Department for Transport

Upgrading UK Airspace
Strategic Rationale

Moving Britain Ahead

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Introduction

As an island nation, the UK relies greatly on the speed and global reach of air transport to keep us connected and provide the international access that we need for trade, business and tourism.

Aviation in the UK has grown significantly in the last 40 years driven by globalisation, the growth in real incomes and a greater desire from the public to travel abroad. The aviation sector now adds around £20bn a year to the economy and enables tourists arriving to the UK by air to add a further £21bn. Aviation supports 220,000 UK jobs and is a key driver for future economic growth, especially through global trade – an increasingly important area following our decision to leave the European Union.

Airspace is a key component of our aviation sector with most flights in the UK's airspace being commercial air transport – that is aircraft carrying passengers and freight. The Military also uses the airspace to secure our nation's borders and train their forces. In addition, the UK also has a thriving General Aviation sector, including private pilots in light aircraft, gliders, microlights and a wide range of other operators. As such, the airspace has become a key part of our national transport infrastructure and a scarce, but largely invisible resource.

The UK's aviation industry has expanded enormously since the 1950s and 1960s when much of our airspace structure was first designed. Since then airspace has been added to and adapted in response to growing traffic levels, but many departure routes, for example, at our major airports have been little changed for many years, even several decades. This piecemeal approach to the development of our airspace structure has created several issues with today's airspace that limit the ability to add capacity without making some more fundamental changes.

Today's upper airspace is structured around a fixed network of way points that are based on the position of ground navigation beacons and create bottlenecks. The busy terminal airspace that serves multiple airports, often closely located, has become a complex web of intersecting flight paths that requires a wholesale redesign to increase capacity and allow aircraft to climb and descend continuously. Airspace at lower altitudes around individual airports is also constrained by the reliance on ground navigation. Airports' standard arrival and departure routes need to be upgraded using satellite navigation to add capacity and introduce the flexibility to better manage noise impacts.

Summary of analysis

Aviation traffic forecasts from NATS suggest that commercial air transport will grow by around 2% a year in the UK, from 2.25m flights in 2015 to 3.25m flights in 2030. These forecasts do not include the additional flights that might be generated by a third runway at Heathrow Airport that is planned to go live around 2025.

If the airspace structure is not upgraded, passenger delays are forecast to increase sharply as traffic levels increase. Analysis conducted by NATS on behalf of the Department for Transport (DfT) estimates the impact of future traffic growth on delays if additional airspace capacity is not introduced – specifically, how many flights will be delayed on the ground at UK airports each year because of bottlenecks in the airspace.

In 2015, a lack of airspace capacity resulted in 78,000 minutes[1] of flight delays (equivalent to 54 days of total delay and an average of 9 minutes per delayed flight). These delays, whilst not substantial, are however forecast to grow to 1 million minutes by 2020 if airspace upgrades are not delivered as a matter of urgency (equivalent to 694 days and an average of 15 minutes per delayed flight). At this level, approximately 1 in 10 flights from UK airports would be delayed by more than half an hour with delay 13 times more than that experienced in 2015, an increase of 1200%.

Looking forward to 2030, the NATS analysis predicts that air traffic delays will increase to 5.6 million minutes a year (3,889 days or an average of 26.5 minutes per delayed flight), as traffic grows to an expected 3.25 million flights. If delays reach this level, more than 1 in 3 flights from all UK airports are expected to depart over half an hour late and the average delay would be 72 times more than in 2015, an increase of 7100%. These delays will leave passengers spending a great deal more time at the airport that could have been used more productively or enjoyably elsewhere. The most severe disruptions will leave travellers stranded on aircraft which are waiting on the runway or forced to wait for long periods of time in the departure lounges. The delays will also have significant environmental consequences, for example increased emissions as aircraft are required to spend time taxiing or in holding awaiting clearance to proceed. In addition, these delays would reduce the overall level of resilience of the air transport network, the performance of which can be affected by other factors such as the weather and industrial action.

Commercial air transport is based on reliability – providing passengers with the punctual and consistent service they expect and have purchased with their ticket. If demand grows and delays increase because of a lack of airspace capacity, many scheduled flights may be forced to cancel, causing passengers' significant frustration, inconvenience and the cost of wasted journeys.

Over a period of time, high numbers of cancellations are expected to transfer into a permanent reduction in the supply of flights to some destinations because carriers are forced to withdraw some services to the reliability of their operation. Delays are already forcing some airlines to build buffers into their flight schedules limiting the number of round trips that can be completed in a day.

[1] Delays are minutes per flight. These delays are air traffic control-related and do not include delays caused by the weather, airline or airport technical problems, or other forms of disruption such as industrial action.

The NATS analysis forecasts that without additional airspace capacity, cancellations are expected to consistently exceed 8,000 flights per year by 2030. The cumulative effects of several years of rising delays and cancellations is forecast to lead to c16,000 flights that would have been scheduled not being possible, and this figure would continue to grow after 2030. The analysis suggests that these cancellations will reduce the amount of delays, but even taking them into consideration the delay figure could be as high as 4.4 million minutes, 50 times more than in 2015. The anticipated cost of these delays could be a cumulative £1bn (at 2016 values) between 2016 and 2030 with an annual cost of £260million by 2030.

Summary of possible consequences if airspace modernisation does not occur:

- Air traffic delays in 2020, 13 times higher than those in 2015;
- Air traffic delays in 2030, 50 times higher than those in 2015;
- A lost opportunity to fly an additional 25,000 flights between 2015 and 2030 with at least 8,000 short notice cancellations a year by 2030;
- 1 in 3 flights delayed by more than half an hour by 2030 which would be a significant disruption to passengers, airports and the airline industry;
- Total cumulative cost of delay and cancellation from 2016 to 2030 could be c£1bn in 2016 values;
- Cost of delay and cancellation could be running at c£260million a year by 2030; and
- Delays and cancellations would get progressively worse after 2030 as demand for aviation grows.

The UK's plan to modernise airspace

The investment required to upgrade the UK's airspace structure, introduce additional capacity and avoid these delays, cancellations and lost supply is almost entirely funded by the aviation industry. A range of organisations from across the aviation industry are working together on a joint programme to tackle the issues with today's airspace. The programme is known as the Future Airspace Strategy (FAS) Deployment Plan and aims to:

- Save passengers time and avoid delays and cancellations growing into lost supply;
- Cut aviation emissions per flight and save fuel;
- Reduce the noise impacts from aircraft overflying population centres; and
- Further enhance aviation safety.

For passengers**,** the benefits of the FAS Plan are clear. Fewer flight delays and service disruptions at short-notice are expected to save time and improve the passenger experience. Also the capacity to add routes and accommodate new flights will lead to better value, more choice and enhanced global connections that can help drive the UK economy forward.

To achieve this the FAS Plan sets out a range of upgrades to the airspace structure and air traffic control systems that increase capacity and allow aircraft to climb, cruise and descend more efficiently; including:

- Removing the fixed structures in the en-route upper airspace;
- Completely redesigning the busy terminal airspace;
- Deploying Queue Management tools to reduce congestion;
- Introducing more precise and flexible satellite-based arrival and departure routes; and
- Sharing accurate airspace information between airports and air traffic controllers.

Several of the FAS Plan projects are scheduled for deployment before 2019 and are expected to significantly increase the airspace capacity in response to growing traffic levels. Some projects extend out to 2024 and will need to align closely with the introduction of a new runway in the south east that is expected to be entering its final stages of development in a similar timeframe.

Some parts of the FAS Plan have already been implemented successfully. For example, a new route structure based on satellite navigation was implemented in the airspace that serves London City and Stansted airports in 2015. The upgrade adds airspace capacity and will minimise future delays. Birmingham, Bristol, Gatwick and Luton airports have also recently implemented satellite-based routes.

There will be environmental impacts associated with the airspace upgrades that are deployed to accommodate growing traffic levels, but important environmental improvements are also expected as aircraft can follow more fuel-efficient routes, climb sooner, descend quieter and navigate more accurately around populated areas.

One of the most significant environmental impacts associated with aviation is the effects of aircraft noise. Overall the airspace upgrades set out in the FAS Plan are expected to see a reduction in the average noise levels per flight, but the redistribution of noise impacts between different areas will often lead to some disruption for communities living under flight paths. The effects of new, more frequent or concentrated noise may increase the risks of causing general annoyance, sleep disturbance, lower levels of productivity and health impacts.

Aviation noise performance has improved significantly in recent decades driven by the introduction of quieter aircraft. However, some residents experience significantly more noise events due to traffic growth. The Government’s policy on aviation noise is to limit and, where possible, reduce the number of people significantly affected by aircraft noise. This policy was established in an era of less accurate navigation. The introduction of satellite navigation routes can bring more intense levels of aircraft concentration and therefore noise.

But satellite-based routes also offer the opportunity to deploy innovative new operational techniques that can improve the management of aircraft noise, for example by introducing multiple flight paths for noise relief. The Government believes that these techniques should be considered wherever feasible, taking into account local circumstances and preferences in determining whether and which options should be explored.

Some of the techniques involve trade-offs with other airspace objectives such as increasing airspace capacity and saving emissions and fuel burn, which will need to be factored into the decision-making process that is guided by the Government's Airspace Policy and the CAA's Airspace Change Process.

Updates to Airspace Policy and Change Process will be issued in the course of this year following consultations. These consultations will gather the views of aviation stakeholders and the Public and help to ensure that both the policy and process are fit for purpose to support the implementation of the FAS Plan and to manage the costs and benefits of upgrading our airspace in a balanced and sustainable way.

1. Introduction

Purpose and structure of the report

1.1 This report describes the strategic national importance of an industry led investment programme to upgrade the UK's airspace structure. The report was produced by the DfT with the support of the CAA, the UK's specialist aviation regulator, and technical input from NATS, the UK's main provider of air traffic control services. The purpose of the report is to describe in general terms why the UK's airspace is being upgraded and how, and also give an indication of what might happen if the modernisation does not happen. It is aimed at those who have an interest in aviation, including those communities which may be impacted by the industry.

1.2 An efficient and effective airspace structure is important to all who fly; whether for developing business opportunities that benefit the UK or for leisure time with family and friends. Both activities are time sensitive and passengers need confidence that they will get to their destination at the time they expect.

1.3 The UK's airspace structure includes the routes that aircraft fly and the procedures and systems used by air traffic controllers to manage traffic flows. Aviation relies on an efficient and effective airspace structure to fully utilise the capabilities of modern aircraft. The aviation industry has started a major investment programme to upgrade the UK's airspace structure because it is outdated, inefficient, and reaching its capacity. The Government believes that airspace upgrades are essential to provide the aviation capacity our country needs to better meet present and future demands.

1.4 Like other modes of transport, aviation is looking at ways to keep pace with growing traffic levels and to adopt new technologies that benefit passengers and improve environmental performance. If the airspace structure is not upgraded, the lack of capacity is expected to lead to a sharp increase in air traffic delays, which create real costs and disruption for passengers and businesses. In addition, today's quieter and cleaner modern aircraft will continue to use flightpaths that can be inefficient, lower than they need to be, and not optimised to reduce their noise impact or offer relief to communities.

1.5 This report is presented in three parts:

The Introduction provides an overview of the UK aviation sector and airspace structure and describes the background to the FAS.

Part A outlines the main issues with today's airspace structure and examines how passenger delays and flight cancellations may increase sharply between now and 2030 if the industry does not introduce additional airspace capacity. Part A also considers the relationship between airspace upgrades and aviation noise.

Part B describes the main features of the industry led FAS Plan that is intended to tackle the issues with today's UK airspace. The second part of the report also considers the treatment of negative impacts that may arise from the airspace upgrades, especially those affecting local communities that may experience changes to where aircraft are usually seen and heard.

Overview of the UK aviation sector

1.6 Our daily lives are shaped by the speed and global reach of aviation. As an island nation, the UK relies greatly on air transport. From large cities to small communities, aviation keeps us connected with one another and provides the international access that we need for trade, business and tourism purposes. In 2014, the aviation sector directly contributed around £20bn to the UK economy and supported 220,000 British jobs.[2] Spending by tourists that flew to the UK generated £21bn gross value added.[3]

1.7 It is therefore noteworthy that the aviation industry's success has been built on an airspace structure which was established over 40 years ago. Since then, the demand for aviation has increased significantly, driven by globalisation, the growth in real incomes and a greater desire from the public to travel abroad. The aviation industry has expanded accordingly, offering flights to a growing list of destinations across the globe and much greater choice for passengers. This growth has also been further enabled by the emergence of low cost airlines that have dramatically expanded the short haul European aviation market.

1.8 In June 2016, the UK voted to leave the European Union. Although the impact of leaving the EU on the aviation industry is uncertain, the decision focusses attention on the infrastructure required to support trade with the wider global economy. Airspace upgrades that create the capacity to increase the range and frequency of global connections are an important enabler for future GDP growth as passenger numbers continue to increase and the UK re-defines the terms of our relationship with the EU.

1.9 Chart 1 sets out the growth in terminal passenger numbers, i.e. those arriving and departing, at UK airports from 1995 to 2015.[4] Passenger numbers hit a record high in 2015, passing the previous peak immediately prior to the 2008 recession.

[2] Office of National Statistics, National Accounts, 2014.
[3] Office of National Statistics, International Passenger Survey, 2015.
[4] CAA Aviation Data, 2015 (http://www.caa.co.uk/data-and-analysis/)

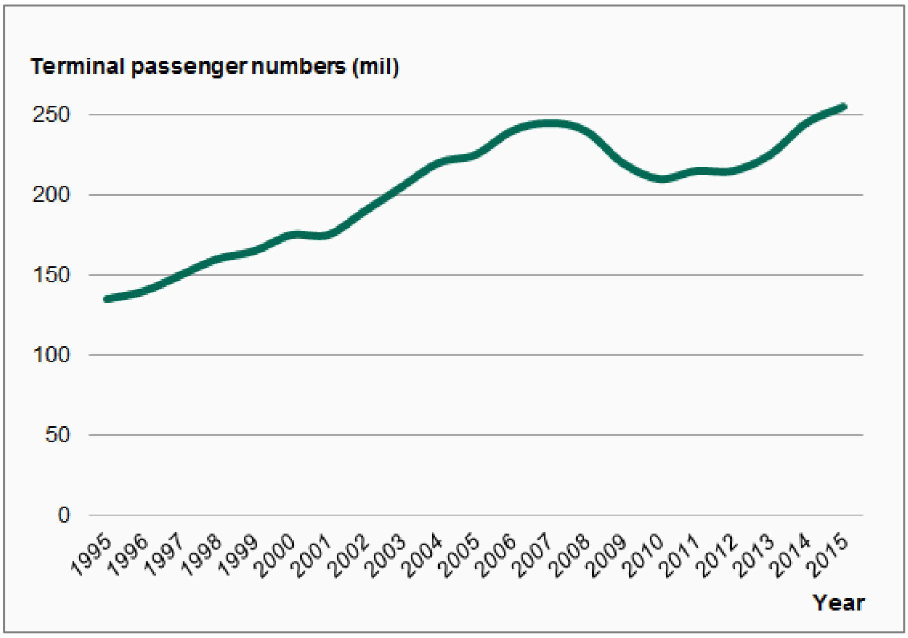

Chart 1: Growth in terminal passenger numbers at UK airports, 1995 – 2015

1.10 Growth in terminal passenger numbers will result in growth in the number of flights through UK airspace although this may not be at the same rate as airlines will absorb the passenger growth in any available seat capacity they have before adding additional flights.

1.11 Flights in UK airspace can be categorised into three types: Commercial Air Transport carrying fare paying passengers and cargo, General Aviation (GA) and Military. There were 2.1m commercial air transport flights in 2015, travelling to and from 49 licensed UK airports.[5] Of these:

- 50% were passenger flights to and from London airports;
- 47% were passenger flights to and from regional airports outside the London area; and
- 3% were air freighters carrying cargo (freight is also carried by passenger flights).

[5] CAA Aviation Data, 2015 (http://www.caa.co.uk/data-and-analysis/)

1.12 Chart 2 sets out the growth in commercial flights at UK airports from 1995 to 2015.[6]

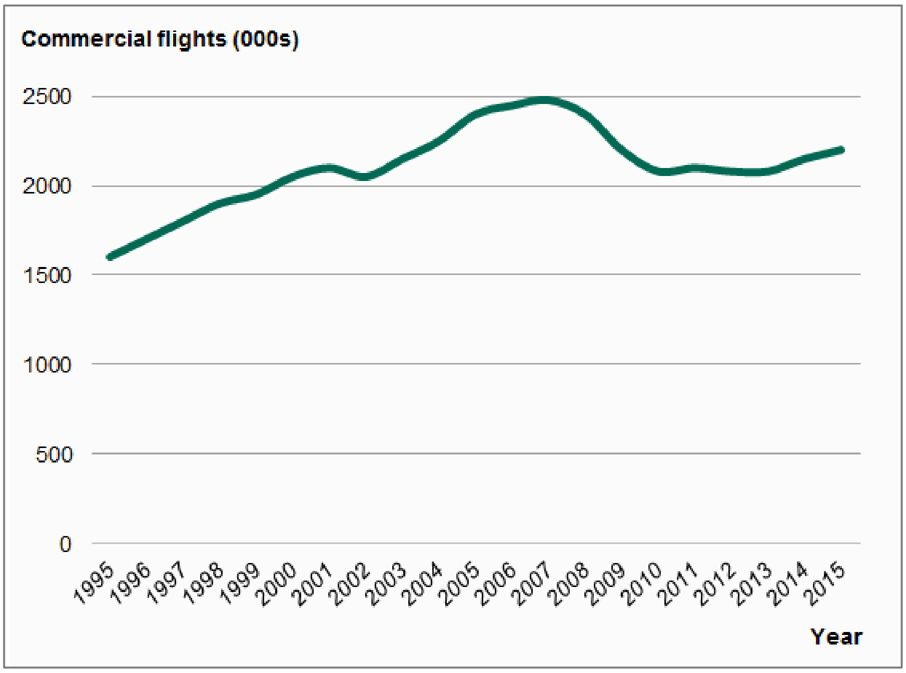

Chart 2: Growth in commercial flights at UK airports from 1995 to 2015

1.13 Despite record airport terminal passenger numbers in 2015, the number of commercial flights has not increased in proportion. This is partly because more passengers have been accommodated on a per flight basis in recent years, due to the use of larger aircraft. For example, Gatwick Airport managed 42m annual passengers in the 12 months to August 2016, a 6.4% increase on the previous year, while annual flights for the same period only increased by 4.5%.[7]

1.14 Air freight is an important part of the commercial aviation sector for consumers and businesses that rely on imports or exports. £101bn of goods travelled via Heathrow in 2014, more than the UK's two biggest shipping ports – Felixstowe and Southampton – combined. 2015 saw 2.5m tonnes of cargo pass through UK airports[8] with Heathrow airport handling around 1.5m tonnes. East Midlands, Stansted, Manchester, Edinburgh and Belfast International airports also handle significant amounts of cargo.

1.15 The UK also has a thriving GA sector that includes traditional fixed wing light aircraft, rotorcraft and gliders, business jets, flight training and surveyors, air sports, balloonists and microlights. This sector requires access to a significant amount of airspace in order for the diverse range of its activities to operate.

1.16 The Military relies on access to the airspace to secure our nation's borders and requires dedicated areas to be reserved for hazardous activities like training fast jet pilots and testing munitions. The military's specific requirements for airspace also change over time.

[6] CAA Aviation Data, 2015 (www.caa.co.uk/data-and-analysis)
[7] Gatwick Airport Limited, 2016 (http://www.gatwickairport.com)
[8] CAA Airport Data, 2015 (www.caa.co.uk/data-and-analysis)

UK airspace is under pressure

1.17 The UK's airspace structure is an essential, but largely invisible, part of our national transport infrastructure, and it is also some of the most complex in the world. However, our airspace is already struggling to keep pace with the growing demand for aviation. More and more traffic is being squeezed into the same congested areas of airspace, causing inefficient flight paths, passenger delays and poor resilience to disruption, such as that which can occur from bad weather or technical difficulties. The skies over the UK will continue to get busier as the aviation industry expands and incorporates new types of operation like unmanned aircraft and space tourism.

1.18 Forecasts from NATS that are based on the long-term relationship between economic growth and the demand for aviation suggest that commercial air transport flights will increase by around 2% a year from 2.25m in 2015 to 3.25m in 2030. These forecasts incorporate the impact of existing capacity constraints and do not include the expected additional growth associated with proposals to build a third runway at Heathrow Airport.[9]

1.19 Much of the debate about the need for additional capacity has been focussed on airports and runways, especially the proposals for a new runway in the south east of England. In October 2016, the Government announced support for a new runway at Heathrow in the next decade which could add up to 260,000 additional flights a year into what is already highly-congested airspace.[10] However, upgrades to the airspace structure are essential, with or without new runways, as many other UK airports are planning to expand to fill their existing spare capacity in the coming years.

The Future Airspace Strategy

1.20 Aviation in the UK is largely privately owned and managed. The Government believes that a competitive aviation market is the most effective way to meet the interests of passengers and other users. The investment required to upgrade our airspace is almost entirely funded by the aviation industry, unlike other parts of the national transport infrastructure, where there is significant Government funding.

1.21 A wide range of organisations from across the aviation industry are working together on the investment programme to upgrade the airspace. The programme is known as the FAS Deployment Plan and is supported by airports, aircraft operators, air traffic control organisations, the Military and the Regulator (the CAA).[11]

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[9] NATS forecasts, 2016.
[10] http://www.heathrow.com/
[11] http://www.caa.co.uk/Commercial-Industry/Airspace/Future-airspace-strategy/Future-airspace-strategy/

1.22 The FAS Plan looks to coordinate the industry's investment in a set of upgrades to the way the UK's airspace is structured, the routes that aircraft fly, and the systems used by air traffic controllers to manage traffic flows. The Plan reaches out to 2030 and aims to:

- Save passenger time and avoid delays through the introduction of extra airspace capacity when and where it is needed;
- Cut aviation emissions per flight and save fuel through more direct routings and improved flight efficiencies;
- Reduce noise from fewer aircraft overflying population centres and holding at lower altitudes; and
- Further enhance aviation safety by reducing airspace complexity and introducing new technologies that help to manage the residual risks.

1.23 The FAS Plan has many components, but is based around five key upgrades, to:

- Remove the fixed structures in the en-route airspace, adding capacity and enabling more direct and free routes;
- Completely redesign the route network in busy terminal airspace to take account of advances in new technology, especially satellite navigation;
- Stream traffic through speed controls in the en-route phase of flight to improve arrival management and reduce the reliance on stack holding in the terminal airspace;
- Redesign airport arrival and departure routes at lower altitudes to allow flights to climb and descend continuously, and better manage the impacts of aircraft noise; and
- Connect airports into the network to provide and receive accurate information about traffic flows which will better manage ground delays and pinch points across the airspace.

1.24 The scope, timing and expected benefits of the FAS Plan airspace upgrades are described in more detail in Part B. Chart 4 illustrates how the upgrades aim to improve the performance of the airspace across each phase of flight.

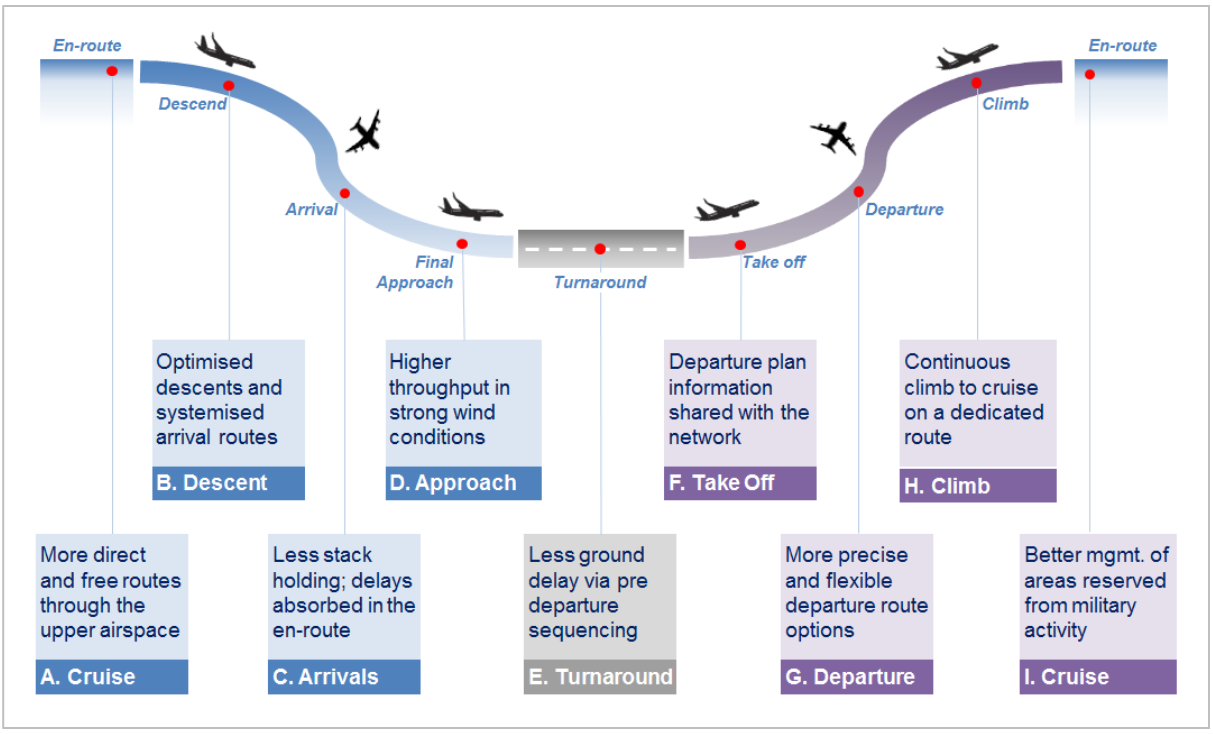

Chart 4: FAS Plan airspace upgrades by phase of flight

Benefits and costs of airspace upgrades

1.25 Airspace upgrades can bring large benefits, especially for passengers and business, but are rarely delivered without some external costs.

- **For passengers,** the benefits of the FAS Plan are clear. Fewer flight delays and service disruptions at short-notice are expected to save time and improve the passenger experience. A more efficient airspace will increase capacity allowing connections to more destinations.

- **For aircraft operators**, the airspace structure is a key determinant of costs, punctuality and environmental performance. More direct and efficient flight paths will mean lower costs for operators because they will save on fuel and be able to enhance the utilisation of their aircraft.

- **For airports,** the sharing of digital information about the inbound and outbound traffic flows using our airspace is expected to improve runway throughput and resilience.

- **For the economy and consumers,** the capacity to add routes and accommodate new flights will lead to better value, more choice and enhanced global connections that can help drive the UK economy forward.

1.26 Although there will be environmental impacts associated with the forecast growth in traffic levels, important environmental improvements are also expected from the airspace upgrades as aircraft can follow more fuel-efficient routes, climb sooner, descend quieter and navigate more accurately around populated centres.

1.27 One of the most significant environmental impacts associated with the airspace upgrades at lower altitudes concerns the effects of aircraft noise. Overall the airspace upgrades are expected to see a reduction in the average noise levels per flight, but the redistribution of noise impacts between different areas will often lead to some disruption for communities living under flight paths. The effects of new, more frequent or concentrated noise may increase the risks of causing general annoyance, sleep disturbance, lower levels of productivity and health impacts.

1.28 The Government has recognised the importance of these issues and is at present looking to update its airspace and noise policies. A key objective of this work is how to balance the benefits of aviation with its local impacts. Within this framework, the aviation industry is being asked to consider ways to better manage the noise impact of their operations. Some of the methods under consideration are described in Part B of this report.

1.29 As the UK's specialist aviation regulator, the CAA is a key stakeholder in the FAS Plan. The CAA sets the initial direction for the FAS. The strategy has now moved into its deployment phase, but the Regulator still plays an important role, producing the processes, standards and guidance needed to ensure that airspace upgrades are deployed safely and in a joined-up manner.

1.30 The Government has directed the CAA to ensure that there is an appropriate balance between environmental and operational factors in any proposed changes to the airspace structure.[12] The environmental impact of proposed changes should be considered at the earliest possible stage. The CAA must also ensure that any airspace change proposals which may have a significant impact on the distribution of aircraft noise near an airport are the subject of an effective consultation exercise with all those concerned.

1.31 The regulatory guidance to industry on how airspace change proposals should be developed and consulted on is currently being strengthened by the CAA to ensure that the options, impacts and decisions associated with each proposal are made transparent and that local communities are sufficiently engaged.

International Developments

1.32 The FAS Plan is closely linked to a wider multi-State programme, known as Single European Sky (SES). The SES initiative was launched by the European Commission in 1999 and now provides the overarching framework to upgrade the airspace and air transport network across Europe. The SES ATM Research (SESAR) Programme is a major public-private initiative to develop new technologies that will improve the way Europe's airspace is managed as part of the broader SES initiative. Many UK organisations have been involved in testing and validating the new technologies.

1.33 Like the FAS Plan the SESAR Programme has now moved into its deployment phase and the European Commission has made over €2.5bn available to support implementation projects. For example, work carried out in a SESAR work package (in which NATS was involved) helped to develop the concept of Time-Based Separation (TBS), whereby aircraft, can be separated by time instead of distance when arriving at an airport. This significantly improves resilience in strong headwind conditions.

[12] Sections 70(2) and 70(3) of the Transport Act 2000 and in other directions and guidance which it has issued to the CAA.

1.34 NATS has built on that initial R&D and, in partnership with Lockheed Martin, developed a TBS solution which has been deployed at Heathrow, helping to maintain landing rates in strong headwind conditions. TBS at Heathrow is expected to save 80,000 minutes of delay per year.[13]

1.35 Globally, airspace structures have seen significant levels of investment in recent years, mainly driven by airport expansions in the Middle East, Far East and China. In North America, a programme known as NextGen is delivering new technologies and airspace changes to tackle similar aviation capacity and efficiency challenges. The International Civil Aviation Organisation (ICAO) is harmonising global developments through a programme of Aviation System Block Upgrades (ASBUs).[14] As a result, the UK aviation industry is increasing its spending on airspace to keep pace with international developments and maintain our country's air links and status as a global hub for aviation.

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[13] Calculated by assessing the numbers of flights impacted multiplied by the time delay per flight. Source: NATS, 2015.
[14] http://www.icao.int/Meetings/anconf12/Pages/Aviation-System-Block-Upgrades.aspx

Progress to date

1.36 Some parts of the FAS Plan have already been implemented successfully. Chart 5 summarises some of the main airspace upgrades delivered between 2014 and 2016.

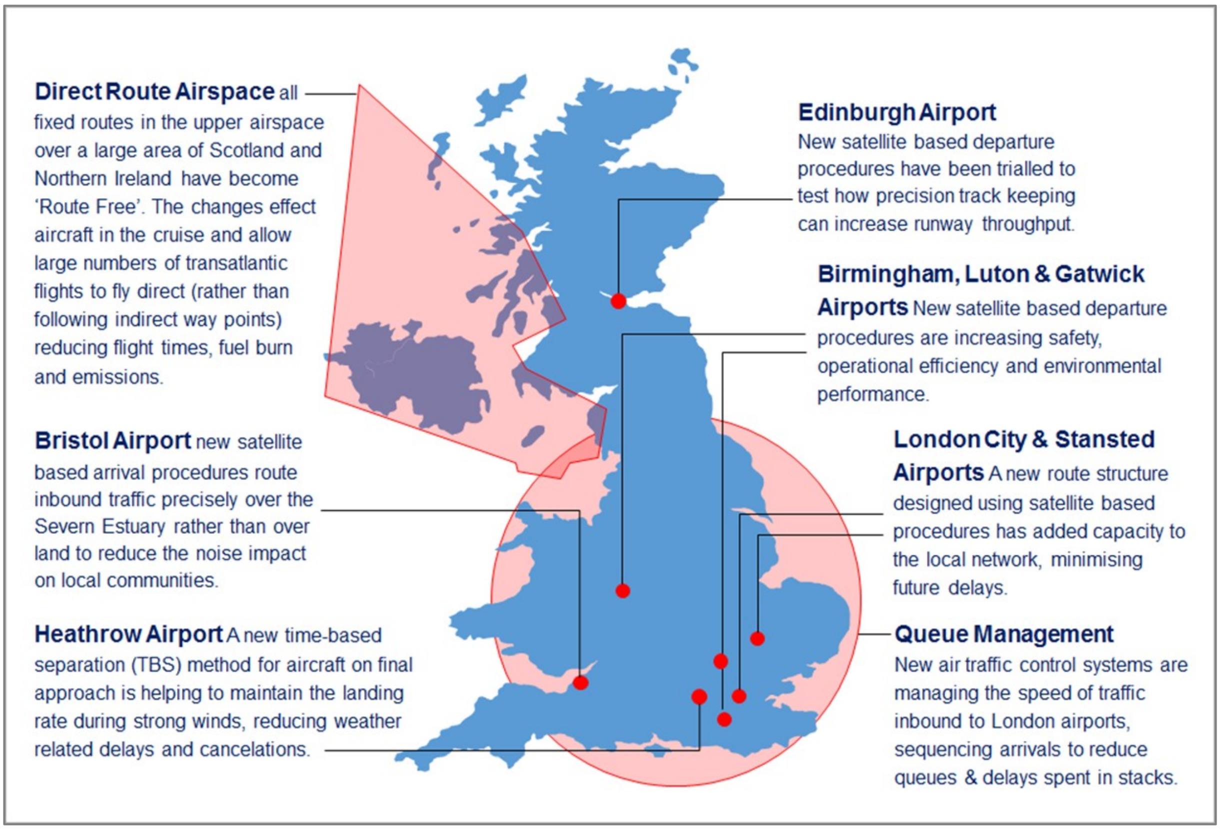

Chart 5: Summary of airspace upgrades delivered between 2014 and 2016.

PART A

The first part of this report outlines the main issues with today's airspace structure and examines how passenger delays and flight cancellations may increase sharply in the next decade or so if the industry does not introduce additional airspace capacity. Part A also considers the relationship between airspace upgrades and aviation noise.

2. Today's airspace

Overview of today's airspace

2.1 The UK's airspace can be divided into two main categories – controlled and uncontrolled. Controlled airspace is created where it is necessary for air traffic control to proactively manage the traffic flying in that airspace. Aircraft flying in controlled airspace do so under the direction of air traffic controllers, and pilots are required to file a flight plan for each journey, providing details such as destination, route, timing and altitude.

2.2 **Controlled airspace** is highly structured and contains a sophisticated framework of features that are mandatory for aircraft operators and air traffic controllers. These features prescribe the capability of aircraft that may operate in an area of airspace, the navigational systems they must use, the location of airways and holding points and the default routes that should be taken between them. The vast majority of commercial flights operate in Controlled Airspace.

2.3 Controlled airspace is subdivided into a variety of areas and zones, including some segregated areas where there are restrictions on flying activities, for example military danger areas used for flight training and testing munitions.

2.4 The guiding principle of air traffic control is that safety is paramount. Controllers keep aircraft safely separated by set distances; for example, aircraft flying in controlled airspace under radar surveillance are normally kept three to five nautical miles apart horizontally or 1,000ft vertically.

2.5 **Uncontrolled airspace** typically incorporates all areas at lower altitudes where there is no operational safety reason for aircraft to be identified and managed by air traffic control (although air traffic controllers sometimes provide an advisory service). Uncontrolled airspace has set boundaries, but in contrast to controlled airspace, is governed only by general rules and principles of operation. The main method of aircraft separation is through pilots visually identifying other aircraft. The GA community operates largely in uncontrolled airspace alongside the Military and a small number of commercial flights.

2.6 Air traffic control is managed by Air Navigation Service Providers (ANSPs). NATS is the UK's main provider, handling all air traffic control in the en-route airspace and the busy terminal airspace over London, Northern England and Scotland. The provision of air navigation services at airports is open to competition in the UK. Some airports choose to manage it themselves, and some let a contract to NATS or another ANSP. In addition, some services in the UK are provided by the Ministry of Defence (MoD). Military controllers work closely with their civilian colleagues to provide a joint and integrated service to all users including those outside controlled airspace.

2.7 The CAA has a general policy of keeping the volume of controlled airspace to the minimum necessary for the effective protection of the air transport network. The creation of additional controlled airspace to maintain safety or to increase the capacity of the air transport network can impinge on the availability of uncontrolled airspace for other users. An appropriate balance is needed therefore that satisfies the economic, security and social requirements of the various types of operation as much as possible.

Issues with today's airspace

2.8 Over the past few decades, the airspace has been added to and adapted in response to growing demand. This piecemeal approach has created inefficiencies that limit the ability to add capacity without making some more fundamental changes. The issues with today's airspace can be grouped into four key areas:

- **The en-route airspace** above around 25,000ft.
- **The busy terminal airspace** from around 25,000ft to 7,000ft that links individual airports with the en-route airspace;
- **The airspace at low altitudes around airports** where dedicated arrival and departure routes link the terminal airspace with runway ends; and
- **The arrangements for managing traffic flows** across the airspace.

2.9 These areas and the related issues are described in the sections below.

Issues in the en-route airspace

2.10 En-route airspace is typically considered to be the airspace above 25,000ft where aircraft are in the cruise phase of flight. Aircraft often fly further than necessary in en-route airspace on flight paths that are determined by the available sequence of way points, rather than the shortest, most direct route to their destination. A range of factors determine the sequence of way points that aircraft plan to follow, including weather conditions (most notably the position of high level winds to be exploited or avoided) and the location of segregated areas reserved for military activity.

2.11 The capacity of en-route airspace is determined by the ability of air traffic controllers to safely manage the flow of traffic through each sector. Traffic flow restrictions are applied to sectors when the volume of traffic exceeds a level that the controllers can manage safely. The restrictions create bottlenecks which cause aircraft to be delayed on the ground pre-departure because of a lack of airspace capacity. Flights that are already airborne when flow restrictions are applied are often directed to fly longer routes at less efficient altitudes and speeds to avoid the bottlenecks.

2.12 The FAS Plan, described in Part B, aims to replace the fixed structure of en-route sectors and way points with Free Route Airspace that removes the bottlenecks and allows aircraft to fly the quickest, most fuel-efficient flight paths.

2.13 Chart 6 uses *Google Maps* to illustrate the main features of the UK's airspace structure, along with the position of airports and the location of segregated areas (in red).

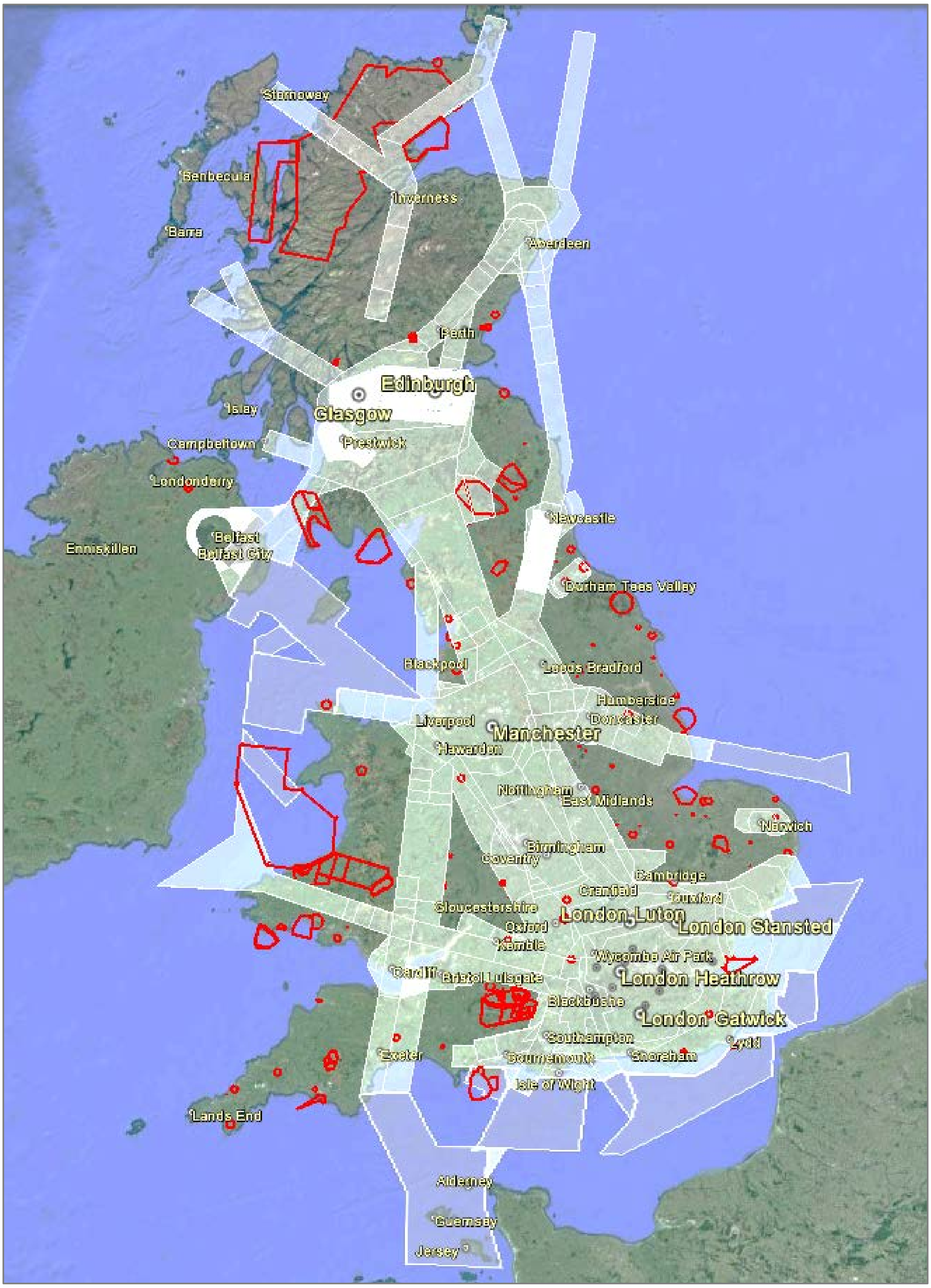

Chart 6: Main features of the UK's airspace

Issues in the terminal airspace

2.14 The terminal airspace from around 25,000ft to 7,000ft is designed to manage high volumes of traffic climbing and descending between individual airports and the en-route. The result is a complex web of intersecting flight paths to and from airports that are in close proximity. For example, Manchester, Liverpool, Leeds Bradford, Birmingham and East Midlands airports collectively manage over 370,000 flights a year[15] and operate in a radius of less than 100 miles. The five largest London airports manage over 1 million flights a year across an area with a radius of less than 60 miles. Chart 7 illustrates the main flows of traffic inbound and outbound to the five London airports on a typical day.

Chart 7: Traffic flows to the five London airports on a typical day

2.15 Chart 7 illustrates the volume and complexity of the interactions between traffic flows in the London terminal airspace. Ideally, departures would climb quickly and continuously through the terminal airspace, and arrivals would descend continuously to the runway with little direction from air traffic controllers. However, in practice, controllers intervene regularly to manage the interactions between departing and arriving traffic, making sure aircraft stay safely separated. Continuous climbs and descends are interrupted by the need for aircraft to return to level flight to avoid crossing traffic. The introduction of these 'steps' of level flight increases aircraft fuel burn, emissions and in some cases noise. The high workload placed on controllers to manage crossing traffic limits the capacity of the terminal airspace, causing delays in a similar way to the en-route bottlenecks.

2.16 Arrival traffic in the terminal airspace is routinely directed into airborne holding stacks, where aircraft fly in a circuit pattern waiting for clearance to land. Airborne holding is used to absorb delays and ensure a steady stream of traffic is presented for landing, maximising airport runway capacity. However, the use of holding stacks creates a 'blockage' in the terminal airspace structure. Departures are kept at lower altitudes to avoid the stacks and in doing so fly longer and potentially noisier routes.

[15] 2015 Air Transport Movements, CAA Airport Data, 2015 https://www.caa.co.uk/Data-and-analysis/

2.17 Departing traffic is managed in different ways, some airports must coordinate their departures with the air traffic control centre this can take time and in periods of high workload this will result in delays for those flights.

2.18 The complexity of the terminal airspace and the lack of spare capacity has weakened its resilience to bad weather and disruption (e.g. technical problems or strike action). Unplanned events often lead to significant delays. Normal service is typically resumed on the next day of operation when airports, air traffic controllers and aircraft operators have used the less busy, but more noise sensitive night period to reset their operations.

2.19 The FAS Plan aims to systemise the terminal airspace, introducing a greater number of dedicated routes to and from individual airports and significantly reducing the number of traffic interactions that controllers need to manage. The FAS Plan also proposes to replace airborne holding stacks with better queue management techniques that absorb delays by slowing aircraft down while they cruise, freeing up the terminal airspace capacity and enabling aircraft to climb more quickly.

Issues in the airspace at low altitudes around airports

2.20 The airspace at lower altitudes around airports – from around 7,000ft to the ground – is reserved for dedicated arrival and departure routes that link the terminal airspace with the end of the runway. The impact of aircraft noise on those living under flight paths is the most important factor, other than safety and feasibility, under consideration when designing arrival and departure routes at lower altitudes.

2.21 Most airport arrival and departure routes in the UK are designed around the position of ground navigation beacons. Although well-known and highly structured, the fixed locations of these beacons often create inflexible and inefficient flight paths. The limited number of beacons mean many flights from different airports often plan to converge on the same pinch points, limiting the flow of traffic, see Chart 8.

2.22 Air traffic controllers intervene tactically to take aircraft off their planned flight paths and avoid pinch points. This is done via a process known as 'vectoring' where controllers instruct pilots to fly a specific compass bearing rather than routeing directly to the beacon. Through vectoring, air traffic controllers are in effect, making up their own endless and variable supply of flight paths to allow multiple aircraft to share the same planned routes and create the airspace capacity needed to meet traffic demand. Chart 8 illustrates the how tactical vectoring is used to add capacity to the airspace and relieve pinch points at low altitudes.

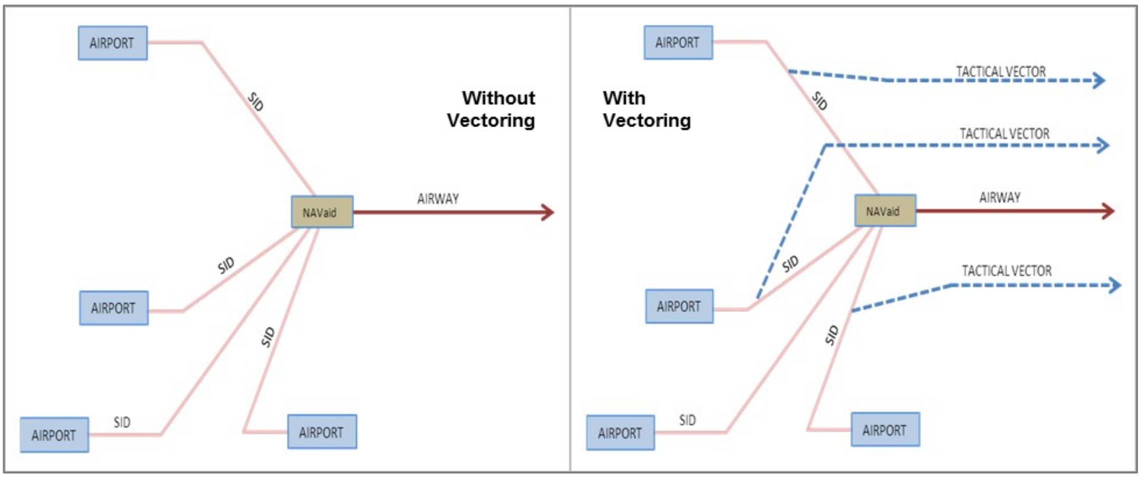

Chart 8: Accommodating traffic demand through tactical vectoring

2.23 The capability of air traffic controllers to operate in this manner has evolved over time to safely and efficiently accommodate growing traffic levels. However, the volume of flights that controllers can safely manage through tactical vectoring is reaching capacity because the physical size of the available airspace sectors through which to vector traffic safely is limited.

2.24 The FAS Plan proposes that airport arrival and departure routes are upgraded to a more precise and flexible satellite-based navigation standard. The introduction of satellite navigation removes the need to rely on ground beacons, offering significantly more flexibility in the way that routes can be designed. Improvements in aircraft navigational performance mean that capacity can be added by implementing more closely spaced arrival and departure routes into the same volumes of airspace and removing the reliance on vectoring.

2.25 The precision and flexibility offered by routes based on satellite navigation also creates opportunities to better manage noise impacts, for example by designing flight paths that avoid population centres and deploying multiple route options to be used at different times there by enabling some dispersion of traffic flows. These opportunities must be balanced against the challenges created by more precise routes that concentrate aircraft noise into narrower contours, which often have a more intense impact on those areas that are affected.

Issues with the management of traffic flows

2.26 Many of the decisions made about managing the flow of traffic through the airspace in line with available capacity are not based on accurate information. There is often little consistent up to the minute information about when flights plan to arrive at airports, turnaround (reload, refuel etc.), and then depart. Airports, airlines, air traffic controllers and other operational organisations like the European Network Management Operations Centre (NMOC) and Ground Handling Agents all use different information, managed by different systems, and updated at different times.

2.27 In the absence of up to the minute information most decisions are based on either the airlines' published schedules that are developed months prior to the day of operation, or their flight plans, submitted at least three hours prior to departure. Neither of these sources are regularly updated to reflect the dynamic nature of the airspace.

2.28 The gaps in information, and the time and effort needed to close them, reduces the effective capacity of the airspace. For example, the lack of accurate information about inbound, turnaround and outbound traffic flows impacts punctuality at airports. Poor punctuality often has significant knock on effects throughout the day in the form of rotational delays. Airlines are strongly incentivised to maintain a high level of punctuality. This creates pressure for airlines to add buffers to their schedules, including a degree of holding on the ground and in the air to their flight plans in the expectation that they will experience some delay.

2.29 The FAS Plan proposes that all airports in the UK are electronically connected with air traffic controllers and NMOC, providing and receiving up to date information about inbound, turnaround and outbound traffic flows to maximise the effective capacity of the airspace.

3. Forecast traffic growth and delays

Introduction

3.1 If the issues that create capacity constraints in today's airspace are not tackled, passenger delays and flight cancellations are forecast to increase sharply as traffic continues to grow. Airspace capacity will ultimately become the constraining factor on growth in the aviation sector and the supply of flights to some destinations may be lost. Analysis conducted by NATS on behalf of the Department estimates the amount of delay and flight cancellations likely to be incurred if traffic grows at the rate anticipated in Chart 3 but no major upgrades to the airspace are introduced, see Annex A.

3.2 The NATS analysis isolates the estimated extent of operational delays and cancellations specifically attributable to a lack of airspace capacity. This analysis includes **only delays due to capacity in en-route airspace and airport departure routes** – so called Air Traffic Flow Management (ATFM) delays. It does not cover weather-induced delays or those caused by technical failures or staffing issues which could add significantly to the amount of delay experienced by passengers and the level of disruption caused.

Expected delays and cancellations if we do not modernise our airspace

3.3 In the NATS analysis, flights in UK airspace, which includes overflights, are forecast to grow from 2.25 million per year in 2015 to 3.25 million in 2030 (an increase of 44%). Without additional capacity, more and more flights will be delayed on the ground at UK airports each year because of the bottlenecks in en-route, terminal and low altitude airspace.

3.4 The relationship between demand, capacity and delay is non-linear. As specific sectors of airspace reach capacity, small further increases in demand can cause significant increases in delay that have knock-on effects across the network.

Expected delays

3.5 In 2015, airspace capacity constraints caused a total of 78,000 minutes (54 days of total delay or an average delay per delayed flight of 9 minutes in UK airspace) of ATFM delay across the 2.25 million flights. Without additional airspace capacity, these delays are forecast to increase to 1 million minutes (694 days and an average of 15 minutes per delayed flight) by 2020, as traffic grows to an expected 2.6 million flights. This is 13 times the number of delays experienced in 2015, an increase of 1200%. By 2020, the NATS analysis predicts that 1 in 10 departures from UK airports would be delayed by more than half an hour.

3.6 Looking forward to 2030, the NATS analysis predicts that delays will increase to 5.6 million minutes a year affecting many more flights than in 2015 (the equivalent of 3,889 days and an average of 26 and a half minutes of delay per delayed flight), as traffic grows to an expected 3.25 million flights. This is over 70 times (7,100%) the delays experienced in 2015. If delays reach this level, one in three flights from the UK are expected to depart over half an hour late and many scheduled shorthaul flights would be forced to cancel due to higher numbers of daily rotations and shorter scheduled turn-around times allowing for less resilience in delays.[16]

3.7 Chart 9 illustrates the forecast increase in annual delays as traffic grows steadily from 2015 to 2030, if no additional airspace capacity is introduced.

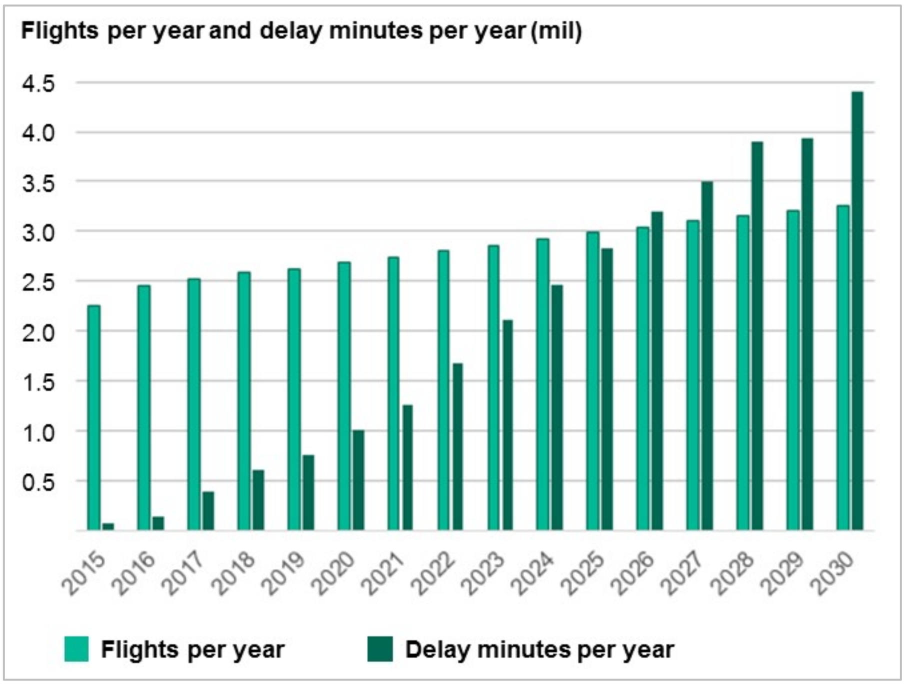

Chart 9: Traffic growth and increase in delays with no additional airspace capacity

3.8 Commercial air transport businesses are based on reliability – providing customers with the punctual and consistent service they expect and have purchased with their ticket. In this forecast, as demand grows and delays increase overtime, it is reasonable to assume that cancellations will not be scheduled because commercial carriers are forced to withdraw some services to protect punctuality and consistency.

Cancellations

3.9 Without additional airspace capacity, flight cancellations are expected to be consistently over 8,000 per year by 2030 and the cumulative effect of several years of rising delays and cancellations is forecast to lead to c16,000 flights that would have been scheduled, not being possible to operate. Beyond 2030, the delays, cancellations and lost supply are expected to continue growing at an increasing rate as demand for flights grows.

[16] Assuming that a shorthaul aircraft typically operates 5 flights per day and a turn-around time of 30 minutes, a 45 minute delay on the first rotation compounded by further delays on the next rotations cannot be recovered. The model assumes that in an increasing number of cases over time, this will result in cancellation of one rotation for the aircraft's schedule in order to protect the overall operation and avoid operating restrictions including crew hours and night flight curfews.

3.10 Chart 10 sets out the expected increase in cancellations per year caused by air traffic delays and how they are expected to transfer into a permanent loss of supply.

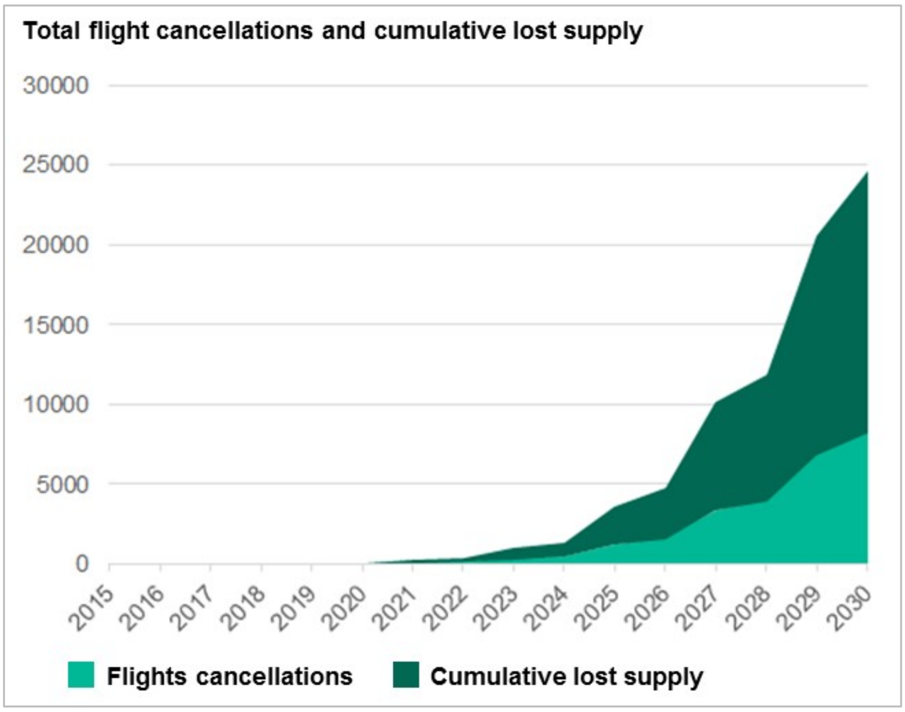

Chart 10: Forecast increase in flight cancellations per year and cumulative lost supply

3.11 There are many factors that influence these forecasts, the above NATS analysis is set out in Annex A and describes in more detail a view of the potential loss of services should the delay scenario in paragraph 3.6 develop. This analysis shows high levels of impact, whether from flight delays, short notice cancellations or constraints on the number of scheduled flights, in the absence of airspace modernisation. These impacts affect all involved in aviation and will essentially reduce the quality, value and provision of air transport services.

3.12 Aviation is an important component of this country's economy providing benefits to passengers, connecting family and friends, enabling tourism, trade and the movement of high-value goods. It facilitates growth in GDP and connects the whole of the UK to trading partners around the world. Delays, cancellations and caps on growth will inhibit these benefits and bring costs to the UK, not just to airports, airlines and their passengers.

Possible delay and cancellation costs

3.13 The DfT has considered the possible cost implications of the delay and cancellation figures suggested in the NATS analysis. The DfT analysis suggests that the cumulative additional costs of delay and cancellations for the aviation industry and passengers between 2016 and 2030 could be over £760 million in 2016 values. By 2030, the cost of air traffic delays could be running at c£140million a year added to which there would be cancellation costs in excess of £120million a year. The analysis therefore points to a scenario that with no airspace modernisation the additional costs borne by the aviation industry and its customers could be c£260million a year and rising thereafter. Annex E provides more details on the assumptions made by the DfT and a breakdown of the possible costs if airspace modernisation does not occur. These cost estimates do not account for the impact and wider costs of flights that cannot be scheduled in the absence of airspace modernisation.

4. The impact of aviation noise

Introduction

4.1 In addition to mitigating the impact of traffic growth on delays, airspace upgrades also have a significant effect on aviation noise.

4.2 The predominant source of transport noise exposure is from roads. The European Environment Agency reported that within Europe's major cities approximately 70 million people are exposed to road noise above 55 decibels compared with just under 10 million to rail noise and less than 3 million to aircraft noise.[17]

4.3 Notwithstanding these findings, aviation noise generates considerable interest as it tends to cover larger geographical areas and can be more difficult to mitigate effectively. Aviation noise currently affects more people in the UK than any other country in Europe.[18] It impacts the quality of life of not just those who live close to airports but can also be a genuine nuisance to those living many miles away.

4.4 Aviation noise performance has improved significantly in recent decades driven by the introduction of quieter aircraft. However, whilst noise levels per flight have often reduced, some residents experience significantly more noise events due to traffic growth. The community perception of noise at many airports across the UK has, if anything, worsened in recent years.

Government policy on aviation noise

4.5 The Government's policy on aviation noise is to limit and, where possible, reduce the number of people significantly affected by aircraft noise. There is no one threshold at which all individuals are adversely affected by noise in terms of health and severe annoyance, but the risk will increase as noise exposure also increases. There may therefore be instances when exposing more people to lower levels of aircraft noise may result in fewer people being adversely affected than if a smaller number of people were exposed to very high levels of noise exposure.

4.6 The Government's policy has historically been that it is better to concentrate aircraft over the fewest possible routes. This policy was established in an era of less accurate navigation. Recent trials and airspace changes have been accompanied by increased opposition to the more intense levels of aircraft concentration that typically accompanies the introduction of new routes based on satellite navigation. The Government acknowledges that multiple routes can sometimes have benefits, and wants to ensure they are considered where they can offer communities affected by

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[17] Managing Aircraft Noise, CAA Publication (CAP) 1165, 2014. http://publicapps.caa.co.uk/modalapplication.aspx?appid=11&mode=detail&id=6251

[18] Managing Aircraft Noise, CAA Publication (CAP) 1165, 2014. http://publicapps.caa.co.uk/modalapplication.aspx?appid=11&mode=detail&id=6251

noise relief from noise, or defined periods of respite. Local circumstances and preferences should be taken into account in determining whether and which options for multiple routes should be explored. The Government also acknowledges that multiple routes may not always be a viable option, due to capacity limitations for instance, or because it may not be possible to place them far enough apart to have perceptible noise benefits. Alternatively, they may be introduced for purposes other than noise.

Revision of Government guidance on air navigation

4.7 Many in the aviation industry believe that noise has contributed more than any other factor to the lack of investment in airspace upgrades at low altitudes during recent years. Across the country, where airports have introduced new flight paths to accommodate traffic growth and offer new connections, local protests have become common. As such, the issues associated with managing aviation noise not only disturb local communities but also have a direct impact on passenger choice and value. Tackling these issues, in part through the FAS Plan described in Part B of this report, offers the potential to improve the quality of life for those living close to airports and deliver a better deal for passengers.

4.8 The Government has recognised that there is a need to provide further guidance to the aviation industry to assist it when considering new or revised flight paths. The Government is therefore due to publish revised guidance to the aviation industry later this year on how to assess environmental impacts, such as those associated with single or multiple routes options. This guidance will also set out how these impacts should be evaluated by airspace change sponsors against other relevant considerations.[19]

[19] In the forthcoming revision of the Air Navigation Guidance and also in an update of the guidance on the use of WebTAG (https://www.gov.uk/guidance/transport-analysis-guidance-webtag). The WebTAG guidance includes, or provides links to, advice on how to: set objectives and identify problems; develop potential solutions; create a transport model for the appraisal of the alternative solutions; and how to conduct an appraisal which meets the department's requirements.

5. Conclusion to Part A

5.1 The UK's aviation industry has expanded enormously since the 1950s and 1960s when much of our airspace structure was first designed. Since then airspace has been added to and adapted in response to growing traffic levels. This piecemeal approach has created several issues with today's airspace that limit the ability to add capacity without making some more fundamental changes.

5.2 The en-route airspace is structured around a fixed network of sectors and way points that are based on the position of ground navigation beacons and create bottlenecks. The terminal airspace has become a complex web of intersecting flight paths that needs a wholesale redesign to increase capacity and allow aircraft to climb and descend continuously. Airspace at lower altitudes around airports is also constrained by fixed ground based navigation. Airports' standard arrival and departure routes need to be upgraded using satellite-based navigation techniques to allow for more closely space flight paths and the flexibility to better manage noise impacts.

5.3 Traffic levels are forecast to continue growing from 2.25m flights a year in 2015 to 3.25m in 2030. If the airspace is not upgraded to tackle today's issues and add capacity, then passenger delays and flight cancellations are expected to rise sharply. Analysis conducted by NATS predicts that delays will increase from 78,000 minutes in 2015 to 5.6 million minutes a year by 2030 if no additional airspace capacity is deployed. In practice this means 1 in 3 departures from UK airports would be delayed by more than half an hour and over 8,000 scheduled flights a year would consistently be forced to cancel. The cumulative effect of rising delays and cancellations caused by a lack of airspace capacity is forecast to lead to c16,000 flights that would have been scheduled becoming lost supply by 2030. The cumulative cost of these delays and cancellations between 2016 and 2030 could be £1bn by 2030 with annual costs running in excess of £260million a year to the aviation industry and their customers.

5.4 The forecasted delays by 2030 would represent significant disruption to airline and airport operations and cause significant inconvenience to passengers. The delays would also have an adverse environmental effect. The Government recognises therefore that if we want our aviation industry, and indeed the UK in this era of global trade, to remain competitive and successful we must upgrade our airspace structure and minimise the risk of crippling air traffic delays in the future.

5.5 The aviation industry has started a major programme known as the Future Airspace Strategy to coordinate the upgrade programme and ensure that airspace capacity does not constrain the many valuable services and opportunities that aviation provides. The second part of this document describes the main features of the FAS Plan to introduce more direct routes in the en-route, redesign terminal airspace, stream traffic to avoid queuing and better manage noise impacts.

PART B

The second part of this report describes the main features of the industry led Future Airspace Strategy Plan that are intended to tackle the issues with today’s airspace. Part B also considers the treatment of negative impacts that may arise from the airspace upgrades, especially those affecting local communities that may experience changes to where aircraft are usually seen and heard.

6. FAS Vision

Introduction

6.1 The FAS Plan was developed collaboratively by airports, aircraft operators, air traffic control organisations, the Military and the CAA, all of whom are aligned to a common vision, to deliver:[20]

"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 FAS Plan

6.2 To achieve this vision, the FAS Plan aims to align industry investment plans behind a common mission; to:

- **Save passenger time and avoid delays** through the provision of additional airspace capacity when and where it is needed across the air transport network;
- **Cut aviation emissions per flight and save fuel** by enabling greater efficiency;
- **Better manage noise impacts** by reducing the number of aircraft overflying population centres and holding at lower altitudes; and
- **Further enhance aviation safety** by reducing airspace complexity and introducing new technologies that help to manage the residual risks.

6.3 The FAS Plan has many components, but is based around the following key upgrades:

- **En-route airspace upgrades** to remove the fixed structures, adding capacity and enabling more direct and free routes;
- **Terminal airspace upgrades** to fundamentally redesign the route network taking advantage of advances in technology, especially satellite navigation;
- **Queue management upgrades** to stream traffic through speed controls in the en-route and reduce the reliance on stack holding in terminal airspace;

[20] www.caa.co.uk/FAS

- **Airspace upgrades at lower altitudes** to redesign airport arrival and departure routes, allowing flights to climb and descend continuously and better manage the impacts of aircraft noise; and

- **Airspace information upgrades** to provide and receive accurate data about traffic flows to better manage ground delays and airspace bottlenecks.

6.4 Chart 11 illustrates how these upgrades are expected to improve the performance of the airspace across each phase of flight – from cruise to cruise via, descent, arrival and turnaround, take-off, initial departure and climb.

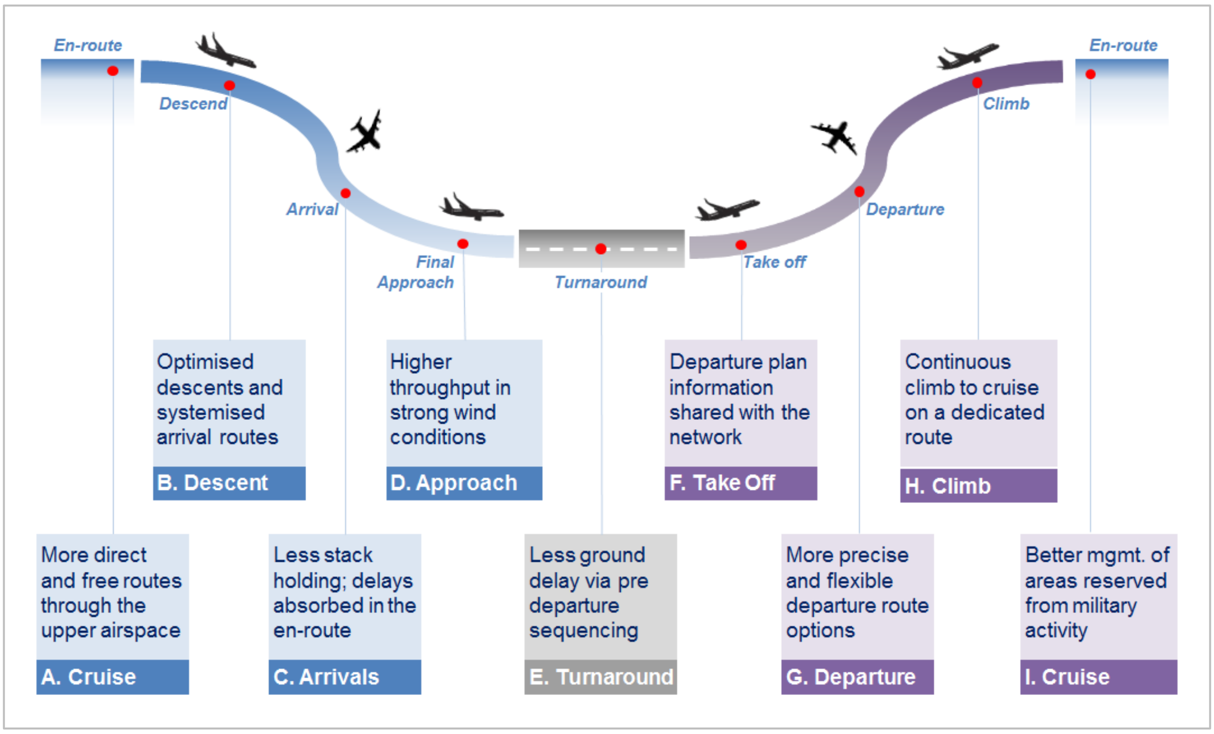

Chart 11: FAS Plan airspace upgrades by phase of flight

6.5 The remainder of Part B describes the main FAS Plan projects to deliver the airspace upgrades in each phase of flight.

7. En-route airspace upgrades

Introduction

7.1 The goal of the FAS Plan in the en-route airspace (above c25,000ft) is to remove the fixed structure of published routes and way points, adding capacity and enabling aircraft to follow more direct and environmentally efficient flight paths. There are three main projects in the FAS Plan that are delivering the en-route airspace upgrades between 2015 and 2022:

- **The introduction of Direct Route Airspace;**
- **The introduction of Free Route Airspace; and**
- **The Flexible Use of Airspace (FUA) reserved for military activity.**

Direct Route Airspace

7.2 Direct Route Airspace refers to the introduction of a significant number of additional plannable entry and exit points to each en-route sector. The additional points supplement the pre-existing framework of fixed way points that are based on the position of ground navigation beacons. Aircraft use satellite navigation to route directly between the most efficient combination of entry and exit points from sector to sector.

7.3 Direct Route Airspace allows aircraft to fly the quickest, most fuel-efficient flight paths. Air traffic controllers can manage larger volumes of traffic by removing the dependency on a few fixed way points, adding capacity to the en-route airspace. Introducing a large array of point to point combinations also increases the options available to traffic that must route around areas of poor weather or segregated areas, strengthening the resilience of the airspace.

7.4 NATS is leading the implementation of Direct Route Airspace across all regions of the UK's en-route network, starting with the airspace above Scotland and Northern Ireland. A large proportion of the transatlantic flights between North America, the UK and Europe route through this airspace. The first phase of the project was implemented in 2015 and saw 300 additional entry and exit points introduced to the en-route sectors above 25,000ft in the west of Scotland.

7.5 Chart 12 sets out the volume of Direct Route Airspace that was introduced in 2015 (notified as 'DRA'), along with the location of a major segregated area (EG D701), which is often reserved for military activities. Commercial air transport use the direct route options to plan the most efficient flight path through or around D701 depending which areas are reserved.

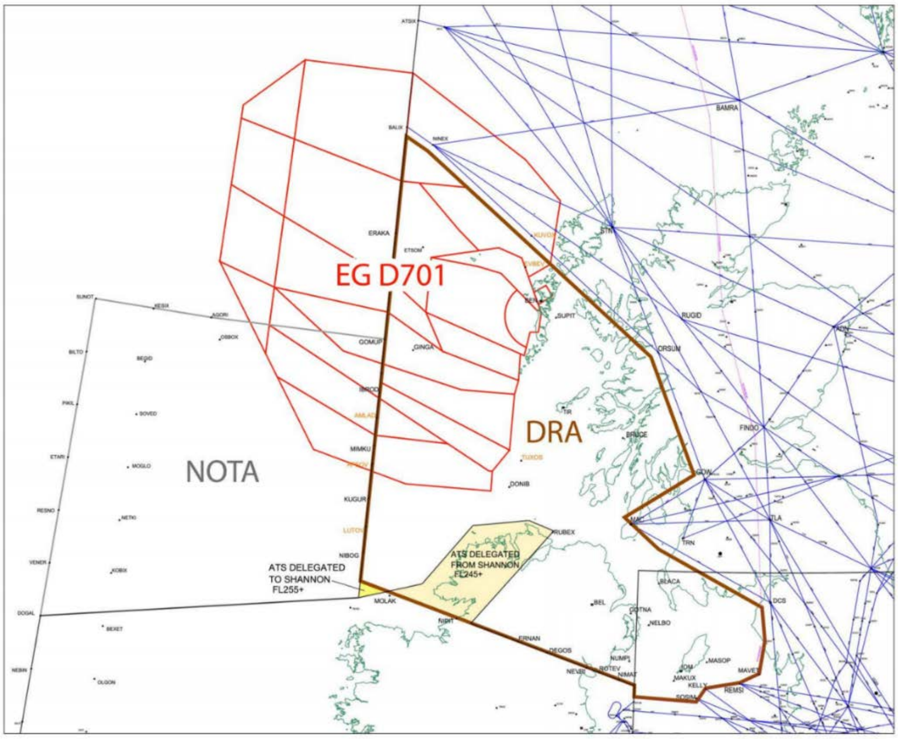

Chart 12: Volume of Direct Route Airspace (DRA) introduced to date. Source NATS

7.6 NATS has analysed traffic samples of flights using the Direct Route Airspace to estimate the average track distance and fuel burn savings. The samples were drawn from the UK flight data base and adjusted for differences in aircraft performance. Based on this modelling, the Direct Route Airspace introduced so far is expected to benefit approximately 55,000 flights per year.[21]

7.7 The next phase of Direct Route Airspace is due to go live in 2019 and will see more additional way points introduced over a much larger volume of Scotland and Northern England. Phase 2 is expected to increase the amount of traffic able to benefit from Direct Route Airspace to over 150,000 flights per year. A new set of air traffic control systems will be deployed into NATS' Prestwick Centre in the same timeframe to allow controllers to manage a larger number of flights with more routeing options, significantly increasing capacity.

7.8 The successful deployment of electronic tools to support en-route controllers in NATS' Swanwick Centre provides an indication of the potential airspace capacity benefits. The toolset known as iFACTS was implemented in 2011 and helps controllers to detect conflicts between traffic flows sooner and more easily, allowing them to comfortably accommodate more flights. NATS estimate that iFACTS has generated a 12% overall increase in airspace capacity in the London Area Control operations where it was deployed.

7.9 In addition to the capacity gains, NATS estimate that the introduction of Direct Route airspace over Scotland and Northern England will generate between 3,000 and 5,000 tonnes of fuel burn savings per year from 2019 when Phase 2 of the programme is expected to go live.

[21] Source: NATS. Approximately 50% of the total number of flights using the Direct Route Airspace.

Free Route Airspace

7.10 Free Route Airspace is a further evolution of the Direct Route Airspace concept that sees the removal of all published way points from en-route sectors. This means traffic can plan and re-plan flight paths through large volumes of the en-route airspace without reference to any established routes or fixed way points. Aircraft can fly a fully optimised trajectory taking into account flight time, fuel burn, network delays and weather.

7.11 NATS is part of an ANSP alliance known as Borealis that has been established to deliver a single volume of Free Route Airspace across the UK, Ireland, Iceland, Denmark, Sweden, Norway, Finland, Latvia and Estonia.[22] The alliance aims to ensure that traffic is free to fly an optimised trajectory across the entire region's airspace above 25,000ft with no route structure or way point constraints.

7.12 Borealis Free Route Airspace is planned for introduction between 2020 and 2022, and will replace the Direct Route Airspace deployed in the meantime. Along with the significant capacity gains, NATS estimates that by removing the constraints to an optimum flight profile in the en-route, free route airspace will generate around 4,000 tonnes of fuel burn savings per year from 2022. Chart 13 illustrates the regions to be covered by Borealis Free Route Airspace.

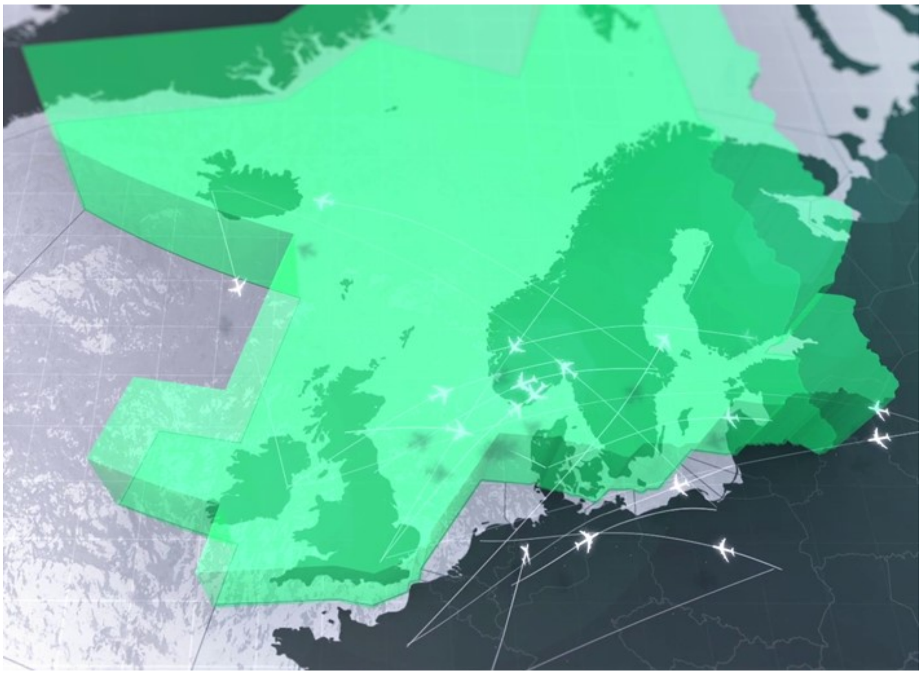

Chart 13: Region to be covered by Borealis Free Route Airspace. Source NATS

Advanced Flexible Use Airspace

7.13 Some areas of the en-route airspace are segregated for Military activities. The military book the airspace temporarily and hand it back for civil use when it is not required. The process of temporarily booking and handing back segregated areas that are shared between civil and military users is known as Flexible Use of Airspace (FUA). Upgrades to the systems and processes used to manage FUA can increase

[22] http://www.borealis.aero/Home.19.aspx

airspace capacity and flight efficiency by allowing commercial traffic to flight plan and fly directly though segregated areas more effectively when they are not booked.

7.14 Data collected by the CAA about FUA in the UK suggests that there are significant capacity benefits to improving how segregated areas are structured, reserved by the military and returned for civil operations. For example, in 2015 only 40% of the segregated airspace that was booked three hours prior to operation was used. The remaining 60% might have been made available for civil use. However even when segregated airspace was released for civil operations in 2015 only 20% of commercial flights that could have used it did.[23] Therefore a significant amount of potential airspace capacity is being lost.

7.15 Improvements in the management of FUA can optimise the use of existing capacity and help to increase capacity by supporting the implementation of Free Route Airspace. NATS, the MoD and the CAA are working together in a joint project to strengthen the technology and processes used for reserving segregated areas. A trial to introduce a new digital reservations tool for the military was completed in September 2016 along with a roadmap for its wider deployment. The tool is being accompanied by new processes to book airspace at short notice and to return it quickly if it is no longer needed.

7.16 The Government recognises that there will always remain a requirement for the military to retain some fixed segregated areas of airspace which can be reserved for hazardous activities. These areas are essential to maintain operational capability and meet a range of military training and development objectives. While the adoption of new technology and processes provides scope for greater dynamism in the reservation and use of segregated areas, to increase airspace capacity, national security requirements will mean some volumes of airspace will remain inaccessible at certain times.

[23] Data compiled by the CAA for the Single European Sky Performance Scheme. Source: CAA.

Summary of the en-route airspace upgrades

7.17 Table 1 summarises the main projects that are delivering en-route airspace upgrades, the timeframes for their implementation and their expected benefits.

Project	Description	Timeframe	Benefits
Direct Route Airspace	Deployment of additional entry and exit points to each en-route sector so that aircraft can fly more direct routes.	2015 – 2020	Capacity gains; and 3 – 5 KT(kiloton) of fuel savings per year.
Free Route Airspace	Removal of all fixed way points and routes so aircraft can fly a fully optimised trajectory across the UK en-route and State boundaries	2020 – 2022	Capacity gains; and Around 4 KT of fuel savings per year.
Advanced Flexible Use Airspace	Deployment of new technology and processes to improve the reservation and release of segregated areas for military activity.	2017 – 2022	Capacity gains and fuel burn savings by enabling greater civil uptake of segregated areas.

Table 1: Summary of the en-route airspace upgrades

8. Terminal airspace upgrades

Introduction

8.1 The goal of airspace upgrades in the terminal areas (from around 25,000ft to 7,000ft) is to completely redesign the route structure using satellite navigation, introducing a highly systemised framework that reduces the interactions between inbound and outbound traffic flows and minimises the reliance on stack holding. There are three main projects in the FAS Plan that are delivering terminal airspace upgrades between 2015 and 2024:

- **The Prestwick Lower Airspace Systemisation Programme;**
- **The Swanwick Airspace and Terminal Control Improvement Projects; and**
- **The Queue Management Programme.**

Prestwick Lower Airspace Systemisation Programme

8.2 The Prestwick Lower Airspace Systemisation (PLAS) Programme is a joint airport and air traffic control initiative to upgrade the terminal airspace in the Midlands, Northern England and Scotland between 2017 and 2020. The PLAS programme will redesign the airspace structure that serves flights to/from Manchester, Liverpool, Birmingham, East Midlands, Leeds Bradford, Newcastle, Glasgow, Glasgow Prestwick and Edinburgh airports.

8.3 The programme will improve the linkages between these airports and the south east of England, Ireland, mainland Europe, the Middle East and North America. A more advanced route structure designed to satellite navigation standards will be deployed to increase airspace capacity and separate arrival and departure flows onto dedicated routes. The airports engaged in the programme will upgrade their arrival and departure routes at lower altitudes in the same timeframes (see Section 9 of this report).

8.4 Re-designing the terminal airspace across the Midlands, Northern England and Scotland is a large and complex undertaking. It will require the production of detailed route design options, consultations with aviation stakeholders and many local communities, and a major transition planning exercise from the current airspace to a new way of working. However, the PLAS programme represents the most significant opportunity to introduce additional airspace capacity in the UK between now and 2020 and is also expected to generate large emissions and fuel burn savings per flight.

8.5 NATS estimate that the PLAS programme will generate a 5% to 10% increase in airspace capacity in the region. Along with these capacity gains, NATS estimate by systemising the inbound and outbound routes in PLAS airspace that aircraft will save between 32,000 and 42,000 tonnes of fuel burn per year by 2019.

Swanwick Airspace and Terminal Control Improvement Projects

8.6 A major upgrade to the busy terminal airspace over London will be required to support the development of an additional runway in the south east of England. The timelines for a runway development are still being debated, but a complete overhaul of the London terminal airspace is not expected before 2024. In the meantime, NATS is delivering two projects that aim to maximise the existing capacity and efficiency of London terminal airspace - The Swanwick Airspace Optimisation Project and the Terminal Control Improvement Project.

8.7 The Swanwick Airspace Optimisation Project aims to redesign sectors of London terminal airspace to add capacity and deploy new satellite-based navigation routes to reduce the track miles flown by traffic inbound to Heathrow and Gatwick airports.

8.8 The Terminal Control Improvement Project will coordinate the implementation of small-scale changes to increase capacity and efficiency in London airspace. The improvements include new electronic support tools for air traffic control and data sharing to better order departure flows. In addition, some areas of airspace that are frequently used by the GA community will be simplified as part of the project to reduce infringements into controlled airspace and further enhance safety.

8.9 Both London terminal airspace projects are expected to deliver between 2017 and 2020. NATS estimate that projects will deliver up to 5% more capacity in London terminal airspace by 2020 and the reduction in track miles flown by aircraft will generate between 10,000 and 30,000 tonnes of fuel burn savings per year depending on how the final design balances capacity and efficiency improvements.

Queue Management

8.10 Queue Management refers to the use of new sequencing tools by en-route air traffic controllers to stream arrival traffic into the terminal airspace. Flights inbound to busy areas of terminal airspace are often subject to congestion that results in queuing and delays. In today's airspace, arrival queues are managed on a 'first come, first served' basis using airborne holding stacks, as described in Section 2 of this report.

8.11 The use of holding stacks to manage arrival queues, limits the capacity of terminal airspace, burns extra fuel, and can increase noise disturbance. The main objective of Queue Management is to absorb arrival delays in the en-route, removing the need for as much stack holding in the terminal. Holding in some form may always be necessary to maintain high runway utilisation rates but this should average at around 1 to 2 minutes per delayed flight rather than 8 to 10 minutes that is typical today.

8.12 Queue Management upgrades were implemented for traffic inbound to Heathrow airport between 2013 and 2015. The upgrades are being further enhanced during 2017 and 2018 through the deployment of new measures to collaborate with Dutch, Irish and French air traffic controllers, significantly expanding the volume of airspace where Queue Management techniques can be applied and delays can be absorbed.

8.13 Traditionally, NATS controllers are only able to manage the congestion caused by inbound traffic flows when flights enter UK airspace, which can be as close as 80NM from the airport. This limits the effectiveness of Queue Management techniques and can result in additional time spent in the holding stacks.

8.14 The introduction of Cross Border Queue Management means if delays in UK holding stacks begin to build up, controllers in the Netherlands, France and Ireland will be asked to slow down aircraft at anywhere from 350NM to 550NM from landing to help minimise delays.

8.15 NATS estimate that Queue Management will transfer around 60,000 delay minutes from the holding stacks to the en-route by 2020. Along with these airspace capacity gains, NATS estimate Queue Management delivers between 5,000 and 7,000 tonnes of fuel burn savings per year by absorbing delays in a more efficient way. Chart 14 illustrates the airspace covered by Queue Management.

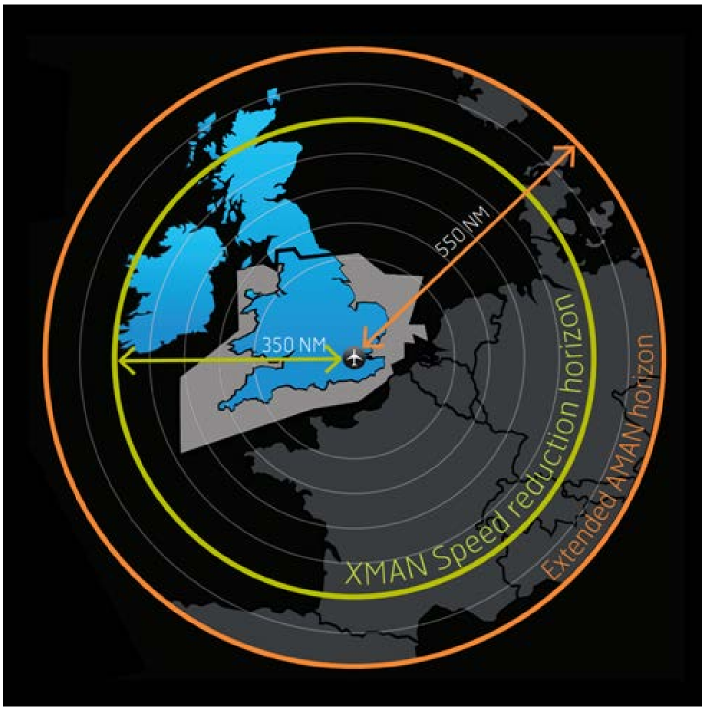

Chart 14: Range of the extended Queue Management

Summary of the upgrades in terminal airspace

8.16 Table 2 summarises the main projects that are delivering terminal airspace network upgrades and the expected timeframes for their implementation.

Project	Description	Timeframe	Estimated Benefits
Prestwick Lower Airspace Systemisation	Complete redesign of the terminal airspace serving the Midlands, Northern England and Scotland.	2017 – 2019	5% to 10% capacity increase; and 32 – 42 KT of fuel savings per year.
Swanwick Airspace and Terminal Control Improvements	Maximise existing capacity and efficiency in London terminal airspace, including new arrival routes and controller tools.	2017 – 2019	Up to 5% capacity increase; and 10 – 30 KT of fuel savings per year.
Extended Queue Management	Extension of the Queue Management horizon from 350 to 550 miles to better absorb arrival delays.	2018 – 2022	60,000 delay minutes transferred to the en-route; and 5 – 10 KT of fuel savings per year

Table 2: Summary of the upgrades in terminal airspace

9. Airspace upgrades at lower altitudes

Introduction

9.1 The goal of upgrading airspace at lower altitudes below 7,000ft, by implementing satellite-based arrival and departure routes, is to provide sufficient capacity between the terminal airspace and runway ends, while better managing the impact of aircraft noise on local communities.

Airport upgrades to arrival and departure routes

9.2 Table 3 sets out the airports that are expected to upgrade their arrival and departure routes between 2017 and 2020 – introducing more precise and flexible flight paths based on satellite navigation and removing the reliance on ground navigation beacons. The airports in the Midlands, Northern England and Scotland are designing their upgraded routes to integrate with the PLAS terminal airspace redesign programme described in section 8. Other airports are designing upgraded routes to better meet their own requirements.

Airport	Description	Timeframe
Glasgow Edinburgh Glasgow Prestwick Manchester Liverpool Leeds Bradford Doncaster Birmingham East Midlands	Satellite-based arrival and departure route upgrades to align with the PLAS terminal airspace redesign programme and enable more continuous climb and descent operations.	2017 - 2020
Luton Stansted Bristol Heathrow Gatwick	Satellite-based arrival and departure route upgrades to better meet local requirements, especially multiple route options to better manage noise impacts on local communities and closely spaced departure routes that can increase runway throughput.	2017 - 2020

Table 3: Summary of planned airport arrival and departure route upgrades

9.3 At lower altitudes, the impact of aviation on those on the ground takes greater precedence. The airports are responsible for managing the effects of airspace upgrades on their local communities. Some airports may choose to replicate their existing arrival and departure routes with satellite-based upgrades to minimise any changes in the established patterns of aircraft noise. However, the track keeping precision of satellite navigation typically concentrates aircraft noise into narrower contours, which often have a more intense impact on the areas affected.

9.4 Other airports may choose to go beyond simply replicating flight paths and use the precision and flexibility of satellite navigation to offer more noise abatement and respite options to local communities, or deploy multiple departure routes that can increase runway throughput during peak times. Any proposals to change flight paths must follow the CAA's airspace change process which includes requirements to consult closely and in detail with other aviation stakeholders and those local communities which may be affected. The CAA's airspace change process follows the guidance and directions which the Government has presented to it and which is currently being revised.[24]

9.5 The introduction of satellite-based navigation provides significant opportunities to deploy innovative new noise management techniques. These have been collated in a CAA document - CAP 1378[25] that is intended to provide information for airspace change sponsors on potential options. The techniques presented in CAP 1378 are by no means exhaustive but provide a description of some of the potential airspace design concepts that may offer mitigations to those impacted by aircraft noise.

Higher throughput in strong headwind conditions

9.6 The throughput of arrival traffic landing in strong headwind conditions can be increased using advanced air traffic control tools, maintaining existing airspace capacity when bad weather would otherwise cause delays. If aircraft are flying into a strong headwind on their final approach they take longer to reach the runway, which creates delays. These delays are typically absorbed through stack holding. The Time Based Separation (TBS) tool uses real time wind data from inbound flights to calculate the optimal safe spacing between each aircraft in order to optimise the landing rate.

9.7 NATS deployed the TBS tool into service at Heathrow Airport in May 2015, where there are about 60 days a year when strong headwinds reduce the airspace capacity and are the cause of significant delays. TBS at Heathrow is expected to save 80,000 minutes of delay per year and generate significant fuel burn savings from less stacking.[26] TBS is expected to become the norm for other capacity constrained airports like Gatwick and Manchester by 2024.

9.8 A project to enhance the TBS tool at Heathrow, by introducing an even more accurate approach to spacing different combinations of aircraft on arrival is expected to generate further benefits. Enhanced TBS is currently in an R&D phase and is aimed for deployment before 2019. An initial review of the benefits suggests that the enhanced tool may generate the capacity for one additional flight per hour.

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[24] Air Navigation Directions 2001 (amended 2004) issued by the SofS for Defence and SofS for Transport, and the Air Navigation Guidance, DfT January 2014, both of which are due to be revised later this year.
[25] CAP 1378 - Airspace Design Guidance: Noise mitigation considerations when designing PBN departure and arrival procedures (https://publicapps.caa.co.uk/docs/33/CAP%201378%20APR16.pdf)
[26] Source: NATS, 2015.

10. Airspace information upgrades

Introduction

10.1 The goal of airspace information upgrades is to increase airspace capacity by improving the operational decisions made by airports, airlines and air traffic control using more accurate traffic flow data. In today's operation many airspace management decisions that determine capacity are not routinely informed by accurate data about when aircraft plan to depart, when they actually take-off or when they are expected to arrive in a particular sector of airspace. Most organisations use different data sets that are refreshed at different times. This constrains capacity unnecessarily and weakens the resilience of the airspace.

10.2 A wider community of stakeholders also suffer from the lack of up to date traffic flow data upon which to base their decisions. Border control agencies, airport terminal retail providers, taxi, rail and coach operators, members of the public meeting passengers, freight companies and transport information providers would all benefit from airspace information upgrades.

10.3 There are two main projects in the FAS Plan that are delivering airspace information upgrades to improve airspace management and add capacity:

- **The roll-out of Airport Collaborative Decision Making Systems; and**
- **The roll-out of Departure Planning Information Systems.**

Airport Collaborative Decision Making Systems

10.4 Airport Collaborative Decision Making (ACDM) involves the introduction of new systems and processes at larger capacity constrained airports to enable the creation, refinement and exchange of runway and airspace data, including:

- The progress of each flight's turnaround activities;
- Up to date times for each flight to push back from stand and take off; and
- The optimal sequence of departures to maximise runway and airspace performance.

10.5 With this information ACDM systems allow air traffic controllers to construct an optimised sequence of departures tailored to maximising runway throughput and airspace capacity. ACDM systems also gather the latest estimated landing times for inbound flights to improve the management of ground operations that is often the cause of air traffic delays.

10.6 Heathrow was the first airport in the UK to introduce an ACDM system in 2013. The use of ACDM at Heathrow has demonstrably reduced the time aircraft spend taxiing and queueing on the ground and generates valuable traffic flow data to optimise airspace capacity.

10.7 Gatwick Airport also introduced ACDM in 2014. As part of the FAS Plan, it is envisaged that ACDM systems will be introduced to the UK's next five largest airports – Manchester, Stansted, Luton, Edinburgh and Glasgow – between 2017 and 2022. The capacity constraints around these airports are less acute than Heathrow and Gatwick, however departure delays are a regular feature of the operation particularly during the busy first wave of departures from 06.00 to 09.00.

Departure Planning Information

10.8 Part of the function of the ACDM systems described above is to provide network management organisations and air traffic controllers with departure planning information (DPI) messages about each flight. DPI information is needed to optimise traffic flows across the UK and European airspace.

10.9 DPI provision involves an electronic message being submitted from airports to the European Network Management Operations Centre at the exact time that each aircraft pushes back from the stand. The information is then relayed to local air traffic control centres across the UK and Europe. The DPI messages includes valuable data such as the aircraft target take off time, taxi time to the runway, actual take off time and route through the airspace that can be used by air traffic controllers to maximise airspace capacity.

10.10 The FAS Plan is developing and deploying new software for airports to share DPI messages. The Government provided the funding for an initial investment in DPI provision at 7 UK airports that do not have ACDM systems between 2013 and 2015. The project is led by the Transport Systems Catapult, a Government sponsored innovation centre. DPI messaging was rolled-out to Manchester, Stansted, Luton, London City, Edinburgh, Glasgow and Aberdeen. Flights from these airports account for around 35% of all commercial air transport in the UK.

10.11 The DPI software upgrades are planned for implementation at a further 10 to 15 UK airports between 2016 and 2019, ultimately covering around 80% of commercial air transport flights from UK airports.

11. Operational techniques to improve the management of aircraft noise

Introduction

11.1 The plans to upgrade airport arrival and departure routes at lower altitudes present an opportunity to deploy innovative new operational techniques that can improve the management of aircraft noise. The Government believes that airports, airlines and air traffic controllers should ensure that these techniques are adopted wherever feasible. Some techniques are being operated by industry already. Others are the subject of on-going research and development projects. Typically, the techniques tend to apply specifically to either arrivals or departures, although the adoption of multiple techniques may result in cumulative improvements.

11.2 The Government's current overall objective on aircraft noise is to limit and where possible reduce the number of people in the UK significantly affected.[27] Typically this has meant a priority has been placed on reducing the overall number of people over flown. The accuracy of new routes based on satellite navigation offers the potential to reduce the total number of people directly over flown as flight paths become more concentrated. However, some operating techniques propose the introduction of more routes to disperse traffic, offering some relief from aircraft noise and tackling the impacts of intense concentration generated by satellite navigation.

11.3 In broad terms the FAS Plan considers the introduction of four key noise management operational techniques which are described in greater detail below. These are:

- Traffic dispersion for noise management;
- Traffic concentration for noise management;
- Noise respite approaches; and
- The redistribution of noise impacts.

Traffic dispersion for noise management

11.4 Dispersion, or dispersed aircraft tracks, refers to air traffic control instructing departing traffic to follow the same general routing yet fly a variety of different flight paths when measured over the ground. Dispersion can be achieved by (and is often a natural consequence of) a combination of factors such as the way the routes are designed, aircraft performance and pilot or air traffic control behaviour. The introduction of techniques that offer more dispersion for noise management will inevitably spread flight paths and therefore noise impacts over a greater area. This

[27] Aviation Policy Framework, DfT, 2013.

may often result in a greater number of people impacted by aircraft noise, but to a lesser extent.

Traffic concentration for noise management

11.5 Concentration of aircraft is the opposite of dispersion and is a consequence of the accuracy of routes designed to satellite-based navigation standards. It takes place when aircraft are instructed to follow the same routing consistently and fly very similar flight paths over the ground. The accuracy and predictability associated with satellite navigation means it is possible to make a more efficient use of airspace and add capacity by allowing large volumes of traffic to route through smaller blocks of airspace potentially avoiding population centres. The obvious costs of concentration, however, fall to the minority of people that are affected by more intense noise impacts.

Noise respite approaches

11.6 In contrast to general concentration and dispersion of traffic flows for noise management, respite approaches must be planned. For example, it may be planned that different runways are used at different times of day, providing communities with predictable relief from the noise impacts of departures from either runway. Another example could be alternating or changing between multiple departure routes, following a variety of flight paths to the same point further en-route.

11.7 Respite can be designed into airspace structures more easily once arrival and departure routes are upgraded to a satellite navigation standard. There is currently no agreed minimum distance between routes such that alternating their use would result in perceptible respite for those on the ground. The extent of the respite offered will depend on how far routes are moved and at what height the aircraft operate. Respite may be both concentrating traffic, as all the flights during a period will be on a single route, and dispersing as traffic will be spread over a larger area, albeit with a distinct time driven pattern.

The redistribution of noise impacts.

11.8 The upgrade of arrival and departure routes at lower altitudes using satellite navigation offers more flexibility than the conventional ground based alternatives. This allows flight paths and the associated noise impacts to be re-distributed away from noise sensitive areas. Of course, this assumes that there is an adjacent area that is less sensitive to noise that the flight paths can be moved over. The relative noise sensitivity of respective areas is hugely complex to estimate and must be carefully considered where re-distribution is the aim.

11.9 Annex G provides some examples of low level arrival and departure concepts and potential options which could be deployed to manage the impact of aircraft noise on those communities affected.

12. Conclusion to Part B

12.1 The FAS Plan aims to tackle the issues with today's outdated and increasingly inefficient airspace structure and provide the capacity required to accommodate growing traffic levels without incurring the significant additional delays forecast in Part A if nothing is done. The Plan also considers the treatment of negative impacts related to aviation noise that may arise from airspace upgrades.

12.2 The FAS was developed collaboratively by airports, aircraft operators, ANSPs, the Military and the Regulator. The airspace related investment plans of each of the participating organisations are aligned to a common vision for the future of UK airspace. The primary mission of the organisations engaged in the FAS is to avoid a sharp increase in delays, cancellations and lost supply as traffic grows. The Plan also aims to cut aviation emissions and fuel burn per flight and better manage noise impacts.

12.3 The investments in the FAS Plan can be grouped into five main upgrades:

- Removing the fixed structures in the en-route airspace;
- Completely redesigning the terminal airspace;
- Deploying Queue Management tools to reduce congestion and the level of airborne stack holding;
- Introducing more precise and flexible airport arrival and departure routes; and
- Sharing accurate airspace information between airports and air traffic controllers to maximise available capacity.

12.4 Some FAS Plan projects, like the introduction of Time Based Separations at Heathrow and Direct Route Airspace over Scotland, Northern England and Northern Ireland are already implemented and delivering benefits. Others, like the development of Queue Management tools and the redesign of terminal airspace structures are fully underway. Several of the FAS Plan projects are scheduled for deployment before 2019 and are expected to significantly increase the airspace capacity in response to growing traffic levels. Some projects extend out to 2024 and will need to align closely with the introduction of a new runway in the south east that is expected to be entering its final stages of development in a similar timeframe.

12.5 The FAS Plan's ambition to upgrade airspace at lower altitudes presents an opportunity to deploy innovative new operational techniques that can improve the management of aircraft noise. Operational techniques like traffic dispersion and concentration for noise management reasons, noise respite approaches and the redistribution of noise impacts are enabled by the plans to upgrade airport standard arrival and departure routes to a satellite navigation standard.

12.6 The Government believes that airports and ANSPs should ensure that these techniques are adopted wherever feasible. Many of the techniques involve some form of trade off with other airspace objectives such as increasing airspace capacity and saving emissions and fuel burn, which will need to be factored in to the decision-making process, with the support of the CAA’s updated Airspace Change Process.

13. Report Conclusions

13.1 This report, compiled with the assistance of the CAA and the technical support from NATS, highlights the clear rationale for airspace modernisation. The UK's airspace structure, and the technology and processes which underpin it, is increasingly becoming outdated. The Government therefore supports fully the ambitious Future Airspace Strategy, the implementation of which is now well under way. We also welcome the approach and the collaborative nature which the industry is demonstrating in pressing ahead with implementing the strategy.

13.2 The detailed analysis work by NATS, which is summarised in Section 3 of this report and in Annex A, paints a rather bleak picture of what might happen to air traffic delays if we do not modernise our airspace. The Department has taken significant effort to understand the modelling and forecasts used by NATS and we are satisfied that the high-level results are a realistic outcome and the assumptions made are sensible. For further detail on analytical assurance please see Annex F. We have already seen, for example, air traffic delays increase sharply in 2016 which helps to demonstrate the point being made in this report that our airspace structure is coming under increasing pressure. These delays affect not just the airlines and their passengers but as our aviation sector becomes less able to deal with growing demand and constraints on airspace the wider economy will begin to suffer.

13.3 Safety is, and will continue to be, the overriding priority of the Government, the CAA, and the aviation industry. If we do not modernise our airspace, the need to ensure adequate safety levels will by necessity require aircraft to be delayed on the ground or held in stacks before they land. The costs of these delays and cancellations will need to be met by passengers, airports and the airlines. Families going on their annual holiday abroad may all too frequently experience long waits in departure lounges not knowing when their aircraft will be ready or have to cope with a short notice cancellation. We have seen in the late 1980s and in 1999 the impact of air traffic control delays at airports – indeed the high level of delays experienced in 1999 (due to the Kosovo crisis at that time) led to the creation of the Single European Sky. The aviation industry was, however, able to adapt to the increasing demand for air travel and air traffic delays reduced significantly. It has only been in the last 2 or 3 years that delays have again begun to rise as the demand for air travel increases and the volume of air traffic growth continues. As happened in response to the previous bouts of high air traffic delays, the aviation industry must do what it can to put in place measures to free up capacity and provide an efficient and safe airspace that can cope with both current and future demand requirements. The FAS is the means to do this.

13.4 Fortunately, the industry is seeking to implement the FAS and we therefore do not expect that air traffic delays will reach the levels forecasted in the NATS analysis. Nevertheless, it is also important to note that air traffic-related delays are just one component of the reason why aircraft are delayed. Weather, technical issues, strike action, and disruption in other countries, will exacerbate the level of delay experienced, particularly on peak demand days of the year (for example, the start of the school holiday period). Such delays add further pressure onto the air traffic network and passengers are likely to be more concerned about the level of delay they are experiencing rather than the specific cause, particularly as delays are often the result of a number of different factors. Consequently, the aviation industry must not just address the airspace capacity issues which the FAS does, but it must also take a more holistic approach and seek to make improvements that enhance the passenger experience. The quality of this experience is at the heart of the issue, and increasing air traffic delays are bound to impact adversely on it. Over time, this will have a detrimental effect on the UK aviation industry and on the ability of the UK to trade and do business in the global market place.

13.5 Airspace modernisation must, however, be undertaken with full consideration being given to its environmental impacts. Recent experience at a number of airports has demonstrated the strength of local feeling which can be aroused if communities do not understand why airspace changes are being proposed or do not even know about them until after their implementation. The Government has therefore taken steps to reconsider its airspace and noise policies with the objective of ensuring that airspace modernisation can take place but with the industry being required to undertake more options analysis work and to consult better. Once the new proposals are put in place, the Government expects that the industry will not only learn from past experience but will also seek to adopt best practices for minimising any noise impacts. Unless the industry does this, the successful delivery of the FAS is likely to be compromised and the UK will ultimately suffer.

13.6 The Government will continue to monitor the implementation of the FAS through its membership of the FAS Deployment Steering Group and the FAS Regulatory Programme Board, as well as with its many links with the aviation industry and with local communities. We also consider that the proposed new Independent Commission on Civil Aviation Noise will play a key role in trying to ensure that the industry and communities work together for mutual advantage. Ultimately, if we see that airspace modernisation is falling behind the demands of our airspace users and that delays are increasing as suggested in the NATS analysis, the Government will need to consider if there is anything substantive it can do to help ensure that we do have an airspace structure worthy of our great aviation heritage.

Annex A: NATS Do Minimum Forecast Traffic Growth and Delays

Introduction to the Do Minimum Forecast

A.1 High-level modelling and analysis has been carried out to provide a clear indication of the degree to which current UK airspace capacity is able to deal with the forecast increase in traffic demand. This analysis provides a profile of the likely delays that air traffic would incur if demand increases as expected while only minimal airspace capacity enhancements are made.

A.2 This situation is here termed the 'Do Minimum' scenario. The assessment of that scenario could be regarded as a two-stage process:

i. Produce forecast of traffic volumes; and

ii. Assess airspace capacity in light of handling forecast traffic volumes.

A.3 Note that this analysis deals <u>solely</u> with NATS-attributable delay caused by a shortfall in airspace capacity. It does NOT include weather related delay, nor delay due to NATS' staffing or technical issues.

Forecasting

A.4 Forecasts are central to informing business, investment and operational planning, and allow a response to be planned for future air traffic and industry related needs. There is a well-established link between economic growth and passenger demand that is recognised industry-wide. In long term forecasting, economic forecasts will be the most significant factor in determining future passenger demand and traffic volumes.

A.5 Predictions of future traffic volumes are integral to airspace modelling and air traffic management (ATM) simulation. They are also important in assessing the impact of airspace change projects and enabling cost-benefit analysis to be conducted. In the context of ATM, en-route delays are often an indication of airspace inefficiency. Airspace needs to be assessed in terms of whether there is sufficient capacity to handle the throughput of predicted traffic. A lack of capacity will lead to delays, and these should be mitigated through effective airspace management and capacity planning to enhance the efficiency of the airspace.

Analysis

A.6 NATS' Analytics Department has constructed a UK-wide 'Do Minimum' scenario using the Eurocontrol[28] NEST tool (Network Strategic Tool). This aims to demonstrate the impact on delays and cancellations likely to be incurred if traffic grows at the rate anticipated but only minimal airspace capacity enhancements are made to the airspace and procedures to accommodate it.

A.7 The 'Do Minimum' scenario is established as a baseline against which the benefits (avoidance of the delays through provision of sufficient airspace capacity) of the proposed airspace changes can be measured in subsequent stages of the FAS programme. It is essentially a 'Do Nothing' option (in terms of changes in airspace design) but allowing for incremental small increases in capacity that come about as a result of having well-practiced procedures, staff familiarity with the airspace sectorisation, and utilisation of improved support tools.

A.8 NEST is a tool designed for network managers and Air Navigation Service Providers (ANSPs) to support airspace design, capacity planning and post operations analysis. The tool's input data include consolidated pan-European airspace and route network and traffic data provided and verified by Eurocontrol network management. The tool's functionality allows simulating traffic forecast, regulations and resulting pre-departure flow management delays taking into account the network effect. Note that only en route capacity delays have been modelled in NEST, which comprise only a small proportion of total delay.

Approach

A.9 The approach for the Do Minimum scenario comprises the following components:

i. Incorporate an Airac traffic sample (25/6/15 to 22/7/15) into NEST and set up the sector opening scheme in the model to reflect that for the sample period;

ii. Calibrate the model such that it replicates actual 2015 observed delay;

iii. Grow the traffic sample in NEST using NATS 2015 Base Case forecast, as agreed with DfT, and run the model for each year from 2016 to 2030;

iv. 'Annualise' the results based on the proportion of delay observed in the sample period relative to the delay for the whole year in 2015 (July 2015 represents approximately 22% of the delay for that year); and

v. The output is the estimated delay for each modelled year against the 'Do Minimum' change in airspace design.

A.10 The results produced in this way would be expressed purely as delay (minutes and cost). It should be recognised that, in practice, this level of delay would not be tolerated by the airspace users. The modelled results are therefore subjected to two stages of 'post-modelling' adjustments:

[28] European Organisation for the Safety of Air Navigation, an intergovernmental organisation composed of 41 Member States, including the UK committed to delivering improved air traffic management performance across Europe. See https://www.eurocontrol.int/

i. Assume a ‘cancellation assumption’. In this analysis, it has been assumed that delays over 45 minutes could be cancelled, reducing this threshold over time as traffic increases (see A.18 below); and

ii. Acknowledge that there will be ‘lost movements’, i.e. supply that is not possible to schedule at all given the delays and cancellations experienced in the current and previous year.

Assumptions and methodologies

A.11 The following are the major assumptions that underpin the Do Minimum scenario modelling for each of the three stages of the process – SPAM, NEST and post-modelling application.

SPAM

A.12 NATS internal traffic forecast model, the Second Passenger Allocation Model (SPAM), is predominantly used for internal business/operational planning. Key factors in running the model are as follows:

i. Economic forecasts – key driver of passenger demand growth;

ii. Load factor evolution;

iii. Evolution of aircraft size;

iv. Future airport capacity;

v. Non-commercial traffic (business/military); and

vi. Does not take into account airspace constraints.

A.13 For the Do Minimum scenario modelling, the NATS Base Case forecast for 2015 has been used to produce the year-on-year growth in traffic applied to the July 2015 traffic sample incorporated into NEST. See Annex B.2 for a more detailed description of how SPAM works.

A.14 Use of the NATS 2015 forecast was agreed with DfT’s Aviation Capacity Economics team following a comparison and reconciliation of NATS and DfT UK traffic forecasts for 2015.

NEST

A.15 NEST was designed by Eurocontrol for network managers and ANSPs for airspace design, capacity planning and post operations analysis. The tool’s input data include consolidated pan-European airspace and route network and traffic data provided and verified by Eurocontrol network management. The tool's functionality allows simulating traffic forecast, regulations and resulting pre-departure delays taking into account the network effect. Annex C provides more details on how NEST works.

Post-modelling application

A.16 Having modelled delays from 2015 to 2030 by setting the forecast levels of traffic against the current airspace design, the results are modified by incorporating the probability of cancellations occurring and the likelihood of lost supply where it is known in advance that flights are not worth scheduling due to the high probability of lengthy delay or cancellation.

A.17 The cancellation assumption comprises two elements:

i. A 'trigger point' in terms of delay minutes, above which a flight becomes a cancellation candidate; and

ii. An assumed percentage of those flights above the trigger point that will be cancelled.

A.18 The application of the two assumptions is captured in this table:

Year	Trigger (mins)	% impacted
2016	45	0
2017	45	5
2018	45	5
2019	45	10
2020	45	10
2021	45	15
2022	45	15
2023	45	20
2024	45	20
2025	40	25
2026	40	25
2027	35	30
2028	35	30
2029	30	35
2030	30	35

A.19 The lost supply assumption is:

i. From the following year onwards flights consistently cancelled as per the cancellation scenario will be dropped from the schedule, and

ii. The resultant flights are split between tactical cancellations and lost supply on a 1:2 ratio (the rationale being that, as cancelled flights accumulate, airlines would prefer to not schedule than to be forced to cancel tactically and would take steps to do so).

A.20 For each year, once the cancelled and 'lost' flights are estimated, the associated minutes of delay are removed from the total delay minutes to give the full composite picture. Annex D provides the context and background on these assumptions.

Forecast impact of the Do Minimum scenario

A.21 This section describes the results from the NEST modelling and the post-modelling application.

Modelled delay for sample period

A.22 First, the base year, 2015, traffic sample for 25/6 to 22/7 that is calibrated against actual observed delay, provides the following outputs:

Scenario	No. of flights (000)	Total delay (minutes)	Delay per flight (seconds)	No. of delayed flights (000)	Delay per delayed flight (minutes)
2015 Baseline	200	17,328	1.91	9	8.9

A.23 The traffic sample was then grown using the 2015 NATS Base Case forecast for each year from 2016 to 2030 to estimate the delays during the same period.

Annual delay

A.24 The NEST delays modelled for 2016 to 2030 were 'annualised' using the current proportion of 2015 delay for the sample period relative to the delays for the whole year, i.e. 22%. This provides the following 'delays only' results from the modelling:

NEST outputs

Year	No. of flights	Total delay minutes	Average delay	No. of delayed flights	Delay per delayed flight
2016	2,455,770	147,632	0.06	14,332	10.30
2017	2,519,620	398,305	0.16	33,050	12.05
2018	2,585,130	601,859	0.23	45,809	13.14
2019	2,629,077	761,264	0.29	53,995	14.10
2020	2,686,917	1,003,886	0.37	67,259	14.93
2021	2,743,342	1,277,082	0.47	80,841	15.80
2022	2,800,952	1,691,827	0.60	100,864	16.77
2023	2,859,772	2,160,227	0.76	119,241	18.12
2024	2,919,827	2,536,977	0.87	133,100	19.06
2025	2,981,144	3,028,773	1.02	149,200	20.30
2026	3,043,748	3,449,518	1.13	161,945	21.30
2027	3,101,579	4,008,959	1.29	177,318	22.61
2028	3,157,407	4,515,695	1.43	188,818	23.92
2029	3,204,768	4,918,905	1.53	199,018	24.72
2030	3,252,840	5,632,014	1.73	212,073	26.56

Cancellation/lost supply scenario

A.25 The cancellation and lost supply rationale described in Annex D has been applied to the NEST outputs to produce the following estimated cancelled and lost supply, and a modification to the delay minutes to account for those flights now re-categorised as cancelled or lost:

Year	Revised delay minutes	No. of cancellations	Lost supply	Total
2016	147,632	0	0	0
2017	398,294	0	0	0
2018	601,793	1	0	1
2019	760,954	5	1	6
2020	1,001,492	16	32	48
2021	1,264,940	80	161	242
2022	1,669,710	138	277	415
2023	2,104,953	328	656	983
2024	2,461,048	442	884	1,327
2025	2,838,274	1,215	2,430	3,645
2026	3,195,325	1,577	3,155	4,731
2027	3,496,158	3,380	6,761	10,142
2028	3,896,324	3,969	7,937	11,906
2029	3,937,129	6,852	13,704	20,556
2030	4,408,638	8,216	16,432	24,648

Confidence assessment

A.26 All models, information sources and references used in this analysis are part of NATS' standard forecasting and modelling toolkit, and in the case of NEST, is in common use by ANSPs and others across the European ATM community.

A.27 It should, however, be noted that this is a very high-level analysis, taking UK airspace as a single entity and therefore inevitably subject to generalisations. Whilst analysis of greater granularity would not be expected to radically alter the results, it would nevertheless reveal the regional and local variations that contribute to these generalised results.

A.28 Annex F provides an assurance statement, using DfT guidelines, and the content of which has been agreed with the DfT.

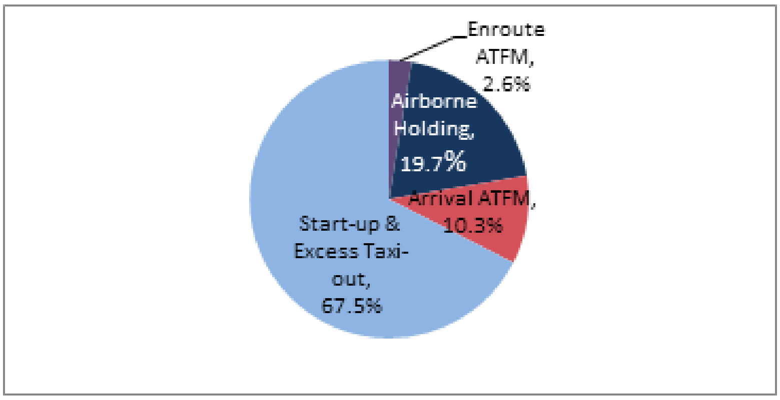
Category of delay modelled in this analysis

A.29 This section sets out an explanation of the category of delay that is modelled in the FAS 'Do minimum' scenario. In short, it is only delay caused by insufficient airspace capacity that is modelled (around 1% of all delays currently). This is only one element of NATS attributable delay and does not include staffing or technical delays, nor weather.

A.30 How this is derived can be explained with reference to actual 2015 and 2016 (year-to-date) delay.

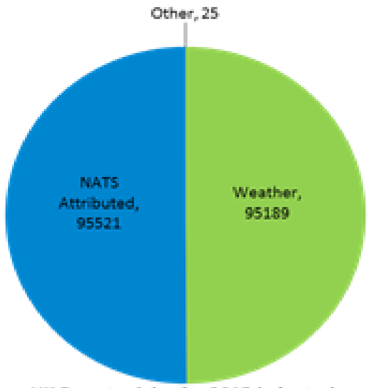
2015

A.31 The NEST modelling produced 17k minutes of capacity delay in the sample period, around 80k for the year. The following pie chart shows total en route ATFM at 2.6% or 191k, and the table gives this in the context of all categories of delay.



Flight Phase	Mins Delay
Enroute ATFM (ATFM)	191,000
Airborne Holding	1,460,000
Arrival ATFM	760,000
Start-up/Taxi-out	5,000,000

A.32 En-route ATFM can itself be broken down around 50/50 (95k each) into NATS attributed and weather delay, as follows.



UK Enroute delay for 2015 (minutes)

A.33 Capacity delay usually (2016, as shown below, is an exception) accounts for around 80-90% of the NATS attributable element; in 2015, 78k minutes of delay were categorised as en route capacity delay.[29]

2016

A.34 The NEST modelling for 2016 produced 32k minutes of delay in the sample period, around 147k for the year. Extracting year to date delay for 2016 from NATS Business Intelligence data warehouse has produced a figure of over 207K minutes in 2016. This suggests that the NEST modelling has underestimated 2016 delay by 30-40%. However, NATS considers that a good proportion of this delay was caused by abnormally high 'Project' and 'Staffing' delays experienced this year.

[29] Source for above diagrams and figures: Delay slides for NATS Board workshop, 7th April 2016 – date from NATS Analytics Business Intelligence data warehouse.

Annex B: NATS Forecasting

B.1 NATS uses software called Second Passenger Allocation Model (SPAM) to forecast passenger movements to/from UK airports, as well as air traffic movements and flights for the NATS Air Traffic Control Centres. SPAM was developed by the CAA but was transferred to NATS when CAA and NATS separated in 1999.

B.2 SPAM is a mathematical model whose main purpose is to distribute forecast passengers between the individual UK airports and then convert them into forecasts of flights. The Passenger Allocation process, of which the Shadow Cost algorithm forms the main part, uses Multinomial Logit equations to allocate passenger demand (by origin, destination and passenger type) to routings (single or multiple flights) to produce passenger forecasts by route. These in turn are converted to seat and air traffic movement forecasts by route, using LARAME (the function used to convert passengers to ATMs) and load factor graphs respectively.

B.3 NATS forecasting process produces a UK Traffic Forecast that includes High, Low and Base case scenarios. Base case is the most likely scenario given available data and knowledge at the time of the forecast. Low and High case scenarios highlight the upper and lower case risks. Apart from traffic arriving and departing in the UK, the forecast includes overflights, business jet, cargo and military flight forecasts that are modelled outside of the main process and incorporated as part of a consolidated forecast.

B.4 The main driver behind the passenger forecasts is economic growth. We base our economic growth assumptions on the data from Oxford Economic GDP forecast for the UK and other developed and emerging markets. Apart from the GDP growth, NATS forecasting process incorporates:

i. Assumptions for UK airport capacities;

ii. Changes in aircraft size and load factor over time;

iii. Impact of air passenger duty; and

iv. Potential pass-through costs to passengers from the emissions trading scheme.

B.5 A variety of data used as an input for the process include:

i. UK Flight Database (details on all flights controlled by all NATS Air Traffic Control Centres which includes some military flights);

ii. UK Airports Statistics CAA (Passengers and Flights);

iii. CAA Airport Surveys (information on passenger characteristics);

iv. International Passenger Survey (IPS);

v. EUROCONTROL STATFOR Data on Flight and Service Unit data; and

vi. Oxford Economics (OE) (Economic forecasts).

B.6 The accuracy of NATS forecasts is monitored internally on a monthly basis.

Annex C: The Network Modelling and Analysis Tool (NEST)

C.1 The network modelling and analysis tool (NEST) is owned by Eurocontrol and used by its member organisations (which includes the UK) to undertake this type of analysis. As such it is a referenceable entity/artefact, with further information available at:

https://www.eurocontrol.int/services/nest-modelling-tool

C.2 In UK airspace there are over 150 elementary and combined sectors. Each sector has an assigned capacity value to it which defines the number of flights a sector controller can handle. Knowing sector capacities along with traffic demand helps to define the opening scheme, i.e. the order in which sectors are opened and closed.

C.3 Accurate estimate of sector capacity is essential in order to be able to simulate delay in NEST. In order to make sure that sector capacities are up to date and reflect reality every year a calibration exercise is conducted. It is normally done for a selected summer month when the traffic and associated delay are at their highest. The calibration exercise consists of intuitive adjusting of sector capacities and running regulation and delay simulation until the point when NEST simulated delay for each sector coincides with the delay observed in reality. Simulated delay is compared to actual delay at sector and local area group level and also day-by-day. This exercise allows us to 'train' NEST and provide confidence that the output of the delay simulation in NEST can be relied upon for the future scenarios.

C.4 As a result of the 'by sector' calibration, delay generated in future years as a result of traffic growth is also on a sector-by-sector basis rather than simply a global figure. NEST picks up the SPAM outputs, clones traffic based on the forecast growth, and estimates the delay for each year's traffic volume.

Annex D: Rationale for constraints to growth as a result of increased Air Traffic Delays

D.1 Airport Coordination Limited (ACL) scheduling requires adherence to block times for Level 3 slot coordinated airports of +/-30 minutes and requires 80% of flights to achieve these block times. Repeated offenders are fined and may have their slot rights withdrawn.

D.2 Block times are calculated based on historic performance not on predicted data. Hence consistent delays will be dealt with tactically during the season but when planning the next equivalent season (e.g. Summer or Winter) consistent historic poor On Time Performance (OTP) will be assessed and may result in dropping the city pair from the schedule.

D.3 Lack of ability to forecast future season's performance means that, as indicated above, the reaction to poor performance will typically be 1 year in arrears.

D.4 Slots are traded between operators and slots at peak times can be scarce (as in high demand) so it may often not be possible to obtain different slots that enabled extended block times.

D.5 Missing slots/consistent delays can have knock on effect to flight rotations and connections and OTP is particularly important for corporate clients which tend to be the highest value for the airline.

D.6 Shorthaul and low cost operators business model is based on high airframe and crew utilisation and short turn-arounds of typically 25 minutes for morning rotations and again for the afternoon's rotations with typically a crew change at midday.

D.7 Consistent delays of greater than 30 minutes will knock on throughout the rotations and may mean cancellations in order that the schedule can be recovered e.g.

i. Many airports have night curfews, so build-up of delay through the day will result in cancellation if the scheduled rotations are forced into curfew;

ii. Likewise, crew hours are limited by EASA flight time limitations and crews cannot regularly exceed planned operating hours; and

iii. Even if the same schedule were to be attempted, delays effectively mean that more aircraft and crew are required to service the same schedule, hence UK operations become less commercially viable.

D.8 Strategic removal of flights will tend to be done on a commercial basis such that lower value flights such as those from lower density regions are removed first (e.g. BA tend to cancel shorthaul in favour of protecting longhaul and Virgin cancellation of Little Red and CityJet cancellation of Cork – LCY). The impact can be reduced frequency and connections to/from UK regions.

D.9 Suspended scheduled flights will release aircraft & crew which are likely to be re-deployed to other regions outside of the UK.

D.10 The issue is airspace so the scheduling committees at the airport will continue to try and fill the runway slots.

D.11 Heathrow & Gatwick will continue to try and operate a full schedule due to the value of slots but will become increasingly less economic as shorthaul connections become more of an issue

D.12 Proposal for modelling:

i. Model demand & delays in UK domestic out to 2030;

ii. Determine number of flights which would be tactically cancelled based on previous rationale for “Do Nothing Analysis”; and

iii. Assume in the following year onwards that flights consistently cancelled per item 2 will be dropped from the schedule.

Annex E: Airline cost calculations

Introduction to the analysis

E.1 As detailed in Annex A, NATS undertook the modelling of the ‘Do Minimum’ scenario on behalf of DfT, using the Eurocontrol NEST tool. The outputs of this process include (amongst other items) forecasts of aggregated annual flights, delay minutes and the number of cancellations.

E.2 DfT analysts have applied Eurocontrol standard values for costs of delay and cancellations[30] to these outputs in order to produce estimates for the annual and total costs to airlines of delays and cancellations, as modelled under the NATS ‘Do Minimum’ scenario.

E.3 This section sets out the various assumptions and methodologies behind these figures, as well as presenting the results, and provides an assessment of confidence in the analysis as a whole.

Assumptions and methodologies

E.4 The analysis itself is based on information acquired from the following sources:

i. Delay and cancellation outputs from NATS ‘Do Minimum’ central scenario;

ii. Eurocontrol standard values for cost of delays and cancellations;

iii. Bank of England exchange rate data;[31] and

iv. Treasury UK GDP deflator series (November 2016 update).[32]

Delays

E.5 Data is available from Eurocontrol which estimates the cost to airlines of delays. This estimate is expressed as a per minute cost in euros, in 2014 prices. We have converted this estimate into £ using the Bank of England average €/£ exchange rate for 2014 and then deflated to 2016 prices using the HM Treasury UK GDP deflator series. This produced a per minute average delay figure of £32.90 (when weighted 50/50 between ground and air delays). It should be noted this figure captures costs to airlines only (i.e. fuel, crew costs, parking charges, passenger compensation), and does not include ‘passenger opportunity costs’, nor APD/tax impacts, or other societal costs.

[30] See http://www.eurocontrol.int/sites/default/files/publication/files/standard-input-for-eurocontrol-cost-benefit-analyses-2015.pdf
[31] See http://www.bankofengland.co.uk/boeapps/iadb/
[32] See https://www.gov.uk/government/statistics/gdp-deflators-at-market-prices-and-money-gdp-november-2016-the-autumn-statement

E.6 The delay cost per minute figure was then multiplied by the volume of delay minutes in each year attributed to ATFM by NATS to produce annual and cumulative estimates for the costs of these delays to airlines, for the period 2016 to 2030. Output values for selected years are presented alongside corresponding NATS estimates for flight numbers[33] and delay minutes in the following table (all cost estimates presented to 3 significant figures) – note that the present value figure is discounted using the standard 3.5% rate:

	NATS 'Do Minimum' outputs		DfT estimates
Year	No. of flights	ATFM delay minutes	Cost to airlines (2016 £)
2016	**2,455,770**	**147,632**	**£4,860,000**
2020	**2,686,917**	**1,001,492**	**£32,900,000**
2025	**2,981,144**	**2,838,274**	**£93,400,000**
2030	**3,252,840**	**4,408,638**	**£145,000,000**
Present value: 2016-30	**42,941,893**	**32,182,664**	**£762,000,000**

E.7 Data is not available on UK-specific delay costs. Instead we have used Eurocontrol data for system-wide average costs. We are assuming therefore that European averages for costs of delay are a good proxy for UK-specific delay costs, but we think this is a reasonable assumption.

E.8 Eurocontrol provides information on a number of different causes why aircraft can be delayed. We have selected the most appropriate for the purposes of our analysis – this is "tactical delays without network effects".

E.9 Delays accrued on the ground, and in the air, have differing costs. For the purposes of this modelling, a 50/50 split between air and ground delays was assumed, in order to reflect the fact that limited airspace capacity would impact both areas. When weighted accordingly, this produces the per minute cost of £32.90 outlined above. This cost decreases to £24.80 per minute assuming all delays are ground based and increases to £41 per minute assuming all delays are air based.

E.10 As delay cost estimates are presented on the basis of departure delays, the analysis inherently assumes that departure and arrival delays are equivalent, i.e. the aircraft arrives at its destination without making up any of its departure delay on its journey.

E.11 The analysis is not broken down by length of delay, although the costs to airlines of a heavy delay can be higher due to the need to compensate passengers under EU legislation. This is because the Eurocontrol figure assesses the cost of an average 1 minute delay to the airline, and its values seek to take account of the potential for higher costs for a longer period of delay.

Cancellations

E.12 For cancellations, a Eurocontrol estimate for the average Europe-wide cost to an airline of a cancellation was adopted from their standard inputs. Again, this figure was converted to £ and inflated to 2016 prices using the same methods as with delays. This produced a figure of approximately £14,400 for the average per flight cost of cancellation,[34] which was then multiplied by the NATS outputs on numbers of

[33] This includes all domestic and international commercial, military, relevant general aviation and overflights (aircraft in UK airspace that do not land in the UK).

[34] This value relates to cancellation on the day of operation and includes: service recovery costs, i.e. passenger care and compensation costs (passenger vouchers, drinks, telephone calls, hotels); loss of revenues; interline costs; loss of future value, i.e. passenger opportunity costs (individual passenger delay expressed in value); crew and catering costs; passenger compensation for denied boarding and missed connection (estimated on the application of the EU regulation); luggage delivery costs; and operational savings

cancellations per year resulting from ATFM delays in order to produce annual and cumulative cost estimates, for the period 2016 to 2030. Output values for selected years are presented alongside corresponding NATS estimates for flight numbers and ATFM cancellations in the following table – again, the present value figure is discounted by 3.5% per annum:

Year	NATS 'Do Minimum' outputs		DfT estimates
	No. of flights	ATFM cancellations	Cost to airlines (2016 £)
2016	**2,455,770**	**0**	**£0**
2020	**2,686,917**	**16**	**£231,000**
2025	**2,981,144**	**1,215**	**£17,500,000**
2030	**3,252,840**	**8,216**	**£118,000,000**
Present value 2016-30	**42,941,893**	**26,219**	**£248,000,000**

E.13 When the cumulative cost to airlines across the assessed period is summed with that of delays, the total estimate of additional airline costs attributable to the 'Do Minimum' scenario is in excess of £1 billion to 2030.

E.14 As with the delay costs assessment, by relying on Eurocontrol data, the analysis inherently assumes that the Europe-wide average figures are a good proxy for UK-specific data, which was unavailable. In addition, for cancellations, the analysis assumes that the system-wide average cancellation cost is a good proxy for the short-haul cancellation cost (as it is assumed the majority of cancellations under the 'Do Minimum' scenario are on short haul services). A simple comparison of the system-wide figure with that for traditional network and low cost carriers suggests this is likely to be the case.

Confidence assessment

E.15 All additional information used in this post-modelling analysis beyond that used in the NATS forecasts was acquired from published government, central bank or inter-governmental sources, and is in line with best practice guidance.

E.16 The analysis itself is reliant on European average values for delay and cancellation costs, provided by Eurocontrol, which may differ from UK-specific values, though not drastically so, as a large proportion of delay and cancellation costs is made up by passenger compensation, for which legislation is currently set at a European level, and the market for other input costs (e.g. fuel) is global.

E.17 Cost estimates produced are at a high level, based on aggregate data, and are therefore inevitably subject to generalisations. Had data been available, analysis at a more granular level would have produced more accurate results, though it is unlikely these would have differed drastically from the values presented within this document. This analysis is relatively high level, however this is proportionate to the Strategic Case that it supports.

E.18 Annex F provides an analytical assurance statement in line with DfT guidance.

(fuel, airport and navigation fees, maintenance, handling outstations, lounges, outstations). The value does not include ground handling costs. Source: Eurocontrol, cost and benefit analyses 2015, page 11, http://www.eurocontrol.int/sites/default/files/publication/files/standard-input-for-eurocontrol-cost-benefit-analyses-2015.pdf

Annex F: Analytical Assurance Statement – Low/Medium rating

F.1 This analysis is for a report outlining the strategic rationale for UK airspace modernisation. The purpose of the analysis is to provide a relatively simplistic, high-level indication of the scale of likely flight delays and cancellations, and the associated costs to society, in the do-nothing scenario of not modernising the UK's airspace infrastructure. In doing so it supports the case for backing industry-led airspace modernisation. Although the analysis has been rated as low/medium we are confident that the results can be used as intended to inform a simplistic, high level indication of the scale of impacts in the absence of airspace modernisation.

Scope for Challenge

F.2 The analysis has not been constrained by time nor cost and due to its high level nature, does not estimate the impact on noise or carbon. Further analysis could be used to identify local 'hotspots' (almost certainly in and around Heathrow for example). The 'cancellation assumption' applied to the modelling, an assumption on what proportion of flights delayed over a certain time would be cancelled, has been varied to account for different responses by airlines. None of these would be 'different' conclusions, just different ways of looking at the same picture.

Risk of Error

F.3 The models involved – SPAM and NEST – are utilised by NATS (the UK's national air traffic controller) in its business planning. The models have been quality assured by NATS and Eurocontrol and are used regularly by industry and air navigation service providers (i.e. NATS).

F.4 NATS forecasts are regularly validated against outturn data – see Annex B of the report for further information - which increases the assurance of the forecasts.

Uncertainty

F.5 The outputs of the modelling have been reviewed several times by technical experts in NATS. DfT analysts have quality assured the post-modelling 'cancellation assumption' but do not have the technical experience to quality assure the SPAM and NEST outputs of delay minutes.

F.6 The assumptions relating to the modelling (sectorisation,[35] traffic samples, forecasts) are reliable, being those used in all NATS studies and those by counterparts across

[35] The division of airspace such that the provision of air traffic services is decomposed into manageable workloads.

Europe. However, as with any medium to long term forecast there is inherent uncertainty underpinning the analysis. The main element of the forecasts, commercial air traffic movements, is sufficiently comparable to DfT forecasts of the same type of flights. It is not possible to compare NATS forecasts of overflights, military and non-commercial aviation since DfT does not produce such forecasts.

F.7 Assumptions have been made regarding traffic mix, passengers per flight and airspace sectorisation, but these are not expected to substantially alter the basic scale of the delays issue.

F.8 The cancellation assumptions (see Annex D) are based purely on intuitive logic and can be varied. But they are cautious in terms of underestimating cancellations and any variation is likely to increase rather than decrease the number of cancellations estimated. This approach was taken given the uncertainty in the modelling and the objective to produce an estimate with higher confidence even if that was a conservative, lower bound estimate. Given the growth in traffic forecast the scale of delays and resulting cancellations are as expected – changes in the cancellation scenario may result in relatively small changes in the outputs.

F.9 Post-modelling analysis was conducted by DfT analysts in order to assess the potential future costs to airlines from delays and cancellations under the ‘Do Minimum’ scenario (see Annex A). This made use of established data from Eurocontrol, as well as standard conversion factors from the Bank of England and HMT. Whilst data on costs is based on European average figures, these would be expected to be very similar to UK-specific values, as explained in Annex E.7. In addition, the post modelling analysis work was assured internally by DfT analysts.

Annex G: Low Level Airspace Design Concepts, Options and Impacts

G.1 The following are some examples of low level arrival and departure concepts and potential options which could be deployed to manage the impact of aircraft noise on those communities affected as a result of airspace change utilising the aircraft navigation performance capabilities. These are more fully described in a CAA publication CAP 1378 which was drafted as part of the FAS programme of work. For each concept there are a range of potential options on how they may be applied. Concepts are described generally and then impacts are assessed against the specific options.

Height Bandings

G.2 The concepts and options refer to the height bands based on the altitude priorities described in DfT guidance.[36] It should be noted that these height bands relate to the height achieved at the minimum climb gradient, or shallowest descent profile.

G.3 With respect to departures this means that the 4,000ft threshold referred to for a departure would be expected to be towards the end of the Noise Preferential Route (NPR). However, in reality aircraft have a range of climb profiles; and the majority will climb more than the minimum gradient required. However, if these aircraft remain on the route (and are not vectored) they would follow the alignment of the routes regardless of being higher or lower than the procedure requires.

G.4 This means that care needs to be exercised when considering actual track data alongside these design solutions. For example, a design solution may refer to a threshold at 7,000ft above which populations aren't avoided by a departure route design. Real data may show departures passing 7,000ft well before this threshold; however, this does not mean that they would follow an alternative route on reaching 7,000ft (unless they are vectored).

G.5 For arrivals, the thresholds refer to shallowest descent profile. In reality there is variation in optimal descent profiles. This is because the most efficient and least noisy descent profiles are achieved with engines idling and with an aerodynamically 'clean' configuration (i.e. landing gear & flaps retracted). If their descent is too shallow they will need more power which will increase noise – if they stay high too long and descend too steeply, they may have to use flaps, landing gear, and even air brakes to slow down - all of which create more noise. Aircraft passing a 4,000ft design threshold based on the shallowest approach path may therefore be somewhat higher in reality.

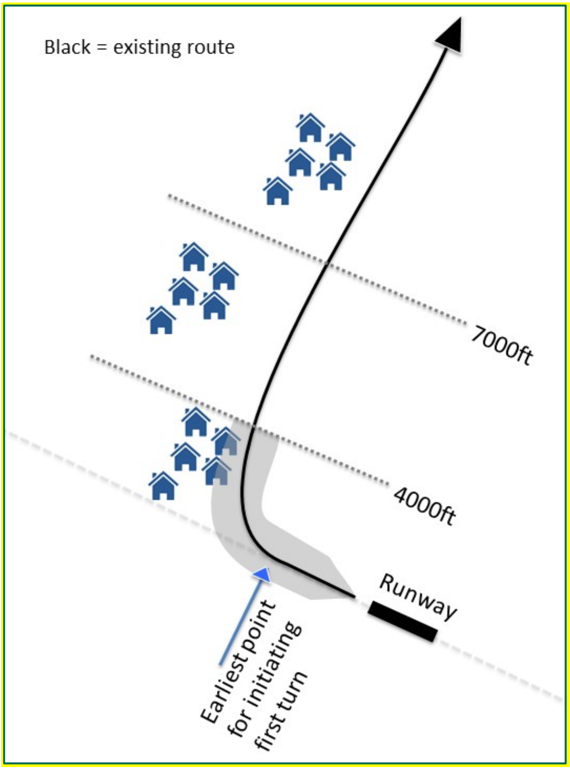
[36] https://www.gov.uk/government/publications/air-navigation-guidance

Departures

G.6 This chapter lists options for mitigating noise impacts through different departure route design concepts and options. The concepts group together options which apply the concept in different height bands.

Concept 1: Single Performance-Based Navigation (PBN) Standard Instrument Departure (SID) to Replace Conventional Routes

Option 1a. PBN SID replication



G.7 The black route signifies the historic nominal centreline. The PBN replication of this route would aim to match the nominal centreline as closely as is possible.

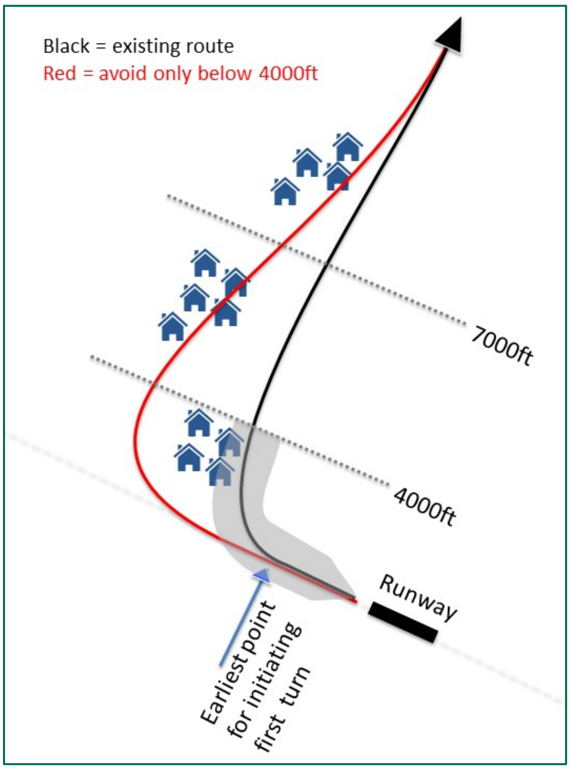
G.8 Replication does not take into account local geography as the aim is to match the existing procedure rather than redesign it.

G.9 Whilst the replication would aim to match the historic procedure in terms of centrelines, the application of PBN would be expected to lead to an increase in concentration as a consequence of improved track keeping.

Noise Objective: Concentration	
Environmental impacts	
Total number of people affected by noise	Fewer people under concentrated route
New populations exposed to noise	None[37]
Intensity/frequency of aircraft experienced by those affected	PBN more accurate therefore greater concentration
Noise Preferential Routes (NPR)	Assuming the NPR can be accurately replicated
Fuel/CO_2 efficiency	No impact
Operational impacts	
Runway Capacity	No impact
Air Traffic Control (ATC) System capacity	No direct benefit in isolation although a system of PBN routes will provide additional ATM capacity
ATC system complexity	No impact
Aircraft capability issues	
Flyability	Some conventional procedures cannot be replicated
Flight Management Computer (FMC) capacity	No impact
Applicability	Replication is the default option for modernising conventional routes

[37] An exact replication will mean no new populations exposed, but conventional procedures that cannot be replicated precisely could mean new populations are exposed.

Option 1b. PBN SID re-design avoiding populations below 4,000ft



G.10 The red route signifies a new PBN route which avoids dense population below 4,000ft. The black route is the original route which is shown for reference – in this solution the black route would be disestablished. After passing 4,000ft, the red route goes back towards the intended direction, ignoring populations which are overflown above 4,000ft.

G.11 In order to avoid the dense population below 4,000ft, the departing aircraft needs to fly straight ahead for longer, possibly outside the current NPR swathe (typically 3km wide). This adds on some distance and could affect runway throughput. It will now fly over new areas.

G.12 This solution was implemented in 2015 on the Luton RWY26 MATCH and DET SIDs although the PBN SID remained within the existing NPR swathe.

Noise Objective: Concentration	
Environmental impacts	
Total number of people affected by noise	Fewer people under concentrated route, fewer people over flown below 4,000ft (but maybe more over flown above this)
New populations exposed to noise	Yes – avoiding populations below 4,000ft will put routes over adjacent less populated rural areas. There could be an increase in the numbers overflown above 4,000ft
Intensity/frequency of aircraft experienced by those affected	PBN more accurate therefore greater concentration
Noise Preferential Routes	NPR will need to be redrawn
Fuel/CO_2 efficiency	Longer route will mean more fuel/CO_2. Possibly more delay on ground with engines running (runway capacity)
Operational impacts	
Runway Capacity	Straight ahead for longer would impact runway capacity
ATC System capacity	No direct benefit in isolation – although a system of PBN routes will provide additional ATM capacity
ATC system complexity	No impact
Aircraft capability issues	
Flyability	No impact
FMC capacity	No impact
Applicability	Noise is the priority below 4,000ft, therefore avoiding populations should be considered as an option for any SID proposal below 4,000ft which goes beyond replication

Arrival Options

G.13 This section lists options for mitigating noise impacts through different arrival route design concepts and options. The concepts group together options which apply the concept in different height bands.

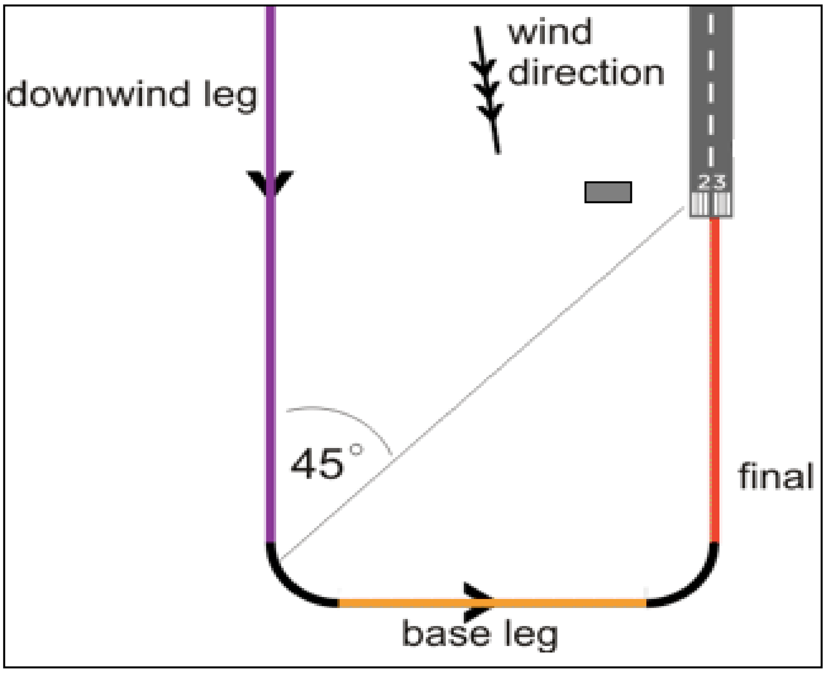
Arrivals Definitions

G.14 Aircraft have to land facing into the wind. The approach path to a runway is generally split into three segments as shown below. The downwind leg runs parallel to the runway and the base leg turns aircraft to intercept the final approach which, in today's systems, head straight on towards the runway.

G.15 In today's 'conventional' air traffic environment there are very few defined routes for everyday use for downwind and base leg, but the final approach path is usually defined by the Instrument Landing System (ILS) which aircraft follow for their approach to the airport.

G.16 This means that traffic is currently vectored on downwind and base leg. The vectoring can vary on a flight by flight basis as aircraft are positioned to achieve a safe and efficient landing sequence.

G.17 Utilisation of PBN standards allows modernising the route structure to allow PBN routes to be defined down to the final approach which will improve predictability although in busy times some vectoring will still be required to maintain the landing sequence (see Runway Capacity).



Continuous Descent Approach (CDA)

G.18 In the UK, in order to keep fuel burn, CO_2 and aircraft noise to a minimum, approach controllers and pilots are trained to try and achieve a Continuous Descent Approach[38] (CDA). When a CDA procedure is flown the aircraft stays higher for longer, descending continuously from the bottom level of the stack (or higher if

[38] http://www.caa.co.uk/docs/68/Basic_Principles_CDA.pdf

possible) and avoiding any level segments of flight prior to intercepting the final approach. A continuous descent requires significantly less engine thrust than prolonged level flight. It may sometimes not be possible to fly a CDA due to airspace constraints or overriding safety requirements.

Curved Approaches

G.19 Curved Approaches are those where aircraft are following a strictly defined PBN approach path from downwind of the airfield and round onto final approach. At some point the aircraft may even be required to switch 'mode' depending on the landing system in operation at the airfield in question.

G.20 Curved approaches vary in their technical demands on the navigational capability of the aircraft, the airfield and ATC equipment. Curved approaches provide the ability to allow a much shorter minimum final approach, from, typically, 7 or 8nm down to 4 or even 3nm. However, the technical demand on the aircraft's navigational performance, the relevant immaturity of curved approaches and the resultant reduction in runway throughput during peak hours (if they were to be used by all arrivals) means that curved approaches cannot currently be used widely enough as a method of providing noise relief in order to support all high intensity runway operations.

Network Enablers for Low Altitude Navigation noise solutions

G.21 The options presented in this section relates to PBN routes that deliver aircraft through low level airspace onto the runway. As described earlier, there will always be circumstances where aircraft need to be vectored off these PBN routes to maintain safety and capacity. However the degree to which this is required will depend on the way in which aircraft are delivered onto these routes from the network airspace that sits above. In turn, this will depend on how the network airspace is configured and managed.

G.22 Managing the way in which multiple aircraft arrive simultaneously is key to the performance of PBN routes. If the network is configured and managed so that the aircraft 'bunches' are sorted into an orderly stream before they join the low level PBN routes, it is more likely that aircraft can be left to follow the low level routes autonomously. Conversely, if 'bunching' is not addressed in the network airspace, air traffic control will be required to tactically manage the aircraft in the lower airspace – providing more instructions that lengthen or shorten flight paths which means less route adherence and a greater variation in track distribution.

G.23 Multiple aircraft arriving within a short time frame are currently managed through holds in the network airspace (for major airports these are generally at 7,000ft or above). These are effective at absorbing inbound delay but are not a particularly efficient means for generating a single, orderly stream of arrivals – hence at busy airports there is a tendency for dispersed arrival traffic patterns at low levels.

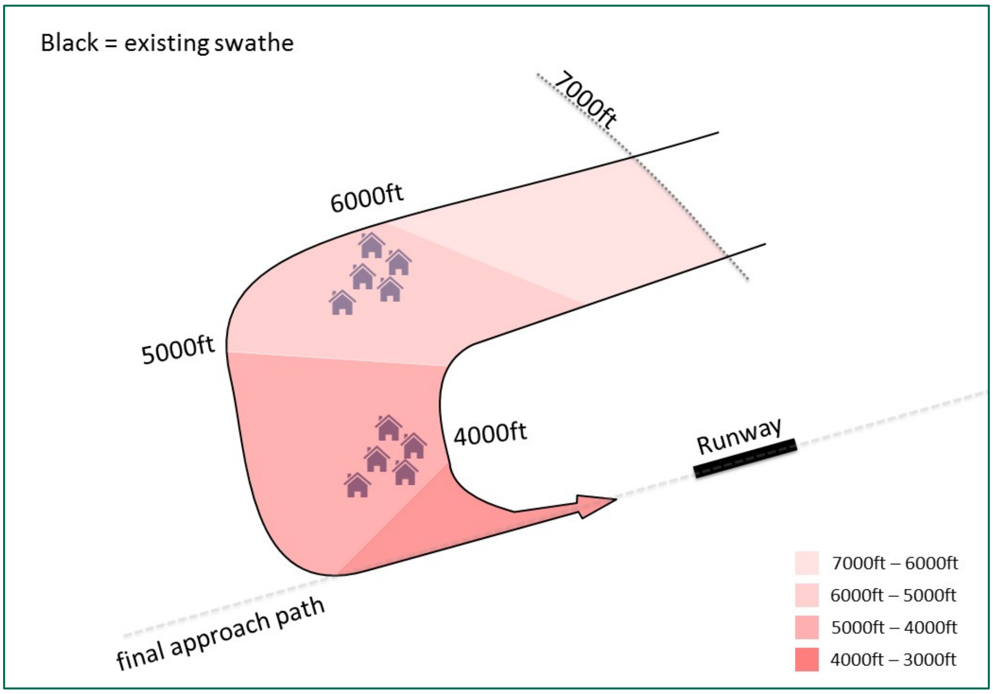
G.24 In a future PBN environment there are other techniques, with associated route structures, that can work alongside or instead of holds to generate a more orderly stream. The two principle techniques are referred to as 'Point Merge' or 'Tromboning'. These concepts are for managing airborne delay, generally[39] in higher level airspace above 7,000ft, rather than being techniques to mitigate noise. However, it is worth noting that the efficiency of any low level PBN route structure will

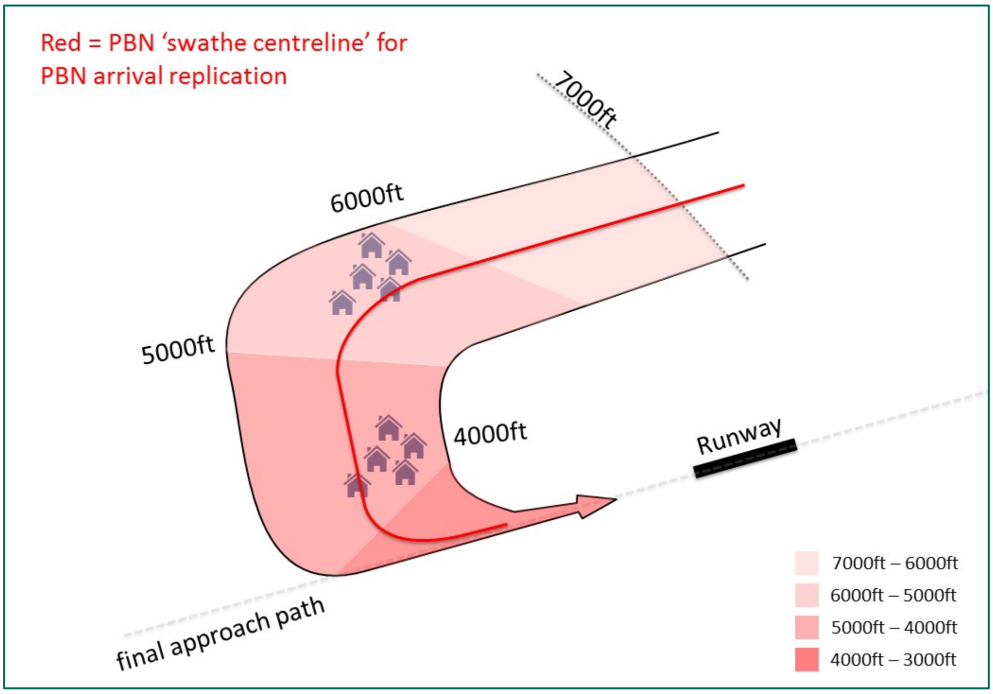
[39] These techniques are not necessarily limited to higher level airspace.

be limited unless there is an appropriate network design that delivers an orderly sequence of arrivals.

Arrival Concept 1: Single PBN routes for arrivals

Option 1a: PBN arrival "replication"



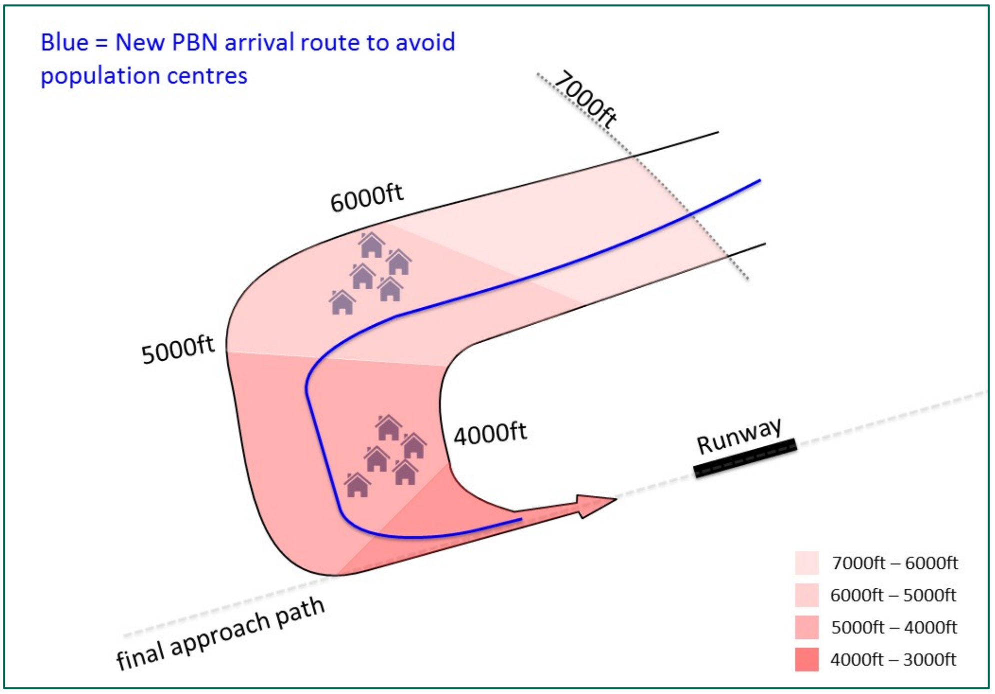


G.25 The current arrival swathe is depicted by the extremities of the black arrows. The swathe covers 2 areas of dense population. Replicating this arrival flow by means of a single PBN route requires that route to be in the middle part of that swathe (the most frequently used path) and provides a single consistent point of interception of the final approach.

G.26 Replication here means that potential PBN capabilities are not utilised to provide relief in specific areas. In this circumstance, traffic is concentrated on the red centreline. This was implemented at Bristol airport in 2014.

Noise Objective: Relief, Dispersal	
Environmental impacts	
Total number of people affected by noise	Reduced
New populations exposed to noise	No
Intensity/frequency of aircraft experienced by those affected	Increased for those under the route
Noise Preferential Routes	N/A
Fuel/CO_2 efficiency	Positive impact. Optimised final approach and the route allows the Flight Management System (FMS) to fly an optimised CDA
Operational impacts	
Runway Capacity	Reduced runway throughput unless vectoring still allowed
ATC System capacity	Reduced ATC workload means they can optimise the final approach spacing
ATC system complexity	The existence of a route reduces ATC workload even if vectoring still sometimes required
Aircraft capability issues	
Flyability	No issues – positive impact for operators
FMC capacity	No Issues
Applicability	Replication, that matches the centre of today's distribution of traffic is the default option for modernising approach tracks

Option 1b: A single PBN arrival route avoiding population centres



G.27 PBN is used to avoid overflight of specific areas, in this case, areas of dense population.

G.28 The blue route avoids those areas and concentrates arrivals onto a single track, subject to the issues described in the Runway Capacity section of this document.

G.29 This has been successfully applied at Bristol airport for their easterly approaches in 2014, as the replicated route was adapted to minimise flight over land.

Noise Objective: Relief, Dispersal	
Environmental impacts	
Total number of people affected by noise	Reduced
New populations exposed to noise	No new populations although a PBN route means concentration of aircraft along that route
Intensity/frequency of aircraft experienced by those affected	Increased for those under the route
Noise Preferential Routes	N/A
Fuel/CO_2 efficiency	A single, optimised route enables FMS to fly the aircraft, enhancing CDA performance however the route length may have increased to avoid population
Operational impacts	
Runway Capacity	Reduced runway throughput unless vectoring still allowed
ATC System capacity	Reduced ATC workload means they can optimise the final approach spacing
ATC system complexity	The existence of a route reduces ATC workload even if vectoring still sometimes required
Aircraft capability issues	
Flyability	Positive impact as FMS can fly the aircraft
FMC capacity	No impact
Applicability	Applicability depends on the height of the proposed change and local requirements for noise relief should be agreed as part of the design options