Ames Research Center

easyJet

# First Annual Report
# NASA – easyJet Collaboration on the Human Factors Monitoring Program (HFMP) Study


Ashok N. Srivastava, PhD. Project Officer for NASA

Phil Barton, Project Officer for easyJet Airline Company, Ltd.


*October 1, 2010*

Prepared by:


NASA Ames Research Center, Code TI, Moffett Field, CA

EasyJet Airline Company Ltd, London Luton Airport, England

Stinger Ghaffarian Technologies Inc., Moffett Field, CA

San Jose State University, San Jose, CA

Institutes for Behavior Resources, Inc., Baltimore, MD

**Table of Contents**

1. Introduction ..... 4
Background ..... 4
Project Overview ..... 4
Data Collection ..... 6
2. Individual Crew Performance ..... 10
Background ..... 10
Approach to Data Analysis ..... 10
Approach to Modeling ..... 12
Model Assessments ..... 13
Progress to Date in Data Analysis and Modelling ..... 16
3. Aircraft Performance ..... 21
Background ..... 21
Approach to Flight-Data Analysis ..... 21
Approach to Aviation Safety Report Analysis ..... 23
Approach to Fusing Information from Flight Data and ASR ..... 25
Progress to Date on Analyzing Flight Data and ASR's ..... 26
4. Correlation of Individual with Aircraft Performances ..... 27
5. References ..... 28

## Executive Summary

This is the first annual report jointly prepared by NASA and easyJet on the work performed under the agreement to collaborate on a study of the many factors entailed in flight- and cabin-crew fatigue and documenting the decreases in performance associated with fatigue. The objective of this Agreement is to generate reliable, automated procedures that improve understanding of the levels and characteristics of flight- and cabin-crew fatigue factors, both latent and proximate, whose confluence will likely result in unacceptable flight crew performance. This study entails the analyses of numerical and textual data collected during operational flights. NASA and easyJet are both interested in assessing and testing NASA's automated capabilities for extracting operationally significant information from very large, diverse (textual and numerical) databases, much larger than can be handled practically by human experts.

This report presents the approach that will be used in processing and analyzing the data to which easyJet will grant NASA access for identifying decrements in aircraft performance and examining their relationships to decrements in crew member performance due to fatigue. The decisions on the approach were based on large samples of both the numerical and textual data that will be collected during the four experiments planned under the Human Factors Monitoring Program (HFMP). Results of preliminary analyses of these sample data are presented in this report.

Most of the milestones scheduled for completion during this first year were achieved in essence if not precisely in the expected detail. Limitations in the accomplishments were due, in part, to delays at easyJet in developing the software needed to put the raw flight-recorded data into a format compatible with NASA's algorithms for analyses. In fact, at the time of writing this report, NASA had not yet received the flight data collected during the first experiment in September 2009, although NASA has been accessing easyJet's flight data on a daily basis since April 1, 2010. Another factor that limited some of the accomplishments was the number of deficiencies found in the data collected during that first experiment relating to individual crew performance and fatigue.

As this report was being prepared, the second experiment with cabin crews as subjects had started and data from that experiment are expected to be ready for analyses by mid-to-late October 2010. The third experiment with flight crews as subjects is expected to be conducted during early Spring 2011.

# 1. Introduction

## Background

Fatigue has been traditionally defined as a physiological state in which there is a decreased capacity to perform cognitive tasks and an increased variability in performance. While fatigue is often attributed to periods of extended wakefulness in which ample recovery sleep is not obtained, research has shown that performance and alertness levels are largely influenced by the complex interaction between sleep and the 24-hour biological clock (circadian rhythm). In addition, time on task can further increase fatigue. Field-collected data have demonstrated that sleep times and neurobehavioral functioning of flight and cabin crews can be compromised by irregular schedule, multiple flight legs, long duty days, reduced time off, early report times, less-than-optimal sleeping conditions, and jet lag. The brain's sleep and circadian systems are continuously challenged by these operational demands, thus contributing to both acute and chronic fatigue.

Maximizing alertness and performance levels during aviation operations is critical to maintaining the continued safety of the National Airspace System. Although research has established empirically based knowledge of sleep and circadian principles, the aviation industry and its regulators have had difficulty aligning these scientific findings with operational requirements. Thus, the challenge of fatigue among aviation employees has steadily increased along with concerns over fatigue-related air safety that are exacerbated by the increasingly complex operations that continue around-the-clock. Accident statistics, reports from pilots, and operational flight studies all show that fatigue is a clear concern within aviation operations. Therefore, there is a need to develop scientifically valid fatigue-management approaches that lead to continuous safety enhancements by identifying and addressing both physiological and operational fatigue factors across time and changing circumstances.

A Fatigue Risk Management System (FRMS) is one approach that is data-driven, scientifically based process that allows for continuous monitoring and management of safety risks associated with fatigue-related error. This process leads to continuous safety enhancements by identifying and addressing fatigue factors across time and changing physiological and operational circumstances. Key components of the FRMS approach are: 1) access to fatigue related data; 2) fatigue analysis methods; 3) identification and management of fatigue drivers, and 4) application of fatigue mitigation procedures.

## Project Overview

In recognition of the important influence of fatigue on flight- and cabin-crew performance in commercial airline operations, easyJet Airline Company Ltd. has initiated the Human Factors Monitoring Program (HFMP) study. The HFMP includes a series of studies being conducted to better understand how both latent and proximate causal fatigue factors potentially contribute to impaired flight- and cabin-crew performance. NASA is collaborating with easyJet on the HFMP studies by providing technologies and methodologies to enable a data-driven and scientifically based process that supports

easyJet's Fatigue Risk Management System (FRMS). The process will allow easyJet to monitor and manage safety risks associated with fatigue-related error. This process could serve as the foundation of FRMS within other air-carrier operations.

The project includes acquiring, processing, integrating, and interpreting large quantities of diverse numerical and textual data collected from aircrew and cabin-crew participants during easyJet's normal operations with different scheduling strategies. Under the terms of a Space Act Agreement (SAA) with easyJet, NASA has been granted access to the following data: 1) aircraft performance, 2) individual demographic information, 3) subjective questionnaires, 4) individual physiological measures and; 5) objective neurocognitive variables. NASA is considering these data from two perspectives independently. The Intelligent Systems Division (Code TI) is analyzing the aircraft-performance data and the Human Systems Integration Division (Code TH) is analyzing the crew-performance data. Subsequently, the results of these two efforts will be combined to examine the relationship between aircraft performance and crewmember performance.

Code TI's role is to develop and apply algorithms that automatically extract information on anomalous events from the flight-recorded data and to fuse that information with information extracted automatically from the easyJet's Air Safety Reports (ASR). The developed algorithms will contribute to NASA and easyJet's joint efforts to develop efficient and reliable methodologies that can extract and merge information from large, diverse data sources to assist aviation safety analysts to: 1) identify expected and unexpected events or trends in system performance that could compromise the safety of the system; and 2) identify the latent and proximate causal factors of the events identified to enable data-driven decisions on interventions or mitigations.

Code TH's role is to analyze the physiological and neurocognitive measures, collected as part of the easyJet data-collection process to track individual levels of fatigue and performance across the entire time-course of the duty cycle. Individual fatigue and performance levels will be further analyzed in conjunction with personal profile variables to identify potential causal factors of fatigue.

EasyJet is seeking answers to the following specific questions:

1. Is there reliable evidence that levels of fatigue can be correlated with scheduling strategy **AND** is there reliable evidence that scheduling strategy is a causal factor of performance-degrading levels of fatigue?
2. What is the minimum set of measures to reliably indicate that identified aircraft performance decrements were probably related to fatigue?
3. Pragmatically, which measures can be implemented during normal operations to monitor for levels of human fatigue that could affect performance?
4. What are the data sources that provide reliable information on the consequences of performance-degrading levels fatigue?
5. What are the data sources that provide reliable information on the latent and proximate causal and contributing factors of human fatigue?
6. What are the fatigue profiles of operators based on individual measures over the course of flights? Are these indicators convergent?

The overall goal of this research is to identify the simplest reliable measurement system for monitoring fatigue, crew performance, and aircraft performance. This will be accomplished by minimizing the number and complexity of a combination of objective measurements that are shown to have reliable associations with changes in performance and fatigue levels.

At NASA, this work has become incorporated within the Data Mining and Knowledge Discovery Theme and the Human Systems Solutions Theme of NASA's System-wide Safety and Assurance Technologies (SSAT) Program.

At easyJet, the HFMP is under the auspices of their Fatigue Risk Management System, which has been incorporated as part of easyJet's Safety Management System.

### Data Collection

The HFMP calls for data collection on 22 subjects during each of the four experiments conducted by easyJet. Flight crews are the subjects for experiments 1, 3, and 4 and cabin crews for experiment 2. Each subject is to be either on Flexible Roster Variation (FRV) or Fixed-Pattern Design (FPD) schedule, as diagramed in Figure 1.

| | | | | Block A | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | D/O | D/O | D/O | E1 | E2 | E3 | L1 | L2 | D/O | D/O | D/O |

| Block B | | | | | | | Block C | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| E1 | E2 | E3 | L1 | L2 | D/O | D/O | E1 | E2 | E3 | L1 | L2 |

**FRV Schedule of 23 Consecutive Duty and Off Days**

| | | | | Block A | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| D/O | D/O | D/O | D/O | E1 | E2 | E3 | E4 | E5 | D/O | D/O | D/O |

| Block B | | | | | Block C | | | |
|---|---|---|---|---|---|---|---|---|
| L1 | L2 | L3 | L1 | L2 | D/O | D/O | D/O | D/O |

**FPD Schedule of 21 Consecutive Duty and Off Days**

D/O=Day Off; E=Early Departure; L=Late Arrival

**Figure 1 – Schedules of Duty Days and Off Days**

The following data are to be collected during the four experiments:

Aircraft Performance Data:

- In-flight recorded data – trace records and exceedances
- Air Safety Reports

Individual Crew Demographic Information:

- Schedule data (rosters)
- Demographic data-age, commute distance, base, flying experience, family status, etc.

Individual Crew Physiological and Cognitive Data:

- Samn-Perelli – subjective alertness scale
- Mood scale - subjective
- Fatigue countermeasures employed per sector

- PVT - psychomotor vigilance task
- Sleep data-actigraphy (Actiwatch)
- Sleep diary information
- NASA TLX questionnaire data
- Hassle factors questionnaire data
- Morningness/Eveningness Questionnaire (MEQ)
- Checklist of Individual Strength (CIS)
- Epworth Sleepiness Scale (ESS)
- Bio-harness data (Electrocardiography (ECG); Respiration Rate (RR); Skin Temperature (ST); Posture (indicates upright or supine body position); and Physical Activity (three axis accelerometer)),
- Crew portal questions on sleep quantity and alertness pre/post duty

Table 1 presents details on the data that were collected, the days and times for each, and the methods of recording. All data were annotated with a common time-stamp (GMT) to enable their linkage. These measures are fully explained in Stewart (2009). The line item identified as "FOQA" is the in-flight-recorded data. FOQA means Flight Operational Quality Assurance, which is the name given to the program in the US that entails continuously recording, monitoring, and analyzing data on hundreds of flight parameters recorded during flight in parallel with the system associated with the mandated "black box" from which data are typically analyzed after an accident.

**Table 1 - HFMP study measures**

| | **Training Day 1** | **Baseline days** | **Duty days (Block A, B & C)** | **Non-operated duty(standby)** | **Day off/Recovery** | **Method of Data collection** |
|---|---|---|---|---|---|---|
| ***Samn Perelli-subjective alertness scale*** | Instructed how to use | Morning = 1-2 hrs after waking<br>Mid-day = 8-9 hrs after waking<br>Evening = 1-2 hrs before sleeping | Pre Duty (on wake up +30 min)<br>TOD<br>Post duty (duty log-off) | Morning<br>Mid-day<br>Evening | Morning<br>Mid-day<br>Evening | Paper and pencil |
| ***PVT-psychomotor vigilance task PDA*** | Instructed how to use | Morning = 1-2 hrs after waking<br>Mid-day = 8-9 hrs after waking<br>Evening = 1-2 hrs before sleeping | Pre Duty (on wake up +30 min)<br>TOD<br>Post duty (duty log-off) | Morning<br>Mid-day<br>Evening | Morning<br>Mid-day<br>Evening | PDA |
| ***Use of Fatigue Countermeasures**** | Instructed how to use | Associated with sector PVT, completed on turnaround (PVT test completed top of descent) | Turnarounds, throughout roster , Post duty (duty log-off)<br>Rosters vary by individual – refer to master spreadsheet for duty timing. | Not collected | Not collected | Paper and pencil |
| ***NASA TLX*** | Instructed how to use | Not collected | Turn arounds<br>Post duty (duty log-off) | Not collected | Not collected | Paper and pencil |
| ***Hassle factors*** | Instructed how to use | Not collected | Turn arounds<br>Post duty (last sector-duty log-off) | Not collected | Not collected | Paper and pencil |
| ***Mood/sleepiness scale*** | Instructed how to use | Once per day | Once per day before first sector (on wakeup + 30 min)<br>Evening (pre sleep on Bio Harness download) | Twice per day on wake-up +30 min<br>Evening (pre sleep on Bio Harness download) | Twice per day on wake-up + 30 min<br>Evening (pre sleep on Bio Harness download) | Laptop |
| ***Sleep diary*** | Instructed how to use | Pre-sleep<br>Post-sleep (30 minutes after waking) | Pre-sleep<br>Post-sleep (30 minutes after waking) | Pre-sleep<br>Post-sleep (30 minutes after waking) | Pre-sleep<br>Post-sleep (30 minutes after waking) | Paper and pencil |
| ***Actigraphy*** | Instructed how to use | Continuous | Continuous | Continuous | Continuous | Actigraph |
| ***Bio harness-Physiological variables*** | Instructed how to use | < 16 hrs (daytime) | < 16 hrs (daytime; during duty) | < 16 hrs (daytime) | < 16 hrs (daytime) | Bio harness |
| ***FOQA*** | N/A | Collected/flight/individual | Collected per flight/individual | Not collected | Not collected | A/C FDM system |

| ***Questionnaires*** | | | | | | |
|---|---|---|---|---|---|---|
| ***CID-checklist of individual strength*** | Completed training day only | Not collected | Not collected | Not collected | Not collected | Paper and pencil |
| ***M/E-morning evening scale*** | Completed training day only | Not collected | Not collected | Not collected | Not collected | Paper and pencil |
| ***ESS-epworth sleepiness scale*** | Completed training day only | Not collected | Not collected | Not collected | Not collected | Paper and pencil |

*Summary of Countermeasures:

| **FATIGUE COUTERMEASURES EMPLOYED** | **TICK** | **QUANTITY** |
|---|---|---|
| **Cockpit napping** | | Time & duration |
| **Activity Breaks** | | Time & duration |
| **Caffeine intake** | | No. Cups |
| **Crew communications** | | |
| **Increased monitoring and cross checking** | | |
| **Workload sharing/offload** | | |
| **Increased briefing times and time for task actioning** | | |
| **Automation application/reliance** | | |
| **Cockpit lighting** | | |
| **Crew offload/replacement** | | Sector & no. crew |

## 2. Individual Crew Performance

### Background

Code TH's role is to analyze the physiological and neurocognitive measurements, collected as part of the easyJet data collection process to track individual levels of fatigue and performance across the entire time-course of the duty cycle. Individual fatigue and performance levels will be further analyzed in conjunction with personal profile variables to identify potential causal factors of fatigue. The goals of this research are to

1. Identify scheduling factors, physiological measures and cognitive variables that have potential for predicting degraded levels of cognitive functioning.
2. Develop recommendations for fatigue mitigation and scheduling adjustments to maximize performance and alertness levels during aviation operations.
3. Identify the fatigue-related measures and data sources of individual-performance effectiveness that are feasible for inclusion in an FRMS so as to enable continuous monitoring and management of fatigue-related safety and performance risks during aviation operations.

### Approach to Data Analysis

The data collected during actual flight operations (across the FRV or the FPD schedules of duty and non-duty times) will be analyzed to track the level of performance capability for each participant over the course of each data collection period to: 1) determine if there is a causal correlation between individual performance decrements and various fatigue variables and 2) identify potential causal factors of fatigue. In pursuing this objective, it is important to note that not all degradations in human performance are due to fatigue and not all levels of fatigue produce significant decrements in human performance. The following causal relationships will be explored:

**Figure 2 – Representation of Code TH Data Analyses**

The approach, as depicted in Figure 2, is to analyze the objective and subjective measures collected for individual participants over the course of the scheduled days of duty- and days off shown in Figure 1. Any decrements in individual crewmember performance over the roster period will be assessed to assess causal relationships with measurements of fatigue levels. The measured levels of fatigue over the course of the roster schedule will be further explored to determine if they are causally correlated with any of the latent or proximate factors identified in the demographic information and survey questions for that individual.

The physiological, cognitive, and demographic data detailed in Table 1 can be categorized relative to each of three elements of Figure 2 as described below:

**Individual Performance and Perception of Work**

PVT – Psychomotor Vigilance Task (Objective, neuro-cognitive)

NASA TLX
Hassle factors } Subjective, cognitive

An individual's perception of his/her workload and hassle factors may influence his/her performance. PVT, TLX, and hassle factors will be treated as independent variables. However, a question at this point is whether TLX and hassle factors can be combined into a single metric of the individual's perception of his/her task. The data will be examined for a correlation between TLX and hassle factors.

A notional representation of an individual's performance and perception of workload is to plot these characteristics for each subject over the course of the schedule of duty and off days (see Figure 1) on a graphic similar to that depicted below in Figure 3. If no reliable evidence of a correlation between TLX and hassle factors is found, the hassle factors would become a third dimension in a presentation such as Figure 3.

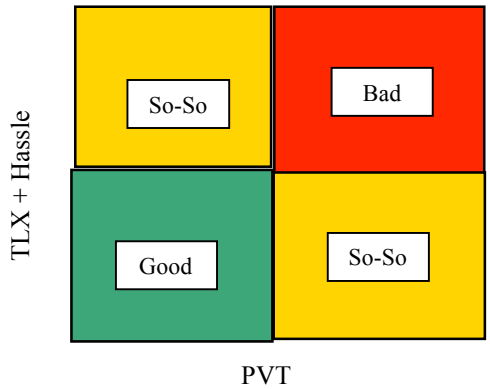



**Figure 3– Notional Presentation of Individual Performance and Perception of Work**

**Level of Fatigue**

Samn-Perelli – subjective alertness scale
Mood scale
Sleep diary
Actigraphy
Bio-harness - Physiological variables
Use of Fatigue Countermeasures

Questions to be considered for this element will be assessed to determine whether any or all of these measures of fatigue can be combined into a single reliable metric of 'fatigue level' and whether they can all be weighted equally for all individuals for evidence of causal correlation with the individual's performance and perception of workload. Additional measures including the Samn-Perelli scale, Mood/sleepiness scale, and Sleep diary combined with the supplementary information from Actigraphy, Bio-harness, and Use of Fatigue Countermeasures to provide a measure of Level of Fatigue relative to each subject's baseline. For example, cumulative sleep debt for each crewmember over the

course of the 23 days can be calculated, based as reported sleep need and objectively recorded sleep/wake data collected.

**Potential Causal Factors of Fatigue/Personal Profile**

Demographic questionnaires
Schedule data (roster)
CID
MEQ
ESS

Causal correlations between each participant's level of fatigue and personal profiles of age, commute distance, base, flying experience, family status, etc. will be assessed. Checklists of Individual Strength (CID), Morning-Eveningness Questionnaire (MEQ) and Epworth Sleepiness Scale Questionnaires will be evaluated with consideration of individual schedule data. The Morning-Eveningness-Questionnaire, which indicates a person's circadian preference, will be explored for a causal correlation of sleep deprivation with the roster schedule and the participant's personal profile.

In addition to exploring the data on each participant individually, group statistics for each of the measures related to identification of Level of Fatigue will also be calculated. One objective is to determine whether any of the measures that have demonstrated a causal correlation with fatigue show no significant variability in the data among that sample group for that roster schedule. If that should be the case, it opens the possibility of generalizing that particular measure to the full population. This can also be used to assess the informational value of a particular measurement and help in minimizing the number of useful measures.

### Approach to Modelling

In parallel with the data analyses described above, the easyJet work schedule and sleep data will also be processed through the SAFTE/FAST model.[1] A validated model of human fatigue will be useful for prediction and for risk assessment of proposed interventions by using it to explore their impacts prior to implementation. The complementary work on analyzing all of the data will provide a measure for validating the model, a basis for deciding on interventions, and a pragmatic way to routinely monitor to identify the systemic consequences of changes.

SAFTE is a computerized model that predicts changes in cognitive performance based on the sleep/wake schedule and the body's internal clock. It includes: a circadian process, a circadian sleep propensity process, a sleep fragmentation process, and a phase adjusting feature for time zone changes.

The SAFTE (Sleep, Activity, Fatigue and Task Effectiveness) model will be used to evaluate the schedules in which easyJet is collecting data to:

[1] Dr. Steven Hursh (President, Institutes for Behavior Resources, Inc.) developed the SAFTE™ (Sleep, Activity, Fatigue and Task Effectiveness) biomathematical model of human fatigue and circadian variation with support from U.S. Departments of Defense (DoD) and Transportation (DOT).

a. Identify fatigue drivers associated with scheduling (roster) strategy. This is based on the following 5 fatigue factors evaluated in NTSB investigations:
   - Recent sleep (< 8 hrs in previous 24 hrs)
   - Chronic sleep debt (> 8 hrs)
   - Hours awake (> 17 hrs)
   - Time of day (between midnight and 0600)
   - Out of phase (> 3 hrs)
b. Determine the effects of a scheduling (roster) strategy on operator performance.

**Model Assessments**

During the past ten years, the US DOT and the US DOD sponsored development of the SAFTE™ model of human fatigue and circadian variation, and the FAST™ scheduling tool to anticipate and avoid fatigue in transportation operations. The SAFTE™ model has received a broad scientific review and was found to have the least error overall of any comparable current model. (Hursh, Balkin, Miller, and Eddy, 2004; Hursh, Redmond, Johnson, Thorne, Belenky, Balkin, Storm, Miller, and Eddy, 2004). A test of the model against 2-½ years of railroad accident data and work histories prior to those accidents found that model predictions of decreased operator effectiveness were reliably related to increased accident risk ($r = -0.93$, $p < 0.01$). (Hursh et al., 2006; Dean, et al. 2007).

The science behind SAFTE led to the development of FAST™ (Fatigue Avoidance and Safety Tool), a computer application designed to predict and prevent fatigue in operational settings. The output of FAST is an empirically derived performance-effectiveness score used to quantify potential fatigue risks. FAST™ allows entry of proposed schedules and generates graphical predictions of performance along with tables of estimated effectiveness scores for objective comparison (see Figure 4 below). Optimal schedules may be selected based on average effectiveness for proposed work periods or critical events. A sample chart from FAST™ is shown below with hours and days along the x-axis and percent cognitive effectiveness on the y-axis (see Figure 4). The graph shows variations in effectiveness across a two-week work cycle with a two-day break in the middle. The red bars on the bottom scale indicate work intervals and the blue bars indicate sleep periods. The graph is red when performance coincides with work periods. This example is for a case in which work occurs primarily at night and sleep is occurring primarily during the day and is limited to about seven hours of sleep per day.[2]

[2] It has been shown that the fatigue level below an Effectiveness Score of 70% (the red area of the figure) degrades reaction time to be about equal to the degradation associated with a Blood Alcohol Content of 0.08.

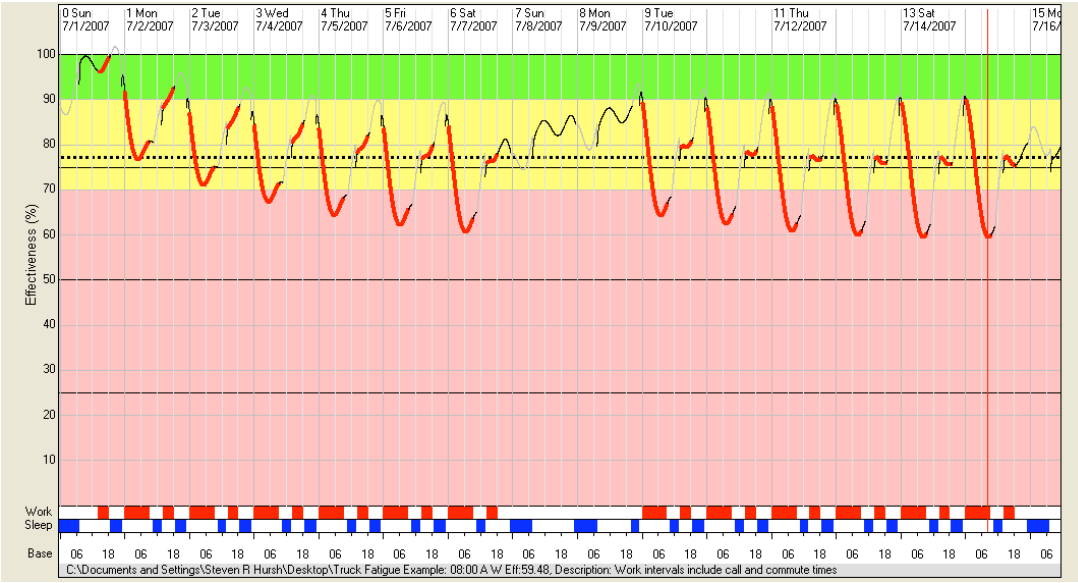



**Figure 4. Sample fatigue analysis showing the percent mental effectiveness across a work schedule using FAST.**

The FAST™ software has been specifically designed for applications in transportation and industrial settings. The FAST predictions will provide an assessment of how predicted performance (effectiveness) varies with various other variables. Cognitive effectiveness is defined as a predictor of speed of reactions and vigilance in laboratory tests that is inversely related to fatigue. It is expressed as a percent of the average person's best performance (cognitive speed) when well rested. Both the SAFTE model and proprietary FAST application are critical fatigue management tools used in a variety of applications.

The primary analysis is an "effectiveness profile" that describes how duty time is distributed across a range of effectiveness bins from high performance (>95) to low (< 55). Additional analyses will show how effectiveness varies across duty intervals varying in length and how effectiveness varies on duty at different times of the day. Largely, this will be a descriptive analysis but we could look at how these various patterns vary with demographic variables described above provided. These pilot data will inform us about the quality of the data and the complexity of the analysis for future studies. Ultimately, the modeling results will be related to pilot-performance data collected across the roster period.

The data will be analyzed in the following fashion:

1) Transform the adjusted effectiveness scores by means of the function E* = 100/E (where E represents the effectiveness score and E* its transformed value). The inverse of the effectiveness score has been shown to be highly correlated with reaction times on the Psychomotor Vigilance Task (PVT) and to the probability of a "lapse" (reaction times > 500 ms) that itself is highly correlated to the probability of an accident. The transformation effectively "rationalizes" the effectiveness scores, so that a difference of *x* between two transformed scores has approximately the same meaning regardless of the

actual values. Predictions of the FAST model will be compared to actual PVT performance collected on both duty and non-duty days.

2) Compute the difference of the inverse effectiveness scores between corresponding half-hour intervals in blocks A and B and in blocks B and C. By corresponding intervals, we mean half-hour intervals at the same time of day on the same day in the block. This process cancels out the circadian component of effectiveness variation without recourse to the formula used by FAST, since both scores are estimated at the same point in the circadian rhythm (time of day). It also acts to cancel any regular secular change in effectiveness scores as the subject progresses through the five-day block of work. This allows us to treat the half-hour difference in transformed effectiveness scores as replicated observations within any given day. The process has the disadvantage of removing some data from consideration, since a difference can only be computed when an effectiveness score exists for a subject in the corresponding half-hour interval on the corresponding day in both blocks i.e., if the subject was recorded as being on duty at that time on that day in both blocks.[3]

   We propose to further restrict attention to *paired* differences--i.e., for each half-hour interval within the 5-day work period where the difference between blocks A and B exist, the difference between blocks B and C would also exist, and vice versa. This would require that effectiveness scores exist for precisely the same half-hour intervals in each of the 3 blocks, essentially restricting analysis to the intersection of the subject's work periods across the 3 corresponding days in the 3 blocks.[4]

3) Perform a General Linear Model (GLM) analysis as the more flexible and robust equivalent of a 3-factor analysis of variance (ANOVA) on the paired differences of the transformed effectiveness score, with factors defined as:

| | |
|---|---|
| Subject | 6 levels (A, D, E, G, N, and U) |
| Block differences | 2 levels (A-B, B-C) |
| Day in block | 5 levels (Day 1, 2, 3, 4, 5) |

   Each combination of factors defines a cell. The analysis treats 6 x 2 x 5 = 60 cells, or 10 cells per subject. The GLM will be used because it is more robust than standard ANOVA when confronted with a combination of very small cell sizes (two cells have only 4 observations each), a wide range in cell sizes

[3] In the data from the first experiment, there are a total of 883 paired differences of the form A-B and B-C. This looks like a significant loss of information, but note that the number of block levels has been reduced from 3 blocks to 2 block differences. The collection of paired differences yield 883/2 = 441.5 observations per treatment level, whereas the raw data contains 1,421/3 = 473.67, so the number of data points per treatment level has been reduced by 32.17, or about 6.8%.

[4] In the data from the first experiment, this would reduce the amount of data available to 419 pairs of differences, or 838 differences all told, with the smallest block size being 4 pairs (subject D on Workday 5, when the intersection is limited to 16:00-18:00). In fact, this further restriction does not reduce the number of data points by very much: there are a total of 883 unpaired differences, so restricting analysis to paired differences entails a loss of 883-838 = 45 pairs, or 5%. From the standpoint of the original data, with 473.67 data points per level, this represents a reduction of (473.67 - 419)/473.67 = 11.5% observations per treatment level from the original data.

(ranging from 4 through 21), and unequal within-cell variances. We will test for normality using the Shapiro-Wilk procedure and for equality of cell variances with Levene's test.

4) A difference in effectiveness between the 8-day schedule (3 off, 5 on) and the 7-day schedule (2 off, 5 on) will show up as a difference between the mean values for B-C (controlling for subject and day in block) and those for A-B. A difference between early starts and late finishes will show up as a difference between mean values for days 1-3 versus means for days 4-5; one possible test (if GLM results warrant) is to collapse data from workdays 1-3 into an early-report level and workdays 4-5 into one late-finish level and test for a significant difference in mean paired differences between these two levels.

None of the above should be construed to mean that other analyses are excluded from consideration. We will remain sensitive to the import of results from these procedures and apply them to suggest directions for further investigation. One concern is that the grain size of ½ hour is too large especially as the average flight leg is not much more than that. While this might satisfy easyJet's interest in the effect of scheduling on individual performance, obtaining exact times for the events would be beneficial in correlating decrements in crew performance during the course of each flight with an aircraft event.

### Progress to Date in Data Analysis and Modelling

During September 2009, the first of the four experiments was conducted by easyJet using the sample group of flight crews on rosters all of which operated under the FRV rule set. During that month, a high number of flight duties per crewmember operated under the FRV rule set and, therefore, produced the largest set of data to test the parameters of the FRV rule set.

Data collection occurred on crews that were scheduled to operate three consecutive early start duties followed by two late finish duties (Block A). This allowed for collection of sleep and performance data during the first schedule transition. Following Block A, three days off were provided. The second duty block (Block B) contained one further transition change and the duty sequence closely reflected timings and workload of Block A, for comparison purposes. Another two rest days were provided following Block B. Data were also collected for another 5-day period block (Block C) in order to compare performance levels following two days off to that following three days off.[5]

In addition to developing the initial concept of an approach for this study described above, the focus of the work on individual performance to date has been on using the data set from this first experiment for familiarization, exploratory analyses, and evaluation of their quality and quantity for achieving the objectives of this research and answering the questions that have been posed. The following discussions pertain to these

[5] The schedule can vary for each base due to the fact that the commercial model at each base is different. Therefore, start and finish times per duty day may differ among bases.

initial examinations of the data. The results presented refer to group data instead of individual data. However, after examining the group data the results will focus on individual data such as to be able to create an individual profile based on the measures collected.

***Demographic Characteristics of Participants***

Twenty-two commercial aviation pilots (19 males and 3 females) volunteered to participate in the first study between September 2, 2009 and October 3, 2009. The participants were between 20 and 35 years of age (M = 26, SD = 4) of different nationalities (20 British, 1 Danish, and 1 Italian). They had an experience of M = 501.14 (SD = 362.43) commercial hours and M = 417.95, SD = 143.30 easyJet hours. One subject who had an experience of 2000 commercial hours. Additional information that would be useful in future experiments are the type of aircraft for which they are certified and the portion in the current aircraft. These and other basic demographic characteristics for all participants in the first experiment are included in Appendix A. However, data from the questionnaires on MEQ, CID, and ESS were not received.

***PVT***

The analyses conducted for PVT were limited because the data received from easyJet to date included only the mean reaction times. Reliable comparisons for PVT during baseline periods and during duty days cannot be made because information on the timing of PVT administration was lacking as well as considerable amounts of data. In general, there were no significant differences in the mean values of PVT measured during the rest days or the times of day at which those measurements were made. During duty days, there was observed a steady increase in mean value of the RT for D4 (the day with a long schedule) although it was not significant. However, some preliminary analyses on PVT for the group are included in Appendix B. Further analyses will explore individual data.

The measures that will be incorporated, based on most commonly used PVT performance metrics published in previous studies will consist of the following: 1) lapses – the cumulative number of reaction times exceeding 500ms – a consistent indicator of deficits in sustained attention; 2) median reaction times – to measure central tendency in response times uninfluenced by outliers; 3) optimum response times – or fastest 10% of reciprocal response times for all trials – an indication of the best performance a participant is capable of producing.

***NASA TLX***

Preliminary analyses were conducted on the TLX raw data due to the fact that the weighted data received from easyJet to date are incomplete. The use of only raw data is based on research that has shown high correlations between the weighted and unweighted scores (Byers, Bittner, & Hill, 1989; Moroney, Biers, Eggemeier, & Mitchell, 1992). Thus, in the present study a simple arithmetic mean was computed across subscales of the NASA TLX and it was treated as a subjective workload score. Each workload rating score has 6 subscales of mental workload (mental demand, physical demand, temporal demand, effort, performance and frustration). There was a main effect of effort per block ($F$ (2, 668) = 6.83, $p$ = .001) with lower effort during Block A ($M$ = 50.61, $SD$ = 19.79)

compared with Block B and Block C ($M$ = 55.35, $SD$ = 20.83 and $M$ = 57.66, $SD$ = 21.930 respectively). Across six subscales, performance was rated the highest for all blocks. The NASA TLX data will be analyzed in similar fashion for each participant and in combination with hassle factors to determine their effect on pilot performance. A summary of the workload subscales for each block is included in Appendix C.

***Workload Hassle Factors***

The workload hassle factor data was received with some empty cells in the spreadsheet and it is not clear if they represent missing data or whether no hassle factor workload questionnaire was completed (due to no hassle factors being experienced). A summary of the hassle factors encountered by each individual is included in Appendix D.

***Samn-Perelli***

The Samn-Perelli dataset received does not include the actual time when the Samn-Perelli scale was completed and recorded. It is possible to determine approximate times during the rest days by looking at the scheduled times of administration. However, it is harder to determine the times during duty days because the actual times of the flight sectors differ from the scheduled times and the actual times were provided only for the whole duty day. Large individual variability in the Samn-Perelli measurements was observed among the 21 pilots as shown in Appendix E(1). The subjective fatigue ratings were not significantly different among the rest periods as shown in Appendix E(2); the subjective fatigue ratings were significantly different across the times of day (morning, afternoon, evening; $F(1.94, 294.34) = 123.97$, $p < .001$) as shown in Appendix E(3). There were also significant differences across the times of day during the duty days (F3.30, 132.17) = 48.405, $p < .001$ as shown in Appendix E.

***Fatigue Countermeasures***

Similar to the hassle factors dataset, it is not clear whether empty cells represent missing data or whether no fatigue countermeasures were employed. A summary of fatigue countermeasures employed by pilots is provided in Appendix F. Caffeine was the most preferred fatigue countermeasure, followed by crew communications.

***Actigraphy***

The actigraphy provides objective measures of sleep/wake cycles. The analyses of these data will focus on differences between baseline sleep obtained during rest days, sleep obtained during duty days, and recovery sleep obtained after duty days. Data on recovery sleep for Block C were not obtained for this experimental period. The average sleep time obtained through actigraphy was M = 6.38, SD = 1.55 and the average sleep efficiency (%) was M = 78.75, SD = 9.76. The sleep times and the sleep efficiencies recorded for each pilot are shown in Appendix G. There was a significant main effect of duty day $F(3, 456) = 12.45$, $p = .000$, with the average sleep time before the first duty day being the lowest compared to other days. It is possible that the pilots did not adjust their sleep time for the duty schedule although their first day of the duty block started very early in the morning.

***Bio-harness***

The bio-harness equipment was not delivered to easyJet in time to train the subjects for the first experiment. However, after the 20 sets of equipment and small laptop computers were delivered, NASA personnel visited easyJet and instructed easyJet personnel so that they will be able to train subjects for the remaining three experiments.

***Sleep Diary***

To confirm data collected by Actiwatch, sleep quality and total sleep time will be calculated for each individual based on information from the sleep diaries followed by correlations between actigraphy data and sleep-diary data. Sleep diary data correlated well with actigraphy data ($R = .179$, $p = .001$) even though the average sleep time ($M = 8.09$, $SD = 1.95$) recorded in the sleep diary was higher than that recorded by the actigraphy ($M = 6.38$, $SD = 1.55$).

***Model Assessments***

There are 962 records with work and sleep histories for 22 individuals collected between September 2, 2009 and October 3, 2009 inclusive. Work records for the subjects were coded alphabetically A through V and consist of start and end dates and times for work shifts. Sleep records consist of start and end dates and times for sleep periods, as reported by the subject. There is not necessarily a direct correspondence in any given record between the Duty start/end times and the Fall Asleep Time (FAT) and Wake Up Time (WUT), although they will always refer to the same subject. The 'WorkTimes' and 'SleepTimes' files needed to be created separately.

All 22 of the subjects for data collected from the first experiment were on a FRV schedule (see Figure 1). The earliest report time on days 4-5 is nearly 3 hours later than the latest report time on days 1-3, and the earliest finishes on days 4-5 are [with one exception] all later than the latest finishes on days 1-3.

| | Workday 1 | Workday 2 | Workday 3 | Workday 4 | Workday 5 |
|---|---|---|---|---|---|
| Earliest report time | 6:00 | 4:40 | 4:40 | 10:35 | 10:35 |
| Latest report time | 7:40 | 6:40 | 5:55 | 16:30 | 16:30 |
| Earliest finish | 11:24 | 9:32 | 9:39 | 19:35 | 17:35 |
| Latest finish | 18:00 | 16:30 | 15:03 | 1:10* | 23:30 |

* - Following day

The data sleep/wake cycles and duty schedule data have been evaluated for inconsistencies, such as duty periods that start prior to the earlier one ending, duplicate data, very long sleep intervals (greater than 12 hrs), missing sleep data (greater than 36 hrs without sleep), or incomplete data (sleep start without a sleep end or vice versa).

Although there were adequate data collected on sleep histories for most of the 22 subjects, there were only 6 pilots for whom there were complete and consistent work and sleep records required to be eligible to be run through FAST Batch. 'Incomplete' means the apparent omission from the subject history of one or more work shifts or sleep

intervals and 'inconsistent' means showing work or sleep intervals that overlap with other work or sleep intervals.

It should be noted that omission of sleep periods is more serious than omission of work intervals. FAST computes effectiveness scores for work periods based on the subject's sleep history. When there is a gap in the work history but sleep periods are completely reported, scores for work intervals after the gap remain valid and usable. When sleep periods are missing, all effectiveness scores computed after the gap are rendered invalid. Effectiveness scores (output) are calculated in FAST based a person's previous sleep period (plus some other factors). If an individual reports 0-hrs sleep in the sleep diary, then this period is considered 1 night of total sleep deprivation. For example, if a person awoke on Day 1 at 0700 and stayed awake throughout the night until the next morning and we wanted effectiveness scores for 0700, the sleep history would be considered 24 hrs of total sleep deprivation and this would be used to calculate the effectiveness score. However, if a person awoke on Day 1 at 0700 and stayed awake until midnight and then did not wake until 0700 the next morning, their effectiveness scores would be calculated with 7 hours of total sleep.

The challenge lies with the following. When using sleep diaries, people are sometimes noncompliant or forgetful and do not enter all of their sleep periods. When no sleep period is entered, we assume that no sleep was obtained and this is not always the case. Some records in the easyJet data have been identified that we are not sure if they just forgot to enter their sleep period or they actually stayed awake continuously.

However, it should further be noted that sleep interval estimates captured by actigraphy would be more reliable than those self-reported so long as there are no hardware or software glitches. Although actigraph records for these subjects were not considered in the development of this analysis plan for the modeling work, the actigraph data will help us to confirm what is going on, allowing the estimates of effectiveness to be more accurate. In some of the records where people have no sleep periods reported, we tend to think that they just forgot to enter it since we would hope that pilots were not reporting to work after 2 days of continuous sleep deprivation.

In the data from the first experiment there were only 6 subjects with full work and sleep logs for all 23 days of the FRV schedules, with a total of 1,421 half-hour work intervals for which FAST computed effectiveness scores. The work and sleep records for these 6 subjects (coded A, D, E, G, N, and U) were converted from Excel into ACCESS database suitable for FAST and were processed using the FAST Batch program. Based on the self-reported start and end times of sleep periods, effectiveness scores (on a range from 0 to approximately 110, with higher score equating to greater effectiveness) were generated for each full half-hour of the day (starting at midnight and half-hour intervals thereafter) during which they were on duty. These same analyses will be conducted using objective, actigraphy data. See Appendix H for the results of the analyses performed to date using FAST.

## 3. Aircraft Performance

### Background

Code TI's role is to develop and apply algorithms that automatically extract information on anomalous events from the flight-recorded data and algorithms that automatically extract anomalous event information from easyJet's Air Safety Reports (ASR). The aim is to identify relationships between anomalous events and/or exceedances identified in the flight data and their possible causes identified in the ASR's. Additionally, Code TI will work with Code TH to identify events in flight-recorded data that can serve as surrogates for indications of fatigue in physiological data collected during some flights. The idea is to use these surrogates in the clear majority of flights for which physiological data cannot be collected. The developed algorithms will contribute to NASA and easyJet's joint efforts to develop efficient and reliable methodologies to extract and merge information from large, diverse data sources. The goals of this research are to assist aviation safety analysts to:

1. Identify expected and unexpected operationally significant events or trends in aircraft performance that could compromise the safety of the system.
2. Identify the latent and proximate causal and contributing factors of the events identified to enable data-driven decisions on interventions or mitigations.
3. Identify the events in which flight-crew fatigue was a contributing or causal factor.

### Approach to Flight-Data Analysis

The purpose of Code TI's work in flight-data analyses is to discover the unexpected events that could compromise the safety of operations to complement and supplement the search for the expected events that is currently typically performed under the Flight Operational Quality Assurance (FOQA) programs. The expected events are usually defined by a single variable that has exceeded a value during a particular phase of flight that is considered outside of the established Standard Operating Procedures (SOP's). The algorithms developed by Code TI search for sets of continuous parameters and binary switches that contribute to an event that is considered statistically anomalous in a multivariate comparison with normal operations.[6] The automatic identification of the contributions of the particular continuous and discrete parameters entailed in the identified anomalous event assist the domain expert in ascertaining its operational significance. The algorithms are designed to process very large data sets (collected at the rate of over 10,000 Kb per flight and about 2.5 Tb per year) in nearly real time.

An outline of the approach, which has been named the Multiple Kernel Anomaly Detection (MKAD), for detecting the unexpected anomalous events in the numerical flight-recorded data is diagrammed in Figure 5.

[6] Safe "Normal" operations are not always completely consistent with the SOP's.

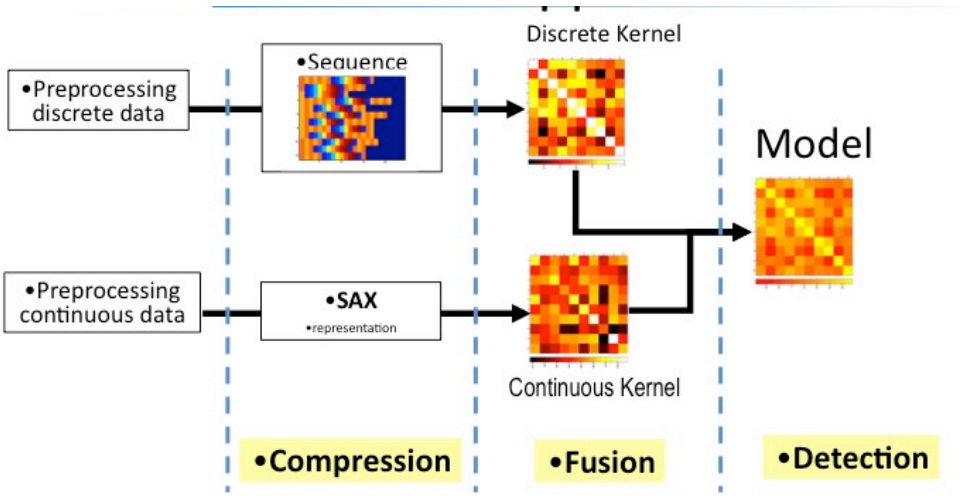



**Figure 5 – Outline of Approach**

Initially, the discrete and the continuous data are processed independently. Compression of the discrete data is achieved using processes based on the previously developed algorithm called sequenceMiner, that detect and characterize anomalies in large sets of high-dimensional symbol sequences that arise from recordings of switch sensors in the cockpits of commercial airliners. sequenceMiner works by performing unsupervised clustering (grouping) of sequences using the normalized longest common subsequence (LCS) as a similarity measure, followed by a detailed analysis of outliers to detect anomalies. An outlier sequence is defined as a sequence that is far away from the cluster center. The algorithms provide a coherent description to an analyst of the anomalies in the sequence when compared to more normal sequences.

Compression of the continuous data uses **S**ymbolic **A**ggregate appro**X**imation (SAX -invented by Eamonn Keogh and Jessica Lin in 2002), which provides a symbolic representation for time series that allows for dimensionality reduction and indexing with a lower-bounding distance measure.

These steps are followed by a fusion process in which discrete and continuous kernel functions are developed. Kernels are used in kernel regression to estimate the conditional expectation of a random variable. The discrete and continuous kernels are fused into a single model that is used for detection of anomalous events that associated with multivariate (continuous and discrete) parameters for comparison with the expected events found by the search for prescribed exceedances.

Currently, the FOQA-like exceedances are identified for easyJet by Airbus and it contractor using its proprietary software called AirFASE. Through existing agreements among Airbus, easyJet, and ONERA, ONERA will undertake the task of identifying the exceedances in the flight data that are collected during the HFMP experiments. Through existing agreements among ONERA, easyJet, and NASA, these exceedances will be made know to NASA. Code TI personnel with assistance from subject matter experts will compare the results of the search for the unexpected events using NASA's anomaly

detection algorithms with the exceedances identified by ONERA using AirFASE. Based on previous similar experiments, we expect to find the comparisons to fall into three categories. There will be anomalous events that are identical to those prescribed exceedance events found using AirFASE. The multivariate information obtained using the algorithms for anomaly detection will complement the single variable exceedances information and give the safety analyst a better understanding of the event.

There will be a second category of events that are identified as an exceedance for which no anomalous event has been identified. Each of these is likely to have a different explanation. Reasons that we have found in pervious studies have been exceedances based on computed parameters within the AirFASE processing that were not recorded and available to the search for anomalies or exceedances that occur so frequently that they are not identified as anomalous events when compared to normal operations.

The third category will be events that have been identified as anomalous but have not been found using AirFASE. Figure 6 indicates the types of events that might be discovered based on searching the combination of continuous and discrete variables.

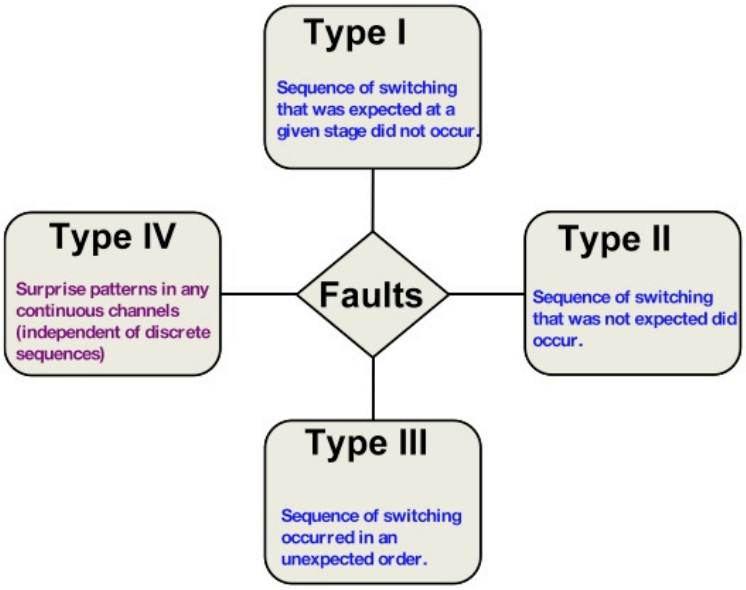



**Figure 6 – Types of Anomalies**

Events in all three of these categories along with the identification of the parameters that caused them to be considered a statistically significant event will be of value to the subject matter experts in identifying those events considered to be operationally significant. Newly discovered events that are deemed operationally significant could then be used to define a pattern to be used in a routine search of past or future flights for prescribed events.

### Approach to Aviation Safety Report Analysis

Code TI's work on text analysis is to develop algorithms to extract information from the textual data of easyJet's Aircraft Safety Reports that indicate the crew's

perspective on factors entailed in the reported event. In particular, the search of the ASR's will be to find reports in which the crew has identified human fatigue as a contributing or causal factor. Our approach is based on extracting Topics from free-form text using Latent Dirichlet Allocation (LDA). Frequently, more than one Topic is associated with each event. A Topic is defined by a set of words. The number of Topics to be identified in a set of textual reports is pre-specified as are the number of words to define a Topic.

The assumptions of the LDA are that

A document (D) is a mixture of multiple topics (T)

- Topic (T) has several words associated with it
- A document is generated by:
  1. First selecting a topic
  2. Selecting a word associated with that topic
  3. Repeating steps 1 and 2, for as many words as desired to form that document
- Collection of such documents forms a corpus (C)

The problem for LDA is, given C (a data set of textual reports), to find T. The process was tested on a set of 66,311 ASRS reports composed of 59 defined events (ASRS anomaly categories) and the following are 3 of the Topics that were found:

| TOPIC 1 | TOPIC 2 | TOPIC 3 |
|---|---|---|
| autoplt | time | apch |
| acft | day | rwy |
| spd | leg | visual |
| capture | contributing | ils |
| mode | factors | twr |
| rate | hrs | lndg |
| level | crew | loc |
| engaged | factor | arpt |
| leveloff | fatigue | final |
| vert | night | missed |
| ctl | trip | clred |
| disconnected | rest | msl |
| selected | duty | intercept |
| fpm | flying | vectored |
| light | long | sight |
| clb | late | gar |
| pitch | previous | terrain |
| manually | incident | field |
| warning | lack | uneventful |
| pwr | alerter | ctl |

Each of these Topics reflects fatigue as being, at least, a contributing factor. Examples of ASRS anomalous events in which fatigue-related Topics such as these were involved were

Altitude Deviation
Spatial Deviation
Ramp Excursion
Landing with Clearance
Runway Incursion
Unstabilized Approach

In the absence of a well-defined categorization of easyJet's ASR's into prescribed anomaly classes, we will leverage the rich categorization of ASRS reports and transfer the knowledge learned from those reports to categorizing ASR's into the ASRS anomaly categories. We will use the expertise that has already identified certain ASRS anomalous events with fatigue to determine which of the Topics identified by LDA are fatigue related with high probability and also which of the Topics occurred in a particular ASRS event. The appeoach for us would be to develop a classifier (e.g., Mariana) and a clustering technique (e.g., LDA) that have learned on the ASRS database and then test all of the ASR documents through both of these with the purpose of finding documents that, (1) with high probability, address LDA topics that relate to fatigue and (2) with high probability, relate to various ASRS anomaly categories. The point of this is to find reports that indicate both fatigue and some safety problem. This would allow us to transfer the information learned from ASRS to ASR and verify if similar documents exist in both. Of course, we will look to subject-matter experts at easyJet for final confirmation and validation of our findings.

### Approach to Fusing Information from Flight Data and ASR

We will explore the relationships between the information extracted from the flight-recorded data and the information from the ASR's. While the flight data tell us *what* happened, the ASR's might give us clues as to *why*. Our focus for this study will be on indications in an ASR that fatigue might have been a factor in a corresponding anomaly or aircraft performance event in numeric flight data. Of course, not all aircraft performance events are crew fatigue related. Therefore, we will start with the ASR's that our analysis of the narrative has found indicate a high probability that the crewmember believed fatigue was a factor. Using the flight identification and the time stamp, we will relate the information from each fatigue-related ASR to the event(s) that have been identified in the corresponding flight. Domain experts from easyJet will be asked to review our identified correspondences to determine if the statistical anomalies that we identify correspond to operationally significant anomalies. This use of ASR's to identify the potential of fatigue having been a factor in an event will provide useful information for the analysis that will merge information on decrements of individual crew performance with decrements in aircraft performance.

The fusion method just described is a largely manual fusion method, in that the only automated parts are anomaly detection within the numeric data and anomaly identification within the ASR's. We are performing research to fully automate the process of finding correspondences between anomalies that appear in the numeric data and anomalies described in the text. We plan to extend the MKAD method described above to allow text reports for the same flight as available numeric data to be incorporated; thereby allowing MKAD to find flights that have anomalies in both numeric and text data, and identify correspondences between

anomalies in both types of data. As mentioned before, one difficulty to be overcome is that some flight data do not have corresponding ASR's. We must ensure that the method that we use utilizes ASR's when available but does not skew results when an ASR is not available.

### Progress to Date on Analyzing Flight Data and ASR's

The tasks for this year have focused on the relatively small sample flight-recorded datasets received by NASA to date and the resolution of issues of data transmission, data quality, and transformations needed to make the data format compatible with analysis method. The work associated with extracting information from the continuous and discrete numerical data and the work associated with extracting information from textual data have, so far, been performed independently.

#### *Flight-recorded Numerical Data*

As of the writing of this report, NASA has not yet received the flight-recorded data collected during the first experiment with flight-crews during September 2009. However, beginning on April 1, 2010, easy Jet made flight data available to NASA on a daily basis for data analysis. Since then NASA has been able to collect over 98,000 flights (1.1TB) over 5 months and performed anomaly detection using algorithms that were developed at NASA. We used 47,000 flights that were available at the time of this study (mid July) to test the MKAD methodology for anomaly detection. For purposes of this demonstration, the algorithm focused only on the landing phase of flight for analysis from 10,000 ft to landing. The results are presented in Appendix I and are divided into three categories: Events that were found to be Statistically Significant, events that we have called Heterogeneous, and a large number of Go Arounds. The contributing parameters that were identified by the algorithm are listed along with a plot for each anomaly. No attempt was made yet to relate these to FOQA exceedances or to assess their operational significance. Consideration is being given to a further study of the identified Go Arounds to see if it possible to define the circumstances (the precursors) that required a Go Around. Of course, the information will not be available from the flight data if the Go Around was in response to a command from ATC.

#### *Aviation Safety Report Analysis*

LDA was applied to a set of 12,665 easyJet ASR's to identify Topics in the free text. Although many Topics were identified using the LDA, we focused our attention in a preliminary study on one Topic that might relate to crew fatigue. The words associated with this Topic are shown below:

**TOPIC**
duty
food
time
safety
sector
rest
night
delayed
hours
water
early

long
room
days
risk
sandwiches
period
hotel
days

The words in this Topic point in several interesting directions. One is the issue with duty hours being long. Then some of the reports point to insufficient rest at night either at home or a hotel room. There is also a class of reports that talk about problems with the quantity and quality of crew food. In Appendix J, we present 10 ASR's with the highest probability of being associated with this Topic.

As of the writing of this report, we have still not received the flight data from the first experiment. Therefore, we made no study of the linkage of the numerical data and the ASR reports. When we receive linked flight data and ASR's, we hope to match ASR's that we have identified with fatigue with the aircraft performance data to establish a causal relationship between any such report and the associated flight performance. The additional problem that we found in the ASR's that we received so far was that, as exemplified in the 10 reports in the Appendix J, the fatigue-related reports did not, for the most part, address any specific event that occurred but rather they spoke of company policies that may have been contributing factors to fatigue.

### 4. Correlation of Individual with Aircraft Performances

Finally, the aircraft performance during the course of the roster schedule of duty and off duty days described in Figure 1 will be associated with the individual performance of the crew on that flight. All data have been time stamped to enable such linkage. It should be noted that not all anomalies or exceedances found in the aircraft performance data will be due to, or even associated with, decrement of human performance and that degradation of human performance will not always cause an anomaly or an exceedance in aircraft performance.

The overall goal of assessing potential causal factors of fatigue using demographic variables, CID, MEQ and ESS is to determine if there is reliable evidence demonstrating that crew fatigue is a causal or primary contributing factor in the occurrence of particular exceedances or anomalies in aircraft performance. If that is realized, then a possible pragmatic approach by easyJet for proactive management of safety risk due to fatigue is to develop a personal profile for each crewmember using his/her demographic on age, commute distance, base, flying experience, family status, etc.; Morning-Eveningness; CID; ESS; and, possibly, other characteristics. Each crewmember could then be matched to a roster best suited to minimize the potential of his/her fatigue over its course. Thus, continuous support of easyJet's Fatigue Risk Management System (FRMS) would simply entail maintaining an updated personal profile for each crewmember that addresses all of the known characteristics related to the potential of fatigue.

## 5. References


Byers, J. C., Bittner, A. C., & Hill, S. G. (1989). Traditional and raw task load index (TLX) correlations: Are paired comparisons necessary? In A. Mital (Ed.), Advances in industrial ergonomics & safety (Vol. 1, pp. 481-485). London: Taylor & Francis.

Dean, D.A. II, Fletcher, A., Hursh, S.R., and Klerman, E.B. (2007). Developing Mathematical Models of Neurobehavioral Performance for the "Real World", Journal of Biological Rhythms. Vol. 22, No. 3, 246-258.

Hursh S.R., Balkin, T.J., Miller, J.C., and Eddy, D.R. (2004) The fatigue avoidance scheduling tool: Modeling to minimize the effects of fatigue on cognitive performance. SAE Transactions, 113, 1, 111-119.

Hursh SR, Redmond DP, Johnson ML, Thorne DR, Belenky G, Balkin TJ, Storm WF, Miller JC,

Eddy DR. (2004). Fatigue models for applied research in warfighting. Aviation, Space and Environmental Medicine, 75, 3, 44-53.

Hursh, S.R., Raslear, T.G., Kaye, A.S., and Fanzone, J.F. (2006) Validation and Calibration of a Fatigue Assessment Tool for Railroad Work Schedules, Summary Report, U.S. Department of Transportation Federal Railroad Administration, Office of Research and Development Washington, DC 20590, DOT/FRA/ORD-06/21.

Moroney, W. F., Biers, D. W., Eggemeier, F. T., & Mitchell, J. A. (1992). A comparison of two scoring procedures with the NASA Task Load Index in a simulated flight task. Aerospace and Electronics Conference, 1992. NAECON 1992, Proceedings of the IEEE 1992 National (Vol. 2, pp. 734-740). Dayton, OH: NAECON.

Stewart, S. (2009). Human Factors Monitoring Program**:** Fatigue Risk Management Scientific Study Methodology. easyJet Airline Report, December 3, 2009.

**Appendix A**

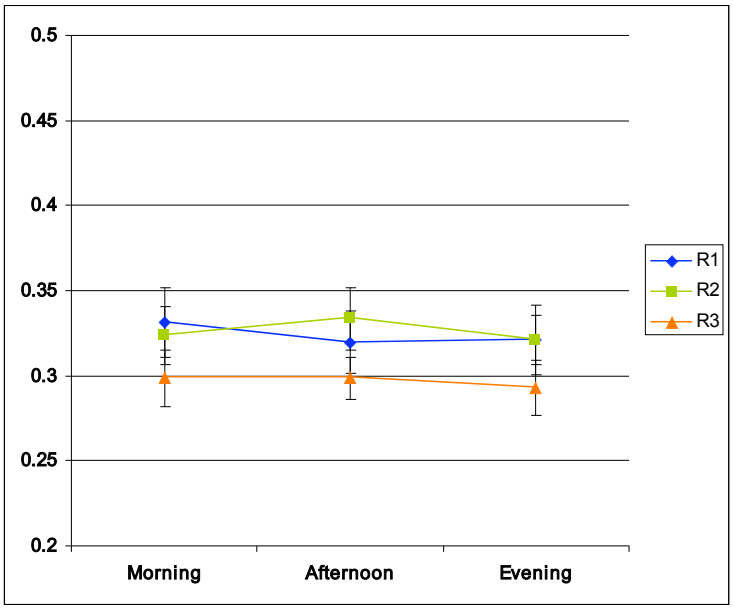
**Basic statistics for demographic characteristics.**

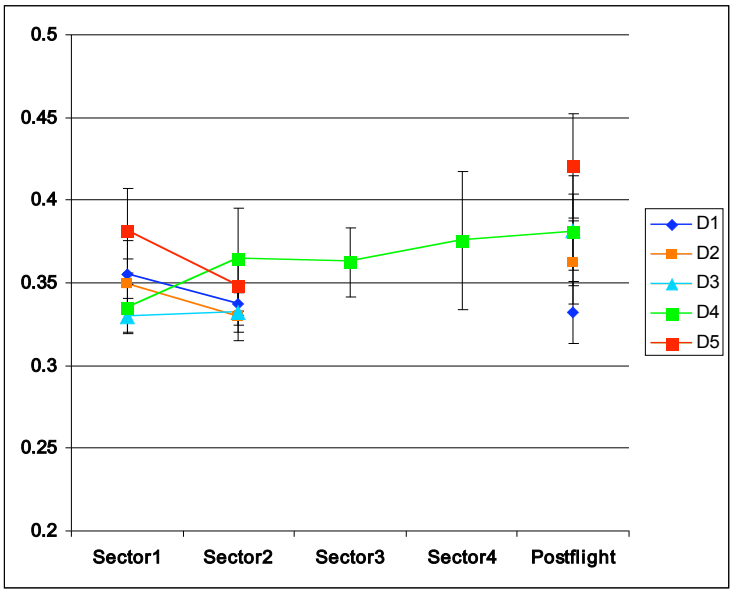
| | N | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|---|
| Age | 22 | 20 | 35 | 26.45 | 4.044 |
| PermComm in minutes | 14 | 15.00 | 60.00 | 33.5714 | 20.04117 |
| TempComm in minutes | 8 | 5.00 | 300.00 | 67.5000 | 97.79717 |
| Commercial Hours | 22 | 260 | 2000 | 501.14 | 362.425 |
| Hours on Type | 22 | 260 | 700 | 435.23 | 141.189 |
| Easyjet Hours | 22 | 220 | 700 | 417.95 | 143.300 |

## Appendix B

## PVT

The mean response time (RT) for all pilots during rest days and duty days are shown in the following figures by time of day on rest days and by sector on duty days. (R1 = rest period before Block A, R2 = rest period before Block B, R3 = rest period before Block C; D1, D2, D3, D4, and D5 are the averages of PVT for each of the corresponding days across all the duty blocks.)

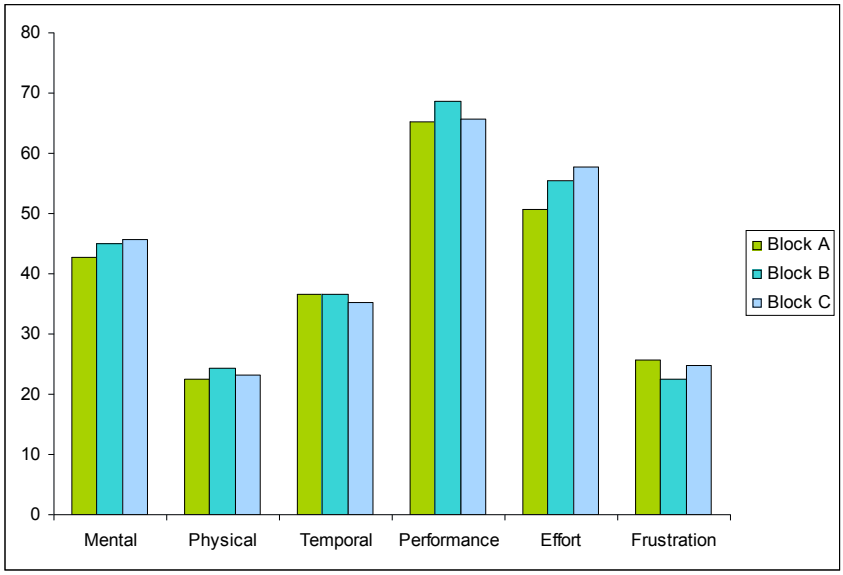


## Appendix C

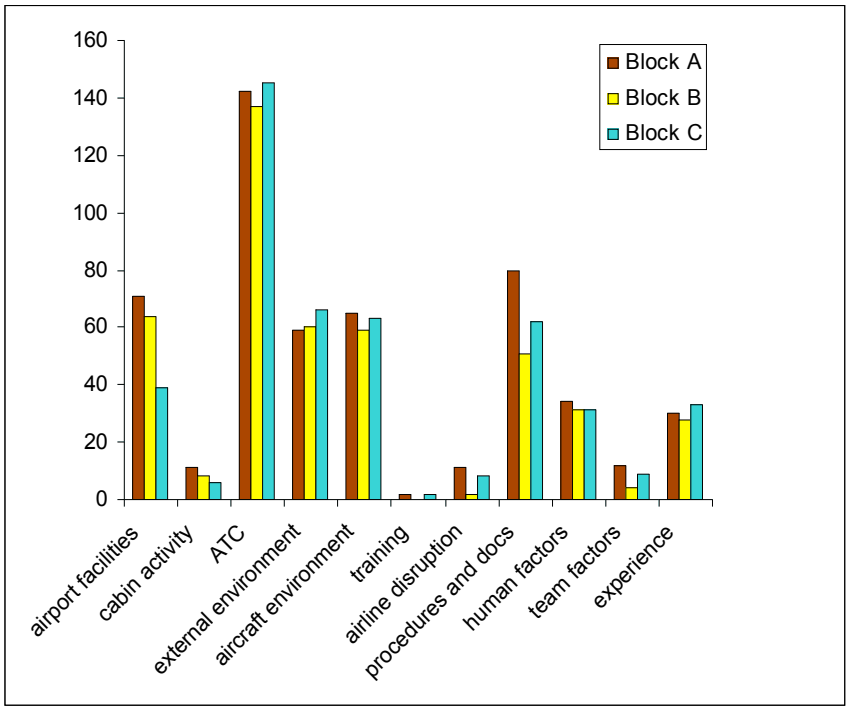
## NASA TLX

NASA TLX workload ratings are shown for each duty block.




## Appendix D

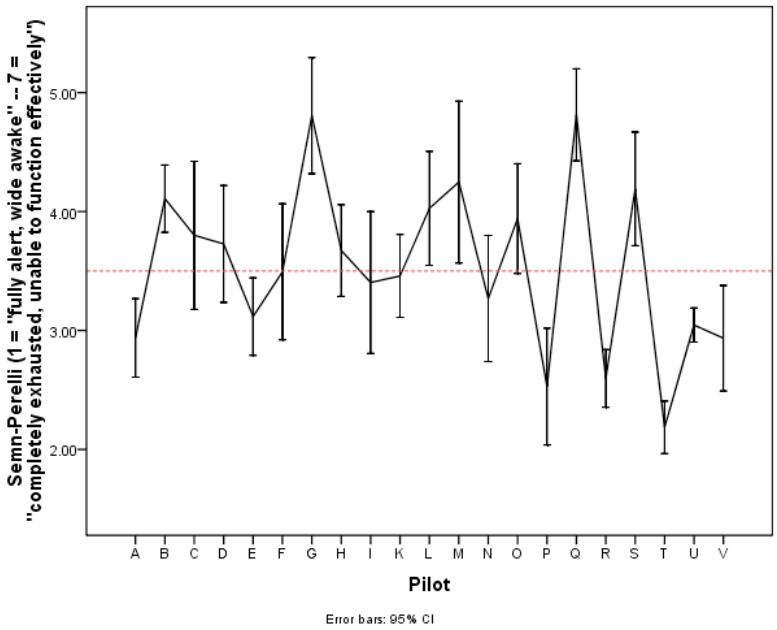
## Summary of Hassle Factors Encountered by Pilots during each Duty Block



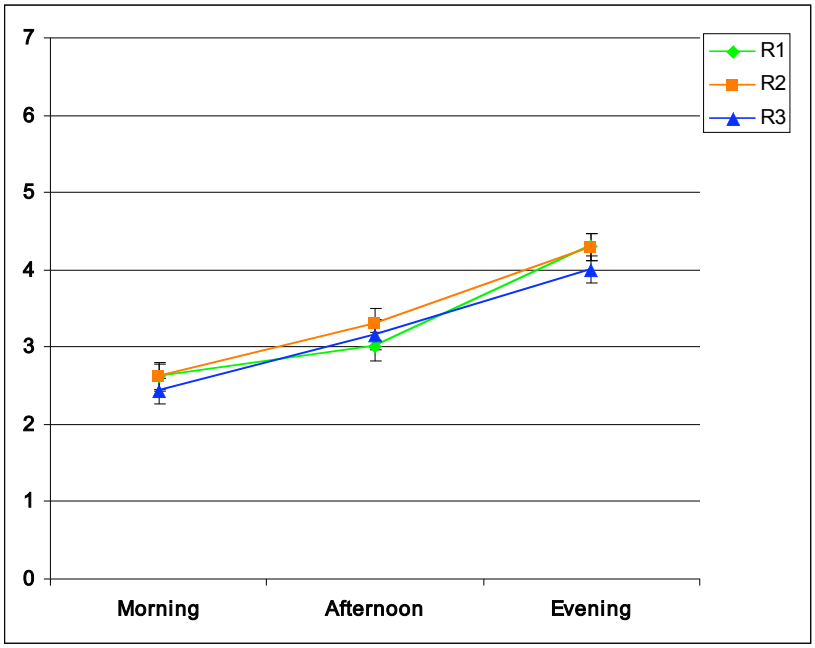
## Appendix E

## Samn-Perelli

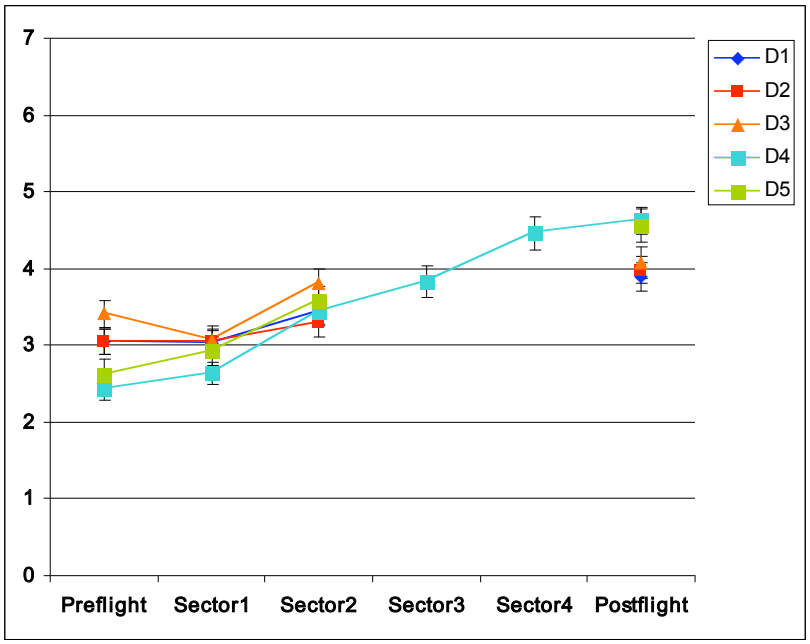
(1) Samn-Perelli subjective fatigue assessment for each subject




(2) Samn-Perelli subjective fatigue ratings during rest days

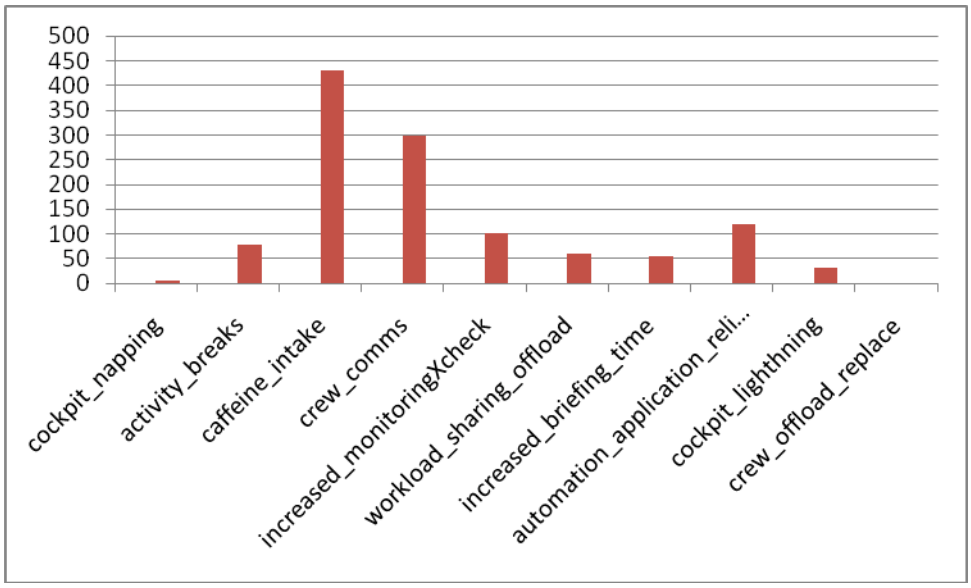


(3) Samn-Perelli subjective fatigue ratings during duty days

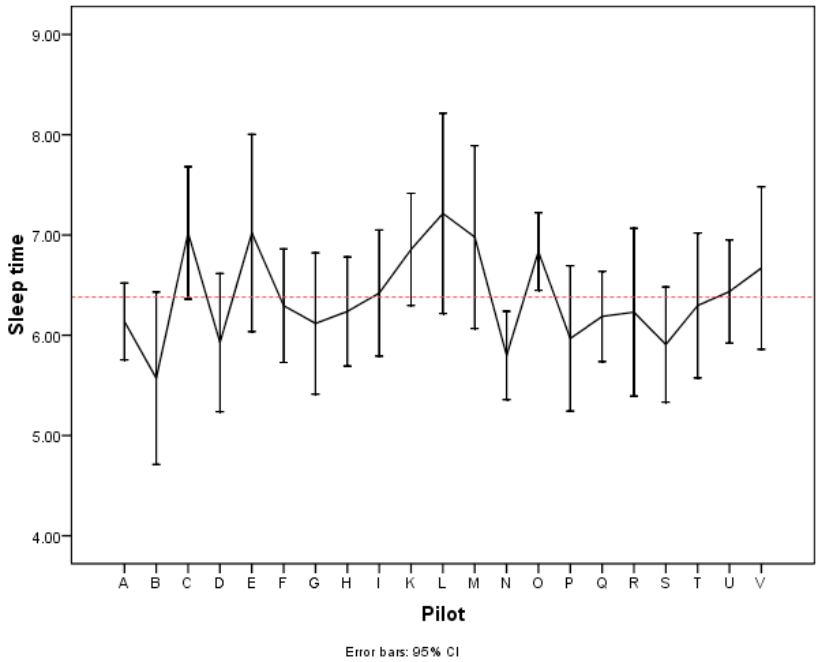


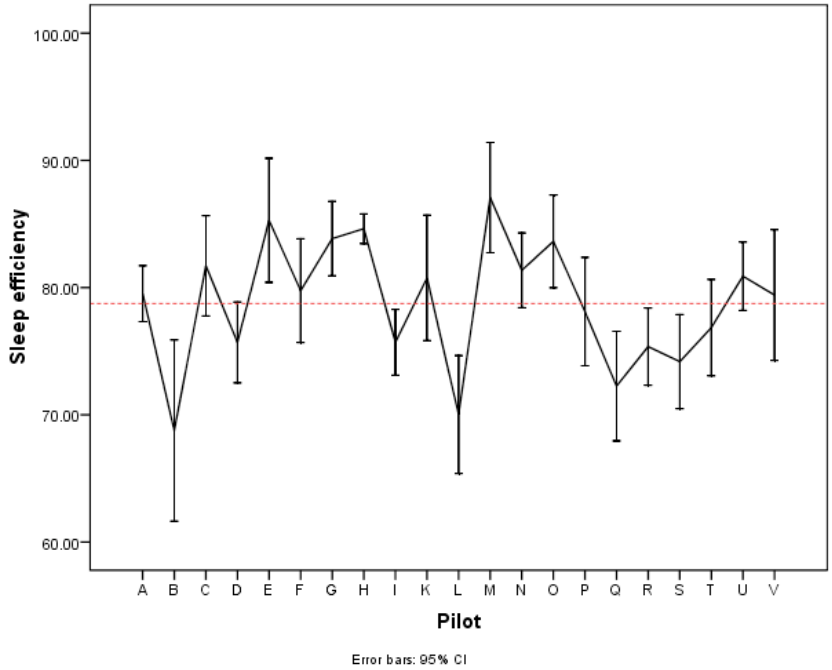

## Appendix F

## Fatigue countermeasures employed by all subjects



# Appendix G
## Actigraphy sleep time and sleep efficiency (%)

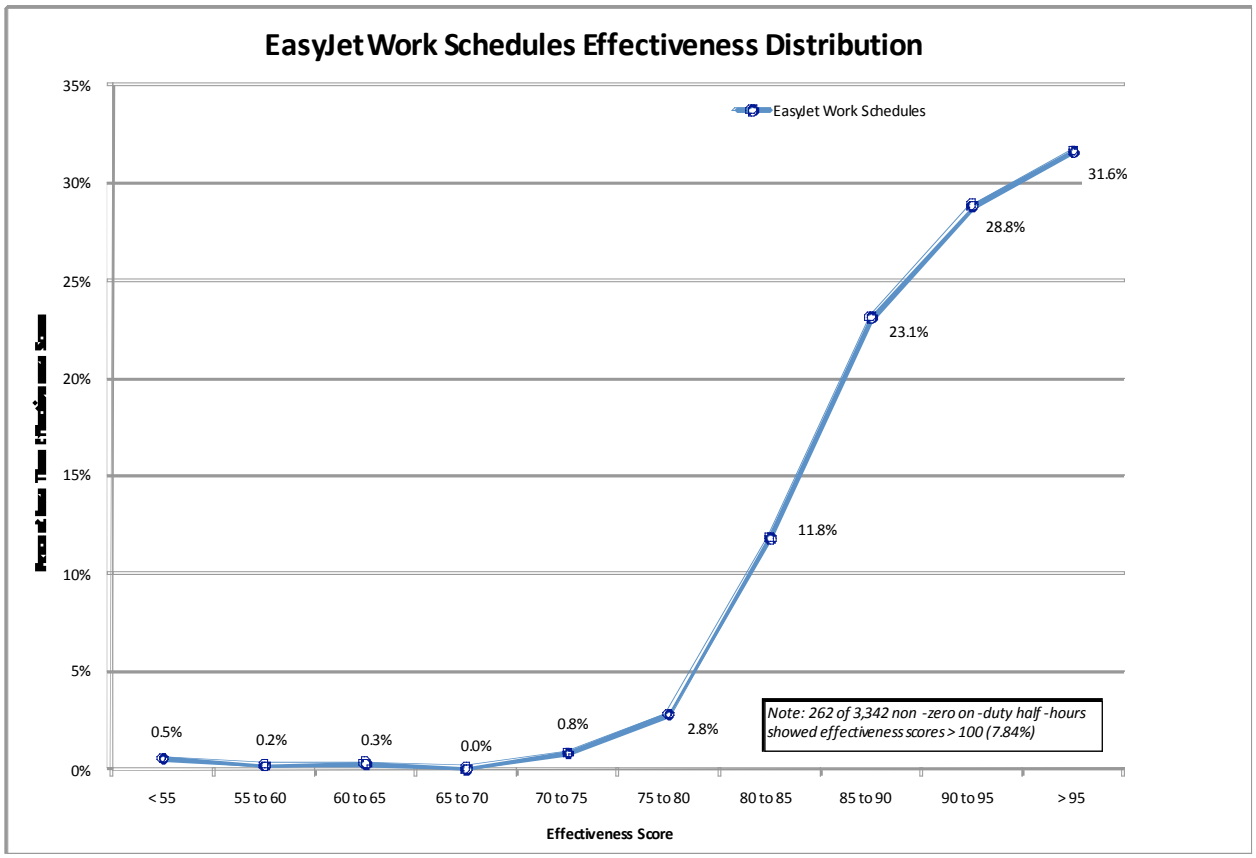


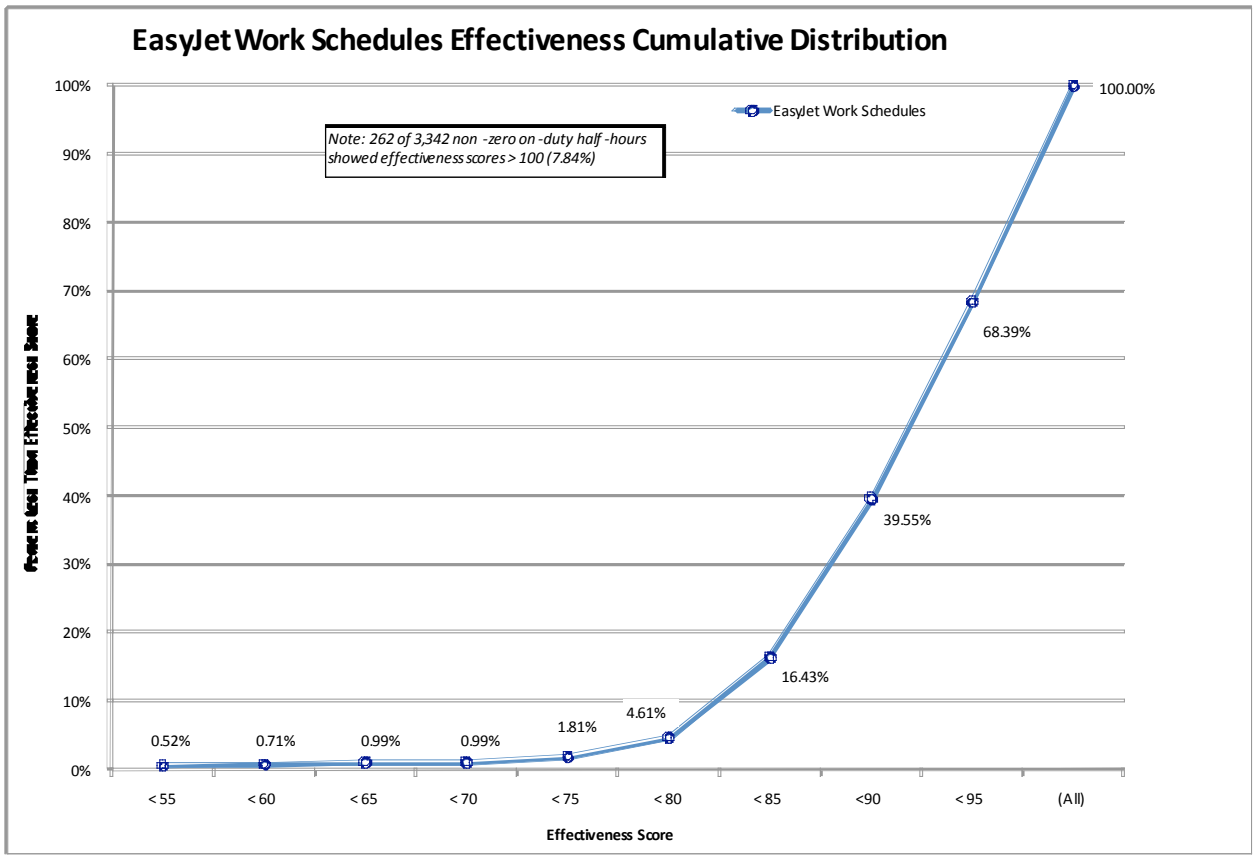
# Appendix H

## Results of FAST Analyses

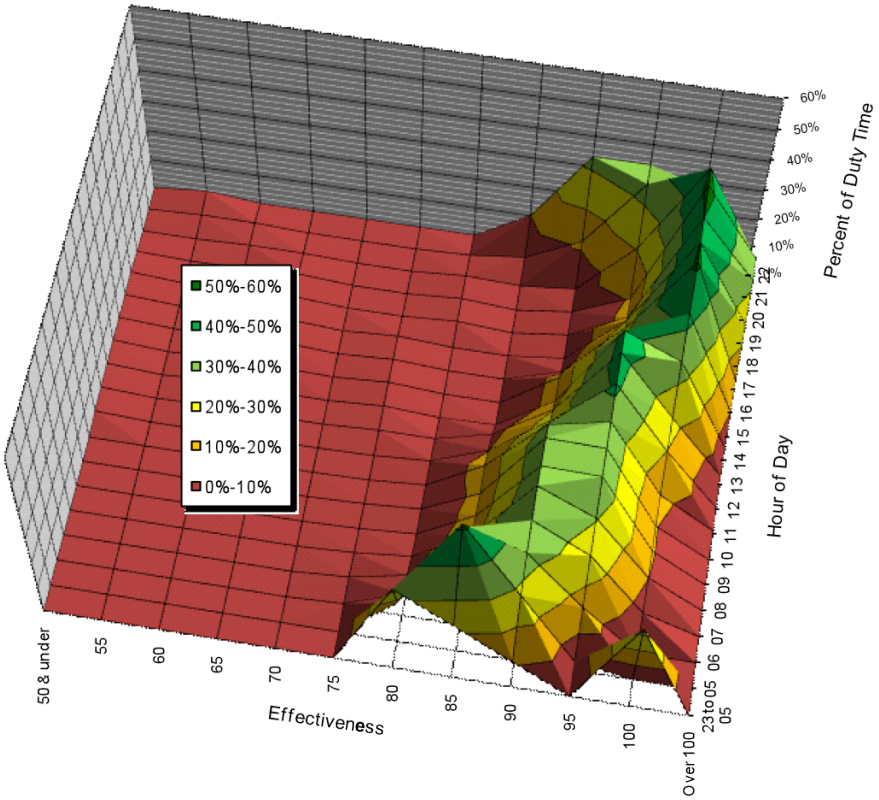
**Question: What % of time at X Effectiveness?**



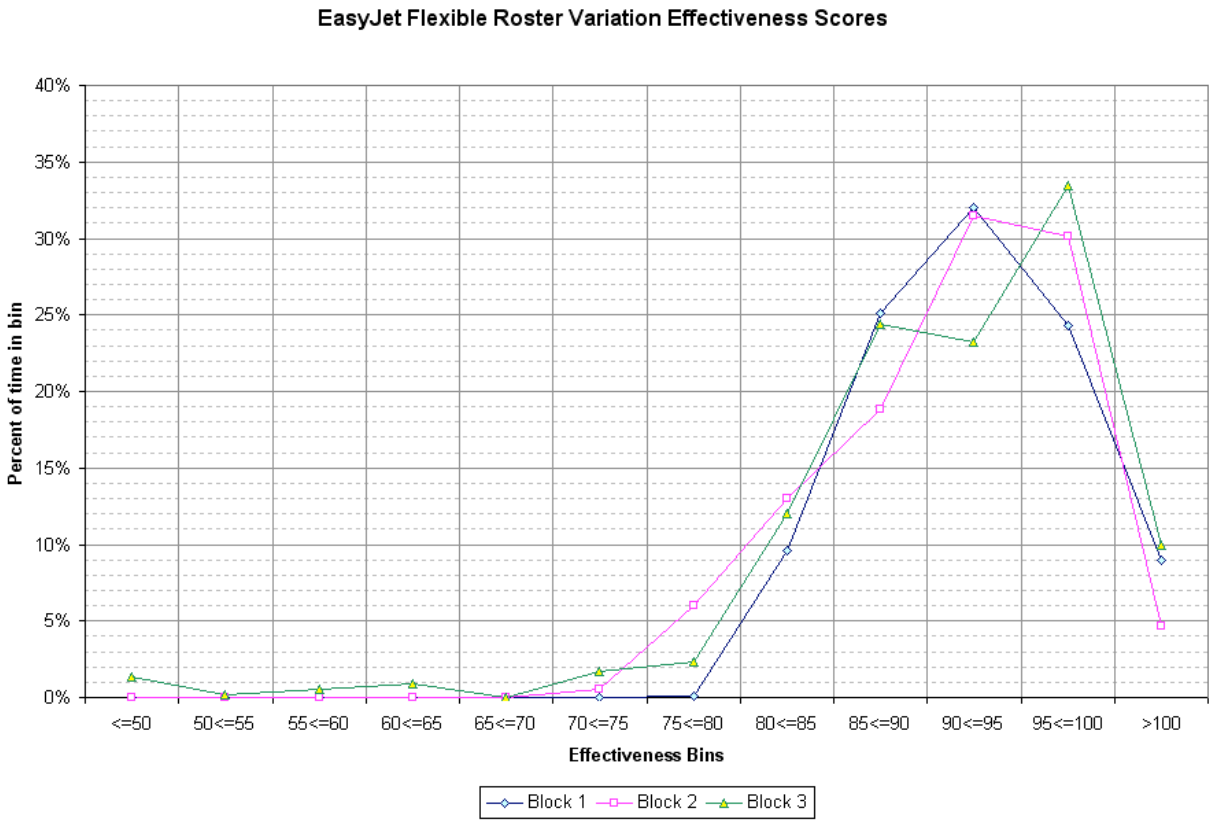
## Question: What % of time Below X Effectiveness?



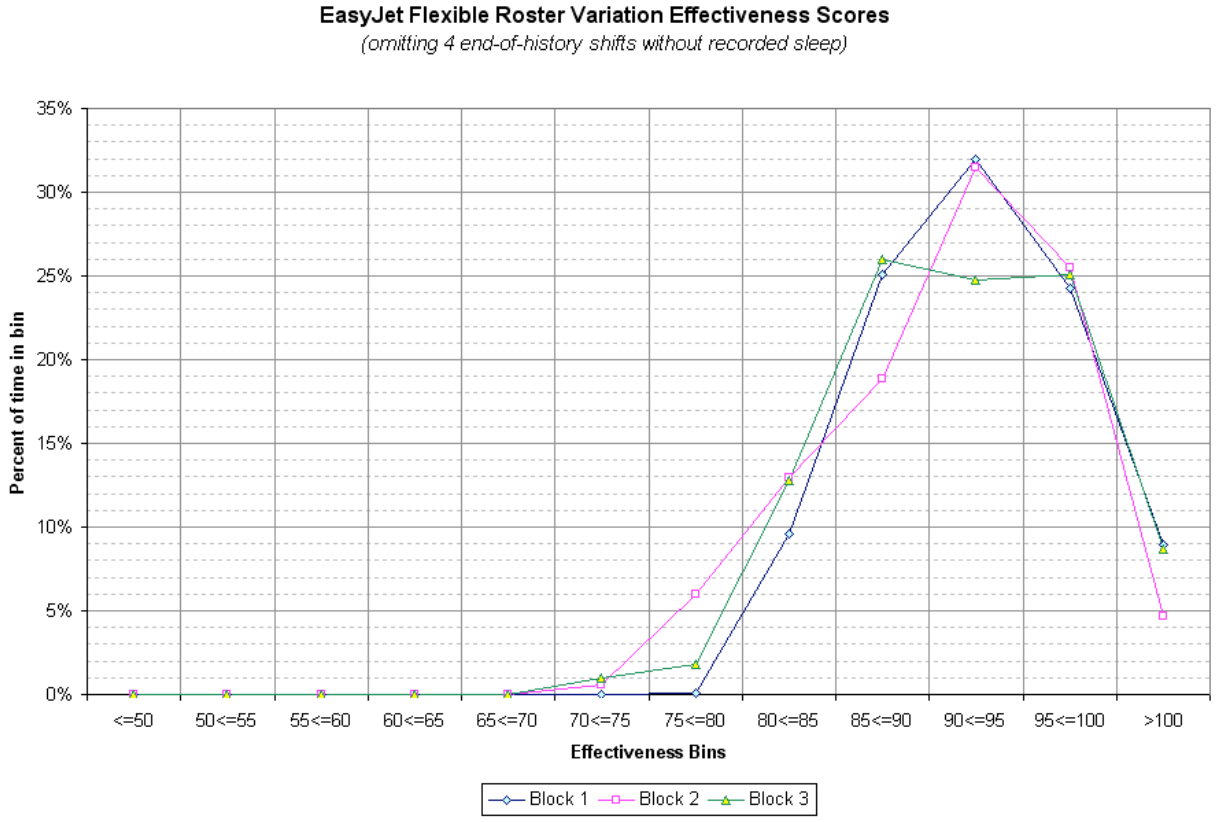
**Question: How does Effectiveness on Duty Vary Around the Clock?**



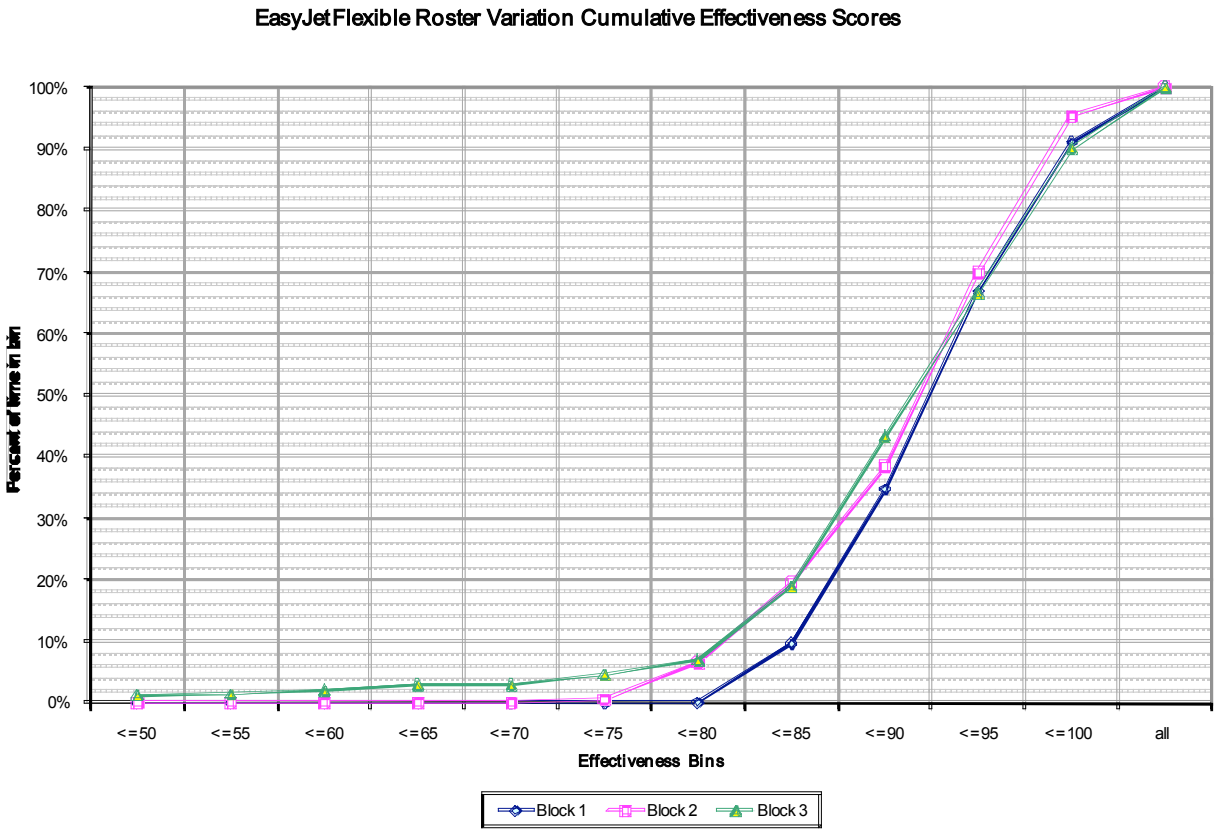
## Question: How Does Effectiveness Change Across Blocks of Duty?



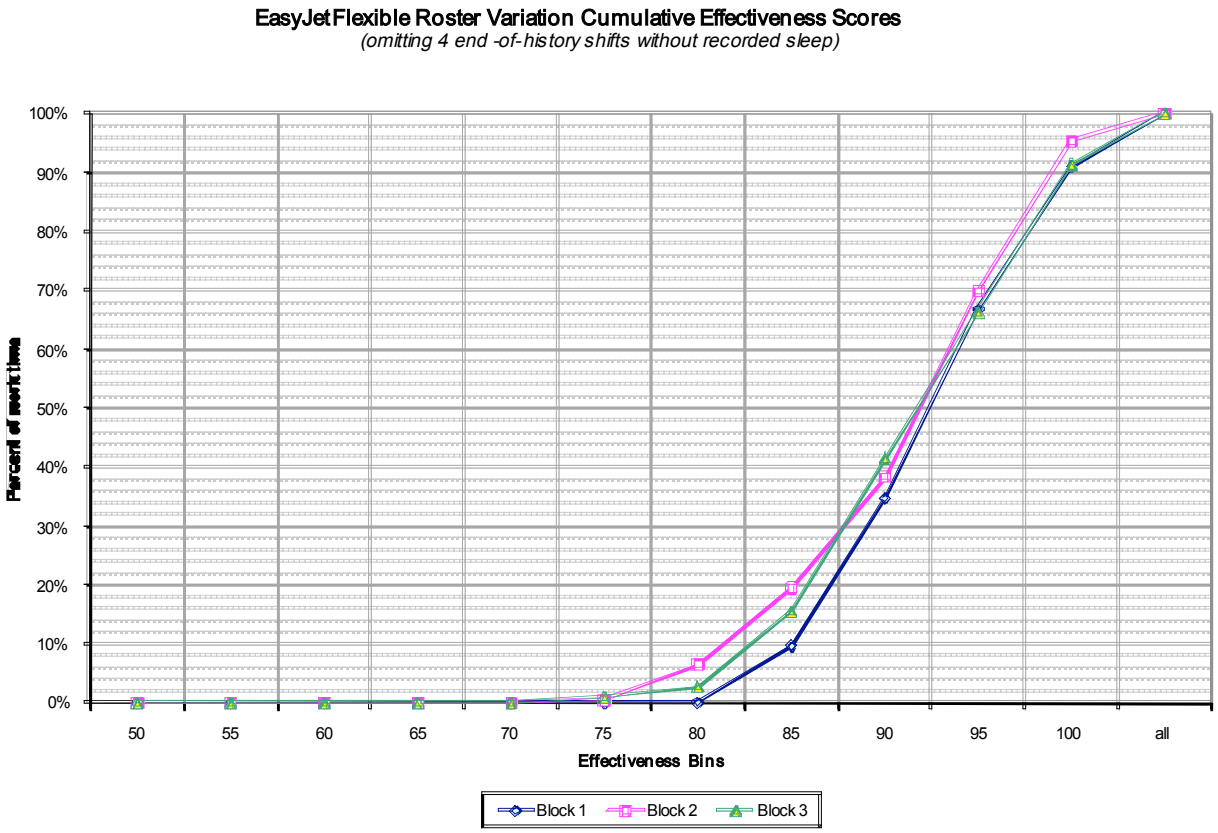
## Question: How Does Effectiveness Change Across Blocks of Duty?



## Question: What % of time Below X Effectiveness for Each Block?



## Question: What % of time Below X Effectiveness for Each Block?



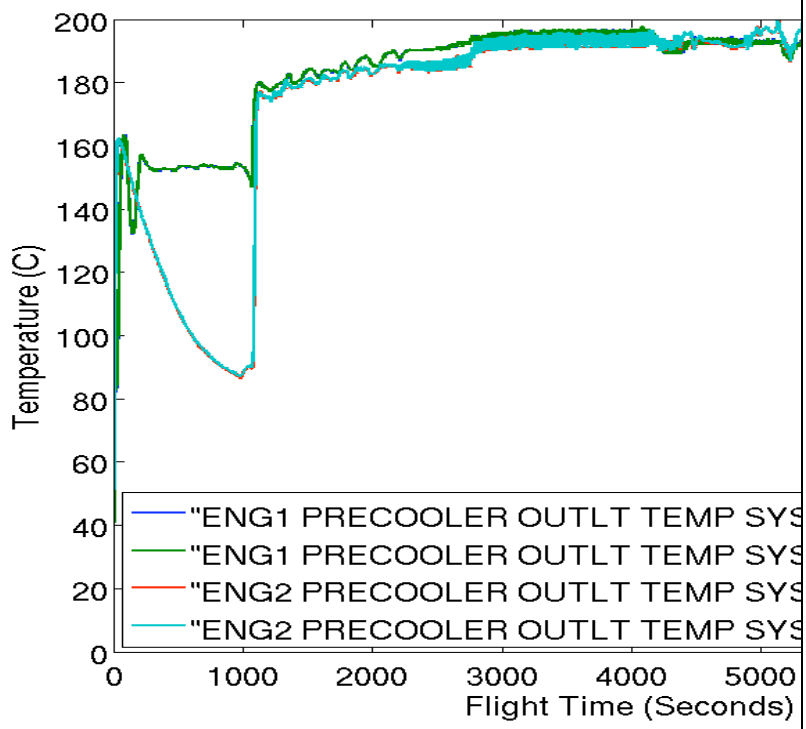
**Appendix I**
**Results of Application of MKAD to Identify Anomalies in a Set of easyJet Flight Data**

A preliminary analysis using MKAD was made of the flight-recorded data from 47,000 easyJet flights acquired between April and July 2010. The algorithm focused on the landing phase of flight for analysis from 10,000 ft to landing. The identified anomalous events are presented below as Statistically Significant Anomalies, Heterogeneous Anomalies, and Go Arounds. The pertinent parameters identified by the algorithm are listed along with a plot for each anomaly.

## *Statistically Significant Anomalies:*

The following flights were identified by NASA's MKAD algorithm as anomalous because they were found to have statistically high or low values on the listed parameters.

| Flight Name | Anomaly Descriptions |
|---|---|
| **Oil Temperature Anomalies** | **Engine 2 oil temperature differs from engine 1 oil temperature. Sampling of nominal flights do not exhibit this behavior.** |
| FlightData__20100507T064529 | Engine 2 Oil Temperature above 115 degrees. (See Figure 1). |
| FlightData__20100621T174309 | Engine 2 Oil Temperature above 115 degrees. (See Figure 2). |
| FlightData__20100523T085048 | Engine 2 Oil Temperature above 115 degrees. (See Figure 3). |
| FlightData__20100619T135707 | Engine 2 Oil Temperature above 115 degrees. (See Figure 4). |
| **High descent rate at low altitude** | **The following flights exhibited high descent rates down to 3500 ft. However, vertical speeds did not exceed known thresholds.** |
| FlightData__20100529T070348 | High vertical speed on approach. -5000 ft/min @ 3500 ft. (See Figure 5 ). |
| FlightData__20100428T075739 | High vertical speed on approach. -4500 ft/min @ 3550 ft. (See Figure 6). |
| **High wind speed during approach** | **The following flights experienced high wind speeds during final approach. Cross wind gusts were not above known landing exceedances.** |
| FlightData__20100531T113243 | High wind speed. Gusts 60 KNTS @ 3000 ft. Gusts of 30-40 KNTS @ landing. (See Figure 7). |
| FlightData__20100515T144736 | High wind speed Gusts 55 KNTS @ 3000 ft. Gusts 30 KNTS @ landing. (See Figure 8). |
| **Drop in Engine Pre-Cooler Outlet Temperature** | **The following flights showed a drop in the pre-cooler outlet temperature during descent from cruise. There were no visible effects seen in EGT or engine performance in the FOQA data.** |
| FlightData__20100529T131206 | Drop in Engine Pre-Cool Outlet Temp below 100 Deg C during descent. (See |

| | |
|---|---|
| |  <br>Figure 9). |
| FlightData__20100421T085723 | Drop in Engine Pre-Cool Outlet Temp below 100 Deg C during descent. (See Figure 10). |
| FlightData__20100522T132159 | Drop in Engine Pre-Cool Outlet Temp below 100 Deg C during descent. (See Figure 11). |

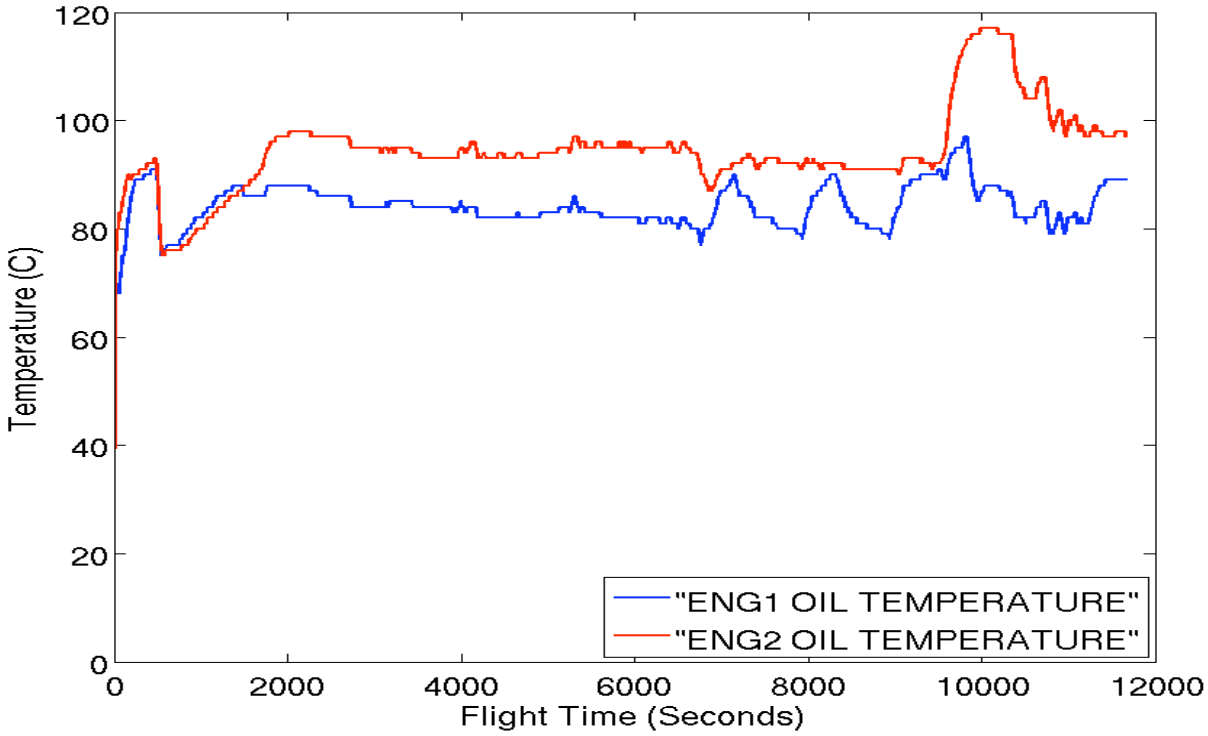



Figure 1 Engine 2 oil temp anomaly.

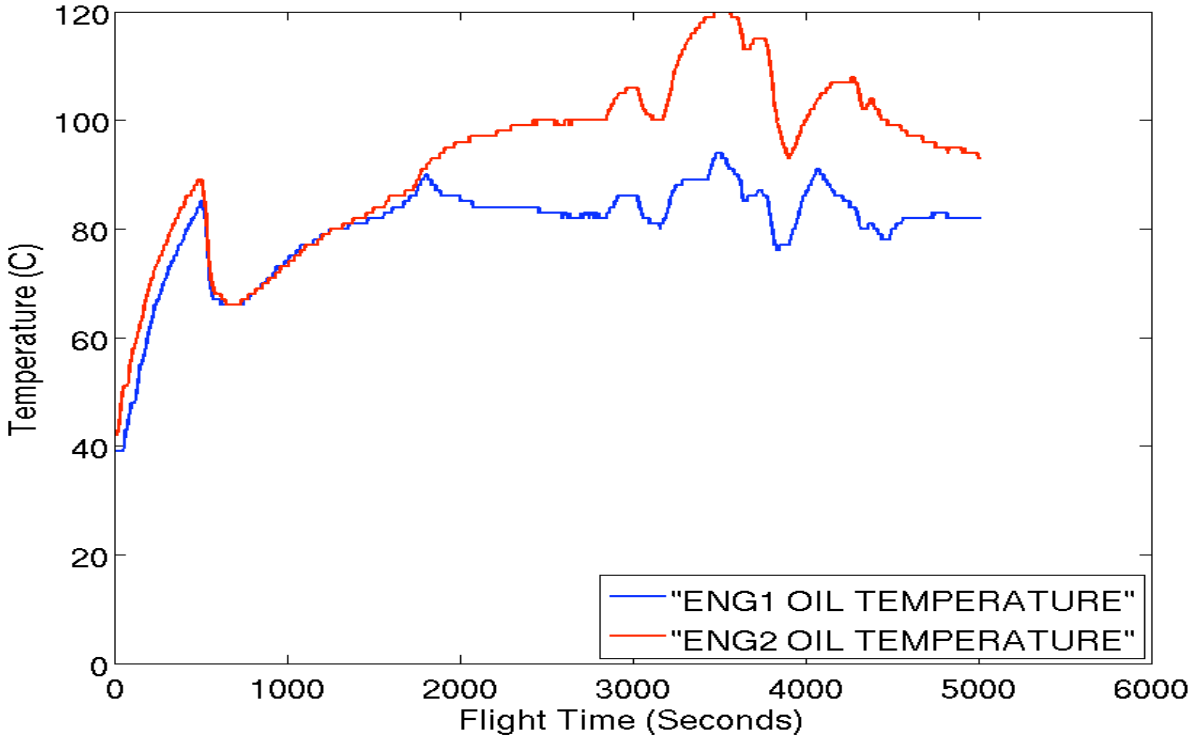



Figure 2 Engine 2 oil temp anomaly.

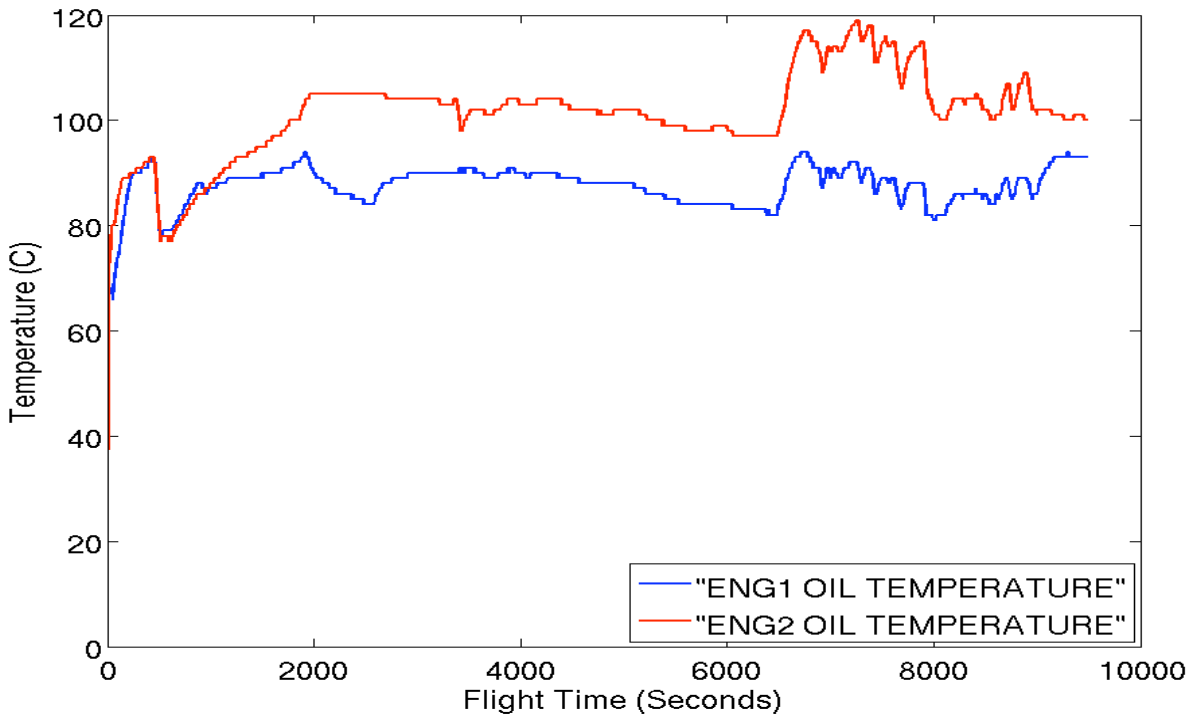



Figure 3 Engine 2 oil temp anomaly.

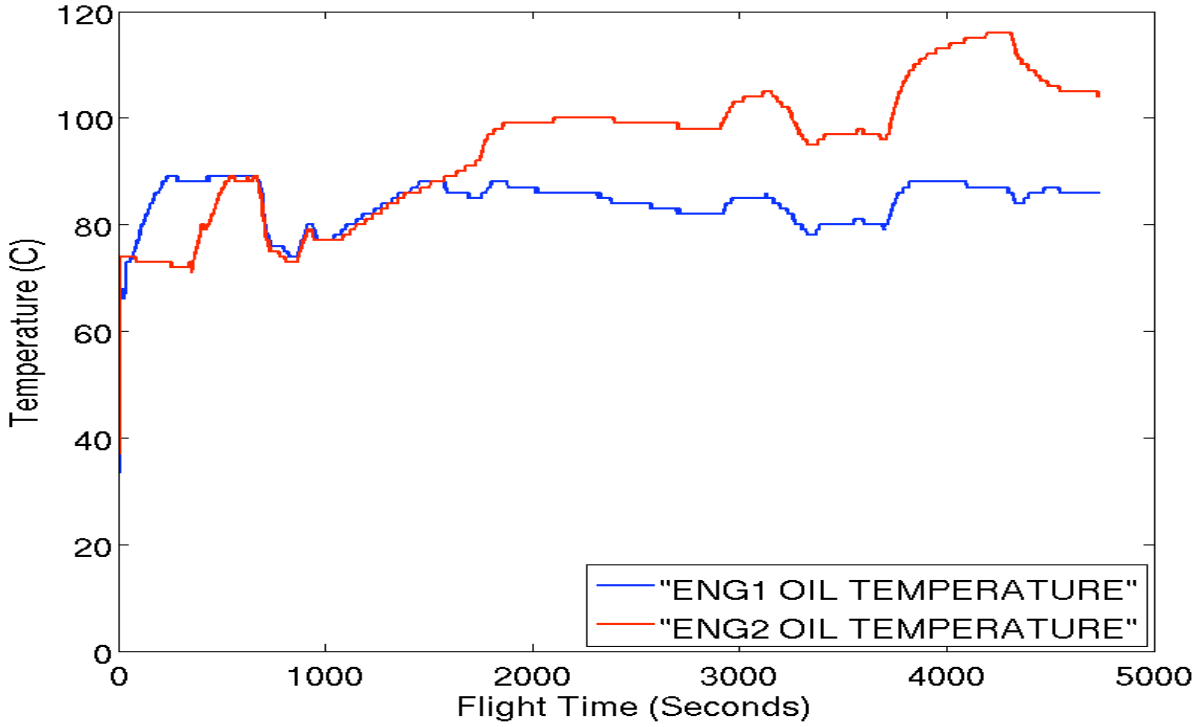



Figure 4 Engine 2 oil temp anomaly.

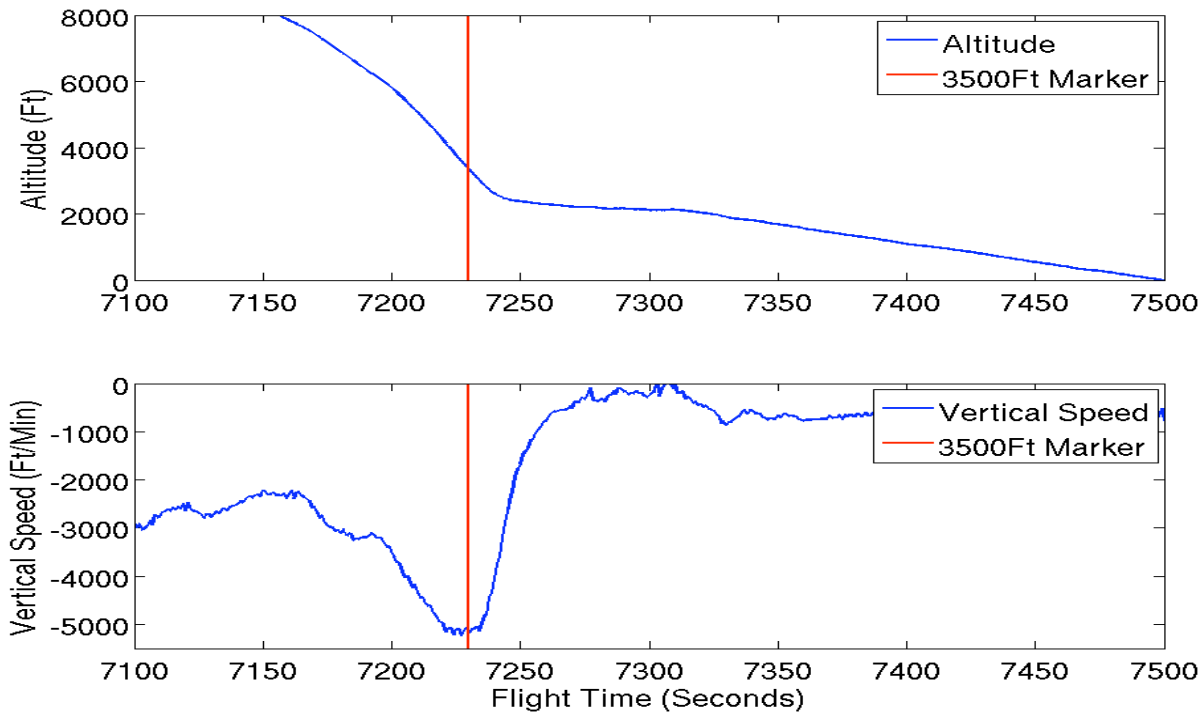



Figure 5 High descent rate anomaly.

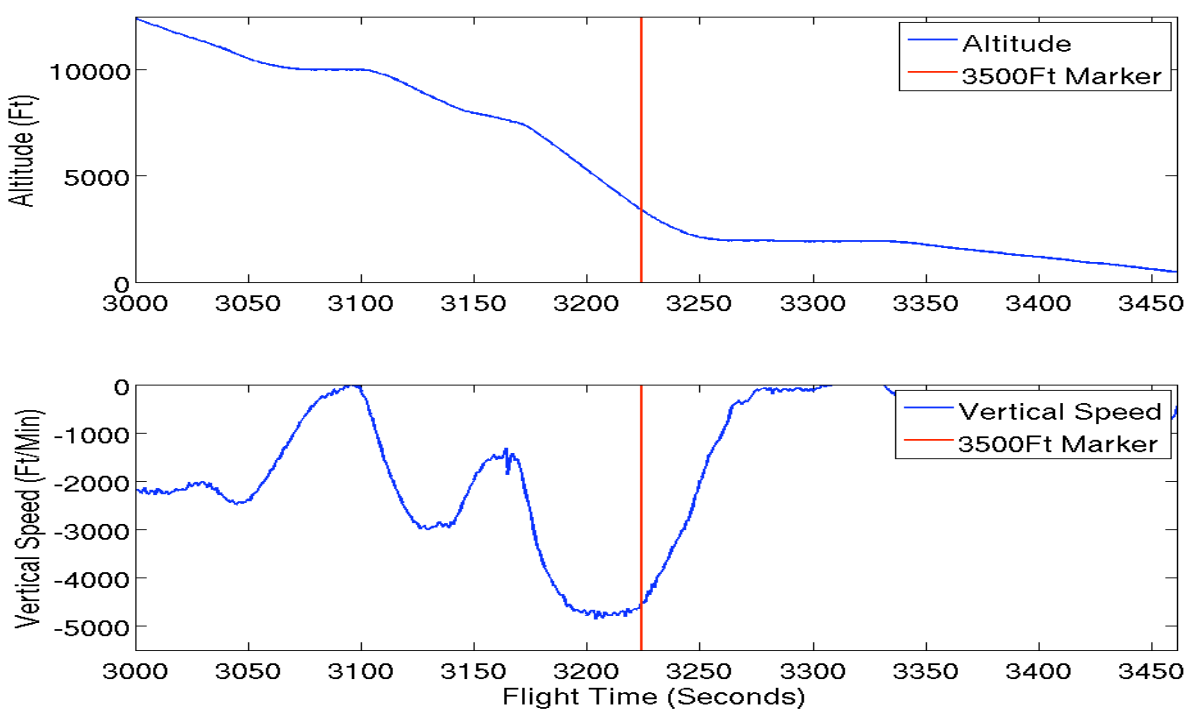



Figure 6 High descent rate anomaly.

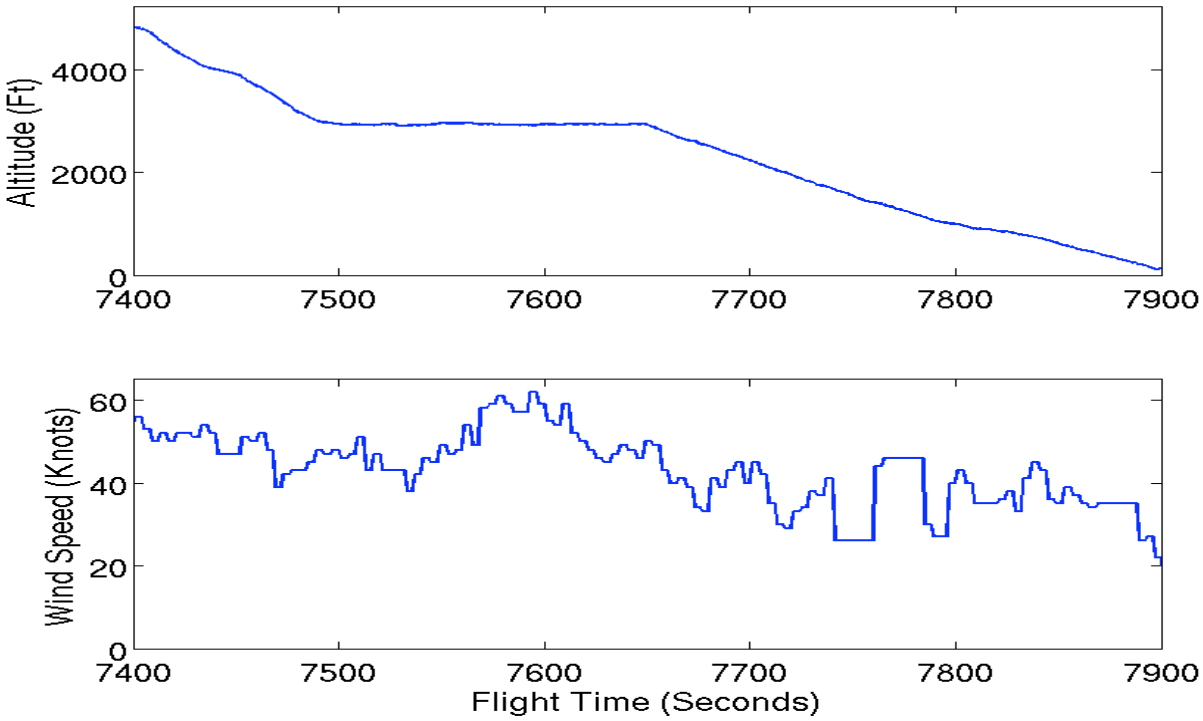



Figure 7 High wind speed anomaly.

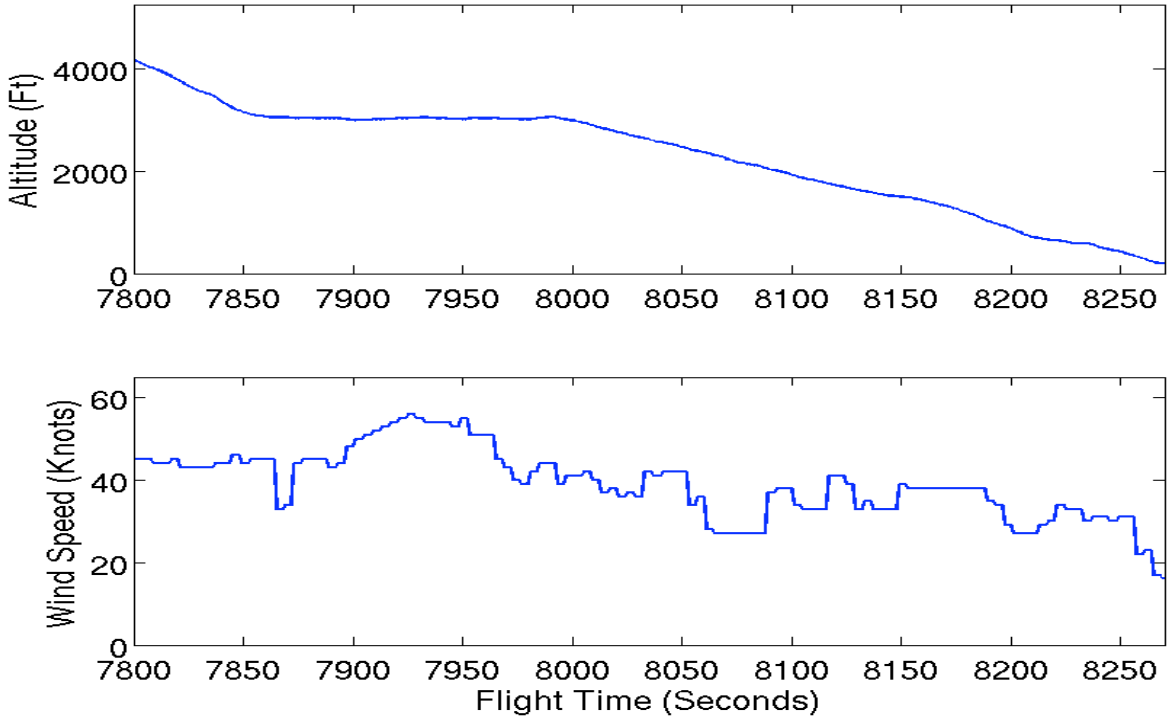



Figure 8 High wind speed anomaly.

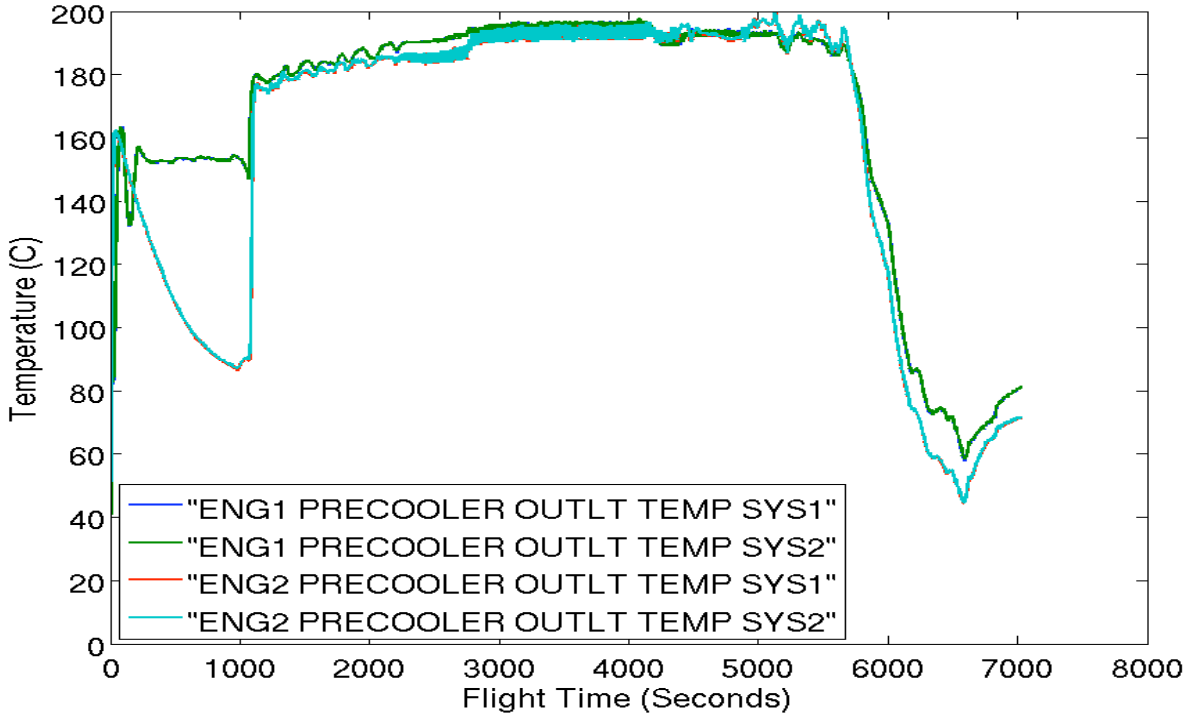



Figure 9 Engine pre-cooler temp anomaly.

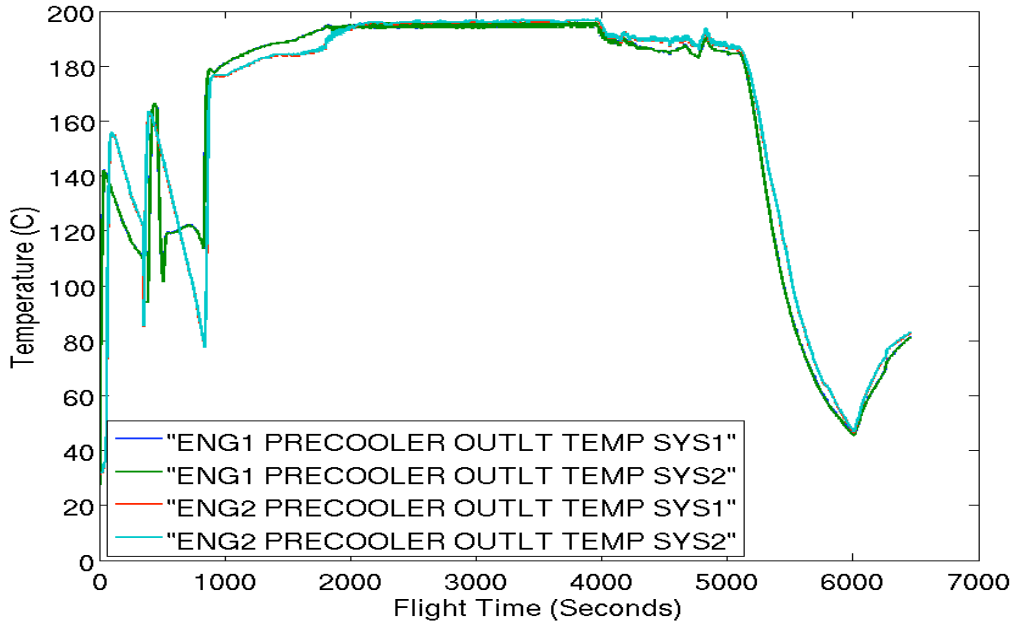



Figure 10 Engine pre-cooler temp anomaly.

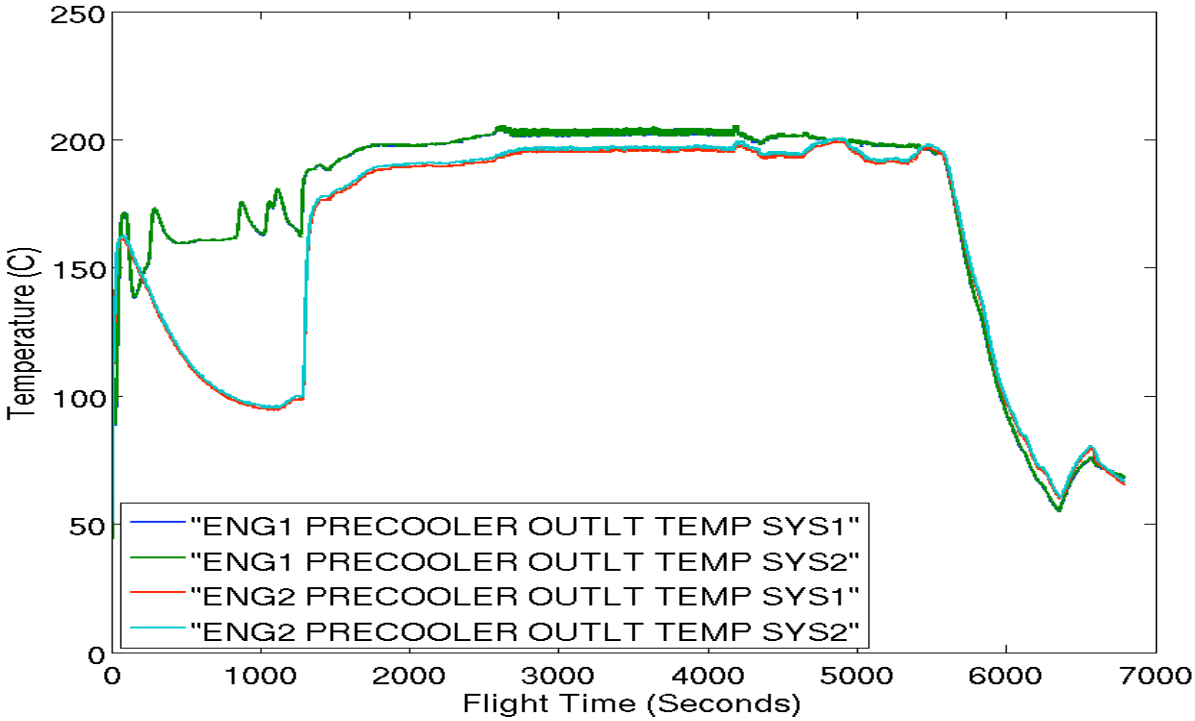



Figure 11 Engine pre-cooler temp anomaly.

## *Heterogeneous Anomalies*

The following anomalies were identified by the algorithm to have contributions from both discrete and continuous parameters. A domain expert classified the events as a wave off. The wave offs are similar to go arounds, except that they occur at higher altitudes and further from the airport. The first 2 wave offs in Figures 12 and 13 were confirmed to have latitude and longitude tracks similar to go arounds, where the aircraft flies over the airport. Therefore, the GPS tracks for these two flights are not presented here. However, the wave off in Figure 14 occurred at the same time the pilot received an immediate climb signal. After the warning, the flight does not fly over the airport but turns away and circles around before landing as seen in its GPS track in Figure 15.

| Flight Name | Anomaly Descriptions |
|---|---|
| FlightData__20100423T105649 | Wave Off @5000 ft . Landing Gear deployed and retracted. (See Figure ). |
| FlightData__20100508T071150 | Wave Off @3000 ft. Landing Gear deployed and retracted. (See Figure ). |
| FlightData__20100425T193450 | Wave Off @4000 ft. "Immediate Climb" signaled and "Pitch Go Around" activated. (See Figures 14 and 15). |

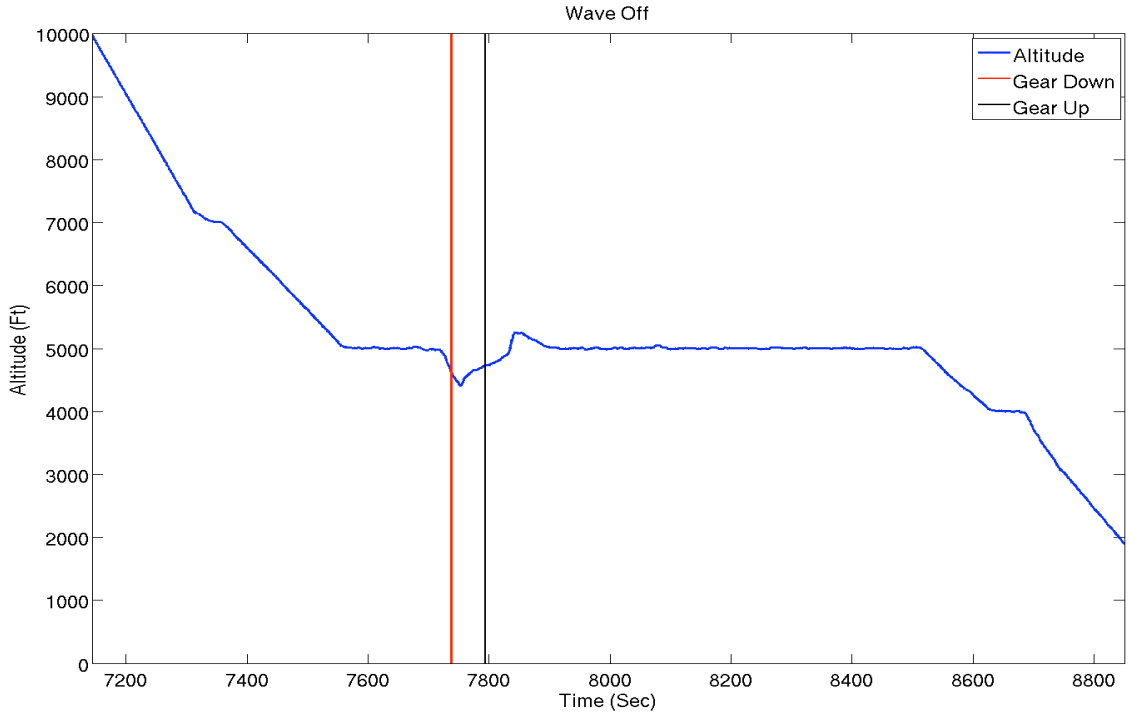



Figure 12 Wave off anomaly at 5000 ft.

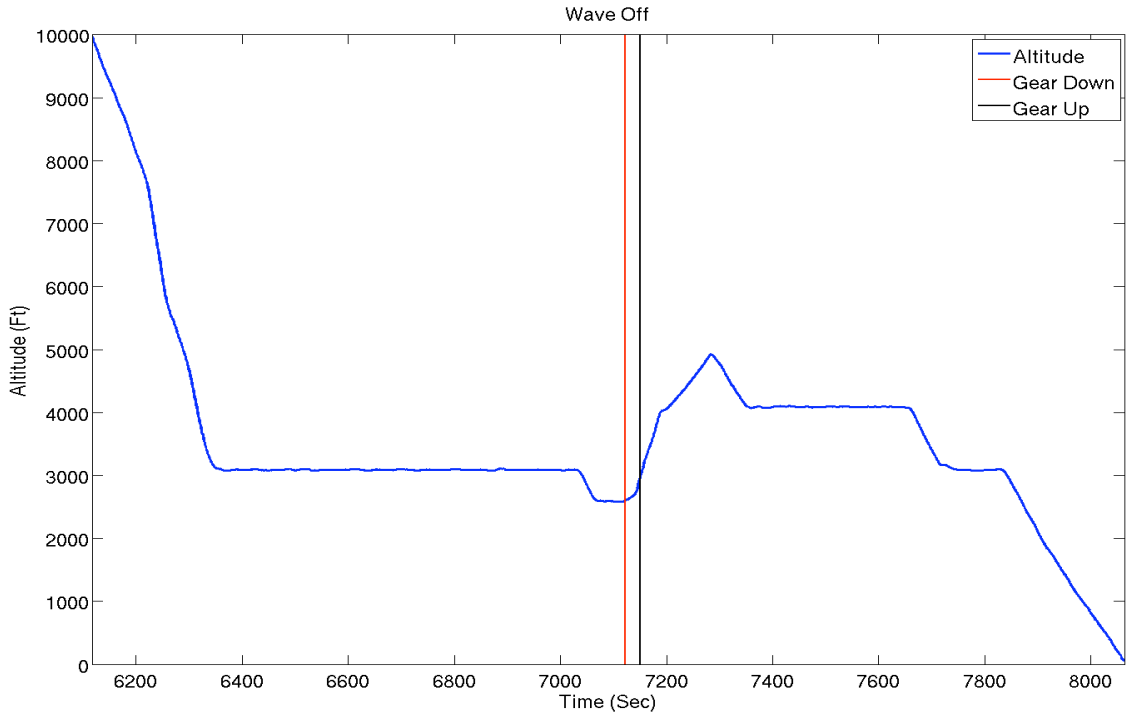



Figure 13 Wave off anomaly at 3000 ft.

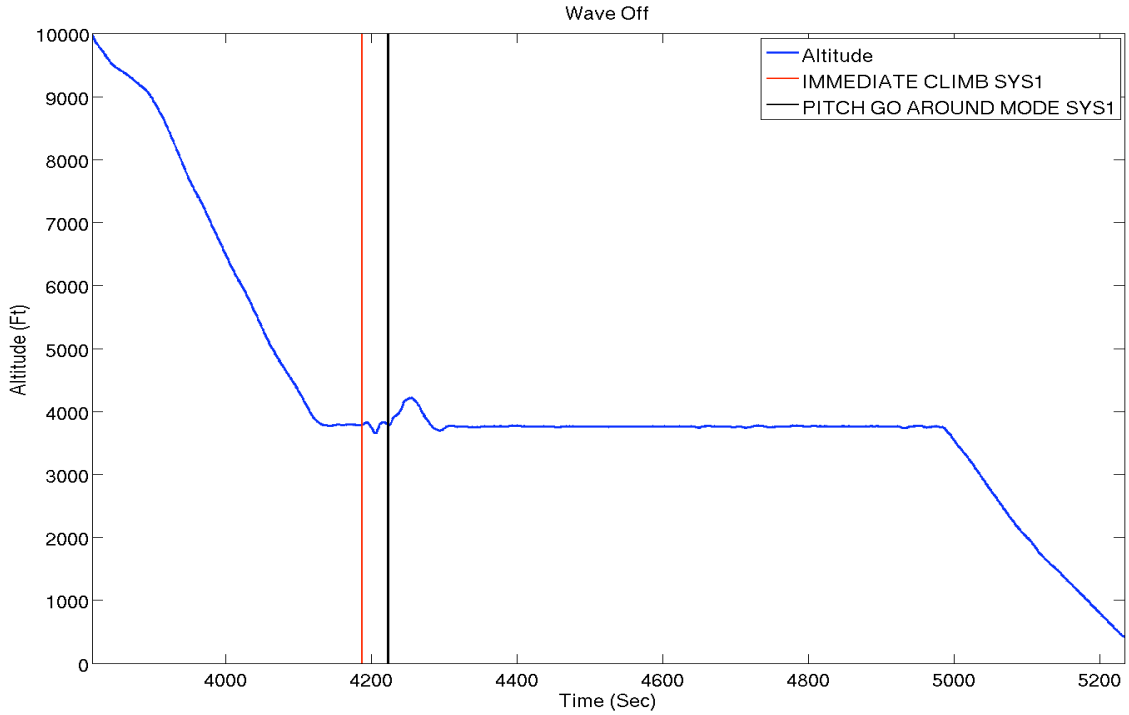



Figure 14 Wave off anomaly at 4000 ft.

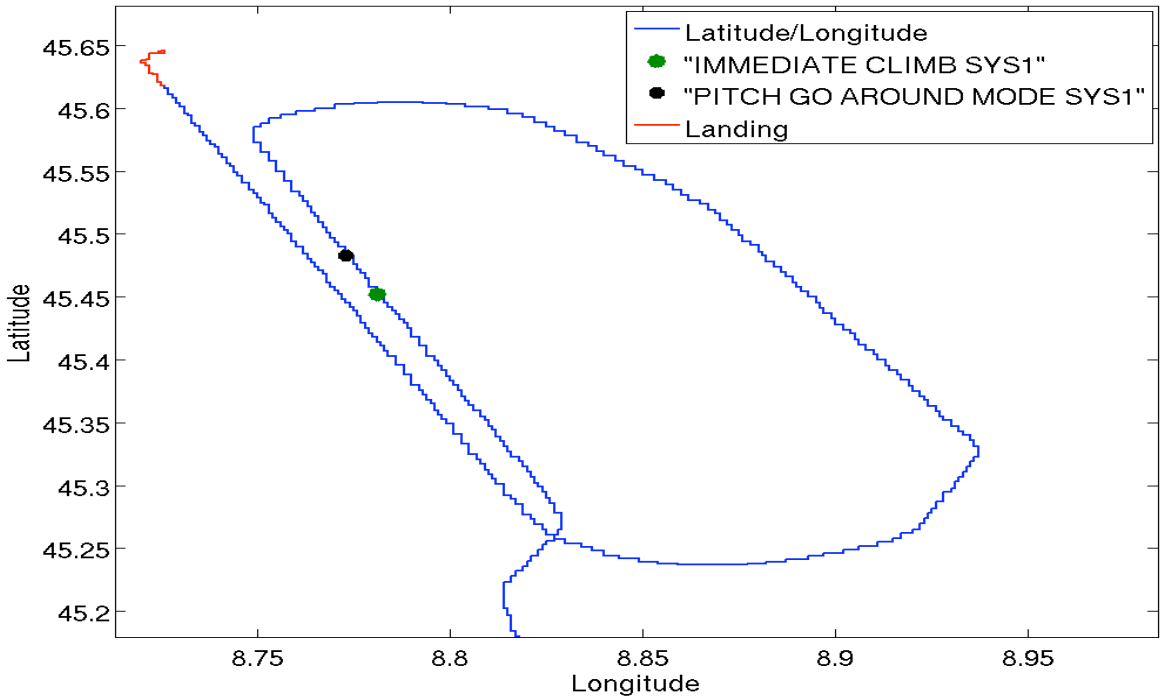



Figure 15 Wave off lat/lon anomaly.

## *Go Arounds*

The following flights were identified by the algorithm to be Go-Arounds. The flight profiles are not shown due to the number of flights listed. The flights are listed to demonstrate that the algorithm is able to pick up atypical events.

| Flight Name | Anomaly Descriptions |
|---|---|
| FlightData__20100413T161708 | Go Around |
| FlightData__20100421T105545 | Go Around |
| FlightData__20100423T224432 | Go Around |
| FlightData__20100424T073655 | Go Around |
| FlightData__20100425T094246 | Go Around |
| FlightData__20100425T110147 | Go Around |
| FlightData__20100507T183325 | Go Around |
| FlightData__20100508T065903 | Go Around |
| FlightData__20100512T123116 | Go Around |
| FlightData__20100513T125157 | Go Around |
| FlightData__20100518T074328 | Go Around |
| FlightData__20100518T180203 | Go Around |
| FlightData__20100523T113758 | Go Around |
| FlightData__20100526T152650 | Go Around |
| FlightData__20100526T180002 | Go Around |
| FlightData__20100528T174201 | Go Around |
| FlightData__20100529T134337 | Go Around |
| FlightData__20100530T095713 | Go Around |
| FlightData__20100530T150239 | Go Around |
| FlightData__20100601T151910 | Go Around |
| FlightData__20100602T071002 | Go Around |
| FlightData__20100607T084549 | Go Around |
| FlightData__20100608T103645 | Go Around |
| FlightData__20100613T124539 | Go Around |
| FlightData__20100613T150721 | Go Around |
| FlightData__20100614T143347 | Go Around |
| FlightData__20100619T090929 | Go Around |
| FlightData__20100620T110110 | Go Around |
| FlightData__20100621T064700 | Go Around |
| FlightData__20100422T170558 | Go Around |
| FlightData__20100423T102559 | Go Around |
| FlightData__20100424T073126 | Go Around |
| FlightData__20100424T162855 | Go Around |
| FlightData__20100425T051221 | Go Around |
| FlightData__20100505T134047 | Go Around |
| FlightData__20100508T080839 | Go Around |
| FlightData__20100513T111722 | Go Around |
| FlightData__20100513T181417 | Go Around |
| FlightData__20100514T145952 | Go Around |
| FlightData__20100515T135331 | Go Around |
| FlightData__20100518T093509 | Go Around |

| | |
|---|---|
| FlightData__20100520T164544 | Go Around |
| FlightData__20100523T131639 | Go Around |
| FlightData__20100524T083259 | Go Around |
| FlightData__20100529T194005 | Go Around |
| FlightData__20100531T081701 | Go Around |
| FlightData__20100614T104507 | Go Around |
| FlightData__20100614T122651 | Go Around |
| FlightData__20100620T084134 | Go Around |
| FlightData__20100621T141700 | Go Around |

## Appendix J
## Results of Application of LDA on a set of Easyjet ASR reports

The following 10 ASR reports were identified using LDA with the topic defined in the text by a set of words that appear to be related to fatigue.

**#1**

ASR Crew fatigue: This report raised as this practice is not isolated to this single event recorded here. Attached report: A planned 4 sector day LGW-AMS-LGW then LGW-ALC-LGW - 10 hrs 20 min duty. First outbound sector delayed due to inbound aircraft being late. Finally we swapped onto another aircraft. Crewing apparently already aware of a potential FTL issue for Cabin Crew. Cabin Crew asked to call Crewing. ACARS msg from crewing en-route LGW-AMS, 'would Flight Crew work into discretion?' I told crewing, "No" as we would then be on minimum rest (for the next day's 10 hr 40 min duty finishing in the early hours). Duties too fatiguing and concerns about our times to do so safely. There is little or no spare time on a LGW-AMS sector to assess the wider implications of duty times. On our return flight AMS-LGW, ACARS msg from crewing that I was to passenger to ALC on the outbound (No 3) sector, then operate the final leg (No 4) ALC-LGW as the Commander. Another Capt (who started home stby at 07:00Z; then called for Airport Stby; then called out to operate LGW-ALC; to then position on the aircraft back to LGW (his long duty is a separate issue). The F/O operating LGW-AMS-LGW was stood down on return to LGW as stby cover available, with another F/O called out to operate LGW-ALC-LGW in his place. As there was no Capt stby cover available, I was being forced by crewing to operate as they (crewing) were now claiming an FDP for me based on 3 sectors, not 4 sectors. This raised a problem of interpretation. Para 7.1.10.2 of the easyJet FTL□s reads as follows:- 7.1.10.2 Positioning within a Flying Duty Period If a crew member carries out a positioning journey within a Flying Duty Period containing a claimed split duty then that positioning journey will be counted as a sector when calculating the allowable Flying Duty Period. Para 7.1.4.22 of the FTL reads as follows:- DEFINITIONS 7.1.4.22 Split Duty - A flying duty period, which consists of two or more sectors, separated by less than a minimum rest period. Now put those two statements from above together and they read as follows:- If a crew member carries out a positioning journey within a Flying Duty Period containing a flying duty period, which consists of two or more sectors, separated by less than a minimum rest period (split duty), then that positioning journey will be counted as a sector when calculating the allowable Flying Duty Period. That describes exactly the situation we were in. Having operated 2 sectors, I was being positioned to ALC to operate a 4th sector - a flying duty period, which consists of two or more sectors, separated by less than a minimum rest period. However, EZY Crewing claimed para 7.1.10.1 Positioning to Meet easyJet Requirements All time spent on positioning to meet easyJet requirements shall count as duty, but positioning does not count as a sector when calculating the Flying Duty Period. There is an issue of interpretation. Crewing were claiming I was allowed a max FDP based on a 3 sectors duty, not 4 sectors (because I was positioned on one sector). This plan, they said, would not require the use of any Capt□s discretion. I did position to ALC, and did operate back phone calls from crewing made sure I was left in no doubt about the legality of their stance. And, at the end of the day, whether you count this as 3 or 4 sectors I did operate into discretion on the ALC-LGW sector based on either 11:30 (3 sectors) or 10:45 (4 sectors). A 12:03 FDP and 12:33 DP. A long, tiring duty culminating in un-forecast fog at LGW. A CAT IIIB landing at the end of a long duty made all the more wearisome and worrying by the insistence of crewing that their interpretation of the

FTL's are sacrosanct and to disobey their instructions would be recorded against you as, ‘Refused Duty’. Can we be reasonably expected to operate out of our HOME BASE, realising that we will be going into Capt's discretion? LGW is a large base which is supposed to have sufficient crew to meet and support all easyJet's crewing/flight requirements. The FTL Procedure Manuals have been compiled for the use and guidance of Rostering and Crewing staff to enable them to perform their duties so as to ensure the safe and efficient operation of the airline. I feel that the issue here was a plan by crewing to continue operations by any means. It seems ironic, that you can't work 4 sectors, but can work 3, with a positioning sector thrown in. Positioning in a passenger seat on low cost or charter/economy flights is probably less relaxing than operating the flight. There is a barrage of noise in the cabin from revellers, kids/babies and the cabin crew PA's. A seat it maybe, but rest it is not. This is NOT a First or Business Class seat designed for comfort and rest. It's disappointing that it is apparently 'legal' to position crew during an FDP and for it not to count towards a sector and therefore allow the Company to extend the duty by that means. This alleviation by the Authority is ill conceived for modern day commercial operations, and one would hope that with the expansion of low cost ops and the high flying and duty hours that crew now work, the Authority will review the regulations in the light of (their?) experience and look towards revising this outdated exception.

**#2**

Please see attached page and copy of roster. Para 26 of MOR submitted by Capt ******** on 26 May 2010 Whilst away from base in LYS I received a roster change for 24 May to operate LYS BIA LYS RAK LYS departing at 1430 local with a FDP of 10:55, however, because a normal report time of 1330 local would have given an allowable FDP of 10:45 the roster showed a report time of 1255 (1:35 before departure) thereby bringing the duty into a less penalising allowable FDP of 11:45. I did not spot this discrepancy immediately. However, this practice of altering the report time to take advantage of a more generous FDP is specifically prohibited in both the company Operations Manual OM A 7.1.12.2 and CAP 371 which I quote below. "13.2 The utilisation of a non-standard reporting time, except by use of a dispatch crew, designed to take advantage of an increased FDP from a more favourable time band, must not be used." The duty which commenced on 23 May finished 1:11 later than scheduled at 02:46 local which meant the report for the next duty would have to be delayed until 1346 (11 hours rest in hotel) which the crewing officer had changed. This delay to the report time for duty later that day pushed the earliest report time into the more limiting allowable FDP which would mean that I was being rostered into discretion. I pointed this out to the crewing officer who said it was allowed under OM A 7.1.9.1 and CAP371 as quoted below. "10.1 When a crew member is informed of a delay to the reporting time due to a changed schedule, before leaving the place of rest, the FDP shall be calculated as follows. When the delay is less than 4 hours, the maximum FDP allowed shall be based on the original report time and the FDP shall start at the actual report time. Where the delay is 4 hours or more, the maximum FDP shall be based on the more limiting time band of the planned and the actual report time and the FDP starts 4 hours after the original report time." I did not accept this argument as the above provision is only in the case of delay between having completed rest and report but the crewing officer countered this with the fact that it was the day of operation ie we were beyond midnight and it did not show up as a violation on AIMS. He also did not accept that the original roster with the report time of 1:35 before departure was wrong. After a long and thorough discussion involving the crewing manager I ended the conversation with the statement that I would not be operating as per the roster, that in

my view it was illegal and they would have to make some other arrangements. I was told I would have to discuss the matter with my PM later that day. Overnight the first 2 sectors were removed. I attach a copy of my roster showing the initial roster change on 22 May unfortunately a local technical problem prevented me from taking a copy of the roster with the delayed report time of 1146 for 24 May. The First Officer, SFO *******, with whom I flew with throughout my duties in LYS had the same roster.

**#3**

1st early (of 2) out off block 2E+3L. Captain unfit to continue FLT to LFPG. NMC informed by ACARS. Fatigue report will be submitted. Cpt: Just finished reserve period with many late/early/late transitions. Had 3 days off before starting block of 5 days, 1st + 2nd day early. Had very bad sleep + wake up +/- 15 times. Tried to perform scheduled duty, but unable / unsafe to finish. Other information Fatigue report Following being removed form duty due to fatigue on D1, Captain was SICK for D2-D5 of this duty block. FAID Narrative: Peak FAID score is 26, which is rated 'low'. Forecast sleep for the prior 24, 48 & 163 hrs is greater than minimums. Investigation Synopsis: The Captain lodged an ASR regarding fatigue and was removed from duty after S2 on D1 of a 5-day duty, following 3 days off. this was the first duty following the Captain's reserve month. D1 was an early 2-sector duty. The Captain was subsequently removed from the remainder of teh duty block due to sickness. All duty and block hours are well within limits. there are some fatigue pre-cursors in the Captains 8 week history, 9 nights away from base (2,2,2,3). Reserve month was as follows: 3 late duties - hotel rest 10 days off - 2 D/O, 6 LVE, 2 D/O 4 late duties - hotel rest 2 days off - preceded by a late finish and followed by an early start- only 1 quality rest period 2 early duties 1 day off 3 late duties There were no elongated duties, no transitions, no minimum rest and no sub-optimal rest periods. The rostered duties are unlikely to result in a high risk of fatigue. The Captain reported a broken nights rest prior to D1. This is the likely cause of his fatigue, and may have been an early symptom of the sickness that he experienced over D2-D5 of the duty block.

**#4**

ASR A new setup of crew food were introduced to day and had we been catered correct we would for six people had 4 breakfast containing 1 package of musli at 40g a tiny breadroll and a piece of fruit (plum in some) + 2 breakfast with a hot option, a tiny roll and fruit. On top six sandwiches each of 126g made up of white toast bread with various mayonaise filings. So crew are expected to operate for 7hrs 25 min on a total food intake of 166g which for a grown up is well below what is needed to operate a plane safely at a reasonable nutrition level. If this is not changes it's a serious safety issue for the operation of the plane. As the case were there was a lack of catering and food were taken out of the pax bar but had ..... catering been on board normal ..... have ..... (unreadable) food on a day's work onboard! CSR Starting ffrom today, there is a change in the crew food loading. For the 6 crew onboard there are 2 hot breakfast meals and 4 musli-breakfast meals. The musli has 40 gram of weight and furthermore there is a sandwich for every crew member, which is 125 gram. So in total, a crew member has 165 gram of food to eat during the day! This can have serious influence on crew health onboard (working with an empty stomach) and also concentration problems and safety problems. If a CCM does not have enough to eat, this can lead to difficulties with concentration, safety caanot be guaranteed anymore. I would seriously suggest to have a well-thought look into this matter!

**#5**

This report is only regarding myself (Captain). I got up at 0330L, showered, & ate a large breakfast at home of 3 shredded wheat, a bowl of stewed fruit & a cup of tea. Left home at 0430L to report at 0600L. Already feeling hungry on the first flight, I had the crew breakfast provided of 2 Weetabix, a bread roll (no jam or marmalade!) & an apple. This is a much reduced quantity than used to be supplied. Having consumed this, I still felt hungry. At 1015L, the hypoglycaemia started. Luckily I had a muesli bar in my case, wheich I ate. During this time I felt very hungry, light headed, & very distracted - a flight safety issue! (Especially as I was training). The only other crew food supplied was a 'round' of sandwiches. These I consumed at 1130L. Again, too unsubstantial to provide sustanance until arriving back in BRS at scheduled 1525L. By 1300 the hypoglycaemia returned, with the same physiological effects. Thankfully, both Capt (trainee) and SFO had food that they gave me. In conclusion, in a scheduled duty of 9:55, I was only supplied with crew food that would not sustain a 4 year old! This reduction in the quantity & quality of crew food is causing flight safety issues and must be addressed. Due to delays, my total duty was 0500 - 1510z. I was out of home from 0430L - 1830, ie 14 hours. Crew food must be re-instated to provide suitable sustainance for adults to cover the whole duty.

**#6**

ASR Just finished a week of late duty in LYS and hotel - ACC not up to an acceptable standard after a long 4 sector duty with close to max discretion I was back at hotel at 05.00am was woken up at 10.00am by cleaners working in the corridor. After 5 hrs sleep on reduced rest before my next duty I went down to get some food. Just to learn they didnt have any food before 4.00pm and no room service! Same experience with cleaners waking you up the following days. There are no safety locks on the doors so on day 5 I was woken up at 10 am again (finishing 03am the night before) by the door being shut despite 'do not disturb' sign on the door. 5 min later I got a call from reception asked when I would check out. Other issues: I stayed there for 4 nights and the room was only cleaned once since I was on late duty and it appeared the cleaners were gone by mid-day. At one occasion I locked myself out of my room and reception I had to wait for more than 10 min to find any staff so I could get a new key. What if you have an emergency. The fact that you dont get any food and no proper sleep after early morning, together with the other issues makes this hotel totally unsuitable for night stopping with our working pattern doen in LYS. I will seriously consider to refuse similar duty in LYS if I have to stay at Kyriad hotel!

**#7**

I am forced to live in hotels at base and cannot obtain food before early duty on this flight. I was provided with only one cold breakfast = 1 x Danone [125g] yoghurt, 1 x Kellogg muesli [40g] + one small [unmarked, but +/- 7cm x 4cm] bread roll with butter + jam - and 1 x cold salad (pollo con pasta: s/n F3363703) [160g] + 2 pcs of fruit. "Snacks" are too salty to be safely eaten regularly, but crisps are there. That's all, from 05:15 (L) wake up to 16:20(L) off-duty plus delays - more than 10 hrs duty: No hot fod at all, in a period in which I would usually consume one or two hot meals [It has been 23 hrs since I ate a hot meal]. Ther are long-term

issues here but fundementally, insufficient food for the length of duty, to continue safely. OTHER INFO & SUGGESTIONS ... more food: 2 meals? Always one hot per crewman. which need not be a 'breakfast' - any hot meal any time of day is OK. (or, better than none)

**#8**

Day 5 early (07.08.09) originally rostered as short summer sby 0500-0900. On checking out from day 4 duty, days had roster change for a transition into a 4 sector late duty LYS-CIA. I decided to exercise my option to decline a short notice change and the crewing officer agreed and returned me to short summer sby 0500-0900. Later I logged into AIMS to discover I had been put back onto the same duty LYS-CIA! In my opinion this was an outrageously underhand tactic by crewing and probably illegal - certainly outside the spirit of the rostering agreement. I once again called crewing to query this change and exactly the same cycle of events occured again - roster changed back to sby on phone, then soon after another roster change for another trnasisiton to lates - this time an afternoon ALC flight. I phone crewing again and explained again that I did not wish to transition to a late duty on my 5th early day - I was then changed to long early sby 0200-1000. At 0720 I was called from sby to operate late NAP. With report time 1030, duty finish at 1740 schedule. This resulted in a duty length of 16hrs 10mins! This is unacceptable for the 5th early duty day. Needless to say I operated the flight as requested. Next time I will refuse the duty.

**#9**

Duty rostered -LGW-MAN-LGW-NCE-LGW Duty period planned 11hrs 30min Aircraft - GEZTI with oven inop Arrived ast aircraft to find following crew food: 5 beef pot noodles. 1 chow mein pot noodle, 4 egg & cress sandwiches. 2 tuna, 2 ham & mustard, 5 snack packs. Following issues need to be addressed: 1 A pot noodle, sandwich & snack pack is insufficient food for an 11hr 30 duty - not conducive to fatigue management. 2 How are six crew to divide 9 sandwiches? 3 5 sandwiches and pot noodles of same flavour incurs a risk of multiple crew food poisoning. Oven found to be servicable - hot meals requested upload on return from MAH. Aircraft with inop oven should not be tasked on such long crew duties. Gate gourmet need to start using their brains!

**#10**

Crew food uploaded at Belfast for a 10-5hour, four sector duty. After the first sector the cabin crew informed the flight deck as to the poor quality of the food, which included a mouldy, rotten apple that had contaminated a proportion of the rest of the food. On arrival in Belfast the Gate Gourmet shift manager came to the aircraft & was appraised of its poor quality while admitting that the hot meal & fruit presented was unfit for human consumption. Apparently it is supplied sealed from the supplier & she was unaware of its content. Questions must be asked as to the preparation/storage of the food if it is already mouldy before it gets to the aircraft. Eating rotten contaminated food is a health & safety issue that could also cause crew incapacitation with the subsequent knock on effects. This does not take into account the affect on crew morale of such consistently poor quality food & raises the point as to how it is actually possible to produce

such a low quality product let alone charge the company for it. Photos of crew meal/rotten fruit to be e-mailed to catering manager at H89.