ANNEX D TO PIR REPORT DATED APRIL 2017

ROUTE 4 RNAV 1 SID (26 May 16) ASSESSMENT

Abbreviations/terminology:

DER Departure End of Runway (normally the end of the physical length of the runway)

WP (flyover) Waypoint (flyover means that the aircraft will fly over the position of the waypoint before turning to intercept the next segment of the procedure)

WP (flyby) Waypoint (flyby means that the aircraft will anticipate the turn before the waypoint to allow tangential interception of the next segment of the procedure)

Path Terminator Is a set of defined codes, each of which defines a specific type of flight path and a specific type of termination of that flight path. Examples of these in the Route 4 SID are course to fix (CF) and track to fix (TF).

The coding that is used within the Flight Management System (FMS) to capture the defined path and which is stored in the navigation data base is reflected through an Industry standard called ARINC Specification 424. The current version is ARINC 424-20, although earlier versions are still employed in many navigation data bases with varying functional capability. RNAV 1 defines a subset of functional blocks termed as 'Path Terminators' for use in design of instrument flight procedures. In this way, all RNAV 1 qualified aircraft are capable of executing leg transitions and maintain tracks consistent with ARINC 424 path terminators. The required path terminators for RNAV 1 are:

- Initial Fix (IF)
- Track to Fix (TF)
- Course to Fix (CF)
- Course from a Fix to an Altitude (FA)
- Direct to a Fix (DF)

Although RNAV 1 defines the above Path Terminators, only a subset has been used in the designs for the London Gatwick RNAV 1 SIDs. Those used are described as follows:

Track to Fix (TF)

A TF leg is defined as a geodesic path between two fixes. The first fix is either the previous leg termination or an IF leg. The termination fix is normally provided by the navigation database, but may also be a user-defined fix.

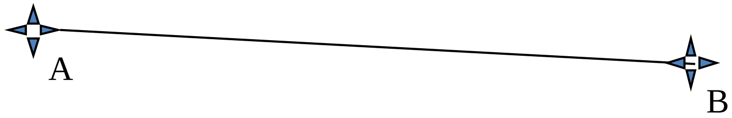

Figure 3 Track to Fix (TF) Leg

Path: Geodesic Path between A and B with Termination at Fix B

Course To Fix (CF)

A CF leg is defined as a geodesic path that terminates at a fix with a specified course at that fix. The inbound course at the termination fix and the fix are provided by the navigation database. If the inbound course is defined as a magnetic course, the source of the magnetic variation is needed in order to convert magnetic courses to true courses.

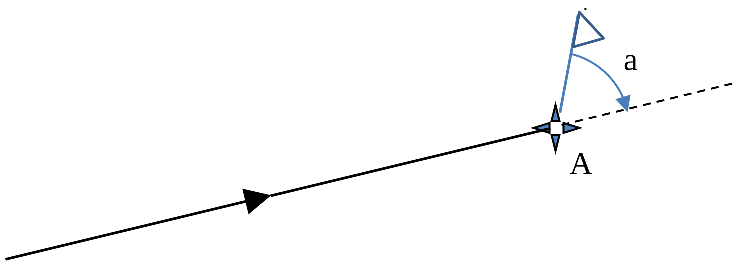

Figure 4 Course to Fix (CF) Leg

Path: Geodesic Path to Fix A with Inbound Track "a" with Termination at Fix A

Track Dispersion Is where the flights tracks over the ground of a procedure are varied due to differing aircraft types, operator standard operating procedures (SOPs) and wind conditions as examples. Track dispersion tends to spread the noise over a wider area.

Track Concentration Is where the tracks over the ground are concentrated on predictable flight paths. Concentration of tracks can allow for noise sensitive areas to be avoided but it is not always possible to avoid all populated areas.

SID Nominal Track (NT) The nominal track is the intended track to be flown as shown on the procedure chart used by flight crews. The adherence to this published nominal track will vary in accordance with how the procedure has been designed to achieve either dispersion or concentration of flight tracks.

Airport / SID Designator: Gatwick Rwy 26 RNAV SIDs: LAM2X, BIG2X, CLN4X, ADMAG2X[1]

Baseline: The baseline for the Gatwick Route 4 SID is that our assessment of revisions to Route 4 are derived from the CAA's letter to GAL on 23 May 2016, namely that the new RNAV SID should be a satisfactory replication of the re-aligned corrected conventional SID.

GUIDE TO TRACK DISPERSION AND DENSITY DIAGRAMS

Attached to this document are the track dispersion and density plots which have been provided by GAL. These are similar to those shown in the original CAA PIR report for ease of comparison. To fully understand this review, readers will have to view the track dispersion diagrams which are associated with the descriptions of track dispersion, track density and altitude band diagrams.

The explanations of track distribution are described using references to locations shown on the diagrams to help to describe impacts of the RNAV1 SID replications. For traffic samples used to illustrate impacts in 3 altitude bands (4-5000ft, 5-6000ft, and 6-7000ft), these are for a one week period in July 2016. These altitude plots illustrate when aircraft reach the relevant altitude band and are used to illustrate the flight paths flown by both the conventional departures and RNAV1 departures when they are at and above 4000ft and illustrate the dispersion of traffic, where they are remaining on the SID without radar vectoring and where aircraft are being vectored.

[1] Since RNAV SIDs were introduced in November 2013, the Dover SID was renamed ADMAG and truncated by 33NM.

Track dispersion diagrams portray each aircraft track on a map, based on radar data. Tracks are overlaid upon each other, such that if many tracks are overlaid on top of each other, individual tracks may no longer be visible. They are useful for illustrating the dispersion of the traffic pattern, but are not as useful for determining the density/concentration of tracks.

Track density diagrams portray the concentration of flight tracks using a colour code to indicate differing concentrations of flight tracks. They are sometimes referred to as "heat plot" diagrams. Whilst they can be used to illustrate traffic dispersion, they are most useful for illustrating if traffic is concentrated along a route or over a geographic location. Depending on the key used for portraying track concentration, individual tracks towards the outer limits of the dispersion may not be visible on the diagram.

In order to illustrate how we have arrived at our decision, we have also included a diagram of the proposed revised conventional SID corrected for magnetic variation. This is a draft of the chart which will be incorporated into the UK AIP – see Annex C.

GUIDE TO OUR ASSESSMENT OF MODIFIED ROUTE 4 SID (26 MAY 2016)

In the Table 1 below, for analysis purposes, we have divided the analysis of the track dispersion of the modified RNAV SID design into three segments:

- Segment 1 is from take off to approximately the Rusper / Newdigate minor road, i.e. the initial "straight-out" segment, before the turn.

- Segment 2 is from approximately the Rusper / Newdigate minor road to a position just to the west of the A217 between Horley and Reigate, i.e. the 180° turn.

- Segment 3 is from a position just to the west of the A217 between Horley and Reigate extending eastwards, i.e. the eastbound track after the turn.

The CAA reviewed 6 months of traffic dispersion plots from 26 May to 26 November 2016; however, to simplify this report, we are just referring to the Gatwick track dispersion plot from July 2016 as this has proved to be the busiest month for Route 4 movements since implementation of the revised RNAV SID on 26 May 2016. During July 2016, it should also be noted that Runway 26 was used for 30 days of the month due to the prevailing westerly winds.

The CAA feels that the traffic patterns displayed for July 2016 are consistent with the traffic patterns for the other months since May 2016. It should also be noted that on certain days, strong winds prevailed from the south west which tends to cause 'ballooning' of aircraft outside the limits of the NPR swathe particularly around the second half of the turn; this may be evident from the July plots, however, this is more apparent when viewing the daily plots for this month, and indeed other months when such winds prevail. All these daily data plots are available on the CAA website which will demonstrate the effects of stronger winds from the south to south-west.

All data received from Gatwick for the remaining 5 months, will also be included on the CAA website to show the complete data received for this PIR.

In this assessment we refer to a number of diagrams supplied by GAL for the period of July 2016. These are:

- Track dispersion plots up to 3900ft amsl.
- Track dispersion plots at 4000ft amsl.
- Track Density diagrams.
- Altitude band track dispersion plots for a selected week in July in the bands:
  - 4000-5000ft
  - 5000-6000ft
  - 6000-7000ft.

In Table 1, we are showing our assessment of the modified RNAV 1 SID.

- Column 2 describes the relevant segment of the SID design, with an approximate geographical description.
- Column 3 shows the design path terminator used in the design.
- Column 4 describes what track keeping is expected from the corrected conventional SID, i.e. whether concentration or dispersion is expected.
- Column 5 describes a vertical profile comparison between the modified RNAV 1 SID and the corrected conventional SID.
- Column 6 is a qualitative description of the track-keeping of the modified RNAV 1 SID (traffic pattern) & comparison to the corrected conventional SID.
- Column 7 is a qualitative comparison of modified RNAV 1 SID traffic pattern with the traffic pattern from original RNAV SID (2013) and the traffic pattern from original conventional SID still in operational use.
- Column 8 indicates whether the expected track-keeping has been achieved.
- Column 9 indicates whether the SID is being flown correctly by operators and whether the design is acceptable.
- Column 9 indicates whether the CAA considers that the environmental impact of the SID design is acceptable based on the 6 months review of data supplied by GAL.

The PIR analysis team has compared the impact of the modified RNAV1 SID replication (26 May 2016) with the corrected conventional SID design using a number of traffic samples. From the July 2016 sample shown with this analysis, in Table 1, we indicate the characteristics of the RNAV track dispersion as a result of the RNAV1 SID replication and whether the anticipated impact has been realised.

We are comparing the actual traffic pattern displayed by the modified RNAV 1 SID against the traffic pattern which would be expected from the corrected conventional SID (this SID has yet to be approved and implemented). Our description of this comparison is set out in column 6 of the Table 1 below. We can do this because we know that the modified RNAV1 SID design is based on how the extant conventional SID has been coded by various aircraft operators' database coding houses. Also the review of the conventional SID took into account that originally the easterly track of the SID was based on the NPR and the SID has been amended to achieve this requirement.

In the modified RNAV 1 SID, the first waypoint (KKW02) is a flyover waypoint, followed by a path terminator which is a 'course to fix' (CF) to the next waypoint (KKE09). This design results in dispersion around the first turn with the aircraft establishing on a track to intercept the eastbound track of the RNAV SID design towards the next waypoint KKE09. This has the same characteristic as the extant conventional SID and also, the corrected conventional SID.

The difference between the tracks of the extant conventional SID and the corrected conventional SID is that there has been a slight change in the eastbound track of one degree. This means that the new track of the corrected conventional SID will result in departing aircraft flying along the NPR centreline towards the Detling VOR flying along the Detling radial of 259 degrees magnetic which is slightly further south than the currently published conventional SID track of 260 degrees magnetic towards position Acorn, then Detling.

As the eastbound track of the modified RNAV SID will take aircraft to waypoint KKE09, this positions aircraft back onto the centreline of the NPR after the first turn. We are therefore able to determine that the modified RNAV 1 SID track will have the same characteristics of dispersion followed by gradual concentration towards KKE09 which is equivalent to the extant conventional SID track towards ACORN. Once the corrected conventional SID is approved and implemented, the modified RNAV SID will also have a very similar distribution of flight tracks as the corrected conventional SID along the NPR centreline. The charts at Annex A and Annex C below help to demonstrate the similarities of the modified RNAV 1 SID and the corrected conventional SID:

In Table 1 Column 6, the comparison is the basis on which we decide whether or not the modified RNAV 1 SID has met its objective. In Column 7, we are describing the traffic pattern displayed by the modified RNAV 1 SID in terms of the traffic patterns displayed by the original RNAV 1 SID and then the extant conventional SID. This second comparison is for descriptive purposes only.

Table 1 – CAA Assessment of the Modified Route 4 RNAV 1 SID

Serial **(1)**	**Segment / Stage / Phase of SID & Waypoint** **(2)**	**Path Terminator Employed** **(3)**	**Expected Track Keeping Performance Criteria (Dispersion or Concentration) [this is a description of what we expect the traffic pattern to be from a corrected conventional SID]** **(4)**	**Vertical Profile Description – comparison of modified RNAV SID to corrected conventional SID** **(5)**	**Qualitative description of the track-keeping of the modified RNAV SID (traffic pattern) & comparison to corrected conventional SID** **(6)**	**Qualitative comparison of modified RNAV SID traffic pattern with:** **1. Traffic pattern from original RNAV SID.** **2. Traffic pattern from original conventional SID** **(7)**	**Track-keeping Achieved?** **If No, (List deviations from nominal track of SID with explanation and provide evidence)** **(8)**	**SID Flown Correctly by Operators If no provide details** **SID Technical Design Acceptable (Yes/No)** **(9)**	**Environmental Impact as Expected (based upon Column 6) (Yes/No)** **(10)**
1	DER-WP 1 (Flyover) (**KKW02**) (Take-off – straight ahead) segment to WP1 The Rusper/ Newdigate Road	Course to Fix (CF)	**Concentration.** Vast majority of traffic to be closely aligned with the SID nominal track (i.e. a high degree of concentration). This is because ac are climbing to a flyover WP (KKW02). This segment is the first stage of the SID and most traffic will be below 4,000ft as they fly this segment. Therefore we expect no evidence of tactical vectoring (unless required for safety reasons).	The vertical profile is unchanged up to KKW02 due to obstacle and noise abatement requirements. Aircraft have not reached 4000ft amsl by KKW02.	The departures are concentrated on the centreline of the SID to KKW02. Some aircraft do appear to be turning prior to KKW02. Note: some aircraft are not bound by NPR noise abatement procedures – see Note 8 of EGKK AD 2.21. This is the traffic pattern that we would expect from the corrected conventional SID.	1. The traffic pattern in terms of concentration is the same as was evident from the original RNAV SID up to KKW02, except that, in the original RNAV design, aircraft were flying slightly further west before commencing the turn. With regards to altitude of aircraft, some evidence of a small number of aircraft just above 4000ft before turn commences. 2. The traffic pattern in terms of concentration is the same as was evident from the original conventional SID up to	Yes	Yes	Yes

Serial (1)	Segment / Stage / Phase of SID & Waypoint (2)	Path Terminator Employed (3)	Expected Track Keeping Performance Criteria (Dispersion or Concentration) [this is a description of what we expect the traffic pattern to be from a corrected conventional SID] (4)	Vertical Profile Description – comparison of modified RNAV SID to corrected conventional SID (5)	Qualitative description of the track-keeping of the modified RNAV SID (traffic pattern) & comparison to corrected conventional SID (6)	Qualitative comparison of modified RNAV SID traffic pattern with: 1. Traffic pattern from original RNAV SID. 2. Traffic pattern from original conventional SID (7)	Track-keeping Achieved? If No, (List deviations from nominal track of SID with explanation and provide evidence) (8)	SID Flown Correctly by Operators If no provide details SID Technical Design Acceptable (Yes/No) (9)	Environmental Impact as Expected (based upon Column 6) (Yes/No) (10)
						KKW02. No evidence of aircraft below 4000ft before commencing turn.			
2	WP1 to WP2 **KKW02** to **KKE09** WP2 is Flyby First Turn 180° (wrap-around) Newdigate/ Rusper road to a position just west of the A217 Horley to Reigate Road	Course to Fix (CF)	**Dispersion.** As the design of this procedure is such that ac fly to a flyover WP (KKW02) before turning, then follow a SID design path terminator of a 'CF' to the next WP (KKE 09), this means that there will be expected dispersion around this segment. A 180 degree turn will therefore result in a wide dispersion unlike concentration which is expected in the first segment. For a conventional SID that matches the	The vertical profile is unchanged to KKE09 which is due to obstacle and noise abatement requirements.	The departures are dispersed across the centreline of the SID after passing KKW02 to such an extent that they are widespread across the swathe of the NPR. However, the is a greater concentration of traffic on the western half of the NPR swathe than on the eastern half. The majority of traffic appears to be within the NPR swathe, around the entirety of the turn but evidence of a small number of aircraft beyond the western limit of the NPR swathe. The number of aircraft displaying these wider	1. The traffic pattern in terms of concentration is different to the original RNAV SID up to KKE09. Traffic is dispersed across the width of the NPR swathe, whereas in the original RNAV design, traffic was more concentrated around the turn albeit it having a wider turn radius resulting in flight outside the western extremity of the NPR swathe. In the revised RNAV design, there are less aircraft outside the extremity of the NPR swathe below 4000ft amsl.	Yes. **Remarks:** Some A/C "ballooning" in the turn, due excessive speed as a result of tailwinds. and/or A/C cutting the corner on the inside of the NPR, due operator SOPs.	Yes	

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			existing NPR, we would still expect the majority of traffic to be within 1.5km either side to the SID NT if they are below 4,000fin line with the dispersion achieved with the existing conventional SID (this is because of how the conventional SID has been coded by data base coders resulting in the dispersion seen with the conventional SIDs). Therefore, the degree of dispersion is not intrinsically different to what would result from a conventional SID. For aircraft that are at or above 4000ft on this segment, we would anticipate some tactical vectoring which means that there will be evidence of aircraft tracks no longer		turns increases on those days when strong winds from the south to southwest prevail. This is particularly evident on 1st, 9th, 10th, 11th and 20th July 2016. Some aircraft do appear to be turning prior to KKW02 and are therefore evident outside the NPR swathe but inside the turn. As traffic completes the turn and flies towards KKE09 the pattern shows that the concentration of traffic converges back towards the SID centreline, in alignment with the NPR. There is evidence that some aircraft are being tactically vectored, taking them south of the centreline of the SID. This starts to become	Tactical radar vectoring at and above 4000ft is occurring further south than was the case with the original RNAV SID. With regards to altitude of aircraft, most aircraft on the original RNAV SID were above 4000ft amsl by KKE09; this remains evident in the revised design. Note: It is important to note, than it the comparison sample there were 2538 flights in June 2014, whereas in July 2016, there were 4795 flights The traffic pattern in terms of concentration is the same as was evident from the original conventional SID up to KKE09 except that on the inside of the turn, more			

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			aligned with the SID NT. For this segment on Route 4, we would expect a large proportion of aircraft will have achieved an altitude of 4,000ft by the time they complete the turn. In days when there are strong south westerly winds, we would expect to see aircraft flying outside the NPR swathe (previously termed "ballooning" in the PIR report), because aircraft will pick up extra ground speed with the additional tail wind component. This will then cause the flight track of aircraft with a groundspeed in excess of the max 220KIAS to deviate from the NPR swathe where pilot		apparent after passing South Holmwood in the turn and before passing south of Leigh. Most, if not all aircraft are above 4000ft by the time of reaching KKE09. This is the traffic pattern that we would expect from the corrected conventional SID.	traffic is further east towards and directly over Newdigate. Note: It is important to note, than it the comparison sample there were 2727 flights in July 2013, whereas in July 2016, there were 4795 flights With regards to altitude of aircraft, most aircraft on the original conventional SID were above 4000ft amsl by KKE09; this remains evident in the revised design.			

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			intervention has not occurred.						
3	WP2-WP3-WP4 **KKE09** to **KKE11 to KKE15** WP3 is Flyby From the A217 towards the east	Track to Fix (TF)	**Dispersion / vectoring / some concentration.** For this segment of Route 4, most aircraft will be at or above 4,000ft. Therefore, we would expect track-keeping to show evidence of tactical vectoring, but also some concentration for those aircraft which have not been vectored from the SID. That concentration is expected to be closely aligned to the nominal track of the corrected conventional SID. For descriptive purposes, we would expect to see	The vertical profile is unchanged from KKE11 which is the same as the extant conventional SID.	After passing KKE09 (approximately the A217), there are three apparent elements of track dispersion. The majority of traffic on this segment is above 4000ft and may legitimately be vectored off the SID and are not deemed to have contravened the NPR requirements. The first element appears to be aircraft being vectored to the north side of the SID (NPR), the second element appear to aircraft remaining on	1. The pattern of traffic concentration and dispersion is similar to that displayed for the original RNAV SID, but the key difference is that the revised traffic pattern is displaced further south with the main core along the SID (NPR). This displacement is approximately 1.5km to the south. 2. The pattern of traffic concentration and dispersion is comparable to the conventional SID with two key differences. These are: (1) Whilst both SIDs	Yes, other than when radar vectored.	Yes	

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			aircraft returning to the NPR (centreline) unless they have been vectored. Expectation would be as aircraft proceed further east, there will be more vectoring and therefore a lower proportion of flights would remain on the SID NT.		the SID which is aligned with the NPR, and the third element appears to be aircraft which are being vectored towards the east (south of the SID (NPR) centreline. In the first element, this represents a low percentage of the total departures which tend to fly directly over the areas of South Earlswood, Whitebushes and South Nutfield tracking towards Hurst Green, then further to the north east. In the second element, there is a clear continuing concentration of traffic above 4000ft on the SID (NPR) towards Salfords and South Godstone, then further to the east .	show a degree of concentration of traffic that remains on the SID, the revised RNAV SID shows a greater degree of concentration than the original conventional SID. (2) The revised traffic pattern is displaced further south with the main core along the SID (NPR). This displacement is approximately 800-1000m to the south.			

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					In the third element, there is a distinct pattern of aircraft being vectored towards the east directly over the areas of Outwood, Blindley Heath towards Edenbridge. The volume of traffic in this third element is greater than in the first element. As can be seen from the altitude band plots, most aircraft are at or above 5000ft by the end of the NPR (approximately Outwood), but also, a significant number are at 6000ft or above by the A217.				