Preliminary Technical Overview on Network Air Traffic Management (ATM) Issues and Constraints

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Introduction

A 'Blank Sheet of Paper' Approach to Design

1. Redesigning Heathrow’s airspace for the introduction and operation of a new third runway will involve a number of design stages. We will start with a ‘blank sheet of paper’ then, progressively, move through design prototypes with ever increasing detail, ending with a single final preferred design which will be submitted to the Civil Aviation Authority (CAA) for assessment.

2. This technical document describes work undertaken during the initial, ‘blank sheet of paper’ phase of the design. A blank sheet approach means that we started with no preconceived ideas, constraints or boundaries, and so this initial work has investigated various operational and technical issues to identify the art of the possible.

Design Components

3. We sought to gain an understanding of the technical building blocks which we can use later in the design process when we start developing prototype route systems. These technical building blocks are generically referred to as design components. Design components are complementary to the airspace design principles covered elsewhere in the consultation material (see Heathrow Expansion: Airspace Consultation Document). The principles define the broad criteria that the design aims to achieve, whereas the components are the technical building blocks which can be put together in different configurations to meet the criteria in different ways.

4. Design components include air traffic management (ATM) concepts, systems and characteristics that broadly define how the operational airspace could work. As this is the first stage in the design process it does not represent a final position on the subjects covered. The technical design of the route network for the introduction and operation of a third runway will break new ground in terms of UK airspace design and therefore many of the concepts considered will be developed and assessed further as the design process continues.

5. The work on design components focussed, primarily, on ATM operational and technical issues which might need to be addressed in the later development of prototype systems. The development of prototype systems will also need to consider a range of other factors - such as the benefits and potential effects for communities as well as fuel efficiency, but at this stage in the design process we are investigating each design component in isolation. We will look at the various ways in which they can be combined during the next phase of the design process when we start to put together options for prototype route systems.
Who was involved in this work?

6. This work has involved technical specialists covering a range of disciplines including aircraft and airfield operations, aviation noise specialists, air traffic control, airspace design and airframe performance.

Who is the audience for this document (Tier 3)?

7. This document is provided as background information for a technical audience to demonstrate the breadth of technical considerations for airspace design. It is stressed that at this stage the issues are being addressed in isolation, with a view to discontinuing solutions that are not technically or operationally viable, before prototyping commences.
Final Approach Design Components and Considerations

8. Investigations have been undertaken to identify and assess the operational issues relating to final approach configuration for normal operations. This work is described below.

Potential maximum landing rates

Vectoring to Final Approach

9. Work has been undertaken to consider theoretical landing rates for normal operations considering only the Air Traffic Control (ATC) operational requirements for the approach.

10. Vectoring could, potentially, enable sustainable landing rates of c.39/Hr on 2 of Heathrow’s 3 runways simultaneously, subject to the ‘ICAO SOIR’ criteria and further work on safety assurance. This is, in part, limited by speed adherence.

11. 39/hr gives a theoretical landing rate of c.78/hr considering only the final approach requirements. This is more than sufficient to enable growth as per the NPS and provide resilience/recovery from unusual circumstances that can affect traffic flows, for example, adverse weather conditions.

12. A limiting operational factor may be the ability of the NATS Swanwick sectors to consistently deliver such high numbers of arrivals given the complexity generated by other low-level traffic in the Heathrow Radar Manoeuvring Area (RMA) — this will be considered in later stages of the design process when analysing the outputs from the design principle consultation (see Heathrow Expansion: Airspace Consultation Document).

Vectoring and RNP combinations to Final Approach

13. Vectoring to one runway and utilising an RNP-AR approach for the other is currently estimated to enable a sustainable landing rate of c.63/hr – with 39/hr on the vectored runway and c. 24/hr from a RNP-AR route (this is compatible with the Mixed mode runway operating at full ADA capacity) that could enable arrivals on this runway to operate independently. There is potential for the RNP-AR contribution to increase over time.

14. The number of RNP-AR arrivals possible would be dependent on:
   - sufficient numbers of RNP-AR approved aircraft
   - resolution of resilience issues — in particular those associated with 250ft decision height currently applicable to aircraft on an RNP-AR route which would make it unavailable for use in CAT II/III conditions (CAT I/II/III are international weather-related classifications which define the ‘decision height’ for various visibility conditions, at which aircraft either commit to landing, or commence a missed approach procedure).
   - the development of network airspace and tools to improve the presentation of aircraft from the wider network
• ATCO familiarity with RNP-AR arrival procedure

Heathrow Approach Complexity

Enablers and Mitigatory strategies

15. The following were identified as potential enablers to manage complexity for a future Heathrow approach operation:

- A potential need for a Final Approach Controller (FIN) for each final approach, each with their own frequency
- A potential need for/ability to run a longer final approach than today in order to safely integrate arrivals into the final approach streams to different runway combinations
- The Swanwick sectors and the European network ability to consistently deliver high numbers of arrivals – to be resolved through coordination with the FASI-South development of the network

16. Further work is required to determine the point at which traffic would reach levels that would necessitate the above enablers.

Complexity issues to be managed

17. The following were identified as issues to be resolved to manage complexity for a future Heathrow approach operation:

- The size of a Radar Manoeuvring Area (RMA) could potentially be restricted owing to adjacent airport operations
- Missed approaches in a more complex operational environment both from an ATC and Cockpit viewpoint
- Modality and Runway direction changes - Additional spacing may have to be built in the arrival streams to generate the time to safely switch runway operating modes (either same direction or from easterlies to westerlies). This would potentially reduce capacity for a period when switching runway operating modes for respite, runway inspections or otherwise. This could be mitigated by scheduling runways switches in less disruptive periods.

Pilot Complexity (including Traffic Collision Avoidance System (TCAS))

18. The more predictable and consistent the operation, the easier it is to manage and the safer it is. Pilots regularly commented, during the investigations and workshops, that Heathrow today has one of the most predictable and safest approach operations in the world.

19. Crew need confirmation of the landing runway prior to cockpit before commencing the approach (good practice normally requires this to be at least twenty minutes before final or top of descent). For a late, unplanned runway switch, this confirmation is required by at least 8nm in good visibility and, ideally, before commencing intermediate approach.
20. The proximity of aircraft on parallel approaches could potentially create issues for TCAS depending on airline Standard Operating Procedures (SOPs). SOIR advises to turn off Resolution Advisories; this is done by some operators, but most operators will not do this. There is no evidence of a TCAS issue in current Tactically Enhanced Arrivals Mode (TEAM) operations even during good visibility when spacing can be reduced. This will require further investigation for any combination(s) of parallel approach solutions.

21. The work to date has highlighted no pilot/cockpit complexity issues that are blockers to developing the airspace for a third runway at an expanded Heathrow (3R), but that engagement with airlines and pilot representatives through the design process will be critical to ensuring solutions are operationally viable for pilots.

Tower Air Traffic Control (ATC) Complexity

22. The work to date has highlighted that there are no tower ATC complexity issues that are blockers to developing the 3R airspace, but has highlighted some logistical issues that would need consideration.

23. In particular:

- ensuring visibility to all runway exit points in an expanded operation.
- label clutter on the ATM
- frequency allocation/availability (assuming a dedicated controller for each runway is required).
- the complexity associated with changing operational modes/directional changes in a 3-runway operation

Low Visibility Procedures (LVPs)

24. Today, the whole of Heathrow enters LVPs even if meteorological conditions affect only one runway. With the increase in airport size, an extra runway could increase the likelihood of the airport entering LVPs – future design work should consider the opportunities for a more flexible approach to LVPs.

Flight Management Computer (FMC) Capacity

25. On-board aircraft Navigation Databases/Software are a potential limiting factor due to the low volumes of operational aeronautical data it can hold.

26. This is an airline issue which is wider issue than just 3R; it also affects all organisations involved in the FAS modernisation programme for the UK and, more generally, modernisation of the international ATM network. As such, it may even limit the number of additional routes that could be implemented for operational purposes, or for respite and/or dispersal. Further work to understand the limitations and their implications will be undertaken in the next phase once design principles, and the requirements for additional routes, have been established.
Steeper Approaches

27. A technical review of steeper approach options has been undertaken and described below.

General ATC/Pilot Considerations Including Speed Adherence

28. There are potential issues with achieving consistent speed control at the 4DME marker including and in particular the timing of the reduction from 180Kts to 160Kts which can affect spacing accuracy and resultant workload for ATC. This is one reason why the average peak landing rate is c.39 hr when + 44/hr is achievable but not always sustainable in today’s ATM environment.

29. Inside 4nm (5nm for the A380) speed control reverts to the pilot to manage, not ATC. Aircraft need to be stable, at their landing speed, by 1000ft (c.3nm). This doesn’t give much time to transition from 160Kts to their required landing speed.

30. This is a very critical stage of flight with high workload for both Pilot and ATC. Even subtle variations to the basic straight-in 3° final approach has consequences to workload:
   - the effect of wind speed and direction on the aircraft;
   - the energy management of the aircraft;
   - the ability to adhere to ATC speed instructions;
   - the accuracy of final approach spacing; the ability to accept a tailwind component,
   - the landing flare and Runway Occupancy Time (RoT).
   - engine braking and braking to vacate management

31. If the final approach design does not provide sufficient flexibility to account for these factors, the result is likely to be a reduction in landing rates.

32. Variations to final approach vertical angles and lateral paths may require different, or a mix of different landing aids/technologies may add to the complications of this already critical phase of flight. Certain approach types (especially PBN applied ones) are also reliant on aircraft equipage, airframe and crew certification.

33. Mixing different types of approach may also increase ATC complexity and have the potential to impact workload, capacity and throughput.

3.0° Glide Path and approach angles

34. All aircraft that use or plan to use Heathrow are capable of a 3° Instrument Landing System (ILS) approach. Not all such aircraft are equipped with RNP APCH (RNAV Approach) – Heathrow’s current RNP APCH equipage is c.86% although this is expected to be closer to 100% by 2025.

35. Doc 8168 PANS-OPS states CATII/III approaches can only be performed on approach angles up to 3.0°.

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1 Not to be confused with RNP-AR
36. CATII/III approaches are achievable via ILS, MLS or GLS (GBAS CAT II/III not yet certified but could be anticipated within the 3R time frame).

Up to 3.2° Glide Path and approach angles

37. Doc 8168 PANS-OPS says CATII/III states that any approach angles greater than 3.0° should be for obstacle avoidance only. However, it is becoming widely acknowledged that approach angles of up to 3.2° have minimal impact on airline and ATC operations in normal (CAT I) conditions. Heathrow have run two successful trials operating 3.2 RNAV approaches and we have approached the CAA with request that they consider whether to use the trial output to pursue an amendment or exception to the PANS-OPS criteria mentioned above.

38. Subject to Landing Distance Available (LDA) and differences to PANS-OPS and ICAO, approach angles of up to 3.2° in CATII/III conditions could also be acceptable without any negative operational impact (see next section). No noteworthy operational issues have been identified during Heathrow’s ongoing 3.2° Slightly Steeper Approach trial.

3.2° to 3.49° Glide Path and approach angles

39. Once the angle increases above 3.2°, it may become more difficult to maintain a constant approach speed. Many things including speed and aircraft energy management, manual flare, ability to accept a tail wind component and the ability of the pilot to take in all the necessary information including visual references can be more difficult to achieve as the approach angle increases from their norm. For the manual flare, it is first a matter of descent rate rather than approach angle e.g. a 3.0° approach angle with a strong tail wind increases the descent rate.

3.5° Glide Path and approach angles and above

40. Single European Sky ATM Research (SESAR) 06.08.08 suggests approach angles of up to 3.5° are ‘manageable’ but higher than 3.5° are much more difficult to manage (aircraft energy and flare manoeuvre management). Note that in this context, the report is talking about individual landings and not referring to sustaining a high intensity runway operation.

41. Doc 8168 PANS-OPS states that the maximum approach angle for a CAT I precision approach is 3.5° (3.0° for CAT II/III). It also says that ‘Glide path angles above 3.5° should be used in approach procedure design only for obstacle clearance purposes and must not be used as a means to introduce noise abatement procedures.’

Approach Angle Summary

42. Doc 8168 PANS-OPS requirements are:
- No CAT II/III above 3.0°
- No CAT I above 3.5°
- No ILS angles greater than 3.5° for Noise Abatement only
- The minimum/optimum descent gradient is 3° for a precision approach (or approach with vertical guidance). Descent gradients steeper than the optimum should not be used unless all other means to avoid obstacles have been attempted.

43. From a regulatory standpoint, ICAO does not currently support angles of approach steeper than 3.0° for CAT II/III. 3.0° is the operationally known ideal to cover all aircraft in all weather conditions.

44. 3.2° is therefore an achievable minimum angle for CAT I approaches into an expanded Heathrow with three runways, subject to CAA approval and suitable safety assurances.

45. From an operational standpoint, for CAT II/III approaches the angle may be limited to 3.15° because of equipage/certification. Fleet capabilities at/beyond 2025 will determine what is achievable for the design of steeper approaches for 3R, however, by 2040 it is considered reasonable to attain 3.5 degrees – we will continue working towards this for CAT III, but this is dependent on manufacturer certification and airline uptake.

46. Consideration would also need to be given to approach angles of 3.0° in certain circumstances, if it enabled a significant benefit elsewhere (e.g. this could be where a lower approach angle enabled a departure route to climb above the arrival stream rather than being held down by it) or if it may be needed in certain circumstances to generate height differential between adjacent approaches for separation purposes.

47. 3.5° approaches for CAT I conditions are PANS-OPS compliant and will be considered. Assessment will have to consider the potential for an increase in RoT and missed approaches, which, in turn, could lead to a reduction in landing rate.

**Segmented approach design (with segment angles above 3.5° to a final angle of 3.2°)**

**Regulatory**

48. The transitions from the steeper to shallower approach angle should be no later than 1500ft. The shallower angle should not exceed the maximum permissible by ICAO, or UK regulator for CAT I, or CAT III final approaches for the reasons outlined above.

**Trials**

49. Heathrow, together with NATS and BA, gained agreement from the CAA for 10 test flights to investigate technical issues associated with segmented approaches. These identified 1500ft as the optimum point to transition which was at approximately 5nm from touchdown. A 1500ft transition to the shallower angle can be achieved by raising of the aircraft nose to reduce its decent rate and speed. This could result in quieter approach due to the idle thrust descent, not like todays CDA
which requires thrust. This was considered to be close to an optimal noise performance, but not necessarily the optimal operational performance.

50. An angle greater than 4.5° would not be advisable as it would become extremely difficult to lose the speed at the transition point in time for landing.

51. Importantly, a segmented approach would require the aircraft to be back at c.160Kts prior to starting the approach as there is no capacity to reduce speed on the steeper segment.

Practical considerations

52. The main issues surrounding segmented approaches are:

- How to design them/what type of approach
- Potential guidance mode changes required by crew
- Impact on Standard Operating Procedures (SOPs)
- Speed Management
- Airline authorisation and associated aircrew licencing may be required before any aircrew would be allowed to fly a segmented approach. This would depend on the angles utilised.

Segmented Approach Design/Equipment and procedures

53. There are currently no PANS-OPS criteria for segmented approaches upon which to base segmented approach design. Criteria for applying a segmented approach in an airspace design for a third runway would need to be developed as part of the ongoing design process, if segmented approaches are identified as part of the noise mitigation package.

54. The system requirements for a segmented approach have been considered. A single ILS system is only capable of one approach angle and therefore is not an option for a segmented approach.

55. A segmented ILS approach based on two ILS systems is possible but would require a mode/frequency change by crew. This would be a considerable addition to crew workload. Moreover, avionics systems may not cope with such a tuning change during the approach without prohibitive impacts e.g. Guidance mode reversion. A two ILS solution is, therefore, not a favoured option for defining segmented approaches, should they be required.

56. A single GLS ground station is capable of broadcasting multiple Final Approaches Segments and approach angles, however they would be classified as different approach procedures and again require a GLS tuning (channel, new approach) change by crew with resulting additional workload and avionics/cockpit impacts. A GLS solution is, therefore, not a favoured option for defining segmented approaches, should they be required.
57. The test flights discussed in the previous section (para.50) were undertaken using RNP APCH Baro-VNAV criteria, which demonstrated that these criteria can be used to develop segmented approach procedures.

58. RNP APCH with LPV minima (down to 200ft) are discarded as the FAS data block can only code a single 3D segment (i.e. a single approach angle). From an avionics perspective, they are treated like the ILS or GLS e.g. the FAS Data Block only encompasses the final shallow approach segment. Moreover, LPV approaches are not a practical solution for segmented approach due to extremely low SBAS equipage.

59. A Baro-VNAV segmented approach would generally be the simplest from a pilot perspective on most aircraft types. However, the Baro-VNAV procedure is susceptible to the effect of temperature variation. The higher the temperature the steeper the approach angle. A segmented Baro-VNAV approach, with challenging approach angles, would therefore change slightly day to day due to temperature variation which adds an additional complexity into the cockpit.

60. To overcome the 250ft system minima issue associated with Baro-VNAV RNP APCH, another option may be RNP or potentially even RNP APCH to xLS but this requires a guidance mode change (VNAV to Glide Slope capture and more crew workload). Additionally, some avionics designs are not compatible with this type of transition.

61. A RNP APCH Baro-VNAV is a potential option for defining segmented approaches, should they be required, however, this would only be possible in CAT I or better.

Potential mode changes required by crew for Baro-VNAV to xLS operation

62. Mode changes on final approach have the potential to be problematic. The approach phase of flight generates high cockpit workload and mode changes could influence the possibility of both human error and, to some extent, unpredictable aircraft behaviour.

Speed management and runway throughput

63. Segmented approaches may increase the difficulty for ATC in delivering the approach spacing on a single mode arrivals runway. One concept could be to set spacing achieved further up the approach, with all aircraft set at 160Kts at the appropriate distance apart. This would require modifications to the currently utilised TBS (Time Based Spacing) systems with new algorithms to account for the steeper/changing angles and effects of the different winds.

Special authorisation required

64. PANS-OPS design criteria do not exist for segmented approaches and FMS logic differs between suppliers. Operators may therefore require specific operational approval to fly such potentially challenging approaches, such as the case at London
City\(^2\). For this reason, they may not be viable for routine 24/7 operations but could be flown by approved operators at specific times.

**How steep is too steep?**

65. At some point the speed management of the aircraft will require more drag and will increase noise and/or distribute the noise differently.

66. The steeper the approach angle, the greater the possibility that the aircraft will need to reduce speed by lowering the landing gear (if not already), deploy more flaps/slats (if not already) or, finally, deploy the speed brake - all of which generate more and/or move the noise generated and potentially impact fuel efficiency and related emissions.

67. Further work is required to identify the point at which a steeper approach becomes too steep, such that noise and emissions impacts from speed management outweigh the benefit of aircraft being higher for longer.

\(^2\) London City does not have a segmented approach but a single 5.5° glide path which requires individual operator approval.
Departures - Operations and Separations

Departure Separations in normal conditions

68. Investigations have been undertaken to identify and assess the operational issues relating final departure separations for normal operations. This work is described below.

Navigation Specification

69. The higher the navigation specification, the greater the ability to offer solutions for capacity, safety, respite or environment. However, not all aircraft have, or can be economically equipped to, the highest currently available specifications.

70. By 2025, it is anticipated that the clear majority of Heathrow’s airlines will be equipped up to and including RNP1+RF (or A-RNP). Data suggests current Heathrow RNP1 equipage of c.82%3 (RF capability unknown).

71. The higher specification of RNP-AR potentially opens the possibility of much more accurate use of Vertical Navigation (VNAV) for departures. The criteria for RNP-AR, which would provide even better lateral containment of departures is still in development, however, it will likely require operators to demonstrate that they can achieve the required gradients even with One Engine Inoperative (OEI). This gives assurance that those aircraft will make the gradient required and, in a complex and highly systemised airspace environment, could be critical.

72. The ‘AR’ necessitates aircraft capability and both airframe and crew certification. Heathrow currently has over 80 airlines with many crews likely to only fly to the airport a handful of times per year. This crew variation will potentially increase as the number of flights/operators increase.

73. For airlines, a considerable amount of crew training as well as investment in on-board equipment will be necessary if RNP-AR is used. Requiring all crews and airframes to be RNP-AR capable and approved would be costly, and could generate significant complexity for crew rostering.

74. Current data suggests Heathrow RNP-AR equipage of only c.8-10%. Note this figure is equipage/capability and not necessarily operating approval. While this figure is low, this functionality should not be discounted as the Best Equipped, Best Served ethos could still provide benefit (this is covered in one of our proposed design principles - see Heathrow Expansion: Airspace Consultation Document).

Complexity of Solution(s)

75. Complexity in the route system, in terms of the number of routes and potential interactions may impact ATC workload and situational awareness. This can, potentially, limit capacity and have safety implications. Furthermore, increased

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3 Eurocontrol Flight Plan PRISME Data Jan-Dec 2016
route complexity to provide respite or dispersal in one area may generate adverse noise impact through concentration in other areas.

76. The higher the complexity, the greater the requirement for tool support and conformance monitoring and the greater the reliance on Industry (NATS/HAL/Aircraft manufacturers and Airlines) to deliver technical solutions. Additional external dependencies, for example iTEC4 and conformance monitoring tools over and above the existing requirement for LTMA-wide Airspace Change, will add more risk to the Future Expansion Programme.

77. Examples of such tool support requirements are:

- ATC Conformance Monitoring and Alerting of aircraft adherence to departure SID routing and vertical/lateral/longitudinal profiles. Note that in a Terminal Departure mode, there may be a higher dependency on this type of functionality than compared to a Compass Departure Mode (see next section).

- Longitudinal Departure Separations. RECAT-EU5 pair-wise separations and Reduced Divergence Departures (RDD)6 are expected to require additional tool support for the Departure Controller.

78. Limiting complexity will be a consideration in all future designs, but it is not possible to measure complexity with a single metric and so this will remain a largely subjective part of the design process, relying on ATC inputs to come to a considered view.

Compass versus Terminal Departures

79. Fundamentally, there are usually two modes of operation for managing the departures across the airfield and in the air: ‘Compass Departures or Terminal Departures’.

80. A purely ‘Compass’ departures mode of operation is when any aircraft departing on a Northbound route (heading 271° through to 090°) would depart from the northern most runway in operation and any aircraft departing on a Southbound route (heading 091° through to 270°) would depart from the southernmost runway in operation. A more flexible compass mode would be to segment these compass heading swathes according to departure demand, i.e. if there are two thirds of the flights heading south then the northern runway may also be used for more flights heading towards the east or west (e.g. heading between 225° through to 135°) and the southern runway reserved only for those heading south (e.g. heading between 135° through to 225°).

81. A ‘Terminal’ departures mode of operation is when an aircraft departs from the runway nearest the stand/terminal it has been parked at, so that an aircraft heading south may depart from the northern runway if it happens to be the closest to its

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4 A new flight data processing system being implemented by NATS and several European partners
5 http://www.eurocontrol.int/articles/recat-eu
6 Safety assurance work that enables less than 45° divergence between departures whilst still catering for 1-minute departure intervals.
stand. Likewise, a northbound aircraft may depart from the southern runway. This is more efficient for the ground operation but does mean that if two such aircraft take off at similar times they must be crossed over once airborne: where this crossover occurs requires is part of the design criteria.

82. Compass Departures make the airspace design and Air Traffic Management more achievable and have potential noise/CO2 benefits. However, it would have negative impacts to the ground operation - increasing complexity and taxi-times on the ground (which in turn can affect noise and local air quality) and will also negatively affect runway throughput if runway crossings are required.

83. Terminal Departures are the opposite; shorter taxi times, reduced runway crossings and lower complexity on the ground but may require more complex airspace design which could limit airspace capacity and may decrease environmental efficiencies in the air (e.g. low altitude level-off and increased track miles required to enable crossovers).

84. Both terminal and compass departures are to be investigated further but it is likely that the solution will be a hybrid which balances the workload, complexity, and environmental impacts between both Ground and Air. Technical considerations of such a hybrid solution will include:

- mature Terminal and Runway scheduling tools,
- accurate Target Start up Approval Times (TSATs) / Off Block Times (OBTs) and Ground Movement Control,
- a flexible Airfield Infrastructure (for example, Code F Taxiways around the end of runways),
- an optimised airspace design to the highest navigation specification practical,
- advanced ATC conformance monitoring tools combined with a highly systemised airspace operation, at least in the vicinity of Heathrow Airport but most likely well into the wider ATM network.

FMC Capacity

85. FMC capacity would potentially be a limiting factor on the number of routes that can be implemented for operation, respite or dispersal reasons. This is a worldwide airline issue that is outside the scope of Heathrow expansion to resolve. This is described in more detail in the arrivals section (para. 25+) above.
**Airspace Systemisation**

86. A technical review of airspace systemisation requirements to support a future Heathrow airspace design has been undertaken and described below:

**Overview**

NERL and the south-east airspace

87. NATS En-route Limited (NERL) currently operates under licence and that requires the organisation to ensure the safe and expeditious flow of traffic through UK airspace. The licence is based on the principle that NERL will manage the competing demands for airspace on a broadly first come, first serve basis and that all aircraft operators should be offered fair and equitable access (within safe and practical limits).

88. In busy areas of the network like the London Terminal Manoeuvring Area (LTMA), air traffic control (ATC) must currently intervene tactically on a regular basis to de-conflict traffic in the same volumes of airspace and deliver on the terms of the NERL licence. Tactical intervention is workload intensive and limits airspace capacity – it is broadly accepted that the wider airspace system in the south east of England is reaching the capacity limit achievable with the current system which relies on tactical intervention.

89. To deliver the required throughput from a new runway at Heathrow alongside the expected growth at other London airports, it is also broadly accepted that the UK’s airspace management will need to move away from the tactical system.

**Airspace Systemisation and FAS**

90. The alternative is ‘Airspace Systemisation’. This is the term used to describe the introduction of new route structures that are designed, as far as practically possible, to procedurally de-conflict inbound and outbound traffic flows to/from multiple airports with minimal tactical intervention. The CAA’s future airspace strategy (FAS) is based around the concept of airspace systemisation, and all major UK airports and NATS are committed to realising FAS as part of a modernisation programme to bring the UKs airspace infrastructure up to date.

91. While systemisation has many benefits, an airspace systemisation design that fully de-conflicts all future LTMA traffic flows with minimal tactical intervention would be impossible to achieve without some flight paths becoming less than optimally efficient.

92. This means that although the overall capacity, efficiency and resilience of the network is envisaged to increase significantly with airspace systemisation, some airspace users (and the airports that serve them) may experience a net reduction in environmental performance in certain areas of their operation.

93. Systemisation, and the reconfiguring of LTMA airspace to accommodate it, will directly affect other airports in the south east and, potentially, also impact other
airspace users such as MoD, General Aviation, and aircraft operating from the many small local airfields in the South East.

94. Finding the right balance between meeting the UK economic need for a growing aviation sector, alongside the individual needs of airports, airlines, MoD, GA and other aviation groups will be a key part of the ongoing design process. Furthermore, systemisation has a potential local environmental impact, some perceived as positive and some as negative, which is also a key consideration.

95. There will inevitably be differing views on what is determined to be optimal design, and so introducing systematisation in Heathrow’s airspace and beyond will require Government and the CAA to provide clarity their expectations for trade-off decisions where network optimisation, environmental performance, other airspace users and the broader national interest are concerned.

Systemisation Manager (SYSMAN)

96. Tool support for systemised airspace will be required to accommodate the growth in traffic from 3R (alongside expected growth at other London Airports). NATS in partnership with SESAR are developing such a tool for deployment in the wider UK route network – this is called SYSMAN and is expected to be operational before 3R. It will use data from airport and ATM systems to monitor demand on airspace routes; it will automatically take appropriate action where excess demand exists to ensure a smooth flow of traffic with minimal intervention.

97. SYSMAN is required to de-conflict traffic departing from busy airports within TMAs. This airspace will become ‘Systemised Airspace’ using PBN to reduce the need for controller intervention. Although the airspace structure will reduce the number of conflicts that require tactical intervention, tool support is required to ensure peak demand on busy routes is effectively managed. SYSMAN will complement Heathrow’s Airspace Capacity Management and Queue Management tools to achieve this.

98. SYSMAN will use data from AMAN/DMAN/EFPS systems where available to monitor demand on routes within the airspace. This data will enable an early assessment of airspace demand to be made before aircraft start-up. In the first iteration, the tool will be capable of suggesting a resolution where excess demand exists. This may involve re-ordering departures or using alternative airspace options such as offload SIDs. The early presentation of data will ensure airport TSATs remain stable and airlines can plan an alternative SID earlier.

99. As the concept matures the SYSMAN tool will eventually be capable of sending by data-link, clearances to aircraft to ensure they are separated from other aircraft, further reducing controller workload per aircraft and therefore enabling the growth required by future Heathrow.

Mode S SFL

100. Systemisation will require the strict adherence of aircraft to defined vertical, lateral and longitudinal profiles, known as ‘Trajectories’. It is likely that advanced controller
tool support will be required which can automatically monitor aircraft’s adherence to a trajectory which may include a requirement to verify an aircraft’s immediate intention.

101. Currently, an aircraft selected level is one of the parameters that is downlinked via Mode S and displayed to controllers which provides them with the ability to challenge any observed variation with their ATC clearance. This downlinked level is derived from the aircraft’s Mode Control Panel (MCP) which, in many cases is the final cleared level on an Instrument Flight Procedure (IFP), with confirmation of intermediate steps being given verbally over the RT.

102. In a highly tactical environment, instructions are given verbally by air traffic control, and likewise confirmed back verbally by the pilots. In a highly systemised environment which requires automated conformance monitoring verbal confirmation is both time consuming and would not directly feed into ATC systems. Consequently, short term conflicting alerting systems could potentially be triggered falsely, generating ‘nuisance’ alerts. This is not a limiting factor but does require further work to ensure appropriate PBN coding and FMC operation to meet the requirements for airspace systemisation.

This further work is being progressed by NATS as part of the wider modernisation programme for the UK.
ATM review of CAP1378 on Noise Mitigation Solutions

Overview

103. The CAA document CAP1378 Titled “Airspace Design Guidance: Noise Mitigation Considerations when Designing PBN Departure and Arrival Procedures” presents potential concepts for the design of PBN routes to mitigate noise impacts.

104. The concepts presented in CAP1378 report have been reviewed by operational experts to identify where there may be ATM constraints which affect their feasibility for an 3R airspace.

105. Note that no judgment was made on the environmental merits of each option. This will be inferred from the design principles questions (see Heathrow Expansion: Airspace Consultation Document).

106. Note that flexibility in the final route positioning will be a major part on the success of any of the CAP1378 concepts in terms of avoiding population or other noise sensitive areas. This flexibility will, amongst other things, depend on safety assurance requirements, the PBN specification, associated PANS-OPS design criteria and integration into the wider network all of which will need detailed consideration as the design process matures.

107. The result of this work is described below. CAP1378 provides descriptions and diagrams for each concept which are not repeated here – it is recommended that readers refer to CAP1378 alongside the assessments presented in this section.

FMC Capacity

108. Note that FMC capacity, as described in the arrivals section above, would be an issue for any solution where there is a significant increase in the number of PBN arrival or departure routes.

Departures

109. This section describes the initial consideration of CAP1378 design options relating to departures.

SID replication

110. It is not always possible to exactly replicate conventional SID centreline via PBN due to the CAA and PANS Ops regulations. It is known that exact replication is not possible for a number of Heathrow’s existing SIDs. This is because the current extant PBN regulations include some restrictions/assumptions on design criteria that have not historically applied to conventional SIDs (e.g. turn radius and segment length limitations). Furthermore, many of the existing conventional SIDs were
originally designed decades ago with reference to a fleet mix with different performance capabilities.

111. Furthermore, the existing SIDs may not leave space for routes or missed approach procedures from a new NW runway, and so the resultant design of any new routes/procedures could be constrained. If this proves to be the case it would not be possible to build an operationally, or noise efficient airspace design for the NW runway around wholesale replication of the existing SIDs.

112. While this would limit wholesale replication it would not preclude the new design having some replicated SIDs as part of the solution.

113. Complete replication of existing SIDs has therefore been discounted as a basis for 3R. This does not preclude replication of some individual SIDs if deemed appropriate.

PBN SIDs that avoid population density below 4,000ft, below 7,000ft and above 7,000ft

114. This depends on the number of SIDs required as a baseline for a three-runway operation to deliver the required 3R departure schedule. The higher the number of SIDs and spread of departures required in the broad/baseline design, the lower the flexibility to avoid populations. Because routes are expected to diverge to some degree the available room will increase (through simple geometry) further along the route as aircraft climb away for the airport. This means that, considering only the Heathrow routes, it will generally be easier to avoid populations under the latter part of the routes where aircraft are at higher altitudes, and more challenging to do so nearer in at the lower altitudes.

115. Interactions with routes to and from adjacent airfields will potentially limit climb profiles and lateral tracks in places – this may impact the ability to be flexible to avoid populations or achieve other noise related design principles.

116. The lower the number of initial departure tracks from each runway the more flexibility there will be in their positioning which could help achieve some of the noise related design principles. Reduced departure intervals along the same initial departure tracks would be an enabler for a reduced number of departure tracks.

SID constrained by existing Noise Preferential Routes (NPRs)

117. Being constrained to stay within all existing NPRs would result in the difficulties outlined in the SID replication section above.

118. Furthermore, opportunities for effective respite routes may be limited if routes heading in the same direction are limited to be within the same NPR corridor (i.e. a single 3km corridor rather than a new NPR for each respite route). This would be
the case if the separation required for effective respite is greater than what is achievable in a single 3km corridor.

119. A review and potential relocation of the NPRs will be part of a later design phase for an expanded Heathrow.

SIDs from adjacent runways that merge as soon as possible after departure

120. If both the routes were in operation at the same time ATC could not depart aircraft on the two routes simultaneously because the tracks merge (please refer to the diagram in CAP1378) and, therefore, aircraft would not be safely separated. In the case of any busy departure route this is likely to be an unacceptable restriction on runway throughput.

121. However, it would be possible to have this configuration if the routes were in operation at different times.

122. In general, this means that this configuration is not appropriate for a terminal departure design where the routes would be in operation simultaneously, but would be an option for a compass departure design where one of the routes would be the primary route, and the second a contingency only to be used when the main route/runway was unavailable.

Respite SIDs that merge with the primary route at 4,000ft, at 7,000ft or above 7,000ft

123. This depends on what distance is required between routes and the number of SIDs required as a baseline for a three-runway operation to deliver the required 3R departure schedule. The higher the number of SIDs and spread of departures required in the broad/baseline design, the lower the amount of space/flexibility to add in additional respite routes. Because routes are expected to diverge to some degree the available room will increase further along the route as aircraft climb away for the airport. This means that, considering only the Heathrow routes, it will generally be easier to add respite routes to the latter part of the routes where aircraft are at higher altitudes, and more challenging to do so nearer in at the lower altitudes.

124. Noise propagates further laterally with aircraft height and this may be lead to a mitigation to have higher routes further apart to provide effective respite.

125. More detailed analysis of this option from CAP1378 will be undertaken in the next phase of design, taking into consideration the design principles established following this consultation, and ongoing work to define respite being reported through the Heathrow Community Noise Forum (with results to be reported in 2018).
126. Interactions with routes to and from adjacent airfields will, potentially, limit climb profiles and design profiles in places – this may also impact the ability to fit in additional respite routes.

127. The lower the number of initial departure tracks from each runway, the more flexibility there will be in their positioning and so greater the ability to add in respite options. Reduced departure intervals along the same initial departure tracks would be an enabler for a reduced number of departure tracks, and therefore indirectly the ability to provide respite options at lower altitudes in the vicinity of the airport (as discussed in the previous section relating to PBN SIDs (para. 115+) that avoid population density).

128. Complexity is also an issue with multiple respite options. This may be exacerbated by runway mode switching which adds complexity to the operation. This is because runway mode switching would mean that ATC would already be required to develop situational awareness for a number of different runway and related route configurations. The addition of respite routes as an extra set of variables may constitute an extra layer of complexity on top of this. Therefore, there is likely to be a trade-off between provision of respite through runway switching and the ability to have multiple route options.

Offload SID which re-joins other SIDs after passing 4,000ft or 7,000ft.

129. It is not technically possible for an aircraft to depart on one SID and then be tactically switched to another when above a certain altitude. This is because of flight planning issues and high cockpit workload of switching SIDs mid-flight.

130. This concept would therefore need a completely new SID which follows an existing route until 4,000ft or 7,000ft and then routes towards the appropriate network link route.

131. This concept was considered possible although more likely to be feasible outside of peak periods due to complexity and potential runway throughput issues.

Multiple SIDs for traffic dispersal below 4,000ft, below 7,000ft or above 7,000ft

132. A random allocation to achieve a spread of traffic was considered technically possible, although the issue of available space that would limit the number of respite routes (as described above) would equally apply here also.

133. There would also be several Human Factors issues to address. In the Tower, it is likely that tool support would be required if different SIDs have different departure separations, as this would ensure that ATC apply the appropriate separation.
134. Multiple SIDs with random allocation would increase the risk of crews selecting incorrect SIDs. Further work into migrations for crew error would need to be undertaken should multiple SIDs be developed.

Arrivals

135. The greater the number of PBN routes and the greater the restrictions imposed on ATC to adhere to that PBN route structure, the greater the likelihood of less accurate final approach spacing leading to a reduction in landing rates. CAP1378 provides descriptions and diagrams for each concept which are not repeated here – it is recommended that reader refer to CAP1378 alongside the assessments presented in this section.

Single PBN arrival routes to replicate or minimise population overflown

136. 740K ATMs would not be possible if this was the sole approach method for the main landing runway (see earlier section on landing rates). However, it is feasible and could have a place in the final design/operation during times of lower demand.

Single PBN arrival routes with vectoring allowed

137. There are no significant operational issues with this kind of design. The flexibility to be able to vector will be essential to provide efficient spacing and sufficient throughput. Such vectoring would provide some dispersal in the base leg and join point.

Two PBN arrival routes for different times

138. Having more than one PBN route in operation at different times is also operationally feasible. However, there would be potentially significant Human Factors issues to address and chances of crews selecting incorrect PBN routes. Should this occur it could lead to poorer spacing, predictability and CDA compliance, or at worst safety issues. Further investigation into whether these issues could be sufficiently mitigated would be required if this option is to be considered further.

Multiple PBN arrival routes, one to be used at a time

139. Such a concept would see several routes to a runway, alternated through planned rotation. In principle, this is feasible subject to all the comments above. The greater the number of routes and frequency of alternation, the increased likelihood of human factors issues for controllers and pilots leading to poorer spacing, predictability and CDA compliance, or at worst safety issues. Further investigation into whether these
issues could be sufficiently mitigated would be required if this option is to be considered further.

140. A high number of available arrival routes could have flight planning and fuelling implications although these weren’t considered to be insurmountable. The more significant issue was that of a lack of predictability.

**Multiple PBN arrival routes for managed dispersion**

141. This option is not considered appropriate for a Heathrow operation because a degree of vectoring will be required to ensure efficient spacing on the final approach. A schedule that cycles through a number of fixed routes would not allow this flexibility.

142. Theoretically, ATC could tactically switch between arrival routes to pick and choose to enable more accurate spacing. However, as this choice would be tactical, with little or no notice, it is expected to be unachievable from a flight deck workload perspective.

143. If the goal is to create swathes of aircraft to replicate today’s vectoring, then the operational solution would be continuing to vector arrivals as this is also optimal for spacing.

**Vectoring areas**

144. Not a PBN concept but still a potential noise mitigation measure and one which has been previously trialled at Heathrow, where ATC were required to keep aircraft on base-leg to a defined area. This is operationally feasible.
Ground Airspace Special Visual Flight Rules (SFVR) Low Level Interactions

Overview

145. An initial review of the likely SVFR low level interactions was undertaken. The result of this work is described below.

146. This work has focused only on the nature of the likely interactions, rather than specific airspace requirements. Subsequent detailed design work will identify CAS requirements, which will identify where additional CAS may be required and where existing CAS may no longer be required. HAL will seek the minimum airspace required to meet the operational and environmental objectives of the third runway.

Helicopter (Heli) Routes

147. H2 is the most affected route, and crossing three runways would be very challenging. There could be an option for predicted timings for the use of the Heli routes during certain Ops – westerly versus easterly for example.

148. H3. Current restrictions, during easterly operations, of H3 traffic versus super heavy departures would also have to apply for the new runway.

149. H4, H5 & H7 no expected impact.

150. H9 North/South would be in closer proximity to the new northern runway and its operation would be affected by all arrivals, departures and missed approaches. The current reporting points at Sipson and M4 J4 would need to be moved further North.

151. H10, a review of the height restrictions between Brentford and Kew Bridge would be required against any new departures and approaches.

152. Northolt Heli Operations will continue to use the existing Heli route structure and IFR procedures and so we do not expect any direct impact.

VFR Transit Routes

153. All VFR Transit routes between Thorpe Park, Ascot, Burnham and Denham would have to be assessed against procedures for easterly arrivals and westerly departures/missed approaches.

154. VFR Transit route between Battersea and Brent – no impact.
ATZ and LFA

155. The White Waltham ATZ definitions would need to be assessed in the design for any new approach procedures to, or appropriate SID climb gradients from the new runway.

156. Fairoaks LFA – the climb gradient of any new or revised Heathrow departures to the south is to be considered against Fairoaks.

157. Brooklands LFA, as above and note that Brooklands are understood to be planning a new grass runway.

Other

158. Restricted Areas – no impact

159. Inner Area of the LCTR - a change in the NW quadrant of the inner area near Iver to accommodate arrivals, departures and missed approaches from the new runway end in that vicinity would need to be assessed.

160. GA infringements – changing the shape or segmentation of the Heathrow Zone depending on ops may impact GA infringements (Positive or negative impact)

161. Air Ambulance/ etc – changes to procedures and the zone would need to be highlighted to relevant operators. A three-runway operation will make integration of these operators a more complex task.

162. North of M4 procedures - the procedure will need reworking as would no longer be deemed separated due to the location of the new runway.

163. Royal Flights – similar to the M4 procedure comment above, only flights to Windsor Castle affected.

164. Non-standard Flights - their acceptance and operation would need careful consideration by GS airports for integration into the three-runway operation and airspace.

165. Heli Aiming Point on the ground at Heathrow Airport – A northern HAP may be required due to complexity of crossing Helicopters during three runway ops.

166. London City Flight Calibrator – a similar but more complex task to accommodate during three runway ops, the procedures to accommodate this would need to be reviewed.

167. Farnborough Flight Calibrator - see comment above.

168. Private Landing sites – some landing sites within the inner area may be less accessible and will require a higher workload to handle.