Research Proposal

May 2024

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Executive Summary

The UK has a strong heritage in aerospace technology development, including well-established research capability within its universities, academic institutions and research and technology organisations. The move to liquid hydrogen as a fuel source, as recommended by the ATI's FlyZero project, will be the biggest disruptor to the aerospace technology landscape since the introduction of the gas turbine. The transition to liquid hydrogen will require significant and rapid development of new technologies if the UK is to maintain its market share; the UK already has strengths in many of these areas, underpinned by a strong research base and innovative industrial R&D network. Nonetheless, a hydrogen fuel storage and delivery system will require a greater depth of knowledge of the behaviour of cryogenic hydrogen than is currently present within industry or academia. Thus, the ATI's Hydrogen Capability Network (HCN) has identified a need to bolster research in the UK to support fuel system technology development, with a particular focus on fundamental and pre-normative research to ensure the knowledge can be leveraged throughout the UK aerospace supply chain.

During the first 12 months of the HCN, the following topics were identified as requiring particular focus:

- Cryogenic hydrogen thermofluids behaviour
- Multiphysics understanding of materials at cryogenic temperatures
- Health and safety modelling of failure cases for cryogenic hydrogen systems and validation
- Hydrogen handling protocols.

We will now develop these topics into collaborative strategic research projects, taking into account the international landscape and industrial priorities. Strategic decisions on which institutions should develop which capability will be necessary to minimise duplication and maximise value for money. The HCN will work with Government to secure funding to address the research challenge for liquid hydrogen alongside other strategic interventions the HCN will recommend over the next 12 months.

Introduction

The FlyZero project developed roadmaps covering the technologies needed for liquid hydrogen flight to be viable[1]. These cover topics that are both generic (such as automation and digital twins) and specific (such as aerodynamic modifications to manage dry wings, fuel cell development and gas turbine hydrogen combustion), as illustrated in Figure 1. In work carried out by the Hydrogen Capability Network (HCN), involving engagement with key stakeholders, it has been demonstrated that the UK has strong existing knowledge and research capability in many of the topics required to deliver an aircraft capable of liquid-hydrogen-powered flight. There is, however, a clear exception with on-aircraft cryogenic hydrogen fuel storage and delivery systems. Thus, intervening to accelerate the development of fundamental knowledge and capability in this area within the UK will enhance the UK's ability to contribute to the development of zero carbon aircraft. This aligns directly with both Government's Net-Zero policy objectives and the objectives of the HCN.

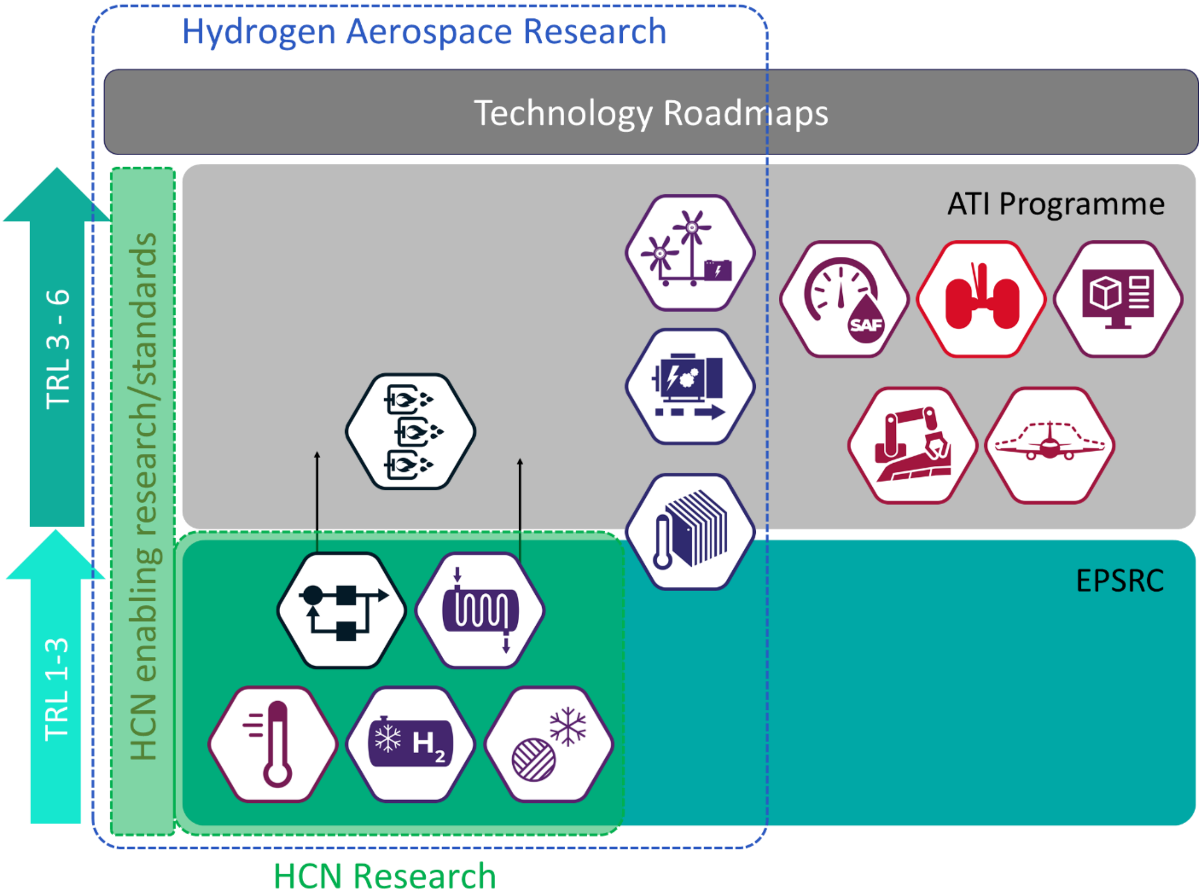

Figure 1 Technologies in which development is required to deliver LH2 powered flight

The challenge relates specifically to the storage and movement of hydrogen fuel between the fuel tanks and power source across a large range of fluid temperatures and pressures. Key research areas include the management of the transition from liquid to gaseous states in a controlled manner to ensure component function and life; the impact of hydrogen on the component integrity; and how to sense and manage hydrogen leaks safely, particularly in flight. While the requirements have initially

[1] FlyZero Reports Archive - Aerospace Technology Institute (ati.org.uk)

been driven by aerospace, there is relevance to other sectors that have plans for the use of liquid hydrogen in the future, and a link to these requirements is being maintained through the Hydrogen Innovation Initiative (HII)[2].

Case for Intervention

Mid technology readiness level (TRL) research has recently been initiated by several aerospace companies in collaboration with their partner research organisations. This is focussed on developing fuel delivery systems, to demonstrate hydrogen power plant, both gas turbines and fuel cells. While this research will deliver an understanding of the challenges of the technology and will commence the development of the hardware and systems, the optimisation of such systems in a rapid manner requires the underpinning fundamental physics and chemistry. To facilitate this the following is required:

- More coordination of UK aerospace cryogenic hydrogen research, ensuring collaboration and minimising duplication and gaps in capability
- Ensuring open access to the knowledge and research, thus facilitating capability development in the supply chain
- Active engagement cross-sector and in particular the low temperature physics community to ensure rapid knowledge transfer.

To understand the UK's position, demand and requirements the HCN held a research workshop with 34 relevant organisations across academia, industry and RTOs. There was a large amount of support for coordinated intervention and the following topics were highlighted as critical gaps that require dedicated effort to accelerate:

- Cryogenic hydrogen thermofluids
- Multiphysics modelling of materials at cryogenic temperatures
- Health and safety modelling of failure cases for cryogenic hydrogen systems
- Hydrogen handling protocols.

A strong space industry in France, Germany, and America has led to historic LH2 research, which means that this capability gap is not as pronounced within these countries, although there is still a need to mature the technology for aerospace applications. Consequently, these countries have a competitive advantage with respect to generating the technology required for liquid hydrogen powered flight. On recent visits to Germany, it is clear that this gap is beginning to be addressed through co-ordinated strategic hydrogen aviation research projects led by the Deutsches Zenturm für Luft- und Raumfahrt (DLR). If this gap is not proactively addressed in the UK, incumbents will look to leverage this knowledge base through funding research overseas, thus further enhancing the gap and increasing the risk of industrial relocation. For example, Airbus UK is actively funding cryogenic research in the US and is building capabilities within Europe.

Although some capability exists in other sectors (e.g. oil & gas) in the handling of cryogenic liquid fuels, there is a need to transfer this knowledge and enhance it through addressing aerospace-specific needs, such as different environmental conditions, including operation at altitude, transient operation and additional regulatory & safety constraints. Many of the Primes have already initiated work to develop mid-TRL level understanding of the design and behaviour of such systems, funded by the ATI; however,

[2] Home - Hydrogen Innovation Initiative

the UK has little or no low TRL fundamental understanding of the relevant phenomena, and this will lead to industry engaging with non-UK academia to fill the gap, e.g. Washington State University[3]. Academia in the UK has initiated research in this area, but the research and funding is not coordinated and does not leverage the knowledge around cryogenics in universities and departments; for example, with Physics Departments not currently linked to the aerospace industry. There is a requirement, therefore, to intervene to coordinate the research programme, actively engage with experts from other industries and manage a dedicated funding stream to boost UK capabilities.

This gap in capability should be addressed as an urgent priority to ensure that the UK's position within the aerospace market is not eroded by this disparity in knowledge, utilising the UK's strength in generating high-quality research. Research by the Infrastructure and Projects Authority (IPA)[4] has highlighted that for every year that industry is absent in a particular area it requires three years of investment and growth to re-establish capability to previous levels.

Case Studies of Similar Interventions

There is precedence that shows the value of specific collaborations in research and how these can accelerate the delivery of particular research topics; for example Hy-RES[5], DARe[6] & UK-MaRes[7] (which are introduced below).

The UK Hub for Research Challenges in Hydrogen and Alternative Liquid Fuels (Hy-RES) covers the generation, transport and usage of hydrogen and alternative liquid fuels such as ammonia. It is comprised of seven core university partners and has received funding from EPSRC of £11m, with the objective to achieve matched funding from industry. It launched in June 2023.

Research Hub for Decarbonised Adaptable and Resilient Transport Infrastructures (DARe) is the UK research hub established to decarbonise transport networks. Launched in September 2023 it has received £10m at 80% of the full economic cost by DfT (£5m), EPSRC, part of UKRI, and UKRI's Building a Green Future fund (£5m).

The UK National Clean Maritime Research Hub (UK-MaRes Hub), launched in September 2023, aims to accelerate the decarbonisation and elimination of air pollution from maritime activity in ports and at sea. It is a consortium of 13 universities together with over 70 industrial, civic and international organisations as project partners – including shipping companies, ports, equipment and service providers, fuel producers and civic bodies. Funding includes £7.4m from the Engineering and Physical Sciences Research Council (EPSRC) and Department for Transport, with an additional £13.9m financial and in-kind match funding from consortium universities and project partners.

While these hubs are working in decarbonisation, their focus is broader; where hydrogen is studied it is primarily in gaseous form and will not drive the understanding of liquid hydrogen, which is currently most pressing for aerospace. Thus, there is a need for additional aerospace-focussed intervention to drive the understanding and development of skills in this key area.

[3] HYdrogen Properties for Energy Research (HYPER) Laboratory | Washington State University (wsu.edu)
[4] IPA investigation into Nuclear Decommissioning Authority 2018
[5] UK Hub for Research Challenges in Hydrogen and Alternative Liquid Fuels (ukhyres.ac.uk)
[6] UK launches research hub to decarbonise transport networks – UKRI
[7] New research hub will decarbonise the UK shipping industry – UKRI

Proposed Intervention & Benefits

It is proposed that the HCN will shape the UK research strategy based on input from industry and ATI technology roadmaps to fulfil its strategic objectives of:

- Reducing the amount of time to commercialise innovation
- Anchor high value jobs in the UK
- Increase the competitiveness of the UK through the growth of global market share in the hydrogen economy.

This will be achieved through the creation of a research network bringing together incumbents with universities that have existing expertise in the field of cryogenic hydrogen. The research will focus on pre-competitive, fundamental physics and chemistry understanding of the challenges involved, thus ensuring that the results can be widely shared across the UK's aerospace sector.

Furthermore, developing this understanding will enable the UK to be a leader in the regulatory environment and global standards setting, maintain and grow market share, and develop the appropriate skills and expertise.

The lack of expertise in this area also impacts the ability of industry to recruit suitably qualified experienced personnel (SQEP) to deliver their research programmes; there is currently no existing talent pipeline in the UK. This intervention will increase the pool of individuals with skills in this area through delivering PhD and post-doctoral students with relevant research experience, and hence also supports the skills development intervention recommended by the HCN. In order to promote collaboration prior to finalising the research programme, a technical conference is proposed, thus initiating community building and establishing links with industry in a timely manner.

Over the next 12 months the Hydrogen Capability Network is planning to complete a detailed mapping of both UK and global capabilities to identify critical gaps that need to be addressed. This, together with consideration of industrial priorities, will be used to scope out an intervention, make strategic decisions of which capabilities to develop at which institution, and develop costed research proposals.

Conclusion

The work of the Hydrogen Capability Network to date has identified the need for a structured intervention to develop the UK's fundamental understanding of the physics and chemistry that will underpin the rapid development of the fuel storage and delivery system on next-generation hydrogen-powered aircraft. It is proposed over the next 12 months that more detailed mapping of the UK's capability relative to the global capabilities should take place. Based on this understanding and driven by industry priorities a costed research proposal will be developed and funding stream identified.

High Level Activities & Maturation

AEROSPACE TECHNOLOGY INSTITUTE | Hydrogen Capability Network

Research Funding Call
Pre-TRL 3 Collaborative research projects to tackle urgent priorities

Low TRL research
Identify knowledge sharing approach

Deliver research projects

Research Hub
Bring together partners with increased co-ordination to drive research further

Deliver hub, including governance, identify research projects, establish additional funding streams,

Additional Activities
Community building through - Annual research conference, networking events, knowledge sharing
Cross-sector engagement - Outreach to cross sector researchers and industrialists