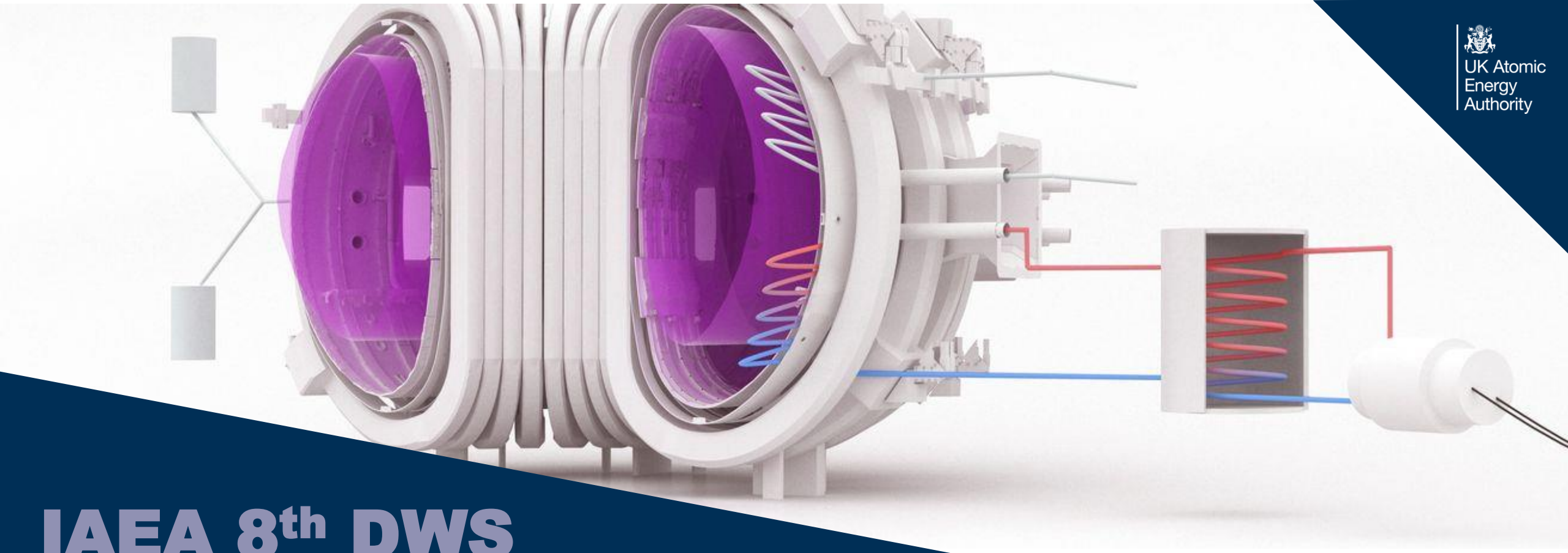


UK Atomic Energy Authority

IAEA 8th DWS

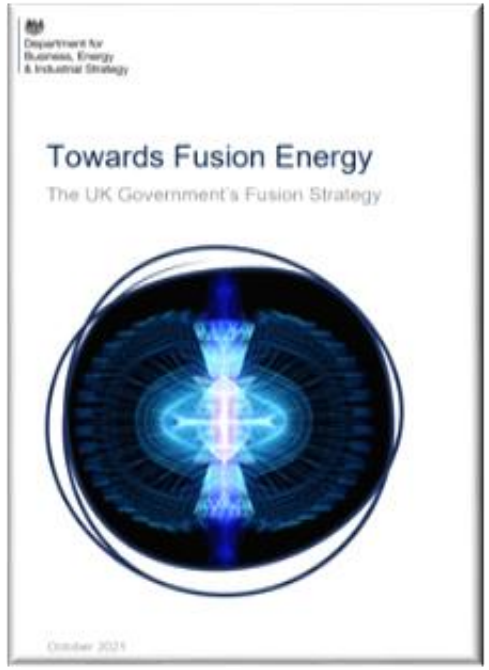
UK facilities anticipated for DEMO blanket preparation

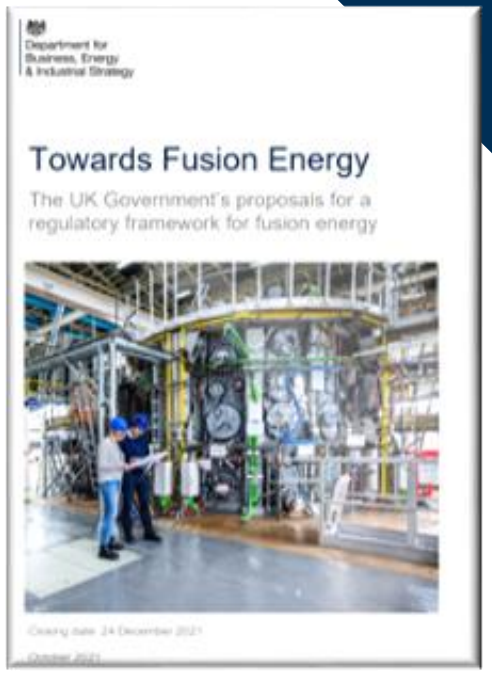
Prof Mike Gorley, Mike.Gorley@ukaea.uk

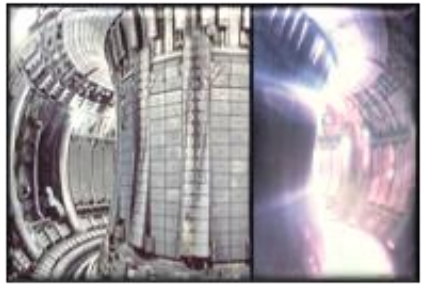
General Landscape in UK

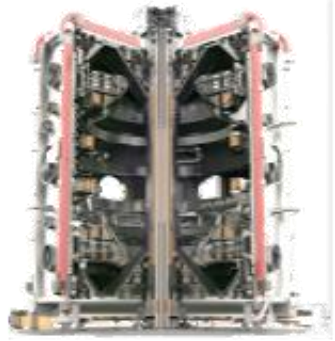
UK Atomic Energy Authority

- UKAEA, leading fusion focused non-departmental public body.
- UK Government strategy for fusion, including dedicated “innovative” regulation proposal.
- Ongoing key support to EU-DEMO and ITER.
- UK Gov lead fusion porotype design - STEP.
- Multiple UK based or major UK invested Fusion Private companies including: First Light Fusion, Tokamak Energy, General Fusion.







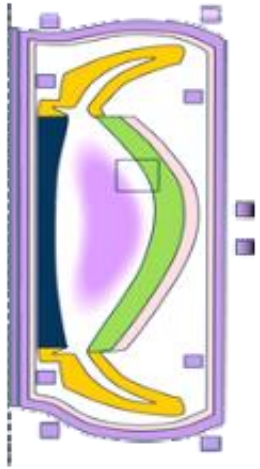


UK Capabilities in Blankets

UK Atomic Energy Authority

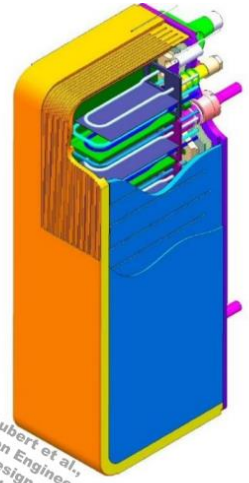
- Key general skills: neutronics, tritium fuel cycle, thermal hydraulics, structural analysis, safety analysis, design and integration tools (including systems models), materials research and development (including modelling of irradiation damage), virtual engineering (supporting “virtual qualification” and in-silico design), etc.

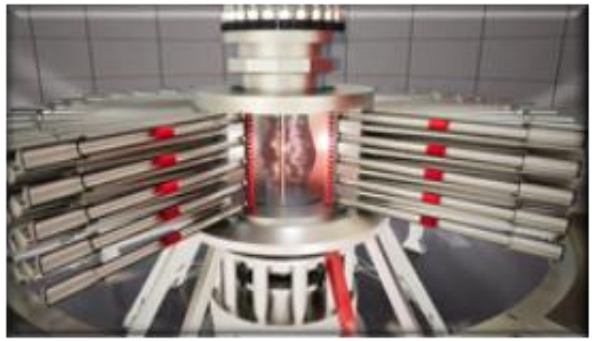
- Talk to focus on UK based facilities:
  - **MRF**
  - **H3AT**
  - **CHIMERA**
  - Range of smaller facilities, including Universities and private industry (not in talk)
  - Future facilities under active review (not in talk)



STEP blanket concept review.

Li curtain. First Light fusion reactor design - https://firstlightfusion.com/ (2021)





Enriched PbLi vortex. General Fusion reactor design - https://generalfusion.com/ (2021)

UK Atomic Energy Authority

Materials Research Facility

Structural and breeder materials development and testing

Materials Research Facility

mrf.ukaea.uk

UK Atomic Energy Authority

"A unique UK facility with world-leading capabilities for safely processing and analysing radioactive material"

- User facility.
- Quick and relative easy access.
- Dedicated tritium and beryllium handling.
- Li handling currently under design.

MRF Equipment Overview

UK Atomic Energy Authority

Sample preparation

- Hot-cell sample preparation (high-active)
- Glovebox sample preparation (low-active)
- Sample processing (non-active)
- Precision Ion-beam Polishing
- Sputter Coater
- Lab-scale EDM cutting, wire & die (non-active)
- 2023: hot-cell EDM/micro-milling/laser cutting

Hot-cell line:

Microstructural Analysis

- SEM (+ EDS, EBSD, TKD, WDS)
- Dual beam FIB
- CSLM with Raman Spectroscopy
- Atom Force Microscope
- X-ray Diffractometer
- 2022/23: p-FIB / TEM / DSC-MS / XRD σ-stage (HT)

Remote ops of SEM:

Thermo-physical characterisation

- Physical Property Measurement System (14T/1.8K-1000K)
- Ion exposure and impregnation system
- Thermal Desorption Spectroscopy
- Laserflash Analysis (LT/HT)
- Dilatometry (LT/HT)
- STA (LT/HT)
- Gas pycnometry
- Impulse Excitation Testing (HT)
- 2023: High-vac DSC + MS

PPMS:

Mechanical testing

- Nano- & instrumented indentation
- Small scale load frame (5 kN)
  - Temperature and Atmosphere control
  - DIC
- Static load frame (10 kN)
- Dynamic load frame (15 kN)
- Ultrasonic Fatigue Rig (20kHz)
- Small Punch test setup (Ø3-8mm)
- 2022: SEM In-situ testing <1000°C

UK Fusion Materials Roadmap

UK Atomic Energy Authority

Materials: Cryoresilience

Materials: Tritium boost, block

Materials: Structural >550°C

Materials: Engineering assurance

Materials: Low activity

Plasma exhaust / heat dissipation
(Super X Divertor)

Plant efficiency
(generate 100MWe net)

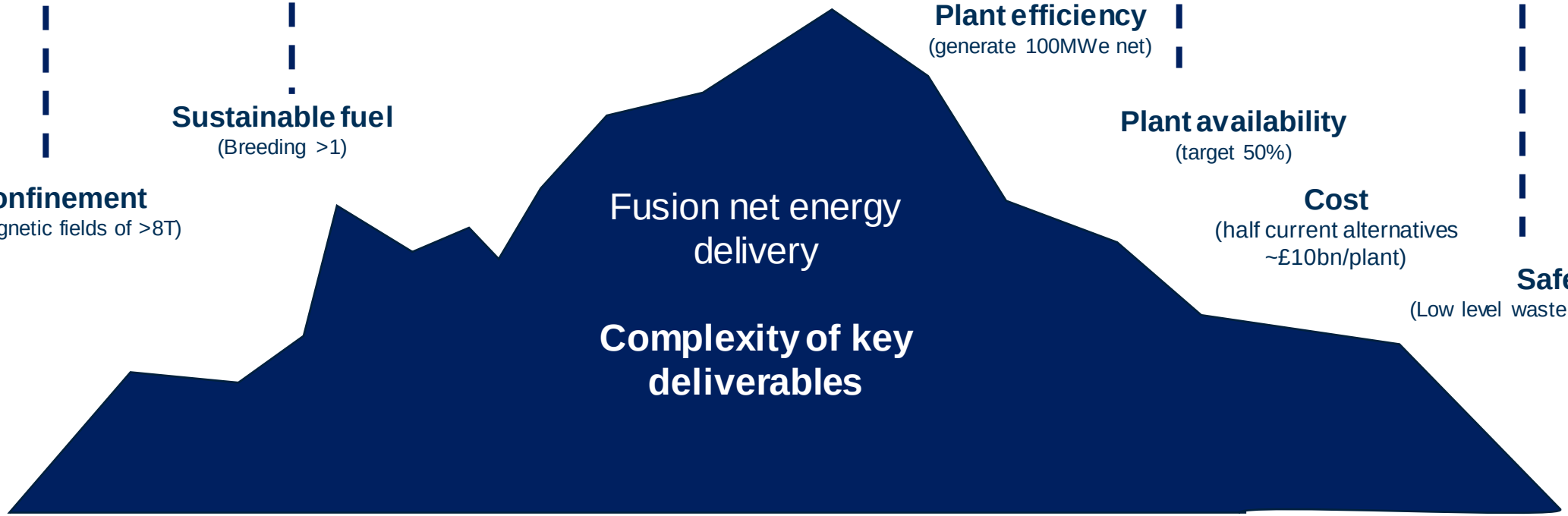
Sustainable fuel
(Breeding >1)

Plant availability
(target 50%)

Confinement
(at magnetic fields of >8T)

Cost
(half current alternatives ~£10bn/plant)

Safety
(Low level waste classifications)



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H3AT - Tritium Advanced Technology

Tritium interactions with materials and blanket within fuel cycle

H3AT Tritium Advanced Technology

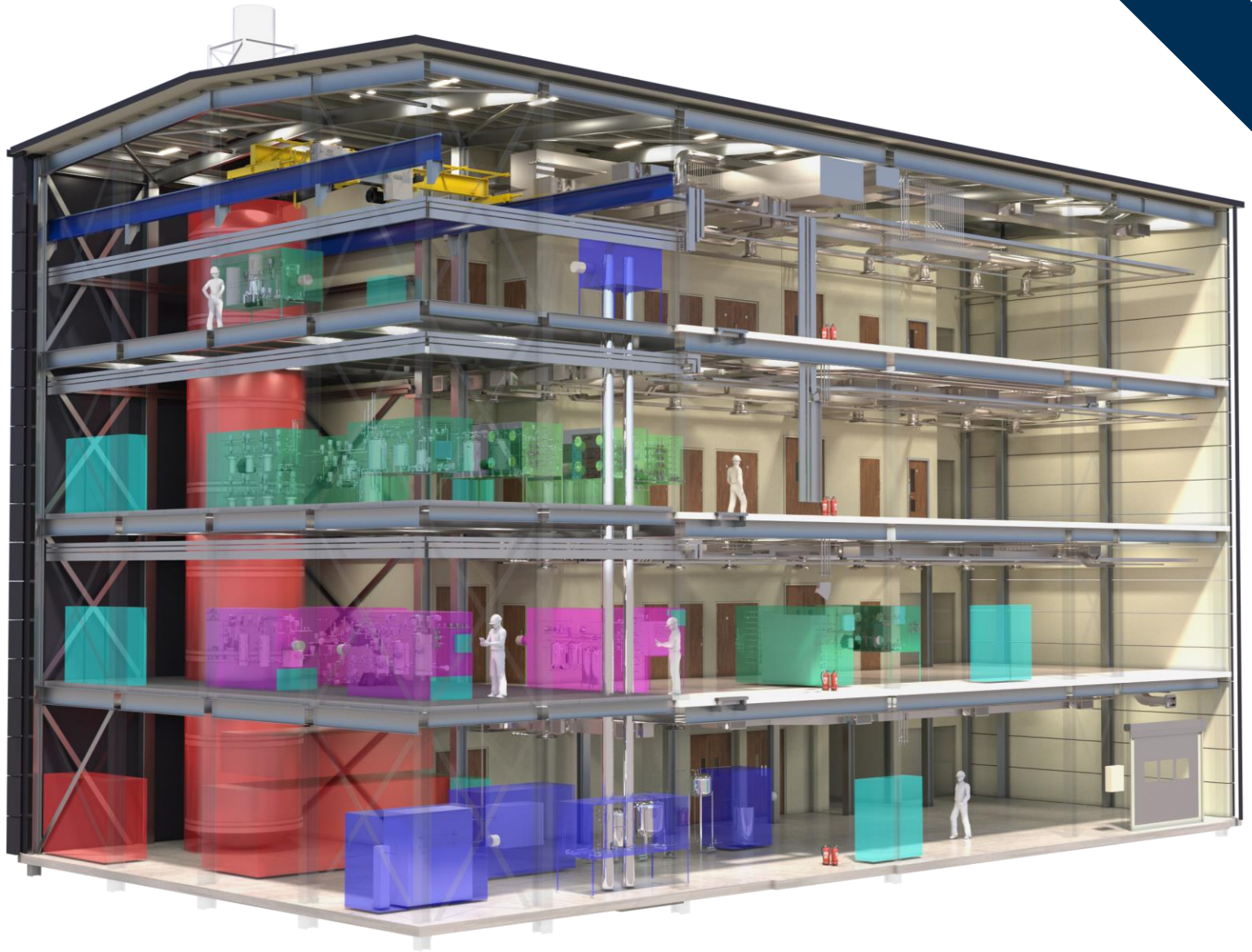
UK Atomic Energy Authority

Dedicated “tritium” centre of excellent, opening 2024.

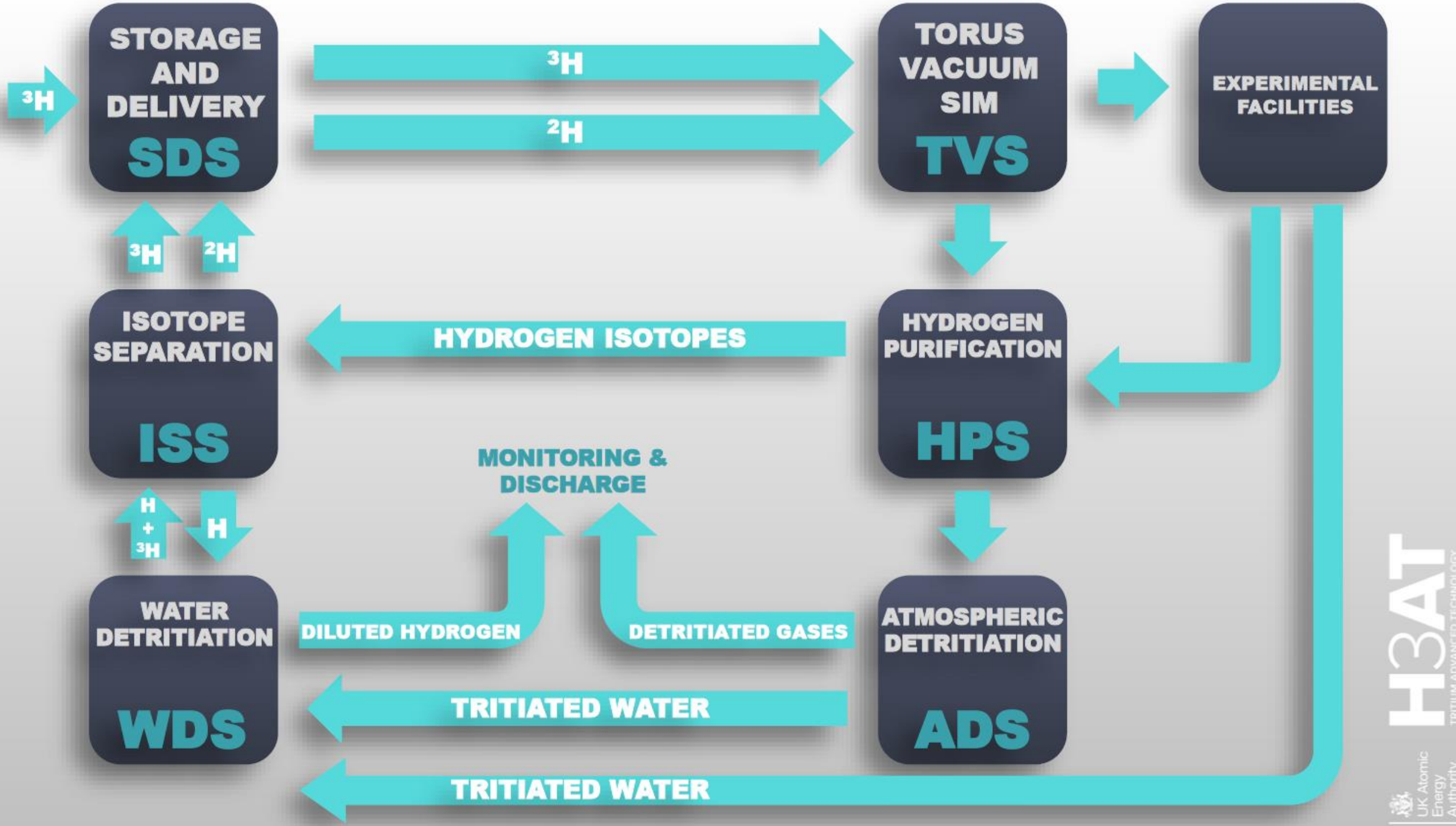
World leading, building from JET, key role in ITER.

“The H3AT facility provides a 1/20th scale simulation of the ITER fuel cycle, modelling all the critical systems of a fusion fuel cycle loop”.

Engaged with Blankets.




We are considerate constructors
UKAEA
Middle Way


STORAGE AND DELIVERY
SDS
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TORUS VACUUM SIM
TVS
EXPERIMENTAL FACILITIES
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^{2}H
ISOTOPE SEPARATION
ISS
HYDROGEN ISOTOPES
HYDROGEN PURIFICATION
HPS
MONITORING & DISCHARGE
H + ^{3}H
H
WATER DETRITIATION
WDS
DILUTED HYDROGEN
DETRITIATED GASES
ATMOSPHERIC DETRITIATION
ADS
TRITIATED WATER
TRITIATED WATER
H3AT
TRITIUM ADVANCED TECHNOLOGY
UK Atomic Energy Authority

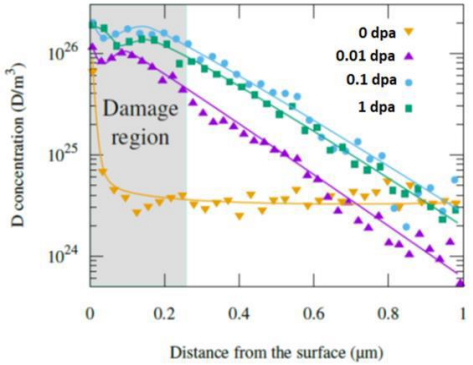
H3AT – user accessible research unit

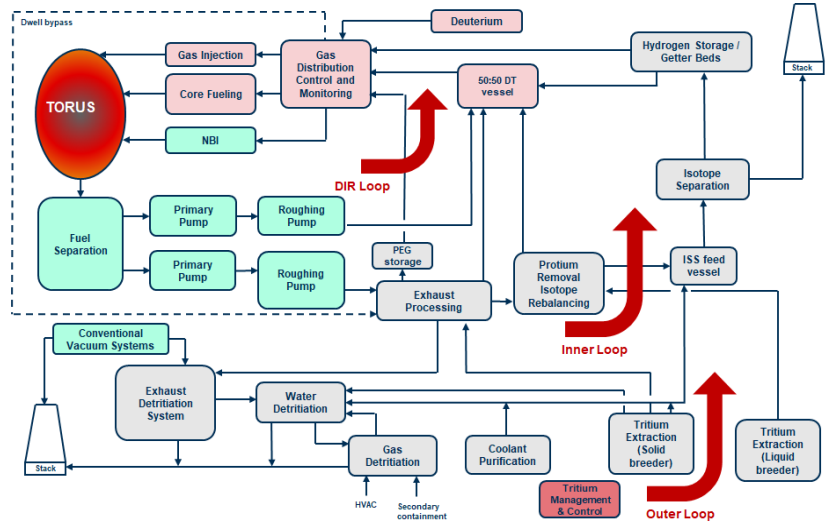
UK Atomic Energy Authority

To ensure fusion has the skills, facilities, scientific understanding, process development capabilities and waste management competence needed for the development of fusion fuel cycles, and the materials required to interact with tritium.

Capabilities though H3AT:

- Tritium Innovation in Science and Engineering
- Tritium Services
- Control and Instrumentation
- Training
- Waste Innovation
- Waste Operations





UK Atomic Energy Authority

CHIMERA - Combined HeatIng and MagnEtic Research Apparatus

Representative scale component validation testing

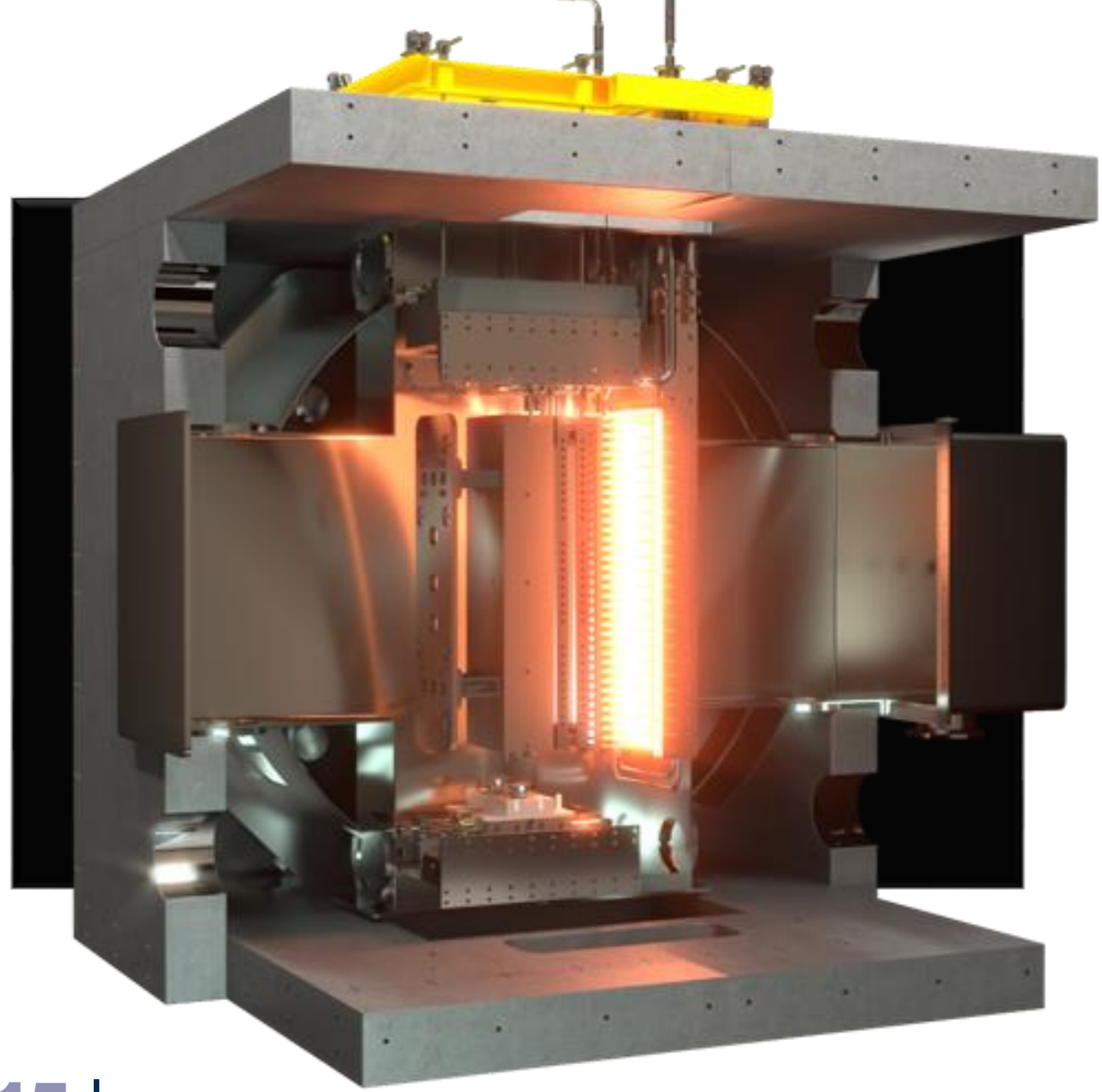
CHIMERA

UK Atomic Energy Authority

Unique, world leading, combinatorial loading facility, online 2024.

Uniquely placed to test and evaluate blankets prior to operation in fusion reactor.

Linked team and virtual engineering, validation and verification of blankets.



CHIMERA

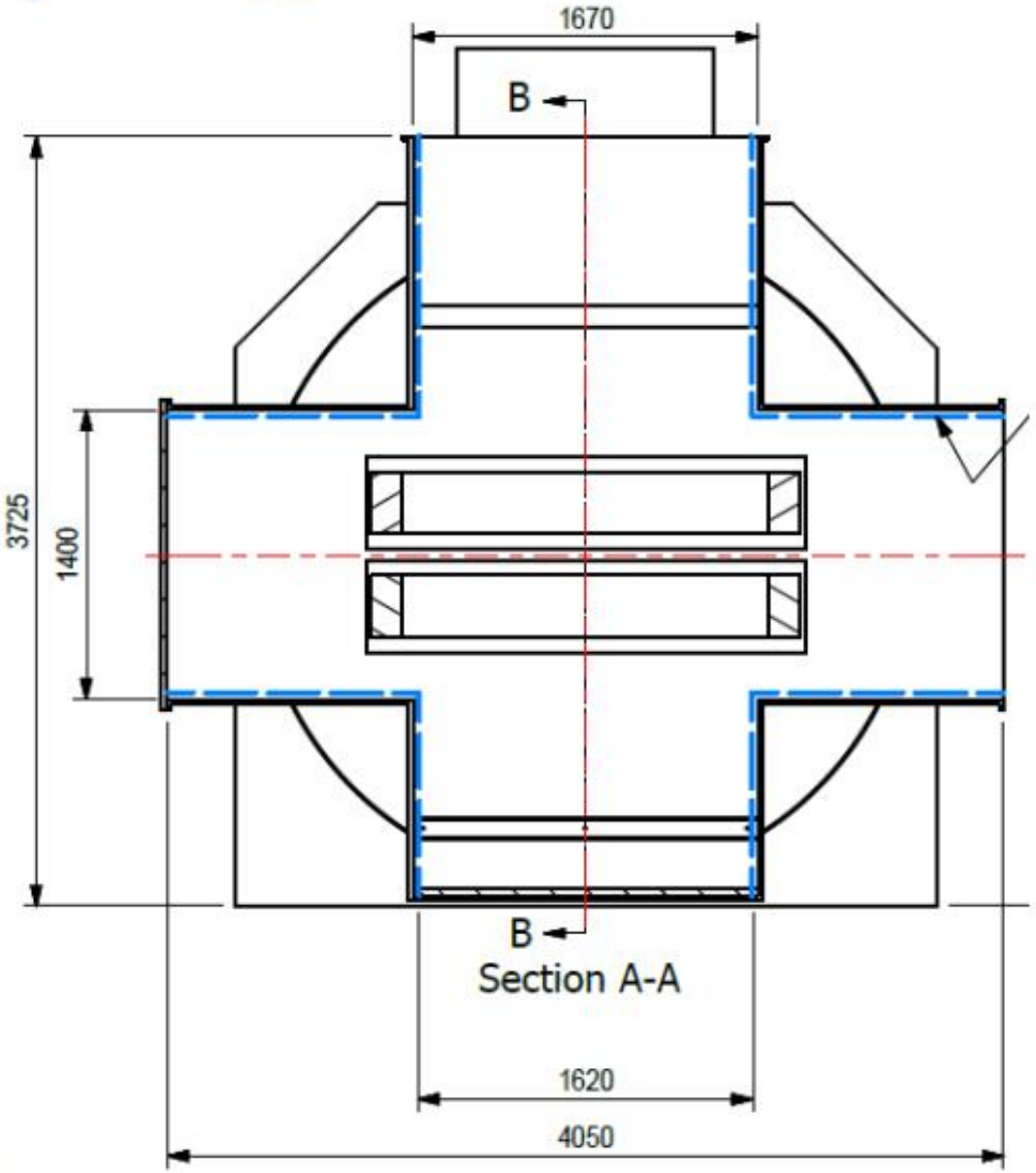
Combined Loads Testing Facility

Component Size	1.7m x 0.5m x 0.7m
Testing Environment	Vacuum or inert gas
Water Cooling	200°C, 15 bar – 385°C, 155 bar
Surface Heating	0.5 MW/m^2 over 1m^2
Simulated Volume Heating	Up to 100 kW
Static Magnetic Field	4 Tesla
Magnetic Impulse	dB/dT ~12 T/s
PbLi loop (upgrade)	Skid-mounted, 17m^3/hr, 280-550°C
Laser (Upgrade)	20MW/m^2 patch heating, 100 MW/m^2 focused heating.

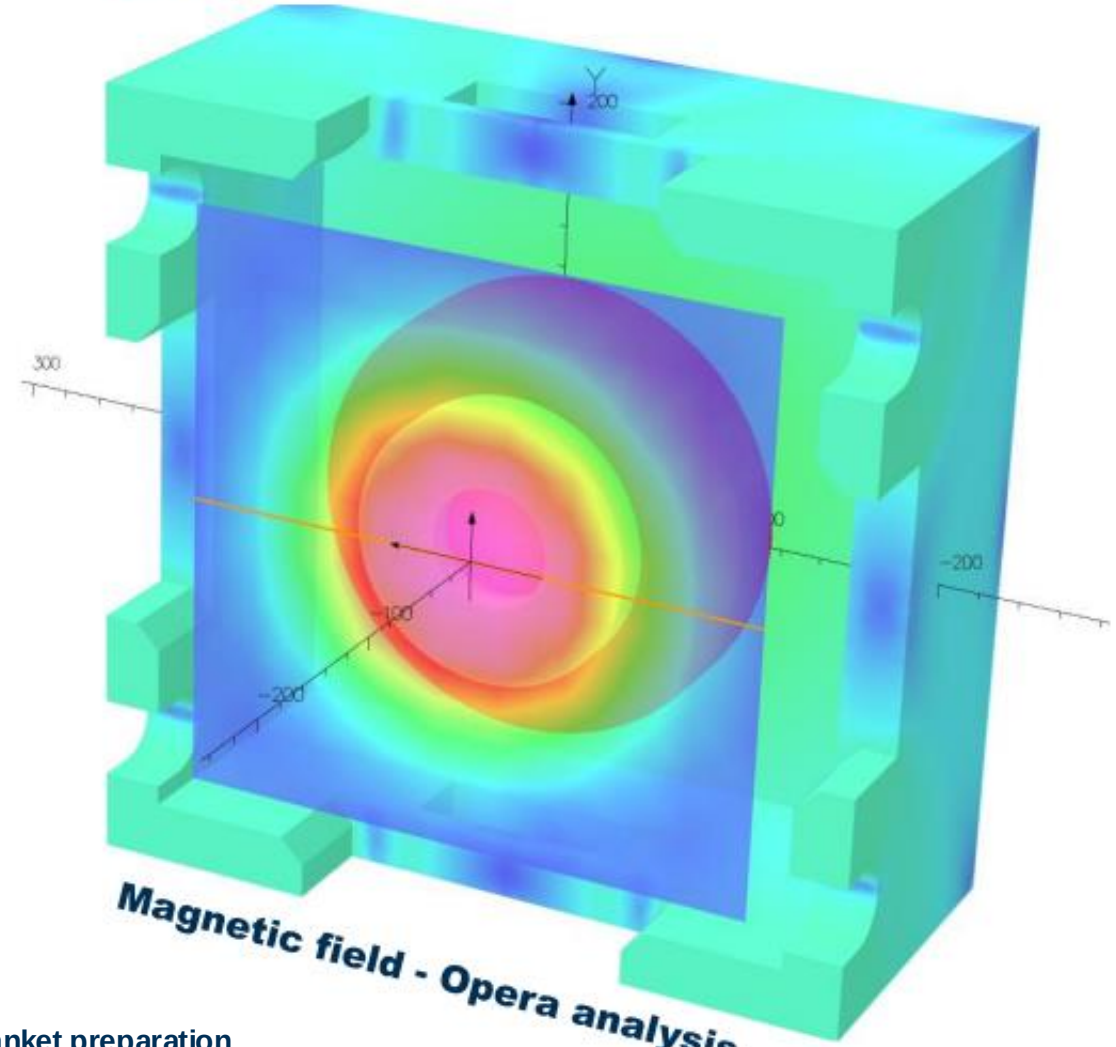
New UKAEA site in South Yorkshire, UK

UK Atomic Energy Authority

1) Magnetic field – functional testing



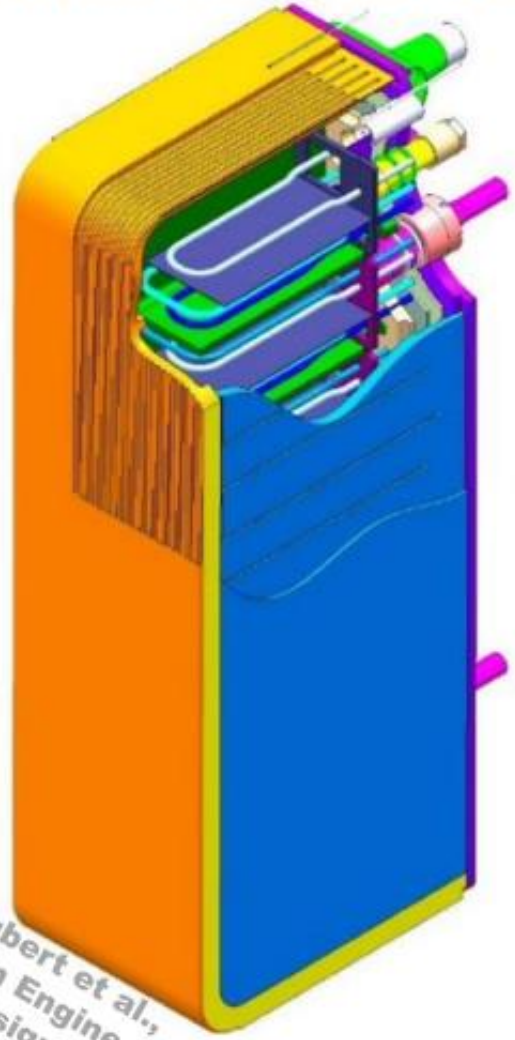
4 T central field
5 T peak



Magnetic field - Opera analysis

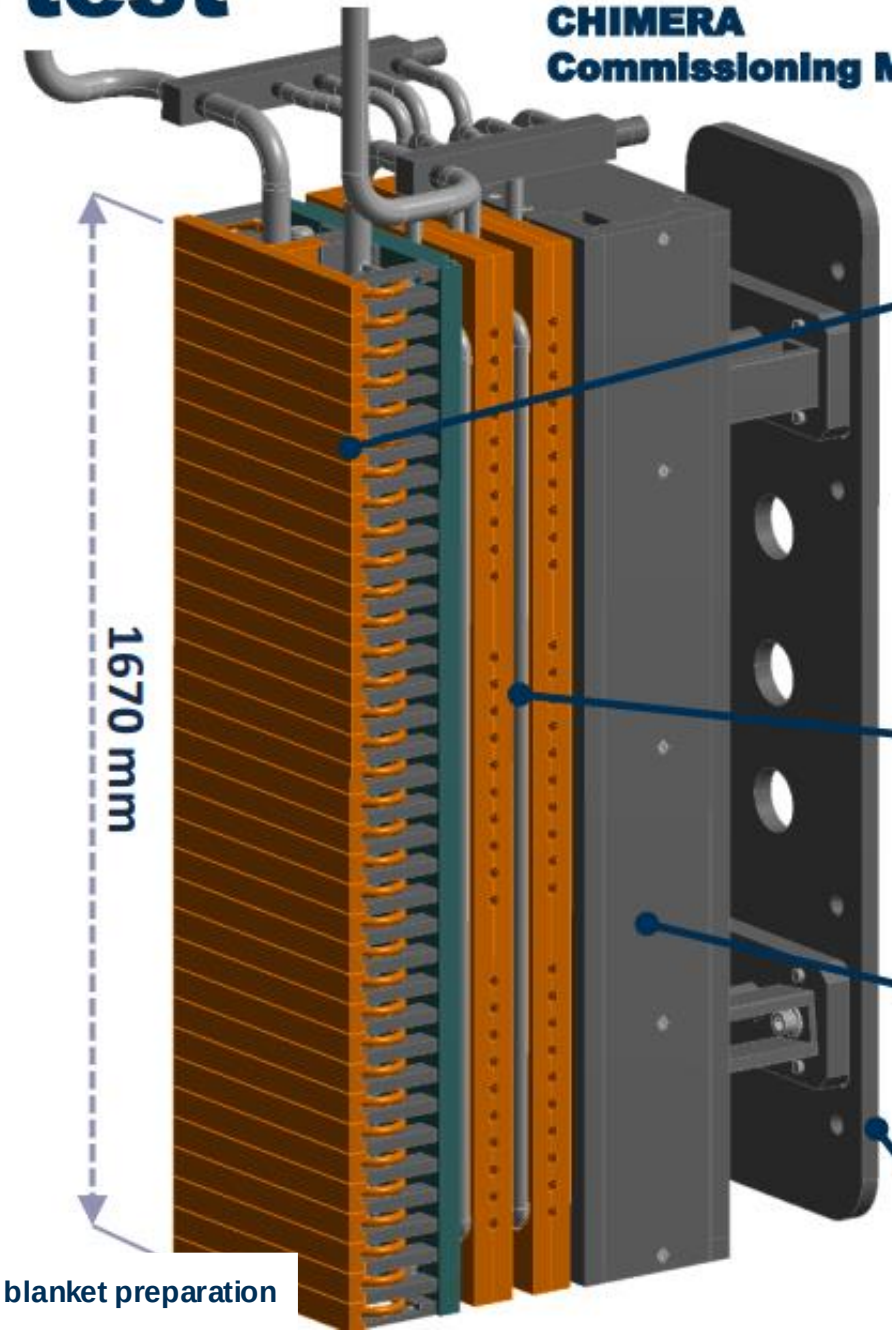
2) “semi-integral” PFC test

ITER WCLL TBM : 1.67 x 0.46 x 0.8 m



J. Aubert et al., Fusion Engineering and Design 160 (2020) 111921

CHIMERA Commissioning Mock-up



FW section – water cooled Cu/CuCrZr (coated heated surface)

Mid-section – resistive heaters

Rear section – ferromagnetic mass

Mounting ‘backplate’

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3) High Heat Flux + magnetic field

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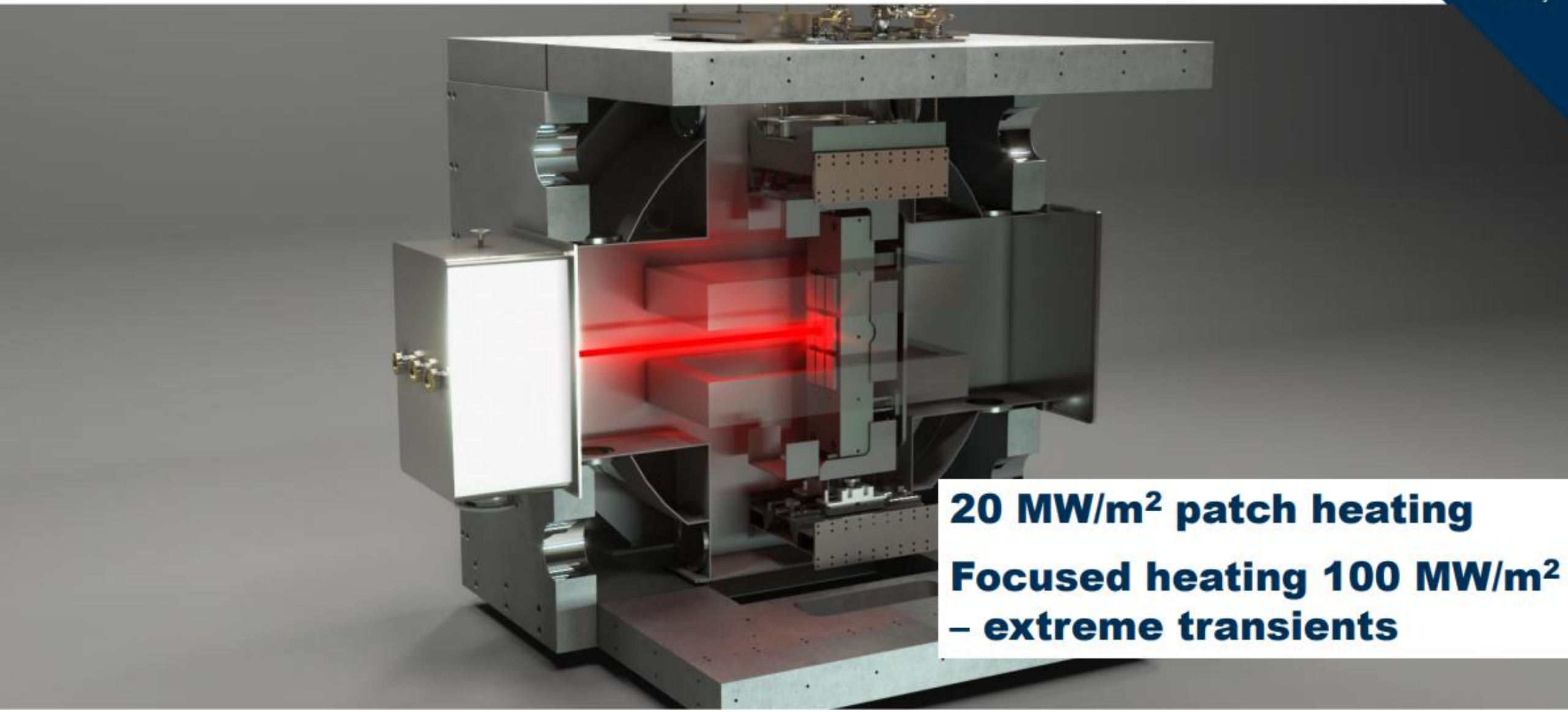


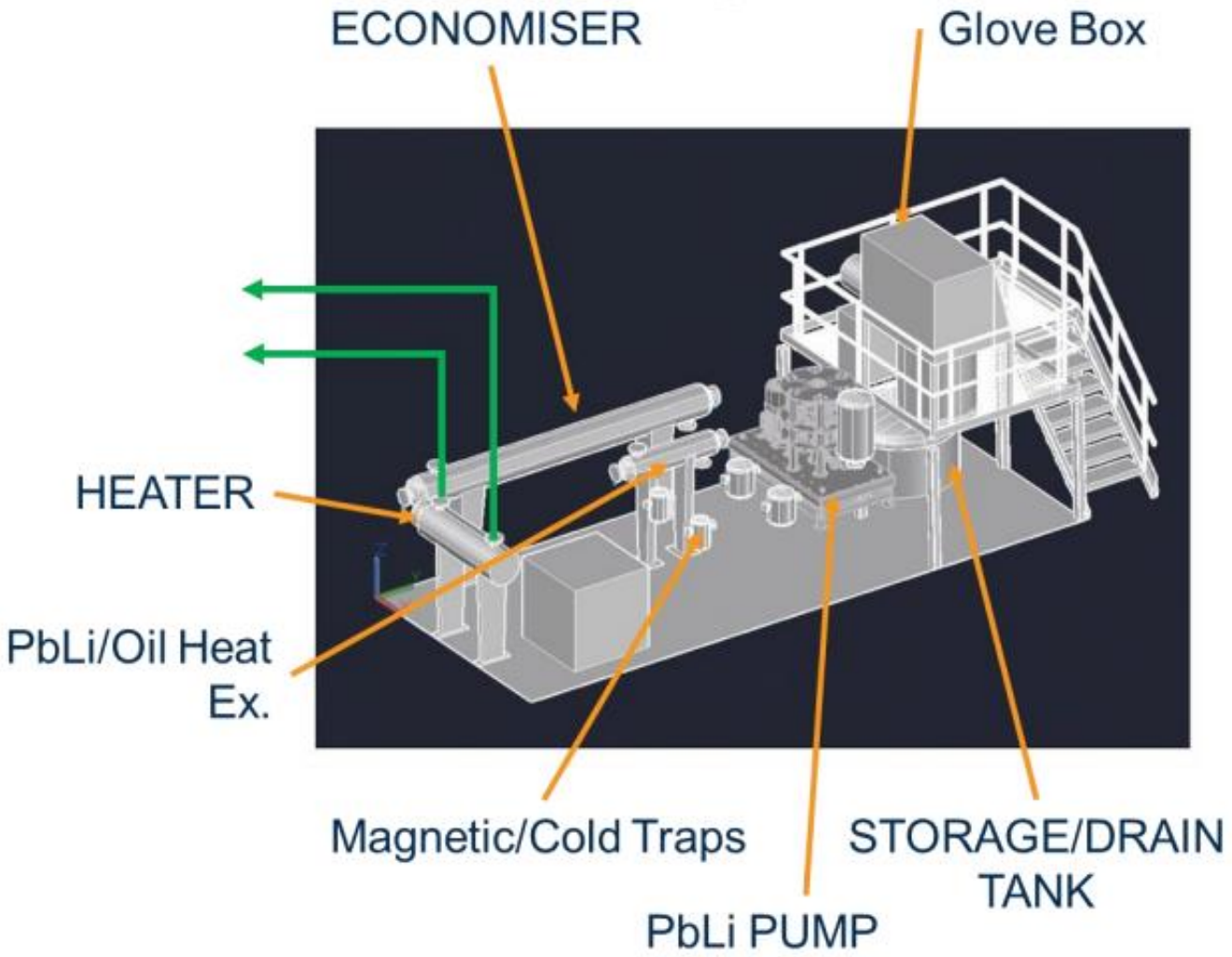
20 MW/m² patch heating

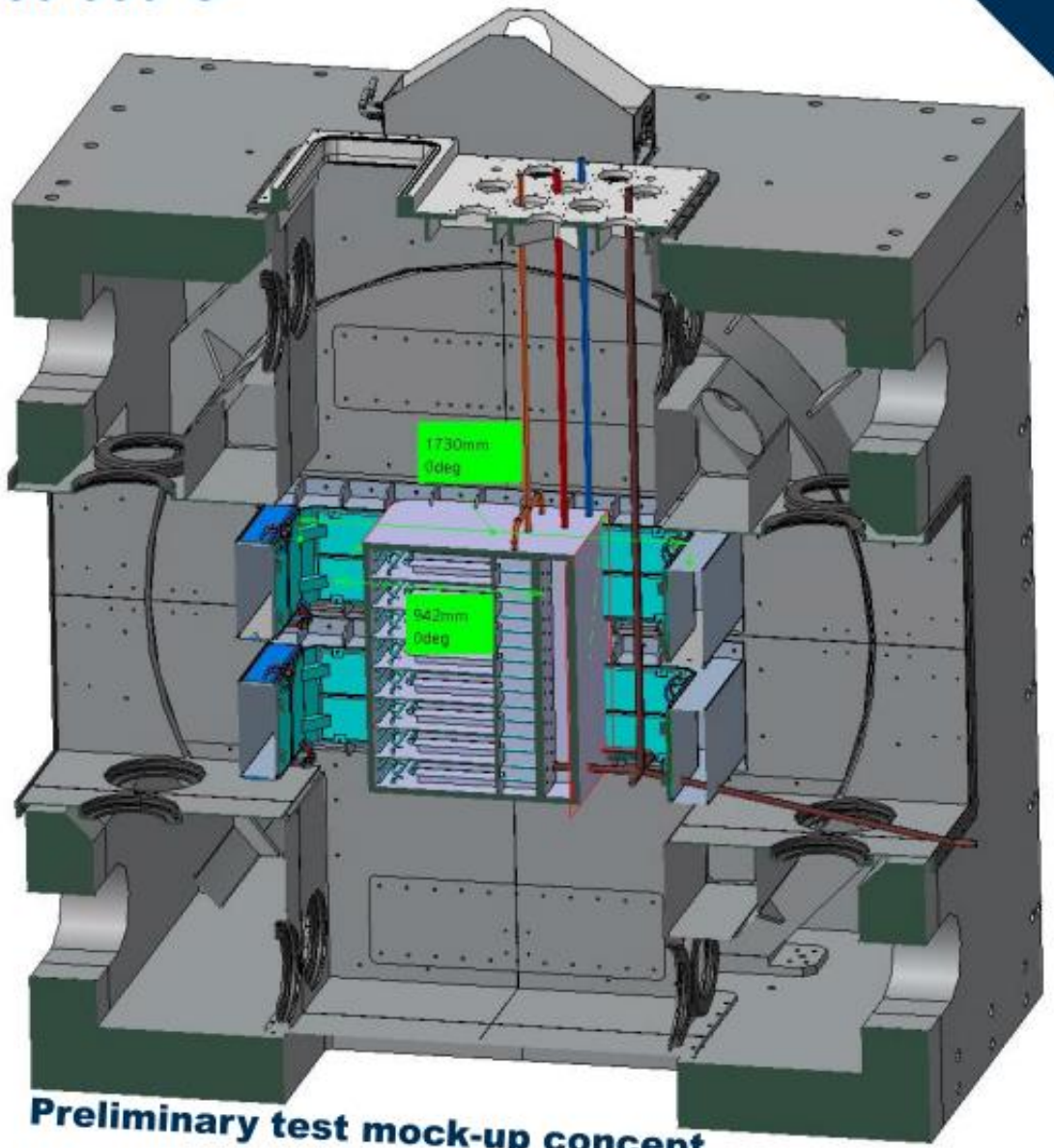
Focused heating 100 MW/m² – extreme transients

4) Liquid metal MHD

- Skid-mounted loop design
- PbLi – flow rate up to 17 m^3/hr
- 280-550°C

e.g. WCLL Blanket testing EUROfusion





Preliminary test mock-up concept

CHIMERA and Project Pegasus

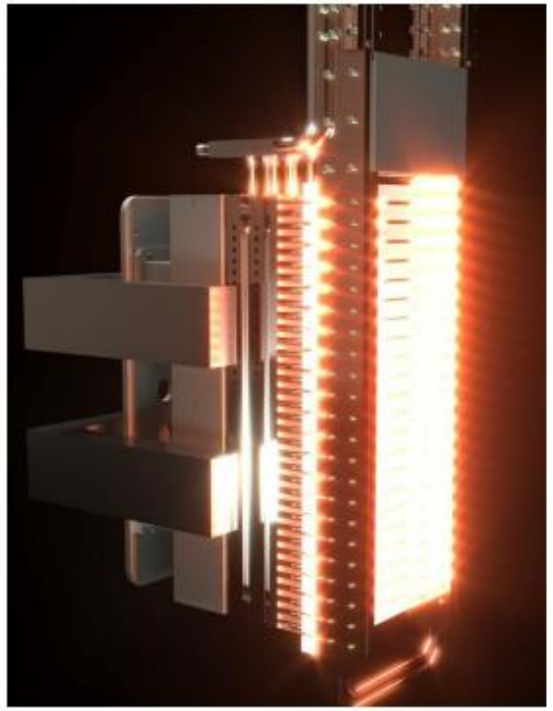
UK Atomic Energy Authority

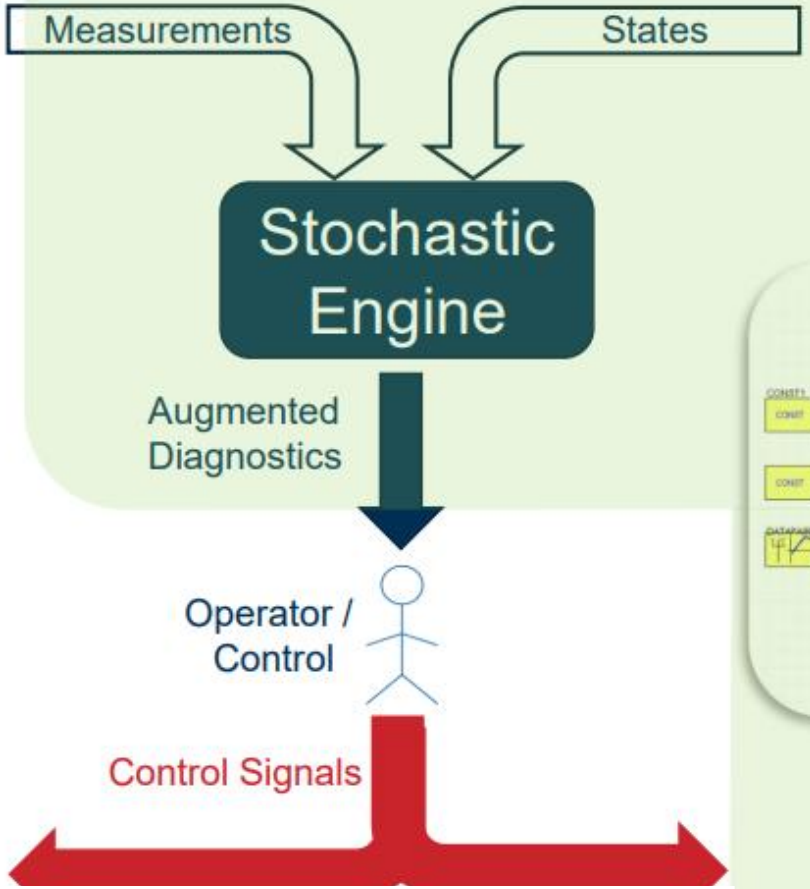
Project Pegasus Goal: develop the process and technologies required for **digital design, qualification and lifetime monitoring**, using CHIMERA as the near-term application and test case

Physical Asset

CHIMERA Commissioning

Sample Under Test

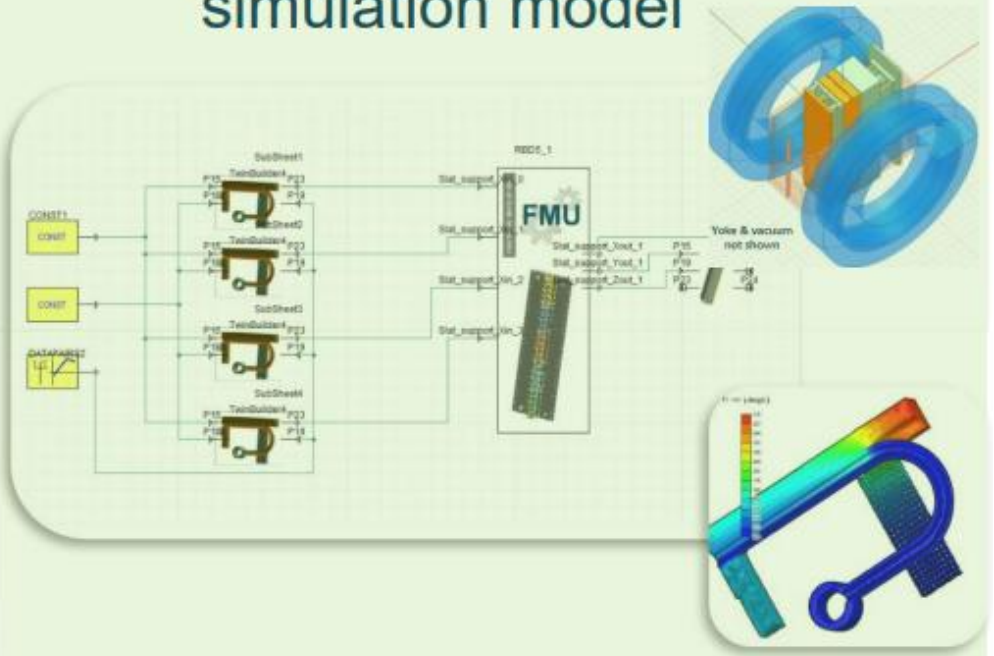




Simulation

Pegasus

Integrated system simulation model



Digital Twin

Summary

UK Atomic Energy Authority

Blanket supporting facilities is going to be a key aspect of developing fusion ecosystem (Opinion M. Gorley, Sep 2022).

UK can offer the fusion community:

- Key skillsets in major aspects needed for blanket development.
- Key facilities for blanket testing and development:
  - **MRF** - Irradiated materials scientific studies
  - **H3AT** - Tritium research and fuel cycle
  - **CHIMERA** – Component testing at representative scale (MHD, static and pulsed magnetic loads, thermally hydraulics, heating), supported by digital replicas.

All of these facilities are designed as “user facilities” with access opertunities for the wider fusion community.

Many Thanks for your Attention