# COMMITTEE ON TOXICITY OF CHEMICALS IN FOOD, CONSUMER PRODUCTS AND THE ENVIRONMENT

## Oil Smells in Aircraft Cockpits:

## Findings of Statistical Analysis into Associated Parameters

**In House Analytical Consultancy**

**Department for Transport**

**&**

**Professor Helen Muir**

**School of Engineering**

**Cranfield University**

**Cranfield**

**Bedford MK43 OAL**

**October 2009**

# Abstract

In 2007 the Department for Transport (DfT) on behalf of the Government's Aviation Health Working Group (AHWG) commissioned Cranfield University to initiate a program of research in Aircraft Cabin Air Quality. The first stage of the program involved a functionality test of equipment capable of detecting the compounds present in the cabin air.

A 'fume event' which occurred during the functionality test led the DfT to decide to conduct a preliminary statistical analysis of the parameters associated with 'fume events'. The DfT In House Analytical Consultancy (IHAC) was commissioned to undertake the work for Cranfield University.

The aim was to conduct an exploratory study to see whether it was possible to use information from the aircraft flight data recordings to identify which combination of factors might increase the probability of a 'fume event', in order that this information could be used to reduce the likelihood of their occurrence.

The results from the statistical analysis are described in this report, together with the implications for the potential use of statistical analyses of flight data records, to provide additional information to support changes to the aircraft systems.

# Contents

# 1. Introduction

In May 2008 the House of Lords Science and Technology Committee published the Government's response to the Update Report on Air Travel and Health (HL Paper 105). In their response the Government agreed to continue and to complete the Aviation Health Working Group (AHWG) sponsored research into cabin air "fume events". Since 2007 the Department for Transport (DfT) on behalf of the AHWG, has commissioned Cranfield University (CU) to act as the project manager to fill the knowledge gap in this area.

During the first stage of the research work (a functionality test of a variety of air sampling devices capable of detecting a wide range of compounds in a cabin air environment - published by CU in January 2008) a "fume event" occurred during a trial flight which led to the present piece of work being commissioned by the Department of Transport. During the trial flight the ‘fume event’ began as the aircraft levelled off at the end of the climb and started the cruise phase of the flight. The rate of climb prior to that time had been extremely steep. This meant that the ‘fume event’ had occurred as the handling of the aircraft went from full throttle to very low throttle. This information, together with other comments made subsequently by some pilots (e.g. that ‘fume events’ are more common on early morning cold starts) raised the possibility that ‘fume events’ may be in some way related to the handling of the aircraft and\or the external environmental conditions. The Department for Transport therefore decided to conduct a statistical analysis of the parameters associated with ‘fume events’ using information available from the flight data recorder and from other measures, such as recent maintenance records, time of day and ambient temperature, in order to try to determine whether any of this information would be found to correlate with the occurrence of a ‘fume event’.

The DfT In House Analytical Consultancy (IHAC) was commissioned to undertake the work for CU. The aim was to conduct an exploratory study to see whether it was possible to identify which combination of factors might increase the probability of the occurrence of a ‘fume event’. It was hypothesised that if this could be determined, and the findings subsequently confirmed by the analysis of data associated with ‘fume events’ on other aircraft, it might be possible to identify the steps which could be taken to reduce the probability of their occurrence. These steps could potentially include changes to the standard operating procedures or to maintenance practices, etc. It should be noted that no information from the trial flight is incorporated in this subsequent analysis of flight data; the trial flight is important only because it raised the possibility of operational parameters playing a part in these incidents.

The relevant data were made available to operational researchers from the In House Analytical Consultancy (IHAC) of the DfT, by an airline participating in the research work.

# 2. Methodology

## 2.1. Objective

The IHAC objective was to perform a statistical analysis on a range of variables associated with aircrafts' engine, pressurisation system and air conditioning, to see if any of these were linked to an increased likelihood of a fume event occurring.

## 2.2. Data

Data were provided by a commercial airline, who agreed to make available all flight data from 2007, as well as access to safety reports filed by pilots after the occurrence of a fume event.

The flight data analysed were limited to a pre-agreed set of 48 parameters relating to the aircrafts' bleed and pressure systems. These parameters were agreed by IHAC, Cranfield University and the airline as an initial stage of this project. A full list of parameters is shown in annex A.

As flight data are recorded continuously throughout a flight, for ease of analysis it was decided that 12 snapshots would be taken at various points throughout the flight. At each point in the flight, it would then be possible to compare flights where there was a fume event and flights where there was not a fume event, to see if their performance varied for any of these parameters. A list of the points in the flight where snapshots were taken is given in Annex B.

## 2.3. Data Preparation

Data were received on a total of 15,468 flights. Of these a total of 60 fume events from crew written reports were identified within the flight data.

The 48 parameters available for analysis were a mixture of discrete variables (with values such as ON/OFF), and continuous variables. In order to carry out the analysis it was necessary to recode all discrete variables into binary values, and all continuous variables into bands. Annex A also includes a list of all the values/bands used in the analysis for each parameter.

Altitude, indicated air speed, crew oxygen pressure and total air temperature were not included in analysis as after further consideration it was felt that these parameters would not, in themselves, be factors that might cause a fume event.

Some flights started in non-standard configuration indicating that a fume event may have occurred on a prior flight on the same aircraft. Following an event planes are run in this configuration until required maintenance is carried out. .

## 2.4. Procedure

Data were analysed to investigate whether there were any statistically significant relationships between certain parameters and the occurrence of a fume event. To assess whether there were differences between flights with and without a fume event, IHAC calculated the number of times different

values were recorded for each parameter, for fume event flights and flights without fume events. For continuous variables, this involved comparing the number of times values were recorded within each of the bands used for analysis (see section 2.3).

Taking each parameter individually, a comparison was then made between the two groups of flights, to see if there were statistically significant[1] differences between the numbers of times different values were recorded for that parameter. This tested the hypothesis that there was no difference between the values recorded for fume event and non-fume event flights. The results show one of two possibilities:

- that the hypothesis cannot be rejected. In other words, we cannot be certain that there is a statistically significant difference between the fume event and non-fume event flights; or
- that the hypothesis can be rejected with a reasonable level of confidence. In other words, we can be broadly certain that there is a genuine difference between the values recorded for the two groups of flights, and that the difference is not random or down to chance.

For some parameters, when looking at certain snapshots, it was necessary to group some bands together to ensure that there were sufficient data within each band for the statistical test to be valid. In some cases, it was not possible to carry out the statistical test at all, as there was insufficient data within certain groups – for example, because the vast majority of values fell within one particular band.

## 2.5. Caveats

There are a number of caveats associated with this analysis that should be noted. As fume event flights were manually identified, it is possible that some flights were incorrectly identified as having a fume event. It is also possible that there may be some instances where a fume event occurred but the pilots did not file a safety report. These flights will be classified as 'non-fume event' flights in this analysis.

It should be noted that no attempt was made to identify the specific point in the flight at which the fume event occurred. Therefore some snapshots will have been taken at points some time before the event occurred, and other snapshots some time after. Flights have been categorised as 'fume event' or 'non-fume event' for the duration of the flight and each of the 12 snapshots, not only those that were taken after the fume event occurred.

[1] Tests for significant difference where carried out using Pearson's chi-square test. In some cases, where the standard requirements for use of the chi-square test were not met, Fisher's exact test was used. Significance was tested at 5% level and, within each snapshot, a Bonferroni correction was made. The Bonferroni correction reduces false positive results when multiple tests are made against the same data set. In this case, the Bonferroni correction should increases the stringency of each statistical test such that the likelihood of a *single* false positive within each snapshot is 5%.

Therefore, although some fume event flight parameters may show statistically significantly different readings in snapshots taken after the event occurred (compared to non-fume event flights), these differences cannot be causal factors of the event happening (although in some cases it is possible that the difference could be a result of action taken to try to mitigate the incident).

It should also be noted that the parameters are reactive. They occurred after the fume event and resulted from pilot input to isolate a smell; they are not a factor in the production of the event.

# 3. Results

## 3.1. Overview

The results of initial analysis to investigate whether there were any statistically significant differences between the values recorded for fume event flights and flights without a fume event are presented in this Section. The results are presented separately for each individual snapshot. In each case, the results focus on those parameters where a statistically significant difference was found between the two groups of flights.

Analysis was carried out to test which parameters showed a statistically significant difference in the values recorded for flights with and without a fume event. Although analysis was carried out separately for the 12 individual snapshots, there were a number of commonalities between the results seen for each snapshot, with many variables showing significant differences for most of the snapshots.

The parameters that showed statistically significant differences between flights with and without a fume event, for at least nine of the 12 snapshots, were:

- AIC_BLD1: Number 1 engine bleed (on/off);
- AIC_BLD2: Number 2 engine bleed (on/off);
- ECS_PAC1: Left air conditioning pack (on/off);
- ECS_PAC2: Right air conditioning pack (on/off);
- ECS_PAC_HIG1: Left air conditioning pack (high/normal).
- ECS_PAC_HIG2: Right air conditioning pack (high/normal).
- PRSO_VLV1: Left pressure regulating shut off valve
- PRECOOL_TMP1: Left pre cooler temperature

There were a number of additional parameters that showed significant differences for some but not all of the snapshots. The table on the following pages shows results for all parameters over each of the twelve snapshots.

- Sig indicates a statistically significant difference between flights with and without a fume event for the relevant snapshot and parameter.
- Not sig indicates that there was no significant difference between the two groups of flights, for that snapshot and parameter.

- No dif indicates that all flights (with or without a fume event) recorded the same value for that parameter, in the relevant snapshot.
- Invalid indicates that it was not possible to carry out the statistical test due to insufficient data.

More detailed results for individual snapshots are shown in Section 3.2. For parameters where a significant relationship was found, tables show the proportion of flights where each value was recorded.

| | | 1<br>Mid taxi out | 2<br>Thrust applied | 3<br>Thrust applied + 1m | 4<br>Thrust applied + 2m | 5<br>Mid climb | 6<br>3 mins into cruise | 7<br>EPR falls - 1m | 8<br>EPR falls | 9<br>EPR falls + 1m | 10<br>Mid descent | 11<br>Landing | 12<br>Taxi in |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AIC_BLD1 | Engine 1 bleed | Not sig | Not sig | Not sig | Sig | Sig | Sig | Sig | Sig | Sig | Sig | Sig | Sig |
| AIC_BLD2 | Engine 2 bleed | Not sig | Not sig | Not sig | Sig | Sig | Sig | Sig | Sig | Sig | Sig | Sig | Sig |
| AIW | Wing anti-ice | Not sig | No dif | No dif | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig |
| AIW1_1 | Wing anti-ice EEC-L | No dif | Not sig | Not sig | Not sig | Not sig | No dif | No dif | No dif | No dif | Not sig | No dif | Not sig |
| AIW1_2 | Wing anti-ice EEC-R | No dif | Not sig | Not sig | Not sig | Not sig | No dif | No dif | No dif | No dif | Not sig | No dif | No dif |
| BLD_OVT1 | Left bleed overheat | No dif | No dif | No dif | No dif | No dif | No dif | No dif | No dif | No dif | No dif | No dif | No dif |
| BLD_OVT2 | Right bleed overheat | No dif | No dif | No dif | No dif | No dif | No dif | No dif | No dif | No dif | No dif | No dif | No dif |
| BLD_PRS1 | Engine 1 bleed duct pressure | Invalid | Not sig | Not sig | Not sig | Sig | Sig | Sig | Sig | Not sig | Sig | Sig | Sig |
| BLD_PRS2 | Engine 2 bleed duct pressure | Invalid | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Invalid |
| COWL_AI1 | Engine 1 anti ice | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig |
| COWL_AI2 | Engine 2 anti ice | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig |
| DUC_TMP_AFT | Duct temperature - aft cabin | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Sig | Invalid | Invalid |
| DUC_TMP_CKPT | Duct temperature - cockpit | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Sig | Invalid | Invalid | Sig | Sig | Not sig |
| DUC_TMP_FWD | Duct temperature - fwd cabin | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Sig | Not sig | Not sig | Invalid |
| ECS_PAC1 | Left aircon pack | Not sig | Not sig | Not sig | Sig | Sig | Sig | Sig | Sig | Sig | Sig | Sig | Sig |
| ECS_PAC2 | Right aircon pack | Not sig | Not sig | Not sig | Sig | Sig | Sig | Sig | Sig | Sig | Sig | Sig | Sig |
| ECS_PAC_HIG1 | Left aircon pack high | Not sig | Not sig | Not sig | Sig | Sig | Sig | Sig | Sig | Sig | Sig | Sig | Sig |
| ECS_PAC_HIG2 | Right aircon pack high | Not sig | Not sig | Not sig | Sig | Sig | Sig | Sig | Sig | Sig | Sig | Sig | Sig |
| EGT1 | Engine 1 exhaust temperature | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Sig | Not sig | Not sig | Not sig | Not sig | Not sig |
| EGT2 | Engine 2 exhaust temperature | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Invalid | Not sig | Not sig | Not sig | Not sig | Not sig |
| EPR1 | Engine 1 Pressure Ratio | Invalid | Not sig | Invalid | Invalid | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Invalid | Invalid |
| EPR2 | Engine 2 Pressure Ratio | Invalid | Invalid | Invalid | Invalid | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Invalid | Invalid |

| | | 1<br>Mid taxi out | 2<br>Thrust applied | 3<br>Thrust applied + 1m | 4<br>Thrust applied + 2m | 5<br>Mid climb | 6<br>3 mins into cruise | 7<br>EPR falls - 1m | 8<br>EPR falls | 9<br>EPR falls + 1m | 10<br>Mid descent | 11<br>Landing | 12<br>Taxi in |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ISOV1 | Isolation valve left EEC | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig |
| ISOV2 | Isolation valve right EEC | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig |
| ISOV1_2 | Isolation valve left TMC | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig |
| ISOV2_2 | Isolation valve right TMC | Not sig | No dif | No dif | No dif | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig |
| N31 | Engine 1 high pressure shaft speed | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig |
| N32 | Engine 2 high pressure shaft speed | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig |
| OIL_PRS1 | Engine 1 oil pressure | Sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Invalid |
| OIL_PRS2 | Engine 2 oil pressure | Not sig | Not sig | Not sig | Not sig | Invalid | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Invalid |
| PACK_FL1 | Left aircon pack flow | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig |
| PACK_FL2 | Right aircon pack flow | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig |
| PACK_VLV_TMP1 | Left pack temperature control valve | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Sig | Sig | Not sig | Not sig | Invalid | Sig |
| PACK_VLV_TMP2 | Right pack temperature control valve | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig |
| PACS_MAINT1 | Left aircon pack fault | No dif | No dif | No dif | No dif | No dif | No dif | No dif | No dif | No dif | No dif | No dif | No dif |
| PACS_MAINT2 | Right aircon pack fault | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig |
| PRSO_VLV1 | Left pressure regulating shut off valv | Not sig | Not sig | Not sig | Sig | Sig | Sig | Sig | Sig | Sig | Sig | Sig | Sig |
| PRSO_VLV2 | Right pressure regulating shut off val | Not sig | Not sig | Not sig | Sig | Sig | Not sig | Not sig | Not sig | Sig | Not sig | Sig | Not sig |
| PRECOOL_TMP1 | Left pre cooler temperature | Not sig | Not sig | Not sig | Sig | Sig | Sig | Sig | Sig | Sig | Sig | Sig | Sig |
| PRECOOL_TMP2 | Right pre cooler temperature | Not sig | Not sig | Not sig | Not sig | Sig | Sig | Sig | Sig | Sig | Not sig | Sig | Sig |
| TMP_DER_STS | Temperature derate status | Sig | Sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig |
| TRIM_VLV_AFT | Aircon trim valve aft cabin | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Invalid | Invalid |
| TRIM_VLV_FLD | Aircon trim valve flight deck | Not sig | Not sig | Not sig | Not sig | Invalid | Invalid | Invalid | Invalid | Invalid | Not sig | Invalid | Invalid |
| TRIM_VLV_FWD | Aircon trim valve fwd cabin | Sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Not sig | Invalid | Invalid |

## 3.2. Snapshot One – Mid Taxi Out

Snapshot 1 was taken during the aircraft's taxi out. For the purposes of data extraction, this was defined as the point where *Flap* became greater than five, and both TLAs had been stable for five seconds.

For snapshot 1, analysis found that there were statistically significant differences between the values recorded for fume event flights and flights without fume events, for the following parameters:

**OIL_PRS1**
**Engine 1 oil pressure**

| Observed | Fumes | No fumes |
|---|---|---|
| 0-39 | 0% | 0% |
| 40-59 | 35% | 51% |
| 60-79 | 27% | 32% |
| 80+ | 38% | 18% |
| Total | 100% | 100% |

Flights where there was a fume event tended to have higher pressure readings than flights where there was not a fume event. 38% of fume event flights had a reading of 80psi or above, compared to 18% of flights without a fume event;

**TMP_DER_STS**
**Temperature derate status**

| Observed | Fumes | No fumes |
|---|---|---|
| - | 22% | 8% |
| Operative | 78% | 92% |
| Total | 100% | 100% |

Fume event flights were significantly more likely than flights without a fume event to have recorded a rated take-off (22% compared to 8% respectively).

**TRIM_VLV_FWD**
**Aircon trim valve fwd cabin**

| Observed | Fumes | No fumes |
|---|---|---|
| 0-32 | 5% | 14% |
| 33-65 | 15% | 15% |
| 66-99 | 50% | 26% |
| 100+ | 30% | 46% |
| Total | 100% | 100% |

The distribution of values for the setting of the forward cabin aircon trim valves differs significantly between fume and non-fume event flights. On 65% of fume event flights, values were recorded in the range 33-100 degrees. For non-fume events greater proportions were below and above this range.

## 3.3. Snapshot Two – Point Where Thrust Applied

Snapshot 2 was taken at the point where thrust was applied. For the purposes of data extraction, this was defined as the point where both TLAs were over 100.For snapshot 2, analysis found that there were statistically significant differences between the values recorded for fume event flights and flights without fume events, for the following parameters:

**TMP_DER_STS**
**Temperature derate status**

| Observed | Fumes | No fumes |
|---|---|---|
| - | 23% | 8% |
| Operative | 77% | 92% |
| Total | 100% | 100% |

Fume event flights were significantly more likely than flights without a fume event to have recorded a rated take-off (23% compared to 8% respectively).

## 3.4. Snapshot Three – One Minute After Snapshot Two

Snapshot 3 was taken one minute after snapshot 2.

For snapshot 3, analysis found that there were no statistically significant differences between the values recorded for fume event flights and flights without fume events.

## 3.5. Snapshot Four – One Minute After Snapshot Three

Snapshot 4 was taken one minute after snapshot 3.

For snapshot 4, analysis found that there were statistically significant differences between the values recorded for fume event flights and flights without fume events, for the following parameters:

| | |
|---|---|
| **AIC_BLD1**<br>**Engine 1 bleed**<br>Observed / Fumes / No fumes<br>On (1) 87% 99%<br>Off (0) 13% 1%<br>Total 100% 100% | Fume event flights were significantly more likely than flights where there was not a fume event to have the variable AIC_BLD1 set at 'off' (13% compared to 1% respectively) |
| **AIC_BLD2**<br>**Engine 2 bleed**<br>Observed / Fumes / No fumes<br>On 92% 99%<br>Off 8% 1%<br>Total 100% 100% | Fume event flights were significantly more likely than flights without a fume event to have the variable AIC_BLD2 set at 'off' (8% compared to 1% respectively) |
| **ECS_PAC1**<br>**Left aircon pack**<br>Observed / Fumes / No fumes<br>On 87% 99%<br>Off 13% 1%<br>Total 100% 100% | Fume event flights were significantly more likely than flights where there was not a fume event to have the variable ECS_PAC1 set to 'off' (13% compared to 1% respectively) |
| **ECS_PAC2**<br>**Right aircon pack**<br>Observed / Fumes / No fumes<br>On 92% 99%<br>Off 8% 1%<br>Total 100% 100% | Fume event flights were significantly more likely than flights without to have the variable ECS_PAC2 set to 'off' (8% compared to 1% respectively) |
| **ECS_PAC_HIG1**<br>**Left aircon pack high**<br>Observed / Fumes / No fumes<br>High 8% 0%<br>- 92% 100%<br>Total 100% 100% | Fume event flights were significantly more likely than flights without a fume event to have the variable ECS_PAC_HIG1 set to 'high' (8% compared to 0% respectively) |
| **ECS_PAC_HIG2**<br>**Right aircon pack high**<br>Observed / Fumes / No fumes<br>High 13% 1%<br>- 87% 99%<br>Total 100% 100% | Fume event flights were significantly more likely than flights without a fume event to have the variable ECS_PAC_HIG2 set to 'high' (13% compared to 1% respectively) |

**PRSO_VLV1**
**Left pressure regulating shut off valve**

| Observed | Fumes | No fumes |
|---|---|---|
| Open | 88% | 99% |
| - | 12% | 1% |
| Total | 100% | 100% |

Flights where there was a fume event were significantly less likely than flights where there was not a fume event to have the variable PRSO_VLV1 set to 'open' (88% compared to 99% respectively)

**PRSO_VLV2**
**Right pressure regulating shut off valve**

| Observed | Fumes | No fumes |
|---|---|---|
| Open | 92% | 99% |
| - | 8% | 1% |
| Total | 100% | 100% |

Flights where there was a fume event were significantly less likely than flights where there was not a fume event to have the variable PRSO_VLV2 set to 'open' (92% compared to 99% respectively)

**PRECOOL_TMP1_RG**
**Left pre cooler temperature (rebanded)**

| Observed | Fumes | No fumes |
|---|---|---|
| 0-99 | 7% | 1% |
| 100-149 | 18% | 16% |
| 150+ | 75% | 83% |
| Total | 100% | 100% |

Fume event flights tended to record lower temperatures than flights without a fume event. For example, 25% of fume event flights recorded a temperature of below 150 degrees, compared to 17% of flights without a fume event

## 3.6. Snapshot Five – Climbing Through 20,000ft

Snapshot 5 was taken at a point approximately in the middle of the aircraft's climb. For the purposes of data extraction, this was defined as the point where the aircraft climbed through 20,000 feet.

For snapshot 5, analysis found that there were statistically significant differences between the values recorded for fume event flights and flights without fume events, for the following parameters:

**AIC_BLD1**
**Engine 1 bleed**

| Observed | Fumes | No fumes |
|---|---|---|
| On (1) | 54% | 99% |
| Off (0) | 46% | 1% |
| Total | 100% | 100% |

Fume event flights were significantly more likely than flights where there was not a fume event to have the variable AIC_BLD1 set at 'off' (46% compared to 1% respectively)

**AIC_BLD2**
**Engine 2 bleed**

| Observed | Fumes | No fumes |
|---|---|---|
| On | 82% | 99% |
| Off | 18% | 1% |
| Total | 100% | 100% |

Fume event flights were significantly more likely than flights without a fume event to have the variable AIC_BLD2 set at 'off' (18% compared to 1% respectively)

**BLD_PRS1_RG**
**Engine 1 bleed duct pressure (rebanded)**

| Observed | Fumes | No fumes |
|---|---|---|
| 0-40 | 32% | 15% |
| 41-50 | 63% | 81% |
| 50+ | 5% | 4% |
| Total | 100% | 100% |

Flights where there was a fume event tended to record lower pressure readings than flights where there was not a fume event. For example, 32% of fume event flights recorded a value of below 40psi, compared to 15% of flights without a fume event.

**ECS_PAC1**
**Left aircon pack**

| Observed | Fumes | No fumes |
|---|---|---|
| On | 54% | 99% |
| Off | 46% | 1% |
| Total | 100% | 100% |

Fume event flights were significantly more likely than flights where there was not a fume event to have the variable ECS_PAC1 set to ‘off’ (46% compared to 1% respectively)

**ECS_PAC2**
**Right aircon pack**

| Observed | Fumes | No fumes |
|---|---|---|
| On | 82% | 99% |
| Off | 18% | 1% |
| Total | 100% | 100% |

Flights where there was a fume event were significantly more likely than flights without to have the variable ECS_PAC2 set to ‘off’ (18% compared to 1% respectively)

**ECS_PAC_HIG1**
**Left aircon pack high**

| Observed | Fumes | No fumes |
|---|---|---|
| High | 20% | 1% |
| - | 80% | 99% |
| Total | 100% | 100% |

Fume event flights were significantly more likely than flights without a fume event to have the variable ECS_PAC_HIG1 set to ‘high’ (20% compared to 1% respectively)

**ECS_PAC_HIG2**
**Right aircon pack high**

| Observed | Fumes | No fumes |
|---|---|---|
| High | 46% | 1% |
| - | 54% | 99% |
| Total | 100% | 100% |

Fume event flights were significantly more likely than flights without a fume event to have the variable ECS_PAC_HIG2 set to ‘high’ (46% compared to 1% respectively)

**PRSO_VLV1**
**Left pressure regulating shut off valve**

| Observed | Fumes | No fumes |
|---|---|---|
| Open | 57% | 99% |
| - | 43% | 1% |
| Total | 100% | 100% |

Flights where there was a fume event were significantly less likely than flights where there was not a fume event to have the variable PRSO_VLV1 set to ‘open’ (57% compared to 99% respectively)

**PRSO_VLV2**
**Right pressure regulating shut off valve**

| Observed | Fumes | No fumes |
|---|---|---|
| Open | 86% | 99% |
| - | 14% | 1% |
| Total | 100% | 100% |

Flights where there was a fume event were significantly less likely than flights where there was not a fume event to have the variable PRSO_VLV2 set to ‘open’ (86% compared to 99% respectively);

**PRECOOL_TMP1_RG**
**Left pre cooler temperature (rebanded)**

| Observed | Fumes | No fumes |
|---|---|---|
| 0-99 | 36% | 1% |
| 100-149 | 18% | 13% |
| 150+ | 46% | 86% |
| Total | 100% | 100% |

Fume event flights tended to record lower temperatures than flights without a fume event. For example, 36% of fume event flights recorded a temperature of below 100 degrees, compared to 1% of flights without a fume event

**PRECOOL_TMP2_RG**
**Right pre cooler temperature (rebanded)**

| Observed | Fumes | No fumes |
|---|---|---|
| 0-99 | 13% | 2% |
| 100-149 | 21% | 10% |
| 150+ | 66% | 89% |
| Total | 100% | 100% |

Fume event flights tended to record lower temperatures than flights without a fume event. For example, 13% of fume event flights recorded a temperature of below 100 degrees, compared to 2% of flights without a fume event

## 3.7. Snapshot Six – Three Minutes into Cruise Phase

Snapshot 6 was taken three minutes after the Cruise phase of flight began.

For snapshot 6, analysis found that there were statistically significant differences between the values recorded for fume event flights and flights without fume events, for the following parameters:

**AIC_BLD1**
**Engine 1 bleed**

| Observed | Fumes | No fumes |
|---|---|---|
| On (1) | 53% | 99% |
| Off (0) | 47% | 1% |
| Total | 100% | 100% |

Fume event flights were significantly more likely than flights where there was not a fume event to have the variable AIC_BLD1 set at ‘off’ (47% compared to 1% respectively)

**AIC_BLD2**
**Engine 2 bleed**

| Observed | Fumes | No fumes |
|---|---|---|
| On | 78% | 99% |
| Off | 22% | 1% |
| Total | 100% | 100% |

Fume event flights were significantly more likely than flights without a fume event to have the variable AIC_BLD2 set at ‘off’ (22% compared to 1% respectively)

**BLD_PRS1_RG**
**Engine 1 bleed duct pressure (rebanded)**

| Observed | Fumes | No fumes |
|---|---|---|
| 0-15 | 19% | 0% |
| 16-30 | 59% | 59% |
| 31+ | 22% | 41% |
| Total | 100% | 100% |

Flights where there was a fume event tended to record lower pressure readings than flights where there was not a fume event. For example, 19% of fume event flights recorded a value of below 15psi, while none of those without a fume event did so.

**ECS_PAC1**
**Left aircon pack**

| Observed | Fumes | No fumes |
|---|---|---|
| On | 54% | 99% |
| Off | 46% | 1% |
| Total | 100% | 100% |

Fume event flights were significantly more likely than flights where there was not a fume event to have the variable ECS_PAC1 set to ‘off’ (46% compared to 1% respectively)

| | |
|---|---|
| **ECS_PAC2**<br>**Right aircon pack**<br>Observed / Fumes / No fumes<br>On 78% 99%<br>Off 22% 1%<br>Total 100% 100% | Flights where there was a fume event were significantly more likely than flights without to have the variable ECS_PAC2 set to 'off' (22% compared to 1% respectively) |
| **ECS_PAC_HIG1**<br>**Left aircon pack high**<br>Observed / Fumes / No fumes<br>High 24% 1%<br>- 76% 99%<br>Total 100% 100% | Fume event flights were significantly more likely than flights without a fume event to have the variable ECS_PAC_HIG1 set to 'high' (24% compared to 1% respectively) |
| **ECS_PAC_HIG2**<br>**Right aircon pack high**<br>Observed / Fumes / No fumes<br>High 46% 1%<br>- 54% 99%<br>Total 100% 100% | Fume event flights were significantly more likely than flights without a fume event to have the variable ECS_PAC_HIG2 set to 'high' (46% compared to 1% respectively) |
| **PRSO_VLV1**<br>**Left pressure regulating shut off valve**<br>Observed / Fumes / No fumes<br>Open 81% 100%<br>- 19% 0%<br>Total 100% 100% | Flights where there was a fume event were significantly less likely than flights where there was not a fume event to have the variable PRSO_VLV1 set to 'open' (81% compared to 100% respectively) |
| **PRECOOL_TMP1_RG**<br>**Left pre cooler temperature (rebanded)**<br>Observed / Fumes / No fumes<br>0-99 53% 7%<br>100-149 20% 30%<br>150+ 27% 63%<br>Total 100% 100% | Fume event flights tended to record lower temperatures than flights without a fume event. For example, 53% of fume event flights recorded a temperature of below 100 degrees, compared to 7% of flights without a fume event |
| **PRECOOL_TMP2_RG**<br>**Right pre cooler temperature (rebanded)**<br>Observed / Fumes / No fumes<br>0-99 32% 5%<br>100-149 22% 42%<br>150+ 46% 53%<br>Total 100% 100% | Fume event flights tended to record lower temperatures than flights without a fume event. For example, 32% of fume event flights recorded a temperature of below 100 degrees, compared to 5% of flights without a fume event |

## 3.8. Snapshot Seven – One Minute Before EPR Begins to Fall

Snapshot 7 was taken one minute before the variable EPR (engine pressure ratio) began to rapidly fall. For the purposes of data extraction, this was defined as the point where the difference between EPR at this point and EPR one minute into the future was greater than -0.25.

For snapshot 7, analysis found that there were statistically significant differences between the values recorded for fume event flights and flights without fume events, for the following parameters:

**AIC_BLD1**
**Engine 1 bleed**

| Observed | Fumes | No fumes |
|---|---|---|
| On (1) | 53% | 99% |
| Off (0) | 47% | 1% |
| Total | 100% | 100% |

Fume event flights were significantly more likely than flights where there was not a fume event to have the variable AIC_BLD1 set at 'off' (47% compared to 1% respectively);

**AIC_BLD2**
**Engine 2 bleed**

| Observed | Fumes | No fumes |
|---|---|---|
| On | 77% | 99% |
| Off | 23% | 1% |
| Total | 100% | 100% |

Fume event flights were significantly more likely than flights without a fume event to have the variable AIC_BLD2 set at 'off' (23% compared to 1% respectively);

**BLD_PRS1_RG**
**Engine 1 bleed duct pressure (rebanded)**

| Observed | Fumes | No fumes |
|---|---|---|
| 0-15 | 19% | 1% |
| 16-30 | 47% | 54% |
| 31+ | 33% | 45% |
| Total | 100% | 100% |

Flights where there was a fume event tended to record lower pressure readings than flights where there was not a fume event. For example, 19% of fume event flights recorded a value of below 15psi, compared to 1% of flights without a fume event;

**DUC_TMP_CKPT**
**Duct temperature - cockpit**

| Observed | Fumes | No fumes |
|---|---|---|
| 0-20 | 9% | 9% |
| 21-40 | 81% | 89% |
| 41-60 | 11% | 3% |
| 61-80 | 0% | 0% |
| Total | 100% | 100% |

Flights where there was a fume event tended to record higher temperature readings than flights where there was not a fume event. For example, 11% of fume event flights recorded a value of above 41, compared to 3% of flights without a fume event;

**ECS_PAC1**
**Left aircon pack**

| Observed | Fumes | No fumes |
|---|---|---|
| On | 53% | 99% |
| Off | 47% | 1% |
| Total | 100% | 100% |

Fume event flights were significantly more likely than flights where there was not a fume event to have the variable ECS_PAC1 set to 'off' (47% compared to 1% respectively);

**ECS_PAC2**
**Right aircon pack**

| Observed | Fumes | No fumes |
|---|---|---|
| On | 77% | 99% |
| Off | 23% | 1% |
| Total | 100% | 100% |

Flights where there was a fume event were significantly more likely than flights without to have the variable ECS_PAC2 set to 'off' (23% compared to 1% respectively);

**ECS_PAC_HIG1**
**Left aircon pack high**

| Observed | Fumes | No fumes |
|---|---|---|
| High | 21% | 1% |
| - | 79% | 99% |
| Total | 100% | 100% |

Fume event flights were significantly more likely than flights without a fume event to have the variable ECS_PAC_HIG1 set to 'high' (21% compared to 1% respectively);

**ECS_PAC_HIG2**
**Right aircon pack high**

| Observed | Fumes | No fumes |
|---|---|---|
| High | 46% | 1% |
| - | 54% | 99% |
| Total | 100% | 100% |

Fume event flights were significantly more likely than flights without a fume event to have the variable ECS_PAC_HIG2 set to 'high' (46% compared to 1% respectively);

**EGT1_RG**
**Engine 1 exhaust temperature (rebanded)**

| Observed | Fumes | No fumes |
|---|---|---|
| <400 | 9% | 2% |
| 400-499 | 14% | 9% |
| 500+ | 77% | 89% |
| Total | 100% | 100% |

Flights where there was a fume event tended to record lower temperature readings than flights where there was not a fume event. For example, 77% of fume event flights recorded a value of above 500, compared to 89% of flights without a fume event.

**PACK_VLV_TMP1_RG**
**Left pack temperature control valve (rebanded)**

| Observed | Fumes | No fumes |
|---|---|---|
| 0-29 | 11% | 2% |
| 30-59 | 37% | 49% |
| 60+ | 53% | 49% |
| Total | 100% | 100% |

The distribution of values for this setting differs significantly between fume and non-fume event flights. On 46% of non-fume event flights, values were recorded in the range 30-59. For fume events greater proportions were below and above this range.

**PRSO_VLV1**
**Left pressure regulating shut off valve**

| Observed | Fumes | No fumes |
|---|---|---|
| Open | 84% | 100% |
| - | 16% | 0% |
| Total | 100% | 100% |

Flights where there was a fume event were significantly less likely than flights where there was not a fume event to have the variable PRSO_VLV2 set to 'open' (84% compared to 100% respectively)

**PRECOOL_TMP1_RG**
**Left pre cooler temperature (rebanded)**

| Observed | Fumes | No fumes |
|---|---|---|
| 0-99 | 53% | 7% |
| 100-149 | 21% | 36% |
| 150+ | 25% | 58% |
| Total | 98% | 100% |

Fume event flights tended to record lower temperatures than flights without a fume event. For example, 53% of fume event flights recorded a temperature of below 100 degrees, compared to 7% of flights without a fume event

**PRECOOL_TMP2_RG**
**Right pre cooler temperature (rebanded)**

| Observed | Fumes | No fumes |
|---|---|---|
| 0-99 | 33% | 6% |
| 100-149 | 33% | 43% |
| 150+ | 33% | 51% |
| Total | 100% | 100% |

Fume event flights tended to record lower temperatures than flights without a fume event. For example, 33% of fume event flights recorded a temperature of below 100 degrees, compared to 6% of flights without a fume event

## 3.9. Snapshot eight – One minute after snapshot seven

Snapshot 8 was taken at the point where the variable EPR (engine pressure ratio) began to rapidly fall. For the purposes of data extraction, this was defined as one minute after snapshot 7.

For snapshot 8, analysis found that there were statistically significant differences between the values recorded for fume event flights and flights without fume events, for the following parameters:

**AIC_BLD1**
**Engine 1 bleed**

| Observed | Fumes | No fumes |
|---|---|---|
| On (1) | 54% | 99% |
| Off (0) | 46% | 1% |
| Total | 100% | 100% |

Fume event flights were significantly more likely than flights where there was not a fume event to have the variable AIC_BLD1 set at 'off' (46% compared to 1% respectively);

**AIC_BLD2**
**Engine 2 bleed**

| Observed | Fumes | No fumes |
|---|---|---|
| On | 77% | 99% |
| Off | 23% | 1% |
| Total | 100% | 100% |

Fume event flights were significantly more likely than flights without a fume event to have the variable AIC_BLD2 set at 'off' (23% compared to 1% respectively);

**BLD_PRS1_RG**
**Engine 1 bleed duct pressure (rebanded)**

| Observed | Fumes | No fumes |
|---|---|---|
| 0-15 | 23% | 6% |
| 16-30 | 30% | 21% |
| 31+ | 47% | 73% |
| Total | 100% | 100% |

Flights where there was a fume event tended to record lower pressure readings than flights where there was not a fume event. For example, 23% of fume event flights recorded a value of below 15psi, compared to 6% of flights without a fume event;

**ECS_PAC1**
**Left aircon pack**

| Observed | Fumes | No fumes |
|---|---|---|
| On | 54% | 99% |
| Off | 46% | 1% |
| Total | 100% | 100% |

Fume event flights were significantly more likely than flights where there was not a fume event to have the variable ECS_PAC1 set to 'off' (46% compared to 1% respectively);

**ECS_PAC2**
**Right aircon pack**

| Observed | Fumes | No fumes |
|---|---|---|
| On | 77% | 99% |
| Off | 23% | 1% |
| Total | 100% | 100% |

Flights where there was a fume event were significantly more likely than flights without to have the variable ECS_PAC2 set to 'off' (23% compared to 1% respectively);

**ECS_PAC_HIG1**
**Left aircon pack high**

| Observed | Fumes | No fumes |
|---|---|---|
| High | 21% | 1% |
| - | 79% | 99% |
| Total | 100% | 100% |

Fume event flights were significantly more likely than flights without a fume event to have the variable ECS_PAC_HIG1 set to 'high' (21% compared to 1% respectively);

**ECS_PAC_HIG2**
**Right aircon pack high**

| Observed | Fumes | No fumes |
|---|---|---|
| High | 42% | 1% |
| - | 58% | 99% |
| Total | 100% | 100% |

Fume event flights were significantly more likely than flights without a fume event to have the variable ECS_PAC_HIG2 set to 'high' (42% compared to 1% respectively);

**PACK_VLV_TMP1_RG**
**Left pack temperature control valve (rebanded)**

| Observed | Fumes | No fumes |
|---|---|---|
| 0-29 | 9% | 2% |
| 30-59 | 40% | 50% |
| 60+ | 51% | 48% |
| Total | 100% | 100% |

Flights where there was a fume event tended to record higher values than flights without a fume event. For example, 31.5% of fume event flights recorded values of 90 degrees or more, compared to 6.4% of flights without a fume event

**PRSO_VLV1**
**Left pressure regulating shut off valve**

| Observed | Fumes | No fumes |
|---|---|---|
| Open | 82% | 100% |
| - | 18% | 0% |
| Total | 100% | 100% |

Flights where there was a fume event were significantly less likely than flights where there was not a fume event to have the variable PRSO_VLV1 set to ‘open’ (82% compared to 100% respectively);

**PRECOOL_TMP1_RG**
**Left pre cooler temperature (rebanded)**

| Observed | Fumes | No fumes |
|---|---|---|
| 0-99 | 47% | 5% |
| 100-149 | 18% | 26% |
| 150+ | 33% | 69% |
| Total | 98% | 100% |

Fume event flights tended to record lower temperatures than flights without a fume event. For example, 47% of fume event flights recorded a temperature of below 100 degrees, compared to 5% of flights without a fume event;

**PRECOOL_TMP2_RG**
**Right pre cooler temperature (rebanded)**

| Observed | Fumes | No fumes |
|---|---|---|
| 0-99 | 33% | 5% |
| 100-149 | 26% | 27% |
| 150+ | 40% | 68% |
| Total | 100% | 100% |

Fume event flights tended to record lower temperatures than flights without a fume event. For example, 33% of fume event flights recorded a temperature of below 100 degrees, compared to 5% of flights without a fume event

## 3.10. Snapshot Nine – One Minute After Snapshot Eight

Snapshot 9 was taken one minute after snapshot 8.

For snapshot 9, analysis found that there were statistically significant differences between the values recorded for fume event flights and flights without fume events, for the following parameters:

**AIC_BLD1**
**Engine 1 bleed**

| Observed | Fumes | No fumes |
|---|---|---|
| On (1) | 56% | 99% |
| Off (0) | 44% | 1% |
| Total | 100% | 100% |

Fume event flights were significantly more likely than flights where there was not a fume event to have the variable AIC_BLD1 set at ‘off’ (44% compared to 1% respectively);

**AIC_BLD2**
**Engine 2 bleed**

| Observed | Fumes | No fumes |
|---|---|---|
| On | 80% | 99% |
| Off | 20% | 1% |
| Total | 100% | 100% |

Fume event flights were significantly more likely than flights without a fume event to have the variable AIC_BLD2 set at ‘off’ (20% compared to 1% respectively

**DUC_TMP_FWD_RG**
**Duct temperature - fwd cabin (rebanded)**

| Observed | Fumes | No fumes |
|---|---|---|
| 0-20 | 6% | 1% |
| 21-40 | 31% | 35% |
| 41+ | 63% | 64% |
| Total | 100% | 100% |

Fume event flights tended to record lower temperatures than flights without a fume event. For example, 6% of fume event flights recorded a temperature of below 21 degrees, compared to 1% of flights without a fume event

**ECS_PAC1**
**Left aircon pack**

| Observed | Fumes | No fumes |
|---|---|---|
| On | 56% | 99% |
| Off | 44% | 1% |
| Total | 100% | 100% |

Fume event flights were significantly more likely than flights where there was not a fume event to have the variable ECS_PAC1 set to ‘off’ (44% compared to 1% respectively);

**ECS_PAC2**
**Right aircon pack**

| Observed | Fumes | No fumes |
|---|---|---|
| On | 76% | 99% |
| Off | 24% | 1% |
| Total | 100% | 100% |

Flights where there was a fume event were significantly more likely than flights without to have the variable ECS_PAC2 set to ‘off’ (24% compared to 1% respectively);

**ECS_PAC_HIG1**
**Left aircon pack high**

| Observed | Fumes | No fumes |
|---|---|---|
| High | 20% | 1% |
| - | 80% | 99% |
| Total | 100% | 100% |

Fume event flights were significantly more likely than flights without a fume event to have the variable ECS_PAC_HIG1 set to ‘high’ (20% compared to 1% respectively);

**ECS_PAC_HIG2**
**Right aircon pack high**

| Observed | Fumes | No fumes |
|---|---|---|
| High | 41% | 1% |
| - | 59% | 99% |
| Total | 100% | 100% |

Fume event flights were significantly more likely than flights without a fume event to have the variable ECS_PAC_HIG2 set to ‘high’ (41% compared to 1% respectively

**PRSO_VLV1**
**Left pressure regulating shut off valve**

| Observed | Fumes | No fumes |
|---|---|---|
| Open | 81% | 100% |
| - | 19% | 0% |
| Total | 100% | 100% |

Flights where there was a fume event were significantly less likely than flights where there was not a fume event to have the variable PRSO_VLV1 set to ‘open’ (81% compared to 100% respectively);

**PRSO_VLV2**
**Right pressure regulating shut off valve**

| Observed | Fumes | No fumes |
|---|---|---|
| Open | 93% | 100% |
| - | 7% | 0% |
| Total | 100% | 100% |

Flights where there was a fume event were significantly less likely than flights where there was not a fume event to have the variable PRSO_VLV2 set to ‘open’ (93% compared to 100% respectively);

**PRECOOL_TMP1_RG**
**Left pre cooler temperature (rebanded)**

| Observed | Fumes | No fumes |
|---|---|---|
| 0-99 | 48% | 9% |
| 100-149 | 26% | 36% |
| 150+ | 24% | 55% |
| Total | 98% | 100% |

Fume event flights tended to record lower temperatures than flights without a fume event. For example, 48% of fume event flights recorded a temperature of below 100 degrees, compared to 9% of flights without a fume event

**PRECOOL_TMP2_RG**
**Right pre cooler temperature (rebanded)**

| Observed | Fumes | No fumes |
|---|---|---|
| 0-99 | 39% | 8% |
| 100-149 | 33% | 42% |
| 150+ | 28% | 50% |
| Total | 100% | 100% |

Fume event flights tended to record lower temperatures than flights without a fume event. For example, 39% of fume event flights recorded a temperature of below 100 degrees, compared to 8% of flights without a fume event

## 3.11. Snapshot Ten – Mid Descent

Snapshot 10 was taken mid descent. For the purposes of data extraction, this was defined as the point when the aircraft was descending through the mean of the maximum altitude in cruise and the landing airfield altitude.

For snapshot 10, analysis found that there were statistically significant differences between the values recorded for fume event flights and flights without fume events, for the following parameters:

**AIC_BLD1**
**Engine 1 bleed**

| Observed | Fumes | No fumes |
|---|---|---|
| On (1) | 62% | 99% |
| Off () | 38% | 1% |
| Total | 100% | 100% |

Fume event flights were significantly more likely than flights where there was not a fume event to have the variable AIC_BLD1 set at ‘off’ (38% compared to 1% respectively);

**AIC_BLD2**
**Engine 2 bleed**

| Observed | Fumes | No fumes |
|---|---|---|
| On | 75% | 99% |
| Off | 25% | 1% |
| Total | 100% | 100% |

Fume event flights were significantly more likely than flights without a fume event to have the variable AIC_BLD2 set at ‘off’ (25% compared to 1% respectively);

**BLD_PRS1_RG**
**Engine 1 bleed duct pressure (rebanded)**

| Observed | Fumes | No fumes |
|---|---|---|
| 0-15 | 28% | 11% |
| 16-30 | 48% | 57% |
| 31+ | 23% | 32% |
| Total | 100% | 100% |

Flights where there was a fume event tended to record lower pressure readings than flights where there was not a fume event. For example, 28% of fume event flights recorded a value of below 15psi, compared to 11% of flights without a fume event

**DUC_TMP_AFT_RG**
**Duct temperature - aft cabin (rebanded)**

| Observed | Fumes | No fumes |
|---|---|---|
| 0-20 | 0% | 1% |
| 21-40 | 47% | 73% |
| 41-60 | 53% | 27% |
| Total | 100% | 100% |

Fume event flights tended to record higher temperatures than flights without a fume event. For example, 53% of fume event flights recorded a temperature of above 41 degrees, compared to 27% of flights without a fume event

**DUC_TMP_CKPT_RG**
**Duct temperature - cockpit (rebanded)**

| Observed | Fumes | No fumes |
|---|---|---|
| 0-20 | 12% | 12% |
| 21-40 | 73% | 86% |
| 41-60 | 15% | 3% |
| Total | 100% | 100% |

Fume event flights tended to record higher temperatures than flights without a fume event. For example, 15% of fume event flights recorded a temperature of above 41 degrees, compared to 3% of flights without a fume event

**ECS_PAC1**
**Left aircon pack**

| Observed | Fumes | No fumes |
|---|---|---|
| On | 60% | 95% |
| Off | 40% | 5% |
| Total | 100% | 100% |

Fume event flights were significantly more likely than flights where there was not a fume event to have the variable ECS_PAC1 set to ‘off’ (40% compared to 5% respectively);

**ECS_PAC2**
**Right aircon pack**

| Observed | Fumes | No fumes |
|---|---|---|
| On | 73% | 95% |
| Off | 27% | 5% |
| Total | 100% | 100% |

Flights where there was a fume event were significantly more likely than flights without to have the variable ECS_PAC2 set to ‘off’ (27% compared to 5% respectively);

**ECS_PAC_HIG1**
**Left aircon pack high**

| Observed | Fumes | No fumes |
|---|---|---|
| High | 27% | 1% |
| - | 73% | 99% |
| Total | 100% | 100% |

Fume event flights were significantly more likely than flights without a fume event to have the variable ECS_PAC_HIG1 set to ‘high’ (27% compared to 1% respectively);

**ECS_PAC_HIG2**
**Right aircon pack high**

| Observed | Fumes | No fumes |
|---|---|---|
| High | 38% | 1% |
| - | 62% | 99% |
| Total | 100% | 100% |

Fume event flights were significantly more likely than flights without a fume event to have the variable ECS_PAC_HIG2 set to ‘high’ (38% compared to 1% respectively);

**PRSO_VLV1**
**Left pressure regulating shut off valve**

| Observed | Fumes | No fumes |
|---|---|---|
| Open | 87% | 98% |
| - | 13% | 2% |
| Total | 100% | 100% |

Flights where there was a fume event were significantly less likely than flights where there was not a fume event to have the variable PRSO_VLV1 set to ‘open’ (87% compared to 98% respectively);

| | |
|---|---|
| **PRECOOL_TMP1_RG**<br>**Left pre cooler temperature (rebanded)**<br>Observed / Fumes / No fumes<br>0-99: 59% / 31%<br>100-149: 27% / 52%<br>150+: 14% / 17%<br>Total: 100% / 100% | Fume event flights tended to record lower temperatures than flights without a fume event. For example, 59% of fume event flights recorded a temperature of below 100 degrees, compared to 31% of flights without a fume event |

## 3.12. Snapshot Eleven – During Landing

Snapshot 11 was taken during landing. For the purposes of data extraction, this was defined as the point when the *Air : Ground* switch detected *Ground*.

- For snapshot 11, analysis found that there were statistically significant differences between the values recorded for fume event flights and flights without fume events, for the following parameters:

| | |
|---|---|
| **AIC_BLD1**<br>**Engine 1 bleed**<br>Observed / Fumes / No fumes<br>On (1): 52% / 99%<br>Off (0): 48% / 1%<br>Total: 100% / 100% | Fume event flights were significantly more likely than flights where there was not a fume event to have the variable AIC_BLD1 set at 'off' (48% compared to 1% respectively); |
| **AIC_BLD2**<br>**Engine 2 bleed**<br>Observed / Fumes / No fumes<br>On: 75% / 99%<br>Off: 25% / 1%<br>Total: 100% / 100% | Fume event flights were significantly more likely than flights without a fume event to have the variable AIC_BLD2 set at 'off' (25% compared to 1% respectively); |
| **BLD_PRS1_RG**<br>**Engine 1 bleed duct pressure (rebanded)**<br>Observed / Fumes / No fumes<br>0-15: 17% / 4%<br>16-30: 27% / 14%<br>31+: 57% / 82%<br>Total: 100% / 100% | Flights where there was a fume event tended to record lower pressure readings than flights where there was not a fume event. For example, 17% of fume event flights recorded a value of below 15psi, compared to 4% of flights without a fume event |
| **DUC_TMP_CKPT**<br>**Duct temperature - cockpit**<br>Observed / Fumes / No fumes<br>0-20: 17% / 14%<br>21-40: 82% / 86%<br>41-60: 2% / 0%<br>61-80: 0% / 0%<br>Total: 100% / 100% | The distribution of values differs significantly between fume and non-fume event flights. On 86% of non-fume event flights, values were recorded in the range 21-40 degrees. For fume events greater proportions were below and above this range. |
| **ECS_PAC1**<br>**Left aircon pack**<br>Observed / Fumes / No fumes<br>On: 52% / 99%<br>Off: 48% / 1%<br>Total: 100% / 100% | Fume event flights were significantly more likely than flights where there was not a fume event to have the variable ECS_PAC1 set to 'off' (48% compared to 1% respectively); |

| | |
|---|---|
| **ECS_PAC2**<br>**Right aircon pack**<br>Observed / Fumes / No fumes<br>On 75% 99%<br>Off 25% 1%<br>Total 100% 100% | Flights where there was a fume event were significantly more likely than flights without to have the variable ECS_PAC2 set to 'off' (25% compared to 1% respectively); |
| **ECS_PAC_HIG1**<br>**Left aircon pack high**<br>Observed / Fumes / No fumes<br>High 27% 1%<br>- 73% 99%<br>Total 100% 100% | Fume event flights were significantly more likely than flights without a fume event to have the variable ECS_PAC_HIG1 set to 'high' (27% compared to 1% respectively); |
| **ECS_PAC_HIG2**<br>**Right aircon pack high**<br>Observed / Fumes / No fumes<br>High 48% 1%<br>- 52% 99%<br>Total 100% 100% | Fume event flights were significantly more likely than flights without a fume event to have the variable ECS_PAC_HIG2 set to 'high' (48% compared to 1% respectively); |
| **PRSO_VLV1**<br>**Left pressure regulating shut off valve**<br>Observed / Fumes / No fumes<br>Open 82% 100%<br>- 18% 0%<br>Total 100% 100% | Flights where there was a fume event were significantly less likely than flights where there was not a fume event to have the variable PRSO_VLV1 set to 'open' (82% compared to 100% respectively); |
| **PRSO_VLV2**<br>**Right pressure regulating shut off valve**<br>Observed / Fumes / No fumes<br>Open 95% 100%<br>- 5% 0%<br>Total 100% 100% | Flights where there was a fume event were significantly less likely than flights where there was not a fume event to have the variable PRSO_VLV2 set to 'open' (95% compared to 100% respectively); |
| **PRECOOL_TMP1_RG**<br>**Left pre cooler temperature (rebanded)**<br>Observed / Fumes / No fumes<br>0-99 58% 10%<br>100-149 28% 74%<br>150+ 13% 16%<br>Total 100% 100% | Fume event flights tended to record lower temperatures than flights without a fume event. For example, 58% of fume event flights recorded a temperature of below 100 degrees, compared to 10% of flights without a fume event; |
| **PRECOOL_TMP2_RG**<br>**Right pre cooler temperature (rebanded)**<br>Observed / Fumes / No fumes<br>0-99 38% 9%<br>100-149 43% 73%<br>150+ 18% 18%<br>Total 100% 100% | Fume event flights tended to record lower temperatures than flights without a fume event. For example, 38% of fume event flights recorded a temperature of below 100 degrees, compared to 9% of flights without a fume event. |

## 3.13. Snapshot Twelve – During Taxi In

Snapshot 12 was taken during taxi in. For the purposes of data extraction, this was defined as the point two minutes after snapshot 11 was taken.

For snapshot 12, analysis found that there were statistically significant differences between the values recorded for fume event flights and flights without fume events, for the following parameters:

**AIC_BLD1**
**Engine 1 bleed**

| Observed | Fumes | No fumes |
|---|---|---|
| On (1) | 39% | 96% |
| Off (0) | 61% | 4% |
| Total | 100% | 100% |

Fume event flights were significantly more likely than flights where there was not a fume event to have the variable AIC_BLD1 set at 'off' (61% compared to 4% respectively);

**AIC_BLD2**
**Engine 2 bleed**

| Observed | Fumes | No fumes |
|---|---|---|
| On | 72% | 97% |
| Off | 28% | 3% |
| Total | 100% | 100% |

Fume event flights were significantly more likely than flights without a fume event to have the variable AIC_BLD2 set at 'off' (28% compared to 3% respectively);

**BLD_PRS1_RG**
**Engine 1 bleed duct pressure**

| Observed | Fumes | No fumes |
|---|---|---|
| 0-15 | 26% | 10% |
| 16-30 | 74% | 87% |
| 31+ | 0% | 3% |
| Total | 100% | 100% |

Flights where there was a fume event tended to record lower pressure readings than flights where there was not a fume event. For example, 26% of fume event flights recorded a value of below 15psi, compared to 10% of flights without a fume event

**ECS_PAC1**
**Left aircon pack**

| Observed | Fumes | No fumes |
|---|---|---|
| On | 39% | 95% |
| Off | 61% | 5% |
| Total | 100% | 100% |

Fume event flights were significantly more likely than flights where there was not a fume event to have the variable ECS_PAC1 set to 'off' (61% compared to 5% respectively);

**ECS_PAC2**
**Right aircon pack**

| Observed | Fumes | No fumes |
|---|---|---|
| On | 72% | 97% |
| Off | 28% | 3% |
| Total | 100% | 100% |

Flights where there was a fume event were significantly more likely than flights without to have the variable ECS_PAC2 set to 'off' (28% compared to 3% respectively);

**ECS_PAC_HIG1**
**Left aircon pack high**

| Observed | Fumes | No fumes |
|---|---|---|
| High | 19% | 2% |
| - | 81% | 98% |
| Total | 100% | 100% |

Fume event flights were significantly more likely than flights without a fume event to have the variable ECS_PAC_HIG1 set to 'high' (19% compared to 2% respectively);

**ECS_PAC_HIG2**
**Right aircon pack high**

| Observed | Fumes | No fumes |
|---|---|---|
| High | 52% | 3% |
| - | 48% | 97% |
| Total | 100% | 100% |

Fume event flights were significantly more likely than flights without a fume event to have the variable ECS_PAC_HIG2 set to ‘high’ (52% compared to 3% respectively);

**PACK_VLV_TMP1_RG**
**Left pack temperature control valve (rebanded)**

| Observed | Fumes | No fumes |
|---|---|---|
| 0-29 | 41% | 10% |
| 30-59 | 59% | 89% |
| 60+ | 0% | 1% |
| Total | 100% | 100% |

Flights where there was a fume event tended to record lower temperature readings than flights where there was not a fume event. For example, 41% of fume event flights recorded a value of below 30 degrees, compared to 10% of flights without a fume event

**PRSO_VLV1**
**Left pressure regulating shut off valve**

| Observed | Fumes | No fumes |
|---|---|---|
| Open | 83% | 99% |
| - | 17% | 1% |
| Total | 100% | 100% |

Flights where there was a fume event were significantly less likely than flights where there was not a fume event to have the variable PRSO_VLV1 set to ‘open’ (83% compared to 99% respectively);

**PRECOOL_TMP1_RG**
**Left pre cooler temperature (rebanded)**

| Observed | Fumes | No fumes |
|---|---|---|
| 0-99 | 67% | 17% |
| 100-149 | 33% | 82% |
| 150+ | 0% | 1% |
| Total | 100% | 100% |

Fume event flights tended to record lower temperatures than flights without a fume event. For example, 67% of fume event flights recorded a temperature of below 100 degrees, compared to 17% of flights without a fume event

**PRECOOL_TMP2_RG**
**Right pre cooler temperature (rebanded)**

| Observed | Fumes | No fumes |
|---|---|---|
| 0-99 | 44% | 15% |
| 100-149 | 56% | 85% |
| 150+ | 0% | 0% |
| Total | 100% | 100% |

Fume event flights tended to record lower temperatures than flights without a fume event. For example, 44% of fume event flights recorded a temperature of below 100 degrees, compared to 15% of flights without a fume event

# 4. Conclusions

4.1 An analysis was carried out to investigate whether there were any statistically significant relationships between certain parameters and the occurrence of a ‘fume event. 12 snapshots were taken at set points throughout flights, and two groups of flights – those where there was a fume event and those where there was not – were compared for each snapshot to see whether there was any statistical variation in the values recorded for each parameter.

4.2 The results from this statistical analysis showed that there were a number of parameters for which there were significant differences between flights with and without a fume event. Five parameters (AIC_BLD1, AIC_BLD2, ECS_PAC1, ECS_PAC2, ECS_PAC_HIG1, ECS_PAC_HIG2, PRSO_VLV1 and PRECOOL_TMP1) showed statistically significant differences between the two groups of flights in at least 9 of the 12 snapshots. Other parameters showed differences between the two groups of flights for fewer snapshots.

4.3 This study was of an exploratory nature. The methodology could be improved and refined. Nevertheless, it does suggest that this type of data may have the potential to support engineering discussions about how to anticipate and possibly mitigate event occurrence. While the parameters which were found to be significant are reactive - that is to say they resulted from pilot input to isolate a smell and are not a factor in the production of the event - it may be that oil pressures, duct temperatures, and engine power would merit further investigation.

4.4 The methodology used for the analysis presented in this report, involved an investigation of each individual parameter separately. This showed whether or not there was evidence of a relationship between each parameter and the occurrence of a ‘fume event’. However, from this it was not possible to determine whether ‘fume events’ can be linked to the interaction between a number of parameters. Further analysis would be required for this purpose, which could potentially provide information on some of the next steps which could be considered to reduce the probability of their occurrence.

4.5 The approach taken in this study suggests that information from the Flight Data Recordings could possibly be used to provide information to support changes to the aircraft systems. The potential to use statistical analyses of information from the aircraft flight data recorders, to provide additional information on the functioning and maintenance requirements of the aircraft systems could be given further consideration.

# Annex A: Parameters

| Parameter | Description | Bandings for Analysis | |
|---|---|---|---|
| ALT_STD | Altitude (1013mb) – in feet | | † |
| AIC_BLD1 | No 1 Eng Bleed (ON/OFF) | 0 (OFF) / 1 (ON) | |
| AIC_BLD2 | No 2 Eng Bleed (ON/OFF) | 0 (OFF) / 1 (ON) | |
| AIW | Wing anti-ice (ON/OFF) | 0 (OFF) / 1 (ON) | |
| AIW1_1 | Wing anti-ice EEC-L (ON/OFF) | 0 (OFF) / 1 (ON) | |
| AIW1_2 | Wing anti-ice EEC-R (ON/OFF) | 0 (OFF) / 1 (ON) | |
| BLD_OVT1 | Left bleed overheat | - | † |
| BLD_OVT2 | Right bleed overheat | - | † |
| BLD_PRS1 | Engine No 1 bleed duct pressure (psi) | 0-14 / 15-29 / 30-39 / 40-49 / 50+ | |
| BLD_PRS2 | Engine No 2 bleed duct pressure (psi) | 0-14 / 15-29 / 30-39 / 40-49 / 50+ | |
| COWL_AI1 | Engine No 1 anti ice (ON/OFF) | 0 (OFF) / 1 (ON) | |
| COWL_AI2 | Engine No 2 anti ice (ON/OFF) | 0 (OFF) / 1 (ON) | |
| DUC_TMP_AFT | Duct temperature - aft cabin (deg C) | 0-19 / 20-39 / 40-59 / 60+ | * |
| DUC_TMP_CKPT | Duct temperature - cockpit (deg C) | 0-19 / 20-39 / 40-59 / 60+ | * |
| DUC_TMP_FWD | Duct temperature - fwd cabin (deg) | 0-19 / 20-39 / 40-59 / 60+ | * |
| ECS_PAC1 | Left aircon pack (ON/OFF) | 0 (OFF) / 1 (ON) | |
| ECS_PAC2 | Right aircon pack (ON/OFF) | 0 (OFF) / 1 (ON) | |
| ECS_PAC_HIG1 | Left aircon pack high/normal (HIGH/-) | 0 (-) / 1 (HIGH) | |
| ECS_PAC_HIG2 | Right aircon pack high/normal (HIGH/-) | 0 (-) / 1 (HIGH) | |
| EGT1 | No 1 engine Exhaust Gas Temperature (deg C) | Bands of $50^{o}$ | * |
| EGT2 | No 2 engine Exhaust Gas Temperature (deg C) | Bands of $50^{o}$ | * |
| EPR1 | No 1 engine Engine Pressure Ratio | Increments of 0.08 | * |
| EPR2 | No 2 engine Engine Pressure Ratio | Increments of 0.08 | * |
| IAS | Indicated airspeed (knots) | | † |
| ISOV1 | Isolation valve left EEC – Electronic Engine Control (OPEN/-) | 0 (-) / 1 (OPEN) | |
| ISOV2 | Isolation valve right EEC – Electronic Engine Control (OPEN/-) | 0 (-) / 1 (OPEN) | |
| ISOV1_2 | Isolation valve left TMC – Thrust | 0 (-) / 1 (OPEN) | |

| Parameter | Description | Bandings for Analysis | |
|---|---|---|---|
| | Management Computer (OPEN/-) | | |
| ISOV2_2 | Isolation valve right TMC – Thrust Management Computer (OPEN/-) | 0 (-) / 1 (OPEN) | |
| N31 | No1 engine high pressure shaft speed (%) | Bands of 5% | * |
| N32 | No2 engine high pressure shaft speed (%) | Bands of 5% | * |
| OIL_PRS1 | No1 engine oil pressure (psi) | 0-39 / 40-59 / 60-79 / 80+ | * |
| OIL_PRS_2 | No2 engine oil pressure (psi) | 0-39 / 40-59 / 60-79 / 80+ | * |
| OXY_PRS_CRW | Crew oxygen pressure (psi) | | † |
| PACK_FL1 | Left aircon pack flow (no units) | 0-19 / 20-39 / 40+ | |
| PACK_FL2 | Right aircon pack flow (no units) | 0-19 / 20-39 / 40+ | |
| PACK_VLV_TMP1 | Left pack temperature control valve (deg position) | 0-29 / 30-59 / 60-89 / 90+ | |
| PACK_VLV_TMP2 | Right pack temperature control valve (deg position) | 0-29 / 30-59 / 60-89 / 90+ | |
| PACS_MAINT1 | Left aircon pack fault (-/FAULT) | | † |
| PACS_MAINT2 | Right aircon pack fault (-/FAULT) | 0 (-) / 1 (FAULT) | |
| PRSO_VLV1 | Left pressure regulating shut off valve (OPEN/-) | 0 (-) / 1 (OPEN) | |
| PRSO_VLV2 | Right pressure regulating shut off valve (OPEN/-) | 0 (-) / 1 (OPEN) | |
| PRECOOL_TMP1 | Left pre cooler temperature (deg C) | 0-99 / 100-124 / 125-149 / 150-174 / 175+ | |
| PRECOOL_TMP2 | Right pre cooler temperature (deg C) | 0-99 / 100-124 / 125-149 / 150-174 / 175+ | |
| TAT | Total air temperature (deg C) | Bands of $50^{o}$ | † |
| TMP_DER_STS | Temperature derate status – rated/de-rated take-off (-/OPERATIVE) | 0 (-) / 1 (OPERATIVE) | |
| TRIM_VLV_AFT | Aircon trim valve aft cabin (deg position) | 0-32 / 33-65 / 66-98 / 99+ | |
| TRIM_VLV_FLD | Aircon trim valve flight deck (deg position) | 0-32 / 33-65 / 66-98 / 99+ | |
| TRIM_VLV_FWD | Aircon trim valve fwd cabin (deg position) | 0-32 / 33-65 / 66-98 / 99+ | |

† Excluded from analysis

* Data grouped into a smaller number of bands, as necessary for statistical test to be valid.

## Annex B: Snapshots

| Snapshot ID | Description | Definition |
|---|---|---|
| 1 | Mid taxi out | Flap > 5 and both TLAs stable for 5 seconds |
| 2 | Point when thrust is applied | The first point where both TLAs are over 100 |
| 3 | One minute after previous snapshot | 1 minute after [2] |
| 4 | A further one minute after that | 2 minutes after [2] |
| 5 | Mid climb (at the point when the aircraft is halfway between its minimum and maximum altitude) | Climbing through 20,000 ft |
| 6 | Three minutes into the cruise phase of flight | 3 minutes after Cruise phase starts |
| 7 | One minute before EPR begins to rapidly fall | Reduction in EPR from now to 60 seconds in the future greater than -0.25 |
| 8 | EPR begins to rapidly fall | 1 minute after [7] |
| 9 | One minute after EPR begins to rapidly fall | 2 minutes after [7] |
| 10 | Mid descent (at the point when the aircraft is halfway between its maximum and minimum altitude) | Descending through the mean of maximum altitude in cruise and landing airfield altitude |
| 11 | During landing | *Air : Ground* switch detects *Ground* |
| 12 | During taxi in | 2 minutes after [11] |