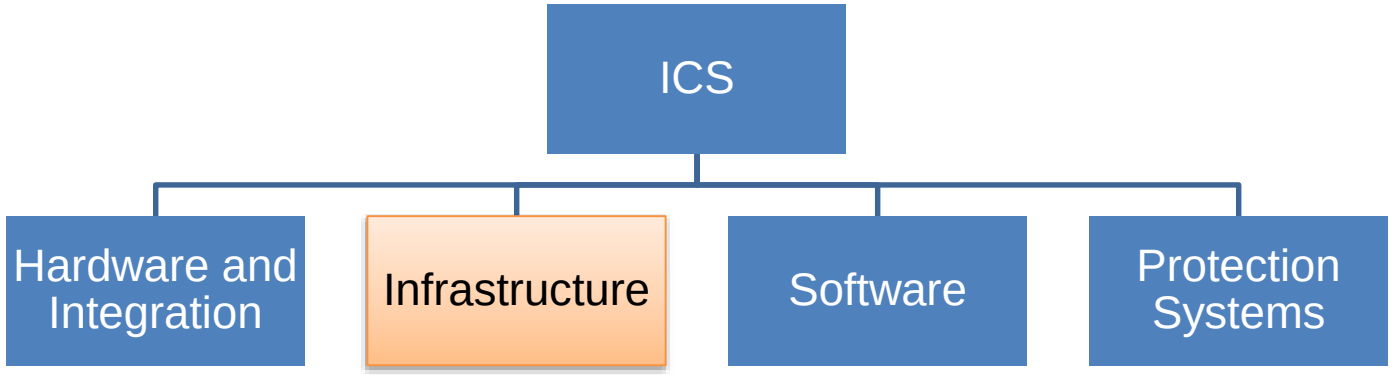
Hardware and Integration

- Timing System
- Electronic platforms
- EPICS Layer
- PLC Programming



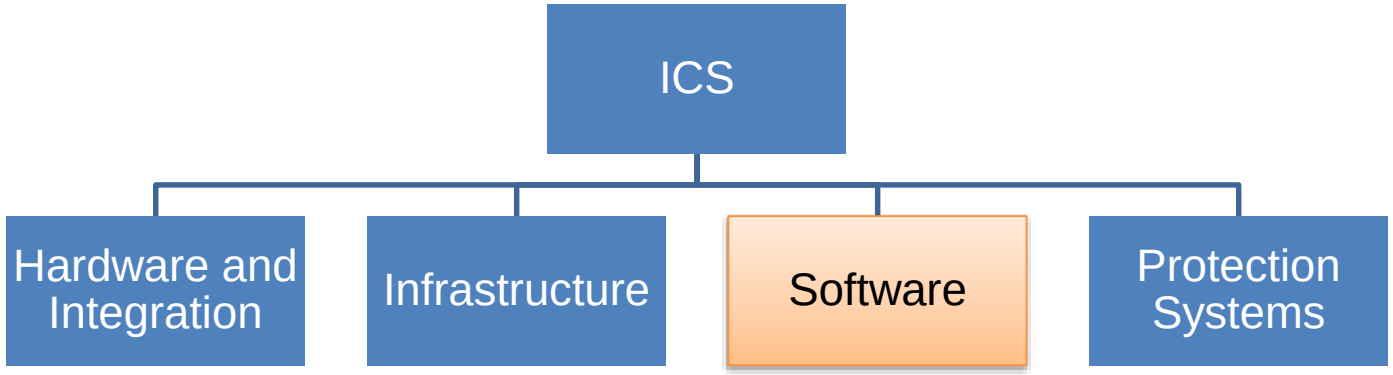
ICS Infrastructure

- Technical network
- Control system computing/storage
- Control Rooms
- Software deployment
- Virtualization



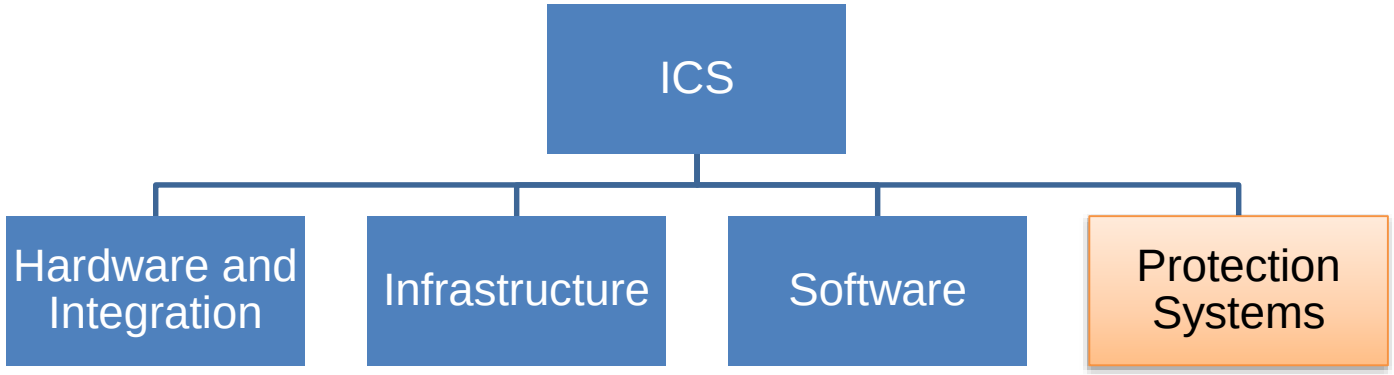
ICS Software

- Control system software applications
- Configuration Management
- Physics online model
- EPICS Core Development



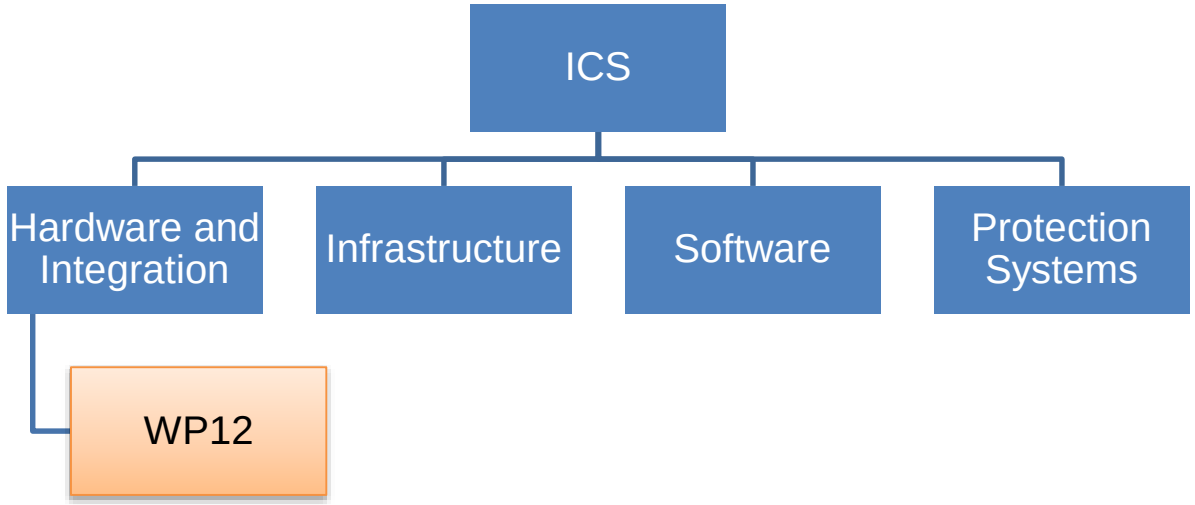
Protection Systems

- Personnel safety system
- Machine protection system



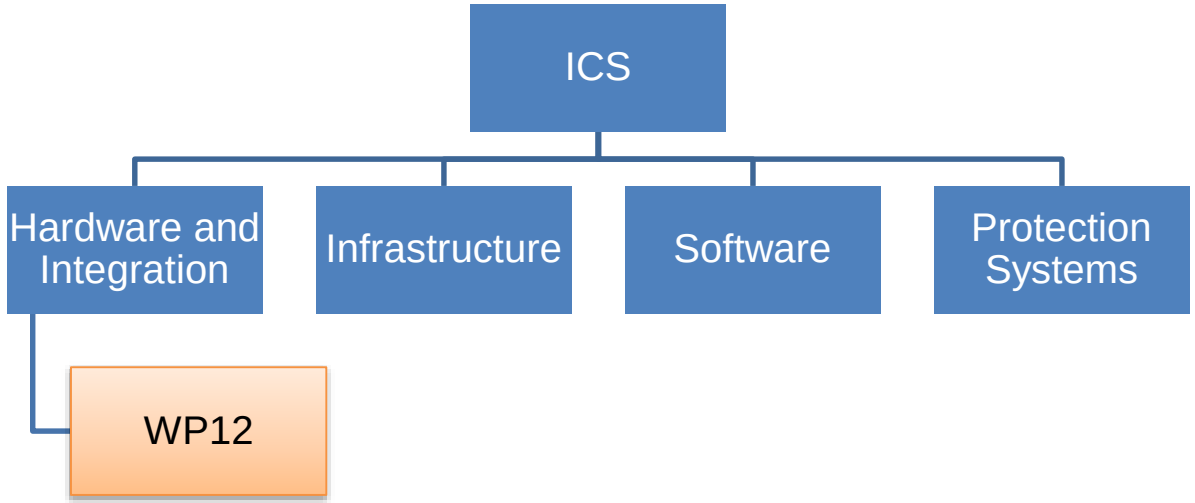
Work Package 12 - Instruments

- ICS point of contact for NSS project
  - Instrument teams
  - Instrument technology groups
  - Sample Environment
  - DMSC



Work Package 12 - Instruments

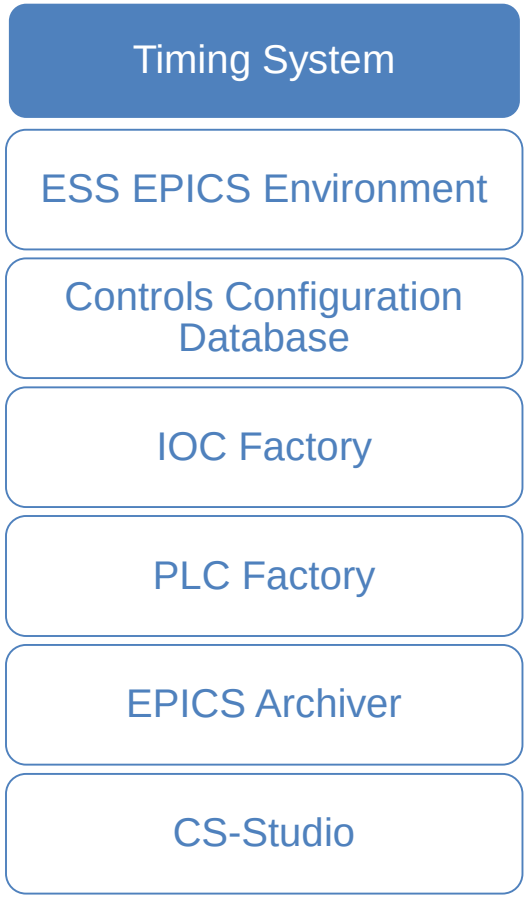
- EPICS and timing system integration for
  - generic technologies
  - sample environment
  - instrument specific equipment
- Supply timing system and EPICS controls hardware to ESS instruments



ICS Technology and Software

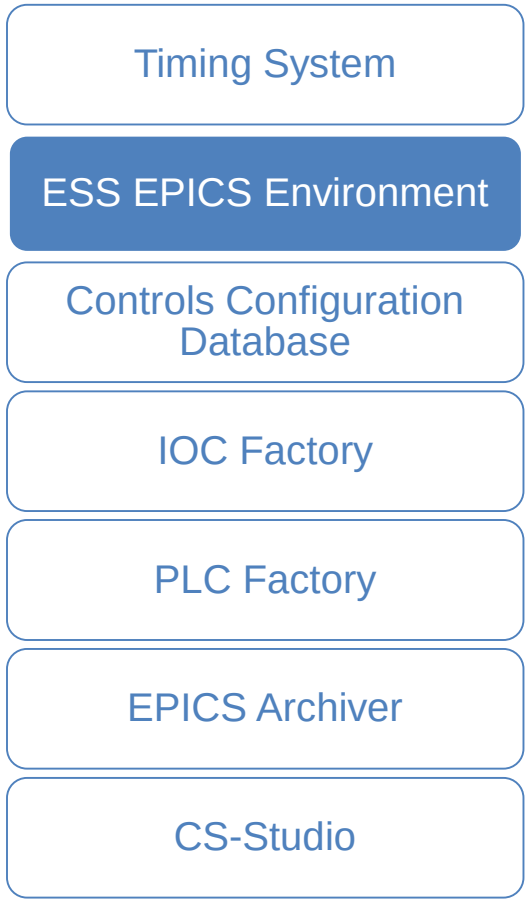
- Timing System
- ESS EPICS Environment
- Controls Configuration Database
- IOC Factory
- PLC Factory
- EPICS Archiver
- CS-Studio

MRF Timing System



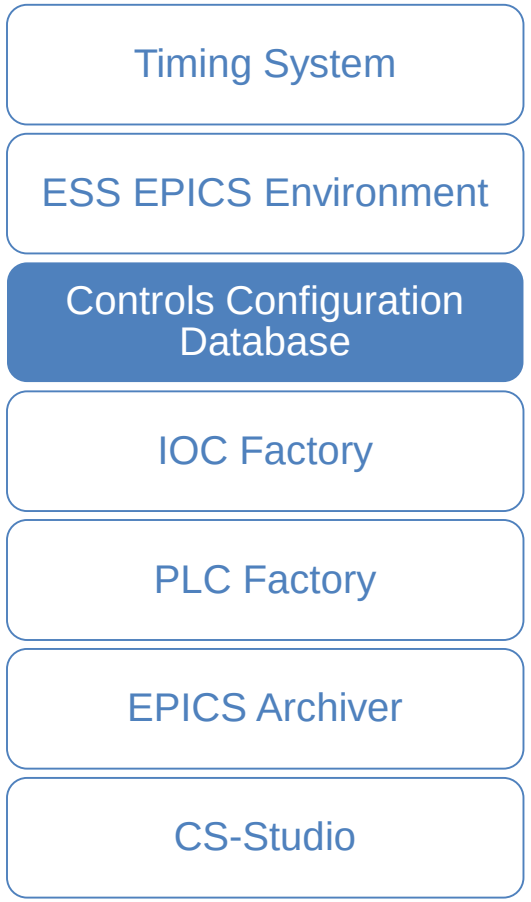
- Micro-Research Finland
- Used to synchronize the entire facility
  - Accelerator
  - Target
  - Instruments
- Provides global event and configuration data
- Directly controls speed and phase of neutron Choppers
- Provides clock and timestamps for neutron instrument data

ESS EPICS Environment (EEE)



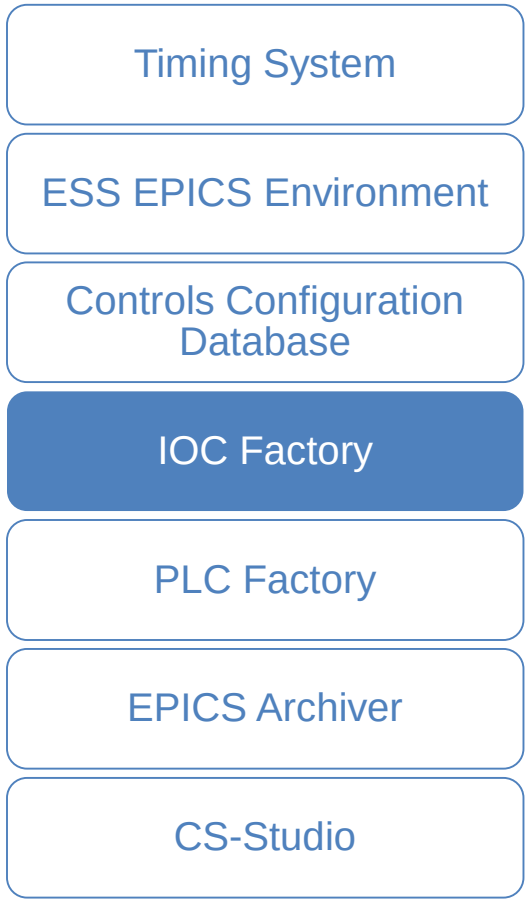
- Build and deployment system for EPICS controls
- IOCs
  - List required modules in startup script
  - Dependencies loaded at runtime
- Deployment using NFS server
  - Control machines know which IOCs to run based on host name

Controls Configuration Database (CCDB)



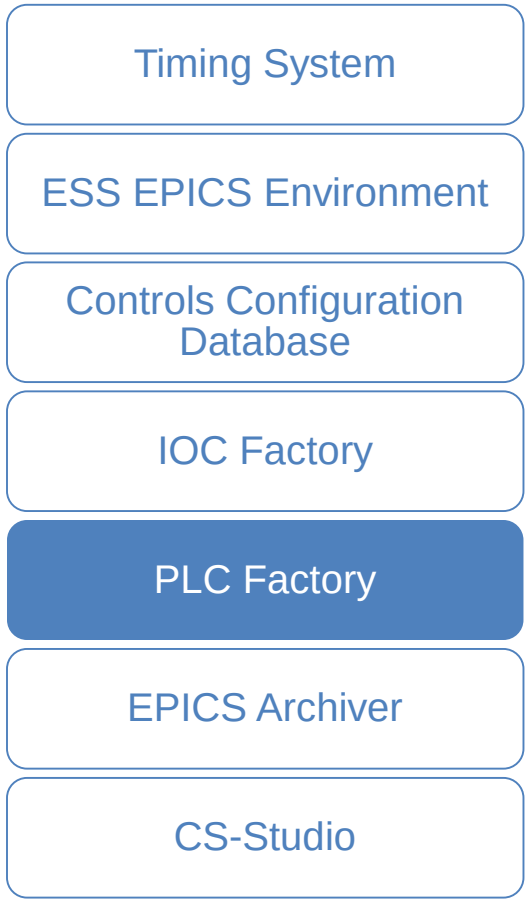
- Used to model ESS control system
- Relationships:
  - Contains
  - Controls
  - Powers
- Model device types
  - Software dependencies
  - Artifacts
- Model connections
  - Specific computer running IOC
  - Specific hardware being controlled
- Several tools consume this data to generate code and automate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

IOC Factory



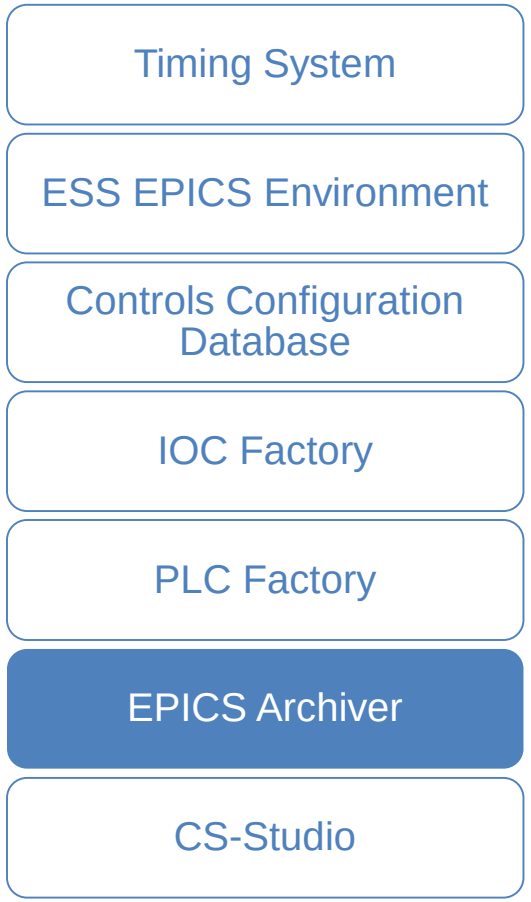
- A tool to manage EPICS IOCs at ESS
  - Configure
  - Deploy
  - Browse
  - Audit
- Consumes control system models from CCDB to generate IOC startup scripts
- Deploys IOC to appropriate server through EEE NFS
- IOC versioning

PLC Factory



- Generates EPICS IOC and PLC code
- Consumes data from CCDB
  - Every device “controlled” by a PLC in CCDB defines a data interface
- PLC code is generated which implements this interface and the communication protocol
  - Just upload this code to the PLC
- An EPICS IOC is generated which automatically exposes this interface on the EPICS layer
  - Just press start

EPICS Archiver Appliance

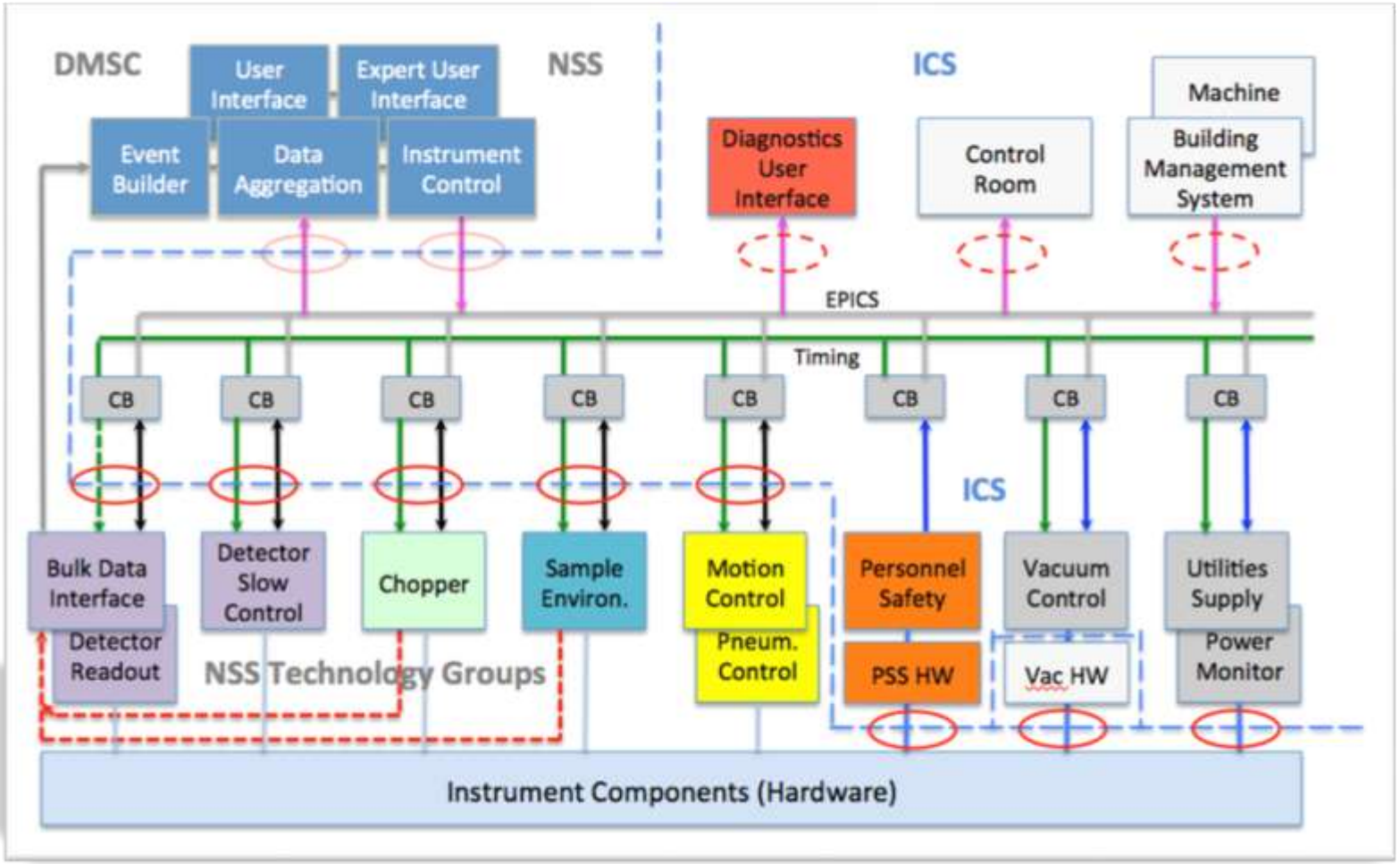


- An EPICS client which continuously records PV values
- Historical values and trends
- Web interface and HTTP API
  - Configure
  - Query
- Data retention and decimation policies

Control System Studio

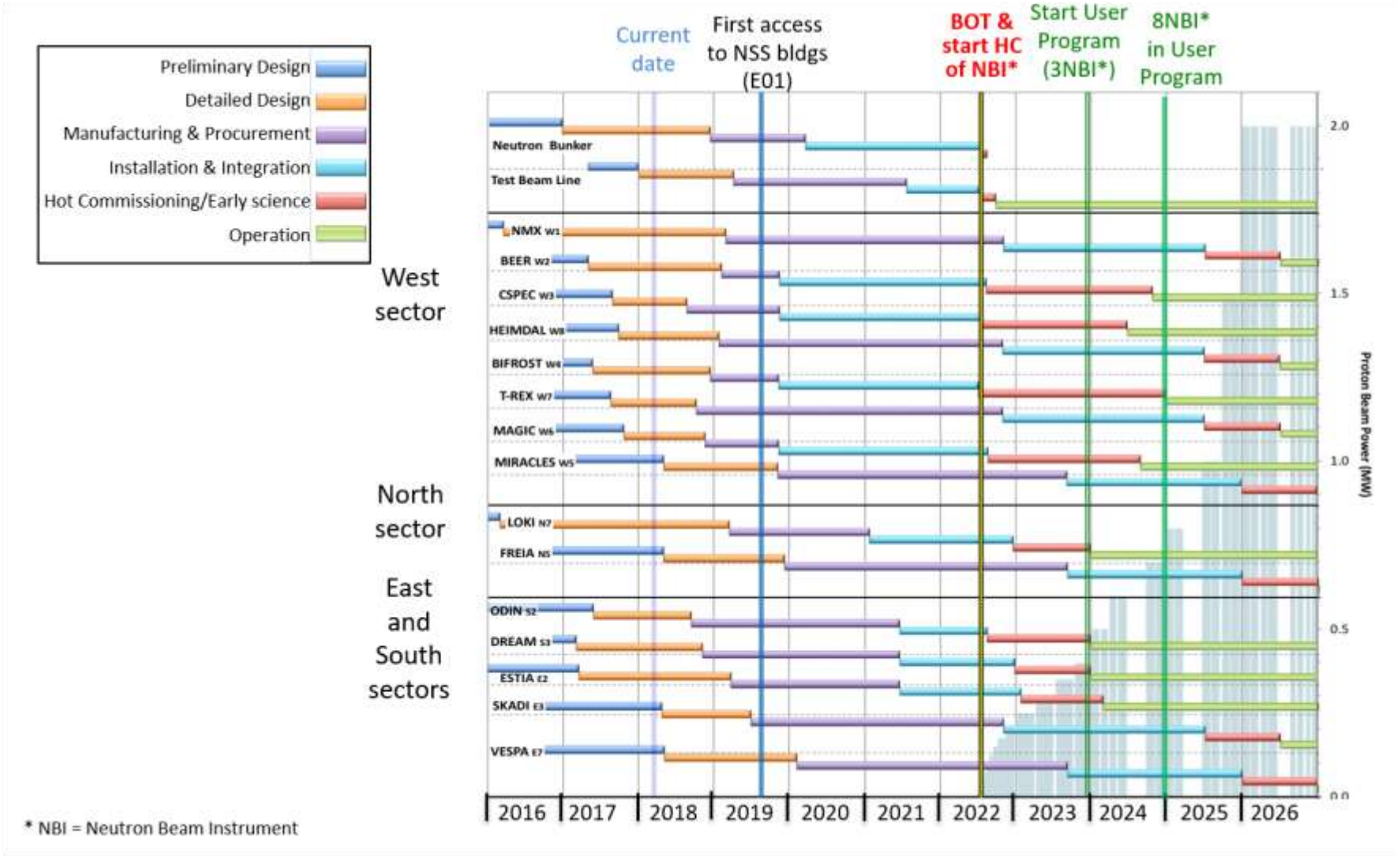
- GUI which can help users interact with EPICS and related software
  - Tools to construct custom Operator Interfaces
  - View historical data from archiver
  - Search for PVs listed in Channel Finder
- Will be used for all expert engineering screens at ESS
  - (NICOS will be used for experimental control)

Overview of NSS-ICS technology



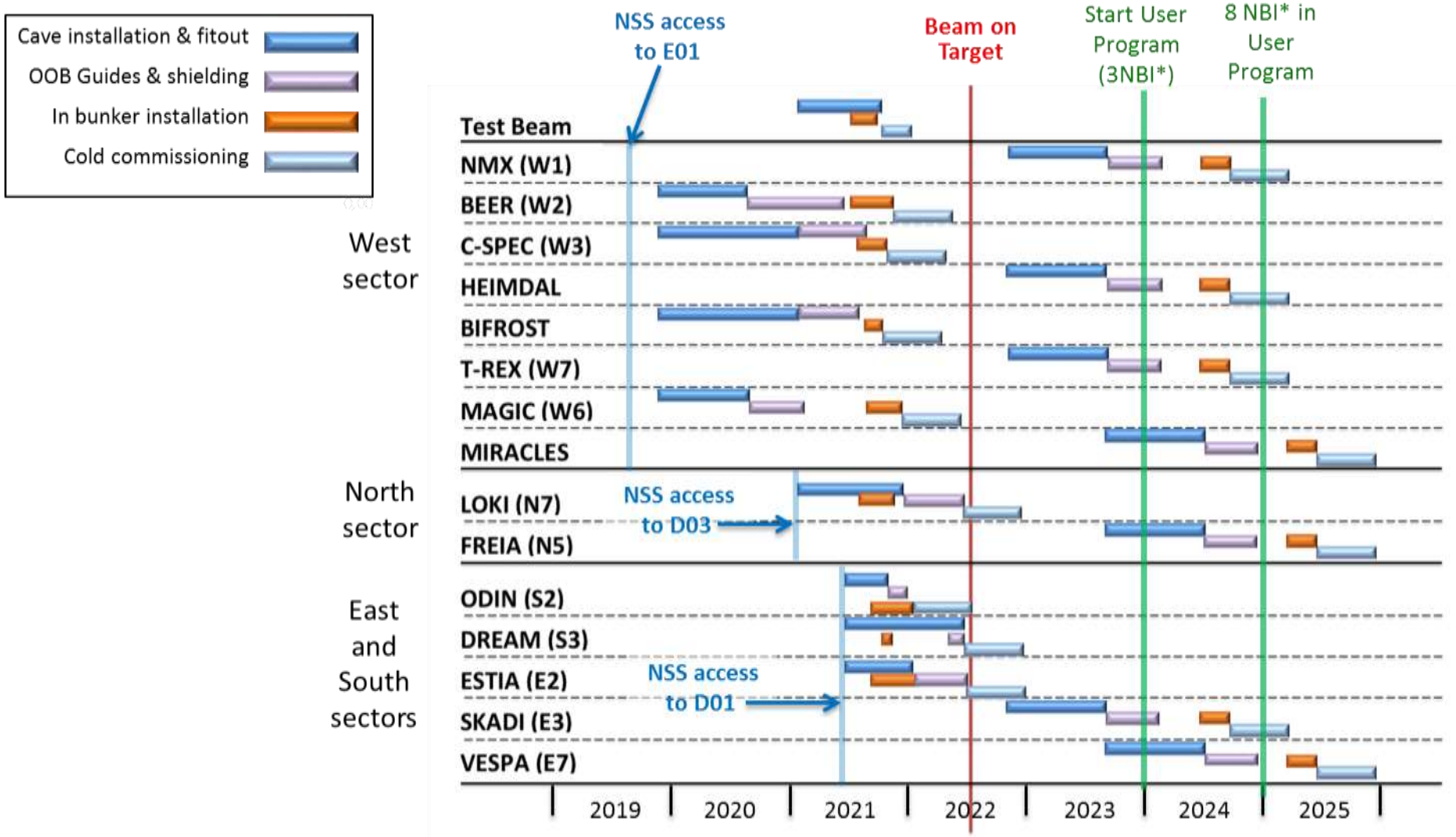
Timeline, Deliverables, and Resources

Instrument Timeline



* NBI = Neutron Beam Instrument

Instrument Timeline



Effort required this year (Choppers)

Date	Type	Description	ICS Deliverables
Now	Milestone	14 Hz tested at V20	• Working timing system configuration at V20 (in sync with detectors)
April 2018	Deliverable	Prototype CHIC	• CHIC prototype fully integrated in EPICS
June 2018	Deliverable	Condition Monitoring	• Chopper condition monitoring system integrated into EPICS
October 2018	Deliverable	High speed Frequencies	• Timing system configuration which supports 7-406 Hz chopper frequencies • Controls solution to select frequency
November 2018	Milestone	System Tested at Airbus	• Working timing system configuration for high speed choppers • EPICS controls for timing system • EPICS integration of Chopper Integrated Controller (CHIC) • Support software

Effort required this year (Detectors)

Date	Type	Description	ICS Deliverables
Now	Milestone	Demonstrator board tested at V20	• EPICS control of demonstrator initialization • Working timing system configuration at V20 (in sync with choppers)
September 2018	Milestone	Master module demonstrated	• Working timing system configurations for demonstrator • Slow control of master module in EPICS • Status monitoring of master module in EPICS
December 2018	Milestone	Generic frontend readout demonstrated	• Slow control of frontend in EPICS • Status monitoring of frontend in EPICS • Calibration/Save and Restore services
Construction Phase	Deliverable	Detector slow controls (HV, Gas handling, etc)	• All supporting equipment for the detectors must be integrated into EPICS

Effort required this year (Motion)

Date	Type	Description	ICS Deliverables
Now	Deliverable	ESTIA R&D Motion Control	• EPICS integration of single axis motors • An in-kind EEE deployment at PSI • Integration of interferometer • Interferometer feedback loop to motion controller
April 2018	Deliverable	V20 Slits Installation	• EPICS integration of slits (virtual axis) • In kind EEE deployment on V20 beamline in berlin
Construction Phase	Deliverable	Timing system integration with Motion Control Unit	• Timing system configuration for high speed motion control
Construction Phase	Milestone	Full MCU functionality demonstrated	• Timing, EPICS, and support software sufficient to demonstrate all MCU functionality necessary for instruments (test stand)

Effort required this year (Sample Environment)

Date	Type	Description	ICS Deliverables
2018	Deliverable	Plug and play solution	• Controls solution (deployment strategy) for mobile and composable sample environment equipment
2018	Deliverable	2018 pool equipment integration	• EPICS integration of sample environment pool equipment needed for basic science capabilities
2018	Deliverable	Utilities panel	• Cooling, gas handling, and power controls for instrument cave utilities panel
2018	Deliverable	Sample alignment camera system	• Camera readout and image processing support for sample alignment system

Effort required this year (DMSC)

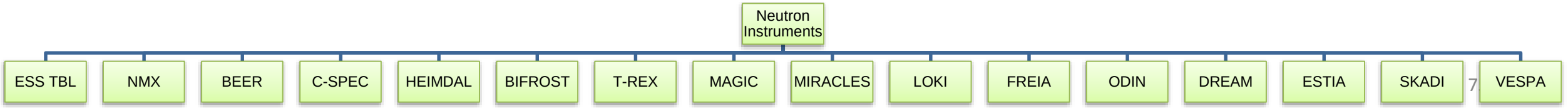
Date	Type	Description	ICS Deliverables
Mid 2019	Milestone	Full data chain processing demonstrated	• Full detector readout system implemented • EPICS metadata and timing fully specified and tested • Slow control metadata from EPICS forwarding demonstrated
Mid 2019	Milestone	User control system (NICOS) ready for beamline operation	• All EPICS and timing and controls concepts demonstrated and incorporated into NICOS

Effort required this year (Instrument Documentation)

Date	Type	ICS Deliverable
June 2018	Deliverable	Chopper Control Design Document
June 2018	Deliverable	Motion Control Design Document
June 2018	Deliverable	Vacuum Control Design Document
June 2018	Deliverable	Cooling Control Design Document
December 2018	Deliverable	Detector Control Design Document
December 2018	Deliverable	Sample Environment Design Document
December 2018	Deliverable	ESS Test Beamline Requirements and Preliminary Design Document
December 2018	Deliverable	ESTIA Controls Requirements and Preliminary Design Document
2018/Early 2019	Deliverable	ODIN Controls Requirements and Preliminary Design Document
2018/Early 2019	Deliverable	DREAM Controls Requirements and Preliminary Design Document

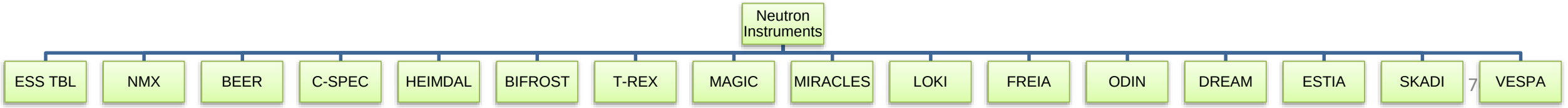
Instrument Documentation

- The neutron instruments are currently going through their detailed design reviews (Tollgate 3)
- The TG3 process has been split into three reviews to allow for early procurement
- ICS is both a reviewer of and contributor to the design documentation of the instruments
  - Conventional controls
  - Personnel safety



WP12 Instrument Documentation

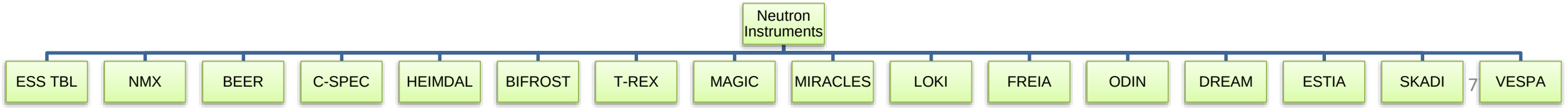
- WP12 will provide preliminary controls design documents for each instrument as input to the TG3s
- WP12 will also provide documentation for
  - Generic controls used on the instrument (chopper, motion, etc.)
  - Instrument specific controls for complex systems (robots, etc.)



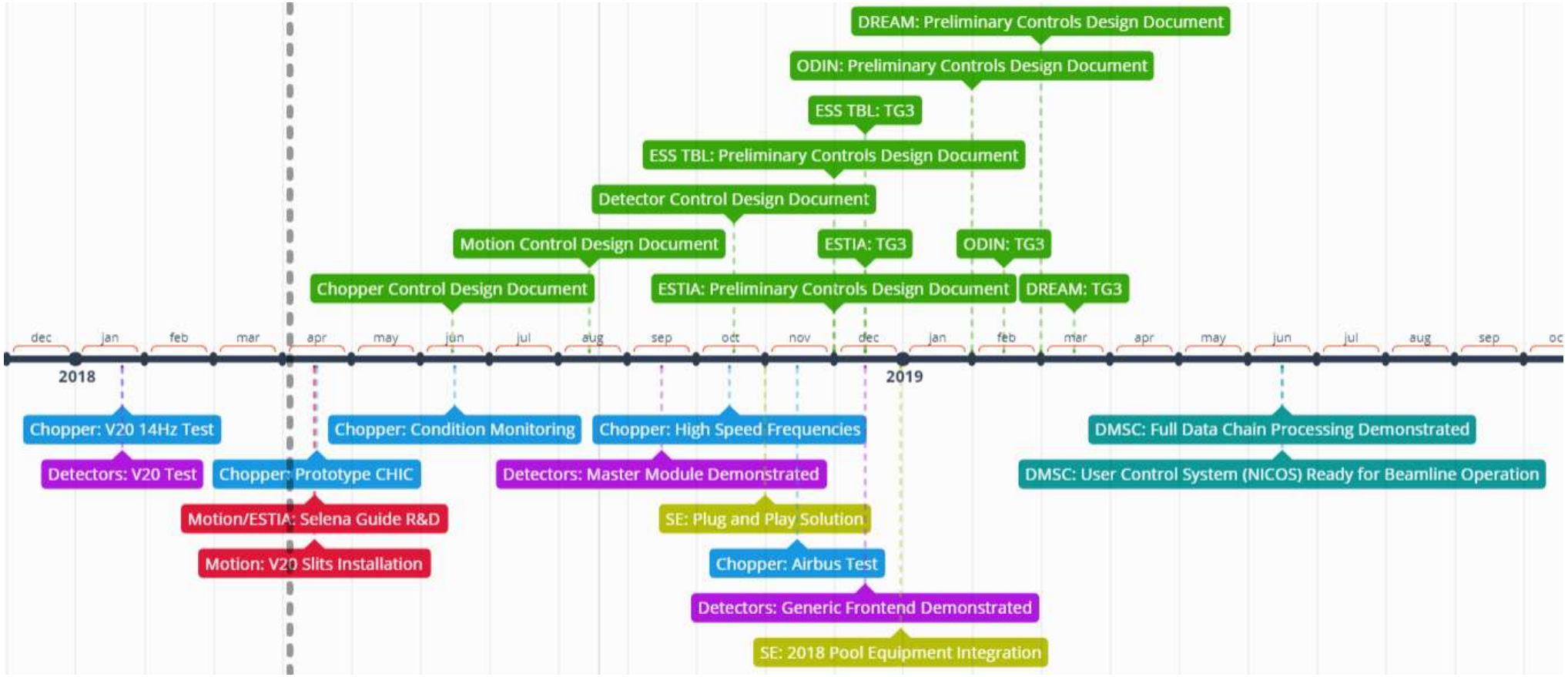
WP12 Instrument Documentation

- Documentation is produced according to the ICS Systems Integration Strategy (ESS-0054678).

- In total, WP12 will produce around 150 individual documents for the instruments and technology groups before 2025.

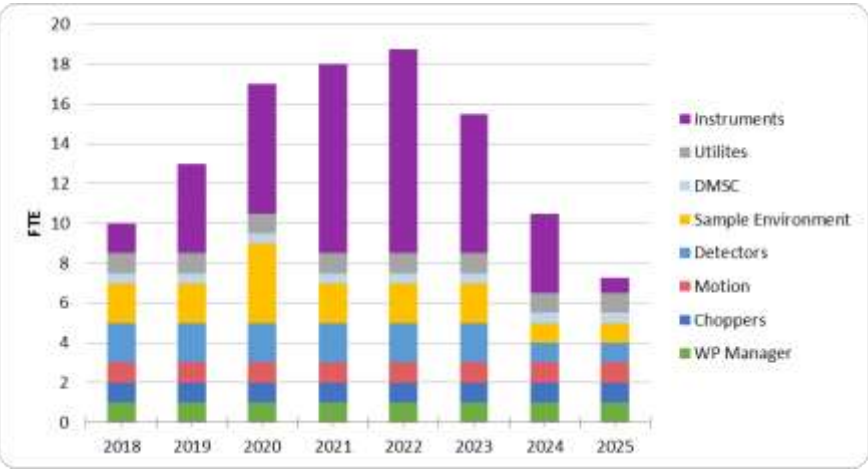


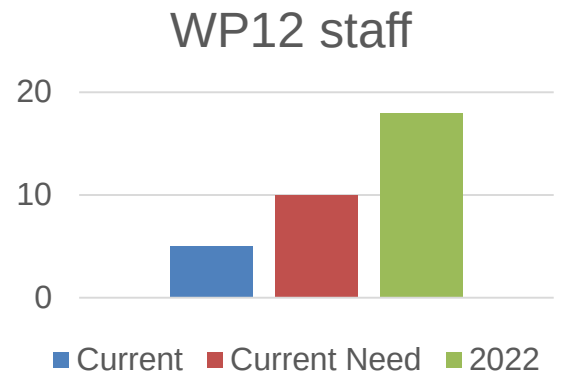
WP12 Timeline



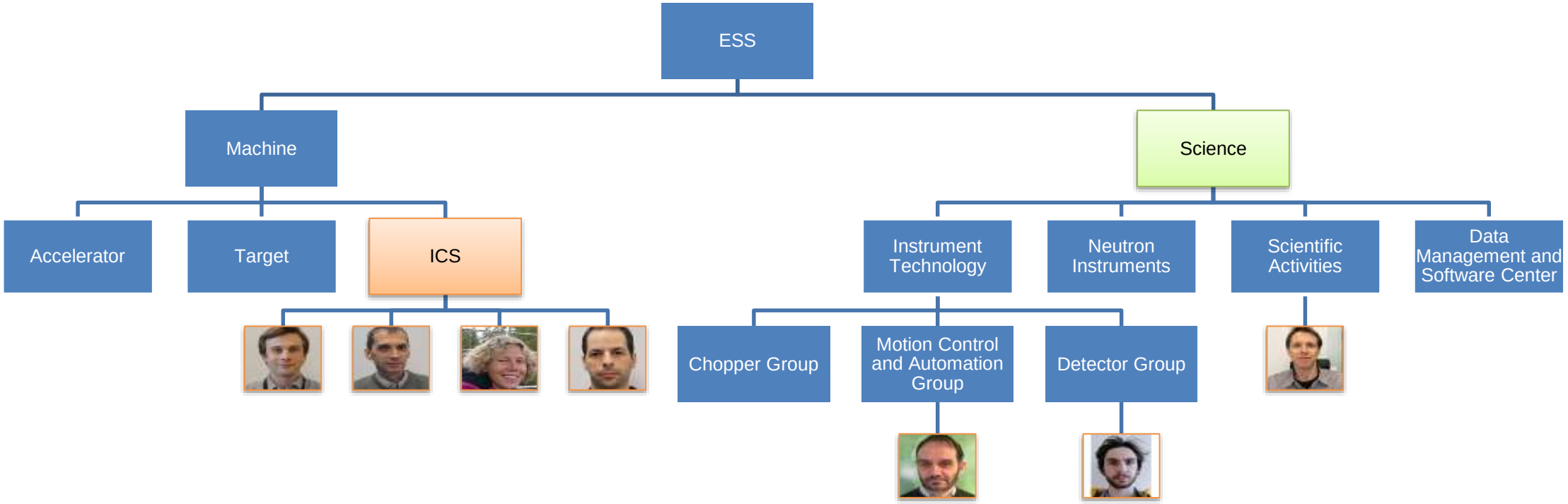
WP12 Effort Estimation

	2018	2019	2020	2021	2022	2023	2024	2025
Total (FTE)	10,0	13,0	17,0	18,0	18,8	15,5	10,5	7,3
WP Manager	1	1	1	1	1	1	1	1
Chopper Group	1	1	1	1	1	1	1	1
Motion Group	1	1	1	1	1	1	1	1
Detector Group	2	2	2	2	2	2	1	1
Sample Environment	2	2	4	2	2	2	1	1
DMSC	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5
Utilities	1	1	1	1	1	1	1	1
Technology Group Total	8,5	8,5	10,5	8,5	8,5	8,5	6,5	6,5
ESS TBL	0,5	0,5	0,5	1	0,25			
ESTIA	0,5	0,5	0,5	1	0,25			
ODIN	0,5	0,5	0,5	1	0,25			
DREAM		0,5	0,5	0,5	1	0,25		
LOKI		0,5	0,5	0,5	1	0,25		
CSPEC		0,5	0,5	0,5	1	0,25		
BEER		0,5	0,5	0,5	1	0,25		
MAGIC		0,5	0,5	0,5	1	0,25		
BIFROST		0,5	0,5	0,5	1	0,25		
NMX			0,5	0,5	0,5	1	0,25	
SKADI			0,5	0,5	0,5	1	0,25	
TREX			0,5	0,5	0,5	1	0,25	
HEIMDAL			0,5	0,5	0,5	1	0,25	
MIRACLES				0,5	0,5	0,5	1	0,25
VESPA				0,5	0,5	0,5	1	0,25
FREIA				0,5	0,5	0,5	1	0,25
Instrument Total	1,5	4,5	6,5	9,5	10,25	7	4	0,75





WP 12 Staff


ESS
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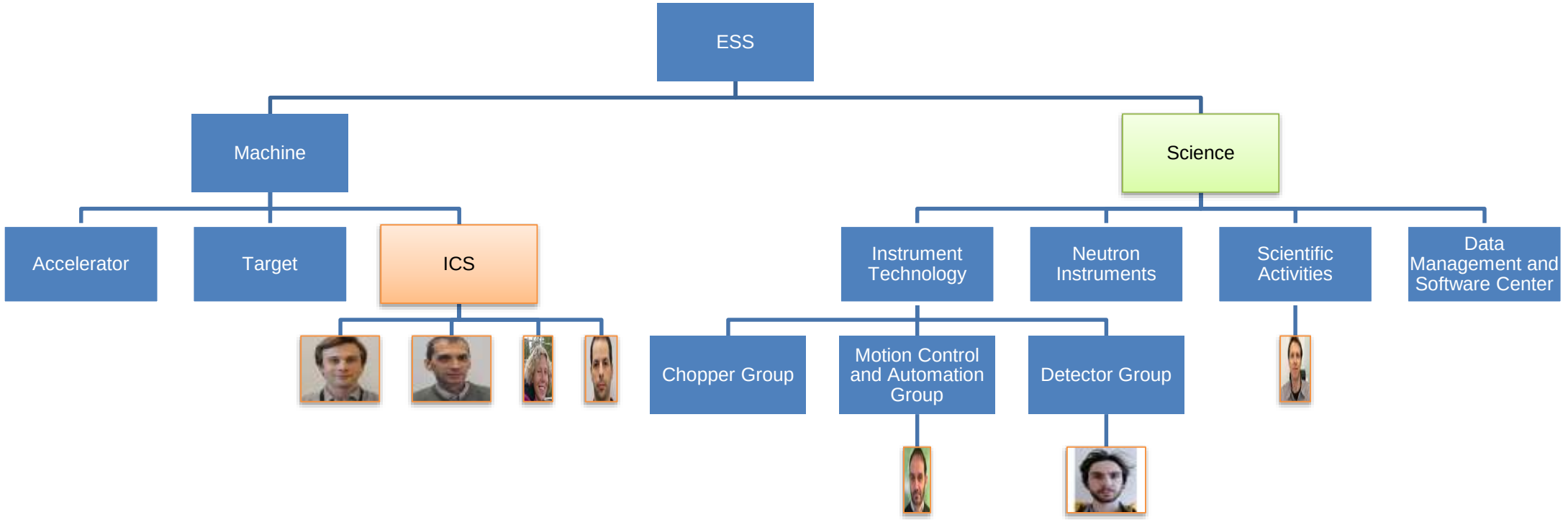
Science
Accelerator
Target
ICS
Instrument Technology
Neutron Instruments
Scientific Activities
Data Management and Software Center
Chopper Group
Motion Control and Automation Group
Detector Group

WP 12 Staff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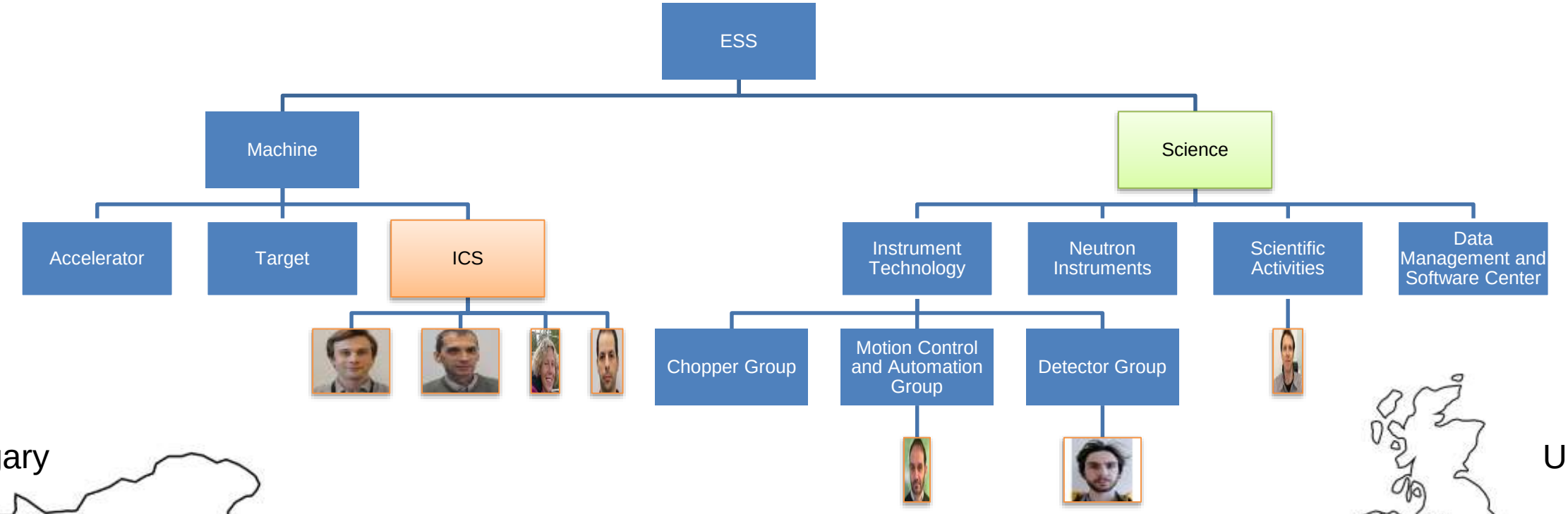
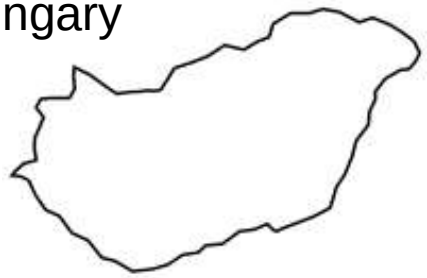
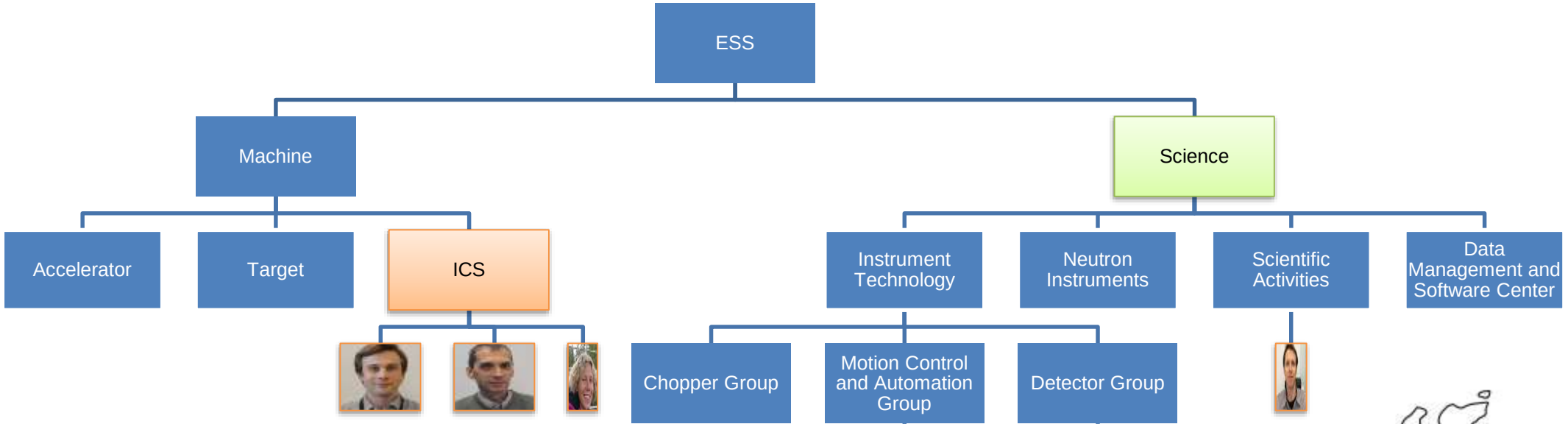


Hungary



UK

WP 12 Staff



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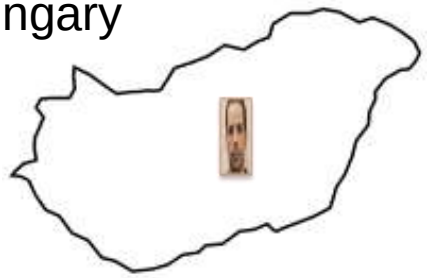

UK

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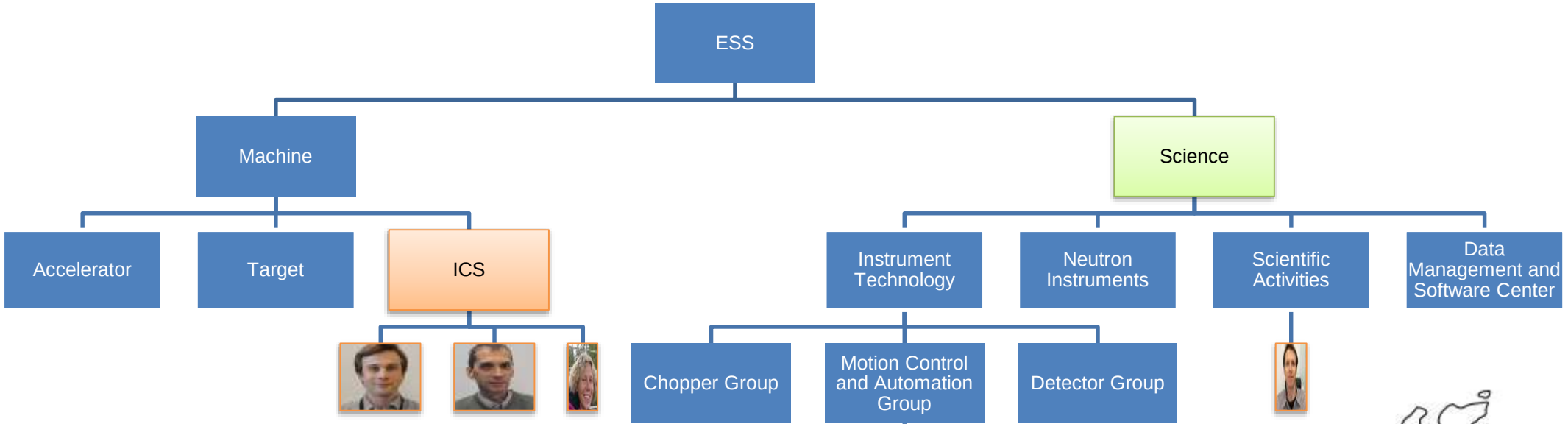

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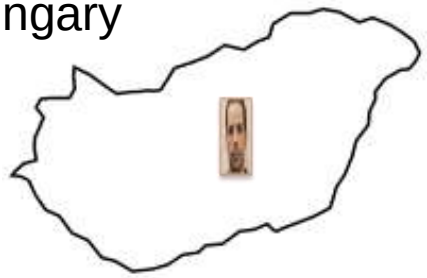


UK

WP12 Staff Allocation

Choppers

Motion 

Detectors 

Sample Environment 

DMSC

Instruments (16)

Documentation 

Integration 

Management 

Proposals

Staff allocation

- Allocate more ICS staff dedicated to Work Package 12
- Staff are needed now to meet demand for
  - Generic instrument technology controls
  - Sample environment development
  - Instrument contact and offsite commissioning
  - Documentation

Focus on core

- Change focus from incremental integration of devices to development of core technologies, workflows and tools.
  - Production environment for instruments
  - Deployment strategy for sample environment equipment
  - Testing and simulation
  - Automation tooling (example PLCFactory)
- We must provide a viable base on which controls can be developed
- Save development time in the peak by becoming more competent now

Prioritization within Sample Environment equipment

- Sample Environment is by far the largest source of unique equipment
- Plan in detail the order of integration
  - Determine equipment on critical path
  - Take procurement dates into account

Lower barrier to entry

- Expend effort to reduce the complexity of writing EPICS controls
  - Workflows
  - Tooling
- Propose use of Python for EPICS integration on applicable projects
- Reduce development time for ICS developers
- Allow scientists to implement the slow controls they care about
  - Support from ICS to ensure quality

Enable in-kind participation

- We must enable early ESS controls adoption by offsite partners (i.e. instrument teams)
  - Support offsite commissioning of instrument components
  - Leverage the controls knowledge of our in-kind partners
  - Develop controls to ESS standards the first time

- Provide the infrastructure needed
  - In-kind virtualization
  - In-kind configuration
  - Compatible workflows

Vertical Integration

- Propose a renewed local vertical integration project

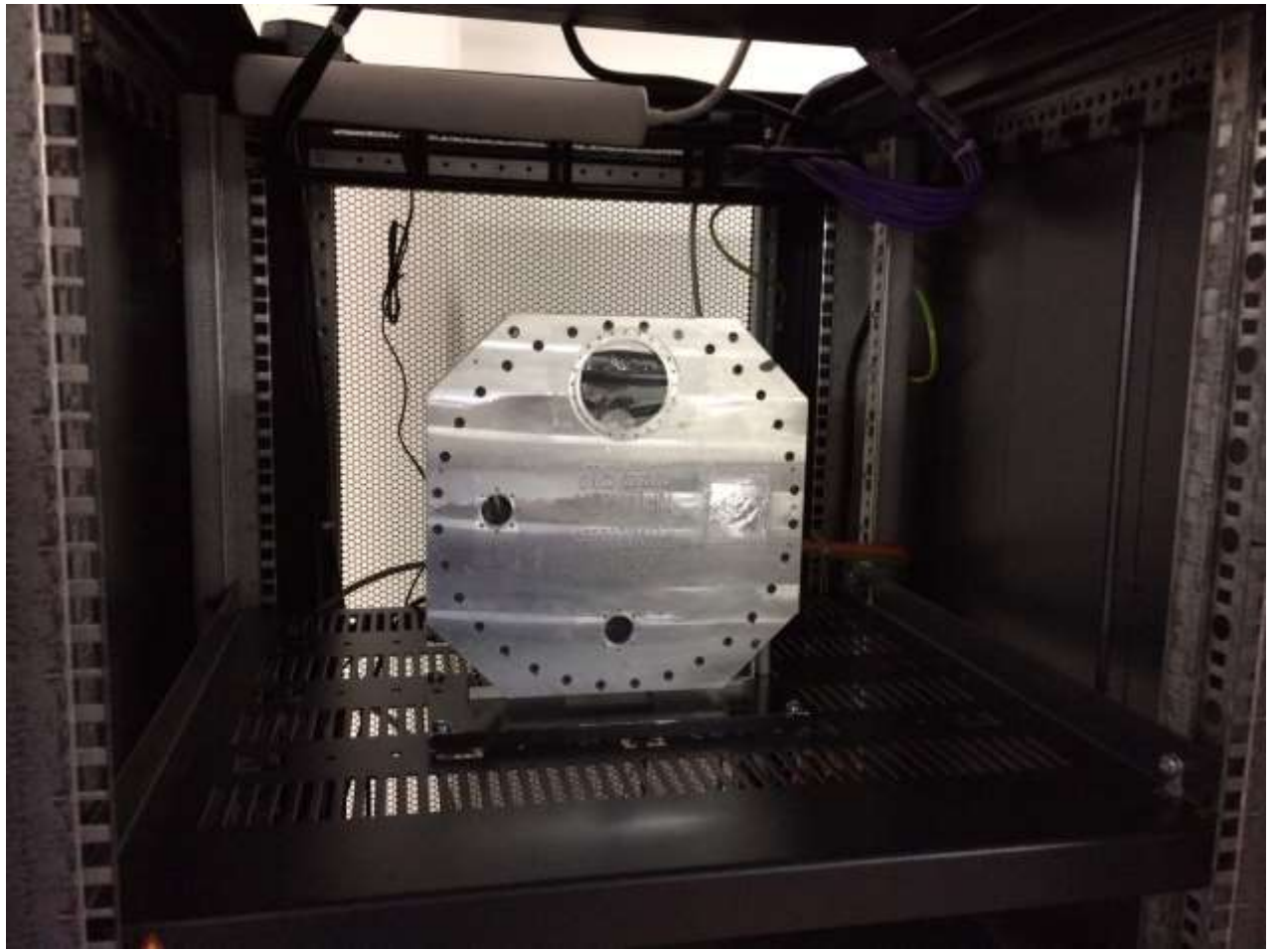
Prototyping: ESS Instrument Integration Project

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

Vertical Integration

- Propose a renewed local vertical integration project
- Continuation of ESSIIP in Utgård lab

Vertical Integration

- Propose a renewed local vertical integration project
- Continuation of ESSIIP in Utgård lab
- Test full control system software stack and environment
  - Instrument network
  - ICS EPICS deployment
  - ICS support software stack
  - User control system (NICOS)
  - Data readout chain
- Prepare for milestone demonstrations at V20 beamline in Berlin

Vertical Integration

- Recreate an instrument beamline in the lab in preparation for ESS Test Beam Line
- These components already exist in Utgård
  - Mock cave
    - Crane
    - Sample alignment
    - Utilities Panel
  - Mobile sample environment equipment
  - Timing system
  - Detectors and readout system
  - DMSC data streaming chain
  - Miniature chopper and CHIC
  - Motion axes and Motion Controller

EUROPEAN SPALLATION SOURCE

Conclusion

Conclusion

- ICS has a very large number of stakeholders and tasks related to the instrument projects
- ICS provides not just controls, but some key technologies like the Timing System and the technical network
- WP12 needs improved resource allocation.
- WP12 needs improved competency and workflows
- Some level-of-effort concerns could be mitigated by making it easier for stakeholders to write their own correct controls
- It is important that we have a local test area to develop the competency and tooling required to deploy on a real instrument.

Questions