Fatigue Management Guide for Air Traffic Services Providers

First Edition, 2016

DISCLAIMER

Front cover photo courtesy of NAV CANADA

EXECUTIVE LETTER

Dear Colleagues,

It is widely recognized that aviation is the world's safest form of transport. This fact represents years of collaborative effort from across the industry and a shared focus on the continuous improvement of our already safe system. In that spirit, Civil Air Navigation Services Organisation (CANSO), International Civil Aviation Organization (ICAO) and International Federation of Air Traffic Controllers' Associations (IFATCA) are pleased to present this manual which has been developed and made available in an effort to familiarize air traffic service providers with the fundamental concepts of fatigue management and provide a guide for their implementation in day to day operations.

Fatigue is an inevitable hazard in the around-the-clock aviation environment, naturally degrading various types of human performance. Fatigue management provides structured methods to address the safety implications of fatigue. This manual describes science-based and operationally-oriented fatigue management processes as well as provides guidance on their implementation from both a prescriptive and performance-based perspective.

The material presented here represents the knowledge and expertise of the ICAO Fatigue Risk Management Systems Task Force and a special air traffic control (ATC)-focused configuration of the group established specifically for the development of ATC fatigue management provisions. The input of this group of experts ensures that this document presents approaches that are widely accessible to the air navigation service providers and air traffic controllers who will be using them.

We are extremely proud to jointly introduce this document, which will contribute to the improved management of fatigue risk and help us achieve our common goal of improving aviation safety worldwide.

Patrik Peters
President and Chief Executive Officer
International Federation of Air Traffic Controllers' Associations

Stephen P. Creamer
Director, Air Navigation Bureau
International Civil Aviation Organization

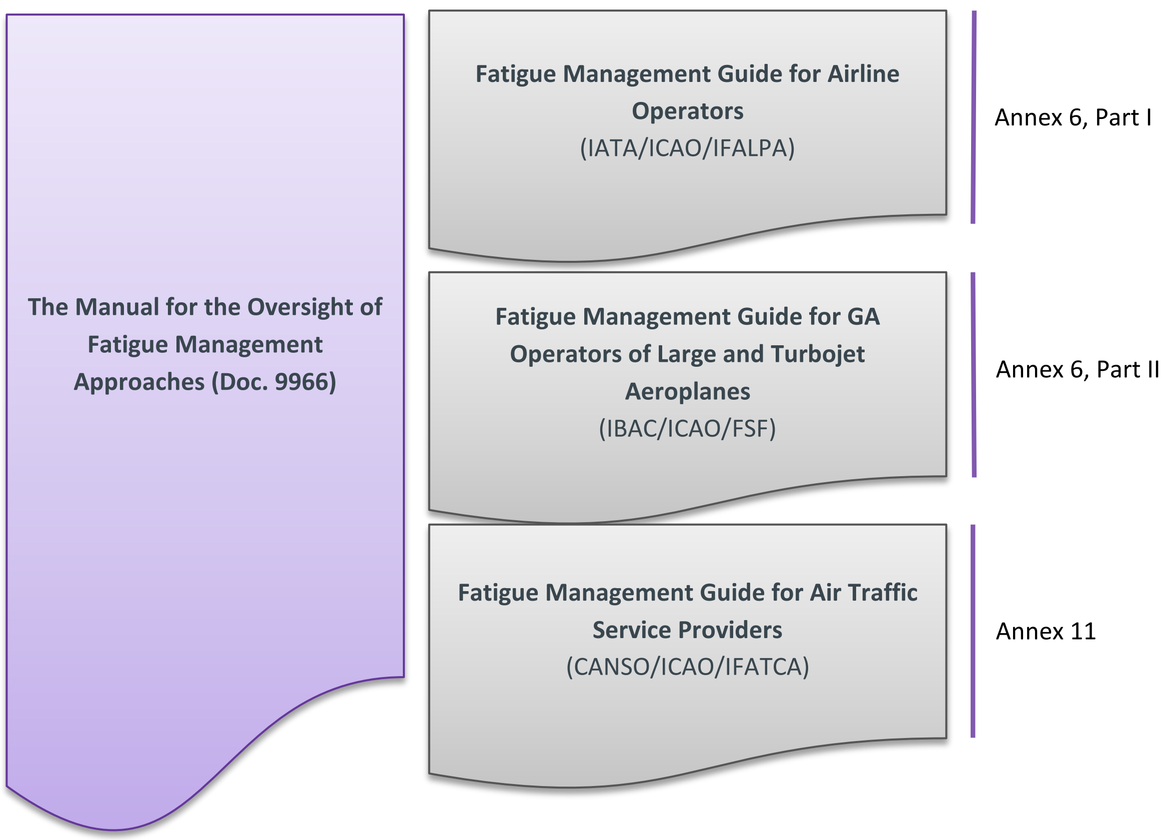
Jeff Poole
Director General
Civil Air Navigation Services Organisation

USE OF THIS MANUAL

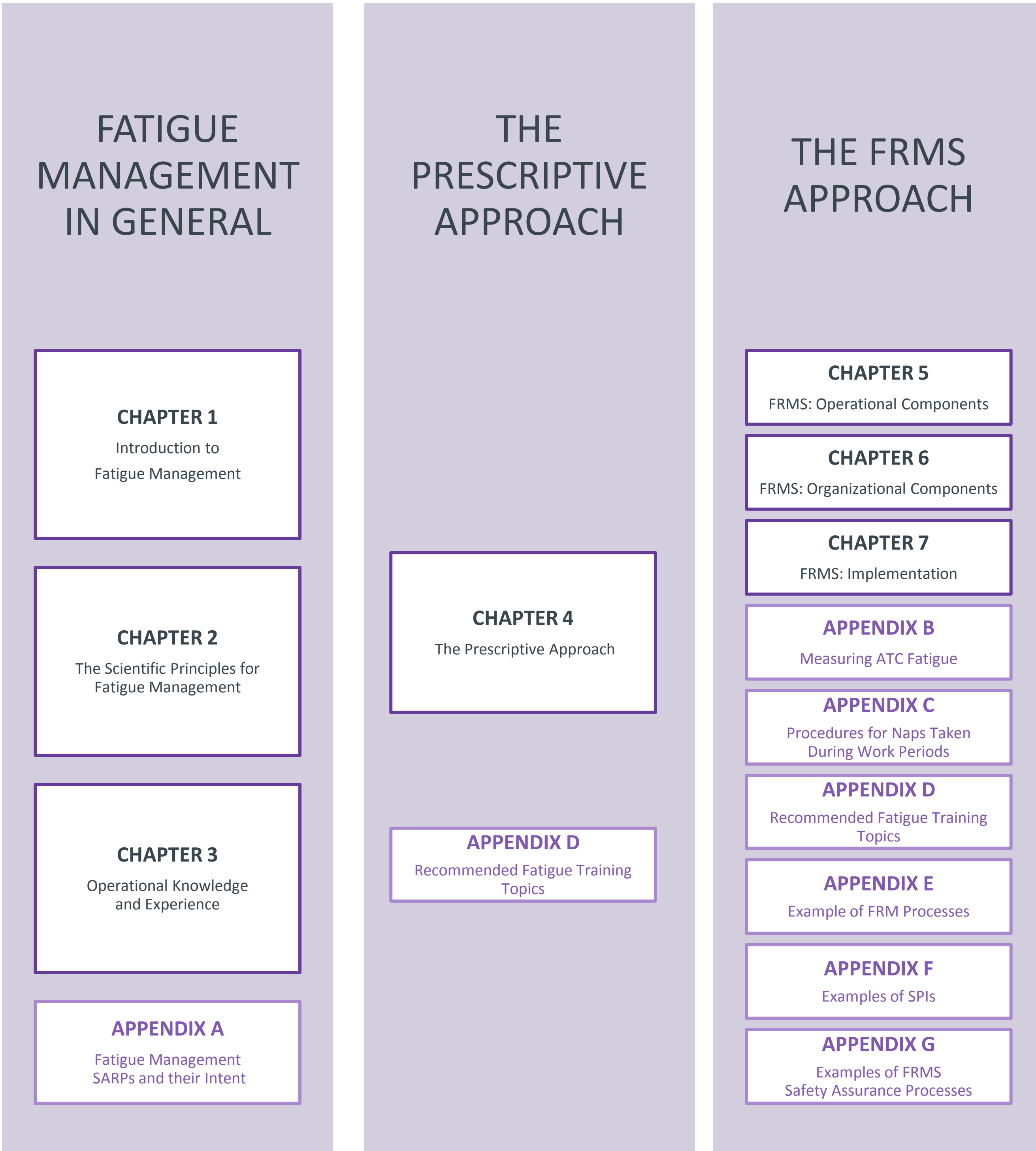
The Fatigue Management Guide for Air Traffic Service (ATS) Providers is one in a suite of manuals related to fatigue management. Developed specifically for ATS Providers, this manual presents information on managing fatigue risks using both a prescriptive approach to fatigue management and FRMS.

This document is designed to be read in association with the ICAO Manual for the Oversight of Fatigue Management Approaches (Doc. 9966). All of the manuals in the suite of manuals are based on the work of the ICAO FRMS Task Force.

The suite of Fatigue Management Manuals, and the Annexes to which they pertain, is as follows:



The following diagram provides an overview of the Fatigue Management Guide for ATS Providers and is presented to assist readers in navigating its contents[1]. The diagram separates the contents of this document into three general areas:



[1] A corresponding diagram is provided in The Manual for the Oversight of Fatigue Management Approaches (Doc. 9966), to assist readers in using these manuals in parallel.

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ACRONYMS

ATC. Air Traffic Controller

ATS Provider. Air Traffic Service provider

FRMS. Fatigue Risk Management System

FSAG. Fatigue Safety Action Group

SPIs. Safety Performance Indicators

WOCL. Window of circadian low

GLOSSARY

**denotes an ICAO definition*

Actigraph. A wristwatch-like device containing an accelerometer to detect movement. Activity counts are recorded per unit time, for example every minute. The patterns of movement can be analyzed using purpose-built software to estimate when the wearer of the actiwatch was asleep, and to provide some indication of how restless a sleep period was (i.e., sleep quality). Actigraphs are designed to record continuously for several weeks so they are valuable tools for monitoring sleep patterns, for example before, during, and after a trip or work pattern.

Actigraphy. Use of actiwatches to monitor sleep patterns. For actigraphy to be a reliable measure of sleep, the computer algorithm that estimates sleep from activity counts must have been validated against polysomnography, which is the gold standard technology for measuring sleep duration and quality. The main weakness of actigraphy is that an actigraph cannot differentiate between sleep and still wakefulness (since it measures movement).

Afternoon Nap Window. A time of increased sleepiness in the middle of the afternoon. The precise timing varies, but for most people it is usually around 15:00-17:00. This is a good time to try to nap. On the other hand, it is also a time when it is more difficult to stay awake, so unintentional micro-sleeps are more likely, especially if recent sleep has been restricted.

Bio-mathematical Model. A computer programme designed to predict aspects of a schedule that might generate an increased fatigue risk for the average person, based on scientific understanding of the factors contributing to fatigue. Bio-mathematical models are an optional tool (not a requirement) for predictive fatigue hazard identification within an FRMS. All bio-mathematical models have limitations that need to be understood for their appropriate use.

Circadian Body Clock. A neural pacemaker in the brain that monitors the day/night cycle (via a special light input pathway from the eyes) and determines our preference for sleeping at night. Shift work is problematic because it requires a shift in the sleep/wake pattern that is resisted by the circadian body clock, which remains 'locked on' to the day/night cycle. Jet lag is problematic because it involves a sudden shift in the day/night cycle to which the circadian body clock will eventually adapt, given enough time in the new time zone.

Countermeasures. Personal mitigation strategies that individuals can use to reduce their own fatigue risk. Sometimes divided into strategic countermeasures (for use at home, for example good sleep habits, napping before night duty), and operational countermeasures, for example strategic use of caffeine.

Cumulative sleep debt. Sleep loss accumulated when sleep is insufficient for multiple nights (or 24-hr days) in a row. As cumulative sleep debt builds up, performance impairment and objective sleepiness increase progressively, and people tend to become less reliable at assessing their own level of impairment.

Day shift. A scheduled shift where the majority of the work hours fall between 0600h and 1400h.

Duty period. A period which starts when air traffic controllers are required by an Air Traffic Service provider to report for or to commence a duty and ends when that person is free from all duties.

Evening shift. A scheduled shift where the majority of the work hours fall between 1400h and 2200h.

Evening Wake Maintenance Zone. A period of several hours in the circadian body clock cycle, just before usual bedtime, when it is very difficult to fall asleep. Consequently, going to bed extra early usually results in taking a longer time to fall asleep, rather than getting extra sleep. Can cause restricted sleep and increased fatigue risk with early duty start times.

***Fatigue.** A physiological state of reduced mental or physical performance capability resulting from sleep loss, extended wakefulness, circadian phase, and/or workload (mental and/or physical activity) that can impair a person's alertness and ability to perform safety related operational duties.

Fatigue Safety Action Group (FSAG). A group comprised of representatives of all stakeholder groups (management, scheduling, operational personnel) together with any additional specialist experts (i.e. scientists, data analysts, and medical professionals), which is responsible for coordinating all fatigue management activities in the organization.

***Fatigue Risk Management System (FRMS).** A data-driven means of continuously monitoring and managing fatigue-related safety risks, based upon scientific principles, knowledge and operational experience that aims to ensure relevant personnel are performing at adequate levels of alertness.

***Hazard.** A condition or an object with the potential to cause or contribute to an aircraft incident or accident.

Internal Alarm Clock. A time in the circadian body clock cycle when there is a very strong drive for waking and it is difficult to fall asleep or stay asleep. Occurs about 6 hours after the **Window of Circadian Low** in the late morning to early afternoon and can cause restricted sleep and increased fatigue risk after night duty.

Jet Lag. Desynchronization between the circadian body clock and the day/night cycle caused by transmeridian flight (experienced as a sudden shift in the day/night cycle). Also results in internal desynchronization between rhythms in different body functions. Resolves when sufficient time is spent in the new time zone for the circadian body clock to become fully adapted to local time.

Micro-sleep. A short period of time (seconds) when the brain disengages from the environment (it stops processing visual information and sounds) and slips uncontrollably into light non-REM sleep. Micro-sleeps are a sign of extreme physiological sleepiness.

Mitigations. Interventions designed to reduce a specific identified risk.

Night shift. A scheduled shift where the majority of the work hours fall between 2200h and 0600h.

Non-duty period. A continuous and defined period of time, outside of a duty period, during which an air traffic controller is free of all duties.

Non-Rapid Eye Movement Sleep (Non-REM Sleep). A type of sleep associated with gradual slowing of electrical activity in the brain (seen as brain waves measured by electrodes stuck to the scalp, known as EEG). As the brain waves slow down in non-REM sleep, they also increase in amplitude, with the activity of large groups of brain cells (neurons) becoming synchronized. Non-REM sleep is usually divided into 4 stages, based on the characteristics of the brainwaves. Stages 1 and 2 represent lighter sleep. Stages 3 and 4 represent deeper sleep and are also known as slow-wave sleep.

Non-REM/REM Cycle. Regular alternation of non-REM sleep and REM sleep across a sleep period, in a cycle lasting approximately 90 minutes.

On-call. A defined period of time, during which an individual is required by the ATS Provider to be available to receive an assignment for a specific duty. Synonymous with ***standby.***

Rapid Eye Movement Sleep (REM Sleep). A type of sleep during which electrical activity of the brain resembles that during waking. However, from time to time the eyes move around under the closed eyelids – the 'rapid eye movements' – and this is often accompanied by muscle twitches and irregular heart rate and breathing. People woken from REM sleep can typically recall vivid dreaming. At the same time, the body cannot move in response to signals from the brain, so dreams cannot be 'acted out'. The state of paralysis during REM sleep is sometimes known as the 'REM block'.

Recovery Sleep. Sleep required for recovery from the effects of acute sleep loss (in one 24-hour period) or cumulative sleep debt (over multiple consecutive 24-hour periods).

Roster. (noun) a list of planned shifts or work periods within a defined period of time. Synonymous with ***Schedule.;***

(verb) assignment of individuals to a schedule or pattern of work. Synonymous with ***Schedule.***

****Safety.*** The state in which risks associated with aviation activities, related to, or in direct support of the operation of aircraft, are reduced and controlled to an acceptable level.

****Safety management system (SMS).*** A systematic approach to managing safety, including the necessary organizational structures, accountability, responsibilities, policies and procedures.

****Safety oversight.*** A function performed by a State to fulfil its responsibility for the effective implementation of safety-related Standards and Recommended Practices (SARPs), guidance material and associated procedures, as well as national regulations, including SMS where required.

****Safety performance.*** A State or a service provider's safety achievement as defined by its safety performance targets and safety performance indicators.

****Safety performance indicator.*** A data-based parameter used for monitoring and assessing safety performance.

****Safety performance target.*** The planned or intended objective for safety performance indicator(s) over a given period.

****Safety risk.*** The predicted probability and severity of the consequences or outcomes of a hazard.

Schedule. ***(noun)*** a list of planned shifts or work periods within a defined period of time. Synonymous with ***Roster***.***;***

(verb) assignment of individuals to a roster or pattern of work. Synonymous with ***Roster***.

Shift Work. Any work pattern that requires an individual to be awake at a time in the circadian body clock cycle that they would normally be asleep.

Sleep. A reversible state in which conscious control of the brain is absent and processing of sensory information from the environment is minimal. The brain goes "off-line" to sort and store the day's experiences and replenish essential systems depleted by waking activities.

Sleep Debt. See ***Cumulative sleep debt.***

Sleep Disorders. A range of problems that make it impossible to obtain restorative sleep, even when enough time is spent trying to sleep. Examples include obstructive sleep apnoea, the insomnias, narcolepsy, and periodic limb movements during sleep.

Sleep Homeostatic Process. The body's need for ***slow-wave sleep*** (non-REM stages 3 and 4), that builds up across waking and discharges exponentially across sleep.

Sleep Inertia. Transient disorientation, grogginess and performance impairment that can occur after wakening. The length and intensity of sleep inertia is greatest when the individual has not had enough sleep, is woken from **slow-wave sleep** (non-REM stages 3 and 4) or woken during the WOCL.

Sleep Need. The amount of sleep that is required on a regular basis to maintain optimal levels of waking alertness and performance. Sleep need is very difficult to measure in practice because of individual differences. In addition, because many people live with chronic sleep restriction, when they have the opportunity for unrestricted sleep, their sleep may be longer than their theoretical 'sleep need' due to recovery sleep.

Sleep Quality. Capacity of sleep to restore waking function. Good quality sleep has minimal disruption to the non-REM/REM cycle. Fragmentation of the non-REM/REM cycle by waking up, or by brief arousals that move the brain to a lighter stage of sleep without actually waking up, decreases the restorative value of sleep.

Sleep Restriction. Obtaining less sleep than needed. The effects of sleep restriction accumulate, with performance impairment and objective sleepiness increasing progressively. The need for sleep will eventually build to the point where people fall asleep uncontrollably (see ***micro-sleep***).

Slow-Wave Sleep. The two deepest stages of non-REM sleep (stages 3 and 4), characterized by high amplitude slow brainwaves.

Standby*.** A defined period of time, during which an individual is required by the ATS Provider to be available to receive an assignment for a specific duty. Synonymous with ***on call.

Time-in-position. The period of time spent by an air traffic controller in the provision of air traffic control clearances, instruction and flight information to facilitate air traffic management.

Transient fatigue. Impairment accumulated across a single duty period, from which complete recovery is possible during the next rest period.

***Unforeseen operational circumstance*.** Unexpected conditions that could not reasonably have been predicted and accommodated, such as bad weather or equipment malfunction, which may result in necessary on-the-day operational adjustments.

Unrestricted sleep. Sleep which is not restricted by any demands. Sleep can begin when an individual feels sleepy, and does not have to be delayed for any reason. In addition, the individual can wake up spontaneously and does not have to set the alarm.

Window of Circadian Low (WOCL). Time in the circadian body clock cycle when fatigue and sleepiness are greatest and people are least able to do mental or physical work. The WOCL occurs around the time of the daily low point in core body temperature - usually around 0200-0600 when a person is fully adapted to the local time zone. However, there is individual variability in the exact timing of the WOCL.

CHAPTER 1. INTRODUCTION TO FATIGUE MANAGEMENT

The aviation industry provides one of the safest modes of transportation in the world. Nevertheless, a safety critical industry must actively manage hazards with the potential to impact safety. Fatigue is now acknowledged as a hazard that predictably degrades various types of human performance, and can contribute to aviation accidents or incidents. Fatigue is inevitable in a 24 / 7 industry because the human brain and body function optimally with unrestricted sleep at night. Therefore, as fatigue cannot be eliminated, it must be managed.

1.1 APPROACHES TO FATIGUE MANAGEMENT IN AVIATION

Fatigue management refers to the methods by which Service Providers and operational personnel address the safety implications of fatigue. In general, ICAO Standards and Recommended Practices (SARPs) in various Annexes support two distinct methods for managing fatigue:

1. The service provider complies with work period limits and non-work period minima defined by the regulator, and manages fatigue hazards using the SMS processes that are in place for managing other types of hazards; or
2. The service provider develops and implements a Fatigue Risk Management System (FRMS) that is approved by the regulator.

These approaches share two important basic features. First, they are based on scientific principles and knowledge and operational knowledge and experience. Both should take into account:

- the need for adequate sleep (not just resting while awake) to restore and maintain all aspects of waking function (including alertness, physical and mental performance, and mood); and
- daily rhythms in the ability to perform mental and physical work, and in sleep propensity (the ability to fall asleep and stay asleep), that are driven by the circadian clock in the brain; and
- the contribution of workload to fatigue and physical and mental performance degradation; and
- the operational context and the safety risk that a fatigue-impaired individual represents in that context.

Second, because fatigue is affected by all waking activities (not just work demands), fatigue management has to be a shared responsibility between the regulators, Service Providers and individuals.

- The regulator is responsible for providing a regulatory framework that enables adequate fatigue management and ensuring that the service provider is managing fatigue-related risks to achieve an acceptable level of safety.
- Service providers are responsible for providing fatigue management education, implementing work schedules that enable individuals to perform their duties safely, and having processes for monitoring and managing fatigue hazards.
- Operational personnel are responsible for arriving fit for duty, including making appropriate use of non-work periods to obtain sleep, and for reporting fatigue hazards.

1.1.1 COMPARING PRESCRIPTIVE AND FRMS APPROACHES

In the prescriptive fatigue management approach, operations must remain within prescribed work period limits and non-work period minima for relevant operational personnel established by the regulator. In addition, the service provider should manage fatigue hazards using the SMS processes that are in place for managing other types of hazards. Chapter Four provides detailed information for Air Traffic Service (ATS) providers on how to implement a prescriptive fatigue management approach.

The FRMS approach represents an opportunity for ATS Providers to use advances in scientific knowledge to improve safety, use resources more efficiently and increase operational flexibility. FRMS is a special type of safety management system focused on managing the actual fatigue risk in the operations to which it applies (rather than addressing fatigue risk in general, which is the basis of prescriptive limits). FRMS has additional requirements to ensure a level of safety that is at least equivalent to that achieved by operating within the prescriptive limitations and using generic SMS processes to manage fatigue hazards.

An FRMS must have at least the following four components:

1. FRMS policy and documentation;
2. Fatigue risk management processes;
3. FRMS safety assurance processes; and
4. FRMS promotion processes.

Chapter Five provides detailed information for ATS Providers on what is required in each of these components to implement an FRMS approach.

Having an FRMS still requires having maximum duty times and minimum non-work periods, but these are proposed by the ATS Provider and must be approved by the regulator. To get approval, the ATS Provider must demonstrate to the regulator that it has appropriate processes and mitigations to achieve an acceptable level of risk. The cost and complexity of an FRMS may not be justified for operations that remain inside duty time limits and where fatigue-related risk is low. Where their State has FRMS regulations, ATS Providers can choose to manage none, some, or all of their operations under an FRMS.

Table 1.1 compares key characteristics of the two fatigue management approaches.

Table 1-1. Comparing key characteristics of prescriptive and FRMS fatigue management approaches

		PRESCRIPTIVE APPROACH	FRMS APPROACH
AIM	Regulator	• Regulator ensures that the Service Provider is managing their fatigue risks to a level acceptable to the State.	• Regulator ensures that the Service Provider is managing their fatigue risks to a level equivalent to, or better than, a prescriptive approach.
AIM	ATS Provider	• ATS Provider manages fatigue risks within constraints of prescribed limits using existing SMS processes.	• ATS Provider identifies their limits, manages their fatigue risks within agreed safety objectives and targets, and monitors them through their FRMS processes. These are continually assessed and may be altered as a result of FRMS experience.
POLICY & DOCUMENTATION	Regulator	• Regulator sets the regulations for prescriptive limits and Service Provider obligations. The prescriptive limits are intended to be outer limits, not targets.	• Regulator establishes FRMS regulations and develops processes for approval and oversight of FRMS.
POLICY & DOCUMENTATION	ATS Provider	• ATS Provider's SMS policy includes fatigue as a hazard to be managed. • ATS Provider documents duty time limits and non-duty time minimums in their operations manual. • ATS Provider maintains records of planned and actual working times.	• ATS Provider has specific FRMS policy signed by the accountable executive. • ATS Provider's policy defines maximum work periods and minimum non-work periods for each operation covered by the FRMS. These limits may be altered by agreement with the Regulator as a result of FRMS experience. • ATS Provider develops full FRMS documentation including description of processes, outputs and training records. • ATS Provider develops specific fatigue report procedures and documentation. • ATS Provider documents decisions and actions made in response to fatigue hazards detected by the FRMS. • ATS Provider maintains records of planned and actual working times.
FATIGUE RISK MANAGEMENT PROCESSES	Regulator	• Regulator identifies generic fatigue hazards within an operational context. • Regulator makes risk assessment based on generic information (scientific principles, literature reviews, best practices). • Regulator identifies prescriptive limits.	• Regulator reviews and approves the ATS Provider's maximum work periods and minimum non-work periods for each part of their operations covered by the FRMS. • Regulator reviews and approves the Service Provider's processes for fatigue hazard identification, risk assessment and mitigation.
FATIGUE RISK MANAGEMENT PROCESSES	ATS Provider	• ATS Provider identifies fatigue hazards mainly through reactive processes, including data collected through existing safety reporting mechanisms. • ATS Provider considers scientific principles when developing work schedules (rosters) that are compliant with prescriptive limitation regulations. • ATS Provider assesses and mitigates their fatigue-related risks using existing SMS processes.	• ATS Provider identifies maximum work periods and minimum non-work periods for each part of their operations covered by the FRMS. • ATS Provider develops and implements reactive, proactive and predictive processes for identifying fatigue. • ATS Provider develops and implements fatigue risk assessment methodologies and adds identify specific fatigue mitigation strategies.

		PRESCRIPTIVE APPROACH	FRMS APPROACH
SAFETY ASSURANCE	Regulator	• Regulator reviews compliance with prescriptive limits. • Regulator reviews ATS Provider’s scheduling practices to evaluate whether they are based on scientific principles. • SMS Safety Performance Indicators are agreed by regulator and ATS Provider.	• Regulator reviews and agrees to ATS Provider-identified Safety Performance Indicators (SPIs). • Regulator may require adjustment of ATS Provider-identified maximum limits and non-duty minimums.
	ATS Provider	• SMS Safety Performance Indicators are agreed by regulator and ATS Provider. • ATS Provider considers changes to its operating environment and any impacts these changes may have on fatigue risks.	• ATS Provider identifies FRMS Safety Performance Indicators. • ATS Provider considers changes to its operating environment and any impacts these changes may have on fatigue risks.
TRAINING AND COMMUNICATION	Regulator	• Regulator provides guidance for safety education and promotional material that includes fatigue.	• Regulator provides guidance for FRMS training and promotional material. • Regulator assesses the Service Provider’s fatigue training programme. • Regulator develops an FRMS approval and oversight training programme for inspectors. • Regulator assesses the effectiveness of their FRMS training programme.
	ATS Provider	• ATS Provider assesses fatigue management training needs using SMS processes. • ATS Provider safety training includes fatigue management specific to the operational context. • ATS Provider keeps safety training records. • ATS Provider considers fatigue when reporting on safety performance. • ATS Provider includes general fatigue information in internal safety communications.	• ATS Provider training includes fatigue management specific to how the FRMS works and roles of the various stakeholders. • ATS Provider assesses the effectiveness of their FRMS training programme. • ATS Provider keeps safety training records. • ATS Provider identifies a feedback process to communicate fatigue issues identified through data collection. • ATS Provider includes fatigue topics in internal safety communications.

1.2 FATIGUE MANAGEMENT IN AIR TRAFFIC CONTROL OPERATIONS

According to ICAO Standards and Recommended Practices (SARPs), where FRMS regulations have been established by a regulator for Air Traffic Controllers (ATCs), the ATS Provider has three options for implementing the two different approaches to fatigue management:

1. The ATS Provider may comply with prescriptive limitation regulations throughout all their operations; OR
2. The ATS Provider may implement an FRMS that has been approved for use throughout their operations; OR
3. The ATS Provider may employ a combination of the two approaches, implementing an FRMS in part of their operations and comply with the prescriptive duty time limitations in other operations.

Where no FRMS regulations are established, the ATS Provider is limited to managing its fatigue risks, using existing SMS processes, within the constraints of the prescribed limits.

ICAO Fatigue Management Standards and Recommended Practices (SARPs) for Annex 11 (Air Traffic Services), along with clarifications of their intent, are presented in Appendix A.

ATS Providers will need to familiarize themselves with the related fatigue management regulations of their national authority.

CHAPTER 2. SCIENTIFIC PRINCIPLES FOR FATIGUE MANAGEMENT

The operational demands in aviation continue to change in response to changes in technology and commercial pressures, but human physiology remains unchanged. Both prescriptive fatigue management regulations and FRMS represent an opportunity to use advances in scientific understanding of human physiology to better address fatigue risks in aviation settings.

Fatigue results in a reduced ability to carry out operational duties and can be considered an imbalance between:

- The physical and mental demands of all waking activities (not only duty demands); and
- Recovery from those demands, which (except requires sleep.

Following this line of thinking, to reduce fatigue in operations, strategies are required to manage the demands of waking activities and to improve sleep. Two areas of science are central to this and are the focus of this chapter.

1. Sleep science — particularly the effects of not getting enough sleep (on one night or across multiple nights), and how to recover from sleep loss;
2. Circadian rhythms — daily cycles in physiology and behaviour that are driven by the circadian clock. Aspects of physiology and behaviour that show circadian rhythms include:
   - subjective feelings of alertness and sleepiness;
   - ability to perform mental and physical work; and
   - ability to fall asleep and stay asleep (sleep propensity).

Fatigue.* *A physiological state of reduced mental or physical performance capability resulting from sleep loss, extended wakefulness, circadian phase, and/or workload (mental and/or physical activity) that can impair a person's alertness and ability to adequately perform safety-related operational duties.

ICAO definition

ICAO requires that regulations are established, based upon scientific principles for the purpose of managing fatigue. These basic principles relate to: 1) the need for sleep; 2) sleep loss and recovery; 3) circadian effects on sleep and performance; and 4) the influence of workload; and can be summarized as:

1. Periods of wake need to be limited. Getting enough sleep (both quantity and quality) on a regular basis is essential for restoring the brain and body.
2. Reducing the amount or the quality of sleep, even for a single night, decreases the ability to function and increases sleepiness the next day.
3. The circadian body clock affects the timing and quality of sleep and produces daily highs and lows in performance on various tasks.
4. Workload can contribute to an individual's level of fatigue. Low workload may unmask physiological sleepiness while high workload may exceed the capacity of a fatigued individual.

These principles are described further in the following sections.

2.1 SCIENTIFIC PRINCIPLE 1: THE NEED FOR SLEEP

Have you ever wondered what happens from the time you fall asleep at night to when you wake up in the morning? If you have slept well, you will wake up feeling physically and mentally refreshed. Your experiences of the previous day will have been sorted, stored, and linked to your existing memories so that you wake up with a seamless sense of who you are. If you have not slept well, you know that the coming day will not be easy.

SCIENTIFIC PRINCIPLE 1

PERIODS OF WAKE NEED TO BE LIMITED. GETTING ENOUGH SLEEP (BOTH QUANTITY AND QUALITY) ON A REGULAR BASIS IS ESSENTIAL FOR RESTORING THE BRAIN AND BODY.

We are meant to spend about a third of our lives asleep. The optimal amount of sleep per night varies between individuals, but most healthy adults require between 7 and 9 hours. There is a widespread belief that sleep time can be traded off to increase the amount of time available for waking activities in a busy lifestyle. Sleep science makes it very clear that sleep cannot be sacrificed without negative consequences. Sleep has multiple functions – the list keeps growing - but it is clear that it has vital roles in memory and learning, in maintaining alertness, performance, and mood, and in overall health and well-being.

2.1.1 TYPES OF SLEEP

A complex series of processes is taking place in the brain during sleep. Various methods have been used to look at these processes, from reflecting on dreams to using advanced medical imaging techniques. Sleep scientists have traditionally looked at sleep by monitoring electrical patterns in brain wave activity, eye movements, and muscle tone.

These measures indicate that there are two very different types of sleep:

- Non-rapid eye movement (Non-REM) sleep; and
- Rapid eye movement (REM) sleep.

NON-RAPID EYE MOVEMENT SLEEP (NON-REM SLEEP)

During non-rapid eye movement sleep (non-REM), brainwave activity gradually slows compared to waking brainwave activity. The body is being restored through muscle growth and repair of tissue damage. Non-REM sleep is sometimes described as “a quiet brain and quiet body”. Across a normal night of sleep, most adults normally spend about three quarters of their sleep time in non-REM sleep.

Non-REM sleep is divided into three stages, based on the characteristics of the brainwaves. Stages 1 and 2 represent lighter sleep (it is not very difficult to wake someone up). It is usual to enter sleep through Stage 1 and then Stage 2 non-REM.

Stage 3 non-REM sleep is also known as slow-wave sleep (SWS) or deep sleep. Basically in slow-wave sleep the brain stops processing information from the outside world and huge number of brain cells (neurons) start firing in synchrony, generating big, slow electrical waves. More stimulation is needed to wake someone up than from non-REM Stages 1 and 2. Waking up from SWS, various parts of the brain have to reactivate in sequence. During SWS, consolidation of certain types of memory is occurring, so SWS is necessary for learning.

Sleep is a complex series of processes that has multiple functions.

The longer you are awake and the more physically active you are, the more slow-wave activity your brain will show in your next sleep period. This slow wave activity reflects your brain's need for sleep that has built up while you are awake. It is often described as the 'sleep homeostatic process'. Thus SWS fits the traditional idea that sleep somehow restores you from the demands of waking activities.

RAPID EYE MOVEMENT SLEEP

There are two different types of sleep: non-REM and REM (rapid eye movement) sleep.

During rapid eye movement sleep (REM sleep) brainwave activity looks similar to waking brainwave activity. However, in REM sleep, from time to time the eyes move around under the closed eyelids — the so-called "rapid eye movements" — and it is often accompanied by muscle twitches and irregular heart rate and breathing. Most adults normally spend about a quarter of their sleep time in REM sleep.

During REM sleep, the brain is repairing itself and information is consolidated from the previous day and being sorted and related to stored memories. People awakened from REM sleep can typically recall vivid dreaming. During REM sleep, the body cannot move in response to signals from the brain so dreams cannot be acted out. (The signals effectively get blocked in the brain stem and cannot get through to the spinal cord.) People sometimes experience brief paralysis when they wake up out of a dream, when reversal of this "REM block" is slightly delayed. Because of these features, REM sleep is sometimes described as a "busy brain and paralyzed body." Figure 2-1 summarizes the proportion of night time sleep that a young adult typically spends in each of the types of sleep.

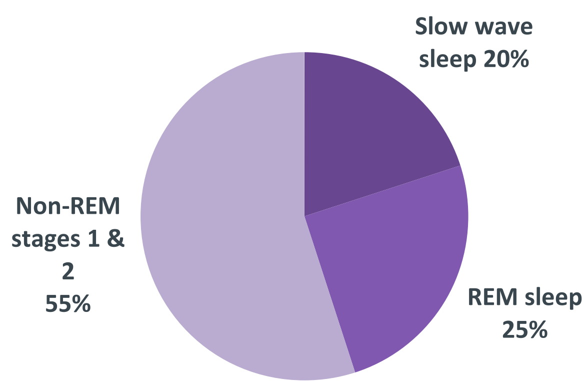

Figure 2-1. Proportion of the night spent in each type of sleep for a young adult

2.1.2 THE NON-REM/REM CYCLE

Across a normal night of sleep, non-REM sleep and REM sleep alternate in a cycle that lasts roughly 90 minutes (but is very variable in length, depending on a number of individual and environmental factors). Figure 2-2 is a diagram describing the non-REM/REM cycle across the night in a healthy young adult who goes to bed at 11:00pm and awakens around 07:30am. Real sleep is not as tidy as this — it includes more arousals (transitions to lighter sleep) and brief awakenings. Sleep stages are indicated on the vertical axis and time is represented across horizontal axis.

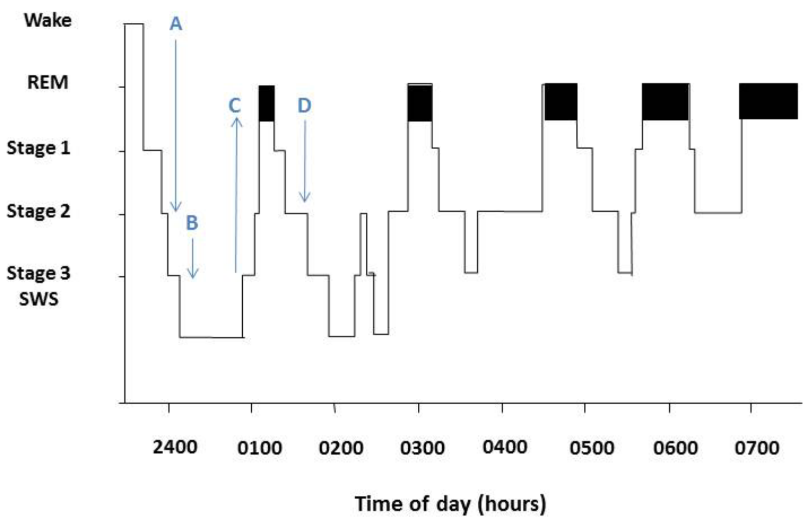

Figure 2-2. The Non-REM/REM cycle across the night for a healthy young adult

Sleep is entered through Stage 1 non-REM and then progresses through Stage 2 non-REM (see 'A' in Figure 2-2) and eventually into slow-wave sleep (see 'B' in Figure 2-2). About 80-90 minutes into sleep, there is a shift out of slow-wave sleep. This shift is often marked by body movements, as the sleeper transitions briefly through Stage 2 non-REM (see 'C' in Figure 2-2) and into the first REM period of the night (REM periods are indicated as shaded boxes in Figure 2-2). After a fairly short period of REM, the sleeper progresses back down again through lighter non-REM sleep (see 'D' in Figure 2-2) and into slow-wave sleep, and so the cycle repeats. In the morning, the sleeper in wakes up out of REM sleep and is likely to be able to remember dreaming.

In each non-REM/REM sleep cycle across a normal night of sleep:

- The amount of slow-wave sleep decreases (there may be none at all in later cycles);
- In contrast, the amount of REM sleep increases.

People sometimes experience grogginess or disorientation when they first wake from sleep. This is known as sleep inertia. It can occur when waking from any stage of sleep but may be worse after longer periods of sleep.

OPERATIONAL IMPLICATION 1.
MITIGATION STRATEGIES FOR SLEEP INERTIA

The possible occurrence of sleep inertia is sometimes used as an argument against napping in the work setting. It would not be desirable to have an individual who is woken up in an emergency and is impaired by sleep inertia.

The risk of sleep inertia can be reduced by having a protocol for returning to active duty that allows time for sleep inertia to wear off (see *Operational Implication 5: Napping as a Fatigue Mitigation, page 28)*. It is suggested that at least 10-15 minutes should be allowed before recommencing safety-related duties or driving.

2.1.3 FACTORS THAT AFFECT SLEEP QUALITY

Sleep quality (its restorative value) depends on going through uninterrupted non-REM/REM cycles (which suggests that both types of sleep are necessary and one is not more important than the other). The more the non-REM/REM cycle is fragmented by waking up, or by arousals that move the brain to a lighter stage of sleep without actually waking up, the less restorative value sleep has in terms of how you feel and function the next day.

For sleep to be fully restorative, it must contain unbroken cycles of non-REM and REM sleep.

OPERATIONAL IMPLICATION 2.
PROCEDURES FOR MINIMISING SLEEP INTERRUPTIONS

Because uninterrupted non-REM/REM cycles are the key to good quality sleep, there should be procedures in place to minimize possible interruptions during both work and non-work periods. All personnel involved in the operations must be made aware of these procedures, which should ensure that an individual who is taking a protected sleep period is not contacted unnecessarily. For example, a call to notify an individual of a schedule change should not occur during normal night time hours or during the morning and early afternoon following a night shift.

For further information on procedures to protect an individual's sleep when on call or standby see *Operational Implication 4: Protocols for Standby, Reserve and On-Call Duties, page 27.*

For further information on procedures to protect an individual's sleep during work periods see *Operational Implication 5: Napping as a Fatigue Mitigation, p 28.*

SLEEP QUALITY AND AGING

Across adulthood, sleep changes significantly. In a study of 2685 men and women aged 37-92 years, the amount of time spent in slow-wave sleep decreased with age and the amount of time in the lighter stages of sleep increased[2]. This change was primarily seen in men with very little change in sleep stages with increasing age for women. The quality of sleep, as measured by the amount of time awake during a normal night of sleep, also declines with age.

It is not yet clear whether these age-related changes in sleep reduce its effectiveness for restoring waking function. Laboratory studies that experimentally interrupt sleep are typically conducted with young adults. In aviation settings, experience (both in terms of skills and knowing how to manage sleep across different shift -work patterns or when flying different trips) could help reduce potential fatigue risk associated with age-related changes in sleep. From both practical and scientific perspectives, age is not considered to be a specific factor to be addressed in order to manage fatigue.

Sleep quality declines as a normal part of aging.

SLEEP DISORDERS

The quality of sleep can also be disrupted by a wide variety of sleep disorders, which make it impossible to obtain restorative sleep, even when people spend enough time in bed trying to sleep. Sleep disorders pose a particular risk for ATCs because, in addition, they often have restricted time for sleep. Fatigue management training should include basic information on sleep disorders and their treatment, where to seek help if needed, and any requirements relating to fitness for duty.

Sleep disorders can reduce the amount and quality of sleep a person can obtain, even when they spend enough time trying to sleep.

CAFFEINE, NICOTINE AND ALCOHOL

Caffeine (in coffee, tea, energy drinks, colas, chocolate and some over-the counter medications) stimulates the brain making it harder to fall asleep and disrupting the quality of sleep. Some people are more sensitive to effects of caffeine than others, but even heavy coffee drinkers will have lighter and more disturbed sleep if they drink coffee close to bedtime (although they may not even notice this). Nicotine in cigarettes is also a stimulant and affects sleep in a similar way. Alcohol on the other hand makes us feel sleepy but it also disturbs sleep. While the body is processing alcohol (at the rate of about one standard drink per hour), the brain cannot obtain REM sleep. Pressure for REM sleep builds up, and sleep later in the night often contains more intense REM periods and is more disturbed as a consequence.

Caffeine, nicotine, and alcohol can disrupt sleep quality.

[2] Redline, S., Kirchner, HL, Quan, S.F., Gottlieb, D.J., Kapur, V. and Newman, A. (2004) The effects of age, sex, ethnicity and sleep-disordered breathing on sleep architecture. Archives of Internal Medicine; 164:406-418.

OPERATIONAL IMPLICATION 3.
USE OF CAFFEINE

Caffeine can be useful to temporarily reduce sleepiness on duty because it blocks a chemical in the brain (adenosine) that increases sleepiness. It can also be used in advance of a period that is likely to be associated with higher fatigue (e.g. the early hours of the morning). Caffeine takes approximately 30 minutes to have an effect and can last for up to 5 hours, (but people differ widely in how sensitive they are to caffeine and how long the effects last). It is important to remember that caffeine does not remove the need for sleep and it should only be used as a short term strategy. For maximum benefit, caffeine should be avoided when alertness is high, such as at the beginning of a duty period, and instead used at times when sleepiness is expected to be high, e.g. towards the end of a long duty period or at the times in the circadian body clock cycle when sleepiness is greater.

ENVIRONMENTAL FACTORS

The sleep environment can affect sleep quality.

Environmental factors can also disturb sleep. Bright light increases alertness (and can be a short-term countermeasure to temporarily relieve fatigue in the work environment). It is much easier to sleep in a dark room. Heavy curtains or a mask can be used to block out light. Sudden sounds also disturb sleep. Masking them using white noise can help, for example tuning a bedside radio between stations, or turning on a fan. Falling asleep requires being able to lower core body temperature (by losing heat through the extremities), so it is easier if the room is cooler rather than hotter. For most people (18-20°C/ 64-68 °F) is an ideal room temperature for sleep. A comfortable sleep surface is also important.

QUALITY OF SLEEP AT WORK AND WHEN ON-CALL (STANDBY)

Studies of flight crew and ATCs taking a planned sleep at work show that their sleep is lighter and more disturbed than expected[3,4]. Nevertheless, there is good evidence that naps improve subsequent alertness and reaction speed and are a valuable mitigation strategy in fatigue management.

Sleep obtained at work is often not as good quality as sleep under normal conditions at home.

Trying to sleep in different locations or under different circumstances can have consequences for the quality of sleep obtained. A study of ATCs taking a planned sleep in the workplace during a night shift showed that less than half of the available time for sleep was actually spent asleep, and that the sleep obtained was light non-REM sleep (despite sleep occurring at an ideal time in the circadian body clock cycle – see *Scientific Principle 3*). ATCs also reported that they found it moderately difficult to fall asleep and that the quality of the nap sleep was relatively poor[5]. Even though sleep was lighter and more disturbed than expected, the nap was found to improve the alertness and reaction speed of ATCs at the end of the night shift. This study, as well as others in different settings, shows

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[3] Signal, T.L., Gander, P.H., van den Berg, M.J. and Graeber, R.C. (2012) In-Flight Sleep of Flight Crew During a 7-hour Rest Break: Implications for Research and Flight Safety. Sleep, 36(1): 109-115.

[4] Signal, T.L., Gander, P.H., Anderson, H. and Brash, S. (2009) Scheduled napping as a countermeasure to sleepiness in air traffic Controllers. Journal of Sleep Research, 18:11-19.

[5] Signal, T.L., Gander, P.H., Anderson, H. and Brash, S. (2009) Scheduled napping as a countermeasure to sleepiness in air traffic Controllers. *Journal of Sleep Research*, 18:11-19.

that naps are a valuable mitigation strategy in fatigue management (see *Operational Implication 5: Napping as a Fatigue Mitigation, page 28*).

Sleep may also be disturbed if there is an expectation of being woken and called back to work. A laboratory study compared the sleep of people who were told on one night that they may be woken and required to respond to a noise, to their sleep on another night when they received no instructions[6]. The findings showed that it took people longer to fall asleep and they spent longer awake during the night when they expected to be woken. In this study the noise never occurred so sleep was not disturbed by external factors. To date no field research (with a real workforce) has been conducted that has looked at how sleep at home might be affected by being on-call/standby and when a call out never occurs.

Sleep obtained when on call may be poorer quality.

2.1.4 THE IMPACT OF CONTINUOUS TIME AWAKE

The longer an individual remains awake, the worse their alertness and performance become. This is due to an increasing homeostatic pressure for sleep associated with the longer period of wakefulness. Sleep is the only way to reverse this.

The US National Transportation Safety Board has examined the relationship between time since awakening (TSA) and errors in 37 aircraft accidents (1978-1990) in which flight crew actions or inactions were causal or contributing factors[7]. The median TSA at the time of the accident was 12 hours for captains and 11 hours for first officers. Six crews were classified as low TSA (both the captain and the first officer were below the median) and six crews were classified as high TSA (both the captain and the first officer were above the median). For low TSA crews, the median time awake was 5.3 hours for captains and 5.2 hours for first officers. For high TSA crews the median time awake was 13.8 hours for captains and 13.4 hours for first officers. Overall, high TSA crews made about 40% more errors than low TSA crews (12.2 versus 8.7 errors), primarily due to making more errors of omission (5.5 versus 2.0 errors). In terms of error types, high TSA crews made significantly more procedural errors and tactical decision errors than low TSA crews.

In air traffic control[8], aircraft maintenance personnel[9] and flight crew[10], research has shown that a nap during a period of work can improve performance and/or alertness. In all these studies the nap at work had no measureable effect on the next sleep episode. Note that not all States permit napping in the work environment.

A short nap can improve alertness and performance and is a valuable mitigation strategy in fatigue management.

[6] Wuyts, J., De Valck, E., Vandekerchove, M., Pattyn, N., Exadaktylos, V. Haex, B., Verbraecken, J. and Cluydts, R. (2012) Effects of pre-sleep simulated on-call instructions on subsequent sleep. *Biological Psychology*, 91:383-388.
[7] National Transportation Safety Board Safety Study 94/01.
[8] Signal, T.L., Gander, P.H., Anderson, H. and Brash, S. (2009) Scheduled napping as a countermeasure to sleepiness in air traffic Controllers. Journal of Sleep Research, 18:11-19.
[9] Purnell, M.T., A.-M. Feyer, and G.P. Herbison, (2002) The impact of a nap opportunity during the night shift on the performance and alertness of 12-h shift workers. Journal of Sleep Research. 11: p. 219-227.
[10] Rosekind, M.R., Graeber, R.C., Dinges, D.F., et al. (1994) Crew factors in flight operations IX: Effects of planned cockpit rest on crew performance and alertness in long-haul operations. NASA Technical Memorandum 108839. Available at: http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19950006379.pdf

OPERATIONAL IMPLICATION 4.
PROTOCOLS FOR STANDBY, RESERVE AND ON-CALL DUTIES

Although standby, reserve and on-call duties lack the certainty associated with scheduled shifts, the same scientific principles still apply. It is important to establish protocols for assigning unscheduled duties that aim to:

- *Minimize interruptions during circadian times when sleep is more likely (*Circadian influences are further discussed in *Section 2.3: Circadian Effects on Sleep and Performance)*.

  During periods of being on standby, reserve or on-call, there will be times when an individual is more likely to be able to sleep. Therefore, interruptions (such as non-urgent phone calls from work) during those times should be minimised as much as possible.

- *Minimize continuous hours of wakefulness before and during duty periods that are unscheduled.*

  When being called-in is highly likely, establishing minimal notification periods before the individual can be asked to report for duty allows the opportunity for some sleep. If minimal notification periods are not operationally feasible, an extended duty is required or a call-back occurs late in the day or during the night, naps will reduce increasing sleep pressure over extended waking hours. Consideration should be given to appropriate napping facilities and the establishment of napping protocols (See *Operational Implication 5: Napping as a Fatigue Mitigation*.

- *Build in some level of schedule predictability*.

  Individuals can maintain a better level of alertness if they have a general idea of what will be expected of them. Therefore, the time of day for potential duty should be predictable and consistent and the number of consecutive days that an individual may be subject to being assigned unscheduled duties should be limited. This provides some level of consistency in the timing of duty periods and allows for individuals to plan and manage their sleep periods.

Further information on assigning unscheduled duties is provided in Section 4.1.3 .

OPERATIONAL IMPLICATION 5.
NAPPING AS A FATIGUE MITIGATION

If a person has been awake for a long period of time or if they have not had enough sleep over one or more days, some sleep is always better than none. Napping is a mitigation that can help maintain performance and alertness in the short term, until a full sleep opportunity is available and utilised. Napping should not be used as a means of extending a duty period, which requires the opportunity for longer sleep periods with the provision of appropriate facilities.

Napping before work: When a duty period starts later in the day (e.g. in the evening or at night) a nap prior to commencing work will reduce the period of wakefulness and help maintain performance and alertness during the work period. It has been shown that napping prior to work does not reduce the amount of sleep obtained during a rest break at work.

Napping during a duty period: A nap during a duty period can help maintain performance during extended work periods or during duty periods at night. How such naps are managed will depend on the context in which they occur and where they can be taken (e.g. for airline pilots: in designated crew rest facilities or on the flight deck (controlled rest); for ATCs: in the ATC unit or in separate rest facilities; for GA pilots: on the aircraft or on the ground). The length of the nap will depend largely on the available time away from duties but it should allow enough time for individuals to fall asleep (it may take people longer than usual to fall asleep in these circumstances) and enough time after waking before recommencing duties to ensure that any sleep inertia has dissipated (see Operational Implication 1: Mitigation Strategies for Sleep Inertia). If napping during a duty period is allowed, specific protocols need to be identified to ensure operational integrity and continued safe operations when this fatigue mitigation measure is necessary. It is also critical that individuals are educated to encourage no change to their preparation for work. That is, if they sleep less before work because they assume they will get a nap at work then the overall benefit of allowing napping may be negated. See Appendix C for an example of protocol for naps taken during work.

2.2 SCIENTIFIC PRINCIPLE 2: SLEEP LOSS AND RECOVERY

Even for people who have good quality sleep, the amount of sleep they obtain is very important for restoring their waking function.

SCIENTIFIC PRINCIPLE 2

REDUCING THE AMOUNT OR THE QUALITY OF SLEEP, EVEN FOR A SINGLE NIGHT, DECREASES THE ABILITY TO FUNCTION AND INCREASES SLEEPINESS THE NEXT DAY.

2.2.1 SLEEP RESTRICTION IN THE LABORATORY

Numerous laboratory studies have looked at the effects of 'trimming' sleep at night by an hour or two (known as *sleep restriction*). Losing as little as two hours of sleep on one night will reduce alertness the next day and degrade performance on many types of tasks. Studies that have restricted sleep on multiple nights in a row have key findings that are important for fatigue management.

EFFECTS OF SLEEP RESTRICTION ACCUMULATE AND ARE DOSE DEPENDENT

The effects of restricting sleep night after night accumulate, so that people become progressively less alert and less functional each subsequent day. This is sometimes described as *accumulating a sleep debt*. This can occur in aviation operations when minimum off-duty periods are scheduled for several days in a row or when the start and/or end times of shifts overlap the normal opportunity for night time sleep for several days in a row.

Figure 2.3 below shows the average amount of sleep loss accumulated (compared to the amount of sleep obtained on days off) across each 24-hour period on a backward rapidly rotating air traffic control shift schedule worked by 28 ATCs[11]. When working an afternoon-day-morning shift pattern, ATCs get less sleep than they do on days off and a sleep debt accumulates. In the first 24-hour period that includes the night shift ATCs sleep more than they usually do on days off and the sleep debt reduces slightly. This 24-hour period starts on midday before the night shift and includes any sleep obtained before commencing the night shift and ends at midday after the night shift.

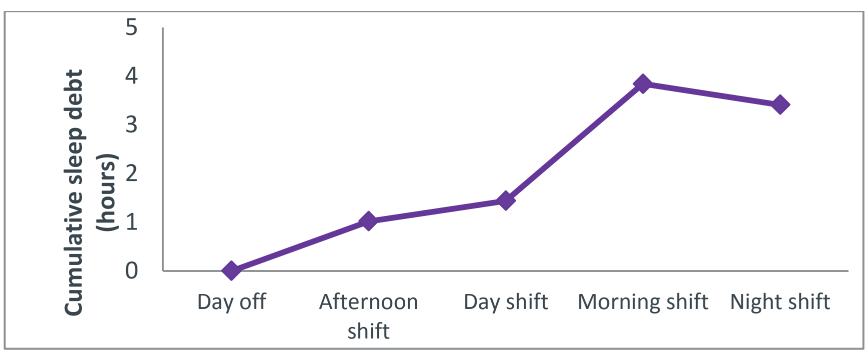

Figure 2-3. Cumulative sleep debt across a backward rapidly rotating air traffic control shift schedule[12]

[11] Signal, T.L. and Gander, P.H. (2007) Rapid counter-clockwise shift rotation in air traffic control: Effects on sleep and night work. *Aviation Space and Environmental Medicine; 78*: 878-85.
[12] Figure supplied courtesy of Prof. T. L. Signal.

The shorter the time allowed for sleep each night, the faster alertness and performance decline. For example, one laboratory study found that spending 7 hours in bed for 7 consecutive nights was not enough to prevent a progressive slowing down in reaction time[13]. The decline was more rapid for a group of participants who spent only 5 hours in bed each night, and even more rapid for a group who spent only 3 hours in bed each night. This is described as a *dose-dependent* effect of sleep restriction. Figure 2-4 summarizes the results of this study.

The effects of restricting sleep night after night accumulate. Less sleep per night = more rapid performance degradation.

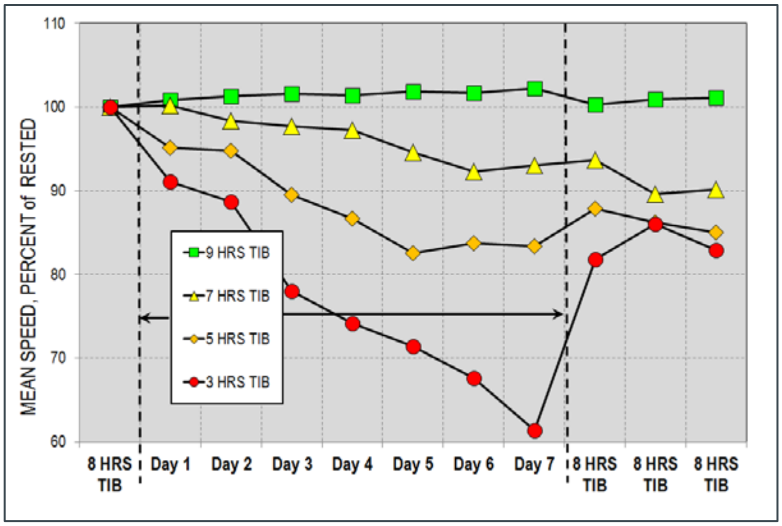

Figure 2-4. Impact of different nightly times in bed (TIB) on daytime performance[14]

SOME TYPES OF TASKS ARE MORE AFFECTED THAN OTHERS

Insufficient sleep impacts many facets of cognitive functioning with the most consistent and largest effects found when measuring processing speed and attention. However, brain imaging studies suggest that the brain regions involved in more complex mental tasks (for example anticipating events, planning and determining relevant courses of action - particularly under novel situations) are the most affected by sleep loss and have the greatest need for sleep to recover their normal function.

[13] Balkin TJ, Thorne D, Sing H, Thomas M, Redmond D, Wesensten N, Williams J, Hall S, Belenky G. Effects of Sleep Schedules on Commercial Motor Vehicle Driver Performance. U.S. Department of Transportation Federal Motor Carrier Safety Administration Report No. DOT-MC-00-133, May 2000.

[14] Figure adapted from Figure 2-24 of U.S. Department of Transportation Federal Motor Carrier Safety Administration Report No. DOT-MC-00-133, May 2000)

HOW YOU FUNCTION VERSUS HOW YOU FEEL

For the first few days of severe sleep restriction (for example, 3 hours in bed), people are aware that they are getting progressively sleepier. However, after several days they no longer notice any difference in themselves, even though their alertness and performance continues to decline. In other words, as sleep restriction continues, people become increasingly unreliable at assessing their own functional status. Both objective and subjective tests are useful in fatigue management. Objective ratings of fatigue and sleepiness are often considered more reliable for measuring fatigue-related impairment (see Appendix B).

People are not very accurate at judging their alertness and performance after sleep has been restricted for several days.

SLEEPINESS CAN BECOME UNCONTROLLABLE

The pressure for sleep increases progressively across successive days of sleep restriction. Eventually, it becomes overwhelming and people begin falling asleep uncontrollably for brief periods, known as micro-sleeps. During a micro-sleep, the brain disengages from the environment (it stops processing visual information and sounds). In the laboratory, this can result in missing a stimulus in a performance test. Driving a motor vehicle, it can result in failing to take a corner. Similar events have been recorded on the flight deck during descent into major airports and in ATCs at the end of a night shift[15].

Sleepiness eventually becomes overwhelming and results in uncontrollable micro-sleeps.

SOME PEOPLE ARE MORE AFFECTED THAN OTHERS

Individuals vary widely in their ability to tolerate sleep loss.

At least in the laboratory, some people are more resilient to the effects of sleep restriction than others (inter-individual differences). Currently, there is a lot of research effort aimed at trying to understand why this is, but it is still too early for this to be applied in fatigue management (for example, by recommending different personal mitigation strategies for people who are more or less affected by sleep restriction).

[15] Signal, T.L., Gander, P.H., Anderson, H. and Brash, S. (2009) Scheduled napping as a countermeasure to sleepiness in air traffic Controllers. Journal of Sleep Research, 18:11-19.

LIMITATIONS OF LABORATORY SLEEP RESTRICTION STUDIES

Laboratory studies are currently the main source of information on the effects of sleep restriction, but they have some obvious limitations. Laboratory studies usually look at the effects of restricting sleep at night and participants sleep in a dark, quiet bedroom. More research is needed on the effects of restricting sleep during the day, and on the combination of restricted sleep and poor quality sleep. This limitation may mean that current understanding of the effects of sleep restriction is based on a 'best case scenario'.

When examining performance effects, laboratory sleep restriction studies have also focused on the performance of individuals, not people working together as a team. More research is needed to improve understanding of how the fatigue levels of individuals affect the performance of two or more people working together. For example, one simulation study with 67 experienced B747-400 crews found that sleep loss in the last 24 hours increased the total number of errors made by the crew (the captain was always the pilot flying)[16]. Paradoxically, greater sleep loss among first officers improved the rate of error detection, but greater sleep loss among captains led to a higher likelihood of failure to resolve errors that had been detected. Greater sleep loss was also associated with changes in decision making, including for some crews, a tendency to choose lower risk options, which would help mitigate fatigue risk. Similar challenges would be expected in other aviation operations.

2.2.2 RECOVERY FROM THE EFFECTS OF SLEEP RESTRICTION

Prolonged sleep restriction may have effects on the brain that can continue to affect alertness and performance days to weeks later[17]. Available laboratory studies do not yet give a clear answer to the question of how long it takes to fully recover from these effects. However, the following findings are reliable.

- Lost sleep is not recovered hour-for-hour, although recovery sleep may be slightly longer than normal sleep at night.
- At least two consecutive nights of unrestricted sleep are required for the non-REM/REM sleep cycle to return to normal.
    - Typically, on the first night of recovery, more SWS will occur, but this can limit the time available for REM sleep.
    - On the second night of recovery, the brain catches up on REM sleep.
    - Recovery of a normal non-REM/REM cycle may take longer if recovery sleep is not at night, or if the individual is not adapted to the local time zone.
- If sleep restriction continues over multiple nights, then the recovery of waking alertness and performance will normally require more than two consecutive nights of unrestricted sleep.
    - Three 8-hour sleep opportunities at night are not enough to recover from 7 nights of sleep restricted to 7 hours per night[18].
    - It has also been shown that extending sleep to 10-hours for one night is not enough to recover from the cumulative effects of 5 nights of sleep restricted to 4 hours per night[19].

Recovery of a normal sleep pattern after an accumulated sleep debt takes at least two nights of unrestricted sleep.

[16] Thomas, M.J.W., Petrilli, R.M., Lamond, N.A., et al. (2006). Australian Long Haul Fatigue Study. In: Enhancing Safety Worldwide: Proceedings of the 59th Annual International Air Safety Seminar. Alexandria, USA, Flight Safety Foundation.

[17] Rupp, T.L., Wesensten, N.J, Bliese, P.D. et al. (2009). Banking sleep: realization of benefits during subsequent sleep restriction and recovery. Sleep, Vol 32, pp 311-321.

[18] Belenky, G., Wesensten, N.J., Thorne, D.R., et al., "Patterns of performance degradation and restoration during sleep restriction and subsequent recovery: a sleep dose-response study," Journal of Sleep Research, Vol. 12, pp. 1-12.

[19] Banks, S., Van Dongen, H.P.A., Maislin, G., et al (2010). Neurobehavioral dynamics following chronic sleep restriction: dose-response effects of one night for recovery. Sleep, Vol 33, pp 1013-26.

Recovery of waking alertness and performance after accumulating a sleep debt may take longer than two nights of unrestricted sleep.

During prolonged low-level sleep restriction, it may be that the brain somehow reconfigures the way it manages tasks, so that we adapt by settling at a stable but sub-optimal level of alertness and performance. However, the prolonged recovery times seen in laboratory sleep restriction studies suggest that return to optimal performance may be a slow process. Longer periods of time off, such as blocks of annual leave, may be important for full recovery.

OPERATIONAL IMPLICATION 6. ALLOWING FOR SLEEP RECOVERY

Because the effects of sleep restriction are cumulative, schedules must be designed to allow periodic extended opportunities for recovery. Recovery opportunities need to occur more frequently when daily sleep restriction is greater, because of the more rapid accumulation of fatigue.

The usual recommendation for a recovery opportunity is a minimum of two consecutive nights of unrestricted sleep. This is not necessarily 48 hours off duty. A 48-hour break starting at midnight will not allow most people two consecutive nights of unrestricted sleep (most people go to sleep before midnight). Conversely, a 40-hour break starting at 20:00 will allow most people two consecutive nights of unrestricted sleep.

THE RECOVERY VALUE OF SPLIT SLEEP

The laboratory studies addressing recovery sleep typically allow participants a single sleep opportunity at night. However, split sleep (a short sleep period at night and another short sleep period during the day) is common in some types of aviation operations. A common shift pattern in air traffic control is an early morning shift followed by a night shift with a short rest break of 8-9 hours in between. Sleep the night before the morning shift is often short and a nap is obtained between the morning and night shifts. For example, ATCs working a 2-2-1 pattern of shifts (two consecutive evening shifts to two consecutive early morning shifts to a night shift separated only by a short rest break of 8-9 hours in between) obtained just over 5 hours of sleep the night before the first morning shift and 2.5 hours of sleep between the morning and night shifts[20]

Laboratory studies suggest that having a restricted sleep period at night plus a daytime nap has equivalent recovery value to an identical total amount of sleep taken in one consolidated block at night.[21] However, these are short-term studies that take place in dark, quiet laboratory environments with no distractions, and participants are fully adapted to the local time zone. These conditions do not always apply in 24/7 operations, so careful consideration is needed before applying the findings to aviation personnel.

An important advantage of split sleep is that it reduces the length of time that an individual is continuously awake (see *Section 2.1.4 The Impact of Continuous Time Awake, page 26*).

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[20] http://www.faa.gov/data_research/research/media/nasa_controller_fatigue_assessment_report.pdf

[21] Mollicone, D.J., Van Dongen, H., Rogers, N.L., et al. (2008) Response surface mapping of neurobehavioral performance: Testing the feasibility of split sleep schedules for space operations. Acta Astronautica, Vol 63, pp 833-40.

2.2.3 LONG-TERM SLEEP RESTRICTION AND HEALTH

Evidence from laboratory studies and from epidemiological studies that track the sleep and health of large numbers of people across time, indicates that chronic short sleep may have negative effects on health in the long-term. This research suggests that people who report averaging less than 7 hours of sleep per night are at greater risk of becoming obese and developing type-2 diabetes and cardiovascular disease. There is still debate about whether habitual short sleep actually contributes to these health problems, or is just associated with them. What is clear is that good health depends not only on good diet and regular exercise, but also on getting enough sleep on a regular basis. Sleep cannot be sacrificed without consequence.

2.3 SCIENTIFIC PRINCIPLE 3: CIRCADIAN EFFECTS ON SLEEP AND PERFORMANCE

Sleeping at night is not just a social convention. It is programmed by the circadian clock - an ancient adaptation to life on our 24-hour rotating planet.

> ***SCIENTIFIC PRINCIPLE 3***
>
> *THE CIRCADIAN BODY CLOCK AFFECTS THE TIMING AND QUALITY OF SLEEP AND PRODUCES DAILY HIGHS AND LOWS IN PERFORMANCE ON VARIOUS TASKS.*

Like other mammals, we have a circadian master clock located in a small cluster of cells (neurons) deep in the brain. The cells that make up the master clock are intrinsically rhythmic, generating electrical signals faster during the day than during the night. However, they have a tendency to produce an overall cycle that is a bit slow – for most people the 'biological day' generated by the master clock is slightly longer than 24 hours.

This master clock, also known as the circadian body clock, receives information about light intensity through a direct connection to special cells in the retina of the eye (this special light input pathway is not involved in vision). This light sensitivity enables the circadian body clock to stay in step with the day/night cycle. However, it also creates problems for individuals who have to sleep out of step with the day/night cycle (for example any operations that occur during biological night), or who have to travel across time zones and experience sudden shifts in the day/night cycle. The effects of light on the circadian body clock are considered in more detail later in this chapter.

> *The circadian body clock is a pacemaker in the brain that is sensitive to light through a specialized input pathway from the eyes (separate from vision).*

Other parts of the brain and some other organs including the liver, kidneys, and gut, contain peripheral circadian clocks that generate their own local circadian rhythms. (Indeed, every cell in the body contains the 'clock genes' that are the basic molecular machinery for generating circadian rhythms.) The circadian body clock in the suprachiasmatic nucleus (SCN) is at the top of a hierarchy, keeping the rhythms in other parts of the brain and body in step with the day/night cycle and with each other.

> *The circadian body clock programmes humans for daytime wakefulness and night time sleepiness.*

2.3.1 EXAMPLES OF CIRCADIAN RHYTHMS

It is not possible to directly measure the electrical activity of the circadian body clock in the SCN of human beings. However, many circadian rhythms in physiology and behaviour can be measured as a way of indirectly tracking the cycle of the circadian body clock. shows an example of some circadian rhythms of a 46-year old short-haul flight crew member monitored before, during, and after a 3-day pattern of flying on the east coast of the USA while remaining in the same time zone.[22] The black horizontal bars indicate when he was on duty.

- He kept a daily diary of his activities, including when he slept (the shaded vertical bars in Figure 2-5).
- His core body temperature was monitored continuously (shown in the upper panel in Figure 2-5).
- In his logbook, he also rated his fatigue every 2 hours while he was awake, on a scale from 0 = most alert to 100 = most drowsy (shown in the lower panel in Figure 2-5).

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[22] Gander, P.H., Graeber , R.C., Foushee, H.C., Lauber, J.K., Connell, L.J. (1994). Crew Factors in Flight Operations II: Psychophysiological Responses to Short-Haul Air Transport Operations. NASA Technical Memorandum #108856. Moffett Field: NASA Ames Research Center.

His core temperature fluctuated by about 1 degree Celsius across the 24-hour day. Notice that his temperature started to rise each morning *before* he woke up. In effect, his body was preparing ahead of time for the greater energy demands of being more physically active. (If body temperature only began to rise after he started to be more physically active, it would be a lot harder to get up in the morning).

The circadian body clock affects every aspect of human functioning, resulting in cycles of high performance and low performance.

This crew member did not feel at his best first thing in the morning. He tended to feel least fatigued about 2-4 hours after he woke up, after which his fatigue climbed steadily across the day. (He was not asked to wake up every 2 hours across the night to rate his fatigue).

Core body temperature is often used as a marker rhythm to track the cycle of the circadian body clock because it is relatively stable and easy to monitor. However, no measurable rhythm is a perfect marker of the circadian body clock cycle. For example, changes in the level of physical activity also cause changes in core temperature, which explains the small peaks and dips in temperature in Figure 2-5.

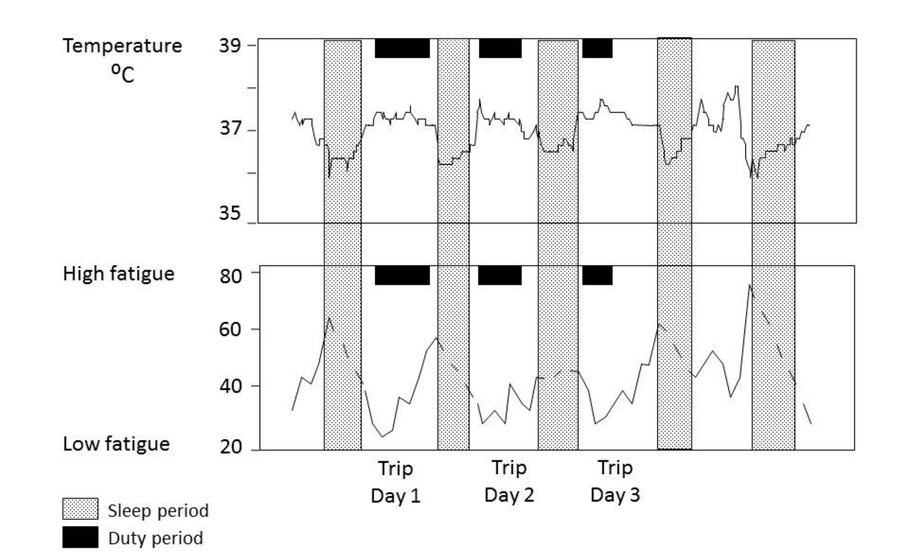

Figure 2-5. Circadian rhythms of a short-haul pilot

2.3.2 SLEEP REGULATION: THE CIRCADIAN BODY CLOCK AND THE SLEEP HOMEOSTATIC PROCESS

The circadian body clock is one of two key processes that regulate sleep timing and quality (the other is the sleep homeostatic process, which is described in more detail below). The circadian body clock has connections to sleep-promoting and wake-promoting centres in the brain, which it modulates to control the sleep/wake cycle. It also influences the timing and amount of REM sleep. Just after the minimum in core body temperature, the brain goes more quickly into REM sleep and stays in REM for longer than at any other time in the circadian body clock cycle. This is sometimes described as a circadian rhythm in 'REM sleep propensity'. Thus, during a normal night of sleep, the longest bouts of REM sleep occur in the last non-REM cycles towards morning.

Figure 2-6 is a diagram that summarizes the relationships between sleep and the circadian body clock cycle (tracked here by the circadian rhythm in core body temperature). The figure is based on data collected from 18 night cargo pilots on their days off, i.e., when they were sleeping at night. The core body temperature was monitored continuously and they recorded their sleep and duty times in a daily diary. Their average core body temperature rhythm has been simplified (the continuous curve). The dot represents the average time of the temperature minimum, which is used as a reference point for describing the other rhythms. Although these data were collected during night cargo operations, they can be used as an illustrative example for any individual working at night.

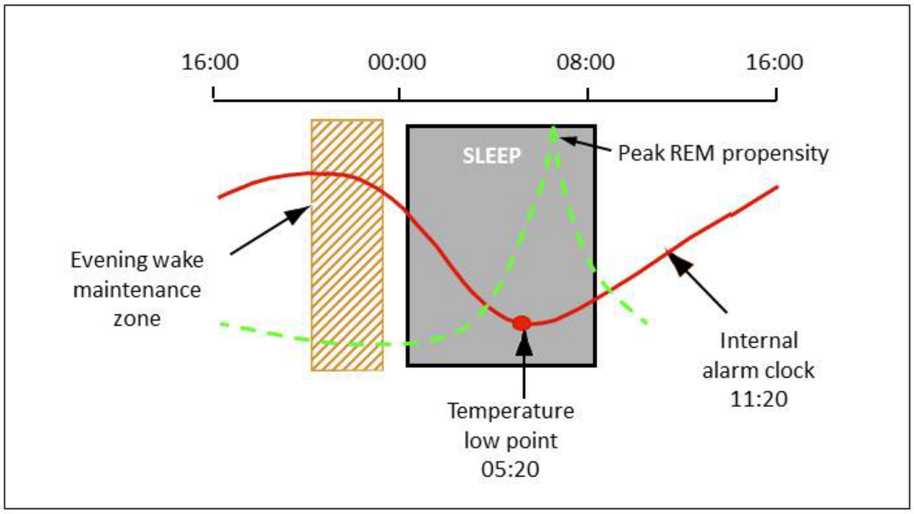

Figure 2-6. Relationship between normal sleep at night and the circadian body clock cycle[23]

Figure 2-6 highlights the following relationships:

- Sleep normally begins about 5 hours before the minimum in core body temperature.
- Wakeup normally occurs about 3 hours after the minimum in core body temperature.
- REM sleep propensity peaks just after the minimum in core body temperature (the dashed curve).
- As core body temperature begins to rise, the circadian body clock sends an increasingly strong signal to the brain centres that promote wakefulness, sometimes called the 'circadian alerting signal'. About 3 hours after waking up, the homeostatic pressure for sleep is low (see below) and the circadian alerting signal is strong enough to make it very hard to fall asleep or stay asleep. This is sometimes referred to as the *internal alarm clock*.
- The circadian alerting signal is strongest just before usual bedtime. This makes it very difficult to fall asleep a few hours earlier than usual, and this part of the circadian body clock cycle is known as the *evening wake maintenance zone*.

The circadian clock exerts strong influence over sleep, creating windows when sleep is promoted and windows when sleep is opposed.

The time around the daily minimum in core body temperature is the part of the circadian body clock cycle when people generally feel most sleepy and are least able to perform mental and physical tasks. This is sometimes described as the *Window of Circadian Low (WOCL)*.

The second key process regulating sleep timing and quality is the sleep homeostatic process. This can be summarized as: your brain's need for sleep builds up while you are awake and the only way to discharge this pressure is to sleep. The homeostatic process can be tracked by the amount of slow-wave sleep.

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[23] Figure provided by Prof. P. H. Gander, adapted from Gander PH et al (1998) Gregory, K.B., Connell, L.J., Graeber, R.C., Miller, D.L., and Rosekind, M.A. Flight crew fatigue IV: overnight cargo operations. *Aviation, Space, and Environmental Medicine 69:*B26-B36.

- Across time awake, the pressure for slow-wave sleep builds up. The longer you are awake, the more slow-wave sleep you will have in the first few non-REM/REM cycles when you next sleep.
- Across sleep, the amount of slow-wave decreases in each subsequent non-REM/REM cycle. In other words, the pressure for slow-wave sleep is discharged across the sleep period.

Discharging the homeostatic pressure for sleep seems to take priority - slow-wave sleep is always greatest in the first non-REM/REM cycles, regardless of when that sleep occurs in the circadian body clock cycle.

The Window of Circadian Low (WOCL), which occurs around the time of the daily minimum in core body temperature, corresponds to the time of day when people feel most sleepy and are least able to perform.

The circadian body clock and the sleep homeostatic process interact to produce two times of peak sleepiness in 24 hours.

1. Sleepiness is greatest when people are awake during the *WOCL*, which occurs around 3-5 am for most people on a normal routine with sleep at night.
2. Sleepiness increases again in the early afternoon - sometimes called the *afternoon nap window* (around 3-5 pm for most people). Restricted or disturbed sleep at night makes it harder to stay awake during the next afternoon nap window.

The precise timing of the two peaks in sleepiness is different in people who are *morning types* (whose circadian rhythms and preferred sleep times are earlier than average) and *evening types* (whose circadian rhythms and preferred sleep times are later than average). Across the teenage years, most people become more evening-type. Across adulthood, most people become more morning-type. This progressive change towards becoming more morning-type has been documented in flight crew members across the age range 20-60 years.

The combined effects of the sleep homoeostatic pressure and the circadian body clock can be thought of as defining 'windows' when sleep is promoted (the early morning and afternoon times of peak sleepiness) and 'windows' when sleep is opposed (the time of the internal alarm clock in the late morning, and the evening wake maintenance zone).

2.3.3 HOW LIGHT SYNCHRONIZES THE CIRCADIAN BODY CLOCK

The cells (neurons) in the circadian body clock spontaneously generate electrical signals faster during the day than at night (usually described as 'firing' faster during the day than at night). Light exposure effectively increases the firing rate of the clock cells. Depending on when in the body clock cycle light is received, there are three possible outcomes:

1. Light in the morning shortens the body clock cycle in that cycle (known as a phase advance);
2. Light in the middle of the day does not change the body clock cycle length (no phase change); or
3. Light in the evening lengthens the body clock cycle in that cycle (known as a phase delay).

Figure 2-7 shows graphically how these different responses are possible. The solid line in each panel represents the circadian rhythm in firing rate on the circadian body clock cells.

- In the left hand panel, light speeds up the rising part of the body clock cycle, leading to a phase advance.
- In the middle panel, light causes no phase change.
- In the right hand panel, light slows down the falling part of the body clock cycle, leading to a phase delay.

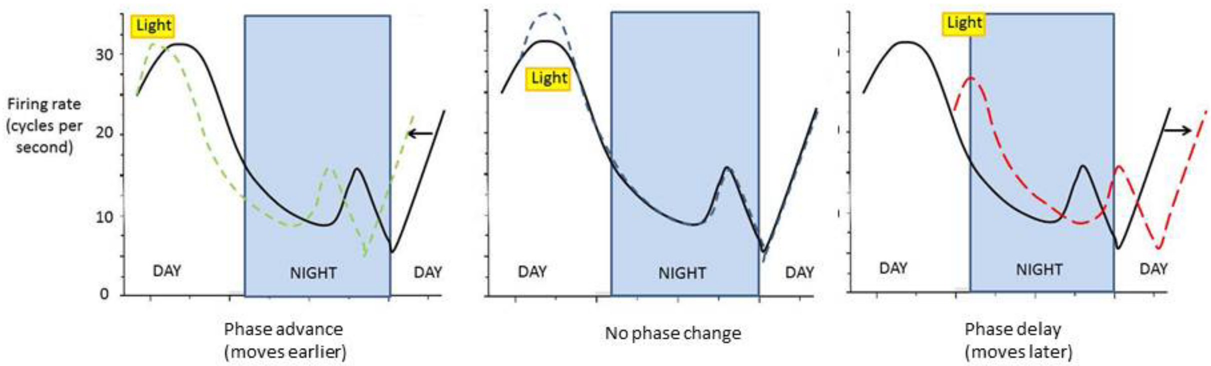


Figure 2-7. Effects of light on the circadian body clock

Bright light causes bigger shifts in the circadian body clock cycle than dim light, and the clock is particularly sensitive to blue light.

In summary, for an individual fully adapted to the local time zone and sleeping regularly at night:

- light exposure after the circadian temperature low point in the morning will result in a phase advance of the body clock cycle;
- light exposure in the middle of the day will have minimal effect on the body clock cycle;
- light exposure in the evening before the circadian temperature low point will result in phase delay of the body clock cycle.

Light in the morning shortens the circadian body clock cycle and light in the evening lengthens the body clock cycle.

In theory, this means that just the right amount of light exposure at the same time every morning would speed up a slightly slow circadian body clock cycle just enough to synchronize it to exactly 24 hours (most of us have an innate body clock cycle slightly longer than 24 hours). In practice, staying in step with the day/night cycle is more complex than this. In modern industrialized societies, people have very haphazard exposures to light, particularly bright outdoor light. In addition, the circadian body clock is sensitive to other time cues from the environment, for example it can also be moved backwards or forwards in its cycle by bouts of physical activity.

The ability of the circadian clock to "lock on" to the 24-hour day/night cycle is a key feature of its usefulness for most species, enabling them to be diurnal or nocturnal as needed to enhance their survival. However, it can create challenges for individuals involved in 24/7 operations because it causes the circadian body clock to resist adaptation to any pattern other than sleep at night.

In extreme latitudes, where there are long periods of darkness in winter, the biological clock receives less light information to help keep in step with the 24-hour cycle. A small number of studies have looked at the effects on sleep and fatigue in the extreme latitudes and show that in the winter months people go to bed and get up later, have more difficulty falling asleep and may sleep for slightly longer (although other studies find no difference in sleep duration) compared to in summer. Although sleep may be slightly longer, fatigue levels are greater in the winter months at these extreme latitudes.

2.3.4 SHIFT WORK

From the perspective of human physiology, shift work can be defined as any duty pattern that requires a crew member to be awake during the time in the circadian body clock cycle when they would normally be asleep if they were free to choose their own schedule.

The further sleep is displaced from the optimum part of the circadian body clock cycle, the more difficult it becomes for individuals to get adequate sleep (i.e., the more likely they are to experience sleep restriction). For example, individuals working at night are typically on duty through most of the optimum time for sleep in the circadian body clock cycle. This happens because the circadian body clock is 'locked on' to the day/night cycle, and does not flip its orientation to promote sleep during the day when an individual is awake and working at night.

Figure 2-8 is a diagram that summarizes what happened to the circadian biological clock and sleep when the night cargo crew members in Figure 2-6 (see above) were flying at night and trying to sleep in the morning. Again, their average core body temperature rhythm has been simplified (the continuous curve).

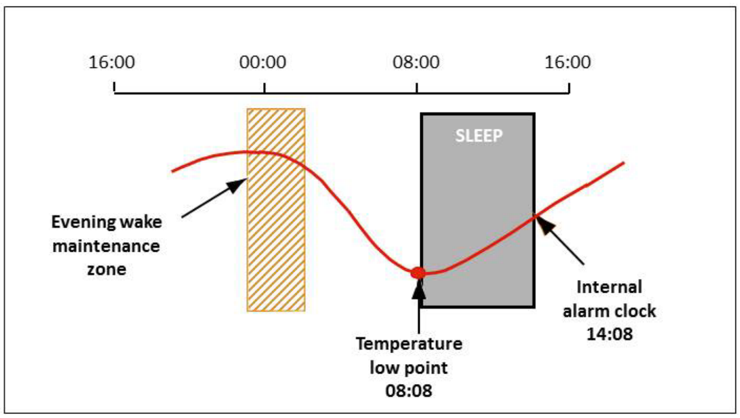


Figure 2-8. Relationships between sleep after night duty and the circadian body clock cycle[24]

On off duty days, when these crew members were sleeping at night, the average time of the temperature minimum was 05:20 (Figure 2-6). When they were flying at night (Figure 2-8) this moved to 08:08, i.e., the average temperature minimum delayed by 2 hours 48 minutes. The circadian body clock did not adapt fully to night duty, which would have required a shift of about 12 hours. As a result, crew members had to sleep in a different part of the circadian body clock cycle after night duty.

- After night duty (Figure 2-8), they fell asleep close to the circadian temperature minimum. In contrast when they slept at night (Figure 2-6), they fell asleep about 5 hours before the temperature minimum.
- After night duty (Figure 2-8), crew members woke up about 6 hours after the circadian temperature minimum, within 5 minutes of the predicted time of the *internal alarm clock*. In contrast when they slept at night (Figure 2-6), they woke up about 3 hours after the temperature minimum.
- Crew members were not asked what woke them up from sleep episodes after night duty, but they rated themselves as not feeling well-rested after these restricted morning sleep episodes.

Early morning shifts also have consequences for sleep, as night time sleep is truncated. Going to sleep earlier in anticipation of an early start the next day does not work for most people as the evening wake maintenance zone (see

[24] Figure provided by Prof. P.H. Gander.

Figure 2-8 above) prevents sleep onset. There have been several studies showing that compared to afternoon or day shifts, ATCs obtain the least sleep prior to morning shifts.

In addition to obtaining less and poorer quality sleep, there are other consequences to working shifts. A changed pattern of work and sleep (if it remains consistent over several days) provides cues to the circadian body clock to realign. The cues from the pattern of work and sleep are in conflict with light information the circadian body clock is receiving. Different rhythms in the body get out of step with each other resulting in circadian disruption. As a consequence an individual may experience fatigue, poorer mood and changes in performance.

SPEED AND DIRECTION OF SHIFT ROTATION

Shift patterns can be classified according to the speed (fast or slow) and direction (forward or backward) of rotation. When the timing of duty periods change rapidly from one day to the next (also known as a rapidly rotating schedule) then the circadian biological clock cannot adapt to the pattern of work and rest. The advantage of this is that on days off an individual's circadian biological clock is still aligned with the normal day/night cycle and symptoms of circadian disruption are minimized. The downside of rapidly rotating schedules is that at certain times, such as on the night shift, an individual will be working when their circadian drive for sleepiness is high and their performance is at its poorest. A slowly rotating schedule (e.g. a week of early morning shifts) is more likely to result in some circadian adaptation but then on days off an individual will be slightly out of alignment with the normal day/night cycle and some re-adaptation needs to occur.

The circadian body clock is not able to adapt immediately to a change in the work/schedules that occur with shift work and night work.

Shift schedules can also rotate forwards (each successive shift or set of shifts occurring later than the one before, e.g. morning, day, afternoon, night shift) or backwards (each successive shift or series of shifts starting earlier than the one before, e.g. afternoon, day, morning, night shift). From what we know about the circadian body clock it would be expected that forward rotating shifts were preferable, as the circadian clock normally runs slightly slow making it easier for individuals to go to bed later and get up slightly later. However, there is not a great deal of information that supports this. In fact a carefully conducted laboratory based study that compared rapidly forwards and backwards rotating air traffic control schedules found no difference in the amount of sleep obtained or the performance of individuals across either of these schedules[25]. What the study did find is that the least amount of sleep is obtained before an early morning shift and ratings of fatigue are highest and performance poorest at the end of a night shift, regardless of the direction of shift rotation.

[25] Cruz, C., Boquet, A., Detwiler, C., and Nesthus, T.E. *A Laboratory Comparison of Clockwise and Counter-Clockwise Rapidly Rotating Shift Schedules, Part II: Performance*. 2002, Office of Aerospace Medicine, Federal Aviation Administration: Washington, DC. and Cruz, C., Detwiler, C., Nesthus, T.E. and Boquet, A. *A Laboratory Comparison of Clockwise and Counter-Clockwise Rapidly Rotating Shift Schedules, Part I: Sleep*. 2002, Office of Aerospace Medicine, Federal Aviation Administration: Washington, DC.

OPERATIONAL IMPLICATION 7.
SCHEDULING

The perfect schedule for the human body is daytime duties with unrestricted sleep at night. Anything else is a compromise. There are, however, general scheduling principles based on fatigue science that should be taken into account when designing a duty schedule:

- The circadian body clock does not adapt fully to altered schedules such as rotating shifts or night work. Some adaptation may occur on slow rotating schedules. There is no clear difference between forwards versus backwards rotating shift schedules.
- Whenever a duty period overlaps an individual's usual sleep time, it can be expected to restrict sleep. Examples include early duty start times, late duty end times, and night work.
- The more a duty period overlaps an individual's usual sleep time, the less sleep the individual is likely to obtain. Working right through the usual night-time sleep period is the worst-case scenario.
- Night duty also requires working through the time in the circadian body clock cycle when self-rated fatigue and mood are worst, and additional effort is required to maintain alertness and performance. Napping before and during a night duty period is a useful strategy (discussed above in *Operational Implication 5: Napping as a Fatigue Mitigation*).
- Night duty also forces an individual to sleep later than normal in their circadian body clock cycle, so they have a limited time to sleep before the circadian alerting signal wakes them up. This can cause restricted sleep following a night shift. To provide the longest sleep opportunity possible, night shifts should be scheduled to end as early as possible and individuals need to get to sleep as soon as possible after coming off duty.
- The evening wake maintenance zone occurs in the few hours before usual bedtime. This makes it very difficult to fall asleep earlier than usual, ahead of an early duty report time. Early report times have been identified as a cause of restricted sleep in aviation operations.
- Across consecutive duty periods that result in restricted sleep, individuals will accumulate a sleep debt and fatigue-related impairment will increase.
- To recover from a sleep debt, individuals need a minimum of two full nights of sleep in a row. The frequency of rest periods should be related to the rate of accumulation of sleep debt.

2.4 SCIENTIFIC PRINCIPLE 4: THE INFLUENCE OF WORKLOAD

The ICAO definition of fatigue describes workload as “mental or physical activity” and recognizes it is a potential cause of fatigue. Workload is, however, a complex concept and there is no universal definition or agreed way of measuring it. However, three aspects of workload are commonly identified:

1. The nature and amount of work to be done (including time on task, task difficulty and complexity, and work intensity).
2. Time constraints (including whether timing is driven by task demands, external factors, or by the individual).
3. Factors relating to the performance capacity of an individual (for example experience, skill level, effort, sleep history, and circadian phase).

SCIENTIFIC PRINCIPLE 4

WORKLOAD CAN CONTRIBUTE TO AN INDIVIDUAL’S LEVEL OF FATIGUE. LOW WORKLOAD MAY UNMASK PHYSIOLOGICAL SLEEPINESS WHILE HIGH WORKLOAD MAY EXCEED THE CAPACITY OF A FATIGUED INDIVIDUAL.

For each type of operation being regulated the factors contributing to workload and the consequences of workload need to be considered. They are likely to be quite different in one operational situation compared to the next. For example, the nature of the workload will be very different in air traffic control compared to flight crew, but also different in an *en route* centre compared to a control tower or in short-haul compared to long-haul flight operations.

Across most types of operations there is fairly wide acceptance of the concept that intermediate levels of workload may contribute least to performance impairment. Low workload situations may lack stimulation, leading to monotony and boredom which could unmask underlying physiological sleepiness and thus degrade performance. Instead of leading to boredom, low workload can also result in an individual making a greater effort to remain engaged which in turn increases their workload. At the other end of the spectrum, high workload situations may exceed the capacity of a fatigued individual, again resulting in poorer performance. High workload may also have consequences for sleep, due to the time required to “wind down” after demanding work.

High and low workload can contribute to fatigue.

High workload may disturb sleep due to the time required to “wind down” after demanding work.

Few studies have attempted to investigate the influence of workload on fatigue or the potential interaction between workload and other causes of fatigue such as time-on-task, time awake, sleep loss and time of day. A field study of fatigue ratings made by ATCs found some evidence for self-rated workload and time-on-task having interactive effects on fatigue[26]. When self-rated workload was low, fatigue ratings remained relatively stable for continuous work periods up to 4 hours. However when workload was high, there was a rapid increase in fatigue after 2 hours of continuous work. These effects of workload became more evident after controllers had been awake for at least 12 hours. The time-of-day variation in fatigue ratings was also influenced by workload, being more marked at low and high levels of workload than at intermediate levels. Operationally, breaks during a duty period are an important way of reducing the decline in performance with increasing time-on-task.

The relationship between workload and fatigue has not been well researched.

[26] Spencer, M.B., Rogers, A.S., Stone, B.M. (1997) A review of the current scheme for the regulation of air traffic controllers hours (SCRATCOH). Farnborough, England: Defense Evaluation and Research Agency.

OPERATIONAL IMPLICATION 8.
PROVIDING BREAKS DURING A DUTY PERIOD

Operationally, breaks during a duty period are an important way of reducing the decline in performance with increasing time on task due to the effects of high workload. Such breaks differ from rest periods between duty periods which are designed to allow for sleep and other recovery as well as preparation for future work.

The length of time working before a break occurs, and the duration of the break are dependent on the type of task being performed. For example, performance on tasks requiring sustained attention, such as monitoring for an infrequent event, has been shown to improve with frequent short breaks. As with any continuous operation, where a task performed by one person is handed over to another person, it is critical to consider the risk of the handover itself. In some cases, less frequent handovers (perhaps with higher levels of supervision) may be associated with a lower overall risk exposure.

CHAPTER 3. OPERATIONAL KNOWLEDGE AND EXPERIENCE

Effective fatigue management not only requires consideration of scientific principles, but also needs to be based on operational knowledge and experience, which is acquired through conducting specific operations over time and managing fatigue-related risks in those operations. These two sources of expertise are complementary.

Science generally aims to develop principles that can be broadly applied. Many of the findings of the scientific studies that underpin the principles in Chapter 2 do not have ATCs as their primary focus, but the findings are extrapolated for use in ATS operations. This means that knowledge of the operational and organizational context, as well as understanding of the constraints and motivations of the workforce must be considered alongside the science to develop an appropriate fatigue management approach.

Note that prior operational experience alone is not sufficient for fatigue management in either prescriptive or FRMS approaches. A safety case requires more than just the argument that 'we have always done it this way'. There needs to be evidence of consideration of scientific principles, risk assessment, and risk mitigation.

In the following two sections, contextual factors are categorised as relating either to the air traffic control operations context or to the broader organizational context. However it can be argued that some factors belong in both categories and clearly the two contexts interact in their effects on fatigue management.

3.1 AIR TRAFFIC OPERATIONS CONTEXT

Aspects of the local environmental and working conditions can affect ATC fatigue levels. Operational context covers factors that the ATC is faced with on a daily basis, for example the weather, the topography around the airport, traffic delays, airspace complexity, level of ATC experience, interactions with other aviation professionals (e.g. pilots), irregular operations, and managing different operational demands (e.g. en route, control tower).

Table 3.1 identifies some of the factors in an operational context that can influence ATC fatigue. Some or all of these factors may be relevant, depending on the specific tasks to be completed by the ATC on the day.

Table 3-1. Examples of factors in the operational context that can influence ATC fatigue

Factor in operational context	Possible effect(s) on fatigue
Work conditions	• The quality of rest facilities and policies for their use • Level of automation • Level of authority and responsibility • Availability of support staff • Temperature and noise • Availability of food and water
Geographical location	• Topography • Remoteness • Weather • Time spent in commuting
Workload	• Traffic density • Task intensity
Irregular operations	• Frequency of duty period extensions necessary to address broader operational risks • Frequency of disruption to schedules • Frequency of being on on-call and the likelihood of being called
Interactions with other aviation professionals	• The need to communicate with pilots in a language other than their native language • Ground crew • Airport staff
Experience levels	• Similar operational demands can result in higher workload levels for in-experienced ATCs than for experienced ATCs • Experienced ATCs may need to support and oversee inexperienced personnel, adding to their workload
Staffing arrangements	• The ability to offer adequate recovery and preparation opportunities to avoid cumulative fatigue • Sufficient staff to cover sickness and other absences • Career stability • Changing employment arrangements (e.g., use of contractors and contractual obligations and constraints) • Sufficient staff to cover the specific operational demands

3.2 ORGANIZATIONAL CONTEXT

Knowledge of the context within which the ATS Provider operates can provide an understanding of the pressures facing the ATS Provider and the factors which affect how it is able to address fatigue issues. Further, within an organization, knowledge of the composition, behaviours and customs of the workforce provides context to the fatigue issues that may affect individual ATCs and groups of ATCs working in specific sectors, as well as how best to manage them. Table 3.2 identifies some of the areas where the organizational context may influence fatigue.

Table 3-2. Contextual factors which may affect fatigue levels and the ability of service provider to address them

Factor in organizational context	Possible effect(s) on fatigue
Career stability	• Commercial pressures • Changing employment arrangements (e.g., labour agreements, use of contract employees)
Fatigue management structure	• Fatigue management is integrated into day-to-day risk management activities versus being the responsibility of an independent group or individual.
Safety reporting behavior	• Effective reporting culture • Ease of reporting fatigue hazards • Implications for a ATC of submitting a report • Actions by ATS Provider in response to fatigue reports
Staffing Levels	• Sufficient to be able to offer adequate recovery and preparation opportunities during and between work periods to avoid cumulative fatigue • Sufficient to cover sickness and other absences • Sufficient to provide level of autonomy consistent with experience levels

3.3 STAKEHOLDER RESPONSIBILITIES

Responsibility for fatigue management must be shared between the ATS Provider and the individual ATC. Operational knowledge provides information about how well that shared responsibility is understood and implemented.

The ATS Provider is responsible for providing:

- adequate resourcing for fatigue management;
- a working environment that has appropriate emphasis on mitigations for fatigue-related risk;
- robust fatigue reporting mechanisms;
- evidence of appropriate responses to fatigue reports;
- schedules that enable fatigue while at work to be maintained at an acceptable level, as well as providing adequate opportunities for rest and sleep; and
- education and awareness training on how the ATS Provider's fatigue management approach works and how ATCs can better manage their own fatigue.

Individual ATCs are responsible for:

- making optimum use of off-duty periods to get adequate sleep;
- coming to work fit for duty;
- managing their own fatigue levels; and
- reporting fatigue issues.

3.3.1 FATIGUE REPORTING

Fatigue management, whether by prescriptive approach or by an FRMS, relies on identification of fatigue hazards and effective safety reporting. It must be acceptable to raise legitimate issues about fatigue without fear of retribution or punishment from both within and outside the organization. The issues associated with fatigue are difficult to detect if people are unwilling or unable to report them.

To encourage an ongoing commitment by staff to reporting fatigue hazards voluntarily (as opposed to mandatory reports), the ATS Provider should:

- Have clear processes for fatigue hazard reporting.
- Be clear that the organization expects ATCs to report fatigue hazards;
- Establish a process for what to do when an ATC considers themselves too fatigued to perform safety-critical tasks to an acceptable standard.
- Identify the implications for individuals of submitting a fatigue hazard report;
- Identify how the organization will respond to reports of fatigue hazards, including acknowledging receipt of reports and providing feedback to ATCs who report.
- Take appropriate actions in response to fatigue reports consistent with stated policy.
- Maintain the integrity of the safety reporting system and reporter confidentiality.
- Provide feedback to ATCs on changes made in response to identified fatigue hazards.

CHAPTER 4. THE PRESCRIPTIVE APPROACH

To manage ATC fatigue, ICAO requires States to develop regulatory limits for work periods and minima for non-work periods and establish associated regulations. However, fatigue science suggests that staying within the prescriptive limits may not be enough on its own to manage fatigue. Other than prescribing actual limits, additional associated regulations are needed to enable effective management of fatigue risks by the ATS Provider within the constraints of the prescribed limits (see Annex 11 SARPs presented in Appendix A). States establish their package of prescriptive limitation regulations in accordance with ICAO Standards and Recommended Standards (SARPs). It is therefore important that ATS Providers familiarise themselves with both the ICAO SARPs and their specific national prescriptive fatigue management regulations.

When complying with prescriptive limitation regulations, ATS Providers are still obliged to use their existing SMS processes to identify and mitigate risks (including those associated with fatigue). There are a number of sources of data already available to an ATS Provider that can be used to identify where fatigue might constitute a hazard. These all involve what ICAO calls 'reactive hazard identification', which means that fatigue is identified after it has occurred[27].

The first part of this Chapter describes how to manage fatigue by operating within the prescriptive limits by constructing schedules based on scientific principles in combination with additional SMS elements, namely: appropriate fatigue management training and education to ensure that all ATCs are competent to carry out their safety-related duties; and reactive processes for fatigue hazard identification, risk assessment, and mitigation (ICAO Annex 19).

The ICAO SARPs allow States to approve applications by ATS Providers for variations to the prescribed limits. However, the SARPs specify that variations can only be approved for exceptional circumstances and approval must be based on a risk assessment provided by the operator. The operator has to show how they will provide a level of safety equivalent to, or better than that achieved by operating within the prescriptive limits. The second part of this Chapter provides guidance on the use of variations and on how to develop a safety case to apply for a variation.

4.1 MANAGING FATIGUE WITHIN PRESCRIBED LIMITS AND ASSOCIATED REQUIREMENTS

An ATS operation that is managed within the prescriptive duty time limits is required to:

1. provide evidence that the prescribed limits are not exceeded and that non-duty period requirements are met;
2. use scientific principles and operational knowledge to construct ATC schedules (rosters);
3. establish a process for assigning any unscheduled duties (such as when on-call) that allows ATCs to avoid extended periods of being awake;
4. include ATC fatigue as one of the hazards managed through its SMS processes; and
5. provide an appropriate level of information on fatigue management in general safety training.

These are discussed below.

[27] The other types of hazard identification are proactive (monitoring fatigue during operations) and predictive (predicting likely fatigue levels in operations before they occur).

4.1.1 COMPLYING WITH PRESCRIBED LIMITS

To provide evidence of compliance with the prescribed duty period limits and non-duty period minima, ATS Providers are required to keep records of planned (scheduled) and actual work periods.

As part of the prescribed limits, a regulator may include flexibility provisions for last-minute duty extensions to allow the ATS Provider to manage on-the-day operational disruptions. Similarly, limits for reducing the minimum rest below the prescribed minimum may also be prescribed. The ability to use these duty extensions and/or rest reductions should depend on the ATC's assessment that they are fit to continue. Where such "flexibility" limits are prescribed, the ATS Provider should manage the frequency of their use as part of their SMS processes. Alternatively, the State may require the use of variations to allow the ATS Provider flexibility to manage operational disruptions on the day. Addressing unexpected operational circumstances and risks is discussed further in Section 4.2.1.

Analysis of periods actually worked compared with those scheduled, coupled with fatigue reports, can be used by the ATS Provider to identify fatigue hazards associated with their scheduling practices (see 4.1.4 below) as part of existing SMS obligations.

4.1.2 CONSTRUCTING ATC SCHEDULES (ROSTERS) USING SCIENTIFIC PRINCIPLES

Principles from fatigue science (Chapter 2) should be used to construct ATC schedules (rosters) that take into account such factors as the dynamics of sleep loss and recovery, the circadian biological clock, and the impact of workload on fatigue, along with operational requirements and contextual factors. When fatigue science and operational knowledge and experience is applied in the building of ATC schedules, fatigue hazards relating to scheduling can be predicted and minimised.

Since the effects of sleep loss and fatigue are cumulative, scheduling practices needs to accommodate the effects of different types of shifts that are worked by ATCs (early starts, day shifts, afternoon shifts, night shifts, etc.), and the effects of working a succession of different types of shifts across a roster term. The following are general scheduling principles based on fatigue science.

- The perfect schedule for the human body is daytime duties with unrestricted sleep at night. Anything else is a compromise.
- The circadian body clock does not adapt fully to altered schedules such as night work.
- Whenever a duty period overlaps an ATC's usual sleep time, it can be expected to restrict sleep. Examples include early duty start times, late duty end times, and night work.
- The more that a duty period overlaps an ATC's usual sleep time, the less sleep the ATC is likely to obtain. Working right through the usual night time sleep period is the worst case scenario.
- Night duty also requires working through the time in the circadian body clock cycle when self-rated fatigue and mood are worst and additional effort is required to maintain alertness and performance.
- Across consecutive duties with restricted sleep, ATCs will accumulate a sleep debt and fatigue-related impairment will increase.
- To recover from sleep debt, ATCs need a minimum of two full nights of sleep in a row. The frequency and duration of recovery periods should be related to the rate of accumulation of sleep debt.
- When on on-call, an increased likelihood of being called in may affect sleep recovery;
- ATCs will require breaks to sustain performance during cognitively intensive periods of time-in-position.

These sorts of principles can be used to develop scheduling rules to construct schedules for different ATC units.

Schedules need to be published sufficiently in advance to allow ATCs to plan for duty and non-duty periods. While late roster changes are sometimes unavoidable, ATS Providers need to keep changes at short notice to a minimum and minimise their impact.

Where ATCs are allowed to “swap shifts”, the ATS Provider will need to provide explicit procedures for doing so, in order that:

- prescriptive limitations are not exceeded at the time of the shift swap or at a later time during the work schedule; and
- shift swapping is monitored to avoid conflict with scheduling principles or practices developed by the ATS Provider.

4.1.3 ASSIGNING UNSCHEDULED DUTIES

Within the prescribed limits, assignment of unscheduled duties to meet unpredictable operational needs is commonly managed through different approaches, e.g. on-call periods, standby, reserve and last-minute roster changes. For convenience, the term “on-call” will be used to cover all of these approaches.

The specific challenges associated with unscheduled duties are their inherent unpredictability and how likely it is that an ATC will be required to undertake duties while on-call. The following considerations are important fatigue management considerations when scheduling on-çall periods for ATCs:

- The need for protected sleep opportunities before and after unscheduled duties. As for any other duty period, the ATC needs an opportunity to plan their sleep (as much as is possible) to enable them to perform to a satisfactory level. He/she also needs to be able to recover from the fatigue accrued across the duty period.
- Adjusting the length of the on-call period in relation to the length of the notification period. Short notification periods require the ATC to be fully rested and immediately ready to undertake the duty. Longer notification periods can offer the opportunity to sleep in preparation for the duty, which allows the ATC to remain available longer to be assigned an unscheduled duty. Therefore the length of the period on-call should be directly related to the length of the notification period.
- Duty length may need to be adjusted in relation to the time spent on call, depending on the length of the notification period.
- The extent to which an on-call period is counted as a work period is related to the level of fatigue it is likely to produce.

The ATS Provider should establish processes to ensure that the assignment of unscheduled duties is actively managed in order to avoid an ATC operating while having been awake for extended periods of time. Such processes should aim to:

- Minimise the extent of disruption to the timing of a planned duty;
- Provide protected sleep opportunities (prior to, during and after unscheduled duties);
- Identify minimal notification periods for changes to planned duties; and
- Limit the number of consecutive days that they may be subject to being assigned unscheduled duties.

This will necessarily mean that periods of **scheduled time on-call** and the **use of last-minute duty extensions** to address unexpected operational disruptions (discussed further in *Section 4.2.1 Variations to Meet Unexpected Operational Circumstances and Risks*) will need to be monitored).

4.1.4 USING SMS PROCESSES TO MANAGE FATIGUE HAZARDS

The ATS Provider is expected to use their existing SMS processes to manage all risks, including those related to fatigue. The ATS Provider’s process for assigning responsibilities for risk assessment of fatigue hazards and mitigation would be the same as is used for other hazards within their SMS.

With regards to identifying fatigue-related hazards, existing SMS processes mainly rely on data that is collected following an event or an incident (reactive). Figure 4-1 summarizes the use of reactive data for identifying fatigue hazards as part of an operator's SMS, for operations that comply with the prescribed duty time limits. The following sections describe the use of SMS processes to identify and mitigate fatigue-related risks in more detail.

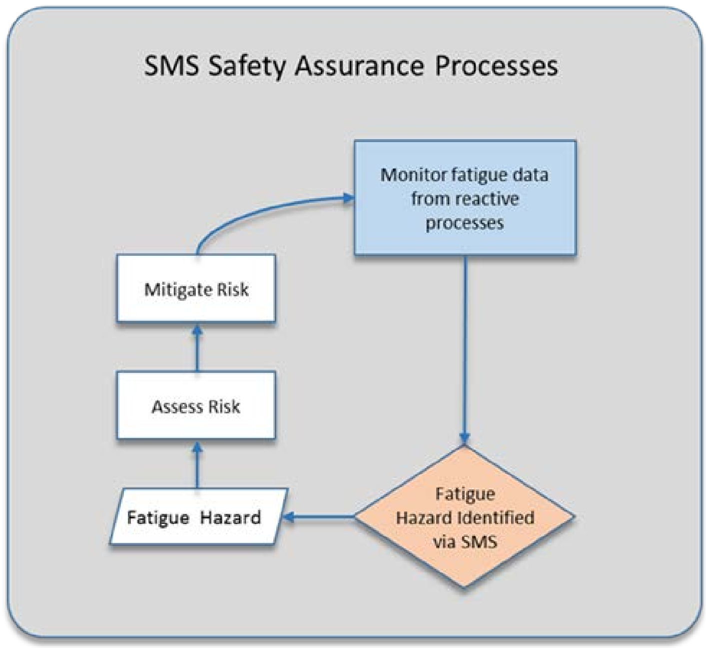


Figure 4-1. Diagram showing the use of reactive processes for identifying fatigue hazards as part of an ATS Provider's SMS, for operations that comply with the prescriptive duty time limits

IDENTIFYING FATIGUE HAZARDS

There are many ways of identifying fatigue hazards. Depending on the size of an Air Traffic Service Provider and the maturity of its SMS processes, some or all of the following examples might be acceptable for use:

- small/non-complex operations might include brainstorming, where the ATS Provider's Safety Committee or a small group of suitably experienced members meet to consider specific operations and identify possible fatigue hazards;
- considering fatigue related results of internally or externally conducted safety assessments/audits;
- considering fatigue related safety information from external sources, i.e. similar service providers, media, information from large data banks of hazard reports (voluntary reporting);
- using data collected through the ATS Provider's SMS processes to monitor trends in fatigue-related safety performance indicators, e.g.:
    - comparing planned versus actual duty periods;
    - consideration of fatigue-related reports received through the ATS Provider's safety reporting system.

COMPARING PLANNED VERSUS ACTUAL DUTIES

ATS Providers are required to keep records of ATC work and non-work periods to provide evidence of compliance with prescriptive limits specified by their regulator. These data on when ATCs actually work can identify times when fatigue might have been higher than expected as compared to the original schedule. For example, an ATS Provider might track how often each month:

- Time-in-position ends at least 30 minutes later than scheduled;
- Work periods that end with high workloads and within the window of circadian low (WOCL); or
- Being on on-call results in undertaking work activities, etc.

These kinds of metrics point to possible mitigations if needed, for example increasing the number of ATCs at a particular time, changing the start time of a particular shift, or managing shift swaps. As part of routine SMS processes, the data need to be monitored regularly to evaluate whether the hazards identified warrant additional action.

COLLECTING FATIGUE-RELATED DATA FROM REPORTS

Hazard reporting has an essential role in SMS. To encourage open and honest reporting of hazards, an ATS Provider must clearly distinguish between:

- unintentional human errors, which are accepted as a normal part of human behaviour and are recognized and managed within the SMS; and

- deliberate violations of rules and established procedures. An ATS Provider should have processes independent of the SMS to deal with intentional non-compliance.

Reports about high fatigue levels or fatigue-related performance issues provide vital information about fatigue hazards in the day-to-day running of an ATS operation. Reports can come from ATCs or other operational staff. As for any other safety hazard, a series of hazard reports citing fatigue on particular time of a schedule may indicate that further action is needed to assess and mitigate that hazard.

ATS Providers should encourage ATCs to use the voluntary reporting system to identify fatigue hazards when:

- a duty period has not commenced or is not completed, due entirely or in part, to fatigue. Filing of such reports should be included as part an established process for reporting 'not fit for duty' due to fatigue identified by the service provider. Also identified should be the subsequent ATS Provider actions in such situations.
- a duty period has been completed in which the ATC believes that the level of fatigue they or other individuals were suffering meant sufficient safety margins had not been maintained throughout their time-in-position or were only maintained following some unplanned mitigating action (e.g. task rotation, reducing the workload of the duty, delaying the subsequent duty start time, creating the opportunity for a nap, increasing supervision/ monitoring, etc.).
- the ATC notices something in their operating environment that is likely to impact on their, or other individuals', alertness to such an extent that safety margins could be reduced to unsatisfactory levels.

An effective fatigue reporting system (regardless of whether it is mandatory or voluntary) should capture data on recent sleep and duty history (minimum last 3 days), time of day of the event, and measures of different aspects of fatigue-related impairment (for example, validated alertness or sleepiness scales). It should also provide space for written commentary so that the person reporting can explain the context of the event and give their view of why it happened. An example of a fatigue report form can be found in Appendix B of this guidance. This information should be included in an ATS Provider's general hazard reporting form as well as in mandatory incident/accident reporting forms. Information on how to report should be covered in fatigue management training.

To encourage ongoing commitment of ATCs to reporting hazards, ATS Providers should take appropriate and timely action in response to hazard reports.

USING FATIGUE MITIGATIONS

Within the prescriptive limits, there may still remain a need for an ATS Provider to manage their fatigue risk by further limiting prescriptive limitations due to their unique operating environment, workload considerations, or other factors.

As well as working to more restrictive limits than those prescribed and constructing ATC schedules using scientific principles, other typical risk mitigations which may also be considered include the provision of napping opportunities, provision of protected sleep opportunities, augmenting staffing levels or providing services from a remote location instead of locally.

SMS processes should require that such risk mitigations are regularly reviewed and assessed to ensure their desired outcome continues.

Table 4-1 provides some examples of organizational-level mitigations for managing fatigue hazards. These are examples only, not exhaustive lists.

Table 4-1. Examples of fatigue hazards and operator controls and mitigations (not an exhaustive list)

Fatigue hazard	Controls	Mitigations
Too many hours on duty	Limit number of hours of operational duty.	Codify restrictions in operating procedures with minimal opportunity for deviation.
Too few hours between shifts	Place a minimum requirement on time between shift and next shift start time.	Scheduling software programmed to preclude shift assignment with less than required off duty time.
Too many shifts in 7 day week	Limit number a shifts eligible for work in a work week.	Ensure employees have time to replenish sleep reservoir by designating ineligibility for duty.
On position during circadian low times	Allow employees the opportunity for recuperative sleep prior to and/or after probable circadian lows.	Ensure that ATCs have ample break opportunities during shifts and ample sleep opportunities between scheduled shifts.
Sleep opportunities after night shifts	Ensure minimum time off duty after night shift ends.	Have limits on shift assignment after a night shift[28] i.e. another night shift or day off the next day.

4.1.5 FATIGUE MANAGEMENT TRAINING

ATS Providers managing fatigue using a prescriptive approach are required to provide basic fatigue management training. This may be included within their SMS training, or as stand-alone training programmes. As part of their SMS activities, information sharing activities (such as awareness-raising notices or information circulars) could also include fatigue management topics.

Training records need to be kept and recurrent training is also recommended. The interval between training sessions and the level of training provided needs to be related to the expected level of fatigue risk in the operations.

[28] Night shift as used here refers to a scheduled shift when the majority of the work hours fall between the hours of 2200 and 0600.

Everyone whose role in the organization can influence ATC fatigue needs to have an appropriate level of fatigue management information and training. The content of training programmes should be adapted to make sure that each group has the knowledge and skills they need for their role in fatigue management.

The fatigue management-related content in training programmes for these individuals should comprise basic scientific principles related to fatigue management and general sleep hygiene as well as content specific to the ATS Provider's unique operational characteristics. This will include information on options for personal mitigation strategies and familiarisation with procedures for activities such as 'shift swapping', reporting in "not fit for duties" due to fatigue, or assigning unscheduled duties. Suggestions for fatigue management training topics can be found in Appendix D.

Table 4-2 provides some examples of personal fatigue mitigation strategies that might be covered in training for ATCs. These have been classified as strategic countermeasures (designed to be used at home or on-call) and operational countermeasures that can be used in during duty hours.

Table 4-2. Examples of Fatigue Hazards and Personal Mitigation Strategies (Not an Exhaustive List)

Fatigue Hazard	Strategic Countermeasure	Operational Countermeasure
Sleep at home disturbed by new baby	Move to a quiet part of the house for final sleep before reporting for duty. Maximize sleep in 24 hours before reporting for duty.	Napping using on-site rest facilities, maximize sleep during rest periods (if available), strategic use of caffeine during shift.
Difficulty sleeping in on-site rest facilities	Maximize sleep in 24 hours before shift.	Use eye mask, ear plugs, arrange a suitable wakeup call. Avoid caffeine for 3-4 hours before trying to sleep. Strategic use of caffeine after rest period.
Non-restorative sleep	See a sleep disorders specialist	Comply fully with recommended treatment.
Unpredictable call-outs mean that it is difficult to ensure adequate sleep prior to duty period	Ensure that sleep environment is dark and quiet, and use sleep hygiene measures to maximize sleep quality. Maximise recovery sleep on off-duty days. When feeling sleepy while waiting for call-out, attempt sleep (prioritize sleep over other activities).	Napping using on-site rest facilities, maximize sleep during rest periods (if available), strategic use of caffeine during shift.
A specific sequence in roster results facing an expected high traffic peak when extremely fatigued.	Submit a hazard report identifying fatigue associated with the specific sequence in the roster.	Napping using on-site rest facilities, maximize sleep during rest periods (if available), strategic use of caffeine during shift; manage time on-position.

4.2 MANAGING FATIGUE UNDER VARIATIONS TO PRESCRIPTIVE LIMITS

Within the prescriptive limitations regulations, ICAO SARPs support the provision of some flexibility to allow the ATS Provider to vary from the prescriptive limitation regulations in order to address operational needs and wider operational risks in certain, limited (exceptional) circumstances.

The intent of the ICAO provision is to minimize, not to encourage ‘regulation through variations’. It is not intended to offer a quick and easy alternative to an FRMS, when a more comprehensive fatigue risk management approach is required. Variations should be for the duration of the exceptional circumstances and managed using identified mitigation strategies.

The ATS Provider’s fatigue management obligations under variations are discussed below according to whether the circumstances are:

- unexpected and beyond the ATS Provider’s control; or
- expected but minor, with the aim of meeting an exceptional operational need.

4.2.1 VARIATIONS TO MEET UNEXPECTED OPERATIONAL CIRCUMSTANCES AND RISKS

Unexpected operational circumstances refer to those that do not occur on a regular basis or cannot be reasonably predicted to occur, based on past experience. If they are able to be reasonably predicted (e.g., known seasonal conditions or day-specific increases in airport traffic), the ATS Provider should be expected to schedule accordingly. The ATS Provider should use mitigations, e.g., schedule “buffer periods” (scheduling additional time to allow for operational variability) or provide additional resources within the prescribed limits, and not rely on the use of variations.

However, it is recognized that unexpected operational circumstances can occur to which an ATS Provider must respond immediately but that can necessitate extending beyond prescribed limits. To enable such on-the-day extensions, the State may establish regulations which:

- prescribe outer limits and the circumstances in which they can be used[29]; or
- permit an ATS Provider the flexibility to manage on-the-day disruptions by requiring them to develop their own on-the-day response protocol.

In unexpected, sudden and extreme operational circumstances (such as an extreme natural disaster or an unexpected, immediate airspace closure), the regulator should have a special process for requesting a variation. The ATS Provider needs to assure the regulator that they will maintain an acceptable level of safety. In any unexpected operational circumstance requiring a variation to the prescribed limits, the following will need to be identified by the State or proposed by an ATS Provider:

- the circumstances in which the variation may be used;
- the operations to which the variation may be applied;
- the necessary mitigations to address the increased fatigue risks; and
- the variation limits (i.e. extension limits and/or limits for minimum rest reductions).

The variation limits are dependent upon the operational circumstances and the ATC making an assessment of their fitness for duty.

The ATS Provider will necessarily monitor the frequency of their use of immediate variations, and provide evidence of compliance with the regulatory requirements for their use.

[29] While discussed under the heading of “variations” in this manual, these prescribed outer limits and conditions may be considered part of the prescribed limits and not variations *per se*.

4.2.2 VARIATIONS TO MEET EXPECTED OPERATIONAL CIRCUMSTANCES AND RISKS

Minor variations to the prescriptive limits may also be allowed in exceptional circumstances to meet expected operational needs and risks, without the need for the ATS Provider to develop a full FRMS. An ATS Provider should check to see if such strategic variations are allowable within their national regulations. Expected but exceptional circumstances may be related to ensuring the provision of adequate air traffic services for the duration of a short-term event (for example, the Olympic Games) or to meet a specific operational need requiring very minimal variations for extended periods of time (for example, extending the duty time of a single ATC one day a week every summer to meet seasonal traffic demands).

When applying for this type of variation, the ATS Provider has to provide a risk assessment and be able to satisfy the regulator that they can manage the variation to provide a level of safety equivalent to, or better than that achieved through complying with the prescriptive fatigue management regulations. The ATS Provider should indicate how the fatigue risk associated with the variation will be managed under their SMS (see Section 4.1.4). Some or all of the following areas may need to be addressed:

- The nature and scope of the variation, including which of the prescriptive rules it affects, the operations to which it applies, and why it is needed.
- The operating environment in which the variation will apply (this may include people, procedures, equipment, stakeholders, the physical environment, the organizational culture, the legal and regulatory environment, natural hazards, and external threats).
- Potential impact of the variation on other services, for example other Air Traffic Control units, airlines or airport services.
- A well-substantiated estimate of the impact of the variation on ATC fatigue, for example using published data from scientific studies or appropriate bio-mathematical models.
- Explanation of how the potential effects of the variation on fatigue will be monitored and documented.
- Description of the processes for risk assessment, if new fatigue hazard(s) are identified as a result of the variation.
- Description of additional mitigations that can be put in place, if needed.

Operating within the prescriptive duty time limits is one approach for managing fatigue. As fatigue-related risk increases, additional strategies need to be added. The point at which an FRMS is required needs to be clearly identified by the regulator, usually after discussions with the ATS Provider.

CHAPTER 5. FRMS: OPERATIONAL COMPONENTS

An FRMS is a specialized system that uses SMS principles and processes to manage the hazard of ATC fatigue. Consistent with SMS, FRMS seeks to achieve a realistic balance between safety, productivity, and costs. However, there are some important features of an FRMS approach that distinguish it from managing fatigue risks using an SMS within prescriptive limits only.

With a prescriptive approach, fatigue is one of the possible hazards that the SMS should consider. The ATS Provider reacts when a fatigue hazard is identified. With FRMS, the ATS Provider must additionally identify and assess potential fatigue risks prior to conducting operations under the FRMS as well as identifying and assessing actual fatigue risks proactively during operations.

An FRMS approach will require additional resources to be allocated to fatigue management, enhanced processes specifically established to address fatigue risks, and more comprehensive fatigue management training than that required when using prescriptive limitations only.

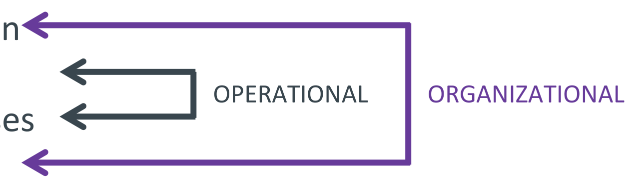
> ***FRMS.*** ***A data-driven means of continuously monitoring and managing fatigue-related safety risks, based upon scientific principles and knowledge as well as operational experience that aims to ensure relevant personnel are performing at adequate levels of alertness.***
>
> ***ICAO definition***

However, where an ATS Provider is able to demonstrate mature SMS processes to effectively manage their fatigue risks, they are well positioned to be able to build on these and transition to establishing an approved FRMS, should they wish to move outside of prescribed duty limits.

5.1 NECESSARY COMPONENTS OF AN FRMS

An FRMS has four components, two of which are operationally focused and two which are organizationally focused:

1. FRMS Policy and Documentation
2. FRMS Processes
3. FRMS Safety Assurance Processes
4. FRMS Promotion Processes



The FRM processes and the FRMS safety assurance processes make up the operational FRMS activities. These operational activities are governed by the FRMS policy and supported by FRMS promotion processes (organizational activities).

The ICAO SARPs have detailed minimum requirements for each of these four FRMS components. This Chapter focuses on the operational FRMS components. Chapter 6 focuses on the organizational FRMS components (the FRMS policy, documentation, and promotion process).

5.1.1 OPERATIONAL ACTIVITIES IN AN FRMS

The operational activities in an FRMS are summarized in Figure 5-1. The FRM processes form a closed loop with: 1) ongoing monitoring of fatigue levels; 2) identification of situations where fatigue may constitute a hazard; 3) risk assessment; and 4) introduction of additional risk mitigations when needed. The effectiveness of all current mitigations is captured in the ongoing monitoring of fatigue data, so the FRM processes form a closed loop. Figure 5.1 includes two FRM process loops to highlight that small hazards and large hazards may be managed somewhat differently within an organization. For example, small hazards may be dealt with entirely within the day-to-day FRM processes, whereas large hazards may require involvement of the wider SMS team in risk assessment and mitigation. Mitigating small hazards usually does not require major financial resources or procedural changes. However successful mitigation of small hazards can have major safety benefits.

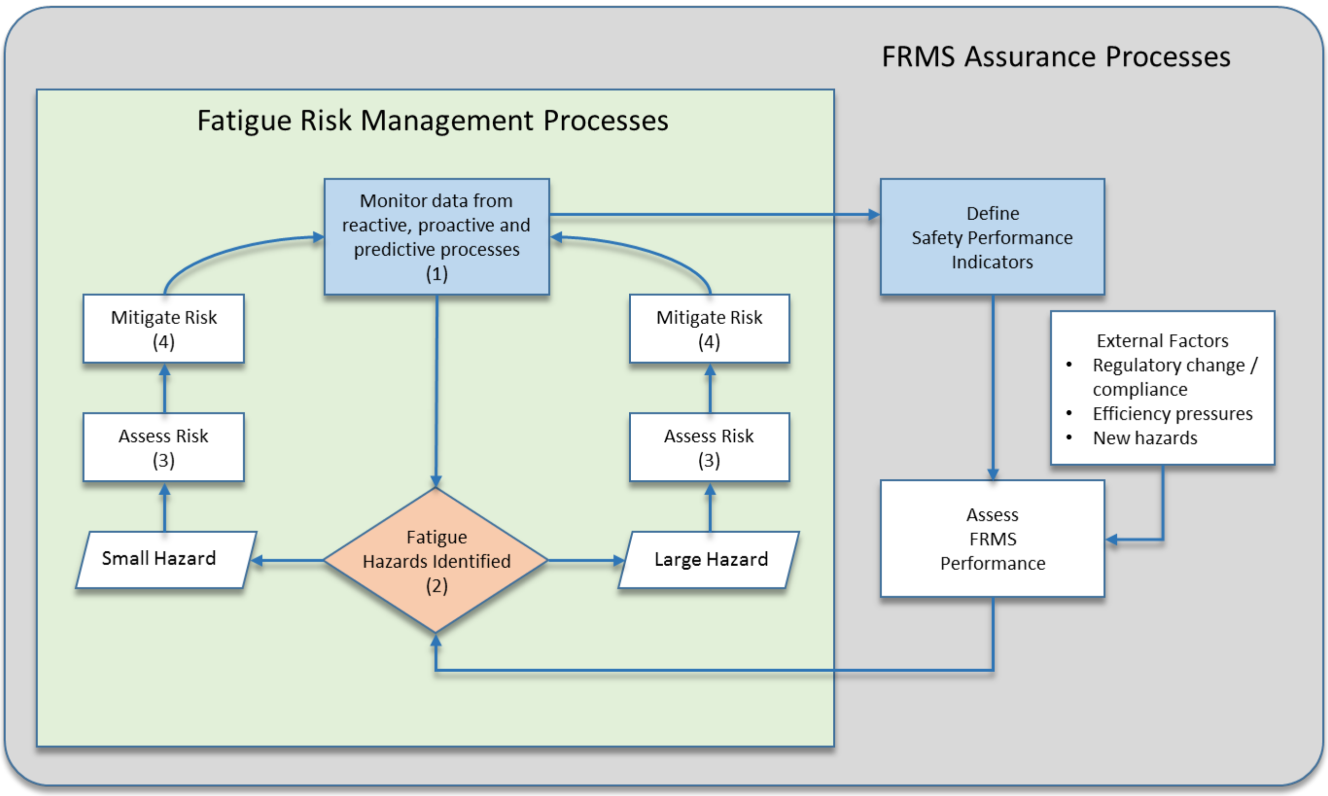


Figure 5-1. Operational activities of an FRMS: FRM and safety assurance processes

A range of data monitored in the FRM process loop is used to generate fatigue safety performance indicators (SPIs). These are used, along with data from sources outside the FRMS, in the FRMS Safety Assurance loop to check whether the FRMS is delivering an acceptable level of fatigue risk and safety. This must meet internal and external standards set by the ATS Provider's FRMS policy and/or by the regulator. The FRMS Safety Assurance loop also monitors external changes that could affect fatigue risk in the operations covered by the FRMS. It identifies emerging hazards and can make recommendations for mitigations and changes to the FRM processes, providing feedback that drives continuous improvement of the FRMS.

The fatigue monitoring data required for operational FRMS activities are more comprehensive than what is required for managing fatigue in operations that operate within the prescriptive limits and are managed under an ATS Provider's SMS (see Figure 4-1). In addition to using reactive data (gathered after an event or incident) to identify fatigue hazard(s), an

FRMS must also use proactive data (monitored during operations) and predictive data (predicting likely fatigue levels in operations before they occur).

5.1.2 THE FATIGUE SAFETY ACTION GROUP

Although not required by the SARPS, it is recommended that ATS Providers establish a Fatigue Safety Action Group (FSAG) with responsibility for coordinating FRMS activities. This manual assumes the establishment of an FSAG.

Since fatigue management must be based on shared responsibility and requires an effective safety reporting culture, it is strongly recommended that the FSAG includes representatives of all stakeholder groups (management, scheduling staff, and ATC representatives) with input from other individuals as needed to ensure that it has appropriate access to scientific, statistical, and medical expertise. Inclusion of all stakeholders is an important strategy for promoting engagement in the FRMS.

The size and composition of the FSAG will vary for different ATS Providers, but should be appropriate to the size and complexity of the operations covered by the FRMS, and to the level of fatigue risk in those operations. In small ATS Providers, a single individual may represent more than one stakeholder group, for example the Air Traffic Control Manager may also be the primary scheduler. Larger ATS Providers may have specialized departments that interact with the FSAG. The regulator needs to be confident that the ATS Provider has considered its operational and organizational profile in deciding the composition of the FSAG.

The principle functions of the FSAG are to:

- oversee the development of the FRMS;
- assist in FRMS implementation;
- oversee the ongoing collaborative operation of the FRM processes;
- contribute as appropriate to the FRMS safety assurance processes;
- maintain the FRMS documentation; and
- be responsible for ongoing FRMS training and promotion.

The FSAG should operate under Terms of Reference that are included in the FRMS documentation and which specify its activities, interactions with other parts of the organization, and the lines of accountability between the FSAG and the ATS Provider's SMS. An example of Terms of Reference for an FSAG can be found in Chapter 6 (6.2.2).

5.2 FRM PROCESSES

From Figure 5-1, the FRM processes of an FRMS form a feedback loop requiring the monitoring of data, the identification of hazards, the assessment of risk and mitigation. The following sections describe the FRM processes of an FRMS in detail. Appendix E provides an operational example of FRM processes.

5.2.1 SOURCES OF DATA FOR FATIGUE MONITORING

FRM processes are data driven. A range of types of data can be useful, and the key is choosing the right combination of measures for each operation covered by the FRMS, both for routine monitoring and when additional information is required about a potential hazard that has been identified, for example by a series of fatigue reports or a change in airspace design.

To be able to identify fatigue hazards, the FSAG needs to have a good understanding of the operational factors that are likely to cause ATC fatigue, which vary across different types of operations.

The following sections describe the various sources of data which can be used for monitoring fatigue in an FRMS.

5.2.2 HAZARD IDENTIFICATION

The ICAO SARPs (Annex 11, Appendix 7) require three types of hazard identification:

1. Predictive

- fatigue hazards identified by examining planned work schedules (rosters), taking into account factors known to affect sleep and fatigue.

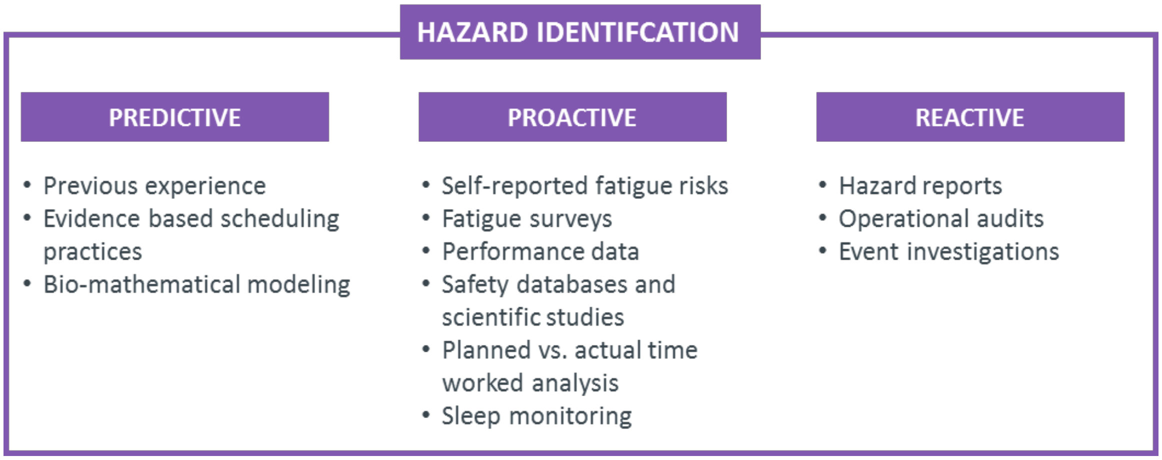
2. Proactive (monitored during operations)

- fatigue hazards identified by measuring fatigue levels in current operations.

3. Reactive (gathered after an event or incident)

- fatigue hazards identified by assessing the contribution of fatigue to safety reports and events that have occurred.

ICAO SARPs also propose suitable types of data and information that can be monitored:

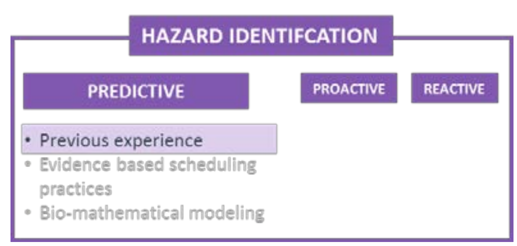


The following sections describe each of these types of data.

PREDICTIVE HAZARD IDENTIFICATION

Predictive processes are designed to identify fatigue hazards by examining ATC scheduling before rosters are actually worked, taking into account factors known to affect sleep and fatigue. ICAO FRMS SARPs (Annex 11, Appendix 7) list three possible ways of doing this: a) previous experience (of the ATS Provider or others in the industry); b) evidence-based scheduling practices; and c) bio-mathematical models. Note that none of these methods is required by the SARPs, and other methods may be used.

PREVIOUS EXPERIENCE



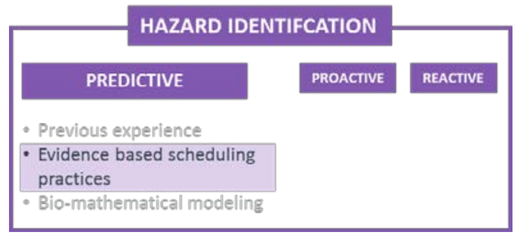
The collective experience of managers, schedulers, and ATCs is an important source of information for identifying fatigue hazards relating to ATC scheduling. For example, ATCs may recognize a particular rostered duty pattern as generating a high level of fatigue. The value of this collective experience can be enhanced by having staff educated about the dynamics of sleep loss and recovery, and about the circadian biological clock. These biological factors help explain why particular scheduling practices affect fatigue (for example, practices such as early starts, long duty days, short recovery periods, daytime sleep opportunities, and working night shifts).

For existing operations, information may already be available that previously identified fatigue hazards associated with different schedules and that recognises the unique demands of different operations. Examples may include: violations of prescriptive duty time rules, violations of prescriptive time off requirements, on-call usage, aviation safety reports (ASR's), and level of sickness absences.

When operational demands are changing, reliance on previous experience can have limitations. Scheduling based only on previous experience may not give the most robust or innovative solutions for new situations. It may also be important to collect data on actual levels of ATC fatigue, to check whether the lessons from previous experience are still valid in the new context.

Another way to identify fatigue hazards related to scheduling, for existing or new rostered duty patterns, is to look for information on *similar types of operations or from other industries with shift work or 24-hour operations*. This could include incident reports and ATC fatigue reports, or published scientific research and other information available on similar duty patterns worked by other ATS Providers or in other industry sectors. The amount of confidence that can be placed in this approach depends directly on how similar these other operations really are to the operation in which you are trying to identify fatigue hazards.

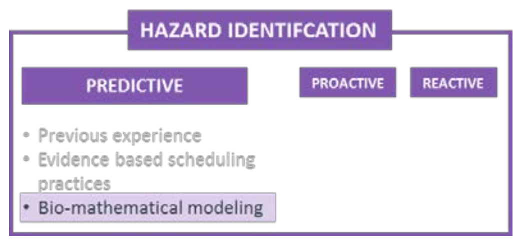
EVIDENCE-BASED SCHEDULING PRACTICES



As summarized in Section 4.1.2, fatigue hazards relating to scheduling can also be predicted when fatigue science is applied in the building of schedules. Evidence-based scheduling rules can be developed by an expert reviewer, for example by a scheduler trained in fatigue hazard identification, or by the FSAG. The scientific basis for the scheduling rules should be recorded in the FRMS documentation. The ongoing monitoring of fatigue levels in the FRM processes provides a mechanism for continuous improvement of evidence-based scheduling rules for an operation.

Potential fatigue hazards may be identified by gathering information on schedules that approach or exceed evidence-based scheduling rules. This could occur due to operational disruptions, ATC sickness or due to ATC roster swaps and trades.

BIO-MATHEMATICAL MODELS



Bio-mathematical models aim to predict aspects of a schedule that might generate an increased fatigue risk. They do not constitute an FRMS on their own, but are only one tool of many that may be used within an FRMS.

Bio-mathematical models begin life as computer programmes used by scientists to test their current understanding of how factors like sleep loss, circadian rhythms, and workload interact to affect human alertness and performance. The modelling process begins by trying to write a programme that can simulate a 'developmental data set' – for example self-rated fatigue and performance measured during a sleep loss experiment in the laboratory. If this works, then the model is used to predict a different situation. Data are then collected in this new situation (a 'validation data set') and model predictions are tested against the new data.

Scientific modelling is a continuous improvement process. As scientific tools, bio-mathematical models are accepted as being incomplete and transient. In scientific best practice, scientists continue designing new experiments to try to find out where their models fail. In this way, they find out where their current understanding is incomplete or possibly wrong. (This is a much more efficient way of increasing scientific knowledge than just doing random experiments.)

A range of bio-mathematical models have been commercialized and are marketed as tools for predicting fatigue hazards relating to scheduling. There are also several models available in the public domain. Used properly, these models can be helpful tools in FRMS, because it is hard to visualize the dynamic interactions of processes like sleep loss and recovery, or the circadian biological clock. To use models properly requires some understanding of what they can and cannot predict. An important question to ask about any model is whether it has been validated against fatigue data from operations similar to those that you are interested in.

Currently available models:

- predict group average fatigue levels, not the fatigue levels of individual ATCs;

- do not take into account the impact of workload or personal and work-related stressors that may affect fatigue levels;
- do not take into account the effects of personal or operational mitigation strategies that may or may not be used by ATCs (caffeine consumption, exercise, improved rest facilities, etc.);
- do not predict the safety risk that fatigued ATCs represent in a particular operation, i.e., they are not a substitute for risk assessment (the next step in FRM processes – see below). Several available models try to predict safety risk by merging safety data from a range of operations in different industries, but their applicability to air traffic operations has not yet been verified.

Bio-mathematical modelling can identify potential fatigue hazards through the analysis of a roster, which can then be used as a trigger for further investigation. The most reliable use of currently available commercial models is for predicting relative fatigue levels – is the fatigue hazard likely to be greater on this schedule versus that schedule? However, model predictions should not be used without reference to operational experience when making decisions about schedule design. On the other hand, data collected in the course of FRM processes could be a rich resource for improving the performance of bio-mathematical models, if model designers follow a continuous improvement philosophy.

The Australian Civil Aviation Safety Authority has published valuable guidance on the use of bio-mathematical models in FRMS[30].

PROACTIVE HAZARD IDENTIFICATION

Proactive processes are designed to identify fatigue hazards by measuring fatigue levels in current operations. Because fatigue-related impairment affects many skills and has multiple causes, there is no single measurement that gives a total picture of an ATC's current fatigue level. For this reason, ICAO recommends using multiple sources of data for proactive hazard identification. To decide on which types of data to collect, the most important thing to consider is the expected level of fatigue hazard. More intensive fatigue monitoring should be targeted at operations where the level of the fatigue hazard is expected to be higher. `

The success of proactive processes (and of the FRMS) depends on the willingness of ATCs to continue participating in data collection. This makes it important to consider the demands placed on ATCs by different types of fatigue measurement (for example, measures such as filling out a questionnaire once, keeping a sleep/duty diary and wearing a simple device to monitor sleep every day, doing multiple performance tests and fatigue ratings across duty days, etc).

The willingness of ATCs to participate will also reflect their level of understanding of their roles and responsibilities in FRMS, and their confidence that the purpose of the data collection is to improve safety. Measuring fatigue levels may involve monitoring ATCs both on duty and off duty, because fatigue levels on duty are affected by prior sleep patterns and by waking activities outside of duty hours. There are ethical considerations around issues such as the privacy of ATCs, confidentiality and use of data, and whether ATCs are really free to refuse to participate (voluntary participation is a requirement in scientific studies involving human participants). Many countries have specific legislation around privacy and workplace responsibilities for safety that may need to be considered, in addition to conditions specified in industrial agreements.

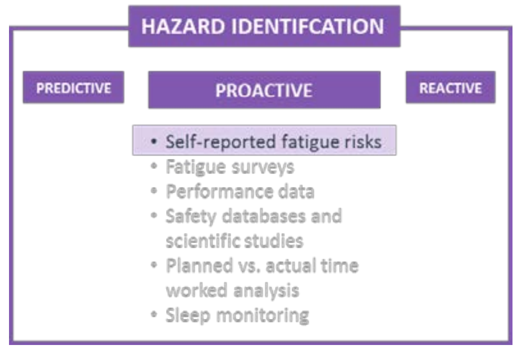
The ICAO SARPS (Annex 6 Part I, Appendix 7) list five possible methods of proactive fatigue hazard identification:

- self-reporting of fatigue risks;
- ATC fatigue surveys;
- relevant ATC performance data;
- available safety databases and scientific studies;
- analysis of planned versus actual time worked; and
- sleep monitoring.

[30] Biomathematical Fatigue Models: Guidance Document
http://www.casa.gov.au/wcmswr/_assets/main/aoc/fatigue/fatigue_modelling.pdf

The following sections work through each of these methods in some detail. Keep in mind that these are options - they are not all required all of the time.

SELF-REPORTING OF FATIGUE RISKS



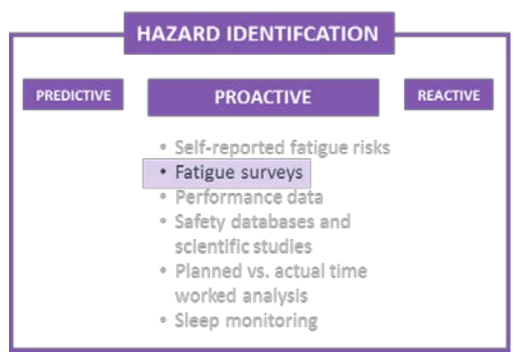
Reports about high fatigue levels or fatigue-related performance issues provide vital information about fatigue hazards in the day-to-day running of an operation, whether fatigue is managed by an FRMS or under the prescriptive duty time limits (Section 4.1.4). Reports can come from ATCs or other operational staff.

Depending on an ATS Provider's SMS hazard reporting system, a separate form for reporting fatigue may not be essential. However, adequate information needs to be gathered. This includes information on recent sleep history (minimum last 3 days), time of day of the event (if the report involves an event), and measures of different aspects of fatigue-related impairment (for example, validated alertness or sleepiness scales). Fatigue reports should also provide space for written commentary so that the person reporting can explain the context of the event and give his/her view of why it happened. An example of a fatigue report form can be found in Appendix B of this guidance. Information to identify fatigue as a contributing factor should also be included in mandatory incident/accident reporting forms.

FRMS education needs to cover the procedures for reporting fatigue. Different procedures may be involved depending on whether or not operational safety is an immediate concern, or for calling in too fatigued to undertake a duty.

Fatigue reports should be analyzed regularly by the FSAG and feedback provided as appropriate to individuals and groups about any actions taken, or why no action was considered necessary. A series of fatigue reports on a particular roster can be a trigger for further investigation by the FSAG. Fatigue reports can also provide useful examples for recurrent fatigue management training.

ATC FATIGUE SURVEYS



ATC fatigue surveys are of two basic types:

1. retrospective surveys that ask ATCs about their past experiences of sleep, fatigue and the factors causing it. These can be relatively long and are usually completed only once, or at long time intervals (for example, once a year); and
2. prospective surveys that ask ATCs to record their experiences of sleep and fatigue in real time. These are typically short and are often completed multiple times to monitor fatigue across a duty period, or roster. They usually include measures such as sleepiness, fatigue, and mood ratings.

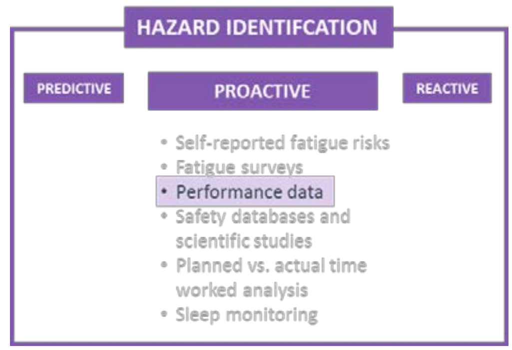
Appendix B of this guidance describes some standard fatigue and sleepiness measures (rating scales) that can be used for retrospective surveys, and others that can be used for prospective monitoring. These scales have been validated and are widely used in aviation operations. Using standard scales enables the FSAG to compare fatigue levels between operations (run by their ATS Provider or others), across time, and with data from scientific studies. This can be helpful in making decisions about where controls and mitigations are most needed.

ATC fatigue surveys can be focused on a particular operation or issue. For example, a series of fatigue reports about a particular rostered duty pattern might trigger the FSAG to undertake a survey of all ATCs working that schedule(retrospective or prospective), to see how widespread the problem is. The FSAG might also undertake a survey (retrospective or prospective) to get ATC feedback about the effects of a roster change.

Surveys can also be more general, for example providing an overview of fatigue across a particular operation type.

Compared to some other types of fatigue monitoring, ATC fatigue surveys can be conducted relatively quickly and inexpensively to provide a “snapshot” of fatigue levels and their potential causes. If a high proportion of ATCs participate in a survey (ideally more than 70%), it gives a more representative picture of the range of fatigue levels and opinions across the whole group. The information gathered in surveys is subjective (ATC’s personal recall and views), so getting a representative picture can be important for guiding the decisions and actions of the FSAG.

ATC PERFORMANCE DATA



Performance measurements provide objective data that can be used to supplement the subjective data collected in fatigue reports and survey responses. Currently there are three main approaches to monitoring ATC performance, each with strengths and weaknesses.

First, a range of simple tests developed and validated in the laboratory can be adapted for use in ATS Provider operations. These measure aspects of an ATC’s performance (for example, reaction time, vigilance, short-term memory, etc.). Things to consider when choosing a performance test for measuring ATC fatigue include the following:

- How long does the test last? Can it be completed at multiple time points (for example, just prior to a duty period, in the operations room during a duty period, and post-duty), without compromising an ATC’s ability to meet duty requirements?
- Has it been validated? For example, has it been shown to be sensitive to the effects of sleep loss and the circadian body clock cycle under controlled experimental conditions?
- Is the test predictive of more complex tasks, e.g., ATC performance in an air traffic control simulator? (Unfortunately, there is very little research addressing this question at present.)
- Has it been used in other aviation operations, and are the data available to compare fatigue levels between operations?

These ‘added performance measures’ have the disadvantage that they interrupt the normal flow of work. In addition, little is known about how an individual’s performance on simple laboratory tests relates to their performance on more complex tasks. However, this is currently the most practical approach available. Appendix B of this guidance describes a performance test that is commonly used to measure ATC fatigue – the Psychomotor Vigilance Task or PVT[31].

Second, there is considerable interest in finding ways to link ATC fatigue levels to operational data. Operational data, such as minimum safe altitude alerts, conflict alerts or actual loss of separation minima, have the advantage of being routinely collected, do not interrupt the normal flow of work, and are relevant to operational safety. The difficulty is that a multitude of factors contribute to deviations from operational norms. To use operational data as a measure of ATC fatigue would require demonstrating consistent changes in operational data that are reliably linked to other measures of ATC fatigue (for example sleep loss in the last 24 hours, time in the circadian body clock cycle, etc.). Research in this area is ongoing.

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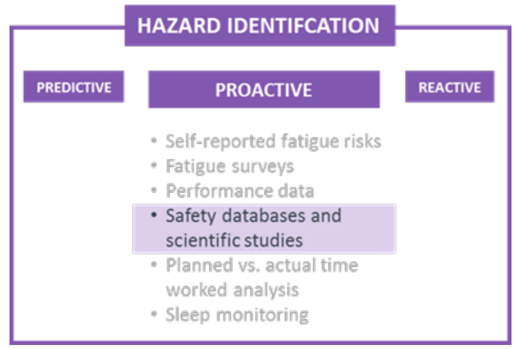
[31] Balkin TJ, Bliese PD, Belenky G, et al. Comparative utility of instruments for monitoring sleepiness-related performance decrements in the operational environment. Journal of Sleep Research*,* 13: 219-227, 2004..

The third approach involves having trained observers rating the performance of ATCs in the operation. However, this is very labour intensive and expensive. Having the observer present may also have an alerting effect and place additional demands on ATCs. These factors currently limit the usefulness of this approach for proactive fatigue hazard identification in an FRMS.

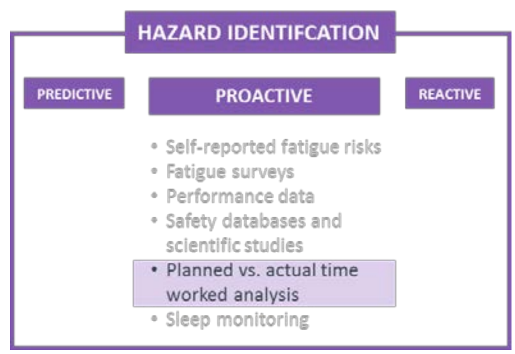
AVAILABLE SAFETY DATABASES AND SCIENTIFIC STUDIES



More general information about fatigue hazards may be available from external safety databases maintained by safety authorities, or databases maintained by research institutions. Because safety events are relatively rare, databases that collect and analyze them are an important additional source of information that complements direct measurement of fatigue levels in the operation(s) covered by the FRMS.   More and more the industry is designing databases that support the identification of threats in normal operations, which could include fatigue.

Scientific research on ATC fatigue in ATS Provider operations is expanding. Many scientific papers can be located by searching on the internet or by contacting the author(s). The particular value of these studies is in their use of more rigorous scientific approaches, which increases the reliability of their findings. The level of detail in some studies may be more than is needed for proactive identification of fatigue hazards. However, most reports and published papers have executive summaries or abstracts that outline the key findings.

ANALYSIS OF PLANNED VERSUS ACTUAL TIME WORKED

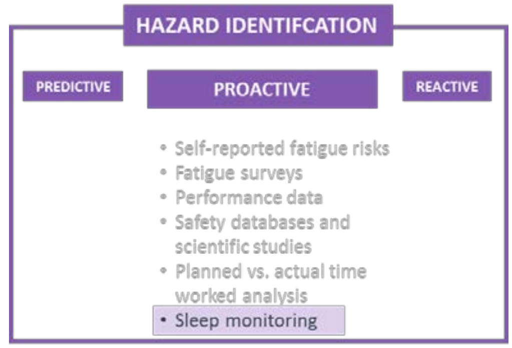


Predictive identification of fatigue hazards is possible during the planning of rostered duty patterns (see above). However, numerous unforeseen circumstances can cause changes to planned rosters, for example weather conditions, unexpected technical problems, or ATC illness. ATC fatigue relates to what is actually worked, not what is planned. Data on when ATCs actually work can identify times in a schedule when fatigue might have been higher than expected from the planned schedule. For example, the FSAG might track how often each month:

- duty periods end at least 30 minutes later than scheduled;
- the maximum scheduled duty day specified in the FRMS policy is exceeded (e.g., duty days longer than 12 hours);
- reserve ATCs are called out on particular duty patterns, at a particular facility, etc;
- roster swapping occurs.

Data on planned and actual rosters is readily available to operators, but the FSAG may need to establish additional processes for analyzing it to identify potential fatigue hazards in specific parts of the operations covered by the FRMS.

MONITORING ATCS' SLEEP



Given the primary importance of sleep loss and recovery in the dynamics of ATC fatigue, another valuable and commonly used method for proactive fatigue hazard identification is sleep monitoring. Sleep can be monitored in a variety of ways, all of which have advantages and disadvantages (for details see Appendix B of this guidance).

The simplest and least expensive method of monitoring sleep is to have ATCs complete a daily sleep diary before, during, and after the duty period being studied. They are typically asked to record when they sleep, and to rate the quality of their sleep, as soon as possible after waking up. This can be done using a paper diary or tablets, smart phones, etc).

A more objective measure of sleep/wake patterns can be obtained by continuously monitoring movement, using an "actigraph". This is a wristwatch-like device that is worn continuously (except when showering or bathing). Data on the amount of movement is recorded regularly (typically every minute) and is downloaded to a computer after several weeks, for subsequent analysis. Because actigraphs are not cheap (yet), usually only a sample of ATCs on a given duty pattern would have their sleep monitored in this way. Current systems also require a trained person to process and analyze the data.

SELECTING MEASURES TO USE FOR PROACTIVE HAZARD IDENTIFICATION

A lot of options have just been described for measuring ATC fatigue. The following general points are intended to help ATS Providers to decide which measures to use for proactive hazard identification and when to use them:

- Fatigue-related impairment affects many skills and has multiple causes, so there is no single measurement that gives a total picture of an ATC's current fatigue level.
- The most important thing to consider in choosing fatigue measures is the expected level of fatigue risk. All measures require resources (financial and personnel) for data collection and analysis. Limited resources need to be used effectively to identify fatigue hazards and to help the FSAG prioritize where controls and mitigations are most needed.
- A core set of measures can be selected for routine monitoring. For example, ATC fatigue reports and regular analyzes of planned versus actual schedules could be used for ongoing monitoring of fatigue hazards.
- An additional range of measures can be available to be used if a potential hazard is identified and the FSAG decides that more information is needed. Again, the measures selected need to reflect the expected level of risk.

Balance needs to be maintained between gathering enough data for the FSAG to be confident about its decisions and actions, and the additional demands that data collection can place on ATCs (sometimes described in science as 'participant fatigue').

REACTIVE HAZARD IDENTIFICATION PROCESSES

Reactive processes are designed to identify the contribution of ATC fatigue to safety reports and events that have occurred. The aim is to identify how the effects of fatigue could have been mitigated, to reduce the likelihood of similar occurrences in the future. The ICAO SARPs (Annex 11, Appendix 7) list four examples of triggers for reactive processes:

- fatigue reports;
- confidential reports;

} i.e. voluntary hazard reports

- audit reports; and
- incident reports (i.e. event investigations).

Depending on the severity of the event, a fatigue analysis could be undertaken by the FSAG, the ATS Provider's safety department, or an external fatigue expert or accident investigation agency. The findings of any fatigue investigation should be recorded as part of the FRMS documentation.

There is no simple test (such as a blood test) for fatigue-related impairment. To establish that fatigue was a contributing factor in an event, it has to be shown that:

- the person was probably in a fatigued state; and
- the person took particular actions or decisions that were causal in what went wrong; and
- those actions or decisions are consistent with the type of behaviour expected of a fatigued person.

A basic method for fatigue investigation is summarized in Appendix B of this guidance.

5.2.3 FATIGUE RISK ASSESSMENT

Once a fatigue hazard has been identified, the level of risk that it poses has to be assessed and a decision made about whether or not that risk needs to be mitigated. For ATS Providers managing fatigue risk within prescribed limits through their SMS, existing SMS risk assessment methodologies may be sufficient. Using an FRMS requires more effort on fatigue-specific risk assessment.

Where an ATS provider operates under FRMS, more effort on fatigue-specific risk assessment is expected, with particular focus on assessing the time in a duty period or pattern of work where potential fatigue impairment poses the greatest risk.

Assessing the risks associated with the hazard of "fatigue" can be challenging because:

- fatigue can diminish an individual's ability to perform almost all operational tasks; and
- there are many factors which can contribute to an individual's level of impairment. Many of these factors may be unpredictable.

Further, not only does an individual's ability to perform safety-related tasks decline with increasing fatigue but their capacity to respond to unexpected increases in task complexity also diminishes. Such increases in task complexity can be associated with managing threats, such an ATC presented with an unexpected surge in air traffic. Conversely, low workload can unmask physiological sleepiness. Fatigue is rarely the sole cause of an event but it is regularly a likely contributor to varying degrees. The level of risk that fatigue presents is dependent on the task and the context in which the task is being performed.

Assessing fatigue risks using any methodology is limited because it is unclear how the complex interactions that exist between fatigue factors should be weighted. All methods need to be used with full recognition of their limitations.

Because of these factors, current methodologies for assessing risks, when applied to fatigue, are all limited to some degree. Further, the usefulness in application of all risk assessment methodologies is directly related to the knowledge and experience of the user. However, with growing maturity of SMS and more operational FRMS experience around the world, advances are continuing to be made in the way fatigue risks are assessed.

USING RISK MATRICES TO ASSESS FATIGUE RISKS

Typically, safety risk is defined as the projected likelihood and severity of the consequence or outcome from an existing hazard or situation. A likelihood and severity matrix is commonly used by many ATS Providers to assess all types of risk and assist them to decide whether it is necessary to invest resources in mitigation. The level of the risk associated with a hazard and whether that risk level is "tolerable" is determined by plotting its position on the matrix. The main disadvantage of using matrices to assess risks is that controls and mitigations are not systematically taken into account.

Table 5-1 presents an example of severity classification categories from ICAO's Safety Management Manual (Doc. 9859, 2013, 3rd Edition). Table 5-2 presents an associated risk assessment matrix.

Table 5-1. Severity Classifications (from ICAO Safety Management Manual, Doc 9859, 3rd Edition)

Severity	Meaning	Value
Catastrophic	- Multiple deaths - Equipment destroyed	A
Hazardous	- A large reduction in safety margins, physical distress or a workload such that crew members or controllers cannot be relied upon to perform their tasks accurately or completely - Serious injury - Major equipment damage	B
Major	- A significant reduction in safety margins, a reduction in the ability of crew members or controllers to cope with adverse operating conditions as a result of increase in workload, or as a result of conditions impairing their efficiency - Serious incident - Injury to persons	C
Minor	- Nuisance - Operating limitations - Use of emergency procedures - Minor incident	D
Negligible	- Little consequences	E

Table 5-2. Safety Risk Assessment Matrix (adapted from ICAO Safety Management Manual, Doc 9859, 3rd Edition)

Likelihood		Fatigue Severity							
		Catastrophic A		Hazardous B		Major C		Minor D	Negligible E
Frequent	5	5A	Accident	5B	Large safety reduction	5C	Significant safety reduction	5D	5E
Occasional	4	4A		4B		4C		4D	4E
Remote	3	3A		3B		3C		3D	3E
Improbable	2	2A		2B		2C		2D	2E
Extremely Improbable	1	1A		1B		1C		1D	1E

When using risk assessment matrices, ATS Providers are expected to customise the severity and likelihood categories. The value of using the severity classifications from to assess fatigue risks is limited because the worst foreseeable consequence of fatigue-affected performance when performing a safety critical task is always catastrophic.

With regards to fatigue risks:

- to understand the severity of consequences, it is necessary to consider not just how fatigued an individual may be, but also the resulting impact on the individual's performance and how that diminished performance will manifest in the workplace.
- it is the task being undertaken (when fatigued) that determines the severity of the consequences. For example, if an ATC falls asleep in the office while performing a routine administrative task, there are no immediate safety consequences. However, if the same ATC falls asleep at their work station while performing a safety critical task, it can lead to an accident.

In other words, to assess different types of fatigue risks using a matrix, different severity classifications are needed to better reflect the variety of possible consequences of fatigue-affected performance. Likelihood classifications will depend on the type of fatigue severity classification used. Therefore, when using risk assessment matrices in an FRMS, it is necessary for fatigue subject matter experts to customise their matrices by carefully selecting how severity and likelihood are classified. The following provide simple examples of how severity and likelihood classifications can be adapted in order to assess different fatigue risks.

SEVERITY CLASSIFICATIONS:

As mentioned above, different severity classifications are needed to better reflect the variety of possible consequences of fatigue-affected performance. Examples of methods for classifying severity classifications include:

- Severity classification may reflect "perceived fatigue levels" on the basis that the more fatigued an individual feels, the more likely their performance will decline. In Table 5-3 the subjective Samn-Perelli Scale is used, although other subjective measures may also be used (see Appendix B of this manual and more detailed description in any of the associated Implementation Manuals).
- Bio-mathematical models aim to predict the average individual's fatigue level at different points across a planned roster. Once the user is able to relate the model's results to the operational context of their organization, severity classifications may be based on defined bio-mathematical model thresholds.
- Severity classification may reflect the number of relevant fatigue factors associated with a specific duty or work pattern, as described in the next section (Assessing a Specific Duty or Work Pattern for Fatigue Risks).

Table 5-3. Example Fatigue Severity Classification: Perceived levels of fatigue.

Samn-Perelli Score	Meaning	Value
7	Completely exhausted, unable to function effectively	A
6	Moderately tired, very difficult to concentrate	B
5	Moderately tired, let down	C
4	A little tired	D
3	Okay, somewhat fresh	E
2	Very lively, responsive, not at peak	E
1	Fully alert, wide awake	E

LIKELIHOOD CLASSIFICATIONS

Generally, fatigue likelihood is based on subjective estimations of how often a particular consequence of fatigue-affected performance might occur. Because this is contextually dependent, there are infinite variables that influence the operational consequences.

Where a specific fatigue factor related to a type of shift or work schedule is being assessed (e.g. < 7h between duties; commencement of duties prior to 7am), the measurable frequency with which an individual may experience or be exposed to it may be preferred to determine likelihood classifications.

ASSESSING A SPECIFIC DUTY OR WORK PATTERN FOR FATIGUE RISKS

In an FRMS, an ATS Provider will need to consider the fatigue risks associated with a specific duty or work pattern in order to determine appropriate mitigation strategies. Many different tools and methods are available to assess risks and often they are used in combination.

One way of estimating the fatigue risk associated with a particular work pattern is through the use of a bio-mathematical model. Current models are generally designed to predict levels of average operator fatigue (performance and/or subjective ratings), not the safety consequences of that fatigue in specific operational environments. While informed use of models can make them very helpful for the purposes of risk assessment, operational decisions should not be based solely on bio-mathematical thresholds.

5.2.4 MITIGATION

The risk assessment process determines whether or not a fatigue hazard requires mitigation. The most important thing to consider in choosing fatigue mitigations is the estimated level of associated fatigue risk. All mitigations require resources (effort, time, costs). Limited resources need to be prioritized where mitigations are most needed to effectively control fatigue risk.

Careful selection of effective fatigue mitigations is based on data, rather than an uninformed urge to “do something”. Identifying suitable mitigations comes from sources such as scientific studies, relevant scientific literature and FRMS experience of the ATS Provider or other similar ATS Providers.

Effective controls and mitigation strategies go beyond rest- and duty-times. For duties that are either very long, start very early in morning, finish late at night or go through the night, controls and mitigations need to be considered in the context of successive days and duties. Special attention needs to be given to the circadian influences on sleep- and wake-times regardless of rest- and work- times. Mitigation strategies that focus solely on an isolated duty may not address the effects of cumulative fatigue and become ineffective across a work roster. Therefore, the identification of fatigue mitigations requires a broad understanding of scientific knowledge, operational experience and applicable regulations. While an ATS Provider’s safety management structure will influence who makes the decision about whether or not a fatigue hazard requires mitigation, it is recommended that the FSAG identify the appropriate mitigations and be consulted in all fatigue mitigation decisions.

5.2.5 MONITORING THE EFFECTIVENESS OF MITIGATIONS

Data monitored in the FRM process loop can be used to generate fatigue safety performance indicators (SPIs). SPIs provide a metric to monitor the effectiveness of fatigue controls and mitigations. If trends in SPIs indicate that current controls or mitigations are not adequate and that a fatigue hazard remains, then a detailed risk assessment of the issue should be conducted in line with the ATS Provider’s processes and new mitigations proposed where necessary. SPIs are also a critical source of information for the FRMS safety assurance processes (see Section 5.3). SPIs need to be identified in consultation with the State during the FRMS approval process (see Chapter 7) and they may change as experience with FRMS builds and as operational circumstances alter.

Appendix F provides examples of safety performance indicators used to examine whether a schedule change actually resulted in the increased opportunities for recovery that were expected.

If the mitigations perform to an acceptable standard (i.e. the relevant SPIs reach their pre-defined acceptable values or targets), they become part of normal operations. If the controls and mitigations do not reduce the fatigue hazard to an acceptable level, it will be necessary to re-enter the FRM processes at the appropriate step. This could require: gathering of additional information and data, re-evaluation of the safety risks associated with the hazard, and/or implementing and evaluating new controls and mitigations.

5.3 FRMS SAFETY ASSURANCE PROCESSES

FRMS safety assurance processes form the second closed loop of the operational activities of the FRMS (see), monitoring how well the entire FRMS is functioning. Using SPIs from the FRM processes, along with information and expertise from other sources, the FRMS Safety Assurance processes have three main functions:

1. To monitor that the FRMS is delivering an acceptable level of fatigue risk that meets the safety objectives defined in the FRMS policy and any other regulatory requirements.
2. To monitor changes in the operational environment and the organization that could affect fatigue risk in the operations covered by the FRMS, and to identify ways in which FRMS performance can be maintained or enhanced prior to the introduction of changes.
3. To provide ongoing feedback that drives continuous improvement of the FRM processes and other FRMS components.

Responsibility for FRMS safety assurance activities may be distributed differently, depending on the number and complexity of operations covered by the FRMS and the size of the ATS Provider. Typically, FRMS safety assurance processes would be the responsibility of the SMS team. Some of the FRMS safety assurance processes may be undertaken by the FSAG. However activities such as audits of the FRM processes should be undertaken by a different organizational unit.

The following subsections describe the functions of the FRMS safety assurance processes further. Examples of FRMS safety assurance processes are provided in Appendix G.

5.3.1 MONITORING FRMS SAFETY PERFORMANCE

Performance of the FRMS should be examined through FRMS SPIs that are identified through a variety of different sources, including:

- Trends in SPIs from the FRM processes (see Section 5.2 above) and the ATS Provider's SMS;
- hazard reporting and investigations;
- audits and surveys; and
- reviews and fatigue studies.

When FRMS SPIs are not at an acceptable level, the controls and mitigations in use may need to be modified via the FRM processes (see Figure 5.1). A review of relevant fatigue studies might provide new ideas. Investigation of how hazard reports are followed up or examination of trends in fatigue-related hazards or incidents may be required. Audit findings may need to be reviewed, checks may need to be made to determine whether FSAG recommendations are followed, whether fatigue-related training is being delivered as expected, or whether the FSAG is functioning according to its terms of reference, to find out why the FRMS is not working as intended. It may also be appropriate to review the SPIs to ensure that they are still appropriate measures of the safety performance of the FRMS.

The use of different SPIs from varying sources to assess FRMS performance is discussed further below.

SAFETY PERFORMANCE INDICATORS (SPIS) FROM FRM PROCESSES

Data monitored in the FRM process loop can be used to generate fatigue safety performance indicators (SPIs). SPIs are also used in the FRMS Safety Assurance loop to check whether the FRMS is delivering an acceptable level of fatigue risk. SPIs provide a metric to guide decision making. For example, changes in SPIs might signal a new fatigue hazard, and they can be used to track the effectiveness of new mitigations.

For SPIs to be useful in decision making, acceptable values or targets need to be set. These acceptable values or targets need to be appropriate to the level of risk in a given operation, and/or in the 'tolerable' or 'acceptable' regions of risk assessments. Having a variety of SPIs is expected to give a more reliable indication of fatigue levels and of the performance of the FRMS. SPIs may also need to be revised as operational circumstances change and it is important to note that different SPIs may be appropriate in different types of operations. SPIs need to be identified in consultation with the regulator during the FRMS approval process (see Chapter 7) and they may change as experience with FRMS builds and as operations evolve.

Common types of fatigue SPIs include:

- operational SPIs that monitor the duty-related causes of fatigue;
- SPIs based on reactive fatigue data. Examples include the number of fatigue reports (e.g., on particular schedule or work pattern), fatigue-related incidents), and measures of absenteeism;
- SPIs based on proactive monitoring of actual levels of ATC fatigue.

OPERATIONAL SAFETY PERFORMANCE INDICATORS

Operational SPIs can often be derived from data that are already routinely collected by ATS Providers. For example, operational SPIs and their acceptable values/ targets can be generated by comparing planned versus actual Rostered duty patterns. They need to reflect the specific causes of fatigue risk in different operations, such as early starts and long duty days in specific on operation type vs. another operation type.

Examples of operational fatigue-related SPIs Include:

Schedule-related fatigue SPIs:

- Number of reported safety events where fatigue due to rostered duty pattern is indicated or reported as a causal or contributing factor.
- Amount and instances of overtime usage.
- Correlating operational SPIs (such as those generated through automated safety nets, e.g conflict alerts, minimum safe altitude warnings, runway incursion alerts) with high fatigue risk times in schedules.

Proactive/reactive fatigue SPIs

- Measured data outside acceptable thresholds (e.g., sleepiness ratings, PVT scores, or inadequate sleep duration).

- Number of fatigue-related incidents (should be normalized over total operations, or another number, such as total number of all voluntary safety reports).

- Number of fatigue-related events associated with a particular schedule for which fatigue reports have been received.

ATC FATIGUE SAFETY PERFORMANCE INDICATORS

Monitoring ATC fatigue as a source of data for SPIs is relatively resource-intensive and time-consuming compared to using routinely collected operational data. However it may be justified in particular circumstances such as: in response to significant fatigue reports on a particular rostered duty pattern (to further identify the extent and severity of the hazard); in response to a safety incident; or as part of the operational validation of a new operation. As a general rule, the type of monitoring undertaken should be appropriate to the expected level of fatigue and safety risk.

BIO-MATHEMATICAL MODEL THRESHOLDS AS SPIS

Threshold values on bio-mathematical model predictions are sometimes proposed as SPIs. Current models are generally designed to predict measures of average fatigue levels (performance and/or subjective ratings), not the safety consequences of that fatigue in specific operational environments. In other words, bio-mathematical models are not a stand-alone substitute for the FRM process loop (this is also true for other types of SPIs).

Given that fatigue affects diverse aspects of waking function, operational decisions should not be based on any single measure of an ATC's functional status, including thresholds applied to bio-mathematical model predictions of an ATC's functional status.

HAZARD REPORTING AND INVESTIGATIONS

The FSAG should record all fatigue hazards identified in the FRM processes, together with any actions taken to mitigate those hazards, in the FRMS documentation. The fatigue hazard register should be regularly evaluated as part of the FRMS safety assurance processes.

Trends in voluntary fatigue reports (by ATCs or others) can also be monitored as indicators of the effectiveness of the FRMS. Safety events in which ATC fatigue has been identified as a contributing factor will be less common than fatigue reports. However, regular review of these events may also highlight areas where functioning of the FRMS could be improved. The value of both these sources of information depends on using appropriate methods for analyzing for the role of fatigue (see Appendix B of this guidance).

AUDITS AND SURVEYS

Audits periodically assess the effectiveness of the FRMS, focusing on the integrity of the FRM processes. They should address questions such as:

- are all departments addressing the recommendations of the FSAG?
- are ATCs using mitigation strategies as recommended by the FSAG?
- is the FSAG maintaining the required documentation of its activities?
- are all SPIs maintaining acceptable values or being actively managed?

Internal audits need to be conducted by a unit in the ATS Provider's organization that is external to the FSAG. Feedback from regulatory audits can provide useful information for FRMS safety performance monitoring. Another type of audit that can be used in this context is to have an independent scientific review panel that periodically reviews the activities of the FSAG and the scientific validity of their decisions. A scientific review panel can also provide the FSAG with periodic updates on new scientific developments relevant to the FRMS.

Trends in SPIs can provide valuable information in an FRMS safety assurance audit. These may include SPIs used by the FSAG in the FRM processes, as well as indicators that capture more global aspects of the safety performance of the FRMS, for example safety performance metrics within the ATS Provider's SMS.

Surveys can provide information on the effectiveness of the FRMS. For example they can document how rostered duty patterns are affecting ATCs, either by asking about their recent experiences (retrospective) or tracking them across time (prospective). Surveys for this purpose should include validated measures, such as standard rating scales for fatigue and sleepiness, and standard measures of sleep timing and quality (see Appendix B of this guidance). Note that a high response rate (ideally more than 70%) is needed for survey results to be considered representative of the entire group, and response rates tend to decline when people are surveyed too frequently ('participant fatigue').

REVIEWS AND FATIGUE STUDIES

A safety review would be carried out to evaluate whether the FRMS is likely to be adequate to deal with a change[32], for example the introduction of a new type of operation or a significant change to an existing operation covered by the FRMS. The review evaluates the likely effects of the change on fatigue risk and the appropriateness and effectiveness of the FRM processes to manage those effects.

In FRMS safety assurance processes, fatigue studies are mainly used as a source of broader information from external sources, about common issues in FRMS (whereas in the FRM processes they are carried out to evaluate specific fatigue hazards). Sources of information can include the experience of other ATS Providers, industry-wide or State-wide studies, or scientific studies. Such information can be particularly valuable in situations where the ATS Provider has limited experience and knowledge on which to build a safety case.

[32] See ICAO Doc 9859 Safety Management Manual.

5.3.2 MAINTAINING FRMS PERFORMANCE IN THE FACE OF CHANGE

The ATS Provider environment is dynamic and changes are a normal part of ATS Provider operations. They may be driven by external factors (for example, new regulatory requirements, or changing security requirements) or by internal factors (for example, management changes, new routes, equipment, or procedures). Changes can introduce new fatigue hazards into an operation, which need to be managed. Changes may also reduce the effectiveness of controls and mitigations that have been implemented to manage existing fatigue hazards.

The ICAO SARPs (Annex 11, Appendix 7) require an ATS Provider to have formal processes for the management of change which must address, but are not limited to,:

- identification of changes in the operational environment that may affect the FRMS;
- identification of changes within the organization that may affect the FRMS; and
- consideration of available tools which could be used to maintain or improve FRMS performance prior to implementing changes.

When a planned change is identified, the FSAG can undertake the following steps.

1. Use the FRM and SMS processes to identify fatigue hazards, assess the associated risk, and propose controls and mitigations.
2. Obtain appropriate management and/or regulatory sign-off that the level of residual risk is acceptable.
3. Document the strategy for managing any fatigue risk associated with changes.

During the period of implementation of the change, FRMS safety assurance monitoring can provide periodic feedback to line managers that the FRMS is functioning as intended in the new conditions. An example would be having a validation period for a new air space configuration, during which additional monitoring of ATC fatigue is undertaken by the FSAG, together with more frequent assessment of SPIs as part of the FRMS safety assurance processes.

Changes in the operational environment may also necessitate changes in the FRMS itself. Examples include bringing new operations under the scope of the FRMS, collecting different types of data, adjustments to training programmes, etc. The FSAG would normally propose such changes and obtain approval for them from appropriate management. FRMS safety assurance monitoring (described in Section 5.3.1) will track the effects of these changes on the overall effectiveness of the FRMS.

5.3.3 CONTINUED IMPROVEMENT OF THE FRMS

The ICAO SARPs (Annex 11, Appendix 7) require an ATS Provider to provide processes for the continuous improvement of the FRMS that must include, but are not limited to:

- the elimination and/or modification of risk controls that had unintended consequences or are no longer needed due to changes in the operational or organizational environment;
- routine evaluations of facilities, equipment, documentation and procedures; and
- the determination of the need to introduce new processes and procedures to mitigate emerging fatigue-related risks.

Identifying emerging fatigue hazards that are not the result of planned changes is also an important function of FRMS safety assurance processes, which take a broader system perspective than the FRM processes. Any newly identified fatigue hazard(s), or combination of existing hazards for which current controls are ineffective, should be referred back to the FSAG for evaluation and management using the FRM processes.

Changes made to the FRMS should be documented by the FSAG so that they are available for internal and regulatory audit.

5.3.4 RESPONSIBILITY FOR FRMS SAFETY ASSURANCE PROCESSES

To deliver effective oversight of the functioning of the FRMS, the FRMS safety assurance processes need to operate in close communication with the FSAG, but with a degree of independence from it. Figure 5-3 describes an example of how responsibility for the FRMS safety assurance processes might be assigned in a large organization.

In this example, the FSAG is accountable to the Safety Team for air traffic control operations. The Safety Team is accountable in turn to the Executive Safety Team. In Figure 5-3, these lines of accountability are indicated by heavy arrows. (In a large organization, there might eventually be separate FRMSs and FSAGs for ATC operations and technical operations.) The thin lines represent information flows.

Primary responsibility for the FRMS safety assurance processes is assigned to a Quality Assurance person or team that is accountable to the Executive Safety Team and:

- maintains close communication with the FSAG;
- makes recommendations to the Safety Team for ATC Operations, as needed to improve the functioning of the FRMS;
- makes recommendations to the Safety Team for Technical Operations, as needed to improve the functioning of the FRMS;
- monitors changes in the regulatory environment and the operating environment that may affect the functioning of the FRMS.

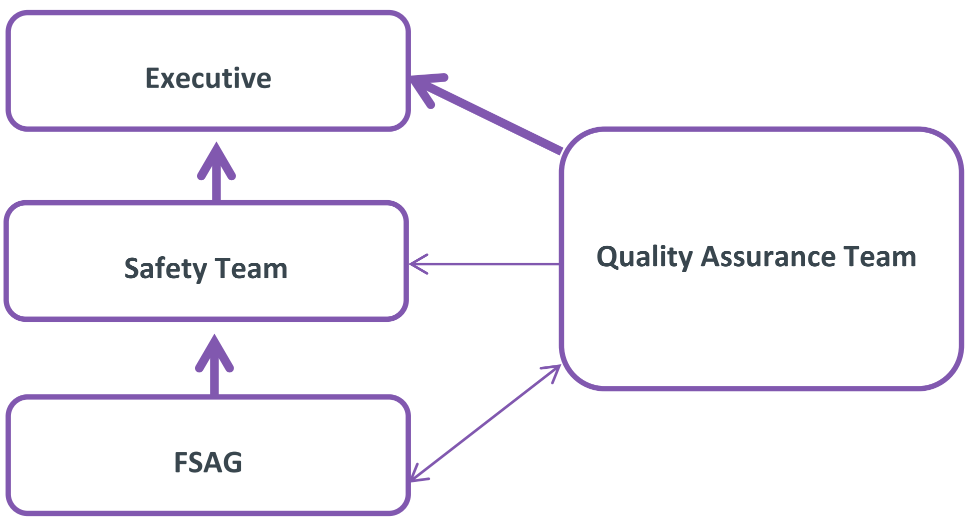


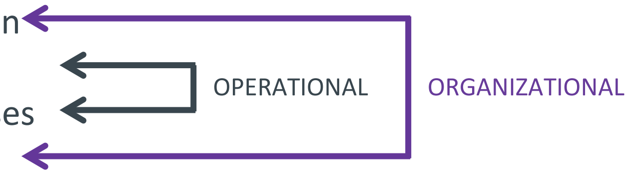
Figure 5-2. Example of assignment of responsibility for FRMS safety assurance processes in the operations department of a large ATS Provider

In a smaller ATS Provider, responsibility for the FRMS safety assurance processes might reside with an individual rather than a team. This individual may also have a variety of other quality assurance responsibilities. A single safety team might be responsible for Air Traffic Control operations.

CHAPTER 6. FRMS: ORGANIZATIONAL COMPONENTS

The operational activities of an FRMS discussed in Chapter 5 are governed by the FRMS policy and supported by FRMS promotion processes, and documentation must be kept of all FRMS activities. These form the organizational components of the FRMS. This Chapter describes the ICAO requirements for these organizational components.

1. FRMS Policy and Documentation
2. FRMS Processes
3. FRMS Safety Assurance Processes
4. FRMS Promotion Processes



6.1 FRMS POLICY

The FRMS policy may be a stand-alone document or be incorporated in an ATS Provider's SMS policy (check your Regulator's requirements). In either case, the ICAO SARPs (Annex 11, Appendix 7) require that the FRMS policy clearly defines all elements of the FRMS, is easily identifiable, and is able to be reviewed in its entirety.

6.1.1 SCOPE OF THE FRMS

An FRMS policy must clearly state which operations are covered by the FRMS. All operations not covered by the FRMS must operate under the applicable prescriptive work period limits and non-work period minima. It is expected that the scope of the FRMS may expand as an ATS Provider's familiarity and experience with FRMS builds, and both ATS Providers and regulators need to give consideration to how this can be accommodated. As an example, the regulator would require an ATS Provider to present a safety case for each new operation to be managed under the FRMS. This safety case is essentially similar to that which an ATS Provider would prepare when applying to operate under a variation from the prescriptive work period limits and non-work period minima (see Chapter 4). The nature and complexity of the safety case needs to be sufficient to persuade the regulator that the ATS Provider can use their FRMS to manage fatigue risk to provide a level of safety equivalent to, or better than that achieved through complying with the prescriptive fatigue management regulations. The following is an example of statements of the scope of an FRMS.

EXAMPLE 1: ATS PROVIDER A - LARGE ATS PROVIDER WITH A WIDE RANGE OF OPERATIONS

This statement of scope allows flexibility for additional operations to be brought under the FRMS without having to change the policy statement. For example, suppose that the Operations Manual initially lists all terminal, low-level, high-level and oceanic operations, and only includes ATCs. Subsequently, ATS Provider A decides that it wants to add its 24-hour towers to the FRMS. With approval from the regulator, the 24-hour towers can be added to the list in the Operations Manual, without requiring a change to the FRMS policy statement. This change makes the FSAG responsible for establishing FRM processes and FRMS safety assurance processes applicable to the 24-hour tower operations. The addition of ATC assistants to the FRMS would require an amended policy statement.

> The FRMS for ATS provider A will apply to all operations as specifically identified in the Operations Manual. All other operations will be conducted under the prescriptive work period limits and non-work period minima.

EXAMPLE 2: ATS PROVIDER B - ATS PROVIDER OPERATING 24/7 AND 16/7 OPERATIONS.

ATS Provider B chooses to operate its 24/7 operations under FRMS and to operate its 16/7 operations under the prescriptive work period limits and non-work period minima regulations.

> The FRMS for ATS provider B will apply to all 24/7 operations as specifically identified in the Operations Manual. All other operations will be conducted under the prescriptive work period limits and non-work period minima regulations.

6.1.2 OTHER REQUIREMENTS FOR AN FRMS POLICY

The ICAO SARPs (Annex 11, Appendix 7) require that the FRMS Policy must:

a. reflect the shared responsibility of management, ATCs, and other involved personnel;
b. clearly state the safety objectives of the FRMS;
c. be signed by the accountable executive of the organization;
d. be communicated, with visible endorsement, to all the relevant areas and levels of the organization;
e. declare management commitment to effective safety reporting;
f. declare management commitment to the provision of adequate resources for the FRMS;
g. declare management commitment to continuous improvement of the FRMS;
h. require that clear lines of accountability for management, ATCs, and all other involved personnel are identified; and
i. require periodic reviews to ensure it remains relevant and appropriate.

SHARED RESPONSIBILITY

Primary responsibility for fatigue management rests with managers who control the activities of personnel and the distribution of resources in the organization[33]. The FRMS is an organizational system that enables them to meet that responsibility. However, the FRMS can only be effective if all stakeholders are aware of their responsibilities and have the commitment, skills and resources to meet those responsibilities.

The particular nature of ATC fatigue as a safety hazard also makes shared responsibility essential. Fatigue is affected by all waking activities, not only work demands (Chapter 2). ATCs have personal responsibility because they can choose the amount of time they spend trying to sleep during available rest breaks, and choose when to use personal fatigue mitigation strategies while on duty. In addition, their cooperation is vital for voluntary reporting of fatigue hazards. Cooperation is also essential when ATC fatigue needs to be measured to provide data for FRM processes and FRMS safety assurance processes. ATCs' willingness to cooperate will depend on their confidence that the ATS Provider is committed to the principles of an effective safety reporting culture. ATC representation on the FSAG can help promote the 'buy-in' of ATCs that is essential for an effective FRMS.

SAFETY OBJECTIVES AND SAFETY PERFORMANCE INDICATORS

The safety objectives in the FRMS policy specify the standards that the ATS Provider and the regulator have agreed must be achieved by the FRMS. The FRMS policy also needs to identify safety performance indicators and targets that will be used to measure how well the FRMS is meeting its safety objectives. Examples of safety performance indicators can be found in Section 5.4

The FRMS policy needs to be reviewed periodically by the ATS Provider, to ensure that it is adequate to meet changing operational demands. In addition, it may be subject to periodic review by the regulator. The example in Section 6.2.1 is intended to be used as guidance, not a template. Each ATS Provider needs to develop an FRMS policy appropriate to their specific organizational context and operational needs.

[33] ICAO Safety Management Manual (Doc 9859)

6.2 FRMS DOCUMENTATION

The documentation describes all the elements of the FRMS and provides a record of FRMS activities and any changes to the FRMS. It is essential for internal and external audit of the FRMS. The documentation can be centralized in an FRMS Manual, or the required information may be integrated into an ATS PROVIDER's SMS Manual. However, it needs to be accessible to all personnel who may need to consult it, and to the regulator for audit.

ICAO (Annex 11, Appendix 7) requires that an ATS Provider must develop and keep current FRMS documentation that describes and records:

a. FRMS policy and objectives (an example is provided in Section 6.2.1);
b. FRMS processes and procedures;
c. accountabilities, responsibilities and authorities for these processes and procedures;
d. mechanisms for ongoing involvement of management, ATCs, and all other involved personnel;
e. FRMS training programme, training requirements and attendance records;
f. scheduled and actual work period limits and non-work period minima, with deviations and reasons for deviations noted; and
g. FRMS outputs including findings from collected data, recommendations, and actions taken.

It is recommended that the documentation includes the terms of reference for the FSAG and that this is maintained on an ongoing basis by the FSAG (an example is provided in Section 6.2.2).

6.2.1 EXAMPLE OF FRMS POLICY STATEMENT

ATS Provider A's Fatigue Risk Management Policy

As a commitment to the continuous improvement of safety, ATS provider A has a Fatigue Risk Management System (FRMS) to manage fatigue-related risks.

This FRMS applies to the operations as defined in the Air Traffic Control Operations Manual. All other operations will operate under the prescriptive fatigue management regulations. The FRMS Manual describes the processes used for identifying fatigue hazards, assessing the associated risks, and developing, implementing, and monitoring controls and mitigations. The FRMS Manual also describes the safety assurance processes used to ensure that the FRMS meets its safety objectives, and how the FRMS is integrated with our industry-leading SMS programmes. Under this policy:

Management is responsible for:

- providing adequate resources for the FRMS;
- providing adequate staffing levels to support rosters that manage fatigue risk within acceptable limits;
- providing Air Traffic Controllers with adequate opportunity for recovery sleep between duties;
- creating an environment that promotes open and honest reporting of fatigue-related hazards and incidents;
- providing fatigue risk management training to Air Traffic Controllers, their managers and other FRMS support staff;
- demonstrating active involvement in and understanding of the FRMS;
- ensuring that the fatigue risks within their area(s) of responsibility are managed appropriately;
- regularly consulting with Air Traffic Controllers regarding the effectiveness of the FRMS; and
- demonstrating continuous improvement and providing annual review of the FRMS.

Air Traffic Controllers are required to:

- make appropriate use of their rest periods (between shifts or periods of duty) to obtain sleep;
- participate in fatigue risk management education and training;
- report fatigue-related hazards and incidents as described in the FRMS Manual;
- comply with the Fatigue Risk Management Policy;
- inform their manager or supervisor immediately prior to or during work if:
  - they know or suspect they or another crew member are suffering from unacceptable levels of fatigue; or
  - they have any doubt about their or another ATC's capability to accomplish their duties.

Fatigue Risk Management must be considered a core part of our business as it provides a significant opportunity to improve the safety and efficiency of our operation and to maximize the well-being of our staff.

Policy authorized by:

(Signed) ___________________________________ Date: ___________________________

Insert Title (Accountable Executive)

6.2.2 EXAMPLE OF TERMS OF REFERENCE FOR AN FSAG

The following example is not a template. Not all the items suggested here will be needed by every ATS Provider. Each ATS Provider needs to consider its operational and organizational profile in deciding the composition of the FSAG, its activities, and its interactions with other parts of the ATS Provider's organization.

ATS Provider B's Terms of Reference: Fatigue Safety Action Group (FSAG)

Purpose

The Fatigue Safety Action Group (FSAG) is responsible for coordinating all fatigue risk management activities at ATS provider B. This includes responsibility for gathering, analyzing, and reporting on data that measures fatigue among Air Traffic Controllers. The FSAG is also responsible for ensuring that the FRMS meets the safety objectives defined in the FRMS Policy, and that it meets regulatory requirements. The FSAG exists to improve safety, and does not get involved in industrial issues.

Terms of Reference

The FSAG is directly responsible to the VP Operations and reports through the Departmental Safety organization. Its membership will include at least one representative of each of the following groups: management, scheduling, and Air Traffic Controllers, with other specialists as required.

The tasks of the FSAG are to:

- develop, implement, and monitor processes for the identification of fatigue hazards;
- ensure that comprehensive risk assessment is undertaken for fatigue hazards;
- monitor risk controls and make recommendations to management on mitigations as needed to manage identified fatigue hazards;
- develop, implement, and monitor effective FRMS performance metrics;
- cooperate with the Safety Department to develop, implement and monitor FRMS safety assurance processes, based on agreed safety performance indicators and targets;
- be responsible for the design, analysis, and reporting of studies that measure Air Traffic Controller fatigue, when such studies are needed for the identification of hazards, or for monitoring the effectiveness of controls and mitigations (such studies may be contracted out but the FSAG is responsible for ensuring that they are conducted with the highest ethical standards, meet the requirements of the FRMS, and are cost-effective);
- be responsible for the development, updating, and delivery of FRMS education and training materials (these activities may be contracted out but the FSAG is responsible for ensuring that they meet the requirements of the FRMS and are cost-effective);
- ensure that all relevant personnel receive appropriate FRMS education and training, and that training records are kept as part of the FRMS documentation;
- develop and maintain strategies for effective communication with all stakeholders;
- ensure that Air Traffic Controllers and others receive response to their fatigue reports;
- communicate fatigue risks and the performance of the FRMS to senior management;
- develop and maintain the FRMS intranet site;
- develop and maintain the FRMS documentation;
- ensure that it has adequate access to scientific and medical expertise as needed, and that it documents recommendations made by these specialist advisors and the corresponding actions taken;
- keeps informed of scientific and operational advances in fatigue risk management principles and practice;
- cooperate fully with the regulator in relation to FRMS auditing; and
- manage effectively and be accountable for FRMS resources.

The FSAG will meet quarterly. Minutes will be taken during meetings and distributed within 10 working days after each meeting. The FSAG will present an annual budget request in [designated part of the financial cycle] and an annual report of all expenditures.

6.3 FRMS PROMOTION PROCESSES

Along with the FRMS policy and documentation, the FRMS promotion processes support the operational activities of the FRMS (FRM processes and safety assurance processes). Promotion processes are an essential component of an FRMS because FRMS, like SMS, relies on effective communication throughout the organization[34]. In fact, while the FRM processes and safety assurance processes may be the “engine room” of the FRMS, the promotion processes form its foundations. On the one hand, there needs to be regular communication about the activities and safety performance of the FRMS to all stakeholders. Depending on the structure of the organization, this may come from the Fatigue Safety Action Group, the SMS, or from an accountable executive responsible for the FRMS communication plan. On the other hand, the operational personnel concerned and other stakeholders need to communicate promptly and clearly concerns about fatigue hazards to the Fatigue Safety Action Group or other relevant management. In all cases, all stakeholders need to have an appropriate understanding of fatigue and their role within the FRMS.

In addressing the need for effective communication, FRMS promotion processes require the implementation of:

- FRMS training programmes; and
- an effective FRMS communication plan.

6.3.1 FRMS TRAINING PROGRAMMES

ATS Providers are required to maintain records of their FRMS training programme and monitor its effectiveness. ICAO also recommends that regulators have competency requirements for FRMS training instructors, who may be part of an ATS Provider’s internal training department or external contractors.

Everyone whose role in the organization can influence the FRMS needs to have an appropriate level of fatigue management training. This includes ATCs, people who design and manage rosters, members of the FSAG and the FRMS safety assurance team, people responsible for overall operational risk assessment and resource allocation in the SMS. It also includes senior management, in particular the executive accountable for the FRMS and operational decision makers in any department managing operations within the FRMS.

The content of training programmes should be adapted to make sure that each group has the knowledge and skills they need for their role in fatigue management under FRMS. This will entail more in depth training than when using only a prescriptive approach.

Suggestions for FRMS training topics can be found in Appendix D.

34 ICAO *Safety Management Manual (SMM)* (Doc 9859), Section 9.1.

6.3.2 FRMS COMMUNICATION PLAN

The ICAO SARPs require an ATS Provider to have an FRMS communication plan that:

- explains FRMS policies, procedures and responsibilities to all stakeholders; and
- describes communication channels used to gather and disseminate FRMS-related information.

The communications plan needs to addresses the frequency and type of communications necessary for the FRMS to be effective.

The FRMS training programmes are clearly an important part of the communication plan. However, training generally occurs at fairly long intervals (for example every 3-5 years). In addition, there needs to be ongoing communication to stakeholders about the activities and safety performance of the FRMS, to keep fatigue ‘on the radar’ and encourage the continuing commitment of all stakeholders. A variety of types of communication can be used, including electronic media (websites, on-line forums, e-mail), newsletters, bulletins, seminars, periodic poster campaigns in strategic locations, etc.

Communications about the activities and safety performance of the FRMS (from the FSAG or other designated management) need to be clear, timely and credible, i.e. consistent with the facts, with previous statements, and with messages from other authorities including the regulator. The information provided also needs to be tailored to the needs and roles of different stakeholder groups, so that people are not swamped by large quantities of information that has little relevance to them.

Communications from ATCs are essential for fatigue hazard identification, for feedback on the effectiveness of controls and mitigations, and in providing information for FRMS safety performance indicators (for example, by participating in surveys and fatigue monitoring studies). For these communications to be open and honest, all FRMS stakeholders need to have a clear understanding of the policies governing data confidentiality and the ethical use of information provided by ATCs. There also needs to be clarity about the thresholds that separate non-culpable fatigue-related safety events from deliberate violations that will attract penalties.

One of the ways ATCs can be encouraged to submit reports is by providing feedback when they do. Every ATC should receive a timely response to their report with some indication of the planned follow-up activity. For example - “To Ms. Smyth; thank you for your fatigue report. This report will be forwarded to the Fatigue Safety Action Group (FSAG). The FSAG is composed of management, scheduling, and ATCs, with other specialists as required. The group meets quarterly to identify adverse trends in fatigue reports, evaluate potential mitigation strategies, and make recommendations to management at the local and national level”.

The communication plan needs to be described in the FRMS documentation and assessed periodically as part of FRMS safety assurance processes.

CHAPTER 7. FRMS: IMPLEMENTATION

Regulatory requirements for FRMS differ slightly between States, and there is no 'off-the-shelf' version of FRMS that can suit all operations. Therefore, ATS Providers considering implementing an FRMS need to check their regulatory requirements carefully and start the dialogue with their regulator as soon as possible. Each ATS Provider needs to work with the regulator to develop an FRMS that is appropriate to the nature and level of the fatigue risk in the operations covered by their FRMS. The regulator and the ATS Provider need to collaborate to ensure that the FRMS will deliver an equivalent or enhanced level of safety to that achieved by operating within the prescriptive limits.

The implementation of an FRMS is done in phases, with the regulator reviewing and approving each phase before the next one can begin. Table 7-1 identifies 4 phases of implementation and summarizes the focus of the ATS Provider and the regulator during each phase.

Table 7-1. Aims of regulator and ATS Provider during different phases of FRMS implementation

		ATS Provider	Regulator
Approval process	Phase 1. Preparation	Developing FRMS capability	Assessment of feasibility
	Phase 2. Trial	Validation of FRMS capability	Assessment of FRMS capability
	Phase 3. Launch	Getting approval	Approval of FRMS
Continued oversight	Phase 4. Continuous Improvement	Embedding FRMS into normal operations	Embedding FRMS into normal regulatory oversight

Figure 7-1 outlines the steps the ATS Provider undertakes within each of the 4 phases. The time taken to progress through all four phases will depend on a range of factors including the complexity of the FRMS, the anticipated level of fatigue risk, and the capability and resources of both the ATS Provider and the regulator. However, the operational conditions that motivate ATS Providers to seek an FRMS usually require timely resolution and from a regulatory point of view, an ATS Provider cannot be allowed to operate outside of the prescriptive limits for an indefinite period using an "FRMS in progress". A regulator should not allow an ATS Provider to continue using an "FRMS in progress" unless there are agreed activities being undertaken to bring the FRMS up to full approval requirements.

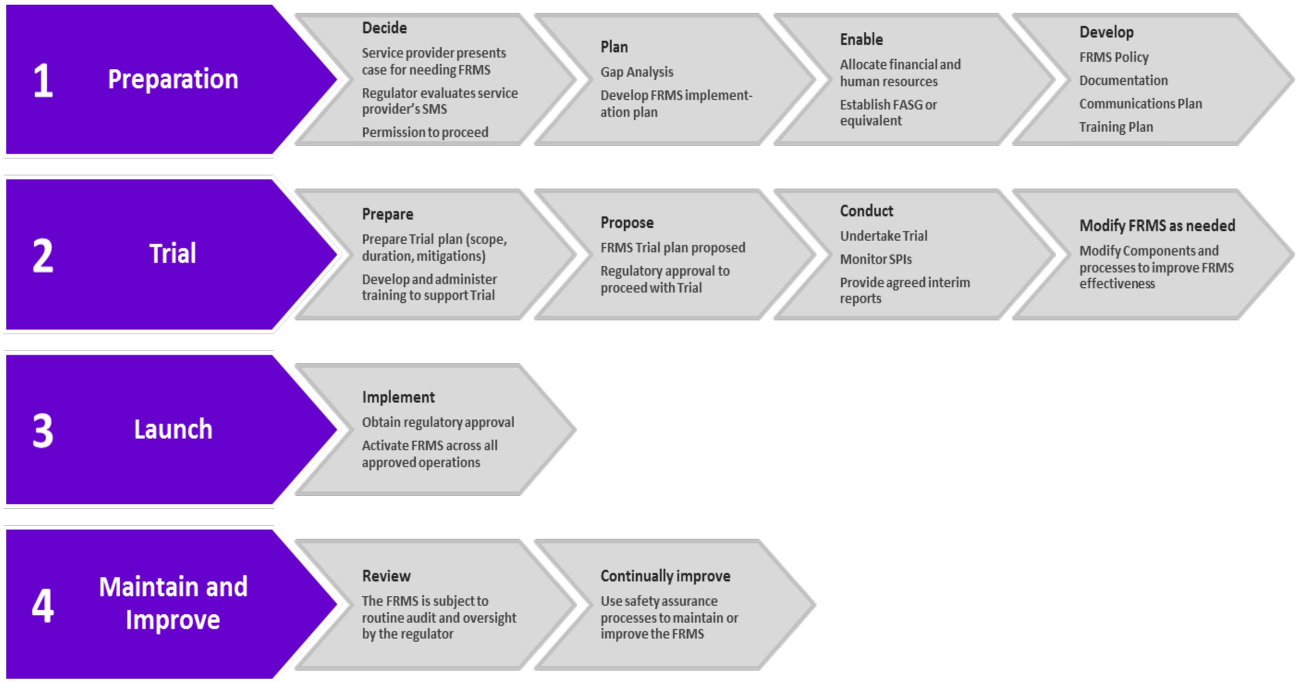


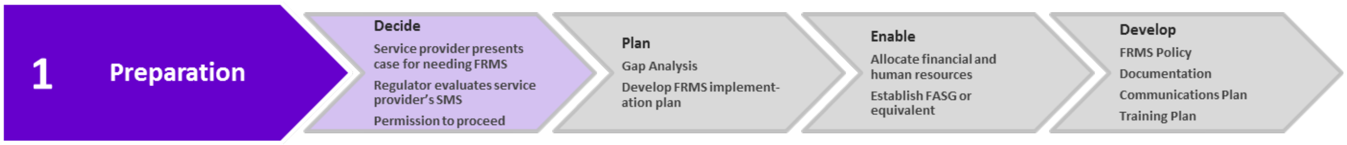
Figure 7-1. Four phases in FRMS implementation

The services of outside consultants may be used to help develop the ATS Provider's FRMS. However, an FRMS requires ownership and commitment by the people who will be using it, and the regulator needs to see evidence of this from the beginning of the implementation process. Outside experts can offer invaluable assistance, but they do not have the ATS Provider's detailed organizational and operational knowledge and experience to develop and implement an FRMS. Consultants should not be the interface between the ATS Provider and the regulator.

7.1 PHASE 1: PREPARATION

The objective of Phase 1 is to establish an overall implementation plan that is acceptable to the regulator and addresses how the FRMS will function, how it will be integrated with other parts of the ATS Provider's organization, who will be accountable for the FRMS, and who will be accountable for making sure that FRMS implementation is successfully completed. Because FRMS processes build on SMS processes, a service provider who is already using mature SMS to manage fatigue risks is likely to transition into Phase 1 of the FRMS approval process with relative ease.

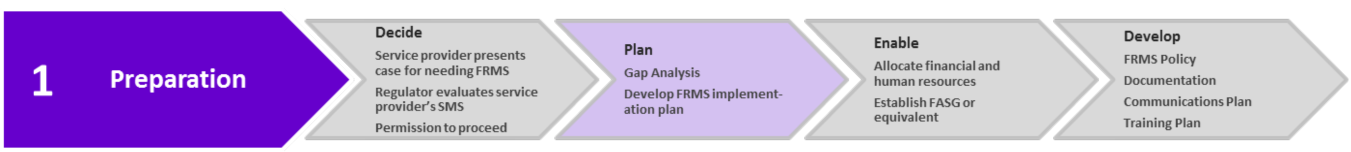
7.1.1 DECIDE



At the beginning of Phase 1, the ATS Provider needs to explain to the regulator why they want to implement an FRMS. The ATS Provider should present a strong business case, operational and/or safety arguments, and a clear case for why the operation(s) cannot be managed within the prescriptive limits.

After receiving this proposal, the regulator will then assess the safety performance and risk management capability of the ATS Provider's SMS as an indicator of their readiness to implement an FRMS. The regulator will be looking for evidence that the ATS Provider has effectively managed fatigue-related risk within the prescriptive limits, using their SMS processes. A crucial element is the demonstration of an effective safety reporting system. Other areas likely to be considered are whether the ATS Provider: provides an appropriate level of fatigue management training; uses the SMS to identify fatigue hazards, assess risk, and implement appropriate mitigations; and has realistic scheduling (with no major ongoing differences between planned and actual schedules).

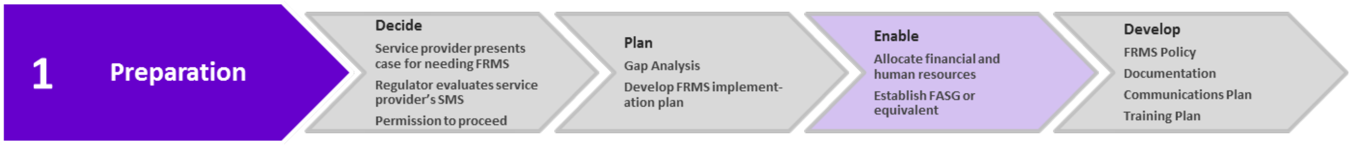
7.1.2 PLAN



Once the regulator has agreed that the ATS Provider can proceed with an application for an FRMS, the ATS Provider conducts a gap analysis. The purpose of the gap analysis is to identify: 1) elements of the FRMS that are already available in existing systems and processes; 2) existing systems and processes that could be modified to meet the needs of the FRMS (to minimize 're-inventing the wheel'); and 3) where new systems and processes are needed for the FRMS.

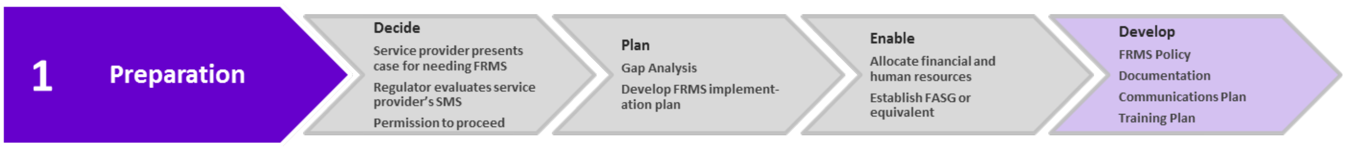
The findings of the gap analysis provide the basis for developing the FRMS implementation plan. Essentially this is a road map, with realistic timelines, that describes how the ATS Provider will progress through all four phases in Figure 7.1. It includes describing how the ATS Provider will proceed with implementing all the required FRMS components and processes (Phase 1), develop and conduct their FRMS trial (Phase 2), refine the FRMS to the stage that it is approved by the regulator and ready to launch (Phase 3) with embedded processes for continuous improvement (Phase 4).

7.1.3 ENABLE



To enable FRMS implementation to proceed, the accountable executive has to be identified, the necessary human and financial resources allocated, and the FSAG or equivalent identified. The stage at which the FSAG is established will vary, according to the size and complexity of the organization and the FRMS, and whether there are suitably qualified people in the organization who are available to begin the Phase 2 activities.

7.1.4 DEVELOP



By the end of Phase 1 (Preparation), all components and processes for the FRMS should be ready for the implementation Trial. The following steps need to be completed.

- A completed gap analysis.
- An FRMS Policy Statement signed by the accountable executive. Developing the policy at the beginning of the FRMS implementation process will assist in defining the scope of the FRMS.
- Allocation of financial and human resources. The accountable executive for the FRMS needs to have the authority and control to ensure that this happens.
- An FRMS implementation plan.
- An FRMS documentation plan. This can be expected to evolve as the FRMS becomes operational.
- An FRMS communication plan. This can be expected to evolve as the FRMS becomes operational.
- Training programme ready for all personnel who will be involved in the FRMS trial in Phase 2.
- An established Fatigue Safety Action Group (FSAG or equivalent) able to undertake Phase 2.

Throughout Phase 1, the onus is on the ATS Provider to consult with, and provide feedback to the regulator to ensure early identification and resolution of regulatory concerns.

7.2 PHASE 2: TRIAL

The objective of Phase 2 is for the ATS Provider to demonstrate their FRMS capability to the regulator. It tests the effectiveness of the FRMS components and processes that were established in Phase 1. For Phase 2, the ATS Provider prepares an FRMS Trial Plan and implements an initial version of the FRMS in the specific operation (s) for which the FRMS is being sought. As the Trial progresses, it is closely monitored by the regulator and modifications may be made to the FRMS components and processes to improve the overall effectiveness of the FRMS.

7.2.1 PREPARE

In preparation for the FRMS Trial, the regulator may ask the ATS Provider to demonstrate that the first version of the FRM processes (Section 5.2) has been implemented. For example, this could involve building on the SMS processes using reactive data (Chapter 4) such as confidential safety reports, accident and incident investigations, audits, and using historical rostering data to compare scheduled and actual duty times and to track exceedances. The FRMS safety assurance processes should also be ready to implement for the Trial.

The ATS Provider must prepare a Trial Plan that details the following:

- The specific operations in which the Trial will take place.
- The anticipated additional fatigue risk associated with bringing these operations under the FRMS (as opposed to remaining within the prescriptive limits). Sources of information for estimating fatigue risk include published scientific studies on similar operations, the ATS Provider's own experience with similar operations, and/or bio-mathematical modelling.
- The monitoring that will be undertaken to track the actual fatigue risk and the SPIs that will be used to determine the acceptability of that risk (Section 5.2.3). The ATS Provider and the regulator will need to agree on how the Trial will demonstrate an equivalent (or lower) level of fatigue risk on operations under the FRMS compared to operations that remain within the prescriptive limits. In some cases, this may require accessing independent scientific expertise to help develop a robust scientific study design to reliably compare levels of fatigue risk in different operations.
- The mitigation strategies that will be used to manage fatigue risk(s) identified through the FRMS processes.
- The duration of the Trial and a timeline specifying the frequency of interim updates and the final report.

As part of preparing for the FRMS Trial, the ATS Provider should also ensure that all relevant personnel have received adequate training to enable them to undertake their roles in the FRMS. This will include ATCs, staff responsible for schedule design and rostering, line managers (where appropriate), and members of the FSAG.

7.2.2 PROPOSE

The ATS Provider proposes their FRMS Trial Plan to the regulator. Some modifications to the plan may be required before it is approved and the Trial can begin.

7.2.3 CONDUCT

The FRMS Trial is conducted according to the plan and its progress is closely monitored by the regulator. This may include:

- the requirement for frequent feedback from the ATS Provider (e.g. e-mail updates, reporting on SPIs);
- the regulator undertaking desktop reviews of the agreed operational SPIs;
- ongoing evaluation of the documentation of FRM processes and activities as they develop;
- on-site visits by the regulator; and
- direct inspection by the regulator of the Trial operation(s).

The regulator will also expect to see the FRMS safety assurance processes operating in a coordinated way with the ATS Provider's SMS.

7.2.4 MODIFY

Throughout the Trial, the agreed SPIs and relevant safety reports will be monitored by the regulator to confirm that the FRMS is delivering the required safety outcomes. The ATS Provider may identify improvements to the FRMS which should be discussed with the regulator. The regulator may also identify improvements to the FRMS. If major changes are needed to the FRMS, the Trial may need to be reworked.

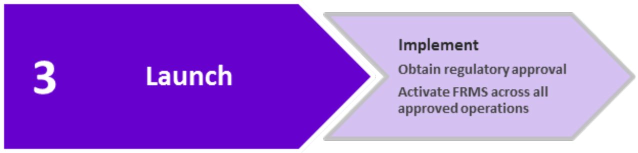
Before the final version of the FRMS can be approved and launched, the regulator has to be confident that it can deliver the required safety outcomes. In Phase 2, the onus is on the ATS Provider to demonstrate that the FRMS safety assurance processes are functioning and confirming that the FRMS is delivering the required safety outcomes within the scope of the Trial.

The ATS Provider should expect to provide a final report documenting the activities and outcomes of the Trial. In addition, the regulator may check if there have been any operational or organizational changes during the Trial period that might have affected the Trial findings. The regulator may also review other relevant information, for example audits of the ATS Provider in other areas, or findings of studies on similar operations.

7.3 PHASE 3: LAUNCH

The objective of Phase 3 is to obtain regulatory approval for the FRMS and implement it across all the operations for which it is approved. The FRMS becomes routine in these operations, but regulatory monitoring remains more intensive to confirm that the FRMS is functioning as approved.

7.3.1 IMPLEMENT



Once the regulator is satisfied that the FRMS is fully functioning and delivering an acceptable level of safety, the regulator approves the FRMS and Phase 3 begins.

The ATS Provider can now activate the FRMS across all the operations that are specified in the approved FRMS. If the ATS Provider wishes to extend the scope of the FRMS to cover additional operations, they will be required to present a safety case and may be required to conduct a further Trial to demonstrate the effectiveness of the FRMS for managing fatigue risk in these additional operations, i.e. return to Phase 2.

During Phase 3, the level of regulatory oversight will typically be lower than during the Trial but must be sufficient to convince the regulator that the FRMS is functioning as intended in all the operations to which it applies. The regulator will require regular updates on trends in agreed SPIs. The frequency of reporting and type of information required will depend on the level of fatigue risk in the operations covered by the FRMS.

7.4 PHASE 4: MAINTAIN AND IMPROVE

During Phase 4, regulatory oversight reduces to routine levels. Regulatory audit may include review of: the ATS Provider's FRMS processes and procedures; internal audits; the activities of the FSAG including actions taken in response to SPI trends, and adjustments to outer limits and mitigations in response to data; any organizational and operational changes that may have an impact on the FRMS; and training practices.

7.4.1 REVIEW AND CONTINUALLY IMPROVE

During Phase 4, the FRMS becomes a routine part of the operations to which it applies. Ongoing review and continuous improvement of the FRMS is achieved through the FRMS safety assurance processes. As in Phase 3, any extensions to the scope of the FRMS will require the ATS Provider to present a safety case and may require a new Trial, i.e. return to Phase 2.

If deficiencies in the FRMS are identified, the regulator will take actions appropriate to the level of risk resulting from the deficiency. These actions may range from administrative changes or FRMS operational changes, to a withdrawal of FRMS approval.

7.5 OPERATIONAL EXAMPLE OF STAGED FRMS IMPLEMENTATION

ATS Provider A has a variety of operations, including towers, terminal, low level, high level and oceanic airspace. It has been operating for 20 years with an excellent safety record. ATS Provider A decides that the prescribed limits do not allow optimal coverage for its oceanic operations, where heavy traffic occurs during the hours of midnight to 3:00 am. ATSP A therefore wishes to implement an FRMS to cover this operation.

This example works through the steps that ATS Provider A could follow to complete Phases 1 to 4 above and implement a fully functional, approved FRMS. It assumes that management at ATS Provider A are familiar with the ICAO guidance materials and with their regulator's FRMS implementation requirements and guidance.

PHASE 1. PREPARATION

1. ATS Provider notifies the regulator that they wish to implement an FRMS.
2. Regulator is satisfied with the safety performance and risk management capability of the ATS Provider's SMS and agrees to consider an application for the FRMS.
3. Responsibility for FRMS implementation assigned to a designated FRMS manager.
4. FRMS policy statement is developed and signed by the accountable executive.
5. The accountable executive allocates resources and authority to support FRMS development.
6. FRMS manager assembles an implementation team and organizes training for the team on FRMS basics and fatigue science (note: fatigue basics would likely have been taught under the prescriptive regime).
7. Gap analysis undertaken by FRMS manager and implementation team.
8. FRMS Implementation Plan is developed by FRMS manager and implementation team.
9. FRMS manager identifies internal stakeholders (department representatives).
10. FRM processes and FRMS safety assurance processes are developed in collaboration with internal stakeholders.

11. FRMS documentation plan developed and first draft established.
12. FRMS communication plan developed and first draft established.
13. Training programme ready for all personnel who will be involved in the FRMS Trial in Phase 2.
14. The FSAG (or equivalent) is established with documented terms of reference, and ready to undertake Phase 2.

PHASE 2. TRIAL

1. Training for all personnel involved in the FRMS Trial is undertaken.
2. FRMS Trial Plan is developed and approved by the regulator.
3. FRM processes and FRMS safety assurance processes are implemented according to the scope of the Trial.
4. Trial is undertaken according to the Trial Plan, with updates and reports on SPIs as agreed with the regulator.
5. Minor modifications to FRM processes and FRMS safety assurance processes are proposed by the ATS Provider and approved by the regulator.
6. Final report on the Trial activities and findings is presented to the regulator.

PHASE 3. LAUNCH

1. Full regulatory approval received.
2. FRMS implemented in operations for which it has been approved.
3. Compliance with all regulatory oversight requirements.

PHASE 4. MAINTAIN AND IMPROVE

1. Regulatory audit returns to routine levels.
2. Continuous improvement through FRMS safety assurance processes and feedback from regulatory audit.

APPENDIX A. ICAO FATIGUE MANAGEMENT SARPS FOR AIR TRAFFIC CONTROLLERS

SARPs related to fatigue management in Annex 11 are found in:

- Chapter 2. General, Section 2.28 – Fatigue Management
- Appendix 6 – Prescriptive Fatigue Management Requirements
- Appendix 7 – FRMS Requirements

A1.1 CHAPTER 2, SECTION 2.28 – FATIGUE MANAGEMENT

2.28.1 *States shall establish regulations for the purpose of managing fatigue in the provision of air traffic control services. These regulations shall be based upon scientific principles and knowledge, with the aim of ensuring that air traffic controllers perform at an adequate level of alertness. To that aim, States shall establish:*

a) regulations that prescribe scheduling limits in accordance with Appendix 6; and

b) where authorizing air traffic services providers to use a fatigue risk management system (FRMS) to manage fatigue, FRMS regulations in accordance with Appendix 7.

Intent: Standard 2.28.1 stipulates the State's responsibilities for establishing regulations for fatigue management. The establishment of regulations for prescriptive limitations is mandatory, while the establishment of regulations for FRMS is necessary only where the State chooses to allow ATS Providers to apply for FRMS approval. Developing FRMS regulations is therefore optional for States. However, both types of regulations need to address the known scientific principles (See Chapter 2).

The prescriptive regulations must be in accordance with Appendix 6 to Annex 11 (see following table) while Appendix 7 to Annex 11 outlines the minimum requirements of an FRMS (see Chapter 5).

2.28.2 *States shall require that the air traffic services provider, for the purposes of managing its fatigue-related safety risks, establish one of the following:*

a) air traffic controller schedules commensurate with the service(s) provided and in compliance with the prescriptive limitation regulations established by the State in accordance with 2.28.1 a); or

b) an FRMS, in compliance with regulations established by the State in accordance with 2.28.1 b), for the provision of all air traffic control services; or

c) an FRMS, in compliance with regulations established by the State in accordance with 2.28.1 b), for a defined part of its air traffic control services in conjunction with schedules in compliance with the prescriptive limitation regulations established by the State in accordance with 2.28.1 a) for the remainder of its air traffic control services.

Intent: Standard 2.28.2 identifies the options the ATS Provider has for the management of its fatigue-related safety risks, depending on whether their State offers FRMS regulations.

Where the State has established regulations for FRMS, ATS Providers have three options for managing their fatigue risks: a) they can comply with the prescriptive limitation regulations in all operations; b) they can choose to implement an FRMS for all operations; or c) they can implement an FRMS in parts of their operations and in other operations comply with the prescriptive limitation regulations. Therefore, this Standard offers the ATS Provider the opportunity to decide which method of fatigue management is most appropriate for its specific types of operations.

Where the State does not have FRMS regulations, ATS Providers must manage their fatigue-related risks, as part of their existing safety management processes, within the constraints of their State's prescribed duty time limitations or State-approved variations to those limitations. As fatigue is not a specific focus of an SMS, as is the case when using an FRMS, the concentration of resources required to manage fatigue-related risks using SMS processes is significantly less (See Chapter 4).

2.28.3 *Where the air traffic services provider complies with prescriptive limitation regulations in the provision of part or all of its air traffic control services in accordance with 2.28.2 a), the State:*

a) shall require evidence that the limitations are not exceeded and that non-duty period requirements are met;

b) shall require that the air traffic services provider familiarize its personnel with the principles of fatigue management and its policies with regard to fatigue management;

c) shall establish a process to allow variations from the prescriptive limitation regulations to address any additional risks associated with sudden, unforeseen operational circumstances; and

d) may approve variations to these regulations using an established process in order to address strategic operational needs in exceptional circumstances, based on the air traffic services provider demonstrating that any associated risk is being managed to a level of safety equivalent to, or better than, that achieved through the prescriptive fatigue management regulations.

Note.— Complying with the prescriptive limitations regulations does not relieve the air traffic services provider of the responsibility to manage its risks, including fatigue-related risks, using its SMS in accordance with the provisions of Annex 19.

Intent: 2.28.3 lists additional Standards for prescriptive fatigue management regulations outside of those that are contained in Appendix 6 relating specifically to aspects impacting on work schedules under a prescriptive scheme.

2.28.3 a) aims to ensure that compliance with the prescriptive limits is not just determined through examination of schedules, which are planned work periods, but also through examination of the periods of time actually worked by ATCs.

2.28.3 b) distinguishes basic fatigue-related training as mandatory for ATCs, whether or not it is incorporated in the training elements of an ATS Provider's SMS.

2.28.3 c) recognises the need for ATS Providers to have some flexibility to make tactical decisions that may require going outside of the prescribed limits in order to meet both operational needs and address overall risk, such as needing to maintain adequate ATC coverage to manage high traffic in association with unexpectedly severe weather conditions. This Standard requires the State to develop a clear process so that an ATS Provider knows exactly what is required of them to make immediate and appropriate changes to address such unexpected operational circumstances.

In contrast to 2.28.3 c) above, 2.28.3 d) relates to the possibility of more strategic responses by ATS Providers to address expected by minor changes to usual air traffic service demands in exceptional circumstances, such as planning for increased traffic during an Olympics, or to meet limited seasonal demands, without the need for the ATS Provider to develop a full FRMS. This Standard requires ATC providers to seek approval for any variations or exceptions to the prescriptive limits that they wish to schedule air traffic controllers to work. These variations should be for a defined period of time(s) and made in association with identified mitigation strategies.

The intent of Standard 2.28.3 d) is to minimize "regulation through variations" and to avoid the approval of variations that meet operational imperatives in the absence of a risk assessment. It is not intended to offer a quick and easy alternative to an FRMS when a more comprehensive fatigue risk management approach is required.

The Note is a reminder of current obligations that, when complying with prescriptive limitations regulations, ATS Providers must continue to use their existing safety management processes to address any fatigue-related risks that may be identified.

2.28.4 *Where an air traffic services provider implements an FRMS to manage fatigue-related safety risks in the provision of part or all of its air traffic control services in accordance with 2.28.2 b), the State shall:*

a) require the air traffic services provider to have processes to integrate FRMS functions with its other safety management functions; and

b) approve an FRMS, according to a documented process, that provides a level of safety acceptable to the State.

Note.— Provisions on the protection of safety information, which support the continued availability of information required by an FRMS, are contained in Annex 19.

Intent:

2.28.4 lists additional Standards for FRMS regulations outside of those that are contained in Appendix 7 relating specifically to the minimum requirements for an FRMS.

2.28.4 a) recognizes the relationship between FRMS and SMS. Because FRMS has a safety function, it needs to complement existing safety management processes within an ATS Provider's SMS in order to maximize their combined effectiveness, to ensure resources are being distributed appropriately across the systems and, where possible, to reduce duplicated processes for greater system efficiency. This Standard means that information from an FRMS will inform an ATS Provider's SMS and vice versa.

2.28.4 b) clarifies the need for the State to have a transparent FRMS approval process that requires an ATS Provider to demonstrate, as final evidence, effectively functioning FRMS processes. It aims to prevent the approval of an FRMS based only on the provision of a documented plan or a desktop review of an FRMS manual. The process for seeking and gaining approval of an FRMS from a State must be made transparent to the ATS Provider(see Chapter 6).

The note serves to highlight that the collection of safety information is essential in implementing an FRMS and needs to be accorded protection in accordance with existing provisions in Annex 19.

A1.2 APPENDIX 6 – PRESCRIPTIVE FATIGUE MANAGEMENT REGULATIONS

*1. **States shall establish prescriptive limitation regulations that take into account acute and cumulative fatigue, circadian factors and the type of work being undertaken. These regulations shall identify:***

a) the maximum:

i) number of hours in any duty period;

ii) number of consecutive work days;

iii) number of hours worked in a defined period; and

iv) time-in-position;

b) the minimum:

i) duration of non-duty periods;

ii) number of non-duty days required in a defined period; and

iii) duration of breaks between periods of time-in-position in a duty period.

Intent: Appendix 6 - 1 identifies those roster features for which the State must prescribe limits, ensuring that prescriptive limitation regulations address basic conditions that will impact on the ATC's ability to maintain an adequate level of alertness throughout work periods occurring across a 24-h day.

Limiting the maximum number of hours worked in any duty period allows provision of an adequate opportunity for sleep recovery to address transient fatigue. Limiting the number of consecutive work days and the number of hours worked in a defined period is a mechanism for providing adequate recovery from cumulative sleep loss. While it is recognized that time spent in-position may be associated with varying workloads, the intent of limiting time-in-position is to specifically address the difficulties of maintaining performance under high workload conditions. For operations where time-in-position is related to only moderate and low workloads, the State may choose to prescribe time-in-position limits for specified operations or may require the ATS Provider to seek a variation to the prescribed limits.

Identifying minimum non-duty periods ensures that duty hours cannot be consistently split across a defined period in such a way as to prevent unbroken periods of recovery sleep. Identifying a minimum number of non-duty days in a defined period provides further opportunity for recovery from cumulative sleep loss. Identifying minimum duration of breaks between periods of time-in-position aims to specifically address the need to recover from periods of high workload in order to maintain performance.

2. **States shall require that the air traffic services provider identifies a process for assigning unscheduled duties that allows air traffic controllers to avoid extended periods of being awake.**

Intent: To address broader aviation safety risks, controllers sometimes have to be available to undertake unscheduled duties, regardless of whether or not they are on on-call. This Standard aims to minimize the likelihood of such unscheduled duties being undertaken when the controller has not had the opportunity to sleep for a long period of time, resulting in a high sleep drive (see Scientific Principle # 2 in Chapter 2). Such processes could focus on limiting the duration of the unscheduled duties, allowing controller's to obtain sleep prior to commencement of unscheduled duties, and/or providing the opportunity for napping during the unscheduled duties.

3. ***The processes established by States in accordance with 2.28.3 c) and d) to allow variations from 1 a) and b) above shall include the provision of:***

- ***a) the reason for the need to deviate;***
- ***b) the extent of the deviation;***
- ***c) the date and time of enactment of the deviation; and***
- ***d) a safety case, outlining mitigations, to support the deviation.***

Intent: This Standard identifies the minimum requirements of any request for variation to prescribed limits, when the ATS Provider is not implementing an FRMS. It aims to ensure that ATS Providers complying with prescriptive limits, identify and mitigate fatigue risks when varying from prescriptive limits for tactical or strategic reasons.

A1.3 APPENDIX 7 – FRMS REQUIREMENTS

States shall require that an FRMS contain, at a minimum:

1. FRMS policy and documentation

1.1 FRMS policy

1.1.1 The air traffic services provider shall define its FRMS policy, with all elements of the FRMS clearly identified.

1.1.2 The policy shall:

a) define the scope of FRMS operations;

b) reflect the shared responsibility of management, air traffic controllers, and other involved personnel;

c) clearly state the safety objectives of the FRMS;

d) be signed by the accountable executive of the organization;

e) be communicated, with visible endorsement, to all the relevant areas and levels of the organization;

f) declare management commitment to effective safety reporting;

g) declare management commitment to the provision of adequate resources for the FRMS;

h) declare management commitment to continuous improvement of the FRMS;

i) require that clear lines of accountability for management, air traffic controllers, and all other involved personnel are identified; and

j) require periodic reviews to ensure it remains relevant and appropriate.

Note.— Effective safety reporting is described in the Safety Management Manual (SMM) (Doc 9859).

1.2 FRMS documentation

An air traffic services provider shall develop and keep current FRMS documentation that describes and records:

a) FRMS policy and objectives;

b) FRMS processes and procedures;

c) accountabilities, responsibilities and authorities for these processes and procedures;

d) mechanisms for ongoing involvement of management, air traffic controllers, and all other involved personnel;

e) FRMS training programmes, training requirements and attendance records;

f) scheduled and actual duty and non-duty periods and break periods between times in position in a duty period with significant deviations and reasons for deviations noted; and

Note.— Significant deviations are described in the Manual for the Oversight of Fatigue Management Approaches (Doc 9966).

g) FRMS outputs including findings from collected data, recommendations, and actions taken.

2. Fatigue risk management processes

2.1 Identification of fatigue-related hazards

Note.— Provisions on the protection of safety information are contained in Annex 19.

An air traffic services provider shall develop and maintain three fundamental and documented processes for fatigue hazard identification:

2.1.1 Predictive.

The predictive process shall identify fatigue hazards by examining air traffic controller scheduling and taking into account factors known to affect sleep and fatigue and their effects on performance. Methods of examination may include but are not limited to:

a) air traffic services or industry operational experience and data collected on similar types of operations or from other industries with shift work or 24-hour operations;

b) evidence-based scheduling practices; and

c) bio-mathematical models.

2.1.2 Proactive.

The proactive process shall identify fatigue hazards within current air traffic services operations. Methods of examination may include but are not limited to:

a) self-reporting of fatigue risks;

b) fatigue surveys;

c) relevant air traffic controller performance data;

d) available safety databases and scientific studies;

e) tracking and analysis of differences in planned and actual worked times; and

f) observations during normal operations or special evaluations.

2.1.3 Reactive.

The reactive process shall identify the contribution of fatigue hazards to reports and events associated with potential negative safety consequences in order to determine how the impact of fatigue could have been minimized. At a minimum, the process may be triggered by any of the following:

a) fatigue reports;

b) confidential reports;

c) audit reports; and

d) incidents.

2.2 Fatigue-related risk assessment

2.2.1 An air traffic services provider shall develop and implement risk assessment procedures that determine when the associated risks require mitigation.

2.2.2 The risk assessment procedures shall review identified fatigue hazards and link them to:

a) operational processes;

b) their probability;

c) possible consequences; and

d) the effectiveness of existing preventive controls and recovery measures.

2.3 Risk mitigation

An air traffic services provider shall develop and implement fatigue risk mitigation procedures that:

a) select the appropriate mitigation strategies;

b) implement the mitigation strategies; and

c) monitor the strategies' implementation and effectiveness.

3. FRMS safety assurance processes

The air traffic services provider shall develop and maintain FRMS safety assurance processes to:

a) provide for continuous FRMS performance monitoring, analysis of trends, and measurement to validate the effectiveness of the fatigue safety risk controls. The sources of data may include, but are not limited to:

1) hazard reporting and investigations;

2) audits and surveys; and

3) reviews and fatigue studies (both internal and external);

b) provide a formal process for the management of change. This shall include but is not limited to:

1) identification of changes in the operational environment that may affect the FRMS;

2) identification of changes within the organization that may affect the FRMS; and

3) consideration of available tools which could be used to maintain or improve FRMS performance prior to implementing changes; and

c) provide for the continuous improvement of the FRMS. This shall include but is not limited to:

1) the elimination and/or modification of preventive controls and recovery measures that have had unintended consequences or that are no longer needed due to changes in the operational or organizational environment;

2) routine evaluations of facilities, equipment, documentation and procedures; and

3) the determination of the need to introduce new processes and procedures to mitigate emerging fatigue-related risks.

4. FRMS promotion processes

FRMS promotion processes support the ongoing development of the FRMS, the continuous improvement of its overall performance, and attainment of optimum safety levels. The following shall be established and implemented by the air traffic Service Provider as part of its FRMS:

a) training programmes to ensure competency commensurate with the roles and responsibilities of management, air traffic controllers, and all other involved personnel under the planned FRMS; and

b) an effective FRMS communication plan that:

1) explains FRMS policies, procedures and responsibilities to all relevant stakeholders; and

2) describes communication channels used to gather and disseminate FRMS-related information.

Intent:	Appendix 7 of Annex 11 details the minimum requirements for each of the four components of an FRMS: 1) FRMS policy and documentation; 2) Fatigue Risk Management processes; 3) FRMS safety assurance processes; and 4) FRMS promotion processes. This Standard is presented in a similar format to that of the SMS framework (Annex 19, Appendix 2) to reflect the consistencies between FRMS and SMS.

APPENDIX B. MEASURING ATC FATIGUE

In operations where fatigue is managed under an FRMS (and potentially operations under a prescriptive approach), it will sometimes be necessary to measure ATC fatigue. There is no single measurement that is the 'gold standard', because fatigue-related impairment affects many skills and has multiple causes. A wide variety of fatigue measures are used in scientific research. The measures described here are examples that have been chosen because:

- they have been shown to sensitive for measuring what they claim to measure (i.e., they have been scientifically validated)[35];
- they do not jeopardize ATCs' ability to perform their operational duties; and
- they have been widely used in aviation, so data can be compared between different types of operations.

New ways to measure fatigue and sleep are always being developed and some will become valuable tools to add to the list below, once they have been validated for use in aviation operations. Meanwhile, in an FRMS it is important to use measures that are accepted by regulators, ATS Providers, ATCs, and scientists as being meaningful and reliable. This avoids the unnecessary cost and inconvenience of collecting data that is of doubtful value.

Fatigue measurements can be based on crew members' recall or current impressions of fatigue (subjective measures) or on objective measurements, such as performance tests and different types of physical monitoring. Each type of measure has strengths and weaknesses. To decide which types of data to collect, the most important consideration should be the expected level of fatigue risk.

B1 AIR TRAFFIC CONTROLLERS' RECALL OF FATIGUE

B1.1 FATIGUE REPORTS

Fatigue reports allow individuals to give vital feedback on fatigue hazards where and when they occur in an operation. People are encouraged to do this by an effective safety reporting culture in which there is a clear understanding of the defining line between acceptable performance (which can include unintended errors) and unacceptable performance (such as negligence, recklessness, violations or sabotage). This provides fair protection to reporters but does not exempt them from punitive action where it is warranted. ATCs also need to be confident that reports will be acted on, which requires feedback from the FSAG, and they need to believe that the intent of the reporting process is to improve safety, not to attribute blame. A series of fatigue reports on a particular shift or across a pattern of shifts can be a trigger for further investigation by the FSAG.

An example of a fatigue report form can be found on the next page. This shows the type of information that needs to be gathered for fatigue to be evaluated, and that should also be included in mandatory incident/accident reporting forms (further information on this is provided in Section B6 of this Appendix). An ATS Provider may have different reporting processes, for example for events where fatigue is a safety concern, versus not a safety concern, or for calling in too fatigued to take or continue a duty period. Information on how to report should be covered in fatigue management training.

[35] Gander PH, Mulrine HM, van den Berg MJ, et al. Effects of sleep/wake history and circadian phase on proposed pilot fatigue safety performance indicators. Journal of Sleep Research 24:110-119,2015.

INDIVIDUAL FATIGUE REPORT

In-Confidence

Instructions

This form is to be used by individuals to report any significant experience or indications of fatigue in themselves or observed in a peer which may affect their ability to work safely.

This form should not be used for general concerns about rostering or software applications used to support rostering. Please direct your issue to the relevant unit manager.

Section A: Your Details

Name		Date of Report	
Position		Unit	
Contact Number		Manager	

Section B: Significant Fatigue

Does this report relate to:	You ☐ A colleague ☐	Colleague's name (if applicable)	
Date of event		Duty time details	**Start:**
Incident number (if applicable)			**End:**

Provide details of the event or your concern

What do you think was the cause of the fatigue hazard? (tick all applicable items)

☐	Health/illness	☐	Long commutes	☐	**Long duty days**
☐	Home issues	☐	Early start times	☐	**Workload (high or low)**
☐	Insufficient sleep	☐	Late finish times	☐	**Poor quality rest (e.g. sleep disturbance due to**
☐	Other: please detail				

Please indicate all the fatigue symptoms which were felt/observed

☐	Involuntary sleep/nodding off	☐	Memory lapses	☐	Poor hand-eye coordination
☐	Trouble focusing on routine tasks	☐	Yawning	☐	Lack of general awareness
☐	Lack of energy or motivation	☐	Sore eyes/rubbing eyes	☐	Poor communicating
☐	Irritability and short-temperedness	☐	Other: please detail		

At the time of the event, did you feel, or your colleague appear to be:		
☐ Very sleepy, great effort to stay	☐ Sleepy but no effort was required to stay awake	☐ Neither alert or sleepy
☐ Quite sleepy, some effort to stay awake	☐ Some signs of sleepiness	☐ Alert

What activities were being undertaken at the time? (e.g. driving, controlling, maintenance work, administration activities, training)

If known, approximately how much sleep was obtained in the 24 and 48 hours prior to the event?	
Prior 24 hours: hrs	Prior 48 hours: hrs

If this is a self report, how long had you been awake prior to the event?	
☐ Self report hrs	☐ Not a self-report

Section C: Any Additional Information (Please use the space below to provide any further information)

When activities that raise fatigue awareness are launched, there is likely to be an increase in fatigue reporting. This 'spike' does not necessarily represent an increase in fatigue occurrences or risk. It may simply be due to people being more likely to report. Other safety performance indicators may need to be evaluated (see Chapter 5, Section 5.4) to decide whether the increase in reporting should trigger further action.

B1.2 RETROSPECTIVE SURVEYS

Retrospective surveys are a comparatively cheap way to obtain information from a group of ATCs on a range of topics such as:

- demographics (age, experience, gender, etc);
- amount and quality of sleep;
- experience of fatigue on duty; and
- views on the causes and consequences of fatigue on duty.

Wherever possible, validated scales and standard questions should be used for gathering information on common topics such as sleep problems. This enables the responses of ATCs to be compared across time, or with other groups.[36]

For example, the Epworth Sleepiness Scale (Figure B-1) is a validated tool for measuring the impact of sleepiness on daily life when used in a research environment or contexts where there is no incentive for people to be dishonest. It is widely used clinically, to evaluate whether an individual is experiencing excessive sleepiness,[37] and information is available on its distribution in large community samples.[38] The ATC is asked to rate each situation from 0='would never doze' to 3 'high chance of dozing', for a total possible score of 24. Scores above 10 are generally considered to indicate excessive sleepiness. Scores above 15 are considered to indicate extreme sleepiness.

Retrospective surveys can also be used to track the effectiveness of an FRMS across time (i.e., as an FRMS safety assurance process – see Chapter 5, Section 5.3).

How likely are you to doze off or fall asleep in the following situations, in contrast to feeling just tired? *(This refers to your usual way of life in recent times.)*				
PLEASE TICK ONE BOX ON EACH LINE				
	would never doze	slight chance	moderate chance	high chance
Sitting and reading	0 ☐	1 ☐	2 ☐	3 ☐
Watching TV	0 ☐	1 ☐	2 ☐	3 ☐
Sitting inactive in a public place (e.g. theatre, meeting)	0 ☐	1 ☐	2 ☐	3 ☐
As a passenger in a car for an hour without a break	0 ☐	1 ☐	2 ☐	3 ☐
Lying down in the afternoon when circumstances permit	0 ☐	1 ☐	2 ☐	3 ☐
Sitting and talking to someone	0 ☐	1 ☐	2 ☐	3 ☐
Sitting quietly after a lunch without alcohol	0 ☐	1 ☐	2 ☐	3 ☐
In a car, while stopped for a few minutes in traffic	0 ☐	1 ☐	2 ☐	3 ☐

Figure B-1. The Epworth Sleepiness Scale

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[36] Note that some measures, for example the Karolinska Sleepiness Scale and the Samn-Perelli Crew Status Check are not designed to be used retrospectively. They are meant to be answered in relation to how you feel at a specific moment in time.

[37] Johns MW. Sleepiness in different situations measured by the Epworth Sleepiness Scale. Sleep 17:703-710, 1994..

[38] Gander PH, Marshall NS, Harris R, Reid P. The Epworth sleepiness score: Influence of age, ethnicity and socioeconomic deprivation. Sleep 28:249-253, 2005.

STRENGTHS AND WEAKNESSES OF RETROSPECTIVE SURVEYS

Retrospective surveys are a comparatively cheap way to gather a range of information. However, time and costs are involved in developing and distributing the survey questionnaire, entering the information into databases (for paper-based surveys) and analyzing the data.

A limitation of retrospective surveys is that the information gathered is subjective, and therefore its reliability is open to question. Reliability is a particular issue when crew members are asked to accurately recall details of past events, feelings, or sleep patterns. This is not to question ATCs' integrity – inaccurate recall of past events is a common and complex human problem. Concerns about whether some ATCs might exaggerate in their responses, for personal or industrial reasons, should be minimal in an effective safety reporting culture. In addition, extreme ratings are obvious when compared with group averages.

ATCs' confidence in the confidentiality of their data is likely to be a very important factor in their willingness to participate in surveys and to provide complete information on questionnaires. Despite limitations, retrospective surveys from time-to-time can be a useful source of information in an FRMS.

B2 MONITORING ATC FATIGUE DURING WORK PERIODS

B2.1 SUBJECTIVE FATIGUE AND SLEEPINESS RATINGS

The following things should be considered when choosing rating scales for monitoring ATC fatigue and sleepiness during air traffic control operations.

- Is the scale quick and easy to complete?
- Is it designed to be completed at multiple time points, e.g. across a shift?
- Has it been validated? For example, has it been shown to be sensitive to the effects of sleep loss and the circadian body clock cycle under controlled experimental conditions?
- Is it predictive of objective measures such as performance or motor vehicle crash risk?
- Has it been used in other aviation operations, and are the data available to compare fatigue levels?

The following two scales meet these criteria.

THE KAROLINSKA SLEEPINESS SCALE (KSS)

This scale (see Figure B-2) asks people to rate how sleepy they feel right now[39, 40,41,42,43] . Any of the values from 1-9 can be ticked, not only those with a verbal description.

1 = extremely alert
2
3 = alert
4
5 = neither sleepy nor alert
6
7 = sleepy, but no difficulty remaining awake
8
9 = extremely sleepy, fighting sleep

[39] Åkerstedt T, Gillberg M. Subjective and objective sleepiness in the active individual. International Journal of Neuroscience 52: 29-37, 1990.

[40] Gillberg M, Kecklund G, Åkerstedt T. Relations between performance and subjective ratings of sleepiness during a night awake. Sleep 17(3): 236-241, 1994.

[41] Harma M, Sallinen M, Ranta R, Mutanen P, Muller K. The effect of an irregular shift system on sleepiness at work in train drivers and railway traffic controllers. Journal of Sleep Research 11(2):141-151, 2002.

[42] Gillberg M. Subjective alertness and sleep quality in connection with permanent 12-hour day and night shifts. Scandinavian Journal of Work Environment and Health 24 (Suppl 3): 76-80, 1998.

[43] Reyner LA, Horne JA. Evaluation of 'in-car' countermeasures to sleepiness: cold air and radio. Sleep 21(1): 46-50, 1998.

Figure B-2. The Karolinska Sleepiness Scale (KSS)

Figure B-3 shows KSS ratings from 25 flight crew members across ultra-long range flights from Singapore to Los Angeles[44,45]. (While not from ATCs, this is included simply to illustrate the use of the KSS scale.)

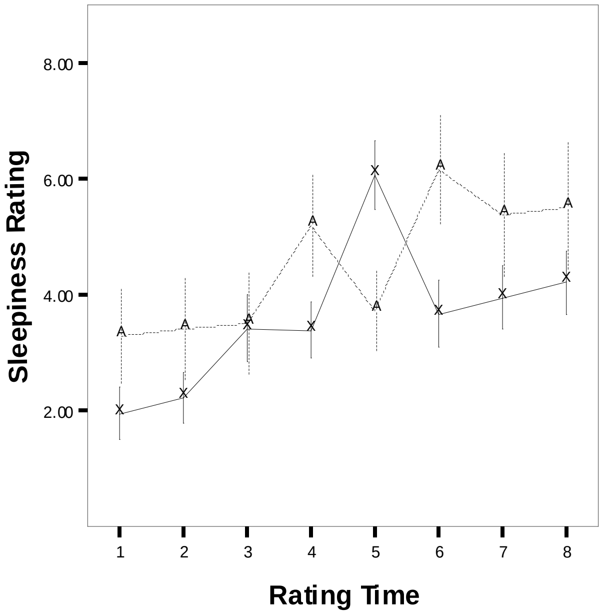

Figure B-3. KSS sleepiness ratings on flights from Singapore to Los Angeles (solid line – data for the command crew; dotted line – date for the relief crew)[46]

From Figure B-3, each flight had two crews (two captains, two first officers). The command crew (solid line) flew both the takeoff and the landing and was allocated the 2nd and 4th in-flight rest periods. The relief crew (dotted line) was allocated the 1st and 3rd in-flight rest periods (they became the command crew for the return flight).

Ratings were made at the following times: rating 1 - pre-flight; rating 2 - at top of climb; rating 3 - before each crew member's 1st in-flight rest period; rating 4 - after each crew member's 1st in-flight rest period; rating 5 - before each crew member's 2nd in-flight rest period; rating 6 – after each crew member's 2nd in-flight rest period; rating 7 - at top of descent; and rating 8 - post-flight before departing the aircraft.

The command and relief crews have different patterns in their sleepiness ratings across the flight, partly as a result of their different in-flight rest patterns.

[44] Flight Safety Foundation. Flight Safety Digest 24 (8-9), 2006.

[45] Signal TL, van den Berg M, Travier N, Gander PH (2004). Phase 3 ultra-long range validation: in-flight polysomnographic sleep and psychomotor performance. Wellington, New Zealand: Massey University, Sleep/Wake Research Centre Report.

[46] Figure provided with permission of Dr Jarnail Singh, CAA Singapore.

THE SAMN-PERELLI CREW STATUS CHECK

This scale asks people to rate their level of fatigue right now, and is a simplified version of the Samn-Perelli Checklist[47,48,49].

1 = fully alert, wide awake

2 = very lively, responsive, but not at peak

3 = okay, somewhat fresh

4 = a little tired, less than fresh

5 = moderately tired, let down

6 = extremely tired, very difficult to concentrate

7 = completely exhausted, unable to function effectively

Figure B-4. The Samn-Perelli Crew Status Check

Figure B-5 shows Samn-Perelli ratings for the same crew members on the same flights as in Figure B-3.

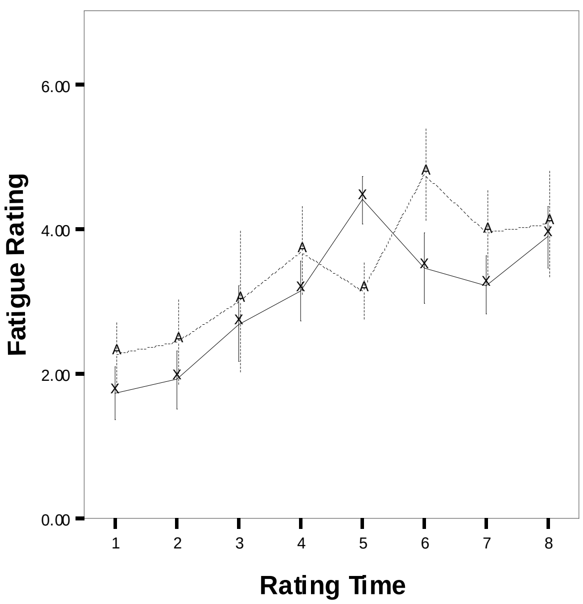

Figure B-5. Samn-Perelli fatigue ratings on flights from Singapore to Los Angeles (solid line – data for the command crew, dotted line – data for the relief crews)

[47] Samn SW, Perelli LP. Estimating aircrew fatigue: A technique with implications to airlift operations. Brooks AFB, TX: USAF School of Aerospace Medicine. Technical Report No. SAM-TR-82-21, 1982.

[48] Samel A, Wegmann HM, Vejvoda M. Aircrew fatigue in long-haul operations. Accident Analysis and Prevention 29(4): 439-452, 1997.

[49] Gander PH, Mulrine HM, van den Berg MJ, et al. Effects of sleep/wake history and circadian phase on proposed pilot fatigue safety performance indicators. Journal of Sleep Research 24:110–119, 2015.

Both the KSS and the Samn-Perelli fatigue scales have been shown in laboratory studies to be influenced by prior sleep history and the circadian body clock cycle[50, 51]. A recent study confirmed both scales are also influenced by prior sleep history and the circadian body clock cycle for ratings made pre-flight and at TOD on long range and ultra-long range flights (237 pilots in 4-piot crews, 730 out-and-back flights between 13 city pairs, 1-3 day layovers)[52].

STRENGTHS AND WEAKNESSES OF SUBJECTIVE RATINGS

Subjective sleepiness and fatigue ratings are relatively cheap and easy to collect and analyze. Furthermore, how a crew member feels is likely to influence their decisions about when to use personal fatigue countermeasure strategies. On the other hand, subjective ratings do not always reliably reflect objective measures of performance impairment or sleep loss, particularly when a person has been getting less sleep than they need (sleep restriction) across several consecutive nights.

Concerns about some ATCs exaggerating on subjective fatigue and sleepiness ratings, for personal or industrial reasons, should be minimal in a just reporting culture as is required for FRMS. In addition, extreme ratings are obvious when compared with group averages.

In an FRMS, subjective sleepiness and fatigue ratings are particularly useful for:

- gathering information from large groups of crew members;
- where data are needed fairly quickly to decide whether more in-depth monitoring is warranted or if additional fatigue risk mitigation strategies are needed; and
- among a range of measures when more intensive monitoring is undertaken in an FRMS (for example during validation of a new route), because they provide valuable insights on crew members' experience of fatigue.

Decision-making by the FSAG can be guided by comparing averages and/or extreme ratings with data gathered on other operations. For example, Figure B-6 shows the percentage of pilots rating KSS at least 7 at pre-flight and at top of descent[53]. (In laboratory studies, ratings of 7-9 have been associated with the onset of micro-sleeps)[54]. Figure B-6 includes data from 82 landing crew members on 2 long range and 3 ultra-long range trips (4-person crews, 3 airlines, 220 flights). While not specifically related to ATCs, these studies serve to illustrate the use of the measurement scale.

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[50] Sargent C, Darwent D, Ferguson SA, Roach GD (2012). Can a simple balance task be used to assess fitness for duty? Accident Analysis and Prevention 455:74-79, 2012.

[51] Fergusson SA, Paech GM, Sargent C, Darwent D, Kennaway DJ, Roach GD. The influence of circadian time and sleep dose on subjective fatigue ratings. Accident Analysis and Prevention 455:50-54, 2012.

[52] Gander PH, Mulrine HM, van den Berg MJ, Smith AAT, Signal TL, Wu LJ, Belenky G. Effects of sleep/wake history and circadian phase on proposed pilot fatigue safety performance indicators. Journal of Sleep Research 24:110–119, 2015.

[53] Gander PH, Mangie JM, van den Berg MJ, Smith AAT, Mulrine HM, Signal TL. Crew fatigue safety performance indicators for fatigue risk management systems. Aviation, Space and Environmental Medicine 85: 139-147, 2014.

[54] Åkerstedt T, Gillberg M. Subjective and objective sleepiness in the active individual. International Journal of Neuroscience 52:29-37, 1990.

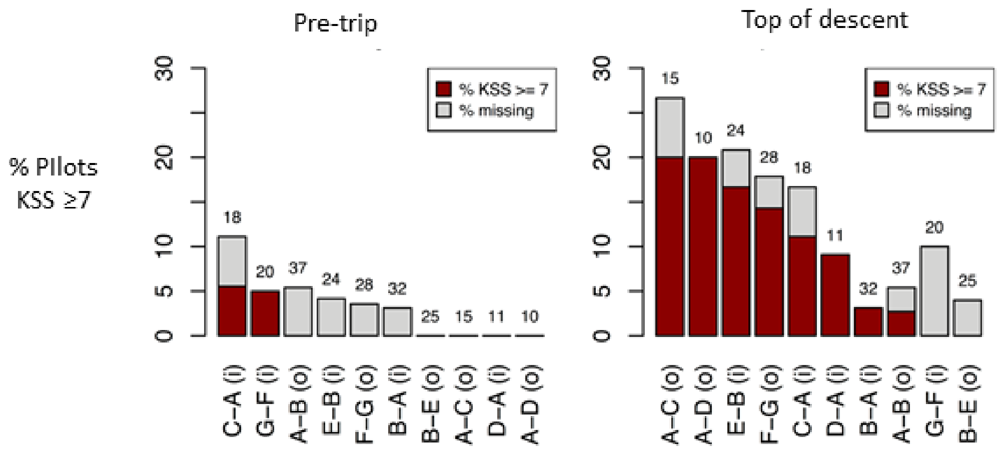

Figure B-6. Percentage of landing pilots in 4-pilot crews who rated their sleepiness at least 7 on the KSS, for 10 long range and ultra-long range flights (adapted from Gander et al, 2014[49]).

Dark bars – percentage of pilots who rated themselves above 7. Grey bars – percentage of pilots in the studies who did not provide a rating at that time point. Letters A through G – different cities. A-B indicates a flight from city A to city B, etc. o = outbound; I = inbound. Values above each bar plot indicate number of crew members included.

For example, one SPI might be that no shift or pattern of shifts has more than 15% of ATCs rating their KSS sleepiness as 7 or higher at the end of a shift. A higher percentage on any shift or across a particular pattern would trigger the FSAG to undertake a risk assessment and examine whether additional mitigation strategies are needed on that flight.

B3 OBJECTIVE PERFORMANCE MEASUREMENT

A range of objective performance tests are used in laboratory studies, but they usually measure very specific aspects of performance (for example, reaction time, vigilance, short-term memory, etc), not the complex combinations of skills needed by ATCs during air traffic control operations. Laboratory tests usually also measure the performance of individuals, not the combined performance of ATCs with each other or with flight crew from aircraft. Nevertheless, some simple performance tests are considered 'probes' or indicators of an ATC's capacity to carry out his or her duties.

The following things should be considered when choosing performance tests for monitoring ATC fatigue and sleepiness during air traffic control operations.

- How long does the test last?
- Can it be completed at multiple time points (e.g., a number of times across a duty period), without compromising a ATC's ability to meet duty requirements?
- Has it been validated? For example, has it been shown to be sensitive to the effects of sleep loss and the circadian body clock cycle under controlled experimental conditions?
- Is it predictive of more complex tasks, e.g., ATC performance in the simulator or during an emergency situation? (Unfortunately, there is very little research addressing this question at present.)
- Has it been used in other aviation operations, and are the data available to compare performance levels?

One performance test that has been well-validated in the laboratory and is widely used in field studies is the Psychomotor Vigilance Task or PVT[55,56,57]. The most widely used version in recent studies is a 5-minute version of the PVT programmed on a smart phone.

A recently published ATC fatigue study[58] administered a 5-min PVT during a 14 day protocol. Each participant self-administered the PVT at three times during their duty period, once in the beginning of their shift, once after a mid-shift break, and once within 1 hour of their shift end time. This allowed for comparisons of objective alertness in the start of a shift to objective alertness at the end of the shift. Tables B-1 and B-2 show lapses and changes from baseline response speed at the beginning and end of each shift.

Independent of the type of shift and day in the duty cycle, lapses increase significantly across shifts (see Table B-1). The same pattern was seen in response speeds across any single shift. Response speeds became slower the longer the controller worked (Table B-2).

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[55] Dinges DF, Powell JP. Microcomputer analysis of performance on a portable, simple visual RT task during sustained operation. Behavior Research Methods, Instruments, and Computing 17: 652-655, 1985.

[56] Balkin TJ, Bliese PD, Belenky G, Sing H, Thorne DR, Thomas M, Redmond DP, Russo M, Wesensten, NJ. Comparative utility of instruments for monitoring sleepiness-related performance decrements in the operational environment. Journal of Sleep Research 13: 219-227, 2004.

[57] Zhou X, Ferguson SA, Mathews RW, Sargent C, Darwent D, Kennaway DJ, Roach GD. Sleep, wake, and phase dependent changes in neurobehavioural function under forced desynchrony. Sleep 34:931-941, 2011.

[58] Orasanu J, Parke B, Kraft N, Tada Y, Hobbs A, Anderson B, McDonnell L and Dulchinos V. (2012) Evaluating the Effectiveness of Schedule Changes for Air Traffic Service (ATS) Providers: Controller Alertness and Fatigue Monitoring Study, Technical Report DOT/FAA/HFD-13/001, Federal Aviation Administration.

Table B-1. Mean Lapses and Standard Deviation at Beginning and End of Shifts

Trial	Mean Lapses	SD
Trial 1 (Beginning of shift)	1.84	4.54
Trial 3 (End of shift)	2.57	5.35

Table B-2. Mean Response Speed (deviation from the baseline) and Standard Deviation at Beginning and End of Shifts

Trial	Mean Response Speed	SD
Trial 1 (Beginning of shift)	-0.000549	.000488
Trial 3 (End of shift)	-0.000694	.000539

In another study[59], a 10 minute version of the PVT was used by 28 ATCs who completed four night shifts (two with early starts [22:30] and two with late starts [23:30]). One early starting night shift and one late starting night shift included a 40-min planned nap opportunity, and on the other night shift no nap was taken. Figure B-7 shows the mean of the slowest 10% of reaction times on each type of night shift. The PVT test was completed at the beginning and end of the shift (test 1 and test 3), and after the nap (or an equivalent time if no nap was taken, test 2). Results seen in Figure B-7 show that ATCs were slower at responding at the end of night shifts when no nap was taken (test 3, red and blue bars) compared to the early starting night shift with a nap (test 3, green bars). On the late starting night shift with a nap, ATCs were faster compared the late night shift with no nap (test 2 and 3, pink bars versus test 2 and 3, blue bars).

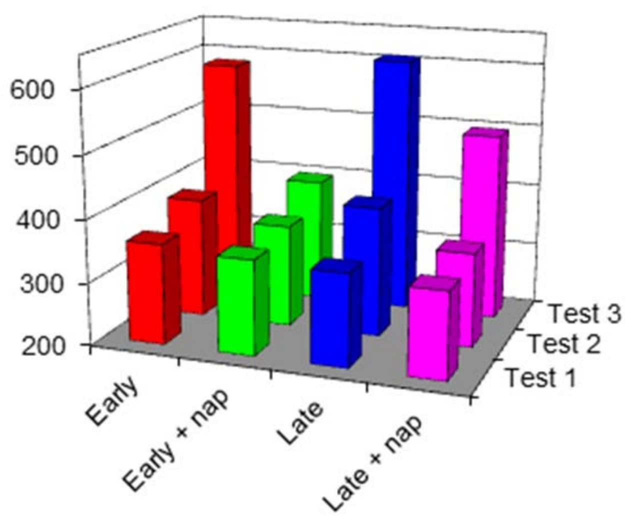


Figure B-7. Mean reaction time on the PVT for ATCs on night shifts with and without a nap[60].

[59] Signal, T. L., Gander, P.H., Anderson, H. and Brash, S. (2009) Scheduled napping as a countermeasure to sleepiness in air traffic controllers. *Journal of Sleep Research*, 18, p 11-19.

[60] Figure supplied by Prof. T. L. Signal, Sleep/Wake Research Centre, Massey University.

STRENGTHS AND WEAKNESSES OF THE PVT

The PVT does not measure important skills such as situation awareness and decision-making. On the other hand, more complex tests to measure these types of skills usually require many practice trials before they can be considered fully learnt and ready to be used for measuring changes due to fatigue. The PVT does not require practice trials, except to make sure that ATCs know how to operate the testing device.

The PVT requires an ATC's constant attention during the test. During this period, ATCs are required to be out of the operational loop.

B4 MONITORING SLEEP

Sleep loss is a key contributing factor to fatigue. In addition, ATCs need to get recovery sleep to return to their optimum level of waking function before reporting for the next work shift. Sleep can be monitored across work days using subjective sleep diaries and/or by objective measures such as actigraphy or polysomnography. Each of these is described in more detail below.

SLEEP DIARIES

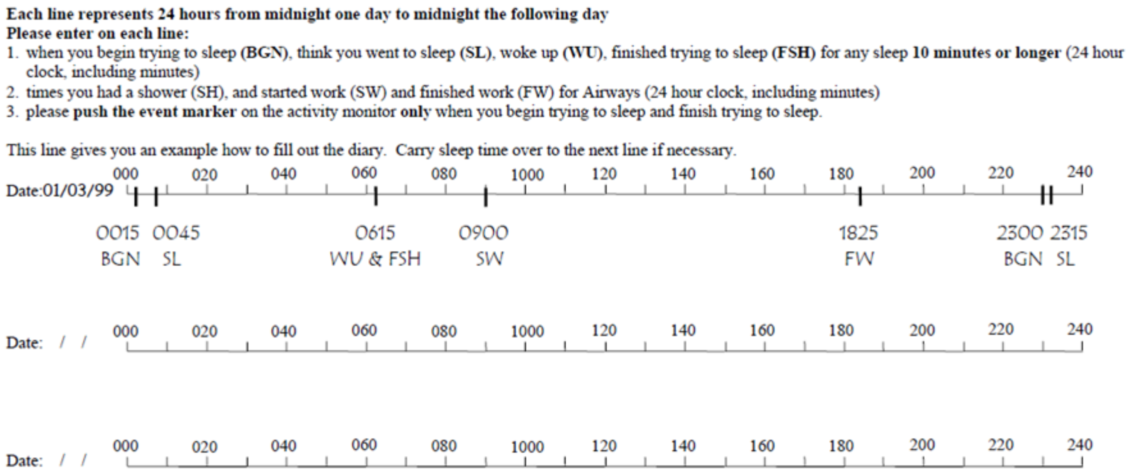
Sleep diaries ask ATCs to record the following information about each sleep period:

- what time they go to bed and get up;
- how much sleep they think they get; and
- how well they think they sleep.

ATCs may also be asked to rate their sleepiness and fatigue before and after planned sleep periods. When sleep is being monitored across a work cycle, ATCs may also be asked to record actual duty times.

Diaries can have different layouts and they are often adapted to include specific information for a given study (for example, reminders about when to do performance tests or workload rating scales). Paper-based diaries are still more common, but electronic versions are also used (e.g., programmed on a smart phone or tablet).

Figure B-8 shows an example of a sleep diary that was used in the study described in association with Figure B-7 (courtesy of the Sleep/Wake Research Centre).


Each line represents 24 hours from midnight one day to midnight the following day
Please enter on each line:
1. when you begin trying to sleep (**BGN**), think you went to sleep (**SL**), woke up (**WU**), finished trying to sleep (**FSH**) for any sleep **10 minutes or longer** (24 hour clock, including minutes)
2. times you had a shower (SH), and started work (SW) and finished work (FW) for Airways (24 hour clock, including minutes)
3. please **push the event marker** on the activity monitor **only** when you begin trying to sleep and finish trying to sleep.

This line gives you an example how to fill out the diary. Carry sleep time over to the next line if necessary.

Figure B-8. Example Sleep Diary.

STRENGTHS AND WEAKNESSES OF SLEEP DIARIES

Sleep diaries are cheap compared to objective forms of sleep monitoring. However, information from paper diaries needs to be manually entered into databases, which can slow down the process of getting answers to a particular operational question. Electronic diaries that can be downloaded avoid this problem. Analysis of diary data also has costs associated.

Sleep diaries are known to be less reliable than objective sleep monitoring. As an example, one study has compared sleep diaries and objective sleep measures from 21 B-777 flight crew members in a layover hotel and in flight[61]. For in-flight sleep:

- *average sleep durations* from diaries were similar to those recorded using polysomnography (the accepted gold standard for recording sleep); but
- the variability among individuals was high. Some crew members over-estimated how long they slept, and others underestimated; and
- crew members' estimates of how long they took to fall asleep, and their ratings of sleep quality were not reliably related to polysomnography measures.

Thus diaries alone may be useful for measuring the sleep duration of groups but *cannot be considered accurate for estimating the sleep duration of any one individual.* In addition, diaries are not generally considered reliable for measuring sleep quality. (However, some very new research suggests that people's reports of their sleep quality may be related to changes in parts of the brain that are not detected by polysomnography, so scientific opinion about the value of self-reported sleep quality may change).

Despite these limitations, sleep diaries are a relatively cheap way of gathering reasonable information on the average amount of sleep obtained by *groups* of ATCs. They are also used to help interpret objective sleep data, as described below.

[61] Signal TL, Gale J, Gander PH. Sleep Measurement in Flight Crew: Comparing actigraphic and subjective estimates of sleep with polysomnography. Aviation Space and Environmental Medicine 76(11):1058-1063, 2005.

ACTIGRAPHY

An actigraph is a small device worn on the wrist that contains an accelerometer to measure movement and a memory chip to store 'activity counts' at regular intervals (for example every minute). Depending on the amount of memory available, they can be worn for weeks to months before the data need to be down-loaded to a computer for analysis.

A new generation of actigraphs is coming onto the market which are much cheaper than older models and have a variety of options including: an event marker button (to place a time mark in the data file, for example when going to bed); light sensors (although if they are worn inside a shirt sleeve this may not be reliable); and a regular watch face so that the wearer does not need to wear a normal watch as well, to keep track of time. Each type comes with custom software that scans through the activity record and decides whether the person was asleep or awake in each recorded epoch (for example every minute).

There are a number of important considerations when choosing actigraphs for use in ATC field studies.

- Validation – actigraphs monitor movement, not sleep. They provide a string of activity counts. For actigraphy to be a reliable measure of sleep, the computer algorithm that decides whether the wearer was awake or asleep in each epoch has to have been validated against polysomnography, the gold standard for measuring sleep (see next section)[13] . An actigraph that has not been validated against polysomnography cannot be considered to provide reliable information on sleep patterns.
- Battery maintenance - available options include batteries that the user replaces as needed, and batteries that the user recharges but cannot remove and that are replaced e.g., annually, by the manufacturer. This requires taking the actigraph out of circulation while it is sent back to the manufacturer.
- How data are downloaded – this is usually done by the user, but some new models require the data to be downloaded by the manufacturer, which can raise issues around data ownership and confidentiality.

Figure B-9 shows the pattern of work and sleep for the 28 ATCs described in Figure B-7 above. The black bars represent the 4 shifts worked and the forward rotating pattern with each shift starting earlier than the previous shift. Information on the timing of work was obtained from the ATCs sleep diaries. The light blue bars are based on average actigraphy data from all the ATCs. The earlier rise times due to the earlier starting shifts can be seen, as well as the afternoon nap prior to beginning the night shift and the short daytime sleep following the night shift. It can also be seen that on days off following the duty pattern the ATCs sleep later than on any other days.

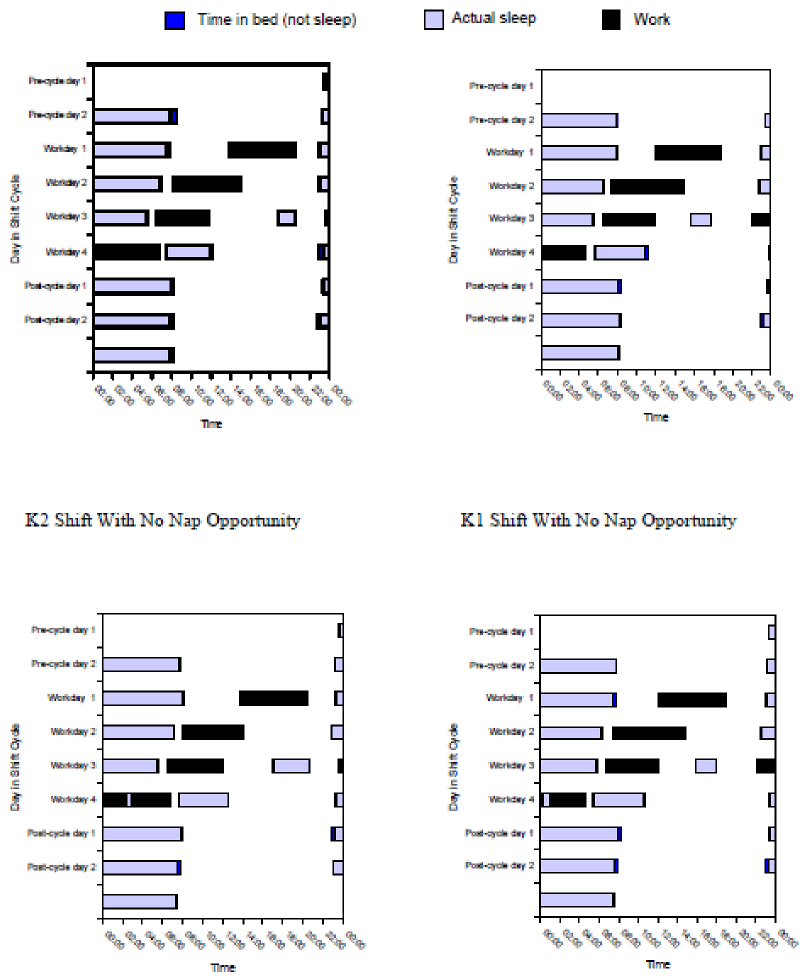


Figure B-9. Graphs created using actigraphy data collected from ATCs across a week of work[62].

STRENGTHS AND WEAKNESSES OF ACTIGRAPHY

As Figure B-9 illustrates, actigraphy is very useful for obtaining objective records of the sleep/wake patterns of ATCs across multiple days. This is currently the most practical and reliable way to look at whether an ATC accumulates a sleep debt across a work week, compared to the amount of sleep they average on days off. Actigraphy can also provide useful information on recovery sleep on days off, or after a particular shift.

Actigraphs are small and unobtrusive to wear, and actigraphy is cheap compared to polysomnography. The main limitation of actigraphy is that it monitors activity (not sleep) and it cannot distinguish between someone being asleep versus being awake but not moving.

On the positive side, actigraphy is reliable for estimating the average sleep duration of groups of people.

At present, the accepted standard for analyzing actigraphy records is to use a sleep diary to identify when an ATC was trying to sleep (as opposed to just sitting still or not wearing the watch). The sections of the record where the ATC was trying to sleep are then analyzed for sleep duration and quality. This type of analysis requires a trained person to work

[62] Figure provided by Prof. T. L. Signal, Sleep/Wake Research Centre, Massey University.

through actigraphy records manually, which is time consuming and fairly costly. Several manufacturers and research groups are looking at ways to bypass the need for this manual scoring, which would make actigraphy much cheaper and faster to analyze. However, the reliability of these new approaches for estimating sleep quantity and quality (compared to polysomography) remains to be demonstrated.

Some ATS Providers using FRMS may choose to develop the capacity in-house to collect and analyze actigraphy. As part of the FRMS Assurance Processes, an external scientific advisory group could be convened periodically to review the actigraphy analyzes and the resulting decisions made by the FSAG.

POLYSOMNOGRAPHY

Polysomnography is the accepted gold standard for monitoring sleep and is currently the only method that gives reliable information on the internal structure of sleep and on sleep quality. It involves sticking removable electrodes to the scalp and face and connecting them to a recording device, to measure three different types of electrical activity: 1) brainwaves (electroencephalogram or EEG); 2) eye movements (electroculogram or EOG); and 3) muscle tone (electromyogram or EMG).

In addition to monitoring sleep, polysomnography can be used to monitor waking alertness, based on the dominant frequencies in the brainwaves, and patterns of involuntary slow rolling eye movements that accompany sleep onset. Figure B-10 shows a flight crew member on the flight deck wearing polysomnography electrodes, which the researcher is connecting to a portable recording device.

Figure B-10: Air Traffic Controllers wearing polysomnography electrodes while at work

Figure B-11 shows an analysis of the polysomnography record of a flight crew member during his first in-flight sleep period on a SIN-LAX flight. Figure B-11 is a graph created by a trained sleep technician who has gone through the entire polysomnographic recording and, using an internationally agreed set of rules, has decided for each 30 seconds whether the crew member was awake, or in which type of sleep he spent most of that 30 seconds. Figure B-11 shows that he took 13 minutes to fall asleep and then spent a total of 17.5 minutes in light non-REM sleep (S1 and S2). However, he woke up

6 times across the sleep period. He did not enter slow-wave sleep (non-REM S3 and S4), or Rapid Eye Movement (REM) sleep.

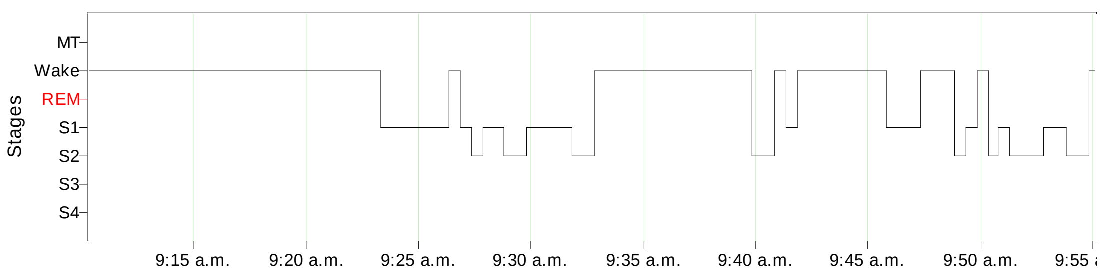


Figure B-11: Polysomnographic record for a crew member's first in-flight rest period on a SIN-LAX flight

Figure B-12 shows the polysomnographic record for the same crew member during his second in-flight rest period on a SIN-LAX flight. In this rest period (in the bunk), he fell asleep in 19.5 minutes and then slept for a total of 144.5 minutes, interrupted by numerous brief periods of waking which totalled 52 minutes. He spent 1.5 minutes in slow-wave sleep, 2 minutes in REM sleep, and the rest of the time in light non-REM sleep (S1 and S2).

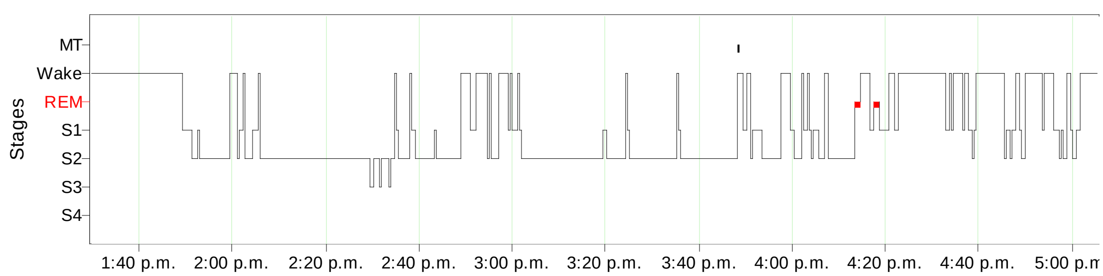


Figure B-12: Polysomnographic record a crew member's second in-flight rest period on a SIN-LAX flight (same crew member as in Figure B-11)

In the study described in Figure B-7, ATCs wore the polysomnographic electrodes while they were awake and working. This enabled objective measures of alertness to be recorded from brain activity (EEG) and eye movements (EOG). Brain activity is analyzed by looking at the amount of activity in different frequency bands (the occurrence of slower brain waves is more likely when someone is sleepier). Eye movement is analyzed by looking for particular types of eye movements that occur when someone is sleepy. In this study, when ATCs did not have a nap, their EEGs showed slower brain waves.

STRENGTHS AND WEAKNESSES OF POLYSOMNOGRAPHY

Figures B-11 and B-12 show the detailed information about sleep quality that can only be obtained from polysomnographic recordings. When it is important to be certain about the amount and type of sleep that crew members are obtaining, polysomnographic monitoring is the most trusted method.

On the other hand, polysomnography is relatively obtrusive and time-consuming. It takes a well-trained technician about 30 minutes to attach the recording electrodes to a person's scalp and face, and check that all the electrical connections are working. For on-duty recordings, the electrical contacts need to be checked periodically (for example before each rest period) to make sure that the signals are still clean. ATCs can be shown how to remove the electrodes themselves. However, the equipment is expensive and fragile and a technician is required to download the data from the recording device to a computer, and to clean the equipment. This means that it is usual for at least one technician to be present before and after periods in which ATCs' sleep is recorded using polysomnography. This is costly.

As previously mentioned, the currently accepted standard for analyzing polysomnography is to have a trained sleep scoring technician work through the entire recording to decide for each 30 seconds whether the ATC was awake, or in which type of sleep he/she spent most of that 30 seconds. For quality assurance, it is usual to have a second trained technician score at least some of the records to check the reliability of scoring between the two technicians. This is time consuming and relatively expensive. A number of groups are working on automated scoring systems for polysomnography, but as yet none of these are widely accepted by the sleep research and sleep medicine communities. Beyond the scoring process, it is necessary to have a qualified person to interpret that significance of diagrams such as Figures B-11 and B-12.

Despite these costs and inconveniences, there have been a number of studies of ATC sleep that have used polysomnography and these have been very informative. While it is unlikely that any ATS Provider would need to develop in-house capacity to record and analyze polysomnography as a routine part of its FRMS, there are situations where the detailed information from polysomnography is needed. For example, in launching the first commercial passenger ULR flights, Singapore Airlines and the Singapore Civil Aviation Authority agreed that a subgroup of crew members would have their sleep monitored by polysomnography during the operational validation of the SIN-LAX route. The data in Figures B-3, B-5, B-7, B-11, and B-12 come from this validation and are used with the kind permission of the Singapore Civil Aviation Authority (Dr Jarnail Singh) and provided by the Sleep/Wake Research Centre at Massey University, New Zealand.

B5 MONITORING THE CIRCADIAN BODY CLOCK CYCLE

The circadian body clock cycle is a contributing factor to ATC fatigue, but it is difficult to monitor during air traffic operations. In the laboratory, the cycle of the body clock is usually monitored by measuring two of the overt rhythms that it drives;

1. the daily rhythm in core body temperature, measured by an ingested core temperature pill or rectally-inserted probe; and
2. the daily rhythm in levels of the hormone melatonin, which is secreted by the pineal gland at night. Melatonin levels can be measured from blood, saliva, or urine samples collected at regular intervals.

There is ongoing research aimed at developing more robust and non-intrusive methods for continuously monitoring circadian rhythms outside the laboratory, including a new generation of temperature 'pills', that are swallowed and transmit temperature measurements as they transit through the digestive system. However, body temperature is also affected by the level of physical activity, and it is complex to separate out this 'masking effect' from the actual circadian clock-driven component of the temperature rhythm (this was done mathematically in Figure B-14).

The second rhythm that is commonly monitored in the laboratory to track the cycle of the circadian body clock is the level of the hormone melatonin. Melatonin can be measured in blood or saliva samples taken at regular intervals, and its metabolites can be measured in urine samples. There are obvious difficulties associated with collection and frozen storage of body fluid samples during flight operations. Another complicating factor is that synthesis of melatonin is switched off by bright light. Thus, if an ATC is exposed to daylight during his/her "biological night" (for example, a few hours either side of the of the temperature minimum in Figure B-14), melatonin secretion will stop. This makes it impossible to track its normal circadian cycle cross a trip such as that in Figure B-14. Analyzing for hormone levels in body fluids is a highly skilled task that needs to done by a reputable laboratory.

STRENGTHS AND WEAKNESSES OF MONITORING THE CIRCADIAN BODY CLOCK CYCLE

There is remarkably little information available on how the circadian body clock is affected by any kind of ATC shift pattern. Better information in this area would improve the predictive power of bio-mathematical models for fatigue hazard identification, and might provide insights on how to tailor personal mitigation strategies for ATCs who are morning-types versus evening-types. A number of groups are actively working on new technologies for monitoring the circadian body clock cycle, but as yet none of these has been validated or demonstrated to be robust enough and practical for use during flight operations.

B5.1 WORKLOAD

At present, there is no clear operational definition of workload or agreed ways of measuring it any operational environment. Two more commonly used measures are the NASA Task Load Index (Figure B-14) and the Overall Workload Scale (Figure B-15).[63]

Place an 'X' in the position that best describes your experience. Note that 'your success in accomplishing tasks' is rated from 'good' to 'poor'.

How mentally demanding was the flight?	Low	|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|	High
How physically demanding was the flight?	Low	|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|	High
How hurried or rushed was the pace of the flight?	Low	|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|	High
How successful were you in accomplishing what you were asked to do?	Good	|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|	Poor
How hard did you have to work to accomplish your level of performance?	Low	|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|	High
How insecure, discouraged, irritated, stressed and annoyed were you?	Low	|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|	High

Figure B-14: The NASA Task Load Index

Overall workload on this flight: *(Please complete on flight deck)*	Low	|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|	High

Figure B-15:The Overall Workload Scale

Instructions for use of the NASA TLX index can be found at: http://humansystems.arc.nasa.gov/groups/tlx/

[63] Hill SG, Iavecchia HP, Bittner AC, Zaklad AJ, Christ RE. Comparison of four subjective workload rating scales. Human Factors 34:429-439, 1992.

B6 EVALUATING THE CONTRIBUTION OF FATIGUE TO SAFETY EVENTS

The primary aim of investigating the role of crew member fatigue in safety events is to identify how its occurrence or effects could have been mitigated, in order to reduce the likelihood of similar events in the future. There is no simple formula for evaluating the contribution of fatigue to a safety event. To establish that fatigue was a contributing factor, it has to be shown that;

- the ATC was in a fatigued state; and
- the ATC took particular actions or decisions that were causal in what went wrong; and
- those actions or decisions are consistent with the type of behaviour expected of a fatigued ATC.

Basic information can be collected for all fatigue reports and safety events, with more in-depth analyzes reserved for events where it is more likely that fatigue was an important factor and/or where the outcomes were more severe.

B6.1 BASIC INFORMATION

To establish whether an ATC was likely to have been fatigued at the time of an event, four pieces of information are needed.

1. The time of day that the event took place. If it was in the WOCL (0200-0600), than fatigue may have been a factor.
2. Whether the ATC's normal circadian rhythm was disrupted (for example, if in the last 72 hours they had been on duty at night, or worked a non-standard schedule).
3. How many hours the ATC been awake at the time of the occurrence. (It may be more reliable to ask 'what time did you wake up from your last sleep period before the event?'). If this is more than 16 hours, then sleepiness may have been a factor.
4. Whether the 72-hour sleep history suggests a sleep debt. As a rough guide, if the average adult requires 7-8 hours of sleep per 24 hours, then an ATC who has had less than 21 hours sleep in the last 72 hours was probably experiencing the effects of a sleep debt. If information on sleep history is not available, duty history can provide information on sleep opportunities.

B6.2 INVESTIGATING FATIGUE IN DEPTH

If answers to the four questions above suggest that the ATC was fatigued at the time of the event, then more in-depth investigation requires looking at whether the ATC or ATC team took particular actions or decisions that were causal in what went wrong, and whether those actions or decisions are consistent with the type of behavior expected of a fatigued ATC or ATC team. The following two checklists provide one example of how this can be done.

Checklist 1 is designed to establish whether the person or crew were in a fatigued state, based on a series of questions or probes that address key aspects of fatigue. The answer to each question is compared to the best case response, in order to build an overall picture of the fatigue hazard. Any departure from the best case response indicates increased risk of fatigue.

Checklist 2 is designed to establish whether the unsafe action(s) or decision(s) were consistent with the type of behavior expected of a fatigued ATC or team.

Checklist 1: Establishing the Fatigued State

Questions	Best Case Responses	Investigator's Notes
Quantity of Sleep **establish whether or not there was a sleep debt**		
How long was last consolidated sleep period?	7.5 to 8.5 hours	
Start time?	Normal circadian rhythm, late evening	
Awake Time?	Normal circadian rhythm, early morning	
Was your sleep interrupted (for how long)?	No	
Any naps since your last consolidated sleep?	yes	
Duration of naps?	Had opportunity for restorative (1.5-2 hrs) or strategic (20 min) nap prior to start of late shift	
Describe your sleep patterns in the last 72 hours. (Apply sleep credit system)	2 credits for each hour of sleep; loss of one credit for each hour awake - should be a positive value	
Quality of Sleep **establish whether or not sleep was restorative**		
How did the sleep period relate to the individual normal sleep cycle i.e., start/finish time?	Normal circadian rhythm, late evening/early morning	
Sleep disruptions?	No awakenings	
Sleep environment?	Proper environmental conditions (quiet, comfortable temperature, fresh air, own bed, dark room)	
Sleep pathologies (disorders)	None	
Work History **establish whether hours worked and type of duty or activities involved had an impact on sleep quantity and quality**		
Hours on duty and/or on call prior to the occurrence?	Situation dependent - hours on duty and/or on call and type of duty that ensure appropriate level of alertness for the task	
Work history in preceding week?	Number of hours working and/or on call and type of work schedule that do not lead to a cumulative fatigue	

Irregular Schedules establish whether the scheduling was problematic with regards to its impact on quantity and quality of sleep		
Was ATC a shift worker (working through usual sleep times)?	Yes (The circadian body clocks and sleep of shift workers do not adapt fully)	
If yes, was it a permanent shift?	No rotating shifts	
If no, was it rotating (vs irregular) shift work?	Yes - Rotating clockwise, rotation slow (1 day for each hour delayed), night shift shorter, and at the end of cycle	
How are overtime or double shifts scheduled?	Scheduled when ATCs are in the most alert parts of the circadian body clock cycle (late morning, mid evening)	
Scheduling of critical safety tasks?	Scheduled when ATCs are in the most alert parts of the circadian body clock cycle (late morning, mid evening)	
Has crew member had training on personal fatigue mitigation strategies?	Yes	

Performance Indicators	Investigator's Notes
Attention	
Overlooked sequential task element	
Incorrectly ordered sequential task element	
Preoccupied with single tasks or elements	
Exhibited lack of awareness of poor performance	
Reverted to old habits	
Focused on a minor problem despite risk of major one	
Did not appreciate gravity of situation	
Did not anticipate danger	
Displayed decreased vigilance	
Did not observe warning signs	
Memory	
Forgot a task or elements of a task	
Forgot the sequence of task or task elements	
Inaccurately recalled operational events	
Alertness	
Succumbed to uncontrollable sleep in form of microsleep, nap, or long sleep episode	
Displayed automatic behavior syndrome	
Reaction Time	
Responded slowly to normal, abnormal or emergency stimuli	
Failed to respond altogether to normal, abnormal or emergency stimuli	
Problem-Solving Ability	
Displayed flawed logic	
Displayed problems with arithmetic, geometric or other cognitive processing tasks	
Applied inappropriate corrective action	
Did not accurately interpret situation	
Displayed poor judgment of distance, speed, and/or time	

APPENDIX C. APPENDIX C. PROTOCOL FOR NAPS TAKEN DURING WORK PERIODS

The following is one example of a napping protocol that may be used as a starting point for ATS Providers to develop their own planned napping protocol:

ATS Provider A will use four general steps to ensure the effective use of planned naps:

1. plan;
2. inform;
3. create an appropriate environment; and
4. return to work.

1. Plan

a) Identify who will take a planned nap –

- Managers may give personnel periods of relief by combining operating positions provided:
  - i. current and anticipated workload permits; and
  - ii. the employee can be quickly recalled
- ATCs may not leave an assigned operating position to take a planned nap unless:
  - i. You are relieved by a person qualified to accept responsibility for that position; and you follow unit directives for the transfer of position responsibility; or
  - ii. you follow unit guidelines for temporarily vacating an operating position if you are the only qualified person in the unit.

b) Identify the length of the planned nap -

- The length of the nap while at work should be about 45 minutes or less. If an employee can only have 5 or 10 minutes for a brief nap, getting some sleep is better than no sleep.
- For a longer planned nap at home, consider about 2 hours. However, be sure not to take a long nap too close to your next planned sleep period, or you may have trouble falling asleep then.

c) Identify specific start and end times for the planned nap.

- Be clear about when you will begin and end your planned nap. It should not be "open-ended."

d) Identify a specific method of waking up.

- Don't leave waking up to chance. Before you go to sleep, be sure you have a reliable way to wake up. You might use an alarm clock or ask a specific person to get you up at the identified wake time.

2. Inform

- Have a specific hand-off procedure for information and activities. Before your nap, make sure that you inform as appropriate that you are going to take a planned nap, when, and for how long. Hand off work responsibilities to specific people and provide important information to your co-workers before taking a planned nap.

3. Create appropriate environment

- Establish a comfortable environment in which to take a planned nap, whether this is in the rest room, TV room or other. The following are general considerations. Try to make the environment as dark and quiet as possible; consider using an eye shade or earplugs. Adjust these and other factors (e.g., position) to your comfort. In a study of rest facilities in commercial aviation, it was reported that the presence of an adequate supply and quality of personal comfort items (e.g., blankets, pillows) was one of the most significant factors associated with comfort and quality of sleep in the rest facility.

4. Return to work

a) Allow a wake-up period after a planned nap.

- The reason to limit the length of a planned nap is to minimize the chance of waking up from deep sleep. If awakened from deep sleep, you might feel groggy or sleepy, an effect called "sleep inertia." Usually, sleep inertia will disappear in about 10–15 minutes. Therefore, allow a "wake-up" period of 10–15 minutes immediately following a planned nap. During this time, you might want to move around, stretch, generally be physically active or talk to help you wake up.
- People sometimes can wake up from a nap and not feel any better. Nevertheless, performance and alertness can still be improved. So, even if you wake up and don't feel much different, the planned nap still can be beneficial.

b) Get back in the loop.

- Get any information from your teammate that will help you safely resume your responsibilities.

APPENDIX D. APPENDIX D. RECOMMENDED FATIGUE TRAINING TOPICS

Table D-1. Some recommended fatigue management-related topics for inclusion in training programmes when using a prescriptive approach and when using an FRMS to manage fatigue.

<table>
<tr><th>Prescriptive Approach</th><th>FRMS</th></tr>
<tr><td colspan="2">Target Group: Flight and Cabin Crew</td></tr>
<tr><td>

The scientific principles that underpin fatigue management.
ATC responsibilities and those of the ATS Provider, for managing fatigue.
Causes and consequences of fatigue in the operation(s) in which they work.
How to identify fatigue in themselves and others.
How to use fatigue reporting systems, including how to report that they are too fatigued to undertake safety-critical duties.
Personal strategies that they can use to improve their sleep at home and to minimize their own fatigue risk, and that of others, while they are on duty.
Sleep disorders and their treatment, where to seek help if needed, and any requirements relating to fitness for duty.

</td><td>

An overview of the FRMS structure and how it works in the ATS Provider's organization, including the concepts of shared responsibility and encouraging effective reporting.
Their responsibilities and those of the ATS Provider, in the FRMS.
The scientific principles that underpin FRMS.
Causes and consequences of fatigue in the operation(s) in which they work.
FRM processes in which they play a vital role, particularly in the use of fatigue reporting systems and implementing mitigations.
The importance of accurate fatigue data (both subjective and objective).
How to identify fatigue in themselves and others.
Personal strategies that they can use to improve their sleep at home and to minimize their own fatigue risk, and that of others, while they are on duty.
Sleep disorders and their treatment, where to seek help if needed, and any requirements relating to fitness for duty.

</td></tr>
<tr><td colspan="2">Target Group: Personnel involved in schedule (roster) design and management</td></tr>
<tr><td>

The scientific principles that underpin fatigue management.
How scheduling affects sleep opportunities and can disrupt the circadian biological clock cycle, the fatigue risk that this creates, and how it can be mitigated through scheduling.
Use and limitations of any scheduling tools and bio-mathematical models or other algorithms that may be used to predict an ATC's fatigue across a schedule/roster.
How to identify fatigue in themselves and others.
How fatigue reports are generated and analyzed.
Personal strategies that they can use to improve their sleep at home and to minimize their own fatigue risk, and that of others, while they are at work.
Sleep disorders and their treatment, and where to seek help if needed.

</td><td>

An overview of the FRMS structure and how it works in the ATS Provider's organization, including the concepts of shared responsibility and encouraging effective reporting.
The scientific principles that underpin FRMS.
How scheduling affects sleep opportunities and can disrupt the circadian biological clock cycle, the fatigue risk that this creates, and how it can be mitigated through scheduling.
Use and limitations of any scheduling tools and bio-mathematical models or other algorithms that may be used to predict the levels of an individual's fatigue across rosters/schedules.
Their role in the FRMS in relation to fatigue hazard identification and risk assessment.
Processes and procedures for planned schedule changes, including:

assessing the potential fatigue impact of planned changes;
early engagement of the FSAG in the planning of changes with significant potential to increase fatigue risk; and
implementing changes recommended by the FSAG.

How to identify fatigue in themselves and others.

</td></tr>
</table>

Prescriptive Approach	FRMS
	• Personal strategies that they can use to improve their sleep at home and to minimize their own fatigue risk, and that of others, while they are at work. • Basic information on sleep disorders and their treatment, and where to seek help if needed.
Target Group: Executive decision-makers and operational risk managers	
• The scientific principles that underpin fatigue management • An overall understanding of ATC fatigue and the safety risk that it represents to the organization. • The responsibilities and accountabilities of different stakeholders in fatigue management, including themselves. • Linkages between fatigue management and other parts of the ATS Provider's safety management system. • Regulatory requirements for fatigue management. • How to identify fatigue in themselves and others. • Personal strategies that they can use to improve their sleep at home and to minimize their own fatigue risk, and that of others, while they are at work. • Basic information on sleep disorders, their treatment, and where to seek help if needed, so they can make organizational decisions about how to manage affected individuals.	• An overall understanding of the scientific principles that underpin FRMS and the safety risk that fatigue represents to the organization. • An overview of the FRMS structure and how it works, including the concepts of shared responsibility and an effective reporting culture, and the role of the FSAG. • The responsibilities and accountabilities of different stakeholders in the FRMS, including themselves. • An overview of the types of fatigue mitigation strategies being used by the organization. • FRMS safety assurance metrics used by the organization. • Linkages between the FRMS and other parts of the ATS Provider's safety management system. • Linkages between the FRMS and other parts of the organization, for example the scheduling department, operational sections, medical department, safety department, etc. • Regulatory requirements for the FRMS. • How to identify fatigue in themselves and others. • Personal strategies that they can use to improve their sleep at home and to minimize their own fatigue risk, and that of others, while they are at work. • Basic information on sleep disorders, their treatment, and where to seek help if needed, so they can make organizational decisions about how to manage affected individuals.
Target Group: FSAG members	
• Not Applicable	• All FRMS components and elements. • The responsibilities and accountabilities of different stakeholders in the FRMS. • Linkages between the FRMS and other parts of the ATS Provider's SMS. • Linkages between the FRMS and other parts of the organization, for example the scheduling department, flight operations, medical department, safety department, etc. • Regulatory requirements for the FRMS. • The scientific principles that underpin FRMS. • How to identify fatigue in themselves and others. • Personal strategies that they can use to improve their sleep at home and to minimize their own fatigue risk, and that of others, while they are at work. • Basic information on sleep disorders and their treatment, and where to seek help if needed. • Basic information on sleep disorders, their treatment, and where to seek help if needed, so they can make organizational decisions about how to manage affected individuals.

APPENDIX E. APPENDIX E. EXAMPLE OF FRM PROCESSES

This example describes the FRM processes, as part of an overall FRMS, that are used by an ATS Provider to extend the length of a night shift beyond prescriptive work hour limits in order to service an increase in early morning air traffic.

Operational Background Information:

The current night shift for the ATS Provider facility runs from 10pm to 6am. Due to an increase in early morning air traffic, there is a need for an additional position to be open between 6am and 7am. It is therefore proposed to extend the night shift from 8 hours to 9 hours with a finish time of 7am. This change will require reducing the length of other shifts in the roster so as to meet contractual obligations.

Figure E-1 summarizes the FRM processes, which are explained in more detail in the sections below.

Data related to operational requirements and factors are gathered and analyzed to support a fact-based initial recommendation for a change to the rostered duty pattern to meet operational demands.

Predictive: Bio-mathematical model predictions are tested against the proposed schedule with increased time on the night shift to identify periods of elevated fatigue hazard. Subject matter and operational experts examine the model predictions for context-specific hazards related to the new schedule which are not identifiable using a model.

Reactive: Safety report and event data from other facilities with similar schedules are reviewed to identify any association with fatigue, and systems are in place for analysis of fatigue contribution to any future safety events.

Bio-mathematical model simulations predict minor safety risk as associated with the proposed schedule. This information is used by subject matter and operational experts to make the risk assessment, and decide that the fatigue-related safety risk will be at an acceptable level throughout the new schedule if the mitigation of a one hour nap is taken by ATCs between 0100 and 0400, and if other operational controls and mitigations are also put in place.

Implement Mitigations: Multiple controls and mitigation strategies are implemented.

Validation Period: Intense data collection during first four months of operation to check bio-mathematical model predictions of fatigue levels and identify and address any fatigue-related hazards and safety risks.

Monitor: Data related to the effectiveness of the controls and mitigations is monitored on an ongoing basis to ensure safety performance indicators are met.

Figure E-1. FRM processes increasing length of night shift

E1 STEP 1. MONITOR DATA

The process of “Monitoring Data” in this example has two components:

1. The first has to do with gathering data to support a fact-based initial recommendation for a change to the rostered duty pattern to meet operational demands.
2. The second has to do with gathering and monitoring data related to the updated roster duty pattern during both a validation period and during full operation to ensure that a level of safety is achieved that is equivalent to that provided for through the agreed to prescriptive work hour limits.

The first step in the FRMS process is to gather data to support an understanding of the operational requirements and factors that could influence how best to extend the night shift from 8 to 9 hours. Some of these data would include the following:

- the number of employees needed to safely provide required services to meet increased air traffic demands;
- the amount of supervision necessary;
- the length and intensity of the remaining shifts;
- shift start and end times;
- the arrangements in place for transitioning from being in an operational position to a rest break;
- availability and quality of rest/break facilities;
- the workload for ATC on position.

The ATS Provider’s reviews data regarding the facility’s watch schedule, employee complement and operational requirements, and this leads to the following initial recommendation to meet increased traffic demands:

- Alter the existing Rostered Duty Pattern as follows:
  a. Increase the length of the night shift from 8 to 9 hours, with an end time move from 6am to 7am, to meet traffic demands.
  b. Reduce the first and second day shifts of the workweek by 30 minutes each, as this appears to have the least amount of impact to the staffing needs of those shifts.

Once this initial recommendation is made, the ATS Provider must then identify any hazards associated with the proposed change to the rostered duty pattern.

E2 STEP 2. HAZARD IDENTIFICATION

In this example, the ATS Provider uses two methods to identify any hazards associated with the proposed change to the rostered duty pattern:

1. Predict possible hazards before they occur by using bio-mathematical fatigue modelling software, and
2. React to hazards that are identified through the review of safety reports and event data.

E2.1 PREDICTIVE PROCESSES

To identify any hazards that may be introduced into the operational work environment as a result of the proposed duty pattern change the ATS Provider uses a bio-mathematical model to predict fatigue levels associated with the new patterns of work. Specifically, “what-if” analyses are conducted by the ATS Provider to evaluate the impact of different lengths of shifts, sleep patterns and different duty pattern start and end times. The resulting data is then reviewed by subject matter experts with operational knowledge and experience, and it is recognized that the WOCL coincides with the period associated with light traffic during the night shift. An optimal work pattern according to the bio-mathematical model is then identified. Risk analysis can then be completed on the proposed rostered duty pattern.

E2.2 REACTIVE PROCESSES

The ATS Provider has systems in place for analysing the contribution of fatigue to safety reports and events, and for determining how to reduce the likelihood of similar events occurring in the future. The ATS Provider conducts an analysis of incident reports gathered from other facilities that run night shifts until 7am and does not identify any substantial increase in incidents which relate to fatigue. The ATS Provider then put plans in place to continually review safety reports and event data to ensure that any fatigue-related hazards associated with the new rostered duty pattern are identified and any associated safety risk is assessed.

E3 STEP 3. RISK ASSESSMENT

A bio-mathematical model can also be used to help assess the risks associated with extending time in position. The algorithms used in the model to distinguish between low, medium and high fatigue levels are examined closely by the ATS Provider, and altered as necessary, to accommodate specific operational conditions that further impact on fatigue outcomes.

The ATS Provider uses its established risk assessment tables for likelihood and severity to assess the impact of fatigue on the operation and the safety risk represented by that fatigue.

Assessment questions used by the ATS Provider include:

- What is the likelihood of the fatigue hazard being present in the operation given the extension of time in position from 6am to 7am?
- What is the likelihood of the fatigue hazard being present if the new roster cannot be followed because of staffing, traffic or other anomaly?
- If fatigue can be predicted to be present in the operation, what is its severity level and how will that impact the safety of the air navigation services provided?

The ATS Provider considers these factors and also the association of traffic volume and complexity, sectors impacted, etc., to the time frames when fatigue hazards will reach increased levels. A determination is made that there is some minor safety risk to the operation associated with the change to the rostered duty pattern. This risk then needs to be controlled or mitigated to maintain operational safety.

E4 STEP 4. SELECT AND IMPLEMENT CONTROLS AND MITIGATIONS

A decision is made by the ATS Provider to control fatigue before it manifests in the operation, and then to mitigate the effects of any remaining fatigue that may then be present.

Controls

- Operations will be staffed with sufficient personnel to ensure adequate breaks and operational coverage.
- Start time and end times for the new arrangements have been selected that are optimal for: minimizing the fatigue safety risk associated with duty tasks during circadian low points; and maximizing sleep opportunities.

- Designated appropriate rest facilities to enhance opportunities for recovery during nap periods have been provided to enhance opportunities for recovery.
- Napping / recuperative break protocols are established and training is developed to ensure optimal sleep debt recovery and elimination of sleep inertia occurs prior to returning to duty.
- Access to food and water (including caffeine) will be made available on-site.

Mitigations

- Napping or recuperative breaks will be utilized to help mitigate accumulated sleep debt. Specifically recuperative breaks of 1.5 hours will be rostered between 0100 and 0400 for all ATCs on the extended night shift.
- Training will be provided to all ATCs and managers on: fatigue mitigation strategies, sleep hygiene, sleep inertia associated with naps / recuperative breaks, and fatigue awareness.
- Procedures for handovers at watch rotations will be developed and monitored for utilization.

Once the rostered duty pattern has been proposed and updated based on hazard analysis, and identified safety risks have been controlled and/or mitigated, the ATS Provider then must complete a four month validation period.

E4.1 MONITOR MITIGATION EFFECTIVENESS

As was mentioned in Step 1., "Monitoring Data", the ATS Provider will now gather and monitor data related to the updated rostered duty pattern during both a validation period and during full operation to ensure that a level of safety is achieved that is equivalent to that provided for through the agreed to prescriptive work hour limits.

The ATS Provider defines a four month validation period, data collection plan and safety performance indicators and reviews these with the Fatigue Safety Action Group. Once approved by the FSAG, the ATS Provider then implements the new rostered duty pattern during the defined validation period and conducts intensive monitoring to ensure operational safety.

Proactive Hazard Monitoring:

The ATS Provider uses a group of subject matter experts and the following proactive processes identify fatigue hazards during the first four months of the new operation to: validate the previous predictions about fatigue levels, and to fine tune the control and mitigation strategies, as needed.

- ATCs are reminded about and encouraged to use any existing fatigue reporting methods.
- Management are reminded of the signs of increased fatigue in their staff and encouraged to follow up any signs of fatigue.
- For the first month of the new rostered duty pattern, a subset of ATC volunteers is asked to wear activity monitoring watches, complete sleep and duty diaries, and rate sleepiness levels and perform PVT tests before, during and after each shift. These data are analyzed and compared to data from similar operations in other facilities and used to compare fatigue levels predicted by the bio-mathematical model.
- After the new rostered duty pattern has been worked for three months, ATC are surveyed to obtain an overview of their experience with fatigue and the effectiveness of different mitigation strategies.

The Fatigue Safety Action Group has regular oversight of all fatigue related data and reports and acts in a timely manner when issues are identified. At the end of the validation period, the ATS Provider prepares a report detailing the data collected and its analysis, and routine processes are defined for fatigue risk monitoring and management on the night operation. This report is reviewed with the FSAG and is also made available to all interested parties.

In this example the safety performance indicators defined during the validation period are reported as acceptable and demonstrate that an equivalent level of safety to the prescriptive work hour limits has been achieved. Therefore, the new rostered duty pattern and its associated controls and mitigations are approved for long term use under the ATS Providers Fatigue Risk Management System and the night operation reverts to routine monitoring for any increased hazards or safety risks. These routine monitoring results are compiled by the ATS Provider and reviewed with the FSAG on a regular basis.

E4.2 LINK TO FRMS SAFETY ASSURANCE PROCESSES

When setting up the new scheduling arrangements, the data needed for FRMS safety assurance processes need to be identified up front so that they can be collected to validate the safety levels of the new operation. For this example, the following safety performance indicators are utilized:

- Data collected during the first four months of the new arrangements is be compared with model predictions and with the same measures from other facilities or prior data collection, to establish whether ATC fatigue and alertness levels are in the range predicted and are acceptable.
- By the fourth month of the new arrangements, the fatigue reporting rate (reports/shift) and average fatigue report risk level are compared to existing operations at other, similar facilities. No “intolerable” fatigue reports should be received.

APPENDIX F. APPENDIX F. EXAMPLES OF SCHEDULE-RELATED SAFETY PERFORMANCE INDICATORS

In this fictitious example, the enroute specialties at an ATS Provider decided to change their schedule. The new schedule was designed with due regard to the fatigue science in efforts to address some fatigue concerns. Given the frequency of shift swaps that occur, the FSAG wanted to compare SPIs based on actual shifts worked. After approximately 4 months on the new schedule, an analysis of 4 months of shifts worked pre-change was compared with 4 months of post-change using the eight safety performance indicators below. The 4 months of pre-change shifts were obtained from the previous year to match seasonal variability. Column A represents the scientific factor related to Fatigue; column B is the SPI; and columns C and D are the percentage of occurrences where the SPI criteria were met. It should be noted that in these cases, the greater the SPI percentage, the greater the fatigue risk.

A. Scientific Factor	B. Safety Performance Indicator	C. % of occurrences pre-change	D. % of occurrences post-change
Acute sleep loss	Less than 10 hours between consecutive duties	0	0
Cumulative sleep debt	Worked more than 5 consecutive shifts	60	20
Recovery Opportunity	Does not receive at least 32 hours off between non-consecutive shifts.	5	2
	During a block of consecutive shifts, does not receive two consecutive night time sleep opportunities with < 3 scheduled hours between 2200-0800.	15	2
Hours of continuous wakefulness	Shift is longer than 12 hours	0	0
Time of day	Consecutive shifts with scheduled work between 2300-0600.	2	2
	Shifts with at least one hour of scheduled work between 0200-0600.	10	12
	Later shift starts three or more hours later than the start time of the previous shift (forward shift rotation)	2	1
	Latter shift starts three or more hours earlier than the start time of the previous shift (backward shift rotation)	19	12

These SPIs allowed the ATS Provider to recognize some areas of strength with regard to the new schedule. For example, there were more recovery opportunities in the new schedule, as well as less opportunity for Cumulative Sleep Debt.

It also allowed the ATS Provider to identify targets for the SPIs to create continuous improvement. For example, a 2-year target of no more than 5% of backward shift rotations.

APPENDIX G. APPENDIX G. EXAMPLES OF FRMS SAFETY ASSURANCE PROCESSES

The following two examples illustrate some FRMS safety assurance processes and describe the specific ways in which they interact with the FRM processes.

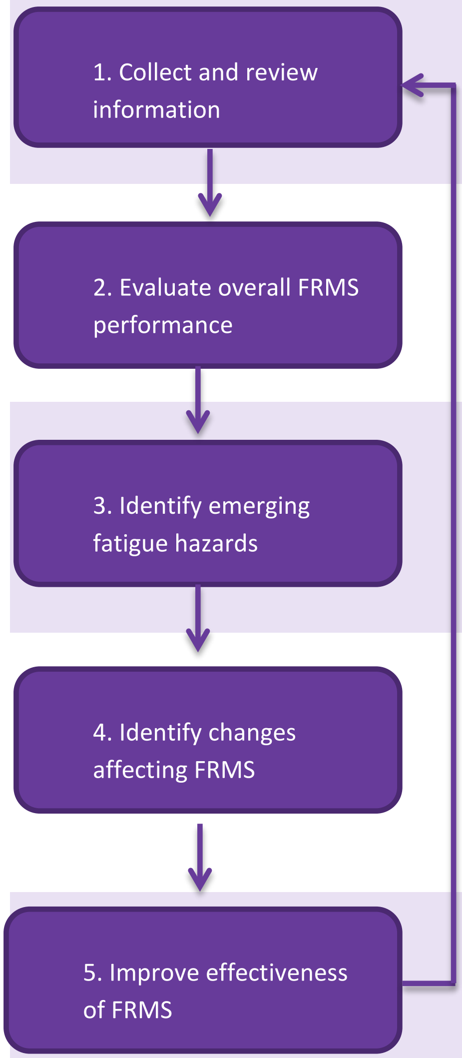
Example 1 (see Figure F-1)

- As the result of a risk assessment (FRM processes Step 3), the Fatigue Safety Action Group sets a controllers maximum daily shift length of 10 hours as one of its FRMS safety performance indicators (SPIs). The target is to have no more than two instances of 10hr on duty per shift violations in a 7 day period. It collects and assesses monthly data on scheduled and actual exceedances of the 10-hour per shift duty limit across all facilities. For three consecutive months, there is an increasing trend in exceedances.

Example 2 (see Figure F-2)

- Here, the use of management's discretion is tracked as an FRMS safety performance indicator. In this example, the Fatigue Safety Action Group has conducted a risk assessment and decided to set the following thresholds for maximum time on duty:
  - intolerable region — discretion used on at least 25 per cent of shifts in a two-month period;
  - tolerable region — discretion used on 10-25 per cent of shifts in a two-month period;
  - acceptable region — discretion used on less than 10 per cent of shifts in a two-month period.

In addition, reasons for the violations must be logged and presented to the Fatigue Safety Action Group.



	FRMS performance indicator — Exceedance of rostering parameters
1	Collect and evaluate monthly exceedances of the any on duty hours limitations.
2	Monthly reviews by the Fatigue Safety Action Group indicate that duties exceeding the maximum daily shift limit of 10 hours are trending upwards.
3	Further analysis shows that most of the trend is due to overtime usage and ultimately due to a shortage of qualified personnel in that facility.
4	Due to an acute loss of personnel to retirement, medical disqualification and promotion the facility is below adequate staffing levels. The Fatigue Safety Action Group recommends an increase in the number of controllers assigned to the facility.
5	An improvement to the FRM processes is introduced. Monthly data are collected and analyzed to monitor the overtime usage and increase in staffing.

Figure F-1. Example of FRMS safety assurance processes (maximum duty period exceedances)

		FRMS performance indicator — Use of manager's discretion
1. Collect and review information	1	Use of manager's discretion recorded in the Operations Log and analyzed monthly.
2. Evaluate overall FRMS performance	2	An individual facility had an, "unacceptable" level of use of manager's discretion (25 % or more of shifts) for three consecutive months, averaging 4 instances of ATCs working more than 10 hrs on duty per shift.
3. Identify emerging fatigue hazards	3	Further analyses identify the main causal factors as an increase in cargo traffic during the late night periods. Traffic management has not identified if the issue will be short lived or long term.
4. Identify changes affecting FRMS	4	Not applicable.
5. Improve effectiveness of FRMS	5	Management adjust shifts of controllers on the evening shift[64] to come in later in order to provide staffing coverage later into the evening. 10hr violations cease and manager's discretion returns to an acceptable level.

Figure F-2. Example of FRMS safety assurance processes (use of manager's discretion)

Data on use of discretion are collected in a log generated by the ATS Provider's facility management order. The Fatigue Safety Action Group analyzes this data monthly to ensure that the schedules being created and executed are realistic, given the usual operating conditions. The data are sorted by facility, to include overtime usage.

[64] Evening shifts are scheduled shifts where the majority of the work hours fall between 1400 and 2200.