FINAL EVALUATION OF THE FUTURE FLIGHT CHALLENGE

Final Report - Annexes

04 APRIL 2025

Contents

Annex A – Industry survey overview

The final evaluation survey aimed to provide an overview of behaviours and perceptions of business and academics that have engaged with the FCC. Fieldwork took place between 6 September and 1 November 2024.

A.1 Methodology

The sample for the survey included:

- Those who had been successful in their application to the Challenge across all three phases;
- Those who had not been successful in any of their applications to the Challenge; and
- Those who had started an application, but not finished or submitted it.

Contact details were shared by the FFC for each round of competitions that had taken place so far. These were then combined and de-duplicated so that any applicants who had applied to multiple competitions were only included in the sample file once. A census approach was used, with all contacts being invited to take part in the survey.

In the final survey, organisations that had attended workshops and networking events organised by UK Business Connect (UKBC) (previously the Knowledge Transfer Network) but had not engaged directly with the FFC through the competition were invited to participate. UKBC shared an open link to this survey among their contacts on behalf of BMG. In total, 36 UKBC contacts participated in the survey.

A mixed-methods approach was used for the survey, encompassing both online and telephone interviews. This mixed-methods approach was employed to maximise response rates and to utilise the sample and resources available as much as possible. If any contacts who were contacted by phone asked to complete the survey online, they were sent a link so that they could complete the survey in that way.

The online and telephone surveys had the same content and the only differences were small wording tweaks to ensure that the question text made sense to the respondent if it was read out by an interviewer over the phone or if it was read on a screen by a respondent. Forty-five surveys were completed online and 100 by telephone.

The survey was designed around the evaluation framework and aimed to answer the research questions in the framework where other sources of primary or secondary information were not available.

While the survey collected a range of useful data and inputs from FFC applicants, it should be noted that there are some limitations to the achieved sample. Some questions were only asked of businesses as they referred to aspects such as turnover, other characteristics, and research and development activity. As such, responses from these questions are based on 89

responses or fewer. While this number is large enough to draw conclusions at a total level, it is not sufficient to allow for subgroup analysis

A.2 Sample composition

The full, de-duplicated sample for the survey consisted of 1,306 individuals. Table 1 shows the overall FFC application status of these individuals, where application refers to an application for an FFC competition.

Table 1 Sample composition by type of engagement with the FFC

Type of engagement	Count of organisations	Percentage of organisations
All applications accepted	431	33%
A mix of accepted and rejected applications	116	9%
All applications not completed/submitted	275	21%
All applications rejected	484	37%
Total	**1,306**	**100%**

Source: BMG

Most contacts for the final survey had only been named in one application to the FFC (79%). Table 2 shows the number of applications in which individual contacts were named (whether the application was submitted or not).

Table 2 Sample composition by number of applications

Number of applications	Count of organisations	Percentage of organisations
One application	1,031	79%
Two applications	165	13%
Three or more applications	110	8%
Total	**1,306**	**100%**

Source: BMG

In total, 145 individuals completed the survey, which represents an overall response rate of 11%, lower than the 17% response rate reported in the baseline and interim surveys. Response rates broken down by total application status are shown below. Those whose applications had not been completed or submitted were less likely to take part in the final survey compared to the interim (7% cf. 14%).

Table 3 Response rate by type of engagement with the FFC

Type of engagement	Complete interviews	Response rate (final survey)
All applications accepted	48	33%
A mix of accepted and rejected applications	25	9%
All applications not completed/submitted	18	21%
All applications rejected	54	37%
Total	**145**	**100%**

Source: BMG

Response rates broken down by number of applications are shown below. As observed in the interim and baseline surveys, those who had engaged with the Challenge through multiple applications were more likely to respond to the survey

Table 4 Response rate by number of applications

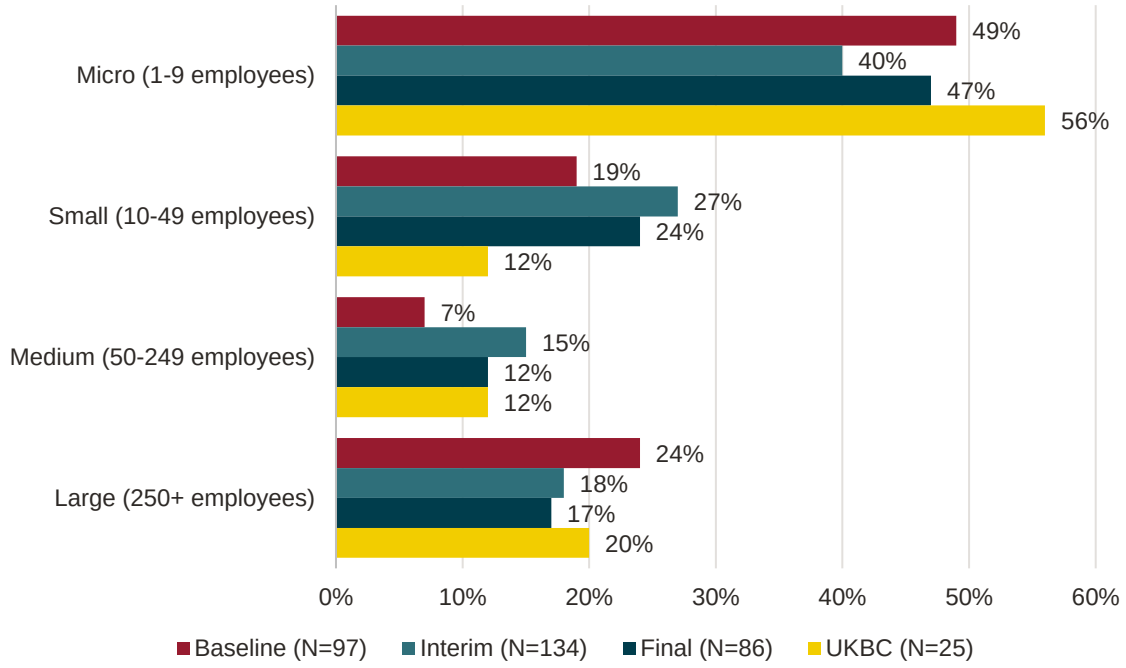
Number of applications	Complete interviews	Response rate (final survey)
One application	109	11%
Two applications	19	12%
Three or more applications	17	15%
Total	**145**	**100%**

Source: BMG

A.3 Characteristics of survey respondents

The distribution of organisational size among survey respondents, as shown in Figure 1, reflects a predominance of micro businesses (1–9 employees) across all survey waves. In the final survey, 24% of respondents were small businesses, an increase compared to the baseline (19%). Large organisations (250+ employees) made up 17% of the final survey respondents, similar to the interim survey (17%) but lower than the baseline (24%). These trends highlight the strong presence of smaller firms in the future flight sector while showcasing a balanced representation of larger firms and their sustained participation across the survey waves

Figure 1 Firm size in the last financial year

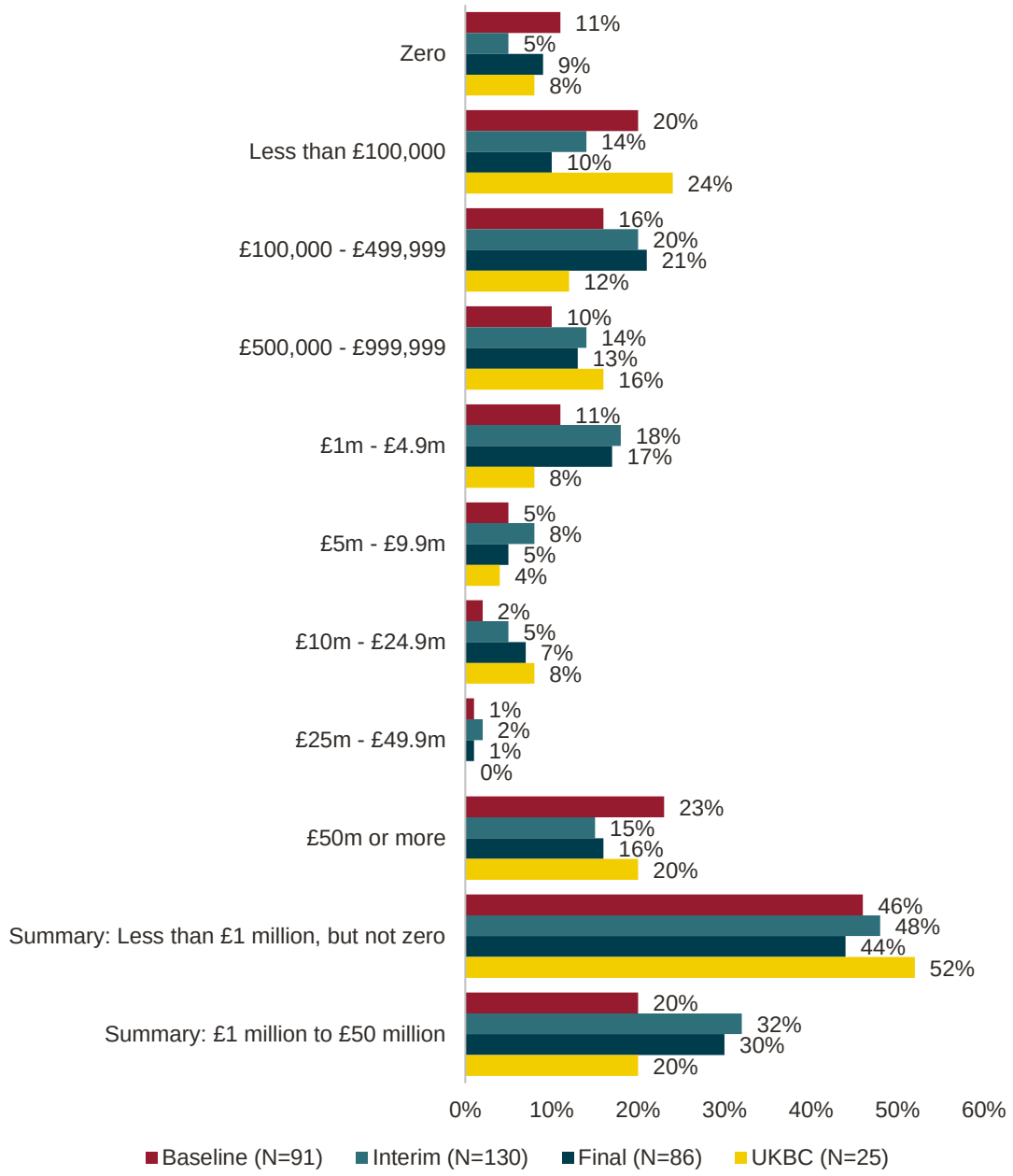


Source: *Industry Survey. A6A/A6B. Which of these bands would best describe the number of UK full-time equivalent employees at your organisation?*

Note: *Base: valid responses. Figures with one asterisk are statistically significant between baseline and interim, two asterisks between interim and final, and three asterisks between baseline and final at the 95% confidence level. Firm size is based on the typical definition used by UK statistical agencies.*

Figure 2 presents the UK turnover distribution for survey respondent organisations, including activities beyond the future flight sector. Among final survey respondents, 44% reported turnover of less than £1 million. Meanwhile, 30% reported turnover of between £1 million and £50 million, consistent with interim survey findings (32%) and a notable increase from the baseline survey (20%). These trends reflect a shift toward higher turnover among respondent organisations, suggesting growth and scaling within the sector over time.

Figure 2 UK turnover in the last financial year



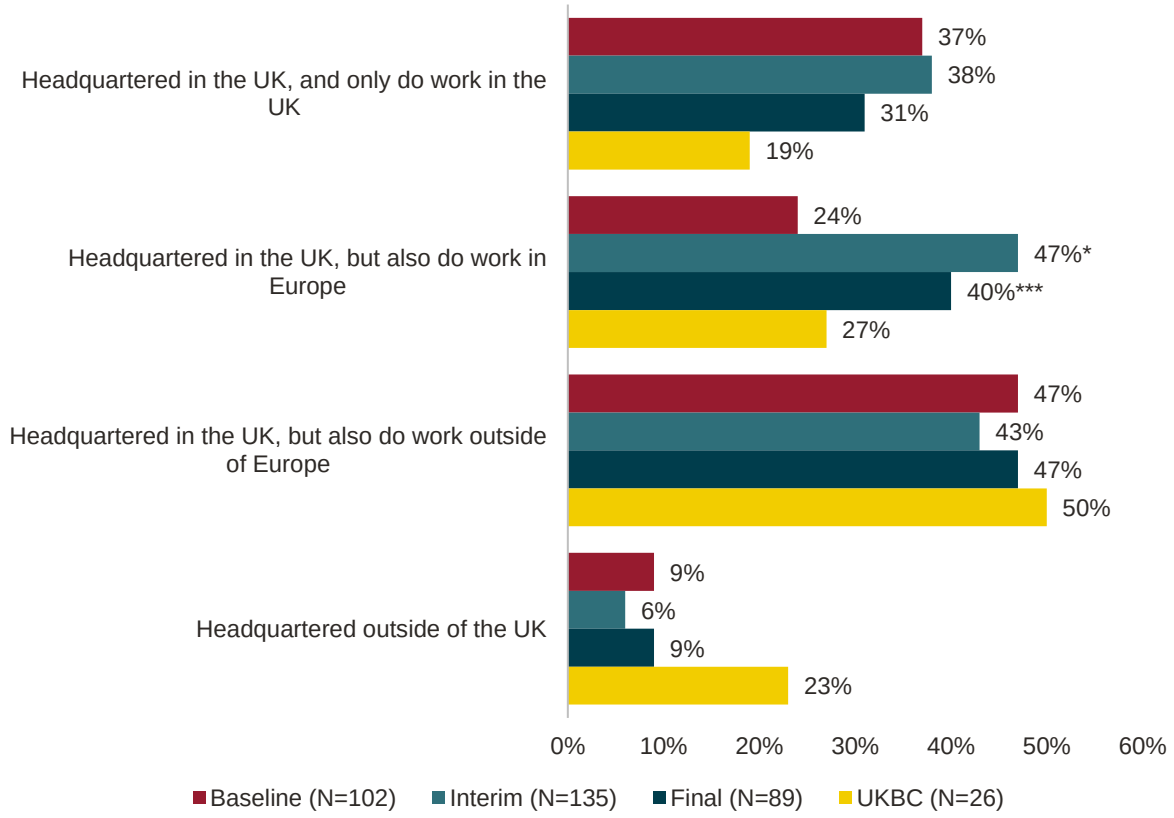
Source: *Industry Survey. A7A. Which of the following bands would best describe your UK turnover for the previous financial year? Please think about all UK turnover, even if some operations are outside of the future flight sector.*

Note: *Base: valid responses. Figures with one asterisk are statistically significant between baseline and interim, two asterisks between interim and final, and three asterisks between baseline and final at the 95% confidence level.*

Figure 3 shows where commercial businesses that responded to the final evaluation survey said they were headquartered. The results remained relatively consistent across survey waves, with 47% of final survey respondents headquartered in the UK but also operating outside Europe, and 31% headquartered and operating exclusively within the UK. Meanwhile, 9% of businesses reported being headquartered outside the UK. Notably, the proportion of businesses headquartered in the UK and working in Europe showed a significant increase

compared to the baseline survey (although not since the interim evaluation), reflecting a growing international engagement of UK-based businesses within the future flight sector.

Figure 3 Headquarters location

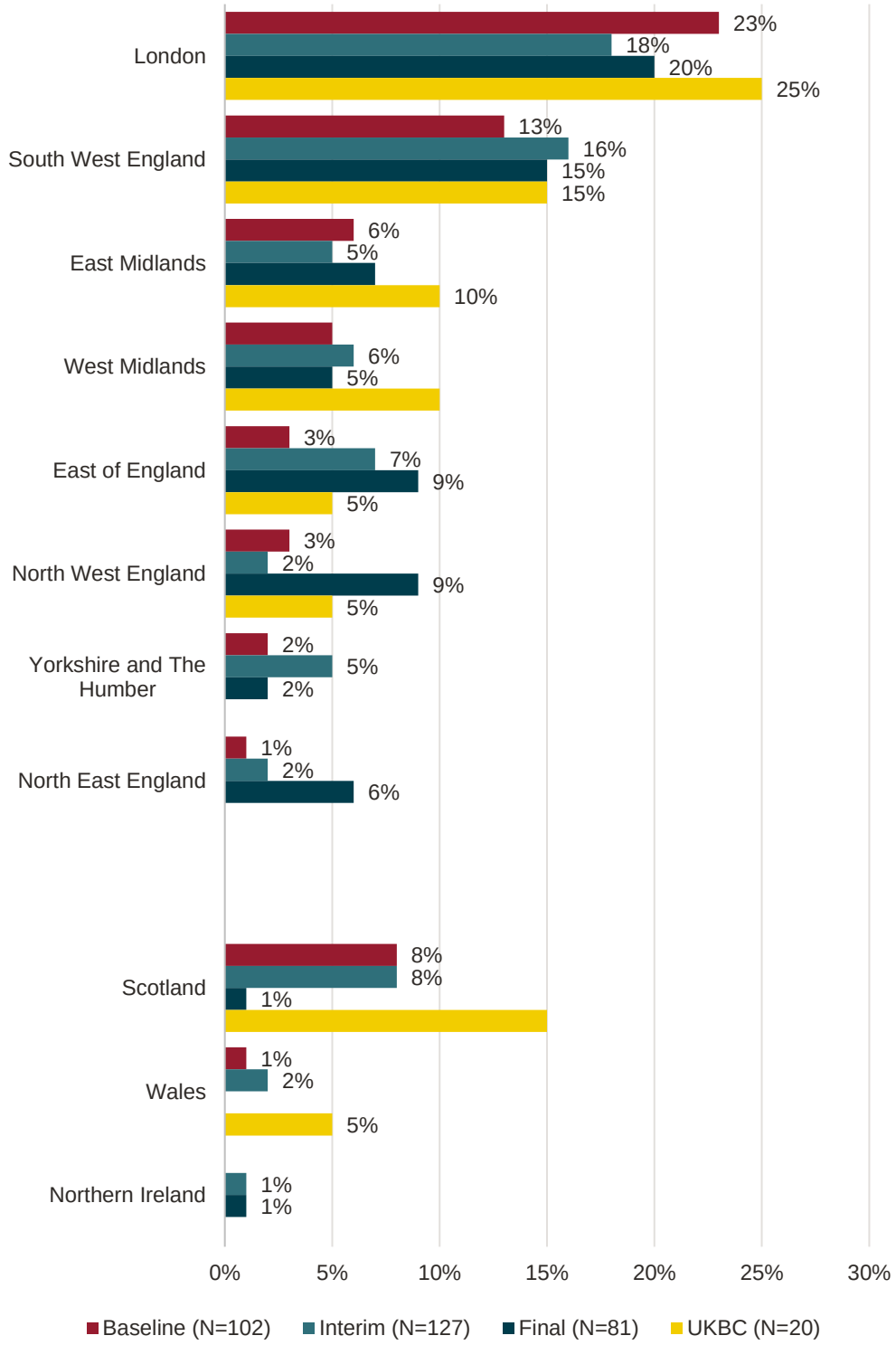


Source: *Industry Survey. A4A.Which of the following best describes your organisation?*

Note: *Base: valid responses. Figures with one asterisk are statistically significant between baseline and interim, two asterisks between interim and final, and three asterisks between baseline and final at the 95% confidence level.*

Figure 4 highlights the regional distribution of respondents' headquarters across the UK. In the final survey, 98% of organisations reported being headquartered in England, marking a significant increase from the 89% reported in the interim survey. Conversely, the proportion of organisations located in the devolved nations has decreased substantially, dropping from 11% to 2%. Additionally, the proportion of organisations headquartered in the North of England has shown significant growth compared to the baseline survey, increasing from 6% to 17%.

Figure 4 Location of UK headquarters by region



Source: *Industry Survey. A4C. What region of the UK is your UK headquarters in?*

Note: *Base: valid responses. Figures with one asterisk are statistically significant between baseline and interim, two asterisks between interim and final, and three asterisks between baseline and final at the 95% confidence level.*

Annex B Secondary data sources

B.1 Crunchbase

The list below presents the sector/activity descriptors to identify companies in the UK that could perform activities within the future flight sector in Crunchbase.

- Drone
- Avionics
- Aircraft
- Air transportation
- Aerospace
- Aviation
- Airspace
- Air mobility
- Vertiports
- Drone management
- Air traffic management
- Aeronautics
- eVTOL
- BVLOS
- Air vehicle
- Future flight
- RPAS
- UAS
- Advance Air Mobility

B.2 Gateway to Research

Table 5 presents the search terms used to identify future flight studies in the Gateway to Research Portal based on their in research titles, research abstracts, project titles, and project descriptions.

Table 5 List of search terms

Category	Search terms
Unmanned Aerial Systems	UAV; UAS; Unmanned Aerial Vehicle; Unmanned Aerial System; Unmanned Aircraft System; Drone,

Category	Search terms
	Uncrewed Aerial Vehicle; Unmanned or Uncrewed + Aircraft, Aviation, Air Vehicle, Air System, Air Operations
Advanced Air Mobility	AAM; Advanced Air Mobility, UAM, Urban Air Mobility
Autonomous Aviation	BVLOS; Beyond Visual Line of Sight; EVLOS, Extended Visual Line of Sight; Detect and Avoid; Electronic Conspicuity; Autonomous + Aircraft, Aviation, Air Vehicle, Air System, Air Operations; Swarm + Aircraft, Aviation, Air Vehicle, Air System, Air Operations
Hybrid Electric Aviation	Electric; Hybrid-electric; Electric Propulsion; Hydrogen Propulsion; Emission; Zero; Sustainable Aviation; SAF; Aircraft batteries; Aircraft + Fuel Cell. Any of the above + Aircraft, Aviation, Air Vehicle, Air System, Air Operations
Future Flight Infrastructure	Vertiport; VTOL; Vertical Take-off and Landing; eVTOL; Charging + Drone, UAS; Charge Station + Drone, UAS
Air Traffic Management	ATM + Future Flight, UAV, AAM, UAM, UAS, Drone); UTM; Unmanned Traffic Management; Unified Traffic Management ; UAS Traffic Management
General	Future Flight Operations; Future Airport; Future Air Transport; Air Transport; Unmanned Flight; ; Future Airspace

Source: Frontier Economics and Frazer-Nash Consultancy
Note: In line with search terms used in the Baseline Report.

B.3 Business Structure Database

Table 6 Number of companies by SIC code

Code	Description	2015	2019	2023
26511	Manufacture of electronic instruments and appliances for measuring, testing and navigation, except industrial process control equipment	1,796	1,747	1,618
27110	Manufacture of electric motors, generators and transformers	359	374	403
30300	Manufacture of air and spacecraft and related machinery	1,006	1,199	924
33160	Repair and maintenance of aircraft and spacecraft	1,654	2,696	2,044
42990	Construction of other civil engineering projects	19,626	19,654	18,223
51101	Scheduled passenger air transport	285	232	226
51102	Non-scheduled passage air transport	581	551	518
51210	Freight air transport	309	824	990
52102	Operation of warehousing and storage facilities for air transport activities	44	71	108
52230	Service activities incidental to air transportation	1,055	1,242	1,319
52242	Cargo handling for air transport activities	212	247	335
61900	Other telecommunication activities	7,010	6,811	6,596
62012	Business and domestic software development	37,013	39,706	40,122
62020	Computer consultancy activities	108,996	141,764	119,061
62090	Other information technology and computer service activities	24,871	24,792	23,922
70229	Management consultancy activities other than financial management	177,118	212,466	189,547
71121	Engineering design activities for industrial process and production	14,659	16,518	14,455
71122	Engineering related scientific and technical consulting activities	19,026	21,589	20,474
71129	Other engineering activities	56,260	59,106	48,340
72190	Other research and experimental development on natural sciences and engineering	4,405	5,078	4,880
74901	Environmental consulting activities	3,811	4,292	5,060

Code	Description	2015	2019	2023
74909	Other professional, scientific and technical activities	49,183	53,088	46,235
77351	Renting and leasing of passenger air transport equipment	260	372	380
77352	Renting and leasing of freight air transport equipment	89	60	44
82990	Other business support service activities	120,204	166,104	143,113
96090	Other personal service activities	33,584	27,469	25,891

Source: BSD

Annex C List of FFC's publications

- UKRI/Innovate UK (2021) "Future Flight Social Science Considerations and Research"
- UKRI/Innovate UK (2021) Future flight vision and roadmap
- UKRI/Innovate UK (2022) "Future Flight Challenge: Mini Public Dialogue"
- UKRI/Innovate UK (2022) "Future Flight Challenge: socio-economic study"
- UKRI/Innovate UK & Swanson Aviation Consultancy (2022) "Market assessment for advanced air mobility in the UK"
- UKRI (2022) "Future Aviation Industry Working Group on Airspace Integration problem statement: 'Future Airspace Integration: Leading the World'"
- UKRI (2023) "Let's get flying: out plan for action (Future Aviation Working Group on Airspace Integration"
- UKRI/Innovate UK (2024) "Future flight use cases: 9 ways future flight will transform aviation"
- UKRI/Innovate UK (2024) "Framework for Future Flight in the UK: Principles from a Deliberative Public Dialogue"
- UKRI/Innovate UK, University of Birmingham and YouGov (2024) Future Flight Survey 2024
- UKRI/Innovate UK (2024) Community Integration Local Planning Guidance Paper

Annex D Case studies

D.1 Case study 1 – Development of SMEs

The role of the FFC in preparing the UK's SMEs for the future of aviation

Summary of main findings

The Future Flight Challenge (FFC) has provided small and medium-sized enterprises (SMEs) in the future flight sector with investment unparalleled by previous UK funding pathways and has provided industry collaboration and a seat on the world stage. These benefits have unlocked a series of technology demonstrations of real-world use cases, offering evidence of the benefits that future flight technologies can provide to end-users and wider society. Increases in technology, regulatory, and operational readiness have resulted in increases in sector collaboration, sector jobs and, in some cases, funding opportunities outside of the Challenge to support sustained SME growth. The greatest challenge for future flight SMEs is sustained investment. Long-term assured investment that is focused on tackling the key regulatory and integration barriers is crucial for ongoing UK SME viability and serves to maintain the UK's competitive edge in the future flight sector.

Case study context

SMEs are an essential component of the future flight industry. Many projects funded by the Challenge are led by SMEs and they play a critical role in delivering the third aviation evolution in the UK. SMEs pave the way for innovation at pace, collaborating with large organisations, academics, and the government to drive forward meaningful change while delivering sector progression. They sit at the heart of innovation across the Challenge and remain a key focus for continued monitoring and support.

Purpose of the case study

This case study explores the incremental effects of the FFC's activities on SME development in the future flight sector. This analysis focuses on two primary aspects:

- First, it identifies the key benefits delivered by the Challenge along with areas of improvement for future programmes.
- Second, it provides information on key SME challenges to inform how the UK can continue to ignite the fire of SME innovation, which will lead to spread of the successful commercialisation of uncrewed air systems (UAS), electric vertical take-off and landing (eVTOL), and hybrid aircraft across the UK.

Evolution of SME landscape – before and after the FFC

Stakeholders interviewed indicated that before the Challenge began in 2019, SMEs were struggling to gain traction and funding, with some organisations leaning on alternative programmes such as the Connected Places Catapult Drone Pathfinder Catalyst Programme or the Flying High Programme delivered by Nesta. Although funding was available, it was not enough to begin climbing the steps towards in-service operations.

> *"Before the challenge, we struggled to get any traction or funding." – Industry interviewee*

> *"Previous supporting projects and programmes were available, but not on the scale of the FFC." – Industry interviewee*

At the time, stakeholders highlighted that there was little collaboration across the sector, with organisations seeing other SMEs as competitors across the market. There was very little evidence of any engagement between SMEs and large organisations, leading to a lack of integration between the innovators and the enablers. Given low technology maturity at the time, there was limited discussions on commercialisation within the sector, primarily the result of a lack of engagement with and from the CAA on strategies to support the implementation of new technologies such as drones and eVTOLs. The low levels of productive activity across the future flight sector were driven by a lack of awareness of future flight use cases by potential end-users, along with negative societal perceptions such as cyber-security, impact on wildlife, and safety.[1] Essentially, the SME future flight landscape was disconnected, slow-paced, and highly focused on technology and less so on in-service provision.

After Challenge intervention in 2019, a clear consensus was shared from a series of interviews with SMEs on how a *"spark of innovation"* had been injected into the SME landscape. Supported by a clear scope, a collaborative environment (through working groups and events), and funding ,[2] growth in the number of SMEs across the sector increased, exploring pathways to build business and kick-start the third aviation revolution.

There was a shared consensus amongst interviewees on how SMEs provide both fundamental and disruptive innovation to the wider future flight industry, highlighting the key benefits of funding, and the development of a future flight UK ecosystem.

> *"The challenge provided a vehicle for UK start-ups to pave the way for urban/advanced air mobility." – Industry interviewee*

Stakeholders indicated that they are closer than ever to understanding how these technologies will co-exist in society, and the benefits they will bring to both urban and rural communities, a key output shared by SMEs. Challenge demonstrations and positive news stories have provided the public with information about the benefits of future flight technologies, leading to

[1] Future Flight Challenge Social Science National Survey and Public Dialogue – Headline Findings

[2] Future flight challenge – UKRI

improved perceptions of the sector and emphasising their potential to positively impact society. In turn, this has increased demand from end-users for in-service operations for "public good".[3] Project CAELUS[4] was highlighted as a key enabler for increased positive public perception of the life-saving benefits of future flight technology and spotlighting UAS use cases to country-wide media outlets.

However, stakeholders interviewed recognised that an increase in sector growth requires both stable funding and clear government aspirations. There was a strong concern among stakeholders that a lack of long-term investment across both the public and private sectors could lead to a loss of sector SMEs and a sudden stall of sector progression. SMEs believed there to be little focus on sector commercialisation, expressing concern that both follow-on funding and continued support are imperative to achieve a stable and economically viable future flight service in the UK.

Stakeholders agreed that future flight funding has accelerated the demonstration of technology, bringing to fruition the integral partnerships and collaborations required to reach the goal of sector commercialisation. This acceleration may also have been positively influenced by the increased defence focus on future flight technologies such as UAS,[5] with some future flight SMEs delivering solutions across both the defence and civil sectors. Notwithstanding the influence of defence funding, the Challenge funding has undoubtedly propelled the sector forward across technology, regulation, and integration. However, some SMEs noted that the impact of Challenge funding had only helped to "seed the market" and *"keep things moving".*

Impact of FFC on UK SME development

The Challenge has been a unique programme for future flight SMEs, with some interviewees highlighting the benefits of their involvement in the *"internationally recognised platform".* With some SMEs stating how *"the Challenge was a complete gamechanger",* the key benefits of the Challenge highlighted by SMEs during the interviews were:

- **Financial support:** Funding to support both technology development and demonstration, largely against end-user use cases, was a key enabler for a growing sector.
- **A collaborative future flight environment:** The Challenge had created a community consisting of SMEs, large organisations, government, and the regulator, all focused on a single common vision that was driven by an organisation whose objective was to "position the UK as a leader in the third revolution of aviation".[6] Several events held by the Challenge had enabled dialogue and collaboration between organisations that SMEs

3 New study finds an appetite for Future Flight technologies if used for public good - Innovate UK Business Connect

4 NHS laboratory specimens delivered by drone for first time by Project CAELUS | University of Strathclyde

5 Defence Drone Strategy - the UK's approach to Defence Uncrewed Systems - GOV.UK

6 Competition overview - Future flight challenge phase 3: strand 1 - Innovation Funding Service

would rarely have engaged with previously, leading to successful multi-facetted projects that delivered solutions across the UK.

- **Programme structure:** The Challenge provided the research and development project flexibility which SMEs needed, while holding each member of each consortium accountable for their progress through effective project management requirements. This flexibility allowed for unforeseen issues that impacted timescales and cost to be effectively managed and mitigated.
- **Access to wider government organisations:** Some SMEs valued the connections with local government organisations that had been orchestrated through the Challenge. This interaction had increased awareness of their projects within their local area, drawing out the benefits of projects for local communities.
- **A seat on the world stage:** The Challenge provided a demonstration platform on the world stage, at international events such as DroneX and the Farnborough Airshow, for innovation that was applicable to a range of use cases. Through investment and networking provided by the Challenge, some SMEs outlined how their technology demonstrations had led to interest from non-UK industry partners and governments. In some cases, project collaborators had transitioned from match funders to clients,[7] leading to additional funding streams for organisations to transition a step closer towards in-service operations.

Alongside their views on the Challenge's benefits, the SMEs also offered constructive criticism and feedback on aspects of the Challenge's structure:

- **Challenge timing:** SMEs interviewed had different opinions on whether the Challenge had been established at the right time or whether it had been too early. Some SMEs felt they had been adequately prepared, primarily from a TRL perspective, to transition towards a compelling end-user use case within the framework provided by the Challenge. Other SMEs argued that further movement on both regulation and commercialisation had been required prior to Challenge kick-off and the result of this may have been a potential gap in investment from now up to in-service provision.
- **Number of funded projects**: It was recognised among SME interviewed that the Challenge had provided adequate funding and leadership to a range of use cases, focusing on technologies such as eVTOL, UAS, and hydrogen/electric air vehicles. However, some SMEs felt that there were too many use cases and technologies and therefore investment was *"spread too thin"*, leading to reduced focus and a *"lack of traction"* on the in-service use case for any specific technology or air vehicle.
- **Focus on commercialisation:** One SME interviewed felt there should be more focus and investment on technologies and use cases that were likely to enter commercialisation sooner than others. Specifically, they commented that a focus on UAS technologies and use cases which require less regulatory rigour than others, such as on-site infrastructure inspections, would help to carve a path to in-service operations quicker than others.

[7] Urban-Air Port secures investment from Hyundai's air mobility business

"We are focussing on too many use cases and technologies that traction on a specific use case is not being captured." – Industry interviewee

- **Future funding:** A common theme discussed amongst SMEs was the quantity of Challenge funding and its short-term nature. SMEs highlighted that many within the future flight space were struggling financially; some SMEs had been purchased by larger organisations or needed to downsize due to the risk around longer-term funding. Although they recognised that the nature of research and innovation came with inherent risk, slow growth in the UK had the potential to limit the value that SMEs bring to the future flight sector.
- **Risk-aware approach:** One SME described this new and growing sector's requirement for *"progressive risk management",* a common approach in today's aviation industry. Under this concept, a future programme would focus on proving the safety and assurance of future flight technologies incrementally, increasing the complexity of the operation step by step towards an in-service operation. Some SMEs felt there should be more of a focus on low-risk use cases (e.g. UAS to support maintenance operations of large structures), and less on the more high-risk and *"futuristic"* use cases (e.g. eVTOL intra-city transport).

"[High-risk use cases] are very exciting at the beginning, but in the end, [the industry] is still a long way away from that. Those use-cases were always going to struggle to get into traction over the timescale of the Challenge, and now this is a risk coming into fruition." – Industry interviewee

"You start off with something that is low risk, you prove its safe, and then iteratively increase the risk by introducing new use cases step by step with lots of evidence." – Industry interviewee

"Without investing enough in the foundations [low-risk use cases], there's a risk that we've tried to skip ten steps [and jump towards the higher-risk use cases]." – Industry interviewee

Overall, SMEs interviewed felt the sector would not be as advanced in the areas of technology, regulation, and operations if the Challenge had not existed. Some SMEs shared their belief that the collaborative events organised by the Challenge were unlikely to have happened and/or unlikely to have included them, which would have denied them the opportunity to build the relationships they now had across the industry.

More specifically, stakeholders indicated that the Challenge had provided a communications channel between SMEs and large organisations, which some SMEs believed would have been unachievable without this intervention.

The grant funding had provided a stepping stone to enabling future technology, with one SME stating that its overall successes in technology and regulatory development in the sector was 80% a direct result of the Challenge, and another stating that it would not exist if the Challenge had not happened. For those organisations which had not been successful in the latest funding

cycle, benefits of the Challenge remained in the form of event invitations, allowing them to engage with the future flight community, sharing knowledge, insights, and ideas.

> *"Without the challenge, we would not have as many connections or use cases, and would not be as technologically advanced without the funding, so we would be a long way behind today if it weren't for the Challenge." – Industry interviewee*

Lessons learnt from the Challenge

There are two distinct threads of feedback from SMEs interviewed as part of this case study. Both provide a reflection of their experiences with the Challenge and help to identify areas of potential improvement for future programmes that focus on the future flight sector.

Tangible progress requires significant concentration on a single use case:

- Technology demonstrations are pivotal to turning innovation into in-service operations, but the cost of prototyping is high.
- The Challenge has provided support to a range of technologies and use cases, leading to a range of highly valuable demonstrations to paint a picture of our future skies.
- With a limited budget, funding has been split across a wide range of organisations and groups, each focusing on delivering a specific use case, environment, and niche operation.
- SMEs stated that an investment significantly greater than that required for a prototype demonstration was necessary to achieve initial in-service operations.
- A progressive risk management approach supported by a comprehensive set of focused demonstrations will lead to breakthroughs in regulation, social acceptance, and technology.
- With many use cases researched and funded as part of the Challenge, there has been little breakthrough on specific operations due to a lack of focus on any specific use case, particularly those which are seen as prerequisites to others.
- Investment in a limited set of future use cases and technologies, to help push operational breakthroughs, may have helped to further support entry into service.
- If progress continues to be slow, there is a risk that the UK future aviation SME community will wither on the vine.

> *"If we don't put enough support into the lower risk use cases, we go nowhere, and all of the work we have put into higher risk use cases is wasted as there's no bridge to commercialisation." – Industry interviewee*

> *"Getting to proof of concept is one order of magnitude less expensive than getting to industrial use. If we spend the same amount of money [as part of a future programme] and spread it equally again, we are going to spend a tenth of what it costs to industrialise a product." – Industry interviewee*

The key barrier to commercialisation is not regulation, it is the ability to scale:

- Regulation was identified as a significant barrier to demonstration activities and to future in-service operations. However, it was noted that it might not be the key blocker for SMEs.
- If regulation was removed as a barrier (regulatory approvals, processes, and airspace management systems in place), SMEs believed they would still not be ready to transition to in-service operations.
- For the sector to transition from a set of technology demonstrations (usually accompanied by additional safety measures) to scalable in-service operations, a significant level of investment would be required.
- There was a lack of focus on commercialisation observed within the Demonstration Phase of the Challenge, leading to SMEs struggling to build organisational strategies for expansion, particularly in the UK. Industry leadership and guidance, supported by a more proactive government mandate, would have helped to outline the next steps along the journey to enable the third aviation revolution with UK SMEs at the forefront.

> *"If the Challenge is to be deemed a success, we have to get some use cases into commercial use, and these have to happen soon." – Industry interviewee*

Looking beyond the Challenge – future needs

The UK future flight sector wants to build on the clear successes of the Challenge. Funding, leadership, and community were highlighted as the most important support constructs of the Challenge that had helped SMEs to thrive. This desire to build on the success generates the following key themes, captured during the SME interview process, that are required for the SME community to continue to grow and prosper in the UK.

Continued financial support

SMEs are often renowned as the organisations which are delivering cutting edge technology solutions at the core of the future flight sector. Challenge funding to date has allowed SMEs to start up and grow in size, capability, and knowledge. Given the inherent nature of SMEs, there is little back-up capital to support times of uncertainty and when funding opportunities are limited. There is a growing concern that if there is a gap in funding and collaboration from the end of the Challenge to a future funding opportunity, many SMEs will not survive any more than 12 months.

> *"By attempting to achieve something great and not quite getting there, we might have ended up doing something damaging." – Industry interviewee*

The UK private funding market is less mature and less open to long-term risks when compared to other markets such as the US. It is therefore incumbent on UK SMEs to demonstrate small, meaningful successes in order to generate interest from investors and remain in business. Without continued funding and support, it is likely that the UK SME ecosystem will be damaged through SME failure, buy-outs from larger organisations (potentially foreign), or relocation to

countries where the funding landscape is more favourable. If the UK government neglects to support the UK SME landscape, a generation of innovative organisations and investors will lose motivation, drive, and money, a set-back from which some SMEs believed it would take a decade for the sector to recover.

> *"The UK is known for promoting innovation but struggles historically to commercialise."* – *Industry interviewee*

The SME community remains adamant that the sector can be a huge success for the UK, providing meaningful support to the general public and wider industry, while supporting the economy and keeping our country's innovation ecosystem thriving.

Engagement events and opportunities for collaboration must remain

SMEs interviewed acknowledged that it was extremely valuable for the Challenge to support engagement opportunities to continue to bring together the future flight community. Collaboration is a cornerstone of the Challenge and events that allowed participation by all organisations, whether SMEs, large organisations, or government, were considered to provide significant benefits for all involved.

A clear pathway to commercialisation

Most of the SME interviewed felt they were far from the point of commercialisation and industrialisation within the future flight sector. When discussing funding, one SME suggested how *"going from proof of concept to in-service operations is 1 or 2 orders of magnitude different"*. Funding to reach this point was stated as "at least a factor of 2 beyond a demonstration". In addition to funding, there is a lack of direction on the processes, approvals, and methods of how to transition from demonstration to in-service operations. A clear directive needs to be put in place to support organisations in the future flight sector to understand how to scale up their technologies into in-service products.

SME interviewed suggested that the UK government could develop future flight service roadmaps, detailing the necessary steps and considerations that organisations must explore along the route to in-service operation. A clear plan and direction from government to fuel both public and private investment could result in a prosperous third aviation revolution within the UK. Roadmaps could be based on technology type or use case and provide guidance and direction, including the following attributes:

- TRL
- Guidance on regulatory compliance processes
- Approach to manufacturing scale-up
- Applicable design standards
- Market integration planning
- How to set up an initial service offering

- How to expand and scale up from an initial service offering
- Intellectual property planning and strategy

Additionally, if the UK wants more significant progress towards in-service operations, it needs to address the following key blocker to sector growth: development of regulation. The pace of regulation development directly impacts the point at which future flight service providers can begin to see the levels of revenue from their UK operations that reduce the requirement for external investment. Meanwhile, business and investment decisions remain challenging in the absence of confidence on when routine operations will be permissible.

D.2 Case study 2 – The role of large organisations

The role of the FFC in preparing large organisations for the future of aviation

Summary of main findings

Large organisations across the future flight sector provide aerospace knowledge alongside the levels of investment required to develop specific use cases, which serves to bolster the strategic direction of the sector and the resources needed for continued growth. The Challenge has provided an opportunity for large organisations to embrace collaboration and partnerships across the sector, helping to identify the *"art of the possible"* with future flight technology and informing how this could be applied to unlock future business opportunities. Many stakeholders interviewed reported having more employees focused on the future flight sector, with the Future Flight Challenge (FFC) being a vital driver of these staffing increases. The key challenge that remains unanswered is how to progress towards end-to-end demonstrations and provide evidence of how future flight technologies will operate in a real-word environment. Demonstrations of integrated operations were reported as important for unlocking internal investment and avoiding loss of momentum in the sector.

Case study context

According to stakeholders interviewed, experience, credibility, and funding are three key attributes that large organisations bring to the emerging future flight sector. These organisations included some of the largest established companies in UK aerospace, and their needs and drivers must be understood, alongside those of newcomers to the future flight industry, to nurture their continued collaboration and ongoing commercial viability.

Most large organisations involved in the Challenge are established in the aerospace sector and have multiple well-developed income streams, unlike many future flight small and medium-sized enterprises (SMEs), which remain highly reliant on Challenge funding. For some large organisations, their future flight technology teams did not exist or were a small percentage of the wider business, giving them low levels of influence over strategic investment decisions for future flight.

"For large organisations it might be hard to make sure the goals of [the Future Flight sector] are aligned with the goals of the wider organisation." – Large organisation interviewee

"The business has so many things that it needs to change that are more pressing than looking to the future and looking at something like [future flight technology] that 'hopefully' will have a benefit, but that benefit is quite some time off yet." – Large organisation interviewee

"[Future flight technology] is still probably on the 'nice to do' pile." – Large organisation interviewee

Purpose of the case study

This case study explores the incremental effects of the FFC on the role large organisations play in the future of aviation in the UK. This analysis focuses on two primary aspects:

- First, it identifies the key threads from the Challenge that have delivered progression over the last four years.
- Second, it provides the views of large organisations on their key challenges and required next steps. This understanding will inform how the UK may continue to kindle the fire of innovation, leading to successful commercialisation of uncrewed air systems (UAS), electric vertical take-off and landing (eVTOL), and hybrid aircraft in our skies.

Evolution of the large organisation landscape – before and after the FFC

The third aviation revolution provides an avenue for large organisations to explore new market services and to demonstrate more efficient solutions as part of existing operations. While most large organisations felt their involvement in the future flight sector was unlikely to be a large income stream in the short term, the Challenge did provide a platform for them to understand how emerging technologies such as UAS could improve operational efficiency, safety, and net zero efforts.

Prior to the establishment of the Challenge in 2019, regulation was identified as a key blocker for some organisations in for the development of future flight technologies, UAS in particular. The UAS regulatory landscape prior to the Challenge, particularly around beyond visual line of sight (BVLOS) operations, had impeded UAS technology operators in their ability to undertake UAS trials which would lead to economic benefit.

"[Before the Challenge] we were much smaller in terms of number of flight hours and number of pilots." – Large organisation interviewee

"[Internal projects] were established before the Challenge, but nothing really went anywhere. My view is that it's very ad-hoc as to whether it's worth it due to the cost of the observers which was the limiting factor." – Large organisation interviewee

Following Challenge intervention, large organisations had observed positive progression in areas such as technology development, regulation, and social acceptance. They now had a better understanding of how they could transfer existing capabilities and invest into the new emerging future flight sector.

> *"[The Challenge] are part of the CAA sandbox and they're actively shaping what future regulation might look like in this space and how we can conduct things in unsegregated airspace." – Large organisation interviewee*

> *"The Challenge highlighted a few areas where the investment should go." – Large organisation interviewee*

Impact of FFC on large organisations

Interviews with large organisations revealed three key benefits that the Challenge had provided them:

- **Collaboration and partnerships:** The Challenge had developed a *"future flight community"* of proactive and supportive organisations which were eager to pave the way towards the third aviation revolution. It was highlighted that *"honest conversations"* on topics such as sector blockers were key to building community trust and respect, helping to build relationships that expanded outside of the Challenge. There was significant emphasis on a community *"coming together to solve the problems*", rather than a typical, more isolated or competitive approach.

> *"It was felt that [the events] were useful from a networking perspective, to understand what the bigger picture is, and how us as a large organisation fit into the bigger picture. This created some follow-up discussions for us." – Large organisation interviewee*

> *"[The Challenge has] given an opportunity to work collaboratively with potential partners and competitors, all working together to collaborate and move the industry forward. [It allowed us to] see what opportunities there were to use our existing expertise, and how that existing expertise can apply to these new capabilities, such as BVLOS drones. We put a lot in, but at the same time, we have gained a lot of new capability that we didn't have before the programme started." – Large organisation interviewee*

- **Opportunity to generate new markets, products and services:** The Challenge provided a platform for large organisations to better understand the scope of technology application, leading to the identification of relevant business opportunities.
- **Clarity on "what is possible":** Demonstration activities had highlighted barriers to implementation, helping to inform future business cases and provide clarity on the cost and risks. Partnerships developed within Challenge consortia were considered vital to inform internal strategies for future flight sector growth.

> *"[Without the Challenge] we probably still would be thinking, what can we do?" – Large organisation interviewee*

Large organisation interviewed shared how the Challenge had led to both national and international recognition of their organisations, placing them as global industry leaders through project delivery, events, and general media coverage.

Recruitment of internal roles, such as strategic directors who will shape the progression of future flight technology, were observed across most large organisations and, in some cases, the development of new teams with a sole focus on enabling in-service operations. Conferences and workshops enabled by the Challenge were considered to have been of great benefit, bringing people together to network and discuss novel technologies and were described as an *"eye opener"* by some interviewees. Interviewees reported significant benefits from workshops that had a distinct and focused outcome, such as the future flight skills workshop. The well-bounded activity had delivered a positive outcome for some organisations, generating feelings of accomplishment and progression which had led to motivation and commitment to the future flight vision.

> *"[Our organisation has] definitely grown, if you started with 2-3 people we are about 10 now so quite a significant growth, and it's only going to grow further. It is now a stand-alone department that didn't exist before." – Large organisation interviewee*

Some participants saw the Challenge as a bridge between large organisations and SMEs, helping them to support one another. An example expressed by some SMEs during interviews was the frustration they had felt around their perception of the long timescales for decisions and progress in large organisations (a factor often recognised by large organisations themselves). The Challenge had helped to overcome these types of frustration by encouraging effective and open communication, leading to quicker harmonisation and conclusion than would have otherwise been the case. These Challenge interventions had helped future flight consortia to re-focus on the benefit of these differences, rather than perceive them as inherent blockers.

> *"Large organisations have lots of checks and balances, and lots of governance than smaller organisations. [SMEs] can move at the speed of light due to short decision chains, however some organisations have very stringent governance in place, which has caused us challenges because we have not been able to operate at the speed others want to be operating at due to approvals, which for smaller companies would have been easier." – Large organisation interviewee*

Amongst a set of very positive Challenge outcomes, some areas for improvement were identified. The two most common points raised by large organisations were:

- **Commercial viability:** Project demonstrations had delivered valuable insight to the benefits and hurdles of a third aviation revolution, but many large organisations believed that significantly more testing was needed to realise viable in-service operations. Demonstrations undertaken during the Demonstration Phase (2022-2025) were

described by one large organisation interviewee as "not groundbreaking", primarily because the required integrated future flight ecosystem had not been "unlocked" within the Challenge timescale. Some large organisations acknowledged that they were in the early stages of the journey towards in-service operations, but their expectation was that they would have conducted "a magnitude more" during flight test operations to bridge the gap between future use case and in-service operation.

> *"We haven't really achieved that integrated airspace where we can fly in an integrated manner." – Large organisation interviewee*

- **Lack of information sharing:** Each demonstration conducted within the Challenge resulted in valuable information insights and lessons to inform the entry to service of safe and assured flight operations. CAA involvement in these demonstrations was seen as a real benefit, adding credibility and value to the demonstration outcomes. Some large organisations felt there had been a lack of open information sharing across the wider future flight community. Sharing such critical information could have led to a reduction of duplicated effort for others across the industry, allowing all FFC organisations to inform their decisions around common knowledge.

Some large organisations were less aware of the Challenge's contribution to accelerating regulation and policy across the future flight sector. This was due to a lack of their organisation's engagement with the Challenge until the latter stages of the Demonstration Phase and to some naivety on the scope of the journey ahead.

> *"I would expect that most people in [my large organisation] who are interested in [future flight] probably aren't very aware of it." – Large organisation interviewee*

> *"I don't think in terms of wider collaboration with other industrial initiatives, [we] have not been as active as we should have been [with the Challenge]. What is a large organisation doing if they've got ambitions in this space, if they're not getting involved at the cutting edge. I think there is some lack of understanding and naivety in the business about what doing this actually entails longer term." – Large organisation interviewee*

When questioned on the successes of the Challenge, most large organisations interviewed were positive about the progression towards demonstrating safe integration and operation of future air vehicles. Some organisations expected to be closer to commercialisation upon completion of the Demonstration Phase, with some suggestions of "ready-to-go products with no market on which to capitalise". All large organisations agreed that, as a result of Challenge, the sector was closer to enabling the third aviation revolution by identifying and addressing the barriers to in-service operations. Large organisations believed that, while there remained a large amount of work to accomplish, the sector had a strong platform on which to build thanks to the Challenge.

> *"[The Challenge has helped to] highlight the key issues, you can argue that actually it offered more preparation for the next steps." – Large organisation interviewee*

Overall, the majority of large organisations interviewed had observed positive increases in TRL, regulatory development, and understanding of integration (particularly airspace) as a result of the Challenge. Without the Challenge, some organisations interviewed would not have considered how future flight technologies could improve their day-to-day operations, with some suggesting that little to no investment would have occurred. The term "safe space" was used to describe the Challenge, allowing organisations to push boundaries and explore the art of the possible within a government- and regulatory-backed environment.

Conversely, one interviewee suggested that their market growth and investment would have been similar without the Challenge and they had not observed much positive or negative impact due to their growth in operations outside of the UK.

Other countries and non-UK investment groups have provided both investment and vision across the future flight sector around the world. These countries and groups were said to be more understanding of, and sympathetic to, the commercial position of some large organisations, especially those with a head office in the EU.

Some large organisations also expressed the difference in both quantity and sustained investment that was available outside of the UK, and how this had led to the decision to "freeze" UK business until there were more attractive financial incentives.

> *"We have established operations in [a non-UK location, without Challenge input] and we already had the capability to fly from some locations [outside of the UK]." – Large organisation interviewee*

One interviewee described how progress linked to internally funded demonstration activities would have occurred without the Challenge, further highlighting progress that would have occurred despite Challenge intervention.

> *"Internally, there are some BVLOS drone operations. We have a couple of companies doing some work using large specific category drones. That is not being done in any FFC framework, and is all funded from [internal] R&D funds and is 2 years deep in this process." – Large organisation interviewee*

Lessons learnt from the Challenge

There were five distinct threads of feedback from large organisations interviewed as part of this case study. They provide a reflection of experiences with the Challenge and identify areas of potential improvement for future programmes that focus on the future flight sector.

A significant increase in the number of technology demonstrations will help to move the dial on transformative regulation:

- Challenge demonstrations helped the sector to better understand how future flight technologies can be scaled to in-service operations, from UAS delivery to eVTOL taxi use cases. However, the scale of repeated flight demonstrations needed to deliver regulatory

assurance demands the number of flights to be of a magnitude higher than has been achieved.

- Isolated operations, such as those in Temporary Danger Areas (TDAs), are not representative of a future air environment and have not provided the sector with the most beneficial outcomes that would help to define safe UK future flight operations.
- The quantity and pace of testing novel future flight operations needs to increase, an initiative that would provide real impact if led by the CAA and Department for Transport. This would help to add clarity on the timescales to future flight in-service operations, and would mitigate any disparity between government, the CAA, and wider industry timescales.

"Big wins" such as "business as usual" operations will help to unlock further investment:

- Private sector investment is crucial for the continued sustainable growth of the future flight sector. However, some interviewees stressed the need to achieve an initial set of "business as usual" operations as quickly as possible to realise the predicted benefits towards cost and efficiency. This in turn would help to provide evidence on the benefits of future flight technology for others across the industry, leading to increased interest and investment.
- Large organisations have experienced difficulty in securing internal investment for further research and development within the future flight sector due to a lack of clarity around timescales and costs associated with reaching "business as usual" operations. This leads to a significant risk on whether a "return on investment" will be achieved and if so, when. If future investment is to be provided by large organisations, it is critical that the outcomes of that investment lead to viable income streams.
- Private investment goes hand in hand with public investment, meaning that an increase in public spending highlights the government's ambition for a thriving future flight sector. To date, the UK's public investment in future flight compared to the spend of other countries is "a magnitude lower". While the UK shares the same sector barriers as the US, the US investment available to tackle these greatly exceeds investment opportunities in the UK, resulting in "big wins" happening outside of the UK sector.

A more favourable environment for foreign large organisations will allow the UK future flight sector to thrive:

- Commercial constraints on foreign large organisations involved in the Challenge have led to some organisations pausing their UK activities until a more favourable environment is in place.
- The future flight sector will benefit from the experiences and insights of non-UK organisations, helping to bolster new ideas and attract investment. However, commercial constraints relating to funding and tax, along with outcomes relating to Brexit is causing international partners to freeze their growth strategies within the UK.

- Additional challenges have been observed by international companies. Import and export of goods have been problematic and costly. Post Brexit, the free movement of employees between the UK and the EU for extended periods of time is no longer practical, leading to adverse impacts on project support.
- Foreign-based large organisations did emphasise the benefits of the UK future flight market, highlighting its investment opportunities, amicable and competent authorities (including the CAA), and wider market collaborators.
- Therefore, in order to attract foreign future flight businesses into the UK, there should be exploration of ways to create a more attractive UK market and identification of incentives that will lead to UK sector growth.

Increased public awareness marketing of future flight services will better manage consumer expectations:

- One large organisation described the current future flight marketing material relating to eVTOL technologies as selling a service that will not be commonplace for some time. Specifically, marketing an air taxi across London during the initial stages of the Challenge may lead to increased public expectations of such services in the near term.
- If public expectations remain unsatisfied, this could lead to a negative perception of the UK future flight sector and reputational damage.
- Honest and well-managed communication is required to promote and retain UK public interest in appealing future flight services where the general public will be the consumers, while setting realistic expectations of in-service timelines.

A refined focus on specific use cases will aid the overall future flight vision:

- One large organisation interviewee identified the need to focus on a refined subset of use cases to achieve more significant progress towards commercial in-service operations as "business as usual". It believed that use cases focused on UAS would be the most appropriate concepts for achieving this benefit.

> *"I think the problem at this stage is if you look at Future Flight Phases 2 and 3, there were so many different use cases that were involved. I think what would help is if we picked a subset of those and focused our efforts [on future funding programmes] and to bring those to market. If you keep the scope as wide as it has been, you will end up having so many different companies looking at different things." – Large organisation interviewee*

> *"If you try to do too much, then you end up not getting any of those to market and we don't go anywhere." – Large organisation interviewee*

Looking beyond the Challenge – future needs

Large organisations interviewed agreed that it is key for the UK future flight sector to build on the clear successes of the Challenge. Collaboration, market service opportunities, and clarity on the *"art of the possible"* were highlighted as the most important support constructs for large organisations to thrive under the Challenge. The points below summarise the suggestions made by large organisations to allow the industry to build on the progress seen during the Challenge.

Focus on demonstrating a basic "end-to-end service" as a foundation for more complex operations

UAS offer a higher level of maturity across technology and regulation than other future flight technologies such as eVTOL. A CAA publication that sets out a roadmap for UAS BVLOS operations by 2027[8] is an example of how UAS is on the path towards in-service operations. Certification of eVTOL technologies is also progressing but lagging behind UAS, with the CAA's latest documents providing guidance on a platform certification pathway.[9] In addition to regulation, supporting infrastructure for eVTOL is less advanced and in most cases more expensive than UAS.

Although other factors need to be considered, the examples above illustrate that the barriers to market entry are greater for eVTOL than for UAS. To achieve full market readiness, some large organisations believe it is critical to invest, build, and test a full end-to-end solution with one technology and one use case. This will help to achieve validation of the appropriate technology, capability integration, company business models, and supply chains, in order to build a system that is both reliable and sustaining. Large organisations believe that a full-scale operational demonstration using UAS would not only help break down the barriers to entry for other UAS use cases but would also help to inform pathways to market entry for other technologies such as eVTOL, which in turn could lead to a reduction in both cost and time to entry.

Sharing regulatory lessons across industry will accelerate regulatory progression

Flight test activities undertaken as part of the Demonstration Phase (2022-2025) led to an extraordinary level of learning and insight for the CAA and Challenge consortia. However, some large organisations highlighted how demonstration outputs and key lessons learnt were not shared amongst the wider industry. Although some sharing was achieved through presentations at events orchestrated by the Challenge, some interviewees expressed the need for a sharing platform that is open source and accessible for all those working in the industry to access, understand, and act on the lessons learnt across Challenge

8 CAP3038: Delivering Scalable UAS BVLOS in the Specific Category - The UK CAA Technical Strategy Delivery Model | Civil Aviation Authority

9 CAP2537: UK CAA Certification of eVTOL Aircraft | Civil Aviation Authority

demonstrations. This will help the industry to leverage experiences of others, reducing the time and cost of regulatory submissions and proposing further improvements.

Focus on delivering industrialisation and commercialisation

Large organisation interviewees expressed a need for *"scalable and repeatable services"* to add value to the UK economy. Technology and regulatory development were seen as key areas of significant progress as part of the Challenge programme, but there are a wide variety of key factors that are essential to enable a successful in-service operation. Building on the demonstration objectives of the Challenge, it is important for future programmes to identify and test other critical enabling factors that exist outside of technology and regulation. For example, some large organisation interviewees suggested how re-structuring the project teams to mimic a real-world operation would assist in identifying and addressing any unforeseen commercial challenges adversely impacting the sector. Development of a *"customer-supplier"* relationship and moving away from a "leads-subcontractors" structure could support a transition from research project to in-service operation and provide clarity for organisations to invest smartly in preparation for in-service operations.

The sector cannot lose momentum

Some large organisations have invested significant time and effort into building relationships and commercial agreements with end-users. In one case, a large organisation highlighted that it had taken it over four years of effort to build its current commercial position with an end-user. If there is a gap in both government incentive and funding to support the sector after the Demonstration Phase of the Challenge, some large organisations believe these building blocks, which have formed the foundations of multiple customer-provider relationships, will begin to break down, after which these relationships and agreements will need to be rebuilt, requiring more financial investment and time. Continued investment and commitment from the government will help to avoid a gap and maintain positive future flight momentum.

D.3 Case study 3 – Regulatory development

The role of the FFC in shaping UK regulatory development to support the future flight sector

Summary of main findings

The regulatory development of the future flight sector in the UK has progressed notably over the past few years, especially in areas like beyond visual line of sight (BVLOS) operations. The Future Flight Challenge (FFC) has played a pivotal role in accelerating these developments by providing essential funding, facilitating industry-regulator engagement, and supporting the demonstrations of new technologies in controlled environments. While there remain challenges – such as the cost and complexity of equipment reliance and low take-up of electronic conspicuity – the FFC's contributions have been critical in moving the UK's

regulatory framework towards greater maturity, compared to the slow progress of previous years. Continued government support is crucial for advancing the regulatory framework, achieving FFC targets and keeping momentum, which will help maintain the UK's competitive edge in the future flight sector.

Case study context

One of the main challenges that motivated the design of the FFC was the lack of suitable regulation in the UK, which hindered the economically viable development of future flight technologies, particularly unmanned aircraft systems (UAS) and advanced air mobility (AAM).[10] At the time of the creation of the FFC, the traditional regulatory compliance and certification system was not suitable for these advanced technologies and struggled to address crucial aspects such as BVLOS operations. While the Civil Aviation Authority (CAA) provided some guidance through its "Future Air Mobility Regulatory Sandbox" and "Innovation Hub" services, a need was identified for new regulatory guidance and operating models for upcoming future flight technologies to be operational and able to fly in the UK.

The FFC provided £5 million to the CAA in 2021 to accelerate the regulatory readiness of future flight technologies in the UK. This funding aimed to enhance the capacity of the CAA's Innovation Team to support Development and Demonstration Phase projects by establishing points of contact for competition winners, ensuring regulatory planning to facilitate live demonstrations, and accelerating the development of new guidance and regulation.

Additionally, the CAA sits on the Advisory Group and FFC Programme Board and is part of the Future Aviation Industry Working Group on Airspace Integration (FAIWG:AI), working alongside the FFC, Department for Transport (DfT), Connected Places Catapult, and industry stakeholders to gather expert input to inform policy and regulation, with a focus on promoting an integrated airspace.

In 2024, the FFC also collaborated with the British Standards Institute (BSI) to identify gaps in current standards relating to next-generation aviation technologies and develop new ones as required. This has been an additional part of its work around regulation.

At its inception, the FFC anticipated that new regulatory frameworks in the UK for UAS, AAM, and regional hybrid aircraft would be available by 2023, with a goal of opening the airspace to allow BVLOS remotely operated aircraft systems (RPAS) operations by 2024.[11] These new frameworks were also expected to contribute to international standards, facilitating cross-country alignment led by the UK. It was assumed that, in the absence of FFC funding, the CAA would continue developing future flight regulatory frameworks but at a slower pace. Thus, the future flight sector would have faced significant regulatory barriers to innovation,

1010 UKRI (2023) Future Flight Challenge: interim and process evaluation and Future Flight Challenge Business Case.

11 UKRI (2022) Future Flight Challenge: Evaluation Framework (reviewed)

investment and growth, limiting their potential economic contribution to the UK economy and hindering its competitive advantage with respect to other jurisdictions.

During the Development (2020–2022) and Demonstration Phases (2022–2025) of the FFC, the CAA engaged with competition winners to help them understand the regulatory challenges they might face in conducting their proposed demonstrations. This was needed because the projects involved technologies for which there was no existing or appropriate regulation in the UK (e.g., definition of detect and avoid policy concept for BVLOS RPAS). In particular, as part of the Demonstration Phase, the CAA worked closely with consortia to identify their safety risks and mitigation strategies to assure safe demonstration of their technologies.

Although developing regulatory frameworks was not one of the intended outputs of most funded projects, it was expected that this engagement with the industry would also allow the CAA to identify gaps in current regulation and develop new and more suitable regulation and guidance to ensure the demonstration of future flight technologies.

In 2023, the interim evaluation of the FFC identified delayed development of regulatory frameworks and limited progress toward airspace integration as key barriers to advancing future flight technologies in the UK. Many stakeholders interviewed at the time pointed to CAA capacity constraints due to the Covid-19 pandemic and Brexit transition, and the inherent complexity of developing these frameworks for diverse use cases as key factors for contributing to these barriers. However, it was recognised that the pace of regulation in response to innovation in the future flight sector had historically been a challenge as timeframes for developing new regulation are normally longer than the pace of technological development.

Results from the industry survey which supported the interim evaluation also indicated that the UK's regulatory performance had declined relative to other countries between the baseline assessment in 2021 and the interim evaluation in 2023. However, at the time of the interim evaluation certain regulatory developments were underway but had not yet been published and therefore could not be included in the assessment. In addition, the interim evaluation gathered only limited evidence on the FFC's role in influencing either standards or international regulation.

Purpose of the case study

The main objective of this case study is to understand the incremental effects of the FFC's activities on regulatory development within the future flight sector in the UK. This analysis focuses on two primary aspects:

- First, it assesses the extent to which the regulatory barriers identified in the interim evaluation have been successfully addressed, thereby determining the effectiveness of the FFC in facilitating and accelerating the regulatory progress and regulatory readiness of future flight technologies.

- Second, it aims to evaluate the UK's positioning relative to other countries in terms of regulatory responsiveness and innovation, highlighting how the FFC has influenced its ability to keep pace with international advancements.

Evolution of regulatory landscape – before and after the FFC

Development of new policies and regulation

Prior to the establishment of FFC in 2019, the UK's regulatory landscape for future flight technologies was already facing significant challenges. Stakeholders interviewed indicated that these obstacles stemmed from a combination of outdated regulatory frameworks, insufficient guidance, lack of clear pathways to approval, and technological advances outpacing regulation. Stakeholders highlighted that guidance on meeting regulatory requirements to obtain operational authorisations under the current framework – particularly regarding air risk management and mid-aid collision avoidance (detect and avoid) – was limited for both applicants and inspectors. In this context, the reliance on visual line of sight operations was the norm due to safety concerns, and there was little to no framework to support the safe integration of BVLOS in a complex and congested airspace such as that of the UK.

Stakeholders recognised that the regulatory landscape in the UK – particularly for BVLOS drone operations – has evolved significantly compared to previous years, and that there is now more clarity on the long-term position of the regulation. In 2023, the CAA updated its Airspace Modernisation Strategy (AMS) and placed a strong focus on transitioning from a segregated airspace to an integrated system that accommodates all users, including emerging vehicles like BVLOS RPAS. The CAA is also moving forward with the development of key policies and on-going testing and consultation on critical topics related to electronic conspicuity, unmanned traffic management and detect-and-avoid systems.

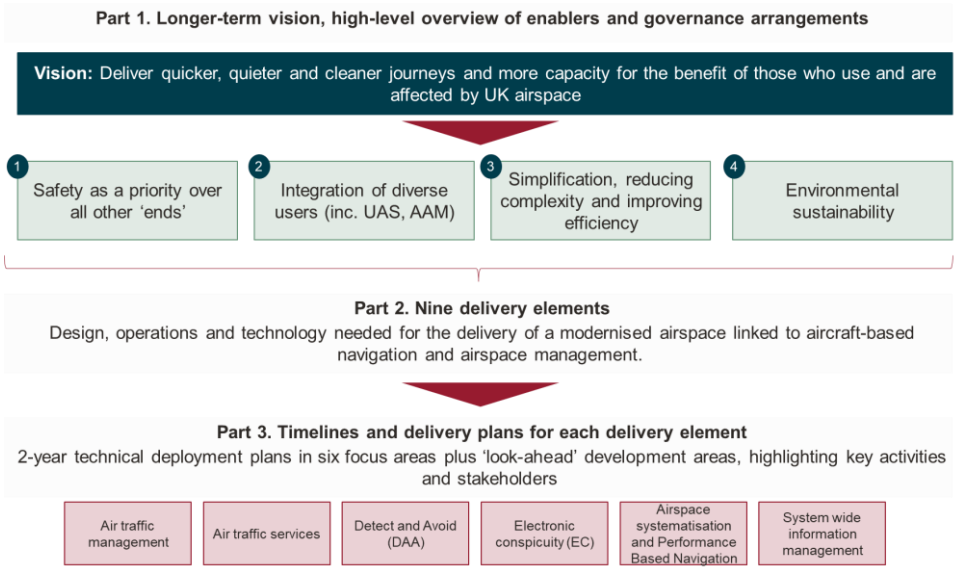
> *"The regulatory landscape in the UK is improving quite significantly because the CAA efforts and CAA resources into the future flight sector are improving and increasing." – Industry stakeholder*

The CAA's Airspace Modernisation Strategy

The AMS summarises the shared vision of the CAA and the DfT to deliver "quicker, quieter and cleaner journeys and more capacity for the benefit of those who use and are affected by UK airspace" by 2040.[12] The AMS was first published in 2018 and it was updated in 2023 to take account of the latest developments in innovation and technology, including drones, aerial taxis, and spacecraft.

12 CAA (2023) Airspace Modernisation Strategy

The AMS sets up a coordinated approach and provides a framework for improving system efficiency, safety, integration of diverse users, and environmental sustainability, ensuring that UK airspace can adapt to evolving technologies and meet international standards. The strategy incorporates inputs from aviation and non-aviation stakeholders, and is divided into three parts:



Indeed, in the last two years, the CAA has published a series of Civil Aviation Publications (CAPs) including policy guidance documents, innovation cases studies, examples of concepts of operations (ConOps), research, and consultations on pieces of regulation that are directly related to FFC objectives.[13] For example, the CAA has launched a consultation on its proposed policy concept[14] for the assurance of detect-and-avoid systems to mitigate mid-air collision risk,[15] one of the biggest barriers to the safe integration of BVLOS RPAS operations, and has published two policy concepts on Atypical Air Environments (AAE) and Temporary Reserve Areas (TRA) to help enable BVLOS operations.[16]

13 These include: CAP 722: Unmanned Aircraft System (UAS) Operations in UK Airspace - Guidance, which provides guidance and policy on the operation of UAS within the UK; CAP 722H: Unmanned Aircraft Systems: Specific Category Operations – PDRA, Guidance and Policy, which describes the concept of pre-defined risk assessment (PDRA) recognised in the UK; CAP 1861: BVLOS in non-segregated airspace, introducing the fundamental principles of operating safety for BVLOS operations; CAP2122: AAM – Taking a use case approach, which outlines CAA's use case approach to exploring AAM and its implications for regulation; and CAP 2533: Airspace Requirements for the Integration of BVLOS Unmanned Aircraft – Policy Concept, that describes a pathway forward to deliver CAA's Airspace Modernisation Strategy's vision of integrating BVLOS RPAS within the UK airspace and set out the use of Temporary Reserved Areas (TRA) to enable BVLOS flying. Additionally, CAA has published research on electronic conspicuity and frameworks to accommodate AAM technologies within the UK's aviation system; and examples of concepts of operations such as *Volocopter – eVTOL (CAP1949), Flylogix - BULOS (CAP2261)* and *Eve – UAM (CAP2272).*

14 A policy concept is a preliminary framework or proposal outlining potential regulatory approaches to emerging aviation technologies and operations.

15 CAA (2024) Detect and Avoid Policy Concept Consultation (still under review)

16 CAP3040: Unmanned Aircraft Operations in an Atypical Air Environment: Policy Concept

A critical development has been the closer collaboration between the CAA and industry. The establishment of the FAIWG:AI working group was perceived to be beneficial by stakeholders interviewed, as it united various parties to create a common action plan with specific milestones and deliverables. In particular, the FAIWG:AI built the foundations for the development of the Future Flight Action Plan,[17] which sets up the UK shared vision for the future flight industry. The plan includes five strategic outcomes including achieving routine BVLOS operations by 2027 and delivering initial piloted operations carrying passengers and cargo for electrical vertical take-off and landing (eVTOL) by 2028.

> *"The CAA has been working more closely with the industry, which has helped us create a common action plan that outlines our objectives for the future." – Industry stakeholder*

Stakeholders also recognised the work that the BSI and CAA are doing in developing the UK Specific Operations Risk Assessment (UK SORA) which will provide a framework to systematically assess the risk associated with UAS operations based on a set of quantitative safety targets and appropriate operational procedures.[18] The SORA framework is widely recognised and adopted as an acceptable means of compliance around the world (including by the European Union Aviation Safety Agency (EASA), Canada, Australia, and New Zealand).

Some stakeholders viewed UK SORA as the most flexible framework for assessing risks to different types of UAS operations within the "Specific Category" (i.e., flying operations with a greater level of risk than basic flying such as BVLOS or dropping items from drones), which could give UK operators an advantage compared to other jurisdictions. The UK SORA is still under consultation but is expected to come into force in 2025 and it will replace the current Operating Safety Case (OSC) approach for UAS.

> *"UK SORA is big achievement because at the moment I think this is the most flexible way to allow all kind of operations in the specific category." – Regulator*

Through the Future Flight Standards Programme, BSI is also focused on establishing essential standards for next-generation aviation technologies, including electric, hydrogen, and uncrewed vehicles like drones and eVTOLs. The initiative includes the creation of a comprehensive standards roadmap and an online Future Flight Standards Hub, which promotes knowledge sharing and best practice.

Stakeholders consulted agreed that the innovation in future flight regulation had been primarily driven by the industry. As the industry matures and the demand for future flight operations grows, there is increasing pressure for regulatory frameworks to evolve to facilitate commercial growth, and for regulators to develop clearer and more flexible guidance. In the UK, this is particularly evident in the case of BVLOS operations, where there is growing demand for applications in logistics, infrastructure inspection, customer deliveries, and emergency

17 DfT (2024) UK Future Flight Action Plan.

18 Proposal to adopt the UK Specific Operations Risk Assessment (UK SORA) as AMC to UK Regulation (EU) 2019/947

services. In contrast, demand for other future flight technologies – such as eVTOL or hybrid-electric aircrafts – remains limited in the UK, and therefore regulation in these areas has been slower.

> *"Changes are happening because there is industry demand to operate in a more flexible way, the market has been established, but is still limited by operational restrictions." – Regulator*

While there has been progress, the development of regulation and standards is still a work in progress as the CAA works towards its long-term objective of an integrated airspace. Policy concepts are only being implemented on a trial basis in controlled environments, with the aim of eventually developing clear guidance and compliance paths for operators and inspectors.

Demonstrations of FFC projects

Between 2023 and 2024, 12 BVLOS projects funded by the FFC were chosen by CAA for controlled trials under the new TRA scheme. These projects involve medical drone deliveries, inspections of infrastructure, flights to remote locations, remote policing, amongst others. A few examples are:

- **Project TRAject** – *Skyports and Air Navigation Solutions*: Implementation of critical systems which enable drone aircraft to detect and avoid crewed aircraft equipped with electronic conspicuity tools. The project uses the CAA's TRA policy to enable safe testing in a managed airspace environment for NHS drone deliveries in Scotland.
- **Open Skies Cornwall** – *Droneprep, Neuron Innovations, University of Southampton, Skyports Drone Deliveries and Thales*: Trial of "Sky-Highways" concept of operations to establish a permanent operational environment in airspace to allow project end users (e.g., NHS, Royal Mail, Falmouth Harbour, Cornwall Council) to benefit from improved connectivity across and into Cornwall, to improve the delivery of essential services in healthcare, emergency response and supply chain resilience.
- **Airspection/Scalable Offshore Wind Project:** Provides safe and reliable drone services for remote inspection of offshore wind turbines, reducing the need for vessels, minimising carbon emissions, and supporting the expansion of the UK offshore energy industry.
- **Project Lifeline** – *Air Ambulance Charity KSS, Everdrone, Altitude Angel, National Air Traffic Services (NATS) and London Gatwick Airport*: Use of drones for emergency medical services including the delivery of critical medical equipment (such as defibrillators, EpiPens and anti-bleeding kits) and live camera feeds to improve situational awareness and decision making during emergencies.

According to the CAA, these trials have allowed them to test how drones can be safety integrated with other airspace users, and gather safety data related to detect-and-avoid systems and electronic conspicuity devices.[19][20]

Stakeholders interviewed agreed that the pace of regulation in response to technological innovation in the future flight sector is still – and is likely to continue to be – a key barrier. In line with findings from the interim evaluation, one of the key factors contributing to the delay in regulatory development is still the complexity of developing regulatory frameworks:

This is an obstacle that many regulators face, as stakeholders interviewed recognised that while technological development is occurring quickly, the development of regulation often lags behind due to the need for thorough risk assessments, stakeholder consultations, and the establishment of safety standards. In some cases, regulators had been working on these regulations for more than a decade without reaching consensus due to the lack of satisfactory results in trials.

> *"We are much in a testing space that can hopefully form up the acceptable means of complying with the regulation. Once we go through the testing process, once, twice…. while we are actively looking for test cases to demonstrate and generate evidence, it might not have gone as far or as fast as everyone hoped." – Regulator*

After the CAA's departure from EASA following Brexit, many stakeholders observed that these regulatory challenges had intensified. A few stakeholders observed that the CAA still faces significant resource constraints that affect its ability to respond promptly to industry needs. This situation has created a gap in regulatory responsiveness, raising concerns about the UK's ability to keep pace with international advancements in the future flight sector. However, it was also recognised that there have been positive changes, as in 2024 the CAA received additional resources from DfT to deliver the Future Flight Action Plan. Nonetheless, one stakeholder noted that there is a risk that CAA's ability to operate independently may be affected as it now fully depends on UK government directives and funding allocations.

> *"After Brexit we found the CAA was quite severely under-resourced…did not have enough capability and capacity to be able to develop regulation at pace. We see now that DfT has committed more resources to the CAA, but we are still in situation where the CAA is not acting as an independent body." – Industry stakeholder*

> *"In the past few years, we have dealt with the consequences of Brexit, which significantly hindered CAA's capacity to develop regulation as quickly as other countries." – Regulator*

Stakeholders also identified other factors that affect both the pace of regulation development and its future compliance. These include the development of safety standards and supporting infrastructure and reliable equipment, such as vertiports, air traffic management systems, and

19 CAA (2023) "New trials move the UK closer to allowing everyday drone deliveries and flying beyond visual line of sight"

20 CAA (2024) "New trials set to help unlock drone deliveries and inspections in the UK"

electronic conspicuity devices. For example, while detect-and-avoid policy concepts are being developed and tested, one stakeholder mentioned that a key challenge relates to equipment reliance, especially for smaller operators, because developing and certifying equipment is costly and complex. Smaller RPAS companies need to develop their own equipment and systems for BVLOS operations in-house, compared to more traditional manned aviation industries that rely on certified manufacturers.

> *"Reliance on equipment is expensive. A lot of equipment does not even exist…the supply chain for the RPAS industry is nowhere near as mature as it is for the large aircraft businesses. It's not going to happen in a hurry." – Regulator*

Standards are essential for reducing industry costs and supporting regulators in approving new operations by streamlining authorisation procedures. While many standards exist or are under development worldwide (e.g., detect-and-avoid standards by the International Civil Aviation Organization (ICAO) and the Radio Technical Commission for Aeronautics), they are primarily tailored to larger, manned aircrafts. Industry stakeholders emphasised the critical need for clear, universally accepted standards to facilitate smoother operations, ensure compliance for equipment manufacturers, and ultimately support the safe demonstration and scaling of industry activities. This requires the CAA to align more closely with international regulators, particularly EASA and the FAA, to foster mutual recognition of certifications. Industry stakeholders saw this alignment as essential to supporting UK exports, enabling international operations for UK-based companies and facilitating market entry for foreign companies wishing to operate in the UK.

> *"I'm not sure there is a lot of advantages in leading, if we end up with a different set of criteria to everyone else because that does make it quite difficult to work with other countries, from an export point of view, it places additional administrative burdens." – Regulator*

Overall, the regulatory landscape for UAS operations in the UK has transitioned from a phase of significant challenge to one marked by cautious optimism. Stakeholders recognised the substantial progress made by the CAA in the last two years, especially in terms of its long-term position, renewed commitment to the sector, and advancements in testing policy concepts, which are crucial for setting the groundwork for a more adaptable regulatory framework.

UK's position in the global regulatory landscape

Stakeholders consulted agreed that the UK faces regulatory challenges similar to those in Europe and other countries. These include public acceptance, airspace integration, and the need for a comprehensive regulatory framework that accommodates new technologies while ensuring safety. These challenges have led most regulators to remain cautious and hesitant to implement bold regulatory changes without broad consensus and a solid foundation of supporting evidence gathered over years.

However, some stakeholders recognised that the UK faces unique challenges in adopting future flight technologies due to its busy and complex airspace, with densely populated areas, stricter low-flying regulations, and limited adoption of electronic conspicuity devices among general aviation. This makes the integration of BVLOS operations more challenging compared to countries like the US, Australia, Canada, the UAE, and China, where less congested or more flexible airspace policies facilitate these operations.

> *"The UK is a small, busy country, and while there are quieter areas in the highlands, the market is not as focused there." – Regulator.*

BVLOS operations in other countries compared to the UK

The UK faces obstacles in maintaining a competitive edge in BVLOS operations, as other countries benefit from larger funding pools, established markets, wider adoption of electronic conspicuity, vast unoccupied spaces for testing and limited general aviation. Based on stakeholder interviews and documentary evidence, a summary of the position appears to be that:

- The **US** is one of the global leaders in BVLOS operations, leveraging substantial government funding – such as the UAS Integration Pilot Program – and strong industry partnerships that support the development of technical standards. The US has also adopted a waiver approach allowing companies like Wing, Amazon Prime Air, DJI, and Parrot to demonstrate the viability of commercial drone operations in small, controlled environments.
- In the **EU,** the approval of low-risk BVLOS operations in some quieter areas is easier than in the UK as there has been a far greater uptake of electronic conspicuity devices in the general aviation community in countries like Germany or France. The UK, however, has been slower in mandating the use of such devices, which creates challenges for integrating drones into shared airspace.
- In **Canada** and **Australia**, BVLOS operations are easier to approve due to the availability of large and unoccupied areas where drone testing can take place with minimal risk to other airspace users. In contrast, the UK's crowded airspace, especially in the south, makes it harder to carve out segregated areas for drone operations, and this limits rapid approval.
- **China** has taken a straightforward approach by designating airspace below 500ft. exclusively for drones, effectively bypassing traditional regulatory steps. This approach has been feasible due to the absence of a substantial general aviation sector in China, as well as the country's centralised regulatory environment. In contrast, the UK's more congested airspace and competing interests between different users make a quick solution unlikely, requiring a longer-term transition.

Despite these challenges, the UK is recognised as making progress in the regulatory space in the last two years, particularly in enabling BVLOS operations, and the CAA is regarded as a technically capable regulator, a leading voice in UAS, and highly respected on the

international stage. Stakeholders noted that the UK's position relative to other countries is characterised by innovation and flexibility, especially in risk assessment and regulatory collaboration, whereas other countries, such as in the EU, often adopt a more structured regulatory approach.

> *"The UK has traditionally been seen as a gold standard regulator, it is very well respected in terms of BVLOS policies, but it is definitely not top of the world because it is harder in the UK than in other countries." – Regulator*

Some stakeholders recognised that the UK's engagement with international regulatory bodies has also increased significantly in the last two years as the CAA has taken a leading role in international working groups like ICAO and the Joint Authorities for Rulemaking on Unmanned Systems (JARUS), sharing its expertise and best practice in air risk assessment and mitigation strategies with other national aviation authorities and EASA. In particular, the CAA has been deeply involved in updating the JARUS's risk assessment framework for UAS operations (i.e., SORA v2.5 and the upcoming SORA v3.0), which takes a more flexible and adaptable approach for assessing risk. This positions the UK as a forward-thinking jurisdiction and sets a precedent that it can influence regulatory approaches globally:

> *"Clearly there was a change in direction, a change in priorities that affected the JARUS work, the UK CAA has really increased interest, and they are in fact leading these efforts." - Regulator*

While the CAA has a lot of involvement in BVLOS international regulation, this is not the same in other future flight technologies. One stakeholder mentioned that the UK is making some progress in other technologies like eVTOL but needs to strengthen its collaboration with international regulatory bodies and continue investing in resources to maintain the UK's competitiveness against other jurisdictions.

Impact of FFC on observed regulatory change

Based on stakeholder interviews, the contribution of the FFC on observed regulatory changes can be summarised in three main mechanisms: (1) driving industry-regulator dialogue through facilitating collaboration, (2) accelerating the development of regulatory frameworks, and (3) promoting an inclusive future flight ecosystem.

Driving industry-regulator dialogue

Before the Challenge, the future flight industry had limited avenues to interact with the regulator. Stakeholders highlighted that the funding the FFC provided to the CAA was essential for facilitating interaction and engagement with the industry. By providing funding and support to various CAA Sandbox projects, the FFC has enabled operators to work with the CAA in shaping future regulations while testing their own technologies under regulatory oversight. This collaboration has also provided the CAA with valuable resources for policy testing, allowing it to gain insights into industry challenges and real-world implications of new technologies, which, in turn, has helped refine current and new regulatory frameworks.

Some stakeholders agreed that without the FFC's support, the CAA might not have received the same level of industry input, which could have slowed the pace of regulatory development.

> *"If FFC was not funding those industries, I am not sure we would have had that engagement with the industry. It has been very useful to develop policies and understand what the industry is thinking. Without the support of the FFC, we would not have been able to run our initiatives on our own." – Regulator*

Other external stakeholders recognised the influence of the CAA's 'Regulatory Sandbox' as an effective way to explore, test, and develop new operational concepts in controlled environments, while providing valuable learning opportunities, identifying regulatory gaps and informing new frameworks which have had international influence. These stakeholders were not necessarily aware of whether all of these efforts were linked to the FFC, with the exception of a few BVLOS demonstrations (e.g., BVLOS offshore energy inspections over the North Sea).

> *"I do not have it all labelled under the FFC, I have it in my mind in other areas, but it seems that the UK coined the term sandbox and everyone had to have a sandbox after the UK because that is where you could do useful exploratory work." – Industry regulator*

The engagement between CAA and the future flight industry has fostered a community among stakeholders, creating a foundation of mutual understanding regarding safety requirements and operational challenges. The FFC serves as a knowledge hub for the industry, offering expertise and facilitating dialogue. Through the FAIWG:AI working group, the FFC has facilitated collaboration between the CAA, DfT, and industry stakeholders to develop a common action plan and build the regulatory groundwork to achieve the UK's vision for the future flight industry.

> *"We recognise that the FFC has been very, very good at positioning themselves as wide experts on the whole future flight ecosystem. From our perspective, they have a really good knowledge of every single little element of future flight." – Industry stakeholder*

While stakeholders observed increased collaboration between the CAA and other national aviation authorities and the EASA as part of international working groups like JARUS and ICAO, there was limited evidence from stakeholders that directly links this engagement with FFC activities or the FFC's funding of the CAA Innovation Team or "Regulatory Sandbox" projects. However, several stakeholders noted that, without the structured support provided by the FFC, the UK might have struggled to remain competitive on a global scale, particularly compared to the US, which benefits from substantial government funding and resources.

As mentioned above, the FFC has facilitated various demonstration projects in coordination with the CAA. According to stakeholders, these real-world applications have provided valuable data and insights to support evidence-based regulatory decisions, allowing regulators to better understand the practical challenges and requirements for BVLOS operations. One stakeholder emphasised the need for better data on drone operations in order to improve safety assessments and streamline the authorisation process.

> *"We have a lack of data on drone flights…we need to discuss with operators to share data…so we can better assess the risk and then we can also be less reluctant to give some authorisations." – Regulator*

Accelerating regulatory development

While a few of the CAA's new publications and policy concepts, such as the guidance on "Carriage of Dangerous Goods by RPAS",[21] can be directly linked to specific projects funded by the FFC, attributing all recent CAA developments solely to the FFC is challenging. However, stakeholders recognised that these advancements were possible largely due to the additional resources the CAA has received in recent years to focus on regulatory innovation for the future flight sector. This is in line with the interim evaluation, which found that FFC funding allowed the CAA to secure capacity and accomplish substantially more innovation work than would have been possible without it.

Moreover, by funding and supporting innovative projects beyond traditional aviation, the FFC has driven the development of technologies that require new regulatory frameworks. Although there remain regulatory gaps, such as the absence of fully developed compliance framework for BVLOS operations, the FFC's contributions have helped reduce some of these gaps. An industry stakeholder noted that these regulatory developments would not have been possible independently, as the CAA would likely not have engaged with these projects without the intervention of the Challenge.

> *"The Challenge had a very positive impact as it was funding various companies and projects the CAA would not have engaged with. And that engagement was very useful in helping the CAA develop its policies and understand the industry's way of thinking. For example in the development and testing of the policy of detect and avoid." – Industry stakeholder*

In addition, the FFC's support of BSI activities was recognised by stakeholders consulted as helpful and valuable in shaping future compliance as it would deliver tangible outputs. Indeed, the FFC has set clear targets for the BSI, as part of its Future Flight Standards Programme, which aim to identify, prioritise, and develop new standards to accelerate innovation in the future flight sector. In particular, the UK SORA framework has been developed in part due to industry engagement driven by FFC-funded projects. This framework will help operators understand the air risk and regulatory requirements for safe BVLOS flights. However, while stakeholders acknowledged that these efforts are useful, they mentioned that the approach to standards and compliance across the industry needs to be more systematic and organised, with a specific emphasis on raising awareness of standards, a challenge that extends beyond the UK.

21 CAP 2248: Carriage of Dangerous Goods by Remotely Piloted Aircraft Systems

BSI's Future Flight Standards Programme

The BSI is leading a UKRI-funded programme to "support safe trials, demonstrations and industrialisation of new classes of air vehicles through standards".[22] As part of this programme, the FFC set out four outputs:

- Flex 1903 Vocabulary: This document creates a lexicon of standard terms and acronyms used within the sector.
- BSI Flex 1904 Operational Design Domain (ODD) Taxonomy for Future Flight Consultation: This document introduces an ODD taxonomy for automated, semi-autonomous, and remotely piloted systems in the future flight ecosystem.
- PAS 1905 Future flight systems – Regulatory principles, management systems and life cycle assurance processes – Guide: Ths is a guide which outlines key regulatory aviation principles, management systems, and life cycle assurance processes, highlighting existing regulations and standards for UAS, RPAS, and AAM aircraft – currently under consultation.
- Flex 1906 SORA Guidance: This will provide acceptable means of compliance for UAS operations, with consultation expected in March 2025 in coordination with the CAA.

In addition to these outputs, the BSI programme has published an interactive standards landscape tool which includes information on over 200 standards across a variety of categories such as UAS, AAM, and digital technologies.

Promoting an inclusive future flight ecosystem

Before the FFC was launched in 2019, a major challenge in the UK was the lack of funding and support for smaller RPAS operators. The availability of funding is crucial for R&D, and larger companies are often the only ones able to afford the initial investments required to meet regulatory standards. The FFC has helped bridge this gap by providing financial support to SMEs in the future flight sector, which has been crucial for their survival and growth. Many small drone operators would not have been able to trial and continue developing their technologies without the FFC funding.

Through this funding, the CAA has also been able to support new companies that are unfamiliar with aerospace regulations, fostering a more inclusive ecosystem. By bringing together diverse stakeholders, the FFC has enhanced communication and interaction between regulators and new entrants in the drone industry, allowing the regulator to better understand the needs and challenges of various operators and make more informed regulatory decisions.

> *"One important point of UK is they are very strong in simplifying communication for new players in the drone domain… because we need to adapt our communication to companies that are not familiar with aviation jargon." – Regulator*

[22] BSI Future Flight Programme

In summary, interviews suggest that the FFC has played a pivotal role in accelerating regulatory development in the UK by promoting collaboration, facilitating real-world demonstrations, fostering innovation, and improving stakeholder engagement. Its impact is particularly evident in driving regulator-industry dialogue, which has allowed the CAA to develop policy concepts and guidance that address real-world operational needs and challenges. Additionally, the FFC has provided essential support to new companies that are unfamiliar with regulatory requirements, helping to build a more inclusive drone ecosystem. However, when it comes to the UK's positioning relative to other countries, some stakeholders found it difficult to directly attribute recent regulatory changes to the FFC, as some external stakeholders remained unaware of the Challenge and its activities

As most stakeholders noted, absence of the FFC would have likely resulted in reduced engagement between industry and the CAA, slower regulatory development, and fewer high-risk projects being tested or implemented. The FFC has provided a vital platform for funding and expertise, which might not have been as readily available, delaying the UK's regulatory progress and leadership in future flight technologies. While some advancements might still have occurred, the FFC's role has been pivotal in accelerating these developments and shaping the future of regulation in the future flight sector.

However, some stakeholders noted that that the Challenge might not have progressed as far as anticipated. In particular, some FFC-funded projects had not advanced as much as they had hoped in terms of demonstrating new technologies. While the FFC has undoubtedly contributed to the acceleration of regulatory development in the future flight sector, stakeholders acknowledged that further progress is needed to fully achieve the programme's objectives.

> *"I do think it has been valuable…it has been very positive. It might not have gone as far as it could have, but there is also a lesson to be learned here: this is taking longer than people might have expected." – Industry stakeholder*

> *"While programmes like the FFC have almost certainly been very helpful in sustaining development and moving towards those objectives, I do not believe we are quite there yet." – Industry stakeholder*

Lessons learnt from the Challenge

As the global aviation landscape becomes increasingly competitive, particularly with countries providing substantial government funding and leveraging geographic advantages, stakeholders interviewed called for the UK Government to enhance its regulatory support mechanisms. By proactively addressing its regulatory challenges, the UK can maintain its competitive edge in the future flight sector while ensuring that its regulatory frameworks remain aligned with technological advancements and best practice. Stakeholders highlighted key lessons from the Challenge in terms of promoting the advancement of regulatory frameworks to support the growth of the future flight sector in the UK.

One critical takeaway is for the UK Government to ensure the **continuation of the work started by the FFC**. Stakeholders agreed that maintaining a consistent team of experts and preserving their knowledge base is essential to avoid setbacks and support ongoing advancements. This continuity helps ensure that the ecosystem developed by the FFC can be fully deployed and utilised effectively, providing a stable foundation for future innovation in the sector, and eventually for the industrialisation and commercialisation of future flight technologies. This support is essential for ensuring that the CAA can efficiently manage the transition from segregated airspace to fully integrated airspace, where all airspace users can safely operate together.

> *"It is quite important to make sure that after Phase 3 finishes, we need to have continuity and then we have the ecosystem deployed." – Industry stakeholder*

> *"I think the approach that the CAA is taking will mean that it is just going to be safer for all users eventually. But to prevent it from becoming a barrier, that effort needs not only to be sustained, but is needs to be expanded, because there will be more work to be done as we approach certification, industrialisation and commercialisation." - Regulator*

Stakeholders highlighted the FFC's strength in **fostering collaboration** between the CAA, the DfT, and industry. Future initiatives should prioritise building strong partnerships among all relevant stakeholders from the outset to establish a well-integrated ecosystem. There was also broad recognition that the CAA's **sandbox model has been highly effective** in trailing emerging technologies, testing new policy concepts and frameworks, and generating safety data to guide policy decisions.

> *"I would keep this sandbox environment where startups innovators can continue to test ideas with the CAA and get advice…that is critical for the next stage of the FFC." – Industry stakeholder*

Some stakeholders further noted that involving the BSI from the start in this process would have amplified the Challenge's impact, as the BSI's role in developing consensus-based standards is essential for shaping regulatory frameworks and supporting compliance.

One stakeholder noted that, regarding the pace of regulation in the UK, it is important that future interventions clearly **disentangle three distinct elements: (1) technical development, (2) regulatory frameworks, and (3) commercial demonstration**, as they each require different processes and timeframes. While emerging technologies can be trialled in controlled environments, developing regulatory frameworks and achieving commercialisation depend on progress across several factors, including safety standards, equipment reliability, and the widespread adoption of electronic conspicuity devices by all airspace users.

Moreover, the UK's densely populated geography and congested airspace present additional challenges for the deployment of future flight technologies, requiring a carefully managed, longer-term transition to safely integrate these technologies into everyday operations. It is essential for all stakeholders to recognise that **achieving a mature regulatory environment**

will take time and resources and require close coordination between the traditional aviation industry, the future flight sector, regulators, and standardisation bodies.

Looking beyond the Challenge – future needs

Looking to the future, industry stakeholders consulted agreed that **flexibility in the regulatory landscape** is essential for supporting industry growth and market sustainability of future flight technologies at scale. While the CAA is working toward a long-term regulatory framework that balances industry needs with safety requirements, stakeholders recognised that achieving this balance will take several years.

Currently, **regulatory frameworks rely heavily on operational restrictions** (e.g., flying in segregated airspace), which can create challenges for the industry's growth and innovation. Transitioning from this to equipment reliance solutions (e.g., detect-and-avoid systems) marks a substantial regulatory shift aligned with industry best practice. This transition is essential for scaling commercial operations, as it shifts accountability for safety and reliability to equipment manufacturers rather than placing the full burden on operators. By moving toward a model that emphasises equipment certification, regulators can build greater trust in the technology used for operations and streamline the regulatory process.

Meanwhile, the **slow uptake of critical technologies like electronic conspicuity devices** in the UK complicates the integration of drones and other future flight technologies. In regions like Europe, particularly in countries such as Germany and France, there has been a more widespread adoption of electronic conspicuity devices, facilitating drone integration in shared airspace. The UK's slower pace in mandating such devices presents additional challenges for seamless integration in a shared airspace environment.

In this context, while there was a **demand for temporary measures** to foster industry growth, there did not appear to be consensus among stakeholders on which measures would be most effective. Some stakeholders suggested that establishing safe segregated airspace areas or dedicated air corridors for BVLOS and eVTOL operations over low-risk, low-density areas could serve as a practical short-term solution while critical supporting technologies mature, equipment and devices are developed and certified, and electronic conspicuity uptake in the UK increases. This approach would allow operators to test early-stage or partially developed technologies, including commercial models, in controlled, lower-risk environments before obtaining full regulatory approval. However, this measure was somewhat unpopular within the industry, as it goes against the long-term regulatory goal of achieving fully integrated airspace.

Additionally, other stakeholders advocated for **simplified regulatory approval pathways** or **temporary exemptions**, allowing them to use technologies that meet interim performance standards without compromising safety. This is especially beneficial for smaller RPAS operators who may lack the resources to fully develop and certify complex equipment, enabling them to participate and remain competitive in the market.

There is an optimistic yet cautious outlook for the industry's future. In particular, the growing demand for commercial BVLOS operations is pushing the regulatory framework to evolve, with the FFC playing a pivotal role in accelerating the testing of new technologies and policy concepts.

Looking ahead, **developing and deploying policies and technical standards** has the potential to streamline commercialisation by lowering costs and simplifying regulatory approvals. Once established, these standards will offer manufacturers and operators a clear pathway to compliance, supporting safer, more efficient scaling of future flight technologies.

Finally, stakeholders agreed that the UK has the potential to be a leader in the UAS and AAM sectors, but this would require ongoing investment and **strategic vision from the government** to match the pace of development seen in other jurisdictions. There was a call for the government to articulate a clear vision and strategy for the future flight sector, ensuring that the UK remains competitive in the global market. One stakeholder mentioned that future interventions should aim for a cross-departmental approach to integrate various government efforts and support the commercialisation and industrialisation of future flight technologies.

> *"We need to see that vision and we need to agree with government what is going to be the strategy to make it happen in the UK. The Challenge can be quite useful to integrate things that need to happen from different departments in a single strategy." – Industry stakeholder*

D.4 Case study 4 – Contribution towards net zero

The role of the FFC in shaping UK net zero across the future flight sector

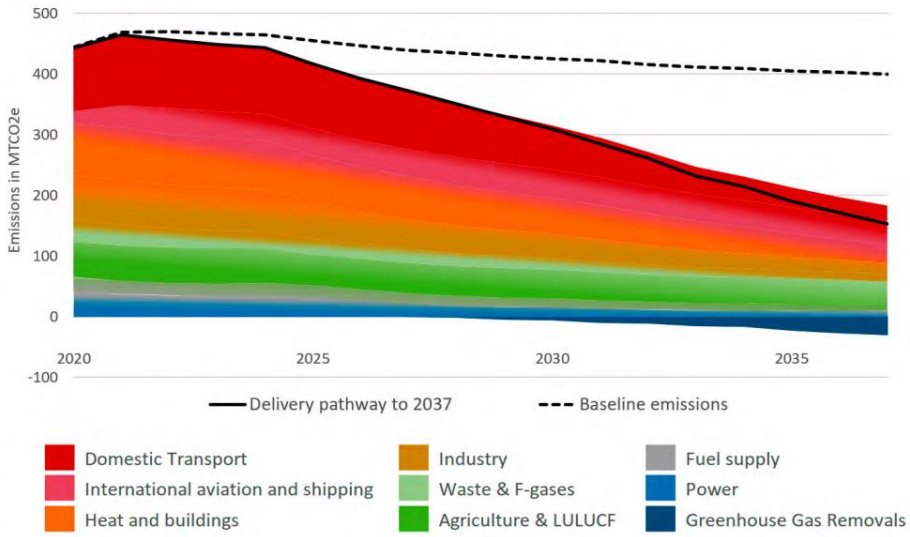
Summary of main findings

The future flight sector can be an integral part of the UK's mission to achieve a net zero aviation sector by 2050. Technologies such as uncrewed air systems (UAS), electrical vertical take-off and landing (eVTOL) aircraft, and hydrogen promise zero operating emissions, in comparison to today's technology. The Challenge has helped to increase the technology readiness level (TRL) of zero-emission technologies, while also increasing the UK's understanding of the regulatory frameworks required to achieve in-service operations and, in turn, realise the net zero benefits. However, through discussions with stakeholders, there is little to no quantitative data on the full lifecycle emissions of future flight technologies and services. Challenge investment has focused predominantly on technology development and regulatory progression, and less on the potential carbon benefits. With little evidence available, it is challenging to draw a conclusion on the impacts the future flight sector may have on the UK's ambition for a net zero aviation industry by 2050. In order to better understand the environmental impact of future flight, a better understanding of scaled-up operations will be needed to support accurate lifecycle emission assessments.

Case study context

In 2021, the UK set out a Net Zero Strategy, building on a set of policies and proposals to help decarbonise all sectors of the UK economy by 2050. According to this strategy, transformation across all sectors will require significant investment and technology advancement to meet the UK's ambitious targets.

At the time, it was estimated that the aerospace sector would play a small role when compared to the emissions of other transport sectors in the UK such as cars and heavy goods vehicles. However, it provides the opportunity for the UK to leverage its net zero aviation leadership[23] in support of other UK-based domestic transport. The figure below provides an understanding of how each sector (including aviation) must look to reduce its emissions if the UK is to achieve its objective of a greener future. [24]



As technologies such as UAS, eVTOL, and hydrogen/electric aircraft begin to take flight, we will see a significant growth of air traffic in our skies over the next few decades.[25] However, combatting emissions while continuing to increase commercial operations, such as passenger flights or delivery services, may lead to an imbalance in achieving our environmental objectives. It is therefore important to explore how future technologies such as UAS could carve a path to delivering organisational growth while embedding solutions that help to achieve our UK 2050 net zero targets

23 https://www.sustainableaviation.co.uk/wp-content/uploads/2023/04/SA9572_2023CO2RoadMap_Brochure_v4.pdf

24 BEIS Analysis 2021.

25 The future of global air travel – Airport World

Purpose of the case study

This case study explores how organisations supported by the Challenge are developing technologies that may impact the UK's vision for a net zero aviation future by 2050.[26] This case study explores the impacts on operational carbon emissions only. Data is not currently available to perform an extensive review of the future flight impacts on non-carbon emissions.

Evolution of net zero across the future flight sector – before and after the FFC

According to stakeholders interviewed, before the Challenge intervention in 2019, future flight organisations were promoting their technologies as having *"zero operating emissions"* while presenting ambitious timelines for their deployment in the UK.[27] Stakeholders highlighted that funding opportunities were available to support future flight technologies, including initiatives from the Aerospace Technology Institute, which launched several funding programs focused on innovations such as hydrogen and eVTOL. These initiatives aligned closely with the Challenge's goal of advancing sustainable air technologies.[28]

Other countries were beginning to make ground in future flight technology, with eVTOL developers such as Joby collaborating with Uber to develop pathways towards regulatory approvals for full-scale platform demonstrations in the US.[29] Although many organisations across the world were helping to construct the foundations of a new eVTOL capability, the focus was more on the use cases and end-user benefit to draw in funding and less on quantifying the net zero impact.

Since the Challenge intervention in 2019, stakeholders interviewed agreed that there have been groundbreaking UAS and eVTOL demonstrations in the UK industry, showcasing how future flight technologies can support a host of use cases. Operations that have been transformed by future flight technologies include transportation of goods, such as emergency blood delivery alongside the UKs air ambulance services,[30] and postal and package delivery by Royal Mail.[31] eVTOL passenger delivery has begun to show promise in the UK.[32] The key sustainability benefit highlighted by stakeholders interviewed is the *"zero operational emissions"* when compared to current comparable vehicles that provide an alternative form of transport. This is the result of battery usage across the future flight sector, including UAS and eVTOL, with some exploring hydrogen propulsion options[33] in the near future.

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26 jet-zero-strategy.pdf

27 Vertical Aerospace VA-X1 (proof of concept)

28 ati-annual-review-2019-20.pdf

29 Joby Demonstrates Autonomous Flight in USAF 'Agile Flag' Exercise | Joby

30 First drones deliver urgent blood samples for Guy's and St Thomas'

31 UK's first drone mail service in Orkney extended to at least 2026 - BBC News

32 VX4-achieves-major-milestone-with-launch-of-Phase-2-piloted-flight-testing.pdf

33 The Future Flight Challenge Phase II - ZeroAvia

For context, a 2.0L diesel car which travels 100 miles will create approximately 33 kilograms of operational CO2 emissions.[34] With UAS and eVTOL both utilising an electric powertrain, they will create zero operational CO2 emissions. The diesel car emissions value is, however, insignificant in isolation because the accumulated carbon emissions from all car and taxi travel across the UK in 2019 was around 55% of emissions (over 67 MtCO2e) across the UKs domestic transport sector, including the contribution from aviation.[35] If only a percentage of all car and taxi journeys could utilise eVTOL for transport or use UAS as a delivery option, the impact of future flight technologies would make a significant impact on UK transport sector decarbonisation.

According to stakeholders interviewed, ongoing technology demonstrations have led to an increased understanding of potential emission savings. However, there is little evidence of focused quantitative research to identify the carbon benefits of future flight technologies once operations have been scaled up to predicted levels. The key benefits to larger organisations identified by stakeholders are to support their net zero targets and to increase operational efficiency, while aiding in identifying new business opportunities

Impact of FFC on net zero

Interviewees recognised how UAS flight activities undertaken as part of the Challenge are demonstrating the viability of electric/hydrogen propulsion systems, leading to net zero operations. In particular, this allowed one large organisation to inform a wider organisational strategy and it now uses future flight technologies to contribute towards its net zero targets. Specifically, future flight technology will play a key role in reducing the large organisation's carbon emissions by 50% for all crewed aircraft operations.

> *"[Following a 50% reduction in flight operations], trying to decarbonise those remaining 50% of flights that we're operating is a focus of the business." – Industry interviewee*

As part of its FFC project, one large organisation had undertaken a carbon assessment of scaled UAS operations in the future. It stressed the importance of looking toward scaled operations, with less focus on individual platforms, which allowed it to capture the scale of the potential carbon savings and the overall impact on the UK's net zero targets. The outputs of this assessment highlighted a large carbon saving benefit to the organisation, which will be used to support future commercial business cases to expand its current UAS fleet of operations.

> *"There are carbon savings to be had, but it needs to be high volume and scaled before you would see a significant benefit." – Industry interviewee*

Sustainability is at the heart of all future flight projects and is a theme echoed by public opinion. The international platform provided by the Challenge allows for "good news stories" across

34 Greenhouse gas reporting: conversion factors 2024 - GOV.UK

35 Climate and Ecological emergency | Bath and North East Somerset Council

the UK to be shared on a global scale, providing a positive glow on the perception of future flight technologies. By providing a platform for organisations to share their successes across the industry, the impact of sustainable technologies and operations will support the public perception of UAS and eVTOL from a net zero perspective.

> *"A method of taking cars off the road by instead using zero-carbon emissions will directly impact zero emissions and local air quality." – Industry interviewee*

One organisation interviewed believed the key role of the Challenge towards net zero was leadership. Described by one interviewee as an "icebreaker", the Challenge was seen to usher in a new generation of technology to underpin net zero operations across various other sectors in the UK. This crucial role has sent a message to invest in net zero technology.

> *"[The Challenge is] acting as the icebreaker, if you like, and that's the crucial role that future flight challenge has done, and that's how it's contributing in a wider way, to the Jet Zero strategy." – Industry interviewee*

Clearly, a small hydrogen PAX8 aircraft alone will have minimal environmental impact. However, the Challenge has allowed the industry to demonstrate what is possible today, breaking down the perceived barriers such as technology maturity, airspace integration, standards, and regulations. One organisation highlighted how hydrogen aircraft technology has taken strides forward under the Challenge's leadership. Some organisations believed the UK could build on Challenge-funded demonstrations and take a global leadership role.

> *"We now have a strong understanding of what the impact of hydrogen looks like." – Industry interviewee*

One organisation interviewed drew a connection between the net zero benefits of future flight technology and the social perception of the sector. Use cases linked to life-saving aids delivered by UAS provide a strong positive perception of the sector. In addition, removal of fossil fuel vehicles on a local level will improve overall air quality, which will provide further social benefits. This in turn will allow the public to observe the positive benefits the sector has to offer.

> *"I think there are greater benefits from a social perspective of this industry than the actual carbon saving aspect of it." – Industry interviewee*

> *"There are far greater health benefits before you get to the carbon benefit." – Industry interviewee*

According to interviewees, Challenge funding has increased technology readiness and paved the way for zero operational carbon emission air vehicles. However, stakeholders recognised that supporting the UK's net zero objectives was not necessarily the key objective of their funded projects. The Challenge was perceived to be more of a "technology enabler", promoting technology demonstrations that could support the UK's net zero objectives, than being the driving force for net zero change.

Stakeholders indicated that the scope of Challenge demonstrations was limited to specific use cases and, for some consortia, it was not a reflection of how the industry perceives the use of future air vehicles in its existing and/or future operations. It was therefore difficult to understand the environmental benefit of the future flight sector based on Challenge intervention. Modelling activities may provide a ballpark measure of environmental impact, but physical, scalable, and measurable demonstrations are necessary to truly increase confidence in predictions and help to add evidence of the total environmental benefit of future flight technologies for the UK's net zero targets.

Some organisations felt that the main effort to decarbonise the sector was the responsibility of the technology developers rather than the organisations which would inevitably act as the customer for net zero technology.

> *"What products and services we can develop and helping market testing about what we can offer. That will bring value to [us]." – Industry interviewee*

> *"[Net zero technology research is] probably outside of perhaps where [we] will be in terms of being that customer, you know, supplies providing you with that capability." – Industry interviewee*

> *"I'm not sure [net zero impact is] driving any decisions directly at this stage on which [technologies] we use, but it's definitely something we consider." – Industry interviewee*

Some organisations suggested that their net zero commitments were a small part of a wider organisational strategy. They believed that the industry was 10-15 years away from eVTOL air vehicles replacing existing helicopter operations, alluding to the challenges of regulation and technology maturity that are causing a deceleration towards a net zero future. Therefore, they believed that there was no immediate need to explore these options to support existing operations.

> *"Future flight technologies might be used to support net zero targets in the future, but right now, the sorts of demonstrations we are involved in are not going to dramatically support net zero." – Industry interviewee*

It is clear that sustainable principles extend beyond more than just the operational carbon emissions of any given platform and across the accumulated lifecycle of the product and/or service. If the true impact of future flight technologies is to be captured, then the full end-to-end lifecycle of the operation needs to be evaluated. This includes research into identifying the Scope 1, 2 and 3 carbon emissions,36 and will help to capture inputs from manufacture to recycling

[36] **Scope 1** emissions are greenhouse gases that an organisation emits from sources it owns or controls directly. **Scope 2** emissions are indirect, deriving from an organisation's purchase of electricity, steam, heat, or cooling. **Scope 3**,

Lessons learnt from the Challenge

For the industry to continue to grow and prosper, it is important to capture industry views on how to improve processes, leadership, and direction across the UK future flight ecosystem. This section collates the suggestions from the interviews undertaken for this case study.

Two key lessons identified by interviewees highlight improvements for future programmes on the topic of net zero:

To fully understand the impact of the future flight sector on net zero, we must first bound our definition of the sector:

- The first step in any major piece of analysis is to first define the future flight sector scope and boundaries. This includes which technologies and use cases are included in the future flight sector, and which are excluded. Some interviewees were unclear about whether their innovations (such as crewed hydrogen operations) were future flight sector-specific, or whether they belonged to the wider aviation environment.
- Some technologies, such as flightpath efficiencies for air vehicles and airspace management solutions, have a foothold in multiple camps. Improved flight operations could have a large impact on carbon emissions for current and future aircraft operations. Due to the crossover and platform-agnostic nature of these technologies, there is disparity on whether solutions such as this belong under a future flight banner.
- By developing a well-bounded definition of the sector, innovators across the sector can work together to provide proposals and projects that are dedicated to enabling the UK's third aviation revolution and quantify the net zero benefit.

Very little environmental modelling will be conducted until stakeholders have a clear idea of how to use the future flight technology:

- Phase 3 provided a flavour of the potential impact that technologies such as UAS and eVTOL can have on day-to-day operations. Delivery services and advanced air mobility have been demonstrated to have strong levels of viability for future operations in the UK. However, some of the larger organisations involved in the Challenge operate large ecosystems of operations across various departments and delivery sectors. While the Challenge provides an insight into possible technology solutions that may support increases in operational efficiency and sustainability across some operations, it does not provide a complete picture of the benefits.

The use cases that have underpinned demonstration activities as part of Challenge projects have helped to define an appropriate solution to a specific challenge. The trade-off to this approach is the inability to observe wider use cases from which future flight technology may

commonly known as the "lifecycle emissions", are those that arise across the value chain, both upstream and downstream. - What are Scope 1, 2, and 3 emissions? | McKinsey

deliver tangible benefit. Organisations interviewed are therefore hesitant to invest in studies on the environmental impact of future flight technologies without having a full-scale picture of how the technology may integrate into future operations. This therefore is a barrier to large organisations looking to quantify the sustainability benefits of the sector.

Looking beyond the Challenge – future needs

It is important for the UK future flight sector to build on the clear successes of the Challenge. Identification, application, and demonstration of sustainable future flight solutions were highlighted as the most important sustainability support constructs provided by the Challenge.

Based on stakeholders interviewes, two key considerations to inform sector strategy beyond the Challenge are detailed below.

Future programmes to include a dedicated requirement to quantify scaled net zero benefits:

- Operational carbon emission reduction was understood to be the key sustainability benefit of the future flight sector. However, there is little to no evidence to support the conclusion from a scaled-up perspective. A focused requirement would help to quantify the sustainability benefits of scaled-up operations.
- Consideration of the wider emission scopes (i.e., all activities that are captured within Scopes 1, 2 and 3 operations) should also be considered for calculation. Manufacturing and third-party activities can form a large part of an operation's overall carbon emissions and may negate and overshadow any savings identified from operational emissions. The UK has an opportunity to "lead" on truly sustainable future flight operations, which can only occur if the full lifecycle is considered from manufacture through to disposal. This will also help to better quantify the benefit of future flight technologies toward the UK's net zero targets while supporting organisations to meet their internal emissions targets.

Unlocking infrastructure to support in-service operations will open avenues for net zero technology implementation:

- There are some future flight technologies which require significant levels of infrastructure and ground support to enable future flight operations, from refuelling points and charging ports to airspace constructs and support staff.
- To date, there are very few areas across the UK that can satisfy the appropriate level of requirements needed to enable future net zero technologies such as eVTOL.

If the UK wishes to unlock technologies that may provide tangible benefit to the UK's net zero ambition, investment into supporting infrastructure must be agreed. An option may be to explore airfield sites such as general aviation airports, which may already meet some of the requirements necessary to support in-service operations and may be open to investment and market opportunities.

D.5 Case study 5 – Commercialisation and industrialisation

The role of the FFC in preparing the UK future flight sector for commercialisation and industrialisation

Summary of main findings

The FFC has enabled novel technology demonstrations along with increases in regulatory awareness of safe and assured flight operations, both of which have helped build the foundations of a thriving future flight industry in the UK. Progression has led to increased industry awareness of the scope of the tasks ahead, including the identification of key barriers that need to be overcome to achieve the next major step for the industry: in-service operations. The Challenge has supported the sector to develop a series of regulatory strategies and industry action plans that define pathways towards industrialisation and commercialisation, within which Challenge demonstrations have shaped new ideas. To achieve safe and assured operations, definition of upcoming challenges accompanied by a comprehensive plan are necessary to transform the industry from demonstration to in-service operations. It is necessary to fully understand the key barriers to both commercialisation and industrialisation as early as possible, to allow testing of the constructs that underpin progression towards in-service operations.

Case study context

The general concepts of industrialisation and commercialisation are well defined by economists, but what these terms mean in the context of the Challenge is less clear. The following definitions were developed for the Challenge to clarify the meaning of industrialisation and commercialisation of future flight technologies. Both concepts become increasingly important to consider as technology matures and certification readiness increases, and where research and innovation start to become productive.

Industrialisation of future flight technologies: In general, industrialisation is concerned with the integration of new technologies into the industrial sector so that they contribute to society and to gross domestic product. More specifically, from a future flight perspective, industrialisation includes the following considerations:

- Technological developments to encourage industrialisation include airspace integration aspects such as electronic conspicuity, detect-and-avoid, and uncrewed traffic management systems for unmanned aerial systems (UAS) – and the establishment of standards to justify certification arguments.
- Industrial airworthiness and manufacturing standards to support safety, environmental, security (including cyber security), and quality control requirements.
- Economic promotion to address research and development (R&D) of current technological limitations, such as battery technology and alternative fuel sources.

- Physical infrastructure such as vertiports in the built environment and suitable electricity distribution networks.
- Operational factors including remote pilot competencies for UAS (and electrical vertical take-off and landing (eVTOL) in the longer term) and the use of increasing levels of automation and autonomy for both UAS and eVTOL platforms.

Commercialisation of future flight technologies: This is the process of bringing novel and new technologies (products and/or services) to market and realising an acceptable economic benefit (return on investment) from the technologies within a reasonable timescale. Specific items to consider from a future flight perspective include:

- A significant factor in seeing a return on investment will be the way in which public perception positively or negatively affects acceptance and uptake of UAS and eVTOL ventures. Environmental noise standards and monitoring will be required, as will careful and considered public communications to allay fears over privacy and overflight, and concerns around infrastructure planning policy, plus the legal frameworks that will underpin these concepts.
- The public perception around accessibility, especially for eVTOL technology, will affect commercialisation. Public accessibility has multiple dimensions, including physical accessibility, geographical accessibility, and financial accessibility.

Enablement of beyond visual line of sight (BVLOS) for business-as-usual UAS operations is a key factor in supporting the commercialisation of future flight technologies. Only through allowing BVLOS operations in an acceptably safe way will there be the ability to scale-up operations to reap the efficiency, safety, and cost benefits of drones.

Purpose of the case study

This case study provides insights into how the Challenge has influenced the sector in preparation for in-service operations, supported by a set of industry recommendations on how to break down any barriers to entry that will lead to an economically viable future flight sector across the UK. A series of interviews with technology developers and end-users formed the basis of this case study.

Evolution of industrialisation and commercialisation – before and after the FFC

According to stakeholders interviewed, prior to the Challenge intervention, the focus for the industry was predominantly on technology development and regulatory breakthroughs, along with identifying the right use cases that would inevitably underpin the sector.

Interviewees felt the regulatory landscape was challenging, particularly for BVLOS testing using novel air vehicles. This had an impact on the low numbers of flight operations observed in the years before the Challenge, which caused a missed opportunity to elicit public support. Future flight policy development was slow and relatively immature, providing limited guidance and direction to the relatively small future flight industry. Building on these points, there was

very little consideration towards near-term commercialisation and industrialisation across the sector. Essentially, the sector was too immature to consider commercial models and supply chains, which undoubtedly played a role in the low levels of private sector investment.

Since the Challenge launch in 2019, the roadmap to in-service operations has been a key discussion point in UK Challenge events and wider industry discussions.Co-designed publications including the Airspace Modernisation Strategy[37] and the Future Flight Action Plan[38] have provided the industry with guidance and direction to describe pathways for enabling in-service operations. Specifically, these documents set out plans for the development and industrialisation of emerging aviation technologies and their integration into the existing civil aviation system.

Regulatory challenges, such as the enablement of UAS BVLOS operations, now have strategies in place that will edge the industry closer towards commercial operations.[39] Investment to date has served to demystify the standards and regulation that will underpin consolidated pathways to an organic UK future flight capability.[40] Meanwhile, capability development hurdles linked to future airspace management also now have co-developed roadmaps informed by future flight industry members, alongside the regulatory or government departments.[41]

Opportunities for commercialisation of future flight technologies are on the rise following Challenge intervention. Of note, there is now a growing demand for commercial BVLOS UAS operations to support logistics, infrastructure inspections, and emergency services, which are helping to shape the appropriate regulatory frameworks.[42]

Some organisations (particularly the small and medium-sized enterprise (SME) community) expressed an understanding of the wider scope and effort that will be required to achieve a cohesive and assured future flight UK capability beyond regulation alone. Although interviewees considered it essential that in-service operations arrive as early as possible, the success of the first few entrants was recognised as a more important consideration than speed to market, allowing the sector to build on a successful platform of economically viable, safe, and assured services

37 CAP1711: Airspace Modernisation Strategy 2023–2040 Part 1: Strategic objectives and enablers | UK Civil Aviation Authority

38 UK Future of Flight Action Plan

39 CAP3038: Delivering Scalable UAS BVLOS in the Specific Category - The UK CAA Technical Strategy Delivery Model | Civil Aviation Authority

40 Demystifying Standards and Regulation in Future Flight - Innovate UK Business Connect

41 UKRI-06022023-FAIWG-AI-Lets-get-flying-report-Feb-2023.pdf

42 Project CAELUS - Research & development - NATS

Impact of FFC on commercialisation and industrialisation

Stakeholders interviewed recognised that the Challenge has provided leadership and direction, which has transitioned the sector from stagnation to a commercially viable ecosystem. Stakeholders mentioned that the Challenge has played a key role in facilitating engagement between SMEs and large organisations, helping to form relationships that extend beyond Challenge projects. The Challenge has allowed the industry to identify the sector's biggest blockers to in-service operations through its diverse range of technology demonstrations, which has led to preparation for commercialisation for one large organisation.

> *"The Challenge has given us the inroads to a lot of the same partners who we're working with now, and on other initiatives." – Industry stakeholder*

> *"The Challenge has supported us in getting to [a position in which] we feel that we could commercialise." – Industry stakeholder*

> *"[A next phase] needs to be somewhere between R&D and commercialisation." – Industry stakeholder*

Public perception of future flight technologies has been identified by stakeholders interviewed as part of the case studies as both a barrier to and enabler of in-service operations. Prior to the Challenge, there was public scepticism on the use of UAS, specifically in terms of safety and privacy.[43] Following recent Challenge demonstrations, the public perception of future flight technologies is much more positive, with 68% of the UK public believing that UAS could positively impact their day-to-day activities, according to research undertaken as part of Project XCelerate.[44]

There was some expectation amongst interviewees that the future flight sector would be ready to commercialise upon closure of the Demonstration Phase, but this commercialisation has not yet materialised. Some organisations reported the cause of this to be the slow pace of regulation change.

> *"We entered into this expecting to come out at this point and go into commercialisation, but we can't because the market is not available for us to do that yet. And that is largely because of regulation and the state of regulation at the moment." – Industry stakeholder*

Lessons learnt from the Challenge

There are five key threads of feedback from interviewees which highlight lessons for the industry to achieve successful commercialisation and industrialisation. The lessons provide a

43 Are drones dangerous or harmless fun? - BBC News

44 Public Perception of Drones in the UK 68% Positive - DRONELIFE

reflection of experiences with the Challenge and identify areas of potential improvement for future programmes.

Definite steps towards commercial readiness will increase the sector's "willingness" to invest:

- An additional lack of clarity on *"return on investment"* timescales was reported by a few organisations which had been hoping to achieve in-service operations following the Demonstration Phase but which have since been managing increased investment risk.
- Some organisations shared views about waiting for other organisations and countries to *"pave the way*", allowing them to learn from their experiences and therefore reduce the cost and effort to reach commercial operations.

> *"Why don't we just wait [for other countries to progress]?" – Industry stakeholder*

The industry needs integrated future flight demonstrations that replicate a real-world environment:

- In-service future flight operations will be underpinned by an integrated "system-of-systems" model, which includes the safe management and operation of multiple air vehicles in a single volume of airspace.
- To support regulatory development, operational evidence of this real-world scenario, accompanied by the interactions between systems (such as detect-and-avoid technologies), will need to be rigorously tested, with Civil Aviation Authority oversight, to enable the safe integration and adoption of future flight technologies.
- The Demonstration Phase has consisted predominantly of segregated flight operations which do not adequately reflect a real-world scenario.

Increased awareness of the UK future flight supply chain is required to support commercial operations:

- The network of organisations that underpin the UK's future flight sector will be large and complex, and can include aspects such as raw materials, energy, manufacturing, and transportation. The supply chain for these needs to be reliable and open to support the predicted demand growth for services in the future.
- Currently, the UK's supply chain is not established to support the projected scale of operations anticipated by industry.
- To achieve industrialisation, mechanisms that define the supply chain need to be identified and appropriately funded to avoid stagnation in scaling-up operations and, instead, need to implement a robust UK supply chain ecosystem that supports strong sector growth.

Agreement on key "enabling technology" solutions will build pathways to technology selection:

- Some technologies such as electronic conspicuity are considered key to enabling a safe ecosystem across the future flight sector.
- The sector has raised concerns associated with the pace of progress in identifying a set of approved technologies, alongside the appropriate safety standards, that meet the needs of both industry and regulators.
- While there is recognition, awareness, and consideration of the implications for other more-established air users, the sector cannot progress without agreed standards that underpin design and integrated operations of future flight vehicles.

SMEs can catalyse commercialisation and industrialisation:

- SMEs are the powerhouse of innovation across the future flight sector. Their ability to develop cutting-edge capabilities has led to the Challenge being recognised as a successful, international, and industry-leading programme.
- However, as the industry transitions from R&D programmes to procurement services, some SMEs lack the knowledge, experience, or organisational structures to succeed in government procurement activities.

A requirement remains for large organisations to work closely with SMEs to reach in-service provision, with collaboration being the cornerstone to success. If industrial collaboration was to cease, a significant and perhaps irreversible barrier might cause a loss of UK industry SMEs along with an overall reduction in UK future flight services

Looking beyond the Challenge – future needs

This section summarises the suggestions from the future flight interviews undertaken for this case study. Details of lessons learnt from involvement in the Challenge are discussed, along with views on future sector needs to allow the sector to reach its potential.

Commercial and industrial viability needs to be the key focus of all future programmes

A significant level of effort is required to achieve commercialisation and industrialisation that will enable the introduction of future flight services in the UK. Technology, regulation, and infrastructure are core elements that have taken positive strides through Challenge funding. However, without a significant level of flight testing to inform how these elements are integrated (in addition to a focus on areas such as economic/cost modelling, organisational architectures, capability resilience, and assurance), progress towards in-service operations may stall.

Future consortia may benefit from replicating a real-world commercial structure applicable to in-service operations. This would allow better understanding of the customer-supplier

interactions and reduce the level of effort later required to transition from R&D to in-service operations.

Future flight technical standards are needed to support design and manufacture

Documentation to support future flight operators and the wider supply chain will streamline the core processes that will underpin future flight services. Agreed standards will reduce regulatory approval times and inform production ramp-up activities critical to enabling both in-service operations and scale-up plans. It is important to continue to consult with industry on what standards are needed, along with associated investment to support their accelerated development.

Rapid and focused progression

Future flight technologies are at different levels of technology and regulatory readiness. The Demonstration Phase has funded various future flight technology demonstrations, including UAS and eVTOL flight operations. Technology advancements and integration challenges are now better understood, but overall progress towards in-service operations of any specific air vehicle remains slow, with a growing disparity between industry entry into service timescales and those provided by the UK government. There is also a significant difference between the costs associated with entry into service for UAS versus eVTOL. To observe significant progress across the industry, some interviewees suggested that future funding programmes take a more “use-case” or “technology-focused” approach to future public funding. As an example, investment that is focused on unlocking UAS operations will lead to tangible lessons to inform other use cases, including eVTOL. This may also lead to reduced costs and lower regulatory uncertainty (particularly on the requirements for a future integrated airspace).