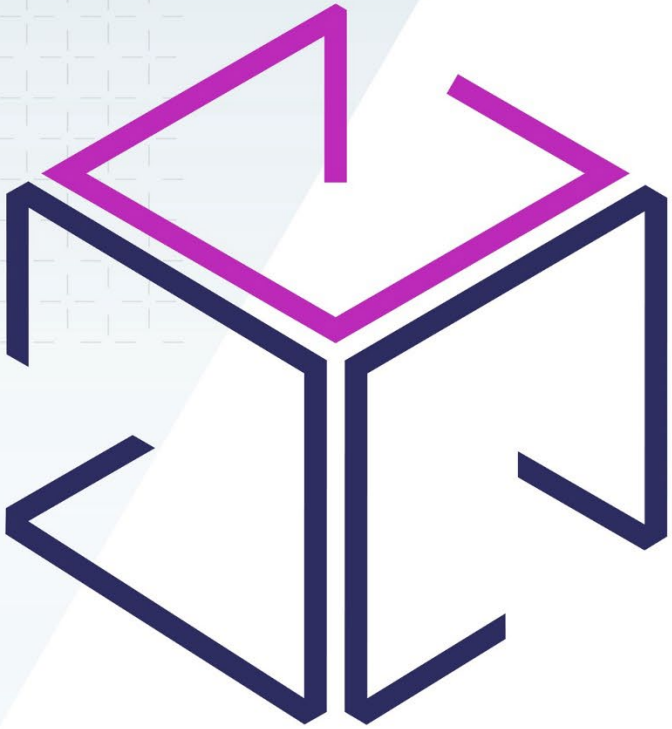
Workforce Foresighting Hub



The design and use of cryogenic hydrogen storage for Aircraft by 2035

A Workforce Foresighting Hub findings report in collaboration with NCC.

Date: March 2025

UKRI Innovate UK

Right skills, right time, right place

Acknowledgements

Attributions - The Workforce Foresighting process integrates data from the following international data sets:

IfATE – Institute for Apprenticeships and Technical Education, England

ESCO – European Skills, Competencies, Qualifications & Occupations, EU

ONet – Occupational Networks Online, USA

In accordance with licence and publishing requirements of these organisations for the use of their data sets, the Workforce Foresighting Hub team states that –

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The ESCO data is used in accordance with the EUROPEAN UNION PUBLIC LICENCE v. 1.2 EUPL © the European Union 2007, 2016

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The method and process used in the Workforce Foresighting process is under development and there may be errors and omissions in the data provided.

This report was produced following workshops undertaken October – December 2024 using the data set and tools available at that time.

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1.0 Executive Summary

1.0 Executive Summary

Section	Title
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1.1 Foresighting cycle summary

The UK is a global leader in the aviation and aerospace sector. By 2050, the UK could grow its market share in civil aerospace from 12% today to 19%, increasing the sector's gross value added to the economy from £11bn to £36bn, and expanding the number of aerospace jobs from 116,000 to 154,000[1].

The ATI FlyZero project has forecast that by 2050, 90% of new aircraft could be hydrogen powered.[2] The UKs largest aircraft manufacturer, Airbus, has announced that they are developing the world's first hydrogen commercial aircraft, with plans to enter service in 2035, which will lead to hydrogen-powered aircraft operating flights at UK airports.

Analysis carried out by Jacobs in their UK Aviation Hydrogen Forecast predicts that demand for hydrogen in aviation will be circa 20,000 tonnes annually by 2035, ramping up to demand of over 350,000 tonnes annually by 2050. This predicted increase clearly shows a required increase in the number of workers skilled in the design of cryogenic tanks.[3]

There are many technology challenges and necessary solutions to enable the industrialisation of hydrogen fuelled aircraft, including:

- Cryogenic storage tanks
- Control valves
- Hydrogen capable pipes
- Sensors
- Refuelling systems
- Fuel cells

This list of technologies was developed during an initial workshop with industrial partners, educators, and technologists, hosted at the National Composites Centre in 2023. These technologies were then analysed to understand which fell into 'Horizon 2': 2025 - 2035. This activity was completed using the Hydrogen technology roadmaps published by the Hydrogen Innovation Initiative in 2024[4].

Following further Hydrogen Skills Alliance discussions with technologists and employers, it was concluded that the critical Horizon 2 technology solutions to meet the challenge were **cryogenic hydrogen tanks and systems.**

This cycle was sponsored by the Aerospace Technology Institute (ATI), which creates the technology strategy for UK Aerospace. Additionally, the ATI leads the Government backed Hydrogen Capability Network, which brings experts together to solve key challenges to realising hydrogen-powered aircraft.

[1] Aerospace Technology Institute, Fly Zero Executive Summary, March 2022
[2] Aerospace Technology Institute, Workforce to Deliver Liquid Hydrogen Powered Aircraft, March 2022
[3] Hydrogen in Aviation Group, Launching Hydrogen Powered Aviation, March 2024
[4] Hydrogen Innovation Initiative, The UK Hydrogen Innovation Opportunity, April 2024

1.2 Organisational change

As the UK moves towards Net Zero across numerous sectors including aerospace, it must ensure that the workforce has the rights skills in the right place at the right time to enable this change. By identifying the key needs, challenges, and gaps faced by the workforce of tomorrow, the UK can be ready for this step change.

Functional Shifts

The Foresighting process identified five primary functional areas where organisational changes are most pronounced:

Design: The Design function will see an increased emphasis on new product engineering and evaluation ahead of development and implementation phases. This shift reflects a need for more innovative and adaptable design capabilities to meet future demands.

Implementation: Organisations will experience changes in their implementation functions, primarily due to greater adoption of new technologies and increased product sales volume. This necessitates a focus on scaling production capabilities efficiently.

Logistics: As production scales up, Logistics functions will need to be adapted to ensure smooth procurement, delivery, and materials management. This includes integrating advanced supply chain management practices to support higher production levels.

Support: The Support functions may see a relative decrease in prominence. However, this could be attributed to data gathering omissions and requires further analysis to confirm.

Enterprise: The Enterprise functions will require increased attention to strategic planning, leadership, management, human resources, and compliance. This is essential for navigating a competitive and regulated market environment.

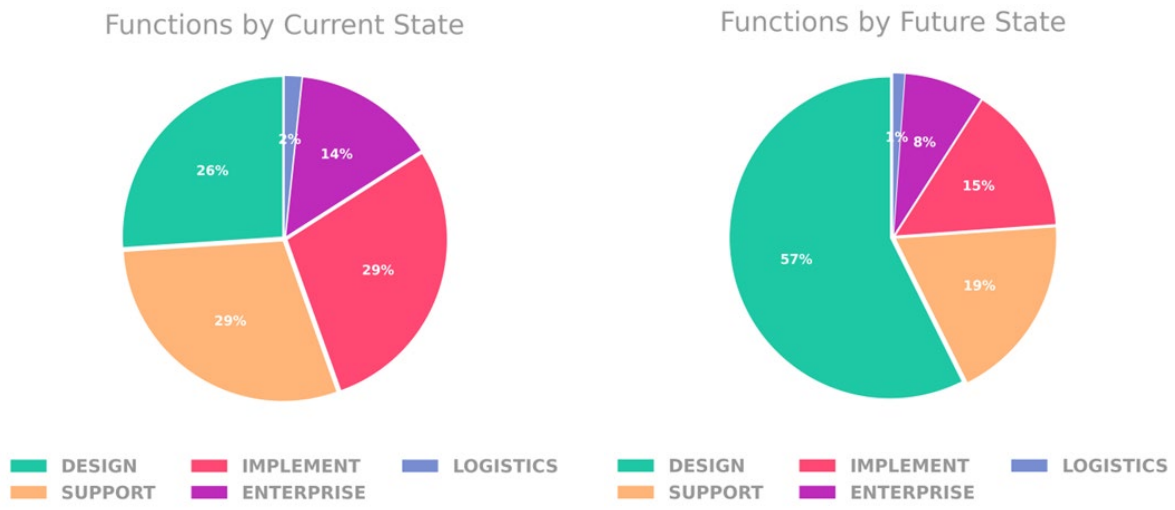

Figure 1: Current and Future Supply Chain - Capability functions Summary by %

1.3 Future Occupational Profile highlights

The Future Occupational Profiles (FOPs) developed in this cycle serve as crucial tools for aligning current workforce capabilities with future industry needs. These profiles were created through Workforce Foresighting workshops, combining capabilities from existing occupational standards and new data gathered during the process. The primary purpose of FOPs is to provide a framework for comparing current occupations with future requirements, facilitating the identification of skills gaps, and informing workforce development strategies.

Key Findings:

Role Adaptation and Development:
FOPs outline the expected evolution of current roles, suggesting necessary adaptations to meet future demands. This includes identifying areas where current occupational standards require updates and where new capabilities should be incorporated.

Employers can use FOPs to evaluate and modify existing apprenticeship standards, ensuring that their workforce is equipped with the skills needed for future roles. This can be achieved through targeted short courses and continuous professional development (CPD) initiatives.

New occupation profiles have been developed that focus on capabilities that demonstrate knowledge of liquid hydrogen, and its effect on the wider design of cryogenic hydrogen storage tanks, such as safety considerations, effect on material properties, and material and design performance in extreme temperatures.

Education and Training Alignment:
Policy makers and educators should review and adapt current curricula based on the requirements highlighted by FOPs. This ensures that new entrants to the workforce are trained in line with future industry needs. Rapid re-skill and up-skill should be the initial focus of this work to ensure that demands are met, not just from education leavers, but also from those either seeking to move roles, those facing the threat of their existing role ceasing to exist and those looking to re-enter the workforce with relevant transferable experience.

The alignment between current educational provisions and FOPs is quantitatively evaluated using fit and surplus metrics. These metrics measure how much existing standards cover the FOPs (fit) and identify any redundant material not required for future roles (surplus). An optimal alignment would have a high fit and low surplus.

Priority Future Occupational Profiles:
The report identifies priority FOPs across the role levels, including Senior Engineer, Junior Engineers, and Technicians roles. These priority profiles (FOPs) highlight the most critical areas for development to meet future capabilities.

Data-Driven Insights:
The development and refinement of FOPs are supported by a robust data set, including international occupational standards and employer feedback. This data-driven approach ensures that the profiles are relevant and comprehensive, reflecting the real-world needs of the industry.

Visualisation tools and detailed instructions provided in the report enable stakeholders to interact with and understand the data, supporting informed decision-making for workforce planning and educational program development.

In summary, the Future Occupational Profiles offer a strategic approach to bridge the gap between current workforce capabilities and future industry needs, providing actionable insights for both employers and educators. It is important that the implications of changes underway in the industry are understood by both industry and trainers to inform a conversation about how those changes may create new roles and change some existing roles, to ensure the industry is fit and adaptable for a changing future. These profiles are instrumental in guiding the adaptation of roles and the development of educational content, ensuring a well-prepared and future-ready workforce.

1.4 Specific areas of concern

The report identifies several critical areas requiring attention to ensure that the industry's workforce can meet future demands. These areas are based on the comparison of current Institute for Apprenticeships and Technical Education (IfATE) standards with the Future Occupational Profiles (FOPs). The specific concerns are as follows:

Poor suitability provision:
Notable examples include:

- Structural Engineer (Senior Engineer)
- Chemical Engineer (Senior Engineer)
- Research And Development Manager
- Systems Engineer (Senior Engineer)
- Aerospace Technician - LH2
- Aerospace Engineer (Senior Engineer) LH2
- Aerospace Engineer (Senior Engineer) Design

Mismatch in Skill Requirements:
There is a significant gap between the skills and competencies required for future roles and those provided by current standards. This gap is due to current standards not fully covering the capabilities needed for today’s engineers and technicians, and also new capabilities required due to new technology. This highlights the need for substantial updates and revisions to the existing training frameworks and curricula to ensure they align with emerging industry needs.

Addressing these areas of concern is crucial for the Aerospace industry to effectively navigate future challenges and leverage new opportunities. This will require a coordinated effort across various sectors to update and refine educational and training standards continually.

To Summarise:

- A small number of the future profiles have high levels of suitability and coverage in the current IfATE occupational standards.
- All (41) future profiles have some levels of suitability and partial coverage in the current IfATE occupational standards.
- Only 1% of the IfATE, apprenticeship standards, Duty Statements identified have a good match to capabilities identified.
- 13% of the duty statements have some suitability to capabilities
- The remaining FOPs do not match with a good degree of suitability to existing standards. The competencies not matching tend to be those that are Design and Implement focused. Adjustment to existing standards can be made to bring them up to date to better serve the identified need.

1.5 Recommended actions

This report outlines a variety of recommended actions and recommendations, specifically:

Need for Enhanced Collaboration: The findings emphasise the necessity for increased collaboration between industry stakeholders, educators, and standard-setting bodies. Such collaboration is essential to develop and implement new standards that can adequately prepare the workforce for future challenges. This includes regular updates to training programs and the incorporation of new technologies and methodologies.

Adaptation of Training and Development Programs: Current training and development programs need to be adapted to include short courses and continuous professional development (CPD) opportunities. This adaptation will help in bridging the gap for incumbent workers and those transitioning into new roles.

Feedback and Continuous Improvement: The Foresighting process should be continuously updated based on feedback from employers and other stakeholders. This iterative process will help in refining the Future Occupational Profiles and ensuring that the workforce development plans are responsive to evolving industry requirements.

Additionally, use the Future Occupational Profiles to:

- To address skill gaps, leverage Future Occupational Profiles (FOPs) to update standards and provide CPD courses for current and transitioning workers. There are opportunities to update existing standards and to make use of the competencies to drive the development of short, as well as long, course outputs.
- Advocate for revised standards aligned with future workforce needs. The Hydrogen Skills Alliance will advocate for standards to be updated to reflect the gaps identified in this report.

The development and growth of hydrogen fuelled aircraft in the UK, from the production of storage tanks to the integration of these systems into aerospace applications, will require substantial investment in skills to support the sector's advancement by 2035. While the strategic direction for workforce preparation remains underdeveloped, readiness can be achieved through a targeted approach that combines re-skilling, up-skilling, and new-skilling

initiatives. These efforts should be tailored to the unique requirements of cryogenic hydrogen manufacturing, storage, and operational integration within the aviation industry.

Re-skilling
Re-skilling focuses on transitioning individuals with parallel competencies into roles across the cryogenic hydrogen storage value chain for aviation. Short courses can equip workers with the necessary skills to manage processes such as the installation of cryogenic tanks, quality control of storage systems, and integration of cryogenic solutions into aircraft designs. As other areas of the aerospace industry contract, and the focus on hydrogen fuelled aircraft increases, there is a natural opportunity to re-skill existing engineers and technicians. Employers can leverage transferable skills from employees working in other areas of aircraft design, supplemented with targeted training, to build a workforce adept at managing the challenges of cryogenic hydrogen storage manufacturing and deployment.

Up-skilling
Up skilling prepares a pipeline of talent to meet future demand, focusing on long-term programs like apprenticeships, degrees, and specialised certifications in aerospace engineering and hydrogen technologies. These initiatives develop foundational competencies in handling of cryogenic hydrogen, understanding of material properties when exposed to hydrogen, and compliance with aviation safety standards. However, given the anticipated rapid growth of the sector, these programs must be supplemented with modular, short-term courses to address immediate workforce gaps while supporting broader, long-term workforce development goals.

New skilling
New skilling prepares a pipeline of talent to meet future demand, focusing on longer-term training programs such as apprenticeships, degrees, and technical qualifications. These initiatives can develop foundational skills for designing components, operating assembly machinery, and ensuring compliance with safety standards and regulations. However, as the projected growth of the sector exceeds the capacity of these programs alone, short modular courses must be integrated to address immediate needs while supporting longer-term workforce development.

A Holistic Approach to Skills Development
A comprehensive approach to skill development across all stages of cryogenic hydrogen tank design will position the UK as a leader in this critical aerospace innovation. This strategy will ensure a highly skilled workforce capable of driving technological advancement, operational efficiency, and compliance with safety standards in the development of hydrogen-powered aviation by 2035.

	Topic	Actions	Who	When	Result
Short Term Actions	Reskilling and Upskilling Current Workforce	Tailor course content to match new capabilities with existing occupational standards, focusing on design and other lifecycle activities.	Educators, Awarding Bodies, Employers	Prepare ahead of the scale-up need	Availability of short-term training for the current workforce to meet immediate technology demands.
	Recruitment from Other Industries	Identify and reskill individuals with transferable skills from other sectors, particularly for high-demand roles such as Maintenance and Operations Engineering Technicians.	Employers, Training Providers	Immediate	Mitigation of workforce shortages in high-demand areas through targeted recruitment and training initiatives.
Medium term actions	Integration of Future Skills Training	Formalise changes to occupational standards and training programs for new entrants, integrating future skills requirements defined by the Future Occupational Profiles (FOPs).	Educators, Awarding Bodies, Employers	As soon as possible for prioritised FOPs	Development of training programs that meet both current and future skills needs, reducing lead time for new workforce entrants
	Modular Approach to Course Updates	Implement modular changes to existing courses rather than complete redesigns, facilitating quicker adaptation to evolving skills requirements.	Educators, Training Providers	Ongoing	Flexibility in educational programs, enabling rapid response to industry needs.
General Actions for Educators	Assessment and Feedback	Review Institute for Apprentice-ships and Technical Education (IfATE) standards and relevant qualifications	Educators, Employers	Ongoing	Comprehensive understanding of current training provisions and identification of areas for improvement.

		with employers, providing feedback and identifying gaps.			
	Commissioning New Continuing Professional Development (CPD) Courses	Evaluate existing CPD provisions, commission new courses where necessary, and facilitate collaboration to maintain a unified approach.	Educators, Training Providers	Short-term	Enhanced CPD offerings to upskill current workforce members across all role levels.
Additional Recommendations	Dissemination of Findings	Set up a working group to create an action plan, share findings widely among stakeholders to influence workforce development initiatives.	Convener, Sponsor, Stakeholders, Industry Groups	Following Publi-cation	Broad access to insights and strategic direction for workforce initiatives
	Ongoing Review and Adaptation	Regularly review findings with stakeholders and adapt Future Occupational Profiles to better fit emerging roles	Stakeholders, Sponsor Leads, Participants	Before Formal Publi-cation	Robust and validated actions.

Table of abbreviated recommendations leading to action:

A/B Review and Dissemination of Findings	Convener and Sponsor to set up working group through the Hydrogen Skills Alliance (HSA) to take the findings and recommendations and create an action plan and advance through the Skills Value Chain to cause action. It is essential to share the findings widely among stakeholders, industry groups, and local skills bodies. This will promote access to the insights gained and influence the strategic direction of workforce development initiatives. The HSA will use the UK Hydrogen Skills Strategy (published in February 2025) alongside this report to guide the cause action phase.
C Short-term action	As part of the working group, educators and employers should collaborate to deliver timely short-term training solutions for the current workforce. This is to cause action regarding developing short term training solutions for the future workforce. This includes developing and offering Continuing Professional Development (CPD) courses that address immediate skills gaps and ensure workers are equipped with the necessary competencies. Additionally, the capabilities identified in this cycle will be mapped against the Hydrogen Skills Framework where possible. Existing training provision will be identified through the Hydrogen Skills Alliance's Landscape Map, to prevent any duplication when creating new short and modular courses.
D Mid-term actions	The ongoing working group mid-term action planning should include a concerted effort to integrate new skills and knowledge into existing training programs. Educators and employers need to update curricula and training standards to reflect the evolving demands of the sector, ensuring that both current employees and new entrants are adequately prepared. This may include working with apprenticeship providers, as well as with universities to outline degree changes.
E. General action for Educators to support Employers' demand for future skills	Employers and educators must work together to review and influence the update of IfATE standards and relevant qualifications. This involves using the insights from the Foresighting process to inform the development of new standards and qualifications that align with future workforce needs. This will contribute to the working group skills framework.
F Further foresighting subjects	The working group should seek additional sponsors and propose further subjects for Foresighting. This continuous cycle of Foresighting will help to stay ahead of emerging trends and technologies, ensuring the workforce remains adaptable and prepared.

By implementing these recommended next steps, stakeholders can ensure that the sector is supported by a skilled and adaptable workforce, capable of meeting the challenges and opportunities of a rapidly evolving industry.

The findings highlight critical gaps in workforce capabilities necessary to support the UK's zero-emission goals. Immediate action, aligned with national strategies and collaborative efforts between educators, industry, and government, is essential to build a future-ready workforce.

1.6 Introducing the Visualisation Tool

Workforce Foresighting Hub's Visualisation Tool:
[Data Capture Overview | HVMC Foresighting | The design and use of cryogenic hydrogen storage for Aircraft by 2035]

The Workforce Foresighting Hub's Visualisation Tool is a powerful, innovative system, which will enable the reader to explore and analyse Foresighting data to determine the capabilities required for future roles. Links throughout this report make it easy to identify existing standards which meet the needs of these future roles and pinpoint where new standards are necessary to develop a skilled workforce equipped to adopt new technologies.

The data is generated by the Foresighting cycles, integrating the expertise of technologists/domain specialists, employers, and educators. The data informs the development of future curriculum and course content as determined by the action plan. Using AI tools validated by human oversight, and by linking to external data sources, the tool identifies differences at the level of occupation/role as well as detailed changes required to knowledge, skills and behaviours thus delivering insights for learners, providers, creators, and assurers of skills.

Detailed instructions on how to use the Visualisation Tool can be found in the appendix.

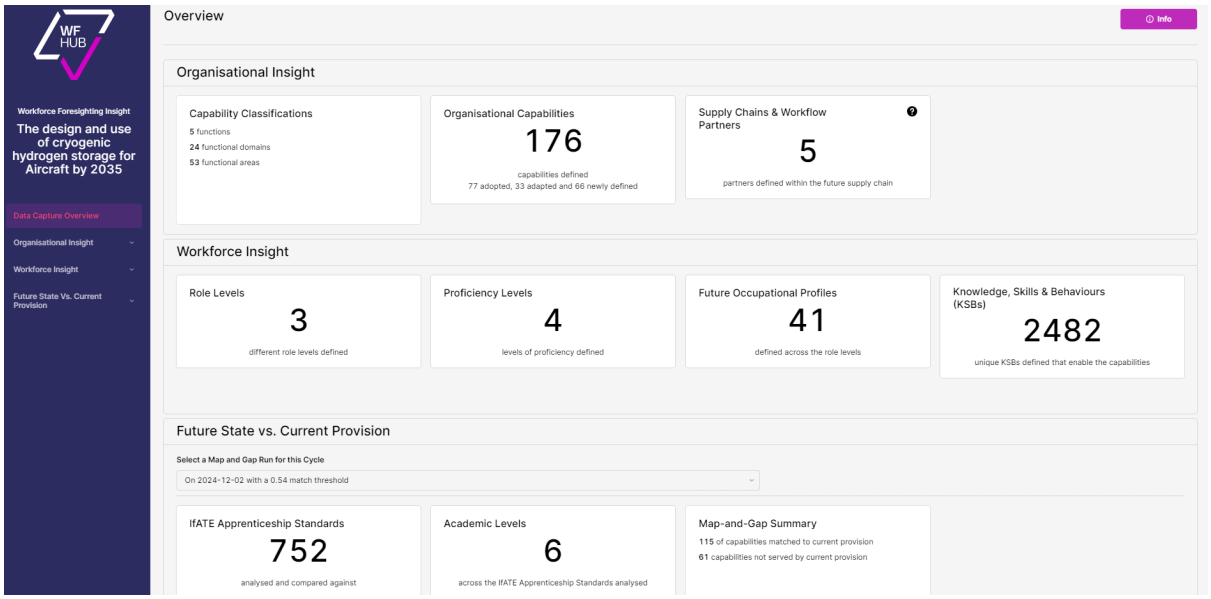

Figure 2 - Visualisation Tool Dashboard

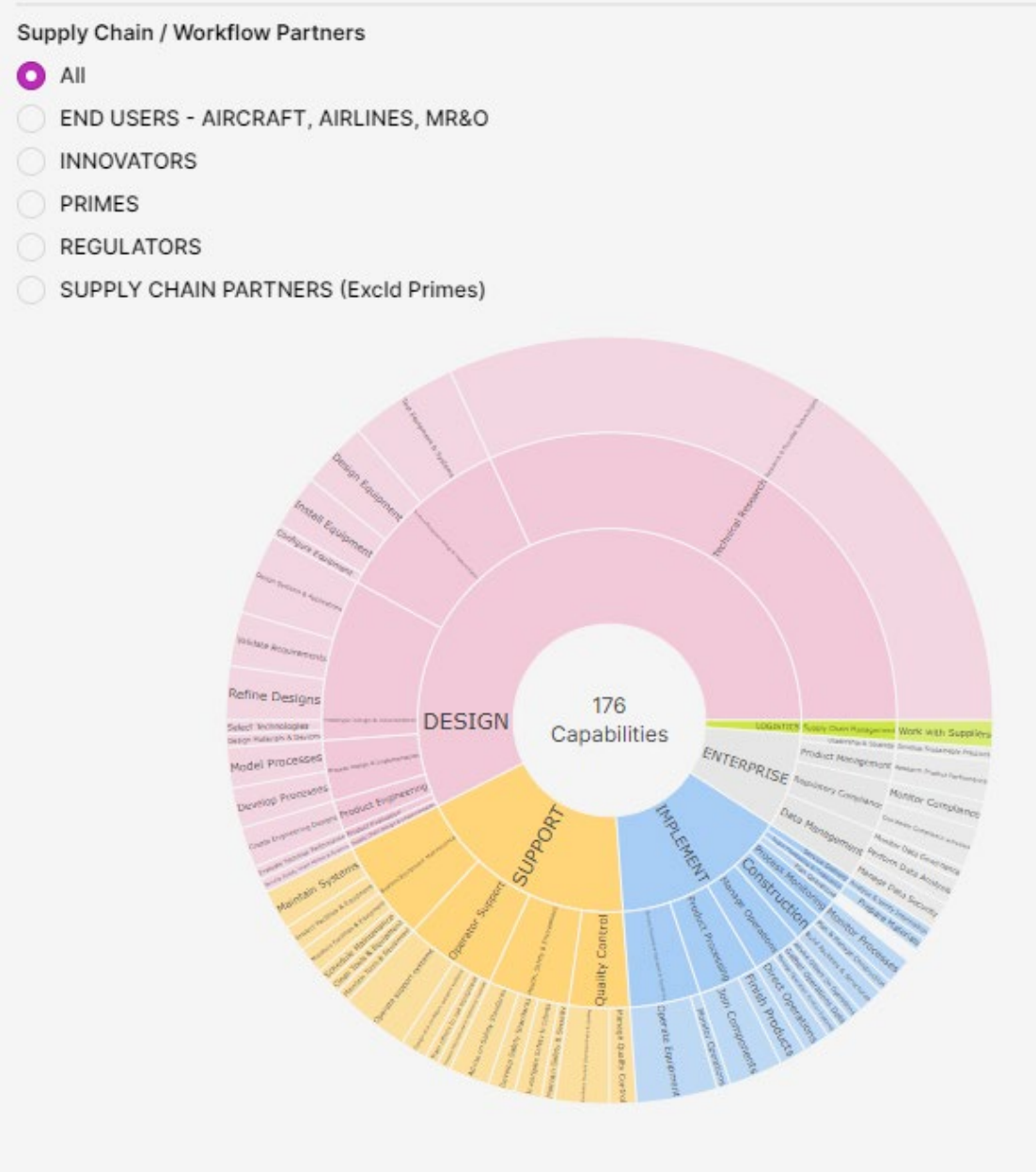

Figure 3 - Supply Chain Capabilities Identified During the Workshops

2.0 Aligning the challenge and solutions with national priorities

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Section	Title
2.1	Positioning and context of national challenge
2.2	Potential and prioritised technology solutions to the challenge
2.3	Workforce Foresighting for chosen prioritised technology solutions
2.4	Current and predicted scale of technology deployment in the UK
2.5	Key stakeholders in Industry and Government

2.1 Positioning and context of national challenge

The aviation industry brings many social and economic benefits to the UK; however, it also has an increasingly significant environmental impact. In 2022, the emissions from civil aviation represented 7% of the UKs total emissions[2], and this percentage is expected to increase in future as other sectors decarbonise. It is vital that these emissions are tackled in a way that capitalises on UK strengths.

The UK government published it's Jet Zero Strategy in July 2022, which included key goals of sector wide net zero flying by 2050, domestic flights and UK airport emissions to achieve net zero by 2040.

To understand how to achieve these goals, the FlyZero project was initiated in late 2020 by the Aerospace Technology institute (ATI) and the Department for Business, Energy, and Industrial Strategy (BEIS) to determine whether zero-carbon emission flight was feasible for large commercial aircraft. The FlyZero project concluded that:

- Zero-carbon emission flight can be a reality. The target to reach net zero by 2050 requires large zero-carbon emission aircraft to enter service by 2035. The scale of the challenge is huge, but the ambition to succeed is strong. It will require a collaborative and urgent approach, with aerospace companies, airlines, airports, governments, regulators, and adjacent sectors such as energy working together at pace.5
- Zero-carbon emission aircraft will be powered by green liquid hydrogen. The UK can become a leader in the necessary technology, systems, and processes, influencing how they are introduced across the world. To do so, it must rapidly develop its infrastructure, capabilities, and regulatory regime for hydrogen.
- To enable large commercial aircraft to enter service by 2035, the UK must also commence an ambitious aircraft research programme on technologies such as cryogenic hydrogen fuel systems, gas turbines, and airframes for ground and airborne demonstration.
- Developing and producing hydrogen powered aircraft will require a workforce with skills that do not exist in the UK's aerospace sector today. It is expected that sub-regional and regional hydrogen fuel cell electric aircraft will enter service by 2030, and that liquid hydrogen gas turbine powered aircraft will follow in the mid-2030s. Skills in hydrogen and cryogenics are particularly lacking in the UK.

Following the conclusion of the FlyZero report, the Hydrogen Capability Network was set up by ATI in 2023. The network has identified that the UK industry is struggling to recruit suitably qualified and experienced to support current net-zero technology development specifically a shortage of cryogenic hydrogen skills which reflects the global shortage of skills in this technology

[5] Climate Change Committee, Progress in reducing emissions: 2023 Report to Parliament, June 2023

2.2 Potential and prioritised technology solutions to the challenge

There are many technology challenges and necessary solutions to enable the industrialisation of hydrogen fuelled aircraft, including:

- Cryogenic storage tanks
- Control valves
- Hydrogen capable pipes
- Sensors
- Refuelling systems
- Fuel cells

This list of technologies was developed during an initial workshop with industrial partners, educators, and technologists, hosted at the National Composites Centre in 2023. These technologies were then analysed to understand which fell into 'Horizon 2' - 2025 - 2035. This activity was completed using the Hydrogen technology roadmaps published by the Hydrogen Innovation Initiative in 2024[6]

Following further Hydrogen Skills Alliance discussions with technologists and employers, it was concluded that the critical Horizon 2 technology solutions to meet the challenge were cryogenic hydrogen tanks and systems.

2.3 Workforce Foresighting for chosen prioritised technology solutions

In the 'identify' stage of this Workforce Foresighting cycle, the following technology solutions were identified:

1. Storage of cryogenic hydrogen (LH2) in tanks for fuelling aircraft
2. Handling, fuelling, and defueling of hydrogen for aircraft and airside transport
3. Regulation of hydrogen fuelled aircraft
4. Sensors and leak detection within hydrogen fuelled aircraft

Through a prioritisation matrix, using information on timescales, scale of the demand, and size of industry affected, the focus of the Foresighting Cycle was **"storage of cryogenic hydrogen (LH2) in tanks for fuelling aircraft"**.

[6] Hydrogen Innovation Initiative, The UK Hydrogen Innovation Opportunity, April 2024

2.4 Current and predicted scale of technology deployment in the UK

The UK is a world leader in the aerospace sector. By 2050, the UK could grow its market share in civil aerospace from 12% today to 19%, increasing the sector's gross value added to the economy from £11bn to £36bn, and expanding the number of aerospace jobs from 116,000 to 154,000[7]

The ATI FlyZero project has forecast that by 2050, 90% of new aircraft could be hydrogen powered.[8] The UKs largest aircraft manufacturer, Airbus, has announced that they are developing the world's first hydrogen commercial aircraft, with plans to enter service in 2035, which will lead to hydrogen-powered aircraft operating flights at UK airports.

Additionally:

- Rolls-Royce is testing hydrogen combustion systems and cryogenic fuel pumps to deliver liquid hydrogen into the engine.
- GKN Aerospace is developing hydrogen fuel cell and fuel systems technologies capable of servicing the commercial regional and sub-regional markets.
- Zero Avia is already trialling aircraft/propulsion systems and aims to have a certified engine by the end of 2025, which startup operator Ecojet plans to use in its commercial operations.
- Go-Ahead has launched a fleet of hydrogen buses around Gatwick airport, with a further 34 on order.
- Tees Valley Transport Hydrogen Hub features demonstration activity at Teesside International Airport for commercial and support vehicles.
- Cranfield University owns and operates its own airport and research aircraft, and is taking a leading role in hydrogen R&D activities

Analysis carried out by Jacobs in their UK Aviation Hydrogen Forecast predicts that demand for hydrogen in aviation will be circa 20,000 tonnes annually by 2035, ramping up to demand of over 350,000 tonnes annually by 2050. [9] This predicted increase clearly shows a required increase in the number of workers skilled in the design of cryogenic tanks.

[7] Aerospace Technology Institute, Fly Zero Executive Summary, March 2022
[8] Aerospace Technology Institute, Workforce to Deliver Liquid Hydrogen Powered Aircraft, March 2022
[9] Hydrogen in Aviation Group, Launching Hydrogen Powered Aviation, March 2024

2.5 Key stakeholders in Industry and Government

Participating stakeholders across industry, educators, and technology development collectively ensure that the output from this foresighting cycle uses expertise from multiple sectors and regions. This includes input and insights from:

- Hydrogen Skills Alliance
- Hydrogen Innovation Initiative
- Hydrogen Capability Network / Aerospace Technology Institute
- National Composites Centre
- Skills Bodies and Awarding organisations
- Aerospace employers, including primes, regulators, tier 2, and supply chain
  - Airbus
  - Parker
  - Civil Aviation Authority
  - Eaton
- Educators including FE and HE organisations

3.0 Results – Findings, Data and Insight

3.0 Results – Findings, Data, and Insight

Section	Title
3.1	Findings, methodology and presentation
3.2	Insight into organisational changes
3.3	Occupational change insight
3.4	Future Occupational Profiles compared with current provision
3.5	Summary and use of the findings
3.6	Recommended next steps

3.1 Findings, Methodology and Presentation

This section describes the future organisational capabilities that will be required to meet the Challenge using the proposed Solution (technology) and which occupations are likely to change to deliver these capabilities. Summary information is provided with a narrative based on the underlying data which is also provided using bespoke visualisations to enable greater insight and access to detail. This section of the report is aligned to the needs of those responsible for Workforce planning – employers, educators, and skills providers. The two parts interpret the data findings and contain links to the relevant visualisation elements.

Organisational changes

Providing insight into Organisational Changes – this indicates how organisations will need to adapt their current capabilities to achieve the implementation of the Solutions that respond to the Challenge addressed by this Foresighting project.

Typically, this will also require the adoption of new capabilities and a change in the distribution of these capabilities across value chain partners. This change in capabilities for an organisation and their value chain partners then defines the skill changes required in the different role levels of each supply chain partner.

Occupational changes

A set of 'Future Occupational Profiles' (FOPs) is produced by the foresight process that demonstrates how current occupations may need to change in the future. FOPs are generated using a combination of attributes from the underlying capability classification and from data collected in the workshops. The FOP generation algorithm works to group capabilities into logical sets reflecting role level, function, proficiency and capability similarity. As part of the foresight process the generated FOPs are reviewed, revised, and distilled by the Employer group. This agreed set of FOPs are then compared with selected current education provision; the default reference is the set of Institute for Apprenticeships and Technical Education (IfATE) occupational standards; to assess which current training and education provision could be used in the future. Two bespoke metrics, match and surplus are used to evaluate the alignment of current provision with the set of FOPs proposed. Summaries are presented of the key findings related to each supply chain partner.

Findings are aimed at both Employers and Education and Training Providers and identify matches and gaps in future training needs compared with current provision to guide further detailed investigation.

Highlighted changes to future provision

The report identifies suggested changes to education and training provision – principally occupational standards that will deliver the knowledge, skills and behaviours required by future occupations. In some cases, this will include the development of short courses and continued professional development (CPD) to upskill the current workforce to meet future needs. Additionally, foresighting outputs can be used to develop programmes, qualifications, and occupational standards for new entrants to the workforce joining via apprenticeship, taught qualification, or other training programme.

The insight and data in this part of the report are primarily aimed at educators training providers, occupational standards bodies, and awarding organisations. Combined with insight arising from the supply chain capability changes, the provision insight offers an effective way for employers to identify training opportunities that align to their future needs.

Method

The Workforce Foresighting Hub process uses a series of structured workshops and surveys to capture and summarise input from relevant sector experts – covering technology, workforce development and education. At several points in the workshop and analysis sequence the Foresighting process utilises large language models and artificial intelligence (AI) to parse and assist in the analysis of the content generated by workshop participants. For example, the AI model can compare capability statements with existing standards more thoroughly and rapidly than human comparison could achieve. All AI derived outputs are reviewed and validated by the participant groups through the workshops and integral quality assurance reviews of the foresight process.

3.2 Insight into organisational changes

Organisational insight indicates how diverse types of organisations in the value chain will need to make functional changes to align their future capabilities to those required to respond to the Challenge being addressed. This provides useful insight for these organisations and in turn, provides a data rich and well-founded basis to understand how future occupations and their skillsets may need to change to meet that challenge. This is developed in section 3.3 of this report.

Organisation functions

The Workforce Foresighting Hub process uses a data structure built on five functional areas which are common to any business:

Design	The function of an organisation that focuses on activities relating to product, service, or solution design.
Implement	The function of an organisation that focuses on activities relating to producing / making / providing its products or services.
Logistics	The function of an organisation that focuses on activities relating to procurement, delivery, materials, or services necessary for operations – service / manufacturing, etc.
Support	The function of an organisation that focuses on activities relating to users, in-service support, repair / maintenance, recycling, end of life disposal.
Enterprise	Core functions of an organisation - e.g., strategic planning, leadership and management, human resources. Digital backbone and data systems. Integration of relevant statutory / regulatory requirements and compliance.

This functional structure is developed to levels of detail that enable the Foresighting process to reference external data sets including ONET (US) Occupational Information Network [1], ESCO – European Skills, Competences, Qualifications and Occupations[2], IfATE – (UK) Institute for Apprenticeships and Technical Education[3].

The five root functions comprise ~ 40 Domains which are broken down to ~ 140 Functional Areas. This architecture is used to position ~ 25,000 capability statements which are the building blocks used in the workforce foresight process. Each capability statement has several attributes. Some are static and reflect the position of the capability statement in the architecture, others are dynamic and are assigned values through a cycle and set of workshops.

The data-architecture is implemented in a bespoke ‘data-cube’ which underpins the foresight process, workshops, and enables extensive use of LLM and AI tools. Additionally, a key

feature of the data-cube is that the data from each foresight topic cycle is added into the data set and can then be used, where relevant, in future cycles. This ensures that the capabilities of the system are dynamic and up to date.

Identifying the Future Supply Chain Capabilities

The following charts and graphs summarise the changes in the set of capabilities that will be required by the supply chain in the future. The pie-charts reflect the distribution of capabilities across the five functions. The future state data is captured in three Technologist workshops and the current state data is generated using information collected about current occupational standards used across the existing supply chain. This latter information is not as detailed as that produced by the workshops and is indicative and used to provide a point of comparison.

These initial pie charts summarise the changes that will be required by the whole supply chain, across the five functions, with an overall increase in Design in line with area of focus.

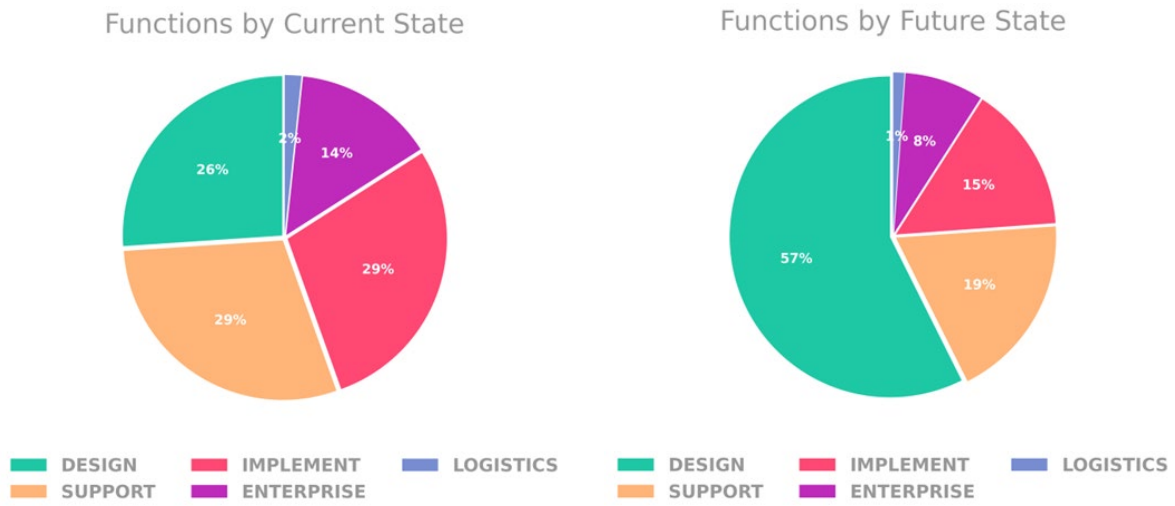


Figure 4: Current and Future Supply Chain - Capability functions summary by %

Please note the current state has been built by proxy using a review of the existing commonly used apprenticeships standards in the industry, while the future state is dependent on data captured through the workshops which may have omissions, so this information is to be used to provide context to trends rather than specific analysis.

This information is useful to indicate relative changes, but the underlying change will be a result of future scale as well as how functions change relative to each other. To gain more detailed insight, these overall comparisons of functional areas are analysed using the current and future capability counts within each function using the next level of classification architecture – Functional Domain.

The graphs show the change in capabilities at domain level within each of the five main functions. These graphs provide insight into both the relative importance of each domain and scale of the changes that will be required from the current state.

The charts that highlight the domain changes across different cycles, will have some variability and empty rows due to the nature of the data.

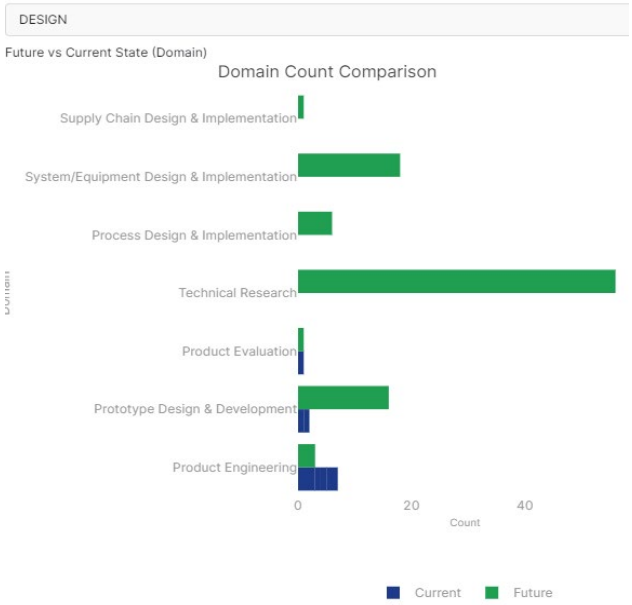


Figure 5 - Design function - Current to Future - Domain changes

The Design function has the highest number organisational capabilities with over half of total capabilities for this cycle, reflecting the cycle focus of Research and Develop Technologies in the design of cryogenic hydrogen storage for aircraft. This data also shows that there are areas of the design function that have not been fully defined in existing standards.

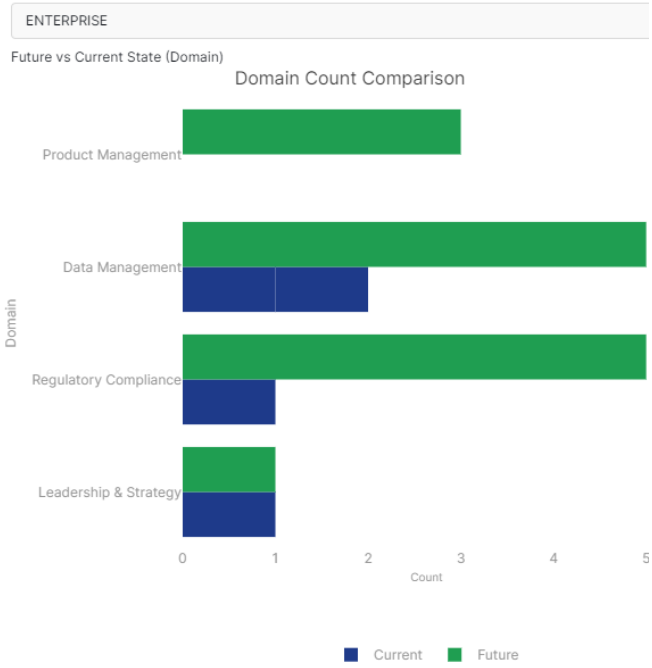


Figure 6: Enterprise function - Current to Future - Domain changes

The Enterprise function approximately 10% of the cycle capabilities, mostly in the Data Management domain and Regulatory compliance Domains. Within the Enterprise function, there is an increase in the product management, data management, and regulatory

compliance Domains required in the future state. In particular, the increase in regulatory compliance roles should be noted, as this reflects the need for an increased knowledge and awareness around the regulations required for cryogenic storage of hydrogen in aircraft.

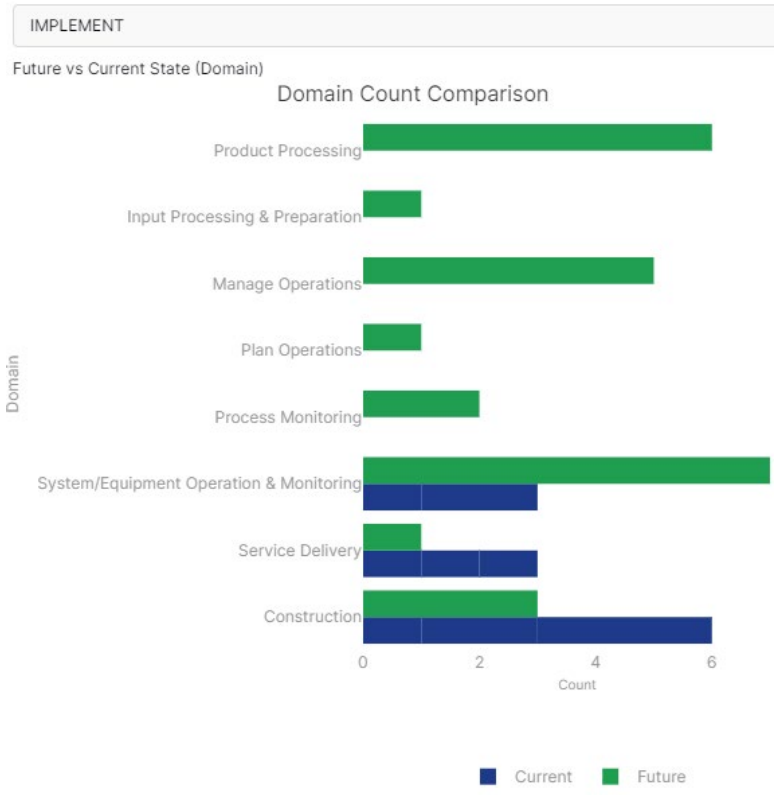


Figure 7: Implement function - Current to Future - Domain changes

The Implement function holds approximately 15% of the cycle capabilities with most of the Domains showing an increased number of capabilities defined in the future state. This again shows that these areas are not fully defined in the current state.

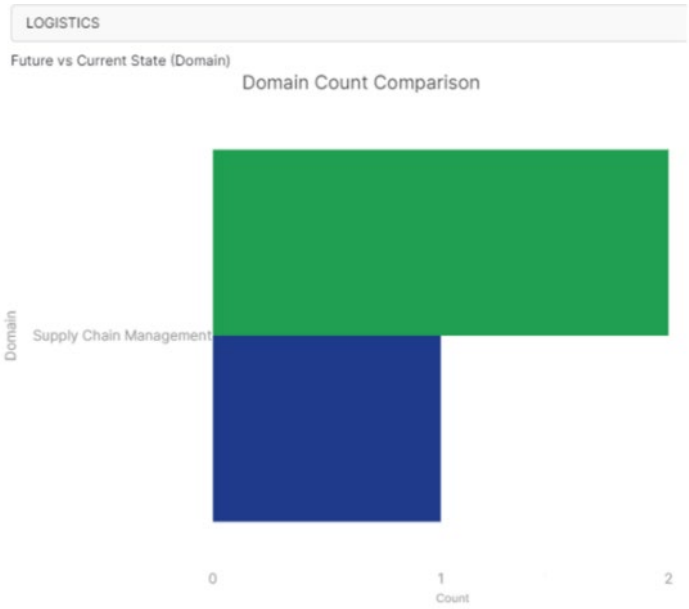


Figure 8: Logistics function - Current to Future - Domain changes

Logistics was low in priority in review of design and use of cryogenic hydrogen reflecting the cycle focus on Design of cryogenic hydrogen storage.

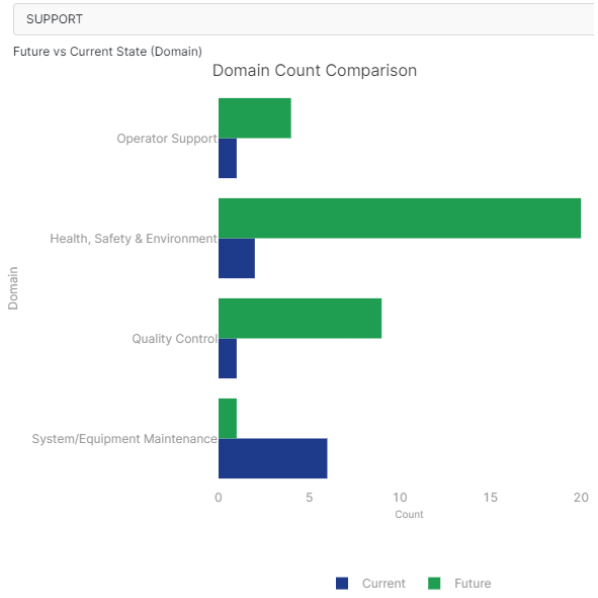


Figure 9: Support function - Current to Future - Domain changes

The 'Support' function has 20% of the cycle capabilities, with the System/Equipment Maintenance domain being the focus. This included capabilities in areas such as Maintain systems. Within the Support function, there is a particularly large increase in the Health, Safety & Environment domain. This clearly shows the need for increased focus on health, safety, and environment within roles, as expected due to different regulations and material properties of hydrogen.

Visualisation Instructions

Detailed instructions can be found in the appendix.

Visualisation Data Link	What is it and what can it be used for?
Organisational Capabilities	*The data presented here can provide an indication of how well served the sector is.* *This page provides a high-level summary of each capability statement generated in the cycle.* *The capability statement describes the depth and nature of each capability within an Organisation against a defined reference.* *The page also provides a way of reviewing the capabilities through the lens of the Capability Classification Framework (Design/Implement/Logistics/Support/Enterprise). This information can be used to provide insight about the types of capabilities and their distribution across the classification framework.* *This can be used to identify which capabilities may be supported by existing provision, and where there may be gaps that require new development to support.*

3.3 Occupational Change Insight

Insight into occupational change uses the understanding of how capabilities will change across business functions (section 3.2) to inform proposals for how occupations and their associated skills sets for each value chain partner may also need be updated to reflect change for each role level within that Partner.

Supply chain partner organisation types

The Workforce Foresighting process recognises that different partners in a Supply Chain will require appropriate capabilities, and these are determined and agreed in the initial workshops.

In this cycle, the following Supply Chain Partners were identified and then used during participant workshops and data analysis to determine the organisational needs:

1. END USERS – Airlines, Airports, Maintenance and Repair Organisations (MROs)
2. INNOVATORS
3. PRIMES – Large companies responsible for overall design and manufacture e.g. Airbus
4. REGULATORS
5. SUPPLY CHAIN PARTNERS (Excluding Primes)

This categorisation enables the analysis and reporting of the major areas of occupational change by business function for each partner, recognising that each will have distinctive characteristics and requirements.

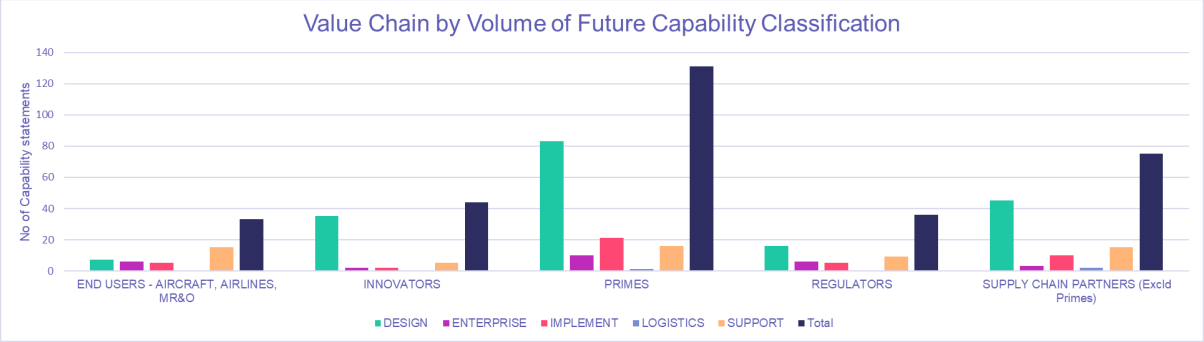


Figure 10: Supply Chain by Volume of Future Capability Classification

This graph illustrates the distribution of capabilities by function across the Value Chain Partners. These capability sets are used to form the set of Future Occupational Profiles within each Role Level. Roles associated with design represent the largest volume of future capabilities in all 5 of the supply chain partners, which clearly shows the focus of this cycle. The largest number of capabilities identified were assigned to 'Primes,' which demonstrates that it is expected that the majority of fuel tank design activities will continue to be carried out by the Primes, as today.

Visualisation Instructions

Detailed instructions can be found in the appendix.

Visualisation Data Link	What is it and what can it be used for?
Value Chain Capabilities	This page provides an overview of the identified capabilities at a Supply Chain / Workflow Partner level. By selecting/deselecting each Supply Chain / Workflow Partner you can review the capabilities identified as required in that area of the Supply Chain / Workflow. This can be used to generate organisational capability profiles for each area of the workflow /supply chain to help prioritise and focus the acquisition of new capabilities that will be required in the future. It can also be used to generate combined organisational profiles, where an organisation may be involved in more than one area of the supply chain.

Role Levels

The Foresighting process uses the concept of Role Levels to represent future occupations. This approach acknowledges that the workforce is not homogeneous, there will be varying levels of proficiency required across a workforce and qualifications and training may be aligned/require different types of vocational or academic qualifications. Additionally, the role level approach seeks to avoid presuming that the future workforce will be "current state plus."

For this cycle, the following role levels were determined through the workshops:

1. Senior Engineer
2. Junior Engineer
3. Technician

Proficiencies

Each of these role levels will require proficiency that relates to their role and the needs of each Supply Chain Partner. The foresight process uses the following proficiencies:

Awareness (A) - Has a foundational knowledge of tools, technology, techniques relevant to sector, industry, and company. Sufficient comprehension to know where to seek further information/details as necessary for a particular issue.

Practitioner (P) - Has the ability to apply and use independently a tool, system, or process. Understands the implications, consequences, and impact for their role/function. Knows what key actions are required and in what context.

Expert (E) - Has detailed knowledge of process, system, tool, or technology. Can support others and identify improvements required for a process, system, or tool. Can implement improvements personally or direct and guide others.

In the workshops participants apply their insight to assign proficiency for each role level for each capability. Individual responses are aggregated to arrive at a consensus.

A summary of the distribution of required proficiency for the role levels in the cycle are:

	Technicians	Junior Engineers	Senior Engineers
Awareness	5	6	8
Practitioner	59	195	2
Expert	48	13	208

As expected, Junior Engineers require practitioner level proficiency for the majority of the capabilities assigned to this level, whereas Senior Engineers have expert level proficiency needed for the majority of their capabilities, as employers defined. With Technicians expectation of two levels of proficiency across Technician workforce. This distribution shows a clear progression in expertise required from engineers to senior engineers as expected, in line with expected career progression over time.

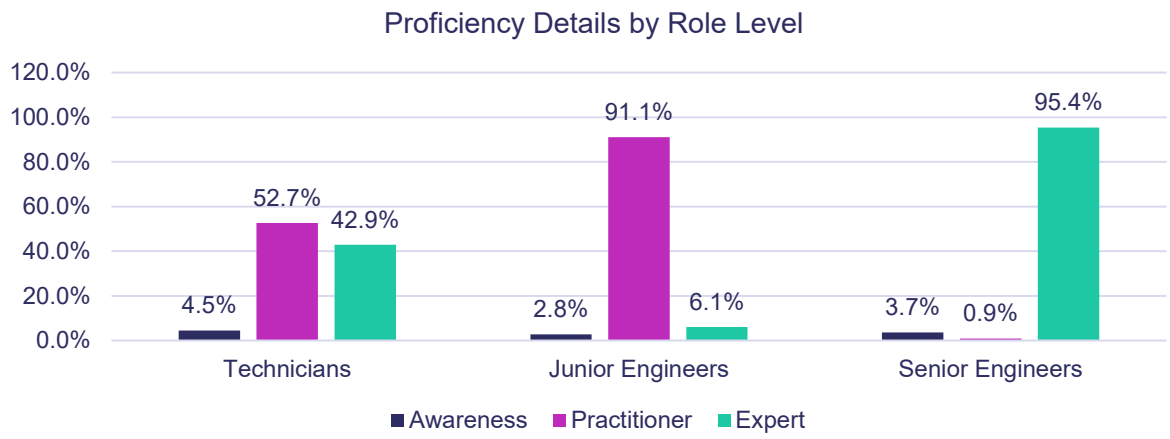


Figure 11: Proficiency details by Role Level

Future Occupational Profiles

The FOPs (Future Occupational Profiles) are a construct created and used during Workforce Foresighting workshops and analysis to capture future skills needs in a form that may be compared with current occupation definitions – typically occupational standards.

The familiar nature and structure of 'FOP's assists with their evaluation and validation by employers and educators and enables the analytical comparison that results in useful indications of matches, surplus and gaps of future skills needs compared with current state. This then allows recommendations for action to be made based on future need and current fit to those needs.

FOPs are used to describe and suggest occupations, or roles, that may be required in the future and provide a framework to indicate capabilities and related duties. They can be used to review the impact on current roles and the adaptation that may be required in the future.

> **Educators** can review current occupational stan13dards against the requirements of the FOPs and interpret which need to be changed to fill the gaps between the current and future state.
> **Employers** can consider existing apprenticeship standards and make a judgement on adapting an existing apprenticeship standard to upskill their workforce to meet the requirements of a particular FOP.
> **Educators** may react to these specified skill requirements from Industry by editing, adapting, or creating new content.

FOPs and indicative skills need

Combining proficiency with the identified FOPs, the following graphs indicate the distribution of identified capabilities within FOPs across the supply value chain for each Role Level to deliver future capabilities.

Senior Engineer Role Level FOPs

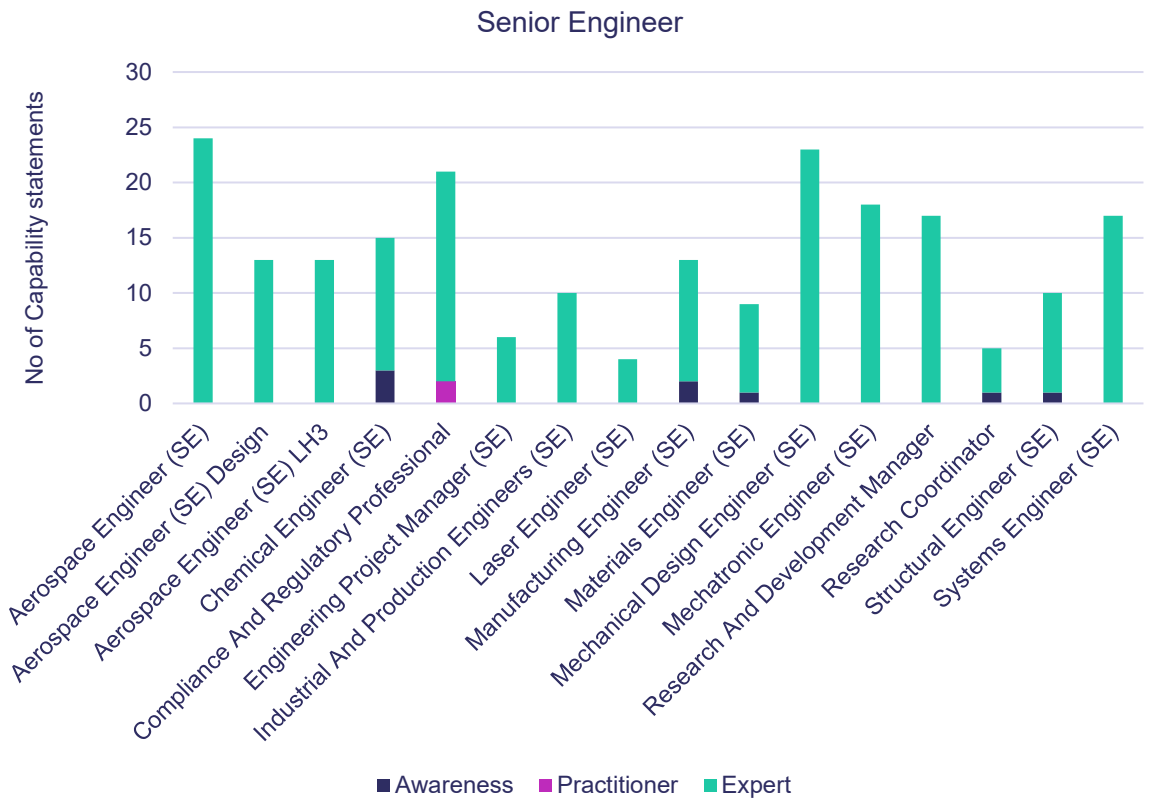


Figure 12: Priority FOPs – Senior Engineer Role Level

Junior Engineer Role Level FOPs

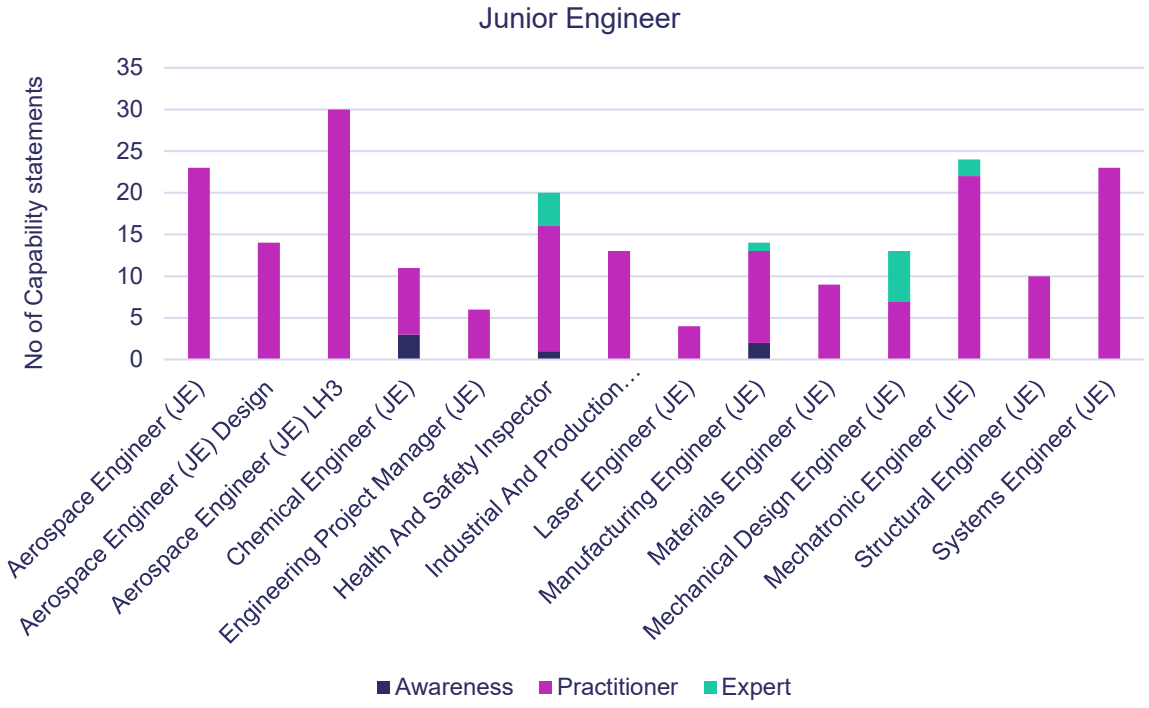


Figure 13: Priority FOPs – Junior Engineer Role Level

Technicians Role Level FOPs

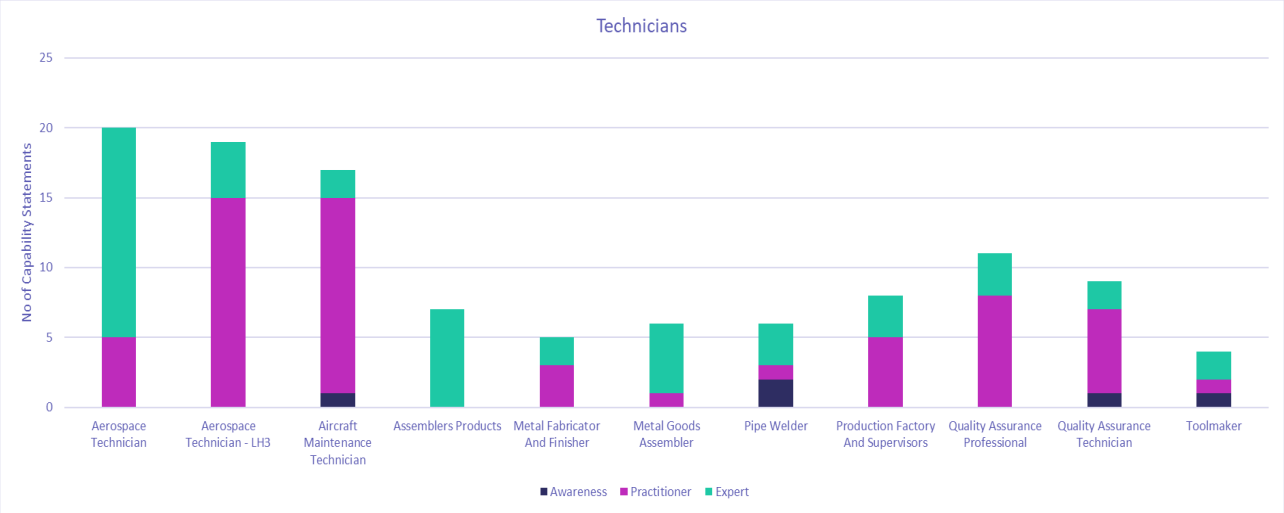


Figure 14: Priority FOPs – Technicians Role Level

Visualisation Instructions

Detailed instructions can be found in the appendix.

Visualisation Data Link	What is it and what can it be used for?
Prototype Future Occupational Profile (P-FOP) Matrix	This page provides a detailed breakdown of future occupational profiles that could be required in the future workforce. These were generated using a combination of attributes collected through the workshops and an algorithm. These suggested profiles were then reviewed and ratified by small groups of employers who were able to add/remove capabilities and uprate/downrate proficiency levels required. You can view all the P-FOPs in a role level by selecting one (or more) of these from the drop down. This will then allow you to select the P-FOPs aligned to that role level. The populated table allows you review and compare different P-FOPs within or across role levels. You can view the capabilities in each P-FOP and the assigned proficiency levels. You can also toggle 'Hide Empty Capabilities' on/off to reduce the view down to only those capabilities included in the role level you are reviewing.

3.4 Future Occupational Profiles compared with current provision

The Workforce Foresighting process has developed two metrics to quantify the alignment between a FOP and a current standard or qualification:

Fit – expressed as a %, it is a measure of the proportion of a FOP that is covered by an existing standard or qualification.
Surplus – expressed as a %, it is a measure of the redundant material in an existing standard that is not required for a FOP.

An ideal existing qualification or standard would have a high fit and low surplus – this implies good coverage of the FOP but with little material that is not relevant to the FOP. Conversely a poor candidate would have a low fit and high surplus. Using these two metrics it is possible to quantitively evaluate, rank, and compare a range of existing provisions against a set of FOPs describing future needs.

By looking at how current occupational standards fit the Future Occupational Profiles, the most suitable and efficient route for change can be determined, e.g. a fit factor of less than 33% probably indicates that the current standard is unlikely to a good candidate for change, however a fit factor of 66% suggests that less adaptation will be necessary to meet future needs.

This interpretation is represented by a simple nine-box model to position the suitability of a given current occupational standard to a future occupational profile:

Factor scores

Fit Factor	*Fit score*	*Surplus Factor*	*Surplus score*
0 - 32%	*1*	*81-100%*	*1*
33-65%	*2*	*51-80%*	*2*
66-100%	*3*	*0 - 50%*	*3*

(Multiplying the Fit score by the Surplus score gives a Suitability Grid score of 1-9 as below)

Suitability Grid

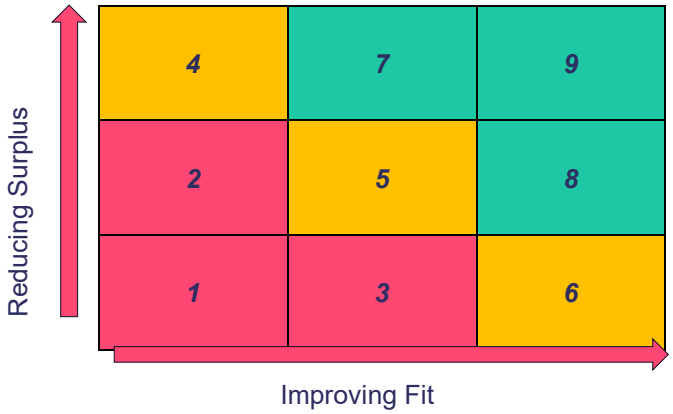


Figure 15: Fit Factor scores and Suitability Grid

Using this score and indicated 'RAG status' the following interpretation can be made:

High Suitability – 7,8,9 – Standards have good coverage for the FOPs identified

Represents good candidates from current occupational standards used as the basis of development to meet FOP requirements and inform elements of short course and CPD provision.

Some Suitability– 4,5,6 – Standards that have some / partial coverage for the FOPs identified.

These are likely to require extended work to meet FOP requirements, further review of the data may be necessary. They are likely to contain some useful information to inform elements of short course and CPD provision.

Low Suitability – 1,2,3 – for standards that have poor / low coverage for the FOPs identified.

These are unlikely to be adaptable to meet future needs but may contain some useful information to inform elements of short course and CPD provision. This can be assessed using the data visualisation tools.

FOP findings compared with current standards

Using the approach described above and applying the 'RAG' scores to each FOP indicating the suitability of current occupational standards selected from the IfATE set, the following tables can be used to identify areas of action and concern for the provision of future skills for each Supply Chain Partner to respond to the Challenge.

The visualisation tool can be used to compare Future Occupational Profiles (FOPs) with existing **IfATE Apprenticeship Standards** and in the future other appropriate standards. It evaluates and displays capabilities as either "Matched" or "Not Matched," by comparing the capabilities outlined in an FOP to the duties defined in a standard.

By extracting the data and reviewing this through the lens of Good, Some and Low suitability of those current standards for that FOP the reader can determine at a high level the overall suitability, (as provided in the supply chain partner graphs below).

Further investigation is required to review the top 10 IfATE standards that most closely align with the individual future occupational profile.

This tool enables the identification of alignment between future capabilities and existing training provisions (currently IfATE apprenticeship standards). When a capability is matched to a standard, users can analyse the data to pinpoint specific statements within the standards that align with the future requirements. This facilitates the identification of existing training materials and activities that can be leveraged or adapted to address emerging workforce needs.

Across the range of roles identified the fit to existing IfATE standards tends to be poor. Figures 21 to 23, along with supporting tables, demonstrate that most roles are not well served by existing qualifications with the IfATE catalogue. With a focus on design, it is possible that the poor fit is in part since a lot of capabilities required in the defined roles are cross-cutting skills, or skills that currently are learned through continued professional development, rather than through apprenticeships.

Additionally, a significant focus of the cycle was on engineer and senior engineer roles, the training provision for which is often through university degree type qualifications, which do not necessarily map to IfATE standards.

As expected, the IfATE standards provision is stronger for the Technician role level than for Senior Engineer.

The overall poor fit of standards means that for employers and providers, it is not easy to simply pick up and use existing programmes. Care will be needed to ensure that the underpinning competencies are delivered within the existing standards, and that additional competencies can be catered for. There is, therefore, a greater need to focus on the use of short course and modular learning to close gaps.

Supply Chain Partner – End Users

Role Family	Primary Value Chain / Workflow Partner	P-FOP	Current Suitability
Technicians	END USERS - AIRCRAFT, AIRLINES, MR&O	Aircraft Maintenance Technician	Some Suitability

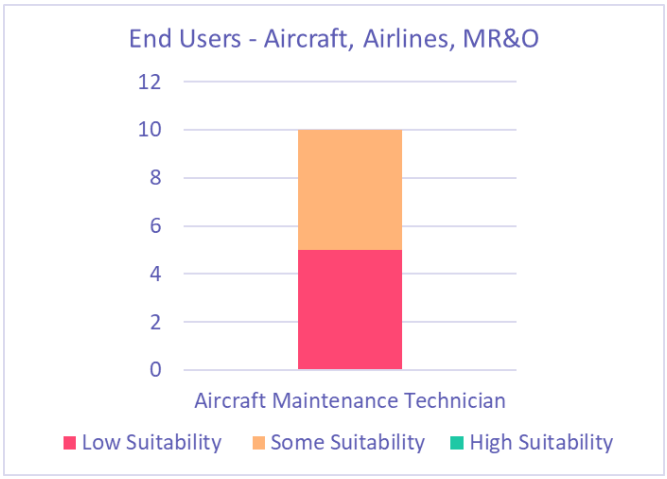


Figure 16: Count of current provision (IfATE Standards) and suitability to FOPs

Supply Chain Partner – Innovators

Role Family	Primary Value Chain / Workflow Partner	P-FOP		Current Suitability
Senior Engineers	INNOVATORS	Systems Engineer (SE)		Low Suitability
Junior Engineers	INNOVATORS	Systems Engineer (JE)		Low Suitability

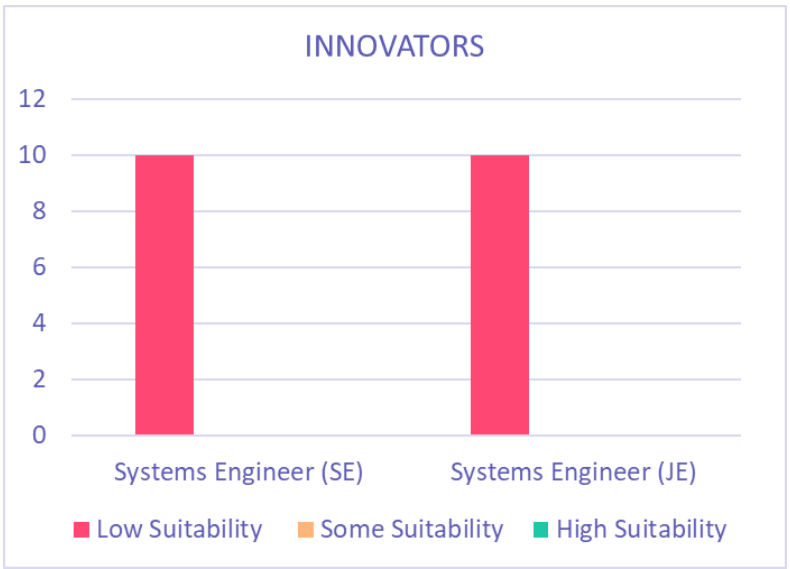


Figure 17: Count of current provision (IfATE Standards) and suitability to FOPs

Supply Chain Partner - Primes

Role Family	Primary Value Chain / Workflow Partner	P-FOP	Current Suitability
Technicians	PRIMES	Toolmaker	Low Suitability
Technicians	PRIMES	Quality Assurance Technician	Good Suitability
Technicians	PRIMES	Quality Assurance Professional	Low Suitability
Technicians	PRIMES	Production Factory and Supervisors	Some Suitability
Technicians	PRIMES	Pipe Welder	Low Suitability
Technicians	PRIMES	Metal Goods Assembler	Low Suitability
Technicians	PRIMES	Metal Fabricator and Finisher	Low Suitability
Technicians	PRIMES	Assemblers Products	Low Suitability
Technicians	PRIMES	Aerospace Technician - LH2	Low Suitability
Technicians	PRIMES	Aerospace Technician	Some Suitability
Senior Engineers	PRIMES	Structural Engineer (SE)	Low Suitability
Senior Engineers	PRIMES	Research Coordinator	Low Suitability
Senior Engineers	PRIMES	Research And Development Manager	Low Suitability
Senior Engineers	PRIMES	Mechatronic Engineer (SE)	Low Suitability
Senior Engineers	PRIMES	Mechanical Design Engineer (SE)	Low Suitability
Senior Engineers	PRIMES	Materials Engineer (SE)	Low Suitability
Senior Engineers	PRIMES	Manufacturing Engineer (SE)	Low Suitability
Senior Engineers	PRIMES	Laser Engineer (SE)	Low Suitability
Senior Engineers	PRIMES	Industrial And Production Engineers (SE)	Low Suitability
Senior Engineers	PRIMES	Engineering Project Manager (SE)	Some Suitability
Senior Engineers	PRIMES	Compliance And Regulatory Professional	Low Suitability
Senior Engineers	PRIMES	Chemical Engineer (SE)	Low Suitability
Senior Engineers	PRIMES	Aerospace Engineer (SE) LH2	Low Suitability
Senior Engineers	PRIMES	Aerospace Engineer (SE) Design	Low Suitability
Senior Engineers	PRIMES	Aerospace Engineer (SE)	Good Suitability
Junior Engineers	PRIMES	Structural Engineer (JE)	Low Suitability
Junior Engineers	PRIMES	Mechatronic Engineer (JE)	Low Suitability
Junior Engineers	PRIMES	Mechanical Design Engineer (JE)	Some Suitability
Junior Engineers	PRIMES	Materials Engineer (JE)	Low Suitability
Junior Engineers	PRIMES	Manufacturing Engineer (JE)	Low Suitability
Junior Engineers	PRIMES	Laser Engineer (JE)	Low Suitability
Junior Engineers	PRIMES	Industrial And Production Engineers (JE)	Low Suitability
Junior Engineers	PRIMES	Health And Safety Inspector	Low Suitability
Junior Engineers	PRIMES	Engineering Project Manager (JE)	Good Suitability
Junior Engineers	PRIMES	Aerospace Engineer (JE) LH2	Low Suitability
Junior Engineers	PRIMES	Aerospace Engineer (JE) Design	Low Suitability
Junior Engineers	PRIMES	Aerospace Engineer (JE)	Good Suitability

Supply Chain Partner – Supply Chain Partners (Excludes Primes)

Role Family	Primary Value Chain / Workflow Partner	P-FOP	Current Suitability
Junior Engineers	SUPPLY CHAIN PARTNERS (Exclude Primes)	Chemical Engineer (JE)	Low Suitability

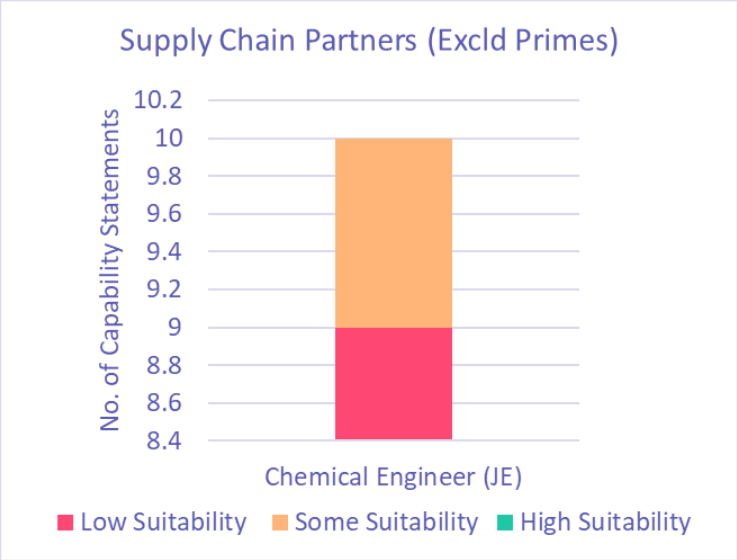


Figure 18: Count of current provision (IfATE Standards) and suitability to FOPs

3.5 Summary of findings

Top Fits

From a FOP perspective and utilising the suitability grid we can determine which of the groups of current occupational standards are more applicate than others.

Matching future occupational profiles to **Institute for Apprenticeships and Technical Education (IfATE)** apprenticeship standards involves aligning the evolving skills, knowledge, and behaviours (KSBs) required in the workforce with existing or emerging apprenticeship frameworks. This ensures apprenticeships remain relevant and support the development of a skilled workforce for future industries.

The FOPs with 'some suitability' as a score resulting from their comparison with current IfATE standards and provision are:

FOP title	IfATE apprenticeship standard
Quality Assurance Technician	Space engineering technician
Engineering Project Manager (SE)	Aerospace engineer
Engineering Project Manager (JE)	Aerospace engineer
Aerospace Engineer (JE)	Aerospace engineer
Aerospace Engineer (SE)	Aerospace engineer

This is a wide-ranging field so use of the data visualisation tool is recommended to access the next layer of detail and review the specific standards that have been identified as having Good Suitability / Some Suitability or Low Suitability.

As a comparison we can also list the standards that score lowest against the required FOPs. This suggests that there is little suitable in the IfATE standards to support these Future Role Profiles.

FOPs with the lowest scores are:

FOP Title
Structural Engineer (SE)
Chemical Engineer (SE)
Research And Development Manager
Systems Engineer (SE)
Aerospace Technician - LH2
Aerospace Engineer (SE) LH2
Aerospace Engineer (SE) Design

A poor fit does not mean that there is no value in existing standards, however it does show that the current published standards do not adequately cover the roles listed. This may be solved through updating existing standards to reflect the FOPs or creating entirely new standards where required. It is likely that it is the specificity of the capabilities required for roles such as 'Aerospace Engineer – LH2' result in the poor fit to existing standards, which do not cover cryogenic hydrogen knowledge in any (or all) capabilities.

Review of Findings

The findings of this section should be reviewed by those involved in the process prior to formal handover. Whilst the data acquisition and analysis were continually quality assured during the workshops and reporting, review and feedback will secure the validity of the actions proposed by the Convener in line with the recommendations that follow in Section 3.6.

The Future Occupational Profiles are the major output of the process and are used to evaluate the need for action. Further work to adapt combinations of FOPs to better fit emerging roles is anticipated as employers plan their actions to meet future needs.

Use of the findings

Whilst some of the FOPS (Future Occupational Profiles) are generic, some are more specific to this cycle. Building on this initial highlighting of opportunities and issues, further direction from Employers is required regarding workforce development plans and the level of demand for specific roles. This feedback shared with Educators can enable the development of the education and training provision for the future. Using the analysis of current IfATE occupational standards to inform the content, level, and delivery of this provision. This deeper investigation will be supported by the data sets and visualisation tools accompanying this report.

Within an organisation a job role might incorporate several occupational profiles or only parts of one depending on the size and scope of the employer. Similarly, a college course might be designed to address one or several occupational profiles alongside or independent of other pre-existing course material. The Future Occupational Profiles and the associated capability sets provide employers with building blocks to help in the design of future roles and inform workforce planning. Similarly, the findings and data provide educators with building blocks to guide the development of course modules and content to prepare the future workforce.

In summary, FOPs can be used to:

- Highlight where roles related to a current occupational standard require updating. For incumbent or transferring workers this could be met by short course and CPD events.
- Influence and inform changes to occupational standards used to define the education and training of new entrants to the future workforce.

Lessons learnt

The Foresighting process is continually updated and improved for future cycles. Some areas for further consideration include:

- Capturing the “Current state” in terms of existing workforce capabilities at the outset would enable helpful comparisons and remove the need to develop a “proxy” current state as for this cycle.
- Additional consultation with stakeholders during the ‘Identify’ and ‘Prepare’ phase of the Foresighting Cycle to ‘seed’ the process with capability sets and existing workforce occupational profiles could reduce the need for level of quality assurance and prevent potential data omissions.

- The scope of the cycle must be clearly defined, and then validated by leads from the outset, with regularly reminders to all participants to ensure a focussed approach to the challenge.

- Participants in early workshops should be given examples of what 'good' looks like for their inputs, as this will result in a higher quality of inputs throughout.

- Participants expectations of the outputs of the foresighting process, and the cause action stage that follows this should be better managed, to ensure that everyone understands what outputs are being created.

The above points will be drawn into future NCC Workforce Foresighting projects.

Visualisation Instructions

Detailed instructions with illustrations can be found in the appendix.

Visualisation Data Link	What is it and what can it be used for?
Prototype Future Occupational Profile (P-FOP) Detail	This page allows you to review a specific Occupational Profile, including the capabilities contained within it and the Knowledge, Skills & Behaviour (KSB) tags associated with the capability. You can select an individual Role Levels and linked P-FOP in the two available dropdowns. The table in the lower section of the page will then be populated with all relevant capabilities. The search control above the table allows you to filter content of any of the columns of data. A key piece of functionality in this table is the presence of the KSB tags associated with the capabilities.
Future KSBs Summary | HVMC Foresighting	This page provides a view of the complete set of capabilities within the cycle along with all the associated KSB tags which are linked to them. It is the superset of all details displayed on the P-FOP detail page. This is used to: • To review the identified Knowledge, Skill, and Behaviour tags for a given capability, to support development of future education and learning material. • To review the requirements from a capability level, rather than a role level/occupational profile grouping.
match_explorer - 3.0	This page allows you to review and compare individual capabilities against 'Duty' statements in an Apprenticeship / Occupational Standard. You can select individual capabilities to review their specific matches. These matches are shown in the bottom panel, including the Standard, the Level, and the Duty Statement this is matched to. You can filter in several ways to focus your review: • By the Capability Classification Framework (left-hand panel). • By capabilities that **are** served by the reference mapping framework – the default is Institute for Apprenticeships and Technical Education (IfATE) provision. • By capabilities that **are not** served by the reference mapping framework, e.g., IfATE provision – these are capabilities required in

	the future that may require new/bespoke training and CPD materials to be developed to upskill/re-skill the workforce. This page can be used to identify where existing provision may exist across the broad spectrum of Occupational Standards, and not just within a narrow range of sector-specific Standards. The data also allows you to identify where provision may already exist to support specific capabilities.
Fit & Surplus Factors	This page allows you to review the 'Fit' and 'Surplus' of Prototype Future Occupation Profiles (P-FOP) against existing training provision e.g. Institute for Apprenticeships and Technical Education (IfATE). It is possible for the 'Fit' and 'Surplus' comparison to total over 100%, as they are two separate calculations based on a two-way comparison.
fit_surplus_matrix - 3.0	This page is a visual representation of the 'Fit and Surplus Factor' insight. You can visually review 'Fit' and 'Surplus' of Prototype Future Occupation Profiles (P-FOP) against existing training provision e.g. Institute for Apprenticeships and Technical Education (IfATE). This can help you identify which provision may align strongest, or which may require adaptation, to provide the suitable provision fit for each future role. It will help you focus in on which provision to focus your attention for analysis.
P-FOP Capability Matches	This page allows you to view the matches between Capabilities and Institute for Apprenticeships and Technical Education (IfATE) Duty Statements. Clicking the arrow next to a number in the 'Matches' column will open a popup with more detail for each Capability. Each capability also includes Knowledge, Skill, and Behaviour Tags, to support with scaffolding future education provision. You can review individual Prototype Future Occupational Profiles (P-FOPS) or review all P-FOPs under a Role Level, to give a more holistic view of Capabilities and Matches Where a future capability has been matched to existing provision (currently, by default, IfATE apprenticeship standards) it is possible to interrogate the data and identify specific statements in standards that align to enable identification of existing training materials and activities that could be used or adapted to meet future requirements. This can be used to review the capability requirements for Role Levels and P-FOPs, from Job / Occupation level through to Knowledge, Skill, and Behaviour level.
FOP_vs_provision - 3.0	This page allows you to compare FOPs against existing IfATE Standards. This is displayed as a Matched/Not Matched Capability, comparing the Capability in a FOP to the Duties in a Standard. The left-hand side allows you to select the Role Level and FOP, while the right-hand modal allows you to compare against the top 10 matched IfATE Standards for that Occupational Profile.
FOP Priorities	This page provides a summary of the maximum Education/Training Provision's Fit Factors identified for each P-FOP

3.6 Recommended next steps

The recommendations in this report emphasise the importance of immediate and coordinated efforts by educators, employers, and other stakeholders to address the anticipated skills gap in the aerospace sector. Actions can be divided into short-term and mid-term strategies.

	Topic	Actions	Who	When	Result
Short Term Actions	Reskilling and Upskilling Current Workforce	Tailor course content to match new capabilities with existing occupational standards, focusing on design and other lifecycle activities.	Educators, Awarding Bodies, Employers	Prepare ahead of the scale-up need	Availability of short-term training for the current workforce to meet immediate technology demands.
	Recruitment from Other Industries	Identify and reskill individuals with transferable skills from other sectors, particularly for high-demand roles such as Maintenance and Operations Engineering Technicians.	Employers, Training Providers	Immediate	Mitigation of workforce shortages in high-demand areas through targeted recruitment and training initiatives.
Medium term actions	Integration of Future Skills Training	Formalise changes to occupational standards and training programs for new entrants, integrating future skills requirements defined by the Future Occupational Profiles (FOPs).	Educators, Awarding Bodies, Employers	As soon as possible for prioritised FOPs	Development of training programs that meet both current and future skills needs, reducing lead time for new workforce entrants
	Modular Approach to Course Updates	Implement modular changes to existing courses rather than complete redesigns, facilitating quicker adaptation to	Educators, Training Providers	Ongoing	Flexibility in educational programs, enabling rapid response to industry needs.

		evolving skills requirements.			
General Actions for Educators	Assessment and Feedback	Review Institute for Apprenticeships and Technical Education (IfATE) standards and relevant qualifications with employers, providing feedback and identifying gaps.	Educators, Employers	Ongoing	Comprehensive understanding of current training provisions and identification of areas for improvement.
	Commissioning New Continuing Professional Development (CPD) Courses	Evaluate existing CPD provisions, commission new courses where necessary, and facilitate collaboration to maintain a unified approach.	Educators, Training Providers	Short-term	Enhanced CPD offerings to upskill current workforce members across all role levels.
Additional Recommendations	Dissemination of Findings	Set up a working group to create an action plan, share findings widely among stakeholders to influence workforce development initiatives.	Convener, Sponsor, Stakeholders, Industry Groups	Following Publication	Broad access to insights and strategic direction for workforce initiatives
	Ongoing Review and Adaptation	Regularly review findings with stakeholders and adapt Future Occupational Profiles to better fit emerging roles	Stakeholders, Sponsor Leads, Participants	Before Formal Publication	Robust and validated actions.

Table of abbreviated recommendations leading to action:

A/B Review and Dissemination of Findings	Convener and Sponsor to set up working group through the Hydrogen Skills Alliance (HSA) to take the findings and recommendation and create an action plan and advance through the Skills Value Chain to cause action. It is essential to share the findings widely among stakeholders, industry groups, and local skills bodies. This will promote access to the insights gained and influence the strategic direction of workforce development initiatives. The HSA will use the UK Hydrogen Skills Strategy (published in February 2025) alongside this report to guide the cause action phase.
C Short-term action	As part of the working group, educators and employers should collaborate to deliver timely short-term training solutions for the current workforce. This is to cause action regarding developing short term training solutions for the future workforce. This includes developing and offering Continuing Professional Development (CPD) courses that address immediate skills gaps and ensure workers are equipped with the necessary competencies. Additionally, the capabilities identified in this cycle will be mapped against the Hydrogen Skills Framework where possible. Existing training provision will be identified through the Hydrogen Skills Alliance's Landscape Map, to prevent any duplication when creating new short and modular courses.
D Mid-term actions	The ongoing working group mid-term action planning should include a concerted effort to integrate new skills and knowledge into existing training programs. Educators and employers need to update curricula and training standards to reflect the evolving demands of the sector, ensuring that both current employees and new entrants are adequately prepared. This may include working with apprenticeship providers, as well as with universities to outline degree changes.
E. General action for Educators to support Employers' demand for future skills	Employers and educators must work together to review and influence the update of IfATE standards and relevant qualifications. This involves using the insights from the Foresighting process to inform the development of new standards and qualifications that align with future workforce needs. This will contribute to the working group skills framework.
F Further foresighting subjects	The working group should seek additional sponsors and propose further subjects for Foresighting. This continuous cycle of Foresighting will help to stay ahead of emerging trends and technologies, ensuring the workforce remains adaptable and prepared.

By implementing these recommended next steps, stakeholders can ensure that the aerospace sector is supported by a skilled and adaptable workforce, capable of meeting the challenges and opportunities of a rapidly evolving industry.

4.0 Appendices

4.0 Appendices

Section	Title
4.1	Mission – What is Workforce Foresighting
4.2	List of participants
4.3	Cycle timeline
4.4	Access to output data - link and authorisation
4.5	Glossary - common language
4.6	References
4.7	Visualisation links and illustrations

4.1 Mission – What is Workforce Foresighting?

Addressing future workforce challenges

The global marketplace is changing at a rapid pace, and the continued development of innovative technologies is creating opportunities for growth in all sectors.

Whilst we are well placed to take advantage in the UK, the Government and industry have identified that we need a workforce able to adapt to new capabilities that require different and often higher skill sets. The 'Manufacturing the Future Workforce' report, published in 2020, states: "Failure to address the workforce development challenge will mean missing out on opportunities to build the UK's manufacturing base and to take market leading positions."

Developing this workforce and preventing a skills shortfall will provide future-thinking organisations with the capabilities to successfully adopt innovation and enable the UK to build a prosperous economy.

The Skills Value Chain

A Skills Value Chain (SVC) approach promotes connectivity between upstream UK innovation and downstream skills systems, as well as enabling better co-operation within education and training provider eco-systems. It aligns and integrates innovation and skills strategies with a common purpose.

The SVC approach was proposed in the 'Manufacturing the Future Workforce' report, which examined global best practice and convened UK pioneers to explore how the UK can develop skills to exploit innovative technologies.

And it starts with Workforce Foresighting.

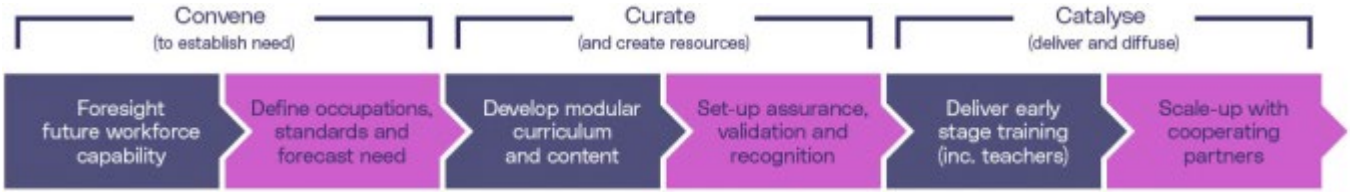


Figure 194: The Skills Value Chain

Workforce Foresighting

Using the Skills Value Chain approach, the UK can start building the skilled workforce required by tomorrow's industries and employers, and understanding what these future needs will be is where Workforce Foresighting comes in.

Workforce Foresighting is a systemic approach to identifying the organisational capabilities and workforce skills necessary to enable industry to adopt and exploit innovative technologies which respond to global, national and sector challenges.

The Workforce Foresighting Hub, initiated and funded by Innovate UK, and built in collaboration with the Catapult Network, provides the processes and data that inform insight and support the recommendations required for industry, policymakers, and educators to respond to continuing change.

Our Vision: To foster the organisational capabilities and workforce skills required to adapt to continuing change and enable adoption of innovative technologies to enable a prosperous UK industry.

Our Mission: To provide the process, insight and recommendations required to identify and address future skills demands to enable the UK to adopt innovation and succeed in the dynamic global marketplace.

Our Goals:

Define future capabilities required across a sector in response to a challenge, or technology innovation and consequently define the skill sets of the workforce of the future.

Understand and explain gaps between technology adoption, organisational capability and workforce profiles that could hamper innovation.

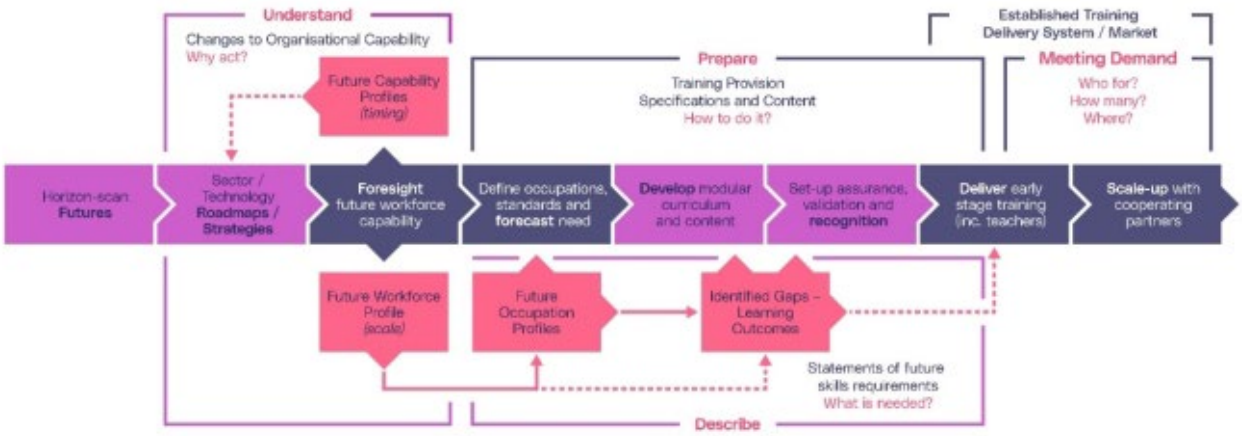
Identify and communicate insights, future requirements and the action required by industry and educators.

Enable and deliver a consistent approach to Workforce Foresighting.

Outcomes:
The process integrates insight from experts in three categories – domain specialists/technologists, employers, and educators. Using a structured and facilitated series of collaborative information-gathering workshops, combined with data from open-source global data sets, the Workforce Foresighting process can produce a wealth of detailed quantitative data to inform action.

At the heart of the Foresighting process are working groups consisting of the industry sponsor and centre of innovation, with support from the Workforce Foresighting Hub team, who undertake detailed analysis to report and summarise key data insights and recommendations for action. This report details future supply chain capabilities, prototype future occupational profiles and identifies changes required to current training provision for the sponsor to take forward and address skills challenges relating to the specific topic.

Figure 20: Workforce Foresighting & Skills Value Chain



Approach used - principles and implementation

The core of Workforce Foresighting is convening three groups of relevant specialists to conduct structured, Delphi-style, facilitated workshops to capture and discuss the set of organisational capabilities that will be required to respond to and exploit technology innovation.

Organisational capabilities are captured using a bespoke classification that has been developed by the Workforce Foresighting Hub. The classification uses a structured common language to enable cross sector and cross centre collaboration and integration of data. Additionally, the classification enables data from several other national and international open-source workforce datasets to be integrated through the same common language. This data is held in a cloud based "data-cube" that is dynamically growing as each Workforce Foresighting cycle adds to the shared data relating to future workforce capabilities.

Using innovative AI and Large Language Model data tools, the data-cube is used to undertake detailed analysis to 'map' future workforce capability requirements against the current education and training provision to identify where existing provision can be used and where new provision, CPD or qualifications are required.

As an agile development project, the Workforce Foresighting Hub team are constantly evolving and improving the detailed workshop process and workshop approach, but always consists of the following stages:

Considering – Clarifying the Challenge to be met (the 'what' and the 'when') and collating solutions (the 'how') as Foresighting topic suggestions align with strategic priorities

Identifying – Gain clarity and consensus about the solutions to be put forward – make the case for Foresighting

Preparing – The convening of specialists and scheduling of workshops

Carrying out – Run Foresighting workshops with experts, collate and analyse data

Communicating – Insights, findings and recommendations gathered from all research in report

Causing action – The driving of action based on the recommendations (promoting progress down the rest of the skills value chain) built on the findings and recommendations of Foresighting

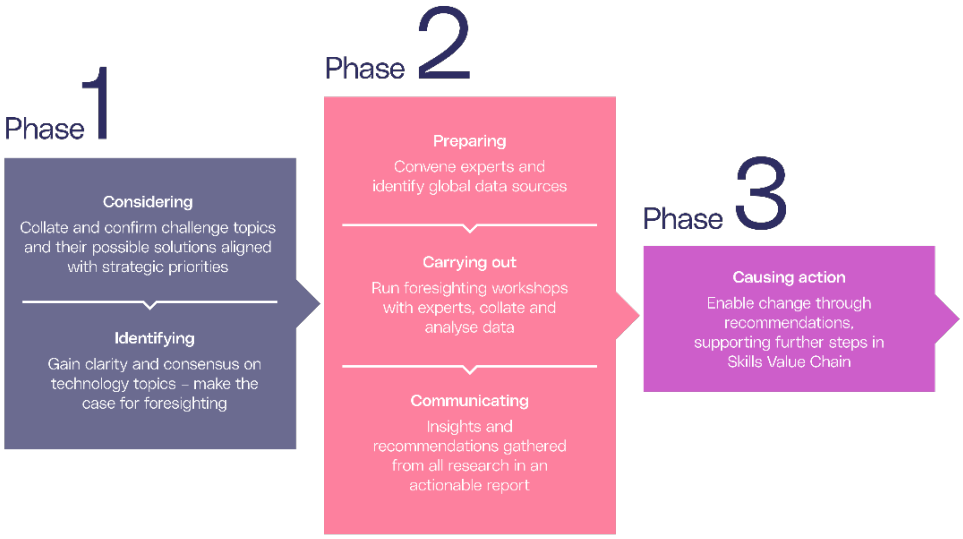


Figure 21: The Workforce Foresighting Process

Forecasting and Foresighting

The result of Workforce Foresighting is understanding why skills requirements will need to change to enable the adoption of innovative technologies, and to define what this change is likely to be in terms of future occupations and shorter-term skills gaps. Forecasting of demand can then take these future focused findings and work with industry and government stakeholders to estimate the quantity of workers necessary for an industry to fulfil emerging skill demands at a given time and place. The two approaches are linked in that Workforce Foresighting identifies the requirements and forecasting can then determine the quantity needed, the people needing the skills and therefore prepare programmes to deliver them.

Outcomes - insights and recommendations

Workforce Foresighting is a data intensive approach that can provide sponsors, stakeholders, and participants with detailed insight about future workforce requirements. A dynamic data set is provided for each cycle to allow all stakeholders and participants to freely access and interrogate the data. Additionally, the Workforce Foresighting Hub team will support the production of a report that provides targeted recommendations that require action to address gaps in training and education provision relevant to the challenge and planned technology solution.

The dynamic data portal provides a range of standard data sets and visualisations. Additionally, users can download data to undertake their own more detailed interrogation of data to guide and inform subsequent actions.

The key aspect is to provide insight about gaps – which capabilities required in the future are not addressed by aspects of current provision – apprenticeship standards, qualifications, or other provision. Gaps represent:

Short term CPD – topics required across the workforce to upskill members of current workforce

Medium term – topics to be included as current provision / standards are reviewed and updated
Longer term – new qualifications and standards that may be needed to equip new entrants

The insight produced by a Workforce Foresighting cycle provides:

Technologists and technical leads with insight of the organisational capability sets required across future supply chain partners in response to the identified challenge.

Employers with insight about possible future roles and occupations that may be required across the whole workforce, operators to researchers, to ensure they are equipped and ready.

Educators with details of the gaps to be addressed by short-course training to upskill the existing workforce and insight about qualifications and provision that will be required to support new entrants in the future.

4.2 List of Participants

Industry Participants	Skills Participants	Technology Participants
Airbus	Bath University	NCC
Enginuity	Cardiff University	ATI
Flexipads	Cranfield	Royce Institute
Gekatex	Loughborough	Queen's University Belfast
OPITO	NWSLC	
Parker	Queens of Belfast	
Civil Aviation Authority	University of Bath	
Eaton	Swansea University	
	EAL	

4.3 Cycle timeline

This cycle started the workshops as part of the Carry Out phase in September 2024. The Carry Out phase concluded in October 2024. This report was prepared following the data validation period and published in March 2025.

4.4 Access to output data - link and authorisation

[Data Capture Overview | HVMC Foresighting]

4.5 Glossary - common language

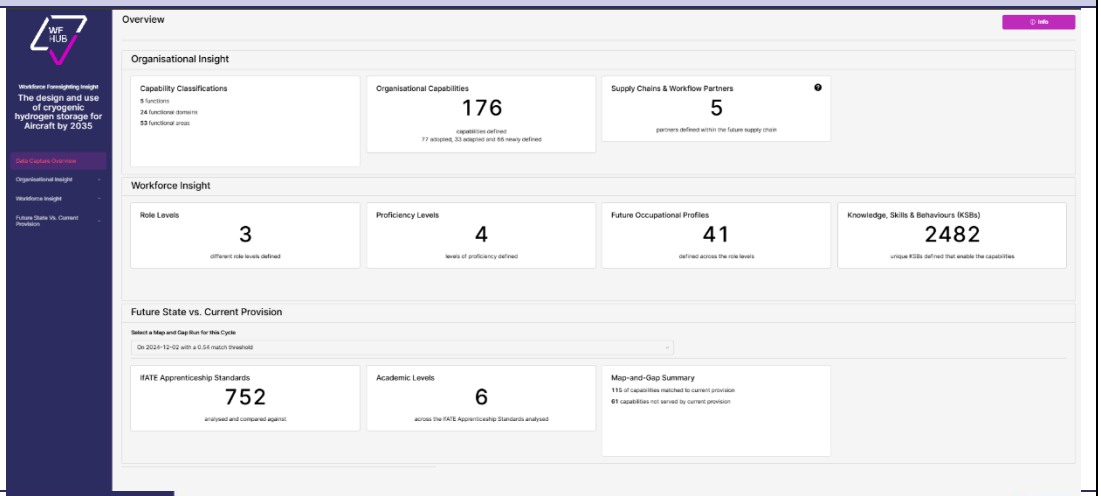
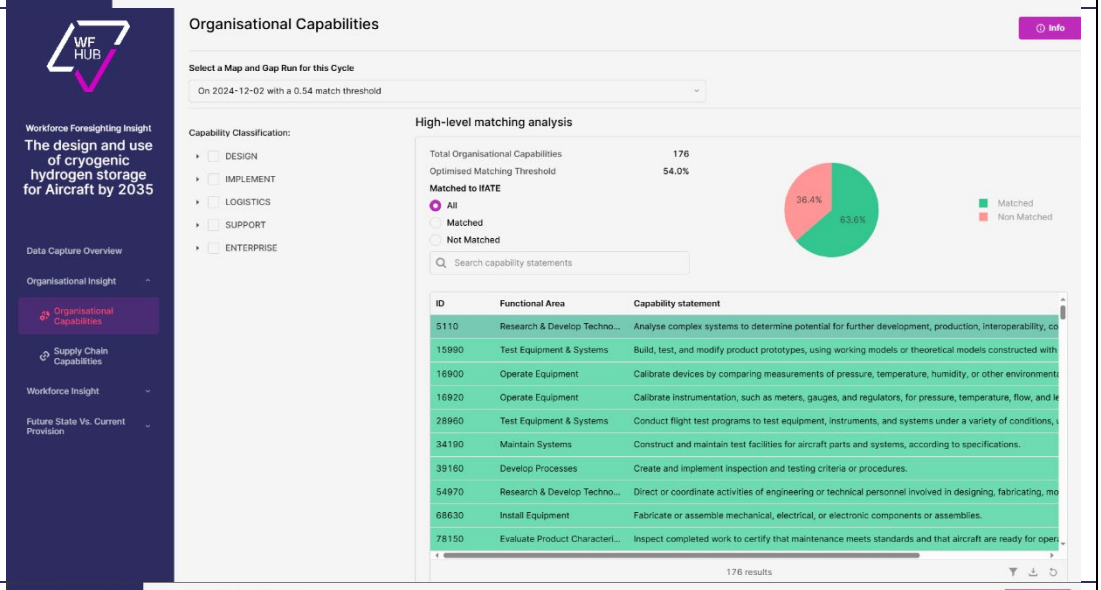
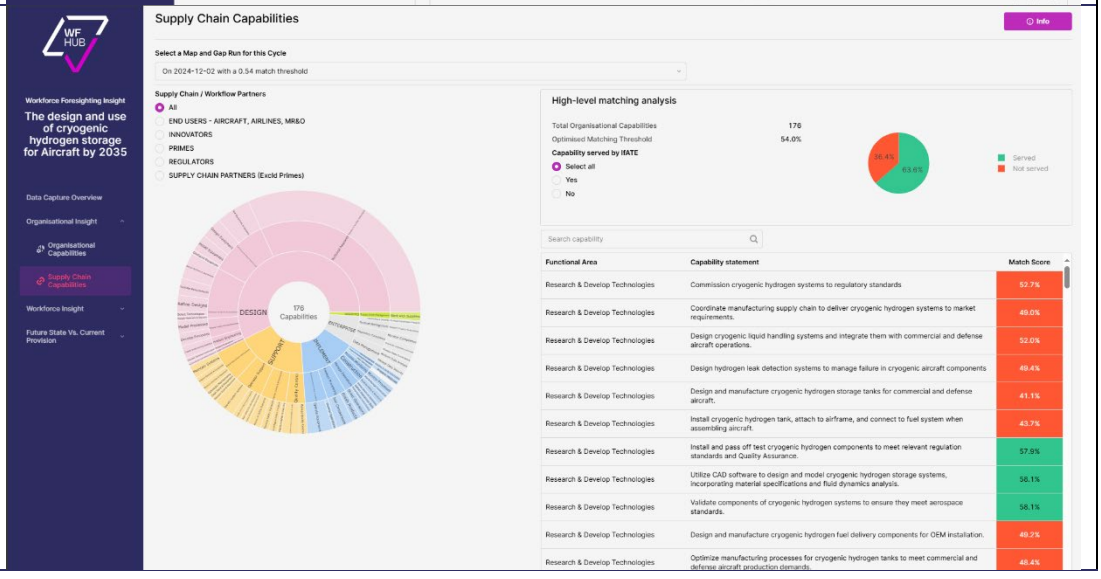
Term	Definition
Impact Domains	Innovate UK domains used as Strategic Categories to assist setting and monitoring priorities
National Challenge (Industry / Sector / Region)	A recognised technological or socio-political threat or opportunity for which there is consensus that workforce action is necessary
Challenge Response	Specific intervention aimed at the challenge
Capability (Organisation)	The collective abilities, and expertise of an organisation to carry out a function, because provision and preparation have been made by the organisation
Capability Classification	Classification provides a common, structured vocabulary to define capability
Capability Statements	Description of the depth and nature of each capability within an organisation
Capability Syntax	Common language to describe each capability application within organisation type
Competencies (Workforce / Individual)	'Proficiency, aptitude, capacity, skill, technique, experience, expertise, facility, fitness related to capability
Competency definition 'KSBs' (Knowledge, Skills, and Behaviours)	Knowledge, Skills, and Behaviours are the elements used to express the required competencies for each Role Level
Competency Domain	Used during Foresighting analysis to provide focus on existing and emerging competency needs
Delphi Process	Foresighting takes a Delphi approach which has come to represent consulting expert opinion. (Harking back to the Delphic Oracle of ancient Greece)
Foresight Cycle	Set of workshops, analysis and reporting that implements the Foresight Process for each subject
Foresight Process	A series of activities which are convened to understand future competence needs, the opportunities available and actions required to deliver the right skills at the right time and place
Foresighting Champion	An individual nominated within a new user organisation of Foresighting to facilitate and lead the use of Foresighting processes and tools with the support of the Project Team
Foresighting Subject	The application of specific technologies in the context of a given challenge and which are candidates for Foresighting
Future Competency Set	The KBS output from the Educator workshop for each Role Level

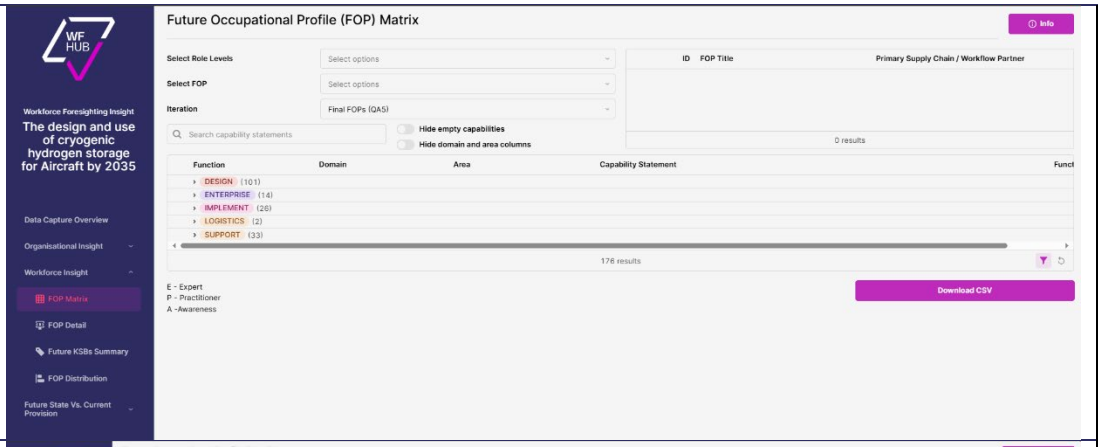
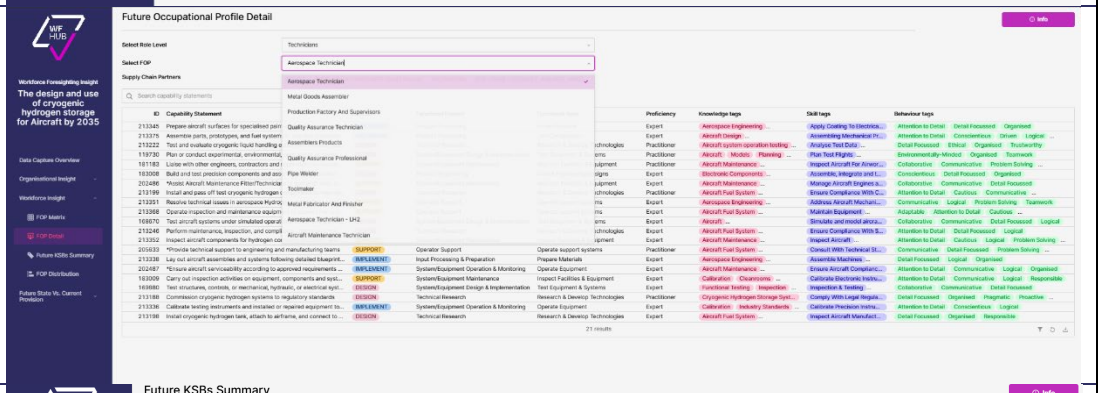
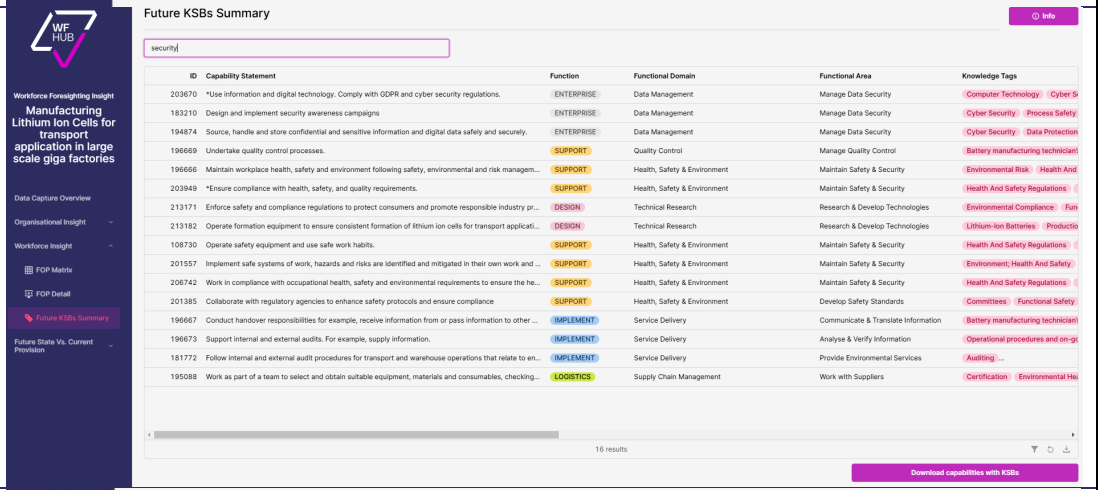
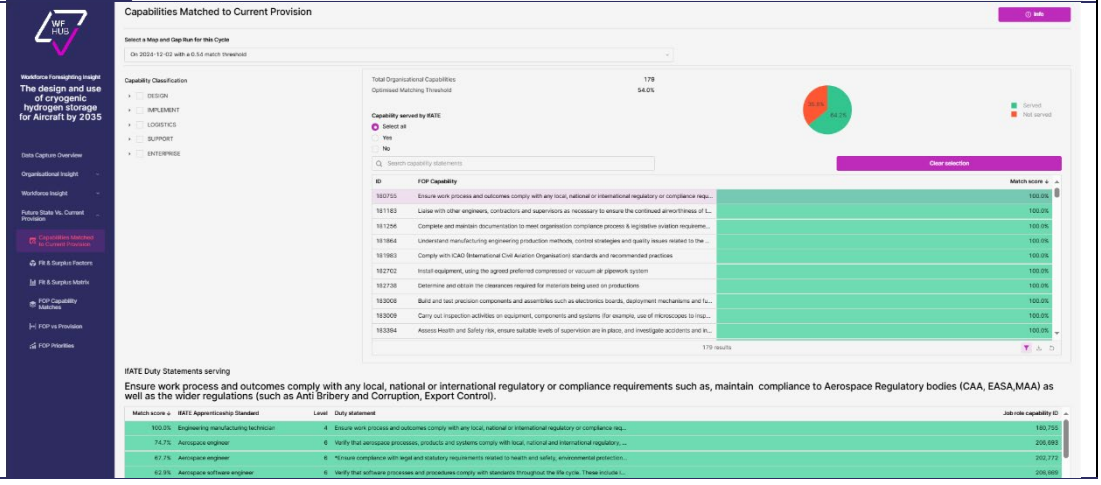
Map and Gap Analysis	A combined expert and automated process that maps the Future Competency Set against a selected reference framework
Organisation Type	Simple description of nature of organisation for which capability is required
Proficiencies	Proficiencies differentiate the degree of competencies required from differing Role Levels to support capabilities
Project Sponsor	Typically, a stakeholder in the challenge being successfully met who requires information to under-write plans to act
Role Level	Role levels are a collective of roles that exist in a typical manufacturing business / industrial sector
Syntax	The way in which a statement is phrased to ensure reliable, repeatable, and meaningful interpretation
Technologies	The technology that could be used to address the challenge
Working Scenario	To provide further context in relation to the subjects and used to position participants thinking during the detailed identification of future capabilities
Workshops	Online sessions used to undertake each step in the foresight process
Roadmaps	Sector, Industry, Regional view of emerging opportunities and their market entry
Participants	Technologists, Educators, Employers

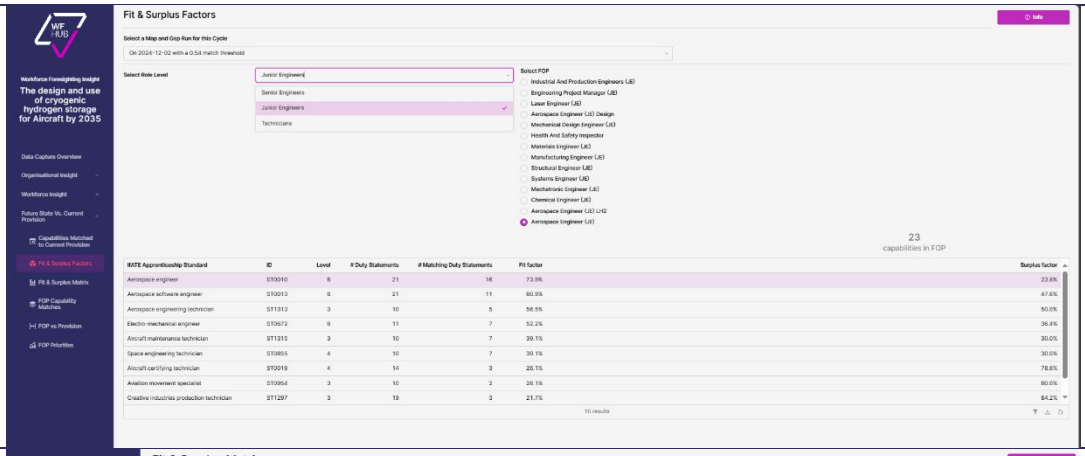
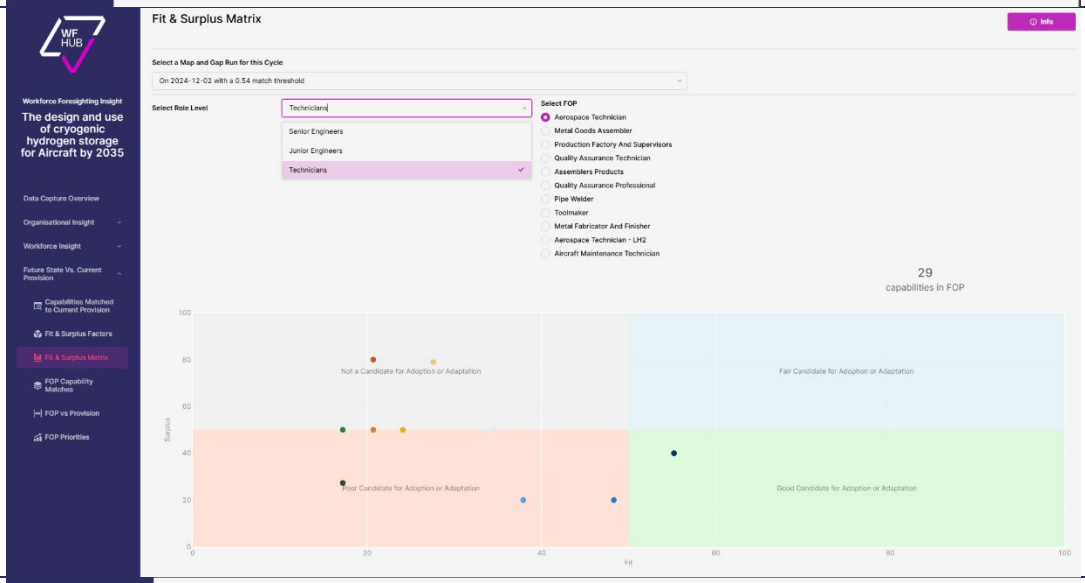
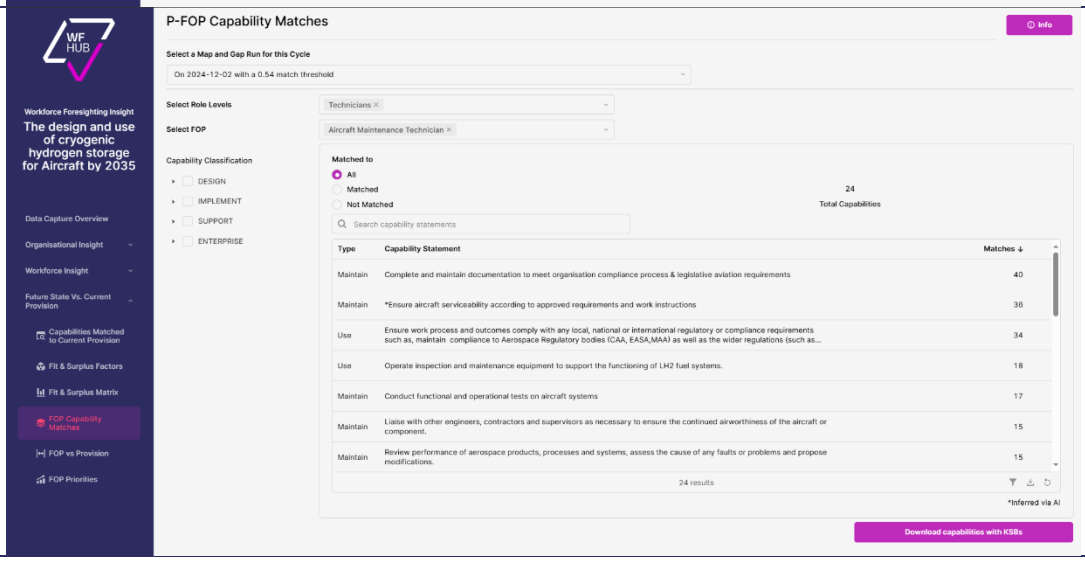
4.6 - References

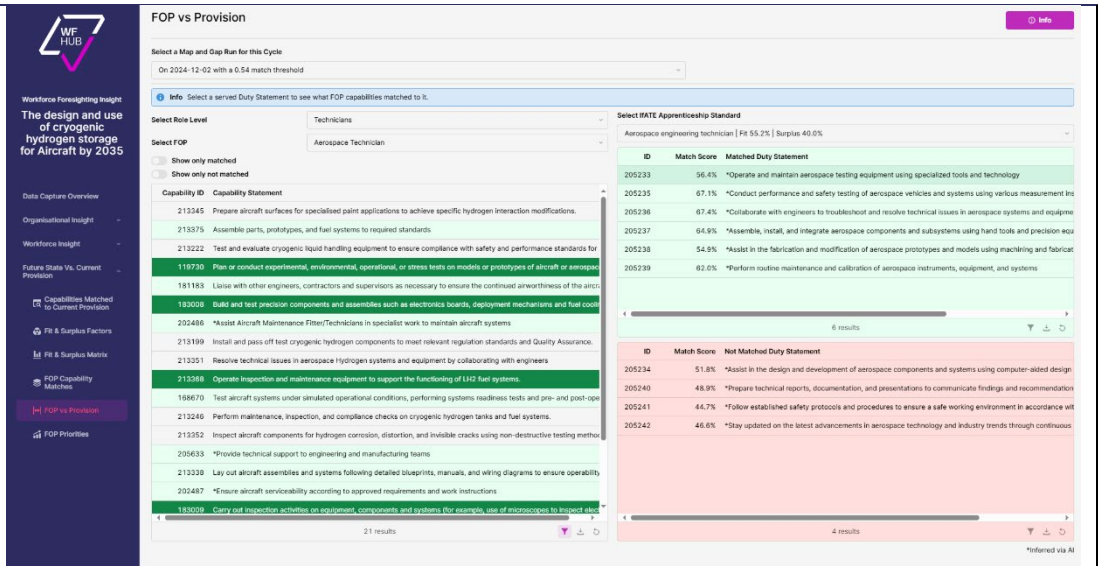
Aerospace Technology Institute, Fly Zero Executive Summary, March 2022
Aerospace Technology Institute, Workforce to Deliver Liquid Hydrogen Powered Aircraft, March 2022
Hydrogen in Aviation Group, Launching Hydrogen Powered Aviation, March 2024
Hydrogen Innovation Initiative, The UK Hydrogen Innovation Opportunity, April 2024

4.7 – Visualisation links and Illustrations

Link to Visualisation	View of data
Data Capture Overview	
Organisational Capabilities	
Value Chain Capabilities	

[Prototype Future Occupational Profile (P-FOP) Matrix]	
[Prototype Future Occupational Profile (P-FOP) Detail]	
[Future KSBs Summary | HVMC Foresighting]	
[match_explorer - 3.0]	

[Fit & Surplus Factors]	
[fit_surplus_matrix - 3.0]	
[P-FOP Capability Matches]	

[fop_vs_provision - 3.0]	
[FOP Priorities]