ESS Intelligent Control System Project

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European Spallation Source ERIC

ESS mission

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

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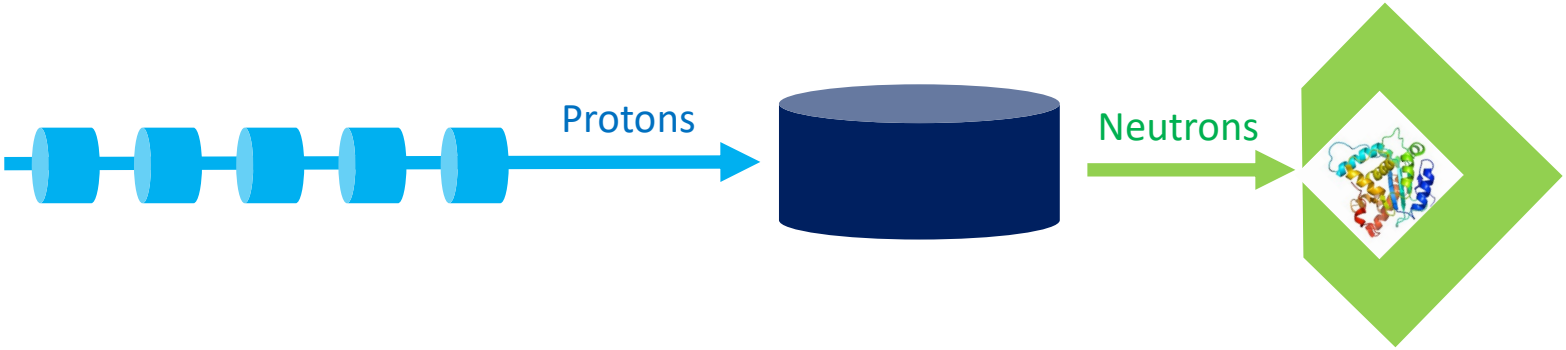
Health

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

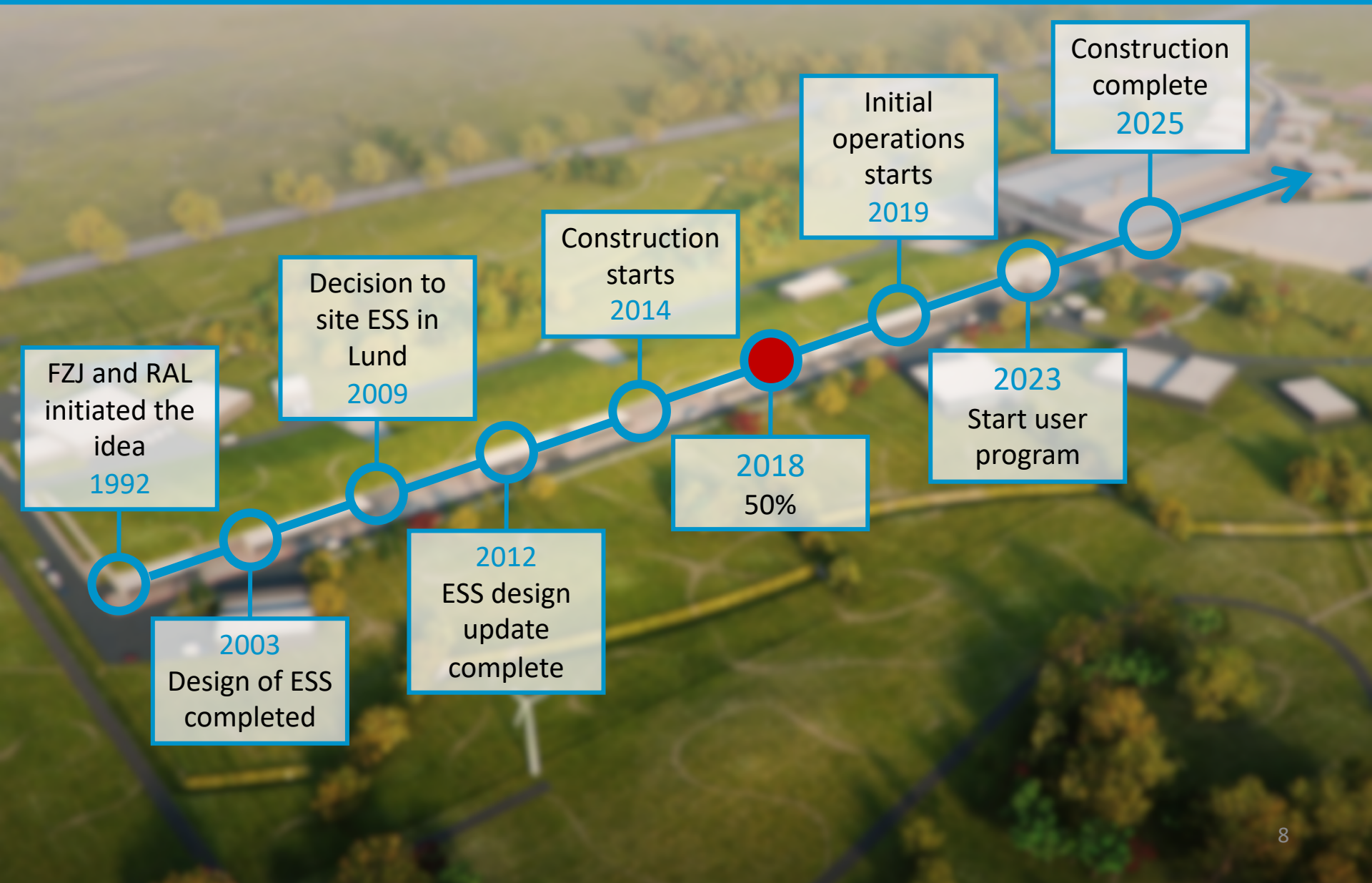
European Collaboration

- Total project cost €1,843M$_{2013}$
- Host Countries Sweden and Denmark
  - Construction 47.5%
  - Cash Investment ~ 97%
- Non Host Member Countries
  - Construction 52.5%
  - In-kind Deliverables ~ 70%

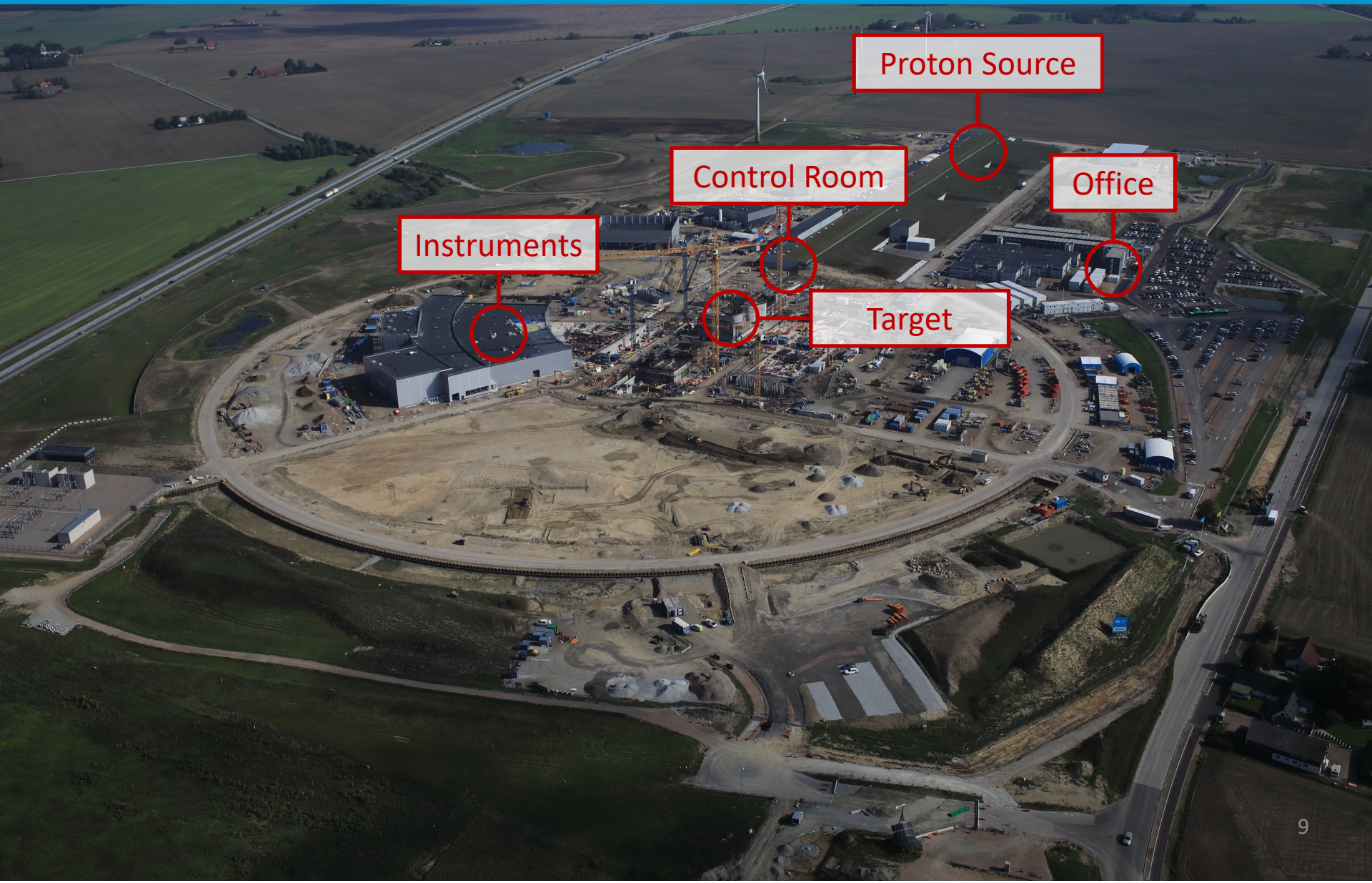
People


• 472 Employees
• 48 Nationalities
• >100 Collaborating Institutions

The ESS journey



Site September 2018



Beam is on!

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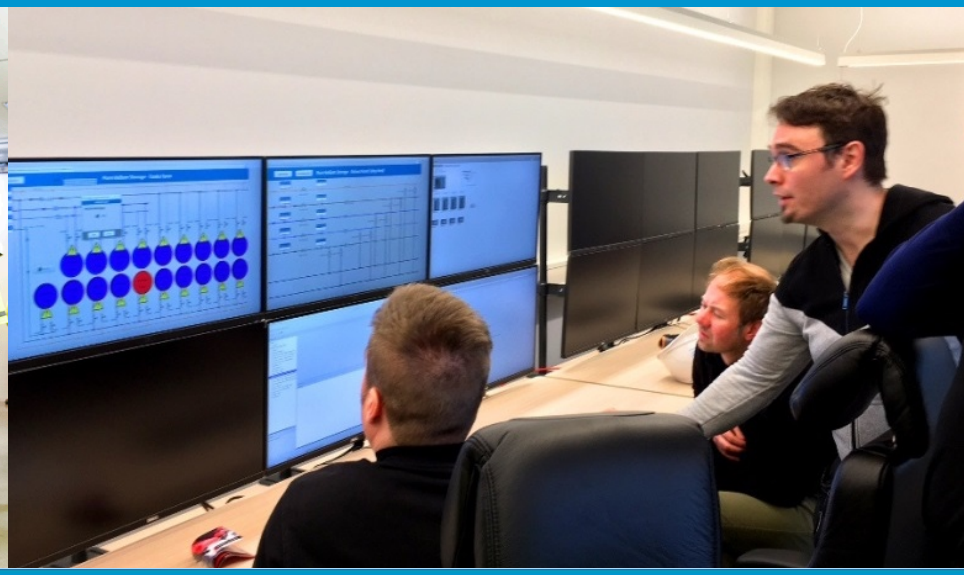
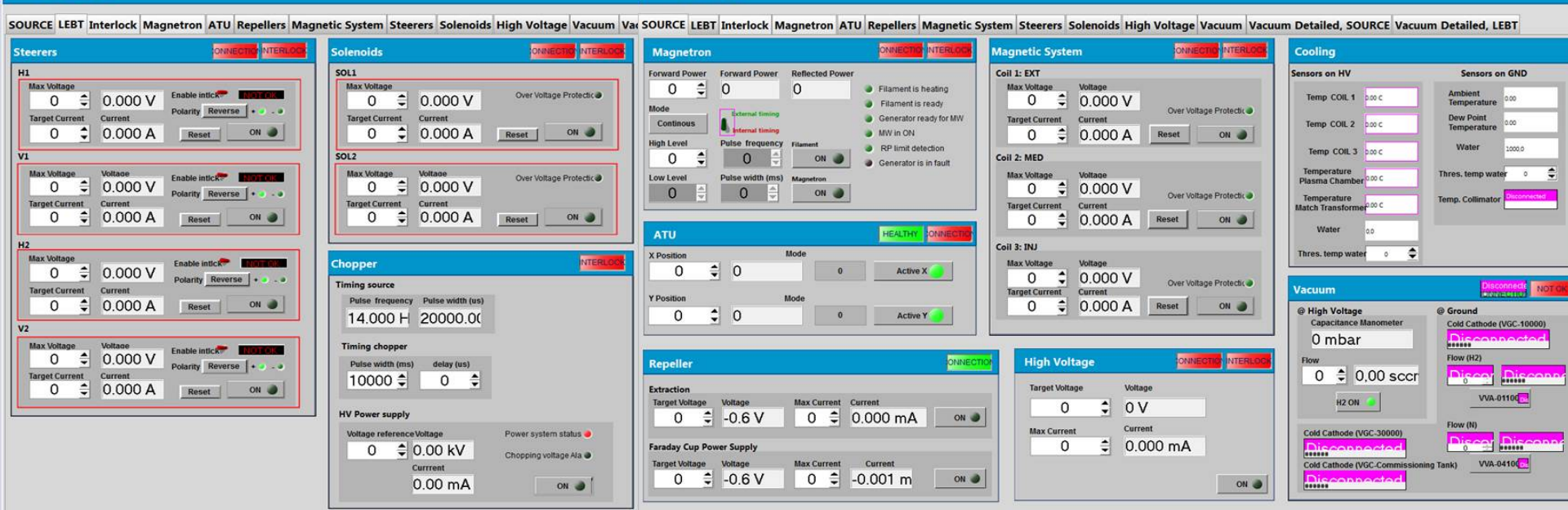


PS-ESS

PS-ESS



Integrated Control System Division

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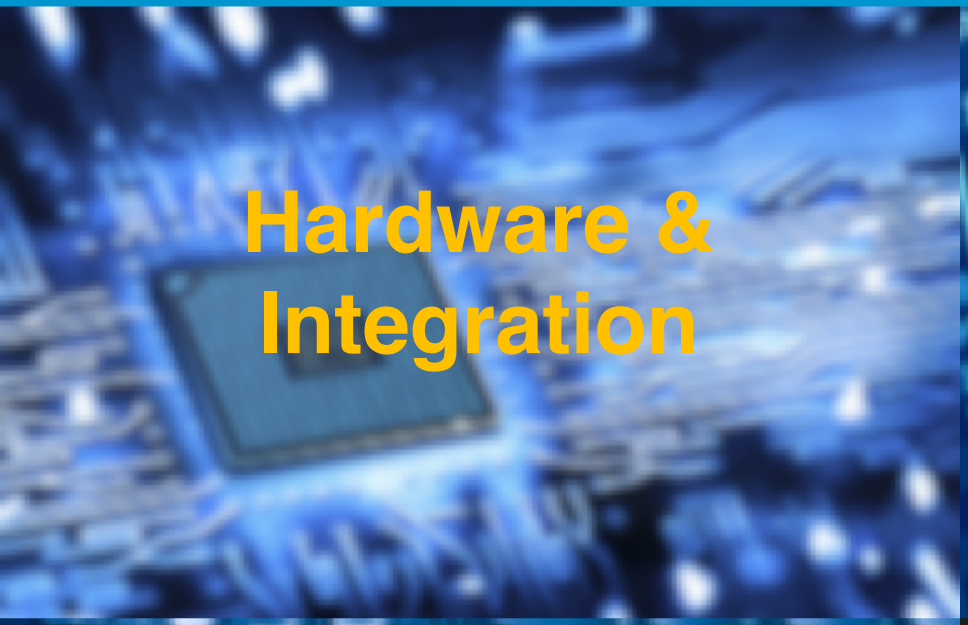

Layer Architecture of the ESS Control System

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Human Users
engineers, operators, scientists, technicians, ...

display ESS facility data, task execution

Applications
GUIs for data analysis, processing and archiving services, system configuration, ...

ESS facility data exchange

Facility Integration
runtime & historical data, complex control functions, configuration databases

system specific data exchange

Local System Control
process and device control, high dependability, executes local control functions

local control, run-time data

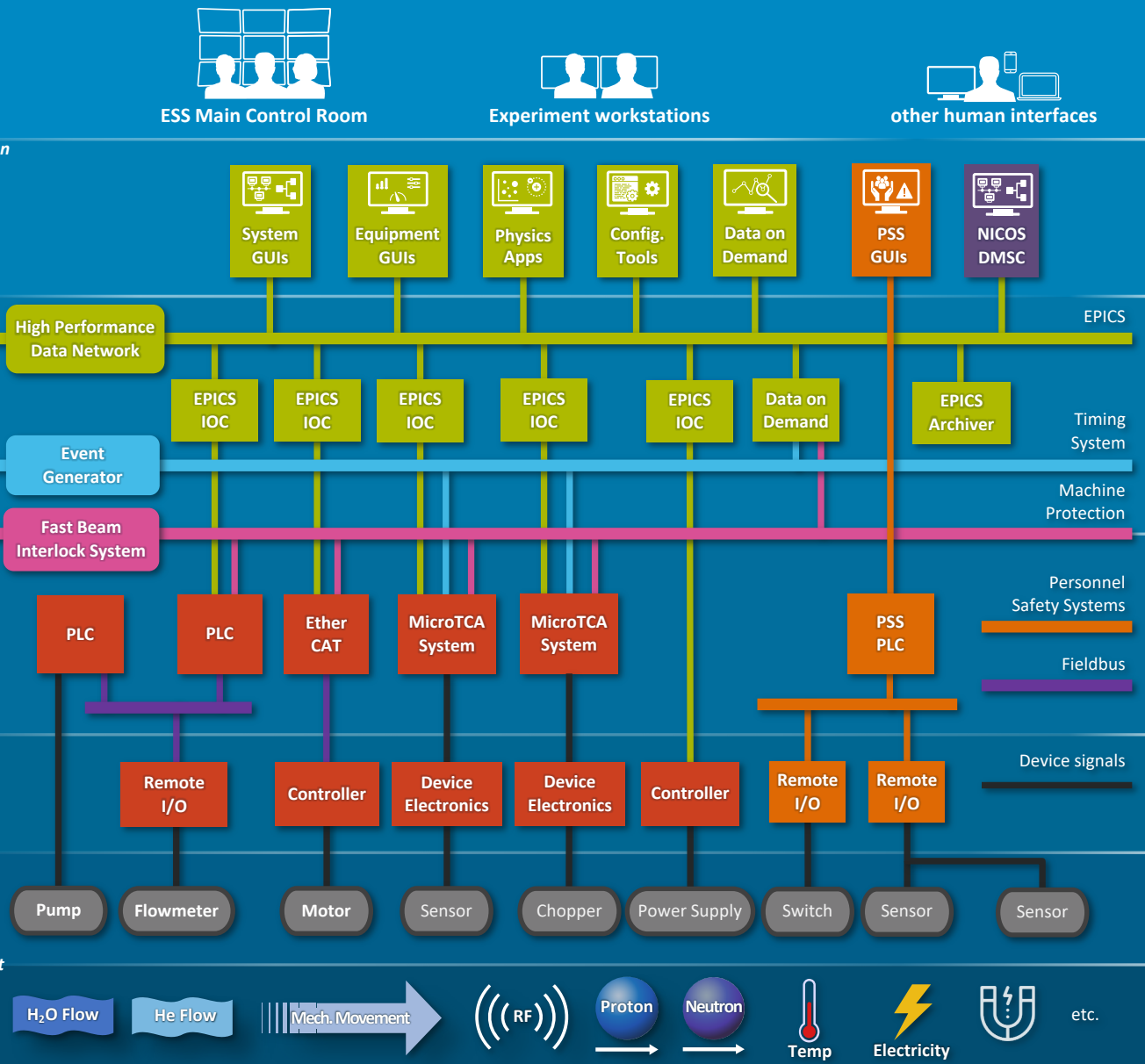
Signal Conditioning (a/d) and Electronics
Analogue and digital signals

device specific signals

Physical Equipment
machinery, sensors, actuators

measure and adjust

Physical Processes



Challenges

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- 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

New approaches

- 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

Intelligent Control System Project

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

In a Nutshell…

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

Research by definition

- 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)

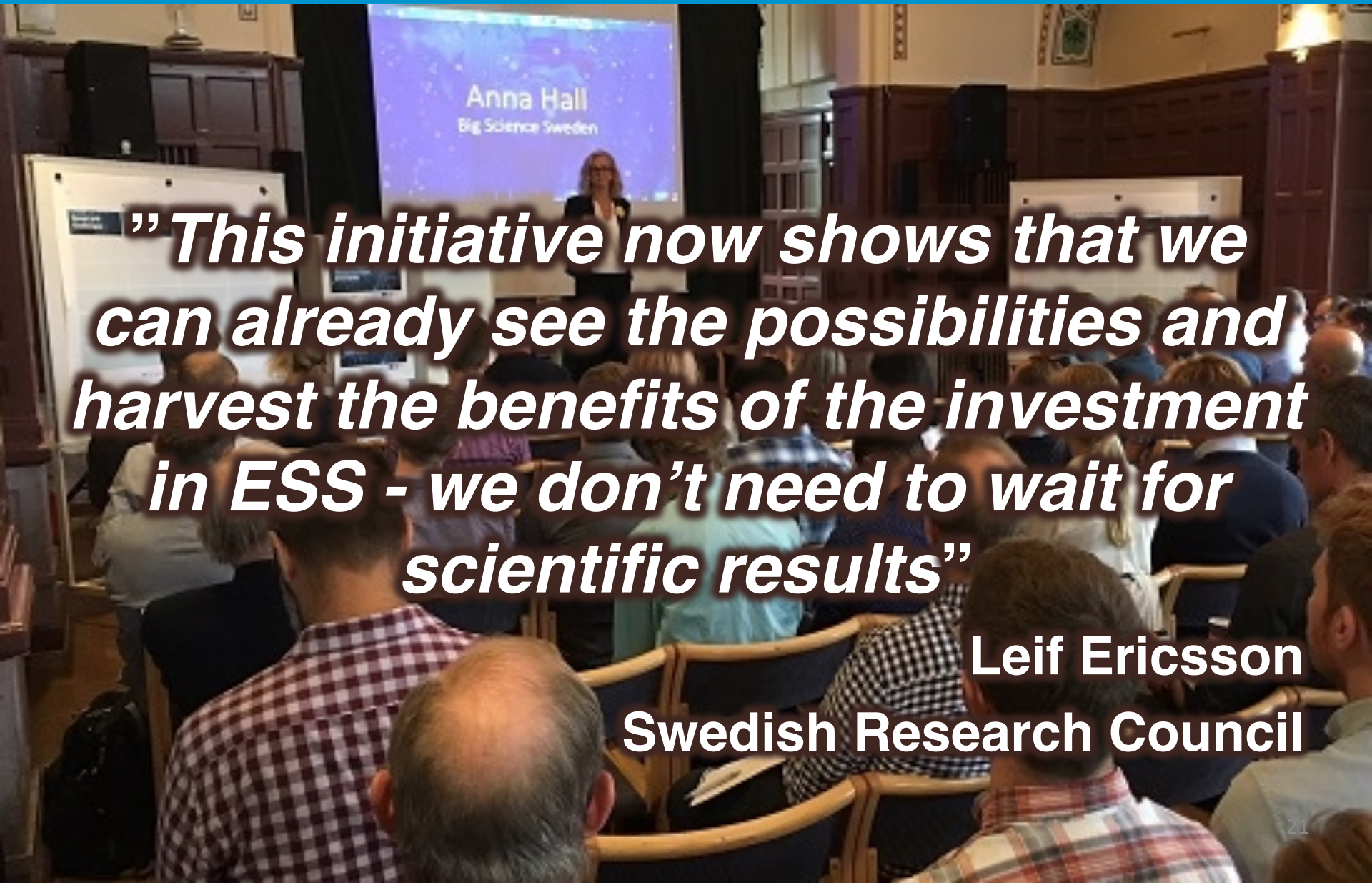
Areas of interest

- Self-driving machine
- Anomality 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.

AI 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

4 year project scope

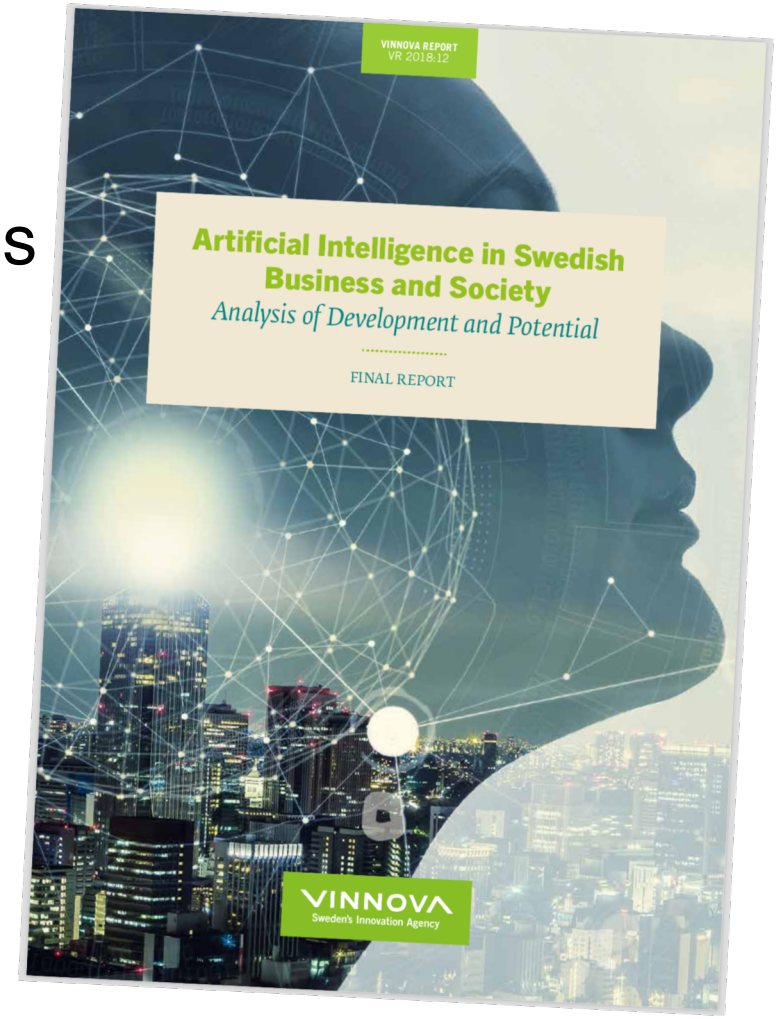
- Speculate how the ESS Machine will be controlled and operated 25 years from now.
- Investigate and document guidelines for how to select domains of a control system where AI is feasible.
- Investigate which data is relevant and how it needs to be structured and pre-processed.
- Select framework and 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

Resources

- 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

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



Goal

Intelligent

~~Integrated~~ Control System

Thank you!

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- More information: europeanspallationsource.se