KPMG

Aviation 2030

Disruption and its implications for the aviation sector

Thriving on disruption series

Major disruption is promised by a range of powerful new technologies and public pressure. Players that turn these trends to their advantage have the opportunity to reshape the industry. In this piece, we evaluate the potential for alternative energy sources, maintenance robotics, and the return of supersonic. We do this through the lens of 5 key player types.

Christopher Brown
KPMG in Ireland

Jono Anderson
KPMG in the US

Kieran O'Brien
KPMG in Ireland

Charlie Simpson
KPMG in the UK

Global Strategy Group

KPMG International

Introduction

Aviation has long been glamorous, but for some players in the value chain, it has also often proved to be unprofitable.

Despite current headwinds, aviation has arguably experienced a golden age: a phase of relatively profitable growth, driven especially by commercial passengers in developing markets. The International Air Transport Association (IATA) forecasts that global passenger numbers will almost double by 2037, reaching 8.2 billion annually.[1] To match that demand, the aviation industry is continuing to raise output to historic highs. In July 2018, Airbus announced that over 37,000 new aircraft – valued at $5.8 trillion – are required over 20 years.[2] With regular retirement of older fleet, that equates to a doubling of the world's passenger fleet to more than 48,000 aircraft.

Operators continue to come and go, but the scaling of profitable models since the 1990s has sustained longer than many would have predicted. Likewise, aviation finance has grown with fleet scale, dozens of specialist lessors now serve a distinct and global need.

About this report

This report combines insights from KPMG member firms recent and ongoing client engagement with secondary research. We have also included several client quotations from sector conversations in late 2019.

Elsewhere in KPMG's Mobility 2030 series,[3] we have looked at changes affecting ground transport, and in 'Getting Mobility off the ground'[4] we considered air-based disruption in short-distance travel. In KPMG's annual Aviation Industry Leaders Report,[5] we look at the 'traditional' aviation industry's topical issues.

In this paper, we focus on select issues for traditional aviation, with that longer-term 2030 lens. In particular, we consider the disruption potential related to developments in:

- Alternative energy sources
- Maintenance robotics
- Supersonic engineering

We do this through the lens of:

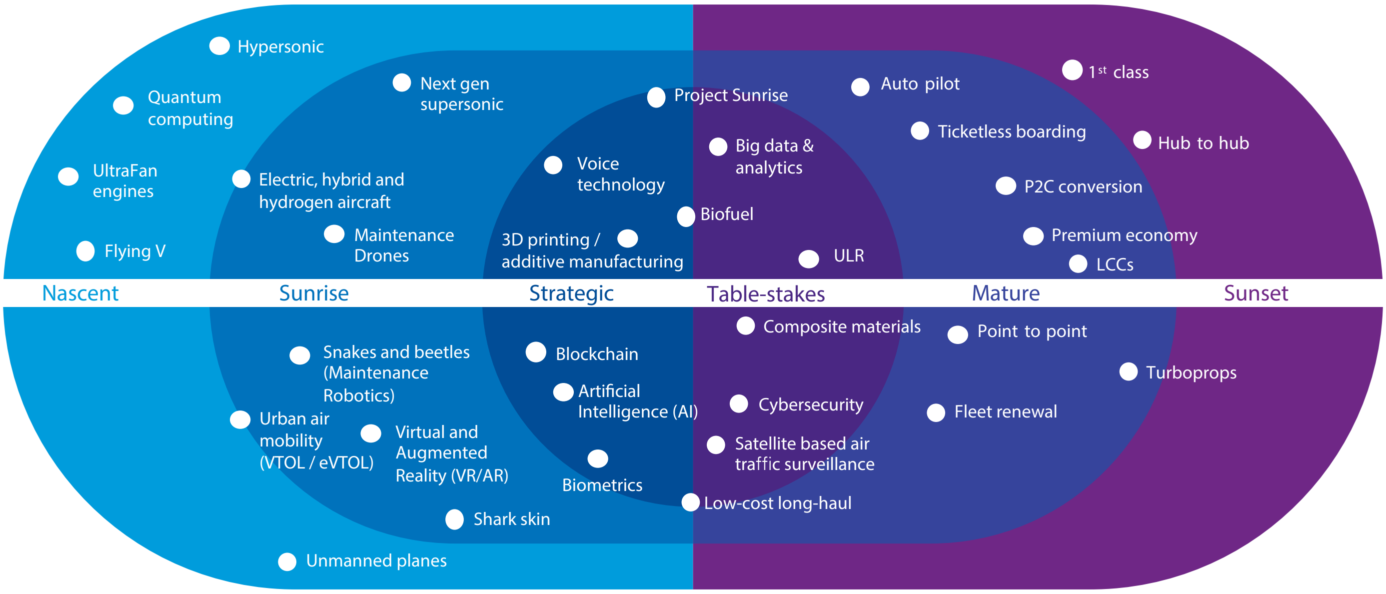
- OEMs (Original Equipment Manufacturers)
- Lessors
- Operators
- MROs (Maintenance, repair and overhaul (organizations))
- Airports

As leading advisors to the global aviation sector, KPMG professionals present a vision of the aviation landscape in 2030 and beyond.

Disruption radar

The landscape of technologies impacting aviation can be visualized in the format below. Our disruption radar groups relevant technologies and business models by their relative maturity, as a guide for business leaders to investment relevance and urgency.

Figure 1: Sector disruption radar with examples (technologies and business models) by illustrative relative maturity



There are many predictions about these and other technologies, with much focus on the technical aspects. Given the investment horizons in this industry are often 15+ years, it logically follows that which business models are winning or failing in the 2030s is already being influenced by decisions today.

Our focus, therefore, is the implications these technologies have on clients' strategic choices and investment cases today.

Figure 2: Framework for disruption

Grouping some of the newer, emergent technologies, we identify some big themes for 2030. Using the framework below, we can explore the implications of each theme by stakeholder.

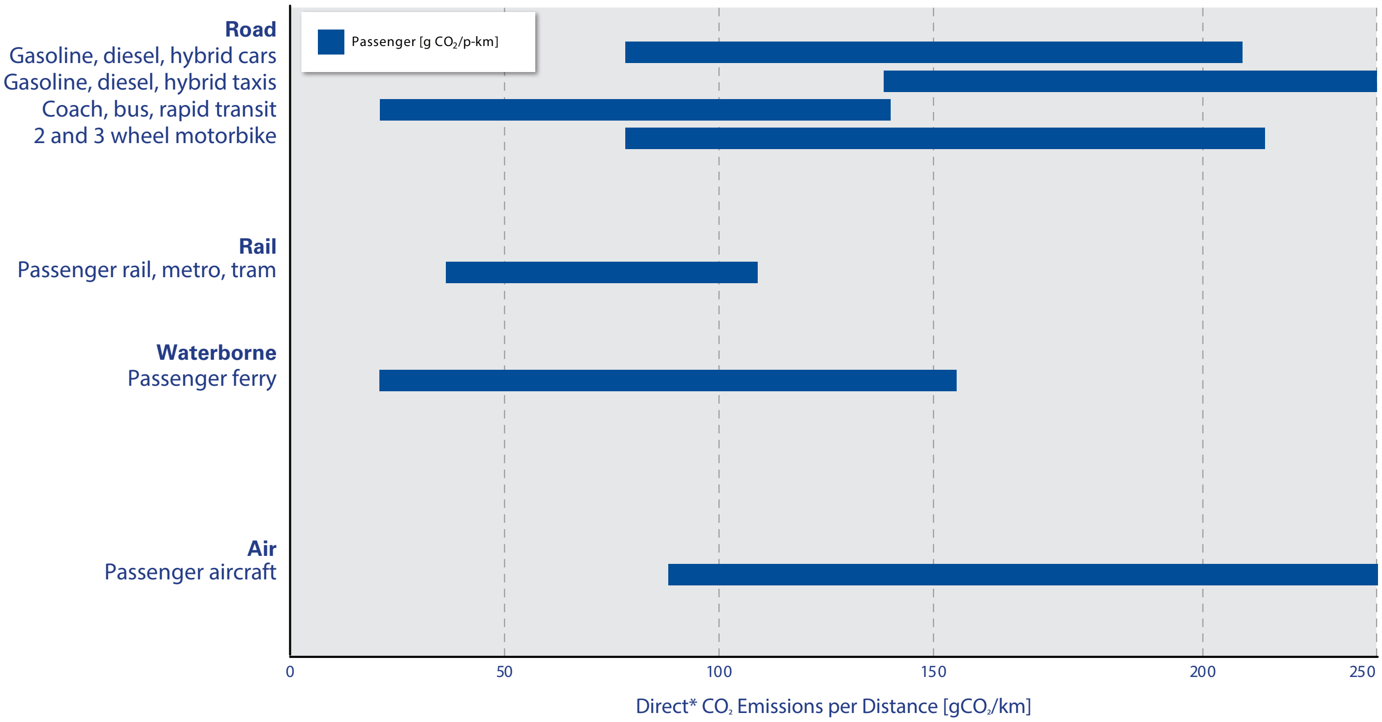
	Area	Examples	Key stakeholders / value chain players: OEMs	Operators	Lessors / Financiers	MROs	Airports
Decarbonization	Plane design	Composite materials (e.g. carbon fibre, aluminium), better aerodynamics (e.g. Flying V), shark skin tech, fleet renewal, quantum computing to accelerate design testing					
	Engine efficiency (Current variations)	Engines with higher bypass ratio / ultra high bypass					
	Alternate sources of energy	Biofuel, electric and hybrid engines					
Digital	Big data & analytics	Predictive maintenance using flight data					
	3D printing / additive manufacturing	Aircraft parts, cabin interiors, engine parts					
	Blockchain	Baggage, retail, distribution, loyalty, maintenance and parts integrity, paperwork, smart contracts and leases					
	GATS	The Global Aircraft Trading System					
	AI	Chatbots, airport congestion, airspace congestion, real time predictive pricing					
	Maintenance robotics	Drones for service scans, 'snakes and beetles', on-board service					
	AR,VR	Immersive IFE, Rolls Royce 'Blisk' for remote maintenance					
	Cyber security	Munich Airport Information Security Hub and other ongoing R&D projects on cyber security					
	Voice Technology	Siri and Alexa for live updates and check-in					
	Biometrics	Biometric boarding					
Speed	Supersonic	Engine and aircraft advances					
	Hypersonic						
Access	New locations	Vertical take-off and landing (VTOL/eVTOL), MaaS in intra-urban and longer distance, non-airport pick up					
	On-demand platforms						

This paper, the first of the Aviation 2030 series, covers the above highlighted areas, considering implications across each of the 5 stakeholder types. Subsequent papers will address other areas.

Alternative sources of energy

Mounting external pressure will not settle for sector's incremental improvements.

Figure 3: Aviation emissions in context, CO2 per passenger kilometer



*The ranges only give an indication of direct vehicle fuel emissions. They exclude indirect emissions arising from vehicle manufacture, infrastructure, etc. included in life-cycle analyses.

Source: The Intergovernmental Panel on Climate Change (IPCC)

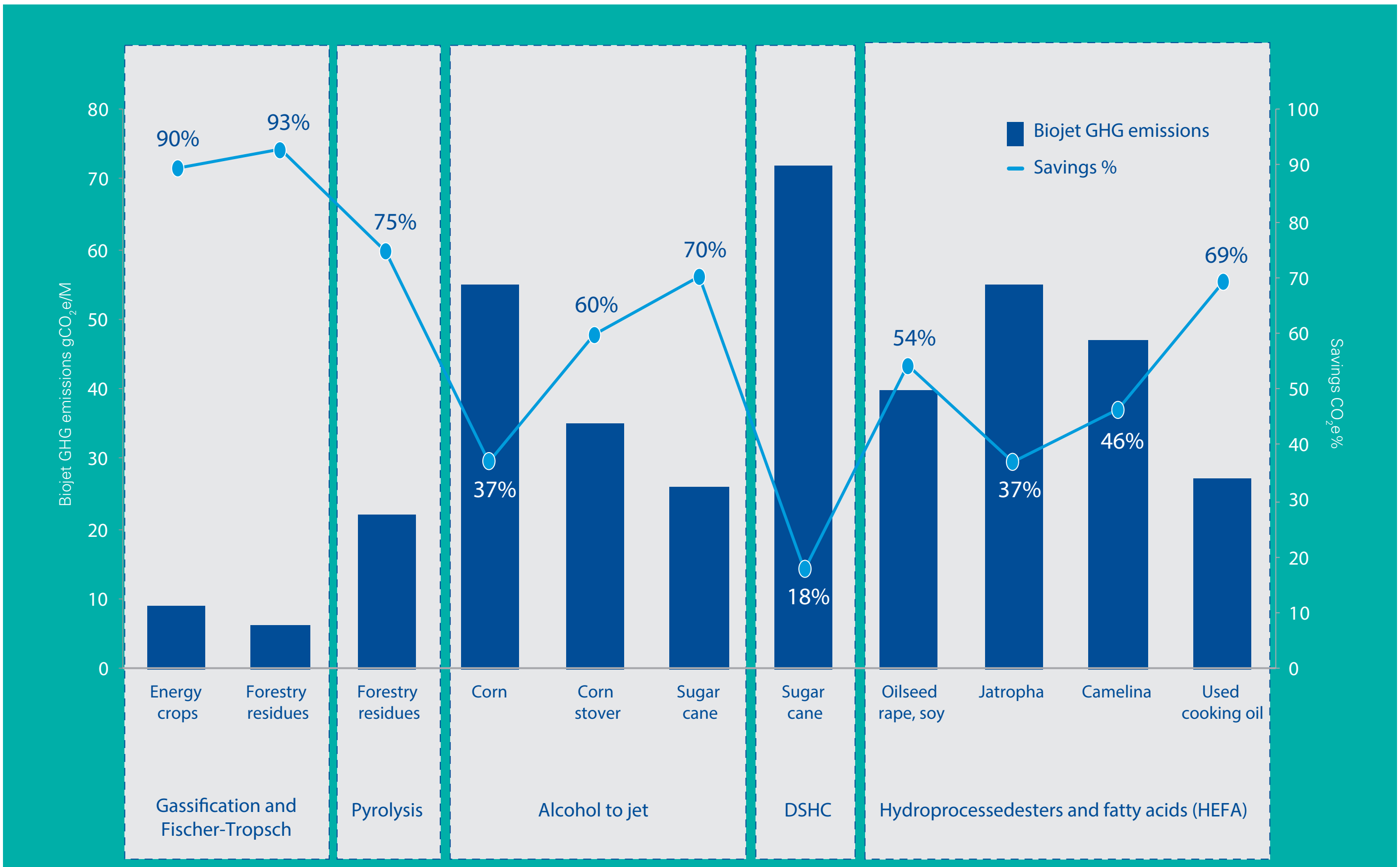
Aviation, as a major greenhouse gas (GHG) emitter,[6] faces severe pressure to reduce its environmental impact, from both consumers and governments.[7] The industry is committed to cutting CO2 emissions to half 2005 levels by 2050.[8] A range of technologies promise to help it do so, but many of the potential game changers, such as fleet electrification, still look remote. Aviation will therefore come under increasing pressure over the next decade.

In part, this demands a better, evidence-based response from the sector. As Figure 3 demonstrates, there is much overlap in emission efficiency per passenger distance. More can and should be done to set modern, fuel efficient fleets in the context of other means of transport - and indeed other aspects of environmental footprint, such as diet, fast fashion or gadget consumerism. There are also the positive externalities that flying has brought, like trade and cross-cultural connections. Do we want to return to a world where only the elite fly again?

However, with words meaning 'the shame of flying' entering Swedish, Dutch, German and Danish, it is clear that aviation will need more than a PR offensive to flourish as consumer environmentalism grows. Shark skin paint will soon begin to bring incremental efficiency gains through reduced air drag.

As figure 4 summarizes, alternative sources of energy, especially waste-derived biofuels, offer realistic prospects of emissions cuts in the near-term, and it is no surprise they are being explored by players such as British Airways, Cathay, United and Virgin. Companies like Neste, LanzaTech, and Velocys, which have signed deals with operators to provide fuel made from waste products, offer opportunities to cut overall lifecycle GHG by over 50%, without encouraging monocultures or deforestation. But these efforts remain small-scale, due to the fragmented nature of the supply chain and the difficulty of securing fuel certification and finance for major production plants.

Figure 4: Well to wake comparison of biofuels versus standard aviation fuel



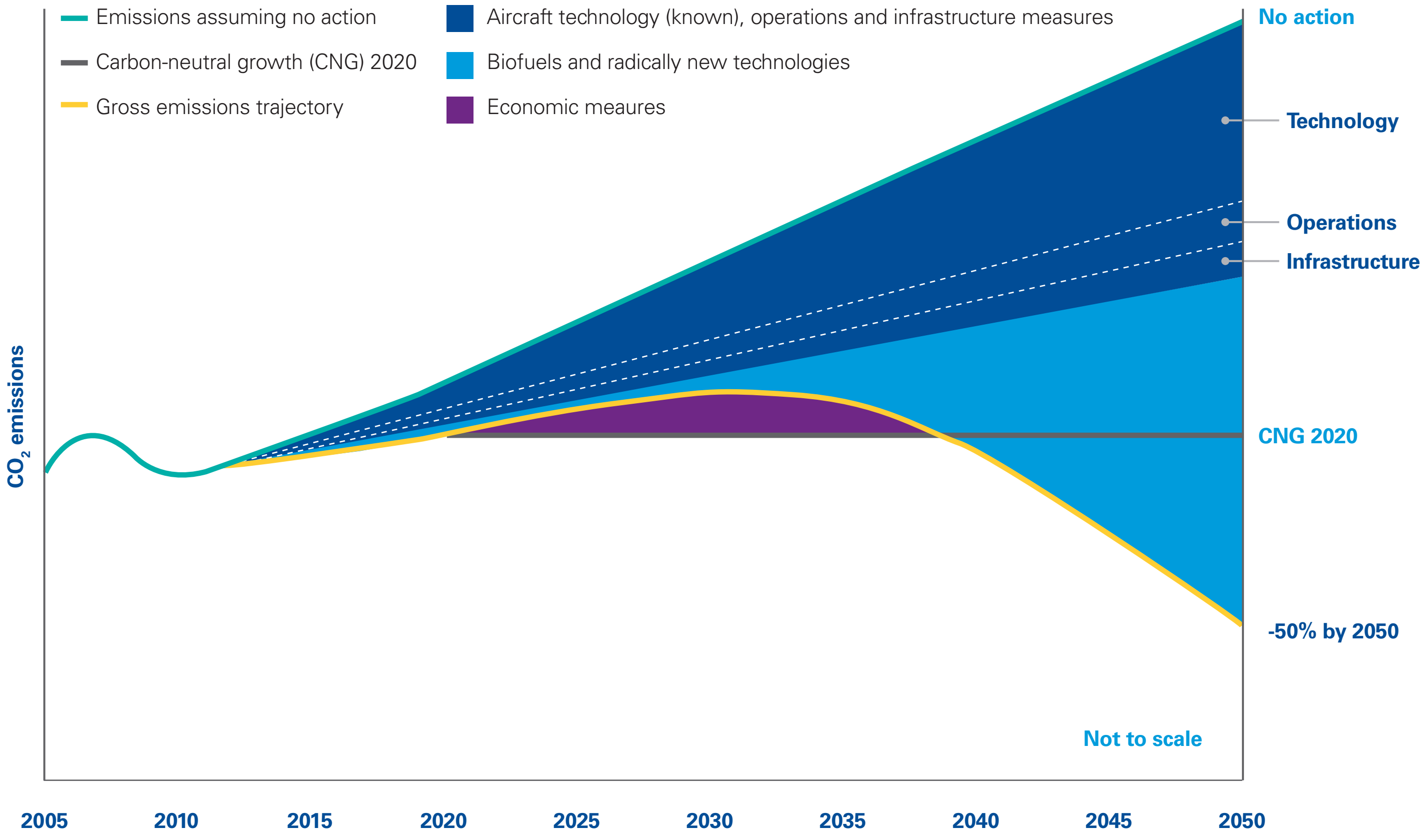
Source: Aviation biofuels, Grantham Institute Briefing paper, Imperial College London

Biofuels have the added complexities of a fragmented supply chain (for used cooking oils and forestry residues) and knock-on effects on food prices (where dedicated crops are used). If operators increase their demand, however, winning business models will be found.

Traditional biofuels will represent a logistical challenge for the global aviation sector – is there enough land to cultivate the required crops and how close is that to current demand? By-products from foodservice and other sectors may be more appealing in that regard. Initially it is likely to be blended fuel while the supply chains mature. We're hugely supportive of using biofuel and will be specifically supporting that in the future. On the ground, we're migrating our vehicles to low emission transmissions and we have targeted net carbon zero across our entire operations by 2050.

Chief Communications Officer, a major European airport

Figure 5: Roadmap for emissions reductions in aviation, as projected by the IATA

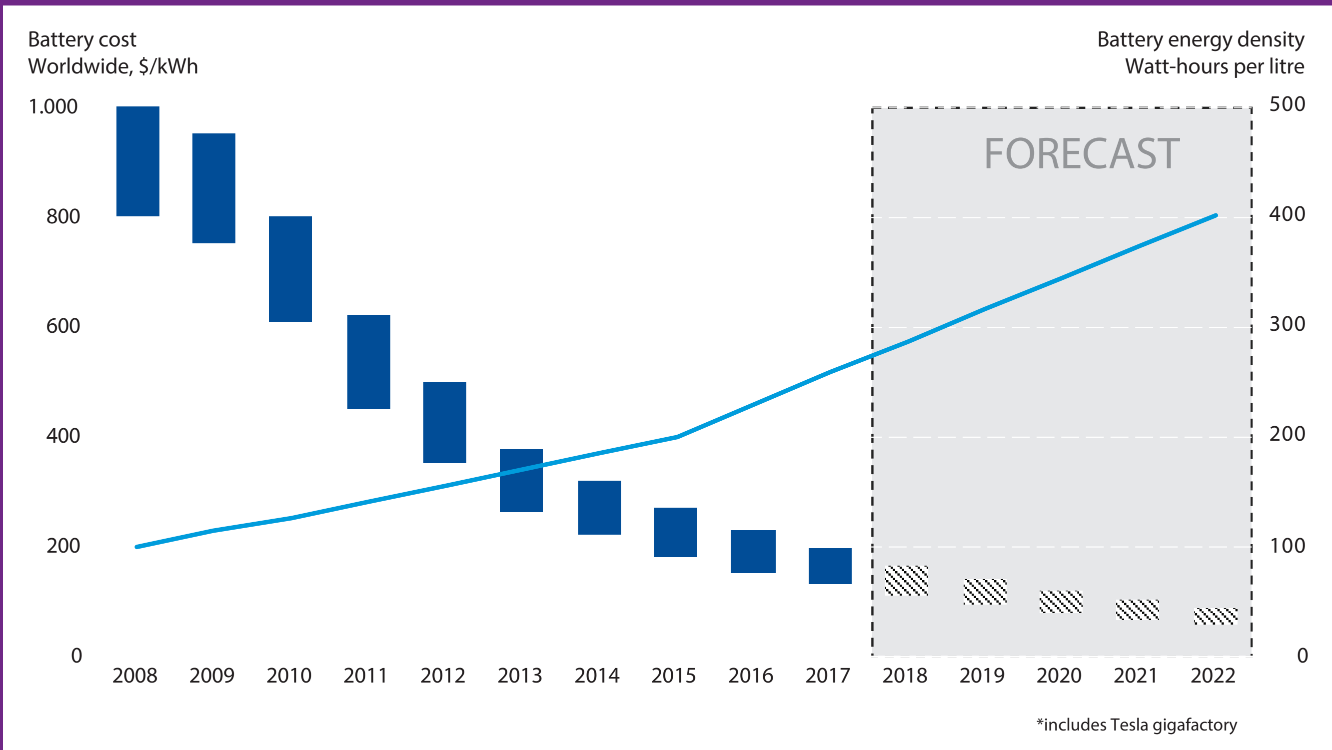


Source: The International Air Transport Association (IATA)

As Figure 5 summarizes, more radical action becomes increasingly important if 2050 goals are to be met. Fleet electrification promises these greater opportunities - ultimately, no emissions at point of use. Recognizing the size of the prize, carrots and sticks are being held out to operators. Heathrow has recently announced that the first electric-hybrid aircraft to be put into service at the airport will be exempt from landing charges for a year.[9] The Norwegian government has announced that it wants all domestic flights to be electric by 2040.[10] Many observers think even this timeframe is optimistic; challenges abound for would-be electric flyers, especially battery power/weight ratios. How can a battery compare with the energy density of fuel? Nonetheless, a number of startups, some backed by major existing players, have tooled up.

Wright Electric and Easyjet have announced plans for a 180-seat electric aircraft to fly routes of up to 300 miles, aiming to operate from 2027.[11] Zunum Aero, backed by Boeing and JetBlue, is working on hybrid electric aircraft for regional routes and is looking to fly in the early 2020s.[12] There are a host of others, but the challenges for all are alike and many observers think the goal of widespread all-electric commercial aviation is decades, not years, away. After Figures 6-7, we list the implications of these technologies for individual stakeholders. Consider, however, a sector-wide challenge. If ambitious technology change will take 10-20 years to commercialize, but public sentiment does not have that patience, will we see a resulting investment gap? Could an environmentally-inspired slowdown in passenger numbers result in insufficient industry profits to reinvest back into R&D and fleet upgrades?

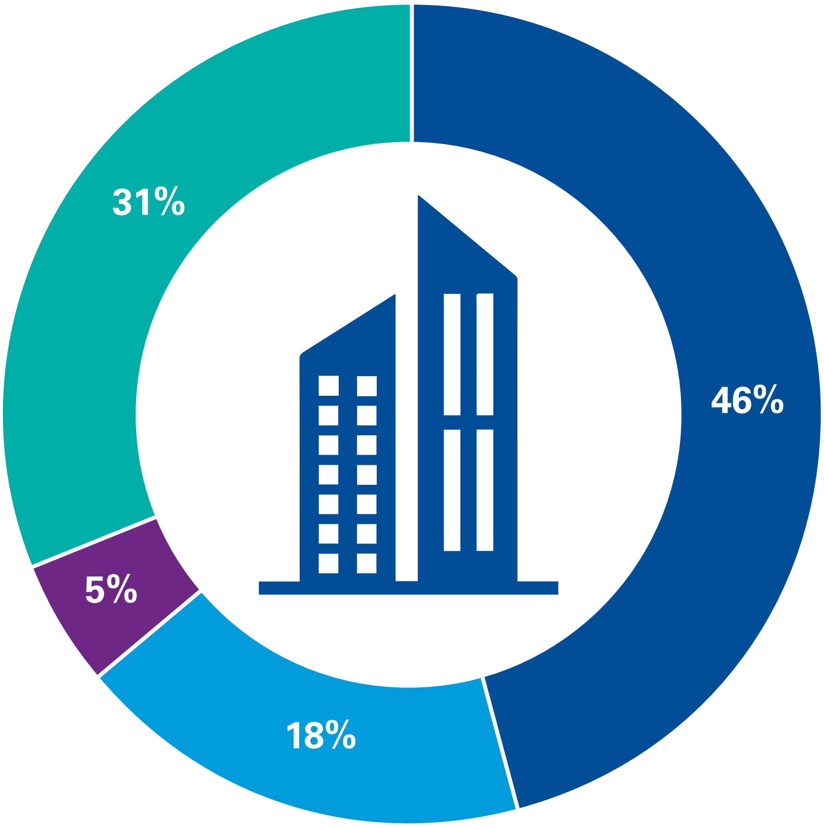
Figure 6: Battery cost and energy density trajectories



Source: The Economist

Can the current trajectory of battery improvements be maintained, or will chemistry get in the way? Novel solutions under research include using the fuselage itself to become part of a battery's capacity.

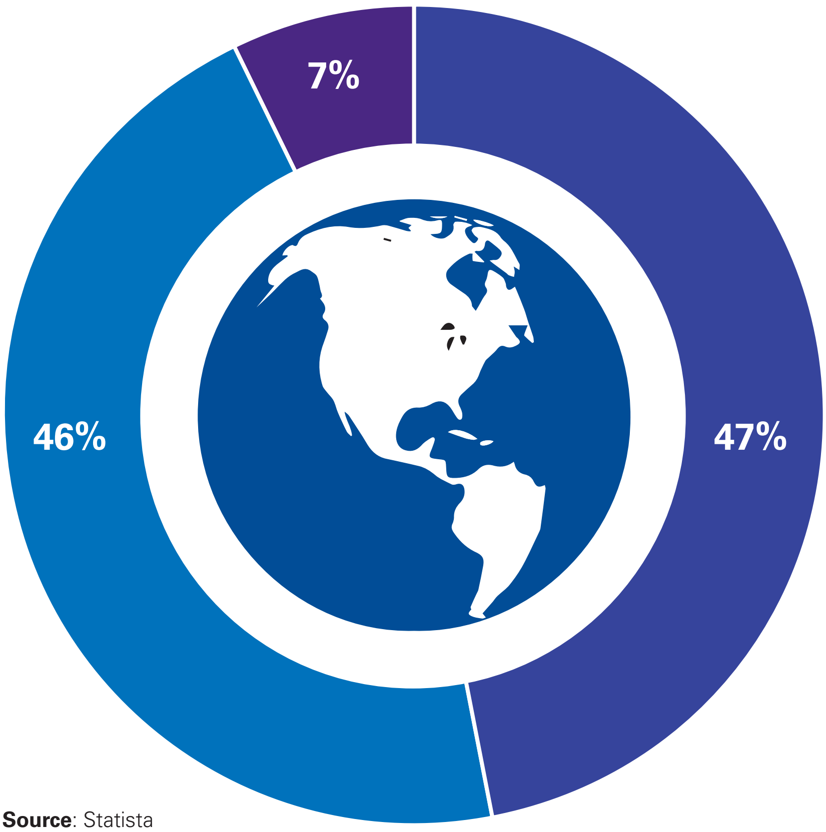
Figure 7a: Propulsion electrification projects by company type



The plurality of around 200 projects looking at alternative propulsion are start-ups. The vast majority of these will fail - but those that look increasingly like winners will prompt valuation battles between OEMs and Private Equity.

- Start-ups & independents
- Big aerospace company
- Motor manufacturers
- Other aerospace company

Figure 7b: Propulsion electrification projects by company origin



The vast majority of these projects and the vast majority of related R&D spend are in Europe and North America. If experience in automotive, and increasingly in conventional aviation holds true, then Asian players may benefit from second mover advantage: learning from the mistakes of others and scaling already viable ideas in large domestic markets.

- Western Europe
- NAFTA region
- Other

Source: Statista

We consider implications of decarbonization efforts by stakeholder type.

OEMs

- Some fuels will require or enable modifications to existing engine designs, as well as new possibilities for operational efficiency and range.[13]
- Difficult strategic decisions to be made about R&D priorities between biofuel optimization, electrification, and incremental improvements of 'business as usual' designs.
- Consider partnerships and/or acquisitions to stay abreast of technological developments in the nascent and rapidly-iterating electric market.
- Find further airframe weight reductions to assist electrification process.
- Overcome perception of batteries as prone to fires and unsafe, involving both designing out the risk of fire or designing in suitable containment methods.

Lessors

- Market for older, higher-emissions models likely to wither as pressure to reduce GHG grows.
- Strategic decisions on fleet renewal to factor in likely operator demand for low-emission models.
- Longevity of new models unlikely to match current fleet, as the pace of development quickens.

Operators

- Will face growing pressure to make low carbon pledges, and to demonstrate progress towards them. In the short term this is likely to mean a public commitment to implementing biofuel as part of emissions reduction measures.
- Face a new safety challenge in the widespread adoption of batteries, which may pose a different fire hazard to that of conventional fuel.
- Extensive testing in order to embrace alternate fuel variants. New fuels' performance across a range of metrics must be assessed prior to deployment.[14]
- Choose partners, from a wide range of options, to deliver biofuel. Negotiate purchase agreements, specifying volumes and timelines - fuel hedging will not be an option.
- May face new taxes to encourage biofuel adoption, especially in the EU.[15]
- Meanwhile electrification of small vertical take-off and landing (VTOL) vehicles enables new point-to-point travel. While initially more likely to displace helicopter, taxi or ferry journeys, it may also begin to impact premium short-haul flight demand in the 2030s (e.g. Heathrow to Manchester, JFK to Dulles). Operators may therefore choose to get involved in eVTOL.

Safety trumps everything in aviation. I believe this and the limitations of current technologies will dampen the pace for electrification of commercial aircraft. Further improvements in engine efficiency, sharkskin paint, and some biofuel blending represent the more likely gains by 2030. Hybrid planes might be the realistic next step after that.

CEO, an aircraft finishing specialist

MROs

- Electric drivetrains, with fewer parts to wear and tear, are likely to require less overall maintenance and could shrink the overall engine MRO market. There will be some compensations, especially in the form of battery inspection and maintenance.
- In the short term, likely to experience an uplift in demand for retrofits, as lessors and operators seek to optimize legacy fleets for new energy sources including biofuel, hybrid-electric and fully electric.
- Will require reskilling of technical workforce to handle new engine designs and technology.

There is a growing consumer led drive for greener sustainable travel which the aviation industry is responding to with a commitment to a 50% reduction in carbon emissions from their 2005 level. Sustainable aviation fuel such as aviation biofuels will be key to this ambition. We will support it whatever way we can. As an airport reducing our carbon footprint is a central theme of our strategic planning and by next year we will have achieved our target of reducing our energy consumption across the airport campus by one-third since 2018.

CEO, a regional transatlantic airport group with MRO investments

Airports

- Will face pressure to integrate biofuels into existing fuel storage and distribution infrastructure.
- Potentially have an opportunity to grow traffic by establishing a lead in biofuel and/or electric handling supply and expertise.
- Getting biofuels cost-efficiently to a critical mass of airports may bring hidden logistical complexity.
- Will require ground equipment for rapid battery recharge to facilitate electric models, including battery cooling technology. This will require new in-house expertise or supplier relationships.
- With electric planes able to operate from much shorter runways, airports may find that the transition to electric opens up major opportunities to reconfigure their current use of space, affecting strategic decisions about expansion.
- Electric planes' comparatively noiseless performance may remove the need for night-time flying restrictions, opening up the possibility of round-the-clock operations at airports that are currently restricted.
- Similar to the dilemma for operators, point-to-point eVTOL presents a threat to airport volumes beyond 2030. Some airports may respond by bringing their capital and operational expertise to city center locations.

Maintenance robotics

The fourth industrial revolution will impact aviation as much in after-sales as initial production.

Aircraft maintenance is a major cost line accounting for around 20% of a plane's operating cost. The process is hugely complex and exacting - it sees planes taken out of commission for weeks, even months, at a time, to be pored over by dozens of skilled technicians using specialized equipment. Exacting safety standards ensure that regular inspection is paramount and will continue to be so.

Multiple technologies promise to bring these costs down. Advances in drone technology, robotics, machine learning, and AI, have huge potential to streamline maintenance schedules and processes.

Examples abound: Rolls-Royce is planning a 'snake' robot capable of winding through the recesses of an engine for a range of purposes, including releasing small camera-enabled 'beetle' robots to send imagery to technicians;[16] Lufthansa Technik has deployed a robot capable of carrying out crack inspections on engine components.[17]

On the inspection side, Airbus and others have demonstrated inspection drones which can perform full external examinations of large aircraft.[18] Others, such as New Zealand's Invert Robotics, and Cranfield University, have developed crawler drones capable of sticking to the exterior of a plane, rather than flying around it, to perform examinations.[19,20]

Other digital technologies are also delivering new efficiencies: Qatar and Rolls-Royce are using VR to train engineers and thereby reduce the need to remove costly assets from circulation for training purposes;[21] Cathay Pacific is just one airline employing predictive analytics to anticipate maintenance demands, and Airbus has partnered with Rockwell Collins to include a predictive analytics package on all new A320s.[22,23] The emergence of startups such as OneAire demonstrates the growing interest in the possibility of AI to yield actionable insights and drive further efficiencies in the maintenance space.[24]
See Figure 8 for more examples.

Figure 8: The digital race has accelerated across all types of MRO

2015

Honeywell / Aviaso

Honeywell acquired Aviaso to provide fuel efficiency and emission saving solutions.

Safran

Safran launched a new entity, Safran analytics. This division was tasked with federating all Safran activities concerning Big data.

2016

Predix

Flydubai and GE launch network insights digital solutions to provide Intelligenet Network software for efficient recovery of disruptions across the airline's fleet of B737 aircraft.

Air France KLM Group / Prognos

Air France KLM's platform Prognos provides predictive maintenance software designed to capture data from aircraft in-flight and on the ground across available connectivity links.

2017

Airbus Skywise

Skywise is an open data platform developed by Airbus for the aviation industry providing insights from large amounts of data to help operators optimize decision-making in maintenance, engineering and flight operations, and in turn reduce costs.

Boeing AnalytX

Boeing AnalytX utilizes Boeing's expertise with data-based information to give empowered decision support to optimize operations and missions.

AAR

AAR launched new digital services (PAARTS STORE and AARive real-time).

Lufthansa Technik / Aviatar

AVIATAR is an independent and open platform for the aviation industry that combines a variety of digital products and services for airlines, MROs, OEMs and lessors in one place.

Rolls-Royce / R^2 Data Labs

Rolls-Royce R2 Data labs uses advanced data analytics, industrial Artificial Intelligence and machine learning techniques, to develop data applications that unlock design, manufacturing and operational efficiencies within Rolls-Royce, whilst creating new service propositions for customers.

2018

SIA Engineering Company / Safran

SIA partned with Safran to collaborate in the field of data analytics.

AAR / Airinmar

AIRVOLUTION, a cloud-based solution for component repairs.

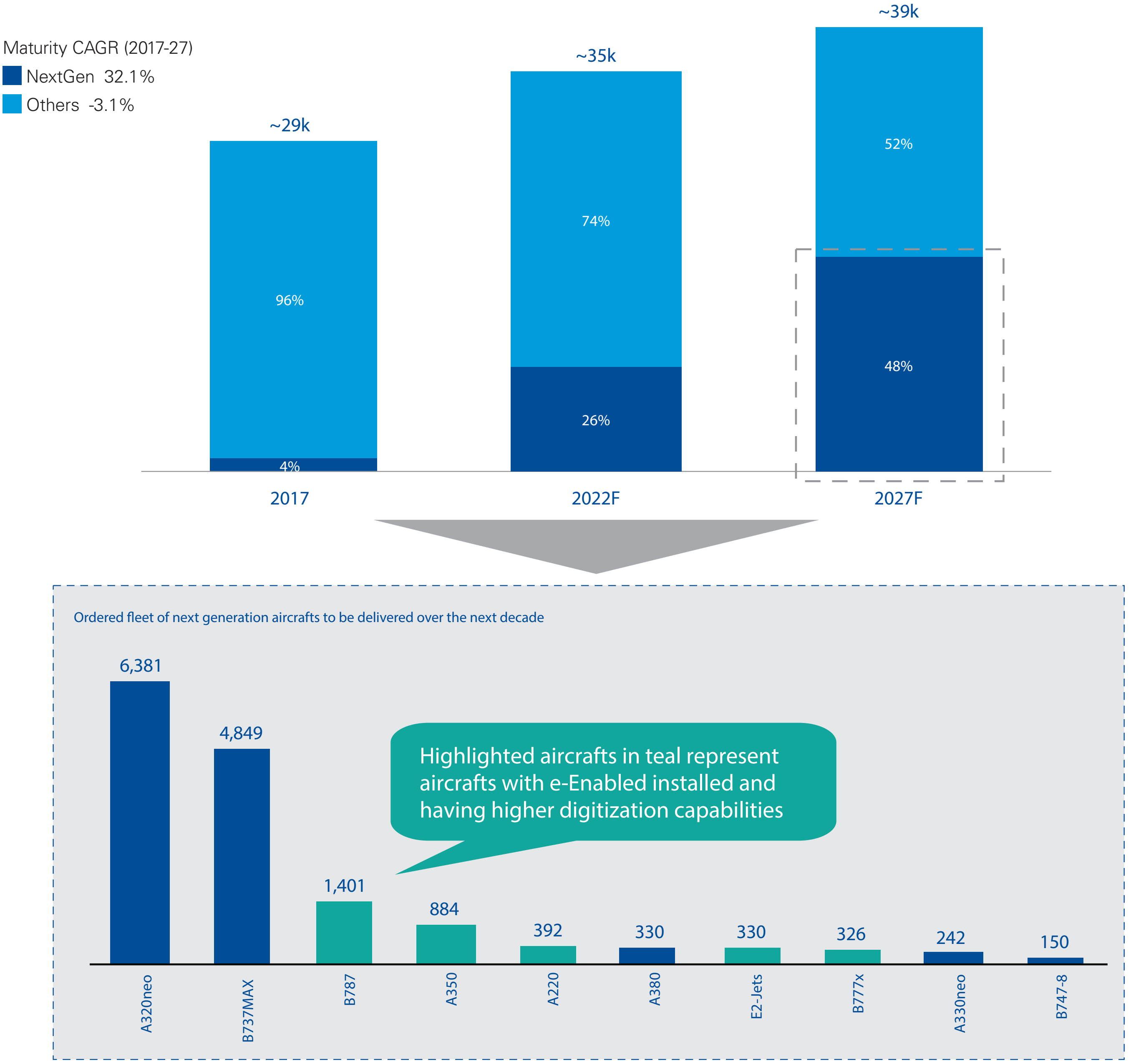
2019

FLYdocs / Safran / SITA / Sky Republic

MRO blockchain alliance to gain greater visibility over the life cycle of aircraft parts.

Digital-backed preemptive maintenance could save operators billions over the next decade. The level of data obtained from next generation aircrafts like Boeing 787s, A350s, Bombardier CSeries (now A220), A320neo, B737MAX, B747-8, A330neo, Embraer E2 Jets and the upcoming B777X means an ever clearer view of each asset's current health and capabilities. With CAGR growth of ~32% (see Figure 9), the NexGen fleet is expected to save airlines ~US$5 billion year on year with digitization of MRO over the next decade (see Figure 10).

Figure 9: Air transport fleet development by maturity



Source: ICF analysis (excludes turboprops)

Figure 10: Cost reduction from digitization

Digitization could enable airlines to save in excess of US$5 billion per year.

Health monitoring and predictive maintenance

Airline industry savings:

~US$3.0bn

(conservative estimate)

Driven by improved dispatch reliability. No fault found reduction, inventory reduction and improved labor productivity.

Fuel cost savings

Airline industry savings:

~US$1.7bn

(conservative estimate)

Continuous flight optimization through live weather updates, speed and altitude optimization.

Delay reduction

Airline industry savings:

~US$0.8bn

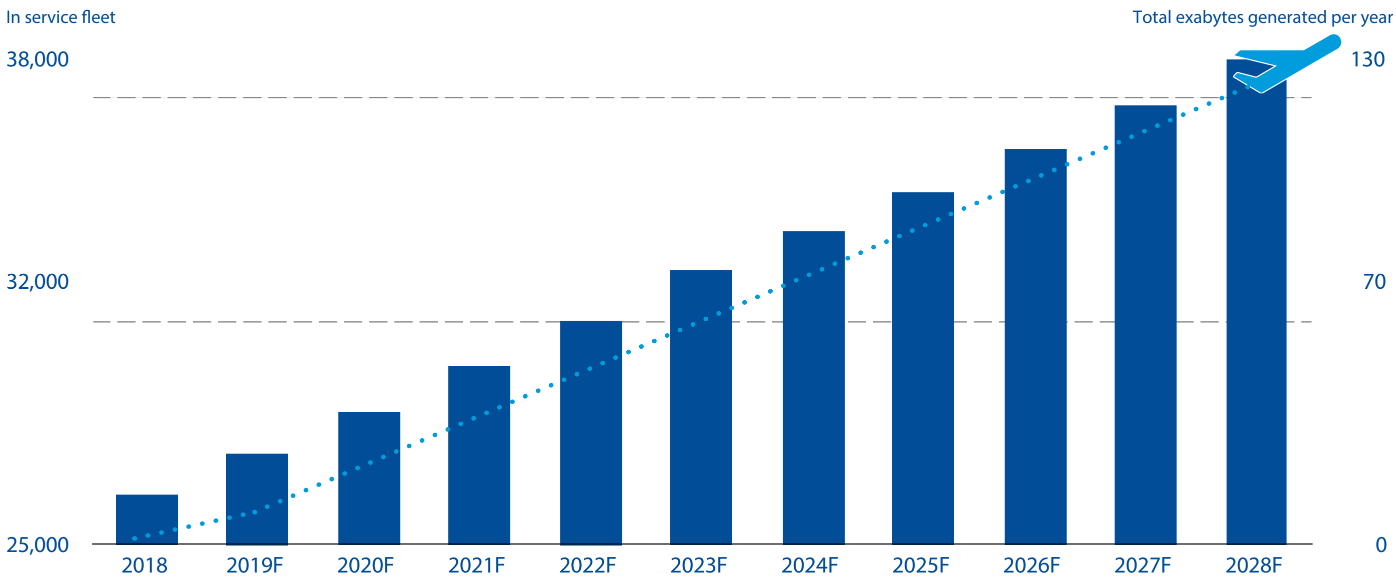
(conservative estimate)

Improved turnaround process, in-flight routing optimization.

Source: KPMG analysis

Figure 11: Data generated from global fleet

In 2028, the global fleet will generate ~127 exabytes of data (that's 127 million terabytes or 127 billion gigabytes):



Source: Oliver Wyman

*Forecast beyond 2026 is based on historical trend

Tempering this optimism in technology, however, are a number of practical considerations. Drones, for example, will face understandable breaks to their deployment in and near hangers within commercial airports. In other areas, like paintwork, what is technically feasible might not yet be economically attractive.

MROs and operators may face the bulk of risks and opportunities.

OEMs

- Robotization is expected to drive efficiencies throughout the manufacturing process, allowing headcount reductions in a notoriously labor-intensive process.
- Strategic partnerships or acquisitions may be needed to capitalize on the opportunities offered by robotics, IoT, data, and analytics.

Lessors

- The impact of robotics from a lessor point of view is relatively limited. Predictive analytics and sensor data will help lessors better predict maintenance events and thus reduce maintenance reserves.
- Lessors may need to rethink the economically useful life of an aircraft as the pace of innovation accelerates – new depreciation curves will mean rethinking the economics of overhauling older planes.

In the area of paintwork, automation is technically feasible but the economics don't yet stack up. Robotics would have to become significantly cheaper to displace the labor cost which is currently required to apply the coatings as part of the overall scope of work, and with advancements in the coatings products, the business case for automation may actually become harder to support.

CEO, an aircraft finishing specialist

Operators

- Robotics and VR will reduce the need for technicians to travel physically to locations to carry out inspection and maintenance work, as well as reduce the need for assets to be removed from circulation for training and/or repair.
- Predictive analytics will enable more accurate planning of shop visits and their costs, facilitating improved budget management and reduced maintenance costs.
- Drones can be used to inspect and scan areas of potential damage before planes are sent to the shop for repair, resulting in less downtime.
- Drones and robots together expected to produce step-changes across a range of metrics, including: punctuality, aircraft downtime, maintenance costs, and safety. At such a rate of change, the rewards for shrewd investment in these technologies will be substantial and the penalties for falling behind the curve could be severe – operators will face difficult decisions about investment priorities.
- Trend monitoring will enable lower inventories of parts as operators are able to predict demand for life-limited parts more accurately. They will also enable more efficient scheduling of shop visits, and improved fleet management.

Maintenance drones are an interesting development, but in practical terms their roll-out will be faster where maintenance facilities are not adjacent to commercial airports. No fly drone zones operate at airports for safety and security reasons. There are many operational risks that still need to be understood and mitigated in relation to drones.

Chief Communications Officer, a major European airport

Airports

- Robots in a wider sense will impact airport operating models as they adapt to a range of tasks: scanning boarding passes, checking bags, delivering baggage to planes, assisting lost passengers, and more. They will help airports handle growing passenger numbers by reducing congestion and increasing alertness to security threats.
- In terms of maintenance, robots may render existing inspection infrastructure – mechanical stands, inspection platforms – obsolete. New infrastructure to support the deployment of drones and robots for passenger management and plane inspection and maintenance will be indispensable.
- New rules or norms will be needed for the widespread deployment of drones and robots at airports, to manage potential safety concerns and overcome passenger skepticism (in parallel with more robust means of identifying and neutralizing uninvited drones).

We see near-term innovation in the paint chemistry and curing as having most relevance. Ink printing could feature; but who knows, beyond 2030, the very need for paintwork may be overtaken by advances in technology. For example, much as the 787 uses electrified gel to dim its windows, in time the aircraft surfaces themselves may be capable of displaying any pattern required at any given time; but as the main purpose for painting an aircraft is corrosion protection, this would require a significant revolution in the composition of the substrate materials which I don't see happening for quite some time.

CEO, an aircraft finishing specialist

MROs

- Predictive analytics will enable more accurate planning of shop visits and their costs, facilitating improved budget management.
- Drones and robots likely to allow MRO players to reduce headcounts and time of maintenance tasks, and increase operating margins in the long term – but it is more crucial than ever for them to make shrewd technology investment calls now.
- Trend monitoring will enable lower inventories of parts as operators are able to predict demand for life-limited parts more accurately. They will also enable more efficient scheduling of shop visits, logistics and fleet management.
- Cost of technical training should reduce with increasing reliance on VR and digital methods instead of live assets.
- Ultimately MROs will need to reshape their business model around a new paradigm of condition-based maintenance.
- With less MRO revenue per airplane likely, investments will be reliant on overall global fleet expansion.

Given our track record of innovation at Shannon and our investment in MRO, we keep a keen eye on advances in robotics maintenance.

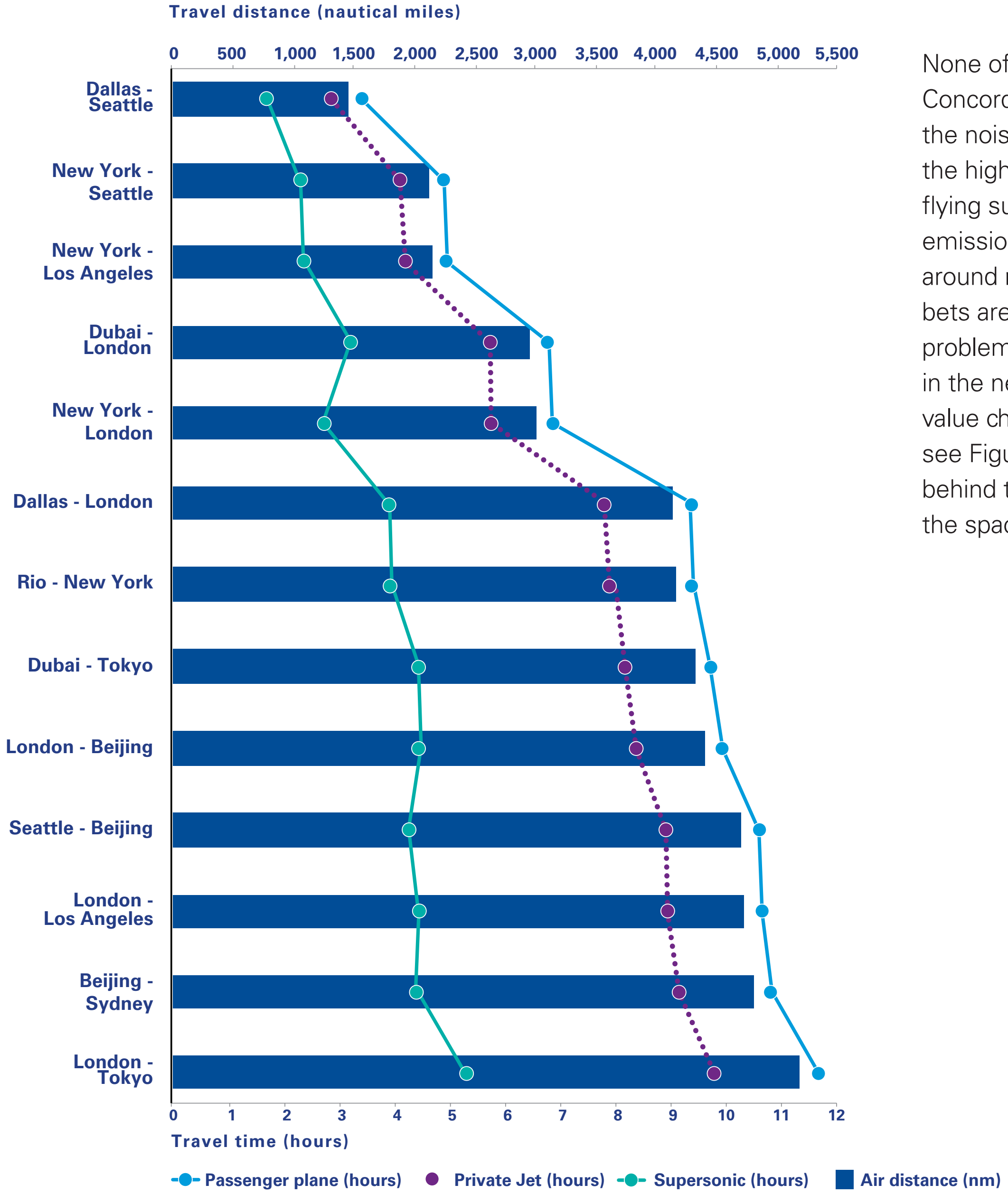
CEO, a regional transatlantic airport group with MRO investments

Return of supersonics

Concorde is no more, but the lure of supersonic flight remains strong.

A new generation of startups, undaunted by the history of supersonic and building on a range of technological advancements, are resurrecting the idea of sub-3-hour flights between New York and London. Travel time at supersonic speed considerably decreases for longer distances (see Figure 12), with Tokyo to London taking ~5 hours instead of ~10 hours.

Figure 12: Supersonic range map



Sources: QSTA range map – Lockheed Martin, Travel time calculator – Paramount Business Jet

None of the challenges that grounded Concorde have gone away: the noise pollution of sonic booms; the high costs of developing and flying supersonic planes; the emissions profile; the uncertainty around market appetite. But major bets are being struck that these problems can be engineered away in the near future, with established value chain players (including NASA, see Figure 13) putting their weight behind the ambitious initiatives in the space.

Figure 13: NASA's goals for supersonic aircraft development[25]

	Early 2020s	2030-2035
	Small Supersonic Airliner	**Efficient Multi-Mach Aircraft**
Design Goals		
Cruise speed	Mach 1.6 – 1.8	Mach 1.3 – 2.0
Range (nm)	4000	4000 – 5000
Payload (passengers)	35 - 70	100 – 200
Environmental Goals		
Sonic Boom	65 – 70 PLdB	65 – 70 PLdB (Low Boom flight) 75 – 80 PLdB (Overwater flight)
Airport Noise	10 EPNdB	10 – 20 EPNdB
Cruise Emissions (Cruise NOx g/kg of fuel)	<10	<5 & particulate and water vapour mitigation
Efficiency Goals		
Fuel Efficiency (pax-miles per lb of fuel)	3.0	3.5 – 4.5

Source: Machine Design

Aerion, building a supersonic business jet, will be taking its engine from GE Aviation and avionics from Honeywell Aerospace.[26] Boom Supersonic, looking to build a supersonic 55-seater, has pre-sold 30 planes to Japan Airlines and Virgin Atlantic.[27] Spike Aerospace, focused on a luxury 12-seater, says it is in 'detailed discussions' with both Rolls-Royce and GE Aviation about supplying engines.[28]

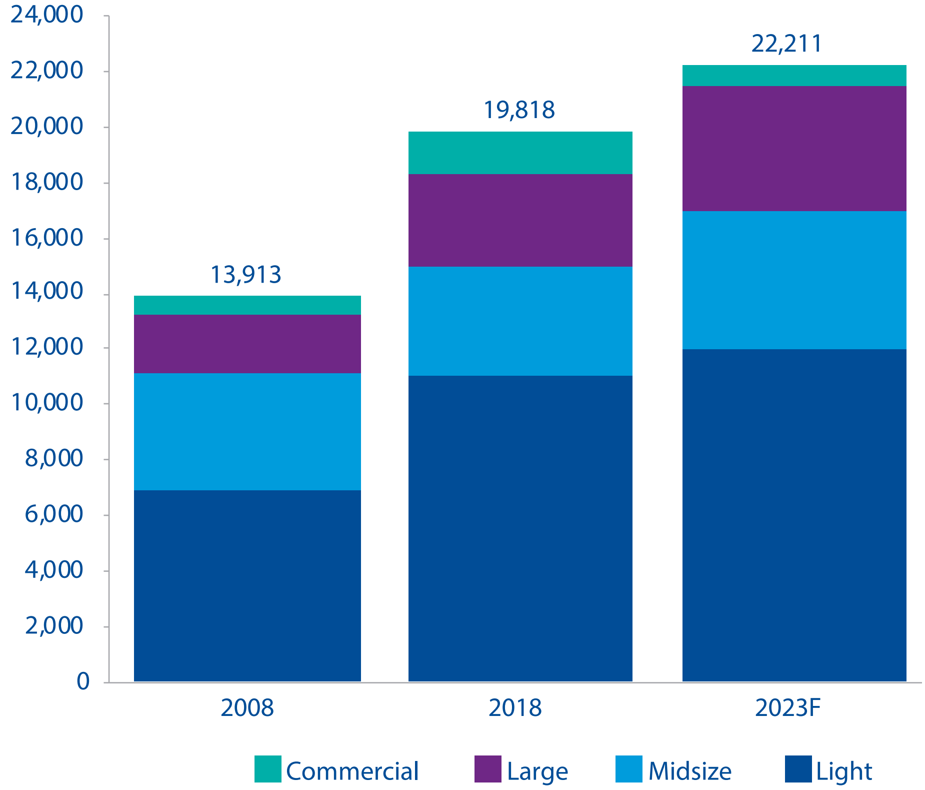
Figure 14: New breed of supersonic OEMs

	BOOM	Aerion Supersonic	Spike Aerospace
	Overture	**AS2**	**S-512**
Payload (passengers)	55 - 75	8 - 11	18
Cruise speed	Mach 2.2	Mach 1.5	Mach 1.6
Range (nm)	4,500	4,200	6,200
Estd. first flight	2020	2023	2023
Customers	Japan Airlines Virgin Atlantic	Flexjet	Two unnamed customers

Sources: Boom, Aerion, Spike Aerospace

The fact that renewed enthusiasm for supersonic is concentrated in business jets, rather than full scale commercial passenger planes, reflects a wider re-segmentation in the market – with improved economics of private charter helping the rise in business jet volumes (Figure 15) and with commercial first class being cannibalized by business class (Figure 16).

Figure 15: Global business jet numbers forecast, 2008-2023F



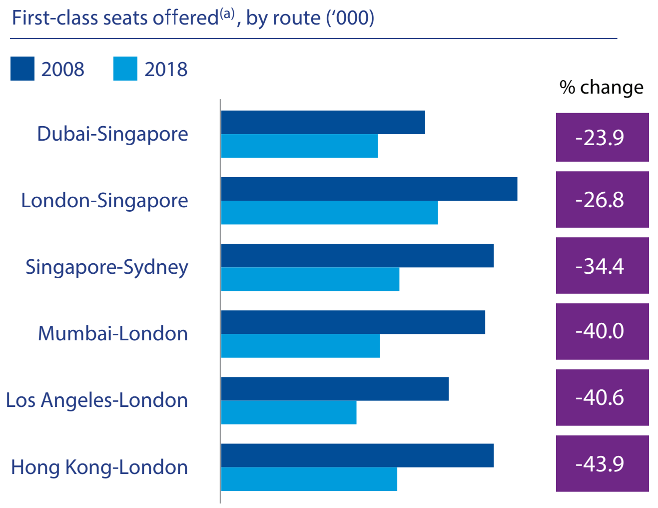
Source: Jetcraft–5 Year Business aviation market forecast

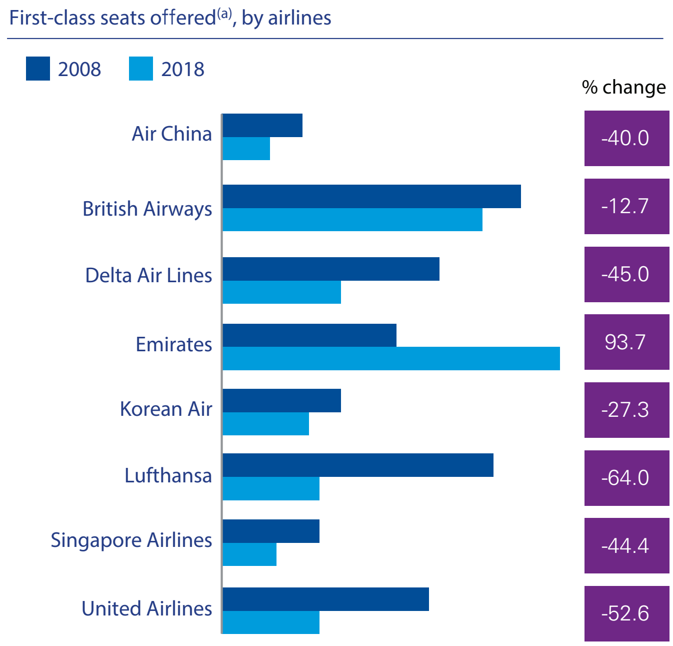
As a growing transatlantic hub we keep an eye on all developments in relation to aircraft developments. However, like any other airport with high runway utilization, we prioritize large commercial aircraft over smaller private operators.

Chief Communications Officer, a major European airport

Figure 16: Reducing demand for first class

The rise of private jets to travel long haul has seen a parallel fall in first class.





Note: (a) For flights longer than 3,000 nautical miles
Source: The Economist

If there is any space in which supersonics can prove their economic viability then, it is perhaps first in this niche.

More generally, proponents of supersonic cite a number of reasons to be optimistic about the 'second wave' of the idea: more efficient engines; advances in engine cooling technology facilitating ever-higher speeds (including hypersonic); advances in material science and biofuels; improved understanding of sonic booms and how to manage them, and a perceived willingness of passengers in the higher end of the market to pay a premium for lower journey times. It remains to be seen whether any of the entrants into this supersonic race will be able to deliver on their lofty ambitions, but it is clear that they are serious about trying, and that all players in the value chain will need to consider the possible impacts of supersonic on them.

The aviation industry may have underestimated the coming environmental backlash. This will challenge concepts like supersonic for anyone beyond a tiny elite as the potential CO_2 per mile per passenger may be difficult to justify.

CEO, an aircraft finishing specialist

The implications here are perhaps biggest for OEMs and smaller airports.

OEMs

- Major new design challenges and market opportunities presented by renewed demand for supersonic jets; manufacturers will need to push beyond the currently possible in order to create engines that can achieve the required velocities whilst also meeting environmental standards.
- Designing out the sonic boom to facilitate overland travel is another major challenge manufacturers will have to solve in order to open up the routes envisaged by supersonic proponents.[29]
- Opportunity to pioneer a new segment in the market and steal a march on competitors; breakthroughs in supersonic technology will facilitate lucrative market capture. At the same time, manufacturers risk being distracted from other, perhaps incompatible, strategic goals, such as environmental harm abatement.

Operators

- Establish existence and size of addressable markets, against a backdrop of substantial ambiguity concerning feasibility, routes, costs, and pricing. Assumptions about this will govern asset leasing decisions and build specs.
- Operators have a major challenge reconciling supersonic travel with low carbon pledges, and will need to understand what environmental performance the public will be willing to tolerate for increased speed 'for the few'.
- Lobby regulators to update noise restrictions in order to pave the way for relatively quieter models to fly.

Lessors

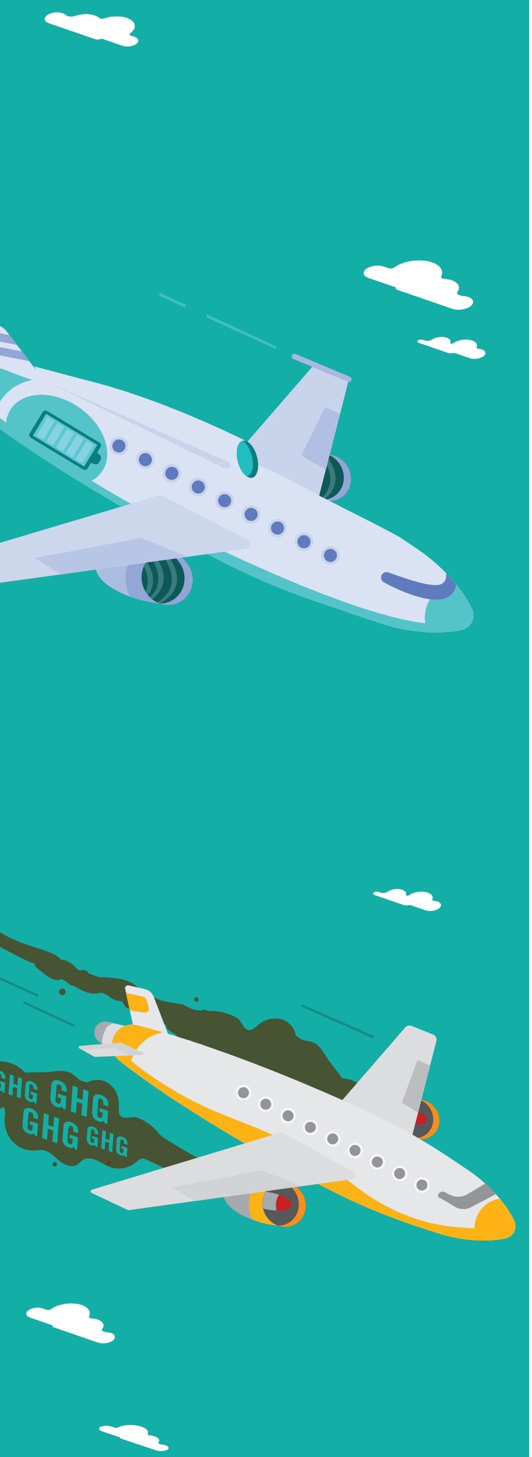
- Early signals from operators suggest they may be more likely to own and co-develop than lease these prestige, high-value assets.
- With longer-term stakeholders, newer Chinese lessors could be early adopters of the supersonic through wet leases to charter airlines or even commercial airlines.

Airports

- Likely to face intense pressure from a range of stakeholders over noise from supersonics as well as their environmental impacts.
- As supersonic aircraft could significantly increase the area around airports exposed to substantial noise pollution, larger, urban airports in particular may not risk their social license to operate, preferring instead expansion of conventional routes.[30]
- With the business jet emphasis for new supersonic projects, those airports most likely to embrace a return of supersonic are smaller, dedicated private airfields or more out-of-town locations.

MROs

- Technicians will need to familiarize themselves with a new generation of supersonic aircraft and parts, requiring extensive retraining and possibly retooling.
- Maintenance contracts for supersonic likely to be more lucrative than for conventional aircraft, with supersonics requiring more regular maintenance and more specialized equipment.



Conclusion

The relative golden age of the aviation sector may well continue – economic recessions notwithstanding – through 2030.

However, a range of societal pressures and new technologies are set to create significant disruption for incumbents. Thus-far profitable business models are likely to be eclipsed by new models built on improvements in robotics, electrification, biofuel tech and supersonic tech. Pressure to digitize, to reduce emissions at the same time as reducing journey times, and to increase aerial access to congested urban centers, are already driving innovation throughout the value chain. All players will need to take a structured look at the potential they face for disruption.

Since aviation requires long investment horizons, given both R&D cycles and asset lifespan, it follows that the winning business models of the 2030s are already being determined by today's investment choices.

So if the examples of disruption we have considered in this paper are not already on your Board's radar - they should be.

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Authors

Christopher Brown
Director
Global Strategy Group
KPMG in Ireland
E: christopher.brown@kpmg.ie
T: +353 1700 4453

Kieran O'Brien
Partner
Aviation Advisory
KPMG in Ireland
E: kieran.obrien@kpmg.ie
T: +353 1410 2456

Charlie Simpson
Partner
Global Strategy Group
KPMG in the UK
E: charlie.simpson@kpmg.co.uk
T: +44 20 7311 3671

Jono Anderson
Principal
Global Strategy Group
KPMG in the US
E: jonoanderson@kpmg.com
T: +1 858 750 7330

Debarun Das
Senior Consultant
Global Strategy Group
KPMG in Ireland
E: debarun.das@kpmg.ie
T: +353 1410 2679

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