UK Atomic Energy Authority

Fusion Futures 24/25 End of Year Report

Foreword

Announced in October 2023, Fusion Futures is a programme designed to develop the fusion ecosystem. It does this through the delivery of a wide range of targeted interventions, spanning industry capability growth, skills development, first of a kind facilities and many more.

While delivered primarily by UKAEA, the programme is designed to focus impact through collaborations with our partners across the sector, with over 300 currently involved!

Having completed the first delivery year, 24/25, I'm extremely proud of the scale of activities and subsequent impacts achieved, not only getting the UK closer to commercialising fusion energy but also capturing significant short-term benefits along the way.

Harry Turnbull-Jones
Head of Fusion Futures

READ THE ANNOUNCEMENT HERE

Fusion Futures Objectives

- To maintain essential fusion research conducted in the UK and seek mutually beneficial international collaborations.
- To enable the UK to maintain its global technical lead in fusion through the delivery of domestic capabilities.
- To create a strong UK industrial sector that leads the world in operationalising and commercialising fusion energy.

PROGRAMME HIGHLIGHTS

- Over 200 industry partners engaged, delivering scientific and financial benefits across the UK fusion supply chain and wider fusion ecosystem.
- Over 50 UK and international universities engaged on a broad range of scientific and commercial activities through multiple projects, from experimental research to programme delivery.
- Over £60m invested in partners across the fusion ecosystem within 24/25.
- Neutron source procured for groundbreaking tritium breeding experiments at new Oxfordshire facility as part of LIBRTI programme.
- International consortia created to conduct these innovative tritium breeding experiments.
- International computing collaborations delivered with world leading companies, leveraging access to infrastructure worth billions of pounds.
- Technology transfer spinoffs mapped out, including in fusion consultancy, medicine and haptics.
- Nearly 800 people engaged in the programme's FOSTER skills drive, from apprentices to doctoral students.

Industry Capability

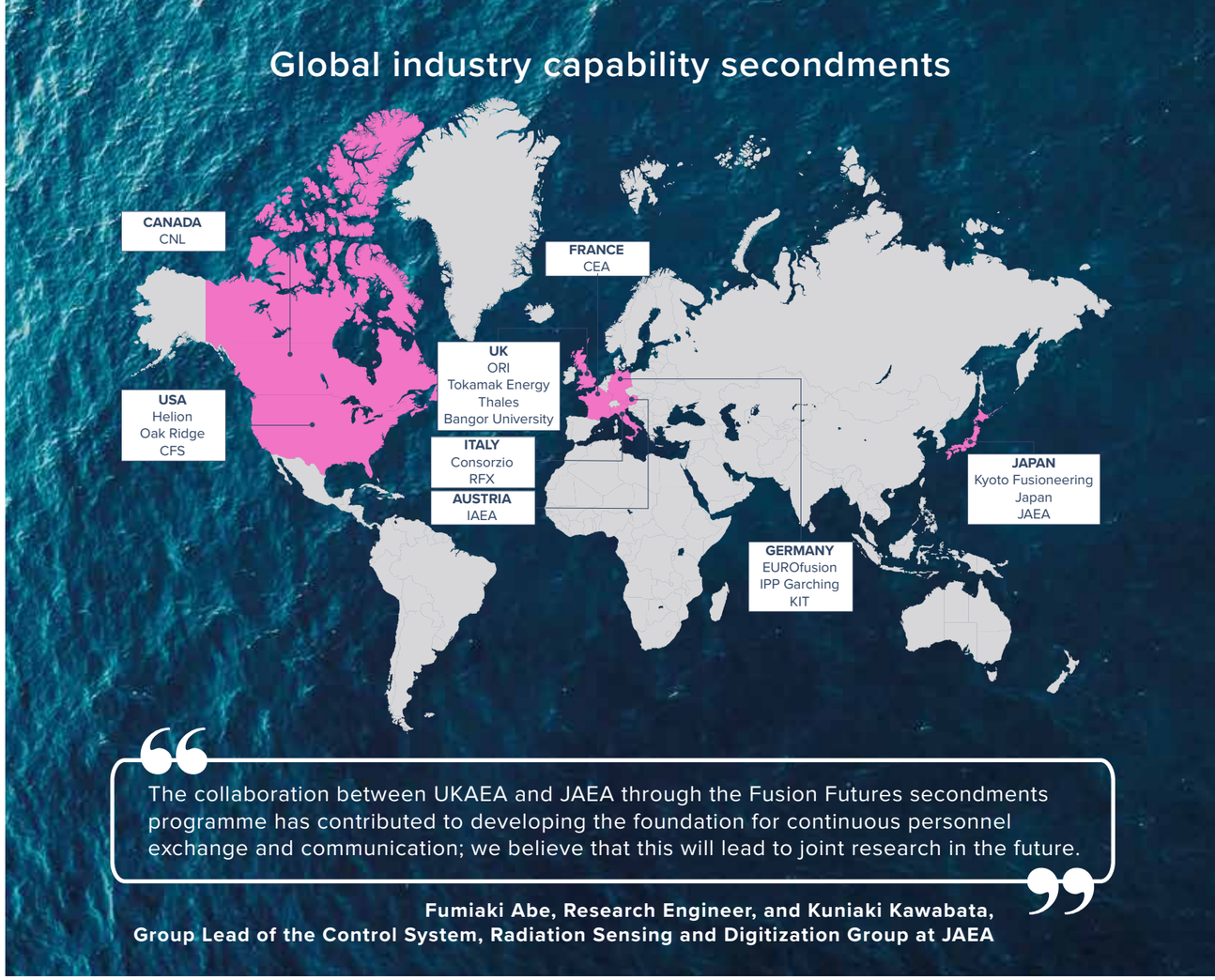
The Industry Capability programme aims to create a strong UK industrial sector through stimulated capability and capacity growth, which leads the world in operationalising and commercialising fusion energy. The programme also aims to ensure the UK maximises its export potential as the global fusion sector continues to grow.

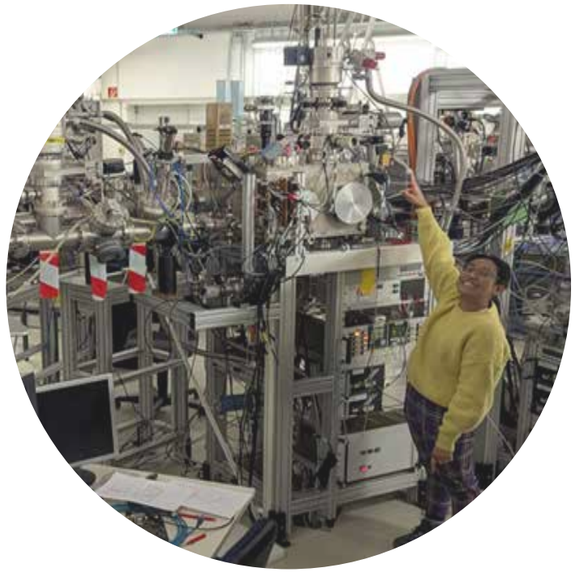
HIGHLIGHTS

- In FY24/25, the programme launched 36 projects across multiple strategic areas for future fusion powerplant development, including Remote Handling, Tritium Fuel Cycle Technology, Plasma and Microwaves, Fusion Diagnostics, Plasma Control Systems, Magneto Hydro Dynamics, Active Waste Management and Materials Testing and Development.
- 22 large-scale, fusion-specific contracts have been awarded, enabling the UK to lead in emerging fusion energy markets, while increasing UK export potential.
- £9.2M of work has been awarded to industry, with 50+ companies engaged on a wide range of projects. Nearly £1 million has been directly awarded to SMEs.
- Key projects have brought SMEs into partnership with one another for the first time, strengthening the UK fusion ecosystem by pooling resources and knowledge.
- Deployment of 44 secondees to 15 organisations across the world giving unique opportunities for UKAEA to retain fusion skillset and develop new competencies.

> Participating in the Fusion Futures programme has been an incredibly successful experience for M5tec during its first year. We've successfully engaged our local supply chain in the manufacturing process, allowing several suppliers to enter the fusion sector for the first time. This initiative has not only expanded local industry capabilities but has also strengthened regional expertise in high-precision component manufacturing.
>
> **Carl Jones, Operations Director, M5tec**

> UKAEA's Fusion Futures Programme has been instrumental in introducing PyrOptik and our measurement capabilities to FORG3D and their innovative welding and wire additive manufacturing technology. The programme has allowed PyrOptik and FORG3D to collaborate closely.
>
> **Iain Scott, Director & Founder, PyrOptik**





UKAEA secondee at IPP Garching in Germany.

Forging new industry partnerships:
CEO Prof Sir Ian Chapman meeting FORG3D,
an SME based in Rotherham

Lithium Breeding Tritium Innovation (LIBRTI)

LIBRTI seeks to create a world leading UK capability to demonstrate the feasibility of powerplant relevant fusion fuel technologies. The programme has been designed to enable industry achieve demonstrations of controlled tritium breeding; a first step towards a predictable, controllable way of generating the fuel required within a self-sustaining fusion fuel cycle.

HIGHLIGHTS

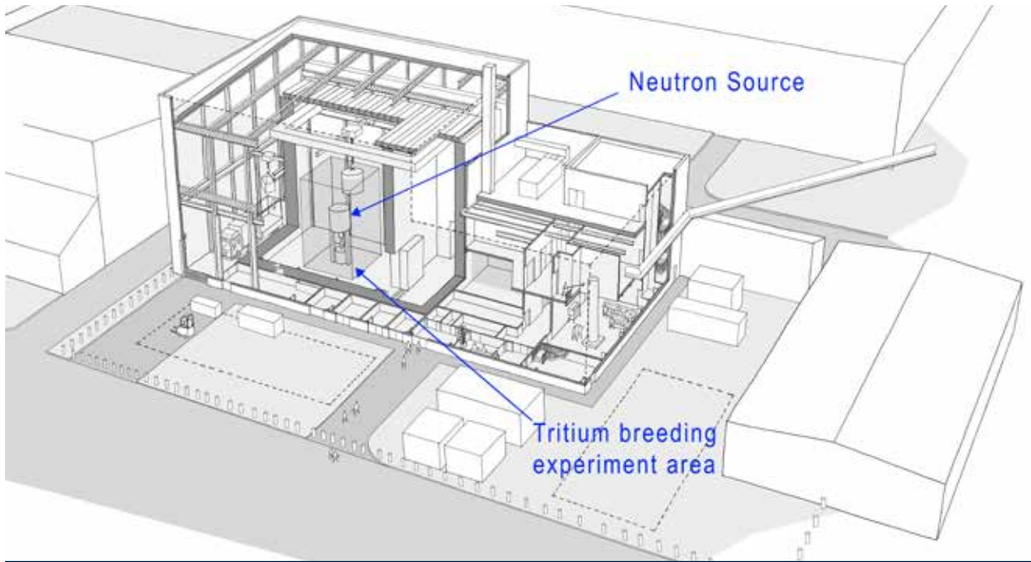
- Signing of a £34M deal which includes the procurement of a deuterium-tritium neutron source from SHINE Technologies, and an R&D component to further augment high flux neutrons, adequate to breed tritium at fusion energies.
- A £9m competitive ‘Mini-feeder’ call enabled LIBRTI to award funding to 11 research projects covering digital development, and solid, liquid, and salt-based breeding technologies.
- MoU signed with Commonwealth Fusion Systems, as well as a Molten Salt Breeder Working Group Charter, to facilitate design of key experiment on LIBRTI from 2027.
- The NEURONE (Neutron Irradiation of Advanced Steels) consortium, part funded by LIBRTI, achieved a UK-first breakthrough in the production of fusion-grade steel on an industrial scale.

What this enables:

- With the award of LIBRTI’s £9m Tritium feeder competition, over a dozen UK universities and fusion SMEswill have the opportunity for new skills build in a variety of topics, from multiphysics modelling and inertial confinement instruments, to digital twin simulator.
- The programme seeks to maximise Industrial growth in fusion fuel technologies and adjacent sectors that position the UK industry to export the technology globally. For example, the programme is actively engaging with the UK Government’s current analysis of opportunities around radio-medical isotopes.
- The majority of the Mini-feeder awards involve UK academia or industry contributing to fusion future technologies, developing a growing UK network of fusion-experienced talent.

> Our partnership with UKAEA’s LIBRTI program is a key milestone for fusion energy... We’re excited to work with UKAEA to develop next-generation fusion solutions to help pave the way to clean, abundant energy.
>
> **Greg Piefer, CEO of SHINE Technologies**

The signing of the UKAEA-SHINE neutron source contract.



Location of LIBRTI neutron source and experiment area.

International Computing

The International Computing programme aims to gain access to world-leading computing research needed for UK fusion delivery, to influence the direction of international research into digital technologies, and to provide a cost-effective way to access emerging digital capabilities.

Recent advances in Supercomputing, Artificial Intelligence (AI) / machine learning (ML), large-scale distributed big data and information management offer the potential to completely transform the way in which future fusion powerplants are designed and validated. This programme aims to harness these advances for the benefit of the fusion sector.

HIGHLIGHTS

- Engagement with 14 world-leading computing organisations, including IBM, Eni, and Los Alamos National Laboratory, on a range of themes. These include exascale computing, data and AI-driven control, and digital twin and enabling technologies.
- Formal collaborations in place with six world-leading computing organisations.
- Access to world-leading computing research needed for UK fusion delivery, specifically access to three exascale computers with a value exceeding £1 billion.
- Collaboration with Eni enabling UKAEA researchers to work with industry to transform successful research ideas into future products and solutions, including accelerating UK advanced control capability for fusion.
- Collaboration with IBM and STFC Hartree Centre enabling AI-driven materials discovery and foundation models for fusion.
- Enhanced world leading open-source simulation tool, giving the ability to solve simulations on exascale computing and to unlock the most powerful simulation capabilities.
- Largest multi-physics simulation of UKAEA's MAST-U tokamak, successfully solved on newly enhanced simulation software. This enabled the capability of efficiently solving the problem with GPU computation speeds. This was developed, solved and validated in collaboration with INL and LLNL on the CSD3 supercomputer.

UKAEA, IBM and STFC Hartree Centre collaboration signing

> Our technical collaborations in the fields of remote handling, robotics, and computing are showing great potential. The complementary, world-class capabilities of Eni and the UKAEA International Computing programme allow us to tackle key fusion challenges and move forward in this cutting-edge technological domain.
>
> **Francesca Ferrazza, Head of Magnetic Fusion Initiatives at Eni SpA**

Programme visit to the DIII-D National Fusion Facility.

Technology Transfer Hub

Developing fusion energy means developing a whole ecosystem of technological advancement. The Technology Transfer Hub realises the near-term benefits of fusion research and helps solve fusion challenges quicker by engaging with other sectors – with spin-off applications to fire safety, disaster relief, computing, batteries, and cancer therapy, amongst others.

HIGHLIGHTS

- Strong relationships established with several business and technical organisations up and down the country, such as Digital Catapult, UKI2S, Oxford Sciences Enterprises, Government Office of Technology Transfer, and Defence and Science Technology Laboratory to leverage external expertise to explore innovation opportunities from a market desirability perspective, helping market discovery and validation of existing innovation projects. External connections and partnerships with Catapults, National Laboratories, Universities and Industry include:
  - Digital Catapult, University of Birmingham, University of Strathclyde, Manufacturing Technology Centre, National Composites Centre, National Physical Laboratory, The Institute of Cancer Research, European Space Agency, Rolls Royce, National Physical Laboratory, Scottish Enterprise.
- Incubation and acceleration of new businesses:
  - New spinout accelerator; Spinout Strategy; Join Ventures Strategy; Entrepreneurship training; Investor events.
  - One new spinout in 2024 – Fusion Energy Partners, offering specialised due diligence and technical consultancy services in the fusion energy sector, has attracted £100,000 investment.
  - Three spinouts (in-progress, aimed for 2025).
- Acceleration of Technology Transfer (exploration and validation):
  - 36 active innovation projects, covering a variety of technology areas and target markets beyond fusion.
- Intellectual Property (IP) protection and management:
  - 62 Invention Disclosures submitted.
  - Seventeen Patents expected to be filed by the end of 25/26.
  - Technology transfer including three licence agreements this year, with several more in progress.

> We often have clients requesting assistance with fire safety problems that require a bit of research to solve... Simvue has been a great help in that regard, saving time, energy, and money... Working with the Technology Transfer Hub team was a hugely positive experience.
>
> **Vern Nicolette, Director, IFC Ltd.**

CASE STUDY

The Simvue platform in action.

Simvue, a scalable Software-as-a-Service (SaaS) platform developed at UKAEA, offers powerful real time tracking, monitoring, and data organisation features that are applicable in other sectors where complex and large-scale simulations are common and costly. Fields such as fire suppression systems, weather modelling, and Formula One aerodynamics simulations identified as sectors where Simvue could offer significant value. Collaboration between UKAEA and International Fire Consulting has highlighted the power of technology to make large-scale simulations more environmentally friendly.

CASE STUDY

Another spinout in progress, MuWave, aims to provide next-generation engineering and technology solutions for high-power microwave systems. The demand for these systems is currently unmet due to high costs, limited production rates, and technological constraints. MuWave's proprietary solutions for Microwave Source and Transmission Line components promise significant price reductions, improved production rates, and enhanced performance. With a market size estimated to exceed £400m over the next 5-7 years, developing this technology could lead to significant yields.

Fusion Opportunities in Skills, Training, Education and Research (FOSTER)

Enhancing fusion skills is a critical part of delivering Fusion energy. FOSTER's mission is to train 2,200 new people for the fusion sector, by working with business to increase the number of apprentices and graduates, universities to increase the number of postgraduates and PhDs, and international partners to increase post-doctoral training opportunities within fusion. Enhancing the provision and development of fusion skills and learning among public and private organisations and academia alike is a critical part of delivering fusion energy.

HIGHLIGHTS

- New partnerships with leading universities to deliver fusion teaching in higher education.
- Established a school outreach programme which has reached 49,800 school students.
- In July 2024 and February 2025 FOSTER hosted its first Fusion Teachers' Conference and Fusion Teachers' Workshop in partnership with The Ogden Trust, Tokamak Energy, and First Light Fusion.
- Established a new Fusion Engineering Academy to provide practical training in fusion engineering disciplines across a two week course aimed at industry and academic professionals seeking to upskill in fusion engineering.
- The establishment of a new Fusion Engineering Centre for Doctoral Training (CDT), with involvement from a number of leading UK universities.
- Two agreements with Singapore-based institutions have been reached for FOSTER's International Fellowship Scheme.
- In its first year FOSTER has supported 31 PhDs, already underway. The programme is also investing in apprenticeships. In combination, these pathways to enhanced fusion knowledge represent a significant investment to upskill the UK workforce.
- Establishment of QuEST-FuSED, a collaborative programme between UKAEA and the Science and Technology Facilities Council (STFC) to accelerate the two organisations' training of engineering apprentices.

UKAEA PhD showcase.

Fusion teachers conference and workshop.

> Outstanding. The overall objective of this academy is to gain a solid grounding in the concepts required for the engineering of tokamaks; this has been well achieved for all of the activities and lectures.
>
> **Fusion Engineering Academy participant**

Secretary of State for DESNZ the Rt Hon Ed Miliband at the QuEST-FuSED workshop.

EUROfusion

Through Fusion Futures the UK has been able to retain third party association to the world-leading EUROfusion research programme. The EUROfusion consortium brings together 4800 researchers, staff and students from its 28 member institutes, 3 associated partners, and 162 affiliated entities from across Europe. The EUROfusion programme has been a central pillar of fusion progress and the fusion community for over a decade.

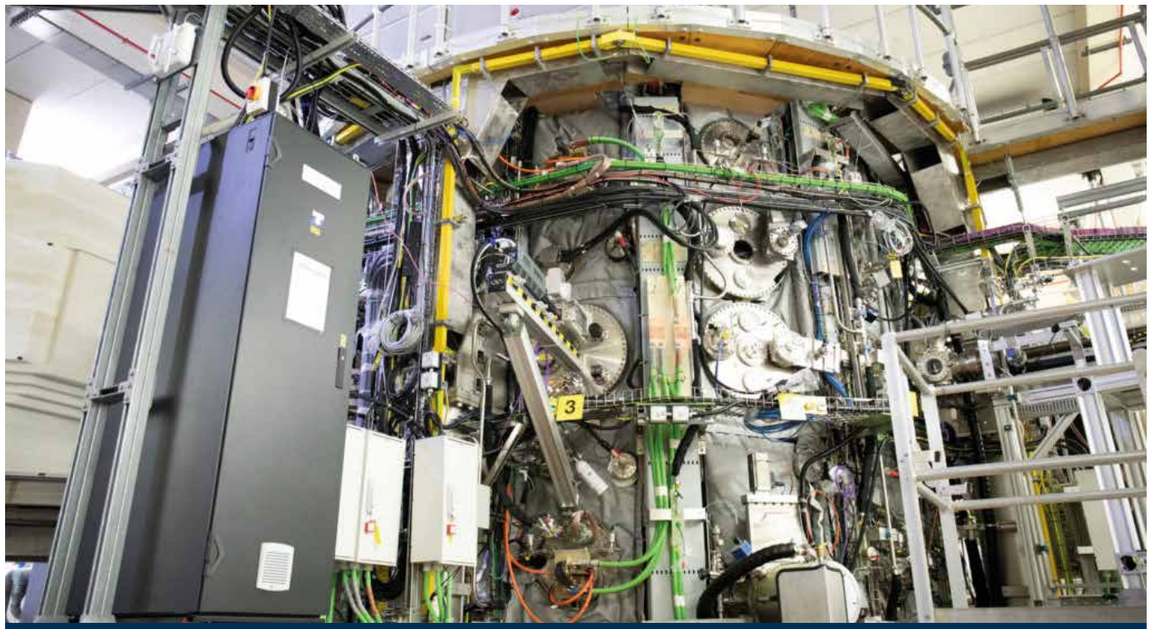
Being part of the EUROfusion association provides the UK with access to a unique network of world experts and facilities across fusion disciplines, including materials science, breeder blanket development, plasma operations, and digital. Our contributions to the EUROfusion roadmap expand UKAEA's expertise via individual and collaborative work. Through work packages such as Tokamak Exploitation, UKAEA has access to the data, scientific output, and operational expertise of many of EUROfusion's tokamaks (ASDEX Upgrade, TCV, WEST, and COMPASS-U).

HIGHLIGHTS

The UK, through Fusion Futures, has been able to benefit from association to EUROfusion, enabling activity on the following work packages:

- **Central Design –** nuclear analysis of the latest Volumetric Neutron Source design with focus on the shielding and nuclear performance of the VNS neutral beam injectors. VNS will provide validation of components under fusion conditions, something which no current facility offers.
- **Remote Maintenance –** enhanced build capability for the development of control systems to handle massive flexible loads. Dextrous manipulators that can handle heavy loads are essential to maintain fusion reactors, which will forbid human access, alongside cross-disciplinary applications outside of fusion.
- **Materials –** Development and testing of a finite element (FE) model for the full MAST-U tokamak. Establishing highly detailed FE modelling capability is an essential step towards using tools for digital validation and digital twins.
- **Tritium, fuelling, and vacuum –** experiments undertaken to understand the nature of fusion generated dusts. This work will help solve existing fission waste issues while ensuring fusion waste is managed in the most effective ways currently possible.
- **Plasma –** exposure of the physics mechanisms at play in the recent JET experiments to investigate the implications for next step D-T tokamaks; development of MAST Upgrade high performance operations. Having a stable plasma operating scenario is critical for reliable and economic power plant operations.

> UKAEA participates in EUROfusion activities as an Associated Partner. EUROfusion is devoted to strengthening the long-standing collaboration with UKAEA even further to make European fusion research more impactful.
>
> **Dr. Gianfranco Federici, EUROfusion Programme Manager**



MAST Upgrade's fourth experimental campaign (ongoing) exploits recently enhanced capabilities (input power, cryo-pumping, new diagnostics) to address plasma challenges relevant to fusion power plants: stable operation at high beta, high elongation and low collisionality; plasma exhaust optimisation; buffering of transient releases of plasma energy to the divertor.

UKAEA CEO Professor Sir Ian Chapman with EUROfusion Programme Manager Dr. Gianfranco Federici.

UPLiFT

Laser Inertial Fusion Technology for Energy (UPLiFT) is an exciting new four-year programme that builds on the recent breakthrough demonstration of fusion energy gain at the US National Ignition Facility (NIF). Led by the Science and Technology Facilities Council's Central Laser Facility, UPLiFT's focus is the development of technologies for laser Inertial Fusion Energy (IFE), with a core emphasis on commercially competitive fusion energy. UPLiFT aims to grow the UK's laser fusion research base and accelerate the development of IFE in the UK.

The Programme focuses on three key areas:

- **Laser development:** the design of a laser fusion drive module.
- **Targetry development:** the development of advanced targets suitable for use in an IFE environment.
- **Physics:** the development and experimental verification of the UK's simulation models on international laser facilities with the aim of identifying an implosion design for a future IFE power plant.

The first year of UPLiFT has seen excellent progress made across all three research areas.

HIGHLIGHTS

- A patent has been filed for a brand-new laser amplifier concept that will be tested and verified in the coming years.
- Experimental set-ups have been built to test new amplifier concepts. The laser team have carried out a global review of potential materials to be used in the new fusion laser.
- A new 3D printer has been delivered capable of printing structures that are 100th the width of a human hair. This will be used to print new target materials.
- A test station has been constructed that will enable the team to test new manufacturing methods for producing targets in large quantities.
- A collaborative team of 31 scientists from the Central Laser Facility and four UK universities has been established, with work already well underway developing and refining the physics models needed to understand the fusion implosions.
- The first experiments at large international laser facilities have been secured and planning work is underway.

> UPLiFT is enabling an unprecedented level of coordination across university groups and national labs in laser-driven inertial fusion. UPLiFT is so important as the UK has world-renowned expertise in this field and, with further funding, can progress towards defining a national inertial fusion experiment.
>
> **Professor Nigel Woolsey, University of York**

UK Atomic Energy Authority

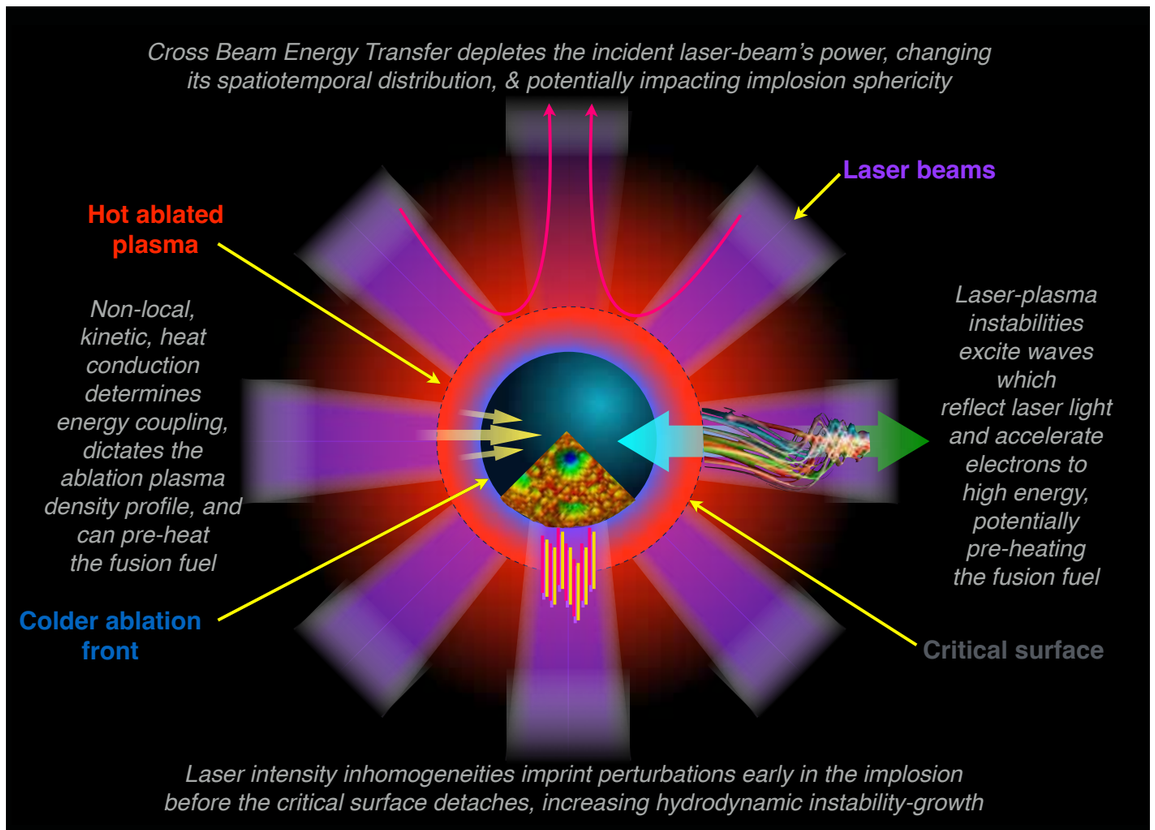
CLF central laser facility

WARWICK THE UNIVERSITY OF WARWICK

UNIVERSITY OF OXFORD

Imperial College London

UNIVERSITY of York



The key 'direct drive' physics UPLiFT is addressing. UPLiFT builds on the NIF's success using the 'indirect drive' method, but by employing the 'direct drive' approach has the potential to improve powerplant efficiency by a factor of five over NIF's approach.

STEP (Spherical Tokamak for Energy Production) Prototypes

STEP Prototypes is a single year programme which channelled work packages into industry to support capability development and the delivery of STEP, the UK's prototype fusion powerplant, currently being built in West Burton, Nottinghamshire.

In total the programme placed over 20 commercial agreements. The total committed value of these commercial contracts is £8.4m.

The programme drove growth in industrial scale by providing access to technically challenging work packages. This will help ensure that companies possess the necessary resources and expertise to support future fusion powerplant development in the UK and internationally.

This programme consisted of numerous projects focused on key enabling areas of STEP. The technical areas covered included Magnets, Cryogenics, Plasma heating and control, Fuelling and Powerplant Efficiency.

HIGHLIGHTS

- ELSA cryogenic test rig upgrade and installation completed. This will provide the ability to test STEP's Re-mountable Magnet Joints (RMJs) architecture and technology.
- Demonstration of the manufacture and performance of STEP magnet technology. This was achieved via the development and validation of small-scale prototypes through to testing of larger scale models under fusion relevant conditions.
- Demonstration of novel manufacturing technique of palladium composite, unlocking STEP isotope adjustment capabilities.
- Successful completion of vacuum cryopump prototype design, a critical enabler for ensuring continuous extraction of impurities from the fuel cycle.
- The design, manufacture and verification tsting of an In-line Raman Spectroscopy Probe for tritium applications.

CASE STUDY

STEP will utilise magnets comprised of high-temperature superconducting cables to provide plasma confinement. We have been working closely with Tokamak Energy to demonstrate manufacture and performance of our novel cable design. This has been achieved through a development process from validation of small-scale prototypes through to testing of a larger scale model under fusion-relevant conditions. This work has been key to underpinning the continued development of the STEP magnets that will feed into fusion plant design.

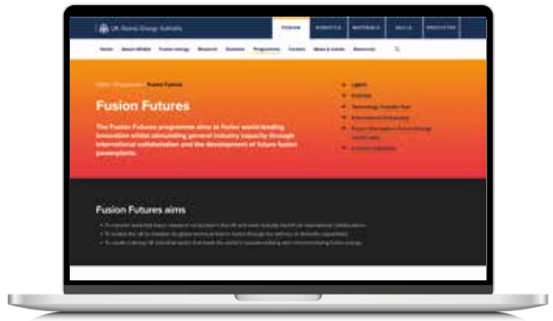
Other Fusion Futures areas

Fusion Concepts in Future Energy Landscapes has this year focused on framing the core questions that should be asked of external experts regarding the uses of fusion in the evolving global energy supply and demand landscapes. The programme will begin engagement on these questions in the coming months.

Cluster Development

- Delivering on the development of Culham Campus as a global hub for fusion innovation.
- Aims to attract private sector investment and companies to the campus.
- Upgrading and repurposing of existing power supply and other infrastructure for enhanced UKAEA operations and private fusion facilities.

UKAEA staff involved in the Industry Capability secondments programme. Secondees have benefitted from strategically important assignments with key partners all over the world.



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The UK Atomic Energy Authority's mission is to lead the delivery of sustainable fusion energy and maximise scientific and economic benefit

UK Atomic Energy Authority

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