AEROSPACE TECHNOLOGY INSTITUTE

Hydrogen Capability Network

Skills Recommendations

May 2024

Contents

Executive Summary

A cryogenic hydrogen skills shortage in the UK is inhibiting the pace of development of the technology required to unlock hydrogen-powered flight. The globally small pool of suitably qualified and experienced people is driving wage inflation and spiralling costs, which will make it harder to compete for talent. Without coordinated activity to bolster this talent pipeline in the short term, this situation will be perpetuated and could restrict the competitiveness of the UK aerospace sector for decades.

Following engagement with industry and academia, the ATI's Hydrogen Capability Network has identified recommendations designed to tackle this shortage for post-graduates within the next 1-5 years to support other initiatives such as the Hydrogen Skills Alliance which will deliver long term benefits. This is achieved through proposing the use of proven approaches from other sectors to attract graduates from specialisms outside of aerospace, for example low-temperature physics. This will be complemented through activities to build a UK community to support the development of the knowledge base, encourage international collaboration to bolster the UK's expertise, and signpost to existing training opportunities to minimise duplication and maximise value to the UK economy.

Recommendations

1. **Signposting** – an open access database signposting existing training opportunities, both in the UK and internationally, and a bursary scheme-style (see below) promotion of PhD, postdoctoral and employment opportunities.
2. **Training support** – bursaries to enable attendance at training courses and conferences, both in the UK and overseas. Investigation of industrial placements and facilitating cross-sector secondment opportunities.
3. **PhD enrichment programme** – Form an initial cohort through bringing together existing PhDs, on-boarding new relevant PhDs, identification of training programmes, establishing an annual conference.
4. **Post doctoral enrichment** – developing skills and industry connections through convening postdoctoral researchers to tackle specific challenges.
5. **LH2 aerospace conference** – community building, knowledge sharing and showcasing aerospace careers opportunities.
6. **Learning-by-doing** – work with test hubs to identify FE & HE to engage with, support development of formal training through funding competitions.

Introduction

The Aerospace Technology Institute (ATI) has been commissioned by the Department for Business and Trade (DBT) to investigate and identify opportunities associated with the transition by civil aviation to liquid hydrogen aircraft in line with HMG Net Zero Policy ambitions.

Currently at the end of Phase 0 of the Hydrogen Capability Network (HCN) programme, the HCN team has been conducting discovery and due diligence to identify potential requirements and potential gaps in the market. As part of this analysis HCN is recommending several strategic interventions to facilitate the adoption of hydrogen technology and allow the UK to create a competitive marketplace in this new critical energy/fuel sector. The global market for aircraft deliveries to 2050 is valued at £4.3tn. In 2050, 20 - 40% could reasonably be assumed to be hydrogen aircraft deliveries, which will continue to accelerate over the following decade.

Through industrial engagement the HCN has identified that there is a challenge in recruiting suitably qualified and experienced people (SQEP) with both aerospace skills and knowledge related to the design and development of LH2 cryogenics. This is already impacting the development of the technology required to deliver LH2-powered flight. Current solutions are either to recruit from strong performers overseas (eg France) or from alternative sectors (eg oil and gas), with candidates then needing additional training in aerospace-specific requirements.

If this is not addressed immediately through interventions to enhance the UK's skills in these technology areas, the UK's talent pipeline will not develop. In turn, the struggle to recruit will become more pronounced and could lead to industry taking this technology development and manufacture overseas. Research by the Infrastructure and Projects Authority (IPA)[1] has highlighted that for every year that industry is absent requires three years of investment and growth to re-establish capability to previous levels.

Current Skills Landscape

Through engagement with industrial partners the HCN has identified that there is a cryogenic hydrogen skills shortage in the UK, which is currently impacting the development of the technology required for LH2-powered flight. Unless this is addressed as a matter of urgency, there is a risk that further technology development will move overseas, where suitably SQEP people are available, thus increasing the risk of industrial flight and jeopardising the UK's prominent position within the aerospace sector.

Several organisations are already engaged in promoting hydrogen related skills. The Hydrogen Skills Alliance in conjunction with the Hydrogen Innovation Initiative is committed to building a skilled workforce to deliver a UK hydrogen economy. This is through creating a database of current skills provisions, carrying out the skills foresighting exercise as outlined in the Manufacturing the Future Workforce[2] report and establishing the demand signal, prior to establishing a skills framework to deliver curriculum content. This is supported by representatives from a wide range of industries and the Hydrogen Capability Network represents the aerospace industry within this. Given the novelty of the technology the foresighting process is likely to take 2-5 years to reach maturity and hence there remains a role for the HCN to accelerate liquid hydrogen skills in the short term and to continue to

[1] IPA investigation into Nuclear Decommissioning Authority 2018
[2] Manufacturing-the-Future-Workforce-Full-Report.pdf (catapult.org.uk)

represent the specific requirements of aerospace for skills associated with liquid hydrogen, as most other industries are focused on gaseous hydrogen.

In parallel, the Aerospace Growth Partnership (AGP) is also looking at the skills requirements for aerospace, which the HCN is also supporting. The AGP is in the process of completing four workshops to establish both the skills gaps and the demand signal. This work covers all skills associated with the technology development, manufacture, maintenance, and end of life considerations, ranging from aerostructures and combustion through to manufacturing and automation, in addition to hydrogen specific skills. This work will conclude mid-2024 with a report outlining the demand and gaps, which will be used to initiate conversations with educators, professional institutions and government. This may in the future evolve into an aerospace academy. The HCN will remain part of this journey, with a particular focus on LH2 skills.

Both strands are focused on long term solutions for meeting the skills needs. As outlined above, however, stakeholder feedback has highlighted that lack of skills related to hydrogen, and in particular liquid hydrogen, is currently inhibiting the development of the technology within aerospace. Therefore, there is a need to develop approaches that will develop hydrogen skills rapidly, leveraging learning-by-doing, which is particularly relevant given the lack of maturity of the technology in aerospace.

Ultimately, all these strands will support the development of a cross-sector hydrogen academy, at which point the requirement for aerospace specific interventions may be superseded, although there will remain a need to ensure that the voice of aerospace is adequately represented in future governance. The potential evolution of the skills environment is illustrated in

Figure 1, although dates and the establishment of hydrogen skills and aerospace hubs will be dependent on activities outside the remit of the HCN.

To establish what actions should be undertaken by the HCN, several case studies of best practice in other industries have been produced, and these are given in the following sections. Based on these, several recommendations are made in the Proposed Intervention section.

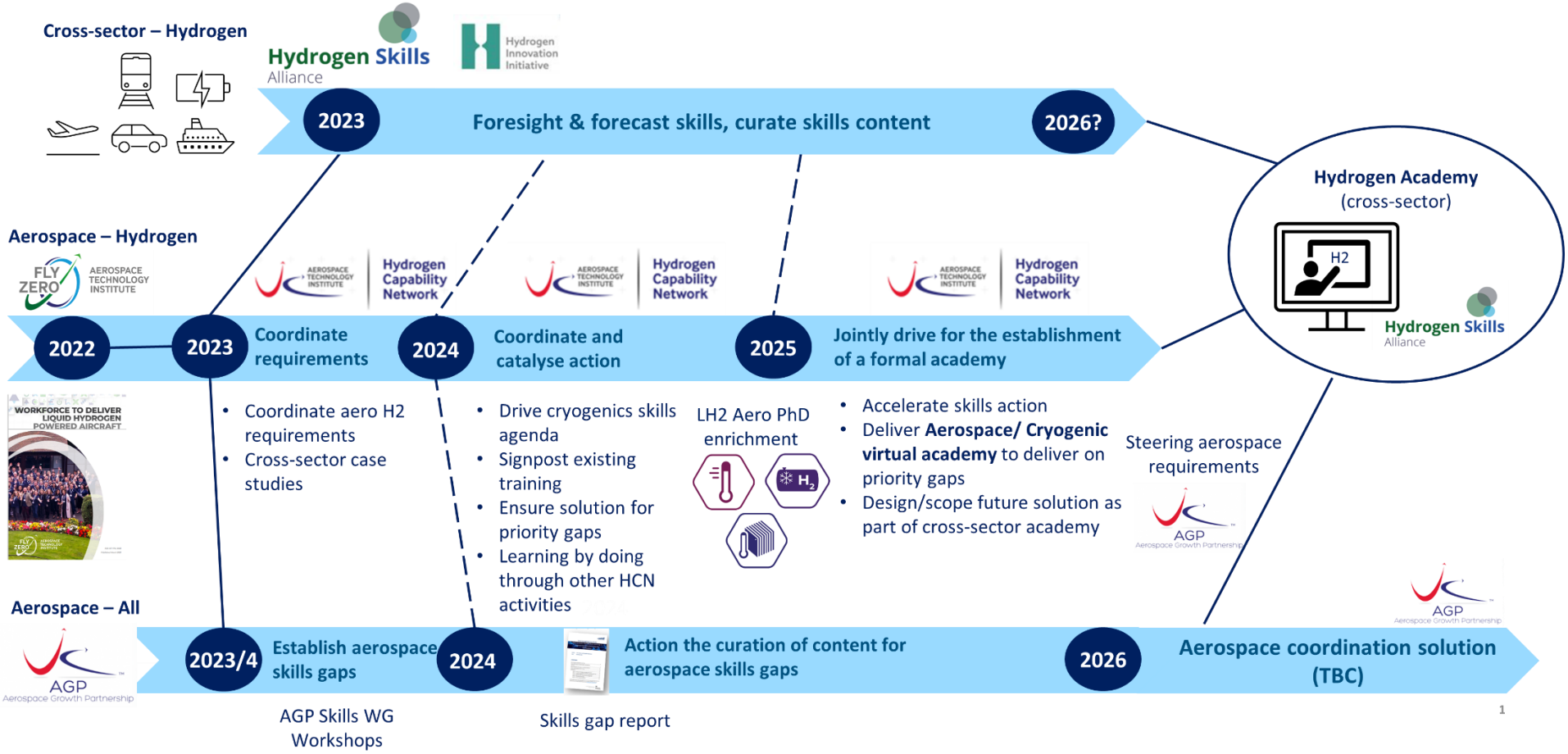


Figure 1 Illustration of current skills interventions for hydrogen and how the HCN skills intervention relates to them

Skills Case Studies

Nuclear Skills Case Study

Civil nuclear power generation is a well-established technology, with the first commercial power station, Calder Hall running from 1956 to 2003. By the time of its decommissioning the industry had an aging workforce as identified in the International Atomic Energy Agency's report in 2004[3], and the growing need for energy security in the years since has led to an increased focus on the development of skills for this sector.

The government's National Skills Academies initiative, set-up up to deliver employer-led centres of excellence in vocational education and training, led to the establishment of the National Skills Academy Nuclear (NSAN[4]) in 2007. This is now a self-funded, not-for-profit organisation delivering training on nuclear fundamentals and behaviours (doing it right when no one is watching), safety and human factors. NSAN also provides a competency framework that is utilised by employers to show that their workforce is made up of suitably qualified and experienced people (SQEP).

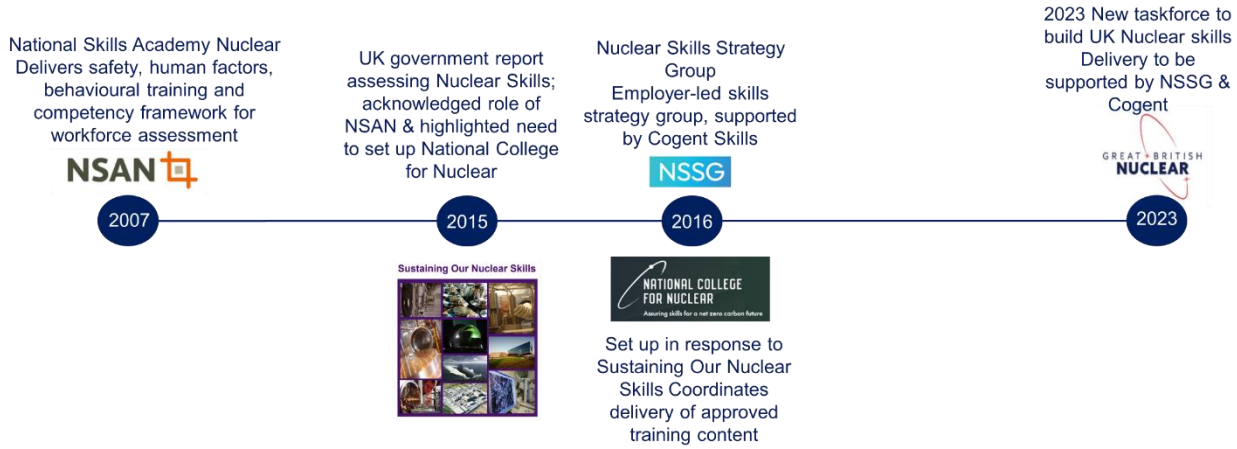
The government report Sustaining Our Nuclear Skills[5] highlighted the role of NSAN in supporting the growth of skills for UK nuclear, while initiating the formation of the National College for Nuclear (NCfN[6]). The NCfN operates a network of course suppliers based around the UK, providing a bridge between skills strategy and its provision through assured curriculum content.

In 2016 the Nuclear Skills Strategy Group (NSSG[7]) launched its first Nuclear Skills Strategic Plan as a successor document to the UK Government 2015 report. The NSSG is the employer-led skills organisation for nuclear, bringing together major employers, government, regulators and trade unions to address the sector's skills challenge. It is supported by Cogent[8] to regularly update its strategy, with the latest version issued in 2020[9], together with detailed workforce assessments[10]. They distinguish between nuclear skills, those specific to the nuclear sector and skills for nuclear, which are cross-sectoral skills such as construction.

In August 2023 the Nuclear Skills Taskforce[11] was launched by the UK government in conjunction with Great British Nuclear[12] to give additional focus on the delivery of a skilled workforce to support UK energy security. The NSSG will continue to support with formulating the strategy and will take a project management role with Cogent in the National Skills Delivery Plan.

[3] The Nuclear Power Industry's Ageing Workforce: Transfer of Knowledge to the Next Generation | IAEA
[4] National Skills Academy Nuclear (nsan.co.uk)
[5] Sustaining_Our_Nuclear_Skills_FINAL.PDF (publishing.service.gov.uk)
[6] National College for Nuclear | Supporting delivery of nuclear missions (ncfn.ac.uk)
[7] NSSG Home | Nuclear Skills Strategy Group (nssguk.com)
[8] Home - Cogent Skills
[9] nssg-strategic-plan-2020-delivering-through-partnership-final-spread.pdf (nssguk.com)
[10] Nuclear Workforce Assessments | Nuclear Skills Strategy Group (nssguk.com)
[11] New Taskforce to build UK nuclear skills - GOV.UK (www.gov.uk)
[12] Great British Nuclear - GOV.UK (www.gov.uk)

Thus, the skills story within the nuclear industry has evolved over a number of years, starting in an ad-hoc manner with the establishment of NSA in 2007 developing to a more strategic approach driven by NSSG and subsequently the Great British Nuclear initiative. The structured approach to generating workforce intelligence and forecasting given by Cogent would be beneficial to the aerospace industry, as this is a rigorous source of historic and future trends and pain points for the industry, which can be used to make the business case for coordinated action to government and educators alike.



Case Study – Driving the Electric Revolution Skills

Although an electric car was first constructed in the 19th century, the first mass produced electric car was available from 1996. Industries other than automotive have also seen increasing electrification and this has accelerated as the need to reduce greenhouse gas emissions has become more apparent. This is a disruptive technology change, which has direct impact on the skills required in the industry, not only for design and manufacture in OEMs and their supply chain, but also for many organisations that maintain the fleet during its lifecycle. Thus, there is a need to for a step change in the skills that the workforce requires to remain current and this needs to be delivered at pace.

In 2020 the High Value Manufacturing Catapult (HVMC) funded by the Gatsby Foundation issued the report Manufacturing the Future Workforce[13] which identified that although the UK excels in research and technology innovation, manufacturers struggle to access the skilled workforce they need to turn this in to profit and maintain competitive advantage. The report recommended the development and application of skills foresighting to identify and articulate future skills requirements related to emerging technologies. The approach is particularly applicable to technology that has reached TRL 4-5 and is most beneficial for the broader supply chain, as the OEMs and tiers 1 & 2 supply chain have sufficient resources to upskill their staff in the face of changing requirements.

This approach was combined with the latest automotive technology roadmaps, that had been updated in 2020 by the Automotive Council and the Advanced Propulsion Centre, to produce the report The Opportunity for a National Electrification Skills Framework and Forum[14]. This report defined the competencies that technicians and engineers would need for this novel technology. It also identified the gaps in the current training provision and checked other sectors for courses that could fill the gaps. In the years since this analysis was completed, these gaps are gradually being filled through a variety of funding including the Emerging Skills Project[15] and Faraday Battery Challenge[16].

In parallel to the structured approach adopted above, Driving the Electric Revolution[17] launched two competitions to fund the development of skills for power electronics, machines and drives (PEMD). In 2021 the Building Talent for the Future[18] competition asked for projects that would support skills, talent and training development for the sector costing between £10-25k. These could range from STEM engagement and supporting ED&I to defining and filling keys gaps in the UKs workforce, with a total budget of £250k. This was followed in 2022 by Building Talent for the Future 2[19] which had a similar remit, a budget of £4.5M with projects either in the range £50k-£1M or less than £50k. The projects demonstrated business need through letters of support from industrial partners. This funding has supported the work of the National Electrification and Skills Framework and Forum, but rather than utilising foresighting to identify skills gaps, these have been identified through industry pull and educators forming partnerships to deliver the content.

[13] Manufacturing-the-Future-Workforce-Full-Report.pdf (catapult.org.uk)
[14] National-Electrification-Skills-Forum-Brochure-FINAL.pdf (catapult.org.uk)
[15] Emerging Skills Project
[16] Faraday battery challenge – UKRI
[17] Driving the electric revolution – UKRI
[18] Competition overview - Driving the electric revolution – building talent for the future – (gov.uk)
[19] Driving the Electric Revolution: Building Talent for the Future 2 - Innovate UK KTN (ktn-uk.org)

In 2021 Driving the Electric Revolution also put out a competition for establishing a PEMD Skills Hub[20]. This launched in 2023 as the Electric Revolution Skills Hub[21], and signposts existing courses from L3-8. It is also launching a Body of Knowledge and evolving tools to allow new entrants to identify skills gaps in their workforces. The hub could receive funding up to £1M and was specified to become self-supporting and to last for a minimum of 10 years.

The evolution in the skills for electrification has been faster than that seen in the nuclear industry, driven by the increased understanding of the need for a structured workforce strategy and by the disruptive nature of the technology, which particularly affects the broader supply chain. The cross-sector nature of the technology benefits from the structured approach, ensuring the leverage of existing and new course content.

[20] Competition overview - Driving the Electric Revolution – PEMD Skills Hub - (gov.uk)
[21] Electric Revolution Skills Hub (ershub.co.uk)

Driving the Electric Revolution
Investing in PEMD for net zero

2019

DER – PEMD Skills Hub Competition
Develop hub as platform to connect training and education with employers and learners

2021

Building Talent for the Future
Competition for PEMD skills projects £10k-£25k

2022

Building Talent for the Future 2
Competition to fund PEMD skills projects £50k-£1m & <£50k

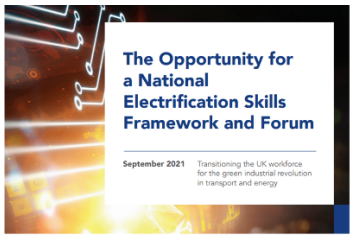
2023

Cross-sectoral hub signposting existing courses, developing Competency framework, collating body of knowledge, evolving tools to assess skills gaps for new entrants

Automotive technology roadmap issued

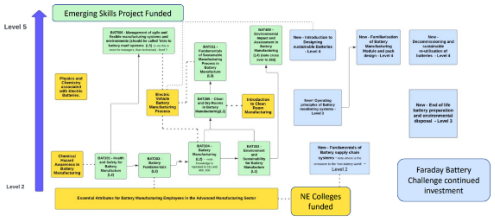
2020

Report into workforce development & its link to innovation. Identifies the skills value stream & skills foresighting



2021

Competencies for technicians & engineers defined, existing qualifications and gaps identified



Course content funded by Faraday Battery Challenge, Emerging Skills Project & FE colleges
Supported by Automotive Council

Case Study – The Faraday Institution PhD Enrichment Scheme

Battery technology and skills in the UK is at an early stage of development and there is a need to increase the number of post-doctoral qualified people to feed into developing the UK's capabilities to ensure competitiveness within this sector. The Faraday Institution is promoting this through its PhD Enrichment Scheme[22] which aims to replicate the benefits of the Central for Doctoral Training schemes[23] through offering up to 15 students per year, a quality training programme and exposure to industry experts and industry tours. Applicants must be undertaking a full-time battery related PhD at a UK academic institution. This enhances the learning potential and builds a cohort of connected, talented people able to support the growth of the industry. It is now starting its 6th year and its first cohort has graduated and all are employed within the UK battery sector.

The Faraday Institution also offers 6-week summer internships[24] for undergraduates and a training budget to support skills development for early career researchers[25] in addition to promoting UK PhD opportunities on its website[26]. There is a focus on building a community of researchers through early career conferences.

This offers a good model of high-level skills development and an approach to build a critical mass of knowledge in a subject in which the UK has historically lagged.

Case Study – Centre for Postdoctoral Development in Infrastructure, Cities and Energy (C-DICE)

The Centre for Postdoctoral Development in Infrastructure, Cities and Energy (C-DICE)[27] is led by Loughborough University and brings together 18 higher education institutions with the aim to promote collaboration and facilitate access to the postdoctoral community in infrastructure, cities and energy. It is a four-year programme designed to build the advanced skill set and talent pipeline, thus accelerating towards a Net Zero society by 2050. They achieve this through four activities.

- utilising the partner institutions to provide training opportunities,
- providing funding for fellowships, placements and secondments,
- setting industry-based challenges to generate novel solutions to reach Net Zero
- delivering knowledge exchange events to promote dissemination.

There are common approaches to those of the Faraday Institution, although an industry challenge 'sandpit' programme is additional. The sandpit challenges create networks of exclusively postdoctoral researchers to solve real-world problems, which are often cross-sector. It enables the researchers to develop the skills needed to create a credible research proposal, including how to write and cost the proposal and to work collaboratively. It offers a great opportunity to develop principal investigator skills early in their careers. It also offers industry access to a broad range of diverse thinking and ideas and hence the possibility for significantly different solutions.

[22] The Faraday Institution PhD Enrichment Scheme - The Faraday Institution
[23] Centres for Doctoral Training (CDT) – UKRI
[24] The Faraday Undergraduate Summer Experience (FUSE) - The Faraday Institution
[25] Early Career Researchers - The Faraday Institution
[26] Battery Related PhD Opportunities in the UK - The Faraday Institution
[27] C-DICE – The Centre for Postdoctoral Development in Infrastructure, Cities & Energy (cdice.ac.uk)

Case Studies – Lessons for Aerospace

- An unstructured approach to skills development leads to long timescales to build the skills base and can still require a specific intervention to accelerate.
- A coordinated cross-sector approach accelerates the sharing of training and maximises the opportunities for those reskilling in this area. It also minimises the duplication of content generation. Such an approach is required for the Hydrogen Industry as a whole, however in the short term the Hydrogen Capability Network should develop a database to support the aerospace industry.
- Specific doctoral and post-doctoral interventions, whether through PhD enrichment or post-doctoral challenges accelerates the development of a community of people sharing knowledge and expertise and attracts and retains people into a specific industry.
- Bursaries offer a means for rapidly sharing knowledge through a community. This would be a particular benefit for liquid hydrogen skills, as the expertise exists overseas.

Proposed Intervention

It is clear from engagement with industry and other initiatives in the hydrogen skills space that there is still a need for an aerospace specific intervention, particularly to address immediate skills shortages. Based on the case studies of interventions in other sectors several activities are proposed, which are detailed below. These can be summarised as leveraging existing skills and training opportunities, community building around the sparse expertise for knowledge sharing, and signposting aerospace as a career route for students who would not typically consider it.

Prior to formulating a long term plan for skills provision, it is proposed that pilot activities will be initiated during the first year, where different activities will be trialled. Their success will be monitored together with stakeholders from industry and academia and improvements or alternative activities identified. These activities will alleviate the skills gaps being experienced now, with minimal cost and minimal long term financial commitment.

By adopting a componentised delivery strategy, it is possible to start realising benefits rapidly. The proposed initiatives are given below and Figure 1 illustrates this cumulative delivery process. The skills covered will range from apprenticeships through to postdoctoral, and will initially focus on liquid hydrogen related skills, though there is scope to expand this to cover the broader hydrogen skill set e.g. combustion.

Recommendations

1. Signposting – an open access database signposting existing training opportunities, both in the UK and internationally, and a bursary scheme-style (see below) promotion of PhD, postdoctoral and employment opportunities.
2. Training support – bursaries to enable attendance at training courses and conferences, both in the UK and overseas. Investigation of industrial placements and looking into cross-sector secondment opportunities.
3. PhD enrichment programme – Form an initial cohort through bringing together existing PhDs, on-boarding new relevant PhDs, identification of training programmes, establishing an annual conference.
4. Post doctoral enrichment – developing skills and industry connections through convening postdoctoral researchers to tackle specific challenges.

5. LH2 aerospace conference – community building, knowledge sharing and showcasing aerospace careers opportunities.
6. Learning-by-doing – work with test hubs to identify FE & HE to engage with, support development of formal training through funding competitions.

Activities 1 and 2 will facilitate access to existing training and skills offerings, whereas activities 3,4 and 5 are focused on reaching out into the non-aerospace skills pool and community building around the scare skills talent pool. Activities 3 and 4 can also facilitate the upskilling of the aerospace research community around LH2 specific skills, through establishing training opportunities within other sectors. The final intervention is to leverage the learning that will come naturally through research activities carried out the LH2 test hubs.

On-going engagement with both the HSA and AGP will continue throughout this process. The HCN will feed in aerospace requirements to the skills foresighting process being run by the HSA and continue to support the AGP in their delivery of more general aerospace skills development. It is possible to envisage the steps outlined above being absorbed into cross-sector initiatives, potentially resulting in a Hydrogen Skills Hub, akin to the Electric Revolution Skills Hub and the possible development of an Aerospace Skills Hub in the same manner.

The HCN is ideally positioned to carry out the management of the programme and budget, running competitions to identify suitable delivery partners, ensuring value for money and timely delivery of the interventions. An advisory group incorporating representatives from industry and, where relevant, educators will ensure the value of the initiatives and on-going relevance of the proposed programme.

Conclusion

Through engagement with industry and academia, the ATI's Hydrogen Capability Network has identified significant skills gaps which puts at risk the development of hydrogen aircraft technologies, particularly in cryogenics. With liquid hydrogen-powered aircraft forecast to play a key role in aviation achieving Net Zero 2050, it is imperative that the sector acts now to address this skills gap and in doing so create a British workforce ready to secure share of a market forecast to be worth £4.3trn to 2050.

As demonstrated in this report, this action will have the biggest long term benefit if it is coordinated, cross-sector and forward looking. The HCN is ideally positioned to play this coordinating role leading in the provision of interventions for the benefit of the aerospace sector and its supply chain as well as maintenance and lifecycle aircraft services.

High Level Activities & Outputs TimelineSkills

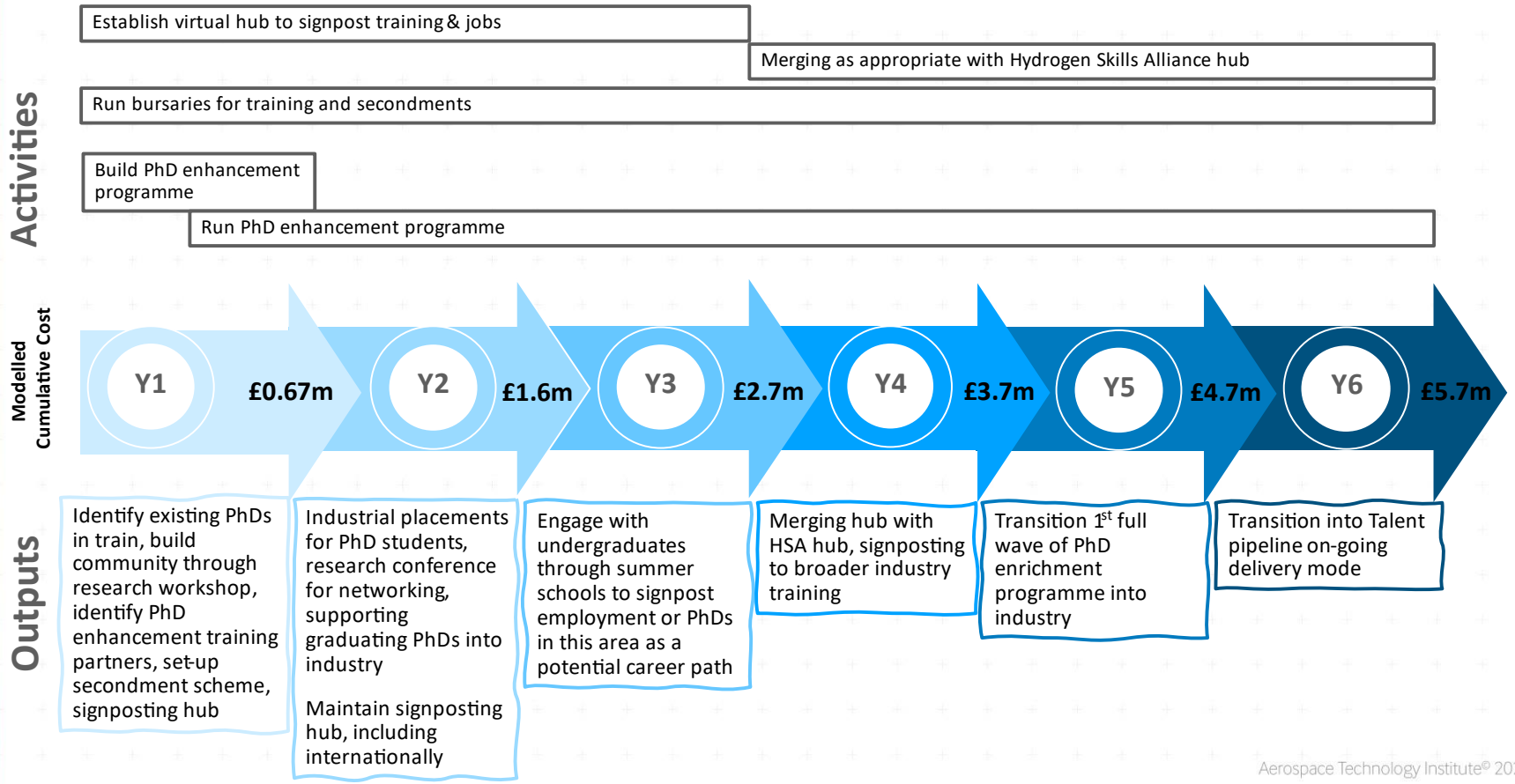


Figure 2 Timeline for skills delivery proposal