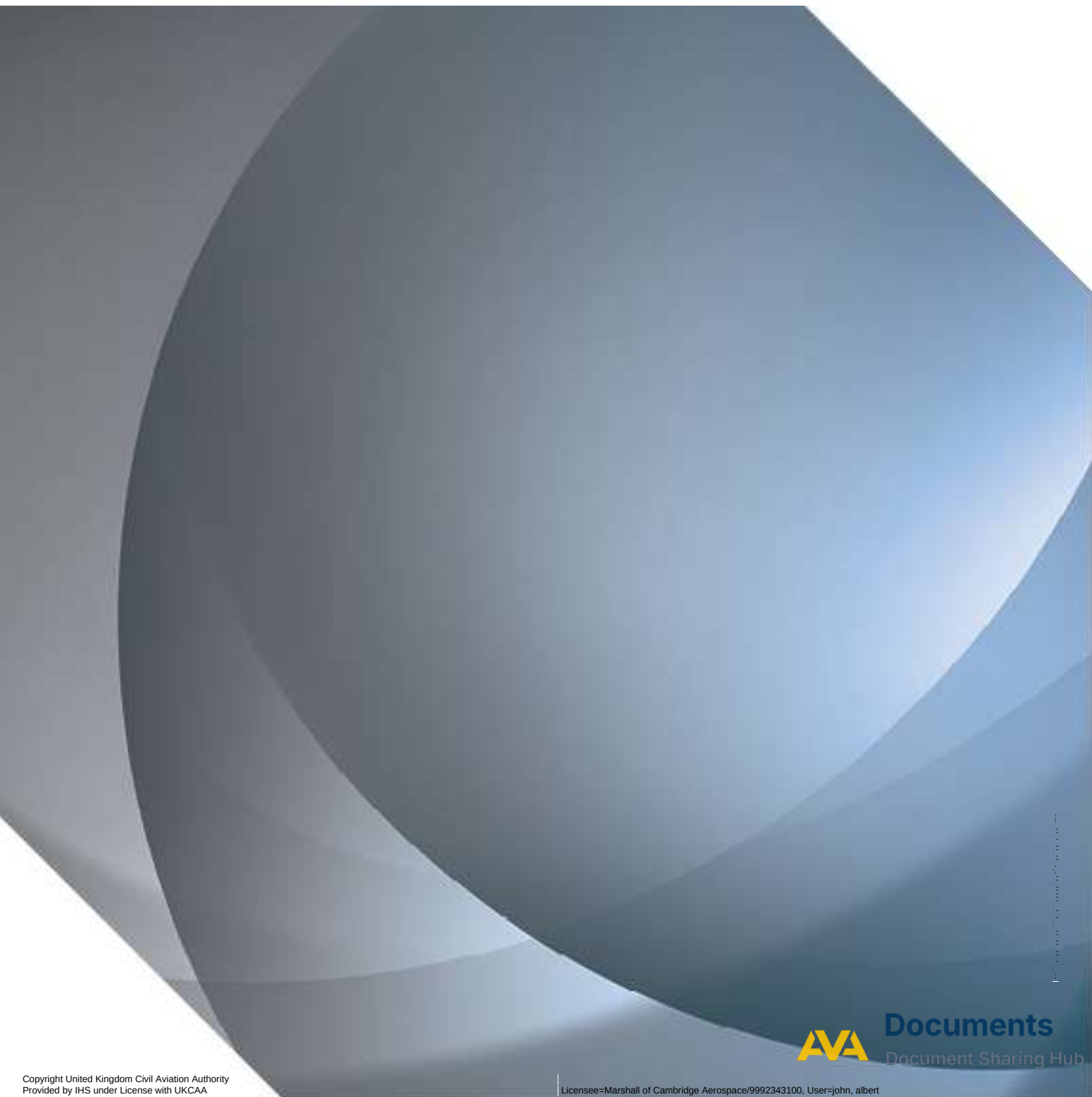


Report of the CAA's Post Implementation Review of the implementation of RNAV-1 Standard Instrument Departures at Gatwick Airport

Annex 6: CAA IFP Recommendations report

Annex 6 to CAP 1346



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CAA IFP Recommendations report: Implementation of RNAV-1 SIDs at Gatwick Airport

The remit of the P-RNAV SID trial which commenced in 2007

- 1 The SID trial related to four conventional SIDs that had been redesigned using P-RNAV design criteria. The P-RNAV SIDs were designed to replicate the nominal track of the conventional SIDs with the advantage of additional waypoints to assist with NPR compliance.
- 2 The four P-RNAV SIDs that were the subject of the trials were:
 - Runway 26L CLN 8M (P-RNAV SID Designated CLN 2X) (one of the Route 4 SIDs)
 - Runway 26L SAM 2M (P-RNAV SID Designated SAM 1X) (one of the Route 1 SIDs)
 - Runway 08R SAM 3P (P-RNAV SID Designated SAM 2Z) (one of the Route 3 SIDs)
 - Runway 08R SFD 8P (P-RNAV SID Designated SFD 2Z) (one of the Route 2 SIDs)

PBN SID replication

- 3 Note: Since the designs of the trial SIDs have been in use, and the full suite of RNAV-1 SIDs were subsequently implemented in November 2013, a Performance Based Navigation (PBN) SID replication policy has been developed and published on the CAA website:
<http://www.caa.co.uk/application.aspx?catid=33&pagetype=65&appid=11&mode=detail&id=5728> This policy states that the definition of a PBN SID replication is:

“The design of an RNAV or RNP procedure that follows the path over the ground of the nominal tracks of the existing conventional procedure as closely as possible”. *Note: it is the path over the ground of the designed conventional procedure and not the nominal centreline of the associated NPR or the current traffic concentration.*
- 4 Following the publication of the PBN SID replication policy, it was recognised that when replicating the track of certain departures, the replication may not reflect the historical track of the conventional SID.
- 5 In some circumstances circumstance magnetic variation has caused unintentional changes to conventional SID tracks flown compared to the nominal track of the conventional SIDs. Designing RNAV-1 SIDs to replicate the tracks currently flown on

the conventional SIDs could lead to a permanent and unintentional location of the nominal tracks of RNAV-1 SIDs. (See Route 4)

- 6 Therefore, when designing RNAV-1 SIDs, the design should reflect an RNAV design which produces a track over the ground which is as close as possible to the designed nominal track of the conventional SID.

Gatwick Trial P-RNAV SID Revisions

- 7 As part of the routine maintenance of instrument flight procedures, aerodrome obstacles surveys are required in order to ensure the data used to inform designs is accurate and up-to-date. Therefore when the trial of the P-RNAV SIDs was completed and prior to the SIDs being promulgated in the Aeronautical Information Publication (AIP), data from the 2012/13 Gatwick aerodrome obstacle surveys highlighted some anomalies associated with the elevation values for the departure end of Runway 26 and some new obstacles affecting the climb gradient. Consequently, the RNAV designs were modified to accommodate these revised criteria. In most cases this resulted in a minor change in climb gradients and consequently in vertical profile for the Runway 26 SIDs. This had little or no impact on the lateral parameter. Full detail of these changes and the rationale for the chosen altitude constraints are explained in detail in Appendix A at the end of this report.

Technical Analysis and Design Recommendation of the Gatwick Airport Standard Instrument Departures (SIDs)

General

- 8 In the Gatwick Airport operating environment, the majority of the aircraft fleet are large air transport types with multi-sensor navigation systems with both GNSS and radio updating of aircraft position supplemented by Inertial Reference System (IRS).
- 9 It is noted that the conventional SIDs as published in the AIP are being flown by operators with the aid of an RNAV coded overlay. This is a navigation database coding that is not provided by the State and is where the normal RNAV design criteria rules are not necessarily applied when aiming to provide a replication of the conventional procedure which is then used as a navigational guidance tool for flight crew. Different operators are likely to be using different overlay coding versions depending which navigation database provider supplied the database and coding therein. This variation is likely to add to the spread of tracks when operators are cleared by ATC on a conventional departure. The parameters that can be varied in the coding are the use of waypoint type (i.e. Fly-over or Fly-by), waypoint position, path terminator and use of speed restriction any or all of which could be tailored for an individual operator or fleet type and FMS. Therefore any conventional procedure that is replicated using RNAV design criteria and a navigation database coding

provided by the CAA and published in the UK AIP will ultimately provide flight tracks that are in a more consistent and therefore concentrated swathe than that provided by the conventional equivalent SID.

- 10 While it is commonly understood that different speeds have an effect on the procedure track flown, it must also be appreciated that the impact of this variation in speed depends on whether the procedure is conventional or an RNAV 1 SID. On the initial departure an aircraft is still accelerating towards the published maximum speed constraint of 220 KIAS. In the conventional SID, where the turn is predicated on a fix defined by a DME distance, the aircraft speed has no bearing on where the aircraft will commence the turn – it will turn at the DME distance. But in the RNAV-1 SID case, the turn is predicated on the placement of a Fly-by waypoint. With the aircraft speed less than the maximum constraint of 220 KIAS the aircraft will be closer to the turning waypoint before the turn is commenced than if it were at the maximum speed based on the turn anticipation logic. Therefore the ground track can be quite different between the conventional and RNAV 1 SIDs, even though the RNAV 1 procedure is a nominal replication of the conventional design using PBN design criteria. An example of this can be seen in the Route 4 analysis below.
- 11 Further information on Waypoint types and Sequencing can be found in CAA's PIR Operational and Technical report at paragraph 19 et seq.

Review of Existing Conventional SIDs

- 12 During the SID analysis of both the RNAV 1 and conventional SIDs it has become apparent that the lack of speed constraints other than a generic max 250 KIAS below FL100 on the conventional SIDs is a cause of deviation from the nominal track of the conventional SID (and on occasions even from the 3km wide NPR compliance monitoring swathe).
- 13 In the UK the CAA has implemented an ICAO requirement where all IFPs published in the UK AIP are required to be reviewed on a 5 yearly basis. This review is where the procedure design criteria, obstacles data, altitude and speed restriction, magnetic variations data, noise abatement and airspace containment requirements and any other operational requirements are assessed and the outcome incorporated into the design to ensure the IFP continues to be fit for purpose.
- 14 This 5 year periodic review is now overdue at Gatwick. CAA IFP's recommendations include that this must be carried out on all conventional SID routes, see detailed recommendations below.
- 15 On completion of this ACP process, including conclusion of the PIR, the PIR requirements below, and CAA's subsequent analysis of Gatwick's actions in response to those, the CAA may suggest that Gatwick propose to CAA it withdraw all conventional SIDs.

Limitations of a SID trial

- 16 In order to assess the flyability of instrument flight procedures (IFP) the CAA allows a process known as a “trial” where a new IFP is trialled by a number of aircraft types under controlled conditions and the results assessed. A trial can be used to provide comprehensive flight validation data but by its very nature that the number of aircraft participating in the trial is limited and being conducted for a fixed period of time it cannot be guaranteed that all issues that may impact an IFP will be captured. As the number of aircraft that participated in the Gatwick trials was small compared to the total number of aircraft departing from Gatwick on a daily basis, the trial had limited ability to collect large amounts of data.

NPR compliance monitoring swathe compliance

- 17 Other than as indicated in Column 3 of the tables below, all RNAV-1 SIDs are contained within that Route’s associated NPR compliance monitoring swathe.
- 18 The term “ballooning” as used in this document refers to where the track flown by an aircraft in a turn deviates from the expected I track. A method of reducing this issue is to reduce the maximum speed allowed to be used in the turn and maintain this speed until the turn has been completed and the aircraft is established onto the next track. This can be achieved by reducing the speed restriction at a waypoint in the turn and the next waypoint after the turn. The impact of “ballooning” can be seen during the analysis of the routes.
- 19 The following is an assessment of the Gatwick RNAV 1 SIDs and a summary of IFP’s recommendations to CAA is presented by Route rather than by individual SID. The analysis includes comparison between data gathered from the conventional aircraft tracks (flown using a coded overlay), P-RNAV trial aircraft tracks and RNAV 1 SIDs aircraft tracks. Data from the CAA’s PIR Route Analysis report and PIR Environmental Analysis report used to reach the conclusions identified in this IFP Recommendations report are listed in column (2) below. Column (7) presents the recommendations after analysis and extensive discussions.

Route 1

(1) Route No.	(2) SID/Data used during analysis	(3) Issue	(4) Initial Options from SARG IFP For PIRG to Consider	(5) Impact of Issue & Initial Options	(6) Outcome of PIRG Final Review of Route Issues & SARG IFP Options	(7) SARG IFP Recommendations
1	Rwy 26 SAM 26SAM Altitude Bands. & Density Pptx	The concentrations of flight tracks into a narrower swathe can be seen with the RNAV 1 SID as compared to the conventional SIDs. The track and NPR adherence is what was expected.	No changes recommended.	N/A	Accepted - no design change required.	RNAV 1 SID is a satisfactory replication. No modification recommended.

Route 2

(1) Route No.	(2) SID/Data used during analysis	(3) Issue	(4) Initial Options from SARG IFP For PIRG to Consider	(5) Impact of Issue & Initial Options	(6) Outcome of PIRG Final Review of Route Issues & SARG IFP Options	(7) SARG IFP Recommendations
2	Rwy 08 SFD 08SFD Altitude Bands. & Density Ppttx ERCD 08SFD Speed _ Data+	The concentrations of flight tracks into a narrower swathe can be seen with the RNAV 1 SID as compared to the conventional SIDs. The core of the RNAV 1 flight track swathe is slightly east of the NPR but well within the NPR swathe. This is very likely to be speed related where the turn at KKE03 is commencing closer to the WP than had been anticipated.	1. The max 220 KIAS speed restriction could remain until KKS08 to help prevent the speed acceleration in the turn resulting in a wider turn at KKE03. The slight ballooning of the a/c as it sequences KKE03 could be reduced by applying a max 220KIAS speed constraint to KKS08. The max 250KIAS speed constraint should then be applied to KKS12. This is allowing the a/c as it sequences KKS08 to accelerate to max 250KIAS. 2. Similarly applying a max 220KIAS speed constraint to	1. Chart and coding table to be amended to amend the speed constraints at KKS08. ERCD to gather ground speed data around turn at KKE03 and provide 'gate' analysis to SARG IFP. SARG IFP to analyse data to determine compliance with NPR swathe before and after RNAV design implemented. SARG IFP to determine whether a	1. The analysis of the ERCD gate speed data provided evidence that the average speed before KKE03 was 203Kts and 263Kts after KKE03. This indicates that aircraft are accelerating in the turn at KKE03 which is confirmed with the slight "ballooning" in the turn. Therefore the track keeping around the first turn at KKE03 could be improved with a speed restriction of 220KIAS max applied to the following waypoint at KKS08. This would prevent the potential for some 'ballooning' of some aircraft types during the turn and would be consistent with speed restrictions applied on other SIDs with similar turning characteristics. 2. If the conventional SID is to be	RNAV 1 SID is a satisfactory replication but could be improved by applying the following options: 1. In the RNAV 1 SID applying a max 220KIAS speed constraint to KKS08 and 250KIAS to KKS12 would minimise the potential of any 'ballooning' in the turn at KKE03 of some aircraft types and would be consistent with speed restrictions applied on other SIDs with similar turning characteristics. 2. If the conventional SID is to be retained, the same

(1) Route No.	(2) SID/Data used during analysis	(3) Issue	(4) Initial Options from SARG IFP For PIRG to Consider	(5) Impact of Issue & Initial Options	(6) Outcome of PIRG Final Review of Route Issues & SARG IFP Options	(7) SARG IFP Recommendations
2 (cont)	Wind Analysis		the conventional SID would improve its track and NPR adherence.	max speed restriction of 220kts is appropriate for KKS08 or at an earlier position 3. Validate that the speed change has the expected impact in a flight simulator.	retained, the same rationale can be applied in the conventional SID by applying a max 220KIAS speed constraint to SFD D21 and max 250KIAS to SFD D17.	rationale can be applied in the conventional SID, by applying a max 220KIAS speed constraint to SFD D21 and max 250KIAS to SFD D17. 3. Validate the SIDs in a flight simulator to ensure that the speed changes have the expected impact. A robust validation will be required where the flyability of the remedial SID is assessed in both Airbus and Boeing flight simulators. The parameters used to assess and stress the procedures must be recorded and must be agreed with the CAA before the validation (flyability assessment)

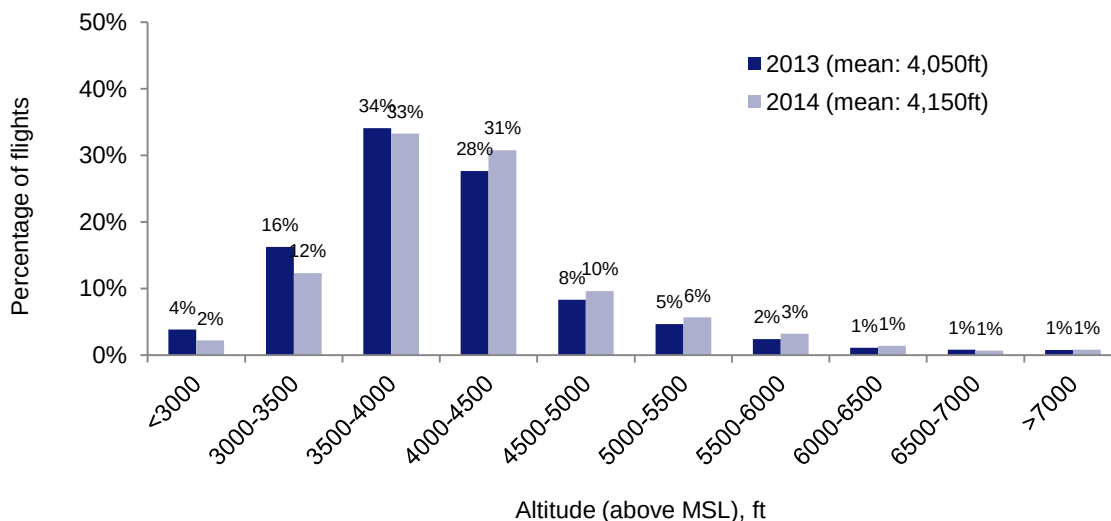
(1) Route No.	(2) SID/Data used during analysis	(3) Issue	(4) Initial Options from SARG IFP For PIRG to Consider	(5) Impact of Issue & Initial Options	(6) Outcome of PIRG Final Review of Route Issues & SARG IFP Options	(7) SARG IFP Recommendations
2 (cont)						process commences.

Route 3

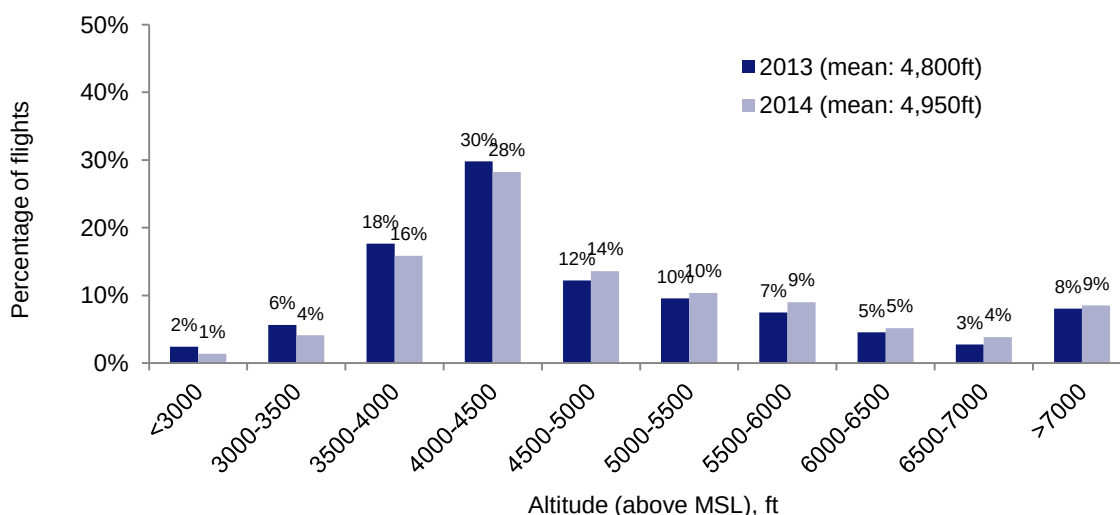
(1) Route No.	(2) SID/Data used during analysis	(3) Issue	(4) Initial Options from SARG IFP For PIRG to Consider	(5) Impact of Issue & Initial Options	(6) Outcome of PIRG Final Review of Route Issues & SARG IFP Options	(7) SARG IFP Recommendations
3	Rwy 08 SAM/ KENET 08 KEN Altitude Bands. & Density Ppttx ERCD Route 3 Gate Analysis	The concentrations of flight tracks into a narrower swathe can be seen with the RNAV 1 SID as compared to the conventional SIDs. The cores of the flight track swathes are similar and this is due in part that the conventional SID first turn point coincides with where the majority of a/c are commencing the turn on the RNAV 1 SID. It appears that the later the turn point on a conventional SID the use of a fly-by WP is effective. 10 Jul 15. Head AAA has requested AR & SARG IFP to consider implications for raising the SID profile to 4000ft earlier in the procedure. Altitude attainment from the GAL PIR data is to be re-examined, and SARG IFP is to advise whether the design profile can be raised. This was an issue raised by public feedback. Whilst initial views are that the 3000ft	1. No changes recommended as the PIR evidence demonstrates this SID is a good replication of the conventional SID and the impact is as expected. 2. In response to the altitude attainment query ERCD will gather ground speed and altitude data at KKN09 and KKW19 to produce 'gate' data and provide details to SARG IFP.	1. No design changes required to be made to the RNAV 1 SID. 2. While the altitude constraints at KKN09 and KKW19 could be considered to be amended, the Route 3 gate analysis provided by ERCD indicates higher altitudes are being attained than the altitude restrictions of 3000ft on the SID procedure. 79% of departures were at/above 4000ft by south abeam Reigate (the midpoint gate in	PIRG having discussed the issues and the outcome of gate data analysis it was decided that no design change was required.	RNAV 1 SID is a satisfactory replication. No modification recommended.

(1) Route No.	(2) SID/Data used during analysis	(3) Issue	(4) Initial Options from SARG IFP For PIRG to Consider	(5) Impact of Issue & Initial Options	(6) Outcome of PIRG Final Review of Route Issues & SARG IFP Options	(7) SARG IFP Recommendations
3 (cont)		restriction at KKW19 is due to interaction with Heathrow Rwy 09 MID SIDs, initial re-examination of the altitude attainment diagrams (see below) indicates a/c are climbed above 4000ft significantly earlier on the SID profile The documented level restriction rationale of the RNAV 1 SID is as follows: • KKE05 +2500: Noise Abatement • KKN09 @3000: Noise Abatement • KKW19 @3000: Airspace Containment and Separation against EGLL DVR SID • KKW26 @4000: Airspace Containment and Separation against EGLL MID SID		the analysis), average alt 4950ft amsl, and 95% were at/above 4000ft amsl by KKW19 with an average altitude of 6550ft AMSL. Therefore in reality altitude attainment of above 3000ft is not an issue.		

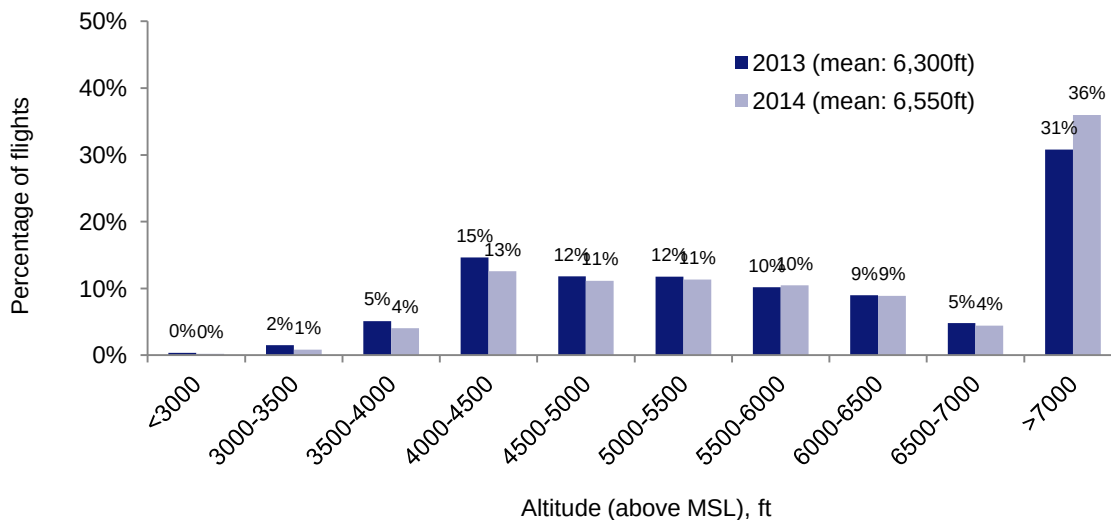
Altitudes of Route 3 departures - Gate 1



Altitudes of Route 3 departures - Gate 2



Altitudes of Route 3 departures - Gate 3



Route 3 Gate layout

