

ESS Intelligent Control System Project

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

Why neutrons?

- Probe structure and motion
- High penetration
- A precise tool
- High sensitivity and selectivity
- Probe for magnetism
- A probe of fundamental properties



Applications



Health



Food

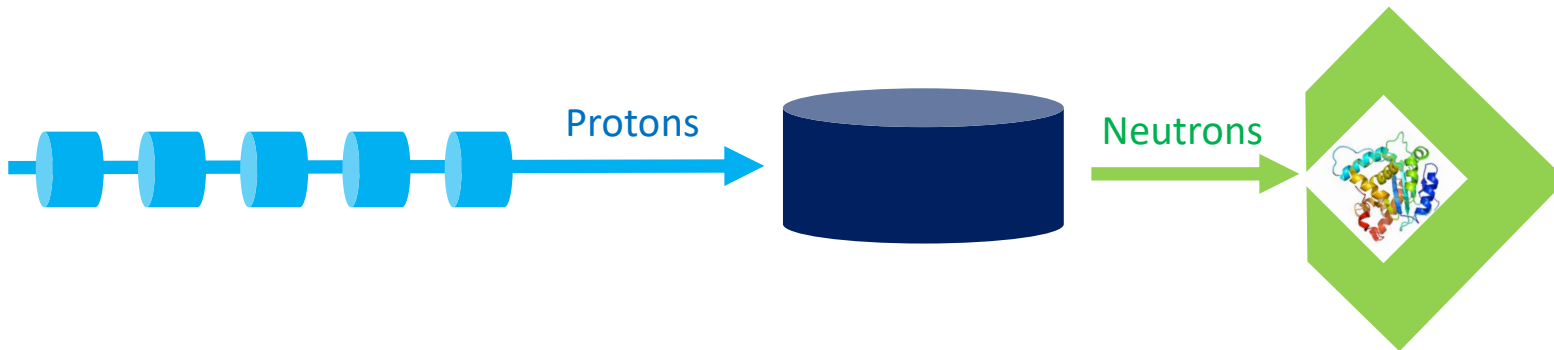


Energy



Material

How spallation works



Accelerator

Superconducting
5 MW protons
2.8 ms pulses
14 Hz repetition rate

Heavy Metal Target

Stainless Steel & Tungsten
11 tonnes
23.3 rpm
Helium cooled
2.6 m diameter
42 neutron beam ports

Instruments

22 instruments



- Total project cost €1,843M₂₀₁₃
- Host Countries Sweden and Denmark
 - Construction 47.5%
 - Cash Investment ~ 97%
- Non Host Member Countries
 - Construction 52.5%
 - In-kind Deliverables ~ 70%

People

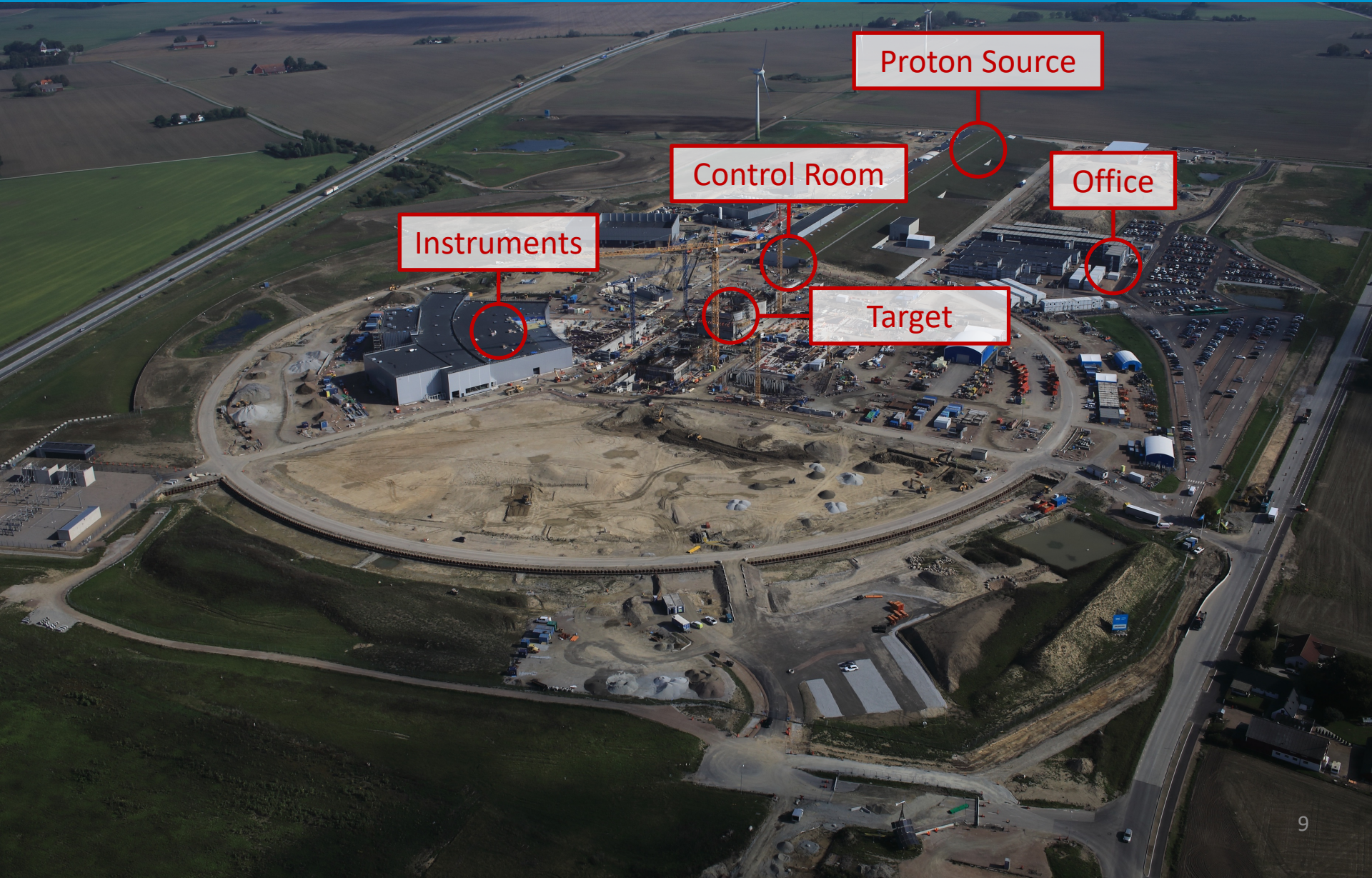


- 472 Employees
- 48 Nationalities
- >100 Collaborating Institutions

The ESS journey



Site September 2018



Proton Source

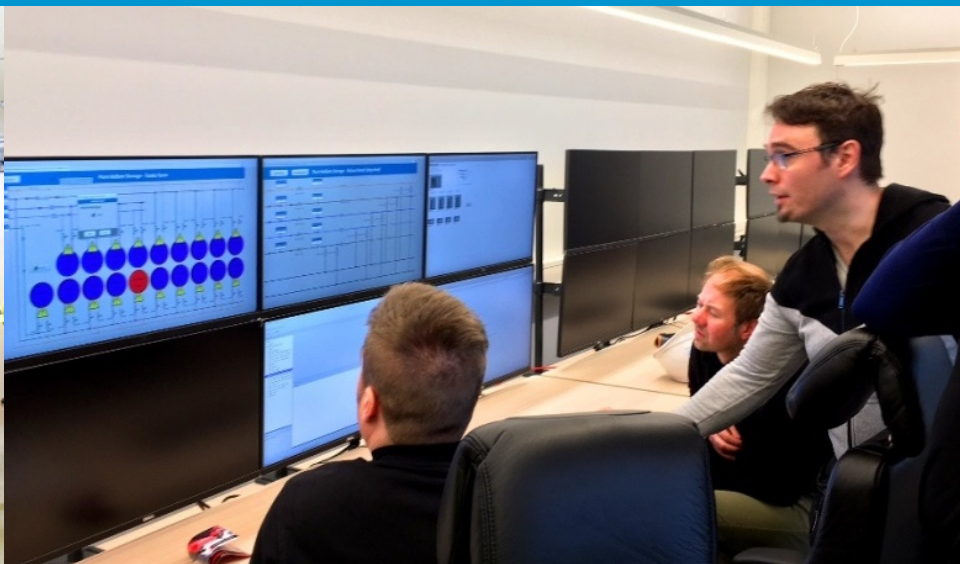
Control Room

Office

Instruments

Target

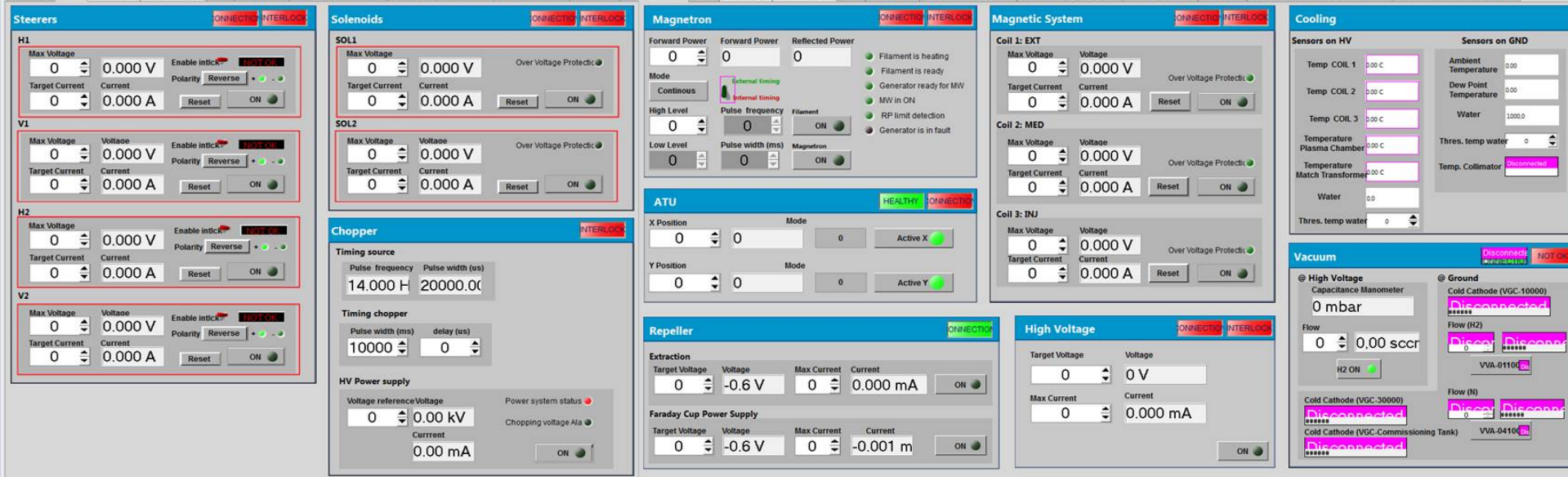
Beam is on!



PS-ESS

PS-ESS

SOURCE LEBT Interlock Magnetron ATU Repellers Magnetic System Steerers Solenoids High Voltage Vacuum Vacuum Detailed, SOURCE Vacuum Detailed, LEBT



The screenshot displays the ESS control interface, organized into several panels:

- Steerers:** H1, V1, H2, V2. Each panel shows Max Voltage (0.000 V), Target Current (0.000 A), and status indicators like "Enable interlock" and "Polarity Reverse".
- Solenoids:** SOL1, SOL2. Shows Max Voltage (0.000 V), Target Current (0.000 A), and "Over Voltage Protection" status.
- Magnetron:** Shows Forward Power (0), Reflected Power (0), Mode (Continuous), Pulse frequency (0), and Filament status (ON).
- ATU:** Shows X and Y Position (0) and Mode (Active X, Active Y).
- Repeller:** Shows Extraction Target Voltage (0), Voltage (-0.6 V), Max Current (0), and Current (0.000 mA).
- Faraday Cup Power Supply:** Shows Target Voltage (0), Voltage (-0.6 V), Max Current (0), and Current (-0.001 m).
- High Voltage:** Shows Target Voltage (0), Voltage (0 V), Max Current (0), and Current (0.000 mA).
- Magnetic System:** Shows Coil 1: EXT, Coil 2: MED, and Coil 3: INJ. Each coil panel shows Max Voltage (0.000 V), Target Current (0.000 A), and status indicators.
- Cooling:** Shows sensors on HV and GND, including Temp COIL 1, Temp COIL 2, Temp COIL 3, and Thres. temp water.
- Vacuum:** Shows High Voltage Capacitance Manometer (0 mbar) and Ground Cold Cathode (VGC-10000) status (Disconnected).

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Hardware & Integration



Software

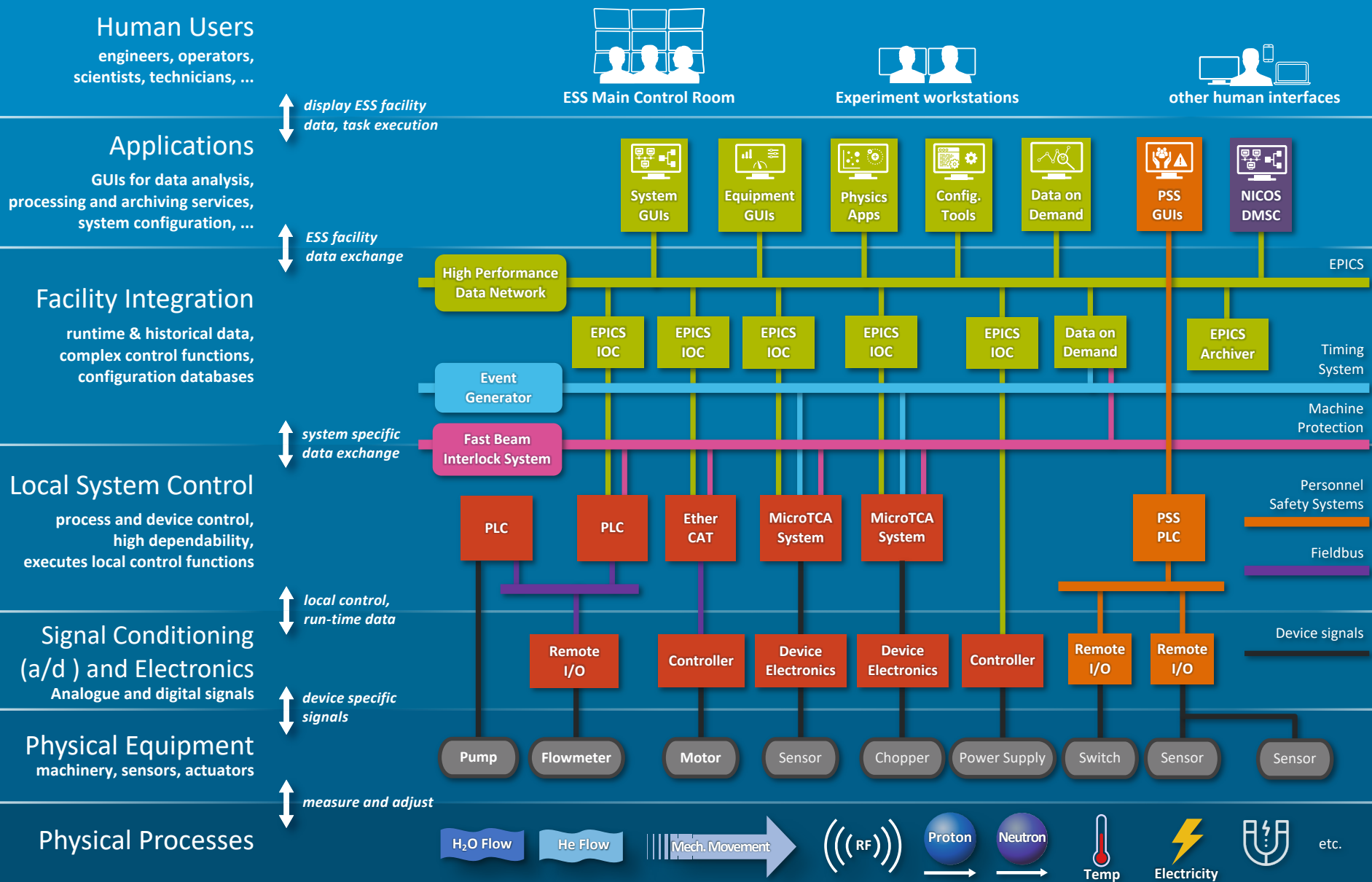


Infrastructure



Safety & Protection

Layer Architecture of the ESS Control System



- The ESS machine is very complex
 - Large variety of systems
 - About 1 600 000 control signals.
- ESS is a user facility with a 95% availability goal
 - High availability requirements on equipment
- The control system plays a key role for the availability of the facility

- 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
- Artificial intelligence assisted control system
 - Project started to explore how modern technologies can be applied



We want to explore if artificial intelligence can be applied to the control system in order to

- Increase facility availability
- Increase efficiency of operation
- Improve human/machine interaction
- Lower operational and maintenance costs
- Decrease commissioning time and effort



***...the integrated
control system is
the brain of the
ESS Machine.***


- In computer science AI is the *study* of "intelligent agents": any device that perceives its environment and takes actions that maximize its chance of successfully achieving its goals.
- When a technique reaches mainstream use, it is no longer considered artificial intelligence.
(known as the AI effect)



- Self-driving machine
- Anomaly detection
- Explainable AI
- Minimize degradation of equipment
- Intelligent Maintenance Systems
- Optimize (stable) output vs cost
- Predict failure
- Root cause analysis
- Data Mining
- Fast and smart: AI in integrated circuits
- ?????

ESS is ideal for AI / ML research

- ESS is a research facility
 - skilled staff and scientific mindset
- ESS is build on scientific collaborations
- ESS belongs to a rich community of research facilities.
 - Similar initiatives at other facilities
- ESS and AI attract students, their supervisor and industry
- ESS has a large variety of systems to control
- ESS will have lots of data for training and validation
- ICS division takes an active part in the EPICS development.



”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”

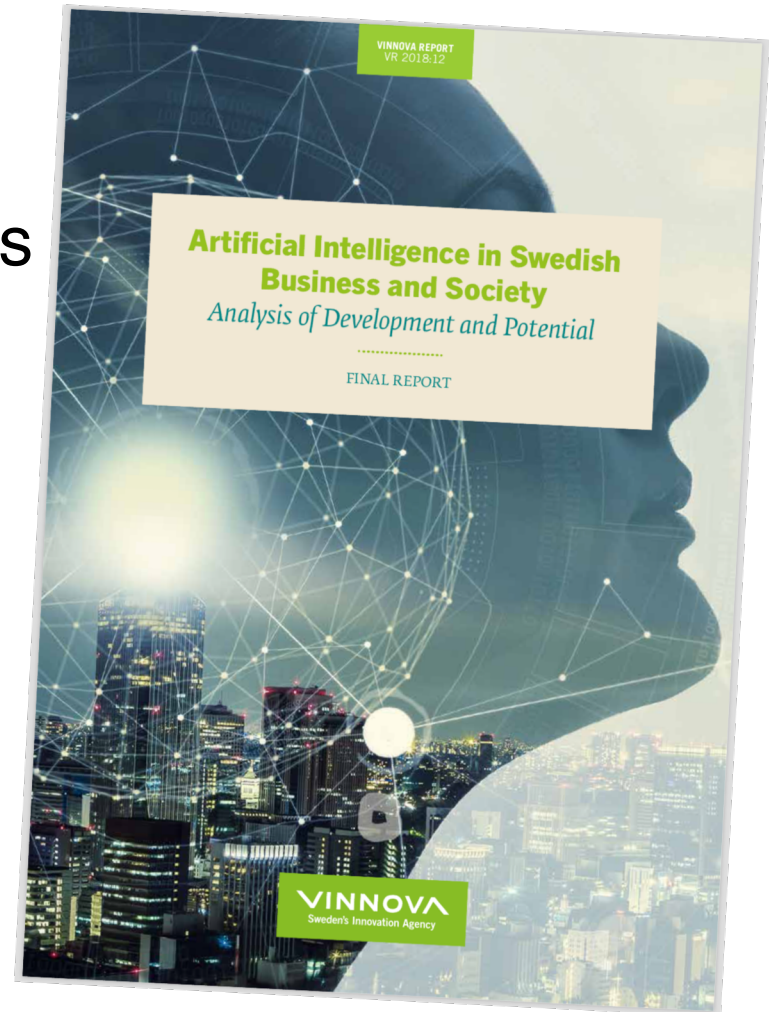
**Leif Ericsson
Swedish Research Council**

4 year project scope

- Speculate how the ESS Machine will be controlled and operated 25 years from now.
- Investigate and document guidelines for how to select domains of a control system where AI is feasible.
- Investigate which data is relevant and how it needs to be structured and pre-processed.
- Select framework and software platform and integrate with EPICS
 - TensorFlow and Keras already installed on ESS JupiterHub.
 - Distinguish between development/test and production (fast, maintainable, reliable etc.)
- Investigate standards.
- Investigate EPICS development needs.
- Demonstrate the benefits through practical application on a subsystem of the ESS facility

- 100% Me 2019-2023
 - Good start given that ESS is in a very constraint and busy construction phase. AI will become important in the next phase.
 - Lots of interests from other colleagues.
 - Other initiatives at ESS have already started that are not part of this project (e.g. machine protection)
- External Collaborators

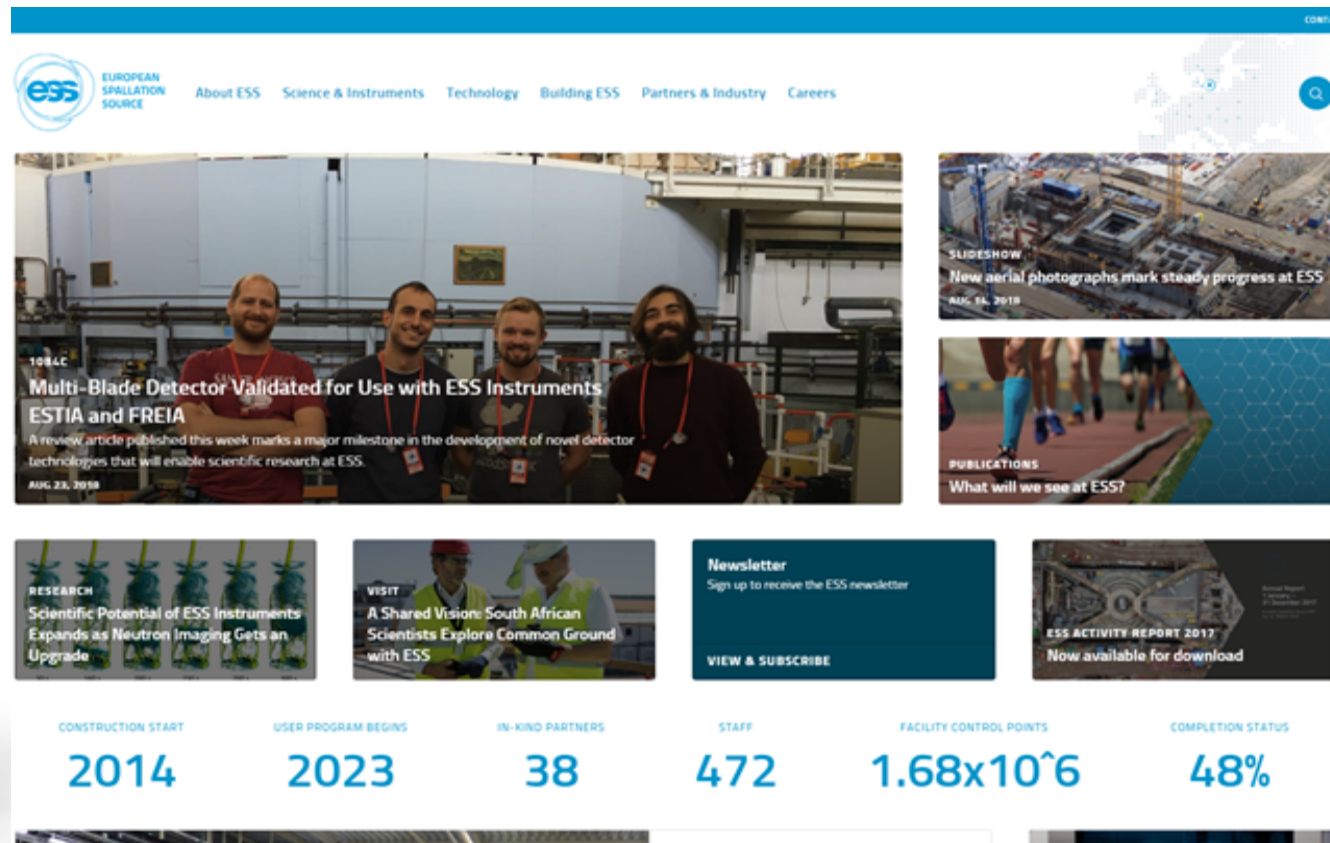
- Faculty of science and technology who need student projects
- Industry developing AI methods who would like to test their methods/systems
- Industry specialized in control systems, who would like to build up competence in ai/machine learning
- Agencies such as Big Science Sweden, Vinnova, VR, RISE
- Other research facilities and collaborating institutes



Intelligent
~~Integrated~~ Control System

Thank you!

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- More information: europeanspallationsource.se



The screenshot shows the ESS website homepage. At the top left is the ESS logo and the text 'EUROPEAN SPALLATION SOURCE'. To the right is a navigation menu with links: 'About ESS', 'Science & Instruments', 'Technology', 'Building ESS', 'Partners & Industry', and 'Careers'. A search icon is visible on the right. The main content area features a large article titled 'Multi-Blade Detector Validated for Use with ESS Instruments ESTIA and FREIA' with a sub-headline 'A review article published this week marks a major milestone in the development of novel detector technologies that will enable scientific research at ESS.' and a date 'AUG 23, 2018'. To the right of this article is a 'SLIDESHOW' section with the text 'New aerial photographs mark steady progress at ESS' and a date 'AUG 24, 2018'. Below the main article are three smaller featured articles: 'RESEARCH: Scientific Potential of ESS Instruments Expands as Neutron Imaging Gets an Upgrade', 'VISIT: A Shared Vision South African Scientists Explore Common Ground with ESS', and 'Newsletter: Sign up to receive the ESS newsletter' with a 'VIEW & SUBSCRIBE' button. To the right of the newsletter is a 'PUBLICATIONS' section with the text 'What will we see at ESS?'. At the bottom of the page is a progress bar with the following data points: 'CONSTRUCTION START 2014', 'USER PROGRAM BEGINS 2023', 'IN-KIND PARTNERS 38', 'STAFF 472', 'FACILITY CONTROL POINTS 1.68x10⁶', and 'COMPLETION STATUS 48%'. A world map is visible in the top right corner of the website screenshot.