OUR APPROACH TO REDESIGNING OUR AIRSPACE NETWORK FOR AN EXPANDED HEATHROW

JANUARY 2019
EXECUTIVE SUMMARY

This document describes our approach to redesigning the arrival and departure routes for Heathrow expansion in the context of the Airports National Policy Statement (Airports NPS). This document describes the operational and technical specifications for future flight paths and is therefore necessarily technical in nature.

We would welcome any feedback on this work: if you have comments on the work to date, or on the design process we are following, please include them in the other comments box on the feedback form.

The document provides a detailed description the feasibility analysis and design process we are using to develop the airspace in line with the requirements of the Civil Aviation Authority (CAA) CAP1616 airspace change guidance. This process is split into several design phases:

a. Component Feasibility – this is where we identify a feasible set of design components which are the building blocks for design.

b. Design Principles – this is where we established the design principles which we will use to evaluate airspace design options. This involved a voluntary public consultation on Airspace principles followed by engagement with a range of stakeholder representatives to finalise them (for full details of this process see the design principles submission for Heathrow expansion).

c. Macro Design Concept – this is where we undertake conceptual design to establish the structure for our new routes/flight paths.

d. Detailed Design - this is where we work out detailed options for the design of the airspace. This phase is preceded by the voluntary Airspace and Future Operations Consultation (this is where we currently are in the process). The subsequent design work is then split into:

   i. Consideration of individual routes (or closely related groups of routes) - where we identify a long list of potential route alignments for each route (or sub-set of routes) in turn.

   ii. Consideration of complete airspace design options. Each airspace design option will include a detailed description of each of the arrival and departure routes that make up the complete system. The airspace design options will comprise of different combinations of the best performing routes from the previous phase.
We will engage with stakeholder representatives at key stages through this phase of detailed design work, and it will conclude with the statutory consultation on our preferred design option (as prescribed by CAP1616).

e. Final Design – where we finalise a design for submission.

The document also describes the ‘macro design concept’ (shortened to ‘macro design’). The macro design description outlines three concepts for departures and four for arrivals that define the underlying airspace structure for the design envelopes. These are:

- Departure Concept 1 – Minimum of three segregated departure routes from each runway
- Departure Concept 2 – Optional additional routes for noise sharing
- Departure Concept 3 – Optional ‘wrap around’ routes for fuel and network efficiency
- Arrival Concept 1 – Pure PBN arrivals (only for mixed mode runways)
- Arrival Concept 2 – PBN to xLS
- Arrival Concept 3 – PBN to xLS with ‘trombone’ and coded shortcuts
- Arrival Concept 4 – PBN to xLS with ‘trombone’ and tactical ATC shortcuts
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Glossary
Acronyms

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1. **INTRODUCTION**

1.1.1 This document describes our approach to redesigning the arrival and departure routes for Heathrow expansion in the context of the Airports National Policy Statement (Airports NPS). The Airports NPS was designated by the Secretary of State for Transport on 26 June 2018.

1.1.2 This document has the following sections:

- Section 2 describes the feasibility analysis and design process for the development of Heathrow’s airspace in the context of expansion, and in line with the requirements of the Civil Aviation Authority (CAA) CAP1616 airspace change guidance.

- Section 3 describes the ‘macro design concept’ (shortened to ‘macro design’) which forms the basis of the design envelopes which we intend to be the starting point for the subsequent detailed design phase.

1.1.3 We would welcome any feedback on this work: if you have comments on the work to date, or on the design process we are following, please include them in the other comments box on the feedback form.

1.1.4 This is a technical document and as such, standard ATC (Air Traffic Control) and aviation industry terminology is used throughout. Terms relating to the design process are also introduced and used. It is assumed that the reader has a level of aviation knowledge. For a non-technical overview of the process and progress to date, please see the *Heathrow’s Airspace and Future Operations Consultation Document* and *How do we seek approval to expand Heathrow?*. A glossary of terms is provided in Appendix A.

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2 For a description of design envelopes see Understanding our design envelopes.
2. EXPANSION AIRSPACE DESIGN PROCESS

2.1 Introduction to Expansion Airspace Design Process

2.1.1 This section describes the feasibility analysis and design process Heathrow is employing in the development of the airspace for expansion.

2.2 Overview of the Design Process

2.2.1 Figure 1 overleaf illustrates the phasing of the design process for the development of Heathrow’s airspace in the context of expansion. An overview of this process is provided in How do we seek approval to expand Heathrow? in the consultation material – this is recommended reading before considering this more detailed technical process description.

2.2.2 There are a number of phases to the overall design process which are listed below and described in detail in the following sections. These phases provide the design steps that take us from a ‘blank sheet’ to a final detailed airspace design. A number of these phases are in addition to the design steps laid out in the CAP1616 airspace change guidance. Compliance with the CAP1616 process is covered in Section 2.8.

Airspace Design Phases for Heathrow Expansion:

a. Component Feasibility – this is where we identify a feasible set of design components which are the building blocks for design. Engagement at this stage was with technical experts from a range of disciplines (see para 2.2.4).

b. Design Principles – this is where we established the design principles which we will use to evaluate airspace design options. This involved a voluntary public consultation on Airspace principles followed by engagement with a range of stakeholder representatives to finalise them (for full details of this process see the design principles submission for Heathrow expansion). Note that this phase was undertaken in parallel with the component feasibility work as illustrated in Figure 1.

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3 The ‘blank sheet’ approach was taken to ensure that all feasible options for a future operation were considered from the outset – nothing was ruled in or out prior to the component feasibility stage.

4 CAP1616 requires only one round of public consultation towards the end of the process once options have been narrowed and full detail is available. We are undertaking two extra/voluntary consultations at key stages preceding this to ensure that all stakeholders have opportunities to feed into the process at key stages of the design – not just during the latter stages.

c. Macro Design Concept – this is where we undertake conceptual design to establish the structure for our new routes/flight paths. Engagement at this stage was with technical experts from a range of disciplines (see para 2.2.4).

d. Detailed Design - this is where we work out detailed options for the design of the airspace. This phase is preceded by the voluntary Airspace and Future Operations Consultation (this is where we currently are in the process). The subsequent design work is then split into:

i. Consideration of individual routes (or closely related groups of routes) - where we identify a long list of potential route alignments for each route (or sub-set of routes) in turn.

ii. Consideration of complete airspace design options. Each airspace design option will include a detailed description of each of the arrival and departure routes that make up the complete system. The airspace design options will comprise of different combinations of the best performing routes from the previous phase.

We will engage with stakeholder representatives at key stages in both phases i and ii of our detailed design work, and it will conclude with the statutory consultation on our preferred design option (as prescribed by CAP1616)4

e. Final Design – where we finalise a design for submission.

2.2.3 The design process to date has involved a broad range of Subject Matter Experts (SME). The roles and responsibilities are shown in Appendix B.
Figure 1 - The phases of our design process for Heathrow expansion

- **COMPONENT FEASIBILITY**
  - Identification of tech
  - ATM Issues and Constraints
  - Component Identification

- **MACRO DESIGN (FLIGHT PATH FRAMEWORK)**
  - Develop macro design concept (Component Assembly)
  - Individual route options
    - Options for route 1
    - Options for route 2
    - Options for route 3
    - ….
  - Airspace design options – for combined route system
  - Consult Prep
  - Statutory Consultation
  - Refine Preferred option

- **DETAILED DESIGN (MICRO)**
  - Airspace & Future Operations Consultation
  - Flight path options

- **FINAL DESIGN**
  - Submit ACP

**Key**
- Design process phases
- Completed activities
- Pending activities
- CAP 1616 Stages

**Stage 1**
- Design Principles (DP) prep
- Airspace Design Principles Consultation
- Design Principles

**Stage 2A**
- Component Identification
- DP finalise
- Route framework and design envelopes

**Stage 2B**
- Individual route options
- Airspace design options – for combined route system

**Stage 3**
- Consult Prep
- Statutory Consultation

**Stage 4**
- Refine Preferred option

We are here...
2.3 **Overview of Component Feasibility**

2.3.1 Before we can start to build options for the design of the airspace, it is necessary to work out the constituent parts i.e. "building blocks" of the design and some broad objectives to guide how they should be put together. We call these the design components and design principles respectively.

2.3.2 Design components are the range of technical building blocks that could be used to construct the design options. For example, a design option for arrivals would need to be constructed from components for intermediate approach, final approach, and additional operational concepts for developing a safe and efficient landing sequence. The aim of this part of the design process was to identify a range of feasible alternatives for each of these component types.

2.3.3 Components were identified over a period of months through research and operational workshops attended by technical specialists across a range of Air Traffic Management (ATM) disciplines (see Appendix B). To ensure a comprehensive list of components, this work considered the components derived from:

   a. existing ATM procedures at Heathrow
   b. air traffic operations at other airports
   c. new ideas suggested from research and innovation, e.g. NATS\(^6\) in-house, SESAR\(^7\), NEXTGEN\(^8\).

2.3.4 This work has been completed and the output published in two tranches. The initial phase of this work was reported on during the Airspace Design Principles Consultation in the report ‘Preliminary Technical Overview on Network Air Traffic Management (ATM) Issues and Constraints’\(^9\). The second tranche is Appendix C – Component Identification Tables (published separately due to size/complexity of the tables).

2.4 **Overview of Design Principles**

2.4.1 The establishment and CAA approval of design principles\(^10\) is a requirement of CAP1616. Our design principles have been established through the Airspace

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\(^6\) www.nats.aero  
\(^7\) www.sesarju.eu  
\(^8\) www.faa.gov/nextgen  
\(^10\) For a summary of our design principles see *Heathrow’s airspace design principles for Expansion*
Design Principles Consultation\textsuperscript{11} and stakeholder engagement and submitted to the CAA. The CAA have assessed the submission, which includes evidence of all the engagement activities, and passed it through the CAP1616 Define gateway which means that we have their approval to move onto the next phase of the design process. The full detail of our design principles submission and the CAA assessment is published on the CAA website\textsuperscript{12}.

\section*{2.5 Macro Design Concept}

2.5.1 Macro design concept is a technical term for what is referred to as the “underlying structure for future flight paths” in the less technical consultation material. As this is a technical document, we are using the term ‘macro design concept’ or just the shortened form ‘macro design’.

2.5.2 The output of this phase of the design process is a macro design ‘concept’, rather than a design option as described in CAP1616 because design detail has yet to be established. For example, it does not define the route position, or the detailed operational practices required to operate them.

2.5.3 The macro design concept defines the broad characteristics of a new Air Traffic Services (ATS) route system; such as the minimum number of routes, their route specification (navigation and climb) and the potential connectivity of each route into the wider ‘en-route’ ATS system of higher altitude (above 7000ft) routes over the UK. As such the work to establish the macro design is a technical exercise.

2.5.4 Working to a conceptual level is appropriate at this stage of the design process because more detailed work and engagement can only be undertaken once there is a design concept to base it on.\textsuperscript{13}

2.5.5 The macro design concept also defines the broad geographical area within which each route would need to be positioned – these are called the design envelopes. The design envelopes are a step in the design process primarily intended to help

\textsuperscript{11} The Airspace Design Principles Consultation material is available at https://hec1.heathrowconsultation.com/
\textsuperscript{13} For example, we are planning a real-time simulation for developing the new method of operation required for an expanded Heathrow—this can only be undertaken once there is a concept to simulate. Likewise, our next phase of engagement and consultation requires a concept. Our first round of consultation and engagement in 2017 was to develop principles to start the CAP1616 design process. At the other end of the CAP1616 process – before we submit our proposal to the CAA—we will consult on full details of the proposal and a set of options. Stakeholder involvement is not just for the start and the end of the process, and so we are undertaking engagement in the intervening period (which includes this second airspace consultation). This consultation bridges the gap between the consultation on principles and the consultation on full design detail. The macro design concept provides the basis for the second consultation as it describes the structure for flight paths and allows us to describe potential impacts and engage with potentially affected parties in a meaningful way, while remaining flexible enough for us to take on board feedback received.
stakeholders and communities better understand how proposed changes could affect them, and therefore offer the opportunity to provide feedback before flight path options are established.\textsuperscript{14}

2.5.6 Macro design concepts are assembled from various combinations of the design components. This process involved workshops with technical experts, used firstly to identify whether it was operationally feasible to combine certain components, and then to assess the potential combinations against the design principles. The workshops and evaluation process will be fully documented in our submission for the CAP1616 Stage 2 gateway (see Section 2.6 for further details of our approach to CAP1616 stage 2).

2.5.7 See Section 3 for a description of the preferred macro design.

**Detailed Design (Micro Design)**

2.5.8 The detailed design\textsuperscript{15} phase develops and assesses detailed options/positioning for each route within the macro design concept. This stage has not yet commenced.

2.5.9 The output of this phase of design will be the airspace design options. Each airspace design option will include a detailed description of each of the arrival and departure route that makes up the complete system.

2.5.10 The macro design concept described in Section 3 will consist of at least 12 individual arrival routes and at least 18 individual departure routes\textsuperscript{16}. To consider as many options as possible for each route, we have split the detailed design process into two distinct steps: ‘individual routes/route groups’ followed by a ‘complete airspace change’ options. We have done this to make sure that we can consider a wide range of potential alignments for each route, and so that potentially beneficial options for individual routes are not overlooked.

2.5.11 It is necessary to split this stage into these two steps to achieve this because the performance of individual route options would be difficult to discern if they were only tested in the context of a complete route system. Furthermore, modelling the whole system to assess a large number of options for individual routes and their combinations would be a limiting factor on the number of individual route options we could consider\textsuperscript{17}.

\textsuperscript{14} For a description of design envelopes see Understanding our design envelopes
\textsuperscript{15} The detailed design phase has previously been referred to as the 'micro design' phase. This term has been superseded by 'detailed design' as this was deemed to be more understandable.
\textsuperscript{16} Our macro design has a minimum of 30 routes for normal civil traffic flows, and the potential for more to meet the various design principles in different ways. This macro design is described in more detail in Section 3.
\textsuperscript{17} Using 30 routes as example - with just 2 options for each the number of potential system combinations reaches over a billion (2 to the power of 30).
In the ‘individual routes’ step we will identify a wide range of potential alignments for each route. Individual routes will be assessed against the design principles – this will include some quantitative overflight metrics. The results of this assessment will be used to create a shortlist of final route alignments for each individual route.

The shortlisted routes will then be combined in different ways to create a longlist of complete airspace design options (each consisting of route systems for arrivals and departures). These will be put through initial appraisal as defined in CAP1616 which will involve further assessment against the design principles to generate a shortlist of airspace design options. Note that initial appraisal requirements are for qualitative assessment, however we intend that our initial appraisal will involve quantitative noise analysis. The shortlist will be put through a full appraisal (as defined in CAP1616), the results of which will identify our preferred airspace design option to feed into our third consultation, which is shown in Figure 1 as ‘Statutory (CAP1616) Consultation’.

This stage has not yet commenced. Feedback from the Statutory (CAP1616) Consultation will be used to confirm and/or adapt the preferred design for our Airspace Change Proposal (ACP) submission to the CAA.

Figure 2 shows the flow diagram of CAP1616 Stage 2: ‘Develop and Assess’. This is shown on the left of Figure 2. The right-hand side of Figure 2 shows how the how the component feasibility, macro design concept and individual route phases described earlier in Section 2 represent extra steps that feed into the CAP1616 process. The relationship between each of these extra steps and the CAP1616 process is described in more detail below.

Our Component Feasibility stage was focussed on identifying feasible building blocks for design options. This work was unconstrained to ensure that the subsequent design exercise was not unduly limited by current design or operational practices. As such, each component was considered individually as a stand-alone concept rather than as part of a design option.

Undertaking feasibility studies in advance of complex design tasks is common practice in aviation and many other sectors to ensure that the design options are built on a solid foundation. This work identifies scope and confirms that there is potential for feasible options that meet the brief and justifies starting the process of
developing and assessing airspace design options. As such this work was undertaken as a precursor to the CAP1616 Stage 2 alongside the work on design principles, so that the two streams: ‘components’ and ‘design principles’ could be brought together to start CAP1616 Stage 2 (the relationship between components and design principles is described in paragraph 2.3.1).

2.7.4 Our component feasibility assessment for airspace to support the Heathrow Expansion commenced in October 2017 and completed in June 2018. The latter stages of this work were undertaken in parallel with Stage 1 of CAP1616 (as shown in Figure 1).

**Macro Design and Detailed Design for Individual routes**

2.7.5 The CAP1616 Stage 2 process (Figure 2 on the left) describes a flow where options are identified and narrowed down to a shortlist of complete design options in one stage. The CAP1616 process maps well to a typical airspace change, for example one involving the re-design of a limited number of routes.

2.7.6 The airspace design for Heathrow expansion is not typical; it will be the largest and most comprehensive airspace change ever undertaken by a UK airport. Furthermore, we are starting with a ‘blank sheet’ approach to the design of our airspace, which is some of the most complex in the world and consists of many individual routes. This blank sheet approach will ensure that we are not constrained in our efforts to find the optimal airspace solution. With this starting point and scope, the number of discrete options for the complete design is virtually infinite.

2.7.7 In order to develop airspace change options as required for CAP1616 stage 2, we are undertaking the extra design activity as described in the previous section. Therefore, instead of one phase of options development (as shown on the left of Figure 2) we are performing the work in three phases as described in the previous sections. This methodical approach to the design enables us to consider a breadth of options that would be impossible if we focussed only airspace change options (i.e. complete system options) from the outset as implied by CAP1616.

2.7.8 Figure 2 shows how these extra activities fit into the CAP1616 stage 2 process. The additional activities are simply a systematic and robust method for undertaking the first step of Stage 2A in CAP1616 for an airspace change of this magnitude.

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18 See footnote 4.
Stage 2B, Stage 3 and Stage 4 of CAP1616 would be undertaken as described in CAP1616.
Our approach to redesigning our airspace network for an expanded Heathrow

**Figure 2 – CAP1616 Stage 2 Steps**

**CAP1616 Stage 1B Airspace Design Principles**
- Define Gateway

**CAP1616 Stage 2 Develop and Assess Steps**
- **Stage 2A: Options development**
  - Sponsor develops airspace change options
  - Sponsor develops design principles evaluation showing how options meet design principles
  - Sponsor publishes portal airspace designs and design principles evaluation
  - The sponsor may choose to undertake simulations or may request a flight trial of one or more options (flight trials would require airspace trial process)

- **Stage 2B: Options appraisal**
  - Sponsor completes ‘critical’ appraisal (phase II) including safety assessment
  - Sponsor publishes appraisal on portal

**DEVELOP AND ASSESS GATEWAY ASSSESSMENT**
- **Stage 3**
- CAA specifies requirements that need to be notified before gateway can be passed
- CAA approval

**Heathrow’s Extra Component Feasibility Steps (Pre CAP1616)**
- Component identification & feasibility assessment

**Heathrow’s Extra Develop and Assess Steps**
- Heathrow develops options for route systems – these are the ‘airspace change options’ as referenced in CAP1616 (follow arrow)
- Test options for individual routes with relevant stakeholders
- Develop and refine individual routes
- Heathrow identifies a wide range of potential alignments for individual routes
- Individual route alignments evaluated against design principles and envelope feedback (qualitative and some quantitative)
- Macro design concepts evaluated against design principles (qualitative)
- Refine macro concept – if necessary

**Airspace & Future Operations Consultation**
- Macro options evaluation
- Published, plus request for feedback on envelopes

**Figure 2**

CAP1616 Stage 2 Steps

Heathrow Extra Development and Assess Steps

Component Identification & Feasibility Assessment

Macro Design Concepts Evaluated Against Design Principles (Qualitative)

Airspace Future Operations Consultation: Macro Options Evaluation
- Published, plus request for feedback on envelopes

Heathrow Identifies a Wide Range of Potential Alignments for Individual Routes

Individual Route Alignments Evaluated Against Design Principles and Envelope Feedback (Qualitative and Some Quantitative)

Test Options for Individual Routes with Relevant Stakeholders

Develop and Refine Individual Routes

CAA Specifies Requirements That Need to Be Notified Before Gateway Can Be Passed

CAA Approval

**Heathrow’s Extra Component Feasibility Steps (Pre CAP1616)**
- Component Identification & Feasibility Assessment

**CAP1616 Stage 1B Airspace Design Principles**
- Define Gateway

**CAP1616 Stage 2 Develop and Assess Steps**
- **Stage 2A: Options Development**
  - Sponsor develops airspace change options
  - Sponsor develops design principles evaluation showing how options meet design principles
  - Sponsor publishes on portal airspace designs and design principles evaluation
  - The sponsor may choose to undertake simulations or may request a flight trial of one or more options (flight trials would require airspace trial process)

- **Stage 2B: Options Appraisal**
  - Sponsor completes ‘critical’ appraisal (phase II) including safety assessment
  - Sponsor publishes appraisal on portal

**DEVELOP AND ASSESS GATEWAY ASSESSMENT**
- **Stage 3**
- CAA specifies requirements that need to be notified before gateway can be passed
- CAA approval

**Heathrow’s Extra Component Feasibility Steps (Pre CAP1616)**
- Component identification & feasibility assessment

**Heathrow’s Extra Develop and Assess Steps**
- Heathrow develops a range of macro design concepts
- Macro design concepts evaluated against design principles (qualitative)
- Refine macro concept – if necessary

Airspace Future Operations Consultation: Macro options evaluation
- Published, plus request for feedback on envelopes

Heathrow identifies a wide range of potential alignments for individual routes

Individual route alignments evaluated against design principles and envelope feedback (qualitative and some quantitative)

Test options for individual routes with relevant stakeholders

Develop and refine individual routes

CAA specifies requirements that need to be notified before gateway can be passed

CAA approval
3. **MACRO DESIGN CONCEPT**

3.1 **Introduction to Macro Design Concept**

3.1.1 This Section summarises the ‘macro design concept’ (shortened to ‘macro design’) which forms the basis of the design envelopes, which we intend to be the starting point for the detailed design phase (also sometimes referred to as the ‘micro’ design phase) that will follow the second airspace consultation for expansion. For details of how this fits into the overall design process, please see Section 2.

3.2 **Context**

3.2.1 The macro design is the result of many months of development and involving workshops attended by a broad range of Subject Matter Experts (SME). The roles and responsibilities of these experts are shown in Appendix B. This was an exhaustive process, involving firstly identifying and evaluating a wide range of ideas for the components that underpin the macro design; and secondly identifying and evaluating a range of concepts for the macro design itself.

3.2.2 The output of this work is a design ‘concept’, rather than a design option as described in the CAA’s Airspace Design Guidance (CAP1616) because design detail has yet to be established. In particular the macro design does not define the route position, nor the detailed operational practices required to operate it, and so consultation at the macro design stage is on design envelopes rather than design detail\(^{19}\).

3.3 **Concepts Considered**

3.3.1 The macro design process considered various operating concepts for arrivals and departures to/from the runway up to where they leave/join the wider ‘en-route’ ATS system at c.7000ft (above this height the airspace is designed and managed by NATS).

3.3.2 A broad range of arrival and departure concepts were assembled from the design components. Each of these was then assessed against the design principles by the subject matter experts. The full list of concepts considered is shown in Appendix D. This is a separately published document in the form of large tables showing how each of the concepts was assessed against the design principles.

3.3.3 This assessment resulted in the identification of four arrival and three departure concepts that would best meet the design principles. At this stage of the design

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\(^{19}\) For a description of the stages of the design process see Section 2
process it is not possible to identify and assess detailed impacts because the macro design concepts do not fix the route position. The assessment was therefore focussed on the potential of the concepts to meet each design principle.

3.3.4 For example, there was a qualitative assessment of whether the concepts could meet the safety and capacity requirements, and also assessment of whether each had enough flexibility to meet the range of other design principles in different ways. This approach was particularly relevant to the noise related principles because we will not know what the best noise configuration is until we can perform detailed noise analysis on specific options. A good concept is therefore one which has scope for establishing a wide range of options for the detailed design phase (as described in Section 2).

3.3.5 The concepts were also referred to as ‘strings’ in the option table at Appendix D. This terminology was used because each concept consisted of a string of components – for example an arrival concept would consist of string of components including the intermediate approach, final approach and any other relevant operational concept such as the method for sequencing. A glossary of terms is provided in Appendix A.

3.3.6 The following sections describe the four arrival and three departure concepts that comprise macro design, and the aims and assumptions that underpin them.

### 3.4 Macro Design Aims & Assumptions

3.4.1 This section provides context for the macro design concept, highlighting what was and what was not a consideration at this stage.

**Route Positioning and Flexibility**

3.4.2 The macro design process is to define concepts that:

- provide a basis for developing detailed options; but which also
- leave as much flexibility as possible in the detailed route positioning, so that there is scope for investigating a wide range of options for the optimal solution - in practice this means a macro design that keeps the design envelopes as wide as is possible.

3.4.3 The macro design does **not** identify specific options for route positioning.

**Runway Alternation**

3.4.4 It is assumed the reader of this technical paper understands the concept of runway mode alternation. The macro design was developed to be flexible to enable any/all of the following four runway mode combinations in either westerly or easterly
operations. These exclude the use of mixed mode on the central runway in line with the Airports Commission work. For an overview of mode alternation see Runway Operations - Respite through Alternation. This also includes the rationale for limiting our work to the modes shown in Table 1.

Table 1 – Runway Alternation – Modes considered for Macro Design

<table>
<thead>
<tr>
<th></th>
<th>‘MLD’</th>
<th>‘MDL’</th>
<th>‘DLM’</th>
<th>‘LDM’</th>
</tr>
</thead>
<tbody>
<tr>
<td>North West (NW) RWY</td>
<td>Mixed</td>
<td>Mixed</td>
<td>Departure</td>
<td>Landing</td>
</tr>
<tr>
<td>Central (C) RWY</td>
<td>Landing</td>
<td>Departure</td>
<td>Landing</td>
<td>Departure</td>
</tr>
<tr>
<td>Southern (S) RWY</td>
<td>Departure</td>
<td>Landing</td>
<td>Mixed</td>
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</tbody>
</table>

3.4.5 Other modes may be possible or required for unusual circumstances; however, the macro design has focused on the four modes in Table 1. The remainder of this document provides conceptual diagrams for the macro design relating to these modes of operation – they are labelled as per the 3-letter acronym shown in the above table. Unusual circumstances will be considered in the detailed design phase.

3.4.6 The scheme for alternating operations will be established through the wider planning process (referred to as an application for a Development Consent Order (DCO)) – for further details see the link in paragraph 3.4.4

Runway Direction

3.4.7 Runway direction is largely dictated by the prevailing wind conditions at the surface and at various heights above the airfield. At Heathrow the wind is predominantly from the West (approximately two thirds of the time), however the airspace must be designed to work safely and efficiently in either directional mode. The design does not affect the decision on the directional preference which is to be established through the DCO process. For further details see Runway Operations – Directional Preference.

Night Flights

3.4.8 The macro design does not affect the decision on changes to the scheduling of night flights, which is being progressed separately through the DCO process. It will be able to accommodate any resultant night regime. For further details see Runway Operations – Night Flights.
Route Use and Flexibility

3.4.9 The design must not limit which aircraft can take off or land on each runway. This requirement will ensure that the airspace design concept is flexible such that it would not limit the ground operation. For example, if aircraft heading to the north could only take off from the north-west runway, those from a terminal in the south of the airport may have extended taxiing times and/or suffer potential queues at intersections. As traffic levels increase, this would lead to increased ground delay and fuel burn that is more likely to affect local air quality and have other environmental impacts in the vicinity of the airport.

3.4.10 This flexibility also provides more opportunities for developing operations that are resilient to unusual circumstances such as extreme weather, while also ensuring that airspace is not a limiting factor to long term growth. These opportunities will be explored in the detailed design phase and so it is important that the macro design is flexible and does not limit scope.

3.4.11 Ensuring that the airspace is configurable in different ways will enable Heathrow to respond to future growth, changing traffic patterns and changing community needs without requiring wholesale redesign of the airspace. As such arrival and departure concepts have been developed in a modular way. This means that different combinations of arrival and departure concepts can be investigated in the detailed design phase.

Unusual and Unplanned Circumstances

3.4.12 The macro design is focussed on normal, undisrupted operations. However, a design optimised for day to day operations is unlikely to also be optimal for dealing with unusual circumstances, for example operation during, or recovery from, extreme weather or volcanic ash cloud events. In such circumstances a different operation may be required which may not fit the macro design described here. Furthermore, a safe operation will need procedures such as those for missed approaches which are unplanned and used by few aircraft. Detailed design for unusual and unplanned circumstances will be considered in the detailed design phase.

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20 This kind of ground operation, where an aircraft heading in a particular direction can only take off from the runway nearest that direction, is referred to as ‘compass departures’. In a compass departure operation, the flights heading north from a southerly terminal are moved to the northerly runway for take-off, while the flights heading south from a northerly terminal are moved to the southerly runway. This means that these flights would cross each other’s path while they are both still on the ground. This can lead to congestion on the ground which has a time, fuel and air quality cost from ground delay. The alternative to compass departures is a ‘terminal departure’ operation, which means these aircraft take off from the runway nearest their terminal and cross over once in flight. This is much more efficient for ground operations but can require a more complex airspace system. Compass and terminal arrivals are the same principle applied to arriving aircraft. Appendix C outlines the Component Identification and Feasibility Assessment work where compass arrival and departures where considered.
Helicopter/drone operations

3.4.13 Potential impacts on helicopter and future drone operations at Heathrow have been considered during the macro airspace design process through a dedicated workshop, and so a broad understanding of the minimum requirements for the helicopter and drone route system have been determined. However, no specific design work has been undertaken on the required route structure; this is to be considered in the detailed design phase and so no description of helicopter routes or drone operations is provided in the macro design.

Integration with the Routes in the Wider UK Route Network and to/from Neighbouring Airports

3.4.14 The macro design has focussed on the Heathrow operation. The Heathrow airspace design must fit within a broader system of ATS routes for neighbouring airports and the UK’s network of routes at higher levels that are managed by NATS. All the ATS routes in the South East of England are subject to review and redesign as a consequence of the CAA’s Airspace Modernisation Strategy. We have a design principle that says “must meet our commitments to the UK Airspace Modernisation Strategy” 21, however, the requirement and constraints of the surrounding route system are not yet known.

3.4.15 NATS and the neighbouring airports are stakeholders in our design process, alongside communities, passengers, airlines etc. and so we expect them to feed back on their requirements as part of our consultation and ongoing stakeholder engagement. The flexibility we are building into our macro design (discussed earlier in this section) aims to provide a basis for finding solutions that will best balance the needs of all our stakeholders, including our operational neighbours.

Air Traffic Control Assumptions

3.4.16 The macro design has been developed through extensive workshop activities involving a range of experts, including air traffic controllers from a range of ATC positions in the Heathrow Tower and the Swanwick Area Control Centre. The result is a set of new macro design concepts (described in the following sections) which have some fundamental differences to today’s operation.

3.4.17 The macro design concepts will be subject to operational testing through a real-time simulation which is scheduled for spring 2019. Detailed operational requirements will be developed for the new concepts following these simulations.

3.4.18 As this macro design involves new methods of operation, the operational requirements identified through the simulation may include brand new working practices and tools. Design to address the operational requirements will be

21 Previously referred to as the UK Future Airspace Strategy.
undertaken as part of the detailed design phase which will follow in 2019 - once the feedback from this consultation has been analysed.

**Departure Macro Design Concepts**

3.4.19 The macro design for departures is based on three concepts:

- Departure Concept 1 – Minimum of three segregated departure routes from each runway
- Departure Concept 2 – Optional additional routes for noise sharing
- Departure Concept 3 – Optional ‘wrap around’ routes for fuel and network efficiency

3.4.20 Each of these is described in the remainder of this section below.

**Departure Concept 1 – Minimum of three segregated departure routes from each runway**

3.4.21 The basic concept for departures aims to provide an airspace structure which would enable all three runways to operate independently, with minimal procedural time or distance intervals between successive departures, and which provides the opportunity for predictable periods of respite through runway alternation.

3.4.22 These aims are achieved by having a minimum of three departure routes from each runway end, and that none of these routes cross in airspace below 7000ft. This configuration means that:

- there is choice as to which route successive departures take (to avoid catch up and the need for longer departure separations).

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22 i.e. a departure from one runway can occur at the same time as a departure on the adjacent runway and equivalent for arrivals
23 i.e. in today’s airspace some aircraft pairs depart with a minute procedural separation. However, others have 2 minutes procedural separation to account for route configurations in which there is a risk of the aircraft behind catching up the one ahead. Our macro design aims to avoid the need for any 2 minute separations. Note that the detailed separation requirements for PBN departure routes are still in development therefore the exact definition of the minimum separation for the range of route configurations has yet to be determined.
24 An additional benefit of ensuring no cross overs is that it avoids the situation where two aircraft flight plans have them heading towards a shared crossing point at a similar time. This would either be managed by ground delay (longer departure separation) or a level off that compromises the continuous climb requirement.
• areas that are impacted by more than one departure route below 7000ft are avoided, meaning that when a route overhead is inactive the respite offered will not be compromised by aircraft on other routes.\(^{25}\)

3.4.23 The runway alternation pattern means that in normal circumstances these routes would not all be active at the same time because at any time one runway would be used for landing. Furthermore, the mixed mode runway would need a minimum of only two departure routes because its departure rate is not expected to be as high as the departure runway.

**Figure 3 – Schematic of the departure route configurations for each of the operating modes**

3.4.24 This concept only determines the minimum number of routes required and the broad areas in which they must be positioned for each runway for the concept to work. As such it leaves opportunities for the detailed design phase to develop detailed design options that meet the range of design principles in different ways.

**Departure Concept 2 – Optional additional routes for noise sharing**

3.4.25 Concept 2 provides further opportunities for noise impact sharing through either respite or dispersion by using additional routes to spread traffic over a wider area.

\(^{25}\) Note that departure routes would also be used as the missed approach procedure (MAP). This means that occasional missed approaches would be seen on these routes during inactive periods. Missed approached procedures are discussed in section 3.7.1
to share noise impacts. These may be different routes for use on different periods, or different routes to spread traffic within a given period. This is shown in Figure 4.

**Figure 4 – Optional additional departure routes for noise sharing**

Concept 3: ‘Optional additional departure routes for noise sharing’ illustration comparing to Concept 1
Example shown is for Westerly operations

<table>
<thead>
<tr>
<th>Departure Concept 1</th>
<th>Departure Concept 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum of 3 departures routes of each runway</td>
<td>Additional route provided for sharing</td>
</tr>
<tr>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>C</td>
<td>D</td>
</tr>
</tbody>
</table>

Note: If used for sharing through respite the additional routes would enable a cyclical pattern. For example this could be that on day one the 3 active routes are A, B & C, on day two they are A, B & D, on day three they are A, C & D, and day four they are B, C and D. This is one example – alternative rotation patterns could also be investigated.

If used for sharing through dispersal all the routes would be active at the same time, spreading flights across 4 (or more) rather than 3 routes.

These diagrams are purely illustrative – route positioning will be established during the micro design phase.

3.4.26 The provision of additional routes for sharing must be considered in the context of the other design principles therefore Departure Concept 2 is taken forward as an option for consideration in detailed design phase, rather than a confirmed feature.

**Departure Concept 3 – Optional ‘wrap around’ routes for fuel and wider en-route network efficiency**

3.4.27 Concept 3 is a further build on Concept 1 to provide opportunities for routes that ‘wrap around’ the departure runway end as they climb. These provide opportunities to address principles to reduce fuel burn/CO2 and maximise operational efficiency. For example, Concept 1 means that an aircraft departing on the southern runway which is ultimately heading north will need to go broadly towards the South/South-West until 7000ft before turning to the north. Concept 3 provides the opportunity for this turn back to occur much earlier – this is shown in Figure 5. The same issues exist in Concept 1 for aircraft wishing to route in a southerly direction form the north-west runway but which must initially head to the North/North-West.
Wrap around routes may also provide options for developing designs that can work in harmony with the airspace modernisation plans being led by NATS and neighbouring airports. This is because getting aircraft heading off in the right direction as early as possible ultimately means that the routes take up less airspace volume overall.

The provision of wrap around routes for fuel and network efficiency must be considered in the context of the other design principles. Therefore, Departure Concept 3 is taken forward as an option for consideration in the detailed design phase, rather than a confirmed feature.

Wrap around routes must be separated from, and not cross the other routes below 7000ft. This means they are only possible off the Southern runway wrapping around to head to the North, and the North-West runway wrapping around to head to the South. They are not feasible from the Central runway.

3.5 **Arrivals Macro Design**

3.5.1 The macro design for arrivals is based on four concepts:

- Arrival Concept 1 – Pure PBN arrivals (only for mixed mode runways)
• Arrival Concept 2 – PBN to xLS\textsuperscript{26}
• Arrival Concept 3 – PBN to xLS with ‘trombone’ and coded shortcuts
• Arrival Concept 4 - PBN to xLS with ‘trombone’ and tactical ATC shortcuts

3.5.2 Before considering each in more detail it is helpful to consider the overall system requirement for arrivals. Like departures, the arrivals system must enable operation in the various mode alternation combinations. This means that during normal operations the system must be able to accommodate:

• the North-West runway in mixed mode, with either the Central or Southern runway operating independently in single landing mode at the same time, and
• the Southern runway in mixed mode, with either the Central or North-West runway operating independently in single landing mode at the same time.

3.5.3 Independent operations for parallel runways require that the approach paths for each runway remain both laterally and vertically separated at all times. We are not considering concepts for normal operations that rely only on vertical separation because this would mean one or both aircraft would not be able to follow a continuous descent which provides an optimised noise profile for arrivals. This is because relying on vertical separation alone would mean one or both aircraft would need a period of level flight, with an associated increase in thrust, at a relatively low altitude before they join the final approach.

3.5.4 Separation is therefore provided through a combination of vertical and horizontal criteria that relies on the navigation accuracy enabled by PBN. This involves one route joining final approach nearer the runway than the other and means that both can plan a Continuous Descent Approach (CDA)\textsuperscript{27}.

3.5.5 When compared to a mixed mode runway, a runway operating in single mode landing will have a higher landing rate. This is because the landing rate on mixed mode runway takes account of the extra time/space left for some departures to take off in between successive arrivals.

3.5.6 Achieving a higher landing rate requires a longer final approach as this gives ATC more space and flexibility to position aircraft efficiently. Given that the single mode landing runway requires a longer final approach than the mixed mode runways, the required separation for independent runway operations will be achieved

\textsuperscript{26} xLS is a term denoting a generic Landing System. At this stage the requirements of the landing system are not yet known so it may be an Instrument Landing System (ILS), a Ground Based Augmentation System (GBAS), Microwave Landing System (MLS) or something else – hence use of the term xLS.

\textsuperscript{27} CDA is a requirement of the Airports NPS and one of Heathrow’s highest priority noise related design principles.
through a later joining point (shorter final approach) on the mixed mode runway. This is illustrated in Figure 6.

**Figure 6 – Route separation example for MLD in Westerly operations**

3.5.7 Figure 7 shows how the combination of shorter and standard final approach legs could form the basis of a respite system based on runway alternation. This is purely illustrative to show how the macro design has flexibility to provide respite. The details of respite schemes will be developed though the DCO – see Runway Operations – Respite through Alternation.

3.5.8 Figure 7 also shows that arrivals for a given runway will only approach from one direction, i.e. arrivals to:

- the North-West runway will always come from the North,
- the Southern runway will always come from the South
- the Central runway will come from either the North or the South – depending on which of the other runways is operating in mixed mode
The remainder of this section provides more detail on each of the arrival concepts.

**Concept 1: ‘Pure PBN’ arrivals**

This is simply a PBN route that delivers traffic in a stream on a consistent track from the wider route en-route network (c.7000ft) down to the runway.

The benefits of this approach are that it is highly predictable, and can deliver flights to a shorter final approach, which provides more opportunities for designs that mitigate noise.

The disadvantage of this approach is that it cannot be used to deliver the full landing runway capacity, because it does not enable the flexibility to optimise the final approach spacing. Therefore, it is only an option for the mixed mode runway because the landing rate on mixed mode runway is lower than for the dedicated single mode landing runway (see paragraph 3.6.5)

It is also not possible to use PBN in low visibility (Category 3) weather conditions. Planning and design for extreme weather will be considered in the detailed design phase.

Multiple PBN arrival routes for noise sharing - either through respite or dispersal – have been considered. This is not a concept in place anywhere else in the world and so remains untested. Furthermore, the macro design process has highlighted some potentially significant operational/safety issues relating to the complexity
they would add to the arrival operation. However, it remains as an option for consideration in the detailed design stage subject to further work to resolve outstanding issues.

**Concept 2, 3 and 4: Arrivals to xLS**

3.5.15 The arrival operation to the main landing runway will need to deliver greater arrival throughput than the mixed mode runway. This requires a degree of flexibility in terms of how aircraft approach and join the final approach, because this flexibility will allow air traffic control to sequence arrivals so that aircraft are optimally spaced to ensure both the safety and efficiency of the runway.

3.5.16 Concepts 2, 3 and 4 offer different opportunities for meeting the range of design principles in different ways. As such they are options that all can exist within one macro system design. For example, different concepts may be used at different times of the day depending on the circumstances, or different combinations may be used over time as traffic grows and aircraft capabilities evolve. Keeping all three options open leaves opportunities for the detailed design phase to develop detailed design options that meet the range design principles in different ways.

3.5.17 The principal difference between Concepts 2, 3 and 4 is the efficiency of each for delivering the required throughput of a single mode landing runway. This is discussed below.

**Concept 2: PBN to xLS**

3.5.18 This concept is similar to the pure PBN approach of Concept 1, except flights are transferred to a final approach landing system (xLS) rather than following a PBN track to the runway. This has limited flexibility in terms of route spacing, and work is ongoing to investigate the efficiency of this method of delivering throughput. Depending on the outcome of this work it may be that its use is limited to periods when landing throughput is not critical, or during Category 3 operating conditions.

3.5.19 Multiple PBN to xLS arrival routes for noise sharing have the same issues as a pure PBN approach – see paragraph 3.6.14.

**Concept 3: PBN to xLS with ‘trombone’ and coded shortcuts**

3.5.20 To provide the flexibility required to maximise landing efficiency on the landing runway it is likely that we will need to use an extended PBN route which has the flexibility to be shortened. This is sometimes referred to as a trombone approach path because it has wide turns that can be shortened as shown in Figure 8:
3.5.21 The trombone is more complex than PBN to xLS because there are multiple shortcut options. A number of systems and operating procedures would need to be adapted to enable this concept.

3.5.22 In Concept 3 these shortcuts would be achieved by using predefined routes that are allocated to the aircraft once the need for a longer or shorter route is known. This will depend on how busy the airspace is and the predictability of the aircraft’s flight through the wider en-route network. This would spread the flight paths to final approach, and while the shortcuts would be pre-determined routes, their allocation would be based on operational need rather than a predictable pattern.

**Concept 4: PBN to xLS with ‘trombone’ and tactical ATC shortcuts**

3.5.23 This is very similar to Concept 3 except that shortcuts are tactical instructions rather than predefined routes. This will be reliant on the judgement of individual Air Traffic Controllers based on information provided by computer-based tools. This has the most flexibility and has similarities to today’s arrival operation – it is a known concept that is in operation at other airports. This means that it has the fewest dependencies for implementation.

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28 As part of the wider modernisation of the UK’s airspace NATS is developing tools that will increase the predictability of flights. These are expected to come on line gradually over the coming decades, which will in turn allow optimisation of local arrival traffic patterns, including more use of fixed PBN routes.
3.5.24 This concept would result in a spread of flights to final approach as illustrated in Figure 9. The spread would be determined by operational need rather than a predictable pattern.

**Figure 9 – PBN to xLS with tactical shortcuts**

These diagrams are purely illustrative – route positioning will be established during the micro design phase.

3.6 **Missed approaches**

3.6.1 A runway in either landing or mixed mode must have a designated PBN missed approach procedure. The macro design accounts for these by having the potential to use one of the departure tracks developed for Departure Concept 1 (or 2) allocated to missed approaches when the runway is in either landing or mixed mode. Because the departures routes are separated from one another, using the same track for a missed approach will mean it is also safely separated from the departure tracks.

3.7 **Macro Design Specifications and Limitations**

3.7.1 The macro design is inherently flexible, as it is designed to provide the underlying structure for routes rather than their detail. However, establishing this structure does mean setting some technical requirements. This section describes the specification for the macro design concept – highlighting minimum requirements, limitations on their application and concepts/design components that have been discontinued.
PBN specification

3.7.2 The arrival and departure routes have been designed to enable simultaneous, or independent, landing or departure on any of the runways. To ensure that aircraft on the routes to/from adjacent runways can be safely separated, this will require a minimum PBN specification of:

- RNP1 + RF for departures;
- RNP AR 0.15 for arrivals with exceptions for the A380 aircraft type which for technical reasons cannot achieve this standard. A380s will be required to meet RNP AR 0.3 and as a result will be restricted in terms of their allocated landing runway in some mode configurations.

3.7.3 Aircraft that are not equipped to these standards will not be able to operate from Heathrow once this design is implemented.

Limitations on multiple routes for spreading and sharing noise

3.7.4 The macro design concept has flexibility to add multiple PBN routes to spread flight paths and share noise - either through respite or dispersal. In practice there will be limitations on the number and location of such routes. The limitations are described below.

Aircraft Flight Management System/Computer (FMS/FMC) capacity limitations.

3.7.5 All current aircraft including those currently on the production line have limited capacity to store route information in their FMS/FMC and the costs of upgrading their FMS/FMC is prohibitive. The number of new PBN routes possible may therefore be limited by the ability to load them into the FMS/FMC database.

3.7.6 The pressure on FMS/FMC capacity is not an issue limited to Heathrow, as the programme of airspace modernisation at other airports (UK and beyond) and in the en-route network above 7000ft all involve new PBN routes and all make similar demands on the FMS/FMC database. An industry wide solution is required to ensure that airspace modernisation and noise mitigation opportunities are not unduly limited by this issue.

3.7.7 We are therefore working with airlines to identify what the FMS/FMC limits are, and whether database management can be made more efficient, but in the short-

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29 For technical background information on PBN specifications see https://www.eurocontrol.int/articles/performance-based-navigation-pbn-applications
30 Note that the amount of data required for coding a PBN arrival route is expected to be much greater than a typical departure route, which means that multiple arrival routes will impose a much greater capacity burden on the FMC than multiple departure routes. Therefore, while FMC capacity will be a limitation on the design of multiple arrival and departure routes for sharing, the limitation on arrival routes is likely to be greater.
Our approach to redesigning our airspace network for an expanded Heathrow to-medium term there will be limitations on route numbers because of FMS/FMC capacity.

**En-route network connectivity limitations.**

3.7.8 Each departure route will need to connect into the airspace above c.7000ft, from where it will join a network of PBN routes that take the domestic flights to their destination airport, or international flights to the UK boundary. The same (in reverse) is required for arrival routes. This wider PBN network for en-route airspace is being designed by NATS as part of the government led programme to modernise UK airspace.\(^{31}\)

3.7.9 These en-route network routes will need to be designed to be safely separated from each other and from those to and from other airports. This means there is a practical limit to the number of connecting routes that are technically feasible in the space available. We are coordinating our changes with NATS as part of the wider UK Airspace Modernisation Strategy, and we are seeking clarification from them on the technical limitation that the en-route network will impose on the number of routes below 7000ft.

**Limitations as a consequence of route interactions below 7000ft.**

3.7.10 The proximity of airports in the London area means that some of our arrival and departure routes will inevitably cross with those of neighbouring airports, before they pass into the en-route network at c.7000ft.

3.7.11 This is a particular issue for Northolt, but also likely to be significant for London City, Gatwick, Luton, Biggin Hill, Stansted and Farnborough routes. All these airports will be re-designing their routes as part of the Airspace Modernisation Strategy. The need to fit in routes for all these airports is likely to limit the space available for our multiple route options in some areas. Accommodating the demand, equitably, for the multiplicity of routes to/from each of the London airports is likely to limit the range of route options that would be available in an unconstrained environment.

**Air Traffic Control complexity limitations.**

3.7.12 Multiple routes increase the complexity of the ATC system. Management of crossing points is a key element of the ATC function. Understanding the geometry of where and how routes cross is part of the controller’s skillset.

3.7.13 Figure 10 illustrates how crossing points increase exponentially with the addition of extra routes. Additional crossing points put more demand on the controller’s

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\(^{31}\) For more detail on airspace modernisation please see [https://consultations.caa.co.uk/policy-development/draft-airspace-modernisation-strategy/](https://consultations.caa.co.uk/policy-development/draft-airspace-modernisation-strategy/)
situational awareness and could introduce the risk that developing aircraft conflicts are missed, or that controller instructions to resolve conflicts are not effective.

**Figure 10 – Rising complexity as a result of multiple routes**

3.7.14 The airspace modernisation programme and PBN will enable a more systemised (computerised) approach to air traffic control, but complexity will remain a limiting factor as an air traffic controller will still require sufficient situational awareness to manually intervene if necessary.

3.7.15 Multiple routes are also likely to add complexity to ATC in the Heathrow Control Tower operation which ensures aircraft take off on the appropriate routes.

**Multiple Routes Summary:**

3.7.16 The next phase for the design process will clarify how the above limitations will limit the capacity for multiple routes at Heathrow. It is inevitable that there will be limits, which mean that choices may need to be made as to where multiple routes can be implemented to best effect.

**Climb Performance**

3.7.17 The fleet operating at Heathrow exhibit a range of climb performance characteristics, influenced by aircraft type, weight (including load factor and fuel load for long haul) and weather. The mix of aircraft may change in the future but the range of performance characteristics that the airspace needs to accommodate will persist.
3.7.18 We are aware from previous engagement that most communities are keen to see increased climb gradients on departures so that they are higher sooner, and therefore overfly fewer people at low altitudes as shown in Figure 11.

3.7.19 Climbing to higher altitudes quickly would also potentially reduce interactions with flights from neighbouring airports and limit the requirement for controlled airspace. This is because aircraft that do not manage to climb above other flight paths that they cross, will often be instructed to level off for a period until they have passed safely, at which point they can resume their climb. Additional controlled airspace at lower levels is required to accommodate flight profiles where such level offs are a possibility. A minimum climb gradient that ensures no levels offs are required therefore helps to reduce the need for controlled airspace.

3.7.20 This points towards the need for a minimum climb gradient as shown in Figure 11. The macro design and associated envelopes are predicated on a minimum climb gradient of 5%. For some flights this may not be the most economical profile resulting in increased engine wear/maintenance costs or limitations on the take-off weight.

Figure 11 – Rationale for minimum climb gradients

The upper graphic illustrates how aircraft take off today with a range of climb gradients, and shows how the minimum altitude of overflight is defined by the lowest climb gradient.

The lower graphic shows how implementing a minimum climb gradient will remove the lowest climb gradients (shown by the grey line marked with 'x') and as a result the minimum altitude of an overflight is higher.
Steeper approaches

3.7.21 The macro design can accommodate a range of steeper approach profiles. The profiles chosen will depend on equipage/certification which will change over time. Final approach profiles of c 3.15° - 3.2° (depending on visibility) are the current assumption for implementation in 2026. This will be clarified in the next phase of design. Investigation into increasing this in the longer term to 3.5° will be undertaken in due course. Gradients of more than 3.5° have been discontinued as part of the component identification and feasibility work on the basis of international research and airspace design guidance.

Segmented approaches

3.7.22 The macro design can also accommodate a range of segmented approach profiles where aircraft descend more steeply in the earlier segment of their approach, before joining the final approach path. However, there are a number of practical difficulties that would need to be addressed, including a lack of formal guidance for their application/assurance/certification. As a result, segmented approaches are not a current assumption for implementation in 2026, but if required for noise mitigation it could remain an option to be considered as part of the evolution of the airspace once implemented.

Continuous Descent Approaches

3.7.23 The practical definition of a continuous descent approach in the UK allows for a level segment of up to 2.5 nautical miles (nm). This is to enable aircraft to stabilise as they establish on the Landing System (xLS) that will guide them to the runway.

3.7.24 The current macro design for expansion assumes that in the future a level segment of up to 2nm will be required for ILS approaches. Not all aircraft will need a level segment, and it will not be required at all for Concept 1 ‘Pure PBN’ approach. However, while the PBN to ILS concept remains an option it is necessary to have this contingency for a level segment built into the formal procedures. This level segment is taken into account in design envelopes which show the worst-case impacts.

3.7.25 We will continue to work with the airlines with a view to reducing this requirement for a level segment in the future.

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**Fuel increase**

3.7.26 The macro design has been developed to achieve the required long-term capacity (with resilience) with maximum flexibility for mitigating noise (including meeting the still to-be-determined DCO requirements for a noise envelope). The consequence is a macro design where flight times and airborne fuel costs may be higher for some flights because:

- the aircraft may take off from, or land on the runway that is most efficient for the ground operation rather than the runway closest to their destination/origin (i.e. a ‘terminal departure’ and ‘terminal arrival’ models);
- the majority of the departure routes climb past 7000ft before crossing each other and heading in the direction of their destination;
- arrivals can only approach the runway from one direction, if this is not the direction they are coming from they will have to fly past the airport in order to get to the start of their approach.

3.7.27 In some cases, this will mean a fuel/time increase on today’s equivalent flights. This could be partially mitigated by:

- continuous climb/descent profiles;
- the ‘wrap around’ routes (see paragraph 3.5.10 - 3.5.13);
- enabling some ‘compass departures’ where aircraft take off from the runway that best suits their destination - compass departures are not as efficient for the ground operation and so opportunities for this mitigation will only exist as traffic grows – once at or near capacity the terminal departure model will be required to maximise runway throughput;
- reduced airborne holding for inbound flights;
- reduced ground delay and fuel burn from terminal departure/arrival operations.

3.7.28 However, the extra fuel cost of this macro design is unlikely to be fully mitigated for all flights given that local capacity and community noise mitigation have primacy in the design objectives for our routes below 7000ft. Some airline fuel costs and average flight times are therefore expected to increase.

3.7.29 A similar issue will exist for arrivals although this will also be mitigated by reduced holding and so inbound flights are less likely to see an overall negative impact.
Weather Contingency for PBN Approaches

3.7.30 Pure PBN approaches cannot be used in all meteorological operating conditions – for example low visibility. Design to deal with this and any other unusual operating circumstance will be undertaken in the detailed design phase.

Helicopter Crossings and Drone Operations

3.7.31 Local helicopter and drone operations for a future Heathrow have not yet been established. Any such local flights crossing the runway will potentially affect runway throughput. Any such effects will be investigated in the detailed design phase, if a requirement for Helicopter crossing or drone operations is confirmed.
# APPENDIX A – GLOSSARY AND ACRONYMS

## Glossary

<table>
<thead>
<tr>
<th>Technical Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design component</td>
<td>A building block for creating macro design options</td>
</tr>
<tr>
<td>Design principle</td>
<td>Guidelines established through a consultation process and approved by the CAA for the creation and evaluation of design options</td>
</tr>
<tr>
<td>Design envelope</td>
<td>A geographical swathe in which a route may be positioned. This swathe will depend on the macro design which defines the airspace structure.</td>
</tr>
<tr>
<td>En-route network</td>
<td>The system of Air Traffic Service routes above the UK</td>
</tr>
<tr>
<td>Landing sequence</td>
<td>This is the order that arrivals are put in prior to landing. This must be managed to ensure that subsequent arrivals are safely separated while also making sure that the separation is not excessive as this would mean fewer landings are possible and that runways are not utilised efficiently. In turn this would lead to more airborne delay for arrivals as they queue waiting for a landing slot.</td>
</tr>
<tr>
<td>Prototype</td>
<td>A system or route definition developed for the purposes of testing a concept, or otherwise informing the design process. Prototypes are not design options.</td>
</tr>
<tr>
<td>Pure PBN</td>
<td>An approach flight path that is defined entirely to a Performance Based Navigation specification, rather than being a mix of PBN and xLS. This is also referred to as arrival Concept 1.</td>
</tr>
<tr>
<td>Macro design concept/macro design</td>
<td>Design of the underlying structure for routes/flight paths. Also includes the conceptual ATC function to operate the routes within the framework structure.</td>
</tr>
<tr>
<td>String</td>
<td>A set of components that together describe an arrival or departure concept. E.g. an arrival concept would consist of a string of components including intermediate approach, final approach, and additional operational concepts for sequencing or delay management.</td>
</tr>
</tbody>
</table>
### Acronyms

<table>
<thead>
<tr>
<th>Abbreviation/Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC</td>
<td>Area Control</td>
</tr>
<tr>
<td>ACA</td>
<td>Airspace Change Assurance</td>
</tr>
<tr>
<td>AMAN</td>
<td>Arrival Manager</td>
</tr>
<tr>
<td>ANPS</td>
<td>Airports National Policy Statement</td>
</tr>
<tr>
<td>APP</td>
<td>Approach</td>
</tr>
<tr>
<td>ATC</td>
<td>Air Traffic Control</td>
</tr>
<tr>
<td>ATCO</td>
<td>Air Traffic Control Officer</td>
</tr>
<tr>
<td>ATM</td>
<td>Air Traffic Management</td>
</tr>
<tr>
<td>ATS</td>
<td>Air Traffic Service</td>
</tr>
<tr>
<td>CAA</td>
<td>Civil Aviation Authority</td>
</tr>
<tr>
<td>CAT</td>
<td>Category</td>
</tr>
<tr>
<td>CDA</td>
<td>Continuous Descent Approach</td>
</tr>
<tr>
<td>CTR</td>
<td>Controlled Traffic Region</td>
</tr>
<tr>
<td>DEP</td>
<td>Departure Enhancement Project</td>
</tr>
<tr>
<td>DMAN</td>
<td>Departure Manager</td>
</tr>
<tr>
<td>DME</td>
<td>Distance Measuring Equipment</td>
</tr>
<tr>
<td>EGKK</td>
<td>Gatwick Airport</td>
</tr>
<tr>
<td>EGLC</td>
<td>London City Airport</td>
</tr>
<tr>
<td>EGLF</td>
<td>Farnborough Airport</td>
</tr>
<tr>
<td>EGLL</td>
<td>Heathrow Airport</td>
</tr>
<tr>
<td>EGWU</td>
<td>RAF Northolt Airport</td>
</tr>
<tr>
<td>eTBS</td>
<td>enhanced Time-Based Separation</td>
</tr>
<tr>
<td>FAF</td>
<td>Final Approach Fix</td>
</tr>
<tr>
<td>FAP</td>
<td>Final Approach Point</td>
</tr>
<tr>
<td>FAS</td>
<td>Future Airspace Strategy</td>
</tr>
<tr>
<td>FASI</td>
<td>Future Airspace Strategy Implementation</td>
</tr>
<tr>
<td>FASI-S</td>
<td>Future Airspace Strategy Implementation - South</td>
</tr>
<tr>
<td>FIN</td>
<td>Final Approach Controller</td>
</tr>
<tr>
<td>FL</td>
<td>Flight Level</td>
</tr>
<tr>
<td>FMC</td>
<td>Flight Management Computer</td>
</tr>
<tr>
<td>FMS</td>
<td>Flight Management System</td>
</tr>
<tr>
<td>GBAS</td>
<td>Ground Based Augmentation System</td>
</tr>
<tr>
<td>GCA</td>
<td>Ground Controlled Approach</td>
</tr>
<tr>
<td>HAL</td>
<td>Heathrow Airport Ltd</td>
</tr>
<tr>
<td>Abbreviation/ Acronym</td>
<td>Description</td>
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<tr>
<td>----------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>HF</td>
<td>Human Factors</td>
</tr>
<tr>
<td>ICAO</td>
<td>International Civil Aviation Organisation</td>
</tr>
<tr>
<td>IFP</td>
<td>Instrument Flight Procedure</td>
</tr>
<tr>
<td>IFR</td>
<td>Instrument Flight Rule</td>
</tr>
<tr>
<td>ILS</td>
<td>Instrument Landing System</td>
</tr>
<tr>
<td>IMC</td>
<td>Instrument Meteorological Conditions</td>
</tr>
<tr>
<td>INT</td>
<td>Intermediate Approach Controller</td>
</tr>
<tr>
<td>IPA</td>
<td>Independent Parallel Approaches</td>
</tr>
<tr>
<td>KTS</td>
<td>Knots</td>
</tr>
<tr>
<td>LAMP</td>
<td>London Terminal Control Airspace Management Programme</td>
</tr>
<tr>
<td>MAP</td>
<td>Missed Approach Procedure</td>
</tr>
<tr>
<td>MOD</td>
<td>Ministry of Defence</td>
</tr>
<tr>
<td>MRS</td>
<td>Minimum Radar Separation</td>
</tr>
<tr>
<td>NATS</td>
<td>National Air Traffic Services</td>
</tr>
<tr>
<td>NDB</td>
<td>Non-Directional Radar Beacon</td>
</tr>
<tr>
<td>NM</td>
<td>Nautical Mile(s)</td>
</tr>
<tr>
<td>PANS-OPS</td>
<td>Procedures for Air Navigation Services - Operations</td>
</tr>
<tr>
<td>PAR</td>
<td>Precision Approach Radar</td>
</tr>
<tr>
<td>PBN</td>
<td>Performance Based Navigation</td>
</tr>
<tr>
<td>PDG</td>
<td>Procedure Design Group</td>
</tr>
<tr>
<td>QNH</td>
<td>Altimeter sub-scale setting to obtain elevation when on the ground</td>
</tr>
<tr>
<td>RAF</td>
<td>Royal Air Force</td>
</tr>
<tr>
<td>RD</td>
<td>Radar Dependency</td>
</tr>
<tr>
<td>RECAT-EU</td>
<td>European Wake Vortex Re-categorisation</td>
</tr>
<tr>
<td>RMA</td>
<td>Radar Manoeuvring Area</td>
</tr>
<tr>
<td>RNAV</td>
<td>Area Navigation</td>
</tr>
<tr>
<td>RNP</td>
<td>Required Navigational Performance</td>
</tr>
<tr>
<td>RNP-APCH</td>
<td>Required Navigational Performance - Approach</td>
</tr>
<tr>
<td>RNP-AR</td>
<td>Required Navigational Performance – Authorisation Required</td>
</tr>
<tr>
<td>RT</td>
<td>Radio Telephone</td>
</tr>
<tr>
<td>RTF</td>
<td>Radio Telephonic Frequency</td>
</tr>
<tr>
<td>SASP</td>
<td>Separation and Airspace Safety Panel (ICAO)</td>
</tr>
<tr>
<td>SBAS</td>
<td>Satellite Based Augmentation System</td>
</tr>
<tr>
<td>SID</td>
<td>Standard Instrument Departure</td>
</tr>
<tr>
<td>SME</td>
<td>Subject Matter Expert</td>
</tr>
<tr>
<td>SOIR</td>
<td>Simultaneous Operation on Independent Runways</td>
</tr>
<tr>
<td>Abbreviation/ Acronym</td>
<td>Description</td>
</tr>
<tr>
<td>-----------------------</td>
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</tr>
<tr>
<td>SOP</td>
<td>Standard Operating Procedures</td>
</tr>
<tr>
<td>STAR</td>
<td>Standard Terminal Arrival Route</td>
</tr>
<tr>
<td>TA</td>
<td>Transition Altitude</td>
</tr>
<tr>
<td>TBS</td>
<td>Time Based Separation</td>
</tr>
<tr>
<td>TC</td>
<td>Terminal Control</td>
</tr>
<tr>
<td>TCAS</td>
<td>Traffic Alert and Collision Avoidance System</td>
</tr>
<tr>
<td>TCAS - RA</td>
<td>Traffic Alert and Collision Avoidance System – Resolution Advisory</td>
</tr>
<tr>
<td>TEAM</td>
<td>Tactically Enhanced Approach Management</td>
</tr>
<tr>
<td>TLPD</td>
<td>Traffic Load Prediction Device</td>
</tr>
<tr>
<td>TOC</td>
<td>Transfer of Control</td>
</tr>
<tr>
<td>TMA</td>
<td>Terminal Manoeuvring Area</td>
</tr>
<tr>
<td>TWR</td>
<td>Tower</td>
</tr>
<tr>
<td>VFR</td>
<td>Visual Flight Rules</td>
</tr>
<tr>
<td>VOR</td>
<td>Very High Frequency Omni-directional Radio Range</td>
</tr>
<tr>
<td>VPT</td>
<td>Visual Prescribed Track</td>
</tr>
<tr>
<td>xLS</td>
<td>X – Landing System</td>
</tr>
<tr>
<td>XMAN</td>
<td>Extended Arrival Manager</td>
</tr>
</tbody>
</table>
APPENDIX B – DESIGN PROCESS ROLES (NAMES REDACTED)
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