



WANTED

AIRSPACE GUARDIAN OF THE FUTURE...

As Egis celebrates 50 years in aviation, we imagine the long-term future of aviation and what relevance air traffic management might have within it.



CONTENTS



03-04

INTRODUCTION

05-09

WHAT WILL DRIVE CHANGE?

10-11

SCENARIOS FOR THE FUTURE

12-22

FOUR SCENARIOS

23-25

IMPLICATIONS FOR THE AIRSPACE
GUARDIAN OF THE FUTURE

26

CONCLUSIONS

INTRODUCTION

At times, it can feel like aviation is a slow-moving industry. But we've come a long way since the first powered flight in 1903. Consumerism, globalisation and advances in technology have all contributed to an industry now enjoyed by almost 12 million fliers on any given day¹.

If anything, the pace of change is increasing. Fifty years ago, in 1969, we were landing on the moon using a guidance computer with less processing power than a modern pocket calculator (and by comparison an iPhone 6 is 120 million times faster than the computer that powered Apollo 11²).

For aviation, 1969 was an especially auspicious year. It was the year that the French Minister of Transport and the German Minister of Economic Affairs signed an agreement at the Paris Air Show for the joint development of the A300 aircraft, thus beginning a company called 'Airbus'. It was the year that the Boeing 747 and Concorde first flew, and that Embraer and Bulatsa³ were created. And it was the year that Egis began its aviation journey, with the birth of Sofreavia, a French company specialising in the commissioning of aeronautical infrastructure, which later joined the Egis family.

THIS PAPER

With so much change in the last half century, what metamorphosis can we expect to see in the next? Using scenario planning techniques, this paper provides our perspective. We focus on how such metamorphosis would change the way air traffic is managed and who would be responsible for managing it. In other words: what will our future guardian of the airspace look like?

Our view is as much a philosophical one as it is an attempt to predict future technological or societal advances. Most forward visioning exercises tend to restrict themselves to 20 years ahead. In looking

beyond that, this is more ambitious, but also more fanciful, since there are so many more unknowns. Nevertheless, there is value in considering the possible paths that lay before us and their implications for aviation and Air Traffic Management (ATM) in particular.

The thinking behind this discussion paper builds on the wider work of Egis in advancing sustainability and mobility in the 'smart' built environment. It also reflects our aviation work with regulators, airports and service providers in recent months, supporting them with their own future visioning and innovation planning.

¹ Source: HSBC

² Graham Kendall, The Conversation

³ The air navigation service provider in Bulgaria

AIRSPACE GUARDIAN OF THE FUTURE

In each of the future scenarios we describe there will be a need for an airspace guardian to manage air traffic. But if the Air Navigations Service Providers (ANSPs) of today want such a role, they will have to adapt. They must anticipate change, avoiding the business paralysis and failure to adapt that blighted companies like Kodak, Nokia, BlackBerry or Xerox. To avoid such a fate, ANSPs should reflect on the issues raised in this paper to stimulate thinking in order to:

- Strategically plan ahead including adaptability in the face of a changing external environment.
- Identify what uncertainty and risks can be planned for ie resilience.
- Consider the impact on the human (both internal staff, users and society).
- Explore new business models, considering for example a more integrated total transport system.
- Support innovation (a challenge for a business where innovation is not a core principle).
- Consider what alliances and partnerships will give them a head start (or help them catch up) and more control over the way in which their future responsibilities may evolve.
- Safely implement change more efficiently and effectively than in the past.

This paper aims to encourage all those with an interest in ATM to think about the actions needed in the next decade or so to remain relevant - not only for what may lie around the corner but for the long-term too. Please join us, for some crystal ball gazing into the role of the future airspace guardian and the different realities that we may face.

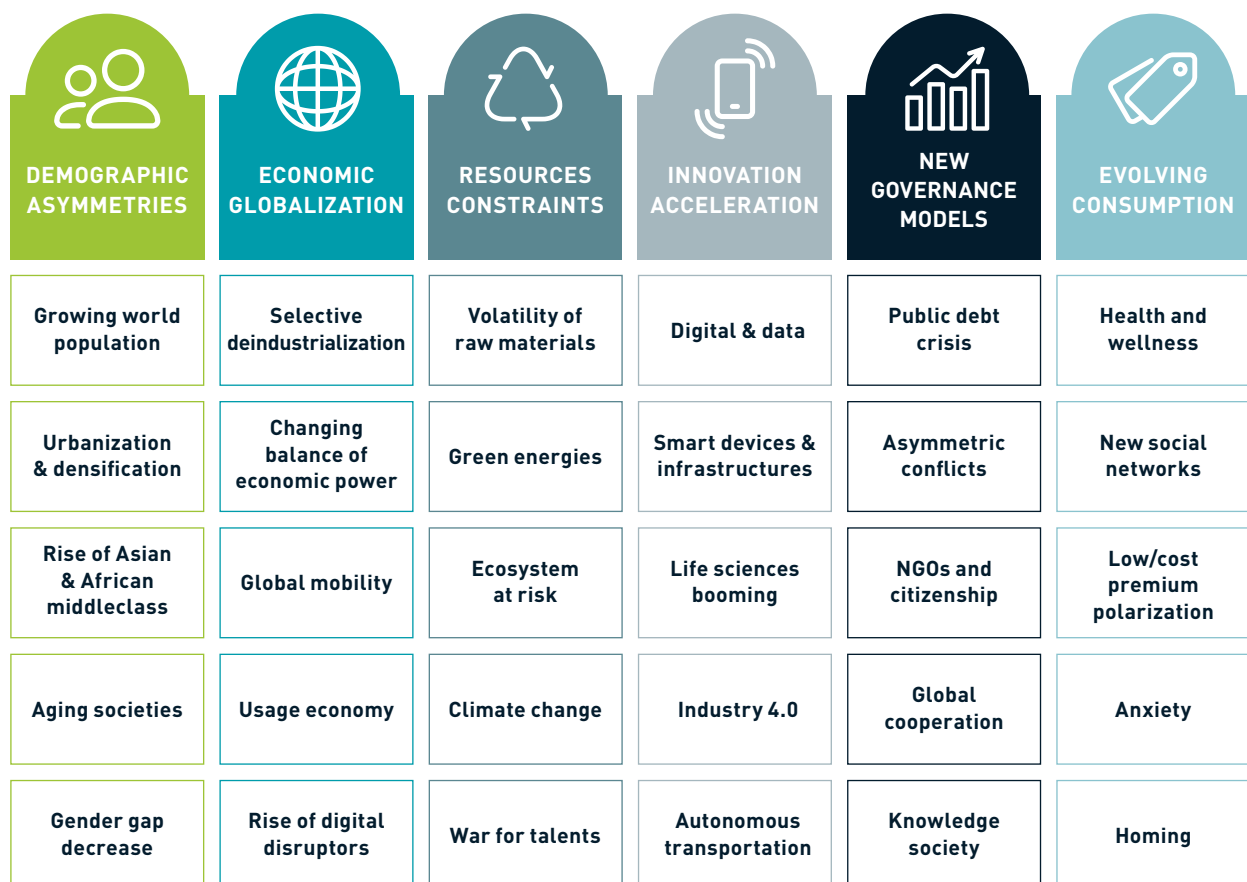
SCENARIO PLANNING

A technique which is commonly used to plan for the more distant future is scenario planning. This technique shifts the focus away from forecast 'probabilities', to consider a range of plausible futures and how they might emerge. They can stimulate and inspire policy and decision-makers, helping them deal with uncertainty and consider paradigm shifts. Scenarios were first used for the US military in the 1950s and were famously used by Shell to prepare for the 1970s oil crisis. Scenario planning has, in recent years, become more widely used in the public and private sectors to explore the future; the Global Europe 2050 scenarios developed by the European Commission are a good example of this.

WHAT WILL DRIVE CHANGE?

Several trends are likely to have a long-term impact on global markets of the future, for example those shown below⁴.

Not all will impact on aviation though. Following discussion amongst our experts, we've considered how the most relevant trends manifest themselves as drivers for industry change. They are outlined as a PESTLE (Political, Economic, Societal, Technological, Legal, Environmental) analysis on the next page. The aim is to determine which will have the greatest impact on the aviation industry, especially ATM, and which is the most uncertain (or unpredictable) in its outcome.



⁴ Source: Oliver Wyman

POLITICAL DRIVERS

Government stability and geopolitical stability will both impact on societal propensity for air travel. Political drivers will be closely related to societal drivers. For example, societal habits in travel are likely to be influenced by trade policy or potentially taxation or environmental policy to curb demand. The IT revolution has empowered people to engage in societal issues and provided people with the tools to hold politicians and governments to account for their decisions and actions. However, it has also enabled authoritarian regimes to use new technology to identify and fight political opposition. Data will be a political tool as well as an economic force – just watch ‘The Great Hack’⁵ if you’re not convinced.

For aviation, the extent to which government policy encourages or discourages market liberalisation is particularly important. Do governments and states closely control aviation (because of its importance to national interests) or do they promote liberalisation, giving private enterprises the freedom to shape the way

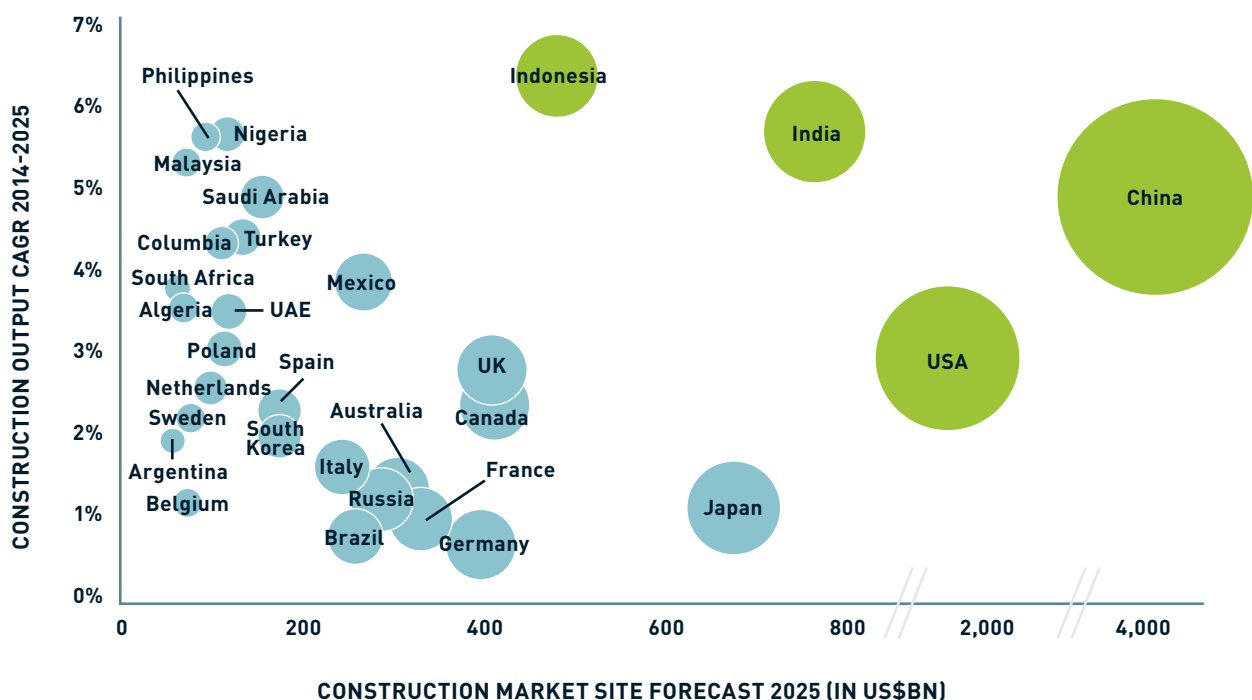
the market evolves? Over the past few decades, aviation has slowly and steadily become more privatised and increasingly free of state control. For example many airlines and airports are now privatised. On the other hand, regional attempts to federate control away from states, such as the Single European Sky project in Europe, have introduced very little in the way of liberalisation due to protectionism.

A further dimension to the political landscape will be the influence that powerful and resourceful private enterprises, such as Alibaba, Amazon, Google or Uber could exert. They are expanding into various aspects of aviation, for example drone operations. Such operations not only bring greater numbers of assets into the airspace but also new challenges to the institutional landscape as such enterprises sit outside of state control and could challenge national policy such as liability regulation or the long-held sovereignty of airspace.

ECONOMIC DRIVERS

The drop in the relative cost of flying has been markedly pronounced over recent decades. A flight across the globe, from the UK to Australia, is now little more than one week’s average wage, compared to 2.5 times the annual wage back in 1947⁶. But it

is difficult to see how cost will continue to decline. A predominantly capitalist agenda has meant that most economies have continued to grow and that citizens have continued to get wealthier, enabling more people to fly. This has in turn facilitated more



competition that has driven prices down allowing even more people to fly, and so on. But growth cannot continue indefinitely – the planet is finite after all. Theories on ‘post-growth’ and ‘circular’ economies⁷ are increasingly gaining traction. The rise of the digital economy has been particularly pronounced with personal data already considered more valuable than oil⁸, heavily impacting the way in which data is regulated and protected.

Economic growth will also vary from region to region with the balance changing over time. China and the

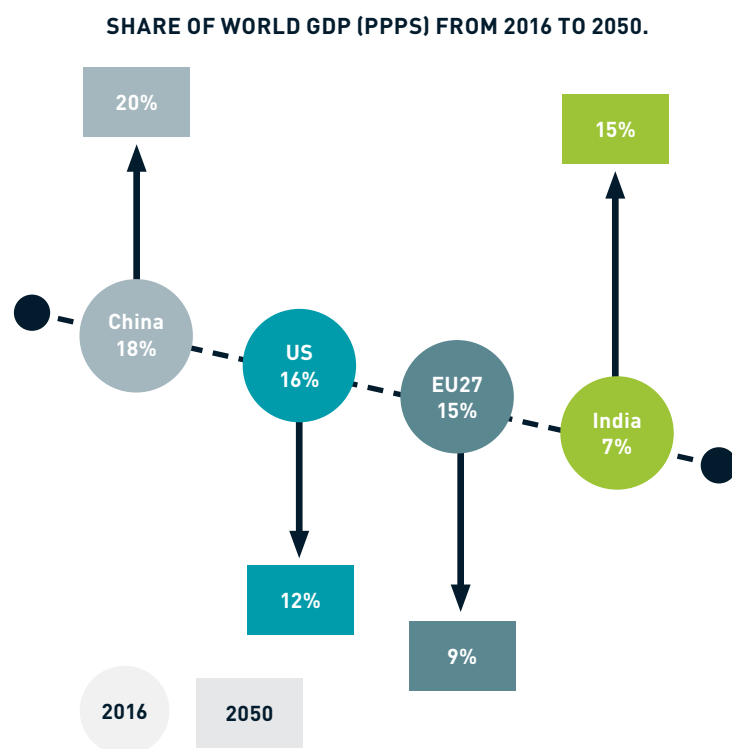
US will continue to be the biggest economic powers for some time – a point starkly shown in the forecast construction market output below⁹. Over time though the balance of power will change as China continues to accelerate, widening the gap with the US.

By 2040, the emerging E7 economies (China, India, Indonesia, Brazil, Russia and Mexico) are expected to be double the size of the G7 (US, UK, France, Germany, Japan, Canada and Italy)¹⁰.

Ultimately, the cost of flying is more likely to increase than to decrease. This is either to curb flights with high emissions; to fund the introduction of more sustainable air travel; or simply because of the increasing scarcity of oil.

SOCIETAL DRIVERS

For the vast majority of humans’ life on earth, we lived in tribes and isolated communities with little need or desire to interact outside of those communities. The industrial and scientific revolutions changed that, eventually arming us not only with the means to fly to every corner of the globe, but also motivating us to fly around the world to experience it. Tourism has exploded with a 5,500% increase in visits from one country to another – 1.4Bn visits in 2018, compared to 25M in 1950⁵. In China alone, overseas trips have increased by more than 1,300% in the last two decades¹¹. Accompanying the growing number of tourists have been the business passengers. They now account for around 12% of passengers by number¹² (and a much higher proportion by profit contribution). Today’s workforce is much more mobile than in the past – 39% of Millennial and Gen Z workers (those born since 1980) have stated they wouldn’t accept a job that doesn’t let them travel¹³.



Sources: IMF for 2016 estimates, PwC analysis for projections to 2050

⁵ Netflix series

⁶ Sunday Times Magazine

⁷ Adam Barrett, The Conversation

⁸ Economist, May 6th 2017

⁹ Oxford Economic Global Construction 2030, data from 2015

¹⁰ PwC analysis for projections to 2050

¹¹ Telegraph

¹² Investopedia

¹³ TripActions

However, attitudes look like they may be changing. The 'flygskam' (Swedish for flight-shaming) movement, and the likes of Extension Rebellion, are gaining momentum, particularly amongst the young, evidenced by coverage of 16-year-old climate activist Greta Thunberg's attendance at the 2019 UN Climate Summit. This momentum will increase pressure to reduce flying in the pursuit of 'climate-friendly' aviation. It is also likely to accelerate the development and more widespread use of alternative means to travelling – for example virtual reality meeting rooms.

Another societal trend is the shift towards urban living and the anticipated rise of 'mega cities'. According to the UN, more than two thirds of the global population will live in urban areas by 2050¹⁴. The required transformation of cities will fuel new modes of transport such as urban air mobility. Light aircraft are expected to have started autonomous operations over major cities as soon as 2025¹⁵.

TECHNOLOGICAL DRIVERS

The ways in which technology will shape our future is hard to predict. Most of what sits on Gartner's Hype Cycle today is expected to happen in the next 10-20 years. Blockchain and IoT platforms, for example, will reach maturity in the next five to 10 years, with digital twins and knowledge graphs hot on their heels. A common theme is increased connectivity between real-world devices and the virtual world. As data connectivity expands exponentially so does the threat of cybercrime and cyber failure.

A data-rich world, with ever more powerful data processing and analytical capability gives rise to a whole new data economy and ecosystem, requiring new skills and oversight.

Technology developments over the next decades will give rise to whole new categories of airspace users, from autonomous drone delivery services and urban air taxis through to commercial space flights. The market for the use of drones, in particular, is

already growing by the day - with 200 concepts in the passenger drones field in 2019 alone¹⁶. The speed of technological advances in aircraft propulsion (alternative fuels, alternative engines) will also play a vital role in air travel trends, influencing government/regulatory policies and societal demand for air travel alike.

There are more technological changes over the horizon than we can possibly count, and already things like 3D printing, robotics, virtual reality and AI are threatening to upturn traditional industries. How far and fast we advance in the coming decades will be strongly influenced by our ethical stance and regulatory response. For example, to what extent are we prepared to allow AI to make decisions, and how far are we prepared to go with integrating biotechnology or DNA modification in humans?

LEGAL DRIVERS

Aviation regulations have historically been developed at a global level through ICAO, the International Civil Aviation Organisation, based on a convention signed by developed countries in 1944. This has often meant development moving at the speed of the slowest player. The last few years have already shown that in many regions, capacity is unable to keep pace with demand. This will only become more pronounced with the introduction of new classes of airspace user. ICAO already recognises the need to develop new regulatory frameworks for today's emerging technologies and operational environments (such as commercial space)¹⁷, but it will also need to find new ways of working and establish new partnerships if it is to keep pace with technological change.

Aviation legislation also takes place at the national level. For example, permission to fly, airspace change, slot allocation, air quality or noise regulations are currently set at individual state level. The legislative response (and speed of response) to change will influence the future direction of aviation in both developed and growing economies.

ENVIRONMENTAL DRIVERS

The environmental 'conscience' of society is strengthening. At a global level the response to climate change is being driven by the 2016 Paris Agreement¹⁸, uniting all the world's nations to keep global temperatures well below 2°C above pre-industrial times, and to limit the amount of greenhouse gases emitted by human activity.

Aviation is a key contributor to greenhouse gas emissions: if global aviation was a country, it would rank in the top 10 emitters¹⁹.

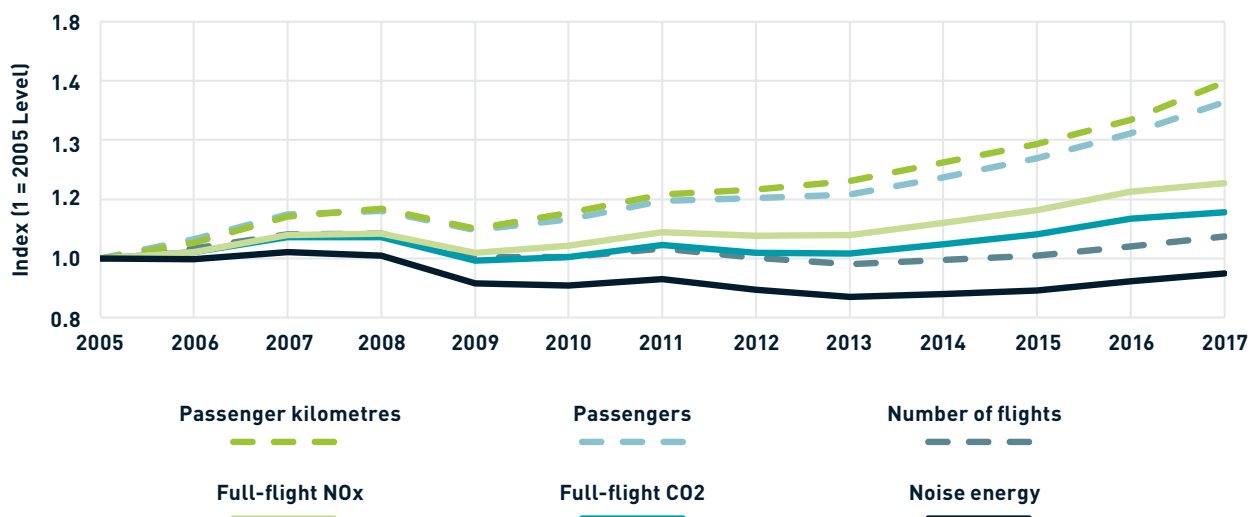
There is a dawning realisation that such an insatiable appetite to fly cannot continue without detrimentally and irrevocably impacting on the environment.

Technological advancements such as electric aircraft could one day make a difference, but this will require a major scientific breakthrough as today jet fuel (Kerosene) has an energy density of 43 times that of a state-of-the-art lithium ion battery²⁰. Furthermore, electric aircraft have a high lifecycle carbon dioxide intensity (an all-electric 180-seat aircraft flying

a 400 nautical mile mission would generate 22% more lifecycle CO₂ intensity per revenue passenger kilometre than the equivalent jet engine aircraft²¹). Bio-based fuels are not yet a viable alternative as feedstock currently costs around \$400 per tonne more than fossil-based fuel²².

The number of flights (not passengers) to and from the EU (including EFTA) has remained relatively constant since 2005, but nitrogen oxide and carbon dioxide emissions (directly attributable to aviation) have increased by around 25% and 15% respectively – only noise levels have decreased (by around 8%) – this is shown in the figure below²³. In essence, despite modest technological advancements, increases in the number of passenger kilometres flown have contributed to more fuel being required and more emissions being produced. Even advances in aircraft technology, improved efficiency and fleet renewal have not been able to stop emissions rising. Commitments to reduce emissions in aviation, such as those of the European Flightpath 2050 vision²⁴, are so far generally considered to be insufficient²⁵.

RELATIVE EVOLUTION OF AIR TRAFFIC AND ENVIRONMENTAL INDICATORS



¹⁴ United Nations

¹⁵ Science & Technology Research

¹⁶ The Drone Market Environment Map, June 2019

¹⁷ ICAO Journal, The Future of Aviation, 2019

¹⁸ Paris Agreement, 2015, UNFCCC

¹⁹ European Commission, Reducing emissions from aviation

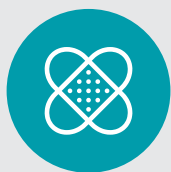
²⁰ Gofman, Evelyn (2003). Elert, Glenn (ed.). "Energy density of aviation fuel". The Physics Factbook.

²¹ Schafer, Andreas W. Energy, Economic, and Environmental Prospects of All-Electric Aircraft. s.l. : University College London.

²² European Aviation Safety Agency. European Aviation Environmental Report. 2019

SCENARIOS FOR THE FUTURE

Each of the drivers described previously has the potential to define quite different outcomes for how global aviation, and indeed ATM, may look many years from now. These drivers also involve many interrelated forces, for example: an economy's health, state policy, societal and geopolitical stability, demographic changes, affordability of air travel and so on. In line with the basic steps of scenario planning²⁶, as first developed by American game theorist and futurist Herman Kahn, it is important to identify the key unknowns for the future and rate each on two scales: **probability of occurrence** and **potential impact**. Through our own internal horizon scanning workshops and discussions, we whittled down a long list, and determined that the two most uncertain and impactful drivers of relevance to future aviation are:



ATTITUDES TO PROTECTING
THE ENVIRONMENT



LEVEL OF MARKET LIBERALISATION, IE THE
EXTENT OF STATE CONTROL AND INFLUENCE
OVER AVIATION

ATTITUDES TO PROTECTING THE ENVIRONMENT: CURTAILED VS EXPANDED AVIATION

As already explained, social and political attitudes to protecting the environment are a very real driver for change and one that we consider will strongly impact the aviation landscape for the coming decades. Existing commitments to reduce emissions in aviation (and more generally) are, so far, insufficient and it seems inevitable that we will be faced with much tougher decisions. The outcome of these decisions will have a high impact as they will affect the number of people flying and the size of the aviation market.

The level of uncertainty is determined by how quickly we could arrive at a point where aviation is considered sustainable. Significant uncertainties exist around the willingness of people to make lifestyle changes and sacrifice travel. Uncertainty also exists over whether those changes will be forced upon people at a political level for the benefit of the environment, despite the potential economic cost. Similarly, the ability of industry to deliver the necessary scientific and technological breakthroughs is another unknown.

We have therefore considered two extremes:

- **Intercontinental air traffic and passenger growth continues at historical levels,** doubling every 15-20 years. This is facilitated by a combination of social and political prioritisation of growth above the environment. Environmental concerns may be addressed either by subsidy from other areas (eg by trading the carbon reductions made in road transport) or through a sufficiently affordable but highly efficient scientific breakthrough that enables emissions to be reduced and traditional fuels to be replaced without impacting growth.
- **Intercontinental traffic and passenger growth is severely curtailed,** even declining compared to 2019 levels. This is due to social and political prioritisation of sustainability and the lack of a sufficiently affordable technological solution. Market-based instruments such as taxes or caps may be used to limit the use of inefficient aircraft and it will take time and significant cost to introduce more efficient aircraft. Alternatively, it could be due to a long-term economic downturn, leading the world to move away from a high growth capitalist agenda towards a 'circular' or 'post-growth' economy.

MARKET LIBERALISATION: OPEN VS CLOSED

Aviation is expected to remain an important enabler of wider economic growth and to play a major role in a country's defence. It will thus continue to be important to the state and will be impacted by politics, and indeed, geopolitics.

There is however much uncertainty, not only in relation to how politics will evolve, but specifically the extent to which state control and influence over aviation will change. To date, the industry has seen a gradual increase in private sector involvement, particularly through the privatisation of many airlines and airports. The question is: to what extent the nation state will 'let go' of aviation in the future? Will states take a nationalistic, protectionist view, only very gradually ceding control to the private sector? Or will states take a more liberal hands-off role to allow market forces to shape the future more quickly?

We have considered the two extremes:

- **Market is liberalised with commercial players driving industry change.** Commercial forces for growth drive changes to the regulatory environment, in much the same way that the liberalisation of the taxi market (eg Uber) has led to changes that regulators have been unable to keep up with.
- **Market remains highly regulated with industry change in the hands of the state.** Trade wars, military conflicts and social crises of identity fuel a rise in nationalism and protectionism that curtails or limits market freedoms.

^{23v} Air emissions accounts by NACE Rev. 2 activity, EC, 2019

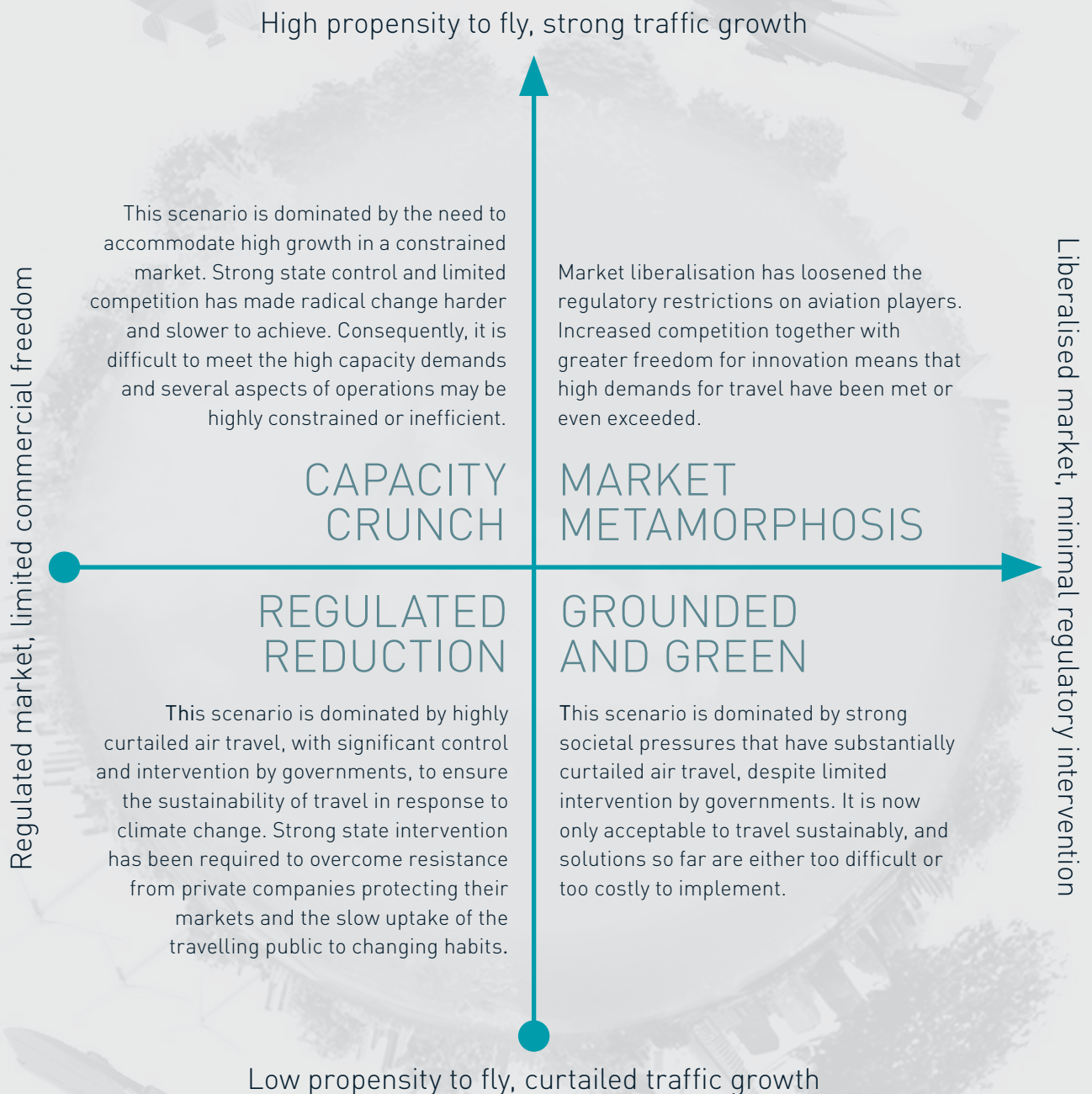
²⁴ 75% reduction in CO₂ emissions per pax km; 90% reduction in NO_x emissions; 65% reduction in noise; no emissions whilst taxiing; recyclable aircraft; Europe as a leader and centre of excellence for sustainable aviation fuels; and Europe is at the forefront of atmospheric research.

²⁵ A report published in 2017 (Victor, David G. "Prove Paris was more than paper promises". s.l.: Nature, 2017) suggests that the Paris Agreements has been relatively ineffective as all major industrialised nations are failing to meet their pledges to control greenhouse gas emissions

²⁶ See text box, and R.Horwarth, 'Scenario Planning: No Crystal Ball Required', Strategic Thinking Institute

FOUR SCENARIOS

The two drivers described in the previous section were used to form two axes to define four future scenarios. These scenarios are presented below.



SCENARIO: MARKET METAMORPHOSIS: STRONG GROWTH IN A LIBERALISED MARKET

Market liberalisation has loosened the regulatory restrictions on aviation players. Increased competition together with greater freedom for innovation means that high demands for travel have been met or even exceeded.

Highly liberalised
market with loosened
regulatory restrictions

Increased
competition with
greater freedom
for innovation

Fully networked
business operating
with no geographical
limitations

High reliance on
networked real-
time data ensuring
a seamless door-to-
door journey for the
passenger



Liberalisation has allowed airlines to break away from any remaining sovereign links and national bases to become fully networked businesses, operating from whatever airport or mega city best serves their strategy. Mega-cities are now a market in their own right; transporting humans around cities has created a market worth \$674Bn in 2040²⁷. The overall journey, particularly in smart-cities, is more seamless, more predictable and offers a more efficient use of time. Autonomous cars or urban air taxis collect passengers and deliver them to the terminal, having completed security and check-in processes on the journey using biometric data and facial recognition technology.

As a result, new partnerships and companies have emerged that integrate the different roles in the transport chain (eg airport operator, ANS provider, aircraft operator, urban air-mobility operator etc) but focussed on specific market segments or route networks that align with their strategy. This is a very competitive space, as competition has appeared from multiple organisations involved in the door-to-door journey, including the expanded manufacturing and supply market (several of the 170 companies developing aircraft powered by electricity²⁸ in 2019 have now become large players). It also comes from increasingly privatised airports which have expanded into wider transport services as part of a strategy to replace lost shopping revenues (which moved online) and parking revenues (which reduced once passengers began travelling to the airport using 'Mobility as a Service').

Aviation now relies heavily on networked real-time data and strong connections to other forms of transport including air taxis and surface travel. This means that lines between different transport modes and even IT companies have become blurred and consequently changed the competitive environment for airlines. Data-driven IT companies now sell or auction tickets and own the relationship with the passenger. These companies have strong buying power over the airlines and have demoted some traditional airlines to become purely operators or asset managers of the aircraft. The same IT companies have also introduced

new experiences for passengers, and greater levels of customisation, enabled through an aircraft that remains fully connected throughout its journey (eg shopping, education/training courses, virtual reality experiences etc).

The commercial freedoms and fight for survival of traditional airlines has encouraged them to innovate. For example, the increased use of autonomous cars and air-taxis has helped people to overcome their previous reservations²⁹ about pilot-less aircraft and several are now in operation – helping to reduce the price of tickets. Airlines have also expanded into new areas through new ventures and business models, including the space-tourism market.

Fed by strong demand, more competition, and increased efficiencies (3D printing, robotics etc) the manufacturing sector has made sufficient progress to enable the introduction of environmentally sustainable aircraft at a cost that doesn't limit aviation growth. This includes electric and hybrid electric aircraft that have better energy density and lower lifecycle carbon dioxide intensity than jet-fuelled aircraft. Those that still use fuel have been converted to bio-based fuel (now produced cost-effectively) or use carbon capture to offset their emissions by filtering the air to capture carbon dioxide molecules³⁰.

Airports still find it hard to introduce runway capacity and continue to be challenged by local stakeholders who object to expansion. Airports do however have more flexibility in the way they manage operations particularly as the new hybrid electric aircraft are much quieter than their predecessors, meaning that noise is less of a concern and there are less restrictions on night flights. Data allows them to more accurately predict operations and they seek more control over the links in the chain, for example surface and air connections to, and from, the airport.

IMPACT ON AIR TRAFFIC MANAGEMENT

Highly networked, data-driven transport connecting aircraft in real-time, with continuous data messages to deconflict and manage the dynamic airspace situation, means that tactical separation and decision making is largely handled by automated software, with inputs being authenticated securely (eg using Blockchain) and calculated either in the air or on the ground. This, coupled with the liberalisation of ANS contracts (driven by liberalisation throughout the rest of the aviation market), has led to a completely different concept of 'ATM'.

As the client base for ATM services has shifted to competing IT companies (who have the relationship with the passenger) rather than airlines (who only now operate the aircraft), the responsibility for passenger safety has also shifted across to IT companies.

Traditional standalone ANS providers no longer exist. Instead, IT companies focus on the overall passenger experience and managing multi-modal traffic to ensure seamless door-to-door journeys.

Some overall state surveillance and management of airspace typically remains to protect national security and to stand guard over sovereign airspace. Liberalisation has reduced the burden of regulatory intervention, which is now focused on safety, environment and ensuring interoperability of systems at a global level.

The expansion of the market, for example with urban air mobility services and space-tourism has created new opportunities for companies as operations stretch vertically (from zero feet to outer space) and due to the reliance of aircraft on better communications infrastructure. A fundamental review of airspace structures has been necessary, just as seen a few decades ago when first trying to integrate drones into the airspace.



²⁷ Morgan Stanley

²⁸ Roland Berger

²⁹ 54%, said they would not fly in a pilotless plane (even if the ticket price was cheaper), according to a UBS survey in 2018 - <https://www-unitingaviation-com>

³⁰ A tiny tweak in California law is creating a strange thing: carbon-negative oil, Quartz, Akshat Rathi

SCENARIO: REGULATED REDUCTION: CURTAILED TRAFFIC IN A CLOSED MARKET

This scenario is dominated by highly curtailed air travel, with significant control and intervention by governments, to ensure the sustainability of travel in response to climate change. Strong state intervention has been required to overcome resistance from private companies protecting their markets and the slow uptake of the travelling public to changing habits. Air traffic has thus been reduced to a sustainable transport solution faster than the highly liberalised, market-driven scenarios.

Dominated by highly curtailed air-travel with significant control and intervention by governments

Highly sustainable transport solution in place driven by state regulation and societal demand

Rationed flight quotas enforced on passengers using a 'environmental quota' status

Aviation supply chain becomes publicly owned due to the lack of growth curtailed by state regulation



The state has passed laws to allocate flights quotas that 'ration' flights or environmental 'credits' to each and every person. The elite or wealthy still take (buy, trade etc) a greater share, though many governments have implemented measures to make it much more equitable than in 2019, when only 3% of the world flew per year³¹.

The lack of aviation growth and limited market freedoms has forced many airlines to exit the market altogether, and others to once again become publicly owned and subsidised - particularly outside of the mega-cities. The airline struggle for survival has accelerated the introduction of cost reductions such as pilot-less aircraft, particularly as the options for long-haul travel are more limited. More radical innovation in the sector has been limited due to the lack of market freedoms and strong state control.

Airlines that have survived the economic pressures have implemented business models built around rationing. This includes managing the

'passenger kilometre' allowance of individuals with mechanisms like 'banks' where allocations are traded and exchanged on a secondary market.

Rationing and scarcity of flights has also led to increased scrutiny from passengers who take a much greater interest in the data associated with the few flights they take (eg flight planning, execution process etc) to ensure their valuable flight allowance is being used efficiently. This has resulted in new pricing strategies - for example paying more for quicker or more popular journeys and being compensated directly by those responsible for inefficiencies.

New types of air travel journeys have emerged, such as 'air cruises' using slow but environmentally friendly (eg hydrogen-powered) airships that act as hotels and give passengers beautiful views as they fly. These environmentally friendly 'airship hotels' require much more time in the air but compensate for this with an enhanced passenger experience, becoming leisure pursuits in their own right.

IMPACT ON AIR TRAFFIC MANAGEMENT

ATM is the responsibility of state-owned actors. The role has evolved to a planning/scheduling, monitoring and enforcement activity, in particular to oversee adherence to environmental quotas and legal emissions limits. Although international traffic has declined substantially, there has been a strong rise in traffic in the lower airspace - particularly around mega-cities. This has led to air traffic management becoming fragmented, with mega-cities adopting different operational concepts more suited to their cities, and usually entirely integrated with all other forms of transport.

There is no need for tactical air traffic control as upper airspace is sparse and most aircraft are pilot-less using pre-agreed, deconflicted routes with any issues dealt with by software on the aircraft.

Lack of traffic generally ensures direct and efficient flight routing. Lower airspace is more complex, with a mixture of self-separating drones and air-taxis, mixing with slow moving airships and the occasional long-haul flight.

It is the responsibility of the state to provide the planning and coordination framework to interface at this lower level, but several different frameworks have emerged to accommodate different needs from one mega-city to another. There is no longer any voice communication between aircraft as all communication is done over secure data connections.

Data is used transparently and passengers can monitor adherence of their flight against their requirements and claim direct compensation from those responsible for any issues during the journey. Different pricing structures exist to encourage the most sustainable forms of flying.

³¹ The Conversation

SCENARIO: GROUNDED AND GREEN: CURTAILED TRAFFIC IN A LIBERALISED MARKET

This scenario is dominated by strong societal pressures that have substantially curtailed air travel, despite limited intervention by governments. It is now only acceptable to travel sustainably, and solutions so far are either too difficult or too costly to implement.

Dominated by strong societal and market pressures that substantially curtails air travel

Air travel must be environmentally stable but is too difficult (or too costly) to achieve

Airspace is less dense than it is today due to reduced passenger demand leading to over-capacity

A new market for 'stay-cations' will develop with travel becoming (once again) the domain of the elite



Competition and over-capacity for a declining demand has led airlines to consolidate - not only with each other but also with related industries including airports, train companies, city transport operators and even equipment manufacturers. In the absence of strong government intervention, airlines were slow to give up their primary businesses easily or quickly. At first, they applied small changes to make their operations more environmentally sustainable (or appear that way), whilst in parallel finding ways of making operations more efficient as passenger demand dropped. Airlines now operate more streamlined business models, using pilot-less aircraft and with far fewer international destinations, ie only those that are profitable and socially acceptable.

Airlines have also sought new sources of revenue from operating airship hotels that cater for people wishing to go on sustainable, longer haul vacations and who are prepared to spend more time in the air. The cost of flying internationally is high, particularly for the few still using fossil-fuel powered commercial jets. Passengers that can afford jet travel and that are prepared to ignore social pressures will travel rarely but with a more customised experience – for example supersonic travel for when time is the priority. With more infrequent jet travel, overall environmental and noise concerns are more manageable; most passengers will be travelling inter-city by air taxi, train or using new sub-terranean highways that have been built to cut journey times in and between cities.

As far fewer people fly on holiday, a market for new types of vacations has developed, including local experiences, those that encourage community engagement, as well as digital virtual reality and sensory immersion experiences that give people the feeling of wellbeing and adventure.

Businesses and economies have had to adapt with business travel substantially reducing compared to 2019. The 'glocal' model has become the norm with

businesses focussing on establishing local presence in more selected markets, but using global knowledge, processes and systems. This is made practical by enhanced virtual reality and video conferencing that captures the fine facial gestures and non-verbal nuances that make up the 60%+ of communication.

A major scientific breakthrough offers the potential for environmentally sustainable inter-continental travel, but the project is so costly that it has not yet received funding and therefore hasn't prevented long-haul air travel from declining. The project is to build an 'orbital ring' around the earth that rotates at a speed to counter gravitational pull. The ring would allow very high speed frictionless maglev trains to transport passengers from one side of the globe to the other in 45 minutes²⁹. The trains would be accessed by commercial space craft or even elevators. The estimated cost is bigger than any single company or country could bear, particularly given the environmental concerns of getting people into space in the first place.

Airports have become fewer and farther between, but more complex as they seek to take advantage of growth industries outside of aviation. In mega-cities they have become part of the urban sprawl and a more integrated part of city travel, handling air taxis, train connections and other forms of ground or subterranean transport. Airport operations centres have expanded to handle more aspects of local and integrated transport networks as well as covering more airports in their network. New runways have not been needed, so airports have instead focussed on maximising operational efficiency and predictability. Data is used, not only for transport operations, but also for increasing the efficiency of built assets to dynamically adapt to a changing environment and purpose, for example using Building Information Modelling (BIM) and digital twins.

IMPACT ON AIR TRAFFIC MANAGEMENT

The drop in long-haul demand has meant that upper airspace is sparse, and there is little need for air traffic control. It is now managed by a few pan-regional entities, mainly focussed on strategic planning, allocating airspace, and ensuring regional interoperability. Tactical operations are now handled by automated systems on the aircraft and ground.

National providers have had to adjust as traffic has declined. Some have joined forces to create the new pan-regional entities, some have formed alliances with private companies to handle lower airspace operations, others have been integrated back into state defence departments and now handle only military traffic.

Lower airspace is very busy around mega-cities, where zero carbon flights transport passengers, recreational fliers and deliveries over short distances. Multiple private providers operating different parts of the city transport network compete for passengers within structures (airspace and surface) and rules laid down by the local municipality. These networks are run from operational centres that typically include airport operations as well as local and integrated transport networks. Passengers looking to escape the city can check in to airship hotels, which fly at low altitudes to offer scenic views of the countryside.



SCENARIO: CAPACITY CRUNCH: STRONG GROWTH IN A CLOSED MARKET

This scenario is dominated by the need to accommodate high growth in a constrained market. Strong state control and limited competition has made radical change harder and slower to achieve. Consequently, it is difficult to meet the high capacity demands and several aspects of operations may be highly constrained or inefficient.

Dominated by the need to accommodate high growth in a relatively constrained regulatory environment (much like today)

Inability to meet capacity demand means passengers seek alternative 'innovative' means of transport

Strong focus on delivering the maximum value out of existing infrastructure and assets

Manufacturing industry strives due to the strong demand from passengers to solve capacity issues



The inability of the market to respond quickly enough to meet demand, means that passengers have sought alternatives from innovative companies operating outside of the regulated market, driven by the sheer demand for a solution – much like Uber began operating outside of regulations in the taxi market all those years ago. As was the case for Uber, these alternative industries have put pressure on those traditional players who failed to evolve.

In particular, as autonomous vehicles and drones became more common and the life and range of electric batteries extended, a new market arose for self-flown aircraft. These relatively small aircraft can be operated with zero carbon using solar powered electric motors. A typical family can now go on short-haul holidays simply by renting the aircraft for the flight. All the 'driver' has to do, is pick the type of journey they want (eg scenic, fastest possible etc). Everything else is taken care of by the software and flight management computer which is connected in real-time to the rest of the air traffic network. It has taken some time for regulations, technology and procedures to catch-up, especially to ensure interoperability across state boundaries, but the market is now huge and a pilot license is no longer necessary.

Longer-haul travel is still mostly by jet, with government policy in place to offset aviation

emissions against other sectors that have been able to reduce their emissions more easily (food and road in particular).

Strong demand has ensured that the manufacturing sector is strong and healthy. Given that this sector is not so affected by state influence, it has become one of the most competitive and powerful parts of the transport chain. As airborne vehicles have become more intelligent (eg pilot-less, self-organising, self-separating etc) and more connected it has meant that manufacturers hold more power. Many of them have expanded into operating the aircraft, pushing some airlines that have failed to innovate out of the market.

Airports are still bottlenecks, unable to expand or introduce sufficient capacity to handle demand. This is largely down to strong state intervention. Their focus is instead on trying to deliver maximum value out of existing infrastructure and assets. Digital twins and augmentation have helped to make built assets more intelligent and adaptive. There has also been a strong move towards re-use of resources to minimise waste and extract maximum value before being returned to the biosphere ie circular economies. Smaller flight operations no longer even use airports and instead operate from other transport hubs – particularly those in mega-cities.

IMPACT ON AIR TRAFFIC MANAGEMENT

Traffic has been steadily growing for decades, each year adding more pressure on an ATM industry that has been failing to keep up.

Passengers have eventually grown tired of the delays and found alternatives to traditional jet airlines – for example using long-range private hire air mobility solutions for international travel.

This new sub-market has grown quickly, forcing ANS providers to introduce changes that ensure connectivity and interoperability between all air vehicles at all altitudes.

Traditional jet aviation has continued to be popular, particularly for long-haul travel. Aircraft manufacturers have taken advantage of innovations in the urban air mobility market to create more intelligent aircraft. Flight planning and execution is now heavily automated, with most of the air traffic control performed onboard the aircraft – a necessity given the sheer volume of traffic.

IMPLICATIONS FOR THE AIRSPACE GUARDIAN OF THE FUTURE

“Every Member State has complete and exclusive sovereignty over the airspace above its territory³².” Today, states delegate the management of air traffic (for civil matters) to ANSPs. By ensuring the safe and efficient movement of aircraft during all phases of operations, these ANSPs are the guardians of the airspace who protect the safety of all those who fly in it and citizens on the ground³³.

Our four scenarios explored how airspace guardians, and the services they deliver, might change in the future. The scenarios envisage varying, though significant, evolution for the ATM industry. Nevertheless, some common themes have emerged. These are discussed below together with their implications for the airspace guardian(s) of the future.

AIRSPACE REFORM

New users, more users and more airspace (eg outer space) will change the way the airspace guardian of the future has to view and manage airspace. Urbanisation and the rise of drones and urban air-mobility services will create a very busy lower airspace around cities. There will be a wide variety of users and needs to be accommodated. This will require highly automated operations to predict and resolve traffic conflicts. On-board and/or ground

systems will likely be required to provide separation management and even self-organisation.

Measures will also be required to segregate the variety of users ranging from supersonic jets and space flights through to slow-moving airships and autonomous vehicles. Space tourism is unlikely to be a mass market solution, but drones and air-mobility solutions could be. Airspace zones may be required to recognise the different user capabilities.

³² Article 1 of the Chicago Convention [ICAO, 2009]

³³ EC 509/2004

BUSINESS MODELS IN THE DIGITAL DATA- DRIVEN ECONOMY

Like many other parts of the future economy, the health of the aviation industry will be impacted by both the success and speed of technical advances in resolving environmental challenges and by social pressure to reduce activity to an ecologically stable limit. It seems likely that the cost of flying will inevitably increase, either to curb emissions; to fund more sustainable air travel or simply because of oil scarcity.

At the same time as the industry strives to reduce its reliance on oil, its reliance on data is increasing. Those that are best able to harness the value of data are therefore likely to hold the most power and command the strongest competitive advantage. This could be: airlines (who have the richest data set today); airports (who have touch points with so many parts of the transport chain); aircraft manufacturers (who hold the key to the aircraft intelligence of the future); ANSPs (who are sitting on more data than they currently know what to do with); or IT companies (who are poised to take over the future relationship with passengers). It seems likely that, as aviation becomes a more seamless and integrated part of a wider transport system, new opportunities will be created and new mergers will materialise that will drive innovation through aggregating and crowd-sourcing products, services and even ideas, leading to mass disruption of existing norms and revenue models.

For ATM, the long-held ICAO principle of non-discriminatory charges could well be replaced with a more market-driven approach - for example, higher prices for faster journeys, more efficient aircraft or even 'surge pricing' that places an economic value on the network capacity to handle demand.

OPPORTUNITY AND RESPONSIBILITY OF MORE INTERCONNECTED INFRASTRUCTURE

Operations will rely on better connected, and increasingly complex infrastructure. This will involve 'beyond-state' or 'border-less' infrastructure such as space-based assets. The first to abandon ground infrastructure might be those who have the least in the first place - ie the emerging economies. Airspace guardians in these regions may well 'leapfrog' the mature states, which are themselves held back by competing ground infrastructure.

A far more integrated and secure communications network will facilitate new data exchanges and increased common situational awareness. With data comes opportunity, but also responsibility, for example the threat of cybercrime and cyber-failure that grows as data connectivity expands.

A network of virtual operational centres will exist that could provide continuity for one another, even though they may normally serve different route networks or services. States will nevertheless continue to ensure fallback solutions for national defence and security reasons.

MULTI-MODAL TRANSPORT COORDINATION

The airspace guardian of the future might need to oversee (and perhaps even compete for) operations across a wide sphere of the transport network to ensure a more seamless and integrated journey. This could mean surface, sub-terranean and space users as well as those in the conventional airspace. Operations centres will strategically plan and referee the allocation of routes (upper airspace, lower airspace, surface, subterranean etc) to those requiring it. It would be more akin to a 'transport network management' role than purely an 'air traffic management' role using increasingly sophisticated technology and machine learning to augment the role of the human. Depending on the level of liberalisation, the networks managed could be competed across borders, or designated as a monopoly contract considered vital to the state.

SAFETY

Safety would remain a priority, but its application might change. The increasingly interconnected nature of aviation will drive a need for a holistic and more dynamic approach to safety. For example, the airspace guardian could own and manage a dynamic safety case to detect and mitigate high-priority safety issues as they emerge and before they become hazards – so called In-time aviation safety management system (IASMS)³⁴. The remit could encompass not only all aspects of the operational aviation system (airports, aircraft operators, related service providers) but also other areas of a more integrated transport system, to ensure seamless door-to-door journeys. This could also include a role in making recommendations for synchronising deployment and procurement as well as in network management.

GEOPOLITICS VS INNOVATION

Governments and states may opt to control aviation to protect national interests, which could constrain the pace of change. Alternatively, states might promote liberalisation in which private enterprises drive a faster pace of change and exert influences that redraw the institutional landscape of the airspace guardian. But if the state steps back, there will be new liability challenges to deal with, for example relating to data accuracy (on which safety critical decisions might be based), data privacy and the role of non-state actors unwilling to take over the liability and risk associated with safety of life services.

Regional or global cooperation will still be required in order to avoid a divergence in standards and interoperability. ICAO's role will be essential to ensure interoperability globally, but most likely move towards governance and enforcement of standards rather than any role in driving or developing them.



³⁴ EurekaAlert!, 'Challenges and research for an evolving aviation system'

CONCLUSIONS

The future may end up looking very different to the scenarios presented in this paper. Every decade there tends to be a hype, that in the following decade disappears or comes to nothing. Remember the dot-com bubble of the 1990s, or the emergence of the BRIC economies? Could we be in the same place with some of the hyped predictions of today?

Nevertheless, our scenarios correspond to some extremes of two uncertain and impactful drivers on aviation and this provides a good envelope to explore the possibilities that lie ahead and a starting point for strategic planning for organisations positioning to be airspace guardians of the future.

Organisations looking for a role in guarding airspace and air traffic of the future should reflect on the themes presented in this paper and how they impact at an individual organisational level. This can then be used as a base case on which to plan. Organisational agility or adaptability will be a key factor for success – particularly in a highly regulated, risk-averse industry such as the provision of ANS. Organisations considered ‘agile’ drive competitive advantage and grow 37% faster than their non-agile peers³⁵. Agile

organisations typically exhibit high-performance cultures, flexible management practices and resources, and organisational structures supporting collaborative rapid decision making and execution. Linked to this is the need to focus on the outcome and objective at leadership level, and to leave the detailed ‘how’ to management and staff. Done badly, staff’s willingness to innovate, change and contribute becomes an empty aspiration.

Organisations are encouraged to consider the relevance of the scenarios in this paper; the probability of them happening; the inevitable or near-inevitable futures that could be most impactful (such as those identified in the figure) and how well prepared they are for them.

New entrants (eg data companies) will arrive to challenge or displace traditional ANSPs (and possibly airlines): particularly IT companies and drone operators

Competition will increase for some parts of the service, eg CNS, terminal services etc

The lines between ATM and airport operations will become increasingly blurred, with ANSPs looking to expand into aspects of airport operations, and airport operators seeking more control of the ANS

New business models and partnerships will emerge eg with technology companies, infrastructure providers, aircraft or drone operators

ATM challenges will increasingly rely on complex data with more variables and datapoints

Airspace changes will be more essential but increasingly difficult

Pressures to reduce the environmental impact of aviation will increase (eg CORSIA), and it will become an evermore important performance objective

Infrastructure will become increasingly remote to the service (eg virtualised, cloud-hosted or space-based)

³⁵ Economist Intelligence Unit (EIU) study in 2009

There was once a time when aviation was at the forefront of innovation but in today's high tech, data centric and rapidly evolving world, air traffic management is looking antiquated. In comparison to other industries it is slow to adapt and is consequently struggling to deliver promised solutions and improvements (eg SESAR and NextGen), let alone to innovate.

If we were to look back five decades at a point 50 years from now, the level of change will undoubtedly have been greater than anything we've seen since 1969. The airspace guardians of that future may not yet exist or perhaps they have already established their foundations. Either way, they will have much to learn from the airspace guardians of today, who in turn should be looking to build the transformative vision and lasting partnerships that can secure their long-term future.



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