The ESS Control System Machine Learning Project

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Integrated control system division

European Spallation Source ERIC

AIME'18 - Academia-Industry Matching Event

Date: 2018-10-30

ESS mission

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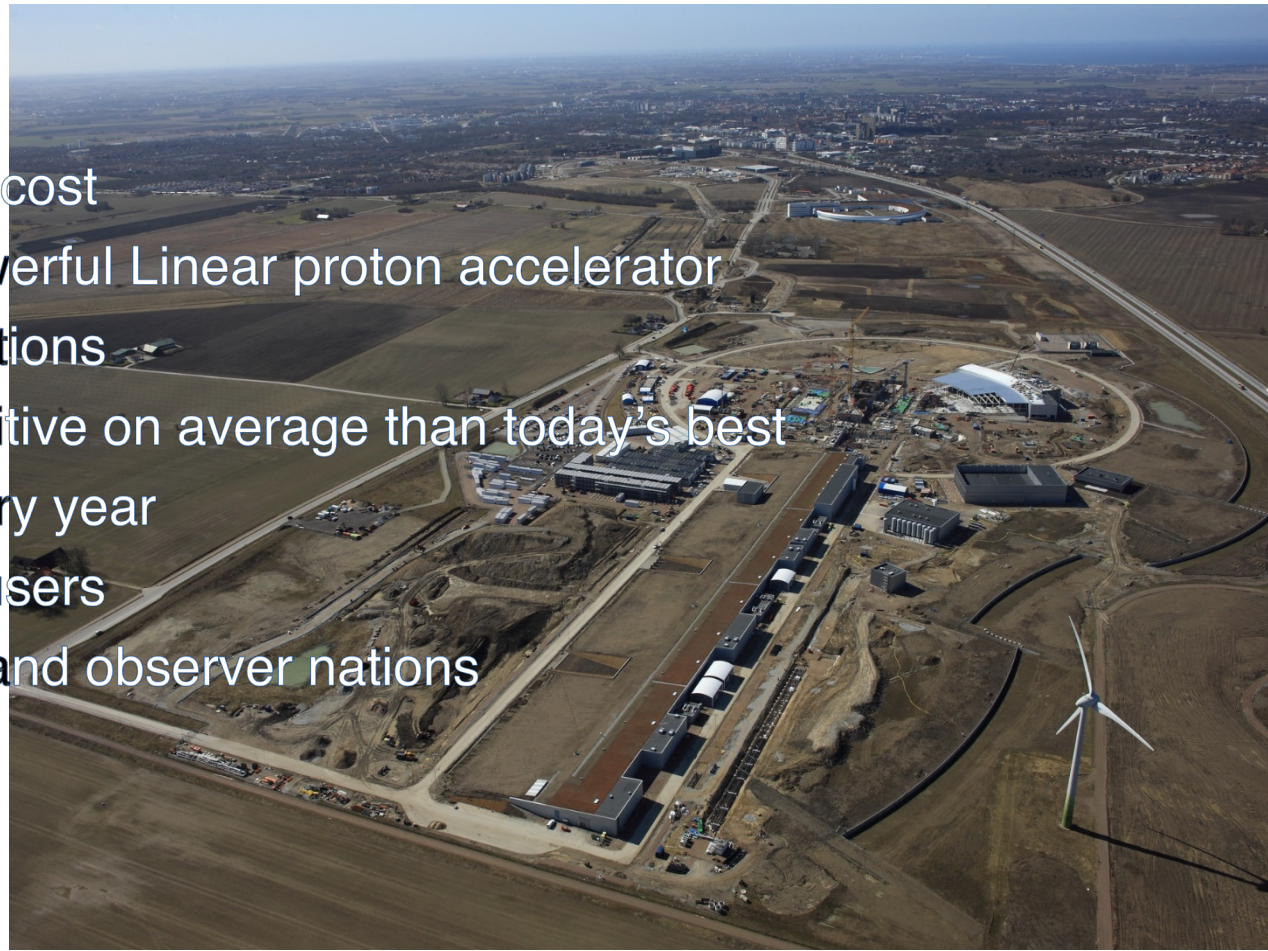
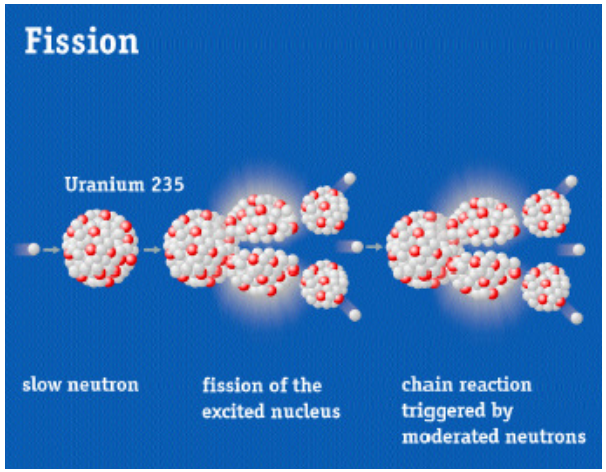
Design, build, and operate the world's leading research facility using neutrons

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



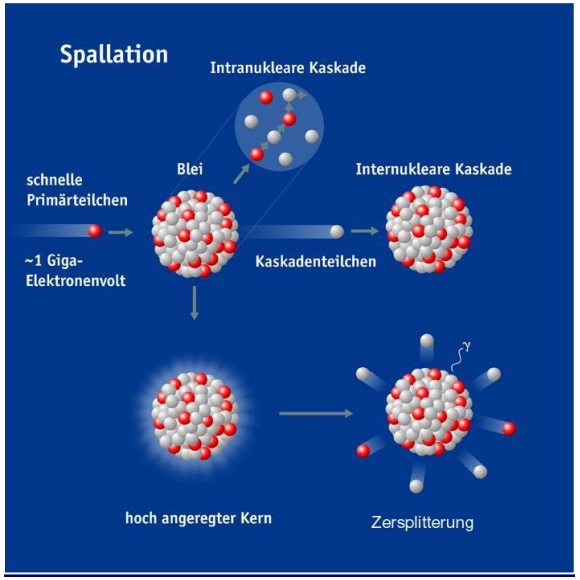
Fission of uranium in nuclear reactor

2-3 neutrons per process

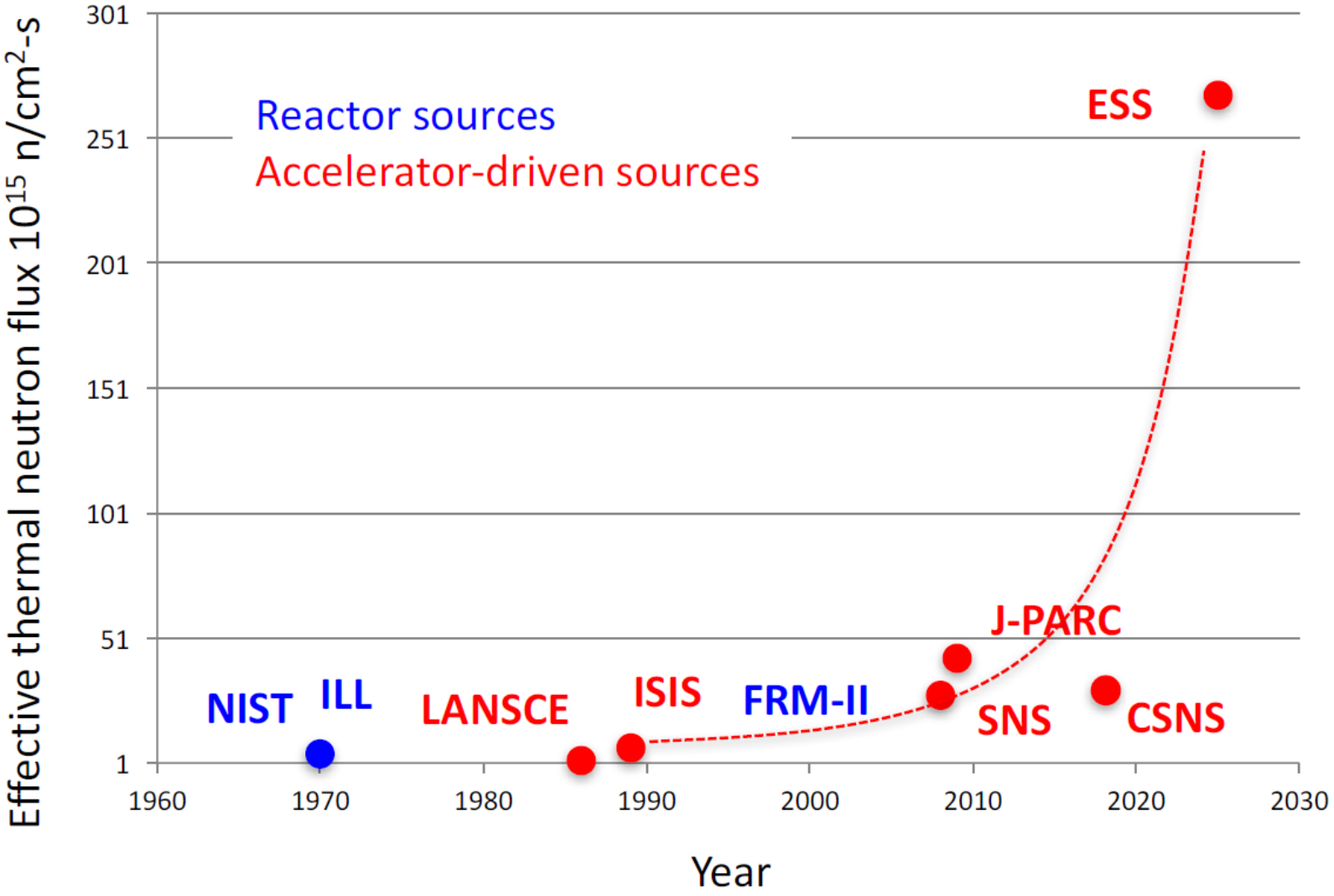
Spallation is a process in which fragments of material (spall) are ejected from a body due to impact or stress. In the context of impact mechanics it describes ejection or vaporization of material from a target during impact by a projectile.

Spallation on target using proton accelerator

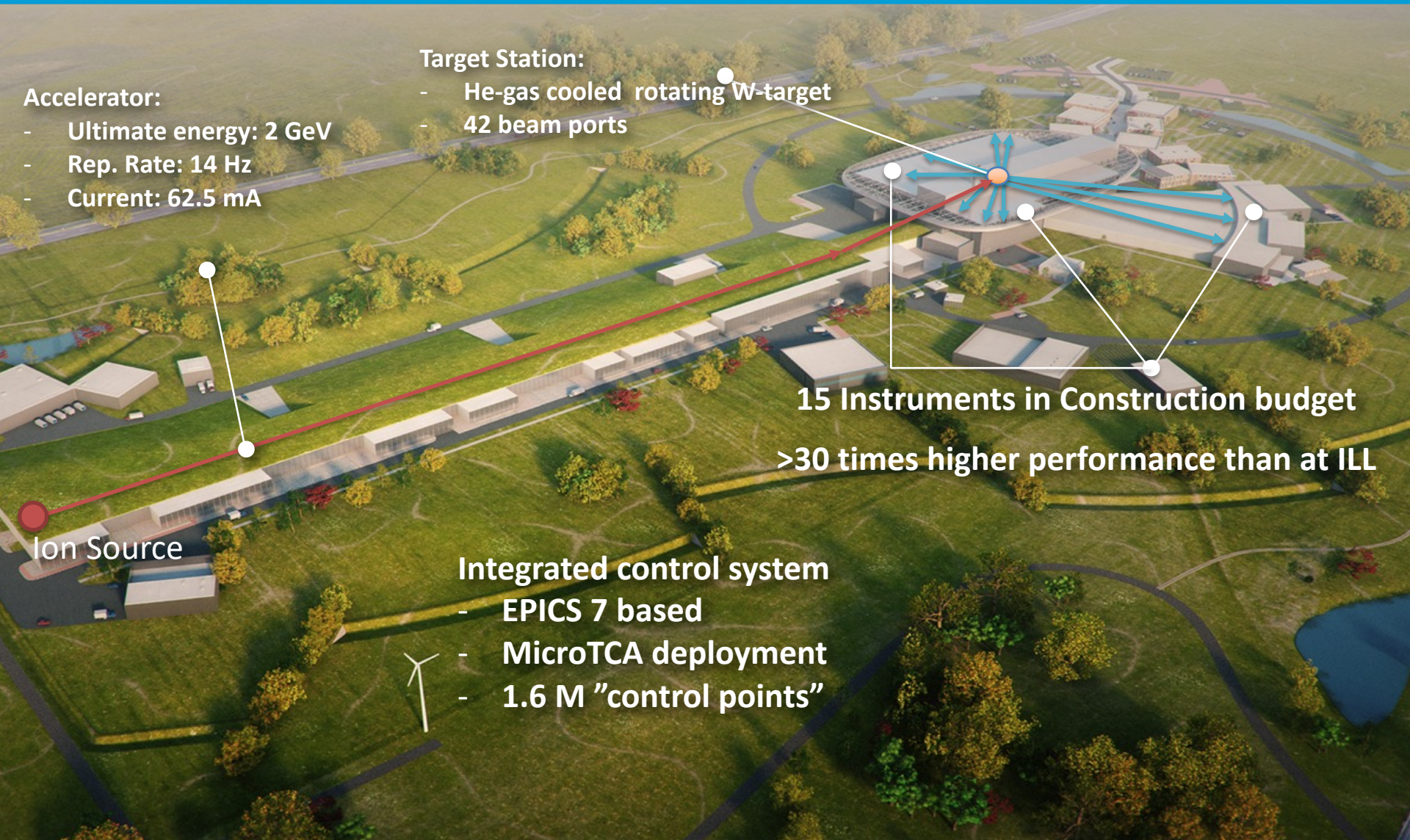
>30 neutrons per process



ESS will be the world brightest neutron source



ESS basic design principle



Financing

Host Countries Sweden and Denmark

Construction 47.5% Cash Investment ~ 97%
Operations 15%

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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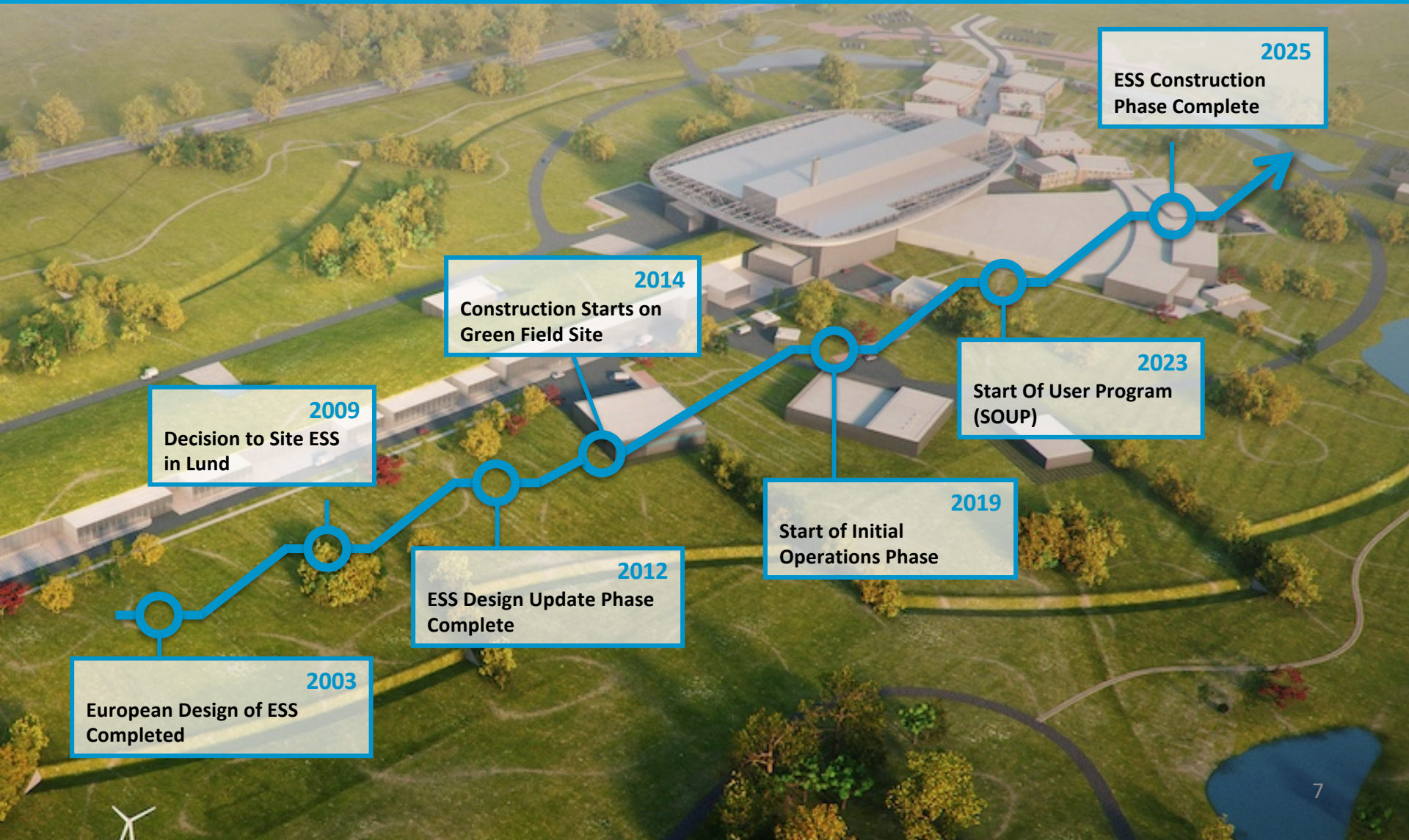

Ion Source ready for first beam

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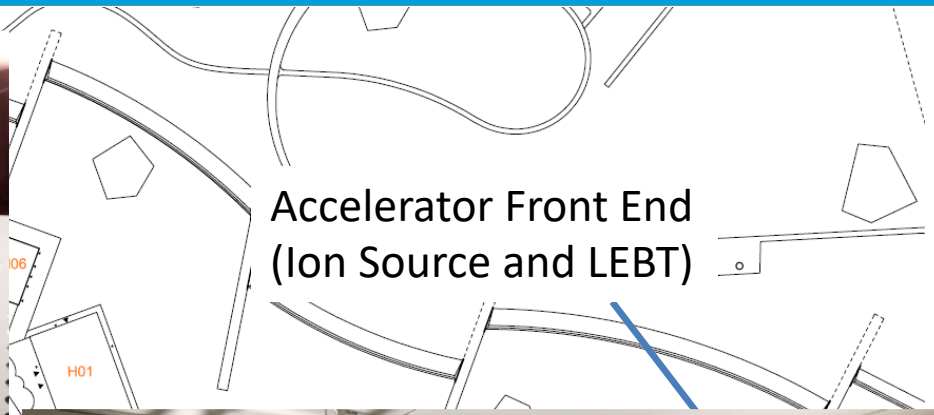

Accelerator Front End
(Ion Source and LEBT)

Key features of the ESS Target Station

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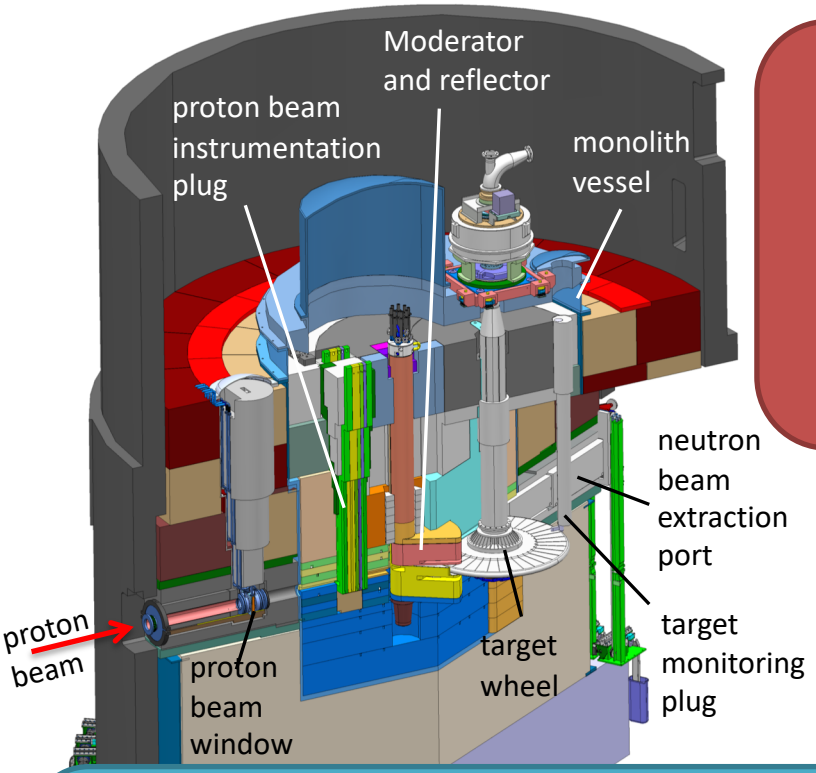


Target Safety System

- Monitors target coolant flow, pressure and temperature, monolith pressure, & target wheel rotation
- Prohibit beam on target if parameters are outside specified limits

Helium cooling of target material

- Mass flow 3 kg/s
- Pressure 11 bar
- Temperature inlet/outlet 40 °C/240 °C

Rotating solid tungsten target

- 36 sectors
- Mass, total 11 tonnes, whereof 3 tonnes of W
- Rotates 23.3 rpm, synchronized with pulsed proton beam 14 Hz

Moderators

- Provisional locations of moderators above and beneath the target wheel, i.e. monolith centre
- 1st MR plug exploits the upper space, offering:
  - ✓ Cold, 30 mm high, liquid H_2 moderators, 17 K
  - ✓ Thermal, 30 mm high, H_2O 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

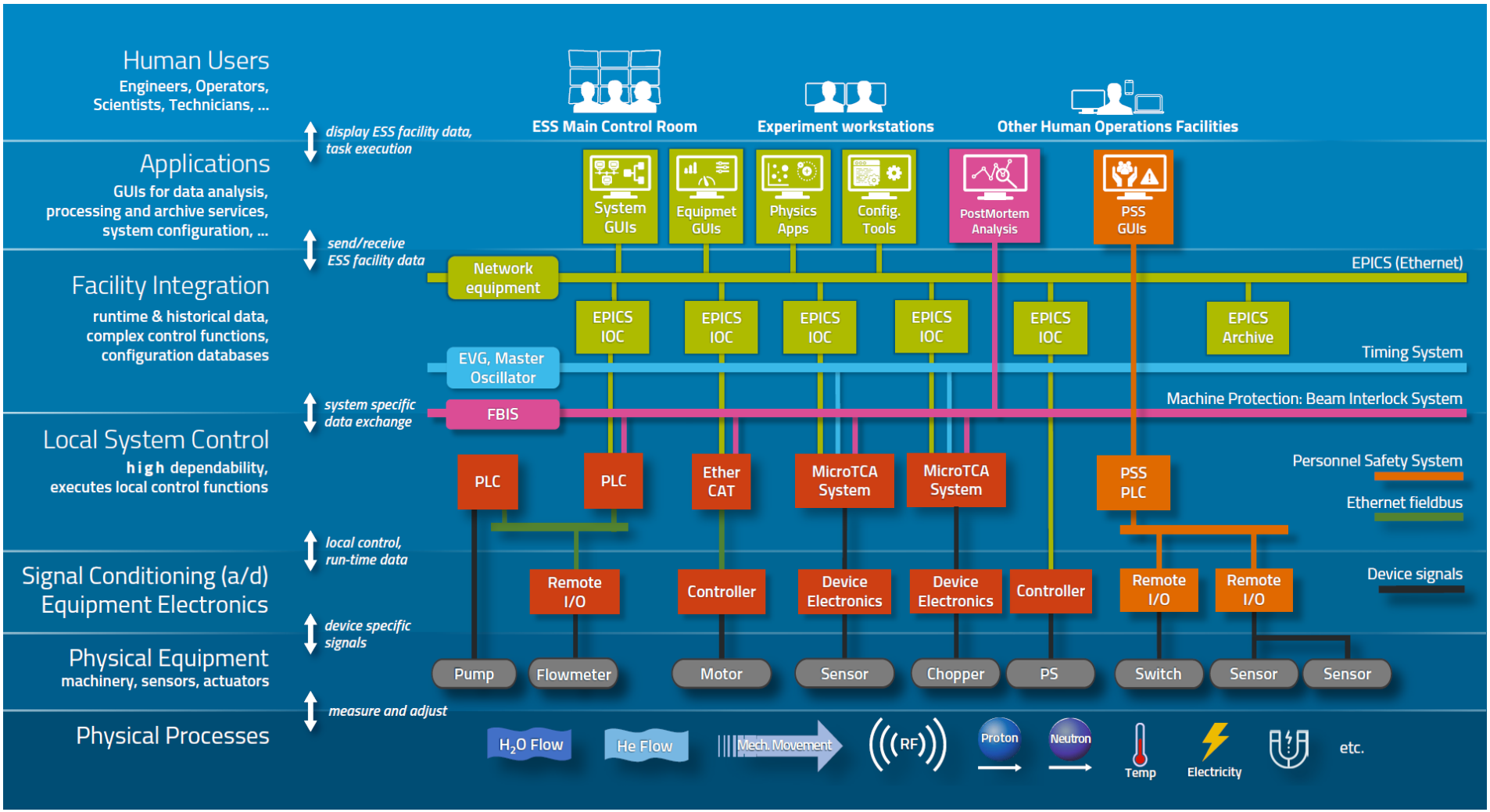
The ESS integrated control system

- 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

- 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

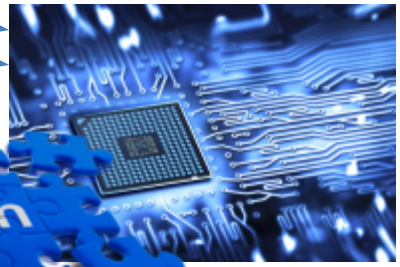


- Layered architecture based on EPICS distributed controls

ICS Project scope

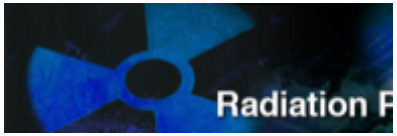
Work package 01	Management and administration
Work package 03	Software core
Work package 04	Hardware core
Work package 05	Machine protection
Work package 06	Equipment
Work package 07	Control system infrastructure
Work package 08	Physics
Work package 09	Personnel safety systems
Work package 10	Integration - Accelerator
Work package 11	Integration - Target
Work package 12	Integration - Instruments
Work package 13	Integration - Conventional facilities
Work package 14	Test Stands
Work package 20	Installation

Software



Electronics

Infrastructure



Safety & protection

Controlling systems from the local control room

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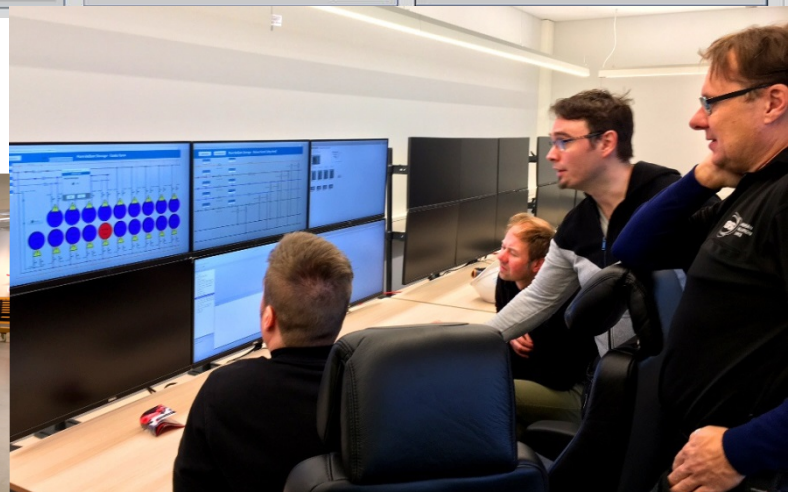
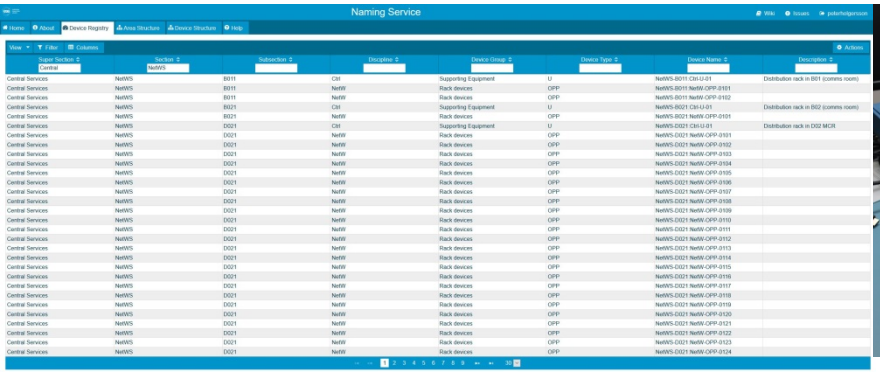
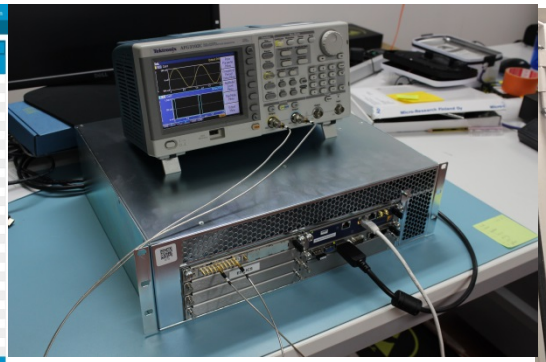
- Recent achievements include controlling the pure Helium storage and the ESS ion source and LEBT from the local control room

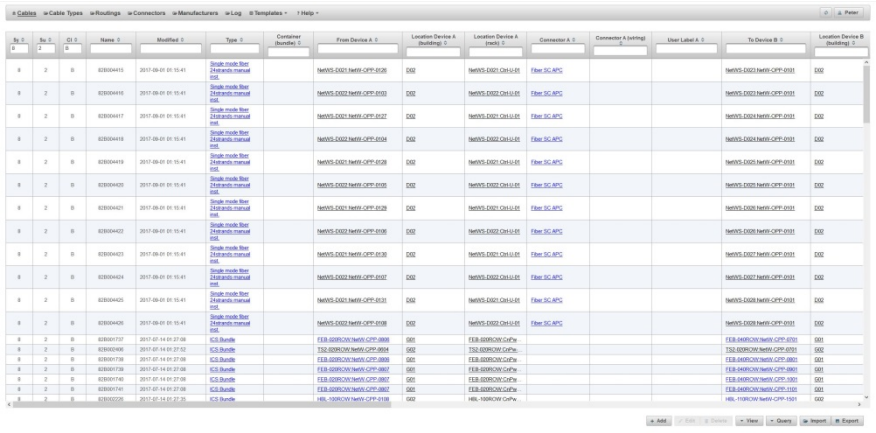


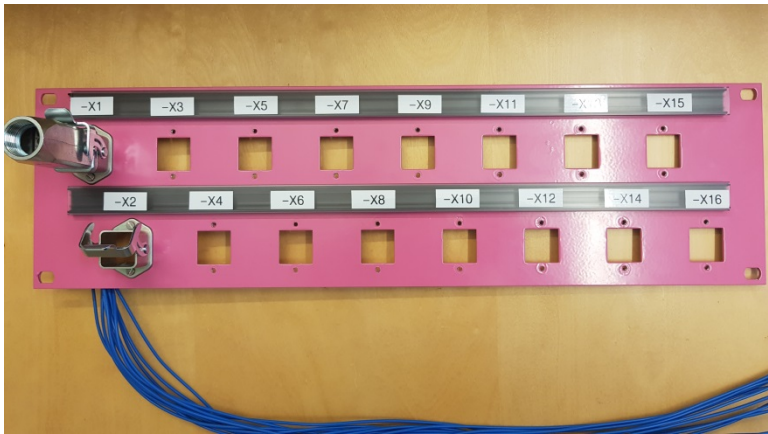
Building control systems



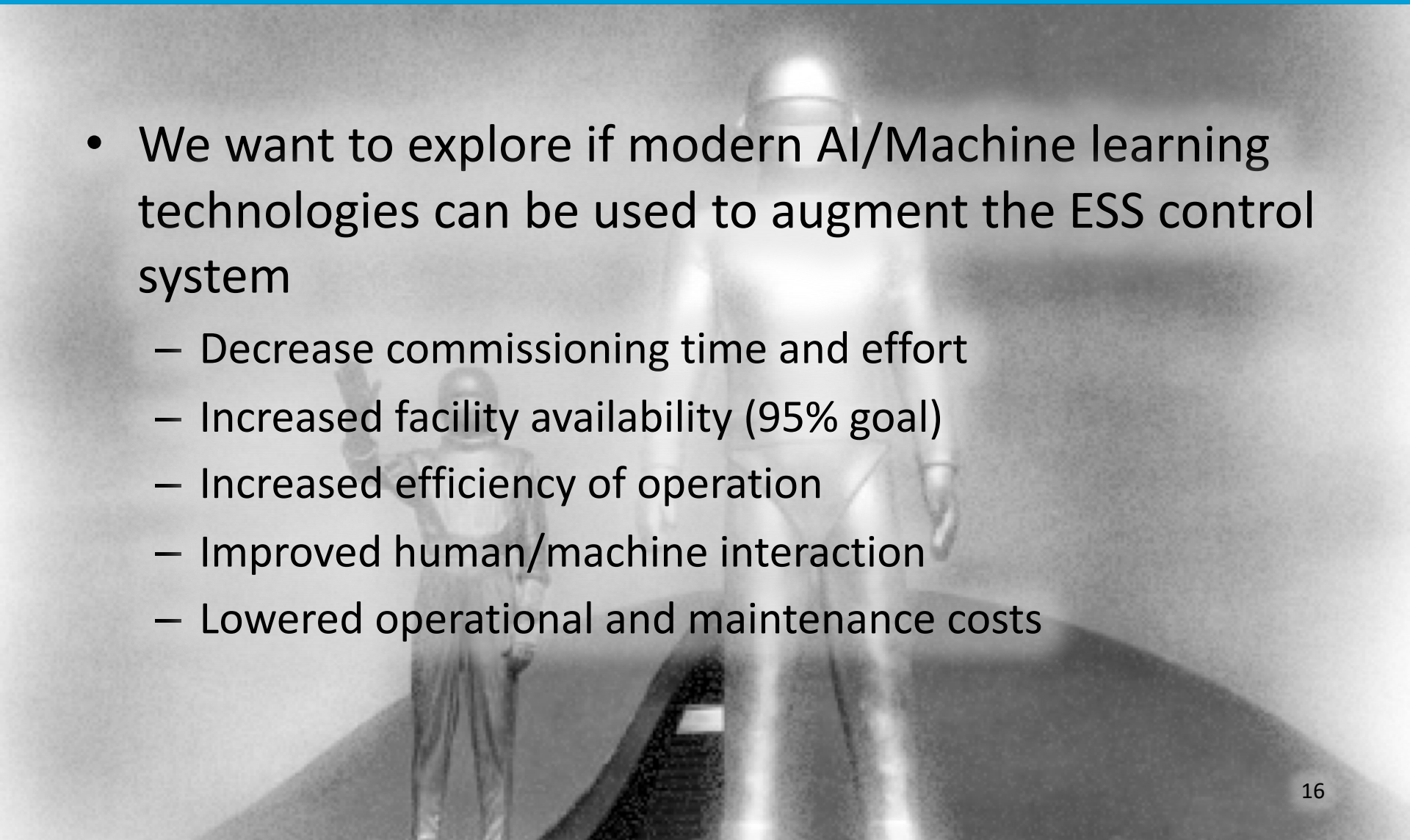


- Many components are being assembled into ICS subsystems and readied for installation
- Meanwhile, work is continuing with maintaining and developing the ICS and EPICS software solutions





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

Control System Machine Learning Project

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- The project is focused around the ESS integrated control system
  - 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

Deliverables

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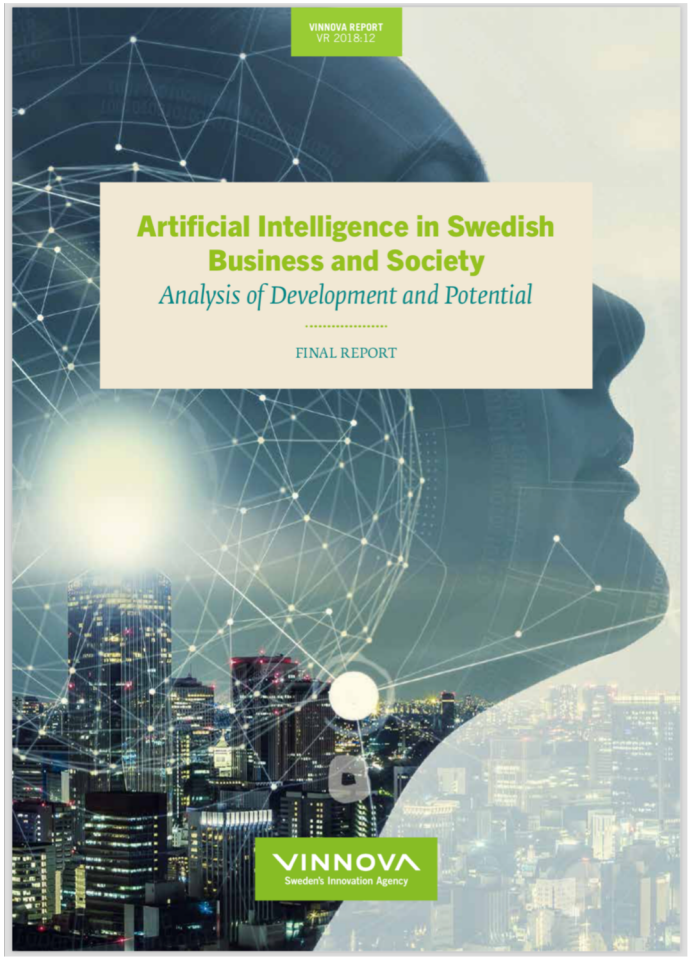
Partners

- 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



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

Thank you!

- Thank you for your attention
  - More information: europeanspallationsource.se
  - Contact: karin.rathsman@esss.se