Australian Government
Civil Aviation Safety Authority

A review of the case for change: Scientific support for *CAO 48.1 Instrument 2013*

CASA SMS & HF Section - Fatigue Management
Standards Division

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List of Abbreviations and Acronyms

AIPA	Australian International Pilots Association
ATSB	Australian Transport Safety Bureau
BAC	Blood Alcohol Concentration
CAO	Civil Aviation Order
CASA	Civil Aviation Safety Authority
CRD	Comment and Response Documents (EASA)
EASA	European Aviation Safety Agency
FAA	Federal Aviation Administration (USA)
FCM	Flight Crew Member
FDP	Flight Duty Period
FRMS	Fatigue Risk Management System
FTL	Flight Time Limits
HK CAD	Hong Kong Civil Aviation Department
ICAO	International Civil Aviation Organisation
ODP	Off Duty Period
NASA	National Aeronautics and Space Administration (USA)
NFRM	Notice of Final Rule Making
NIOSH	National Institute for Occupational Safety and Health (USA)
NPA	Notices of Proposed Amendment (EASA)
RPT	Regular Public Transport
SIEs	Standard Industry Exemptions
UK CAA	Civil Aviation Authority (United Kingdom)
WOCL	Window of Circadian Low

Executive Summary

It has long been recognised in aviation that as fatigue increases pilot performance becomes degraded. It is also accepted that at some point in time performance degrades to such an extent that safety of flight is impacted. It is the purpose of CASA's fatigue management legislation to provide a safety net of effective limits that minimise any restriction on operations while managing this impact on safety to an acceptable level.

CASA reviewed over 200 fatigue studies, research papers and reports and used the best available scientific information as the basis for its rule-set. CASA started by assessing all existing limits to determine the degree to which they could be supported by science. Most of the provisions in CAO 48.1 *are directly supported by the latest peer-reviewed scientific studies. While some of the peer reviewed studies relied upon in this process have not been validated in the aviation context, the major provisions of this rule are based on uncontroversial scientific findings that apply to all human beings.*

There is a remarkable level of agreement in the extensive international scientific evidence about the basic parameters of sleep and alertness in relation to flight operations. Such is this agreement in fact that as far back as 1996 the leading international scientists were able to formulate a consensus document with broad recommendations about how these parameters should be taken into account in formulating flight and duty time regulations. These recommendations have remained largely unchanged since that time and have been supported by subsequent research.

Scientific research and papers, with very few exceptions, do not identify the specific limit that should be applied in any given circumstance. As the number of research papers that support a specific fatigue effect increases there is greater confidence in the level of impairment and the rate of increase of that impairment; however, in almost all cases this still does not take into account the resilience to fatigue existing in a specific sector of the aviation industry. In this regard the science can't specifically set the hard limit; however, it can usually identify a band of rapidly increasing risk.

Different regulators have implemented differing specific flight and duty limits based essentially on the same science. This can be because of differing reliance on other defences within their fatigue management rule-set, requirements in other regulations such as those that set requirements for different types of activities, those that limit operations at certain times of the day and those that set training or licencing standards.

Prescriptive rule-sets have inherent limitations with their application in the modern 24/7 aviation industry. They tend to represent a somewhat simplistic view of safety – being inside the limits is safe while being outside the limits is unsafe – and they represent a single defensive strategy. While they are adequate for most types of operations, they are a one-size-fits-all approach that does not take into account operational differences or differences among pilots. A Fatigue Risk Management System, on the other hand, is able to have defences designed into the system based on science and experience which are specific to that operator's operational circumstances. These defences may be designed in such a way that the operator's flight and duty time limits are tailored to the operation, and which may differ from or exceed the prescriptive limits.

Introduction

The International Civil Aviation Organisation (ICAO) requires that the State of the Operator establish regulations for the purpose of managing fatigue. These regulations shall be based upon scientific principles and knowledge, with the aim of ensuring that flight members are performing at an adequate level of alertness. This brief focuses on the scientific principles and knowledge relied upon by the Civil Aviation Safety Authority (CASA) in the development of *Civil Aviation Order (CAO) 48.1 Instrument 2013*.

It has long been recognised in aviation that as fatigue increases pilot performance becomes degraded. It is also accepted that at some point in time performance degrades to such an extent that safety of flight is impacted. It is the purpose of CASA's fatigue management legislation to provide a safety net of effective limits that minimise any restriction on operations while managing this impact on safety to an acceptable level. The approach taken was by no means a conservative one with the resulting limits assuming relatively optimum conditions and with inherent potential for high levels of fatigue should these assumptions not be met. This potential risk underpinned the specific requirements within the rules for operators and individuals to contribute to managing fatigue risk while still within the limits.

CASA reviewed over 200 fatigue studies, research papers and reports and used the best available scientific information as the basis for its rule-set. CASA started by assessing all existing limits to determine the degree to which they could be supported by science. The decision to change the limit was determined by the strength of the science pertaining to the level of fatigue risk possible in that circumstance. Where applicable science wasn't found and previous experience had not identified a safety issue with a limit it was retained. Most of the provisions in *CAO 48.1* are directly supported by the latest peer-reviewed scientific studies. Where they weren't their retention was based on supporting evidence from experience with the limit. While some of the peer reviewed studies relied upon in this process have not been validated in the aviation context, the major provisions of this rule are based on uncontroversial scientific findings that apply to all human beings.

There is a remarkable level of agreement in the extensive international scientific evidence about the basic parameters of sleep and alertness in relation to flight operations. Such is this agreement in fact that as far back as 1996 the leading international scientists were able to formulate a consensus document with broad recommendations about how these parameters should be taken into account in formulating flight and duty time regulations. These recommendations have remained largely unchanged since that time and have been supported by subsequent research. More recently, the rule-making process undertaken by both the Federal Aviation Administration (FAA) and the European Aviation Safety Agency (EASA) facilitated subsequent recommendations by groups of leading international scientists. This wealth of information was synthesised in CASA's 16 Guiding Principles that were subsequently used to develop the prescriptive limits. For transparency and to encourage dissenting views, these principles were published in the notice of final rule making (NFRM). They are repeated in Appendix A to this paper.

Scientific research and papers, with very few exceptions, do not identify the specific limit that should be applied in any given circumstance. As the number of research papers that support a specific fatigue effect increases there is greater confidence in the level of impairment and the rate of increase of that impairment; however, in almost all cases this still does not take into account the resilience to fatigue existing in a specific sector of the aviation industry. In this regard the science can't specifically set the hard limit; however, it can usually identify a band of more rapidly increasing risk.

Different regulators have implemented differing specific flight and duty limits based essentially on the same science. This can be because of differing reliance on other defences within their fatigue management rule-set, requirements in other regulations such as those that set requirements for different types of activities, those that limit operations at certain times of the day and those that set training or licencing standards. Rules also reflect the nature of the dominant types of operations in that country. The rules are necessarily directed at the manifestation of fatigue risk associated with the nature of a country's specific types of operations. Therefore superficial comparison of specific components of differing rule-sets is unlikely to take into account other defences that may be present, and are relied upon, to manage fatigue risk. Additionally however, there is no doubt that the effect of the socio-political context, the broader operating environment, and the perceived level of resilience in a sector impacts the level of risk that is acceptable to the regulator and this will influence the limits that are selected.

As an example of how the changing context can impact the assessment of acceptable risk, while operators and organisations representing operator groups are now calling for less conservative limits, it was as recent as 2013-2014 that CASA was heavily involved with defending the new *CAO 48.1 Instrument 2013* from a disallowance motion in Parliament. This had been initiated by Australian International Pilots Association (AIPA) on the basis that the limits were not conservative enough. The argument ended up in a Senate technical meeting and the disallowance motion was defeated, ultimately relying on the unions agreeing that the new CASA limits were at least as safe as the existing limits. They did not concede any more ground than that and so are unlikely to support any relaxing of limits in the future.

Prescriptive rule-sets have inherent limitations with their application in the modern 24/7 aviation industry. They tend to represent a somewhat simplistic view of safety – being inside the limits is safe while being outside the limits is unsafe – and they represent a single defensive strategy. While they are adequate for most types of operations, they are a one-size-fits-all approach that does not take into account operational differences or differences among pilots. They typically cannot provide credit for the flexible rostering practices of each operator that allow each operator to specifically target and manage their fatigue risk. In contrast, each individual component of a prescriptive rule-set considers the impact on the pilot assuming that they have been operating up to, or near to the limits of the other components of the rule-set. A Fatigue Risk Management System (FRMS), on the other hand, is able to have defences designed into the system based on science and experience which are specific to that operator's operational circumstances. These defences may be designed in such a way that the operator's flight and duty time limits are tailored to the operation, and which may differ from or exceed the prescriptive limits.

Where the developed prescriptive rules did not allow a specific practice of an operator despite the assertion that it had been conducted to an acceptable level of safety in the past, CASA has taken the stance that the operator was able to take advantage of greater flexibility in their rostering than it is possible to design into a prescriptive rule-set without resulting in excessive complexity. This does not mean that the science underpinning the rules is wrong. It is more likely an example of the underlying limitations of prescriptive limits more generally and the challenges of introducing the required level of complexity across an entire appendix to address the specific case. This tailored approach to fatigue management was seen as being best managed under an FRMS specific to that operator.

Overview of the Report

The objective of this paper is to provide a summary of the manner in which fatigue and sleep science was relied upon to set limits within *CAO 48.1 Instrument 2013*. The intention is not to describe every single study, but to provide an indication of the main thrust and purpose of the research.

CAO Part 48 which preceded the new *CAO 48.1 Instrument 2013* existed largely unchanged since coming into effect as *Air Navigation Order 48* in 1953. The transition to *CAO Part 48* in 1988 did not result in significant changes to the limits. Since 1988 CASA has commenced an update of the fatigue management rules on several occasions without resulting in an amendment to *CAO Part 48*. This paper focuses on the main program of work under Project OS 02/03 Fatigue Risk Management Systems re-initiated on 9th of August 2011.

ICAO requirements:
ICAO requires that the State of the Operator establish regulations for the purpose of managing fatigue. These regulations shall be based upon scientific principles and knowledge, with the aim of ensuring that flight members are performing at an adequate level of alertness.

Project OS 02/03 was re-initiated primarily because the old *CAO 48* and alternative means of compliance did not meet the standard required by ICAO in that they did not reflect accepted scientific principles and knowledge. Specifically, the rules did not consider or adequately take into consideration the effect on fatigue of:

- Start time
- Number of sectors
- Effects of circadian rhythm
- Effects of changing multiple time-zones

Developments in the field of sleep and fatigue science over the past 50 years have shown that a complex relationship exists between work, sleep, time awake, time of day and fatigue. This relationship is especially important to understand in aviation due to the increasingly irregular shift patterns that pilots must work, the increasingly intensive utilisation of pilots, trans-meridian effects or 'jet lag', and the safety sensitive nature of the work.

ATSB data:
Accident and incident data received from the Australian Transport Safety Bureau (ATSB) suggests that there have been approximately 65 incidents/accidents in the last 10 years in which human fatigue was identified as a factor. A proportion of these occurrences have been in the Regular Public Transport (RPT) sector of the industry.

Feedback from the ATSB is that this number is expected to under estimate fatigue as a causal factor due the challenges associated with proving that fatigue—even if it can be shown to be evident—actually influenced the error that contributed to the accident. The main issue is that typically, while fatigue can make an error more likely, the same error can also occur without the presence of fatigue.

In research conducted by the ATSB, fatigue was reported by surveyed flight crew to be one of the top five threats faced by respondents in low capacity air transport (ATSB, 2009).

CASA research:
In 2001, at the request of CASA, Professor Drew Dawson and Associate Professor Greg Roach from the South Australia Centre for Sleep Research conducted a Biomathematical assessment of the existing standard industry exemptions (SIEs). They found that unacceptable levels of fatigue were legally possible across all SIEs.

Development of the Prescriptive Limits

When setting the prescriptive limitations, CASA considered a large body of research numbering in excess of 200 published papers and reports, as well as taking into account regulatory experience with past rules.

CASA has used the best available scientific information as the basis for this rule-set. As discussed in this section, most of the provisions in this rule are supported by the latest peer-reviewed scientific studies. While some of these peer reviewed studies have not been validated in the aviation context, the major provisions of this rule are based on uncontroversial scientific findings that apply to all human beings.

As noted by Akerstedt, Mollard, Samel, Simons, and Spencer (2003, p. 2);

> *"There is a remarkable level of agreement in the extensive international scientific evidence about the basic parameters of sleep and alertness in relation to flight operations. Such is this agreement of fact that the leading international scientists have been able to formulate a consensus document with broad recommendations about how these parameters should be taken into account in formulating Flight Time Limits (FTL) regulations".*

CASA is entirely in agreement with the FAA Flightcrew Member Duty and Rest Requirements, Final Rule (2012, p. 390); when they stated, in support of their equivalent rule-making process that:

> *"…[S]leep science, while still evolving, is clear in several important respects: Most people need eight hours of sleep to function effectively, most people find it more difficult to sleep during the day than during the night, resulting in greater fatigue if working at night; the longer one has been awake and the longer one spends on task, the greater the likelihood of fatigue; and fatigue leads to an increased risk of making a mistake… These uncontroversial scientific findings form the basis for almost all of the major provisions in this rule. The FAA has concluded that, even though some of these findings were not based on aviation data, flightcrew members have the same fatigue concerns as other human beings, and as such, there is no reason to believe that these findings would not apply to flightcrew members".*

In order to construct the prescriptive limits required by ICAO, CASA identified the key fatigue hazards and distilled the available research into 16 guiding principles that addressed these hazards. These principles were published in the Notice of Final Rule Making (NFRM) and are listed at Appendix A. As an example, the science that supports four of these sixteen principles has been summarised below:

1. ***Fatigue risk increases as time awake increases and, even in ideal conditions, the risk of fatigue having a material impact on cognitive and physical performance eventually becomes unacceptable sometime after 16 hours awake.***

- *Multiple studies outline an increased risk of fatigue impairment due to both the duration of the period of wakefulness and time of day factors; Akerstedt et al. (2003), identifies that the fatigue risk and the imbalance component of sleep vs. alertness/wakefulness increases over periods of wakefulness. Samel et al. (1997) and Spencer and Robertson (1999), provide examples of crews having difficulty remaining awake during single sector overnight operations of 11 hours or more (see also Moebus, 2008, p. 15).*

- *Akerstedt and Folkhard (1997) also cited in EASA (2012) identify sleepiness (as one component of fatigue impairment) links to three elements;*
  - *Internal biological patterns (circadian) acclimatised to the persons home environment that initiates patterns of sleep and wakefulness every 24 hours (reset by natural and artificial cues, Zeitgebers)*
  - *A physiological balance process of sleep after a period of wakefulness that initiates after a certain period of time (approximately 16 hours for most individuals)*
  - *Sleep inertia induced by the transition from sleep to wakefulness that occurs immediately after waking and impairs performance temporarily.*
- *Akerstedt, Kecklund, Gillberg, Lowden and Axelsson (2000) outlines that the effect is exacerbated due to time of day factors, where extended duty times (14 hours) transition through 00:00 towards the window of circadian low (WOCL).*
- *Low levels of alertness are identified in two pilot operations following duties as low as 9-10 hours (Powell, Spencer, Holland and Petrie, 2008).*
- *Powell, Spencer, Holland, Broadbent and Petrie (2007) reinforce the influence of duty length on fatigue in reporting that in a study of short-haul pilots and multiple sectors, fatigue was explained, in part, by the length of the duty, and in addition highlighted time of day effects.*
- *Periods of wakefulness and reference to expected practices in the FAA (2012, p. 331) state longer shifts increase fatigue and suggest that the maximum Flight Duty Period (FDP) limit is further reduced during night-time hours and when the WOCL is operated through.*
- *The FAA (2012) cites numerous individual commentators stating that 16 hour duty periods… result in an unsafe amount of fatigue.*
- *The FAA (2012, p. 359), reference to a 13 hour FDP could result in periods of wakefulness in excess of 16 hours before their FDP resulting in a human performance similar to that of an individual over the legal limit for alcohol consumption.*
- *In their study quantifying the performance impairment associated with fatigue Lamond and Dawson (1999) identified that being awake for approximately 17 hours has a similar impairment on many aspects of performance as having a Blood Alcohol Concentration (BAC) of 0.05%. Being awake for approximately 21 hours has a performance impairment equivalent to 0.10% BAC.*

2. Fatigue increases as time at work increases and pilots who have been at work for 12 hours or more are over represented in accident and incident data. Being on duty more than 12 hours should only happen in optimal circumstances.

- *Risk in error or injury contributed to by fatigue elements increases by more than double in the 12th hour of work than during the first 8 hours. (Folkard and Tucker, 2003). This finding is also seen in the FAA (2012).*
- *Goode, (2003) highlights that proportionately accidents associated with pilots having longer duty periods is higher than the frequency of scheduled longer duty periods for all pilots. Periods of operation between 10 – 12 hours of duty time is associated with a 1.7 increased incidence of an accident; those periods over 13 hours result in a incidence rate over 5.5 times as high (FAA, 2012, p. 337).*
- *Some additional elements to influence duty time considerations should also include time of day elements such as night time hours and working through the Window of Circadian Low (WOCL), multiple flight segments and transient fatigue aspects such as out of sync time zones acclimatisation. This is supported by National Institute for Occupational Safety and Health (NIOSH) (FAA, 2012). The FAA has subsequently limited some night time operations to a maximum FDP of 9 hours.*

- *Studies undertaken by the National Aeronautical and Space Agency (NASA) (cited in FAA, 2012, p. 359) identify concern in extending FDP limits due to findings from data that polled corporate pilots that highlighted fatigue concerns for duty times over 8 and 10 hours.*
- *Time of day factors could facilitate an extension during the day to 14 hours based off diurnal patterns between the sign-on hours of 0800 and 1200 (Spencer, 2011; Gundel and Hohe, 2011; cited in EASA, 2012), however reduce to 10 hours for reporting times between 17:00 and 03:59 to manage fatigue risk at night to be aligned with the science applicable to night time operations.*

3. ***Early starts impact quality of sleep and subsequent alertness.***

- *Many studies have shown that early starts decrease the amount of sleep obtained. In general, it is difficult for people to successfully go to sleep earlier than normal. In a recent example, a study of Australian airline pilots (Roach, Sargent, Darwent and Dawson, 2012) found that their amount of sleep increased as the rostered start time became later, with an average of about 5.7 hours for a 0600 start. Self-reported levels of fatigue were also higher with early starts.*
- *EASA (2012, p. 16) states that a start as early as 0600 may prompt a sleep loss of over 90 minutes on average. The resultant being a reduction in the recuperative quality of a night's sleep due to preparation activities and commuting to work.*
- *A general statement that an early start, combined with travel time will significantly reduce the prior sleep length and quality of sleep is supported by a number of studies including Simons and Valk (1997). The study identified that as starts became earlier, there was a greater reduction in sleep achieved. This reduction in sleep outside of diurnal patterns prompted reduced alertness levels.*
- *Circadian patterns of sleep are disrupted by early start times as the report time requires additional time for wakefulness in order to report ready and commute from accommodation or home. This may prompt a large reduction in sleep opportunity and quality (EASA, 2012)*

4. ***Reduction in Maximum FDP for increasing sectors:***

- *MOEBUS Aviation, a group of leading fatigue scientists commissioned by EASA to perform a scientific and medical evaluation of Subpart Q of the EU OPS, cited in their report a number of studies that have shown that fatigue increases with the number of sectors (as an example; Powell, Spencer, Holland, Broadbent, and Petrie, 2007). They recommended that the maximum FDP be reduced by 30 minutes per sector for every sector after the first.*
- *Recent international rule-making efforts has coalesced towards a 30 minute or 45 minute reduction to the FDP limit for each sector flown (e.g., FAA, EASA, Hong Kong Civil Aviation Department (HK CAD) and Civil Aviation Authority – United Kingdom (UK CAA).*
- *In order to tailor the limits more appropriately for regional operators CASA chose to delay the reduction for odd sectors and make a 1 hour reduction for even sectors.*
- *The MOEBUS report (2008) identified that there was limited information on the effect of more than four sectors on fatigue, and called for further studies in this area.*

Comparison with other aviation regulators:

A joint CASA/industry working group reviewed the approaches taken to fatigue management by comparable international aviation safety regulators and considered that, in some cases (such as the management of time zone changes), these approaches were simply not appropriate in the Australian context. Where aspects of these approaches were found to be appropriate to the Australian situation, they informed the approach taken under the new rules. Consistency with the regulatory approach of other leading aviation authorities was a general aim in the development of the new rules. However, because of incompatibilities of approach resulting from variations in the requirements appropriate in different regional contexts, it was not possible to achieve uniformity across the entire rule set.

Comparing *CAO 48.1* by selective quotation of particular parts of the prescriptive limit rule sets of other regulators ignores the additional overlay of other safety measures within *CAO 48.*1 and those foreign rule sets. The same can be said where elements of the CASA rules have been criticised by artificially isolating them from the wider context in which they are meant to operate. To fully appreciate how the rule set is intended to manage fatigue, each layer of protection incorporated in the rules needs to be understood in context of the manner in which it operates as part of a "defences-in-depth" approach that, as a whole, achieves a safe outcome in that context.

An example of where regulators have come to different conclusions is around the issue of the WOCL. WOCL describes the period of time when subjective fatigue and sleepiness are greatest and people are, in comparison to other times of the day, least able to perform, mentally and physically, at their best. One would expect that the body of research on this aspect of human biology would generally be clear. However, regulators have come up with different definitions for the WOCL. The FAA, EASA and HK CAD describe the WOCL as usually being between 2am and 6am. More recent definitions, such as those promulgated by ICAO and CASA, define the WOCL for a human as typically being between 3am and 5am. The net effect of this difference, when applied to the task of determining prescriptive limitations, is that limitations will be different.

An example of where an apparent difference between rule-sets is moderated by differences in other components of the rule-set is the apparent difference in the maximum FDP between the FAA and CASA for multi-crew air transport between 0500 and 0600. If you compare the applicable tables the difference appears to be that the FAA allows a maximum FDP 2 hours longer than CASA. Looking more closely at the FAA limit set, there are significant limitations on operations between 0200 and 0600 that impact on starting an FDP in this 0500 to 0600 time period. Because starting in this period infringes the FAA WOCL (0200-0600) a certificate holder may only schedule up to five consecutive FDPs that infringe this period and each must provide the flight crew member with an opportunity to rest in a suitable accommodation for at least 2 hours, measured from the time that the flight crew member reaches the suitable accommodation. This rest opportunity must be provided between the hours of 22:00 and 05:00 local time and must be scheduled before the beginning of the flight duty period in which that rest opportunity is taken. In addition the rest opportunity that the flight crew member is actually provided may not be less than the rest opportunity that was scheduled, and the rest opportunity is not provided until the first sector of the flight duty period has been completed. If these conditions are not met no operator may schedule and no flight crew member may accept more than three consecutive flight duty periods that infringe on the window of circadian low. In other words, while early starts that commence between 0500 and 0600 are allowed to use a maximum FDP of 12 hours they are limited to 3 consecutive FDPs that commence in this period unless the appropriate rest period of two hours is provided during the FDP.

There are differences between *CAO 48.1* and other international aviation regulators. Many (aviation regulators) such as New Zealand and Canada are in the process of updating their fatigue management rules while the FAA and EASA have only recently completed theirs. A comparison between *CAO 48.1* and the FAA and EASA was conducting during the development of *CAO 48.1* by the project team although at that time both these rule-sets were nearing completion and had not been finalised. An example of this comparison is the overlay of maximum FDP limits based on start time found at Appendix B. This comparison was used to test *CAO 48.1* to ensure there were not anomalies that couldn't be explained.

Prescriptive rules versus FRMS:
Prescriptive rule-sets are limited in their application in the modern aviation industry. ICAO (2012) stated that:

> *"Prescriptive flight and duty time limits represent a somewhat simplistic view of safety – being inside the limits is safe while being outside the limits is unsafe – and they represent a single defensive strategy. While they are adequate for some types of operations, they are a one-size-fits-all approach that does not take into account operational differences or differences among crewmembers.*
>
> *In contrast, an FRMS employs multi-layered defensive strategies to manage fatigue-related risks regardless of their source. It includes data-driven, ongoing adaptive processes that can identify fatigue hazards and then develop, implement and evaluate controls and mitigation strategies. These include both organizational and personal mitigation strategies".*

In a prescriptive rule-set, each individual component of the rule-set must consider the impact on the Flight Crew Member (FCM) assuming that the FCM has been operating up to, or near to the limits of the other components of the rule-set. Therefore, for example, any single flight duty period limit assumes that the preceding FDP was conducted up to the maximum limit and the Off Duty Period (ODP) between the two was a minimum ODP. This is necessary because there is no restriction to stop other components having been maximised. An FRMS, on the other hand is able to have defences designed into the system which are specific to that operator's operational circumstances. These defences may be designed in such a way that the operator's operations manual limits may differ from or exceed the prescriptive limits in tier two.

Where the developed prescriptive rules did not allow a specific practice of an operator despite the assertion that it had been conducted to an acceptable level of safety in the past, CASA has taken the stance that the operator was able to take advantage of greater flexibility in their rostering than it is possible to design into a prescriptive rule-set without resulting in excessive complexity. This does not mean that the science underpinning the rules is wrong. It is more likely an example of the underlying limitations of prescriptive limits more generally and the challenges of introducing the required level of complexity across an entire appendix to address the specific case. This tailored approach to fatigue management was seen as being best managed under an FRMS specific to that operator.

The proposed amendments to the new *CAO 48.1*

The proposed amendments extend the transition period by 1 year (to a total of 4 years) giving more time for operators to update operations manuals to comply with the new rules.

The proposed amendments also adjust some of the prescriptive limitations based on further consideration of existing rostering practices. CASA has assessed what certain sectors of the industry currently do, and has 'tested' these against the available science.

The basic limits in Appendix 1 of the new *CAO 48.1* are proposed to be adjusted to enable earlier and later duty periods, but limiting the duration of them. These changes provide relief to operators who don't roster pilots to the maximum limit but roster them earlier or later than the timeframes currently specified in Appendix 1 of the new *CAO 48.1*. The practical effect of this change is that operators who are able to fit within the amended Appendix 1 limitations would not need risk management processes or fatigue training for their pilots.

The amendments would allow more operators to comply with the prescriptive limitations rather than having to develop, and seek approval for an FRMS.

References:

Akerstedt, T., & Folkard, S. (1997). The Three-Process Model of Alertness and its Extension to Performance, Sleep Latency, and Sleep Length. *Chronobiology International. 14(2),* pp. 115-123.

Akerstedt, T., Mollard, R., Samel, A., Simons, M., & Spencer, M, (2003). *Paper prepared for the ETSC "Meeting to discuss the role of EU FTL legislation in reducing cumulative fatigue in civil aviation".* Brussels: European Transport Safety Council.

Akerstedt, T., Kecklund, G., Gillberg, M., Lowden, A., & Axelsson, J. (2000). Sleepiness and days of recovery. *Transportation Research Part F: Traffic Psychology and Behaviour, 3(4),* pp. 251-261.

Australian Transport Safety Bureau. (2009). *Perceived threats, errors and safety in aerial work and low capacity air transport operations*. Canberra: Australian Transport Safety Bureau.

Dawson, D. & Roach, G. (2001*). Standard industry exemptions from Civil Aviation Order 48: Assessment of worst-case scenarios.* Centre for Sleep Research: University of South Australia. Retrieved from: http://www.casa.gov.au/sites/g/files/net351/f/_assets/main/aoc/fatigue/regs/cao48exemptions.pdf

EASA. (2012). *Comment Response Document (CRD) CRD to NPA 2010-14.* RMT.0322. EASA.

Federal Aviation Administration. (2012). Flightcrew member duty and rest requirements RIN 2120-AJ58. Washington D.C.

Folkard, S., &Tucker, P. (2003). Shift work, safety and productivity. *Occupational Medicine, 53(2),* pp. 95-101

FRMS Manual for Regulators, ICAO Doc 9966, 2012 Edition

Goode, J. (2003). Are Pilots at risk of accidents due to fatigue? *Journal of Safety Research.34* (3) pp. 309-313.

Lamond, N., & Dawson, D. (1999). Quantifying the performance impairment associated with fatigue. *Journal of Sleep Research, 8(4),* pp 255-262.

Moebus, P. (2008). Scientific and medical evaluation of flight time limitations. Zurich: MOEBUS Aviation.

Powell, D., Spencer, M.B., Holland, D., & Petrie, K.J. (2008). Fatigue in Two-Pilot Operations: Implications for Flight and Duty Time limitations. *Aviation, Space, and Environment Medicine, 79(11),* pp. 1079-1050.

Powell, D.M.C., Spencer, M.B., Holland, D., Broadbent, E., & Petrie, K.J. (2007). Pilot Fatigue in Short-Haul Operations: Effects of Number of Sectors, Duty Length , and Time of Day. *Aviation, Space, and Environment Medicine, 78(7),* pp. 698-701.

Roach, G., Sargent, C., Darwent, D., & Dawson, D. (2012). Duty periods with early start times restrict the amount of sleep obtained by short-haul airline pilots. *Accident Analysis and Prevention. 45.* Supplement. pp 22-26

Samel, A., Wegmann, H.M., Vejvoda, M., Drescher, J., Gundel, A., Manzey, D., & Wenzel, J. (1997). Two-crew operations: Stress and fatigue during long-haul night flights. *Aviation, Space and Environmental Medicine,* Vol. *68(8),* pp. 679-687.

Simons, M., &Valk, P. (1997). Early starts: effects on sleep, alertness and vigilance. *Aeromedical Support Issue in Contingency Operations (pp.6.1-6.5). Rotterdam: CP-599*

Spencer, M., & Robertson, K. (1999). The Haj operation: Alertness of aircrew on return flights between Indonesia and Saudi Arabia, DERA Report No. DERA/CHS/PPD/CR980207/1.0, Farnborough, UK.

Appendix A

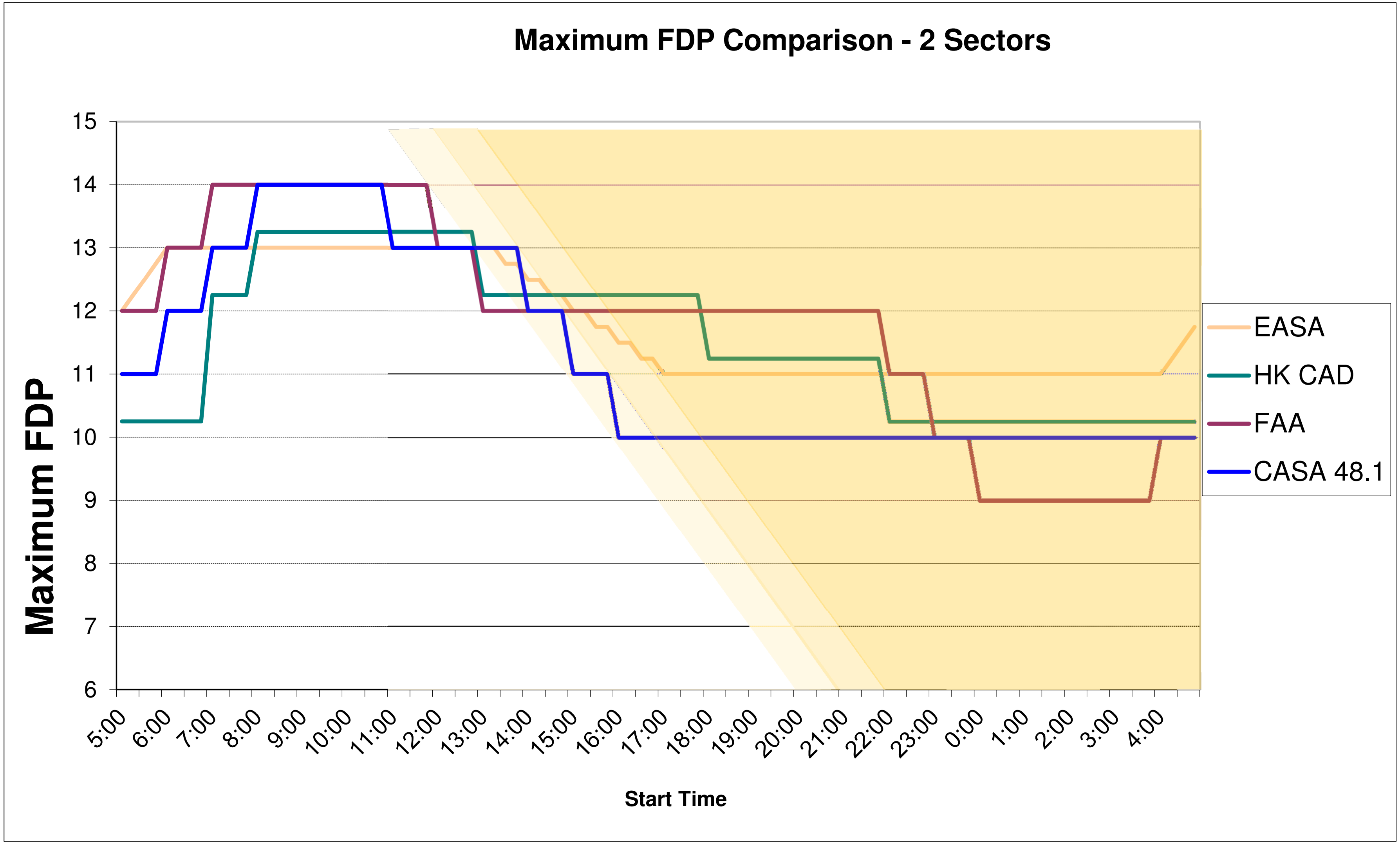
Guiding Principles

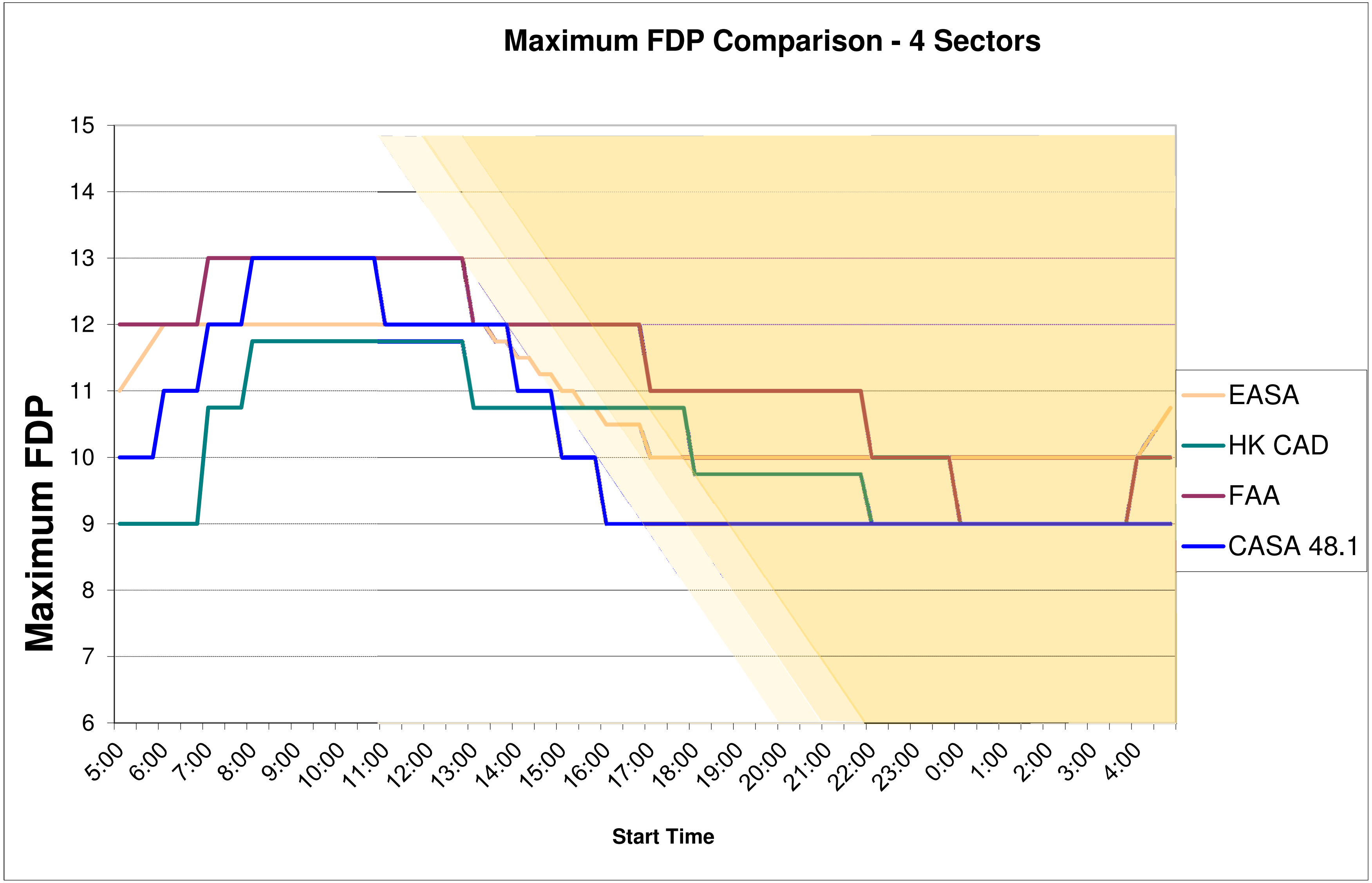
1. Fatigue risk increases as time awake increases and, even in ideal conditions, the risk of fatigue having a material impact on cognitive and physical performance eventually becomes unacceptable sometime after 16 hours awake.
2. Fatigue increases as time at work increases and pilots who have been at work for 12 hours or more are over represented in accident and incident data. Being on duty more than 12 hours should only happen in optimal circumstances.
3. Individual sleep requirements – based on an average figure of 7.5 to 8 hours sleep in a 24 hour period. While it is acknowledged that some adults require less sleep there are some of the population that require more. Additionally, 7.5 to 8 hours sleep after an overnight shift is likely to be less than adequate.
4. Even small restrictions on normal sleep requirements, if continued over a period of days, can have a cumulative detrimental effect on alertness.
5. Alertness is impacted by the time of day, as determined by the individual's body clock.
6. Time zone changes by as little as 1 hour can have an effect on an individual's circadian rhythm and hence alertness at particular times throughout the day.
7. Early starts impact quality of sleep and subsequent alertness.
8. Finishing a duty in the WOCL (Window of Circadian Low i.e., between approximately 0300-0500 when the pressure to sleep is at its very highest) increases the risk of fatigue.
9. Being on duty during the WOCL will increase fatigue and negates the opportunity to take advantage of what is normally the optimum period for good quality sleep.
10. Sleep obtained during the day (or normal awake period) will likely be of a lower standard than sleep obtained during the night (normal sleep period).
11. Sleep obtained when in other than an acclimatised state[1] will be of lower quality than sleep obtained in an acclimatised state.
12. Being in an unacclimatised state impacts on alertness throughout the period an individual is awake.
13. Because a period of standby requires holding oneself ready for a flight duty, it is not considered to be a period of off-duty.
14. Flight crew will use the off-duty period prior to a duty period to prepare adequately for that specific flight duty. If the flight is delayed by less than 10 hours, the operator cannot rely on the flight crew being able to sleep or adequately rest in the period of delay.
15. Recovery to an acclimatised state is quite idiosyncratic. However, broadly speaking the adaptation time increases disproportionately over 6 hours time zone displacement.
16. In-flight rest can be restorative; however, this is dependent on the standard of the in-flight rest facility, whether a full sleep cycle is achieved and the individual's propensity to sleep.

[1] Being in an acclimatised state refers to when an individual's body clock is adjusted to local time.

Appendix B

Comparison of maximum FDP for multi-crew Air Transport for 2 sectors and 4 sectors




Maximum FDP Comparison - 4 Sectors
Maximum FDP
15
14
13
12
11
10
9
8
7
6
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
0:00
1:00
2:00
3:00
4:00
Start Time
EASA
HK CAD
FAA
CASA 48.1