

Introduction

The UK has an estimated turnover exceeding £2bn in the cabin interiors market. Given the breakneck progress of technology in other areas of aircraft design and manufacture, and the need to reduce the environmental impact of aviation, the cabin interiors market is ripe for innovation. In this INSIGHT, the ATI sets out the rationale and opportunity for more innovation in cabin interiors based on market assessment, economic potential and the UK's strong position.

The analysis identifies five technology themes that show great promise for growth and alignment with UK capabilities; it then describes 32 specific high-potential technologies that sit below these themes. This INSIGHT initiates a clear plan to catalyse innovation in UK cabin interiors. The ATI will engage throughout the supply chain to support the formation of collaborations and technology projects, and drive disruptive innovation through new and existing mechanisms.



EXECUTIVE SUMMARY

You arrive at the airport. A driverless zero-emission vehicle has brought you to the leafy terminal building which runs entirely on clean energy. There is a seamless transition through automated biometric security. Shopping done, you board a hydrogen-powered aircraft taking you from LHR to OSL. But what do you experience in the cabin?

The aircraft interior market has evolved progressively, driven primarily by cost and delivery demands. Airlines seek differentiation, which has driven some technological progress, but nothing like what is possible. Given the breakneck progress in other areas of life and the need to reduce the environmental impact of aviation, the cabin interiors market is ripe for innovation.

The market is being fuelled by increased passenger numbers, and cabin refits and modifications. Specific trends such as low-cost carriers, ultra-long-haul flights, business class preference over first class cabins and increasing internet connectivity are driving specific product demands. Overall, aircraft interiors represent between 3% and 10% of an aircraft's value. The global interiors market is forecast to be worth \$19.8bn in 2020, growing at 3.3% CAGR through to 2038. Seat and in-flight entertainment (IFE) systems present the most valuable opportunities by revenue. Connectivity is growing fastest, at 7% CAGR.

The UK supplies at least 7% of the world's aircraft cabin interiors, including over 30% of all aircraft seats. UK companies also design and supply galley systems, monuments¹, and connectivity and power systems. The UK is also home to interior design capabilities unmatched elsewhere in the world. All in, we estimate there are over 250 suppliers in the UK involved in aircraft interiors with a combined turnover exceeding £2.0bn, supporting in excess of 6,000 jobs. UK SMEs generally source locally, retaining much of the associated value-added work in the UK.

The business case for innovation is challenging. Many interiors businesses are too consumed with delivering to demanding schedules and targets to undertake research with longer-term returns. Difficulty in attracting talent, the cost of meeting regulatory compliance, and lack of awareness of the UK technology ecosystem all contribute to low rates of innovation.

Nevertheless, this INSIGHT sets out the rationale and opportunity for more innovation into cabin interiors, based on market need, economic potential and the UK's strong position. It draws on research conducted in-house by the ATI, and with consultants from Cranfield University and Achieving the Difference. Our analysis identified five technology themes within the cabin that show great promise for growth and alignment with UK potential:

- 1. Ultra-performance electronics
- 2. Lightweight integrated structures and sustainable materials
- 3. Passenger environment
- 4. Disruptive in-flight entertainment
- 5. Distributed electrical system technology

Breaking these down further, we propose 32 specific technologies with potential for development, ranging from short-term possibilities such as artificial intelligence (AI)-driven innovations, through to longer-term concepts such as human brain-inspired microchips. These are set out in more detail in section 7 and the technology annex at the end of the paper.

In addition to these potential new concepts, the sector can gain from applying state-of-the-art manufacturing technology such as automated and agile industry 4.0 capabilities, enabling suppliers to better meet the demands of OEMs, airlines and passengers.

The ATI will drive opportunities for technology innovation in interiors in the UK by:

- Engaging the interiors supply chain and increasing awareness
- Supporting formation of collaborations and technology projects
- Driving disruptive innovation from sources of technology traditionally outside the sector

Note: The global response to the COVID-19 pandemic will have a major impact on the global market forecasts and UK supply chain valuation herein. The forecasts are useful as a benchmark and relative value of the aircraft interiors sector. The ATI will revise these analyses in due course. The strategic technology and innovations opportunities are still relevant, as are the innovation challenges and conclusions for the ATI. However, there will clearly be implications for interior product demand as passenger behaviour is shifted towards social distancing and hygiene. ATI support is still available and the case for ATI grant funding is potentially strengthened by the crisis.

¹Monument - larger discretionary items of cabin furniture such as communal seating areas, bars, partitions, lowered ceilings etc.

INTRODUCTION TO AIRCRAFT CABIN INTERIORS

Aircraft interiors are big business. They cover a plethora of technology and products from mechanical structures (e.g. seats, galleys, monuments, stowage) and electrical power systems (e.g. local power distribution, galley equipment, motors) through internet connectivity systems, displays, audio and cabin air, to tables, fabrics, carpets, ovens and coffee machines. This INSIGHT covers products and systems within the passenger cabin - including crew areas - that affect passenger experience or concern emergency escape. It does not cover the cockpit, except pilot seats, or structural floor and window components.

Aircraft interiors are typically supplied through two routes; buyer furnished equipment (BFE) and supplier furnished equipment (SFE). With BFE, the airline selects interiors directly from a supplier (often pre-approved by the airframer). SFE is where the airframer offers cabin solutions to airlines as part of an aircraft's line fit.

Figure 1 depicts a simplified view of the interiors supply chain. Airlines drive demand for cabin products, weighing passenger and brand needs against cost. However, aircraft manufacturers, Tier 1s and smaller suppliers can influence which products reach the market. Airframers can exert control through their integration capabilities and managing approved supplier lists. Few cabin products are truly bespoke owing to the expense of designing, certifying and producing small batches.

Interiors design houses are critical to the cabin value chain. Working with the airlines to formulate design briefs and requirements, they connect engineering solutions to the passenger experience through aesthetic, spatial, ergonomic and functional design.

Certification services are another important part of the interiors value chain. These can be in-house within large Tier 1s providing full cabin offerings, or dedicated certification houses and smaller suppliers that can obtain delegated authority. Design organisation approvals (DOAs) are required by organisations to design and certify aircraft systems; supplementary type certificates (STCs) are required to certify retro-fits and modifications; and parts manufacturing approvals (PMAs) enable suppliers to produce spares.



Figure 1 Aircraft interiors industry structure

The UK punches above its weight in the manufacture and supply of aircraft interior products, with significant clusters in Northern Ireland (~50% of UK interiors output²), Wales (world leading capability for first class and business class seats), South West, South East and across the Midlands (see Figure 2). Aviation Industry Corporation of China (AVIC) has become an important UK presence through acquisitions and establishing a London HQ in 2019. The UK can grow its share by stimulating innovation aligned with UK strengths and market opportunities.

The UK's seven largest aircraft interiors suppliers generated sales of over £1.3bn in 2017, accounting for over 7% of global market share². Top tier companies manufacture passenger seats, crew seats, galleys, stowage and monuments. Seat sales alone from the UK totalled £940m in 2017³, representing one-third of the global market. Collins Aerospace is the largest UK interiors company with £720m in sales². Good capabilities also exist in lighting, satellite connectivity, galley inserts, power, fabrics, general aerospace engineering support and machine shops. Approximately 50% of UK turnover is gross value added (GVA) to the UK economy, and 93% of sales are exported².

Company size diminishes quickly below the largest players. There are over 250 companies⁴ supplying cabin system integrators; including these organisations could take UK sales to over £2.0bn. UK SMEs generally source locally, increasing the UK's value-add.

Through Tier 1 suppliers alone, over 6,000 jobs are supported by aircraft interiors in the UK, with engineering typically accounting for 30% to 85% of staff². Research & development (R&D) spend of Tier 1 suppliers is around 4% and typical R&D spend of Tier 2 suppliers is 5%. However, the majority of R&D spend is on product development, including certification, rather than research and technology (R&T).



Figure 2 UK Supply Chain Map

The UK is also home to 16 world-leading industrial design houses, 14 of which operate out of London and at least 10 have clear aircraft interior expertise (see Figure 3). Design houses are a valuable source of customer insight and customer relationships, giving the UK an important advantage.

²ATI-Achieving the Difference primary research and supply chain analysis
³ONS, 2018, UK Manufacturers' Sales by Product Survey (Prodcom), 19th November 2018
⁴Department for International Trade, 2019, UK Passenger Experience Supplier Directory 2019



Figure 3 Global design agencies by HQ location; Source - ATI Analysis

OVERVIEW OF THE GLOBAL MARKET

Interiors represent between 3% and 10% of total aircraft value, depending on the airline business model and brand. The global interiors market was valued at \$19.0bn in 2019, is forecast to be \$19.8bn in 2020 and expected to grow at 3.3% CAGR through to 2038⁵. This is over double the growth rate of new aircraft sales, driven by aircraft cabin refreshes and retrofit modifications.

Business is won through three primary revenue streams:

- 1. Original equipment line-fit
- 2. Retro-fit (upgrades and modifications during service life)

3. Re-fit (refurbishment and replacement of old interiors, including spares, during service life)

Widebody interiors typically cost four times that of narrowbody interiors, so while volumes of widebody aircraft are lower, both make up roughly the same proportion of the market. The market forecasts provided in Figures 4 and 5 include commercial widebody, narrowbody, regional jet and turboprop aircraft.



Figure 4 Cabin interiors commercial market split

The retro- and re-fit markets are growing at a combined CAGR of 4.1%, almost twice the rate of new build (original equipment)⁵. Between 2019 and 2029, high growth in the IFE and connectivity markets will drive a steeper trajectory.



Figure 5 Commercial aircraft interiors value by system segmentation

Connectivity technology such as SATCOM represents the highest growth market through to 2038. More common to widebody and business jet aircraft, SATCOM is increasingly finding its way onto narrowbodies. IFE is the second largest product segment, growing at over 5% CAGR, with sales driven by narrowbody uptake and airlines updating their fleets at roughly twice the rate of new aircraft deliveries. There is, however, potential for disruptive entrants to drive down the cost of IFE, as well as other electronic equipment.

Aircraft interior furniture, including seats, panels, stowage (luggage bins), monuments and galleys, comprise 40% of the cabin's cost. These segments offer an opportunity to reduce weight and adopt more sustainable materials, besides optimising cabin capacity and the passenger experience.

Business jets provide an additional \$1.4 billion market opportunity for new interiors, with a similar value in aftermarket opportunities. IFE, furnishings, galleys, connectivity and lighting representing the most substantial business jet interior segments. For seats, the business jet market is just ~5% of the total commercial seating opportunity. In helicopters and general aviation, we estimate market values between \$100m and \$150m for 2019, respectively.

MARKET DRIVERS AND SUPPLY CHAIN COMPETITION

Rising aircraft sales and the need to keep existing aircraft fit for service drive overall demand for cabin interiors. Cabins are normally refreshed more than once in an aircraft's life, presenting opportunities for suppliers.

Cost and delivery are imperative to aircraft OEMs and airlines. Purchase price is typically prioritised over longer-term benefits that might be realised through more advanced technology. Innovation, in areas such as lightweighting, energy reduction or sustainable production are welcomed, but only if delivered reliably and at price parity. The fact that aircraft lessors now own close to 50% of the narrowbody fleet, adds another layer of opportunity and requirements for aircraft cabin products.

Economy class cabins are all about maximising capacity while sustaining an acceptable level of passenger comfort. This has driven low cost, compact and highly optimised functional products. These are hotly contested, with a majority share taken by large suppliers. Designers and airlines are very limited in the level of differentiation permitted by catalogued economy cabin suppliers. However, the market has proven big enough and receptive to new players to allow SMEs offering competitive and differentiated products in.

In premium class, passenger experience becomes far more important. Design is important in distinguishing an airline's brand and differentiating through comfort and experience. Twenty years ago, the distinction between business and first class comfort and service was clear. Today, that difference has eroded with competition in business class driving enhancements to comfort, technology and services. Some airlines have sought to enhance their first class configurations, including dedicated beds and improved privacy (and even the odd shower!), but at a cost that has further reduced the market for this level of offering.

The trend for longer-haul flights, enabled by jets such as the A350ULR and 777X, are creating further demands on sustaining passenger comfort and wellbeing. This introduces the potential for novel solutions to support sleep, rest, mental and physical health, entertainment and catering across all cabin classes. The growing availability of high bandwidth internet connectivity during flight will present new opportunities for airlines and internet businesses.

We expect sustainability to play a bigger role going forward. Airlines and aircraft manufacturers are acutely aware of the need to reduce environmental impact with rising public pressure adding to the urgency. Aircraft interiors present the industry with an opportunity to visibly demonstrate improvement. Steps include adopting more sustainable materials, further lightweighting of structures and systems, reducing power consumption and eliminating waste. Coupling these innovations with investment in manufacturing technology can also improve overall productivity and profitability.

Figure 6 illustrates some of the key drivers affecting development of cabin systems:

KEY MARKET DRIVERS	PASSENGER NEEDS
INCREASING GLOBAL AIR TRAFFIC GROWTH OF LONG RANGE OPERATIONS (NARROW & WIDEBODY) FUEL PRICE AND CARBON COSTS SUSTAINABILITY	CONNECTIVITY AND ACCESS TO DIGITAL CONTENT COMFORT, LOW STRESS, SLEEP SERVICE EXPERIENCES IN PREMIUM CLASSES LOW PRICE SUSTAINABILITY AND REDUCING ENVIRONMENTAL FOOTPRINT
AIRLINE	ENEEDS
LOWER EMISSIONS AND FUEL BURN THE BRAND DIFFERENTIATION THROU PASSENGER EXPERIENCE AN ENABLING ULTRA-LONG HAUL OF COMFORT AND CAN LOWERING UPFRONT COST AN REVENUE OP	ROUGH WEIGHT AND POWER REDUCTION IGH CUSTOMISATION, ENHANCING ND NOVEL CONFIGURATIONS PERATIONS THROUGH ENHANCED BIN PERFORMANCE ND IMPROVING PRODUCTIVITY PPORTUNITIES
SUPPLY CHAIN C	OMPETITIVENESS
DELIVERY F TALENT AC INCREASED RAT BROAD CABI LOWERIN SUSTAINABL	RELIABILITY CQUISITION TE AND CAPACITY N OFFERINGS NG COSTS LE PRODUCTS

Figure 6 Market drivers, supply chain and customer needs

Reduced mobility is also becoming a more prevalent issue for airlines and interiors suppliers, demanding novel solutions to accommodate disabled and ageing travellers, whilst maintaining levels of service to all.

Intellectual property (IP) is difficult to protect in interiors as innovative design can be easily replicated once on the market. This is an issue for new and small organisations hoping to break in, putting a premium on quick sales.

The seating market is made of up major suppliers, such as Collins Aerospace and Safran Seats, and over 30 smaller manufacturers and new entrants. Delivery challenges experienced by some of the larger companies have helped to open opportunities for new players.

Roughly half of the market runs through long-term SFE contracts between OEMs and Tier 1 suppliers. Aircraft OEMs integrate their interior offerings through a combination of in-house capability and partnering with selected suppliers. Arguably the BFE route presents better opportunities for innovation, where airlines want to differentiate from the OEM catalogue. OEMs still exert some control on the BFE supply chain, through approved supplier lists. By choosing a non-approved supplier, an airline likely forfeits any associated OEM delivery compensation. Suppliers that delay aircraft deliveries can have SFE contracts terminated or be removed from BFE supplier lists. This pressure to deliver naturally propagates risk aversion and impacts innovation.

SFE arrangements are preferred by OEMs. Airbus and Boeing took the opportunity to tighten control through SFE catalogues for the A350 and B787, with mixed success.

SFE contracts present significant commercial opportunity and stability for suppliers. They become available with new aircraft platform launches, which are currently few and far between, but can also arise due to existing supplier performance. SFE can limit airline choice and conflict with the desire for greater differentiation; it is, however, generally a lower cost solution.

BFE presents greater opportunity on single aisle platforms, and in re- and retro-fits. It is often the only route to market for smaller players with a limited range of products. It is very difficult for smaller suppliers to get onto SFE catalogues without being able to deliver a full cabin offering. New entrants and SMEs can target BFE markets to prove out business modelling and products, to build reputation and a base for steady growth.

CHALLENGES BRINGING INNOVATION TO MARKET

Aircraft interiors face similar innovation barriers to other areas of aerospace. R&D spend for interiors suppliers is typically 4.5% of turnover. Although high, the vast majority is absorbed by product development and certification costs, with little left for new technology research and exploitation. For example, galleys are reconfigured for different aircraft and airlines, requiring re-analysis to verify they remain safe. This creates an order of magnitude of more technical engineering work, compared with similar activity for other aircraft components, such as wing structures.

Aircraft OEMs are endeavouring to provide their own interior product lines and attempting to bring more products under SFE contracts. This is meeting some resistance from airlines and is seen by some as potentially harming innovation.

There is limited financial resource or impetus to invest in higher-risk product and manufacturing technology, despite the potential to deliver valuable benefits. Airlines are generally less willing to invest over the odds in new cabin benefits, even if there is positive return over the asset's lifetime. Additionally, airlines will often allow only short timeframes for delivering the cabin solution often coupled with heavy penalties for failing to meet targets (weight or delivery). This puts considerable pressure on providers to deliver production-ready certified systems.

SMEs are at a disadvantage. They have lower spending power and fewer economies of scale which compound, as smaller suppliers are overlooked as too risky to enrol as SFE line-fit options, or customers may simply prefer a more integrated offering. SMEs have little oversight or influence on regulatory change whereas OEMs and Tier 1s are well plugged-in. Smaller suppliers must often react to such change, which may have a major impact on their bottom line.

In the UK, the fragmented nature of the supply chain below the Tier 1s generally means the UK interiors community is not well connected. There is limited awareness of the opportunities and support available to drive innovation or engage out-of-sector companies to bring new ideas.

There is a clear argument for market failure, which warrants effort to stimulate and enable innovation in cabin systems. Figure 7 summarises these, and other challenges, representing a tall hurdle in bringing innovation to market:



Figure 7 Innovation challenges for interiors business (hurdles not to scale or proportionally representative)

UK OPPORTUNITIES FOR INNOVATION AND TECHNOLOGY

Notwithstanding the challenges discussed in the previous section, opportunities to innovate in the aircraft cabin are plentiful. Technologies exist now that if integrated into the cabin could revolutionise directly or indirectly the passenger experience; these include virtual reality, next generation connectivity and data analytics (AI, cloud, Internet of Things (IoT) and big data). Some airlines are taking matters into their own hands. For example, Delta has set up Delta Flight Products and developed its own IFE⁶ at a fraction of the cost and with superior performance and weight.

Environmental impact can be reduced through new materials, composites, additively manufactured structures and reuse/recycling processes. The galley accounts for one third of the thermal load from the cabin, a significant power draw, that must be cooled through the environmental control system (ECS). This energy waste presents a great opportunity for innovation.

Manufacturing processes could also benefit from automation and use of re-configurable robots to reduce costs, improve delivery and enable the agility to handle design changes and customisation.

Aircraft interiors, with their shorter development cycles i.e. not restricted by new aircraft cycles, offer a prime opportunity for suppliers to innovate faster. This in turn may allow aerospace manufacturers to de-risk or prove-out new technology and new innovative suppliers through interiors business to deploy later, in other aircraft systems. There is potential for interiors technology innovation to accelerate innovation throughout the whole aircraft. One specific example would be to enable composite material recyclability technology to progress faster due to replacement and product cycle frequency.

Working with Cranfield University and Achieving the Difference, the ATI conducted a study of over 1000 cabin systems technologies considering their market size/attractiveness, growth potential, UK positioning, and maturity horizon. 32 specific technologies were then downselected based on these criteria. From this analysis and bringing in broader industry trends, ATI identified strategic opportunities through the following five technology themes, in addition to cross-cutting enabling technologies:

1. ULTRA-PERFORMANCE ELECTRONICS

This includes technology developments in terahertz wireless internet, ultra-fast phase change memory (PCM) data storage, laser data transfer for fibre optics, new efficient conducting materials and brain stimulation electronics. These technologies are enablers to new entertainment, retail and monitoring systems, unlocking new revenue models and passenger experiences. The UK has strong research and industrial capabilities to deliver innovation in ultra-performance electronics.

2. LIGHTWEIGHT INTEGRATED STRUCTURES AND SUSTAINABLE MATERIALS

The UK is well placed in composite structures and additive manufacturing technologies. The findings here are consistent with capability opportunities outlined in our Composite Material Applications for Aerospace and Additive Manufacturing⁸ INSIGHTs. Composite technologies have long been an important material to the interiors sector yet advances in thermoplastic composites and new sustainable materials could be exploited with improved production processes and recyclability. Findings highlight specific opportunities through amorphous metal alloys and architectured 3D materials, that could be exploited to create multi-functional and substantially lighter metallic structures. Strong 3D printed plastics and transparencies as well as future sustainable fabrics are also areas of UK strength that could benefit future cabins.

3. PASSENGER ENVIRONMENT

This offers potential to further tailor the passenger environment and engagement by shielding conversations, either by physical or invisible means, and utilising real-time language translation technology. Use cases of this technology would primarily apply to business travellers. In addition, cabin air technology such as new nano-filters for air enable high efficiency pollutant filters to address the increasing passenger awareness of cabin air quality.

By integrating sensor technologies, data and AI, insights into the cabin environment and passenger wellbeing (health monitoring) can be exploited to enhance services and experience. For example, biometric technologies have advanced significantly in the tech industry and could be leveraged to customise passenger services and climate conditions.

4. DISRUPTIVE IN-FLIGHT ENTERTAINMENT

The rapid development of personal electronic devices and home entertainment has utterly outstripped that of IFE systems in aircraft, making it difficult to meet passenger expectations. Enabling bring your own device (BYOD) is being explored but represents a loss of control for airlines over IFE as a source of differentiation. Immersive virtual reality technology is also being tested to see how they affect passenger behaviour and safety. This is an area primed for big change. Haptics, gesture control and even olfactory systems have market potential and could be a means to improving wellbeing on ultra-long-haul flights.

5. DISTRIBUTED ELECTRICAL SYSTEM TECHNOLOGY

This encapsulates localised power sources, flexible circuits, integrated electrical power systems and components. Optimised electrical power systems present opportunities for energy saving and weight reduction, as well as improved safety. These technologies are important in enabling other technology advancements discussed.

CROSS-CUTTING ENABLERS

Cross-cutting enablers highlighted in the ATI's Technology Strategy, Accelerating Ambition⁹, also apply to aircraft interior manufacturing. These include smart automation and agile manufacturing enabled by digital thread, sensing, data analytics through AI, use of the cloud, and the integrated supply chain. Such digital technologies are explored in more detail within the ATI Digital Transformation INSIGHT¹⁰. This will allow the UK to provide more capacity, whilst being able to deliver unprecedented levels of product quality and variety.

The 32 downselected technologies and accompanying technology roadmaps are discussed at greater length in the Technology Annex.

YATI Composite Material Applications for Aerospace INSIGHT - Sept, 2018 - www.ati.org.uk/media/w4f2120/insight-composites amended-2018-09-20.pdf
YATI Additive Manufacturing INSIGHT - Sept, 2018 - www.ati.org.uk/media/sogpibd0/insight08-additive-manufacturing.pdf
YATI technology strategy Accelerating Ambition - Nov, 2019 - www.ati.org.uk/media/siybi1mm/reduced-ati-tech-strategy.pdf

¹⁰ATI Digital Transformation INSIGHT - Feb, 2017 - www.ati.org.uk/media/f41fb3nc/ati-insight-01-digital-transformation.pdf

NEXT STEPS

The UK is well-positioned to meet emerging demands for innovative and sustainable cabin systems. The ATI sees an opportunity to convene the UK interiors sector around these opportunities. Our next steps include:

1. ENGAGE THE UK AIRCRAFT INTERIORS COMMUNITY

The ATI will build connections throughout the aircraft interiors value chain. Engaging airlines, design agencies, engineering and the manufacturing supply chains to actively promote a strategic vision. Building understanding of the market, technology and regulatory trends. By bringing interiors organisations into the ATI network, we aim to create a multitude of new high-value connections.

2. SUPPORT FORMATION OF COLLABORATIONS AND TECHNOLOGY DEMONSTRATIONS

Some UK suppliers have innovated successfully through public investment and business support such as the Advanced Manufacturing Supply Chain Initiative (AMSCI), the Business Growth Fund, NATEP, Invest Northern Ireland, and the Welsh Government. The ATI will encourage more collaboration by facilitating new relationships. This will aim to create connections that form consortia for collaborative R&T projects, that could attract programme funding from ATI and others. With the UK's strength in design and the wide variety of systems available that impact the look and feel of the cabin, a UK cabin technology demonstrator could be a route to stimulating innovation, focused customer engagement and mark the UK for strategic inward investment.

3. DISRUPTIVE INNOVATION

The ATI has recognised a need to stimulate more disruptive innovation in all quarters of the industry, either from within or from outside the sector. Cabin interiors is no exception. Radical seating concepts, cabin configurations and entertainment system concepts are being discussed but have so far failed to gain real traction. Technologies moving rapidly outside the sector, for example in the consumer electronics and motorsport industries, could be leveraged to change the game. It requires effort to engage startups and technology businesses outside the sector in the opportunities available within the aircraft cabin industry. The ATI will seek opportunities to do this through its networks, for example, its ATI AeroGuru¹¹ events and current first-of-its-kind civil aerospace startup acceleration programme, the ATI Boeing Accelerator¹².

The UK supply chain and wider aerospace sector is invited to comment on this paper, and to consider projects that exploit the proposed opportunities.

Please email responses to the ATI via info@ati.org.uk with a subject title of: Cabins INSIGHT.

TECHNOLOGY ANNEX

This section sets out more detail on the 32 downselected technologies, illustrated through technology roadmaps set out in Figures 8 and 9. For more information please get in touch with ATI; there is plenty more supporting detail on these technologies. The roadmaps show when each technology is expected to reach TRL6 and beyond, based on current levels of expected investment. Each technology could be expedited through dedicated industry research. Technologies in the TRL5/6 space, for interiors, have been deliberately omitted but may still present strong R&T opportunities. The selected technologies focus on high-potential applications specifically within aircraft interiors. Other pan-aerospace technologies, such as those highlighted in other ATI INSIGHTs and Accelerating Ambition, are also strategic for the UK for interiors, where applicable. The 32 technologies are described below:

ULTRA-PERFORMANCE ELECTRONICS

Human brain-inspired microchip	A computer processor unit (CPU) that mimics the neuron structure (and thus, operation) of a human brain. This potentially allows a 9000-fold increase in the processing speed of CPU.
PCM data storage	Phase-change memory (PCM) technology offers a solid-state computer storage device capable of performing up to 7 times faster than the latest solid-state drives (SSDs), and 103 times faster than HDDs. For example, this could significantly reduce the upload time for media to IFE systems.
Laser data transfer	New technology that manipulates lasers through optical fibres; enabling fast, near instantaneous data transfer - speeds of 100 terabit/sec have been demonstrated.
Terahertz wireless transmitters	Technologies that offer ultra-speed wireless data transfer on-board, affecting both avionics and cabin systems. Terahertz transmitters and antenna have the potential to allow stronger, more precise and higher rate transmission (30+Gbps) and compact antennas 30 times smaller than closest competition.
Efficient electricty circuits	A new class of conductive amorphous, soft-magnetic alloys based on low-cost alloy systems such as Fe-Si-B-Nb-Cu (iron-silicon-boron-niobium-copper) that offer high mechanical and magnetic properties, while significantly reducing production costs.
Flexible electronic circuits	Flexible electronics enabled by nano-scale electronic circuit technology. For example, one method allows attaching nanowire electronic circuits to virtually any surface, regardless of its shape or material. Bendable, stretchable, durable electronic circuits have a variety of useful applications, especially in portable use cases.

LIGHTWEIGHT INTEGRATED STRUCTURES AND SUSTAINABLE MATERIALS

Airloys	Airloy is a new material that builds on aerogel technology. Aerogels are made by extracting water from a silica gel using supercritical drying. Airloys use a plastic instead of silica base and offer similar properties to aerogels but with higher strength and lower brittleness.
Architectural materials	Architectured materials are combinations of two or more materials, or of materials and space, configured such that the microstructure and overall architecture of the material is optimised. A 3D printed metallic microlattice is a good example; lighter than aerogel and with superior elasticity.
Amorphous metals	The new type of material, also known as bulk metallic glass (BMG), is as mouldable as plastics while retaining the properties of metals. This is achieved due to its chaotic molecular structure, which causes less intermolecular friction than a crystalline structure.
Self-actuating textiles	Technologies that offer ultra-speed wireless data transfer on-board, affecting both avionics and cabin systems. Terahertz transmitters and antenna have the potential to allow stronger, more precise and higher rate transmission (30+Gbps) and compact antennas 30 times smaller than closest competition.
Bullet-proof skin	A combination of new technologies that could enable ultra-comfort and highly-durable cabin materials. Combining spider silk and milk from genetically modified goats to produce 'bullet-proof skin'; a theoretical thin, lightweight material ~10x stronger than steel, but requiring further development and testing to confirm.
Transparent wood	Natural wood has been manipulated to offer a significant level of transparency through a method that enables low cost and high-volume production. Its incomplete transparency prevents use as a window material, however, it has a variety of applications within the cabin.

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LIGHTWEIGHT INTEGRATED STRUCTURES AND SUSTAINABLE MATERIALS cont.

Strong 3D printed polymer structures	A new method of 3D printing polymer structures, offering mechanical properties comparable to the latest lightweight fibre-reinforced plastics (composites). This is achieved by orientating the molecular domains in line with the print path, in a similar manner to how fibre reinforcement is aligned with the load paths in composites.
Strong	New polymer materials as transparent as glass and with better mechanical properties than aluminium.
transparent	Leveraging a new method of drawing polyethylene in a highly-controlled environment enables the
polymers	production of such a polymer.

Al-based security surveillance	Security surveillance technology using deep learning to passively observe video cameras and process in real time. The technology aims to identify abnormal or high-risk situations/behaviours and automatically alert authorities for early intervention.
Emotional technology	Technology takes visual input from a camera, audio from a microphone as well chemical and human condition (heart rate, skin and breath temperature) to evaluate the precise emotional state of a human subject. Enables the crew to offer highly customisable, personalised/predictive/ pre-emptive passenger service.
Ultra-sensitive chemical detectors	Ultra-sensitive chemical detector technology, that picks up compounds both suspended in the atmosphere and delivered through direct physical contact. For example, highly sensitive volatile organic compound (VOC) detectors for detecting smoke or harmful gases and even bacteria in the air. Also, artificial skin that detects chemicals from direct contact and wearable hydration sensors.
Biometric technology	Technology to enable the use of various biometric authentication systems on-board an aircraft e.g. DNA matching, iris, retina, odour, hand, face, finger, ear and vein recognition.
Conversation shield	Originally developed for the special services to hide confidential discussions, this technology delivers effective active noise altering and cancelling. Enables compact yet private meeting areas in the passenger cabin.
Graphene speakers	A new kind of acoustic speakers based on a single-molecule-thick (30ηm) graphene membrane sandwiched between 2 silicone dioxide electrodes. Offers superior sound quality for relevant applications (personal stereo, cabin address, noise cancelling) at <20% of existing system weight, comparable cost and improved longevity.
Nano scale air/ water filters	A range of new nano-scale materials, such as graphene and metal-organic frameworks, that are potential enablers for high-efficiency pollutant filters.
Food printers	The latest technological advancements in food printing have progressed far enough to be worthy of a high-end restaurant. A large variety of natural and constructed tastes, textures, coatings and other features have enabled truly unique selections of food that can be printed to order.
Universal Al-based real- time translator	The latest technological advancements in food printing have progressed far enough to be worthy of a high-end restaurant. A large variety of natural and constructed tastes, textures, coatings and other features have enabled truly unique selections of food that can be printed to order.

PASSENGER ENVIRONMENT

DISRUPTIVE IN-FLIGHT ENTERTAINMENT

Comfortable infinite walking in VR	New developments have identified the relationship between eye motion and vestibular sense. This has led to VR techniques that allow users to 'walk' infinite distances within VR, without feeling uncomfortable and remaining within a confined physical space.
Haptic technology	Technology that facilitates touching of virtual objects in VR. For example, manipulating the virtual object in VR, including its size, position, orientation, and feeling realistic sensual feedback when touching/interacting with the virtual object.
Olfactory displays	A new type of `display' technology brings in the sense of smell to VR experiences. A compact electronic component that releases small quantities of natural oil-based fragrances in combination to represent desired scents.

DISRUPTIVE IN-FLIGHT ENTERTAINMENT cont.

Gesture recognition	IT technologies with the capability to observe human gestures (full body, hand and facial expressions), and interpret it as computer control inputs. Compact cameras and sensors systems could replace manual remotes.
Brain stimulation during sleep	This technology builds on research into oscillations of brain activity during different physiological states. By delivering audio stimulation, in line with this research, the technology has been proven to have a positive impact on memory function during sleep.

DISTRIBUTED ELECTRICAL SYSTEM TECHNOLOGY

Local power generation	This describes several micro-scale technologies that provide highly-localised power generation, such as harvesting vibration, heat, light and wireless signals. This could power micro-devices, such as sensors, cameras, wireless transmitters, touch elements etc. Used in conjunction with advanced battery solutions these highly-flexible and localised power sources could provide power to passenger devices efficiently, throughout the flight duration.
Electric fire suppression	Novel systems based on destabilisation of flame plasma with electromagnetic fields and acoustic techniques. Instead of starving fires from oxygen, fuel or heat, the technology interacts directly with the cold plasma (of the fire itself) and extinguishes the flame in a matter of seconds.
Printed lighting	A novel technology that involves spray-painting with electroluminescent ink. The material consists of a phosphorescent compound, processed at a nano scale, and emits light when exposed to weak electrical current.
Al-based data centre switch	This Al-based data centre technology enables a control system that oversees supply of power, control of performance, and all other subsequent metrics/systems to fine-tune operation closely in-line with instantaneous demand. This technology could significantly improve avionic and cabin system power consumption, physical weight, and operational effectiveness (safety, reliability and speed).





Figures 8 & 9 Aircraft interiors high-potential technology road map

Figure 10 ranks the 32 downselected, sub-TRL3 technologies by attractiveness to the UK. This includes an assessment of existing UK research and supply chain capability, as well as forecast market value and business opportunity. Notably, as per previous discussion, new materials and manufacturing processes, as well as electrical and electronic technology represent the greatest opportunity to the UK.



Figure 10 The 32 downselected technologies ranked by UK attractiveness (top = most attractive)

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GLOSSARY OF TERMS

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Monument - larger discretionary items of cabin furniture such as communal seating areas, bars, partitions, lowered ceilings etc.

Galley - The galley is the compartment of an aircraft where food/drink is cooked and prepared

In-flight entertainment (IFE) - refers to the entertainment available to aircraft passengers during a flight, generally focusing on the audio-visual equipment.

ACRONYMS

AI	Artificial intelligence
AMSCI	Advanced Manufacturing Supply Chain Initiative
ATI	Aerospace Technology Institute
AGP	Aerospace Growth Partnership
BFE	Buyer furnished equipment
BU	Business unit
CAGR	Compound annual growth rate
CBS	Cabin breakdown structure
CPU	Central processor unit
DOA	Design organisation approval
DOC	Direct operating costs
ECS	Environmental control system
EIS	Entry into service
GA	General aviation
GAMA	General Aviation Manufacturers Association
HDD	Hard disk drive
IFE	In-flight entertainment
IFEC	In-flight entertainment & connectivity
ΙοΤ	Internet of Things
NATEP	National Aerospace Technology Exploitation Programme
OE	Original equipment
OEM	Original equipment manufacturer
PAX	Passenger
РСМ	Phase change memory
PMA	Parts manufacturing approvals
R&D	Research and development
RFQ	Request for quote
SATCOM	Satellite communications
SC21	Supply Chain 21 programme
SC21 C&G	Supply Chain 21 Competitiveness & Growth programme
SFE	Supplier furnished equipment
SSD	Solid state drive
STC	Supplementary type certificates
ТР	Turboprop
TRL	Technology readiness level
VR	Virtual reality

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