UK Atomic Energy Authority

UKAEA contribution to EUROfusion WPMAG 2026–27 (Indicative / draft for discussion)

Presenter: Min Liao, Group Leader – Magnet Technology, Fusion Technology Division

15/01/2026

I - UKAEA contribution to EUROfusion WPMAG 2026–27 (HTS irradiation- test planning and capabilities overview)

UK Atomic Energy Authority

2026 WPMAG Priorities	Relevant UKAEA	2026 Actions
R&W Nb3Sn manufacture & SULTAN tests (PF, CS; 100 m CS)	Magnet Technology Collaborations; Current Active Projects	Lock SULTAN slots; track jacket/cabling/HT; align cryo tests
HV cold feedthrough prototypes	Key Collaboration Domains; Knowledge Exchange	Cryo HV/PD matrix; ENEA/CEA reviews
HTS conductors (50 m) + tests	Magnet Technology Collaborations; Current Active Projects	Finalise DoE; SULTAN fixtures; link to insert coil
X-ray tomography & defect analysis	Key Collaboration Domains (materials/NDE)	Define voxel size & defect taxonomy
REBCO striation studies	Key Collaboration Domains; Future Opportunities	AC-loss rigs; tensile testing in field; design rules
Irradiation & nuclear-load effects on HTS	Key Collaboration Domains	Plan neutron/ion exposures; model degradation vs dose
EU–CN tasks incl. CORC quench test	Current Active Projects; Knowledge Exchange	Align with ASIPP; prep CORC & protection
Process: submit Task Specifications by 13 Feb 2026	Summary (programme note)	IMS trackers; facility schedules; OGS items

II - UKAEA involvement overview

UKAEA Project	WON 14216	Order responsibl
FT-EF26 Bluemira expert (non DES/TSVV)	14216-1000	Clare Casson
FT-EF26 Support BEST	14216-1001	Clare Casson
FT-EF26 Eni collaboration (TSVV-14)	14216-1002	Clare Casson
FT-EF26 WPTRED WEST Tokamak/Hive synergies	14216-1003	Clare Casson
FT-EF26 WPCSE Socioeconomic Studies (SES)	14216-1004	Clare Casson
FT-EF26 WPMAG Eurofusion Magnet	14216-1005	Clare Casson
FT-EF26 WPSA Work Package Commissioning and Enhancements for JT-60SA	14216-1006	Clare Casson
FT-EF26 WPSA Neutronics analysis of JT60	14216-1007	Clare Casson
FT-EF26 WPDES Systems Codes - DEMO	14216-1008	Clare Casson
FT-EF26 WPDES Systems Codes - Bluemira	14216-1009	Clare Casson
FT-EF26 WPDES Systems Codes - Systems Modeller (UQ Studies)	14216-1010	Clare Casson
FT-EF26 WPDES Neutronics support for VNS/EU DEMO	14216-1011	Clare Casson
FT-EF26 WPDES DONES HFTM neutron diagnostics	14216-1012	Clare Casson
FT-EF26 WPDES DONES component movement	14216-1013	Clare Casson
FT-EF26 WPDES DONES safety neutronics analysis	14216-1014	Clare Casson
FT-EF26 WPDES Activated Corrosion Products	14216-1015	Clare Casson
FT-EF26 WPDES ACT	14216-1016	Clare Casson
FT-EF26 WPDES Fluid Activation	14216-1017	Clare Casson
FT-EF26 WPDES ITER Feasibility	14216-1018	Clare Casson
FT-EF26 WPDES JET decommissioning support	14216-1019	Clare Casson
FT-EF26 WPDES Code development in support of nuclear analysis	14216-1020	Clare Casson
FT-EF26 WPMAT DDC	14216-1021	Clare Casson
FT-EF26 WPMAT EDDI-MPH	14216-1022	Clare Casson
FT-EF26 WPMAT SSTT	14216-1023	Clare Casson
FT-EF26 WPDIV Limiter Joining	14216-1024	Hollie Roach
FT-EF26 WPDIV Structural Integrity Task Coordinator	14216-1025	Hollie Roach
FT-EF26 WPDIV AM Tungsten	14216-1026	Hollie Roach
FT-EF26 WPDIV Limiter Task Coordinator	14216-1027	Hollie Roach
FT-EF26 WPDIV HIVE Structural Integrity Validation OR limiter mock-up cyclic testing	14216-1028	Hollie Roach
FT-EF26 WPBB Flow induced Vibration (FIV)	14216-1029	Hollie Roach
FT-EF26 WPBB Heat transfer characterisation of PbLi and Water in WCLL BB (TH Analyst)	14216-1030	Hollie Roach
FT-EF26 WPBB Exploratory Studies on experimental needs for maturing WLCB blanket technolog	14216-1031	Hollie Roach
FT-EF26 WPPWIE COMPASS-U	14216-1032	Hollie Roach
FT-EF26 Travel	14216-1033	Clare Casson
FT-EF26 Management	14216-1034	Clare Casson
FT-EF26 WPSTEL Neutronics Analysis of Stellarator concepts	14216-1035	Clare Casson

UKAEA EUROfusion WPMAG involvement:

- Technical scope: HTS; HV feedthroughs;
- Quench detection; modelling; facilities support
- International collab: EU–CN stream (quench detection, AC-loss reduction, CORC, CS tests);
- ITER/ENEA/CEA/EPFL/ASIPP
- **Resources (2026):** Contribution aligned to the approved WPMAG budget *(~0.2 FTE L5-equivalent; scope limited accordingly)*
- Strategic opportunity: irradiation — aligns to 'HTS degradation under irradiation' call topic
- **Budget/Scope caveat**
- UKAEA activities shown are indicative and subject to (i) confirmed 2026 WPMAG budget (0.2 FTE L5-equivalent) and (ii) facility access approvals/cost recovery (incl. ELSA, SULTAN). No commitment implied.
- Facility engagement subject to internal approval and cost recovery.

II -What we will do- Proposed UKAEA contributions (within approved WPMAG scope))

UK Atomic Energy Authority

Technical Work Packages

- HTS conductor activities – coordination and test definition (SULTAN interface)
- Quench detection R&D (RF waveguide approach)
- Modelling (AC losses, EM–thermal coupling, mechanical stresses)
- Potential cryogenic test support (subject to access approval and cost recovery)

International collaboration streams

- **EU–CN extension:** HTS quench detection, AC-loss reduction, CORC quench test, CS coil testing
- Partnerships with ITER, ENEA, CEA, EPFL, ASIPP
- Joint work on conductor manufacturing modelling

Resource footprint (2026)

- Effort aligned to approved WPMAG 2026 budget (~0.2 FTE L5-equivalent).
- OGS for test hardware & characterisation
- Facility access: MRF (irradiation-compatible PPMS), ELSA, tomography, cryo rigs

Strategic Opportunity (2026–27): Irradiation

- Addresses the WPMAG call topic “HTS degradation under irradiation”
- Uses UKAEA–MRF capabilities
- Relevant to UKAEA internal magnet programmes (illustrative only) .

* STEP used as an internal reference context only (subject to STEP approval for external sharing)..

III - WPMAG 2026–27 Call — UKAEA HTS Irradiation Subtasks

UK Atomic Energy Authority

Core (within approved WPMAG scope)

- Definition of irradiation test matrix and metrics
- Pre/post-irradiation Ic and AC-loss data handling (where approved)
- Dataset structure and metadata for EUROfusion modelling

Conditional (subject to separate agreement & funding) *

- Neutron/gamma irradiation campaigns
- In-situ cryogenic irradiation experiments
- Advanced microstructural characterisation (SEM/TEM)

Collaboration

- Activities involving irradiation campaigns to be defined jointly with **UKAEA Materials Division / MRF governance**

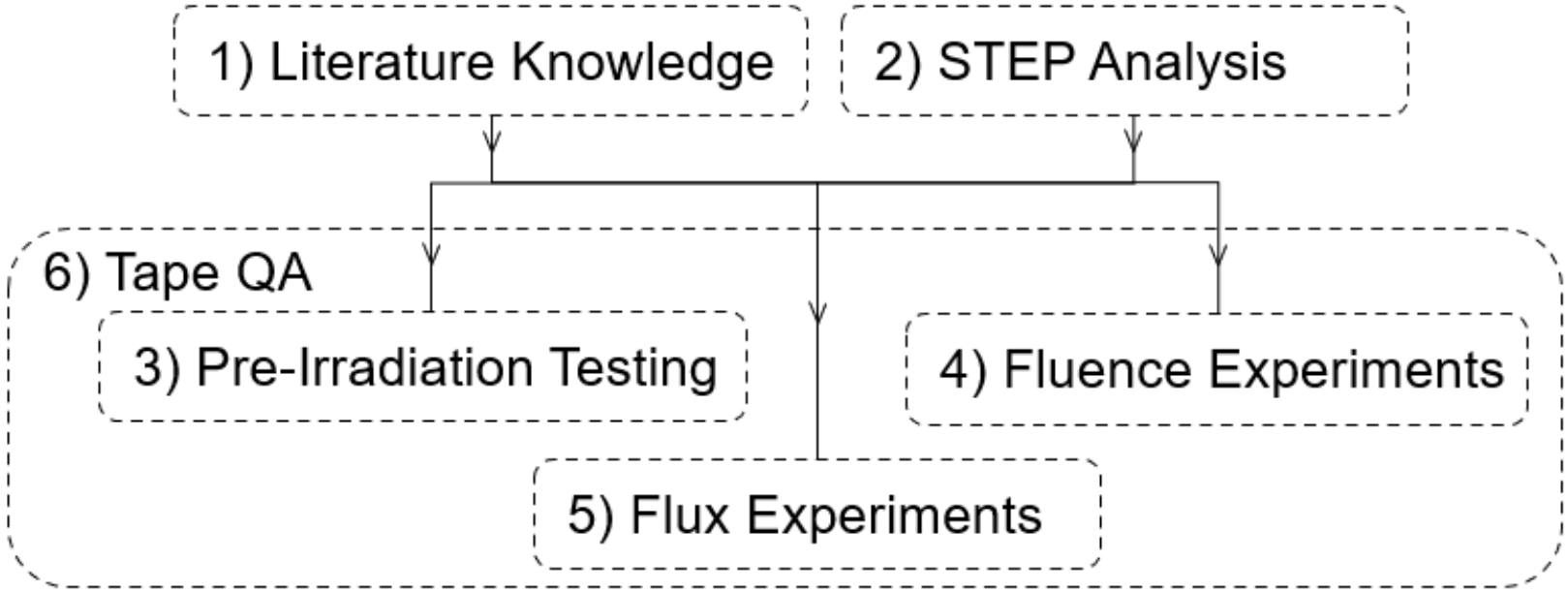
* testing activities are indicative and subject to funding, access approval, and internal governance.

HTS Irradiation test programme aims:

Aim: establish irradiation-related performance limits and testing approaches for commercially available REBCO conductors.

1) Understand what is currently known about commercially available REBCO CC from literature.
2) Determine from analysing design what the required performance is for the REBCO CC to be places in the toroidal (TF) and poloidal field (PF) coils.
3) Determine from 1-2) and testing how the limits of REBCO CC – known as its critical current (I_c) – are affected by changes in T, B, ϕ, ε before irradiation.
4) Determine from 1-3) and testing how REBCO I_c(T, B, ϕ, ε) are affected by fluences of neutron ($Ø_n$) and gammas ($Ø_Y$).
5) Determine from 1-4) and testing how REBCO I_c(T, B, ϕ, ε) are affected by fluxes of neutron ($Ø_n$) and gammas ($Ø_Y$).
6) Determine cost-effective and quick methods of testing REBCO CC ahead of them being assembled into each STEP magnet, known as tape Quality Assurance (QA). Includes each magnet built as part of other test programmes.

Issue: STEP Centre-rod operating lifetime (currently) limited by degradation of REBCO by neutron irradiation



Goal: Understand REBCO subject to neutron irradiation to 1) de-risk and 2) optimise STEP TF centre-rod design.

Contribution from - **Iliffe, William**, Senior Development Engineer - Contractor • Fusion Technology

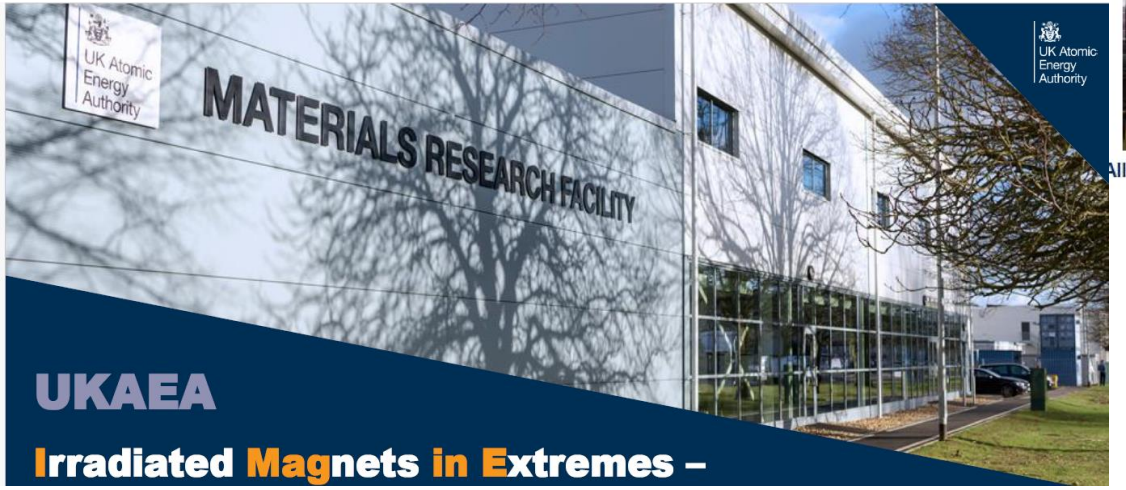
IV - Why UKAEA/credibility — Facilities & Team

UK Atomic Energy Authority

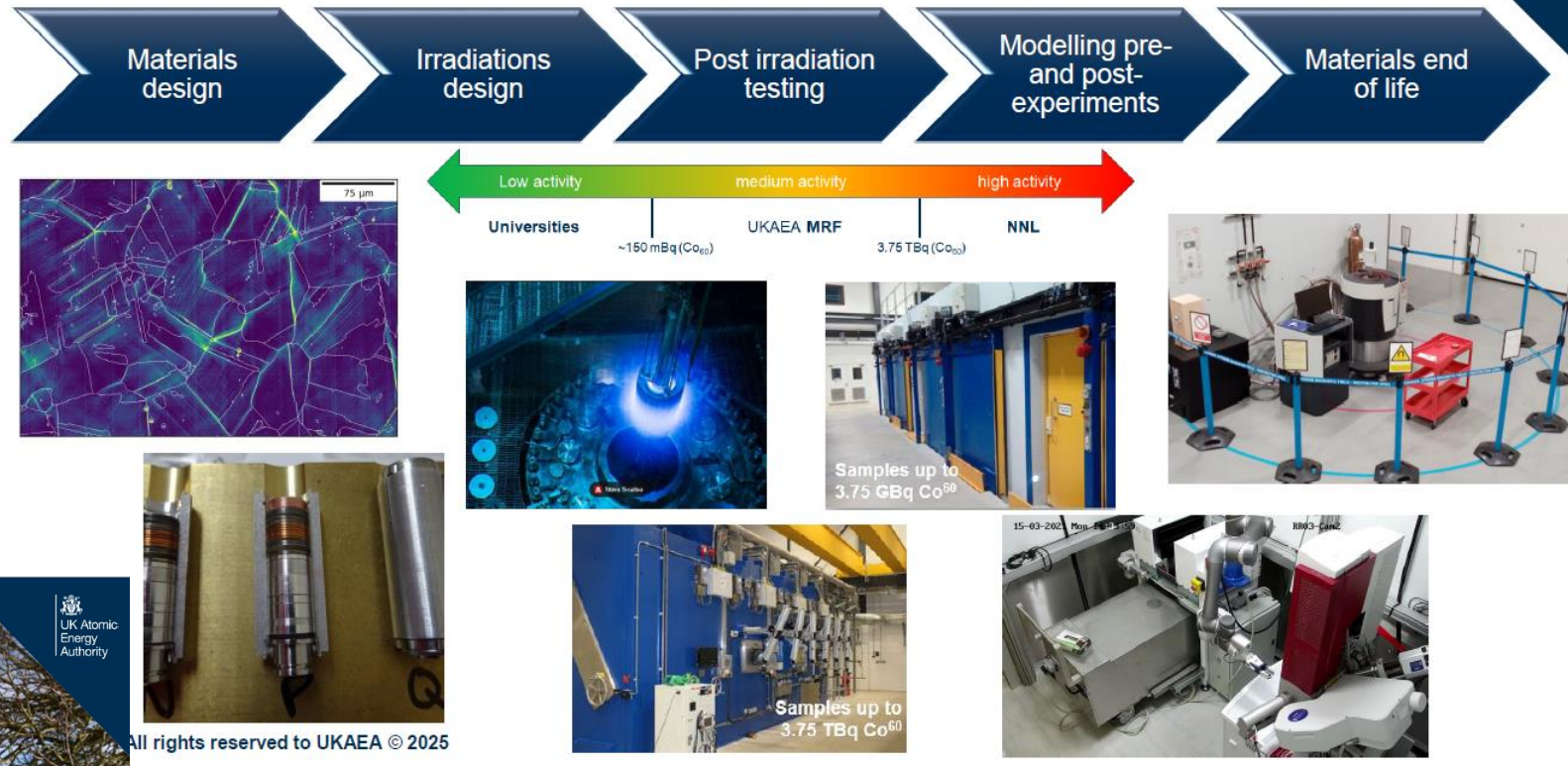
- Facilities: MRF PPMS (1.8–400 K, up to 14 T) for hands-on radioactive materials; ELSA; tomography; cryo rigs
- Team: Chantal group (nuclear materials/irradiation);
- Magnet group (Strategy roadmap, HTS technology, test facility design, AC losses, irradiation)
- Fit to Call: direct match to 'HTS degradation under irradiation'
- ~~with the full chain: irradiation → microstructure → cryo-transport~~
- Capabilities spanning key steps from irradiation to cryogenic characterisation (subject to access and scheduling)

Physical Properties Measurement System (PPMS):

- Electrical, magnetic, and thermophysical characterization
- Operating range: **1.8 K to 400 K**, magnetic fields up to **14 T**
- Measurements include:
  - AC magnetic susceptibility and DC magnetisation
  - Electrical resistance, Hall coefficient, I–V and dI/dV characteristics
  - Heat capacity and thermal transport
- Compatible with “hands-on” radioactive materials (**up to 10 µSv/h at 30 cm**)



UKAEA knows irradiated materials



All rights reserved to UKAEA © 2025

Experimental capability

Controllable irradiation, full PIE characterisation, and integrated cryogenic testing — ~~delivering a full end-to-end workflow~~.
Supporting a defined workflow from irradiation to cryogenic characterisation, within agreed scope.

Team capability

Internationally recognised expertise in nuclear materials, irradiation analysis, and low-temperature electrical testing.

Operation with radioactive materials within licensed limits and RPA approval.

V - How we execute + evidence

UK Atomic Energy Authority

- Facilities: MRF PPMS (1.8–400 K, up to 14 T) for hands-on radioactive materials; ELSA; tomography; cryo rigs
- Team: Chantal group (nuclear materials/irradiation); Oxygen-ion irradiation shows encouraging correlation in selected metrics; neutron benchmarking remains required.
- Magnet group (Strategy roadmap, HTS technology, test facility design, AC losses, irradiation)
- Fit to Call: direct match to 'HTS degradation under irradiation' with the full chain: irradiation → microstructure → cryo-transport

Experimental overview: **HTS Irradiation** test programme

UKAEA capabilities are relevant to the WPMAG irradiation degradation topic, subject to approved scope and resources.

STEP HTS IRRADIATION TEST PLAN

Q. How are STEP addressing these open questions?

A. Perform Experiments!

- In-situ, flux (i.e. irradiation with any source and superconductivity measurements performed **at same time & location**)

University of Oxford · The University of Manchester Dalton Nuclear Institute · Science and Technology Facilities Council – ISIS Neutron and Muon Source · Materials Research Facility

- Ex-situ, fluence, proxy (i.e. uses **ions as a proxy** for neutrons for irradiation and superconductivity measurements performed at *different* time/location)

HZDR Helmholtz Zentrum Dresden Rossendorf · mi2-factory · University of Surrey · Materials Research Facility

- Ex-situ, fluence, neutrons (i.e. uses **neutrons** for irradiation and superconductivity measurements performed at *different* time/location)

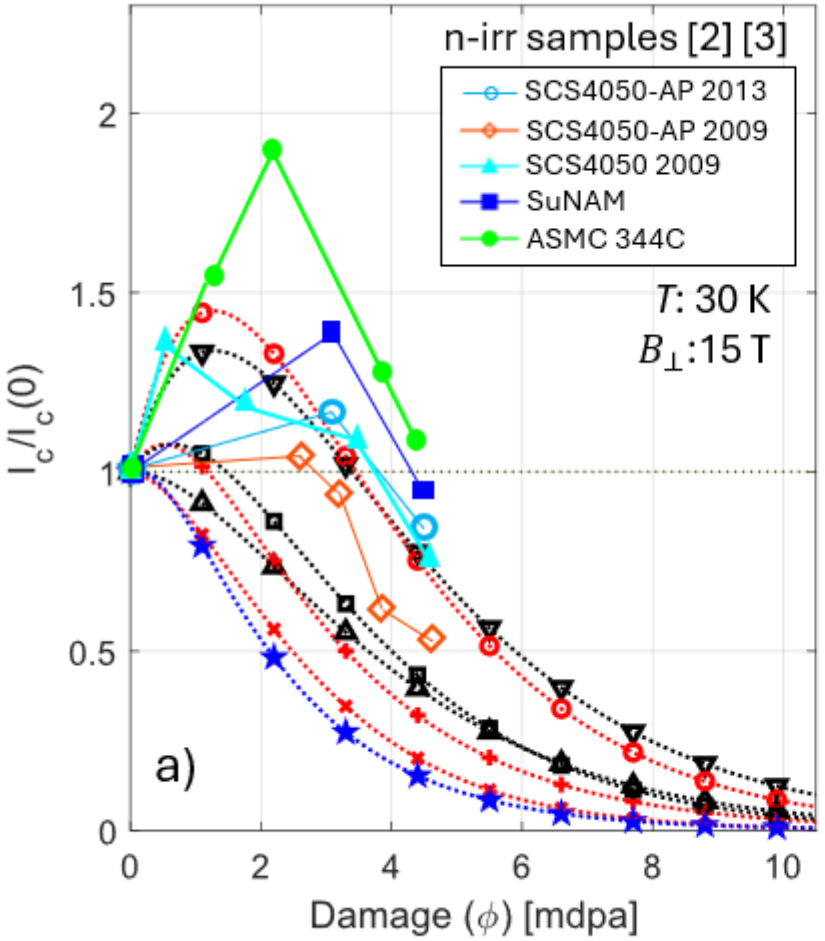
University of Birmingham · CVŘ Research Centre Řež

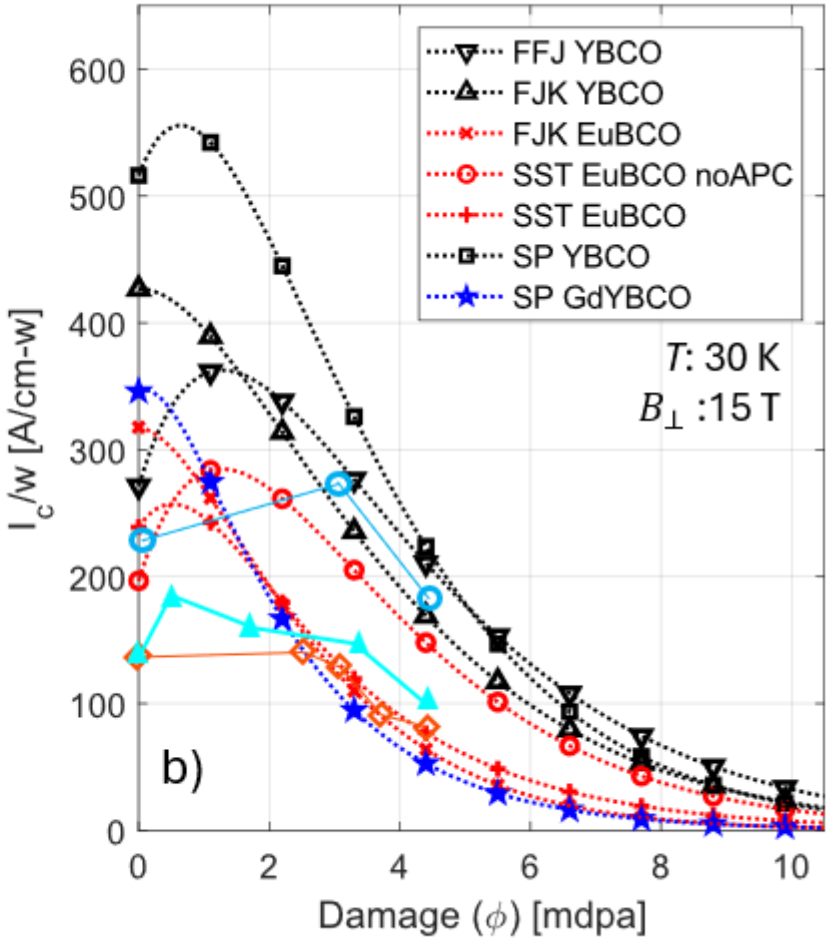
Paper: STEP's progress understanding of REBCO in irradiation environment

IREF25

Using Oxygen Ions as proxy for Fusion neutrons

Results comparison (Ic change, absolute Ic…)





Comparison of a) change in Ic and b) absolute Ic, normalised by tape width, of neutron irradiated REBCO samples and filtered oxygen irradiated samples.

Conclusion: Oxygen Ion irradiation seems to be reasonable proxy
Next step: direct comparison with Neutron irradiated data (Collaboration with TU Vienna)

V - Asks & Next Steps

Propose a scoped plan (workshare and indicative costing) aligned to WPMAG milestones.

- Facilities: MRF PPMS (1.8–400 K, up to 14 T) for hands-on radioactive materials; ELSA; tomography; cryo rigs
- Team: Chantal group (nuclear materials/irradiation);
- Magnet group (Strategy roadmap, HTS technology, test facility design, AC losses, irradiation)
- Fit to Call: direct match to 'HTS degradation under irradiation' with the full chain: irradiation → microstructure → cryo-transport

All asks are to align with the approved 2026 WPMAG budget and agreed facility access routes.

Superconducting Magnet Technology Strategy

UK Atomic Energy Authority

- STEP needs a dedicated SC Magnet Technology Strategy to ensure fusion viability, de-risk magnet integration, & accelerate UK leadership in clean energy.
- This strategy will directly impact STEP's ability to deliver a prototype fusion plant by 2040.
- Why STEP needs a Magnet Strategy

UKIFS Ultimate Plan: HiCRIS - Accelerates Prototype Delivery

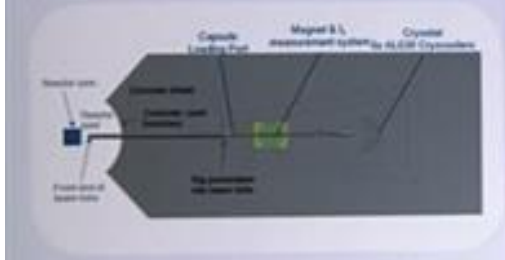
Should be able to measure change in Ic of REBCO subject to neutron irradiation in as close to operational conditions as possible, whilst also being cost effective way.

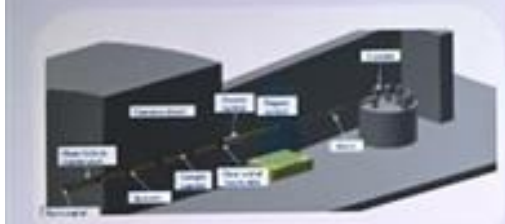
UK Atomic Energy Authority

Prototyping & Testing

HIGH NEUTRON FLUENCE CRYOGENIC IRRADIATION OF SUPERCONDUCTORS (HI-CRIS) RIG

Contribution to UKAEA's Social Values throughout Tranche 1





SOLVE

Design, build and operate a first-of-a-kind test rig to provide confidence in the lifetime predictions of down-selected magnetic components for the SPP.

DRIVE

Leading the way for cryogenic irradiation testing capabilities for the investigation of superconducting materials for fusion technologies and the wider superconducting research community.

CREATE

Create a globally unique experiment, through a collaborative working approach, with a host facility (CVR), subject matter experts, contractors and sub-contractors.

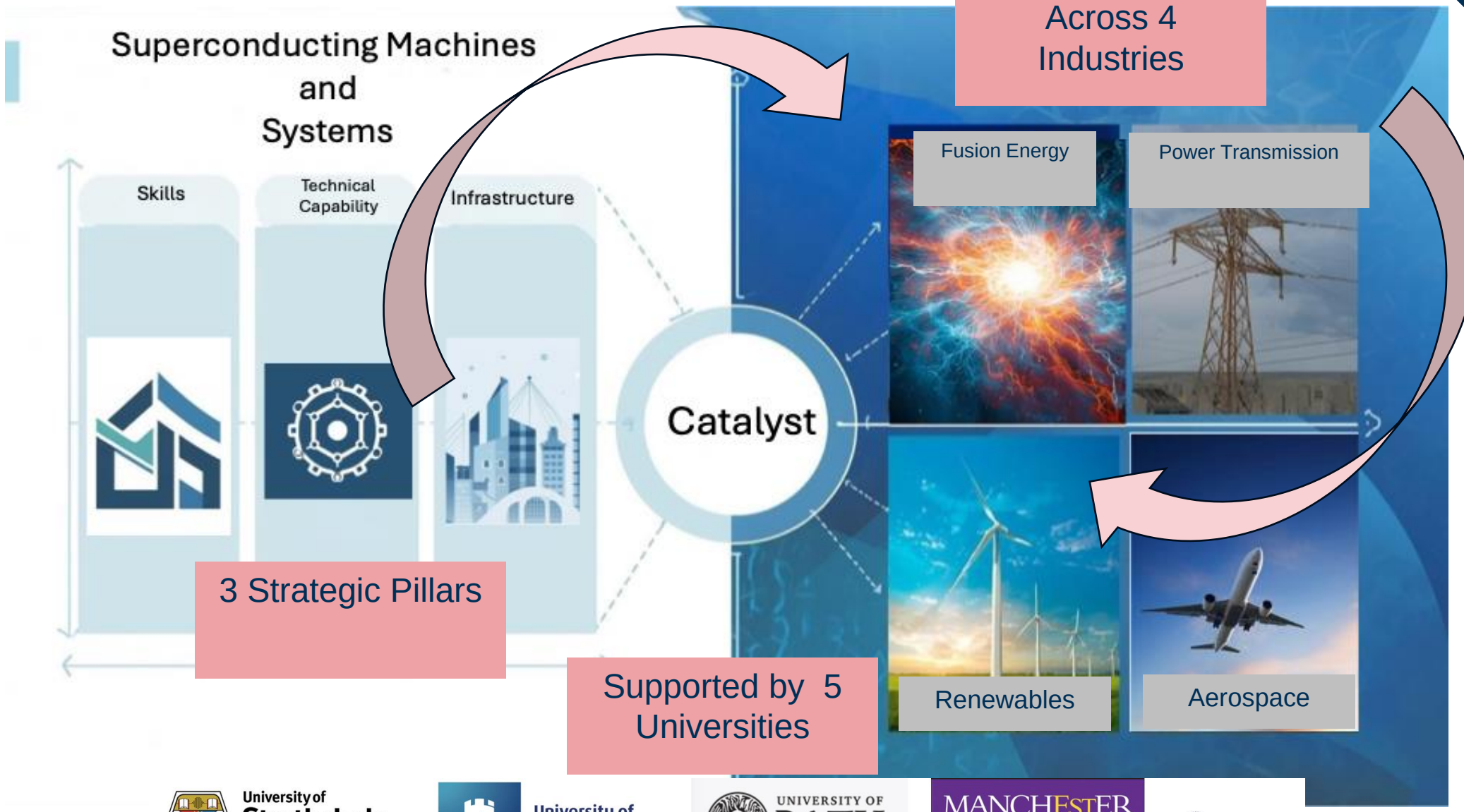
DEVELOP

Develop a multi-disciplinary team of experts to deliver the Hi-CrIS Test Rig, providing results to feed into a strong irradiation research plan within STEP.

ENABLE

Enable down-selected Superconductor (SC) material samples to be investigated under STEP relevant neutron fluences, at cryogenic temperatures, enabling their superconducting properties to be determined and evaluated. The data generated will allow predictions about STEP's performance in fusion in-situ conditions to be made and judged based on STEP's requirements in terms of magnetic lifetime.

Accelerates Prototype Delivery



University of Strathclyde Glasgow

University of Nottingham UK | CHINA | MALAYSIA

University of Bath

The University of Manchester

The University of Edinburgh

Asks & Next Steps

UK Atomic Energy Authority

1. Coordination

Confirm UKAEA scope and contributions for WPMAG 2026–27

Clarify interfaces with CEA / ENEA / EPFL to avoid duplication

Agree workflow and single technical contact points

2. Data & Samples

Finalise availability and access routes for:

- REBCO tapes
- insulation materials
- joints

Agree minimum metadata + FAIR data-sharing rules

Identify what can be shared immediately vs needs approval

3. Test Matrix (Irradiation + AC Loss + Ic)

Prioritise conditions to test first (fluence, spectrum, T, Ic, AC losses, insulation response)

Align with ITER + STEP requirements

Map gaps where EU facilities cannot currently provide coverage

Asks & Next Steps

UK Atomic Energy Authority

4. Planning & Resourcing
Map UKAEA capabilities to each WPMAG milestone
Propose timeline for next coordination checkpoint (Feb/March)
Identify dependencies needing early decision (samples, test slots, analysts)

Key Questions for the Group

- Access to **data**?
- Access to **test facilities**?
- Joint interpretation of **irradiation / Ic** results?
- Preferred visibility route for UKAEA contributions?
- Opportunities for **PhD/Postdoc exchanges**?

UK Atomic Energy Authority

Thank you for your attention

Min Liao
UK Atomic Energy Authority
min.liao@ukaea.uk