INNOVATION AND PROJECT MANAGEMENT

FLY ZERO

AEROSPACE TECHNOLOGY INSTITUTE

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ABOUT FLYZERO

Led by the Aerospace Technology Institute and backed by the UK government, FlyZero began in early 2021 as an intensive research project investigating zero-carbon emission commercial flight. This independent study has brought together experts from across the UK to assess the design challenges, manufacturing demands, operational requirements and market opportunity of potential zero-carbon emission aircraft concepts.

FlyZero has concluded that green liquid hydrogen is the most viable zero-carbon emission fuel with the potential to scale to larger aircraft utilising fuel cell, gas turbine and hybrid systems. This has guided the focus, conclusions and recommendations of the project.

This report forms part of a suite of FlyZero outputs which will help shape the future of global aviation with the intention of gearing up the UK to stand at the forefront of sustainable flight in design, manufacture, technology and skills for years to come.

To discover more and download the FlyZero reports, visit **ati.org.uk**

ACKNOWLEDGEMENTS

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Department for Business, Energy & Industrial Strategy

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EXECUTIVE SUMMARY

FlyZero was setup to determine whether zero-carbon emission flight is feasible for large commercial aircraft, and if a large commercial aircraft could fly across the Atlantic powered by zero-carbon emissions fuel by 2030.

The project scope was broad, covering commercial, economic, infrastructure, and regulatory issues as well as setting out the aircraft technologies required and creating preliminary designs for three zero-emission aircraft.

The FlyZero project was resourced through a unique structure of:

- Secondees from the 13 contributing companies (~55)
- Independent specialists with relevant industrial experience (~35)
- Complemented by an offload strategy (67 packages) to leverage expertise from UK industry and academia

FlyZero united a team of professionals who were passionate about the central cause of reducing the impact of the aerospace industry on the environment. This drove the recruitment activity and led to a clear team charter that was key to delivering the project mission and objectives.

The project employed an Agile methodology, with light touch policies and processes suited to a fast-paced dynamic development activity. **Reduced bureaucracy and a common toolset** was key to enable rapid cross-functional development.

Control of development activities was greatly assisted by the **flexible project management strategy** adopted, that allowed for switching between Agile and traditional techniques to suit the activities of each phase. **Small dynamic cross-functional teams** working on Challenge (sub project) activities enabled the breadth of topics to be covered in the project timeline. The adoption of this working method promoted the consideration of sustainability, commercial and industrial aspects throughout the development process.

A **professional approach to internal communications** greatly assisted with the working environment and team building culture. The ongoing Covid-19 environment limited face-to-face engagement, necessitating remote working practices. **It was essential to build a team culture and ensure an optimal collaborative working environment to achieve the project objectives.**

External governance, with a broad range of stakeholders, was key in ensuring that all aspects of the scope were considered and that the approach and technical direction throughout the project were aligned with the goals.

The development process ran from initial framework definition and key technology identification into a phase of ideas generation, allowing for exploration of the design and aircraft operating space. 27 Scout aircraft were used to further develop the technology bricks to enable concept selection. The three FlyZero concepts, covering regional, narrowbody and midsize, were developed along with the associated technology roadmaps.

A set of **Project Level Objectives were defined, enabling the balanced consideration** of safety, sustainability, commercial and operational drivers. These drove the scoring criteria for technology down-selection.

The project ran a **dynamic campaign of engagement** fit for FlyZero's profile and national significance. The engagement activity promoted awareness of FlyZero and the mission. The outputs included mapping of UK capability, technology road-mapping and showcasing current expertise.

External communication was a key focus as part of the project's remit to inspire and promote the vision of zero-carbon emissions aircraft to the UK public and industry, and to drive the UK's involvement in its development.

The utilisation of 67 offload work packages was highly beneficial to leverage the **knowledge and expertise of UK industry and academia** to support the project's internal work.

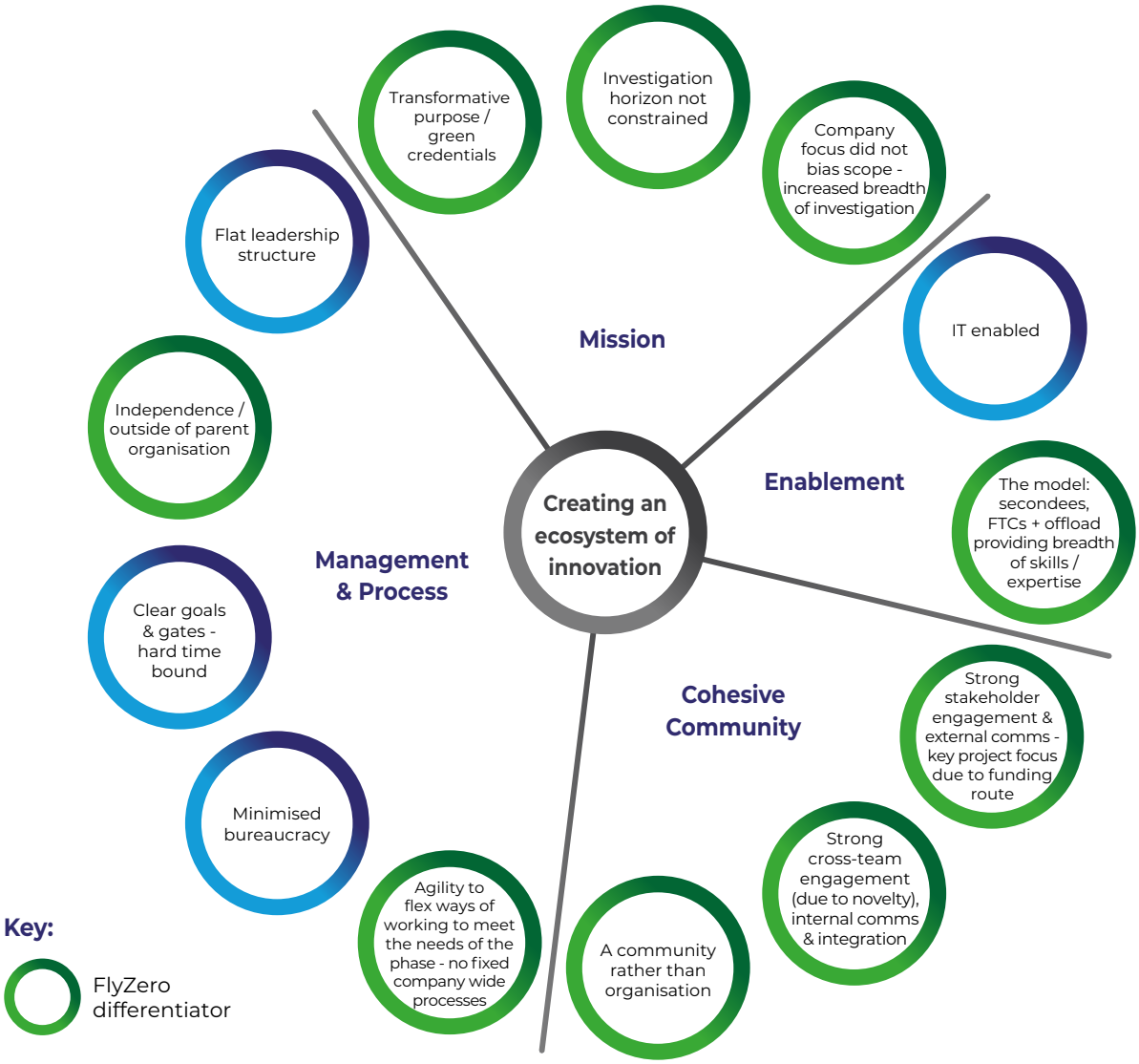


Figure 1 – Ecosystem of Innovation – Key differentiators identified in green.

Figure 1 shows the ecosystem of innovation developed for FlyZero. The success of the FlyZero environment was that it addressed all aspects of the ecosystem, including some that are more difficult to fully address in a conventional company structure. There is no silver bullet – a project leadership team must strive to cover all bases shown in Figure 1 to provide an optimum environment for innovation.

The FlyZero project has successfully delivered its objective of investigating the design challenges, manufacturing demands, operational requirements and market opportunity of potential zero-carbon emission aircraft for commercial flight.

On mission - the project had a transformative purpose with green credentials that was a key motivator for personnel. The investigation horizon was not constrained (for example to 5 or 7 years), as is often the case in an industrial setting, and company focus did not bias the scope leading to a greater breadth of investigation.

On the cohesive community - a strong stakeholder engagement and external communications strategy was implemented due to the funding route. Cross-team engagement was strong due to the novelty aspects and being able to consider the wider picture. There was a feeling of community rather than organisation, due to resource being brought together from so many different sources for an intensive research programme.

On management - the ability to rapidly place offload packages effectively added significant additional resources to the team. There was an ability to flex ways of working due to the lack of inherited process and procedures. A feeling of independence was achieved due to working outside of parent organisations - further enhancing the project's purpose.

The project structure, and its independence, offered a unique opportunity to study the breadth of topics covering not only the potential technical aircraft solutions, but also the infrastructure, commercial and industrial landscape required for operation.

The project recruited a highly skilled and motivated team (recognised in the independent Innovation Management study, see Appendix A) that were attracted to the opportunity to address solutions for sustainable flight and provide the UK with a strategy for the future of the aerospace industry. The no company badge culture brought down the natural boundaries between functions.

The development process, from ideas generation, scout aircraft development and the creation of three concept aircraft, enabled definition of the technology bricks required and the roadmaps for technology maturity.

The FlyZero structure has proven to work well for this dynamic fast-paced project, creating a collaborative interactive team culture and framework – providing an optimal environment to meet project goals and deliver a climate friendly and economically viable vision for the future of the aerospace industry.

01. INTRODUCTION

FlyZero undertook an independent and impartial assessment of the technologies that could have the largest impact on reducing carbon emissions, while meeting competitive cost and operational requirements.

FlyZero used the process of developing concept aircraft to explore the technology, manufacturing capability, skills and supply chains the UK needs to capitalise on the potential future zero-carbon aerospace market. It delivered technology roadmaps to form the basis of onward development.

Sustainability was driven through the wider project to embed the thinking into the design, engineering, industrial and commercial evaluations of the overall programme. A detailed investigation was conducted into the how the market will develop over the coming decades and how to introduce midsize, narrowbody and regional zero-carbon emission aircraft.

FlyZero has presented its independent recommendations regarding research and development (R&D) that is essential for the UK to remain a leading player in the sector going forward. This not only includes the development of the aircraft components but also the development of the UK energy infrastructure in industry and at airports.

There were significant challenges running a research project of this size in a remote working environment. Project management techniques and communications strategies were employed to address this. The project had a rapid ramp up of resource from numerous contributing companies and external sources, a robust onboarding process was introduced to build team culture and enable productivity as soon as was possible.

The offload strategy was expanded to address the resourcing challenges, leading to the contracting and management of 67 work packages. Whilst this was demanding to implement in the project timescales, it did provide access to industrial and academic knowledge and expertise that extended the breadth of subjects that could be studied.

A team of highly skilled engineers and industry professionals were recruited for the project. 13 contributing companies collaborated by providing seconded personnel and technical information to form the core of the project.

An Agile approach was adopted due to the need for an evolutionary development process and the flexibility to respond to changes in requirements. A phased approach was implemented flowing from a diverging ideas generation phase, through detailed assessment leading to concept, technology brick and roadmap definition.

The principal focus was to use small multi-disciplinary teams, working highly collaboratively in short duration loops to deliver the overall project objectives. This was particularly applicable to FlyZero due to its resourcing setup and remote working.

02. WAYS OF WORKING

02.1 PROJECT CHARTER

Our ambitions:

- We want to change the world
- We want to realise zero-carbon commercial flight by 2030, to protect our planet for the next generation
- We want long distance travel to remain safe, reliable and affordable – so our children can visit their family and friends, do business and experience other cultures
- We want to anchor aerospace and its meaningful jobs in the UK for the next generation
- Every team member's role will be part of the team delivering the future

Team Charter - Each day, we will endeavour to:

- Work together as one team, with one vision to create FlyZero
- Build a team culture that is open, sharing, trusting and empowered
- Nurture innovation, creativity and ideas that challenge the norm
- Encourage people to explore the boundaries, take risks and learn from them
- Minimise bureaucracy and processes, focusing on principles and behaviours
- Communicate in a clear and consistent manner
- Value responding to change in a quick and agile way
- Foster a fun environment in the team

The project charter was developed to define the ambitions of the project and to set out the working ethos for the team. Due to team members coming from a wide range of different companies and backgrounds it was vital to define the working environment and build a team culture from the start.

The University of Southampton study **(Appendix A)** noted that "FlyZero attracted highly capable personnel, in part because of their motivation to work on sustainable aircraft. Onboarding 'mini sprints' were a particularly valuable method, both for building social networks and as a learning mechanism."

University of Southampton study (Appendix A)

Southampton Business School supported FlyZero with an independent Innovation Management Research Project, which covered three objectives:

- Analysis of the FlyZero innovation processes
- Empirical review of homeworking project management challenges
- Development of a framework for future innovation process in a UK zero carbon aircraft supply chain

In order to nurture creativity, it was essential to minimise bureaucracy and allow the team to be open and discuss ideas in a cross functional sharing environment. The team brought a broad range and depth of skills and expertise. Working without company badges was key.

02.2 IMPLEMENTATION OF AGILE

Agile Challenge teams were implemented alongside the functional stream activities. The Challenge teams enabled a collaborative environment with multi-functional, multi-disciplinary personnel enabling much greater progress to be made versus a more traditional structure. The challenges were small sub projects, of limited duration (3-6 weeks), focused on answering very specific questions. Whole team report out sessions were held to disseminate the learning across the team, this was found to be a highly effective method of increasing knowledge across all team members.

The University of Southampton study (**Appendix A**) stated "Informal approaches to Agile, which might be called 'Agile-Lite', were the norm in FlyZero and were reported to enhance team communication."

However, they also noted that broader implementation could have been beneficial to the coordination challenge but that knowledge gaps and the fast pace of the project prohibited this. The 'Agile-Lite' approach allowed the project to benefit from Agile principles without intensive team wide formal training.

The stream activities were independent assessments that required less cross functional interaction and were to run alongside the rest of the wider team's activities. These tended to be around the commercial and industrial strategy, with some elements of the sustainability case.

Agile Project Management Methodology

The principle of Agile is to focus on small teams which are multi-discipline and highly collaborative working in short duration loops to deliver the overall project objectives.

It allows for evolutionary development, continual improvement and flexibility to respond to changes in requirement – it follows the scrum pillars of transparency, inspection and adaptation.

The approach was considered most appropriate given the following:

- Fixed time period / budget > high level of uncertainty in scope
- Incremental development > learning on the go
- Short timescales > fail fast approach required to succeed

Case Study: FlyZero Midsize Aircraft Concept Iteration Challenge

FlyZero applied a ringfenced multi-disciplinary Challenge team to optimise the concept aircrafts' fuel burn and range. This involved design changes across system interfaces, including aircraft architecture, fuel tank design, engine by-pass ratio and payload-range assumptions.

A legacy approach would likely have taken up to **three months** due to several formal communication loops, system performance studies and to amend documented requirements and assumptions for successive iterations.

Using an Agile, model-centric approach, the team had clear visibility across functional and physical interfaces. They could directly see the impact of changes in real time, enabling rapid iteration to the optimal design point in **one week**, while simultaneously communicating that to other teams via the model.

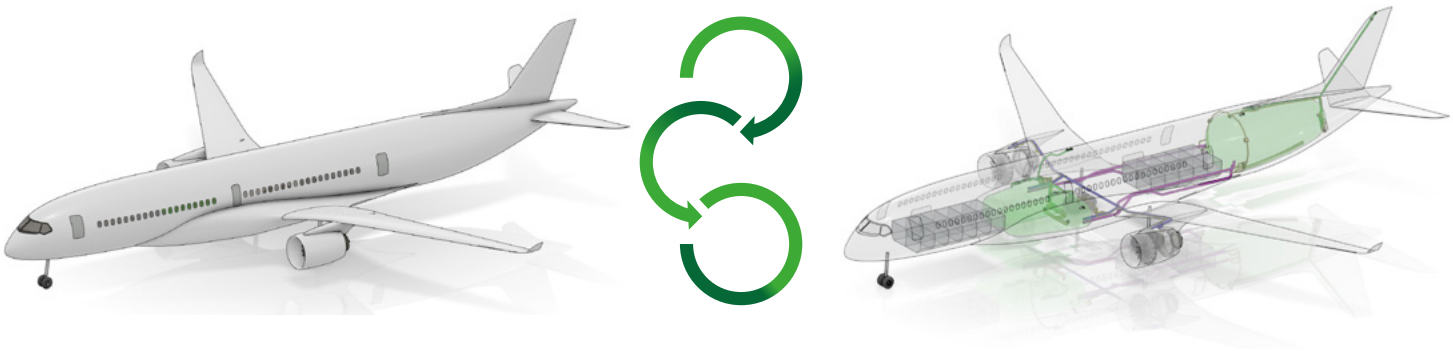


Figure 2 – Aircraft configuration to systems layout.

The accelerated schedule was made possible as there were no commercial or contractual boundaries, with trust built quickly between functions.

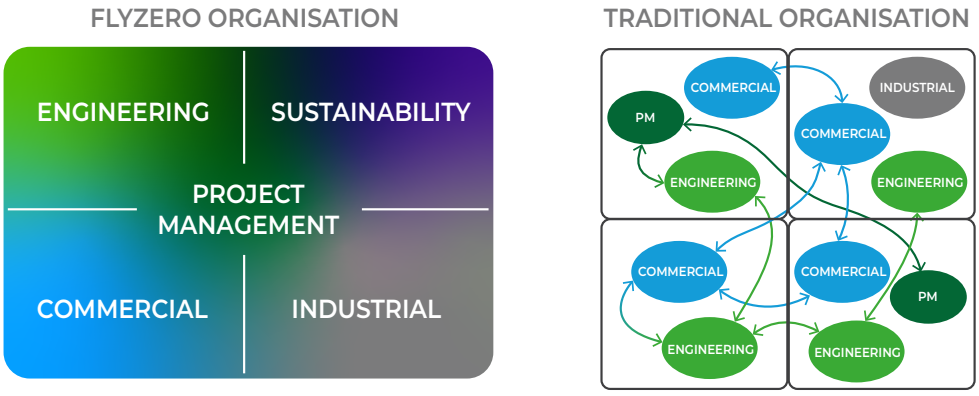


Figure 3 – FlyZero organisation versus a traditional multi-company approach with boundaries.

The integrated FlyZero approach enabled:

- Unbiased and optimised technical solutions, using the best, ring-fenced talent, from across diverse industries
- Common methods and tools, requiring fewer interfaces and data manipulation
- Better understanding of the technical challenges of different functions
- Agile requirements and solution iterations to solve complex, integrated problems

02.3 INTERNAL COMMUNICATION

The FlyZero project was unique: a team of around 100 people mobilised in less than three months, in a remote working environment, delivering a cutting-edge research programme in just 12 months. As a result, there was a continuous focus on building the team culture and ensuring the optimal working conditions for what was a very dynamic project.

Quarterly colleague feedback surveys reflected the success of the working environment with 90% of respondents agreeing "My team supports one another" and almost 3 in 4 people feeling well informed about what was happening across the project. Feedback was used to improve the communication process at each stage.

FlyZero has helped colleagues from across the UK aerospace sector to build lasting networks of contacts. It's hoped that these will facilitate collaboration and ideas sharing, even after their involvement in the project comes to an end. Although limited face-to-face events were held, they still provided an important opportunity to reflect on the successes and enjoy some time networking in person.

The University of Southampton study (**Appendix A**) agreed with the approach stating "Communications professionals have expertise in the nature, timing and style of messaging that managers will not have to the same level. Professional internal communications does not replace but supports the formal communication channels that exist within the project structure."

Weekly full team 'Team Time' sessions were held every Monday as a start the week comms session, to keep the team informed of news, progress, process updates and general communications. A FlyZero SharePoint page was run by the communications team providing announcements, tips and folder links.

Online mural boards (virtual white boards) were used for interactive brainstorming sessions and for Q&A. Mural boards were also used for planning the Challenge teams, enabling the whole team to understand the activities of others and to encourage cross team interaction. An example Challenge mural is shown in **Figure 6**. This tool proved invaluable and was used extensively throughout the project.

Communications during the Agile challenges were performed using a looping schedule with regular review sessions and whole team report outs. At the end of each phase an online retrospective was held using Slido, a web-based survey tool, to gather opinions from the team on what went well and what to improve going forward.

02.4 GOVERNANCE

Due to not inheriting a working infrastructure, policies and processes were developed specially to meet the needs of the project and be deliberately light touch in nature. This encouraged a culture and environment suited to dynamic and fast paced development. The ways of working were communicated through the various whole team meetings and events, small working groups, awareness days and training sessions.

The remit for the FlyZero project was to provide a strategy for the UK aerospace industry to grow in the zero-carbon emission aircraft arena. It was essential that the project received external review on the technical direction and overall strategy, this was provided by the senior and technical advisory boards that included representatives from the broad UK aerospace sector.

Regular reporting was undertaken to the ATI (Aerospace Technology Institute) Board and Executive Management Team, the Aerospace Growth Partnership, Department for Business, Energy & Industrial Strategy (BEIS) and the Department for Transport (DfT). This provided a broad interaction with various stakeholders and added to the review cycle.

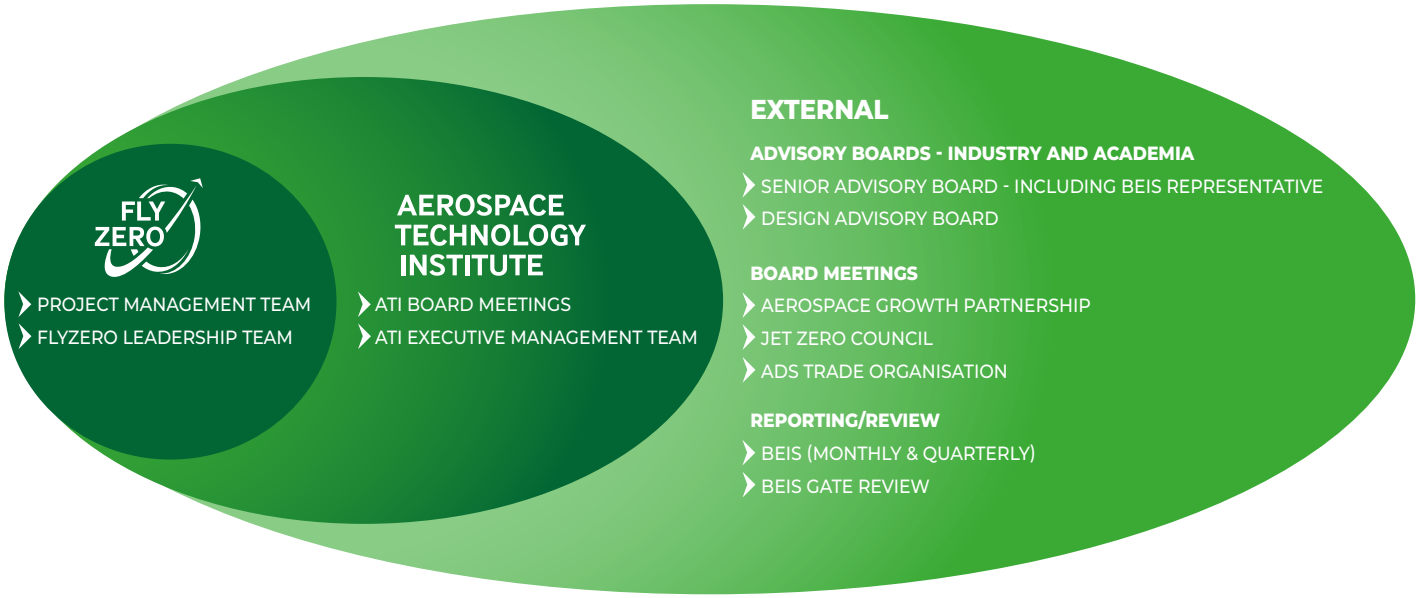
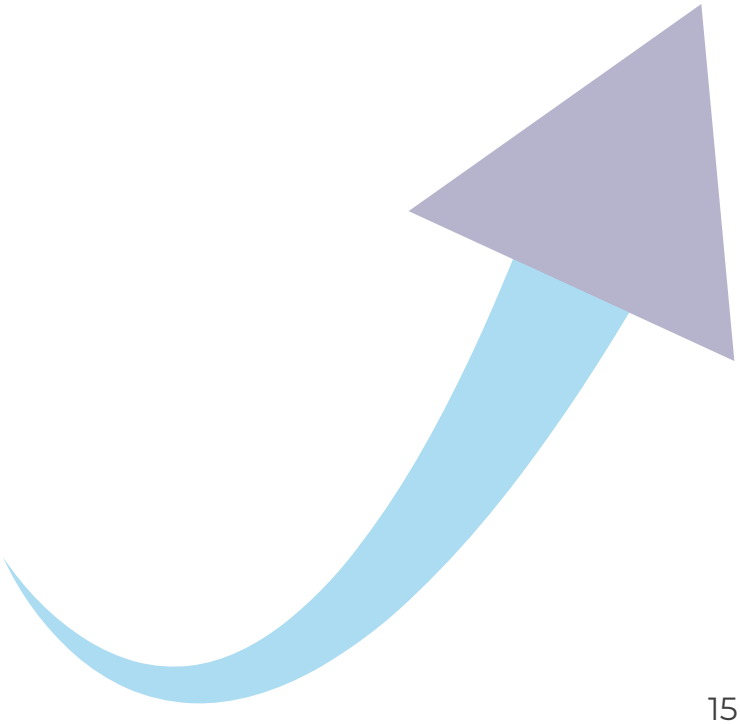


Figure 4 – Governance streams.

A reporting schedule was established to provide a clear project status into BEIS for review. These included monthly and quarterly reports / reviews, along with a mid-term gate review.

Risk management was performed at a programme level and at a function level for technical risks. Monthly reviews were held that fed into the BEIS reporting. The Covid-19 environment was obviously an ongoing challenge for the project, which was mitigated by the online environment, team culture building activities and internal communications strategy.

- Reduced bureaucracy and a common toolset were key to rapid development in cross functional teams from different disciplines (e.g. Airframe and propulsion)
- A professional approach to internal communications greatly assisted with the working environment and team building culture
- External governance, with a broad range of stakeholders, was essential in ensuring that all aspects of the scope were considered and that the approach and technical direction throughout the project were aligned with UK ambition.



03. DEVELOPMENT PROCESS

03.1 PROJECT PHASES

The project started by defining its framework and identifying the key technologies for investigation (Phase 1). During this phase, the Agile challenge teams were set up to accelerate onboarding and create a dynamic working environment moving forward. The small teams were cross functional to increase knowledge sharing.

Phase 2 defined the technology bricks required for the final solutions and allowed for a period of ideas generation around these. Phase 3 drove the technology brick development through the use of 27 Scout aircraft.

The goal of Phase 4 was to complete the main technical content through the development of the three FlyZero aircraft concepts and associated technology roadmaps. Phase 5 focused on the final project deliverables, producing comprehensive outputs for release and knowledge transfer.

PHASE 1	PHASE 2	PHASE 3	PHASE 4A	PHASE 4B	PHASE 5
FRAMEWORK DEFINITION & KEY TECHNOLOGY	**IDEAS GENERATION**	**MID LEVEL ASSESSMENT**	**DETAILED ASSESSMENT**		**OUTPUT DELIVERY**
TEAM / PROJECT SETUP KEY TECHNOLOGY IDENTIFICATION 10 TECHNICAL CHALLENGES HIRED LEADERSHIP TEAM & TEAM MEMBERS ~93	TECHNOLOGY BRICKS DEVELOPMENT - 25 TECH BRICKS RESEARCHED 23 CHALLENGES / STREAMS FIRST EXTERNAL WEBINARS HELD	27 SCOUT AIRCRAFT & SCORING 13 CHALLENGES 23 STREAMS 49 WORK PACKAGES CONTRACTED 26 ACADEMIA / 23 INDUSTRY	15 TECHNOLOGY BRICKS 3 CONCEPT AIRCRAFT 40 CHALLENGES / STREAMS ~70 WORK PACKAGES LIVE		~80 OUTPUTS
FEB - MAR 2021	**MAR - APR**	**MAY - JUL**	**AUG - OCT**	**OCT - DEC**	**JAN - MAR 2022**

Figure 5 – Project Development Process.

Over 100 challenge and stream activities were performed over the course of the project (see **Figure 6**). This enabled the breadth of topics to be covered in the timeframe. Attention was paid to ensure consistent depth of investigation across teams.

The project management model was modified for each phase to best support the activities being performed. Due to the diverging environment of ideas creation in Phases 1 and 2 an Agile style methodology was implemented. During the latter stages (Phases 4a and 4b) a more traditional approach was used, that better suited the development activities to final output creation.

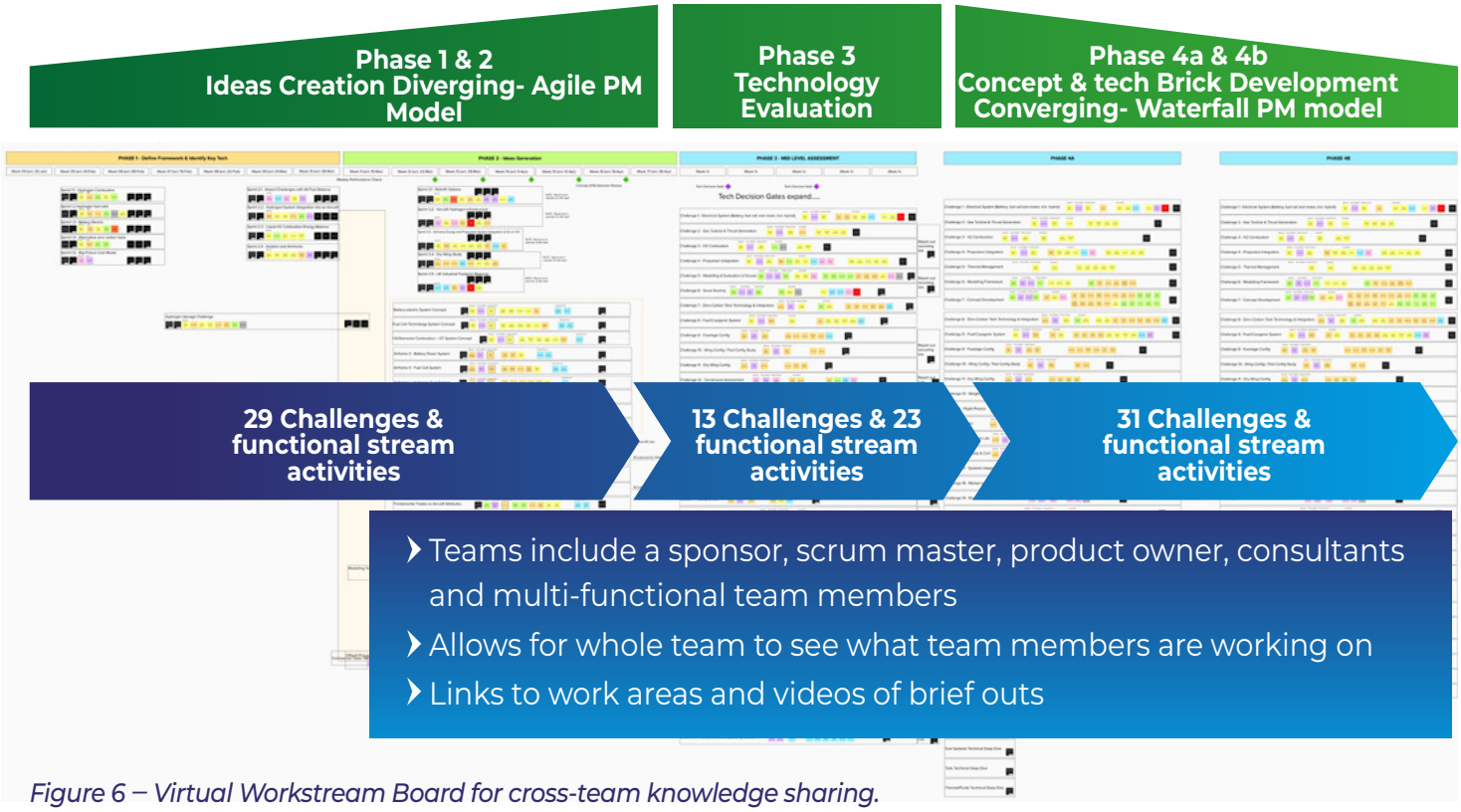


Figure 6 – Virtual Workstream Board for cross-team knowledge sharing.

Virtual workstream boards enabled the whole team to understand what everyone was working on and easily access the findings of previous studies.

Planning brochures were produced for each phase to clearly communicate the process, phase objectives, resource teams and timeline. Meeting structure and governance were setup utilising Agile style techniques. Whole team report out sessions were used to keep all groups coordinated with development activities and an integration hub was implemented to ensure consistency of data versioning.

Figure 6 is a snapshot of the 'Virtual Workstream Board' which, for each Challenge or study, contains links to:

- The tasking document, describing the aim and scope of the study
- The SharePoint working area for the challenge
- All actors, including the leadership team sponsor, scrum master, product owner and all team members
- End of Challenge reports and a video of the report out presentation.

This enabled the whole team to understand what everyone was working on and easily access the findings of previous studies. It also allowed the leadership team to balance team members across the selected challenges and ensure cross functional representation.

03.2 SCOUT AIRCRAFT

FlyZero used the development work on its Scout aircraft to further explore the technology bricks required, rather than viewing them as potential solutions in themselves.

The team's analysis was calibrated against the specifications and performance characteristics of existing aircraft covering payload, range, cruise speed and airport operational requirements.

By fusing technologies together to create the scouts, the team assessed the capability of novel technologies investigating how each scout met the mission requirements, materials, economics, operations and non-CO_2 emissions.

The scout aircraft were used to assess various potential configurations and missions. These included features such as:

- Fuselage widths, shapes and configurations
- Wing, canard and empennage configuration and placement
- Liquid hydrogen tank location
- Engine placement and propulsion types
- Range / speed / altitude performance

The scouts represent a wide range of innovative aircraft configurations each incorporating zero-carbon emissions technologies with the potential to propel the next generation of aircraft. Although the scouts will remain as concepts, they have galvanised the ideas put forward by the experts from across UK aerospace working on FlyZero, and offer a glimpse of the technologies we could see from the airplane window in future.

The internal Lessons Learned process (see **Section 5**) found that team members were further motivated by seeing their work coming to life through the creation of scout aircraft and that it enabled further technical understanding of the technology bricks.

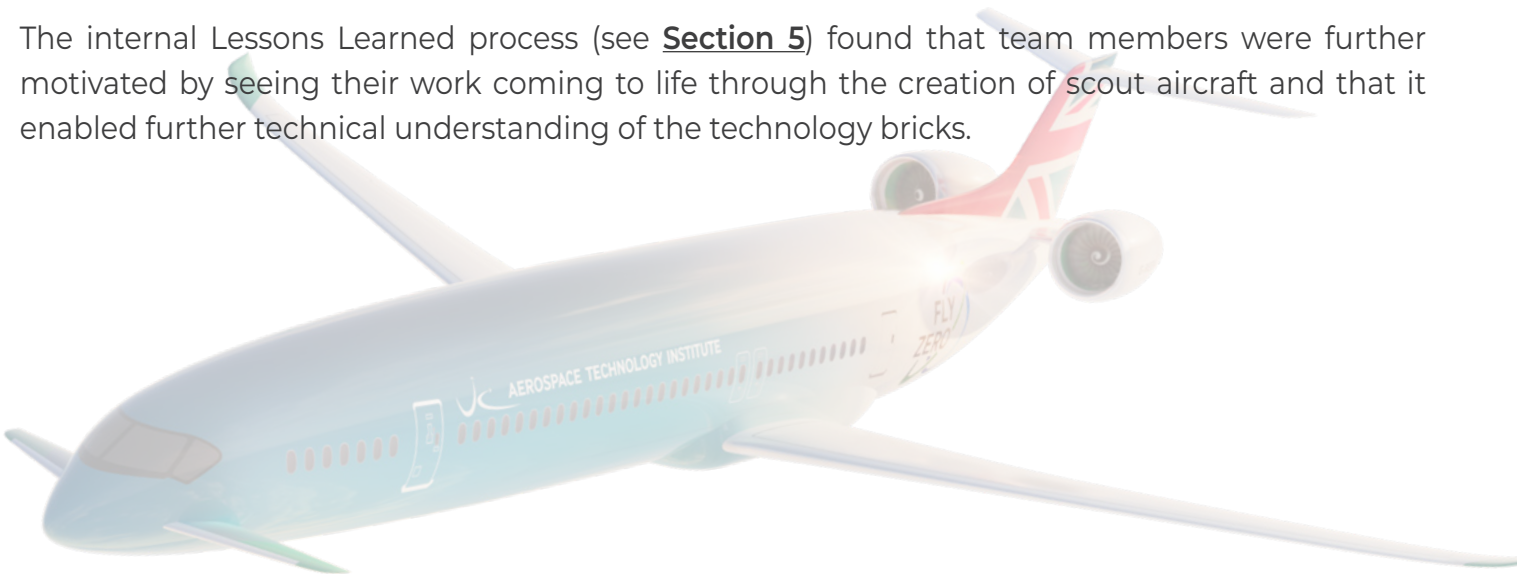


Figure 7 – FlyZero Scout Aircraft.

The scouts underwent detailed performance analysis using an internally developed mission analysis program, called GreenFlyz. The team then evaluated their features through a scoring matrix to identify the technologies, trade-offs and integration studies that need to be further explored and developed.

The scoring system used was derived from FlyZero's own project objectives in **Figure 10**. The whole team had the opportunity to influence the scoring. An external independent company was employed to review the scoring system and down-selection process to ensure there was no unconscious bias. This enabled the cross functional aspects, commercial, industrial and sustainability, to be considered, discussed and evaluated. The integration hub was used to bring these evaluations together.

03.3 CONCEPT AIRCRAFT

The three final FlyZero concept aircraft – the regional, narrowbody and midsize - represent what the team believes will be 2030 technology and zero-carbon propulsion systems. The integrated aircraft team controlled the concept aircraft configurations, allowing for rapid iteration of data to incorporate the technology developments being made and kept the whole team at the centre of development work.

While each concept aircraft was developed to some degree, their primary purpose was as integration vehicles, to explore the implications, challenges and benefits of using specific technologies. Technology roadmaps were developed to detail the current state of each technology, the potential benefits and a roadmap of how to achieve them. Around 10 technology bricks, broken down into technology strands, were developed, with the technology indicators and associated 'tipping points' identified. These 'tipping points' indicate a performance level that would make the technology viable.

In parallel, the commercial team developed the economic and market assessment, including the associated cost models for the aircraft, airports and infrastructure. The scouts and three concepts were evaluated to optimise market potential, with data sets established to provide a view of potential market penetration.

Figure 8 – FlyZero Concept Aircraft.

The sustainability team worked with the wider project to embed sustainable thinking into the design, engineering, industrial and commercial evaluations of the overall programme. The team assessed current limited research into the impacts of hydrogen technologies on climate. Investigations were performed into the Life Cycle Assessment impacts, end-of-life processing and fuel supply environmental impacts of hydrogen.

The industrial strategy team evaluated technology bricks required to achieve the FlyZero architype aircraft, assessing the UK capability and technology maturity against overseas competitors. Roadmaps were created for the key technologies with test (verification and validation) activities identified and test infrastructure required – considering both ground and flying test. This resulted in an investment and intervention strategy to realise zero-carbon emissions flight and how to accelerate the entry into service of zero-carbon aircraft.

03.4 REQUIREMENTS

Over the past couple of decades, there have been several new aircraft development programmes such as the Airbus A380, A350, A320neo and the Boeing 787.

They have all been developed and tailored for specific market segments, with evolutionary performance improvements through more efficient engines and aircraft. From a requirements perspective, this has translated to evolutionary requirements (e.g. 5% fuel burn improvement), with a clear "Customer" driving them. Alongside safety, the requirements have mainly focussed towards a commercially and economically optimised product.

For FlyZero, the fundamental and non-negotiable requirement is achieving a zero-carbon emissions aircraft, whilst still maintaining existing levels of safety. This primary requirement drives a different choice of fuel to conventional kerosene and as a result, a different optimum design space.

Given the strategic nature of the project and its focus on developing concept aircraft rather than a physical product, the emphasis of the requirements capture process is on novel aspects rather than a detailed product specification. The "end customer" is the UK aviation industry. Therefore, the primary consideration has been to document requirements that add real value to it.

A product as complex as an aircraft may appear to have conflicting requirements. For example, the aircraft needs to travel at high-speed but with reduced noise; or it needs to improve fuel burn but be cheaper to manufacture. To ensure that the FlyZero concept aircraft give a balanced consideration to the safety, sustainability, commercial and operational drivers, before even starting to document detailed requirements, a set of six Project Level Objectives were agreed during Phase 2 of the project. These have been listed in **Figure 10**.

Airbus A320neo

Boeing 767-200ER

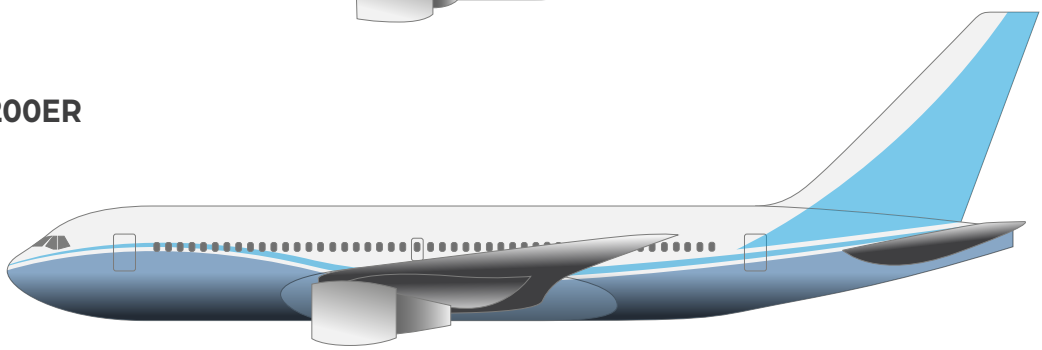


Figure 9 – New aircraft developments.

ID	Objective	Description
PLO-1	*Maximise sustainability impact on the aviation sector*	*Drives achieving true zero CO_2 tailpipe emissions rather than net zero solution, and consideration of climate impacts such as NO_x, contrails, local air quality and noise*
PLO-2	*New technology aircraft safety is at least as good as current standards*	*Introduction of novel technology to achieve zero carbon emissions that ensures a safe product*
PLO-3	*Create UK aerospace value by identifying specific technologies that best support the wider FlyZero sustainability objectives*	*Designing concept aircraft to showcase existing and proposed UK technology, skills and industrial strengths that contibute to sustainable aviation*
PLO-4	*Maximise addressable market potential of the FlyZero aircraft*	*A disproportionately higher percentage of CO_2 emissions are produced by medium and long-haul flying, these have the potential to maximise CO_2 reductions*
PLO-5	*Define FlyZero follow-on activities*	*Defining concepts with a higher potential to highlight technology gaps that require follow-on academia or industrial research*
PLO-6	*The FlyZero concepts are world-class*	*Creation of bold, exciting and futuristic aircraft designs and providing a tangible path to achieve*

Figure 10 – FlyZero Project Level Objectives.

These six Project Level Objectives drove a set of aircraft objectives and scoring criteria that were used during the Scout down-selection process. The final three concept aircraft were derived using the “best features” from the Scouts.

- A phased approach with adaptation of project management style to suit particular phase activities was beneficial in achieving project objectives.
- Small dynamic groups without bureaucracy working in Challenge teams enabled the volume of work. These sub projects answered specific questions, whole team reports outs disseminated findings to the rest of the team.
- The Project Level Objectives enabled the balanced consideration of safety, sustainability, commercial and operational drivers. These drove the scoring criteria for technology down-selection.

04. EXTERNAL ENGAGEMENT

04.1 ENGAGEMENT FRAMEWORK

The Grant Offer Letter, from BEIS, set out the engagement framework and Intellectual Property (IP) arrangements for the project.

The 13 contributing companies provided secondee resource and the opportunity to assist with background IP. All background IP provided for project use was controlled via a memorandum process – identifying sensitive material and ensuring appropriate use on the project.

Confidentiality was controlled via the use of existing agreements; ATI Framework Agreements or FlyZero Contribution Agreement, or by a separate non-disclosure agreement arrangement where these did not exist. Offload partners were covered by a standalone Supplier Agreement.

Technology assessment was carried out both by the 100-strong FlyZero team and by the 50 industrial and academic delivery partner organisations. Consultations were held for roadmap input with the UK research community, where they had relevant knowledge and expertise. In all cases, the project sought review and consensus on outputs from a wide range of organisations.

The formal foreground IP project outputs will be released in the following classifications:

- **Open source** – being available to all companies and organisations
- **Restricted release** – access provided to those who can evidence:
    - Potential to use the information for the benefit of the UK economy; for example, through use of UK-based R&D operation and / or production base
    - Route to exploiting the output with potential for the UK to contribute to the reduction of emissions from commercial flight
- **Knowledge transfer** – for future FlyZero phases / ATI use.

04.2 EXTERNAL COMMUNICATIONS AND STAKEHOLDER MANAGEMENT

The project ran a dynamic campaign of engagement, fit for FlyZero's profile and national significance. The engagement activity had a number of objectives: promoting awareness of FlyZero and the mission; supporting recruitment; horizon scanning and fact finding; capability mapping and road-mapping; dissemination / knowledge transfer; and showcasing UK capability.

The top-level stakeholder map and engagement plan is shown below. The engagement plan includes:

- A coordinated campaign of one-to-one engagement with stakeholders
- A series of events – workshops, round tables and webinars
- A campaign of media and public relations

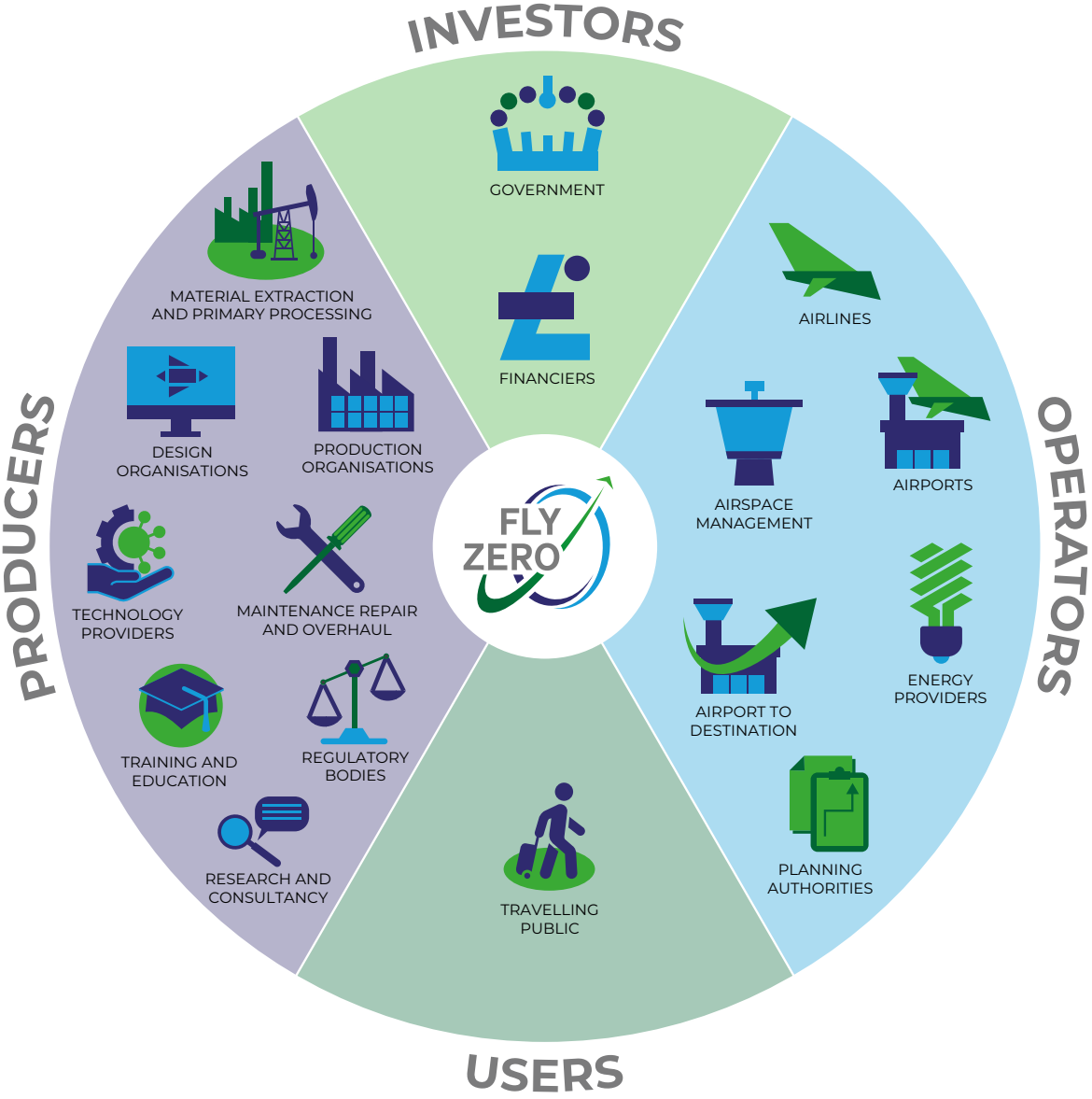


Figure 11 – FlyZero's stakeholder groups - a whole ecosystem view.

The FlyZero Communications and Engagement Strategy was built around three key objectives:

- To support a team culture which generates collaboration and ideas sharing to help galvanise solutions for the challenges this project aims to overcome
- To engage stakeholders in the project and help them get the most from it
- To share an evidence-based vision for the future of aviation with media, public and government

By setting out a vision for the future of zero-carbon emission commercial air travel that would keep families, businesses and nations connected without the carbon footprint, FlyZero has captured the imagination of people across the UK and beyond. Differing from other industrial research programmes, part of FlyZero's remit was to inspire and promote the vision of zero-emissions aircraft to the UK public and industry as well as drive the UK's involvement in its development.

The success of the FlyZero communications and engagement activity is in part down to the timeliness of the project, the creation of striking visual assets and a collaborative approach. FlyZero's positive aspiration for the future of commercial aerospace is in sharp contrast to the 'flight-shaming' sometimes directed at conventional aircraft. By unveiling a liquid hydrogen powered aircraft concept capable of reaching anywhere in the world with just one stop, the project is presenting a positive alternative to calls to restrict air travel.

1 **260 online and print articles on FlyZero's midsize aircraft concept plus two radio interviews and coverage on Sky News.**

2 **Coverage in First News inspiring the next generation.**

3 **1,000 attendees to FlyZero's free webinars.**

4 **24 news items and updates shared on the ATI website.**

5 **Presentations at 50 industry events.**

6 **Direct engagement with ~200 organisa-tions.**

04.3 OFFLOAD WORK PACKAGE MANAGEMENT

FlyZero recruited over 100 personnel during the course of the project. Engagement with academic institutions was in the baseline for the project, this was extended to include industrial offload partners to address the small shortfall in internal resource. In all, 67 work packages were contracted across all functions, providing access to expertise not found internally and extending the breadth of subjects that could be studied in the timeframe.

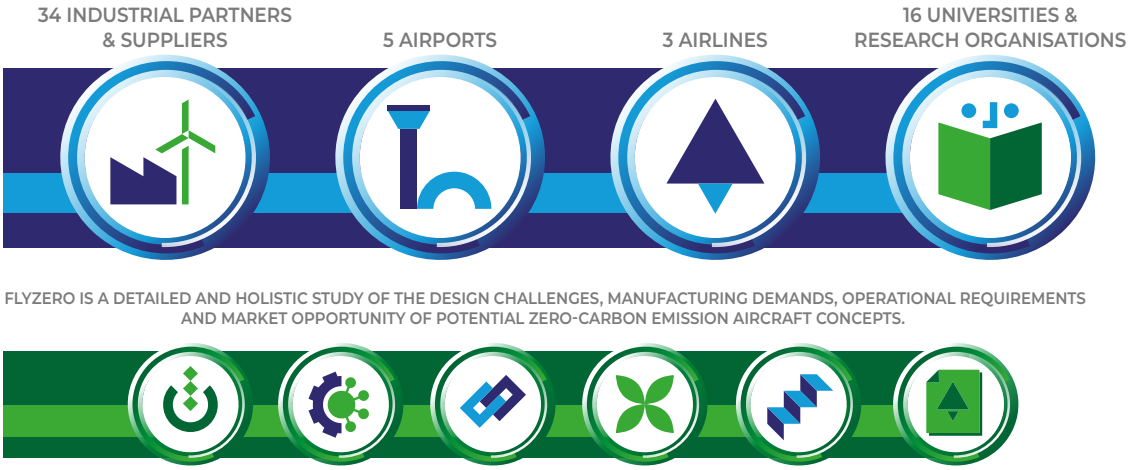


Figure 12 – FlyZero offload engagement.

Industry and academia partners are shown in **Figure 13**.

Industry Offload		Academia Offload
CAA	Jacobs	AMRC- Advanced Manufacturing Research Centre
ADS	Meggitt	Bath University
AERTEC	Mott MacDonald	Bristol University
Airbus D&S	NCC	University of Cambridge
Ansys	Norton Straw	Central St Martins- University of London
ARUP	Orson Associates	Cranfield University
Avalon	Oxford Economics	Leeds University
Belcan	Price Waterhouse Cooper	Loughborough University
CAeS	Qdot Technology	National Composites Centre
CFMS	RAW Aviation Consulting Ltd	Nottingham University
Costain	Reaction Engines	NPL- National Physical Laboratory
Eaton	Ricardo	University of Oxford
Frazer Nash	S2A	Satellite Applications Catapult
HSE	Tisics	Southampton University
Hypermotive	TWI	Strathclyde University
IFM	UKLSL	WMG- Warwick Manufacturing Group
Intelligent Energy	WEC	

Figure 13 – FlyZero offload partners.

A **dynamic campaign of engagement** was run to promote awareness of FlyZero and the mission, capability mapping, road-mapping and showcasing UK capability. This enabled a full investigation into the current capabilities and where the UK can 'play to win'.

External communication was a key focus as part of the project remit to inspire and promote the vision of zero emissions aircraft to the UK pubic and industry, and drive the UK's involvement in its development.

67 offload work packages leveraged the **knowledge and expertise of UK industry and academia** to support the project's internal work.

05. LESSONS LEARNED

The implementation of Agile methodologies drove a continuous lessons learned process and promoted a "fail fast" culture to support this. The project has provided a new and unique environment in which to run a large research project, allowing for both individuals to develop and the project to learn along the way.

Following the best practises of Agile the project ran retrospective sessions, these were conducted at the end of each phase to assess what went well, what could be improved and assess the overall team spirit. These were run as live sessions, where the whole FlyZero team was invited to participate and share their thoughts using an interactive online tool (Slido).

Aside from the retrospective sessions, other lessons learned were captured by the team when participating in the research work conducted by the University of Southampton (see Appendix A) and through personal reflection at various points in the project.

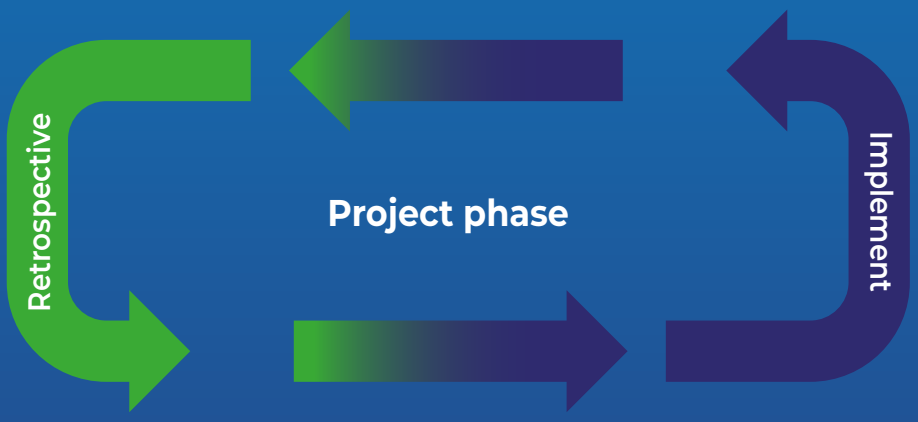


Figure 14 – Agile Retospective.

PHASE 1

The project started with a rapid ramp up of resource from the contributing companies and external recruitment. There were a number of key lessons from this stage regarding the rapid onboarding in the remote working environment:

- Project processes and tools were not in place early in the project, development of these was an immediate priority. Project management engagement prior to the main project start would have been advantageous.
- The move to an offload strategy, to mitigate resourcing issues, meant that contracting and managing an extensive portfolio of work packages became a key focus.
- A positive early lesson learned was for new team members to work in small teams on a research topic full time as part of the onboarding process. This provided an instant purpose and focus from the outset, whilst introducing team members to the FlyZero concept and working environment.

PHASE 2

Phase 2 was commenced with the Challenge team approach that had previously worked well with the onboarding activities. The phase was a period of less structured ideas generation to define the technology bricks required for further assessment. Feedback was that the phase was fast paced and challenging.

- The team saw value in working in small groups to investigate new and familiar topics, and felt it beneficial for knowledge gain and relationship building.
- The Challenge teams enabled a broad range of studies to be performed in a time bound manner. The output of these studies was briefed out to the whole team, thus spreading the rapid learning across the team members and functions.
- The importance of defining clear objectives, roles and responsibilities, alongside communication methods was a key learning in this phase.
- A reduction in meeting time was required to optimise team efficiency.

PHASE 3

Phase 3 saw the definition of the Scout aircraft and the assessment of potential technology bricks. The project management team deployed a clear working week schedule and governance, following Agile principles to address the concerns regarding the amount of time spent in meetings.

- A two-week loop was planned out including specific meetings for reviewing work. This more structured approach led to team members feeling more productive.
- The team saw their work coming to life through the creation of Scout aircraft and further technical understanding of the technology bricks.
- Difficulties were found with prioritisation, collaboration and resource workload between teams due to the growing interdependencies and the remote working environment. This impacted the depth of work on some of the technology bricks. To mitigate this, best practices for working together virtually were shared.

PHASE 4

Phase 4 was a convergent phase with the focus on detailed assessment of the FlyZero concept aircraft and development of the technology roadmaps. The following observations came out of this phase:

- There was a boost of positivity and energy following the whole team in-person event in September 2021. This shows the importance of face-to-face activities.
- The convergence on technical solutions was a key challenge in this phase, challenges were encountered ensuring completeness of technical work and closing out interdependencies. A more formal implementation of Agile at a team level could address this.
- There were also dependencies appearing from offload work packages, many of which had challenging schedules of their own. This put extra pressure on the production of final output reports at a key moment in the project. More in depth scoping of output reports could have identified these dependencies sooner.

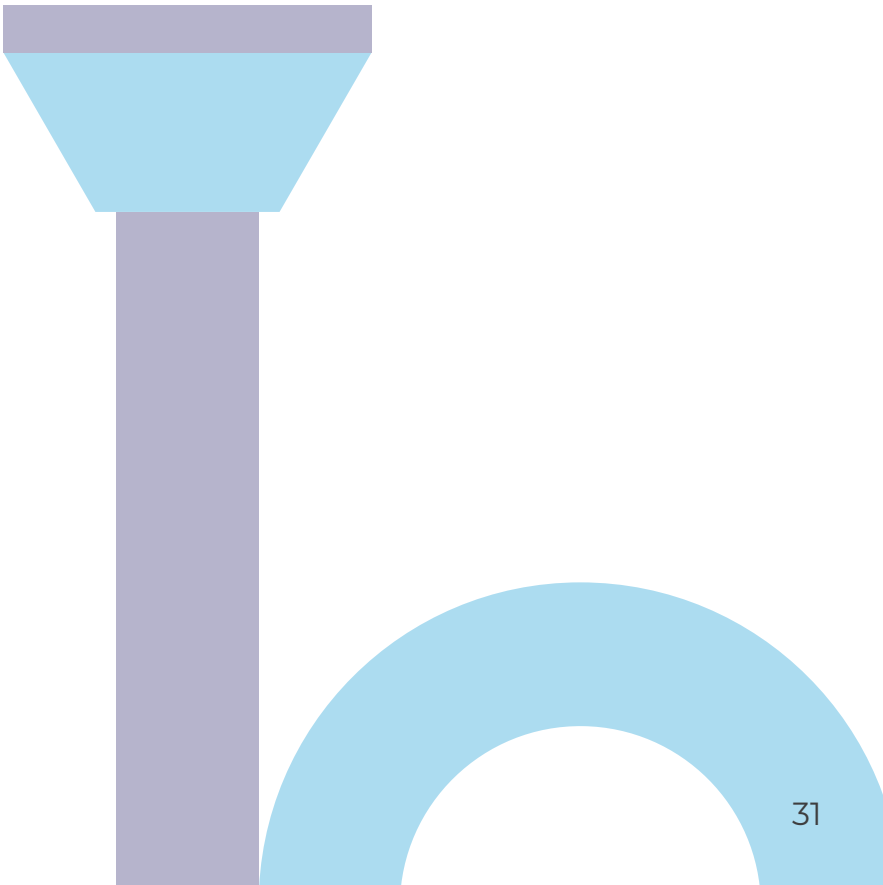
FlyZero has been a significant learning experience for all involved. The unusual experience of running a large-scale project from home has resulted in many lessons learned:

- Ensure processes and tools are implemented before mass onboarding

  Small team (Agile Challenge methodology) worked well for remote working teams

- Challenge teams can enable a high volume of tasks to be undertaken in a time bound manner, with whole team report outs to disseminate findings across the whole team

- Clear objectives, priorities, roles and responsibilities are essential



06. CONCLUDING REMARKS

There is no silver bullet – a project leadership team must strive to cover all bases shown in **Figure 15** to provide an optimum environment for innovation. The success of the FlyZero environment was that it addressed all aspects of the ecosystem - some of which are more difficult to fully address in a conventional company structure.

Figure 15 – Ecosystem of Innovation – Key differentiators identified in green.

On mission:

- The project had a transformative purpose with green credentials; this was identified consistently as a key motivator for personnel and provided a high energy environment
- Investigation horizon timeline was not constrained, as is often the case within an industrial setting
- Company focus did not bias the scope leading to a greater breadth of investigation. This was particularly noticeable with the aircraft, airport and airspace investigation.

On the cohesive community:

- A strong stakeholder engagement and external communications strategy was implemented as this was a key focus of the project due to the funding route
- There was strong cross-team engagement due to the novelty aspects, being able to consider a wider picture than is normally present in an industrial setting
- Due to the team being brought together from so many different sources for an intensive research programme, there was a feeling of community rather than organisation.

On management:

- Once key areas of research were identified - the ability to rapidly place offload packages effectively added significant additional resources to the team
- Due to the lack of inherited process and procedure architecture there was an inbuilt ability to flex ways of working to the specific phase activities
- A feeling of independence was achieved, due to working outside of parent organisations that further enhanced the project's purpose.

The FlyZero project has successfully delivered its objective of investigating the design challenges, manufacturing demands, operational requirements, and market opportunity of potential zero-carbon emission aircraft for commercial flight.

The project structure, and its independence, was a unique opportunity to study the breadth of topics covering not only the potential technical aircraft solutions, but also the infrastructure, commercial and industrial landscape required for operation.

The project recruited a highly skilled and motivated team (recognised in the independent Innovation Management study, see **Appendix A**) that were attracted to the opportunity to address solutions for sustainable flight and provide the UK with a strategy for the future of the aerospace industry. The no company badge culture brought down the natural boundaries between functions.

The development process, from ideas generation, scout aircraft development and the creation of three concept aircraft, enabled definition of the technology bricks required and the roadmaps for technology maturity.

The FlyZero structure has proven to work well for this dynamic fast paced project, creating a collaborative interactive team culture and framework - providing an optimal environment to meet project goals and deliver a climate friendly and economically viable vision for the future of the aerospace industry.

07. APPENDIX A - INNOVATION MANAGEMENT: UNIVERSITY OF SOUTHAMPTON RESEARCH

Southampton Business School supported FlyZero with an Innovation Management Research Project, which covered three objectives:

- An analysis of the FlyZero innovation processes
- An empirical review of homeworking project management challenges for FlyZero
- The development of a framework for future innovation process in a UK zero carbon aircraft supply chain.

Zero-carbon aviation represents a radical innovation, which can be defined as one which contains a high degree of uncertainty, inexperience and cost. Because of these factors, it is difficult for companies to assign large budgets to radical innovation programmes, and as such targeted government intervention could accelerate the delivery of zero-carbon aviation.

Current innovation management methods and funding mechanisms are unlikely to deliver the 2050 net-zero emissions target, at least without carbon offsetting. This research project therefore aims to accelerate the delivery of zero-carbon aviation as part of the FlyZero programme. The approach to managing this radical innovation is the focus of this research project.

This Southampton study presented its findings in four major sections: an analysis of the innovation processes applied in the FlyZero programme; remote working challenges; lessons learned from FlyZero that UK aerospace companies could adopt today; and managing innovation in the future supply chain.

07.1 FLYZERO INNOVATION PROCESSES

FlyZero represents a radical innovation context that will require multiple major advances in technology.

This radical innovation process is complex and includes several elements of uncertainty, including the specific project outputs. The project organisation has several notable features - including the use of secondees, virtual working, low project constraints and low technology readiness.

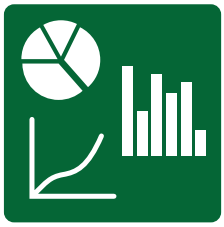
Some elements of Agile working were applied, and the degree of process formality was relatively low. These management features aligned well with the project objective of creating novel designs using emerging technologies **[1]**. There was a danger of applying increasingly formal processes, since the traditional gated models restrict the change that is necessary in innovation **[2]**. Reduced flexibility can increase development time **[3]**, while Agile methods (in software projects) can improve time, cost and quality **[4]**. The key objective of this academic study was to explore the suitability and effectiveness of the innovation process, and to consider how could it be improved.

27 participants from a range of different functions and management levels were interviewed to evaluate the innovation process. A multi-stage qualitative data analysis process was performed on the interview transcripts, using multiple researchers and in two stages. The focus of the analysis was the reported suitability and effectiveness of the innovation process.

The findings are presented under three themes: people, process, and strategy:

In terms of **people**, FlyZero attracted highly capable personnel, in part because of their motivation to work on sustainable aircraft. Onboarding 'mini sprints' were a particularly valuable method, both for building social networks, and as a learning mechanism.

In terms of **process**, the flexible approach enabled a broad exploration of new technologies but did not fully support the coordination of multiple interdependent teams. This problem will increase with scale **[5]**. A more formal implementation of Agile at a team level could address this.



In terms of **strategy**, innovation was very well supported by senior managers, and the wide external engagement was extremely valuable. As an early-stage project representing a major shift in a very large industry, the political environment has a major bearing and adds significant uncertainty. The UK aerospace industry is of interest to government because of its very large scale and its high productivity, employing around 120,000 people with a £35bn turnover **[6]**.

07.2 INNOVATION AUDIT

An innovation audit was conducted, using the well-regarded audit developed by Tidd and Bessant **[7]**. 33 survey responses were included in the data analysis. Five categories – strategy, processes, organisation, linkages and learning – are discussed below:

Notably, the FlyZero project scores well on all dimensions. This survey result supports the qualitative analysis, which found many elements of good practice and anticipated the delivery of high-quality project outcomes.

- **Strategy -** "There is top management commitment and support for innovation" ***(highest scoring).***
- **Processes -** "We have effective mechanisms for managing process change" ***(lowest scoring).***

  FlyZero comment: This reflects the retrospective feedback and subsequent modifications made to the ways of working with each phase.
- **Organisation -** "We work well in teams" ***(highest scoring)***, "Our structure helps us to take decisions rapidly" ***(lowest scoring).***
- **Linkages -** "We work well with universities and other research centres" ***(highest scoring).***
- **Learning -** "We learn from our mistakes" ***(highest scoring)***, "We use measurement to help identify where and when we can improve our innovation management process" ***(lowest scoring).***

The key strengths of FlyZero that will remain important may come under pressure if the project is brought back into the partner companies.

07.3 REMOTE WORKING CHALLENGES

FlyZero is unusual: a project that started in a fully remote work setting and remained largely remote, other than for a small number of team building events and some management team meetings in the latter stages (as pandemic restrictions allowed).

Remote working has both positive and negative effects. The **key negative effect** is that relationships are not as easily formed and that more time is spent in online meetings. Some found problem solving and detailed technical discussions more difficult in the remote setting. The **key positive effect** is that productivity in a remote work setting is higher due to the ability to concentrate on the task in hand. Given the choice, people expressed a preference to work in a hybrid setting. The project recruitment activity benefited from being able to engage with resource from a wider geographical area.

07.4 LESSONS LEARNED FROM FLYZERO

There are three key observations from the project as lessons learned that UK aerospace companies might adopt today. They include Agile, motivation and communication.

Agile

The FlyZero project applied a range of principles and practices that had been derived from Agile. The choice of management method is contextual and needs to fit the existing organisational design and structure. Informal approaches to Agile, which might be called 'Agile-Lite', were the norm in FlyZero and were reported to enhance team communication. FlyZero did not specifically apply Agile methods to the coordination challenge, largely due to knowledge gaps and the fast pace of the project. The UK aerospace industry would benefit from the careful **evaluation of Agile methods** for more widespread use. Training and skills will be critical.

Motivation: Sustainability and Learning

FlyZero personnel were very highly motivated and often this came from the opportunity to create a lasting legacy in green aviation. Aerospace organisations working on green aviation can use their sustainability objectives for recruitment. This will result in wider access to critical engineering skills and could also serve to enhance longer term motivation.

Another important element relating to the high motivation in FlyZero is the freedom to explore new areas. The FlyZero project ran short sprints as part of their onboarding process. This turned out to not only be a cultural onboarding activity with social value, but also an important learning tool with enduring technical value. Existing aerospace companies could make effective use of this 'research sprint' method as part of an ongoing learning and improvement process.

Communication

The FlyZero team included professional personnel for internal communications. One of the major challenges in running a project in a dynamic setting is coordinating the outputs of multiple teams. A professional approach to communications could significantly improve the wider knowledge about the project and signpost any areas that need more detailed coordination. Internal communications should keep people informed and provide channels for feedback. Communications professionals have expertise in the nature, timing, and style of messaging that managers will not have to the same level. Professional internal communications do not replace but supports the formal communication channels that exist within the project structure.

07.5 MANAGING INNOVATION IN THE FUTURE UK ZERO-CARBON AIRCRAFT SUPPLY CHAIN

This section describes how the UK aerospace ecosystem might address the challenge of delivering zero-carbon passenger flights, with a focus on 'how to manage innovation'.

In terms of **intellectual property**, the recommendation is to continue with the business-as-usual practice of protecting new discoveries and inventions with suitable mechanisms, including patents. This strategy of protecting IP should be developed as an active strategy of managing IP as an integrated element of the business model, rather than as a separate activity managed within the R&D department.

The gradual change in the corporate world towards the more active engagement of knowledge exchange partners, and particularly Universities, was crystalised in 2003 by Henry Chesbrough, who coined the term 'open innovation' **[8]**. Open innovation "is a paradigm that assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market" **[9]**. In an open innovation setting firms should be active buyers and sellers of IP. Critically, firms should manage IP as a central and strategic part of the innovation process that includes evaluating the value of IP in the context of the company business model. Most patents are worth very little, and indeed "Technology by itself has no inherent value; that value only arises when it is commercialized through a business model" **[9]**.

A more holistic approach is also required towards **sustainability** in the future supply chain. However, given that the use phase of an aircraft currently is around- 98% of its whole-life carbon footprint (FlyZero estimate), the immediate priority is to reduce the carbon produced during the operation of the aircraft.

A major increase in the **hydrogen supply chain** will be required for the introduction of a hydrogen fuelled aircraft. Significant investment will be necessary to enable new electricity infrastructure to create green hydrogen.

In terms of **innovation management methods**, Original Equipment Manufacturers in the UK aerospace supply chain now have a major opportunity to develop new approaches to managing large-scale novel technology projects. Rigid, plan-driven approaches are unsuitable for uncertain projects. New approaches to requirements, contracts and procurement, risk management, and team coordination should all be considered within a new 'management innovation' project. Widespread and deep changes are required, so that the very nature of the organisations will change. This may prompt the creation of new separate companies, to allow for radically different cultures and processes.

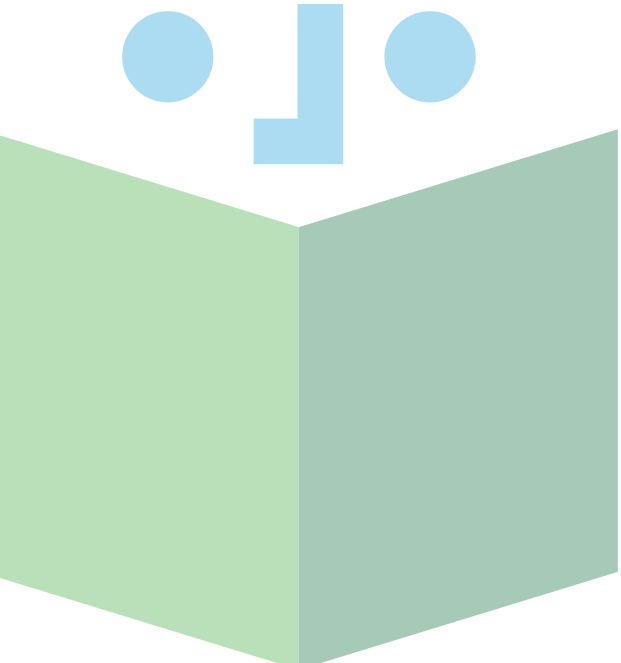
07.6 NEXT STEPS AND FUTURE RESEARCH

The key objectives of this academic study were to explore the suitability and effectiveness of the innovation process, and to consider how could it be improved. The approach was suitable, dynamic and underpinned the success of the project. Strengths and areas for improvement are outlined throughout this section.

One of the key recommendations from an innovation perspective is to invest in organisational design - focusing on the structures, processes and practices that are most suitable (1) in this radical innovation setting and (2) using leading edge digital tools and methods. When combined, this can be considered as a management innovation project.

Taking forward the lessons from FlyZero, the UK aerospace supply chain could improve their recruitment and motivation by emphasising sustainability and could improve innovation by integrating professional internal communications. Both hybrid working (combining the workplace and other locations) and the use of Agile principles in managing uncertain projects, are worthy of significant strategic effort.

Going forward, the UK supply chain must also consider adapting their approach to innovation management due to the inherent uncertainty of zero-carbon aviation and the unsuitability of rigid contracts and governance structures. A "fail-fast" approach would accelerate the development activities necessary to achieve zero-emission aviation.



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08.1 TABLE OF FIGURES

08.2 LIST OF ABBREVIATIONS

ATI	*Aerospace Technology Institute*
BEIS	*Department for Business, Energy & Industrial Strategy*
DfT	*Department for Transport*
FTC	*Fixed Term Contract*
IP	*Intellectual Property*

INNOVATION AND PROJECT MANAGEMENT

FLY ZERO

AEROSPACE TECHNOLOGY INSTITUTE