

EUROPEAN SPALLATION SOURCE

The ESS Control System Machine Learning Project

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ESS mission



Design, build, and operate the world's leading research facility using neutrons

Quick facts

- 1843 M€ construction cost
- 5 MW world's most powerful Linear proton accelerator
- 15 experimental stations
- 20 times more sensitive on average than today's best
- 800 experiments every year
- 2023 first science for users
- 15 ERIC members and observer nations

Spallation? Production of neutrons



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Fission of uranium in nuclear reactor

2-3 neutrons per process



Spallation is a process in which fragments of material (spall) are ejected from a body due to impact or stress. In the context of impact mechanics it describes ejection or vaporization of material from a target during impact by a



Spallation on target using proton accelerator

>30 neutrons per process





ESS will be the world brightest neutron source



ESS basic design principle



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Accelerator:

- Ultimate energy: 2 GeV
- Rep. Rate: 14 Hz
- Current: 62.5 mA

Target Station:

- He-gas cooled rotating W-target
 - 42 beam ports

15 Instruments in Construction budget >30 times higher performance than at ILL

Ion Source

- Integrated control system
 EPICS 7 based
 MicroTCA deployment
- 1.6 M "control points"

Financing



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Host Countries Sweden and Denmark

Construction47.5%Cash Investment ~ 97%Operations15%

Non Host Member Countries

Construction	52.5%	In-kind Deliverables	~ 70%
Operations	85%		

(Jan 2013 pricing)	M€
Conventional Facilities	531.9
Extra CF investment by host countries	-93.0
Accelerator Systems	510.2
Target Systems	155.2
Integrated Control System	73.0
Design & Engineering	33.7
Neutron Scattering Systems	350.0
Project Support & Administration and Licensing	123.8
Contingency	158.2
Total Construction Budget	1843.0



Journey to deliver the world's leading facility for research using neutrons



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Ion Source ready for first beam



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Key features of the ESS Target Station



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Moderators

- Provisional locations of moderators above and beneath the target wheel, i.e. monolith centre
- 1st MR plug exploits the upper space, offering:
 - \checkmark Cold, 30 mm high, liquid H₂ moderators, 17 K
 - ✓ Thermal, 30 mm high, H₂O moderator, 300 K

Diagnostics and instrumentation

- Controlled and integrated commissioning and operation of the accelerator and target
- Fluorescent coating of PBW and target front face
- Optical paths, grid profile monitor, aperture monitor
- Wheel monitoring including position, temperature, vibration, as well as internal structure

The ESS integrated control system



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- The ESS facility is a large and complex machine with very much and diverse equipment that needs to work in synchronization and with well-known configurations
- The Integrated Control System Division (ICS division) is responsible for the control systems within the ESS facility including controls for
 - Accelerator
 - Target
 - Neutron Scattering Systems
 - Conventional Facilities
 - In addition, ICS will implement
 - Machine Protection System
 - Personnel Safety System
- To build a distributed control system of this size is a major undertaking

ESS/ICS challenges

ELSS SC

- The ESS control system complexity is very high
 - About 1 600 000 "process values"
 - Ambitious approach to automation of control system configuration
- Facility availability goals are very high
 - ICS plays a key role for the availability of the facility 95% availability
 - High performance and availability requirements on equipment used
- Some new approaches will be implemented at ESS/ICS
 - Full scale deployment of EPICS 7
 - ESS is committed to contributing to the EPICS community
 - Full scale deployment of MicroTCA.4
 - ESS is involved in a public procurement for innovation initiative
 - Machine learning/Artificial intelligence assisted control system
 - Project started to explore how modern technologies can be applied



Control system architecture







Layered architecture based on EPICS distributed controls

ICS Project scope



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Work package 01 Work package 03 Work package 04 Work package 05 Work package 06 Work package 07 Work package 08 Work package 09 Work package 10 Work package 11 Work package 12 Work package 13 Work package 14 Work package 20

- Management and administration
- Software core
 - Hardware core
 - Machine protection
 - Equipment
 - Control system imrastructure.
 - Physics 🥌
- Personnel safety system
- Integration Accelerator
- Integration Target
- Integration Instruments
- Integration Conventional facilities
- Test Stands

Installation



Software

Integration

The aronics



Safety & protection

Radiation



Controlling systems from the local control room

PS-ESS

PS-ESS



 Recent achievements include controlling the pure Helium storage and the ESS ion source and LEBT from the local control room



Building control systems



- Many components are being assembled into ICS subsystems and readied for installation
- Meanwhile, work is continuing with maintaining and developing the ICS and EPICS software solutions

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	2	8	828002406	2017-07-14 01:27:52	ICS Bundle		TS2-020ROW NetW-CPP-0004	602	TS2-020ROW.CoPw				TS2 000ROW.NetW-CPP-0101	502
	2	8	829001738	2017-07-14 01:27:08	KS Bundle		EEB 020ROW/NetW CPP 0909	901	FEB 600ROW.CrPw				FEB-040ROW/INSIN CPP-0801	501
	2	В	828001739	2017-07-14 01:27:08	ICS Bundle		FEB-629ROW/NetW-CPP-6807	601	FEB-I20ROW CrPw				FEB-040ROW/NetW-CPP-0901	601
	2	8	828001740	2017-07-14 01:27:08	ICS Bundle		FEB 020ROW/NetW CPP 0907	501	EEB 020ROW.CrPw				FEB MOROW/NetW CPP 1901	901
	2	D	828001741	2017-07-14 01:27:08	KS Bundle		FEB-020ROW/NetW-OPP-0802	001	FEB-600ROW.CrPw-				EEE-MOROW/Metw-CPP-1101	501
	2	8	828000228	2017-07-14 01:27:35	ICS Bundle		HBL-100RCW/NetW-CPP-0108	6402	HIL-100ROW CoPw.				HIR-110ROW NetW-CPP-1501	602



Machine learning applications for the ESS control system



- We want to explore if modern AI/Machine learning technologies can be used to augment the ESS control system
 - Decrease commissioning time and effort
 - Increased facility availability (95% goal)
 - Increased efficiency of operation
 - Improved human/machine interaction
 - Lowered operational and maintenance costs



- Unique opportunity to study applications on a rich, large-scale, complex control system
- Large supportive community to back up the project
- The project shall:
 - Investigate and develop interfaces between the EPICS distributed control system and concurrent machine learning frameworks such as Google TensorFlow
 - Demonstrate machine learning benefits through practical application on a subsystem of the ESS facility
 - Investigate and document guidelines for how to select domains of a control system that are useful for machine learning applications and selection of which data that is relevant for a machine learning system

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Deliverables



- The project is focused around the ESS integrated control system
 - Unique opportunity to study applications on a rich, large-scale, complex control system
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Partners

- Project has been developed together with Swedish innovation agencies Vinnova and Big Science Sweden
- We hope to find academic/industrial partnerships interested in joining the project group



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Al workshop Big Science Sweden and ESS

"This initiative now shows that we can already see the possibilities and harvest the benefits of the investment in ESS - we don't need to wait for scientific results"

Leif Ericsson

Swedish Research Council

Thank you!



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• Thank you for your attention

- More information: <u>europeanspallationsource.se</u>
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