Copyright is owned by the Author of the thesis. Permission is given for a copy to be downloaded by an individual for the purpose of research and private study only. The thesis may not be reproduced elsewhere without the permission of the Author.
In-Flight Sleep as a Pilot Fatigue Mitigation on Long Range and Ultra-Long Range Flights

A thesis presented in partial fulfilment of the requirements for the degree of Doctor of Philosophy at Massey University, Sleep/Wake Research Centre Wellington, New Zealand

Jennifer L. Zaslona

2016
ABSTRACT

Objectives: Long range flights operate around the clock with long duty periods for pilots. To mitigate the effects of fatigue, these flights are operated by augmented crews, providing each pilot with the opportunity for sleep in on-board rest facilities. This thesis used a mixed methods approach to investigate the use of in-flight sleep and the factors that influence it.

Methods: Retrospective survey data (291 pilots, five studies) were analysed to provide an overview of pilots’ sleep at home and investigate potential relationships with in-flight sleep. A second project monitored the sleep, fatigue and performance of 35 pilots operating a B767 flight route between Atlanta and Lagos. These projects were supplemented by thematic analysis of pilots’ logbook comments on in-flight sleep (N=123) and on the way they manage their fatigue (N=629).

Results: Pilots viewed in-flight sleep as an important fatigue management strategy and actigraphic sleep monitoring confirmed that the B767 pilots made good use of their in-flight breaks for obtaining sleep. Self-ratings of in-flight sleep quality reflected ratings at home, but were usually poorer. Pilots indicated that the type, location and design of rest facilities affected sleep quality and duration, and identified strategies for minimizing sleep disturbances and improving alertness. Comments indicated that prior knowledge of in-flight break allocations can influence the planning of pre-trip sleep, use of naps, and in-flight sleep. Actigraphic measures of sleep indicated that the B767 pilots obtained more sleep in the 24 hours prior to departure than during baseline days regardless of their subsequent pattern of in-flight breaks, but it is unclear when they were advised about their break pattern. Ratings of sleepiness and fatigue increased across the B767 flights, but
Psychomotor vigilance task performance at the start of duty and at top of descent was not associated with prior wakefulness, prior sleep duration or in-flight sleep duration.

**Conclusions:** In-flight sleep is a well-utilized and effective fatigue mitigation strategy that may be supplemented by other strategies such as flight preparation techniques. To further reduce pilot fatigue risk on long range flights, additional research is warranted into the effects of flight preparation techniques and in-flight break patterns.

*(350 words)*
ACKNOWLEDGEMENTS

This research would not have been possible without the research participants, so to all of those who participated in the various studies included in this thesis, thank you. Your professionalism and careful dedication to the study protocols gave me one less thing to worry about!

To my supervisors, Professor Philippa Gander, Associate Professor Leigh Signal and Dr. Karyn O’Keeffe, thank you for believing in me and giving me this life changing opportunity. Philippa – thank you for your understanding and for supporting me and trusting in my ability to finish this thesis through the ups and the downs, even when it didn’t look possible. Leigh – thank you for patiently answering all of my silly aviation questions and plethora of emails. Karyn – thank you for always having a smile and patient answer for me when I knocked on your office door and for accompanying me on the steep learning curve that was the qualitative component of this thesis. I feel extremely privileged and lucky to have had such a wonderful supervisory team - this success is as much yours as it is mine.

I’m also indebted to our industrial partners without whom these projects would not have been possible. Particular thanks to Captain Jim Mangie, Adrienne Phillips and the rest of the Fatigue Risk Management Team at Delta Air Lines who were instrumental in the design and undertaking of project 2 and patiently answered all of my operational questions. I’d also like to gratefully acknowledge the following individuals and organizations for their permission to include data in these analyses: Dr Jarnail Singh, the Civil Aviation Authority of Singapore, and Singapore Airlines; Captain Wynand Serfontein and South African Airways; and Captain Chip Benton and United Airlines. I am also beholden to the Commonwealth Scholarship and
Fellowship Plan who made this study opportunity possible by awarding me a doctoral scholarship.

To my colleagues at the Sleep/Wake Research Centre, thank you for welcoming me into your team with open arms. In particular, thank you Margo van den Berg for putting up with my frequent intrusions into your office, for your mixed modelling wizardry and for always having a helpful and patient answer to my endless stream of questions! Thank you also Dr. Lora Wu for helping me with statistics, R and SAS code and not rolling your eyes at me when I asked stupid questions. Dee Muller, thank you for being my cheerleader, always having an encouraging word and for reassuring me that I was on the right track. I’m also grateful to Hannah Timms for her help with data entry and administrative tasks and to Dr. Alex Smith and Dr. Marine Corbin who provided valuable statistical assistance when I was in over my head with my analyses. To my PhD buddies, old and new, thank you for providing support and distraction along the way and for sharing with me your wisdom and experiences.

I’m also grateful to Dr. Greg Belenky, Dr. Hans van Dongen, and Dr. Malcolm von Schantz for introducing me to the world of sleep research and setting me on this path when I was still an undergraduate student unsure of what I wanted to be when I grew up.

Thank you to my New Zealand friends and family, for putting up with my crazy schedule and being there for me when home felt a million miles away.

Finally, to my family, thank you for your undying support and patience. Thank you for encouraging me to always reach for my goals, no matter how far away from you they took me. Thank you for reminding me of my progress when I felt at a standstill and for giving me the drive to continue when I lost sight of my goals.
1.3.4 In-fight sleep as a fatigue mitigation in long range and ultra-long range flight operations ................................................................. 56

1.3.5 Other fatigue measures and mitigations ................................................ 65

1.4 Thesis organisation and rationale ........................................................................... 68

1.4.1 Aims of this thesis research ................................................................................ 68

1.4.2 Mixed methods research and pragmatism ............................................................... 70

1.4.3 Structure of this thesis ......................................................................................... 72

CHAPTER 2 Retrospective questionnaire analyses (Project A) ................................. 73

2.1 Methods .................................................................................................................. 74

2.1.1 Ethics .................................................................................................................. 75

2.1.2 Questionnaire ...................................................................................................... 75

2.1.3 Creating a common database .............................................................................. 77

2.1.4 Data analysis ....................................................................................................... 78

2.2 Results .................................................................................................................... 85

2.2.1 Participant demographics ................................................................................... 85

2.2.2 Correlations between self-reported sleep variables ........................................... 92

2.2.3 Factors correlated with sleep quality at home ................................................... 92

2.2.4 Factors correlated with difficulties falling asleep .............................................. 93

2.2.5 Factors associated with reporting better than average sleep at home ............... 93

2.2.6 Factors associated with nighttime sleep duration at home ................................ 96

2.3 Summary of findings .............................................................................................. 99

CHAPTER 3 Delta B767-300ER bunk study (Project B) .............................................. 101

3.1 Methods ............................................................................................................... 102

3.1.1 Ethics ............................................................................................................... 102

3.1.2 Study design ....................................................................................................... 103

3.1.3 Measures ............................................................................................................ 104
### Table of contents

3.1.4 Data management .................................................................108
3.1.5 Data analysis ........................................................................111

3.2 Results .......................................................................................126

3.2.1 Pilot demographics ..........................................................126
3.2.2 Trip information .................................................................128
3.2.3 In-flight break patterns and rest opportunities ..................129
3.2.4 Duty periods prior to the study trip .................................132
3.2.5 Sleep across the study period ...........................................133
3.2.6 Subjective ratings of fatigue and sleepiness ......................138
3.2.7 Evolution of psychomotor vigilance task performance ....141
3.2.8 Effects of prior sleep and wakefulness on pilot fatigue measures pre-flight and at top of descent.................................................................................................................143

3.3 Summary of findings ...............................................................153

### CHAPTER 4  Pilots' perspectives on in-flight sleep (Project C) ............ 157

4.1 Abstract ..................................................................................157
4.2 Introduction .............................................................................158
4.3 Methods ..................................................................................160
4.4 Results ....................................................................................162

4.4.1 Personal factors affecting in-flight sleep .........................162
4.4.2 Work factors affecting in-flight sleep .................................163
4.4.3 In-flight waking function ....................................................166
4.4.4 Flight safety ..........................................................................168
4.4.5 Commuting ..........................................................................168
4.4.6 Flight deck napping .............................................................168

4.5 Discussion ..............................................................................169
4.6 Conclusions ............................................................................174
CHAPTER 5  Self-reported fatigue management on augmented flights (Project D) ................................................................. 177

5.1 Abstract .......................................................................................................................................................... 177

5.2 Introduction ............................................................................................................................................... 178

5.3 Methods .................................................................................................................................................... 179

5.3.1 Study design and materials ................................................................................................................. 179

5.3.2 Analysis .............................................................................................................................................. 180

5.3.3 Fatigue management strategies ......................................................................................................... 181

5.4 Findings .................................................................................................................................................. 181

5.5 Conclusion ............................................................................................................................................ 186

5.6 Acknowledgements ............................................................................................................................... 187

CHAPTER 6  Discussion ................................................................................................................................. 189

6.1 Integration of findings .............................................................................................................................. 189

6.1.1 Sleep at home versus sleep in flight ................................................................................................. 189

6.1.2 In-flight sleep and waking function ............................................................................................... 191

6.1.3 Allocation of in-flight breaks .......................................................................................................... 195

6.1.4 Flight preparation ............................................................................................................................. 197

6.1.5 Layover duration and sleep strategies ............................................................................................ 198

6.1.6 Post-trip recovery sleep .................................................................................................................. 199

6.2 Strengths and limitations ....................................................................................................................... 200

6.2.1 Strengths .......................................................................................................................................... 200

6.2.2 Limitations .................................................................................................................................... 201

6.3 Recommendations and further research ............................................................................................ 204

6.3.1 Recommendations to operators ...................................................................................................... 204

6.3.2 Recommendations to crews ............................................................................................................ 205
6.3.3 Future research ........................................................................................................205

6.4 Conclusions ..................................................................................................................208

Bibliography ......................................................................................................................211

CHAPTER 2 Appendices .................................................................................................229
APPENDIX 2A Overview of methods from previous studies .............................................229
APPENDIX 2B Pre-Study Questionnaire (B777 studies) ......................................................237
APPENDIX 2C Pre-Study Questionnaire (South African Airways study) .......................241
APPENDIX 2D Pre-Study Questionnaire (Singapore Airlines study) .............................245
APPENDIX 2E Protocol for anomalies in data ....................................................................249
APPENDIX 2F Descriptives from retrospective questionnaire analyses .........................251

CHAPTER 3 Appendices .................................................................................................263
APPENDIX 3A FAA Advisory Circular 117-1 .....................................................................263
APPENDIX 3B Human ethics approval letters .....................................................................271
APPENDIX 3C Participant information sheet and consent form .....................................275
APPENDIX 3D Pre-study questionnaire and duty/sleep diary ............................................279
APPENDIX 3E Actigraphy scoring protocol .......................................................................293
APPENDIX 3F Protocol for actigraphy malfunctions .........................................................295
APPENDIX 3G Criteria for including psychomotor vigilance task data .........................297
APPENDIX 3H Actisoft sleep descriptives .........................................................................309
APPENDIX 3I Subjective ratings descriptives ...................................................................331
APPENDIX 3J Multilevel mixed models of the effects of prior sleep and wake on safety performance indicators ..............................................................343
LIST OF FIGURES

Figure 1.1   Hypnogram of a healthy young adult ................................................................. 34
Figure 1.2   Schematic of the sleep homeostat (process S) (from Gander, 2003, with permission) ............................................................................................................................. 38
Figure 1.3   Schematic of the daily variation in circadian wake drive ................................. 39
Figure 1.4   The opponent process model of sleep-wake regulation (from Dijk & Edgar, 1999) ......................................................................................................................... 40
Figure 1.5   Required processes in a Fatigue Risk Management System ............................ 54
Figure 1.6   Phases of flight defined in this thesis ................................................................. 57
Figure 1.7   Schematic of the organisation of the projects and research questions of this thesis research ...................................................................................................................... 70
Figure 2.1   Total sleep duration per night categorized into short, normal or long sleepers ............................................................................................................................. 87
Figure 2.2   Self-reported type of sleeper ............................................................................. 89
Figure 2.3   Type of sleep aid used by drug class ................................................................. 89
Figure 2.4   Sleep quality in the bunk .................................................................................. 90
Figure 2.5   Reported effects of bunk sleep on alertness ..................................................... 91
Figure 2.6   Reported effects of bunk sleep on performance ................................................ 91
Figure 3.1   Time periods (24-hour intervals) for analysis in Actisoft ............................... 115
Figure 3.2   Schematic of predominant in-flight break pattern in this study .................... 129
Figure 3.3   Reported duty periods in the days prior to the studied trip (all crew) .......... 132
Figure 3.4   Outbound break, rest and sleep durations by break pattern ........................... 135
Figure 3.5   Inbound break, rest and sleep durations by break pattern ............................. 136
Figure 3.6   Total in-flight break, rest and sleep durations by break pattern and flight segment .................................................................................................................... 137
Figure 3.7   Duration of prior wakefulness at duty start .................................................... 143
List of figures

Figure 3H.2 Total sleep time across the study (crew members with at least one day of baseline) .............................................................326
Figure 3H.3 Sleep efficiency across the study period (crew members with at least one day of baseline) .........................................................327
Figure 31.1 Mean fatigue ratings across the outbound flight by break pattern ..........340
Figure 31.2 Mean fatigue ratings across the inbound flight by break pattern ..........340
Figure 31.3 Mean sleepiness ratings across the outbound flight by break pattern ......341
Figure 31.4 Mean sleepiness ratings across the inbound flight by break pattern ......341
LIST OF TABLES

Table 2.1 Pilot demographics by study ................................................................. 86
Table 2.2 Usual sleep at home by study ................................................................. 88
Table 2.3 Pilot sleep habits at home ....................................................................... 88
Table 2.4 Correlations between different variables relating to sleep at home and sleep in the bunk ................................................................. 92
Table 2.5 Variables included in the logistic regression model ....................... 94
Table 2.6 Odds ratios and 95% confidence intervals for "better than average sleep" at home ................................................................. 95
Table 2.7 Variables included in ANCOVA of factors affecting self-reported nightly home sleep duration .................................................. 96
Table 2.8 ANCOVA of factors affecting self-reported nightly home sleep duration .... 97
Table 2.9 Estimated differences in self-reported nightly home sleep duration for the categorical variables ........................................ 98
Table 3.1 Frequencies of different home time zones by crew position .......... 126
Table 3.2 Pilot demographics by crew position .................................................. 127
Table 3.3 Flight details .......................................................................................... 128
Table 3.4 Outbound flight segment break patterns by bunk type .................... 129
Table 3.5 Estimated break start and end times in domicile time (EDT) .......... 130
Table 3.6 Frequency of pre-trip naps by break pattern ..................................... 133
Table 3.7 Frequency of pre-trip naps by frequency of napping at home .......... 134
Table 3.8 Crew sleepiness ratings: effect of flight segment, time of rating and break pattern ................................................................. 139
Table 3.9 Post-hoc comparisons of Karolinska Sleepiness Scale ratings at key times during the flights .................................................. 139
Table 3.10  Crew fatigue ratings: effect of flight segment, time of rating and break pattern ................................................................................................................................... 140
Table 3.11  Post-hoc comparisons of Samn-Perelli fatigue ratings at key times during the flights ...................................................................................................................................... 140
Table 3.12  Mean PVT response speed: effect of flight segment, test time and break pattern ................................................................................................................................... 141
Table 3.13  Slowest 10% of PVT responses: effect of flight segment, test time and break pattern ................................................................................................................................... 142
Table 3.14  Fastest 10% of PVT responses: effect of flight segment, test time and break pattern ................................................................................................................................... 142
Table 3.15  Pre-flight mean PVT response speed: effect of flight segment, break pattern, time awake and total sleep in the last 24 hours ................................................... 147
Table 3.16  Pre-flight slowest 10% of PVT responses: effect of flight segment, break pattern, time awake and total sleep in the last 24 hours .................................. 147
Table 3.17  Pre-flight fastest 10% of PVT responses: effect of flight segment, break pattern, time awake and total sleep in the last 24 hours .................................. 148
Table 3.18  TOD mean PVT response speed: effect of flight segment, time awake and total sleep in the last 24 hours ..................................................................................... 148
Table 3.19  TOD slowest 10% of PVT responses: effect of flight segment, time awake and total sleep in the last 24 hours ..................................................................................... 149
Table 3.20  TOD fastest 10% of PVT responses: effect of flight segment, time awake and total sleep in the last 24 hours ..................................................................................... 149
Table 3.21  Pre-flight KSS ratings: effect of flight segment, time awake and total in-flight sleep time .............................................................................................................................. 150
Table 3.22  Pre-flight Samn-Perelli ratings: effect of flight segment, time awake and total in-flight sleep time .............................................................................................................................. 150
Table 3.23  TOD KSS ratings: effect of flight segment, time awake and total sleep in the last 24 hours .............................................................................................................................. 151
Table 3.24  TOD Samn-Perelli ratings: effect of flight segment, time awake and total sleep in the last 24 hours .............................................................................................................................. 151
Table 3.25  TOD KSS ratings: effect of flight segment, time awake and total in-flight sleep time .........................................................................................................................................152
Table 3.26  TOD Samn-Perelli ratings: effect of flight segment, time awake and total in-flight sleep time .........................................................................................................................................152
Table 5.1  Categorisation and frequency of occurrence of fatigue management strategies identified by pilots .........................................................................................................................................181
Table 2F.1  Commute time in hours (median, range) by study .....................................................................................................................................251
Table 2F.2  Number of occasions on which the aircraft bunk was used in the last 12 months ....................................................................................................................................255
Table 2F.3  Use of the aircraft bunk in the last 12 months (where have flown study specific aircraft type longer than 12 months) .....................................................................................................................................255
Table 2F.4  Sleep in the aircraft bunk .............................................................................................................................................................256
Table 2F.5  Cabin seat for in-flight rest .............................................................................................................................................................258
Table 3G.1  Number of PVT tests included and excluded based on pre-defined criteria .....................................................................................................................................298
Table 3G.2  Mean PVT response speed at each test time on outbound and inbound flights by rest break pattern .....................................................................................................................................300
Table 3G.3  Slowest 10% of PVT responses at each test time on outbound and inbound flights by rest break pattern .....................................................................................................................................301
Table 3G.4  Fastest 10% of PVT responses at each test time on outbound and inbound flights by rest break pattern .....................................................................................................................................302
Table 3G.5  Percentage of pilots experiencing lapses (≥1 response with a reaction time >500ms) or no lapses on the PVT at each test time on the outbound and inbound flights .....................................................................................................................................303
Table 3G.6  Number of lapses on the PVT at each test time on outbound and inbound flights by rest break pattern .....................................................................................................................................304
Table 3H.1  Total Sleep Time (minutes) across the study period (26 pilots with at least one day of baseline) .....................................................................................................................................310
Table 3H.2  Sleep efficiency (%) across the study period (26 pilots with at least one day of baseline) .....................................................................................................................................311
<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3H.3</td>
<td>Frequency of pilots with multiple sleep periods per 24 hours across the study (26 pilots with at least one day of baseline)</td>
</tr>
<tr>
<td>3H.4</td>
<td>Total Sleep Time (minutes) across the study (all pilots)</td>
</tr>
<tr>
<td>3H.5</td>
<td>Sleep efficiency (%) across the study (all pilots)</td>
</tr>
<tr>
<td>3H.6</td>
<td>Frequency of pilots with multiple sleep periods per 24 hours across the study (all pilots)</td>
</tr>
<tr>
<td>3H.7</td>
<td>In-flight sleep by rest break pattern (all pilots)</td>
</tr>
<tr>
<td>3H.8</td>
<td>Total sleep time, sleep efficiency, and time awake prior to duty start and TOD (26 pilots with at least one day of baseline)</td>
</tr>
<tr>
<td>3H.9</td>
<td>Total sleep time, sleep efficiency, and time awake prior to duty start and TOD (all pilots)</td>
</tr>
<tr>
<td>3H.10</td>
<td>Time since end of last rest period at duty start and at TOD (26 pilots with at least one day of baseline)</td>
</tr>
<tr>
<td>3H.11</td>
<td>Time since end of last rest period at duty start and at TOD (all pilots)</td>
</tr>
<tr>
<td>3H.12</td>
<td>Comparison of sleep duration and sleep efficiency in the last 24 hours pre-flight to baseline</td>
</tr>
<tr>
<td>3H.13</td>
<td>Comparison of sleep duration and sleep efficiency in the last 24 hours of layover to baseline</td>
</tr>
<tr>
<td>3H.14</td>
<td>Effect of post-trip days on sleep duration and efficiency</td>
</tr>
<tr>
<td>3H.15</td>
<td>Post-hoc comparisons of effects of post-trip days compared to baseline days</td>
</tr>
<tr>
<td>3I.1</td>
<td>Sleepiness, fatigue and sleep quality ratings for pilots’ main sleep period on pre- and post-flight days</td>
</tr>
<tr>
<td>3I.2</td>
<td>Karolinska Sleepiness Scale ratings across flights by break pattern</td>
</tr>
<tr>
<td>3I.3</td>
<td>Samn-Perelli Crew Status Check fatigue ratings across flights by break pattern</td>
</tr>
<tr>
<td>3I.4</td>
<td>Percentage of pilots with Karolinska Sleepiness Scale ratings ≥7 on outbound and inbound flights by rest break pattern</td>
</tr>
<tr>
<td>Table 3</td>
<td>5</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Table 3</td>
<td>J.</td>
</tr>
<tr>
<td>Table 3</td>
<td>J.</td>
</tr>
<tr>
<td>Table 3</td>
<td>J.</td>
</tr>
<tr>
<td>Table 3</td>
<td>J.</td>
</tr>
<tr>
<td>Table 3</td>
<td>J.</td>
</tr>
</tbody>
</table>
### Abbreviations and Technical Terms

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>actigraphy</td>
<td>Method of monitoring rest/activity rhythms over a period of days or weeks using a wrist worn device containing an accelerometer</td>
</tr>
<tr>
<td>AIC</td>
<td>Akaike's Information Criterion</td>
</tr>
<tr>
<td>ANCOVA</td>
<td>Analysis of covariance</td>
</tr>
<tr>
<td>ANOVA</td>
<td>Analysis of variance</td>
</tr>
<tr>
<td>ANTE(1)</td>
<td>First-order ante-dependence</td>
</tr>
<tr>
<td>AR(1)</td>
<td>First-order auto-regressive</td>
</tr>
<tr>
<td>ATL</td>
<td>Atlanta, USA</td>
</tr>
<tr>
<td>augmented flight crew</td>
<td>A flight crew that comprises more than the minimum number required to operate the aeroplane and in which each flight crew member can leave his or her assigned post and be replaced by another appropriately qualified flight crew member for the purpose of in-flight rest (definition from ICAO, 2010, Attachment 4, section 4.2.1)</td>
</tr>
<tr>
<td>AW-64</td>
<td>Model of actigraphy device</td>
</tr>
<tr>
<td>awakenings</td>
<td>Term used in reference to recalled periods of wakefulness during the sleep period</td>
</tr>
<tr>
<td>baseline</td>
<td>24 hour period (beginning at 1600 UTC) that is free of duty and does not overlap with the last 24 hours prior to duty or the first 24 hours after duty</td>
</tr>
<tr>
<td>BIC</td>
<td>Bayesian Information Criterion</td>
</tr>
<tr>
<td>blocks off</td>
<td>Moment when the aircraft first moves out of the gate at the start of the flight</td>
</tr>
<tr>
<td>blocks on</td>
<td>Time at the end of the flight when the aircraft finally comes to rest at the gate</td>
</tr>
<tr>
<td>c-statistic</td>
<td>Also termed concordance index, is a measure used to compare the goodness of fit of logistic regression models. It is a measure of the probability that the prediction of the outcome is better than chance</td>
</tr>
</tbody>
</table>
alone. A value of 0.5 indicates that the model prediction is no better than chance while a value of 1 indicates the model prediction is correct 100% of the time. Typically values above 0.7 are interpreted as the model being a reasonable fit while values above 0.8 indicate a strong model. (definition derived from documentation available in University of Manitoba, 2011)

CAAS
Civil Aviation Authority of Singapore

class 1
type of on-board rest facility; bunk or other lie-flat sleeping surface in an area separate from the flight deck and passenger cabin, where pilots can control a number of environmental factors (definition from Federal Aviation Administration, 2012b)

class 2
type of on-board rest facility; seat (in passenger cabin) that reclines to a flat or near-flat position and is separated from passengers by at least a curtain (definition from Federal Aviation Administration, 2012b)

class 3
type of on-board rest facility; seat (on flight deck or in passenger cabin) that reclines at least 40° providing leg and foot support (definition from Federal Aviation Administration, 2012b)

crew rest seat
refers to a class 2 or 3 facility located in the passenger cabin

cruise
low workload phase of flight between TOC and TOD during which pilots may have to opportunity for in-flight sleep

CS
compound symmetry

dB(A)
unit of measure of the loudness of sounds (decibels) adjusted for the way sounds are perceived by the human ear

domicile time
refers to time (in terms of time zone) at pilot's home base (i.e., departure airport of the outbound flight)

duty end
time when a pilot signs off duty after a flight (typically 1 hour after arrival)

duty start
time when a pilot reports for duty (signs on) prior to a flight (typically 2 hours prior to an international departure)

EEG
electroencephalography

EDT
Eastern Daylight Time

EMG
electromyogram
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>EOG</td>
<td>electrooculogram</td>
</tr>
<tr>
<td>EST</td>
<td>Eastern Standard Time</td>
</tr>
<tr>
<td>FAA</td>
<td>US Federal Aviation Administration</td>
</tr>
<tr>
<td>fatigue mitigation</td>
<td>a strategy, attitude or action used to minimise the effects of fatigue and/or the likelihood of fatigue occurring (also termed 'fatigue mitigation strategy' or 'mitigation')</td>
</tr>
<tr>
<td>FDP</td>
<td>flight duty period</td>
</tr>
<tr>
<td>flight segment</td>
<td>term used to refer to a single flight (i.e., flight without stopovers) between two points</td>
</tr>
<tr>
<td>flying crew</td>
<td>refers to the two pilots flying the aircraft during take-off and landing in an augmented crew</td>
</tr>
<tr>
<td>FRM</td>
<td>fatigue risk management</td>
</tr>
<tr>
<td>FRMS</td>
<td>fatigue risk management system</td>
</tr>
<tr>
<td>hypnogram</td>
<td>graphical representation of sleep architecture derived from the sleep stages identified from a polysomnographic recording</td>
</tr>
<tr>
<td>IATA</td>
<td>International Air Transport Association</td>
</tr>
<tr>
<td>ICAO</td>
<td>International Civil Aviation Organisation</td>
</tr>
<tr>
<td>IFALPA</td>
<td>International Federation of Airline Pilots' Associations</td>
</tr>
<tr>
<td>IGT</td>
<td>Iowa Gambling Task</td>
</tr>
<tr>
<td>JFK</td>
<td>New York city, USA</td>
</tr>
<tr>
<td>JNB</td>
<td>Johannesburg, South Africa</td>
</tr>
<tr>
<td>KSS</td>
<td>Karolinska Sleepiness Scale</td>
</tr>
<tr>
<td>landing</td>
<td>high-workload phase of flight between TOD and blocks on</td>
</tr>
<tr>
<td>landing crew</td>
<td>refers to the two pilots flying the aircraft during landing in an augmented crew</td>
</tr>
<tr>
<td>lapse</td>
<td>lapse in attention (typically a reaction time longer than 500ms)</td>
</tr>
<tr>
<td>LAX</td>
<td>Los Angeles, USA</td>
</tr>
<tr>
<td>LOS</td>
<td>Lagos, Nigeria</td>
</tr>
</tbody>
</table>
LR  long-range flight
mitigation  see ‘fatigue mitigation’
N1  NREM stage 1 sleep; stage 1 sleep
N2  NREM stage 2 sleep; stage 2 sleep
N3  NREM stage 3 sleep; also termed slow wave sleep
NIH  US National Institutes of Health
NREM  non-rapid eye movement sleep
OR  odds ratio
PAX  passengers
PF  pilot flying
PM  pilot monitoring
polysomnography  method of monitoring sleep using physiological measures; typically conducted in in a laboratory setting
post break 1  end of pilots’ first in-flight rest period; time at which PVT test and post-sleep subjective ratings are completed
post break 2  end of pilots’ second in-flight rest period; time at which PVT test and post-sleep subjective ratings are completed
post-flight  phase of flight between blocks on and duty end
pre-break 1  start of pilots’ first in-flight rest period; time at which pre-sleep subjective ratings are completed
pre-break 2  start of pilots’ first in-flight rest period; time at which pre-sleep subjective ratings are completed
pre-flight  phase of flight between duty start and blocks off
prospective  term used in reference to research designed to investigate situations and experiences occurring at the time of the study (e.g., in this thesis the data from the duty/sleep diary is prospective as participants are asked to record events of the study as they occur)
PSG  polysomnography
PVT  psychomotor vigilance task
xxvi
<table>
<thead>
<tr>
<th><strong>Abbreviations &amp; technical terms</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>relief crew</td>
</tr>
<tr>
<td>relief pilot</td>
</tr>
<tr>
<td>REM</td>
</tr>
<tr>
<td>rest break</td>
</tr>
<tr>
<td>rest break pattern</td>
</tr>
<tr>
<td>rest period</td>
</tr>
<tr>
<td>rest facility</td>
</tr>
<tr>
<td>retrospective</td>
</tr>
<tr>
<td>RT</td>
</tr>
<tr>
<td>SCN</td>
</tr>
<tr>
<td>SD</td>
</tr>
<tr>
<td>SE</td>
</tr>
<tr>
<td>SIN</td>
</tr>
<tr>
<td>SOL</td>
</tr>
<tr>
<td>SP</td>
</tr>
<tr>
<td>SPI</td>
</tr>
<tr>
<td>SWS</td>
</tr>
<tr>
<td>take-off</td>
</tr>
<tr>
<td>TIFST</td>
</tr>
<tr>
<td>TOC</td>
</tr>
<tr>
<td>TOD</td>
</tr>
<tr>
<td>TOL</td>
</tr>
<tr>
<td>Abbreviation</td>
</tr>
<tr>
<td>--------------</td>
</tr>
<tr>
<td><strong>TST</strong></td>
</tr>
<tr>
<td><strong>ULR</strong></td>
</tr>
<tr>
<td><strong>UTC</strong></td>
</tr>
<tr>
<td><strong>VIF</strong></td>
</tr>
<tr>
<td><strong>wake maintenance zone</strong></td>
</tr>
<tr>
<td><strong>WAT</strong></td>
</tr>
<tr>
<td><strong>window of circadian low</strong></td>
</tr>
<tr>
<td><strong>WOCL</strong></td>
</tr>
</tbody>
</table>
Il est peu et de réussites faciles,
et d'échecs définitifs.

~Marcel Proust