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CONSULTANCY
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Advanced Manufacturing AMTecH

AMTECH

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SYSTEMS • ENGINEERING • TECHNOLOGY

FRAZER-NASH CONSULTANCY

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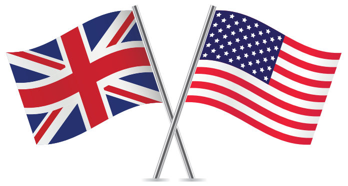


Multi-disciplines

35+
Established technical groups

Delivering from

11 UK offices

4 Australian offices

Accreditations

Member of NIA Nuclear Industry Association

the nuclear institute

young generation network ygn

Our values

At Frazer-Nash we are guided by our values in everything we do, collaborating to support our customers in delivering some of the country's most important projects.

We care

We care about each other, and we work with openness and collaborate effectively – thinking about our clients and our people and responding to their needs.

We are trusted

Effective collaboration is founded on trust. We seek the trust of our customers and colleagues by delivering on the commitments we gave to them.

We deliver success

We deliver value and success to our customers and to our business. We continually strive to be the best at what we do.

We want to do things that matter

We seek out interesting and satisfying work that helps make a difference in society.

KBR

We Deliver®

At KBR, we partner with government and industry clients to provide purposeful and comprehensive solutions with an emphasis on efficiency and safety. With a full portfolio of services, proprietary technologies and expertise, our employees are ready to handle projects and missions from planning and design to sustainability and maintenance. Whether at the bottom of the ocean or in outer space, our clients trust us to deliver the impossible on a daily basis.

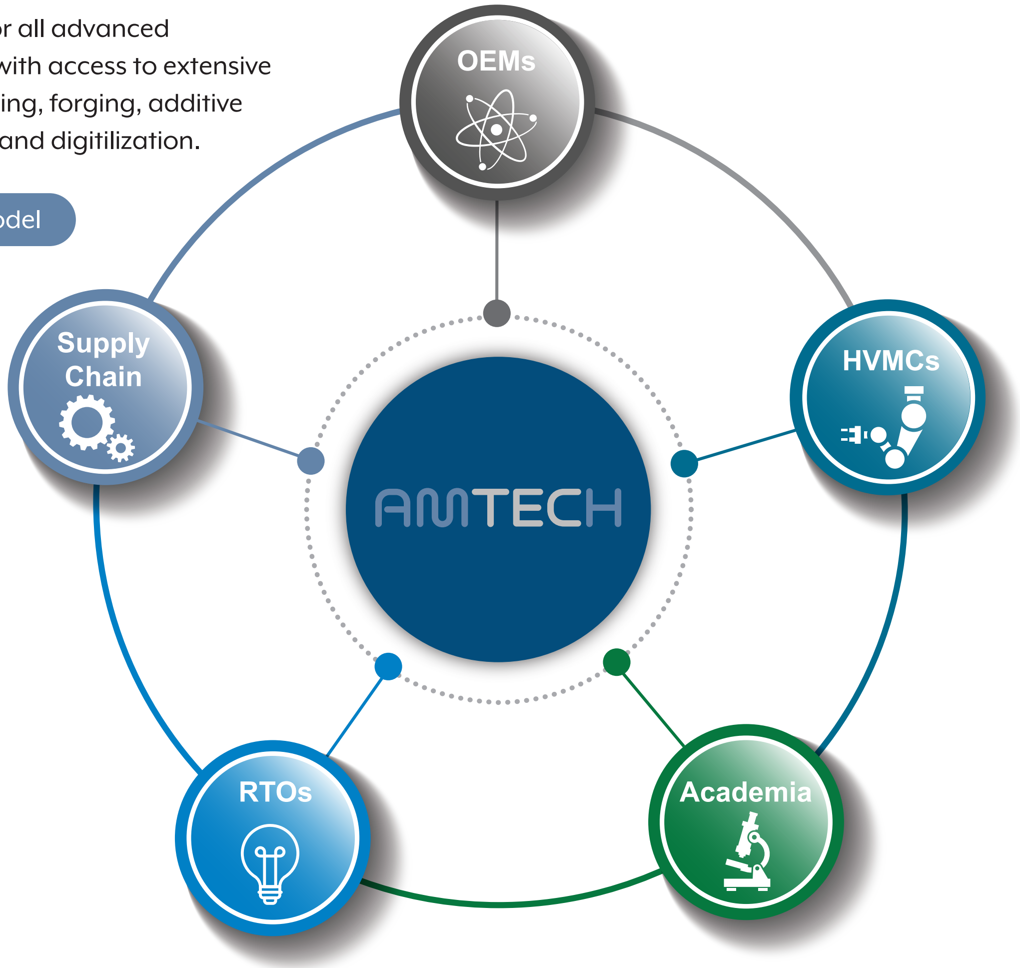
What is the Frazer-Nash Advanced Manufacturing Technology Hub (AMTecH)?

The Frazer-Nash AMTECH vision:

"Recognized as a world-leading, independent design and manufacturing consultancy, providing optimized solutions and contributing to the delivery of clean energy solutions."

AMTecH is the gateway to expertise for all advanced manufacturing technology enquiries with access to extensive manufacturing capabilities from forming, forging, additive manufacturing to codes & standards and digitilization.

The AMTecH model



Collaboration partners

generalfusion

NUCLEAR AMRC

LUCIDEON

first light

mtc Manufacturing Technology Centre

IDOM

cavendish nuclear part of Babcock International Group

TWI

UK Atomic Energy Authority

WMG THE UNIVERSITY OF WARWICK

AFRC ADVANCED FORMING RESEARCH CENTRE UNIVERSITY OF STRATHCLYDE

UNIVERSITY of STRATHCLYDE ADVANCED NUCLEAR RESEARCH CENTRE

SHEFFIELD FORGEMASTERS

MIDCAL

AMTecH will support manufacturing technology research, capability development, and will support new build projects, from concept to in-service operations, ultimately aiming to reduce the risk of quality and cost issues in production and operation and ensure the security of supply.

This service offering is in conjunction with a full new product introduction process, aligned to industry standard best practise and IAG, Advanced Product Quality Planning (APQP) principles.

We also offer supply chain development support to help businesses solve complex operational, productivity and capability issues to ultimately strengthen the position of manufacturers in global competitiveness.

For more information visit our website **https://www.fnc.co.uk/advancedmanufacturing**

For further information and to discuss your specific manufacturing & supply chain needs, contact:

Lauren Ednie, AMTecH Campaign Lead:
l.ednie@fnc.co.uk

Michael Cartwright, Senior Consultant:
m.cartwright@fnc.co.uk

Nigel Pready, Group Leader / AMTecH Tech Lead:
n.pready@fnc.co.uk

Ian Bunce, Senior Consultant:
i.bunce@fnc.co.uk

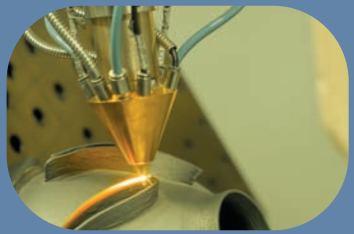
Steve Lawler, Business Manager:
s.lawler@fnc.co.uk

Alex Reeve, UKAEA Manufacturing Framework Lead:
a.reeve@fnc.co.uk

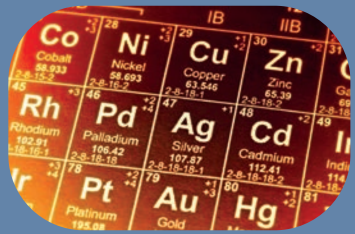
https://www.fnc.co.uk/what-we-do/your-industry/process-and-manufacturing/advanced-manufacturing/

Capability

Additive manufacturing and near-net shape forming – high-integrity production and customization of large metal components.



Material, chemistry, and surface engineering – enhanced material characteristics and performance in reactors and other extreme environments.



Controls and instrumentation – digital sensors, instruments and safety systems for nuclear power plants and other industries.

Automation and digitalisation – robotics, artificial intelligence, and data-driven manufacturing to improve productivity and develop new capabilities.

Analysis and simulation – high-fidelity data-driven models for processing and materials optimization, plant construction and operations.

Codes and standards – ensuring innovative manufacturing techniques meet relevant industry standards.

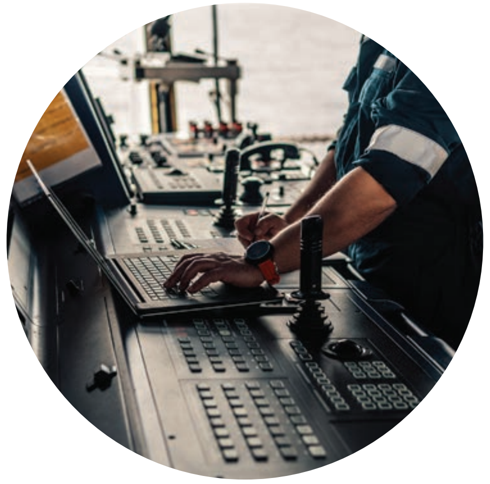
Machining technologies – New and optimized processes for the machining complex components.

Joining technologies – mechanised welding and solid-state bonding methods, including arc, power beam and diffusion bonding techniques.

Product and process verification – developing high-quality structural integrity data for performance models and through-life maintenance forecasts.

Technology (or technique) road-mapping - a fundamental and powerful tool for managing the delivery, associated risks, and interdependencies of a maturity development programme. Often over-looked or performed late in a program as a stand-alone process, maturity roadmaps provide a live, concise, and visible overview of a development program.

Factory design, modelling, and event simulation development - detailed analysis of concept facility designs to model flow through a factory or facility, carrying out studies on optimization or modification by developing complex scenario plans to future-proof against change, based on Bayesian techniques.



Equipment Installations - develop verification and validation (V&V) program, capture pre and post installation and commissioning requirements and support FATS and SATS.

Digital manufacturing - including digital twin and industry 4.0 principles.

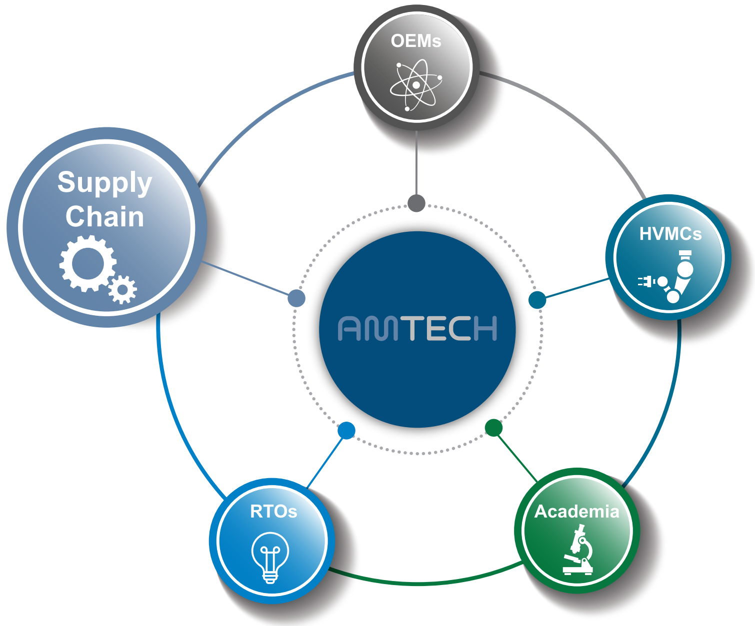
Supply Chain

As the manufacturing sector grows in the UK, developers of new technologies have recognized the need to establish a strong UK supply chain to meet their complex needs.

Our AMTecH team can support you with supply chain mapping, drawing upon our people and their long-standing experience in the UK manufacturing industry.

Through Frazer-Nash, we can help support our fusion-sector clients in many ways, including (but not limited to):

- Providing you with a **supply chain mapping service** against your concept/product requirements.
- **Identifying & accessing facilities** that could support experimental trials, produce demonstrators, and support prototype development work.
- **Identifying & accessing suitable material** processing organizations, including organizations that specialize in powder metallurgy, casting, and hot isostatic pressing, and many more.
- **Identifying & accessing manufacturing & fabrication organizations**, covering additive & subtractive forming processes, joining techniques and inspection services, and many more.
- **Provide introductions to our industrial network** to support the evolution of your design, assembly, and construction of large, complex engineering systems.
- **Independently identify and assess potential suppliers** (‘new to sector’) through our existing customer base & AMTecH partners and support any further or future work, collaboratively against a ‘best athlete’ process.

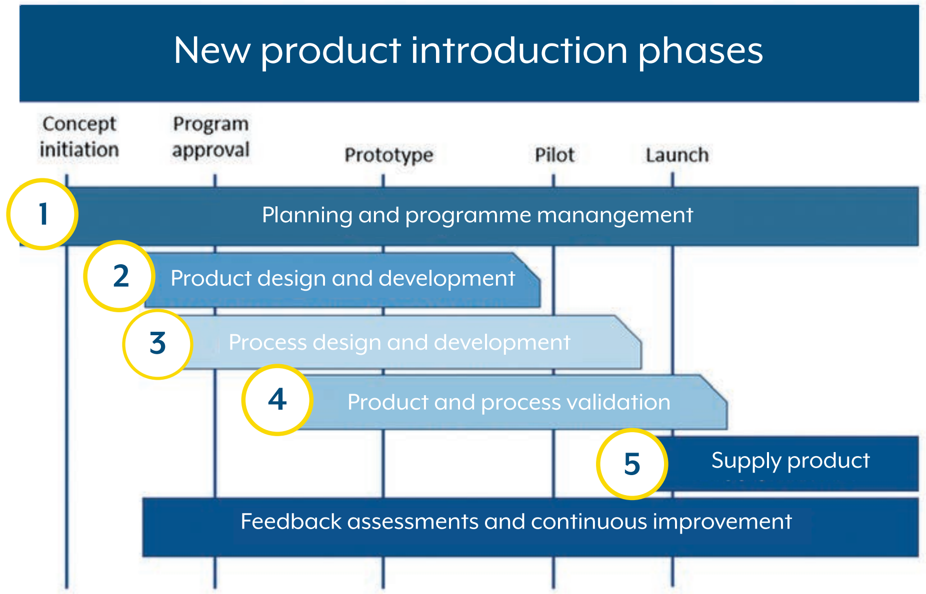


New Product Introduction

The New Product Introduction (NPI) process is a structured landscape based on the APQP process. It allows a supplier to plan and complete tasks which will be necessary to ensure manufactured products are supplied on time, on cost and meet the quality requirements. The process is designed to aid cross functional communication and aims to strengthen activities such as concurrent engineering, product quality planning, design, manufacturing, and the supply chain.

New product introduction phases

There are 5 major phases of the industry standard process, these being;



The incentive for using an APQP process is the potential to achieve a successful product launch in which product and process risks are minimized and profitability is improved.

1. **Planning & programme management**
   - Customers needs understood and requirements captured
2. **Product design and development**
   - Completed design reviews and verifications (CFD, FEA etc)
   - Materials specification
   - DFMEAs / Feature Verification Risk Analysis
3. **Process design and development**
   - Methods of manufacture / Process flow / Value Stream Mapping
   - Process Failure Mode Effects Analysis (PFMEAs) & Control Plans
   - Quality Assurance (Inspection Test Plans, Measurement System Analysis etc.)
4. **Product & Process Validation**
   - Initial process studies and quality assessments
   - Manufacturing capability and repeatability confirmations
5. **Supply Product**
   - Product launch, assessments and improvements
   - Statistical Process Control (SPC) and CPK analysis

Weld Modelling Capability

Challenge

Welding processes apply complex thermal loading and result in complex material behaviour. To be able to model the process, and accurately predict the resultant residual stresses, requires the application of advanced modelling methods and a detailed understanding of material behaviour.

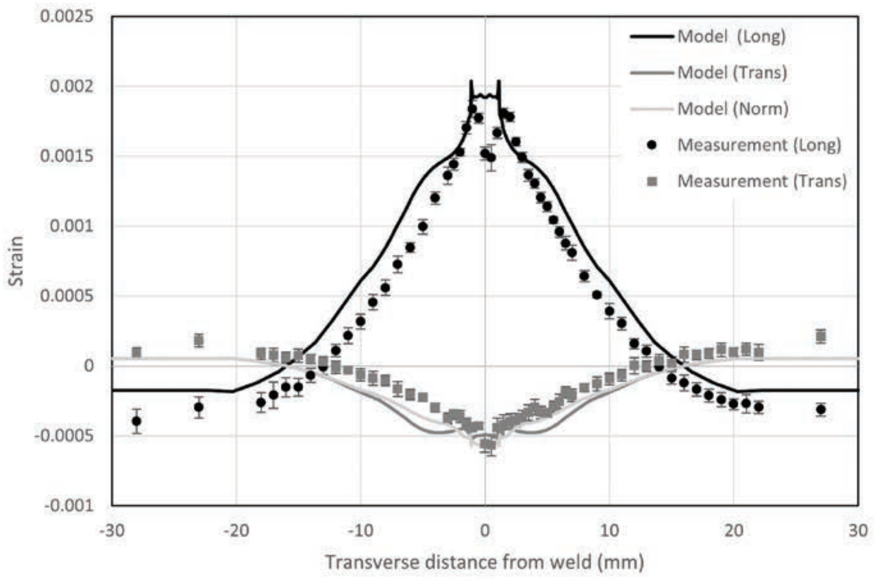
Our Proven Capability

As part of a government funded program to develop the capabilities needed for future generations of nuclear power plant, we developed a method for modelling power-beam welding processes including the prediction of residual stress. We drew on our previous knowledge of weld modelling, to create a method that would enable accurate prediction of residual stresses whilst also being computationally efficient. To validate our method a number of electron beam welded and laser beam welded specimens were created, state of the art methods were then applied to measure the residual stresses in these specimens. We used these residual stress measurements to validate the predictions from our models for the electron beam welded specimens.

Our Expert Knowledge

Through this and previous projects we have developed extensive knowledge in the field of weld modelling, including:

- How to develop weld modelling processes for both arc welding and power beam processes
- What simplifying assumptions can be applied to make the modelling methods efficient and what the limitations of these assumptions are
- How materials behave during the weld modelling process and how to model this? What methods are available to experimentally validate modelling predictions and how best to apply them
- How to make use of residual stress predictions as part of a process to ensure through life structural integrity
- How to predict post-weld distortion and design welding processes to minimize it.



Lead-Lithium Flow Loop Concept Design

Challenge

Lead-Lithium is a promising breeder blanket technology candidate to meet cooling and breeding requirements within a Tokamak. We were commissioned for a Concept Study of a flow loop to allow investigation of molten lead-lithium fluid properties and flow behavior in representative blanket conditions and varying lithium/lead concentrations. Increasing lithium concentration can provide greater tritium breeding ratios.

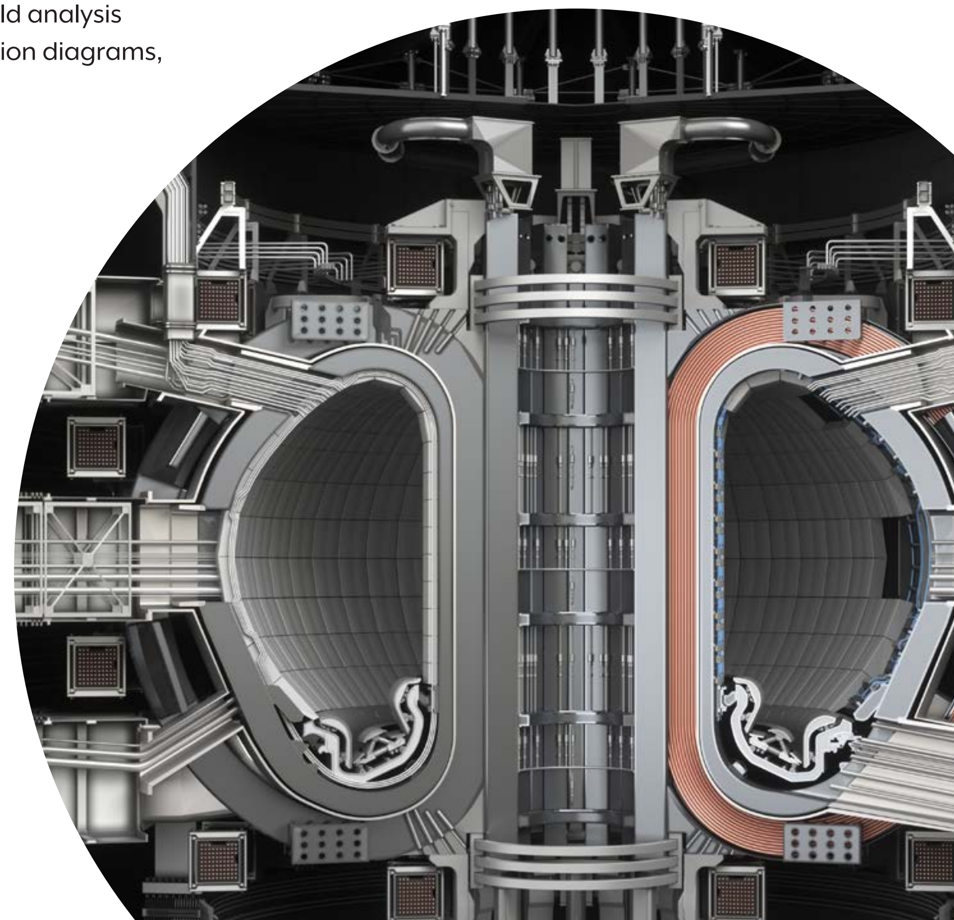
Our Approach

Frazer-Nash applied a systems engineering approach to meet the clients requirements using best practice from industry and scientific communities. Experience from thermal hydraulic system design, previous concept designs and liquid-metal expertise from project partners, underpinned our approach to determine a state-of-the-art flow loop design. Activities included:

- Exploring a range of flow loop options that could meet the developed requirement set for the concept; conducting industry research, literature reviews and supplier engagement equipment;
- Using our in-house technical expertise and processes to down select to preferred options;
- Developing concept design documents to record and substantiate the chosen design, including: heat and mass balances, heat exchanger optioneering, magnetohydrodynamic studies, magnetic field analysis and pressure losses, piping and instrumentation diagrams, hazard identification, and a 2D plot plan.

The Outcome

Our ability to bring together both in-house and industry expertise contributed to the success of this project. We delivered a robust and cost-effective experimental test rig concept design allowing the client to understand the challenges and opportunities associated with building the required loop before committing to significant investment.



Tritium Integrated Control Systems Assessment

Challenge

A key challenge in commercialization of nuclear fusion for net energy gain is the development of tritium systems with low losses. Instrumentation and control for tritium in extended operation is not well understood. There are several challenges relating to efficient management of the limited tritium inventory that must be overcome.

Our Approach

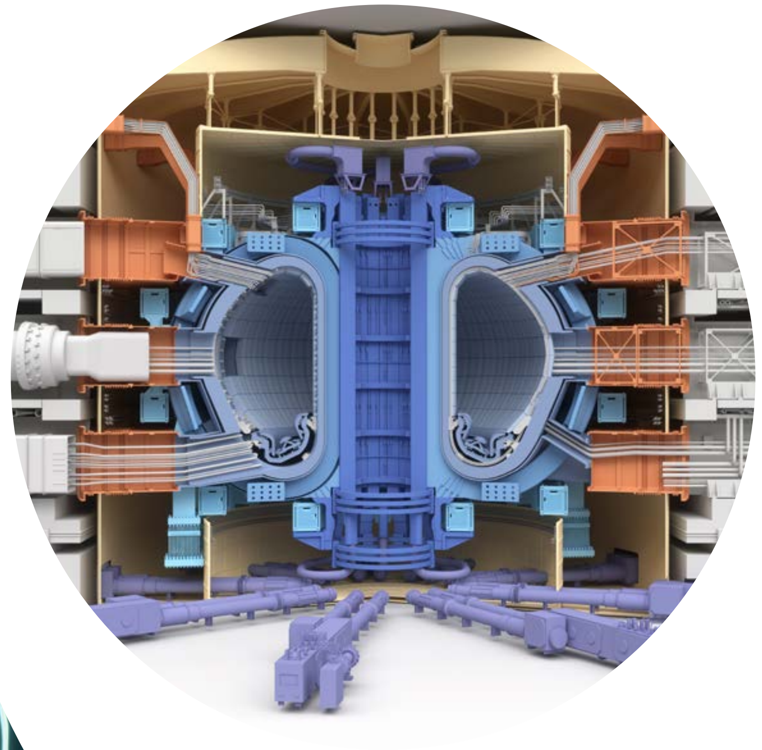
We employed a systems engineering approach to assess the technology feasibility of tritium waste, handling, recovery, and management systems. A discussion of potential technologies that could be employed to achieve the system requirements was presented, with consideration of emergent or novel technologies.

During the study, flow diagrams were produced to increase the understanding of interfaces between the tritium systems. The assessment resulted in the production of an architectural control system concept design for the tritium fuel route.

Due to the sensitivity of the whole plant, several recommendations were made to increase the capacitance in each system, to decouple control of different subsystems.

The Outcome

This work has increased the general understanding of control of tritium in tokamak subsystems. We delivered an architectural design for the tritium handling, recovery and waste route that can be built upon in the future and can be used to inform and support the formal design lifecycle. Moreover, the design provides a baseline to help overcome the tritium efficiency and management challenges associated with the commercialization of fusion.



Turbomolecular Vacuum Pump Assessment

Challenge

TurboMolecular Pumps (TMPs) are required in fusion environments to maintain a high vacuum. However, since the rotors are made from aluminum, a conductive material, and rotate at high speed, they are not compatible with strong magnetic fields experienced in the vicinity of the vacuum vessel, due to eddy current heating and forcing issues. Therefore, an investigation was carried out to find alternative rotor materials that would be suitable for a TMP and improve the capability to operate in the strong magnetic fields found in the vicinity of fusion reactors.

Our Approach

We employed a cross-disciplinary approach to this project. A varied shortlist of different rotor materials options was produced using rotating machinery and electromagnetics experts. Structural and electromagnetic calculations and modelling was performed in order to characterise the suitability of the different materials. A manufacturability study was carried out in collaboration with The Manufacturing Technology Centre (MTC), investigating the various manufacturing routes for multiple rotor materials, outlining where further development is required.

A development roadmap was generated to allow for further investigation of the presented TMP concepts that meet the onerous requirements of high magnetic field operation.

The Outcome

Development and assessment of rotor materials in TMP technologies forms part of our wider strategy to support UK's fusion mission across a number of key disciplines. For example, delivery of this project provided support to the client on advanced technique development, encompassing manufacturing, fabrication, joining, assembly, and through-life technologies, imperative for fusion reactor commercialization. The suggested roadmap will allow our client to assess and optimize the performance of the concepts presented in the report, and develop a route towards prototype manufacture and testing of TMPs.

Additional Case Studies

Design for Manufacture of Nuclear Decommissioning Waste Containers

The client was looking to gain a deeper understanding of the manufacturability methods, potential quality issues and affordability of manufacturing a decommissioning 'Waste Container' design.

We supported by investigating and evaluating, simplified manufacturing methods to expand the supply chain base.
We considered advanced technologies to improve operational and environmental efficiency and evaluated the design requirements to identify opportunities to relax these in order to increase efficiencies.

Development of Image Processing Algorithm for Non destructive In-Process Inspection

Developed a solution to digitalise the welding process with the intention to enable quantification of weld performance through the monitoring of the key weld parameters.

Using the image data collected from the process, we were able to correlate this to the inspection results and determine the quality of the weld.

Manufacturing Engineering Support Services

We were able to provide the client with expert manufacturing engineering access and collaboratively work with the client to make assessments of immature and high-level design concepts in the field of Fusion.

The benefit of this collaboration was to allow the client to understand the feasibility of the design, the current technology gaps within the supply chain and potential costs, and leadtimes to realisation.

Equipment Acquisition on behalf of Client

As part of the capability acquisition process, a wide range of technologies and vendors were explored to ensure that the most applicable solution would be selected. An industry standard Manufacturing Capability Acquistion (MCA) process was used to fulfil the clients requirements.

By independently reviewing the requirements with the client and liaising with the appropriate vendors we were able to identify and procure the best in class solution for the clients needs.

Advantages of AMTECH

Our support encompasses all products, sectors, technologies and functions, and aims to find solutions, drive efficiency, reduce manufacturing and quality risks to assure 'right first time' production. Focused on First Of A Kind (FOAK) products and components, we work with companies in the supply chain to support them overcome the complex manufacturability challenges, as well as helping them to compete by developing new capability, increasing quality and productivity performance and reduce costs.

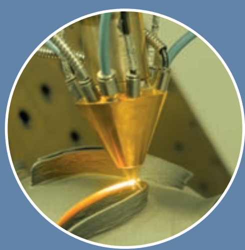
Success

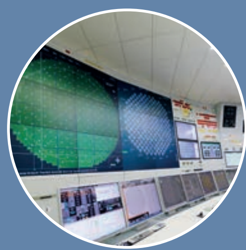
The Frazer-Nash AMTecH model has already been successful, winning a Tier 1 position on the UKAEA Manufacturing Framework. The framework has been set up to help UKAEA access a range of design for manufacturing and advanced engineering skills, which will contribute to the concept development of the STEP (Spherical Tokamak for Energy Production) programme. This programme will support UKAEA to achieve its goal to develop fusion as a new source of safe, efficient and low-carbon energy for future power stations.

The Frazer-Nash consortium brings together a number of organisations renowned for their expertise in nuclear and manufacturing, who will work together to offer a wide spectrum of support to the UK's prestigious fusion programme. The consortium includes Cavendish Nuclear, IDOM, The Manufacturing Technology Centre (MTC), Sheffield Forgemasters, the Warwick Manufacturing Group (WMG), and The Welding Institute (TWI); with additional specialist support being provided by Goodwin International Ltd, Kinectrics, Sigmaphi, ENSA, Tokamak Energy Ltd, Lucideon, and Antec Magnets.

Paula Barham, UKAEA Head of Procurement, said:

"Joining forces with such world-class organisations brings exciting opportunities for us to team-up with a wide range of experts, with this type of collaboration vital to UKAEA succeeding and positioning the UK as a leader in sustainable fusion energy."





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Leatherhead
Surrey
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