Civil Aviation Authority

Airspace for Tomorrow 2

Modernising the United Kingdom's airspace arrangements in a safe, sustainable and efficient way

Overview

The CAA intends that this document should give all those with an interest in the way we use UK airspace a summary of the work being carried out on the proposed Future Airspace Strategy (FAS) that the CAA is developing with colleagues from the Ministry of Defence, NATS, the Department for Transport and other aviation stakeholders.

This document is intended to help you:

- Become better informed on what the FAS is and how it is being progressed by the CAA.
- Have a clearer understanding of the key areas for consideration, the potential judgements to be made in terms of the optimum solution, having regard for all the potential outcomes, and the technical improvements that could be made.
- Gain a better understanding of the potential benefits of modernising the UK's airspace system.
- Understand the proposed arrangements for the stakeholder consultation for the development of the FAS.

Introduction

Much has changed since the first edition of Airspace for Tomorrow (AFT1) was published in October 2009 and the Future Airspace Strategy (FAS) work continues, progressing towards a wider stakeholder consultation on the content later this year. The importance of approaching airspace capacity and efficiency in a way that is sufficiently flexible to accommodate changes in national policy and airport development plans has been underlined by the Government's recent announcement that it will not support the construction of a third runway at Heathrow or a second runway at Stansted or Gatwick.

Airspace for Tomorrow 2 (AFT2) provides a short description of the FAS, a summary of the work process to date and an update of development of the FAS under the seven headings of:

- Strategic Drivers for the FAS.
- Airspace Efficiency.
- Key areas for consideration.
- The modernisation of the airspace.
- Characteristics of 2030 airspace.
- Benefits of modernising the airspace.
- Key risks.

What is FAS?

For those readers who did not have the benefit of reading AFT(1), FAS is a strategic framework that will pull together a complex and diverse set of policy and regulatory issues that will enable judgements to be made that are properly underpinned by cohesive and cogent policy formulation. This will in turn enable air navigation service providers (such as NATS) to create an airspace structure that is fit for the future, effective, efficient and ensures that the UK meets any international obligations that are placed upon it. It is not a detailed implementation plan, although such plans will be driven by the outcome of the FAS work.
The aim of the Future Airspace Strategy is to provide a policy structure to enable a modernised air traffic management system that provides safe, efficient airspace, that has the capacity to meet reasonable demand, balances the needs of all users and mitigates the impact of aviation on the environment.

The Development of the FAS

The work to modernise the UK Air Traffic Management (ATM) system, has been a key focus for the CAA, MoD and NATS over the past 18 months. The detailed analysis undertaken during Phase II was completed by the FAS Development Workstreams in April 2010. During April, the content was combined with the outputs of Phase I to form a first working draft of the Strategy. The draft strategy was reviewed and refined internally across the CAA, MoD and NATS during May 2010. A FAS Challenge Team was set up to review the draft strategy from an independent and external perspective. The Team met in May 2010 and the outcome was positive and constructive[1]. The Strategy is being updated to incorporate a number of enhancements in light of the Challenge Team review and other feedback; the overall thrust of the document remains broadly as originally envisaged and as set out in this document. The CAA will carry out stakeholder consultation, to develop the draft FAS between, November 2010 and February 2011.

[1] The list of Challenge Team members with short biographies is on page 15.

Three Strategic Drivers

There are three broad strategic drivers to modernise the UK airspace system and achieve the FAS vision:

Safety: The implementation of a modernised airspace system is driven by the need to continuously improve safety levels, in particular in light of the forecast growth in demand for airspace and the expected adoption of new technology and operational concepts across the system. The FAS aims to ensure:

- All changes are justified on the grounds that they will directly reduce risk and/or contribute to the development of a fundamentally safer system (as an absolute minimum there must be no adverse effect on safety whilst providing improvements in other areas).

- The right levels of resource are in place to ensure that the transition to a future system can be executed safely, in particular any re-training necessary to implement new technological solutions whilst providing sufficient system resilience for contingency purposes.

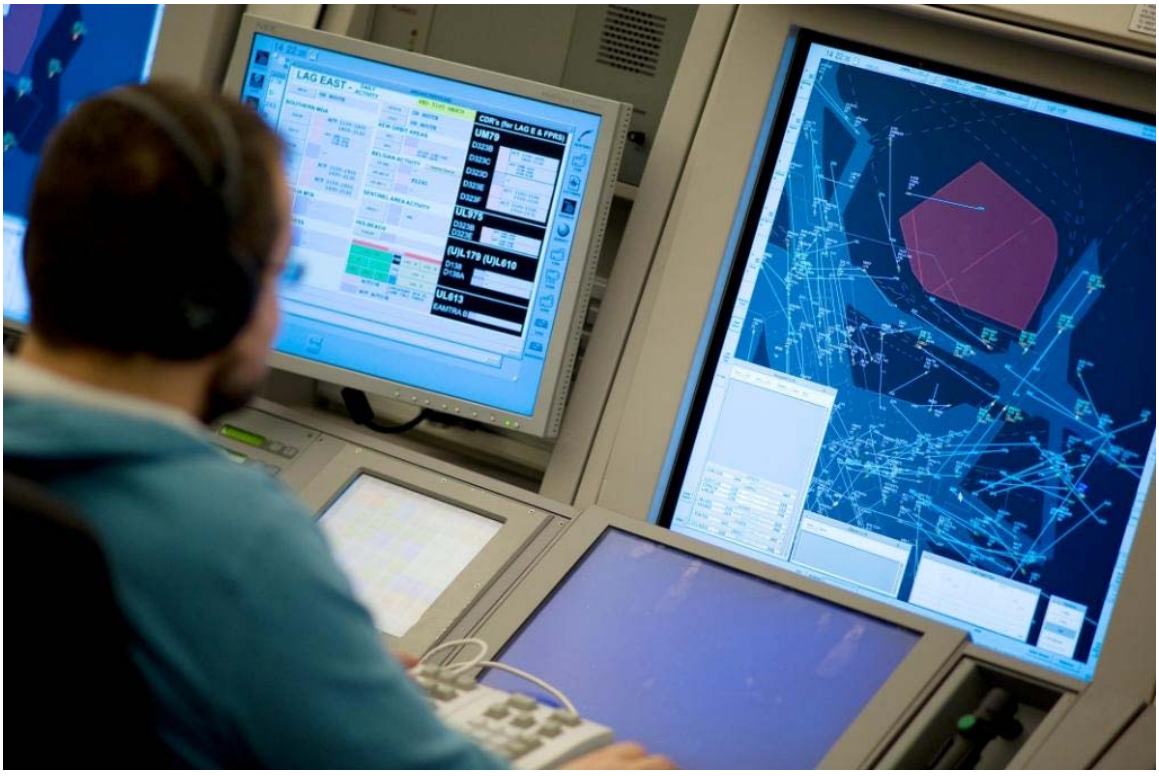
- The appropriate regulatory mechanisms are in place to enable implementation of changes and assure the safety of the new system. This includes developing safety performance indicators to baseline current safety levels, anticipate future performance and monitor actual outcomes.

Capacity: It is likely that the pressure on the UK's airspace system will continue to grow in the long term with a changing profile of demand from different user groups leading to a tightening in the supply and demand balance for airspace at certain times and in certain places. Even in the unlikely event that there is extremely limited growth in air traffic demand, there are already 'hot spots' in the airspace today that could be improved by adopting concepts within the FAS thereby making the system safer and more efficient. The FAS work is proceeding on the assumption that air passenger demand will increase and improvements in capacity are needed for the future. As no new runway capacity in the South East of England is envisaged, it is vital that we optimise the use of the airspace to support the existing infrastructure in the most efficient manner.

The FAS aims to facilitate the development of airspace capacity to accommodate reasonable demand, wherever that demand materialises. Better use of existing resources will be necessary to accommodate increasing demand. The shift to a more flexible and integrated airspace system to improve safety, capacity and efficiency will require complementary investment at airports (in terms of performance) to achieve improvements in the service benefits to passengers. The maximum benefit to passengers will come from improvements to the complete system from boarding gate to disembarkation gate (the gate-to-gate experience) rather than just from the airspace or airborne element of any given flight.

Environment: The proposals in FAS aim to enable aircraft to fly in more environmentally efficient ways while maximising capacity benefits and improving safety. The environmental impact of air travel both locally, in terms of noise and air quality, and globally in terms of climate change, plays an important role in determining how the UK airspace system should develop. The FAS aims to provide a regulatory framework which facilitates the implementation of air traffic management improvements that reduce greenhouse gas (GHG) emissions from aircraft and contribute to minimising aviation's environmental impact. The FAS also provides an opportunity to re-assess existing principles underpinning the treatment of aircraft noise and tranquillity in the context of new air traffic management technologies and operational concepts. The current concentration of effort is on tackling the issues around CO_2 for which the science and its understanding are reasonably mature. This does not mean that the other areas within GHG emissions are being ignored, rather that the understanding with regard to aviation is less mature.

GHG Emissions and Aviation
The most authoritative description of GHG relevant to aviation features in the Intergovernmental Panel on Climate Change (IPCC) report 'Aviation and the Global Atmosphere' published in 1999. This gives a list of species (chemicals) of aviation emissions that are emitted directly into the upper troposphere and lower stratosphere where they have an impact on atmospheric composition. These gases and particles alter the concentration of atmospheric GHG, including carbon dioxide, ozone and methane; trigger formation of condensation trails; and may increase cirrus cloud, all of which contribute to climate change. The chemistry describing how these emissions react together is very complex, but suffice to say that the scientific consensus is that the overall effect is one of warming but some of the species – methane and sulphates – are considered to be coolants. There is also general consensus that total warming (radiative forcing) is larger than that produced by the effect of carbon dioxide alone, although there is uncertainty about its exact extent. It is for these reasons that the term GHG is used in the FAS to ensure the entirety of aviation emissions are considered.



Airspace Efficiency

Balancing trade-off decisions: A range of different factors are affected by the modernisation of the airspace system, for example, costs, environmental sustainability and access to airspace. The resulting effects of these factors will sometimes be complementary; for example, enabling more direct routes or improved profiles could reduce costs faced by users while at the same time mitigating GHG emissions. The factors may be in conflict; for example, expanding controlled airspace to increase capacity could restrict the access to some in the General Aviation community. The term 'trade-off' is used to describe the balancing process used to achieve improvements across the spectrum of issues affecting airspace capacity. It is recognised that this is likely to be a complex process with cost, capacity, efficiency and environmental factors all coming into play at the same time. The FAS will need to consider all these interactions in seeking a workable definition of airspace efficiency.

Broad definition of airspace efficiency: The FAS has considered a number of potential guiding principles for airspace efficiency that could possibly be utilised in the future. These included, for instance, 'physical' efficiency where the guiding principle would be to maximise the number of aircraft through a fixed volume of airspace in a fixed amount of time within safe limits. The concept of 'productive' efficiency was also explored where the guiding principle would be to minimise the total cost of providing controlled airspace capacity. However, in each of the above cases the definitions appear quite narrow in that they exclude potentially important factors.

In terms of a broader definition, FAS work has also considered the concept of 'economic' efficiency, which is intended typically to maximise the value of a scarce resource to society. Under this broad definition, the FAS identified six categories of cost/benefit which, once safety is assured, could be taken into account (and in some way traded-off with a view to generating a balanced and optimal outcome) in pursuit of overall airspace efficiency.

- The Environment: The utilisation of airspace affects others in the form of climate change and noise impacts.

- Access to Airspace: The needs of all users have to be considered and balanced. The exclusion from controlled airspace of certain users (i.e. General Aviation and Defence) has an associated opportunity cost which is equivalent to the value that these other users place on operating in those volumes of airspace.

- Users: A change to the airspace system can result in a change to the costs incurred by users of airspace (e.g. equipage standards, flight times, fuel burn, cost which can be passed on to the consumer.)

- Suppliers: Air navigation service providers incur through-life costs of development and implementation to changes of the airspace system.

- Delays: The costs associated with delays are borne by various parties – most obviously, by the end consumers through being late, missing connections, etc.

- Competition: Changes to the airspace system can, in principle, affect competition, for example between airport operators and airlines. Where competition is affected adversely, it can result in end consumers incurring costs that they would not otherwise.

This broad definition of efficiency has, as yet, only been considered in purely theoretical terms. The next stage in this work is to consider how this would be used in practice, including the role for new metrics, and how this fits with current legal processes and the performance framework that is envisaged under both ICAO and the Single European Sky legislation. This work will need to be taken forward in consultation with aviation stakeholders.

Three Key Areas for Consideration

Aligning with European Developments: The UK airspace system is an integral part of the European air traffic management network and cannot be considered in isolation. The Strategy takes account of the relevance and impact of European developments and aims to ensure alignment and integration with key initiatives. In particular, the strategy considers the alignment with the main Single European Sky (SES) strands which include:

- Single European Sky Air Traffic Management Research (SESAR) programme.
- The development of Functional Airspace Blocks (FABs).
- The Network Management Function.
- The Single European Sky II Performance Regime.

To allow for effective implementation of the proposals in the FAS, the UK needs to determine the right balance between decisions to be taken at the European level and those to be taken nationally, and the interactions between the two. The FAS will support the UK in delivering its European network responsibilities in particular, as the North Atlantic airspace gateway. Technological developments must be interoperable, aligned with SESAR and be cognisant of other development programmes such as the FAA's NextGen programme.

National Policy and Regulation: Changes to the UK airspace system must be aligned with national aviation policy and consistent with regulations. Some of the operational changes proposed may require new or updated policy guidance and regulation; for example, in relation to the interactions between airspace planning and land use planning; the importance to be given to tranquillity in rural areas; the concentration (versus dispersion) of aircraft; and the value to be placed on the long-term stability of terminal airspace structures. In some cases it may be necessary to amend aviation policy to require specific technical outcomes, for example, in terms of navigation performance, in order to deliver optimal solutions.

National Security: National Security must continue to be supported at all stages of the modernisation of the airspace system. In particular, Defence requires access to appropriate airspace to meet national security requirements, but recognises this must be coordinated with the needs of all users. The FAS must accommodate outcomes and objectives that are responsive to changes to the background security situation, either temporarily for events such as the Olympics, or more permanently due to a change in the terrorist threat or geo-political situation.

Modernisation of the Airspace System

Airspace Structure: Today's airspace is characterised by a rigid route structure linking the airspace of the major airports with volumes of airspace between and beneath remaining open and freely available for all. In the future, the management of UK airspace structures will be flexible, moving to dynamic at certain points and times, to accommodate user demands and enable more direct routes and optimal vertical profiles.

Communication: Today, information is primarily shared via radio voice communications. In the future, the introduction of new technology is expected to change the method of communications to allow greater volumes of information to be shared, more quickly and consistently via data link, with less reliance on voice exchanges thus reducing ATC and flight crew workload and the potential for error.

Navigation: Today, flights are planned using a defined route structure based on ground-based navigation aids. In the future, the application of space-based aids will provide increased navigational accuracy and remove reliance on ground-based navigation aids. Navigation performance and functionality requirements will be applied consistently to remove the complexity in busy airspace environments. Steps to achieve navigation improvements have already started and the Directorate of Airspace Policy is developing a new Performance-based Navigation (PBN) policy.

Surveillance: Today, surveillance is based on radar coverage which is independent of information from the aircraft. In the future, the application of space-based navigation will enable dependent surveillance solutions allowing cooperative users to transmit precise positional information to air traffic systems, thereby increasing the situational awareness of both parties. Non-cooperative radar surveillance will be retained in certain circumstances to be used where operationally necessary and for contingency, national security and policing activities.

Air Traffic Management Capability: Air traffic management capability refers to the ability of the air traffic system on the ground to manage the flow of air traffic through controlled airspace. Today, traffic is managed using a defined route structure, allowing track conflicts to be managed by controllers. Aircraft position is tracked independently using ground-based surveillance and information is shared through voice communications. In the future, the application of new technology will enable air traffic systems to manage greater volumes of traffic in more flexible ways. Advanced computer based tools will be required to support controllers in managing the additional complexity in the airspace system in a safe and effective manner.

Characteristics of 2030 Airspace

Routing based on user-preferred 4D trajectories: A 4D trajectory is a set of coordinates defining the path of an aircraft in time and space. The future airspace system will need to allow pilots and controllers, using computer assistance, to negotiate preferred trajectories that are optimal in minimising fuel burn and reducing potential conflicts with other aircraft, especially around the busiest airports. The future terminal environment is likely to remain highly systemised, providing a structure of arrival and departure routes, supported by advanced tools that minimise the requirement for tactical controller intervention. Managing the interface between the preferred trajectory upper airspace environment and systemised lower airspace environment is a key challenge.

Progress towards effective 4D trajectory operations is likely to continue throughout the time frame of the FAS; this capability could develop along these lines:

2011 – 2014
Focus on improving the 2D element, enabling users to fly closer spaced, more direct routes, known as improved horizontal performance.
2015 - 2020
Expand improvements in the 3D element, enabling users to fly more efficient vertical profiles (including continuous climbs and descents) known as vertical performance.
2021 - 2030
Introduce the 4D element, time, to optimise trajectory operations, combining horizontal and vertical performance while ensuring users do not come into conflict.

Flexible, often dynamic, management of the airspace structure through Joint and Integrated, Civil/Military operations: Future airspace structures will need to be flexible, moving to dynamic at certain points and times, to accommodate direct routes and optimal profiles as often as possible. Building on the strengths of the UK's existing Joint and Integrated (J&I)[2] approach to ATS, flexible use of airspace (FUA) will increase capacity and resilience in the system. Cooperation across the full spectrum of airspace users is required to successfully migrate to a flexible and dynamic environment. The procedures and systems that promulgate timely information of airspace constraints and their incorporation into flight planning need to be robust and accessible to all airspace users, including General Aviation, Defence and Commercial Air Traffic. The progression of FUA could develop along these lines:

2011 - 2014
Enhanced application of FUA to maximise the shared use of airspace through civil/military coordination at the strategic, operational and tactical levels.
2015 - 2020
Dynamic management of airspace to enhance the benefits of FUA, accommodating demand by activating temporary controlled airspace structures at shorter notice.
2021 - 2030
Further development of flexible/dynamic airspace is enabled by the removal of fixed airspace structures allowing users to plan and utilise the airspace in, close to, real-time.

Greater cooperation and the increased use of systems and technology to safely manage additional complexity: Introducing user preferred trajectories and flexible and dynamic airspace structures will significantly increase the complexity of the airspace system. Although operators will remain fundamental to air traffic management, their decision-making will be supported by new technologies that predict aircraft trajectories, de-conflict their routes and monitor compliance. An indicative timeline could be as follows:

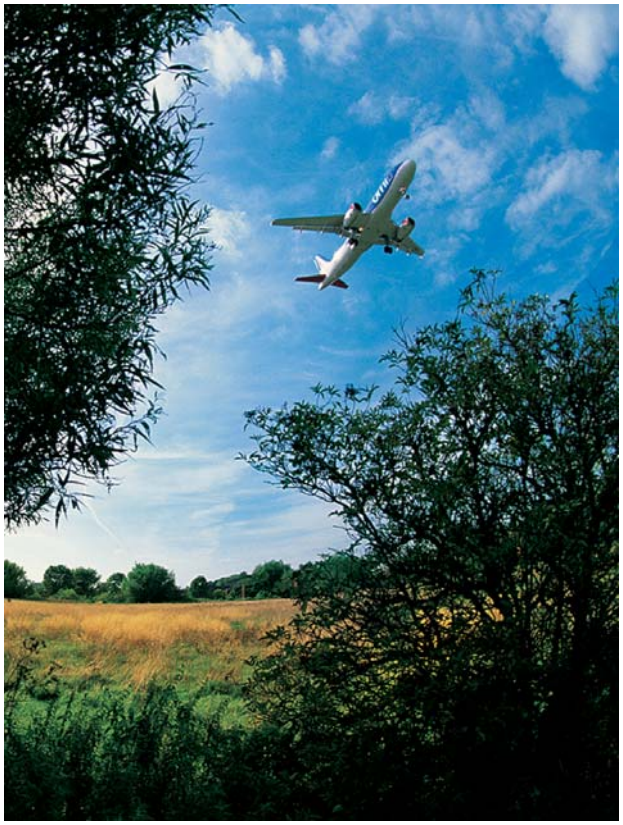
2011 - 2014
Introduction of new technology improves communications, navigation and surveillance enabling improvements in horizontal and vertical performance.
2015 - 2020
Further development of technologies, including arrival and departure management tools, reduced reliance on stack holding during normal operations.
2021 - 2030
Integrated technologies on the ground and in the air manage the majority of conflicts out of the system, while controllers focus on managing the network strategically.

[2] The J&I concept relates to a collaborative approach, by CAA, NERL (NATS En Route Ltd) and MoD, to the separate functions of airspace policy and planning and air traffic service provision within all airspace above Flight Level 100 and controlled airspace below Flight Level 100.

Integrated airspace structures across National and Functional Airspace Block boundaries: The UK's future airspace system will need to be fully integrated as part of the UK/Ireland FAB. The UK/Ireland FAB will provide a key European Network function as the principal gateway to and from the North Atlantic. A common development strategy and regulatory approach will facilitate efficient operations with the FAB and in relation to neighbouring FABs.

FAS can facilitate development of the UK and Ireland FAB to deliver European network development commitments, demonstrated by delivery of cost effective benefits. A performance-driven approach will underpin success and the FABs will support the European wide performance regime. Such an approach could lead to development as follows:

2011 - 2014
In partnership with the Irish Aviation Authority (IAA), develop further economical and environmentally efficient routings to and from the North Atlantic track structure.
2015 - 2020
Integrate across neighbouring states and other FABs through common standards and regulation to drive the overall efficiency of the European network in line with SES II objectives.
2021 - 2030
Develop a free routing/self separation environment, apart from busy terminal airspace. Airspace classifications are grouped into 'managed' and 'unmanaged' categories.



Benefits of Modernising the Airspace

The table below maps out the summary of benefits that could be enabled by the FAS across the key areas of safety, capacity, environment and cost. In the table:

- **Safety benefits** refer to direct increases in the safety level and the ability to maintain current levels of safety while enabling benefits in other areas.
- **Capacity benefits** refer to the ability of an air navigation service provider to supply additional airspace capacity safely, while not expanding the total volume of controlled airspace.
- **Environmental benefits** refer primarily to reducing aircraft greenhouse gas emissions and noise impact.
- **Cost benefits** refer to the ability of users and suppliers to operate in more cost effective ways, ultimately reducing the cost of ATM service delivery.

Safety Benefits	Capacity Benefits	Environmental Benefits	Cost Benefits
- Performance Based Navigation allows routes to be flown more accurately and consistently - Building flexibility and resilience into the system, reduces the occurrence of pinch points and high risk situations - New communications, navigation and surveillance technology improves situational awareness of users and controllers - Simplification of the airspace structure and classification reduces potential for errors, infringements and level busts - A co-operative environment creates safety benefits	- Increased navigational accuracy enables closer spaced routes - Introduction of free routing, systemisation and ATM support tools enables higher volumes of traffic to be managed - Flexible / dynamic structures accommodate demand when and where it occurs - Reduced reliance on stack holding releases airspace for re-design in the busy terminal airspace - Integration of airspace through FABs mean interfaces are simpler and more efficient - Access to sufficient airspace for non CAT users	- Enabling more direct routes and optimal vertical profiles reduces GHG emissions - Continuous climb and descent procedures reduce the total number of people impacted by aircraft noise - FAB integration expands environmental benefits across state borders - Reduced reliance on stack holding reduces GHG emissions from delays in the air	- Enabling more direct routes and optimal vertical profiles reduces fuel burn and costs - Building flexibility and resilience into the system reduces costly delays - Move to space-based navigation aids reduces cost of maintaining and replacing ground infrastructure - Common, simpler approaches to management and regulation through FAB integration reduces costs to users and regulators - Alignment of strategies across different industry partners and across ANSPs allows for a seamless and more cost effective change process as different techniques are introduced

Key Risks

The top three risks associated with the modernisation of the UK airspace system, which the development work will need to seek to mitigate to the greatest extent possible, are:

The Success of SESAR: SESAR is the key ATM research and development initiative in Europe in the timeframe of FAS. Its success hinges upon a continuing willingness by the Joint Undertaking (JU) partners to reach common outcomes and the availability of sufficient funding across many industry partners. If either of these is not available, SESAR may be unable to provide the full range and combination of technological outputs envisaged to deliver timely and cost effective performance improvements, thereby introducing an increased element of risk to the timely modernisation of the UK airspace system. To mitigate this, leading UK aviation companies are managing and participating in SESAR work packages to ensure they deliver outputs relevant to the UK airspace system.

The ability to assure safety of a new system and the transition from today's environment: The implementation of a modernised air traffic management system is dependent on a continuous improvement in safety standards. There is a risk that the level of resources required, or lack of appropriate regulatory mechanisms, to assure the safety of the new systems and the transition to new ways of working, could delay the implementation of changes. The CAA's Safety Regulation Group is reviewing its policies and process for regulation to ensure that its approach to safety and risk identification is both appropriate and timely in relation to future systems and their introduction.

The alignment of industry investment plans: The modernisation of the airspace system proposed in the FAS requires investment in complementary changes across airports, airlines and air navigation service providers. The ability of these stakeholders to produce consistent, viable business cases and align investment plans is a key risk which has been further exacerbated by the global economic downturn. FAS provides the industry with an overview of the strategic direction, enabling aviation stakeholders to make informed investment decisions that align with the Strategy.

Summary

As work on the development of the FAS has progressed, it has become increasingly clear that the UK needs a strategy that approaches the provision of airspace capacity and efficiency in a way that is sufficiently flexible to enable it to respond to future aviation development, at an acceptable cost, whilst minimising aviation's impact on the environment. The FAS will facilitate this by clearly signposting the shift to a fundamentally more flexible and integrated airspace system to improve safety, capacity and efficiency. In modernising the UK air traffic management system, it will be necessary to ensure that safety is improved, or is not adversely affected, while at the same time implementing ATM procedures that contribute to reducing greenhouse gas emissions from aircraft and minimising aviation impact on the environment more broadly.

The concepts in the FAS must address the 'efficiency' of the overall airspace system as it develops. In this context, the development of a concept of efficiency would be useful in order to make balanced judgements when considering the, often competing, factors involved. It is recognised that there are a number of practical implications arising from this approach and that these need to be considered carefully before seeking to implement the concepts that flow from FAS.

To enable the UK to move towards the FAS vision of a modernised airspace structure, the characteristics of the airspace in 2030 have been set out. Routings will be based on user preferred 4D trajectories: airspace structures will need to be flexible and operate dynamically following the UK's Joint and Integrated principles; there will be increased use of systems and technology to safely manage additional complexity and airspace structures will need to be designed to enable integration across Functional Airspace Blocks and national boundaries.

The benefits of the system will be categorised in terms of Safety, Environment, Capacity and Cost. These elements are not only logical, but also aligned with the European SESII and SESAR programmes and the UK/Ireland FAB principles. Ideally, the FAS can be developed to provide a suitable strategy for the UK/Ireland FAB. An effective, flexible and robust ATM structure will enable the UK to contribute to the development of air traffic management network efficiencies in Europe, whilst balancing the demand for airspace usage with the potential impacts on safety, capacity and the environment.

This document was authored by the CAA with support from the Ministry of Defence, NATS and the Department for Transport. Although it does not form part of the formal Future Airspace Strategy stakeholder consultation, if you have any questions or comments you would like to make please contact the CAA at:

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The FAS Challenge Team

Captain David Rowland, RAeS (Team Leader)
Recent Past President of the Royal Aeronautical Society. Retired from British Airways in 1999 having been General Manager of the Concorde Fleet. David has been a member and past Chairman of the Royal Aeronautical Society's Learned Society Board and of the Flight Simulation Group as well as a founder committee member of the aviation industry's environmental group, Greener-by-Design and chaired the Operations sub committee. David is a Fellow of the Royal Institute of Navigation and a Liveryman of the Guild of Air Pilots and Air Navigators.

Tim Johnson, Aviation Environmental Federation
Director of AEF since 1997, Tim has worked with the Federation for over twenty years, having joined as Planning Officer in 1989 with a degree majoring in transport planning. Tim provides the AEF's representation at the International Civil Aviation Organisation as well as on the Department for Transport's External Advisory Group, and other stakeholder advisory roles associated with NATS, the Sustainable Aviation Initiative, the European Commission, and the academic partnership, OMEGA.

Richard Hooke, The Royal Bank of Scotland
Managing Director of RBS' Aerospace & Defence business worldwide. Former Hawker Siddeley Aviation undergraduate apprentice, Richard spent 14 years in various executive roles at British Aerospace before spending 13 years at PricewaterhouseCoopers, where he was Global Aerospace & Defence Leader. Fellow of the Royal Aeronautical Society and visiting lecturer at the UK Defence Academy.

Richard Everitt, Port of London Authority
Qualified as a solicitor in 1974 and joined BAA in 1978. Following the privatisation of BAA in 1987, he joined the Board in 1991 as director responsible for strategy and regulatory matters. He resigned from the BAA Board in 2001 to become Chief Executive of National Air Traffic Services on its part privatisation. He joined the Port of London Authority as Chief Executive in late 2004.

Dr Christian Carey, Smith School, Oxford
The aviation expert as part of the Low Carbon Mobility Centre at the Smith School of Enterprise and the Environment, at the University of Oxford. The Smith School is a multi-disciplinary hub focused on the challenges of climate change. In relation to this Dr Carey's work seeks to understand the future of aviation in an emissions constrained environment, with particular reference to the impact of technology and future business models for airlines.

Dr Tweet Coleman, FAA
Tweet Coleman's career has spanned positions as an FAA program manager and regional representative, Boeing 747 and 727 airline pilot and Dale Carnegie communications coach, with a master's degree in aeronautical science and a doctorate degree in aerospace aviation education from Oklahoma State University. Regarded as a flight safety expert, she has served as the FAA Academy's International Flight Standards Program Manager for the past five years.

Rear Admiral Simon Charlier
Joined the Royal Navy in 1978 starting his career as a Lynx pilot, he has also commanded three ships, HMS SHERATON, NORTHUMBERLAND and CORNWALL and completed numerous staff appointments. He took up his appointment as CINC Fleet's Chief of Staff (Aviation) in February 2008 and moved to establish the new appointment as Director Operations Group of the Military Aviation Authority in April 2010.

Prof Philip Bennett
Fellow of the Royal Academy of Engineering he has held a number of appointments in relation to safety critical systems, most recently as Technology Director for Crossrail from 2007–2009. He has expertise in control systems, hazard and risk analysis and safety-critical systems. He has worked as an international consultant specialising in the assessment and assurance of safety critical systems and is currently a Visiting Professor in the Department of Computer Science at the University of York.

Glossary

ANSP	Air Navigation Service Providers
ATM	Air Traffic Management
ATS	Air Traffic Service
CAA	Civil Aviation Authority
CO_2	Carbon Dioxide
FAA	Federal Aviation Administration (USA)
FAB	Functional Airspace Block
FAS	Future Airspace Strategy
FUA	Flexible Use of Airspace
GA	General Aviation
GASF	General Aviation Safety Forum
GHG	Greenhouse Gas
IAA	Irish Aviation Authority
IPCC	Intergovernmental Panel on Climate Change
J&I	Joint and Integrated
MoD	Ministry of Defence
NATMAC	National Air Traffic Management Advisory Committee
NATS	National Air Traffic Services
NERL	NATS En Route Limited
PBN	Performance-based Navigation
SES II	Single European Sky Two
SESAR	Single European Sky Air Traffic Management Research Programme

LINKS

The CAA Website: http://www.caa.co.uk/

The European Air Traffic Management Master Plan Portal can be found via this link:
https://www.atmmasterplan.eu/http://prisme-oas.atmmasterplan.eu/atmmasterplan/faces/index.jspx

The 2015 Airspace Concept and Strategy can be found via this link:
http://www.eurocontrol.int/airspace/public/standard_page/141_Airspace_Strategy.html

The Navigation Application and Navaid Infrastructure Strategy for the ECAC Area up to 2020 can be found via this link:
http://www.ecacnav.com/downloads/NAV%20Application%20+%20NAVAID%20Infrastructure%20Strategy%2015MAY08%20Agreed%20at%20SCG-8.pdf

Further information on 8.33kHz Channel Spacing can be found on the Eurocontrol Website via this link:
http://www.eurocontrol.int/mil/public/standard_page/cns_com_833.html

The Commission Regulation (EC) No 29/2009 of 16 January 2009 laying down the requirements on data link services for the single European sky can be found via this link:http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:013:0003:0019:EN:PDF

Meeting the UK aviation target – options for reducing emission to 2050. Committee on Climate Change December 2009.
Available at www.theccc.org.uk/reports/aviation-report

4D Trajectory Management

The Eurocontrol web pages on 4D Trajectory can be found via these links:

Prototyping a SESAR 4D Trajectory Environment:http://www.eurocontrol.int/eec/public/standard_page/ETN_2009_2_4D_RI.html

4D Trajectory Management: an initial controller perspective:
http://www.eurocontrol.int/eec/public/standard_page/EEC_News_2008_1_4DTM.html

4D Trajectory Management: an initial pilots perspective:
http://www.eurocontrol.int/eec/public/standard_page/ETN_2009_2_4D_RI.html