Aerospace Electrification:

ACCELERATING THE OPPORTUNITIES IN THE UK

MAY 2021

Contents

Foreword

Aerospace will be the most difficult transport sector to decarbonise.

The high power and energy requirements of aircraft, combined with the requirement for them to be lightweight, compact, and of course safe, means that many of the decarbonisation options available to surface transport do not translate readily to aviation.

Where there is challenge though there is opportunity, and we have been delighted to work with the ATI to bring together voices from industry and from the innovation community. Through this dialogue, we have recognised the strength of the UK in the technologies most likely to deliver against the exacting requirements of this sector. To do so will require a sustained and co-ordinated effort, bringing together diverse stakeholders, and aligning efforts with a strong focus on mission. Success will deliver economic and environmental sustainability to power the aviation sector into a net zero carbon future.

As a result of this joint activity with the ATI, we are pleased to present a structured approach through which the UK can deliver globally leading solutions and take economic benefit from transitioning the aviation sector to a sustainable future.

Prof David Greenwood
Director for Industrial Engagement, and CEO of WMG centre High Value Manufacturing Catapult

As the global aerospace industry maps a route to recovery, achieving sustainable aviation is the single biggest challenge.

Sustainability has always been a priority for the Aerospace Technology Institute and has focused our investments in impactful technology projects. These projects address more efficient, lighter weight wings, more efficient propulsion systems and the use of zero net carbon energy sources, reducing energy use by onboard aircraft systems and more sustainable manufacturing. Addressing the sustainability challenge brings global opportunities for UK industry.

The ATI has identified the electrification of aircraft as one of the biggest levers for achieving sustainability. The UK is regarded as a leader in electric technologies, but these capabilities are not fully engaged in aerospace. We have been working to unlock the potential in the UK supply chain, engaging with companies already in the sector to ensure they are developing the right technologies to meet future needs. As this report identifies, it is also important to engage companies that are successful in other sectors; we need to create the ambition to work in aerospace and transfer expertise and innovative technologies.

This report is the latest of our joint activities with WMG. They are a leader in electric technologies and are widely recognised as an industrial hub for electrification. In WMG we have found a great organisation with which to collaborate, and I look forward to continuing our work together.

Prof Simon Weeks
Chief Technology Officer, Aerospace Technology Institute

Introduction

Between September and December 2020, the Aerospace Technology Institute and WMG, held a series of events looking at the electrification of aviation.

A webinar, *Aerospace Electrification: Accelerating the Opportunity*, brought together over 86 experts from across the UK aerospace sector – from Government, Primes and Tier One suppliers, the supply chain, academia and research organisations – to explore the challenges in designing and manufacturing future aircraft that are powered in more electric or fully electric ways. This was followed up by a series of workshops to dive into the issues raised in the webinar's breakout sessions.

Three specific challenges, all of which must be addressed in the journey to electrifying aerospace, were examined in the course of the workshops: energy storage, machines and drives, and systems integration. High-level recommendations for each of these critical areas were produced – all with the aim of setting a baseline for future industry collaboration and development, and, importantly, for helping to define the potential opportunity for the UK supply chain.

That was the focus of this partnership of the Aerospace Technology Institute (ATI) and WMG. For the ATI, it was an opportunity to hear more from the sector about its ambitions in electric power, to feed into the Institute's own roadmaps for the technology to make this happen, and ultimately to ensure that funding applications for the ATI Programme are keeping the UK ahead in the global race to develop these advanced technologies.

For WMG, a pioneer of electric power in sectors such as automotive and aerospace, the events provided additional insight for their engineers and academics and fed into the strategic direction of their own research programmes – driving innovation to help shape the future of UK aerospace, providing new thought leadership for the UK Government and helping to deliver advanced technologies for the benefit of UK industry.

The ATI and WMG would like to thank the following organisations for their help in developing and facilitating the workshops: Airbus, Collins Aerospace, Electroflight, Rolls-Royce and Yasa.

"THREE SPECIFIC CHALLENGES, ALL OF WHICH MUST BE ADDRESSED IN THE JOURNEY TO ELECTRIFYING AEROSPACE, WERE EXAMINED IN THE COURSE OF THE WORKSHOPS: **ENERGY STORAGE**, **MACHINES AND DRIVES**, AND **SYSTEMS INTEGRATION**."

Executive Summary

Putting to one side the impact of the Covid-19 pandemic, the global aerospace sector is looking at a very exciting future.

There are significant opportunities on the horizon. New markets are emerging with the development of advanced air mobility platforms, while the move towards net-zero aviation is putting a focus on the propulsion of all aerospace platforms. It is a rapidly-changing marketplace in which there will be many new players, technologies and demonstrators.

The UK is in a strong position to take advantage of this, but there are several critical enablers that must be addressed, and this is very time dependent with regard to our global competitors. We must seize the advantages and implement the key recommendations in order to be the first to market, onshore activity in the UK, and deliver scalable technology. While hydrogen and its associated infrastructure are an integral part of reviewing electrical power and net zero technology, as is Sustainable Aviation Fuel, these were not covered by the workshops.

The Government must continue to invest in research programmes, facilities and UK capabilities, and importantly, incentivise the supply chain. At early stage, low volume production, industry ROI is difficult and centralised Government funding is required. Its Ten Point Plan for a **Green Industrial Revolution** will also need to provide clarity and standardisation for the UK's Electrification infrastructure, and build on UK competency in fuel cells.

Future airworthiness requirements will require continued support from the Civil Aviation Authority (CAA), which could expand its role to include areas such as **energy storage certification**. It is important that the latest specialist testing and certification requirements are available in the UK to enable us to compete globally with the latest developments.

The key role of system integrator provided traditionally by the Original Equipment Manufacturer (OEM) or Prime is even more critical than in current aircraft platforms as the electrified, hybrid and hydrogen fuelled systems become more complex and interdependent. That will require industry to **collaborate on technical system boundaries** rather than commercial boundaries. The OEMs and Primes must support new entrants and ensure they can meet qualification and certification requirements.

The increase in complexity will drive a rebalancing of the division between OEM / Prime and supply chain, and with that comes new opportunities: **transferring capability** and competence, and new collaborations within the supply chain that are focused on the integration of multi-functional systems.

The supply chain should be encouraged to explore **cross-sector technology** transfer across energy storage, machines and drives and system integration, to maximise existing potential and knowledge; learning from other sectors will be critical.

The next **1-2 years** are critical for investment and strategic clarity, to ensure the UK keeps pace with the global challenges and considerable overseas competition.
Getting it right now will secure **long-term opportunities**: with the advanced air mobility platforms that are expected to enter service in the mid- to late-2020s, and on to the large commercial aircraft markets, which will be beyond 2035.

By investing in and developing the UK's competencies, we can support the supply chain to understand this growing market and secure the opportunities it offers. In this way, the UK can lead the world in the research, design and manufacture of tomorrow's aircraft.

The UK needs to build on its leading capabilities and **improve its global competitiveness** through upskilling initiatives. There are opportunities for aerospace to align with national initiatives such as the Driving the Electric Revolution Challenge* programme, but there is also a skills gap that is specific to aerospace that needs to be analysed, understood and acted upon.

*The Driving the Electric Revolution Challenge programme, delivered by UK Research and Innovation, is investing up to £80m in a UK-wide programme to develop the UK's clean and resilient supply chains in power electronics, machines and drives (PEMD) (www.der-ic.org.uk).

Energy Storage

Executive Summary

GOVERNMENT

Government investment and incentivisation is critical, and must be comprehensive to anchor the requirements in the UK across:

1. The supply chain.
2. Skills and facilities to enable development and certification for energy storage, to compete globally.
3. Hydrogen / fuel cells: augmentation of policy / R&D for UK to catch up globally.

CERTIFICATION

- How and under what platform can the UK contribute to global aerospace energy storage certification? Timely investment in association with the CAA could create first mover advantages internationally and exploit leading UK expertise; critical given Brexit and departure from EASA*.
- More test house capability is needed to address specialist Aerospace battery and hydrogen/fuel cell needs.

SUPPLY CHAIN

- Provide a clear supply chain strategy for aerospace energy storage technology needs.
- Increase the UK hydrogen supply chain so that this is competitive / with clarity on UK strategy.
- Further encourage cross-sector technology transfer both for battery and hydrogen energy storage.

NEW MARKET, NEW TECHNOLOGY, NEW ENTRANTS

Many new players, technologies and demonstrators in a rapidly changing aerospace electrification market place - need to onshore / exploit activity in the UK by investing, developing and augmenting competencies and supply chain advantages.

SKILLS

UK needs to build on leading capabilities through timely upskilling to develop / commercialise global competency in energy storage technologies to augment competitive positioning.

INDUSTRY

- Clear strategic vision from OEMs and the latest Advanced Air Mobility market entrants for energy storage use cases and certification to create supply chain opportunity and encourage most relevant R&D.
- Need to ensure that cross-collaboration within existing working groups address current challenges and opportunity, particularly with regard to safety and certification.

COLLABORATIVE OPPORTUNITY

Multiple opportunities exist both in challenging the existing aero supply chain partnerships to create new more agile technology advancing engagements, and also increasing effective technology transfer from other sectors to maximise and help demonstrate the latest possibilities.

SCOPE

Investment in energy storage is a critical enabler for More Electric Aircraft (MEA), hybrid and fully electric flight to be exploited in the UK.

TIMEFRAME

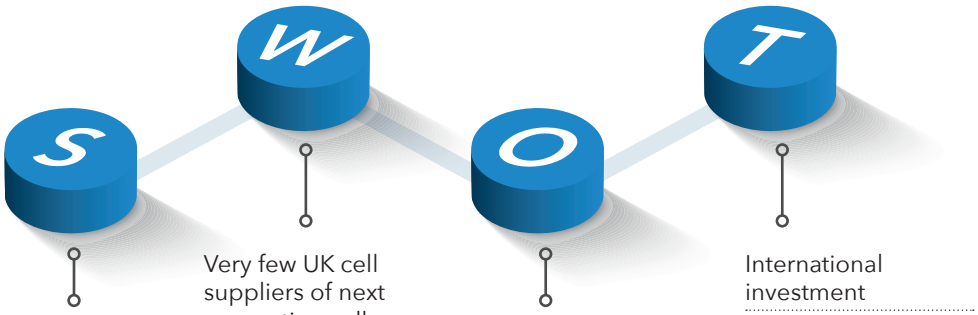
The next 1-2 years are critical for investment and strategic clarity, to ensure the UK keeps pace with the global challenges and considerable overseas competition. It is currently at a tipping point as countries jostle for position on the world stage.

*European Union Aviation Safety Agency

Energy Storage

UK Gap Analysis

CHALLENGE 1:
Energy and power density limitations



Leading UK expertise in R&D (and cross-sector)

Very few UK cell suppliers of next generation cell chemistries / cell manufacturers of AS9100* standard

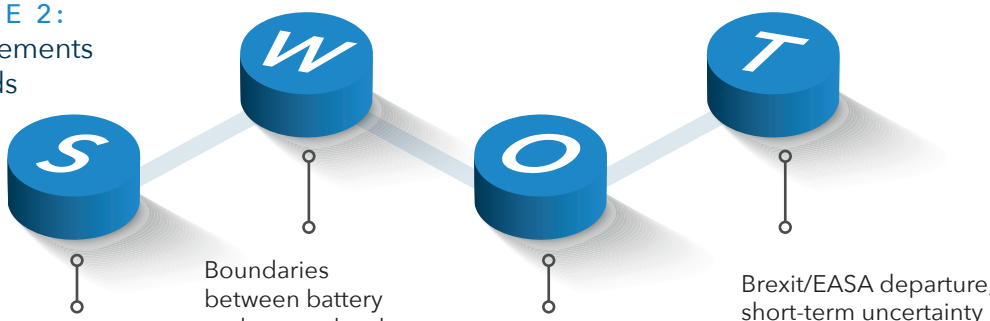
UK competency combined with cross-sector collaboration could provision considerable opportunity

International investment

Business case – ROI

Air frame manufacture not UK based

CHALLENGE 2:
Safety requirements and standards



Existing development / competencies from cross-sector/ Automotive

Good synergies between leading R&D and standards development

Boundaries between battery and system level certification still being defined globally

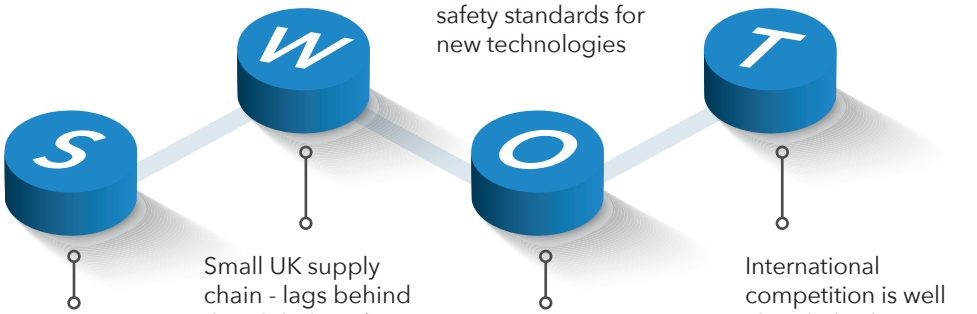
Short-term reduction in UK resources following EU exit

Opportunity to gain a leading global position in energy storage certification, in association with CAA

CAA rebuilding capability as an international regulator. Collaborating with EASA and FAA on safety standards for new technologies

Brexit/EASA departure, short-term uncertainty leading to organisations re-locating or dual locating to provide transitional stability

CHALLENGE 3:
Hydrogen and fuel cell systems



UK has good proximity to the more dominant EU supply chain

UK strength in aero engineering could help provision hydrogen / fuel cell system development – complementing existing knowledge in other sectors

Small UK supply chain - lags behind the global market

Sector knowledge: UK must consider gap analysis to recognise where the critical weaknesses are

Opportunities for reskilling and investment to gain profile and pace of development

Augmentation of UK supply chain – already existing in other sectors

International competition is well ahead – both on hydrogen systems and infrastructure – UK lags behind even in automotive

*AS9100 is the most recent general global Aerospace standard for organisations that design, develop or provide aviation, space and defense products and services, including parts, components and assemblies.

Energy Storage

Key Recommendations

ENERGY STORAGE	CHALLENGE 1: Energy and power	CHALLENGE 2: Safety requirements and standards	CHALLENGE 3: Hydrogen and fuel cell systems
Technology investment	Encourage commercial quality aero cell supplier	Develop a High Reliability Battery Development Centre (HRBDC) open access facility, to address critical aerospace needs Require virtual walk-thru end to end: demonstration of certification and costs	Augment UK supply chain to onshore technology opportunity Develop flight storage design / needs
Skills / training	Incentivise re-skilling within the industry for quickest results	Upskill existing certification-skilled engineers	Upskilling in general required Specifically in uncoupled systems Fuel cell integration upskilling
Supply chain	Determine clarity on UK supply chain strategy to best support needs	Address the risks of non-AS9100 cell suppliers – has direct implications on safety	Urgent increase in hydrogen and fuel cell supply chain and components Consider the technology challenges / opportunities regarding gaseous or cryogenic supply of hydrogen
Certification / standards	Ensure standardisation in infrastructure (lagging currently) Standardise critical measurements e.g. State of health of the energy storage / battery system (SoX)	Accelerate packs through to full certification to demonstrate proper process CAA leadership to support / align with UK positioning	Only limited electric / hybrid demonstrators are currently available so certification support is needed on a global scale, in collaboration with the CAA
Design tools / processes	Processes to support development (e.g. existing - UK Battery Industrialisation Centre (UKBIC) or the proposed future open source facility for aerospace: High Reliability Battery Development Centre HRBDC)	Requirement to understand / design full system requirements and boundaries to support process	Understanding full system integration / Electromagnetic interface is key Development at aircraft design level to accommodate hydrogen / fuel
Collaboration opportunity	OEMs could present strategy for technology and also use cases Partnerships to answer needs of cell, module, pack	Decision: Fast follower or global leader? Consolidate existing global certification data to maximise understanding	Opportunities for partnerships between aero and hydrogen to answer critical challenges – intra/ inter sector
Other	What Government policies could influence the market? E.g. for intra-regional aerospace The UK needs to 'learn fast by doing' i.e. more demonstrators or real-time built technology prototypes Prioritise i.e. what UK will NOT do Pace critical to gain advantage Can UK deliver for certification? How can FlyZero assist in a route to market? What is US approach for safety / standards and how does UK intersect?		

Machines and Drives

Executive Summary

GOVERNMENT

- There is a need to continue to invest in a range of technologies to support the diverse needs of the new platforms adopting electrification to enable net zero aviation.
- Consideration should be given to identifying the benefits of investing in a large scale production facility (gigafactory) for e-machines which could be accessible by UK supply chain companies for manufacturing at the scale required for the emerging aviation market sectors.

CERTIFICATION

Continued support of the CAA in R&D projects is key to ensuring future products meet airworthiness requirements. This is enabling non-aerospace supply chain companies to grow their business into aerospace.

SUPPLY CHAIN

- Develop a digitally enabled supply chain to support the capability and capacity for the aviation market. This includes modelling and simulation, and increasingly automated and digital manufacturing.
- The supply chain for magnet / stator / rotor materials needs to be developed as well as electrical steels.

NEW MARKET, NEW TECHNOLOGY, NEW ENTRANTS

The aerospace market opportunities through net zero technologies will drive significant demand which will require a corresponding scale up in both capability and capacity. High performance machines will be required in all platforms to increase power density and efficiency. The market is changing as new entrants emerge with smaller Advanced Air Mobility platforms which will require significantly higher manufacturing rates.

SKILLS

National initiatives on skills development (e.g. DER) should continue to target capability in digital design / manufacture methods including additive manufacturing, artificial intelligence, and multi-physics modelling.

INDUSTRY

The introduction of e-machines and drives is perceived as a market opportunity for innovation to enable net zero. The existing OEMs and Primes have a role to play to support capability development such that new entrants can meet airworthiness requirements. The key role of system integrator provided traditionally by the OEM / Prime is even more critical than in current aircraft platforms as the systems using e-machines and drives will become more complex and interdependent.

COLLABORATIVE OPPORTUNITY

Supply chain collaboration with learning from other sectors is key. The ATI, DER and Future Flight* all have a role to stimulate and develop these opportunities.

SCOPE

Machines and drives capability is core to future net zero propulsion for aerospace and is critical for all sizes of platform as well as enabling new markets to be established for sub-regional aircraft.

TIMEFRAME

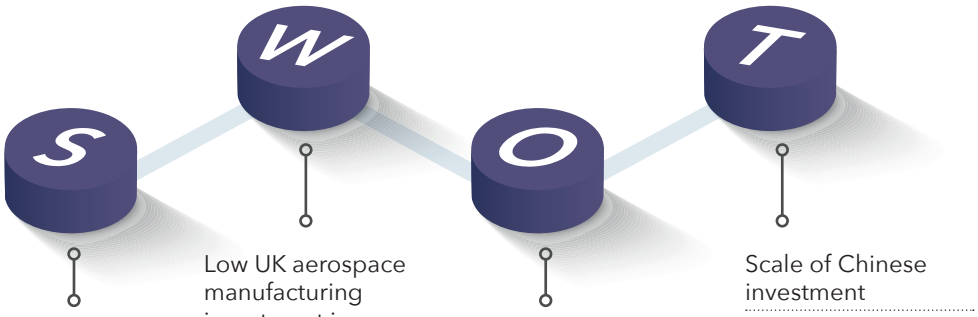
Applications for exploiting new machines and drives are anticipated in the middle of this decade in Advanced Air Mobility. Larger commercial aircraft markets are looking for technology insertion by the end of the decade.

*Future Flight is the public funding call for £125 million investment by the UK government to develop greener ways to fly, such as all-electric aircraft and deliveries by drone, by advancing electric and autonomous flight technologies. The investment is matched by £175 million from industry.
The challenge aims to bring together technologies in electrification, aviation systems and autonomy to create new modes of air travel and capability.

Machines and Drives

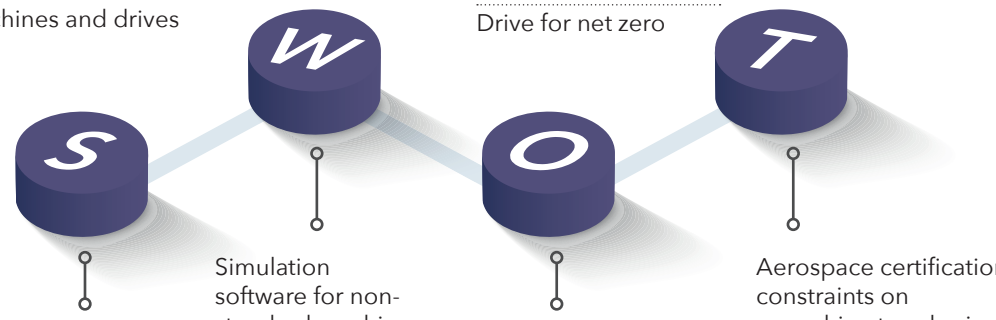
UK Gap Analysis

CHALLENGE 1: Machine technology development



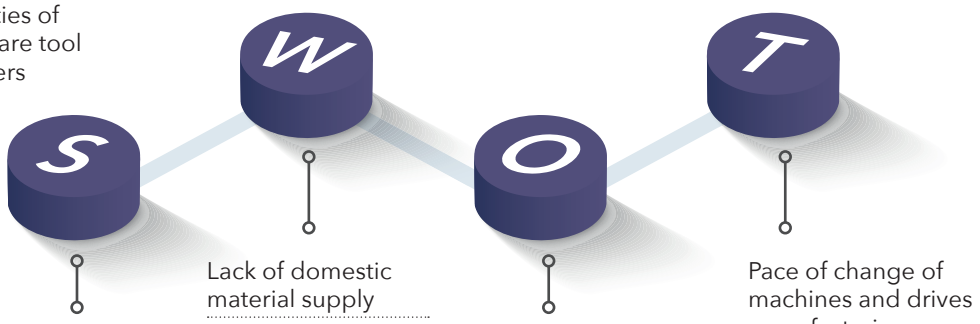
- Aerospace OEMs and Tier 1 manufacturers
- Emerging OEMs driving disruption
- Adjacent sectors developing high performance machines and drives
- Low UK aerospace manufacturing investment in e-machines compared with adjacent sectors
- Extreme operating conditions for aero-space machines
- Creation of e-machine gigafactories
- Anchor cross sector magnet supply chain in UK
- Direction from OEMs on future architectures
- Drive for net zero
- Scale of Chinese investment
- Industry recovery following Covid-19
- Unethical procurement of magnet materials

CHALLENGE 2: Attribute trade-off



- Research and Technology Organisations (RTOs) and Catapults* technical specialisms
- Established industrial and academic research capabilities and collaboration
- Capabilities of UK software tool developers
- Simulation software for non-standard machine configurations
- Building of whole system models is challenging
- Mechanical / environmental test facilities for SMEs
- Creation of a library of 'open access' vehicle level models for Tier 1/2/3 suppliers
- Apply automotive lessons learned on system design and optimisation
- Aerospace certification constraints on e-machine topologies driving divergence with other sectors
- Risk of duplication of R&D by UK companies

CHALLENGE 3: Manufacturability



- UK Government support for net zero (e.g. DER)
- Well established High Value Manufacturing Catapult
- South Wales 'silicon valley' for power electronics / semiconductors
- Lack of domestic material supply
- No UK electrical steel manufacturer
- Medium volume e-machine manufacturing capability
- Build on robotics research to increase automation
- Adoption of Industry 4.0 (e.g. additive manufacturing, computer vision)
- Pioneer design for recycling / circular economy
- Pace of change of machines and drives manufacturing needs to be world leading
- Need to manage use of materials to address reach
- Secure access to raw materials

*Catapults are a UK network of world-leading specialist technology centres established by the UK Government to accelerate research and innovation for industry (hvm.catapult.org.uk).

Machines and Drives

Key Recommendations

MACHINE AND DRIVES	CHALLENGE 1: Machine technology development	CHALLENGE 2: Attribute trade-off	CHALLENGE 3: Manufacturability
Tech investment	Investment in a range of technologies to reflect diverse aircraft requirements	Multi-physics motor analysis tools Machine testing facilities	Support for high value, low volume manufacture
Skills / training	Driving the Electric Revolution Challenge programme - skills initiative developing cross-sector skills for electrification	Multi-physics testing	Application of robotics Working with digital / Artificial Intelligence interfaces
Supply chain	Create a 'one stop shop' to promote UK supply chain and research outputs Investment in gigafactory	Develop supply chain early stage modelling and simulation capability	Develop supply chain plan automated winding, machine tools and capacity
Certification / standards	Explore applicable standards from other sectors that could evolve to meet aerospace	Engage with global OEMs to flow down emerging standards	Agreed standards for end of the line testing
Design tools / processes	Further tool development to support e-machine topologies and thermal management	Workflow development for faster design turnaround	Improved cost modelling to address manufacturing and design
Collaboration opportunity	Co-ordination of ATI, Future Flight and DER to aid linking of non-aerospace supply chains with aerospace sector	Cross-sector collaboration for lessons learned and avoidance of duplicate effort	DER Industrialisation Centres building a network

Systems Integration

Executive Summary

GOVERNMENT

- There is a need to continue to support technology and production systems and invest in a range of technologies to support the diverse needs of the new platforms adopting electrification to enable net zero aviation, including materials.
- Investment in the wider system integration agenda will enable supply chain growth into the aerospace sector.

CERTIFICATION

- Continued support of the CAA in R&D projects is key to ensuring future technology meets airworthiness requirements.
- Demonstration of systems level safety and reliability represents a major challenge in more complex systems.
- New sector entrants will have significant qualification and certification challenges to overcome which will be a role for Primes and regulatory bodies.
- Smaller airframe opportunities to enable UK flying test environments for fixed wing applications.

SUPPLY CHAIN

- Supply chain opportunities exist as future challenges and optimised systems will require system and sub-system levels of engineering rather than discrete component solutions.
- Develop a digitally integrated and aligned supply chain to support the capability and capacity for the aviation market including integrated engineering solutions across suppliers. E.g. modelling and simulation, automated and digital manufacturing, data connectivity, in service monitoring.

SKILLS

- National initiatives on skills development need to target capability in digital design / manufacture methods including systems integration, multi-physics system modelling, additive manufacturing, artificial intelligence, and multi-physics modelling.
- Skills development for whole vehicle architecture and systems engineering are required to optimise future platforms.

INDUSTRY

- Future propulsion architectures will increase system complexity requiring industry to work together on technical system boundaries rather than commercial boundaries.
- Opportunities exist for new entrants across the supply chain transferring capability and competence to support the existing aerospace OEMs and Primes. Key challenges around electrical architecture and high voltage (HV) applications need to be addressed.
- The existing OEMs and Primes have a role to play to support capability development such that new entrants can meet qualification and support certification requirements.
- Collaboration opportunities exist between traditional suppliers for integration of systems enabling multi functional components. Manufacturing and integration challenges will need to be addressed for these systems.
- Thermal management solutions required due to distributed nature of future thermal and electrical systems architectures.
- Increased digitalisation (such as digital modelling / simulation) provides opportunities to prove safety / reliability during development process integrated with physical testing and qualification.
- The key role of system integrator provided traditionally by the OEM / Prime is even more critical than in current aircraft platforms as the electrified, hybrid and hydrogen fuelled systems become more complex and interdependent.

NEW MARKET, NEW TECHNOLOGY, NEW ENTRANTS

- Significant scale up in demand for both capability and capacity across propulsion systems and airframe integration.
- High performance / high robustness solutions required with airframe integration to achieve mission performance targets.
- Scale up and integration of multiple aircraft systems presents opportunities for UK supply chain.

COLLABORATIVE OPPORTUNITY

Supply chain collaboration with learning from other sectors is key. The ATI and CAA will be able to provide the catalyst for UK supply chain opportunities to be exploited.

SCOPE

Systems integration of propulsion architectures and future airframe is critical to net zero propulsion across all platforms and enables new markets to be established.

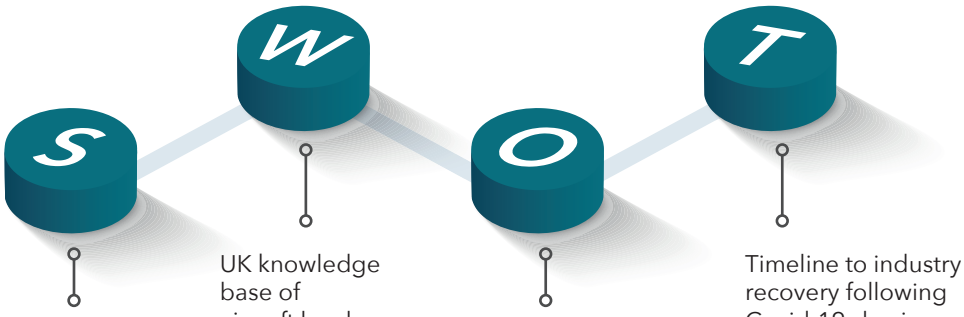
TIMEFRAME

Applications for exploiting airframe and systems opportunities will be beyond 2025 but larger platform applications will be moving towards industrialisation around 2030. Future platform architectures will be beyond 2035.

Systems Integration

UK Gap Analysis

CHALLENGE 1:
Airframe integration



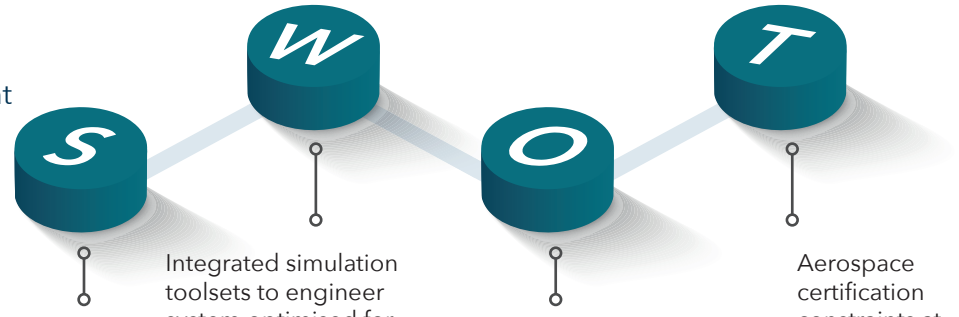
- Aerospace OEMs and Tier 1 manufacturers and supply chain
- Emerging UK based OEMs driving disruption
- Adjacent sector supply chain integration and systems capability
- UK aerospace research capability

- UK knowledge base of aircraft level considerations

- Direction from OEMs on future aircraft architecture - tube and wings, blended body
- Increased complexity enabling system integration mission specific opportunities

- Timeline to industry recovery following Covid-19 slowing new platform investment
- Non-UK airframe providers focus activity in other nations

CHALLENGE 2:
Thermal management



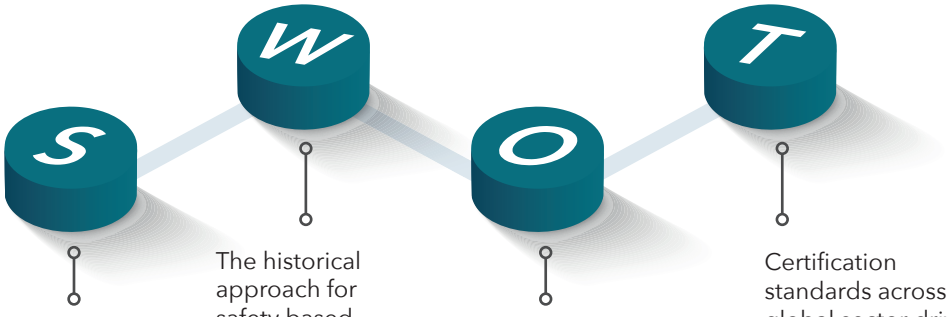
- RTOs and Catapults technical specialisms
- Established industrial and academic research capabilities and collaboration

- Integrated simulation toolsets to engineer system optimised for aircraft mission
- Integrated multi-functional components and structures to optimise overall thermal performance
- Standards for interoperability of components

- Multi-disciplinary mission specific integrated solutions across sectors builds opportunities for modular architectures
- Apply other sector lessons learned on system design, optimisation and manufacturing

- Aerospace certification constraints at vehicle level limit opportunities for optimisation
- Risk of duplication of R&D by UK companies

CHALLENGE 3:
System safety and reliability



- UK Government support for net zero
- FlyZero providing opportunity to identify key "questions" in an open environment
- CAA engagement in development programmes

- The historical approach for safety based on experience or learnings as technology evolves, may not drive the solutions that are needed

- Vertical integration of commercial Aircraft Maintenance, Repair and Overhaul (MRO) and health management enabling predictive maintenance across wider systems
- Future technology safety architecture and validation approaches

- Certification standards across global sector drive UK into component provision
- Qualification and certification test facilities across system and sub-system levels

Systems Integration

Key Recommendations

SYSTEMS INTEGRATION	CHALLENGE 1: Airframe integration	CHALLENGE 2: Thermal management	CHALLENGE 3: System safety and reliability
Technology investment	Investment in a range of technologies to reflect diverse mission requirements but keeping solutions simple	Future sustainable propulsion thermal management toolchains Cooling research to integrate and utilise waste heat	System / subsystem test protocols to enable technology validation and risk mitigation Recharging / refuelling / infrastructure safety development Support for high value, low volume manufacture
Skills / training	Building UK capability in whole aircraft Developing integration best practice approaches and solutions	Aircraft level thermal management and system integration development across sector	Develop skills to assess highly complex system safety HV system safety and training including maintenance
Supply chain	Create a 'one stop shop' to promote UK supply chain and research outputs	Integration of engineering through supply chain to deliver system level activity	Identify and develop supply chain plan to deliver across system boundaries Subsystem qualification enabling technology upgrade during airframe life
Certification / standards	Review smaller aircraft opportunities to establish UK test environments Explore potentially applicable standards from other sectors	Engage with global OEMs to flow down emerging standards	Ensure global OEMs' engagement with emerging standards Demonstrate safety by fault tolerance Broaden CAA engagement across technology development and deployment
Design tools / processes	Enable general aviation as first adopter to prove technology and supply chain Full life cycle impact as part of systems engineering approach	Extension of design tools to new platform needs to address thermal management challenges Multi-system integrated testing platforms	Employ increased digitalisation to prove safety and reliability (including sensor modelling / digital twins to assess / identify faults)
Collaboration opportunity	Opportunity to develop collaborative test environments across suppliers and Primes The correct scale of environmental chambers / rigs to validate complex systems	Cross-sector collaboration for lessons learned and avoidance of duplicated effort Integration of UK supply chain to deliver system solutions	Assessment of safety standards and systems across industry sectors Building public / customer confidence in new airframe platforms
Other	Cross-sector supply chain collaboration to enable UK supply chain benefits Sharing lessons learned across non-IP sensitive areas Build cross-supply chain modelling integration		

Industry Contribution and Acknowledgements

WMG and the ATI would like to thank the organisations from across the supply chain who contributed to the content of this report.

Over four events we had 86 companies of different sizes and profiles participate in the project. We are especially thankful to the industry leads who led the work around three main challenges.

INDUSTRY CONTRIBUTORS:

Marc Holme, Collins Aerospace

Martin Dowson, WMG centre HVM Catapult

Paul Harris, Rolls-Royce Plc

Tim Woolmer and Tom Hillman, Yasa

Sarabpal Bhatia, Airbus

Doug Campbell, Electroflight

> "Investment is urgently needed to deliver cutting-edge energy storage capability and certification in the UK, to drive our knowledge and understanding forward in this critical area. Funding that allows for this rapid acceleration, helping upskill the sector and prepare for electric flight will bring exceptional economic and environmental benefits to the UK. The workshops and this report have helped bring the industry together and focus on what is needed to secure the UK's position in this emerging field."
>
> **Doug Campbell,**
> *Technical Director at Electroflight*

> "It's essential that we develop an aligned strategic approach to the funding and research portfolio for electrified aviation to ensure we anchor the knowledge, skills, OEMs and supply chain in the UK for the exciting emerging sector of the industry, and these ATI-WMG sponsored events help to align the key stakeholders on the priorities across the sector."
>
> **Martin Dowson,**
> *Head of Battery Systems Engineering and Research at WMG, University of Warwick*

Industry contribution and acknowledgements

"The UK aerospace industry has a long history of innovation and cutting-edge development that spans more than 100 years. The global need for emission reduction sets future challenges for cleaner aviation, that UK industry is well placed to meet. Through enhanced collaboration across sectors and the development of key technologies, centred on highly efficient electrical architectures and the associated infrastructure, the UK can be well placed for the next 100 years of aviation innovation. This workshop has been an important enabler for these cross-sectoral discussions that will help to shape our futures."

Marc Holme,
Senior Director, Electronic Controls and Motor Systems at Collins Aerospace

"As with many advances in aerospace, a specific technology development may be the catalyst however the understanding and implementation of a fully integrated system gives the opportunity of a viable product or service, this is proving true for electrification in aerospace. The collaborative workshops and outputs have provided opportunity identification and networking for existing and new aerospace sector entrants, supporting sector transition and growth."

Paul Harris,
Chief of Technology - Intelligent and Optimised Systems, at Rolls-Royce Plc

"It was motivating to hear so many companies recognising the same challenges but also identifying and promoting the key technologies that will solve them."

Tom Hillman,
Lead Simulation Engineer at Yasa

THIS REPORT WAS PREPARED BY:

Alison Meir, Head of Business Development, WMG centre HVM Catapult

Mark Scully, Head of Technology - Advanced Systems and Propulsion, Aerospace Technology Institute

David Rawlins, Chief Technology Officer, WMG centre HVM Catapult.

With support from Ana Paula Cordeiro, John Warehand, Julia Laevskaya and other experts at the ATI and WMG, University of Warwick.

Contacts:

Aerospace Technology Institute

Martell House
University Way
Cranfield
MK43 0TR

01234 907 930

info@ati.org.uk

WMG, University of Warwick

International Manufacturing Centre
6 Lord Bhattacharyya Way
University of Warwick
Coventry
CV4 7AL

024 765 24871

wmgbusiness@warwick.ac.uk