



# FRMS

**Fatigue Risk Management Systems**  
**Manual for Regulators**

First Edition – 2012

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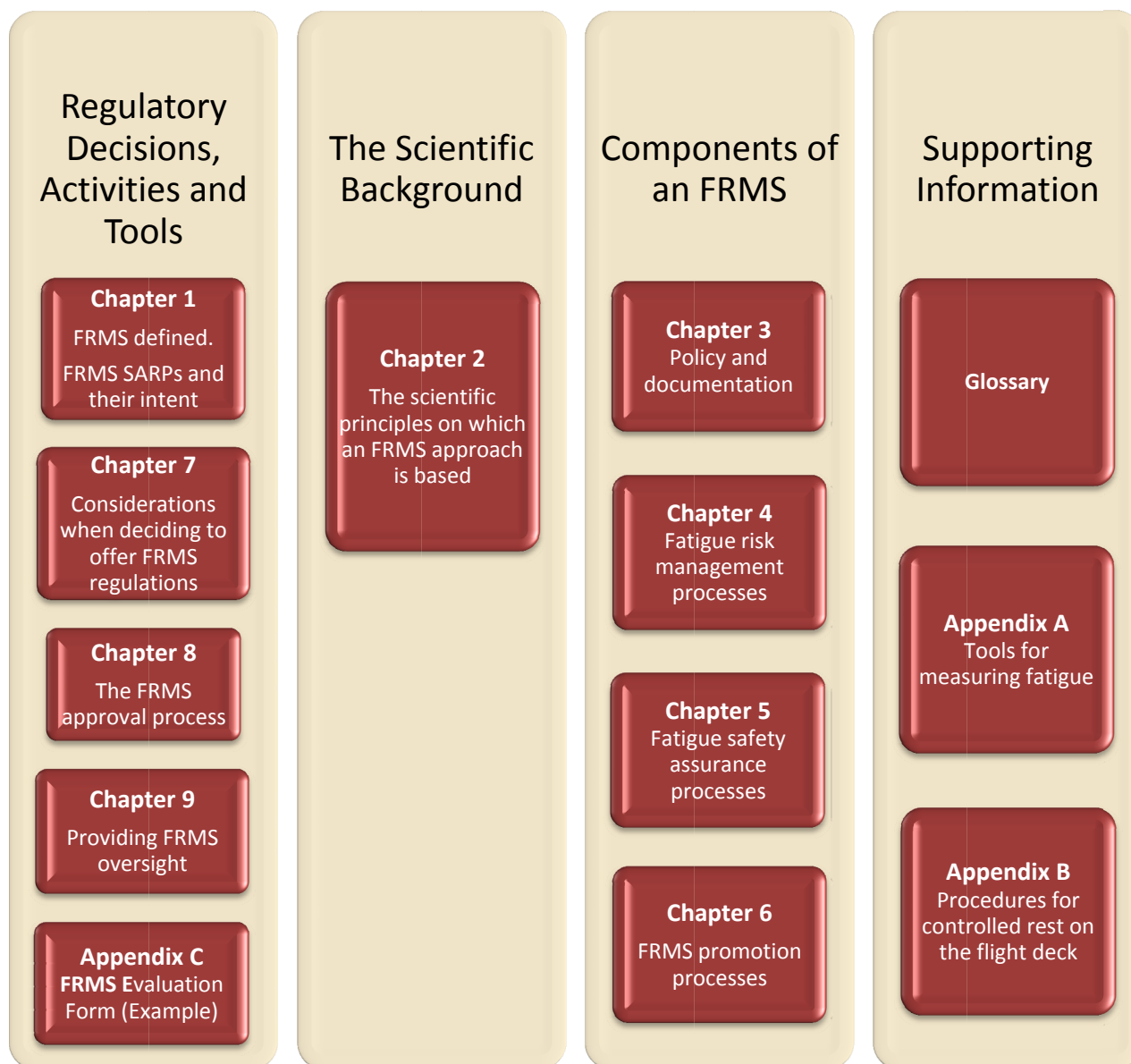
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## OVERVIEW OF THIS DOCUMENT

The purpose of the FRMS Manual is to provide States with information on how an FRMS should function, its regulation and its oversight. The chapters in this document relate to different general areas as follows:





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# GLOSSARY

\* denotes an ICAO definition

**Actigraphy.** The 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 sleep and still wakefulness look the same on an actigraph (since an actiwatch measures movement).

**Actiwatch.** 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 analysed 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). Actiwatches 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. Actiwatches provide graphs of movement as output (actigraphs).

**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 to 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.

**Augmented flight crew.** A flight crew that comprises more than the minimum number required to operate the aeroplane so that each crew member can leave his assigned post to obtain in-flight rest and be replaced by another appropriately qualified crew member.

**Augmented long-range operations.** Flights where the flight duty period is extended through the use of augmented crews, allowing crew members the opportunity for in-flight rest.

**Biomathematical model.** A computer programme designed to predict crew member fatigue levels, based on scientific understanding of the factors contributing to fatigue. All biomathematical models have limitations that need to be understood for their appropriate use in an FRMS. It is an optional tool (not a requirement) for predictive fatigue hazard identification (ICAO Annex 6, Part 1, Appendix 8, Section 2.1).

**Chronic fatigue.** In fatigue risk management, chronic fatigue refers to the sleepiness and performance impairment that accumulate when sleep is restricted day after day. These effects can be reversed by obtaining adequate recovery sleep (also see cumulative sleep debt).

**Chronic fatigue syndrome.** A medical condition, the diagnosis for which requires a person to meet two criteria:

1. Have severe chronic fatigue for at least six months or longer that is not relieved by rest and not due to medical or psychiatric conditions associated with fatigue as excluded by clinical diagnosis; and
2. Concurrently have four or more of the following symptoms: self-reported impairment in short-term memory or concentration severe enough to cause substantial reduction in previous levels of occupational, educational, social or personal activities; sore throat that is frequent or recurring; tender lymph nodes in the neck or armpits; muscle pain; multi-joint pain without swelling or redness; headaches of a new type, pattern or severity; unrefreshing sleep; and post-exertional malaise (extreme, prolonged exhaustion and sickness following physical or mental activity) lasting more than 24 hours.

The fatigue and impaired memory or concentration must have disrupted normal daily activities, along with other symptoms that must have persisted or recurred during six or more consecutive months of illness and must not have predated the fatigue. ([http://www.cdc.gov/cfs/general/case\\_definition/index.html](http://www.cdc.gov/cfs/general/case_definition/index.html))

**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.

**Controlled rest on the flight deck.** An effective mitigation strategy to be used as needed in response to fatigue experienced during flight operations. Recommended procedures for controlled rest on the flight deck can be found in Appendix B. It should **not** be used as a scheduling tool, i.e., as a planned strategy to enable extended duty periods.

**Controls.** System-level defensive strategies designed to minimize fatigue risk on an ongoing basis. Examples include: scheduling rules; monitoring staffing levels at crew bases; selection of appropriate in-flight crew rest facilities; and protocols for in-flight rest and controlled rest on the flight deck.

**Countermeasures.** Personal mitigation strategies that crew members can use to reduce their own fatigue risk. Sometimes divided into strategic countermeasures (for use at home and on layovers, for example, good sleep habits or napping before night duty) and operational countermeasures (for use in flight, for example, controlled rest on the flight deck).

**\*Crew member.** A person assigned by an operator to duty on an aircraft during a flight duty period.

**Crew pairing.** A set of scheduled flights on which a crew member is rostered for one or more days.

**Cumulative sleep debt.** Sleep loss accumulated when sleep is insufficient for multiple nights (or 24-hour 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.

**\*Duty.** Any task that flight or cabin crew members are required by the operator to perform, including, for example, flight duty, administrative work, training, positioning and standby when it is likely to induce fatigue.

**\*Duty period.** A period which starts when flight or cabin crew members are required by an operator to report for or to commence a duty and ends when that person is free from all duties.

**Evening type.** A person whose natural sleep time is later than average as a result of the characteristics of their circadian biological clock. There is also a developmental trend to become more evening-type across puberty, which reverses for most people in adulthood.

**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. This 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 or extended wakefulness, circadian phase, or workload (mental and/or physical activity) that can impair a crew member’s alertness and ability to safely operate an aircraft or perform safety-related duties.

**Fatigue risk management.** The management of fatigue in a manner appropriate to the level of risk exposure and the nature of the operation, in order to minimize the adverse effects of fatigue on the safety of operations.

**Fatigue risk management system policy.** A required component of an FRMS (ICAO Annex 6, Part 1, Appendix 8, Section 1.1). THE FRMS Policy must: identify the elements of the FRMS and its scope; reflect the shared responsibility of all stakeholders in the FRMS; state the safety objectives of the FRMS; be signed by the accountable executive of the organization; be communicated throughout the organization; declare management commitment to effective safety reporting, to providing adequate resourcing for the FRMS, and to continuous improvement of the FRMS; identify clear lines of accountability for the functioning of the FRMS; and require periodic reviews of the FRMS.

**\*Fatigue risk management system (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.

**Fatigue safety action group (FSAG).** A group comprised of representatives of all stakeholder groups (management, scheduling, crew representatives, together with specialist scientific, data analysis and medical expertise as required), that is responsible for coordinating all fatigue management activities in the organization.

**Fatigue safety assurance.** FRMS safety assurance processes monitor the entire FRMS to check that it is functioning as intended and meeting the safety objectives in the FRMS policy and regulatory requirements. FRMS safety assurance processes also identify operational and organizational changes that could potentially affect the FRMS and identify areas where the safety performance of the FRMS could be improved (continuous improvement).

**\*Flight data analysis (FDA).** A process of analysing recorded flight data in order to improve the safety of operations.

**\*Flight duty period.** A period which commences when a flight or cabin crew member is required to report for duty that includes a flight or a series of flights and which finishes when the aeroplane finally comes to rest and the engines are shut down at the end of the last flight on which he is a crew member.

**\*Flight time — aeroplanes.** The total time from the moment an aeroplane first moves for the purpose of taking off until the moment it finally comes to rest at the end of the flight.

**FRMS training.** Competency-based training programmes designed to ensure that all stakeholders are competent to undertake their responsibilities in the FRMS.

**Homeostatic sleep pressure.** See *Sleep homeostatic process*.

**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 in the late morning to early afternoon about six hours after the **window of circadian low** 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 trans-meridian flight (experienced as a sudden shift in the day/night cycle). Also results in internal desynchronization between rhythms in different body functions. Common symptoms include wanting to eat and sleep at times that are out of step with the local routine, problems with digestion, degraded performance on mental and physical tasks, and mood changes. 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.** System-level interventions designed to reduce a specific identified fatigue risk. Examples include: increasing the number of crew members at a base; use of reserve crew; educating crew members on how to obtain optimal in-flight sleep; Captain's discretion to re-organize in-flight rest arrangements on the day of flight in response to crew members' fatigue levels and operational conditions.

**Morning type.** A person whose natural sleep time is earlier than average as a result of the characteristics of their circadian biological clock. There is also a developmental trend to become more morning-type across adulthood.

**Nap.** A brief period of sleep, usually defined as less than half of a full night-time sleep period. Naps as short as five minutes have been shown to provide (temporary) relief from the cumulative effects of sleep loss — also see **controlled rest on the flight deck**.

**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 four 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.

**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). Recovery sleep may be slightly longer than usual, but lost sleep is not recovered hour-for-hour. Two nights of unrestricted sleep (when a crew member is fully adapted to the local time zone) are typically required for recovery of normal sleep structure (non-REM/REM cycles). Recent laboratory research suggests that recovery of optimal waking function may take more than two nights of recovery sleep.

**\*Rest period.** A continuous and defined period of time, subsequent to and/or prior to duty, during which flight or cabin crew members are free of all duties.

**Roster/rostering.** Assignment of crew members to a schedule.

**Safety management.** The systematic management of the operational risks associated with flight, engineering and ground activities in order to achieve as high a level of safety performance as is reasonably practicable.

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

**Safety performance.** The level of safety achieved in a risk-controlled environment measured against a safety level deemed as low as reasonably practicable.

**Schedule.** Sequence of flights designed to meet operational requirements and effectively manage resources including crew members.

**Shift work.** Any work pattern that requires crew members to be awake at a time in the circadian body clock cycle that they would normally be asleep. It is problematic because the circadian body clock is sensitive to light and tends to remain “locked on” to the day/night cycle rather than adapting to the work pattern. Shift work is usually associated with sleep restriction, together with a requirement to work during times in the circadian body clock cycle when performance and alertness are sub-optimal (for example, through the **window of circadian low**).

**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. A complex series of processes characterized by alternation between two different brain states: **non-REM sleep** and **REM sleep**.

**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. More than 80 different sleep disorders that can cause varying amounts of sleep disruption have been identified. Examples include obstructive sleep apnea, 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 as the brain progresses through the process of waking up. Sleep inertia can occur on waking from any stage of sleep but may be longer and more intense on waking from **slow-wave sleep** (non-REM stages 3 and 4) or after sleep periods or naps containing a high proportion of slow-wave sleep.

**Sleep need.** The amount of sleep that is required on a regular basis to maintain optimal levels of waking alertness and performance. It 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 ("trimming" sleep) across at least two consecutive nights. 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 (EEG dominated by 0.5-4 Hz).

**Standby/standby duty.** A defined period of time, at the airport, at the hotel, or at home, during which a flight or cabin crew member is required by the operator to be available to receive an assignment for a specific duty without an intervening rest period.

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

**Trip.** A scheduling expression describing the time from when a crew member initially reports for duty until he returns home from the sequence of flights and is released from duty. A trip may include multiple flights and many days of travel.

**Ultra-long range operations (ULR).** Operations involving any sector between a specific city pair in which the planned flight time exceeds 16 hours, taking into account mean wind conditions and seasonal changes (as defined by the Ultra-Long Range Crew Alertness Steering Committee, Flight Safety Foundation (2005). *Flight Safety Digest* 26).

**Unforeseen operational circumstance.** An unplanned event, such as unforecast weather, equipment malfunction, or air traffic delay that is beyond the control of the operator. In order to be considered unforeseen, the circumstance would occur or become known to the operator after the flight has begun (after the moment the aeroplane first moves for the purpose of taking off).

**Unrestricted sleep.** Sleep which is not restricted by duty demands. Sleep can begin when a crew member feels sleepy and does not have to be delayed because of duty demands. In addition, the crew member can wake up spontaneously and does not have to set the alarm to be up in time for duty.

**Window of circadian low (WOCL).** Time in the circadian body clock cycle when subjective 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 3:00 to 5:00 when a person is fully adapted to the local time zone. However, there is individual variability in the exact timing of the WOCL, which is earlier in morning-types (larks) and later in evening-types (owls), and may move a few hours later after consecutive night shifts.

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# Chapter 1. Introduction to fatigue risk management systems (FRMS)

## 1.1 WHAT IS A FATIGUE RISK MANAGEMENT SYSTEM?

ICAO has defined fatigue as:

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

Fatigue is a major human factors hazard because it affects most aspects of a crew member's ability to do his<sup>1</sup> job. It therefore has implications for safety.

A Fatigue Risk Management System (FRMS) is defined as:

*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.*

An FRMS aims to ensure that flight and cabin crew members are sufficiently alert so they can operate to a satisfactory level of performance. It applies principles and processes from Safety Management Systems (SMS) to manage the risks associated with crew member fatigue. Like SMS, FRMS seeks to achieve a realistic balance between safety, productivity and costs. It seeks to proactively identify opportunities to improve operational processes and reduce risk, as well as identify deficiencies after adverse events. The structure of an FRMS as described herein is modelled on the SMS framework. The core activities are safety risk management (described in the Standards and Recommended Practices (SARPs) as FRM processes) and safety assurance (described in the SARPs as FRMS safety assurance processes). These core activities are governed by an FRMS policy and supported by FRMS promotion processes. The entire system must be documented to the satisfaction of the State of the Operator.

Both SMS and FRMS rely on the concept of an effective safety reporting culture<sup>2</sup>, where personnel have been trained and are constantly encouraged to report hazards whenever observed in the operating environment. To encourage the reporting of fatigue hazards by all personnel involved in an FRMS, an operator must clearly distinguish between:

- unintentional human errors, which are accepted as a normal part of human behaviour and are recognized and managed within the FRMS; and
- deliberate violations of rules and established procedures.

An operator should have processes independent of the FRMS to deal with intentional non-compliance.

To encourage an ongoing commitment by personnel to reporting fatigue hazards, the organization must take appropriate action in response to those reports. When an effective safety reporting system exists, a large percentage of safety reports from operational personnel relate to identified or perceived hazards, instead of to errors or adverse events.

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1. In this manual, the use of the male gender should be understood to include both male and female persons.

2. See ICAO's *Safety Management Manual (SMM)* (Doc 9859).

## 1.2 WHY THE AVIATION INDUSTRY IS INTRODUCING FRMS

The traditional regulatory approach to managing crew member fatigue has been to prescribe limits on maximum daily, monthly and yearly flight and duty hours, and require minimum breaks within and between duty periods. This approach comes from a long history of limits on working hours dating back to the industrial revolution. It entered the transportation sector in the early 20th century in a series of regulations that limited working hours in rail, road and aviation operations. The approach reflects early understanding that long unbroken periods of work could produce fatigue (now known as “time-on-task” fatigue) and that sufficient time is needed to recover from work demands and to attend to non-work aspects of life.

In the second half of the 20th century, scientific evidence began accumulating that implicated other causes of fatigue in addition to time-on-task, particularly in round-the-clock operations. The most significant new understanding concerns:

- the vital importance of adequate sleep (not just rest) for restoring and maintaining all aspects of waking function; 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 daily cycle of the circadian biological clock in the brain.

This new knowledge is particularly relevant in the aviation industry which is unique in combining round-the-clock operations with trans-meridian flight.

In parallel, there has been an increase in the understanding of human error and its role in accident causation. Typically, accidents and incidents result from interactions between organizational processes (i.e., workplace conditions that lead crew members to commit active failures) and latent conditions that can penetrate current defences and have adverse effects on safety<sup>3</sup>. The FRMS approach is designed to apply this new knowledge from fatigue science and safety science. It is intended to provide an equivalent or enhanced level of safety while also offering greater operational flexibility.

Prescriptive flight and duty time limits represent a somewhat simplistic view of safety — being inside the limits is safe while being outside the limits is unsafe — and they represent a single defensive strategy. While they are adequate for some types of operations, they are a one-size-fits-all approach that does not take into account operational differences or differences among crew members.

In contrast, an FRMS employs multilayered defensive strategies to manage fatigue-related risks regardless of their source. It includes data-driven, ongoing adaptive processes that can identify fatigue hazards and then develop, implement and evaluate controls and mitigation strategies. These include both organizational and personal mitigation strategies. While an FRMS is based on scientific principles, its application within various aviation contexts requires operational experience and knowledge. An FRMS should not be provided to an operator by a consultant; it needs to be developed, understood and managed by people who have comprehensive experience in the complex operational environment to which it will apply. In this way, various data analyses can be meaningfully interpreted taking into consideration particular contexts, and workable operational strategies can be developed.

The cost and complexity of an FRMS may not be justified for operations that remain inside the flight and duty time limits and where fatigue-related risk is low. Some operators may therefore choose to place only certain parts of their operations under an FRMS or not implement an FRMS at all. Nonetheless, where an FRMS is not implemented, it remains the operator’s responsibility to manage fatigue risks through its existing safety management processes.

It would be a misconception to think of an operator with an FRMS as having no flight and duty time limitations. In fact, an operator continues to have flight and duty time limitations but these are identified through its own FRMS processes, specific to

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<sup>3</sup> Gander, P., Hartley, L., et al, “Fatigue risk management: Organizational factors at the regulatory and industry/company level,” *Accident Analysis & Prevention*, March 2011, Vol. 43(2), pp. 573-90.

a defined operational context, and are continually evaluated and updated in response to its own risk assessments and the data the operator is collecting. It is up to the regulator to assess whether the risk assessments, mitigations and data collected are appropriate, and whether the flight and duty time limitations identified are reasonable responses as evidenced in safety performance indicators. This means that FRMS necessitates performance-based regulation.

In essence, FRMS regulations will define a process for operators and regulators to manage fatigue risk, rather than prescribe limits that do not consider aspects specific to the organization or operating environment.

### 1.3 ICAO STANDARDS AND RECOMMENDED PRACTICES FOR FATIGUE MANAGEMENT

This section describes the SARPs relating to the management of fatigue experienced by flight and cabin crew. These SARPs provide a high-level regulatory framework for both prescriptive flight and duty limitations and FRMS as methods for managing fatigue risk. Both methods share two important basic features:

1. Along with considering operational requirements, they are required to take into consideration the dynamics of transient and cumulative sleep loss and recovery, the circadian biological clock, and the impact of workload on fatigue.
2. Because fatigue is affected by all waking activities not only work demands, regulations for its management are necessarily predicated on the need for shared responsibility between the operator and individual crew members. So, whether complying with prescriptive flight and duty limitations or using an FRMS, operators are responsible for providing schedules that allow crew members to perform at adequate levels of alertness, and crew members are responsible for using that time to start work well-rested. The requirement for shared responsibility in relation to FRMS is discussed further in Chapter 3.

FRMS also shares the building blocks of SMS. This means that an FRMS is predicated on: effective safety reporting; senior management commitment; a process of continuous monitoring; a process for investigation of safety occurrences that aims to identify safety deficiencies rather than apportioning blame; the sharing of information and best practices; integrated training for operational personnel; effective implementation of standard operating procedures (SOPs); and a commitment to continuous improvement. So, together, the foundations of prescriptive flight and duty time limitations and SMS form the building blocks of FRMS (see Table 1-1).

**Table 1-1. FRMS building blocks**

<b>Prescriptive flight and duty time limitations</b>	<ul style="list-style-type: none"> <li>• Addresses transient and cumulative fatigue</li> <li>• Shared operator-individual responsibility</li> </ul>
<b>SMS</b>	<ul style="list-style-type: none"> <li>• Effective safety reporting</li> <li>• Senior management commitment</li> <li>• Continuous monitoring process</li> <li>• Investigation of safety occurrences</li> <li>• Sharing of information</li> <li>• Integrated training</li> <li>• Effective implementation of SOPs</li> <li>• Continuous improvement</li> </ul>

However, an FRMS, as a management system focused on fatigue, also has added requirements beyond that which would be expected of an operator complying with prescriptive flight and duty time limitations and managing its fatigue risks through its SMS. In meeting these additional FRMS-specific requirements, an operator with an approved FRMS may move outside the prescribed limits. Therefore, the fatigue management SARPs in Section 4.10, Annex 6 — *Operation of Aircraft, Part I — International Commercial Air Transport — Aeroplanes*, include particular Standards that enable the effective regulation of FRMS. These are, in turn, supported by Appendix 8, which details the requirements for an FRMS.

### 1.3.1 Section 4.10 of Annex 6, Part I:

The SARPs related to fatigue management of flight and cabin crew are as follows:

#### Annex 6, Part I

#### 4.10 Fatigue Management

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

- a) regulations for flight time, flight duty period, duty period and rest period limitations; and
- b) where authorizing an operator to use a Fatigue Risk Management System (FRMS) to manage fatigue, FRMS regulations.

4.10.2 The State of the Operator shall require that the operator, in compliance with 4.10.1 and for the purposes of managing its fatigue-related safety risks, establish either:

- a) flight time, flight duty period, duty period and rest period limitations that are within the prescriptive fatigue management regulations established by the State of the Operator; or
- b) a Fatigue Risk Management System (FRMS) in compliance with 4.10.6 for all operations; or
- c) an FRMS in compliance with 4.10.6 for part of its operations and the requirements of 4.10.2 a) for the remainder of its operations.

4.10.3 Where the operator adopts prescriptive fatigue management regulations for part or all of its operations, the State of the Operator may approve, in exceptional circumstances, variations to these regulations on the basis of a risk assessment provided by the operator. Approved variations shall provide a level of safety equivalent to, or better than, that achieved through the prescriptive fatigue management regulations.

4.10.4 The State of the Operator shall approve an operator's FRMS before it may take the place of any or all of the prescriptive fatigue management regulations. An approved FRMS shall provide a level of safety equivalent to, or better than, the prescriptive fatigue management regulations.

4.10.5 States that approve an operator's FRMS shall establish a process to ensure that an FRMS provides a level of safety equivalent to, or better than, the prescriptive fatigue management regulations. As part of this process, the State of the Operator shall:

- a) require that the operator establish maximum values for flight times and/or flight duty periods(s) and duty period(s), and minimum values for rest periods. These values shall be based upon scientific principles and knowledge, subject to safety assurance processes, and acceptable to the State of the Operator;
- b) mandate a decrease in maximum values and an increase in minimum values in the event that the operator's data indicates these values are too high or too low, respectively; and
- c) approve any increase in maximum values or decrease in minimum values only after evaluating the operator's justification for such changes, based on accumulated FRMS experience and fatigue-related data.

4.10.6 Where an operator implements an FRMS to manage fatigue-related safety risks, the operator shall, as a minimum:

- a) incorporate scientific principles and knowledge within the FRMS;
- b) identify fatigue-related safety hazards and the resulting risks on an ongoing basis;
- c) ensure that remedial actions, necessary to effectively mitigate the risks associated with the hazards, are implemented promptly;

- d) provide for continuous monitoring and regular assessment of the mitigation of fatigue risks achieved by such actions; and
- e) provide for continuous improvement to the overall performance of the FRMS.

**4.10.7 Recommendation.**— *States should require that, where an operator has an FRMS, it is integrated with the operator's SMS.*

**4.10.8** An operator shall maintain records for all its flight and cabin crew members of flight time, flight duty periods, duty periods, and rest periods for a period of time specified by the State of the Operator.

The intent of each of these SARPs is discussed below.

STANDARD	INTENT
4.10.1	<p>Standard 4.10.1 stipulates the State's responsibilities for establishing regulations for fatigue management. The establishment of regulations for prescriptive limitations remains mandatory, while the establishment of regulations for FRMS is optional for the State. Both types of regulations need to address the known scientific principles, including the dynamics of transient and cumulative sleep loss and recovery, the circadian biological clock, and the impact of workload on fatigue, along with knowledge gained from specific research and operational experience and requirements. Further, both types of regulations need to emphasize that within an operation the responsibility for managing fatigue risks is shared between management and individual crew members (discussed in Chapter 3).</p>
4.10.2	<p>Standard 4.10.2 aims to make clear that, where the State has established regulations for FRMS, operators then have three options for managing their fatigue risks: a) they can do so solely within their State's flight and duty time limitations regulations; b) they can choose to implement an FRMS for all operations; or c) they can implement an FRMS in part of their operations and use prescriptive flight and duty time limitations in other operations. Therefore, this Standard intends to allow the operator to decide which method of fatigue management is most appropriate for its specific types of operations. Given this choice, it is likely that many operators will embrace the safety and operational benefits offered through an FRMS approach.</p> <p>Where the State does not have FRMS regulations, operators must manage their fatigue-related risks within the constraints of their State's prescriptive flight and duty time limitations or State-approved variations to those limitations. Many will choose to do so through their existing safety management processes. However, an FRMS approach, as described herein with its added requirements, can also be applied within prescriptive flight and duty period limitations.</p>
4.10.3	<p>It is recognized that prior to the FRMS Standards, many States had approved variations to the prescribed flight and duty time limitations for operators. In some cases, these variations relate to very minor extensions, and Standard 4.10.3 allows an operator to continue to have minor extensions to scheduled operations without having to develop and implement a full FRMS. Approval of the variation is subject to the provision of a risk assessment acceptable to the regulator.</p> <p>The intent of Standard 4.10.3 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. Nor is it intended to be used to address deficiencies due to inadequate prescriptive regulations. Importantly, it applies only in "exceptional circumstances."</p>

STANDARD	INTENT
4.10.4	<p>Standard 4.10.4 means that approval is given when the operator can clearly demonstrate that all FRMS processes are functioning effectively. It is not simply given based on a documented plan to put an FRMS in place or a desktop review of an FRMS manual. Standard 4.10.4 also means that operators need to support an iterative approach to developing an FRMS (also described in Chapter 8).</p> <p>Approval for the overall FRMS can be given only once all four component processes (discussed in Chapters 3, 4, 5 and 6, respectively) are developed, and the State has confidence that the operator can adjust flight and duty times appropriately (i.e., both over and under prescriptive limitations), can put mitigations in place in accordance with evidence provided through its FRMS, and that the effectiveness of the FRMS has been proven over time using the safety assurance processes. During the last phase of development, and prior to gaining approval, the operator will be working to agreed-upon limits determined through the fatigue risk management processes. These limits may be outside prescriptive flight and duty regulations for the particular operations on which the operator's initial FRMS efforts are focused. This last phase of development is necessary in order to validate the FRMS safety assurance processes and is essentially a defined trial period for the entire FRMS.</p> <p>Once approval has been given, and in the operations to which the FRMS applies, the operator is able to use its FRMS to move away from flight and duty time limitations to a new limit that can be supported by data within the State-approved upper boundary of the FRMS (see 4.10.5).</p> <p>Should an operator seek to misuse an FRMS to benefit from duty times that cannot be supported by scientific principles, collected data and other FRMS processes (i.e. that does not meet the minimum requirements of an FRMS as identified in Appendix 8 of Annex 6, Part I), the State would have to withdraw its approval of the FRMS. The operator would then be required to comply with prescriptive limitations.</p>
4.10.5	<p>4.10.5 is a "change management" SARP, aiming to assist the regulator in the successful introduction of the performance-based regulations that FRMS requires.</p> <p>4.10.5 a) requires the operator to identify an upper boundary which flight and duty times will not exceed and a lower boundary under which no rest period will be shortened even when using mitigations and processes within an FRMS. It aims to offer an extra layer of insurance and sets clear expectations amongst all stakeholders.</p> <p>4.10.5 b) provides regulators with a less drastic alternative to withdrawing approval for an FRMS when an adjustment will suffice to ensure that an equivalent level of safety is maintained. It intends to be proactive, in that it addresses less serious situations where an operator's data indicate a trend that suggests the values may be too high or too low.</p> <p>4.10.5 c) ensures that operators who have demonstrated the responsible and comprehensive management of their fatigue-related risks through a mature FRMS are not prevented from gaining its full benefits by unnecessarily restrictive constraints.</p>
4.10.6	<p>4.10.6 provides high-level minimum requirements for an FRMS and notes more detailed minimum requirements not appropriate for the main body of the Annex, in Appendix 8. Essentially, 4.10.6 provides the "broad brushstrokes" of what an FRMS must have, while Appendix 8 fills in the components in more detail. This Standard is presented in a similar format to SMS Standard 3.3.4 (Annex 6, Part I) to reflect the similarities and consistencies in approaches between FRMS and SMS.</p>

STANDARD	INTENT
	<p>For the regulator, 4.10.6 means that it will be necessary to provide adequate assessment and oversight of a) to e). Processes and documentation will have to be developed that outline the State's approval and oversight criteria in line with the regulations that are developed. This manual aims to provide detailed information to assist the regulator in achieving this.</p>
4.10.7	<p>4.10.7 recognizes the relationship between FRMS and SMS. Because FRMS has a safety function, it should be complementary to existing safety management processes within an operator's SMS. Ideally, where multiple systems are utilized to identify hazards and manage risk they should be integrated 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. So, an operator wishing to implement an FRMS and who already has sufficiently mature SMS processes in place should be able to readily adopt and understand the fundamental processes of an FRMS. Examples of such maturity would include the routine use of hazard identification, risk assessment and mitigation tools, and the existence of an effective reporting culture (refer to Doc 9859, paragraph 2.8.13 ff). Where such systems are already in place, it should not be necessary for an operator to develop entirely new processes to implement FRMS. Rather, FRMS can build upon the organization's existing risk management and training processes.</p> <p>To avoid overlooking or prioritizing risks inappropriately, the importance of coordinating FRMS and existing safety management processes cannot be overemphasized. For example, from an SMS viewpoint, a succession of ground proximity warnings at the same point, on the same approach, and on the same flight number, may well be attributed to inadequate pilot training in altitude management and maintenance of the localizer and glide slope. Without the particular focus and methods of measurement associated with an FRMS, it may not be as obvious that the succession of ground proximity warnings occurred on flights that were part of a particularly fatiguing sequence which resulted in tired pilots not paying enough attention. Both possibilities need to be considered and therefore the two systems designed to do this cannot work in isolation.</p> <p>However, the degree of integration between an operator's SMS and its FRMS will depend on many factors, including the relative maturity of the two systems, and operational, organizational and regulatory considerations. Further, given that the level of maturity for each operator's SMS will vary significantly, the operator is not required to have an SMS accepted by the State before establishing an FRMS. Thus, 4.10.7 is a Recommended Practice rather than a Standard.</p> <p>Where an operator does not wish to implement an FRMS or has had its FRMS approval revoked, the regulator should require the operator to use its SMS to manage fatigue-related risks within prescriptive limitations.</p>
4.10.8	<p>Irrespective of which method of fatigue management is used (i.e., compliance with prescriptive flight and duty limitations or implementation of an approved FRMS), all operators are required to maintain records of working periods, with or without flight duties, for flight and cabin crew. It is up to each regulator to stipulate the period of time which these records must be kept.</p>

### 1.3.2 Appendix 8 to Annex 6, Part I

Appendix 8 gives detailed requirements for an FRMS which must include, at a minimum, the following components:

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

Table 1-2 shows how these components map to the requirements of SMS.

**Table 1-2 Comparing SMS and FRMS Components**

SMS Framework	FRMS
1. Safety policy and objectives	1. FRMS policy and documentation
2. Safety risk management	2. FRM processes <ul style="list-style-type: none"> <li>• Identification of hazards</li> <li>• Risk assessment</li> <li>• Risk mitigation</li> </ul>
3. Safety assurance	3. FRMS safety assurance processes <ul style="list-style-type: none"> <li>• FRMS performance monitoring</li> <li>• Management of operational and organizational change</li> <li>• Continuous FRMS improvement</li> </ul>
4. Safety promotion	4. FRMS promotion processes <ul style="list-style-type: none"> <li>• Training programmes</li> <li>• FRMS communication plan</li> </ul>

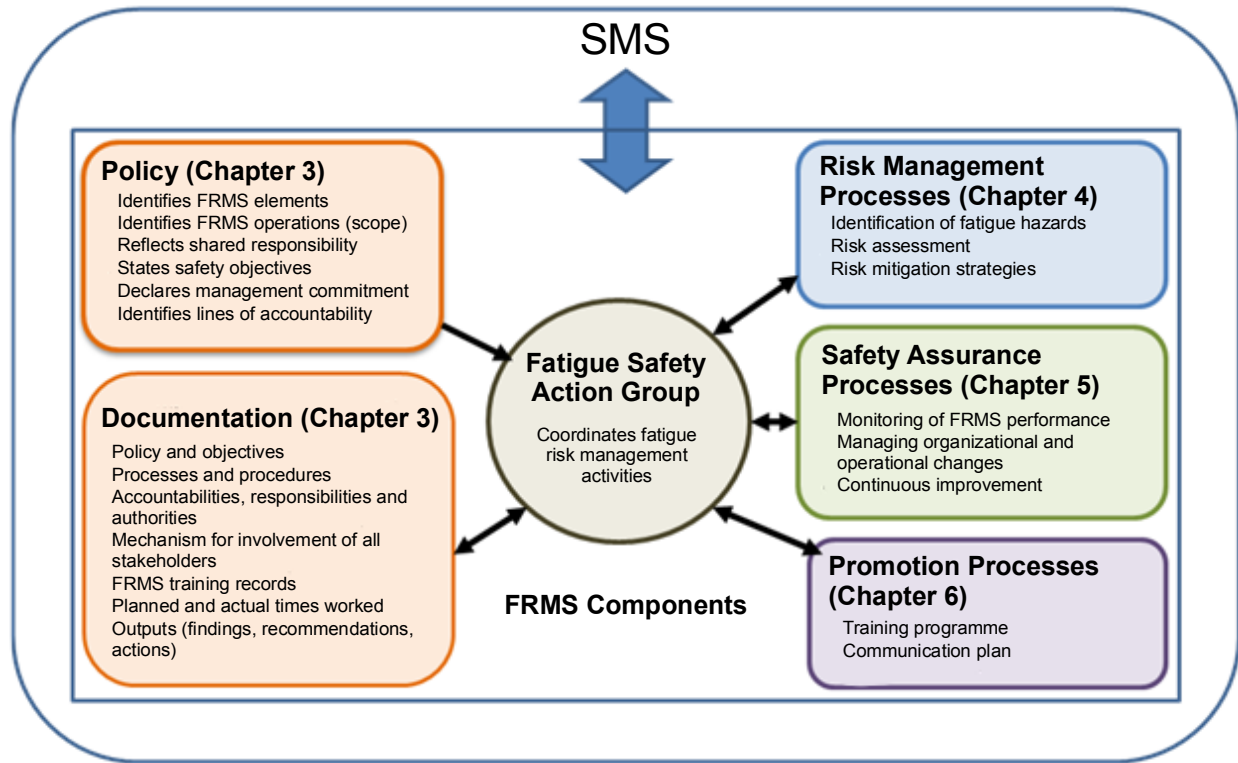
The core operational activities of the FRMS are the FRM processes and the FRMS safety assurance processes. They are supported by organizational arrangements defined in the FRMS policy and documentation and by the FRMS promotion processes.

## 1.4 STRUCTURE OF THIS MANUAL

Figure 1-1 shows a basic framework linking the required components of an FRMS. For ease of explanation, Figure 1-1 presents a single, central, functional group, designated as the “Fatigue Safety Action Group,” responsible for all of these FRMS components. The Fatigue Safety Action Group includes representatives of all stakeholder groups (management, scheduling, and crew members) and other individuals as needed to ensure that it has appropriate access to scientific and medical expertise. However, depending on the organizational structure, some of the Fatigue Safety Action Group functions as described in this manual may be undertaken by other groups within the organization (discussed further in Chapter 3). The important thing is that, irrespective of who does them, all of the component functions required under an FRMS be performed.

Communication between the FRMS and the SMS (in both directions) is necessary to integrate the management of the fatigue risks into the broader risk management activities of the SMS. Even so, the regulator will need to be able to distinguish the FRMS activities from the SMS functions to allow adequate monitoring.





**Figure 1-1 Linking the required components of an FRMS**

The detailed structure of an FRMS, and the specific ways in which it links to an operator's SMS, will vary according to:

- the size of the organization;
- the type and complexity of the operations being managed;
- the relative maturity of the FRMS and the SMS; and
- the relative importance of the fatigue risks.

The FRMS approach is based on applying scientific principles and knowledge to manage crew member fatigue. Chapter 2 introduces the essential scientific concepts that are needed to provide adequate oversight of an FRMS. Chapters 3, 4, 5, and 6 each deal with one of the required FRMS components. Chapter 7 discusses considerations for the State prior to making the decision whether to offer FRMS regulations. Chapter 8 steps through the approval process of an FRMS, while the continued oversight of an FRMS is discussed in Chapter 9.

For ease of reference, a glossary of terms appears at the front of this manual. Appendices A and B provide extra information to support the concepts that are provided in the preceding chapters. Appendix A provides more detailed information on methods of measuring fatigue as part of the FRM processes presented in Chapter 8, Appendix B also supports Chapter 3 by providing further information on using controlled rest on the flight deck as a mitigator of fatigue risk. Finally, Appendix C provides an example of an FRMS evaluation form for use in the regulatory oversight of an FRMS.



## Chapter 2. Science for FRMS

### 2.1 INTRODUCTION TO SCIENCE FOR FRMS

The FRMS approach represents an opportunity for operators to use advances in scientific knowledge to improve safety and increase operational flexibility. To provide effective oversight, States should be aware of the scientific principles on which the FRMS approach is based. These are reviewed in this chapter.

In Chapter 1, the ICAO definition of crew member fatigue was given as:

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

In flight operations, fatigue can be measured either subjectively by having crew members rate how they feel, or objectively by measuring crew members' performance (Chapter 4 and Appendix A).

Another way of thinking about this is that fatigue is a state that results from an imbalance between:

- the physical and mental exertion of all waking activities (not only duty demands); and
- recovery from that exertion, which (except for recovery from muscle fatigue) requires sleep.

Following this line of thinking, to reduce crew member fatigue requires reducing the exertion of waking activities and/or improving 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 them; and
2. Circadian rhythms — the study of innate rhythms driven by the daily cycle of the circadian biological clock (a pacemaker in the brain). These include:
  - rhythms in subjective feelings of fatigue and sleepiness;
  - rhythms in the ability to perform mental and physical work, which affect the effort required to reach an acceptable level of performance (exertion); and
  - rhythms in sleep propensity (the ability to fall asleep and stay asleep), which affect recovery.

### 2.2 ESSENTIAL SLEEP SCIENCE

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 is not a tradable commodity.

### 2.2.1 What is happening in the brain during sleep

There are a variety of ways of looking at what is happening in the sleeping brain, from reflecting on dreams to using advanced medical imaging techniques. Currently, the most common research method is known as polysomnography (see Appendix A for details). This 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). Using polysomnography, it is possible to identify two very different kinds of sleep.

#### ***Non-rapid eye movement sleep***

Compared to waking brain activity, non-rapid eye movement sleep (non-REM sleep) involves gradual slowing of the brainwaves. The amplitude (height) of the brainwaves also becomes larger as the electrical activity of large numbers of brain cells (neurons) becomes synchronized so that they fire in unison. Heart rate and breathing tend to be slow and regular.

People woken from non-REM sleep do not usually recall much mental activity. However, it is still possible for the body to move in response to instructions from the brain. Because of these features, non-REM sleep is sometimes described as “*a relatively inactive brain in a movable body.*”

Non-REM sleep is usually divided into four 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.

Stages 3 and 4 represent deeper sleep (it can be very hard to wake someone up). Stages 3 and 4 are characterized by high amplitude slow brainwaves and are together often described as **slow-wave sleep** (or deep sleep).

Slow-wave sleep has a number of important properties. Pressure for slow-wave sleep builds up across waking and discharges across sleep. In other words:

- the longer you are awake, the more slow-wave sleep you will have in your next sleep period; and
- across a sleep period, the proportion of time spent in slow-wave sleep decreases.

This rising and falling of pressure for slow-wave sleep is sometimes called the **sleep homeostatic process**, and it is a component in most of the biomathematical models that are used to predict crew member fatigue levels (see Chapter 4).

Even in slow-wave sleep, the brain is still about 80 per cent activated and capable of active cognitive processing. There is growing evidence that slow-wave sleep is essential for the consolidation of some types of memory and is therefore necessary for learning.

#### **OPERATIONAL NOTE:**

##### Mitigation strategies for sleep inertia

Operationally, slow-wave sleep may be important because the brain can have difficulty transitioning out of it when someone is woken up suddenly. This is known as sleep inertia — feelings of grogginess and disorientation, with impaired short-term memory and decision-making. Sleep inertia can occur coming out of lighter sleep, but it tends to be longer and more disorienting when someone is woken abruptly out of slow-wave sleep.

This is sometimes used as an argument against the use of controlled rest on the flight deck or in-flight sleep. It would not be desirable to have a crew member woken up because of an emergency be impaired by sleep inertia. This argument is based on the effects of sleep inertia seen in laboratory studies.

However, studies of napping on the flight deck and of sleep in on-board crew rest facilities show that sleep in flight contains very little slow-wave sleep. (It is lighter and more fragmented than sleep on the ground.) This means that sleep inertia is much less likely to occur waking up from sleep in flight than would be predicted from laboratory sleep studies. The risk of sleep inertia can also be reduced by having a protocol for returning to active duty that allows time for sleep inertia to wear off.

Overall, the demonstrated benefits of controlled napping and in-flight sleep greatly outweigh the potential risks associated with sleep inertia. To reduce the risk of sleep inertia after controlled rest on the flight deck, it is recommended to limit the time available for the nap to 40 minutes. Given the time taken to fall asleep, a 40-minute opportunity is too short for most people to enter slow-wave sleep. Refer to Appendix B for suggested Flight Operations Manual procedures for controlled napping.

### **Rapid eye movement sleep**

During rapid eye movement sleep (REM sleep), brain activity measured by polysomnography looks similar to brain activity during waking. However, in REM sleep, from time to time the eyes move around under the closed eyelids — the so-called “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 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 highly activated brain in a paralysed body.*”

Dreams have always been a source of fascination, but are difficult to study using quantitative scientific methods. They have been interpreted as everything from spiritual visitations to fulfillment of instinctual drives, to being a meaningless by-product of activity in various parts of the brain during REM sleep. The current neuro-cognitive view of dreaming argues that it results from brief moments of consciousness when we become aware of all the processing that our brains normally do “off-line,” i.e. when they are not busy dealing with information coming in from the environment through the senses and are not being directed by our conscious control. This “off-line” processing includes reactivating memories and emotions from previous experiences and integrating them with experiences from the latest period of waking. Dreams in this view are a glimpse into your brain reshaping itself so that you can wake up in the morning still yourself, but as a slightly revised version as a result of your experiences yesterday, and ready to start interacting with the world again.

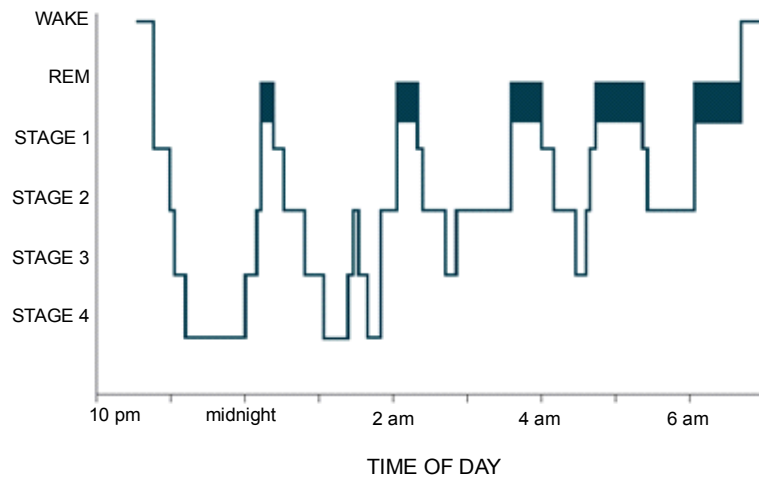
People vary greatly in their ability to recall dreams, and we generally only recall them when we wake spontaneously out of REM sleep (and then only fleetingly unless we write them down or talk about them). Nevertheless, most adults normally spend about a quarter of their sleep time in REM sleep.

### **Non-REM/REM cycles**

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 factors). Figure 2-1 is a diagram describing the non-REM/REM cycle across the night in a healthy young adult. 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<sup>1</sup>.

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<sup>1</sup> Gander P., *Sleep in the 24-Hour Society*, Open Mind Publishing, Wellington, New Zealand, 2003, ISBN 0-909009-59-7.



**Figure 2-1** Diagram of the non-REM/REM cycle across the night in a young adult

Sleep is entered through Stage 1 non-REM and then progresses deeper and deeper into non-REM. About 80 to 90 minutes into sleep, there is a shift out of slow-wave sleep (non-REM Stages 3 and 4). This is often marked by body movements, as the sleeper transitions briefly through Stage 2 non-REM and into the first REM period of the night. (REM periods are indicated as shaded boxes in Figure 2-1.) After a fairly short period of REM, the sleeper progresses back down again through lighter non-REM sleep and into slow-wave sleep, and so the cycle repeats.

The amount of slow-wave sleep in each non-REM/REM cycle decreases across the night, and there may be none at all in the later cycles. In contrast, the amount of REM sleep in each non-REM/REM cycle increases across the night. The sleeper depicted in Figure 2-1 wakes up directly out of the final REM period of the night and so would probably recall dreaming.

Interestingly, slow-wave sleep always predominates at the beginning of a sleep period, regardless of when sleep occurs in the day/night cycle or in the circadian body clock cycle. There seems to be a priority to discharge the **homeostatic sleep pressure** first. In contrast, the time from sleep onset to the first bout of REM (the REM latency) and the duration of each REM bout varies markedly across the **circadian body clock cycle**. The circadian drive for REM sleep is strongest a few hours before normal wakeup time. These two processes — the **homeostatic sleep process** and the **circadian body clock** — are the main components in most of the biomathematical models that are used to predict crew member fatigue levels (see Chapter 4).

**Operational Note:**  
Mitigation Strategies for Sleep Loss

Restoration of a normal non-REM/REM cycle is one measure of recovery from the effects of sleep loss. Lost sleep is not recovered hour-for-hour, although recovery sleep may be slightly longer than usual.

- On the first recovery night, there is more slow-wave sleep than usual. Indeed, there can be so much slow-wave sleep that there is not enough time to make up REM sleep.
- On the second recovery night, there is often more REM sleep than usual.
- By the third recovery night, the non-REM/REM cycle is usually back to normal.

Operationally, this means that schedules need to periodically include an opportunity for at least two consecutive nights of unrestricted sleep, to enable crew members to recover from the effects of sleep loss.

This does not equate to 48 hours off. For example, 48 hours off duty starting at 02:00 would only give most people the opportunity for one full night of unrestricted sleep. On the other hand, 40 hours off starting at 21:00 would give most people the opportunity for two full nights of unrestricted sleep.

Additional nights may be needed for recovery if a crew member's circadian body clock is not already adapted to the local time zone (see Section 2.3).

### 2.2.2 The issue of sleep quality

Sleep quality (its restorative value) depends on going through **unbroken** 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.

#### **Operational Note:**

##### Mitigation Strategies to Minimize Sleep Interruptions

Because uninterrupted non-REM/REM cycles are the key to good quality sleep, operators should develop procedures that minimize interruptions to crew members' sleep.

Rest periods should include defined blocks of time (sleep opportunities) during which crew members are not contacted except in emergencies. These protected sleep opportunities need to be known to flight crews and all other relevant personnel. For example, calls from crew scheduling should not occur during a rest period as they can be extremely disruptive.

Operators should also develop procedures to protect crew member sleep at layover and napping facilities. For example, if a rest period occurs during the day at a layover hotel, the operator could make arrangements with the hotel to restrict access to the section of the hotel where crew members are trying to sleep (such as no children, crew members only) and instruct its staff to honour the necessary quiet periods (for example, no maintenance work or routine cleaning).

### **Quality of in-flight sleep**

As mentioned above, polysomnography studies show that crew members' sleep in on-board crew rest facilities is lighter and more fragmented than sleep on the ground<sup>2</sup>. Sleep during flight deck naps is also lighter and more fragmented than would be predicted from laboratory studies<sup>3</sup>. Nevertheless, there is good evidence that in-flight sleep improves subsequent alertness and reaction speed and is a valuable mitigation strategy in an FRMS.

2 Signal, T.L., Gale, J., and Gander, P.H., "Sleep Measurement in Flight Crew: Comparing Actigraphic and Subjective Estimates to Polysomnography," *Aviation, Space, and Environmental Medicine*, November 2005, Vol. 76(11), pp. 1 058-63.

3 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, Moffett Field: NASA Ames Research Center.

Studies of sleep in hypobaric chambers at pressures equivalent to cabin pressure at cruising altitude indicate that the fragmented quality of in-flight sleep is not due to altitude<sup>4</sup>. Several studies have asked crew members what disturbs their sleep on board. The factors most commonly identified are random noise, thoughts, not feeling tired, turbulence, ambient aircraft noise, inadequate bedding, low humidity, and going to the toilet.

### **Sleep quality and aging**

Across adulthood, the proportion of sleep time spent in slow-wave sleep declines, particularly among men. In addition, sleep becomes more fragmented. For example, one study with 2 685 participants aged 37–92 years found that the average number of arousals (transitions to lighter sleep and awakenings) rose from 16 per hour of sleep for 30-54 year-olds to 20 per hour of sleep for 61-70 year-olds<sup>5</sup>.

These age-related trends are seen in the sleep of flight crew members, both on the ground and in the air<sup>6</sup>. A study of in-flight sleep on delivery flights of B-777 aircraft (from Seattle to Singapore or Kuala Lumpur) found that age was the factor that most consistently predicted the quality and duration of bunk sleep. Older pilots took longer to fall asleep, obtained less sleep overall, and had more fragmented sleep.

It is not yet clear whether these age-related changes in sleep reduce its effectiveness for restoring waking function. Laboratory studies that experimentally fragment sleep are typically conducted with young adults. On the flight deck, experience (both in terms of flying skills and knowing how to manage sleep on trips) could help reduce potential fatigue risk associated with age-related changes in sleep.

### **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 trying to sleep. Because flight crew members often have restricted time available for sleep, sleep disorders pose a particular risk. It is recommended that FRMS training (Chapter 6) include basic information on sleep disorders and their treatment, where to seek help if needed, and any requirements relating to fitness to fly.

## **2.2.3 Consequences of not getting enough sleep**

Even for people who have good quality sleep, the amount of sleep they obtain is very important for restoring their waking function. An increasing number of laboratory studies are looking at the effects of “trimming” sleep at night by an hour or two (known as **sleep restriction**). There are several key findings from these studies that are important for FRMS.

The effects of restricting sleep night after night accumulate, so that people become progressively less alert and less functional day after day. This is sometimes described as **accumulating a sleep debt**. This is a common occurrence for crew members (see below), for example when minimum rest periods are scheduled for several days in a row.

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4 Mumm, J.M., Signal, T.L., Rock, P.B., et al., “Sleep at simulated 2438 m: effects on oxygenation, sleep quality, and post-sleep performance,” *Aviation, Space, and Environmental Medicine*, August 2009, Vol. 80(8), pp. 691-97.

5 Redline, S., Kirchner, H.L., Quan, S.F., et al., “The effects of age, sex, ethnicity, and sleep-disordered breathing on sleep architecture,” *Archives of Internal Medicine*, February 2004, Vol. 164(4), pp. 406–18.

6 Signal, T.L., Gander, P.H., van den Berg, M., “Sleep in flight during long rest opportunities,” *Internal Medicine Journal*, 2004, Vol. 34(3), p. A38.



The shorter the time allowed for sleep each night, the faster alertness and performance decline. For example, one laboratory study found that spending seven hours in bed for seven consecutive nights was not enough to prevent a progressive slowing down in reaction time<sup>7</sup>. The decline was more rapid for a group of participants who spent only five hours in bed each night, and even more rapid for a group who spent only three hours in bed each night. This is described as a **dose-dependent** effect of sleep restriction.

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.<sup>5</sup>

Full recovery of waking function after sleep restriction can take **longer than two nights** of recovery sleep (i.e., longer than it takes the non-REM/REM cycle to recover). Indeed, chronic sleep restriction may have effects on the brain that can affect alertness and performance days to weeks later<sup>8</sup>.

For the first few days of severe sleep restriction (for example, three 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 although their alertness and performance continues to decline. In other words, as sleep restriction continues, people become increasingly unreliable at assessing their own functional status. This finding raises a question about the reliability of subjective ratings of fatigue and sleepiness as measures of a crew member's level of fatigue-related impairment (see Appendix A).

At least in the laboratory, some people are more resilient to the effects of sleep restriction than others. 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 an FRMS (for example, by recommending different personal mitigation strategies for people who are more or less affected by sleep restriction).

In general, more complex mental tasks such as decision making and communication seem to be more severely affected by sleep loss than simpler tasks. Brain imaging studies also suggest that the brain regions involved in more complex mental tasks are the most affected by sleep deprivation and have the greatest need for sleep to recover their normal function.

Laboratory sleep restriction studies are currently the main source of information on the effects of sleep restriction. However, they have some obvious limitations. The consequences of reduced alertness and poor task performance are quite different in the laboratory than for crew members on duty. Laboratory studies usually look at the effects of restricting sleep at night and participants sleep in a dark, quiet bedroom. This may mean that current understanding is based on a "best case scenario." More research is needed on the effects of restricting sleep during the day, and on the combination of restricted sleep and poor quality sleep. Laboratory studies also focus on the performance of individuals, not people working together as a crew.

One simulation study with 67 experienced B747-400 crews has demonstrated that sleep loss increased the total number of errors made by the crew<sup>9</sup>. The study design was set up so that the pilot-in-command was always the pilot flying. Paradoxically, greater sleep loss among first officers improved the rate of error detection. On the other hand, greater sleep loss among pilots-in-command 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 a tendency to choose lower risk options, which would help mitigate the potential fatigue risk. Simulator studies like this are expensive and logistically complex to conduct properly, but they provide vital insights on the links between crew member sleep and operational fatigue risk.

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7 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*, 2003, Vol. 12, pp. 1-12.

8 Rupp, T.L., Wesensten, N.J., Bliese, P.D. et al., "Banking sleep: realization of benefits during subsequent sleep restriction and recovery," *Sleep*, 2009, Vol. 32 (3), pp. 311-21.

9 Thomas, M.J.W., Petrilii, R.M., Lamond, N.A., et al., Australian Long-haul Fatigue Study. In: *Enhancing Safety Worldwide: Proceedings of the 59th Annual International Air Safety Seminar*. Alexandria, USA, Flight Safety Foundation, 2006.

### Sleep restriction in flight operations

The idea of **sleep restriction** implies that there is an optimum amount of sleep that people need to obtain each night. The concept of **individual sleep need** is an area of active debate in sleep research. One way to measure sleep restriction that avoids this problem is to look at how much sleep crew members obtain when they are at home between trips, compared to how much sleep they obtain during trips.

Table 2-1 summarizes data on sleep restriction across different flight operations that were monitored by the NASA Fatigue Program in the 1980s.<sup>10</sup> In these studies, crew members completed sleep and duty diaries before, during, and after a scheduled commercial trip. For each crew member, his average sleep duration per 24 hours at home before the trip was compared with his average sleep duration per 24 hours on the study trip. During night cargo and long-haul trips, crew members often had split sleep (slept more than once in 24 hours).

Scheduling has undoubtedly changed since these studies, so the data in Table 2-1 are likely to be unrepresentative of the current situation in many cases. However, they indicate that sleep restriction is very common across different types of flight operations.

**Table 2-1 Sleep restriction during commercial flight operations**

	Short Haul	Night Cargo	Long Haul
Crew members averaging at least 1 hour of sleep restriction per trip day	67%	54%	43%
Crew members averaging at least 2 hours of sleep restriction per trip day	30%	29%	21%
Length of trip	3-4 days	8 days	4-9 days
Time zones crossed per day	0-1	0-1	0-8
Number of crew members studied	44	34	28

*Note.— The night cargo trips included a one-to-two night break in the sequence of night shifts. Splitting long-haul trips into 24-hour days is rather arbitrary because the average duty day lasted 10.2 hours and the average layover lasted 24.3 hours.*

A growing amount of evidence, from both 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 short sleepers 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. In addition, flight crew members as a group are exceptionally healthy compared to the general population. 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 is definitely not a tradable commodity.

<sup>10</sup> Gander, P.H., Rosekind, M.R., and Gregory, K.B., "Flight crew fatigue VI: an integrated overview," *Aviation, Space, and Environmental Medicine*, 1998, Vol. 69, pp. B49-B60.

**Operational Note:****Mitigation Strategies for Managing Sleep Debt**

Sleep restriction is common across different types of flight operations. Because the effects of sleep restriction are cumulative, schedules must be designed to allow periodic 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 for a minimum of two consecutive nights of unrestricted sleep. Some recent laboratory studies of sleep restriction suggest that this may not be enough to bring crew members back up to their optimal level of functioning. There is evidence that the sleep-restricted brain can stabilize at a lower level of functioning for long periods of time (days to weeks).

Especially in irregular operations, procedures that allow a crew member to continue sleeping until needed can reduce the rate of accumulation of sleep debt. For example, if an aircraft with an anticipated repair time of 07:30 will not actually be ready until 11:30, then a reliable procedure that allows the crew member to continue sleeping would be beneficial. One airline has a system where the operator contacts the layover hotel to update the report time by slipping a message under the crew member's door. The hotel provides a wake-up call one hour before pickup time.

**2.3 INTRODUCTION TO CIRCADIAN RHYTHMS**

Sleeping at night is not just a social convention. It is programmed into the brain by the circadian body clock, which is an ancient adaptation to life on our 24-hour rotating planet. Even very ancient types of living organisms have something equivalent, which means that circadian biological clocks have been around for several billion years.

A feature of circadian clocks is that they are light sensitive. The human circadian clock monitors light intensity through a special network of cells in the retina of the eye (this special light input pathway to the circadian clock is not involved in vision). The clock itself resides in a fairly small cluster of cells (neurons) deeper in the brain (in the suprachiasmatic nuclei (SCN) of the hypothalamus). The cells that make up the 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 circadian body clock is slightly longer than 24 hours. The sensitivity of the circadian body clock to light enables it to stay in step with the day/night cycle. However, that same sensitivity to light also creates problems for crew members who have to sleep out of step with the day/night cycle (for example, on domestic night cargo operations), or who have to fly across time zones and experience sudden shifts in the day/night cycle.

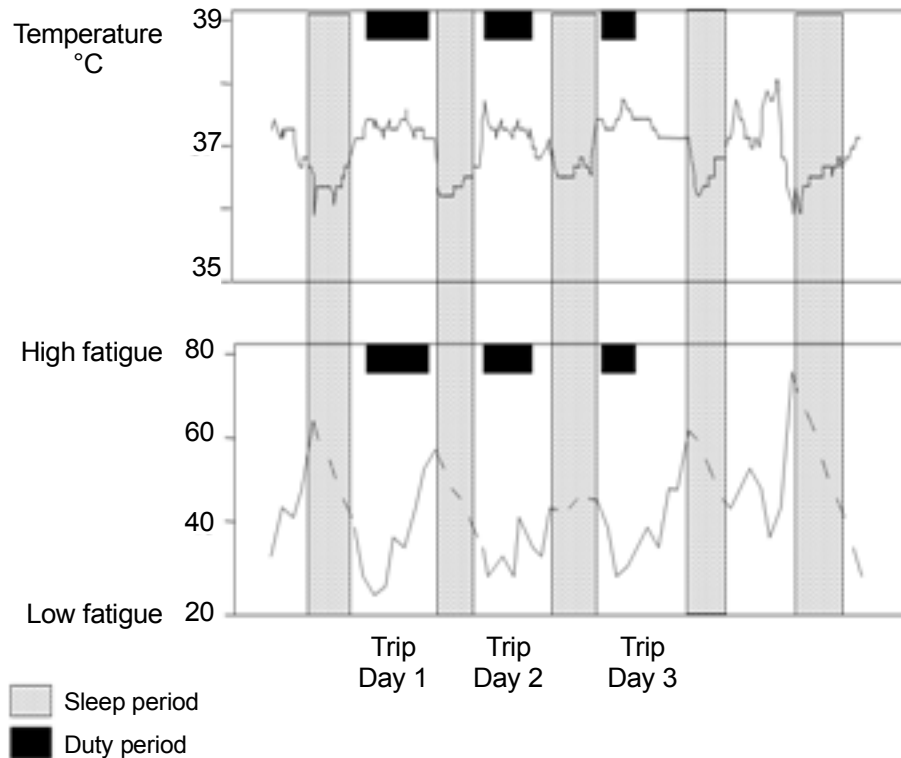
**2.3.1 Examples of circadian rhythm**

It is not possible to directly measure the electrical activity of the circadian body clock in human beings. However, almost every aspect of human functioning (physical or mental) undergoes daily cycles that are influenced by the circadian body clock. Measuring overt rhythms in physiology and behaviour is like watching the hands of an (analogue) wrist watch. The hands move around the watch face because they are driven by the time-keeping mechanism inside the watch, but they are not part of the time-keeping mechanism itself. Similarly, most circadian rhythms that can be measured, such as rhythms in core body temperature or self-rated fatigue, are driven by the circadian body clock, but they are not part of the biological time-keeping mechanism.

Figure 2-2 shows an example of circadian rhythms in core body temperature and self-rated fatigue of a 46-year-old short-haul crew member monitored before, during, and after a three-day pattern of flying on the east coast of the USA (staying in the

same time zone).<sup>11</sup> The crew member had his core temperature monitored continuously and kept a sleep and duty diary, in which he noted his sleep times and rated the quality of his sleep, as well as rating his fatigue every two hours while he was awake (on a scale from 0 = most alert to 100 = most drowsy).

Core body temperature typically fluctuates by about 1°C across the 24-hour day. Note that the crew member's core temperature starts to rise each morning *before* he wakes up. In effect, his body is beginning to prepare 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.)



**Figure 2-2** Circadian rhythms of a short-haul pilot

Looking at his self-rated fatigue, this crew member did not feel at his best first thing in the morning. He tended to feel least fatigued about two to four hours after he woke up, after which his fatigue climbed steadily across the day. The dashed line across the sleep period indicates that he was not asked to wake up every two hours to rate his fatigue across this time.

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 2-2.

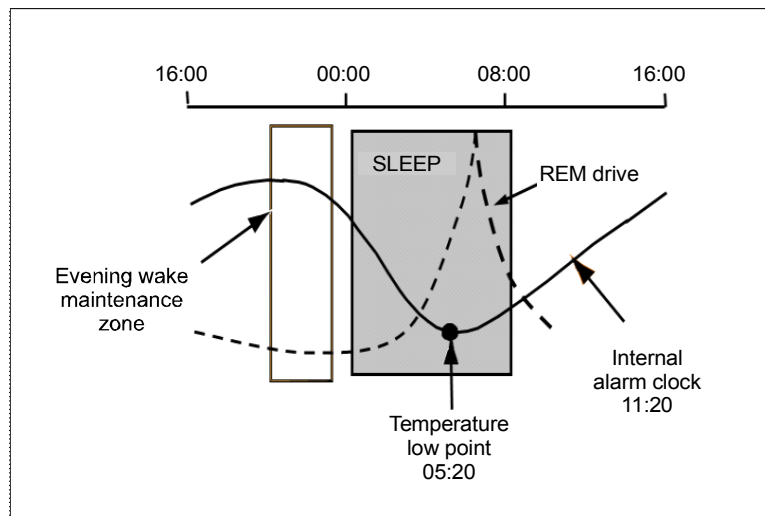
<sup>11</sup> Gander, P.H., Graeber, R.C., Foushee, H.C., Lauber, J.K., Connell, L.J., *Crew Factors in Flight Operations II: Psychophysiological Responses to Short-Haul Air Transport Operations*, 1994, NASA Technical Memorandum #108856. Moffett Field: NASA Ames Research Center.

The daily minimum in core body temperature corresponds to the time in 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)**.

### 2.3.2 The circadian body clock and sleep

As mentioned in Section 2.2, the circadian body clock influences sleep in a number of ways. (It has connections to centres in the brain that promote wakefulness and to opposing centres that promote sleep, as well as to the system that controls REM sleep.) Figure 2-3 is a diagram that summarizes the effects of the circadian clock on sleep. It is based on data collected from 18 night cargo pilots on their days off, i.e., when they were sleeping at night<sup>12</sup>. Like the crew member in Figure 2-2, they also had their core temperature monitored continuously, and kept sleep and duty diaries.

The core temperature rhythm is summarized as a simple (continuous) curve. The daily time of the minimum in temperature (shown by the black dot) is the average for all crew members and is used as a reference point for describing the other rhythms. Note that changes in temperature are *not the cause* of the other rhythms. The core body temperature rhythm is being “read” like the hands of an analogue wrist watch, as a way of following the underlying cycle of the circadian body clock.



**Figure 2-3 Summary of the influences of the circadian body clock on sleep at night**

Figure 2-3 summarizes the following features of sleep at night (when crew members are fully adapted to the local time zone).

- Sleep normally begins about five hours before the minimum in core body temperature.
- Wake up normally occurs about three hours after the minimum in core body temperature.
- REM sleep is entered fastest, and REM periods are longest and most intense, just after the minimum in core body temperature. This is sometimes described as the peak of the **circadian rhythm in REM propensity** (the dashed curve in Figure 2-3).

<sup>12</sup> Gander, P.H., Rosekind, M.R., and Gregory, K.B., “Flight crew fatigue VI: an integrated overview,” *Aviation, Space, and Environmental Medicine*, 1998, Vol. 69: B49-B60.

- A variety of laboratory protocols have demonstrated people are extremely unlikely to fall asleep 6 to 8 hours before the minimum in core body temperature. This has become known as the **evening wake maintenance zone**.
- Laboratory studies also show that as body temperature begins to rise, there is an increasing pressure to wake up. This peaks about six hours after the circadian temperature minimum. This is sometimes referred to as an **internal alarm clock**, because it is very hard to fall asleep or stay asleep during this part of the circadian body clock cycle.

The interaction between the homeostatic pressure for sleep and the circadian variation in sleepiness driven by the body clock results in two times of peak sleepiness in 24 hours:

- a peak in the early hours of the morning — the so-called **Window of Circadian Low (WOCL)**, which occurs around 03:00 to 05:00 for most people; and
- a peak in the early afternoon — sometimes called the **afternoon nap window** (around 15:00 to 17:00 for most people). Restricted sleep at night or disturbed sleep 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 of 20 to 60 years.

The combined effects of the homeostatic pressure for sleep and the circadian biological 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).

#### **Operational Note:**

##### The Circadian Body Clock, Sleep, and FRMS

- The daily minimum in core body temperature corresponds to the time in the circadian body clock cycle when people feel most sleepy and are least able to perform mental and physical tasks. This is sometimes called the Window of Circadian Low (WOCL) and it is a time of high risk for fatigue-related error. In FRMS incident investigations, it is important to estimate the time that errors occur relative to the expected time of the WOCL.
- The WOCL can occur in flight during domestic night operations and during long-haul and ULR operations when the duty/rest cycle is out of step with crew members’ circadian body clock cycles.
- The evening wake maintenance zone occurs in the few hours before usual bedtime. This makes it very difficult to fall asleep early the night before an early duty report time. This has been identified as a cause of restricted sleep and increased fatigue risk in short-haul operations that require early starts.
- The increasing drive for wake that accompanies the increase in core body temperature in the morning makes it difficult to fall asleep or stay asleep later in the morning and in the early afternoon. This has been identified as a cause of restricted sleep and increased fatigue risk in night cargo operations, which require crew members to delay their main sleep period until the morning.
- The internal alarm clock and the evening wake maintenance zone can also interfere with the in-flight sleep and layover sleep of long-haul and ULR crew members when the duty/rest cycle is out of step with crew members’ circadian body clock cycles.

### 2.3.3 Sensitivity of the circadian body clock to light

At the beginning of this chapter, there was a brief description of how the circadian body clock is able to track light intensity in the environment. This enables it to stay in step with the day/night cycle, even although it has a tendency to generate a “biological day” that is slightly longer than 24 hours.

The effect of light on the circadian body clock changes according to when in the clock cycle the light exposure occurs. For a crew member adapted to local time and sleeping at night:

- light exposure in the morning (after the temperature minimum) causes the circadian clock to speed up temporarily, resulting in a phase advance (equivalent to crossing time zones in an eastward direction);
- light exposure in the middle of the day has very little effect; and
- light exposure in the evening (before the temperature minimum) causes the circadian clock to slow down temporarily, resulting in a phase delay (equivalent to crossing time zones in a westward direction).

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

In theory, this means that just the right amount of light exposure at the same time every morning would speed up a 24.5-hour circadian clock cycle just enough to synchronize it to exactly 24 hours. In practise, 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, notably social cues, and 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 has become a disadvantage in the round-the-clock society because it causes the human circadian body clock to resist adaptation to any pattern other than sleep at night.

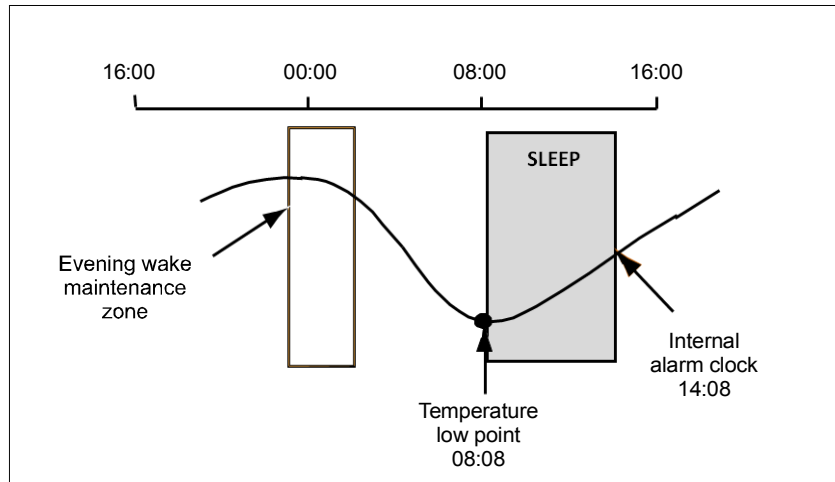
### 2.3.4 Shift work

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 that they would normally be asleep.

The further sleep is displaced from the optimum part of the circadian body clock cycle, the more difficult it becomes for crew members to get adequate sleep (i.e., the more likely they are to experience sleep restriction). For example, crew members flying domestic night cargo operations 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 crew members are flying at night.

Figure 2-4 summarizes what happened to the circadian biological clock and sleep when the night cargo crew members in Figure 2-3 were flying at night and trying to sleep in the morning. (Recall that they had their core temperature monitored continuously across eight day-trip patterns, and kept sleep and duty diaries.)

The core temperature rhythm is summarized as a simple (continuous) curve. Looking back at Figure 2-3, when these crew members were off duty and sleeping at night, the average time of the temperature minimum was 05:20. In Figure 2-4, when they were working through the night, the average time of the temperature minimum shifted to 08:08 (a delay of 2 hours, 48 minutes). This confirms that the circadian body clock did not adapt fully to night duty (which would have required a shift of about 12 hours).



**Figure 2-4 The circadian body clock and sleep after night duty**

The incomplete adaptation of the circadian clock forced crew members to sleep in a different part of the circadian body clock cycle after night duty.

At home before the trip (Figure 2-3), they went to sleep about five hours before the temperature minimum and woke up about three hours after the temperature minimum.

After night duty (Figure 2-4), they went to sleep close to the circadian temperature minimum and woke up about six hours later. The average time of waking up after morning sleep periods was 14:13. The predicted time of the **internal alarm clock** (six hours after the temperature minimum) was 14:08. Crew members were not asked what woke them up, but they rated themselves as not feeling well-rested after these restricted morning sleep episodes.

Another consequence of the incomplete adaptation of the circadian body clock to night duty was that crew members were often operating the last flight of the night in the WOCL when they would be expected to be sleepy and having to make additional effort to maintain their performance. No fatigue-related incidents were observed on these flights (all crews were accompanied by a flight deck observer). However, all flights were routine, i.e., there were no operational events that tested the capacity of these crew members to respond to non-routine situations.

#### **Operational Note:**

##### Mitigation Strategies for Night Duty

- Night duty forces crew members to sleep later than normal in their circadian body clock cycle. This means that they have a limited amount of time to sleep before the circadian body clock wakes them up. Consequently, they need to get to sleep as soon as possible after coming off duty.
- Getting off duty earlier increases the time available for sleep in the morning, before the circadian body clock makes it difficult for crew members to stay asleep.
- Napping before going on duty is beneficial to help maintain alertness and performance through to the end of the night.



- Napping during the duty period (for example, on the ground while aircraft are being loaded and unloaded) is beneficial to help maintain alertness and performance through to the end of the night. The napping opportunity should be limited to 40-45 minutes, with an additional 10-15 minutes allowed to ensure that sleep inertia (if any) has dissipated.
- In some operations, it may be possible to schedule a longer sleep opportunity during the night, for example, during loading and unloading of freight, or during continuous duty overnight periods. Providing a sleeping room away from the aircraft and protected time to sleep would increase the amount of sleep that crew members are able to obtain. Once again, an additional 10-15 minutes should be allowed, to ensure that sleep inertia (if any) has dissipated.

### 2.3.5 Jet lag

Flying across time zones exposes the circadian body clock to sudden shifts in the day/night cycle. Because of its sensitivity to light and (to a lesser extent) social time cues, the circadian body clock will eventually adapt to a new time zone. Studies with participants flown as passengers have identified a number of factors that affect the rate of adaptation to a new time zone. These factors include the following.

- The number of time zones crossed — adaptation generally takes longer when more time zones are crossed.
- The direction of travel — adaptation is usually faster after westward travel than after eastward travel across the same number of time zones.

This probably reflects the fact that most people have a circadian body clock that has an innate cycle slightly longer than 24 hours, which makes it easier to lengthen the cycle to adapt to a westward shift (a phase delay).

After eastward flights across six or more time zones, the circadian body clock may adapt by shifting in the opposite direction, for example shifting 18 time zones west rather than six time zones east. When this happens some rhythms shift eastward and others westward (known as resynchronization by partition) and adaptation can be particularly slow.

Rhythms in different functions can adapt at different rates, depending on how strongly they are influenced by the circadian body clock.

This means that during adaptation to the new time zone, rhythms in different body functions can be disturbed from their usual relationships to one another.

Adaptation is faster when the circadian body clock is more exposed to the time cues that it needs to lock onto in the new time zone. This relates to the extent to which people adopt the pattern of sleep, eating, etc., in the new time zone and the amount of time they spend outdoors in the first few days.

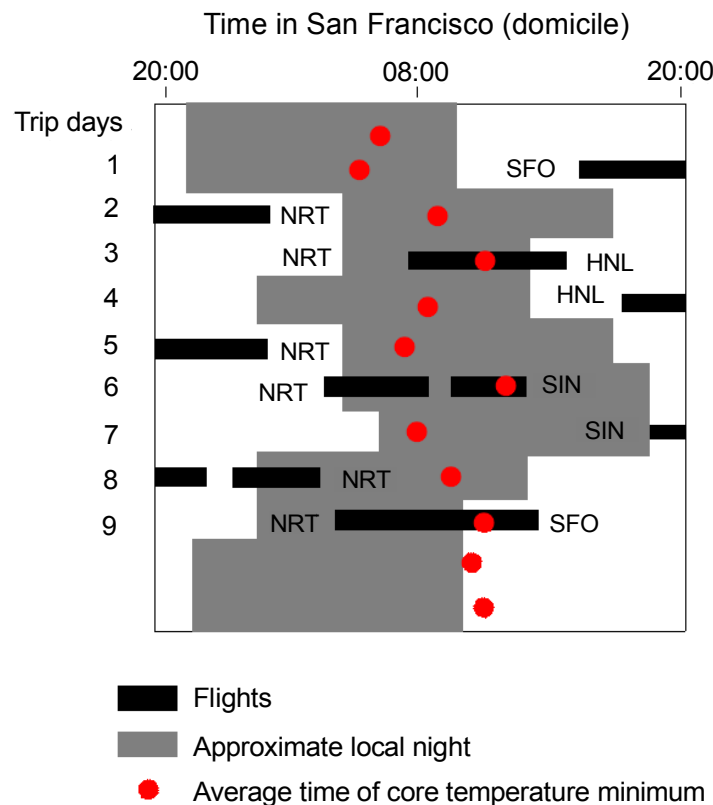
Beginning a trip with a sleep debt seems to increase the duration and severity of jet lag symptoms.

During the period of adaptation to the new time zone, common symptoms include wanting to eat and sleep at times that are out of step with the local routine, problems with digestion, degraded performance on mental and physical tasks, and mood changes.

The situation for long-haul and ultra long-range (ULR) flight crew is different to that for the passenger who plans to spend long enough at the destination to adapt fully to local time. Typically, layovers in each destination last only one to two days, after which crew members are asked to operate a return flight or additional flights in the destination region, followed by the return flight(s) to their city of origin. This means that the circadian body clock does not have enough time to adapt to any of the

destination time zones. In addition, the combination of a long duty day followed by one to two day layovers gives a duty/rest cycle that does not follow a regular 24-hour pattern, so the circadian body clock cannot lock on to the duty/rest cycle.

Relatively few studies have tracked the circadian body clock across commercial long-haul trip patterns and none has tracked it across ULR operations. Figure 2-5 depicts data from one NASA study conducted in the mid-1980s on B747 200/300 operations (three-person crews consisting of a pilot-in-command, first officer, and flight engineer)<sup>13</sup>. Similar trip patterns are still being flown by some operators but with an additional pilot, not a flight engineer. Participants had their core body temperature monitored continuously and kept sleep and duty diaries before, during, and after this trip, which included four trans-Pacific flights plus one round trip within Asia (NRT-SIN-NRT). The dots on the graph indicate the time of the temperature minimum (averaged for six crew members per day).



**Figure 2-5 Study tracking the circadian body clock across multiple trans-Pacific flights**

By the end of this trip pattern, the temperature minimum had delayed by about 4.5 hours, giving an average drift rate of about 30 minutes per 24 hours (or an average cycle length of the circadian body clock of about 24.5 hours). The drift presumably was the result of the fact that the circadian body clock did not have any 24-hour time cues to lock on to, with the non-24-hour duty/rest cycle and every layover in a different time zone.

One consequence was that the temperature minimum (corresponding to the **WOCL**) sometimes occurred in flight, for example, on the last flight from NRT to SFO. At these times, crew members would be expected to be sleepy and having to make

<sup>13</sup> Gander, P.H., Gregory, K.B., Miller, D.L., Rosekind, M.R., Connell, L.J., and Graeber, R.C., "Flight crew fatigue V: long-haul air transport operations," *Aviation, Space, and Environmental Medicine*, 1998, Vol. 69, pp. B37-B48.

additional effort to maintain their performance. This would be an ideal time to take an in-flight nap (crew members did not have in-flight sleep opportunities on this trip).

Another consequence was that when crew members returned home, their circadian body clocks were on average 4.5 hours delayed with respect to local time and took several days to readapt.

### **Layover sleep patterns on long-haul and ULR trips**

The fact that long-haul and ULR crew members seldom stay long enough in any destination time zone to become adapted to local time has effects on their layover sleep. Often, crew members split their sleep, having one sleep period on local night and another corresponding to local night in their home time zone, which overlaps the preferred part of the circadian body clock cycle for sleep (at least for the first 24 to 48 hours in a new time zone).

Another factor affecting layover sleep, particularly for unaugmented crews who do not have the opportunity for in-flight sleep, is that long-haul duty days are often associated with extended periods of waking. For example, in a series of long-haul trips studied by the NASA Fatigue Program the average period of waking associated with a duty day was 20.6 hours (the average length of a duty period was 9.8 hours)<sup>13</sup>. Across these long periods of waking, **the homeostatic pressure for sleep** builds so that crew members tend to sleep, at least for a short time, soon after arrival at the destination layover hotel. For example, this is a common pattern after eastward night flights across multiple time zones. A short sleep is taken soon after arrival, during the local afternoon, and then the main sleep period is then taken during local night.

FRMS training for long-haul and ULR crew members needs to include discussion of the effects of trans-meridian flights on the circadian body clock and sleep. One way to reduce the complexity of this material is to develop specific guidance for sleep and the use of personal fatigue mitigation strategies on different routes.

#### **Operational Note:**

##### Effects of Different Types of Long-Haul Trip Patterns on the Circadian Body Clock

Relatively few studies have tracked the circadian body clock across long-haul trip patterns, and many are over 20 years old. The available studies suggest that different types of trip patterns affect the circadian body clock in different ways.

- Sequences of back-to-back trans-meridian flights (separated by 24-hour layovers) that do not return to the domicile time zone for long periods of time (such as the pattern illustrated in Figure 2-5) tend to cause the circadian body clock to drift on its innate cycle, which is typically slightly longer than 24 hours. This is probably because these trips contain no regular 24-hour pattern to which the circadian body clock can synchronize. When they arrive back in their home time zone, crew members need additional days to readapt to local time.
- Sequences of out-and-back trans-meridian flights (separated by 24-hour layovers) that return to the home time zone on alternate layovers seem to enable the circadian body clock to remain synchronized to the home time zone. For example, a trip pattern studied by the NASA Fatigue Program involved three back-to-back return flights between the US West Coast and London (six flights in total) with 24-hour layovers between each flight. Returning to their home time zone on every second layover appeared to keep crew members' circadian body clocks (monitored by the core temperature rhythm) synchronized to West Coast time. As a result, crew members obtained relatively good sleep on the West Coast layovers and did not need additional days to readapt to West Coast time at the end of the trip.
- There is some evidence that when crew members stay longer in the destination region, for example, doing several days of local flying with minimal time zone changes before flying the long-haul trip home, their circadian body clocks begin to adapt to the destination time zone. This may improve layover sleep. On the other hand, when they arrive back in their home time zone, they need additional days to readapt to local time.

The scarcity of data on what happens to the circadian body clock across different long-haul trip patterns is one reason most current biomathematical models do not have a validated approach for simulating what happens to the circadian clock across sequences of trans-meridian flights (see Chapter 4).

## 2.4 SUMMARY OF ESSENTIAL SCIENCE FOR FRMS

Discoveries in sleep science and circadian rhythms provide a strong scientific basis for FRMS. The science does not address every detailed operational question and it never will. In other words, there will always be a need to combine operational experience and scientific knowledge to come up with workable controls and mitigations to manage fatigue risk in an FRMS.

The scientific basis for FRMS can be continuously improved if data that are routinely collected as part of FRM processes (Chapter 4) and FRMS Assurance processes (Chapter 5) can be shared in appropriate ways in the public domain.

### **Operational Note:** Key Facts about Sleep

Sleep is vital for recovery from fatigue. Two aspects of sleep are important — the amount of sleep and the quality of sleep.

#### *Amount of sleep*

- Sleep restriction is common in flight operations.
- Not getting enough sleep leads to: feeling sleepier, difficulty staying alert, getting irritable, slower reactions, poorer coordination, slower thinking, getting fixated on part of a problem and losing the big picture (loss of situation awareness), less creative problem solving, and reduced memory consolidation (impaired learning).
- The effects of restricted sleep accumulate:
  - the rate of accumulation of fatigue is related to the rate of sleep loss (less sleep per day = more rapid accumulation of fatigue);
  - sleep pressure eventually becomes uncontrollable, which results in unintentional sleep (microsleeps or unintended naps).
- Lost hours of sleep do not need to be recovered hour-for-hour.
- At least two consecutive nights of unrestricted sleep are required to recover from the cumulative effects of multiple nights of restricted sleep. Unrestricted sleep means being free to fall asleep when tired and wake up spontaneously, with sleep occurring at the appropriate time in the cycle of the circadian body clock. In some cases, this recovery period can be built into schedules (for example, with short day-time duty periods).
- Controlled napping can temporarily relieve the symptoms of sleep loss. It is a valuable personal mitigation strategy, for example, prior to a night duty period or on long-haul flights.
  - A NASA study of controlled rest on the flight deck showed improved alertness at the end of unaugmented long-haul flights (8 to 9 hours) when flight crew members were given a 40-minute nap opportunity in their flight deck seat.

### Quality of sleep

- Good quality sleep involves regular cycles through two different types of sleep — Rapid Eye Movement sleep (REM sleep) and non-REM sleep. A full non-REM/REM sleep cycle takes roughly 90 minutes.
- Sleep that is fragmented by multiple awakenings, or arousals into lighter stages of sleep, breaks up the non-REM/REM cycle and is less restorative than continuous sleep.
  - Sleep in on-board crew rest facilities is lighter and more fragmented than sleep in hotels or at home. This does not appear to be an effect of altitude.
- Both flight deck naps and in-flight sleep in crew rest facilities contain very little deep non-REM sleep (known as slow-wave sleep), so sleep inertia is less likely after in-flight sleep than is predicted by laboratory studies.

Two main physiological processes interact to regulate sleep:

- The homeostatic sleep process is evident in the pressure for slow-wave sleep that builds up across waking and discharges across sleep.
- The circadian body clock regulates the timing of REM sleep and dictates the preference for sleep at night.

The interaction between the homeostatic pressure for sleep and the circadian body clock results in two times of peak sleepiness in 24 hours:

- a peak in the early afternoon (the afternoon nap window) that occurs around 15:00 to 17:00 for most people; and
- a peak in the early hours of the morning (the window of circadian low or WOCL) that occurs around 03:00 to 05:00 for most people.

*Note.— These two processes are the main components in most of the biomathematical models that are used to predict crew member fatigue levels (see Chapter 4).*

### Operational Note:

#### Key Facts about the Circadian Body Clock

- 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).
- The circadian biological clock generates an innate “biological day” that is slightly longer than 24 hours for most people. Its sensitivity to light enables it to stay in step with the 24-hour day/night cycle.
- Almost every aspect of human functioning (physical or mental) undergoes daily cycles that are influenced by the circadian body clock.
- The daily minimum in core body temperature corresponds to the time in the circadian body clock cycle when people feel most sleepy and are least able to perform mental and physical tasks. This is sometimes called the Window of Circadian Low, and it is a time of high risk for fatigue-related error.

### *Shift work*

- 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 that they would normally be asleep.
- The ability of the circadian clock to “lock on” to the 24-hour day/night cycle makes it resist adaptation to any pattern other than sleep at night.
- The fact that the circadian body clock does not adapt fully to altered sleep/wake patterns has two main consequences:
  - duty days that overlap crew members’ usual sleep times (particularly all-night operations) tend to cause sleep restriction; and
  - crew members who are working through the window of circadian low can be expected to be sleepy and have to make additional effort to maintain their performance.
- The further sleep is displaced from the optimum part of the circadian body clock cycle, the more difficult it becomes for crew members to get adequate sleep.
- In scheduling, the frequency of recovery breaks (at least two consecutive nights of unrestricted sleep) needs to reflect the rate of accumulation of sleep debt.

### *Jet lag*

- Flying across time zones exposes the circadian body clock to sudden shifts in the day/night cycle. Because of its sensitivity to light and (to a lesser extent) social time cues, the circadian body clock will eventually adapt to a new time zone.
- The rate of adaptation depends on the number of time zones crossed, the direction of travel (faster after westward flights) and the extent to which the circadian body clock is exposed to the 24-hour cues in the new time zone (outdoor light, sleeping and eating on local time, etc.).
- Layovers of 24 to 48 hours are not long enough to allow the circadian body clock to adapt to local time.
- Different types of long-haul trip patterns affect the circadian body clock in different ways:
  - Sequences of back-to-back trans-meridian flights that do not return to the domicile time zone for long periods of time tend to cause the circadian body clock to drift on its innate cycle. On return to the home time zone, additional days are needed to readapt to local time.
  - Sequences of out-and-back trans-meridian flights that return to the home time zone on alternate layovers seem to enable the circadian body clock to remain synchronized to the home time zone.
  - On trips that include longer periods in the destination region, for example, several days of local flying before the return flight home, the circadian body clock begins to adapt to the destination time zone. This may improve layover sleep. On the other hand, on return to the home time zone, additional days are needed to readapt to local time.
- On long-haul layovers, sleep is affected by competition between physiological processes (the homeostatic sleep drive and the circadian biological clock) and a preference for sleeping during the local night.

- Route-specific recommendations for personal fatigue mitigation strategies may be useful in FRMS training for long-haul and ULR crew members.

**Operational Note:**

## How Much Sleep in 24 hours is Enough?

This common question is usually aimed at trying to get a “magic number” for the minimum amount of sleep that a crew member needs, or the minimum rest period that needs to be scheduled. From a sleep science perspective, the answer is “it depends on many factors, including individual differences.” Some of the things it depends on are:

- Recent sleep history — one restricted sleep period is a smaller fatigue risk for a crew member who is starting out well-rested than for a crew member who has already accumulated a sleep debt;
- The amount of sleep a crew member needs to be fully rested (which varies among crew members);
- Whether the crew member is likely to obtain good quality sleep during the restricted sleep period. (For example, is sleep at home, in an on-board crew rest facility, in a layover hotel? Does the sleep opportunity occur at an appropriate time in the circadian body clock cycle?);
- Whether sleep is shortened because a crew member has to stay awake for an extended time beforehand (increasing the homeostatic pressure for sleep and the risk of micro-sleeps prior to the sleep period);
- Whether sleep is shortened because a crew member has to stay awake for an extended time afterwards (increasing the homeostatic pressure for sleep and the risk of micro-sleeps prior to the next sleep period);
- Whether the crew member will be trying to work through times of increased circadian sleep drive (the early hours of the morning and mid-afternoon when the circadian body clock is adapted to local time);
- The criticality of the tasks that a crew member will be undertaking after the restricted sleep period;
- Other defensive strategies that are in place to manage the safety risk if that crew member is fatigue-impaired as a result of the restricted sleep period; and
- When the opportunity will occur for recovery from the effects of the restricted sleep period. (For example, is it the first in a series of restricted sleep periods, or is it followed by two unrestricted nights of recovery sleep?)

From a safety perspective, the answer is that no single defensive strategy is 100 per cent sure. (The same desire for simplicity is a risk with biomathematical models that define a “safety threshold” for crew member fatigue. For example, there is a tendency to believe that an operation is safe if it is predicted to be below the threshold, but unsafe if it is predicted to be above it.) In an FRMS, safety comes from having a data-driven multilayered system of defenses to manage fatigue risk, not from a reliance on simple thresholds. The FRMS answer is: measure crew member fatigue levels, do a risk assessment, and implement controls and mitigations as needed. These processes are the subject of Chapters 5 and 6.





## Chapter 3. FRMS policy and documentation

### 3.1 INTRODUCTION TO FRMS POLICY AND DOCUMENTATION

This chapter describes what should be included in an FRMS policy and other documentation required to record its activities. The policy and documentation define organizational arrangements that support the core operational activities of the FRMS (the FRM processes and the FRMS safety assurance processes). The linkages between policy and documentation and other FRMS components are outlined in Figure 3-1.

The FRMS policy specifies the operator's commitment and approach to the management of fatigue risk. If acceptable to the State, it may be appropriate in some cases for the operator to incorporate its FRMS policy in its SMS policy. However, it should be noted that Appendix 8 to ICAO Annex 6, Part I, requires an operator to clearly define all elements of the FRMS in its policy. It must be possible to distinguish the operator's FRMS policy from the general SMS policy to allow separate review.

The FRMS documentation describes the components and activities of the entire FRMS. It makes it possible for the effectiveness of the FRMS to be audited (internally and externally) to check whether it is meeting the safety objectives defined in the FRMS policy. Maintaining the required documentation is one of the recommended functions of the Fatigue Safety Action Group.

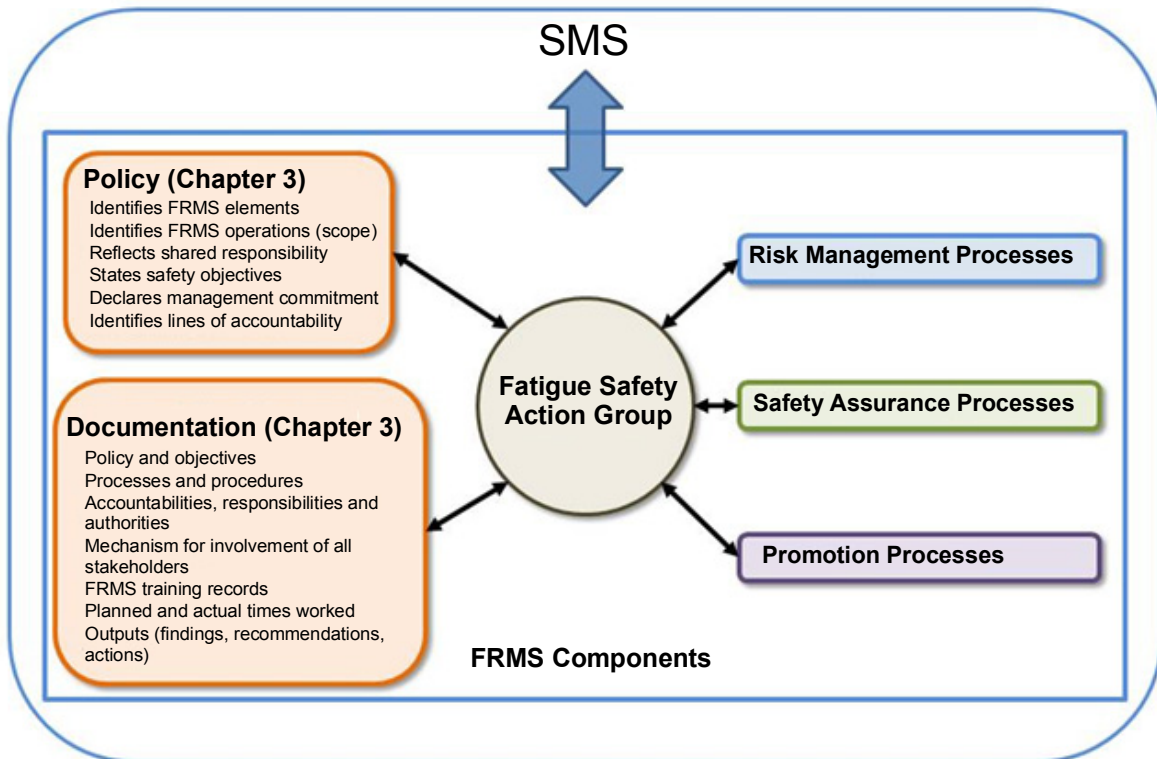


Figure 3-1 Linkages between FRMS policy and documentation and other FRMS components

The ICAO requirements for FRMS policy and documentation are as follows (Appendix 8 to Annex 6, Part I).

### Appendix 8 to Annex 6, Part I

#### 1. FRMS policy and documentation

##### 1.1 FRMS policy

- 1.1.1 The operator shall define its FRMS policy, with all elements of the FRMS clearly identified.
- 1.1.2 The policy shall require that the scope of FRMS operations be clearly defined in the operations manual.
- 1.1.3 The policy shall:
- a) reflect the shared responsibility of management, flight and cabin crews, 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, flight and cabin crews, and all other involved personnel are identified; and
  - i) 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 operator 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, flight and cabin crew members, and all other involved personnel;
- e) FRMS training programmes, training requirements and attendance records;
- f) scheduled and actual flight times, duty periods and rest periods with significant deviations and reasons for deviations noted; and
- g) FRMS outputs including findings from collected data, recommendations, and actions taken.

### 3.2 APPENDIX 8, PARAGRAPH 1.1: FRMS POLICY

1.1.1 The operator shall define its FRMS policy, with all elements of the FRMS clearly identified.

The FRMS policy provides the umbrella under which the FRMS operates. While an FRMS may be an integral part of an operator's SMS, SMS and FRMS require two separate approval processes. Consequently, whether the operator's FRMS Policy has been written as a stand-alone document, as a component of its SMS Policy, or as part of its overall Safety Policy, any aspects of the FRMS policy must be easily identifiable as such. This means that the FRMS policy can be reviewed in its entirety and is clearly distinguishable from other safety policy statements.

### 3.2.1 Scope of the FRMS

1.1.2 The policy shall require that the scope of FRMS operations be clearly defined in the operations manual.

ICAO Standard 4.10.2 (of Annex 6, Part I) requires that, where FRMS regulations are provided, States allow an operator to choose whether it will use the FRMS to manage fatigue risk in all its operations, or only in designated specific types of operations (for example, a particular fleet, a particular route or ULR operations only). All operations not covered by the FRMS must operate under the applicable prescriptive flight and duty time limits.

Because a policy statement is typically a short and stable document, it does not have to detail the scope of the operations to which the FRMS applies, but it does have to identify where these are detailed. For example, an operator policy statement may indicate that the scope of the FRMS is defined in the Flight Operations Manual. This means that State-approved changes in scope do not require a rewrite of the initial FRMS policy statement.

As an operator's familiarity and experience with FRMS builds, it may wish to expand the scope of the FRMS. This could be viewed as a natural evolution of the FRMS, and the regulator will need to give consideration to the requirements that would govern expanding the scope of an FRMS.

The following text boxes show examples of statements of the scope of an FRMS.

#### Example 1

Airline A — large international carrier with 11 different fleet types

The FRMS for Airline A will apply to all operations as specifically identified in the Flight Operations Manual (FOM). All other operations will be conducted under the prescriptive flight and duty time regulations.

In Example 1, the Flight Operations Manual initially lists the entire B-777 fleet and Ultra-Long Range (ULR) flights on the B-787, and only includes pilots. Subsequently, Airline A decides that it wants to add its A-330 fleet to the FRMS.

With approval from the regulator, the A-330 fleet can be added to the list in the Flight Operations Manual that identifies operations covered by the FRMS, without requiring a change to the FRMS policy statement. This change makes the Fatigue Safety Action Group responsible for establishing FRMS processes to identify fatigue hazards in the A-330 operations, assess the risks, and develop and implement controls and mitigations. FRMS safety assurance processes also need to be established to monitor the effectiveness of the FRMS in managing fatigue risk in the A-330 operations.

The addition of cabin crew members to the FRMS would require an amended policy statement, as follows.

The FRMS for Airline A will apply to all operations as specifically identified in the Flight Operations Manual (FOM) and Cabin Operations Manual (COM). All other operations will be conducted under the prescriptive flight and duty time regulations.

#### Example 2

Airline B — Domestic carrier operating both scheduled and charter operations with three fleet types. Airline B chooses to operate its charter operations under FRMS and to operate its scheduled operations under the prescriptive flight and duty time regulations.

The FRMS for Airline B will apply to all flight crew members in all charter aircraft operations.

**Example 3**

Airline C — Two aeroplane on-demand carrier that chooses to cover all its operations under FRMS

The FRMS for Airline C will apply to all flight crew members in all operations.

1.1.3 The policy shall:

- a) reflect the shared responsibility of management, flight and cabin crews, 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, flight and cabin crews, and all other involved personnel are identified; and
- i) require periodic reviews to ensure it remains relevant and appropriate.

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

Appendix 8, Section 1.1.3, identifies the minimum requirements that must be addressed in the FRMS policy. Essentially, these identify the prerequisites of an FRMS. As for the management of fatigue-related risks within prescriptive flight and duty limitations, FRMS necessitates shared responsibility between the operator and individual crew members, because of the particular nature of fatigue.

Fatigue is affected by all waking activities, not only work demands. It is sometimes described as a “whole-of-life issue.” For example, crew members 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 (Chapter 4). They have a responsibility to use rest periods effectively prior to duty periods to enable them to start work fit for duty. In addition, their cooperation is vital for voluntary reporting of fatigue hazards, and when fatigue levels need to be measured for FRM processes (Chapter 4) and FRMS safety assurance processes (Chapter 5). Crew members’ willingness to cooperate will depend on their confidence that the operator is committed to the principles of an effective safety reporting culture<sup>1</sup> (Chapter 1).

However, management is also, and primarily, responsible for the management of fatigue risk because it schedules the work activities of personnel and the distribution of resources in the organization<sup>2</sup>. The FRMS is an organizational system that enables management to meet that responsibility.

As with SMS, the accountable executive when signing the FRMS policy accepts accountability for the FRMS, either directly or through supervision and management of others, including those to whom the accountable executive has delegated responsibility.

The safety objectives in the FRMS policy specify what the operator wants the FRMS to achieve. To track whether the FRMS is meeting these objectives, its performance needs to be monitored. Examples of safety performance indicators and targets that can be used to measure how well the FRMS is meeting the safety objectives can be found in Chapters 4 and 5.

The FRMS policy needs to be reviewed periodically by the operator to ensure that it is adequate to meet changing operational demands. In addition, it should be subject to periodic review by the regulator.

<sup>1</sup> ICAO’s *Safety Management Manual (SMM)*, (Doc 9859)

<sup>2</sup> ICAO’s *Safety Management Manual (SMM)*, (Doc 9859)

### 3.3 EXAMPLES OF FRMS POLICY STATEMENTS

The following examples are intended to be used as guidance, not templates. Each operator needs to develop an FRMS appropriate its specific organizational context and operational needs.

#### 3.3.1 FRMS policy statement for a major air carrier

##### **[Insert Company Name] Fatigue Risk Management Policy**

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

This FRMS applies to the operations as defined in the Flight Operations and Cabin Operations Manuals. All other operations will operate under the prescriptive flight and duty time 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 crewing levels to support rosters that minimize fatigue risk;
- providing flight and cabin crew 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 flight, cabin crew 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 flight and cabin crew regarding the effectiveness of the FRMS; and
- demonstrating continuous improvement and providing annual review of the FRMS.

Flight and cabin crew 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 crew member'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) \_\_\_\_\_

**Insert Title** (Accountable Executive)

Date: \_\_\_\_\_

### 3.3.2 FRMS policy statement for a smaller operator providing medical evacuation services

#### **[Insert Company Name] Fatigue Risk Management Policy**

The unique challenges we face in our international medical evacuation operations here at **[Insert Company]** include 24-hour on-call schedules, a need for immediate response in all weather conditions, and many flights landing at unprepared locations. These challenges require our flight crews to perform at the highest levels of competence and professionalism at all times. They also mean that we are exposed on a regular basis to elevated fatigue risks, which are best managed through a Fatigue Risk Management System (FRMS).

We need to manage these risks carefully in order to make consistently sound decisions, particularly to balance the critical needs of patients with the requirement for safe operations. This can only be achieved through the shared responsibility and commitment of management, crew members (pilots, doctors and nurses) and our support staff (e.g. crew schedulers) to ensure our fatigue risks remain acceptable.

**[Insert Company Name]** will ensure that management, crew and support staff, and all other relevant personnel are aware of:

- the potential consequences of fatigue within our company;
- the unique challenges and fatigue risks confronting our staff due to the nature of our operations;
- the importance of reporting fatigue-related hazards; and
- how to best manage fatigue.

To achieve this we have developed specific policies and procedures within our Safety Management System (SMS) for the management of fatigue risks. These are documented in the FRMS sections of our SMS Manual and apply to all operational staff.

Management is responsible for:

- appropriately resourcing the SMS;
- providing adequate crewing levels to support rosters that minimize fatigue risk;
- providing crew 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 crew and other support staff;
- demonstrating active involvement in and understanding of our fatigue risks;
- regularly consulting with crew regarding the effectiveness of fatigue management; and
- demonstrating continuous improvement and providing annual review of fatigue management.

Crew and support staff are required to:

- make appropriate use of their rest periods (between shifts or periods of duty) to sleep;
- participate in fatigue risk management education and training;
- report fatigue-related hazards and incidents;
- comply with the Fatigue Risk Management Policy and Practices as contained within our SMS;
- 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 crew member's capability to accomplish their duties.
- seek external support in accordance with our company policies and procedures to ensure, whenever possible, that third parties (e.g. Chief Pilot, Operations Manager) who are not part of your crew are used to support crew decision making. Whenever crew members have doubts about their fatigue risk they are requested to use the company's 24-hour hotline.

The effective management of fatigue is critical to ensuring that our company can deliver a quality service to our customers.

**Policy authorized by:**

(Signed) \_\_\_\_\_

**Insert Title** (Accountable Executive)

Date: \_\_\_\_\_

**3.4 APPENDIX 8, PARAGRAPH 1.2: FRMS DOCUMENTATION**

1.2 An operator 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, flight and cabin crew members, and all other involved personnel;
- e) FRMS training programmes, training requirements and attendance records;
- f) scheduled and actual flight times, duty periods and rest periods with significant deviations and reasons for deviations noted; and
- g) FRMS outputs including findings from collected data, recommendations, and actions taken.

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

As a way of meeting these requirements, it is expected that an operator create a functional group that is responsible for coordinating the fatigue management activities within the organization. Such a group is referred to here as the Fatigue Safety Action Group. The principle functions of the Fatigue Safety Action Group are to:

- develop and maintain the FRMS documentation;
- manage the FRM processes (Chapter 4);
- contribute to the FRMS safety assurance processes (Chapter 5); and
- be responsible for the FRMS promotion processes (Chapter 6).

However, in order to ensure that the focused management of fatigue risks does not result in unintended consequences in overall risk management, some of the functions of the Fatigue Safety Action Group as described here may in fact be undertaken by the SMS team or other functional groups. Regardless of who undertakes these functions, the regulator will need to observe and monitor all of the functions required under an FRMS.

The composition of the Fatigue Safety Action Group should reflect the shared responsibility of individuals and management by including representatives of all stakeholder groups (management, scheduling staff, and crew members and/or their representatives) and other individuals as needed to ensure that it has appropriate access to scientific and medical expertise. It should operate under Terms of Reference that are included in the FRMS documentation and which specify the lines of accountability between the Fatigue Safety Action Group and the operator's SMS.

The size and composition of the Fatigue Safety Action Group will vary for different operators, but should be related to the size and complexity of the operations covered by the FRMS, and to the level of fatigue risk in those operations. In small operators,

a single individual may represent more than one stakeholder group, for example, the chief pilot may also be the primary scheduler. In very small operators, there may not even be a designated Fatigue Safety Action Group, simply extra items on the safety meeting's agenda, as long as all fatigue risk management activities are documented. Larger airlines will have specialized departments that interact with the Fatigue Safety Action Group.

While the regulator may wish to observe Fatigue Safety Action Group meetings as part of its oversight activities, the regulator is not a required part of this group. The regulator may also wish to review the minutes and outputs of such meetings as part of its continuous oversight activities (see Chapter 9).

Appendix 8, paragraph 1.2 f), also requires that significant deviations in scheduled and actual flight times, duty periods and rest periods, and reasons for those significant deviations, be recorded by operators. As an initial step, the Fatigue Safety Action Group, or other appropriate entity within the organization, will need to identify through a risk assessment process, differences between scheduled and actual flight times, duty periods and rest periods that will be considered significant within the context of their specific operations.

For example, identified significant differences may include:

- for a particular city pair, any occasion where actual flight time exceeds planned flight time by 30 minutes;
- for a particular trip, any occasion where actual duty time exceeds planned duty time by 60 minutes;
- for a particular layover, any occasion where the rest period is reduced from the planned rest period by 60 minutes.

As a result, the significant deviations should be used as indicators to help identify potential fatigue hazards (discussed in Chapter 4) and may also be used to monitor the performance of the FRMS itself (Chapter 5). Further, the Fatigue Safety Action Group will also be responsible for establishing a process for monitoring such significant deviations and documenting any subsequent actions taken.

Such definitions will need to be provided to the regulator for its acceptance, and it will be important that there is a clear understanding between the regulator and the operator as to what constitutes a significant deviation. The regulator may also use these to identify criteria for reporting requirements.

### **3.4.1 Example of terms of reference for a fatigue safety action group**

This example is designed to cover the needs of a large operator. This is not a template. Not all the items suggested here will be needed by every operator. The regulator needs to be confident that the operator has considered its operational and organizational profile in deciding the composition of the Fatigue Safety Action Group, its activities, and its interactions with other parts of the operator's organization.



**[Insert Company Name] 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 [insert Company name]. This includes responsibility for gathering, analysing, and reporting on data that facilitates the assessment of fatigue-related risk among flight crew members. The FSAG is also responsible for ensuring that the FRMS meets the safety objectives defined in the FRMS Policy, that it meets regulatory requirements, and that the FRMS informs the SMS to facilitate the management of safety risks in general. The FSAG exists to improve safety and does not get involved in industrial issues.

**Terms of Reference**

The FSAG is directly responsible to the Senior VP Flight 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 crew members, 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;
- develop, implement and monitor controls and 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 crew member 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 crew members 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;
- keep 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 monthly. Minutes will be taken during meetings and distributed within ten 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.

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# Chapter 4. Fatigue risk management (FRM) processes

## 4.1 INTRODUCTION TO FRM PROCESSES

This Chapter works through the basic steps for setting up FRM safety risk management processes, which are very similar to SMS safety risk management processes.<sup>1</sup> The main difference is that SMS processes are designed to address all types of risks. FRM processes within an FRMS are specifically designed to manage the risks related to crew member fatigue.

FRM processes (represented in the blue box in Figure 4-1) are one part of the day-to-day operations of the FRMS. They are designed to enable the operator to achieve the safety objectives defined in its FRMS Policy and are managed by the Fatigue Safety Action Group.

FRM processes:

- Identify where fatigue is a hazard;
- Assess the level of risk that a given fatigue hazard represents; and
- If necessary, put in place controls and mitigation strategies, and monitor to make sure that they manage the risk at an acceptable level.

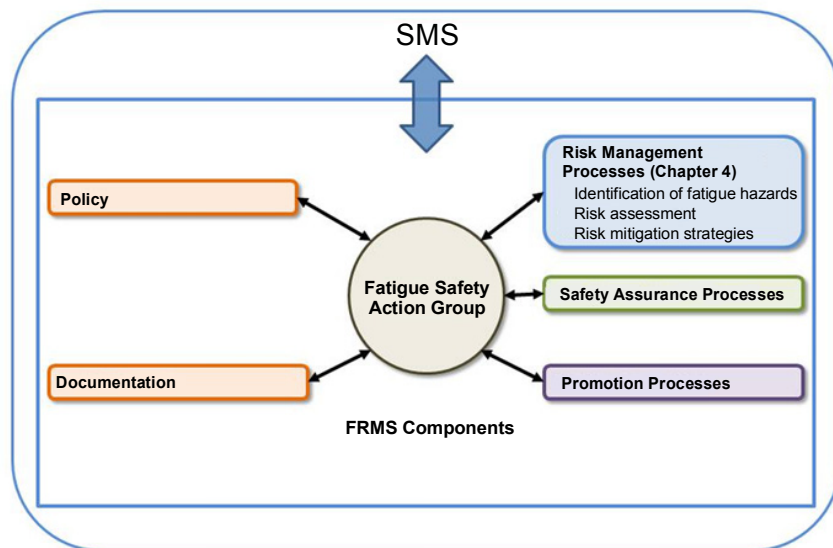


Figure 4-1 Linkages between FRM processes and other FRMS components

To do this, FRM processes require different sorts of data, including: a) measures of the fatigue levels of crew members; and b) measures of operational performance. Examples of these types of measures are described later in this chapter. The key is choosing the right combination of measures for each operation that is covered by the FRMS. However, just collecting data is not enough. Data analysis needs to be used to inform decisions made by the Fatigue Safety Action Group and others

<sup>1</sup> See ICAO's *Safety Management Manual (SMM)* (Doc 9859).

accountable for the FRM processes and for FRMS safety performance (Chapter 5). The ICAO requirements for FRM processes are contained in Appendix 8 to Annex 6, Part I and are as follows:

### Appendix 8 to Annex 6, Part I

## 2. Fatigue risk management processes

### 2.1 Identification of hazards

An operator 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 crew 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) operator or industry operational experience and data collected on similar types of operations;
- b) evidence-based scheduling practices; and
- c) biomathematical models.

2.1.2 *Proactive*. The proactive process shall identify fatigue hazards within current flight operations. Methods of examination may include but are not limited to:

- a) self-reporting of fatigue risks;
- b) crew fatigue surveys;
- c) relevant flight and cabin crew performance data;
- d) available safety databases and scientific studies; and
- e) analysis of planned versus actual time worked.

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;
- d) incidents; and
- e) flight data analysis events.

### 2.2 Risk assessment

2.2.1 An operator shall develop and implement risk assessment procedures that determine the probability and potential severity of fatigue-related events and identify when the associated risks require mitigation.

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

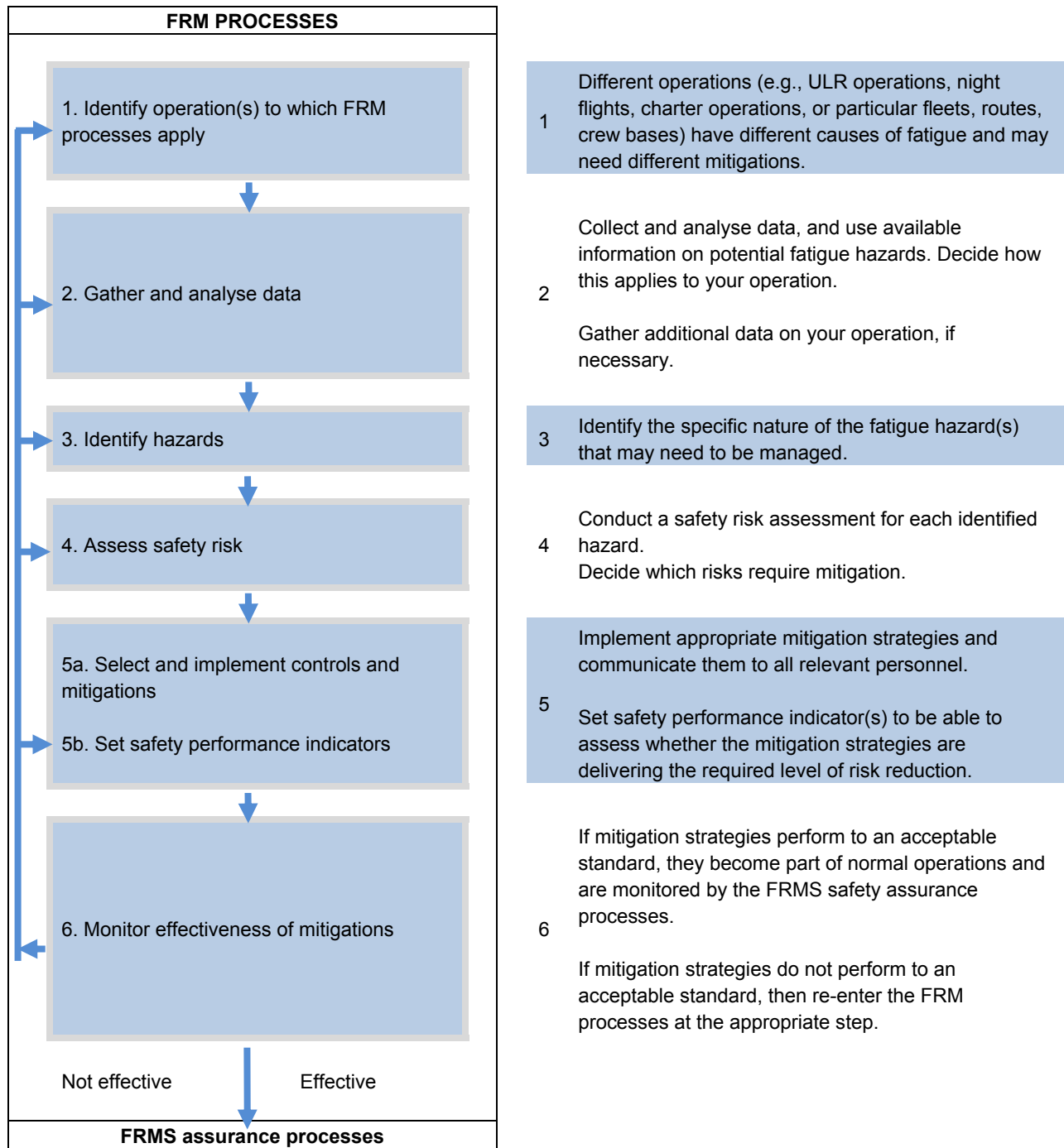
- a) operational processes;
- b) their probability;
- c) possible consequences; and
- d) the effectiveness of existing safety barriers and controls.

### 2.3 Risk mitigation

An operator shall develop and implement risk mitigation procedures that:

- a) select the appropriate mitigation strategies;
- b) implement the mitigation strategies; and
- c) monitor the strategies' implementation and effectiveness.

Figure 4-2 summarizes the steps in FRM processes. Each step is described in more detail below.



1 Different operations (e.g., ULR operations, night flights, charter operations, or particular fleets, routes, crew bases) have different causes of fatigue and may need different mitigations.

2 Collect and analyse data, and use available information on potential fatigue hazards. Decide how this applies to your operation.  
Gather additional data on your operation, if necessary.

3 Identify the specific nature of the fatigue hazard(s) that may need to be managed.

4 Conduct a safety risk assessment for each identified hazard.  
Decide which risks require mitigation.

5 Implement appropriate mitigation strategies and communicate them to all relevant personnel.  
Set safety performance indicator(s) to be able to assess whether the mitigation strategies are delivering the required level of risk reduction.

6 If mitigation strategies perform to an acceptable standard, they become part of normal operations and are monitored by the FRMS safety assurance processes.

If mitigation strategies do not perform to an acceptable standard, then re-enter the FRM processes at the appropriate step.

Figure 4-2 FRM Processes

## 4.2 FRM PROCESSES STEP 1: IDENTIFY THE OPERATIONS COVERED

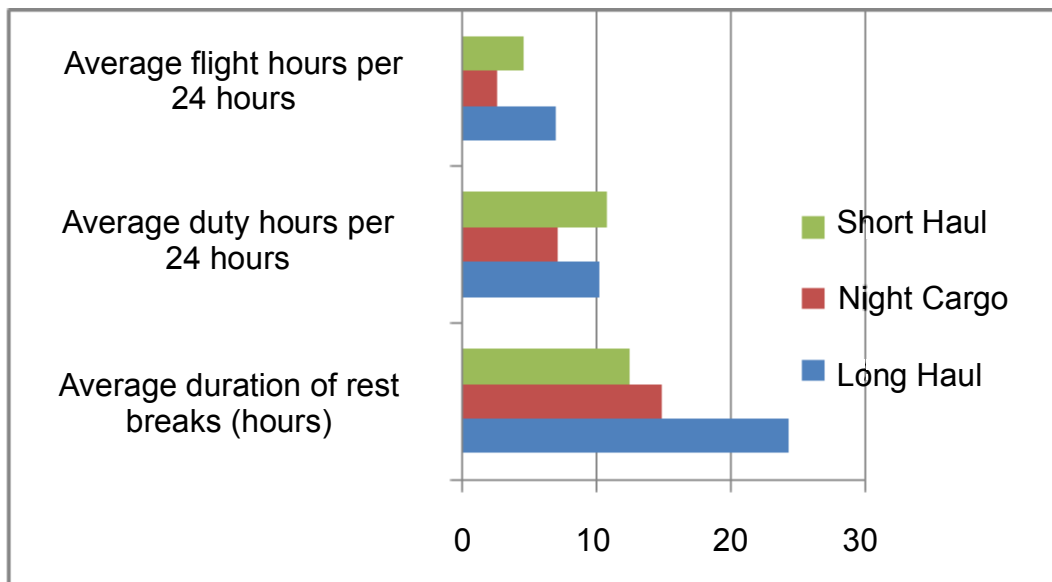
To meet ICAO FRMS Standards, States should allow an operator to choose whether it will use the FRMS to manage fatigue risk in all its operations or in specific types of operations only (only a particular fleet, only ULR operations, etc.). It is important that the operator clearly identifies to which operations the FRMS pertains.

Further, as described in Chapter 2, different types of flight operations can involve different causes of crew member fatigue and may require different controls and strategies to mitigate the associated risks. Within its FRMS, an organization may need to develop multiple sets of different FRM processes for different operations. These should be clearly identifiable. On the other hand, in some cases it will be possible to include multiple types of operations under one set of FRM processes.

## 4.3 FRM PROCESSES STEP 2: GATHER DATA AND INFORMATION

In Step 2, the Fatigue Safety Action Group gathers required data and information to be confident that they can identify the likely fatigue hazards in operations that are covered by the FRM processes. To do this, the group needs to have a good understanding of the operational factors that are likely to cause crew member fatigue.

To illustrate some of the considerations in different operations, Figure 4-3 compares flight and duty times in daytime short-haul, domestic night cargo, and long-haul operations studied by the NASA Fatigue Program.<sup>2</sup>



**Figure 4-3 Average flight, duty, and rest periods in a sample of daytime short-haul, domestic night cargo, and long-haul operations**

<sup>2</sup> Gander P.H., Rosekind M.R., Gregory K.B., "Flight crew fatigue IV: a synthesis," *Aviation, Space, and Environmental Medicine*, 1998, Vol. 69(9), pp. B49-B60.

The daytime short-haul operations (two-person crews) had the longest daily duty hours, averaged five flights per day, and had the shortest rest periods. However, they crossed a maximum of one time zone per 24 hours, and the rest breaks occurred at night during the optimal part of crew members' circadian body clock cycle for sleep. The main causes of fatigue identified in this scientific study were:

- restricted sleep caused by short rest periods and early duty report times; and
- high workload, flying multiple sectors in high-density airspace across long duty days.

The domestic night cargo operations (two pilots, one flight engineer) had the shortest duty periods, averaged three flights per duty period, and had longer rest periods than the short-haul operations. They also crossed a maximum of one time zone per 24 hours. However, the night cargo crew members' rest periods occurred during the day, and their circadian body clocks (tracked by their core body temperature rhythms) did not adapt to this pattern. The main causes of fatigue identified in this scientific study were:

- shorter, less restorative sleep during the day; and
- being required to work at night, at the time in the circadian body clock cycle when self-rated fatigue and mood were worst, and when additional effort would be required to maintain alertness and performance.

The long-haul operations (two pilots, one flight engineer) had long duty periods, but averaged only one flight per duty period and had the longest rest periods. However, every layover was in a different time zone, with a maximum of eight time zones crossed per 24 hours. The crew members' circadian body clocks (tracked by their core body temperature rhythms) did not adapt to the time zone changes nor to the non-24-hour duty/rest pattern (averaging ten hours of duty and 25 hours of rest). The main causes of fatigue identified in this scientific study were:

- long periods of wakefulness (average 20.6 hrs) associated with duty days (there were no on-board crew rest facilities);
- on some flights, having to operate the aircraft at the time in the circadian body clock cycle when self-rated fatigue and mood were worst, and additional effort was required to maintain alertness and performance;
- split sleep patterns and short sleep episodes on layovers (usually some sleep at local night and some at body clock night); and
- on some trip patterns, the circadian body clock drifted away from crew members' domicile time zone. As a result, additional time for circadian readaptation was needed for full recovery after the trip.

These examples illustrate a fundamental principle in FRMS — that flight and duty time limitations do not capture all the causes of fatigue, which are different in different types of operations.

Table 4-1 summarizes the different duty-related causes of fatigue identified in these studies, all of which pre-dated ULR flights and involved scheduled operations. The very long duty days in ULR operations might be expected to cause fatigue, but the use of augmented crews and the availability of on-board crew rest facilities for in-flight sleep are important mitigation strategies. Unscheduled operations pose particular challenges, because it is hard to plan sleep when you do not know when you have to work, or for how long.

Other potential causes of work-related fatigue include:

- additional tasks that are performed immediately prior to a flight or at intermediate points during a series of flights;
- high total duty time and flight time over specified periods (per month, per year), which increases the risk of cumulative fatigue;

- not having the opportunity for adequate recovery sleep after one trip (or set of consecutive duties) before starting the next trip; and
- other related tasks that crew members may be required to perform before or after flight duty, for example, training activities, administrative duties, or baggage loading and unloading.

**Table 4-1 Summary of identified work-related fatigue causes (from NASA field studies 18)**

Cause of fatigue hazard	Type of operations		
	Domestic short-haul	Domestic night cargo	Long-haul
Restricted sleep due to short rest periods	X		
Restricted sleep due to early duty report times	X		
Multiple high workload periods across the duty day	X		
Multiple sectors	X	X	
High-density airspace	X		
Long duty days	X		X
Extended wakefulness on duty days			X
High workload during circadian low		X	X
Shorter sleep periods at wrong times in the circadian cycle		X	X
Circadian disruption (due to night work)		X	X
Split sleep patterns and short sleep episodes on layovers		X	X
Circadian disruption (due to crossing multiple time zones)			X
Circadian drift (changes in circadian pattern) following extended patterns			X

*Note.— These are the causes of fatigue identified in these particular studies, not an exhaustive list.*

When FRM processes are being set up, it is not always necessary for the operator to gather new data for Step 2. It may be possible to identify potential fatigue hazards based on information and operational experience from similar types of operations flown by the operator or other carriers, or from published scientific studies of fatigue in similar operations. This is illustrated at the end of the chapter in the example on how to set up FRM processes for a new ULR route.

For existing routes being moved into the FRMS, data that is already routinely collected by the operator can be analysed to help identify fatigue hazards, for example, the use of captain's discretion, on-time performance, violations of prescriptive flight and duty time rules, level of sickness absences, and standby usage, or Aviation Safety Reports (ASRs) that mention fatigue. It should be noted that it is a requirement of the FRMS SARPs (Appendix 8 to Annex 6, Part I, 1.2 g) that the operator collect data on significant deviations to scheduled and actual flight times and duty periods, along with the reasons for these significant deviations (previously discussed in Chapter 3).

Once the FRM processes become fully operational, data collection and analysis are part of the operator's day-to-day function, so a range of data will be available routinely for Step 2. In addition, the Fatigue Safety Action Group may sometimes decide to undertake non-routine data collection to better understand specific fatigue hazards (for example, a one-off fatigue survey at a crew base, or a targeted monitoring study on a route where fatigue is identified as a concern). The different types of information and data that can be collected are described in the following sections and in Appendix A.



#### 4.4 FRM PROCESSES STEP 3: HAZARD IDENTIFICATION

Appendix 8 to ICAO Annex 6, Part I, requires that an operator develop, maintain and document three types of processes for fatigue hazard identification:

1. predictive processes;
2. proactive processes; and
3. reactive processes.

All of these processes gather various kinds of information and data to continuously monitor the levels of fatigue risk in the operation(s) covered by the FRMS. These processes enable the Fatigue Safety Action Group to make data-driven decisions “based upon scientifically valid principles and measurements” as stated in the ICAO definition of FRMS.

As already mentioned, various types of data are involved including measures of operational performance, which operators are familiar with, and measures of the fatigue levels of crew members, which will be less familiar to most operators. The following sections and Appendix A provide guidance about measuring crew member fatigue. Interpreting crew fatigue data also requires expertise. On some occasions, it may be appropriate for the Fatigue Safety Action Group to seek external scientific advice in this area. However, it is also possible for an operator to develop in-house expertise in fatigue data collection and analysis. This usually involves a “fatigue champion” who is interested and motivated to develop skills as required. The complexity of operations and the level of fatigue risk need to be considered when evaluating the need for, and level of, expert advice.

##### 4.4.1 Predictive hazard identification processes

In an FRMS, predictive hazard identification focuses on establishing crew schedules and conditions that consider factors known to affect sleep and fatigue in order to minimize their potential future effects. Appendix 8 to ICAO Annex 6, Part I, lists three possible ways of doing this: a) previous experience (of the operator or others in the industry); b) evidence-based scheduling practices; and c) biomathematical models.

###### ***a) Previous experience***

The collective experience of managers, schedulers and crew members is an important source of information for identifying aspects of a proposed schedule that may be associated with increased fatigue. For example, crew members may recognize a particular destination within a proposed schedule as generating a high level of fatigue because of their past experience of regular delays there caused by heavy traffic. Schedulers may know that a particular city pairing regularly exceeds planned flying time. Where noise is a known problem, management may organize for crew to stay in another hotel.

Various information sources should be used. For existing operations, information about schedules may already be available that could be analysed to check for potential fatigue hazards. Examples include the use of captain’s discretion, on-time performance, violations of prescriptive flight and duty time rules, standby usage, Aviation Safety Reports (ASRs), and level of fatigue reports.

When operational demands are changing, relying on previous experience can be limiting. Scheduling based on previous experience only may not give the most robust or innovative solutions for new situations. It may also be important to collect data on actual levels of crew 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 routes, is to look for information on similar routes. This could include incident reports and crew fatigue reports, or published scientific research and other information available on similar routes flown by other operators. The degree 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 (see the ULR example at the end of this chapter).

### **b) Evidence-based scheduling practices**

The value of experience can be enhanced when fatigue science is also applied in the building of schedules. This means considering factors such as the dynamics of sleep loss and recovery, the circadian biological clock, and the impact of workload on fatigue, along with operational requirements. Since the effects of sleep loss and fatigue are cumulative, evidence-based scheduling needs to address both individual trips (multiple, successive duty periods without extended time off), and successive trips across rosters or monthly bid-lines. The following are examples of 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. It does adapt progressively to a new time zone, but full adaptation usually takes longer than the 24 to 48 hours of most layovers.
- Whenever a duty period overlaps a crew member'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 a crew member's usual sleep time, the less sleep the crew member 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, crew members will accumulate a sleep debt and fatigue-related impairment will increase.
- To recover from sleep debt, crew members need a minimum of two full nights of sleep in a row, when they are fully adapted to the local time zone. The frequency of rest periods should be related to the rate of accumulation of sleep debt.

These sorts of principles can be used by an expert reviewer, for example, by a scheduler trained in fatigue hazard identification, or by the Fatigue Safety Action Group, to develop evidence-based scheduling rules. The scientific basis for the scheduling rules should be recorded in the FRMS documentation. This approach can be validated by monitoring the reported or estimated levels of fatigue across the schedules using the tools described below and in Appendix A. Validation data can be used, in turn, to refine and improve evidence-based scheduling rules for an operation.

### **c) Biomathematical models**

Biomathematical 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 modeling 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 modeling is a continuous improvement process. Biomathematical models are accepted as being incomplete and transient scientific tools. 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 biomathematical 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 crew members;
- do not take into account the impact of workload or personal and work-related stressors that may affect fatigue levels;
- cannot take into account the effects of personal or operational mitigation strategies that may or may not be used by crew members (caffeine consumption, exercise, improved rest facilities, etc.);
- do not predict the safety risk that fatigued crew members represent in a particular operation, i.e., they are not a substitute for risk assessment (Step 4 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 flight operations has not yet been validated.

The most reliable use of currently available models is probably 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 biomathematical models, if model designers follow a continuous improvement philosophy.

Note that Appendix 8 to Annex 6, Part I, states that methods for predictive fatigue hazard identification **may include but are not limited to:** operator or industry operational experience and data collected on similar types of operations, evidence-based scheduling practices, and biomathematical models. In other words, none of these methods is required, and other methods may be used.

#### 4.4.2 Proactive hazard identification processes

In an FRMS, proactive hazard identification processes focus on monitoring fatigue levels in an operation. Because fatigue-related impairment affects many skills and has multiple causes, there is no single measurement that gives a total picture of a crew member's current fatigue level, and multiple sources of data are required.

To decide on which types of data to collect, the most important thing to consider is the expected level of fatigue risk. In other words, it is not a good use of limited resources to undertake intensive data collection with multiple measures on a route where the fatigue-related risk is expected to be minimal. Resources should be targeted towards operations where the risk is expected to be higher.

##### ***The importance of collaboration***

Appendix 8 to Annex 6, Part I, requires that an operator's FRMS Policy "reflect the shared responsibility of management, flight and cabin crews, and other involved personnel." Regulators will need to find evidence of this sharing of responsibility.

The success of proactive processes (and of the FRMS) depends on the willingness of crew members to continue participating in data collection. This makes it important to consider the demands placed on crew members by different types of fatigue-related data collection (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 before during and after a trip, doing multiple performance tests and fatigue ratings across flights).

The willingness of crew members 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. Gathering fatigue-related data may involve monitoring crew members 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 crew members, confidentiality of data, and whether crew members 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.

Appendix 8 lists five possible methods of proactive fatigue hazard identification:

- a) self-reporting of fatigue risks;
- b) crew fatigue surveys;
- c) relevant flight crew performance data;
- d) available safety databases and scientific studies; and
- e) analysis of planned versus actual time worked.

The following sections describe each of these methods in some detail. It should be noted that these are options. **They are not all required all of the time.**

#### *a) Self-reporting of fatigue risks*

Crew members' reports about high fatigue levels or fatigue-related performance issues are vital to keep the Fatigue Safety Action Group informed about fatigue hazards in day-to-day operations. A series of fatigue reports on a particular route can be a trigger for further investigation by the Fatigue Safety Action Group.

An effective fatigue reporting system requires an effective reporting culture<sup>3</sup>. It needs to:

- use forms that are easy to access, complete, and submit;
- have clearly understood rules about confidentiality of reported information;
- have clearly understandable voluntary reporting protection limits;
- include regular analysis of the reports; and
- provide regular feedback to crew members about decisions or actions taken based on the reports and lessons learned.

A fatigue report form (either paper-based or electronic) should include information on recent sleep and duty history (the minimum should be the last three 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 his view of why it happened. An example of a fatigue report form can be found in Appendix A.

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<sup>3</sup> See ICAO's *Safety Management Manual (SMM)* (Doc 9859).

### b) Crew fatigue surveys

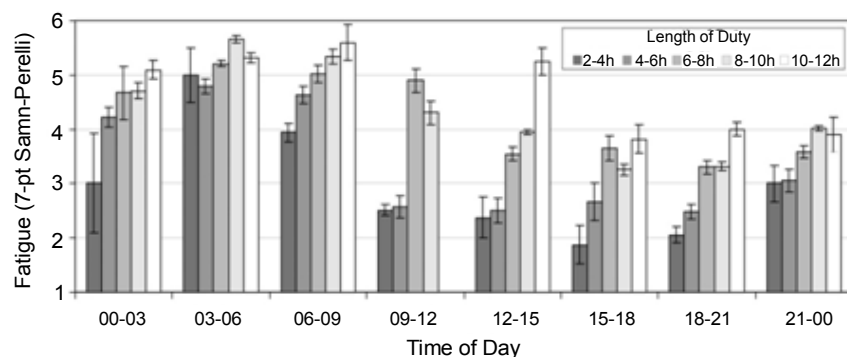
Crew fatigue surveys are of two basic types:

1. Retrospective surveys that ask crew members about their sleep and fatigue in the past. 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 crew members about their sleep and fatigue right now. These are typically short and are often completed multiple times to monitor fatigue across a duty period, trip or roster. They usually include measures such as sleepiness, fatigue and mood ratings.

Appendix A 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 Fatigue Safety Action Group to compare fatigue levels between operations (run by their own operator 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.

Crew fatigue surveys can be focused on a particular operation or issue. For example, a series of fatigue reports about a particular trip might trigger the Fatigue Safety Action Group to undertake a survey of all crew members flying that trip (retrospective or prospective) to see how widespread the problem is. The Fatigue Safety Action Group might also undertake a survey (retrospective or prospective) to get crew member feedback about the effects of a schedule change.

Surveys can also be more general, for example, providing an overview of fatigue across a particular aircraft fleet or operation type. Figure 4-4 shows an analysis of the effects of time of day and duty length on fatigue ratings at top of descent (using the Samn-Perelli fatigue scale — see Appendix A). These data come from the Air New Zealand FRMS and include 3 181 ratings made across a three-month period, at the end of one-to-two sector short-haul duty days that stayed in the crew members' domicile time zone (two-person crews)<sup>4</sup>. For short duty periods (two to four hours) there is a clear time-of-day variation in how fatigued crew members feel at the top of descent, with highest average ratings between 03:00 and 06:00, and lowest average ratings between 15:00 and 18:00. In contrast, at the end of long duty periods (10 to 12 hours), fatigue ratings remain high from 00:00 to 09:00, and there is a second peak in fatigue between 12:00 and 15:00. These ratings show an interaction between time-on-task fatigue (duty duration) and the daily cycle of the circadian body clock. In addition, crew members who are at the end of a 10 to 12 hour duty period between 12:00 and 15:00 will have had their sleep restricted by an early duty report time.



**Figure 4-4 Effects of time of day and duty length on fatigue ratings at top of descent in short-haul operations across a three-month period**

4 Powell D., Spencer M.B., Holland D., Petrie K.J., "Fatigue in two-pilot operations: implications for flight and duty time limitations," *Aviation, Space, and Environmental Medicine*, 2008, Vol. 79, pp. 1 047-50.

Compared to some other types of fatigue monitoring, crew fatigue surveys can be conducted relatively quickly and inexpensively to provide a “snapshot” of subjective fatigue levels and their potential causes. If a high proportion of crew members participate in a survey (ideally more than 70 per cent), it offers a more representative picture of the range of subjective fatigue levels and opinions across the whole group. Since the information gathered in surveys is subjective (crew members’ personal recall and views), getting a representative picture can be important for guiding the decisions and actions of the Fatigue Safety Action Group.

### c) Crew 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 crew member performance: 1) simple tests developed in the laboratory, which measure aspects of an individual’s performance (for example, reaction time, vigilance, short-term memory); 2) flight data analysis (FDA), which examines the relationship between identified elements of aircraft performance and pilot performance; and 3) having trained flight deck observers rate the performance of crew members on the flight deck (for example, Line-Oriented Safety Audit).

For monitoring crew member fatigue levels *during an operation*, the first approach is currently the most practical. A range of objective performance tests are used in scientific research. Things to consider when choosing a performance test for measuring crew member fatigue include the following.

1. How long does the test last? Can it be completed at multiple time points (for example, in the operations room during pre-flight preparations, near top of climb, near top of descent, and post-flight before disembarking from the aircraft), without compromising a crew member’s ability to meet duty requirements?
2. 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?
3. Is the test predictive of more complex tasks, e.g., crew performance in a flight simulator? (Unfortunately, there is very little research addressing this question at present.)
4. Has it been used in other aviation operations, and are the data available to compare fatigue levels between operations?

Appendix A describes a performance test that is commonly used to measure crew member fatigue – the Psychomotor Vigilance Task or PVT<sup>5</sup>.

There is considerable interest in finding ways to link crew member fatigue levels to FDA data, particularly during approach and landing. FDA data has the advantages that it is routinely collected and is relevant to flight safety. The difficulty is that a multitude of factors contribute to deviations from planned flight parameters. To use FDA data as an indicator of crew member fatigue would require demonstrating consistent changes in FDA data that are reliably linked to other indicators of crew member fatigue (for example, sleep loss in the last 24 hours, time in the circadian body clock cycle). Research in this area is ongoing.

Using trained flight deck observers to rate the performance of crew members on the flight deck is very labour-intensive and expensive. Having the observer present may also have an alerting effect and place additional demands on crew members. These factors currently limit the usefulness of this approach for proactive fatigue hazard identification in an FRMS.

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<sup>5</sup> Balkin T.J., Bliese P.D., Belenky G., et al, “Comparative utility of instruments for monitoring sleepiness-related performance decrements in the operational environment,” *Journal of Sleep Research*, 2004, Vol. 13, pp. 219-27.

*d) Available safety databases and scientific studies*

More general guidance about fatigue hazards may be available from external safety databases, such as Aviation Safety Reports (ASRs) and Mandatory Occurrence Reports (MORs) maintained by safety authorities, or databases maintained by airline organizations or research institutions. Because safety events are relatively rare, databases that collect and analyse them are an important additional source of information that complements direct assessment of fatigue levels in the operation(s) covered by the FRMS.

A fairly large amount of scientific research has been undertaken on crew member fatigue in flight operations. Some of this is available on the web, for example, many studies from the NASA Fatigue Countermeasures Program can be downloaded free from

<http://human-factors.arc.nasa.gov/zteam/fcp/FCP.pubs.html>

This type of research tends to be costly and labour-intensive and not all types of aviation operations have been studied in depth. 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.

*e) Analysis of planned versus actual time worked*

The planning of schedules and rosters based on fatigue science as well as operational requirements permits predictive identification of fatigue hazards (Section 4.4.1 above). However, numerous unforeseen circumstances can cause changes to planned schedules, for example, weather conditions, volcanic ash, unexpected technical problems, or crew member illness. Crew member fatigue relates to what is actually flown, not what is planned. Thus another proactive approach for identifying fatigue hazards is to analyse actual schedules and rosters for factors such as on-time performance, exceedances of the flight and duty time limits specified in the FRMS, and schedule manipulation by individual crew members.

*Monitoring crew members' sleep*

Given the primary importance of sleep loss and recovery in the dynamics of crew member 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 A).

- The simplest and cheapest method of monitoring sleep is to have crew members complete a daily sleep diary before, during, and after the trip(s) 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 an electronic device such as a Personal Data Assistant (PDA).
- 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 crew members on a given trip would have their sleep monitored in this way. Current systems also require a trained person to process and analyse the data.
- In rare cases, where the expected fatigue risk is high or uncertain (for example, in new types of operations), portable polysomnographic recordings may be used to monitor sleep both in-flight and during layovers. This involves applying electrodes to the scalp and face to record electrical signals coming from the brain (electroencephalogram or EEG), eye movements (electro-oculogram or EOG) and chin muscles (electromyogram or EMG). Polysomnography is the "gold standard" method for evaluating sleep quality and quantity, but it is relatively invasive for participants and expensive both in terms of equipment and because it requires manual scoring and analysis by a trained technician.

### Selecting measures of crew member fatigue

Several options have just been described for assessing crew member fatigue levels in order to identify fatigue hazards. Appendix 8 is clear that the five methods it lists can be used — it does not say that they must be used or that other methods cannot be used. The following general points are intended to help regulators in determining whether operators are using appropriate measures for the appropriate purpose.

1. Fatigue-related impairment affects many skills and has multiple causes, so there is no single measurement that gives a total picture of a crew member's current fatigue level.
2. 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 Fatigue Safety Action Group prioritize where controls and mitigations are most needed.
3. A core set of measures can be selected for routine monitoring. For example, crew fatigue reports and regular analyses of scheduling and rostering variations could be used for ongoing monitoring of fatigue hazards.
4. An additional range of measures can be available to be used if a potential hazard is identified and the Fatigue Safety Action Group decides that it needs more information about that hazard. Again, the measures selected need to reflect the expected level of risk. For example:
  - A series of complaints about a particular layover hotel prompts a brief on-line survey of crew members who use that hotel, to see how widespread the problem is and whether it merits action.
  - A series of fatigue reports is received about a tag flight on the end of a particular trip. This prompts monitoring of the sleep, sleepiness, and fatigue ratings of crew members flying that trip, using sleep diaries and subjective rating scales. Data collection continues for a month, followed by data analysis, so that within three months the Flight Safety Action Group will have the information it needs to reach a decision and plan any necessary controls and interventions (for example, having another crew take the tag flight).
  - An operator with limited long-haul experience gets the regulators' agreement to begin developing an FRMS in order to undertake ULR operations on a specified city pair. As part of gaining regulatory approval for the overall FRMS, the operator is required to undertake intensive monitoring of crew member fatigue during the first four months of the operation. This includes monitoring sleep before, during, and after the trip using actigraphs and sleep diaries, as well as ratings of sleepiness and fatigue and PVT performance tests pre-flight, within 30 minutes of top of climb, before each in-flight rest period, within 30 minutes of top of descent, and post-flight before leaving the aircraft. The regulator requires a report on the findings no later than six months after the launch of the operation.
5. Balance needs to be maintained between gathering enough data for the Fatigue Safety Action Group to be confident about its decisions and actions and the additional demands that data collection can place on crew members.

#### 4.4.3 Reactive hazard identification processes

In an FRMS, reactive processes are designed to identify the **contribution of crew member fatigue to safety reports and events**. The aim is to identify how the effects of fatigue could have been mitigated and to reduce the likelihood of similar occurrences in the future. Appendix 8 to Annex 6, Part I, lists five examples of triggers for reactive processes:

- a) fatigue reports;
- b) confidential reports;
- c) audit reports;



- d) incidents; and
- e) Flight Data Analysis (FDA) events (also known as Flight Operations Quality Assurance or FOQA).

Depending on the severity of the event, a fatigue analysis could be undertaken by the Fatigue Safety Action Group, the operator's safety department, or an external fatigue expert. 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:

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

To show that the person or crew were likely to be in a fatigued state, ideally you would have information about:

- how much sleep they need to feel fully rested;
- how much sleep they had in the 24 hours before the accident (acute sleep loss);
- how much sleep they had in the 72 hours before the accident (cumulative sleep debt);
- how long they had been awake at the time of the event (extended wakefulness);
- whether their workload was unusually heavy or light leading up to and during the event;
- whether they were in a sleepy part of the circadian body clock cycle at the time of the event (early morning or mid-afternoon, body time); and
- when they last had the opportunity for full recovery from sleep debt (at least two nights of unrestricted sleep in a row, fully adapted to the local time zone).

This information generally has to be gathered after the event, based on the recall of the people involved and should be confirmed where possible by anyone with whom they spent time leading up to the event. Where it is not possible to get this information, the duty history can give an idea of what opportunities the person or crew had for sleep.

There are no simple rules for interpreting this information (how much acute sleep loss do you need to be fatigue-impaired? how much cumulative sleep debt?). Transport Canada has proposed a method for fatigue investigation that provides useful guidance for answering these questions, and for deciding if the crew member's actions or decisions are consistent with the type of behaviour expected of a fatigued person or crew, although it has not yet been validated in aviation operations. This method is summarized in Appendix A.

#### 4.5 FRM PROCESSES STEP 4: 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. Fatigue risk assessment follows SMS principles (combining risk probability and risk severity). It evaluates the potential for injury, equipment damage, or loss due to a fatigue hazard, and provides recommendations about management of that risk, as summarized in the following tables.<sup>6</sup>

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<sup>6</sup> ICAO's *Safety Management Manual (SMM)* (Doc 9859).

**Table 4-2a Defining fatigue risk probability**

Fatigue risk probability		
	Meaning	Value
Frequent	Likely to occur many times (has occurred frequently)	5
Occasional	Likely to occur sometimes (has occurred infrequently)	4
Remote	Unlikely to occur, but possible (has occurred rarely)	3
Improbable	Very unlikely to occur (not known to have occurred)	2
Extremely improbable	Almost inconceivable that the event will occur	1

**Table 4-2b Defining fatigue risk severity**

Fatigue risk severity		
	Meaning	Value
Catastrophic	<ul style="list-style-type: none"> <li>– Multiple deaths</li> <li>– Equipment destroyed</li> </ul>	A
Hazardous	<ul style="list-style-type: none"> <li>– A large reduction in safety margins, physical distress or a workload such that crew members cannot be relied upon to perform their tasks accurately or completely</li> <li>– Serious injury</li> <li>– Major equipment damage</li> </ul>	B
Major	<ul style="list-style-type: none"> <li>– A significant reduction in safety margins, a reduction in the ability of crew members to cope with adverse operating conditions as a result of increase in workload or as a result of conditions impairing their efficiency</li> <li>– Serious incident</li> <li>– Injury to persons</li> </ul>	C
Minor	<ul style="list-style-type: none"> <li>– Nuisance</li> <li>– Operating limitations</li> <li>– Use of emergency procedures</li> <li>– Minor incident</li> </ul>	D
Negligible	<ul style="list-style-type: none"> <li>– No significant consequences</li> </ul>	E

Table 4-2c Fatigue risk assessment matrix

Risk probability		Fatigue risk				
		Risk severity				
		Catastrophic A	Hazardous B	Major C	Minor D	Negligible E
Frequent	5	5A	5B	5C	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

Table 4-2d ICAO risk tolerability matrix

Suggested criteria	Assessment risk index	Suggested criteria
<b>Intolerable region</b>	5A, 5B, 5C 4A, 4B, 3A	Unacceptable under the existing circumstances
<b>Tolerable region</b>	5D, 5E, 4C, 4D 4E, 3B, 3C, 3D 2A, 2B, 2C	Acceptable based on risk mitigation. May require management decision
<b>Acceptable region</b>	3E, 2D, 2E, 1A 1B, 1C, 1D, 1E	Acceptable

However, it should be noted that these tables are provided as general examples only. In reality, each operator must develop its own criteria for levels of severity and probability. There are no right and wrong criteria, but whatever criteria are identified, they must be agreed upon and widely understood by the people who will then use them to make risk assessments. Depending on an operator's safety management structure, the Fatigue Safety Action Group may identify the severity and probability criteria, and then use these to assess the fatigue-related risks and the need for mitigation in an FRMS.

#### 4.6 FRM PROCESSES STEP 5: RISK MITIGATION

When it is decided that a particular fatigue hazard requires action, then controls and mitigations must be identified and implemented. The specific expertise of the Fatigue Safety Action Group should be used in the selection of these controls and mitigations. All involved personnel should clearly understand the hazard and the controls and mitigations designed to reduce the associated risk.

Table 4-3 provides some examples of organizational-level mitigations for managing fatigue hazards. These are examples only, not exhaustive lists.

**Table 4-3 Examples of fatigue hazards and operator controls and mitigations (not an exhaustive list)**

Fatigue hazard	Controls	Mitigations
Back-to-back night flights	Scheduling rules do not permit back to-back night flights.	Software is programmed to prohibit scheduling of back-to-back night flights. Reserve crew available to cover exceptional circumstances.
Lack of ULR crew in departure city base	All flights scheduled >12 hours require evaluation of staffing levels at crew base in departure city. Established crew staffing policies to support operation and monitor staffing levels to ensure that policy requirements are being met.	Relocate additional crew members to departure city base. Ensure that sufficient reserve crews are available to support ULR flight schedules.
Lack of ULR crew in en-route divert base	Establish reserve crew staffing at en-route base to support diversions	Reserve crew call-out.
Reports of inadvertent crew napping on the flight deck	Scheduling rules, trip construction, rostering, crew augmentation policies to enable in-flight rest, improved on-board crew rest facilities	Scheduling changes to improve layover sleep opportunities. Flight Operations Manual procedure for controlled rest on the flight deck developed.
Crew members not getting enough sleep in on-board rest facilities	Pay attention to design of crew rest facilities when ordering aircraft. Retro-fit problem aircraft. Flight Operations Manual contains rules for organizing in-flight rest	Provide crew members with education on how to obtain optimal in-flight sleep. Captain's discretion on the day allowed for organization of in-flight rest.
Interrupted sleep periods in crew hotels	Scheduling rules, trip construction, rostering.	Internal procedures to restrict crew contacts during rest periods. Hotels required to provide segregated crew rest hotel areas, minimizing noise.
Landings at a confluence of circadian low, extended work period, and high work demands.	Scheduling rules, trip construction, rostering.	Protocols for in-flight rest and controlled rest on the flight deck.

The effectiveness of implemented mitigations must be assessed, which requires setting safety performance indicators such as the following.

*Schedule-related indicators*

- Number of flight deviations (or flight completions not accomplished) on specific city pairings, due to fatigue, lack of staff, medical emergencies, etc.
- Number of bids for pairings identified as high fatigue risk (e.g. back-to-back night flights).
- Number of crew duty day exceedances into allowable excesses (as determined through risk assessment. For example, longer than 14 hours.)

- Number of flight duty periods determined to be “significantly” later than scheduled.\*
- Number of flight duty periods longer than a specified number of hours without a rest break within the duty.
- Number of flight times more than a specified number of minutes longer than planned (e.g., 30 or 60 minutes).
- Number of flight duty periods starting within window of circadian low (WOCL).
- Number of landings within the WOCL.
- Number of duty periods with more than a specified number of flight sectors.
- Number of duty periods with more than a specified number of aircraft changes.
- Number of successive early wakeups, especially combined with long “sits” between flights or long duty days.
- Number of reduced rest breaks within duties (by more than a specified number of minutes determined to be “significant”).\*
- Number of reduced rest breaks between duties (by more than a specified number of minutes determined to be “significant”).\*
- Number of reserve crew call-outs (on particular flights, at a particular crew base, etc.).

\*This indicator is a specific requirement of an FRMS, (Section 1.2 f) of Appendix 8 to Annex 6, Part I), and is discussed in Chapter 3.

#### *Proactive/reactive fatigue indicators*

- Measured data outside acceptable thresholds (e.g., sleepiness ratings, PVT scores, or inadequate layover sleep duration).
- Numbers of fatigue reports (sorted in many ways such as by crew base, seat, augmented flights, fleet types, operational types, etc.).
- Number of fatigue-related incidents.
- Number of fatigue-related FOQA events associated with a particular schedule for which fatigue reports have been received.
- Absenteeism/fatigue calls.

The implications of such safety performance indicators should be considered within the context of the entire operation, to distinguish between acceptable and unacceptable risk.

If the controls and mitigations perform to an acceptable standard (i.e., they bring the risk into the tolerable region — see Table 4-2d), they become part of normal operations and are monitored by the FRMS safety assurance processes. If the controls and mitigations do not perform to an acceptable standard, then it will be necessary to re-enter the FRM processes at the appropriate step. As indicated in Figure 4-2, this could require: gathering of additional information and data, and/or re-evaluation of the fatigue hazard and the associated risks, and/or identification, implementation and evaluation of new or revised controls and mitigations.

## 4.7 EXAMPLE: SETTING UP FRM PROCESSES FOR A NEW ULR ROUTE

In 2005, recommended guidelines for ULR operations were developed by a Flight Safety Foundation consortium group — the Ultra-long Range Crew Alertness Steering Committee. This group identified ULR operations as scheduled operations that exceed 16 hours. This 16-hour distinction for ULR operations has since become broadly accepted.

This example works through FRMS processes that could be used for establishing a new ULR operation. It is developed from an actual safety case for a new ULR route that received regulatory approval, but it is an example not a recipe. The accepted approach for ULR operations is to evaluate each city pair to be flown<sup>7</sup>. Figure 4-5 summarizes the FRM processes, which are explained in more detail in the text.

### 4.7.1 Step 1 – Identify the operation

The operation to which these FRM processes apply is a new ULR route between City A and City B (described here as the A-B-A route).

### 4.7.2 Step 2 – Gather data and information

Information and data are potentially available from two types of existing operations: long-haul operations that are similar but have flight times under 16 hours; and ULR operations already being flown by other operators. The relevance of the available information depends on how closely the existing operations resemble the proposed new ULR operation. The following factors need to be considered:

- crew complement and facilities for in-flight rest.
- crew domicile (if crew members are domiciled in the departure city and they have had sufficient time off since their last trans-meridian flight, it can be assumed that their circadian body clocks are adapted to domicile time).
- departure time of the outbound flight (local time and likely body clock time).
- outbound flight duration and time zones crossed.
- arrival time of the outbound flight (local time and likely body clock time).
- duration of the layover.
- departure time of the return flight (local time and likely body clock time).
- return flight duration and time zones crossed.
- arrival time of the return flight (local time and likely body clock time).
- depending on the actual city pairs being served, it may also be relevant to compare winter and summer schedules for take-off and landing times and flight durations.

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<sup>7</sup> Flight Safety Foundation, *Flight Safety Digest*, Vol. 22 (No. 5-6), 2003, and Vol. 24 (No. 8-9), 2005.

In this case, another operator has been flying a ULR trip between City C and City D. This existing operation has the same crew complement and similar departure times, flight durations, layover durations and patterns of time zone crossings as the A-B-A route. As part of the regulatory approval process for the C-D-C route, the operator was required to conduct a six-month operational validation, which included intensive monitoring of crew member sleep and fatigue. The operator generously makes these findings available for use in the A-B-A safety case through an independent scientific team who were involved in the C-D-C data collection and analysis. (The expertise of the scientific team ensures that the findings are interpreted and applied to the A-B-A route in an appropriate manner.)

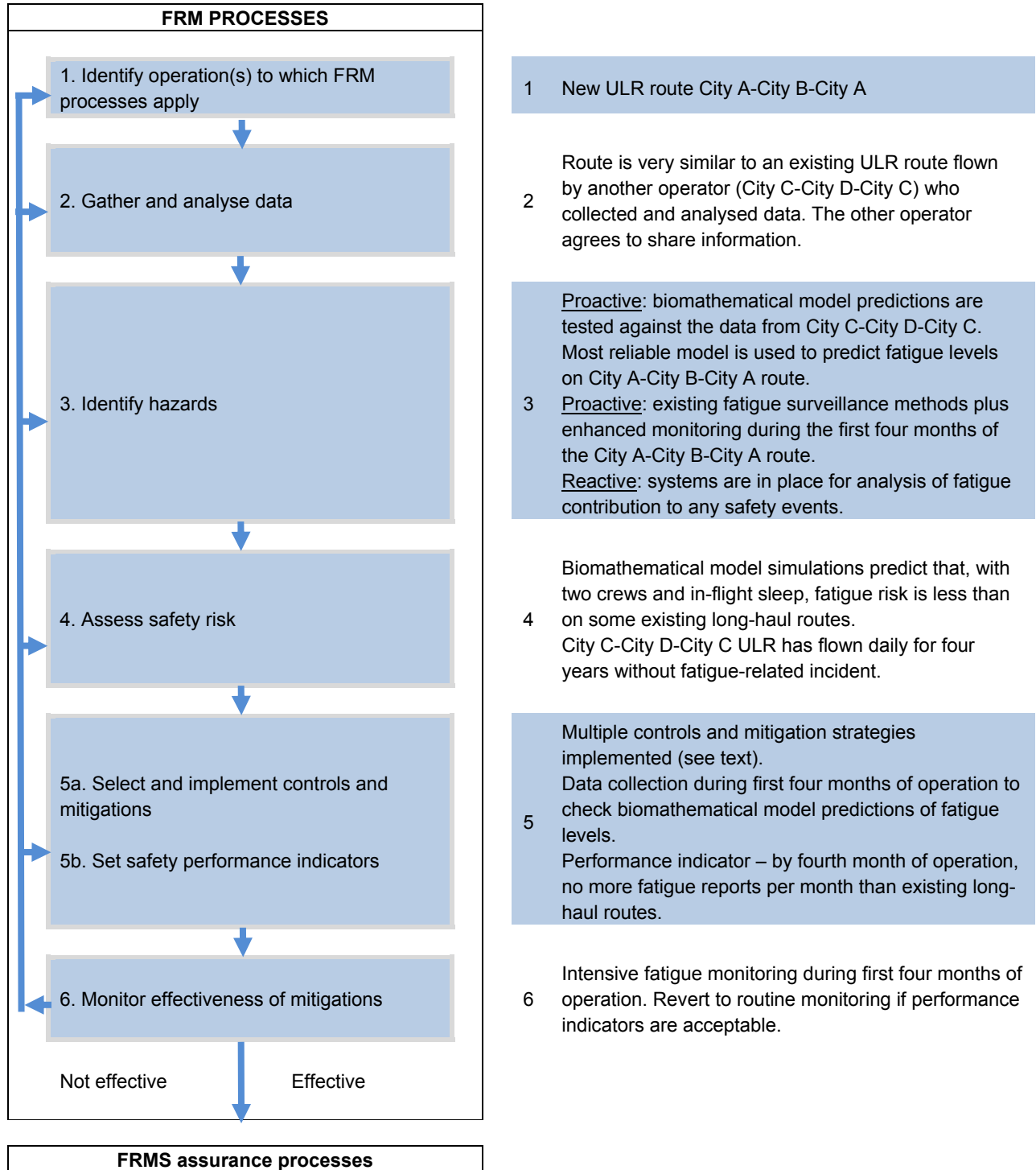


Figure 4-5 FRM processes in setting up a new ULR route



### 4.7.3 Step 3 – Identify hazards

#### *Predictive processes*

The operator already has experience with several long-haul routes using the same aircraft and crew complement and with similar departure times and time zone crossings to the A-B-A route but that remain under the 16-hour flight time limit that is used to define ULR. This experience has guided development of the operational plan for the A-B-A ULR route.

Two biomathematical models are available that can be used to predict the likely levels of crew member fatigue or alertness on the A-B-A route. The data collected on the C-D-C route are used to test how well these models can predict the sleep and fatigue of crew members before, during and after ULR operations.

One model makes the following predictions for the C-D-C route: that crew member fatigue levels increase significantly across both the outbound and return flights; that layover sleep is too short to enable recovery before the return flight; and that fatigue levels are potentially unsafe by the end of both flights. These predictions are directly contradicted by PVT performance data and subjective sleepiness and fatigue ratings collected during the first six months of the C-D-C operation, which has flown daily without major incident for four years. The operational data and experience are considered more reliable than these biomathematical model predictions.

On the other hand, the second model reliably predicts the duration of in-flight sleep on the C-D-C route (to within the range of variability seen among the crew members monitored). This model is chosen to predict crew member alertness on the A-B-A route.

#### *Proactive processes*

The following proactive processes for identifying fatigue hazards are proposed for intensive monitoring during the first four months of the new operation, to validate the predictions about fatigue levels and fine tune the mitigation strategies, as needed.

- Crew members are reminded about and encouraged to use existing fatigue reporting forms.
- For the first month of the operation, a senior flight crew member will be present in the Flight Operations Centre for the first and last few hours of every flight on the A-B-A route, to ensure rapid and appropriate management response to any fatigue-related issues that arise.
- For the first month of the A-B-A operation, a subset of crew member volunteers is asked to complete a sleep and duty diary (with fatigue and sleepiness ratings) before, during and after an A-B-A trip. These data will be compared to the same measures collected during the C-D-C operational validation.

Other proactive fatigue monitoring processes that could be used include:

- Asking all crew members to complete fatigue and sleepiness ratings at the top of descent on each flight, for the first month of the A-B-A operation.
- Surveying all crew members after the A-B-A operation has been flown for three months, to obtain an overview of their experience of fatigue and the effectiveness of different mitigation strategies (scheduling, in-flight rest facilities, layover hotels, etc.).
- Having a subset of crew member volunteers who wear actiwatches and complete sleep diaries before, during and after a complete trip on the A-B-A route. In addition they would complete fatigue and sleepiness scales and undertake PVT performance tests at key times across each flight. These data would be compared to the same measures from the C-D-C operational validation.

### *Reactive processes*

The operator 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 future. Special attention will be paid to ensuring that any fatigue reports or incidents from the A-B-A operation are analysed quickly and appropriate action taken.

#### **4.7.4 Step 4 – Assess safety risk**

The biomathematical model used to predict crew member alertness on the A-B-A route has previously been used to predict alertness on a range of two-person and three-person long-haul routes. These predictions indicate that minimum alertness levels on the A-B-A route are likely to be higher than on some existing long-haul routes, notably three-person westward return night flights with duty periods of about 14 hours, and long overnight flights with two-person crews.

Two sets of operational experience support the prediction that the A-B-A route does not pose excessive fatigue hazards: 1) the safety record of the C-D-C operation which has flown daily for four years; and 2) the A-B-A operator's experience with similar long-haul routes using the same aircraft and crew complement, but remaining under the 16-hour flight time limit.

#### **4.7.5 Step 5 – Select and implement controls and mitigations**

In this example, the following controls and mitigation strategies are proposed for the A-B-A operation.

- The aircraft chosen for the route has the best available on-board crew rest facilities.
- All crew members flying the new operation are domiciled in the departure city.
- All crew members flying the new operation receive specific education on personal and organizational strategies for managing fatigue on the A-B-A operation. This includes discussion on how to make best use of in-flight and layover sleep opportunities.
- All crew members have protected time off duty to enable two full nights of sleep in the departure city time zone, so that they have the opportunity to begin the A-B-A operation fully rested.
- There is a clear policy defining on-call arrangements and the provisioning of relief crew.
- The flight crew includes two captains and two first officers, so that a single captain does not have sole command responsibility for entire ULR flights. This is in accordance with the Flight Safety Foundation ULR recommendations.
- There is a clear policy on the distribution of in-flight rest opportunities, so that crew members can plan how best to use them.
- Each crew member has two rest opportunities per flight, to ensure that he has at least some rest time overlapping his normal sleep time and that he has a second opportunity to get some sleep if, for any reason, he is unable to sleep during his first in-flight rest period.
- Meals may be taken by the flight crew on the flight deck, in order to maximize the amount of time for sleep during in-flight rest periods.
- The layover hotel has been carefully vetted to ensure that it provides adequate facilities for sleep, eating and exercise.
- A procedure is implemented between Flight Operations and the layover hotel to provide notification of delays without having to wake crew members.

- There are clear procedures on the management of flight delays.
- There are clear procedures on the management of flight diversions.

The following safety performance indicators are identified:

- Data collected during the first four months of the A-B-A operation will be compared with model predictions and with the same measures from the C-D-C validation, to establish whether crew member fatigue and alertness levels are in the range predicted.
- By the fourth month of the A-B-A operation, the fatigue reporting rate (reports/flight segment) and average fatigue report risk level should be comparable to existing long-haul routes. No “intolerable” fatigue reports should be received (see Table 4-2.d).

#### **4.7.6 Step 6 – Monitor effectiveness of controls and mitigations**

There is a defined validation period for the first four months of the operation that involves more intensive monitoring. The Fatigue Safety Action Group will have regular oversight of all data and fatigue reports coming in and will act in a timely manner when issues arise.

At the end of the validation period, a report will be compiled and routine processes will be defined for fatigue risk monitoring and management on the A-B-A route. This report will be available to all interested parties. If the performance indicators are acceptable, the A-B-A operation will revert to routine monitoring.

#### **4.7.7 Linking to FRMS safety assurance processes**

Normally, the FRM processes do not operate in isolation from the FRMS safety assurance processes (described in detail in the next chapter). However, when setting up FRMS in an organization, or for a new type of operation, the data needed for FRMS safety assurance processes are not available before the operation(s) begin flying. This means that it is necessary to have a staged approach to FRMS implementation, which is described in Chapter 7.

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## Chapter 5. FRMS safety assurance processes

### 5.1 INTRODUCTION TO FRMS SAFETY ASSURANCE PROCESSES

The FRM processes described in Chapter 4 are the part of the day-to-day FRMS operations that focus on identifying fatigue hazards, assessing safety risks, putting in place controls and mitigation strategies, and monitoring their effectiveness.

This chapter works through the basic steps in FRMS safety assurance processes, which form another layer in an operator's defenses against fatigue-related risk. FRMS safety assurance processes are also part of the routine operation of the FRMS, and they monitor how well the entire FRMS is functioning. They:

- check that the FRMS is functioning as intended;
- check that it is meeting the safety objectives defined in the FRMS policy;
- check that it is meeting regulatory requirements;
- identify where changes in the operating environment have the potential to increase fatigue risk; and
- identify areas for improvement in the management of fatigue risk (continuous improvement of the FRMS).

To do this, FRMS safety assurance processes use a variety of data and information as safety performance indicators that can be measured and monitored over time. Having a variety of safety performance indicators, plus a safety target for each, is expected to give better insight into the overall performance of the FRMS than having a single measure. Safety performance targets must fall in the tolerable region defined in the risk assessment process (see Section 4.5), and they may need to be revised as operational circumstances change.

Figure 5-1 outlines the linkages between the FRMS safety assurance processes and other components of the FRMS. The information, data and safety performance indicators from the FRM processes provide a source of information for the FRMS safety assurance processes. In addition, the FRMS safety assurance processes:

- use information and expertise from other sources, both from within the operator's organization and external to it, to evaluate the functioning of the FRMS;
- evaluate trends in safety performance indicators to identify emerging or changed hazards and refer these back to the FRM processes;
- identify changes in the operating environment that could affect fatigue risk and refer these back to the FRM processes; and
- provide input about ways to improve the operation of the FRMS.

Some of the FRMS safety assurance processes can be undertaken by the Fatigue Safety Action Group, while others (for example, audits of the FRMS) would normally be undertaken by other units within the operator's organization. The responsibility for different FRMS safety assurance activities may be distributed differently, depending on the size of the organization. For example, larger operators may have a separate FRMS safety assurance team and/or a designated FRMS safety assurance manager. Communication (in both directions) between the FRMS safety assurance processes and the SMS is necessary, since the safety performance of the FRMS will impact on the overall safety performance of the operator.

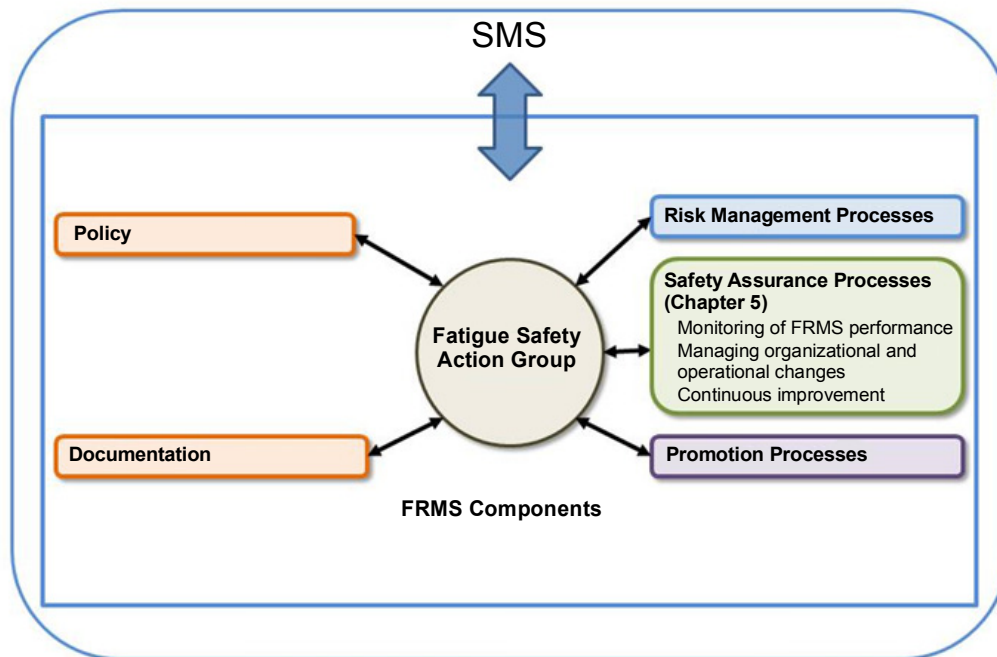


Figure 5-1 Linkages between FRMS assurance processes and other FRMS components

The ICAO requirements for FRMS safety assurance processes are as follows.

**Appendix 8:**  
**3. FRMS Safety Assurance Processes**

The operator 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;
- b) provide a formal process for the management of change which shall include but is not limited to:
  - 1) identification of changes in the operational environment that may affect FRMS;
  - 2) identification of changes within the organization that may affect 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 risk controls 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.

Figure 5-2 summarizes the steps in FRMS safety assurance processes. Each step is described in more detail below.

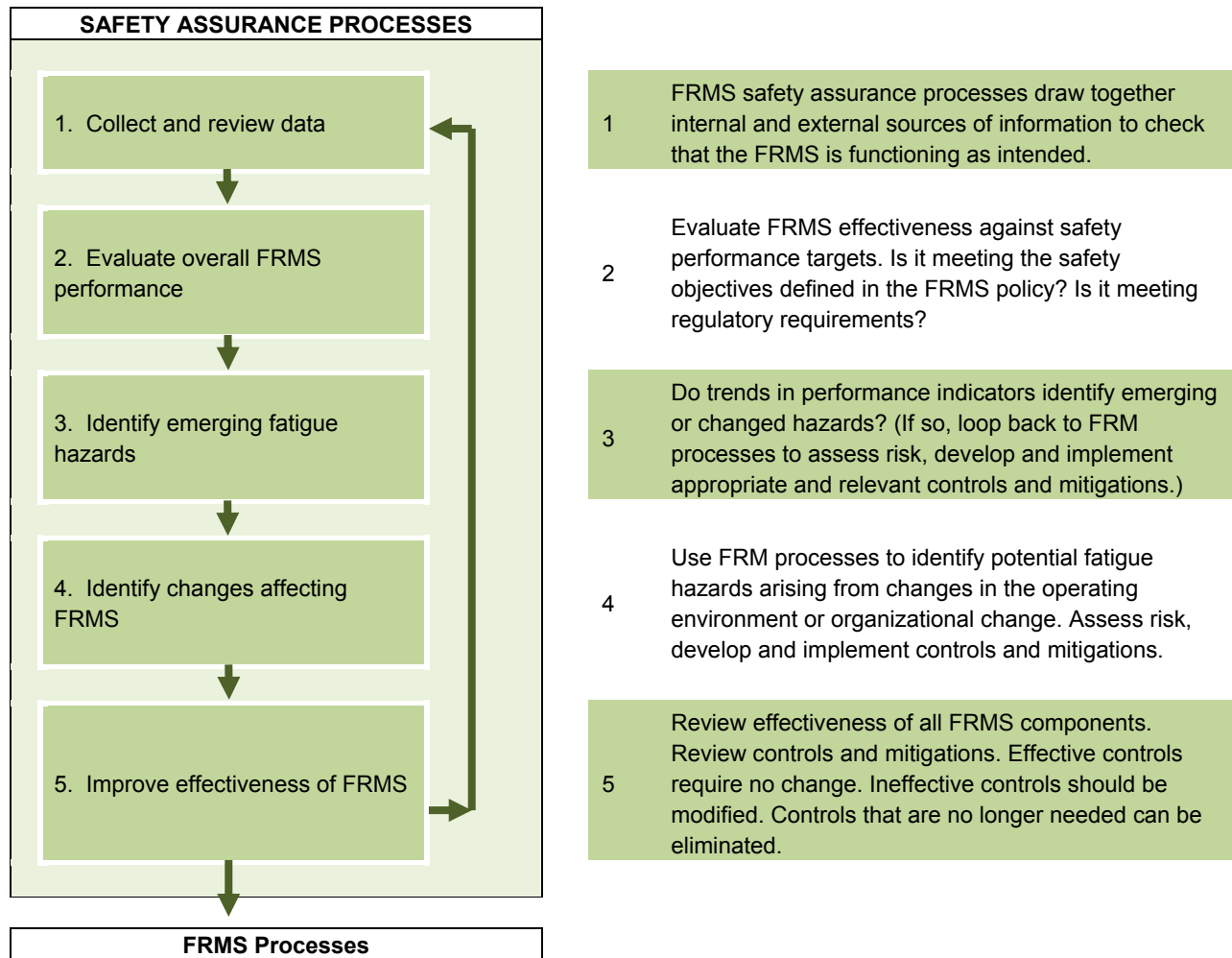


Figure 5-2. FRMS safety assurance processes

## 5.2 FRMS SAFETY ASSURANCE PROCESSES

### 5.2.1 Step 1 – Collect and review data

Step 1 involves bringing together and reviewing information gained through the FRM processes to examine the overall performance of the FRMS. Performance of the FRMS should be examined by identifying a variety of safety performance indicators. These should include those specific to the FRMS as well as SMS safety performance indicators. Examples of safety performance indicators specific to an FRMS will include measures obtained through the FRM processes, such as:

- the number of exceeded maximum duty days in operations covered by the FRMS;
- the number of voluntary fatigue reports per month;
- the average “fatigue call” rate by flight crews on a specific pairing (trip);
- the ratio of fatigue reports from ULR operations covered by the FRMS to fatigue reports from the long-haul operations covered by the prescriptive flight and duty time regulations;
- attendance at FRMS training sessions;
- results on FRMS training assessments;
- the level of crew member participation in fatigue-related data collection;
- the number of times fatigue is identified as an organizational factor contributing to an event.

Appendix 8 to ICAO Annex 6, Part I, indicates that identification of safety performance indicators may result through examination of:

1. Hazard reporting and investigations;
2. Audits and surveys; and
3. Reviews and fatigue studies.

#### 1. Hazard reporting and investigations

Trends in voluntary fatigue reports by crew members and others can provide valuable insights into the effectiveness of the FRMS. Safety events in which crew member 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 analysing the role of fatigue (see Chapter 4 and Appendix A).

#### 2. Audits and surveys

Audits and surveys can provide measures of the effectiveness of the FRMS without having to rely on fatigue levels being high enough to trigger fatigue reports or fatigue-related safety events (both of which are relatively rare events).

Audits focus on the integrity of, and adherence to, the FRM processes. These audits should answer questions such as:

- Are all departments implementing the recommendations of the Fatigue Safety Action Group?
- Are crew members using mitigation strategies as recommended by the Fatigue Safety Action Group?
- Is the Fatigue Safety Action Group maintaining the required documentation of its activities?



Audits can also periodically assess the effectiveness of the FRMS, for example, by looking at the status of FRMS safety performance indicators and targets.

Audits are external to the Fatigue Safety Action Group, but may still be internal to the operator, i.e., conducted by other units within the organization. In addition, 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 periodically review the activities of the Fatigue Safety Action Group and the scientific integrity of their decisions. A scientific review panel can also provide the Fatigue Safety Action Group with periodic updates on new scientific developments relevant to the FRMS.

Surveys can provide information on the effectiveness of the FRMS. For example, they can document how schedules and rosters are affecting crew members, 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 Chapter 4 and Appendix A). A high response rate (ideally more than 70 per cent) 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”).

### 3. *Reviews and fatigue studies*

In general, safety reviews are used to ensure that safety performance is adequate during times of change, for example, during the introduction of a new type of operation or a significant change to an existing operation covered by the FRMS.

A review would start by identifying the change (for example, moving a trip to a crew base in a different time zone, changes in on-board crew rest facilities, significant changes in the total trip, or a change of equipment being used for the trip). It would then evaluate the appropriateness and effectiveness of the FRMS activities relating to the change (for example, proposed methods for fatigue hazard identification, the risk assessment process, proposed controls and mitigations to address the fatigue hazard(s), and measures of their effectiveness to be used during the implementation of the change).

Fatigue studies as part of FRMS safety assurance processes are undertaken when an operator is concerned about a broad fatigue-related issue for which it is appropriate to look at external sources of information. These could include the experience of other operators, industry-wide or State-wide studies, and scientific studies. These sources of information can contribute in situations when safety arguments based on the limited experience and knowledge within that operator may not be enough. Fatigue studies in this context are mainly used for gathering information about large-scale issues in FRMS, rather than for identifying specific fatigue hazards.

## 5.2.2 Step 2 – Evaluate FRMS Performance

The aim of Step 2 is to validate the effectiveness of the fatigue controls and mitigations (Appendix 8 to Annex 6, Part I). It involves analysing the information gathered in Step 1 to check whether:

- all specified FRMS safety performance targets are being met;
- all specified FRMS safety performance indicators remain in the tolerable region defined in the risk assessment process (see Section 4.5);
- the FRMS is meeting the safety objectives defined in the FRMS policy; and
- the FRMS is meeting all regulatory requirements.

The following are examples of safety performance targets that could be used in FRMS safety assurance processes and that correspond with the safety performance indicators identified above (for additional examples see Section 5.8 of this chapter).

- The length of the maximum duty days in operations covered by the FRMS does not exceed the limits defined in the FRMS policy. This is reviewed monthly by a computer algorithm and trends across time are evaluated every three months.
- By the fourth month after the introduction of a new operation, there should be a stable low number of voluntary fatigue reports per month, or a clear downward trend in the number per month (allowing time for crew members and other affected personnel to adjust to the new operation). The Fatigue Safety Action Group should provide a written report on the validation phase of the new operation, including analysis of all fatigue-related events and voluntary fatigue reports, and documentation of the corresponding adjustments made in fatigue controls and mitigations.
- No specific pairing (trip) exceeds the average fatigue call rate by flight crews by more than 25 per cent.
- ULR operations covered by the FRMS do not attract any more fatigue reports than the long-haul operations covered by the prescriptive flight and duty time regulations.
- In the last quarter, the Fatigue Safety Action Group has met as often as is required in the FRMS policy and has maintained all the documentation of its activities that is required for internal and regulatory auditing.
- All personnel responsible for schedule design and rostering have met annual FRMS training requirements as specified in the FRMS promotion processes.
- Measures of the effectiveness of FRM training and education programmes (see Chapter 6 for examples).
- Quarterly levels of absenteeism are below the target specified for each operation covered by the FRMS.

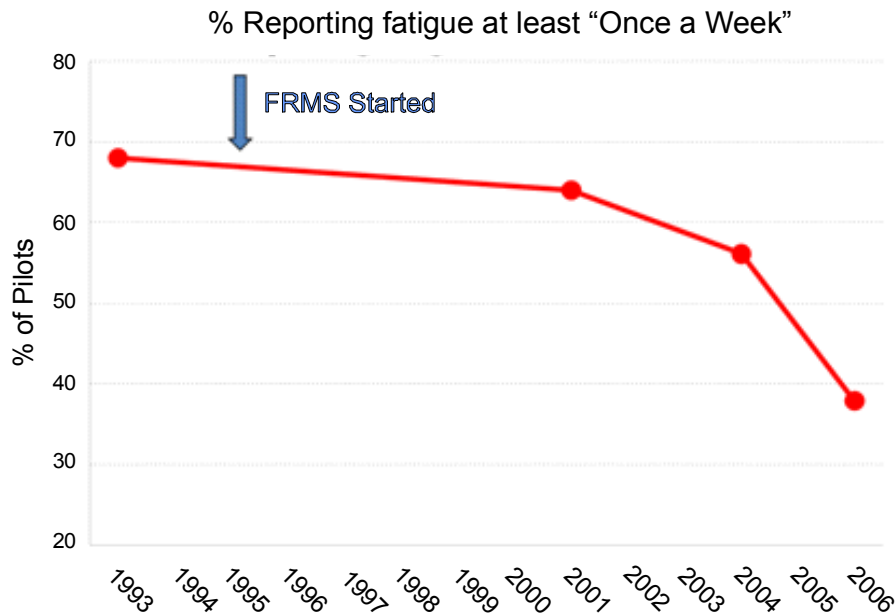
When FRMS safety performance targets are not met or when safety performance indicators are not at an acceptable level, the controls and mitigations in use may need to be modified by re-entering the FRM processes at Step 2 or beyond (see Figure 4-2). Regulators should require that operators notify them when values for specific safety performance indicators reach particular values. The regulator can then assess how the operator intends to address this problem and monitor its progress.

For the operator, it may be appropriate to seek additional information from outside the organization (for example, by looking at fatigue studies). It may be necessary to undertake a review of compliance of crew members and other departments with the recommendations of the Fatigue Safety Action Group. It may also sometimes be necessary to review the functioning of the Fatigue Safety Action Group itself, to find out why the FRMS is not working as intended.

Figure 5-3 tracks a measure of the effectiveness of the Air New Zealand FRMS across time<sup>1</sup>. It shows that the percentage of pilots reporting duty-related fatigue occurring at least once a week has declined across a series of surveys conducted between 1993 and 2006.

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<sup>1</sup> Figure 5.3 is used by kind permission of Dr David Powell.



**Figure 5-3 Declining reports of crew member fatigue across successive Air New Zealand surveys**

### 5.2.3 Step 3 – Identify emerging hazards

Analysis of trends in safety performance indicators may indicate the emergence of fatigue hazards that have not previously been recognized through the FRM processes. For example, changes in one part of the organization may increase workload and fatigue-related risk in another part of the organization. Identifying emerging fatigue risks is an important function of FRMS safety performance processes, which take a broader system perspective than FRM processes. Any newly identified fatigue risk, or combination of existing risks for which current controls are ineffective, should be referred back to the Fatigue Safety Action Group for evaluation and management using FRM processes (risk assessment, design and implementation of effective controls and mitigations).

### 5.2.4 Step 4 – Identify changes affecting FRMS

In our dynamic aviation environment, changes are a normal part of flight operations. They may be driven by external factors (for example, new regulatory requirements, changing security requirements or changes to air traffic control) or by internal factors (for example, management changes, new routes, aircraft, 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. Step 4 of the FRMS safety assurance processes aims to identify when new hazards may be a result of change.

Appendix 8 to ICAO Annex 6, Part I, requires that an operator has FRMS safety assurance processes that provide a formal methodology for the management of change. These must include (but are not limited to):

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

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

A change management process is a documented strategy to proactively identify and manage the safety risks that can accompany significant change in an airline<sup>2</sup>. When a change is planned, the following steps can be followed:

- Use the FRM processes to identify fatigue hazards, assess the associated risk, and propose controls and mitigations.
- Obtain appropriate management and/or regulatory sign-off that the level of residual risk is acceptable.
- During the period of implementation of the change, use the FRMS safety assurance processes to 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 ULR route, during which additional monitoring of crew member fatigue is undertaken, together with more frequent assessment of FRMS safety performance targets and indicators. Documentation of the change management strategy in relation to fatigue management is also the responsibility of the Fatigue Safety Action Group.

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 Fatigue Safety Action Group should propose such changes and obtain approval for them from appropriate management.

#### **5.2.5 Step 5 – Improve effectiveness of FRMS**

Ongoing evaluation by the FRMS safety assurance processes not only enables the FRMS to be adapted to meet changing operational needs, it also allows the FRMS to continuously improve the management of fatigue risk. In doing so, risk controls that have unintended consequences or that are no longer needed due to changes in the operational or organizational environment can be identified then modified or eliminated through the FRM processes. Examples include:

1. Routine evaluations of facilities, equipment, documentation and procedures; and
2. The determination of the need to introduce new processes and procedures to mitigate emerging fatigue-related risks.

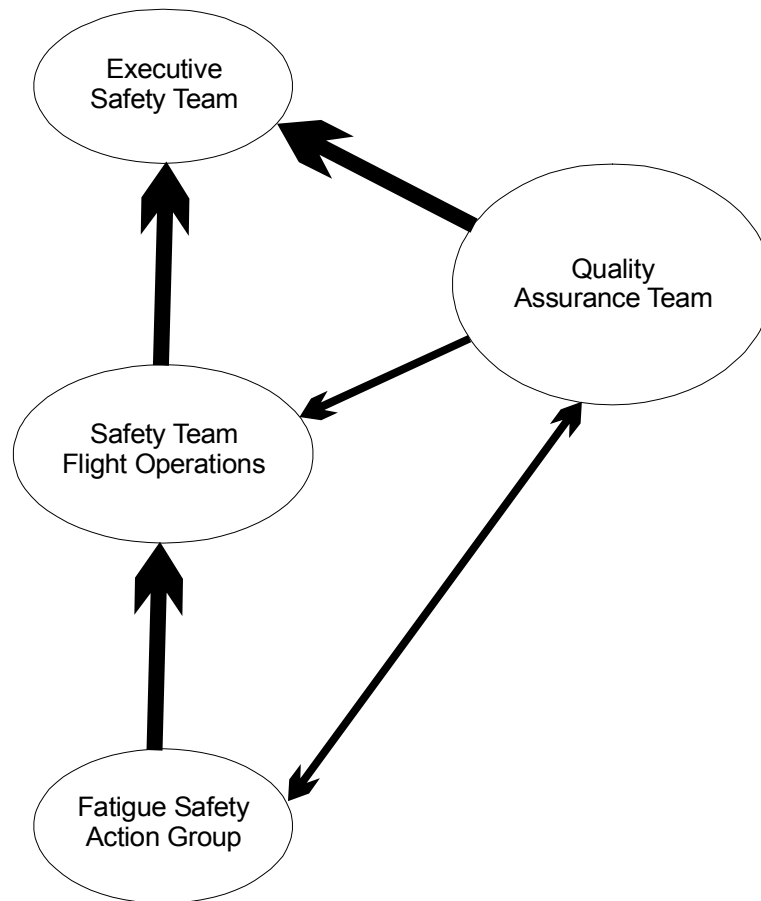
It is important that changes made to the FRMS be documented by the Fatigue Safety Action Group so that they are available for internal and regulatory audit.

### **5.3 ASSIGNING RESPONSIBILITY FOR FRMS SAFETY ASSURANCE PROCESSES**

To deliver effective oversight of the functioning of the FRMS, and to examine its functioning in relation to the SMS, the FRMS safety assurance processes need to operate in close communication with the Fatigue Safety Action Group, but with a degree of independence from it. The aim is to avoid the Fatigue Safety Action Group reviewing its own performance. Figure 5-4 describes an example of how responsibility for the FRMS safety assurance processes might be assigned in a large organization.

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<sup>2</sup> ICAO's *Safety Management Manual (SMM)* (Doc 9859).



**Figure 5-4 Example of assignment of responsibility for FRMS safety assurance processes in the flight operations department of a large organization**

In this example, the Fatigue Safety Action Group is accountable to the Safety Team for Flight Operations. The Safety Team for Flight Operations is accountable in turn to the Executive Safety Team. In Figure 5-4, these lines of accountability are indicated by heavy arrows. (In a large organization, there might eventually be separate FRMSs and Fatigue Safety Action Groups for flight operations, maintenance, ground operations and in-flight services.) 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 Fatigue Safety Action Group;
- makes recommendations to the Safety Team for Flight Operations, as needed to improve the functioning of the FRMS;
- makes recommendations to the Safety Team for Maintenance, as needed to improve the functioning of the FRMS;
- makes recommendations to the Safety Team for Ground Operations, as needed to improve the functioning of the FRMS;
- makes recommendations to the Safety Team for In-Flight Services, as needed to improve the functioning of the FRMS; and

- monitors changes in the regulatory environment and the operating environment that may affect the functioning of the FRMS.

In a smaller operator, 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 flight operations, in-flight services, ground operations and maintenance.

#### **5.4 EXAMPLES OF FRMS SAFETY ASSURANCE PROCESSES INTERACTING WITH FRM PROCESSES**

Figure 5-5 summarizes interactions between the FRM processes and the FRMS safety assurance processes. Together, these two sets of processes form the “engine” of the FRMS. Both function in a dynamic way in response to the information and data collected, and each is responsive to changes in the other.

The following examples illustrate some FRMS safety assurance processes and describe the specific ways in which they interact with the FRM processes.

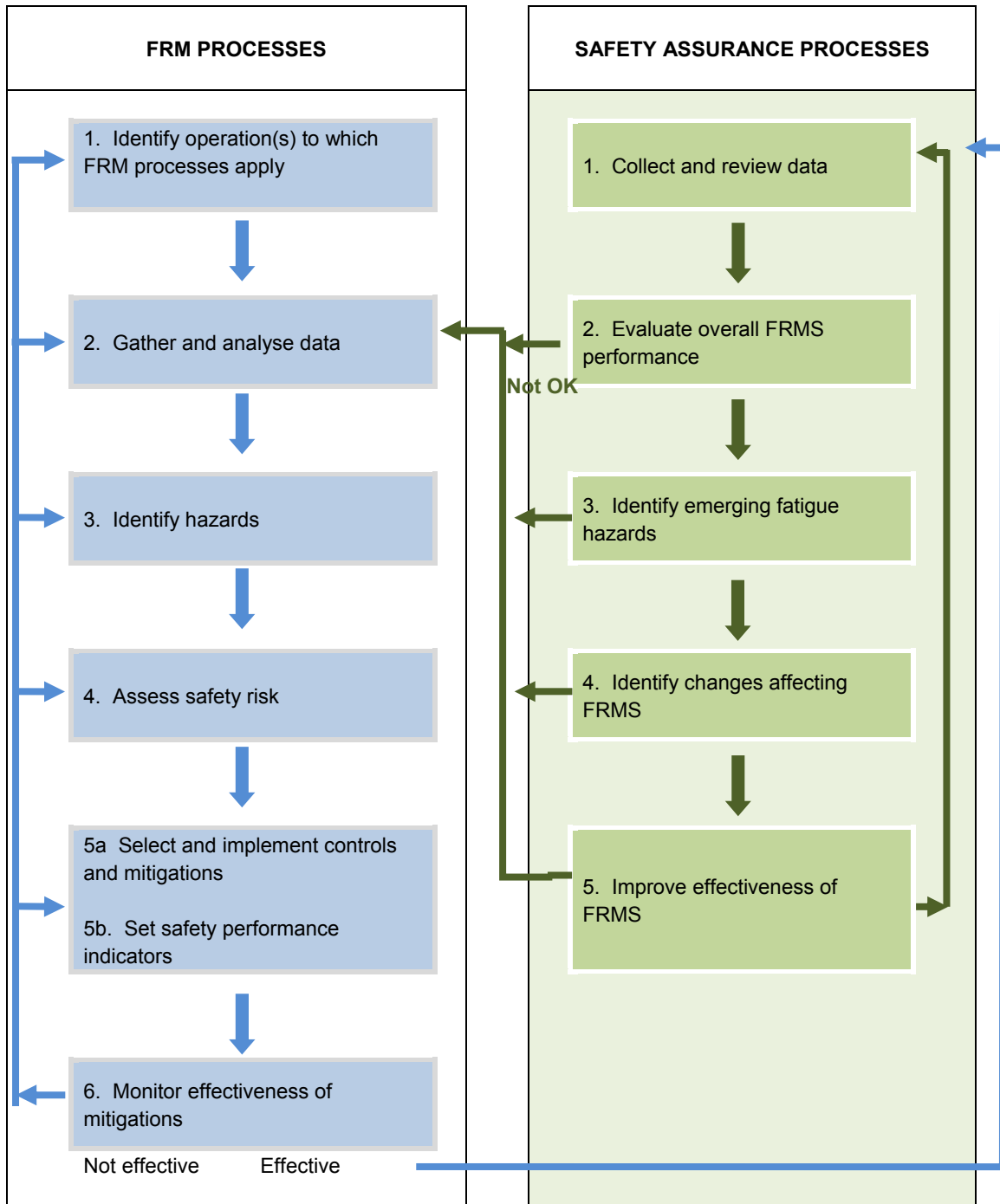
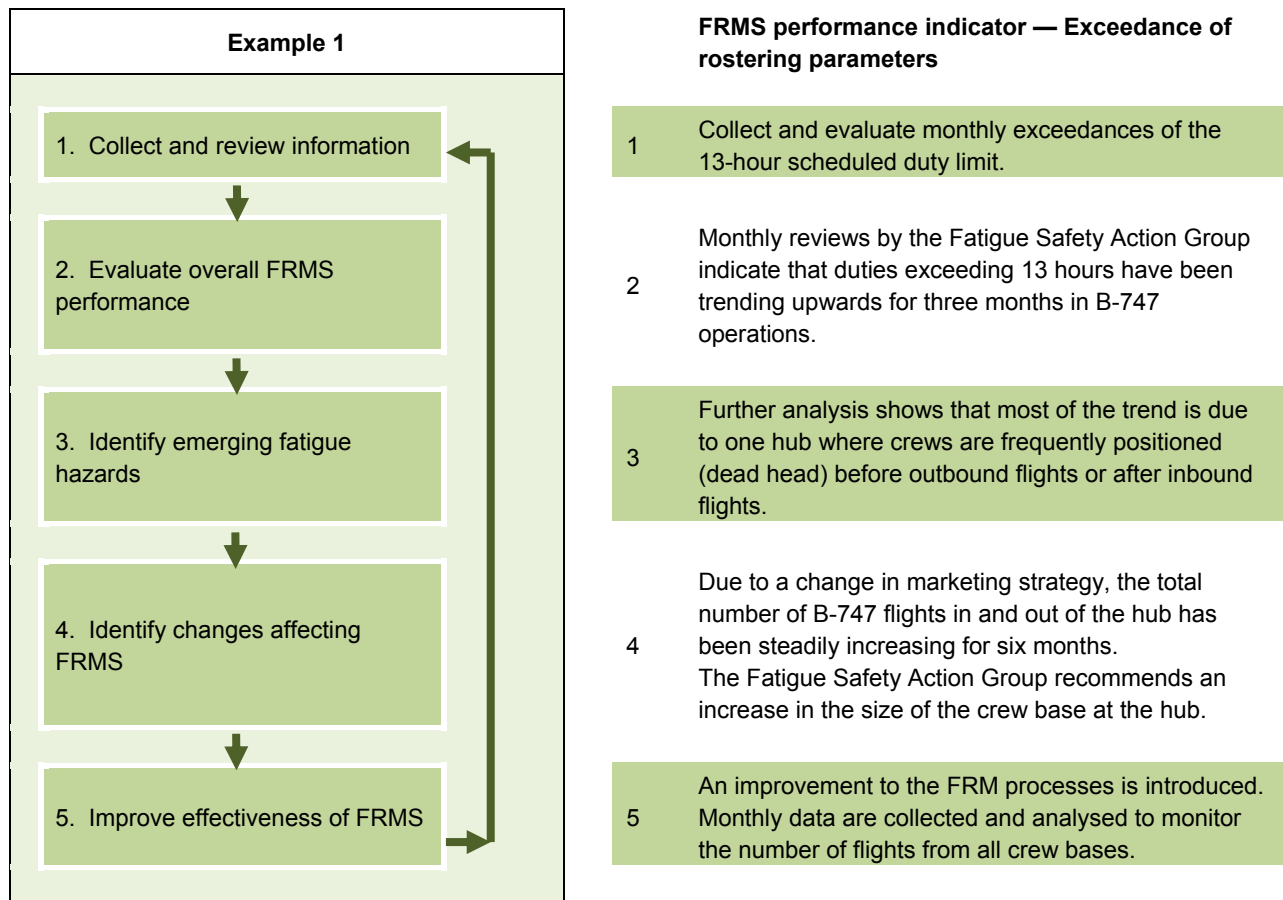


Figure 5-5 Interactions between FRM processes and FRMS safety assurance processes



**Figure 5-6 FRMS Safety Assurance Processes — Example 1**

In the example in Figure 5-6, as the result of a risk assessment (FRM processes Step 4), the Fatigue Safety Action Group sets a duty length of 13 hours as one of its FRMS safety performance indicators (SPIs). The target is to have no more than two instances of duties in excess of 13 hours per week in B-747 operations. It collects and assesses monthly data on scheduled and actual exceedances of the 13-hour duty limit across all its B-747 flights in and out of the hub. For three consecutive months, there is an increasing trend in exceedances.

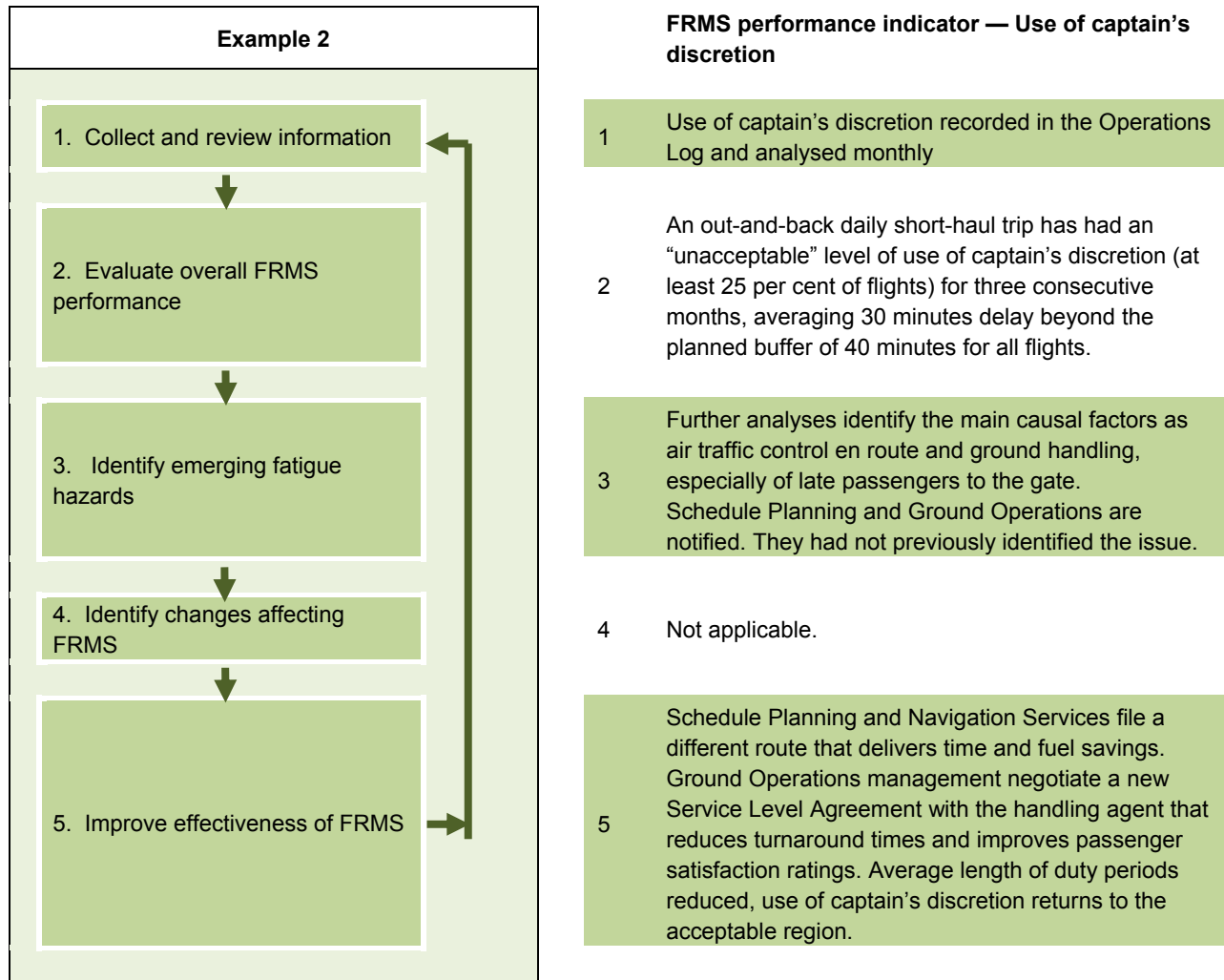
A short-haul example is described in Figure 5-7. Here, the use of captain's discretion is tracked as an FRMS safety performance indicator. Most State regulations allow for flight duty periods to be increased on the day of operation at the discretion of the relevant captain.

In this example, in the FRMS processes, the Fatigue Safety Action Group has conducted a risk assessment (see Table 4-2 d) and decided to set the following thresholds for short-haul flights:

- intolerable region — discretion used on at least 25 per cent of flight duty periods in a two-month period;
- tolerable region — discretion used on 10-25 per cent of flight duty periods in a two-month period;
- acceptable region — discretion used on less than 10 per cent of flight duty periods in a two-month period.

In addition, delays of more two hours must be logged and presented to the Fatigue Safety Action Group.

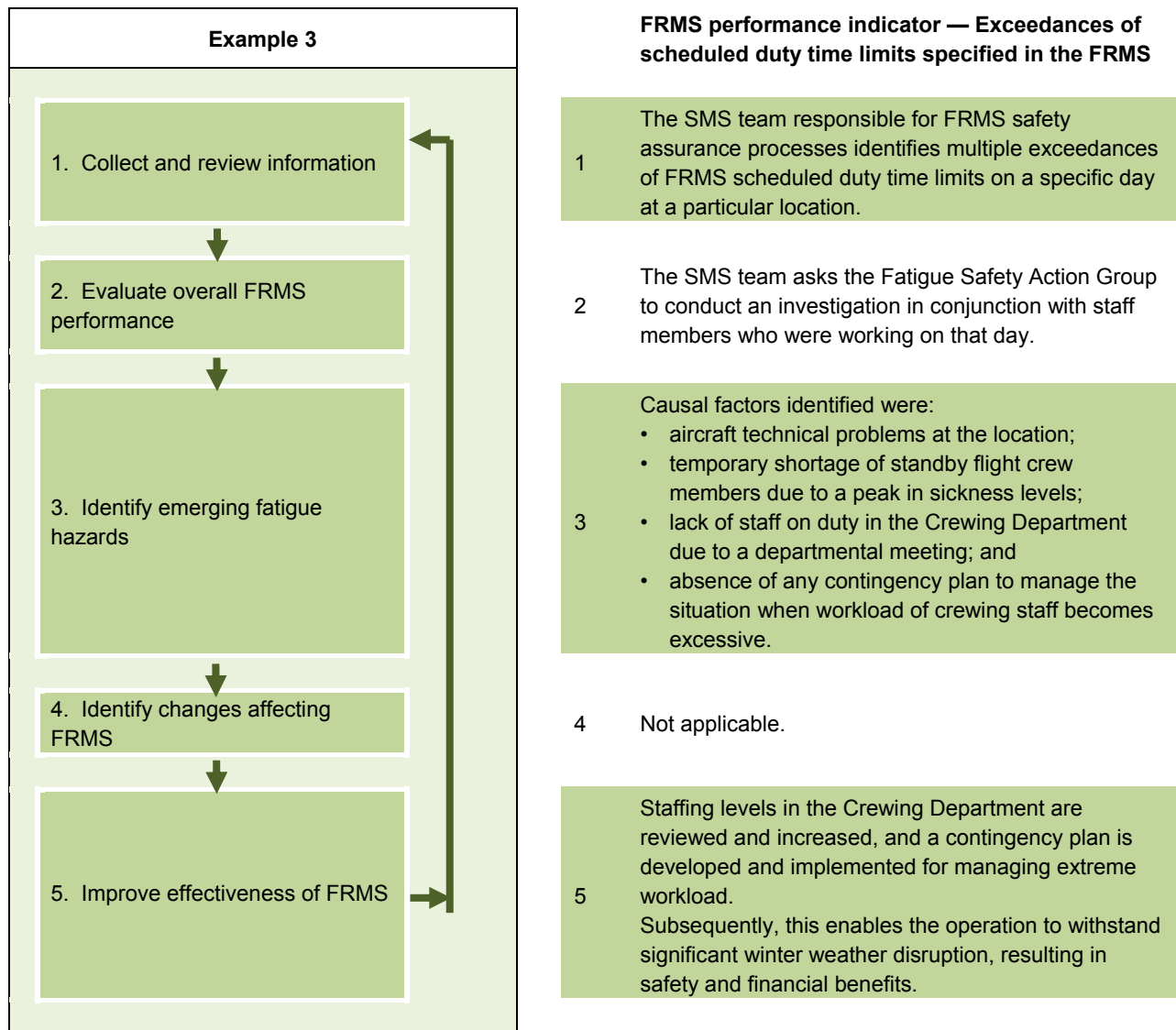




**Figure 5-7 FRMS Safety Assurance Processes — Example 2**

Data on use of discretion are collected in a log generated by the operator's crew management system. The Fatigue Safety Action Group analyses this data monthly to ensure that the trips being created by the scheduling software are realistic, given the usual operating conditions. The data are sorted by trip (sequence of consecutive flight duty periods), distinguishing between regular scheduled trips (that recur for several roster periods, e.g., monthly bid lines) and trips that are introduced temporarily to cover variations in scheduling or crew member availability at a particular crew base. Data are also analysed by crew member rank, category and qualifications to see, for example, if trips with more frequent use of discretion are avoided by more senior crew members).

The next example (Figure 5-8) looks at an operator whose FRMS uses scheduled maximum values for planning purposes that are well within the established risk-assessed, regulator-approved outer boundaries of the FRMS. In this example, on a particular day at a particular crew base, the maximum value of scheduled duty time periods defined in the FRMS has been exceeded multiple times.



**Figure 5-8 FRMS Safety Assurance Processes — Example 3**

Every exceedance of the scheduled duty times requires submission of a report to the Fatigue Safety Action Group, which is added to the FRMS documentation for regulatory audit. In addition, the FRMS safety assurance processes require that the reasons for each exceedance be investigated and that, if required, corrective action be taken. In this example, the functions of FRMS safety assurance are undertaken by the SMS team as part of their broader SMS safety assurance functions. This is to ensure that the management of fatigue risks does not result in unintended consequences in overall risk management, that the actions taken by the Fatigue Safety Action Group are not self-monitored, and that there is appropriate distribution of resources across both the FRMS and the SMS.

In this example, the monthly review of exceedances by the SMS team responsible for FRMS safety assurance processes identifies a cluster of exceedances that occurred on the same day in the same place. They notify the Fatigue Safety Action Group. The Fatigue Safety Action Group contacts the line manager responsible for crewing resources on the day and asks him to interview the staff on duty on that day. The investigation reveals that there were a series of problems that coincided on that

particular day, which combined to produce the outcome of multiple exceedances of the scheduled duty time limits. It is unlikely that this same combination of problems would recur. However, the effectiveness of the FRMS is improved by a series of measures that improves the management of staff in the crew office in times of unexpected high workload.

Monthly analyses of exceedances of the scheduled duty time limits specified in the FRMS could consider:

- the total number of Level 1 and Level 2 exceedances;
- the areas of the organization involved in exceedances;
- causes and extenuating circumstances; and
- patterns of overdue submission of reports on exceedances.

The Fatigue Safety Action Group is responsible for developing and implementing any recommended mitigations, in consultation with the team responsible for the FRMS safety assurance processes.

Figure 5-9 describes an example that uses another type of FRMS safety performance indicator — a code incorporated in the rostering software that indicates when a crew member is approaching the limit for maximum allowable monthly flight hours. If the code is set to trigger below the flight hours' limit defined in the FRMS policy, then this provides a buffer that enables some flexibility and reduces the risk of exceedances. In effect, it acts as an alert level.

Each month, the Fatigue Safety Action Group analyses how often the code is activated, i.e., how often crew members are approaching the maximum monthly flight hours, and where this is happening. An increasing trend in code indicates increasing workload for flight crew members and can be due to an increasing number of flights being scheduled, or a reduced number of crew members available to fly them, or both. Seasonal analyses are also undertaken to indicate whether this is a normal cyclical pattern that requires short-term remedial action or a separate upward trend that requires long-term remedial action.

In Example 4, monthly analyses by the Fatigue Safety Action Group have revealed that occurrences of scheduled and actual flight hours triggering the code have increased in July compared with June, for captains at a particular crew base.

*Note.*— It is possible to incorporate a variety of codes in the rostering software to track when different rostering parameters are approaching limits specified in the FRMS. These codes can be separated into categories, for example, by fleet, crew member rank and crew base, and analysed in a variety of ways, including:

- number of times that codes occur for actual versus rostered schedules;
- analysis of which duty or flight hours limit is most frequently approached, and in which part of the operation this is most likely to occur;
- month-by-month trends in numbers of codes occurring;
- rolling 13-month trends (recalculated each month for the last 13 months, to cover a full cycle of seasonal changes);
- longer-term trends, for example, three-yearly trends by crew member rank.

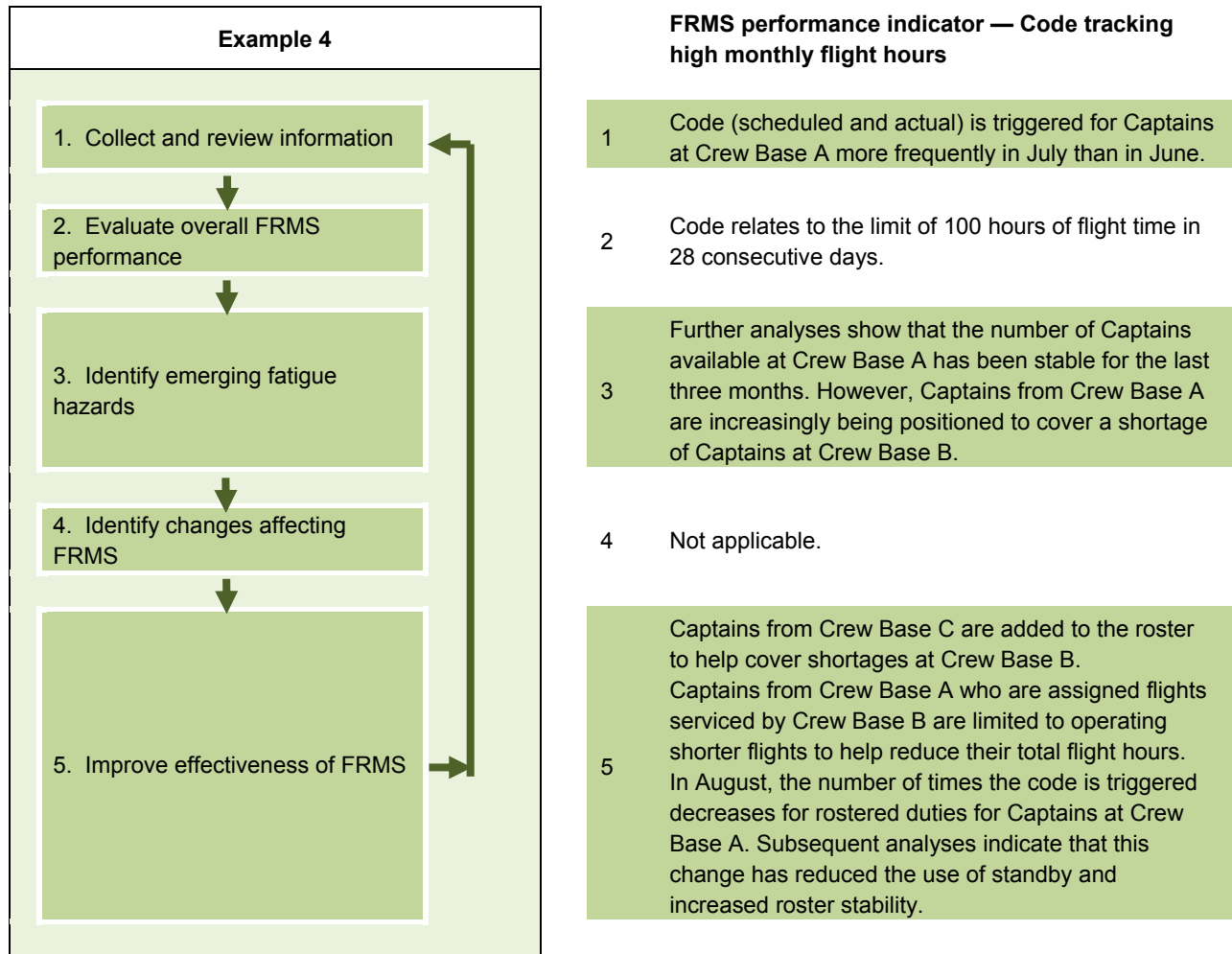


Figure 5-9 FRMS safety assurance processes — Example 4

# Chapter 6. FRMS promotion processes

## 6.1 INTRODUCTION TO FRMS PROMOTION PROCESSES

This chapter details the requirements for FRMS promotion processes that include training programmes and a communication plan. Figure 6-1 outlines the linkages between the FRMS promotion processes and other FRMS components. Along with the FRMS policy and documentation, the FRMS promotion processes support the core operational activities of the FRMS (FRM processes and FRMS safety assurance processes).

Like SMS, FRMS relies on effective communication throughout the operator’s organization<sup>1</sup>. 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, crew members and other stakeholders need to communicate promptly and clearly concerns about fatigue hazards to the Fatigue Safety Action Group or other relevant management.

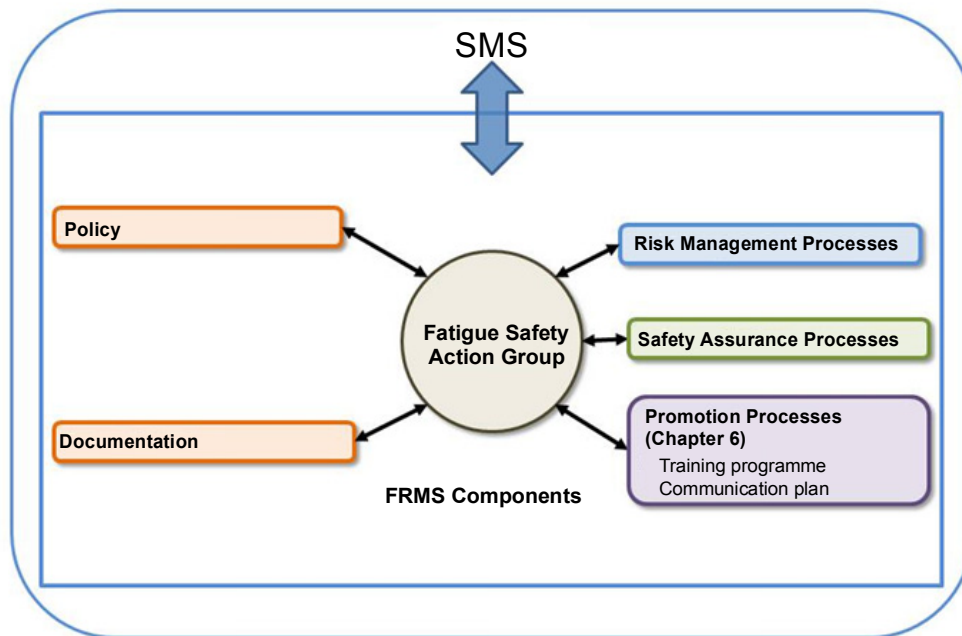


Figure 6-1 Linkages between FRMS promotion processes and other FRMS components

<sup>1</sup> ICAO Safety Management Manual (SMM) (Doc 9859), Section 9.1.

All involved personnel should be trained and competent to undertake their responsibilities in the FRMS, and standards for initial and recurrent training should be specified in the FRMS documentation. A special feature of FRMS training is that key principles of fatigue science — managing sleep and understanding the effects of the circadian body clock — are relevant not only to individuals' roles in the FRMS at work but also to their lives outside of work, for example, in safe motor vehicle driving and in staying healthy. Thus FRMS training covers issues that everyone can identify with, and this can help promote the concept of shared responsibility in an FRMS.

The ICAO requirements for FRMS promotion processes are as follows (Appendix 8 to Annex 6, Part I).

#### **Appendix 8 to Annex 6, Part I**

#### **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 operator as part of its FRMS:

- a) training programmes to ensure competency commensurate with the roles and responsibilities of management, flight and cabin crew, 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.

## **6.2 FRMS TRAINING PROGRAMMES**

In addition to the above requirements, Appendix 8 to ICAO Annex 6, Part I, requires that an operator maintain documentation that describes and records FRMS training programmes, training requirements and attendance records. It further recommends that regulators have competency requirements for FRMS training instructors, who may be part of an operator's internal training department or external contractors.

### **6.2.1 Who needs to be trained**

For an FRMS to be effective, all personnel who contribute to FRMS safety performance need to have appropriate training. This includes crew members, crew schedulers, dispatchers, operational decision-makers, all members of the Fatigue Safety Action Group, and personnel involved in overall operational risk assessment and resource allocation. It also includes senior management, in particular the executive accountable for the FRMS and senior leadership in any department managing operations within the FRMS.

### **6.2.2 Curriculum**

The content of training programmes should be adapted according to the knowledge and skills required for each group to play its part effectively in the FRMS. All groups require basic education about the dynamics of sleep loss and recovery, the effects of the daily cycle of the circadian body clock, the influence of workload, and the ways in which these factors interact with operational demands to produce fatigue (see Chapter 2). In addition, it is useful for all groups to have information on how to manage their personal fatigue and sleep issues.

The ICAO SMS guidance (Doc 9859) recommends a “building-block” approach to training. Applying this approach to FRMS, training for **crew members** could address the following areas:

- an overview of the FRMS structure and how it works in the operator’s organization;
- their responsibilities and those of the operator, in the FRMS, including effective safety reporting;
- 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; and
- basic information on sleep disorders and their treatment, where to seek help if needed, and any requirements relating to fitness to fly.

FRMS training for personnel involved in **crew scheduling** could address the following areas:

- an overview of the FRMS structure and how it works in the operator’s organization, including the concepts of shared responsibility and an effective reporting culture;
- a robust understanding of 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;
- comprehensive training in the use and limitations of any scheduling tools and biomathematical models or other algorithms that may be used to predict the levels of crew member fatigue across schedules and rosters;
- their role in the FRMS in relation to fatigue hazard identification and risk assessment;
- processes and procedures for assessing the potential fatigue impact of planned scheduling changes, and for ensuring that the Fatigue Safety Action Group is engaged early in the planning of changes with significant potential to increase fatigue risk;
- processes and procedures for implementing scheduling changes recommended by the Fatigue Safety Action Group;
- 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; and
- basic information on sleep disorders and their treatment, and where to seek help if needed.

FRMS training for **members of the Fatigue Safety Action Group**, and for others with responsibility for safety decision-making that affects FRMS performance, could address (at least) the following areas.

- a full understanding of all FRMS components and elements (policy and documentation; processes for hazard identification, risk assessment, mitigation, and monitoring; safety assurance processes for monitoring FRMS performance, managing change, and for continuous improvement of the FRMS; and FRMS promotion processes, including training and communication);
- the responsibilities and accountabilities of different stakeholders in the FRMS;
- linkages between the FRMS and parts of the operator’s overall safety management system;

- linkages between the FRMS and other parts of the organization, for example, the scheduling department, flight operations, or the medical department;
- 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; and
- basic information on sleep disorders and their treatment, and where to seek help if needed.

FRMS training for **senior management** could address the following areas.

- an overall understanding of crew member fatigue and the safety risk that it 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 Fatigue Safety Action Group;
- 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 operator's safety management system;
- linkages between the FRMS and other parts of the organization, for example, the scheduling department, flight operations, or the medical department;
- 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; and
- basic information on sleep disorders and their treatment, and where to seek help if needed.

Examples of training materials developed by the NASA Fatigue Countermeasures Program for flight crew in different types of operations are freely available on the internet.<sup>2</sup>

- the original generic training package "Crew Factors in Flight Operations X: Alertness Management in Flight Operations Education Module" is available at:  
[http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20020078410\\_2002126547.pdf](http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20020078410_2002126547.pdf)
- the training package "Crew Factors in Flight Operations XIV: Alertness Management in Regional Flight Operations Education Module" is available at:  
[http://human-factors.arc.nasa.gov/zteam/PDF\\_pubs/REGTEM\\_XIV.pdf](http://human-factors.arc.nasa.gov/zteam/PDF_pubs/REGTEM_XIV.pdf)
- the training package "Crew Factors in Flight Operations XV: Alertness Management in General Aviation Education Module" is available at:  
[http://humanfactors.arc.nasa.gov/publications/B\\_Flight\\_Ops\\_XV\\_GAETM1.pdf](http://humanfactors.arc.nasa.gov/publications/B_Flight_Ops_XV_GAETM1.pdf)

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<sup>2</sup> Web addresses accurate as of January 2012.



These training packages draw on fatigue-related safety data and scientific research. Each package includes a slide presentation with explanatory text. They are designed to be used as a personal resource by crew members and/or as a live presentation that lasts at least an hour. In addition, the Regional and General Aviation Modules include summaries from a number of NASA studies and safety reports. It should be noted that these materials date from 2001-2002 and need to be updated to include more recent safety and scientific data and to reflect current operating conditions. Nevertheless, they provide useful examples of the type and level of information that can be used in initial FRMS training, particularly for flight crew. They are useful examples, but each operator will need to look at how relevant the training materials are for its particular operational needs.

Table 6-1 provides some examples of personal fatigue mitigation strategies that might be covered in FRMS training for flight crew.

**Table 6-1 Examples of fatigue hazards and personal mitigation strategies (not an exhaustive list)**

Fatigue Hazard	Personal Mitigation Strategies
Sleep at home disturbed by new baby	Move to a quiet part of the house for final sleep before departure. Maximize sleep in 24 hours before departure. Controlled rest on the flight deck, maximize sleep during in-flight rest periods (if available). Strategic use of caffeine in flight.
In-flight sleepiness on non-augmented flights	Maximize sleep in 24 hours before departure. Controlled rest on the flight deck, strategic use of caffeine in flight.
Difficulty sleeping in on-board crew rest facilities	Maximize sleep in 24 hours before departure. Use eye mask, ear plugs, arrange a suitable wake-up call. Avoid caffeine for 3-4 hours before trying to sleep. Strategic use of caffeine after in-flight rest period.
Difficulty sleeping in noisy, poorly-curtained rooms in layover hotel	Submit a fatigue report to the Fatigue Safety Action Group. Use eye mask, ear plugs, arrange a suitable wake-up call. Avoid caffeine for 3-4 hours before trying to sleep.
Non-restorative sleep	See a sleep disorders specialist. Comply fully with recommended treatment.
Unpredictable call-outs	Ensure that sleep environment is dark and quiet, and use sleep hygiene measures to maximize sleep quality. Maximize recovery sleep on off-duty days. When feeling sleepy while waiting for call-out, attempt sleep (prioritize sleep over other activities). Controlled rest on the flight deck, maximize sleep during in-flight rest periods (if available) Strategic use of caffeine in flight.
A specific city pairing results in landing when extremely fatigued	Submit a fatigue report to the Fatigue Safety Action Group. Controlled rest on the flight deck. Maximize sleep during in-flight rest periods (if available). Strategic use of caffeine in flight.
Extended commute prior to scheduled flight duty period	Arrive at duty location with sufficient time to allow adequate sleep, ensuring fitness for duty.

### 6.2.3 FRMS training formats and frequency

There are a variety of ways in which FRMS training can be delivered, each of which has strengths and limitations. Live training sessions with a trained instructor have the advantage that crew members can ask questions about their specific issues or concerns and can learn from each other's experiences. Face-to-face contact with different stakeholders in the FRMS can facilitate relationships and information sharing, and foster trust. However, live training requires coordinating a time and place that groups of participants can attend, and involves time getting to and from the venue, in addition to the time required for the actual training session.

Web-based learning or distributed training (for example, using DVDs) allows greater flexibility in the time and place that training occurs. Individual participation allows participants to proceed at their own pace through the training materials. In Web-based learning, sessions can be networked so that multiple participants can join in with a tutor on-line. Material can also be made interactive (a task has to be completed, for example a short quiz answered, before the participant can move on to the next part of the training). Participants and tutors can interact via designated "chat rooms." Web-based learning programmes can also direct participants to explore a variety of other resources available on the internet. On the other hand, it is harder to eliminate "cheating" when learning assessments are completed on-line than when they are completed in a classroom. This may be important for training evaluation (see below).

Providing different materials and formats for recurrent training can help to maintain interest. For example, recent fatigue reports or Fatigue Safety Action Group interventions can be used as case studies to illustrate and revise concepts covered in the initial training material. Recurrent training can also cover changes to the operations or the FRMS, and scientific and regulatory updates. The frequency and nature of recurrent training needs to be decided by the Fatigue Safety Action Group in consultation with professional trainers (internal or external to the operator), as needed. Many regulators may also prescribe requirements on the frequency of FRMS training.

### 6.2.4 FRMS training evaluation

The effectiveness of FRMS training and education programmes should be periodically evaluated. Examples of evaluation tools can include the following:

- To evaluate immediate knowledge transfer from a training session, participants can be given a short quiz assessing fatigue knowledge, to be completed before and after the training session (for an example, see the text box below).
- To evaluate the amount of knowledge retained, the crew members' use of suggested countermeasure strategies, and the perceived usefulness of training, a survey can be conducted at a fixed time after training (for example, six months).
- Findings from the quiz and surveys can be used to:
  - revise the content of the training package, to improve the training on topics which a significant proportion of crew members have not fully understood;
  - provide feedback to trainers on areas where they may need to change or improve their teaching approaches; and
  - identify areas that need to be reviewed or added in recurrent training.

<b>Quiz (for use before and after initial training)</b>	
<b>Are these ideas true or false?</b>	<b>Please tick one box for each question.</b>
1. Sleep is a time when your brain switches off.	<input type="checkbox"/> True <input type="checkbox"/> False
2. Dreaming sleep is better for you than non-dreaming sleep.	<input type="checkbox"/> True <input type="checkbox"/> False
3. In the end, the only way to get rid of sleepiness is to get some sleep.	<input type="checkbox"/> True <input type="checkbox"/> False
4. You can always beat sleepiness, if you try hard enough.	<input type="checkbox"/> True <input type="checkbox"/> False
5. As you get sleepier, your reaction time slows down.	<input type="checkbox"/> True <input type="checkbox"/> False
6. Napping is a sign of laziness.	<input type="checkbox"/> True <input type="checkbox"/> False
7. The circadian body clock adapts easily to sleeping during the day.	<input type="checkbox"/> True <input type="checkbox"/> False
8. There are two times of day when your circadian body clock makes you feel most sleepy, around 3-5 a.m. and 3-5 p.m.	<input type="checkbox"/> True <input type="checkbox"/> False
9. Having a regular routine at bedtime can help you to fall asleep more easily.	<input type="checkbox"/> True <input type="checkbox"/> False
10. A dark, quiet room helps you sleep better.	<input type="checkbox"/> True <input type="checkbox"/> False
11. If you drink too much coffee and cannot sleep, you should drink some alcohol to help you relax.	<input type="checkbox"/> True <input type="checkbox"/> False
12. Even if you are not sleepy, you should start each flight with a cup of coffee, to fight fatigue.	<input type="checkbox"/> True <input type="checkbox"/> False
13. You are in the cockpit and you feel incredibly sleepy. The best thing to do is not to tell anyone and to try extra hard to stay focused.	<input type="checkbox"/> True <input type="checkbox"/> False
14. Fatigue would not be a problem if the schedules were properly designed.	<input type="checkbox"/> True <input type="checkbox"/> False

### 6.2.5 FRMS training documentation

Appendix 8 to ICAO Annex 6, Part I, requires that an operator keep documentation that describes and records FRMS training programmes, training requirements and attendance records.

### 6.3 FRMS COMMUNICATIONS PLAN

Appendix 8 to ICAO Annex 6, Part I, requires an operator 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 FRMS training programmes are clearly an important part of the communication plan. However, training generally occurs at fairly long intervals (for example, annually). 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, and periodic poster campaigns in strategic locations.

Communications about the activities and safety performance of the FRMS (from the Fatigue Safety Action Group or other designated management) need to be clear, timely and credible, i.e., consistent with the facts and with previous statements. 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 is of little relevance to them.

Communications from crew members are vital 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 crew members. There also needs to be clarity about the thresholds that separate non-culpable fatigue-related safety events from deliberate violations that could attract penalties.

Timely feedback to crew members who submit fatigue reports is vital. Feedback does not require completion of a full investigation. Every crew member should receive a timely response to his report with some indication of the planned follow-up activity. For example, “To Capt Smyth; thank you for your fatigue report yesterday regarding flight 123 from AA to ZZ. This report has been forwarded to the Fatigue Safety Action Group, which is currently investigating an adverse trend in fatigue reports associated with this trip and is evaluating a number of potential mitigation strategies.”

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

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## Chapter 7. Deciding to offer FRMS regulations

FRMS requires a performance-based regulatory approach, and any performance-based regulation offers particular challenges to the regulator. Instead of identifying and then monitoring compliance with prescribed requirements, performance-based regulation requires the identification of acceptable performance outcomes and validation of the system by which the outcomes are achieved. This difference in approach necessitates a change in the knowledge base and skill sets of the various individuals involved in developing the regulations and providing the oversight of these systems. It also has implications for the way in which the regulator and the operator interact and on the regulator's resources.

However, according to 4.10.1 of Annex 6, Part I, the regulator does not have to develop FRMS regulations. Only flight and duty time limitation regulations are mandatory. This chapter discusses some of the issues that should be considered in making the decision whether to provide FRMS regulations and when establishing FRMS regulations.

### 7.1 IS THE STATE'S SAFETY OVERSIGHT SYSTEM MATURE ENOUGH?

FRMS has the potential to both improve safety performance and allow increased operational flexibility. For these benefits to be realized, however, appropriate, experienced and knowledgeable regulatory oversight is as essential as effective implementation by the operators, since FRMS is a performance-based approach. Regulators who have not had significant experience with performance-based regulations should consider very carefully whether they have the resources to develop and oversee FRMS regulations.

The State's Lack of Effective Implementation (LEI) measurement, identified through participation in ICAO's Universal Safety Oversight Audit Programme (USOAP), may provide some guidance to States as to their capability to regulate and oversee an FRMS. The USOAP audits focus on the State's capability to provide safety oversight by assessing whether the critical elements of a safety oversight system have been implemented effectively (Refer to ICAO's *Safety Oversight Manual* (Doc 9734) for additional details). Additionally, the LEI measurement is based on the applicable USOAP protocol questions that are not satisfactorily addressed by the State for each critical element. Consequently, the LEI can be used as a measurement of the maturity of the State's oversight system.

A State with a low LEI score (<30 per cent) should already have the following:

- comprehensive regulation in conformity with International Standards
- consistent regulatory oversight
- an effective incident and accident investigation
- employment of a sufficient number of qualified personnel
- consistent compliance with regulatory requirements by the industry
- effective hazards and incidents reporting system
- consistent coordination of Regional Programmes
- effective hazards and incidents reporting and analysis in the industry.

This means that a low LEI State is able to concentrate on the following areas:

- full implementation of its State Safety Programme (SSP)
- use of technology to enhance safety
- continuous improvement of the civil aviation system
- consistent use of Safety Management Systems (SMS) by the industry
- consistent adoption of industry best practices by the industry
- alignment of industry safety strategies.

Effective FRMS regulation demands focus on these areas. States with medium (30–50 per cent) or high LEI (> 50 per cent) scores do not have safety oversight systems mature enough to allow them to focus on these areas and are likely to have difficulty in adequately regulating and overseeing FRMS.

## 7.2 DO WE HAVE ADEQUATE RESOURCES?

New regulatory approaches create an initial, increased regulatory workload. For States, the decision to allow their operators the option of using FRMS will mean establishing performance-based regulations in accordance with the ICAO Standards for FRMS, while continuing to maintain and oversee prescriptive flight and duty limitations. State employees designated to be responsible for the development of FRMS regulations and for the oversight of FRMS will require adequate knowledge, experience and training with regard to fatigue science and FRMS, and they may initially need the support of fatigue scientists/specialists as advisors. A thorough familiarization with this manual is a good start, but further training and information gathering might be necessary and may require consultation with ICAO or with other States with more advanced and mature FRMS regulations and practices.

Detailed planning to determine the tasks required to support regulatory development of FRMS will maximize the opportunity for a State to adopt processes commensurate with resources. In most cases this may warrant initial activity that adopts a gradual and phased approach to developing FRMS regulations, for example, updating prescriptive flight and duty time limitations and developing specialist fatigue knowledge and skills of the inspectorate staff prior to commencement of the FRMS regulatory process.

Detailed planning will provide a better understanding of the workload and how the resources required can best be used. For example, the State may need to prioritize initial applications to use FRMS. Inadequate planning of the State's resources can lead to inefficient regulatory processes due to lengthy delays with operators gaining FRMS approval. To better understand the resources required, States should consider a number of areas to support the regulatory development process. These include, but are not limited to, the following:

- a) the maturity of existing prescriptive flight and duty limitations and the resources required to enhance these limitations to ensure that current scientific principles and knowledge related to fatigue underpin those regulations;
- b) development of specialist fatigue competency requirements (knowledge, skills, experience) for inspectorate staff who will oversee FRMS. This will require development of competency-based training programmes and may also require on-the-job training and instruction (OJTI) to ensure staff are aware of the intricacies of an FRMS from an operational perspective, particularly where staff have had limited operational exposure to fatigue management and/or SMS;
- c) knowledge in the development, design and implementation of training programmes to allow assessment of the efficacy of learning outcomes developed by the operator within its own FRMS training programmes;

- d) the availability of fatigue scientists to provide support with more technical elements of the FRMS such as the limitations of various tools (for example, biomathematical models). Where limited specialists are available, there may be a conflict of interest if the same specialist is supporting the development of State regulations and also providing direct support in developing an operator's FRMS. Limited access to fatigue specialists may also increase the time needed to develop FRMS regulations, train inspectorate staff and limit the number of FRMS applications the State can handle at any given time;
- e) the resources and time required to develop clear guidelines for operators to ensure they understand the State's regulatory processes, timelines (e.g. how long it may take for approval), how the FRMS will be assessed, costs, etc.;
- f) development of tools to provide standardization and support to FRMS surveillance activities, for example, structured questionnaires for inspectorate staff to use with crew members to elicit feedback on their understanding and the effectiveness of the FRMS. These can be useful in determining such things as the level of understanding of fatigue science and the limitations of various FRMS tools;
- g) assessment of the contribution of fatigue in accident and incident investigations. States may need to consider further training of inspectors or rely on the expertise of the local accident investigation agency;
- h) the likely timeframes and resources for ongoing surveillance, for example, reviewing and collating fatigue data provided by the operator, conducting observation flights, interviewing key staff within the FRMS, and reviewing previous State audits to monitor the system over time to provide indicators of system performance.
- i) resources to ensure the State remains up to date with emerging fatigue science, including updates to the regulatory process, inspectorate training, etc.

To meet their FRMS oversight obligations, States will have to establish and maintain a database that identifies what means of fatigue management each operator is using and, where FRMS is being used, to what part(s) of the operation it applies.

### **7.3 IF WE OFFER FRMS, CAN WE PAY LESS ATTENTION TO OUR PRESCRIPTIVE REGULATIONS?**

No. Prescriptive flight and duty time limitations remain a mandatory ICAO requirement. Both flight and duty time limitations and FRMS have their place within the regulatory framework. It is the State's responsibility to develop scientifically-based prescriptive flight and duty time limitation regulations. Guidance on developing scientifically-based prescriptive regulations are provided in Attachment A to Annex 6, Part I.

While FRMS offers significant benefits over prescriptive regulations, both the regulator and operator should not underestimate the workload required in developing guidance material, processing applications and providing suitable oversight to the FRMS. If the prescriptive regulations are not aligned with appropriate fatigue science or they are too restrictive, it could force larger numbers of operators towards FRMS with a significant and potentially unmanageable workload for all parties. The regulator may not be able to process approvals in adequate timeframes to the frustration and commercial detriment of the operator, and the operators may not have access to adequate specialist resources to support development. Robust prescriptive regulations remain an essential element of the regulatory framework.

Further, prescriptive flight and duty time limitations provide the baseline from which the FRMS is assessed in terms of an equivalent level of safety. An FRMS provides the evidence by which a regulator can approve an alternative means of compliance to the prescriptive limitations for managing fatigue.

The regulator must also consider fall-back options should an operator consistently fail to demonstrate appropriate use of an FRMS (see Chapter 9). Well-developed prescriptive regulations remain a viable option to which an operator can be returned should it be unsuccessful in the use of its FRMS.

#### **7.4 WHAT IF THE STATE ALREADY HAS A PROCESS TO APPROVE AN FRMS AND/OR OPERATORS WITH AN APPROVED FRMS?**

It would be necessary for the State to conduct a review of its existing regulations, guidance material, procedures and processes to identify any gaps between existing practices and the ICAO SARPs. It would also be a requirement to review any approved FRMS against the ICAO SARPs to determine whether any critical gaps exist and whether this may be exposing the operator to unacceptable fatigue risk. For example, if there was no evidence the operator had pro-actively collected any fatigue data to further understand the impact of fatigue on any operations being managed by an already approved FRMS, it is possible the operator and the regulator are unaware of the actual impact of fatigue and the potential fatigue risk. Furthermore, without adequate data it would be difficult to meet the requirements of Standard 4.10.6 c) and d) in providing evidence to develop quality assurance processes and to confirm that continuous improvement of the FRMS has occurred.

So, it will also be necessary for the State to identify a process for the operator to amend its current FRMS to comply with the new FRMS requirements. There will also have to be an identified process for managing operators back under prescriptive flight and duty limitation regulations who cannot or will not amend their FRMS as required.

#### **7.5 WHEN SHOULD OPERATORS APPLY FOR A VARIATION AND WHEN SHOULD THEY BE REQUIRED TO IMPLEMENT AN FRMS?**

Standard 4.10.3 of Annex 6, Part I allows for variations to prescriptive flight and duty time limitations in exceptional circumstances without full FRMS requirements. When establishing its regulations, a State will need to clearly identify what constitutes the “exceptional circumstances” for application to a variation, so that a distinction is made between when variations to prescriptive flight and duty time limitations may be sought by an operator and when they are required to implement an FRMS. Variations tend to be short-term in nature, route-specific, and relate to very minor extensions beyond prescriptive regulations. They are approved on the basis of a risk assessment and use of mitigations acceptable to the regulator.

As a minimum, for an individual operator seeking variation without FRMS, the regulator must be assured that:

- a) there is an acceptable focal person(s) or fatigue management subject matter expert within the organization; and
- b) the operator has proven high standards demonstrated through its routine regulatory oversight audits, so that the State has confidence that the operator can correctly manage the variation and the required mitigations.

Where there are pre-existing approved variations, a means for assessing their continued acceptability needs to be identified. Where it is determined that an FRMS is required rather than a variation, a process for transition also needs to be identified.

#### **7.6 HOW WILL WE ASSESS THE ACCEPTABILITY OF THE OPERATOR-PROPOSED OUTER LIMITS OF ITS FRMS?**

States should require that the operator provide a safety case to support the proposed values for outer limits. The decision to accept or deny the proposed outer limits will rely on a variety of factors including:

- whether or not the operator’s safety case is supported by well-established scientific principles and operating experience;
- research findings from multiple studies and different authors;
- operational insights from multiple sources, including all relevant stakeholders;



- demonstrated maturity of the operator's SMS practices and/or demonstrated ability to manage risk appropriately;
- previous history of regulatory compliance of that operator;
- experience gained through regulatory oversight of a variety of operators implementing an FRMS or giving approval of variations to flight and duty time limitation regulations.

Where the operator wishes to use the FRMS in different types of operations (for example, where they operate long-haul and separately operate short-haul), outer limits should be identified for each operation type. For example, an operator's ULR operations may require a maximum value of 22 hours within which the FRMS can function but this does not mean that the same maximum value is an acceptable boundary for its FRMS with regard to its short-haul operations.

It should be kept in mind, however, that overly restrictive outer limits may mean that an operator achieves no extra operational flexibility in implementing an FRMS. There has to be some room for movement to allow the FRMS to function properly. On the other hand, because these values are extreme limits, they cannot be considered as targets. So, the identified maximum flight and duty and minimum rest values should lean to the outer limits of acceptability taking into consideration the types of operations being undertaken, physiological sleep requirements and circadian factors (following Attachment A guidance), although these should be rarely, if ever, reached. When reached or exceeded, these should be documented, trended and reported to the State. Based on these trends, more stringent oversight of the FRMS may be adopted by the regulator (see Chapter 9).

## **7.7 WHAT ARE THE ASPECTS OF AN OPERATION FOR WHICH FRMS OUTER LIMITS HAVE TO BE DETERMINED?**

When identifying the aspects of an operation for which the operator has to identify maximum values for flight and duty periods and minimum values for rest periods, both transient fatigue (fatigue that is dispelled by a single sufficient period of rest or sleep) and cumulative fatigue (incomplete recovery from transient fatigue over a period of time) need to be addressed.

This means that States should require that there are identified outer limits for a day and across multiple days (for example, weekly, monthly, annually). The guidance material for the development of prescriptive fatigue management regulations in Attachment A of Annex 6, Part I can be helpful here. For example, excerpts from Attachment A indicate that limitations should be specified for the following:

...	
4.7.1.1	The maximum flight time may not exceed: <ol style="list-style-type: none"> <li>a) (*) hours in any flight duty period;</li> <li>b) (*) hours in any [7] consecutive days or (*) hours in any [28] consecutive days; and</li> <li>c) (*) hours in any [365] consecutive days.</li> </ol>
...	
4.7.2.1	Duty hours may not exceed: <ol style="list-style-type: none"> <li>a) (*) hours in any [7] consecutive days or in a week; and</li> <li>b) (*) hours in any [28] consecutive days or in a calendar month.</li> </ol>
...	
4.7.3.1	The maximum flight duty period should be (*) hours.
...	
4.8.1	The minimum rest period immediately before commencing a flight duty period may not be less than (*) hours.
...	

## **7.8 WHY DO WE NOT DEVELOP REGULATIONS THAT REQUIRE FRMS TO BE A COMPONENT OF SMS?**

On the face of it, FRMS is simply a clearly-defined, single-focused management system, so it would appear that the functions of an FRMS should just be incorporated into the functions of an SMS. While the SARPs do not preclude such an approach, there are several complex issues that must be considered before regulating for such an organizational structure.

First, despite initial appearances, FRMS and SMS have different functions and focus. FRMS is an optional management system which focuses only on fatigue-related risks. It allows an operator to establish its own flight and duty time limitations as determined by the FRMS risk management and safety assurance processes. SMS is a required management system, which covers mitigation of all operational risks with no focus on one over the other. Unlike FRMS, an SMS does not permit an operator to move outside of prescriptive flight and duty time limitations. So, the particular requirements of an FRMS far exceed what would be expected of an SMS to manage fatigue-related risks. It is important that the focus and functions of an SMS do not override those of an FRMS and vice versa.

Nevertheless, information from an FRMS should inform an operator's SMS, and vice versa (discussed earlier in Chapter 1, under Standard 4.10.7). Therefore, FRMS must be supported by an oversight process that includes examination of the information flow between the FRMS and the SMS. This is discussed in Chapter 9.

Second, regardless of the similarities in framework and their complementary nature, FRMS has an approval process that differs from the process of acceptance for SMS. Having an approved FRMS does not mean that an operator's SMS is automatically accepted, and conversely, the withdrawal of approval of an FRMS does not mean that an operator is absolved of the responsibility of managing its safety risks (including fatigue) through its SMS processes.

## **7.9 THE FRMS PROVISIONS REQUIRE THAT SIGNIFICANT DEVIATIONS IN SCHEDULED AND ACTUAL FLIGHT TIMES, DUTY PERIODS AND REST PERIODS, AND REASONS FOR THOSE SIGNIFICANT DEVIATIONS, BE RECORDED BY OPERATORS. HOW DO WE MONITOR THAT?**

Not every flight that exceeds a scheduled time by a minute, or rest period that is cut short by two minutes, needs to be recorded. The amount of data collection that would require is not only onerous, but unnecessary. The requirement is for the operator to record "significant deviations" that can be used to highlight when there might be increases in fatigue-related risk. This data can provide information that is useful for both the operator and the regulator. The operator can use information provided by analysis of such data to help manage its fatigue-related risks, and the regulator can use the information as a part of its routine monitoring of an FRMS and as a means to identify when an operator must immediately notify the regulator.

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## Chapter 8. The FRMS approval process

Once the State has decided that it will offer FRMS regulations, it will be necessary for the regulator to identify exactly what it expects operators to do throughout the implementation process to gain final approval for an FRMS. The regulator needs to document its requirements in detail. This chapter deals with establishing a **documented** approval process.

### 8.1 A PHASED APPROACH TO FRMS IMPLEMENTATION

There is no “off-the-shelf” version of an FRMS that will suit all operators. Each operator needs to develop an FRMS that is appropriate to its organization and operations and the nature and level of the fatigue risk(s). A fully functioning FRMS does not happen overnight. The FRMS processes take time to plan and develop so the operator needs to implement its FRMS in stages, as is recommended for SMS<sup>1</sup>.

Figure 8-1 summarizes a phased approach to FRMS implementation.

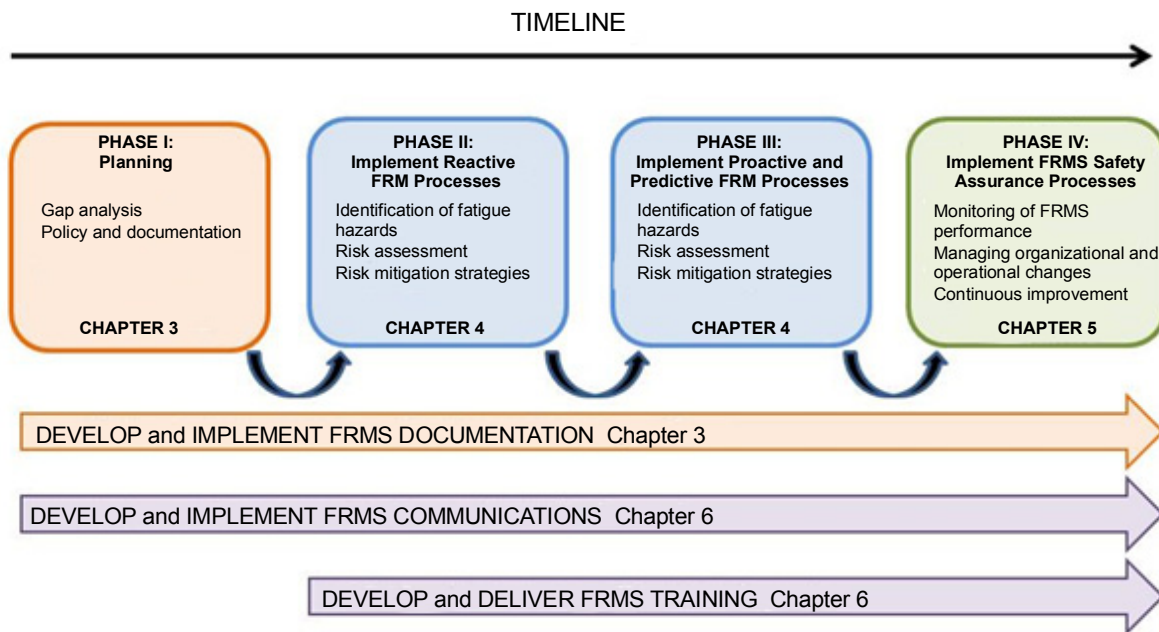


Figure 8-1 Phased approach to FRMS implementation

<sup>1</sup> ICAO's *Safety Management Manual (SMM)* (Doc 9859), Chapter 10.

### 8.1.1 Phase I – Planning

The objective of Phase I is for the operator to arrive at an overall plan to demonstrate to the regulator how the FRMS will function, how it will be integrated with other parts of the operator's organization, who will be accountable for the FRMS, and who will be responsible for making sure that FRMS implementation is successfully completed.

It is recognized that some operators may wish to use outside consultants to "provide them with an FRMS" as a quick and relatively painless way of meeting their regulatory obligations. However, an FRMS requires ownership and commitment by the people who will be using it, and the regulator needs to see evidence of that ownership and commitment from the early stages of its inception. While experts can offer invaluable assistance within an FRMS at certain times, they do not have the operational knowledge and experience of the operator.

Consultants should not be the interface between the regulator and the operator. The relationship between the regulator and the operator concerning the use of FRMS should be identical to their relationship concerning the prescriptive flight and duty time limitation regulations.

#### *Gap analysis and developing an implementation plan*

Many elements needed for an FRMS may already be in place in an operator's organization. One of the first steps in FRMS implementation is therefore for the operator to undertake a gap analysis to:

- identify elements of the FRMS that are already available in existing systems and process;
- identify existing systems and processes that could be modified to meet the needs of FRMS (to minimize "re-inventing the wheel"); and
- identify where new systems and processes need to be developed for the FRMS.

For example, an operator may already have a confidential safety reporting system as part of its SMS. Existing report forms may need to be modified to include the information needed to analyse the role of fatigue in safety events. Additional training may be needed for the staff responsible for analysing safety data to ensure that they know how to analyse for the role of fatigue in events. A procedure will need to be added for information on fatigue-related events to be communicated on a regular basis to the Fatigue Safety Action Group. Fatigue reports may also be used as an FRMS safety performance indicator. In this case, a procedure would need to be added for this information to be evaluated regularly as part of the FRMS safety assurance processes.

Data on scheduled and actual flight and duty times are required to be collected under the prescriptive flight and duty time regulations. An operator that is moving some of its operations into an FRMS could add a variable to the existing flight and duty time databases to identify the operations covered by the FRMS, so that this information can be analysed separately as required for the FRMS (Standard 4.10.8 of Annex 6, Part I). Procedures will need to be added for this information to be communicated to the Fatigue Safety Action Group and recorded as required in the FRMS documentation.

Rostering-related data may already be available for FRMS performance indicators, for example, monthly exceedances on duty limits, use of captain's discretion, use of extended duties, or violation occurrence reports. A procedure will need to be added for this information to be evaluated regularly as part of the FRMS safety assurance processes.

It may be efficient to schedule FRMS training to coincide with other training activities that already bring the target groups together.

The results of the gap analysis are used as the basis for the development of the operator's FRMS implementation plan. Essentially, this provides a road map describing how the development of each of the FRMS processes will proceed, with timelines.

By the end of Phase I, the operator should have:

- 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.
- 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.
- 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 established Fatigue Safety Action Group (or equivalent). The stage at which the Fatigue Safety Action Group is established will vary, according to the size and complexity of the organization and the FRMS, and whether there are suitably qualified people in other parts of the organization who are available to begin the Phase I activities.

In order to move on to Phase II, the operator should be required to provide its FRMS plan to the State for review. This is an opportunity for the State to assess and identify potential problem areas prior to the State or the operator investing excessive time and effort.

### **8.1.2 Phase II – Implement reactive FRM processes**

Phase II requires the operator to implement the (first version) of the FRM processes. It does this by gathering and analysing existing sources of information and data that are relevant to the operations covered by the FRMS. Types of information that may be available include confidential safety reports, accident reports and incident investigations, audits, and historical rostering data (for example, data on scheduled and actual flight and duty times, and exceedances). In effect, Phase II activities consolidate existing fatigue risk management processes and procedures in the organization and introduce controls and mitigations to manage identified deficiencies in the existing system.

By the end of Phase II, the operator should have accomplished the following steps:

- FRM processes based on reactive hazard identification are operational, including risk assessment and the development, implementation and monitoring of appropriate controls and mitigations.
- FRMS documentation processes are established to support the current version of the FRMS.
- FRMS training activities are established to support the current version of the FRMS. (Stakeholders need training to ensure that they are competent to undertake their responsibilities in the FRMS as the implementation plan rolls out.)
- FRMS communication processes are established to support the current version of the FRMS.
- The operator is ready to undertake coordinated safety analyses of this first version of the FRMS, similar to the process used when implementing SMS (ICAO Doc 9859, 10.4).

### **8.1.3 Phase III – Implement proactive and predictive FRM processes**

Phase III adds proactive and predictive fatigue hazard identification processes (discussed in Chapter 4) into the FRM processes established in Phase II.

By the end of Phase III, the operator should have accomplished the following steps:

- FRM processes based on reactive, proactive and predictive hazard identification are operational, including risk assessment and the development, implementation and monitoring of appropriate controls and mitigations.
- FRMS documentation processes are established to support the current version of the FRMS.
- FRMS training activities are established to support the current version of the FRMS. (A single programme to the level required for the full FRMS implementation may be more efficient than partial training at each phase of the implementation.)
- FRMS communication processes are established to support the current version of the FRMS.
- The operator is ready to undertake coordinated safety analyses of this version of the FRMS (ICAO Doc 9859, 10.4).

#### **8.1.4 Phase IV – Implement FRMS safety assurance processes**

Phase IV activates the FRMS safety assurance processes (Chapter 5 of this manual). By the end of Phase IV, the following steps need to be accomplished.

- Roles and responsibilities for assuring the safety performance of the FRMS are established.
- The necessary authorities and communication channels are active.
- FRMS safety performance indicators have been developed and agreed on.
- The procedures and processes for periodic evaluation of the safety performance indicators are established.
- Appropriate feedback is established between the FRM processes and the FRMS safety assurance processes.
- FRMS documentation processes are fully implemented.
- FRMS training processes are fully implemented.
- FRMS communication processes are fully implemented.

In other words, by the end of Phase IV, the FRMS should be fully functional and integrated with the operator's SMS and other parts of the organization, as appropriate. It should be continuously improving and able to respond to changes in the organization and the operating environment.

Regulatory approval for the full FRMS is sought at the end of Phase IV.

#### **8.1.5 Operational example of staged FRMS implementation**

Operator A is a major airline that flies primarily long-range, trans-oceanic flights with multinational crews. It has been flying for 20 years with an excellent safety record. Operator A is interested in starting an FRMS for both of its long-range fleets. The CEO decides to implement FRMS for the entire operation to enhance safety and efficiency.

This example works through the steps that Operator A could follow to establish a fully operational FRMS. It assumes that management at Operator A are familiar with information in the *FRMS Implementation Guide for Operators* (2011, a joint publication by ICAO, IATA, IFALPA) and are ready to start implementation.

*Phase I*

1. Responsibility for FRMS implementation assigned to a designated FRMS manager.
2. FRMS manager assembles an implementation team and organizes training for the team on FRMS basics and fatigue science.
3. Accountable executive for the FRMS allocates resources and authority to support FRMS development.
4. FRMS manager identifies internal stakeholders (department representatives).
5. FRMS policy statement is drafted.
6. Gap analysis undertaken by FRMS manager and implementation team.
7. FRMS documentation plan developed and first draft established.
8. FRMS communication plan developed and first draft established.
9. Implementation plan developed, with initial timeline.
10. Fatigue Safety Action Group established with required stakeholder membership and meets regularly with the implementation team (if different employees) to discuss progress.

*Phase II*

11. Fatigue Safety Action Group works through the FRM process diagram (Chapter 4), using existing information and data for **reactive fatigue hazard identification**.
  - a) Step 1 — Decide whether domestic, international long-haul and ULR operations require different FRM processes. Carry out the following steps for each set of FRM processes.
  - b) Step 2 — Collect and analyse available data and information (for example, confidential safety reports, accident reports and incident investigations, audits, and historical rostering data).
  - c) Step 3 — Identify fatigue hazards(s).
  - d) Step 4 — Establish risk assessment processes and procedures. Clarify linkages to SMS risk assessment and processes for prioritization of risks to be mitigated. (In this large airline example, the FRMS policy statement indicates that the Fatigue Safety Action Group is responsible for prioritizing fatigue risks and for developing, implementing and monitoring fatigue controls and mitigations. It is required to provide monthly reports of these activities to the SMS Safety Review Board, with the intent that this report will become part of the FRMS safety assurance process in the overall FRMS.)
  - e) Step 5 — Select and implement controls and mitigations. Set safety performance indicators.
  - f) Step 6 — Set up processes for monitoring the effectiveness of controls and mitigations.
12. Perform training to ensure that stakeholders are competent to undertake their roles and responsibilities in the FRMS. In this example, it is decided to undertake training to support the full FRMS. Communication channels are set up to provide training updates and reminders when Phases III and IV of the FRMS implementation become active.
13. FRMS communication channels established.

14. Fatigue Safety Action Group provides a coordinated safety analysis of the existing FRMS to the SMS Safety Review Board. (The SMS Safety Review Board is responsible for the FRMS safety assurance functions, in this example.)

#### *Phase III*

15. For each set of FRMS processes established in Phase II, the Fatigue Safety Action Group **identifies appropriate tools for proactive and predictive fatigue hazard identification.**
  - a) Proactive fatigue identification tools are used for assessing routine and complex hazards.
16. Proactive and predictive fatigue hazard identification are integrated in to the FRM processes established in Phase II.
17. All stakeholders have received suitable training and are competent to undertake their roles and responsibilities in the FRMS.
18. FRMS communication channels are operational.
19. Fatigue Safety Action Group provides a coordinated safety analyses of the existing FRMS to the SMS Safety Review Board.

#### *Phase IV*

20. FRMS safety performance indicators are decided collaboratively by the Fatigue Safety Action Group and the SMS Safety Review Board and approved by the accountable executive for the FRMS.
21.
  - Decide which information will be analysed for trends (for example, fatigue reporting rates between similar city pairs, operations, or fleets)
  - Develop criteria for comparing performance with safety objectives (for example, is the overall risk level increasing, is the number of higher risk events increasing, are safety objectives in the FRMS policy being achieved, are regulatory requirements being met).
  - Decide how emerging fatigue hazards are identified. For example, set triggers to identify when action is needed (at what level do adverse trends in performance indicators trigger an investigation of the causes of the trend).
22. Processes are established for identifying changes that could impact the FRMS.
23. Processes are established for evaluating how well Fatigue Safety Action Group recommendations are implemented in other parts of the organization, for example, in scheduling and flight operations.
24. The following safety assurance processes are established.
  - Monthly reporting by the Fatigue Safety Action Group to the SMS Safety Review Board. To include updates on fatigue hazards identified and on the status of agreed safety performance indicators.
  - SMS Safety Review Board is able to call for special reports from the Fatigue Safety Action Group, for example, after significant operational changes such as a newly established route.
  - Quarterly review of trends in confidential crew reports relating to fatigue, to be undertaken by the Fatigue Safety Action Group and reported to the SMS Safety Review Board.



- Quarterly review of trends in exceedances of flight and duty time limits specified in the FRMS Policy, to be undertaken by the Fatigue Safety Action Group and reported to the SMS Safety Review Board.
  - Quarterly review of trends in FRMS safety performance indicators identified in the FRMS policy, to be undertaken by the Fatigue Safety Action Group and reported to the SMS Safety Review Board.
  - Annual review of fatigue hazard identification and mitigation activities of the Fatigue Safety Action Group by an independent FRMS Scientific Advisory Group.
  - Internal audit of the FRMS by a team selected by the SMS Safety Review Board.
  - Annual report of the Fatigue Safety Action Group to the SMS Safety Review Board and the accountable executive for the FRMS, to include the recommendations of the independent FRMS Scientific Advisory Group, findings of audits, and actions taken in response to them.
25. First quarterly audit of FRMS safety performance by the team selected by the SMS Safety Review Board. If audits are satisfactory for one year, internal audit will revert to every six months.
  26. FRMS documentation fully implemented.
  27. FRMS training fully implemented.
  28. FRMS communications fully implemented.

## 8.2 FRMS APPROVAL PROCESS

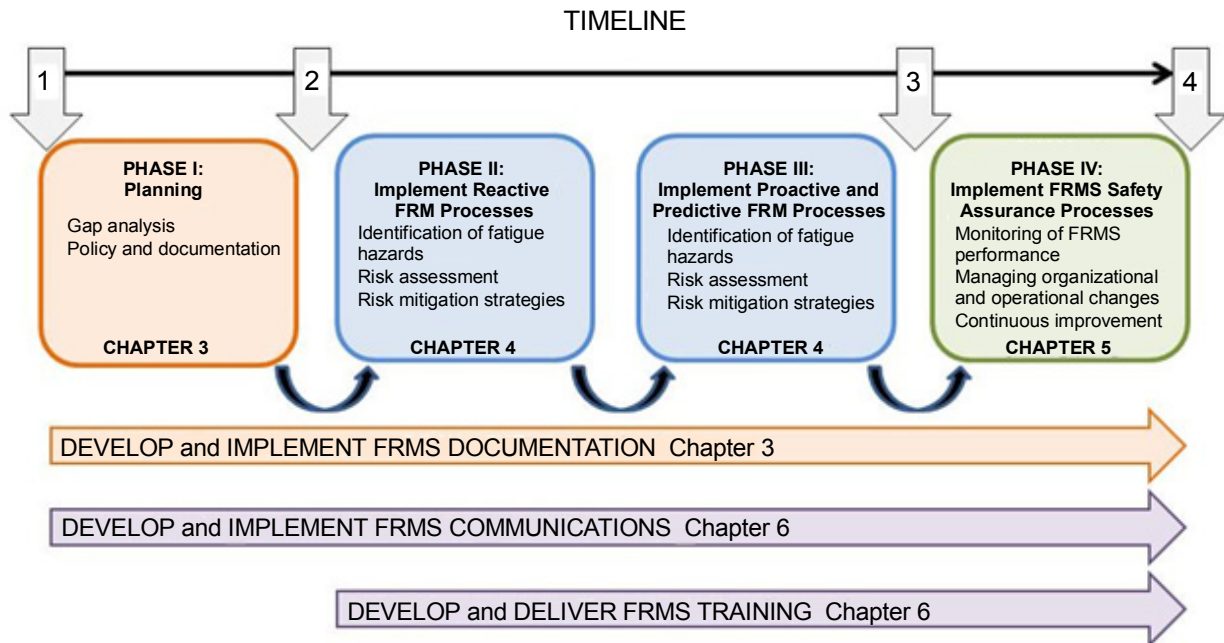


Figure 8-2 The FRMS approval process

The progressive implementation of an FRMS requires a regulatory approval process that monitors and documents its progression.

The regulatory milestones throughout the FRMS approval process are identified at the arrow points in Figure 8-2. All of these need to be achieved before final approval of the FRMS can be given.

To gain full approval, an FRMS for a large and complex operator is likely to take several years, so that enough time has elapsed to allow assessment of safety assurance functions. However, the regulator can still allow the operator to use FRM processes to move beyond prescribed flight and duty time limitations on a trial basis in order that the safety assurance functions can be developed.

Suggested documentation to be completed by the regulator during the course of the approval process is highlighted in each of the sections below. All of the information and evidence collected by the regulator during the approval process contributes to the overall assessment when deciding to grant final approval of the FRMS.

### **8.2.1 Regulatory Milestone 1 – Notification by the operator**

Throughout the progressive implementation of an FRMS there should be contact between the regulator and the operator, starting from the time the operator begins the implementation process. Such early interaction helps establish an open and informed working relationship between the regulator and the operator and allows the regulator to provide clear indication of its expectations and requirements.

One way the regulator can encourage early contact with an operator planning to develop an FRMS is to require written notification of intent. Some States may simply require a letter from the operator stating its intentions, while others may use a more formal application such as a “Notice of Proposed Amendment.” The regulator may also choose to meet the operator face-to-face to discuss its plans.

At this point, the regulator may expect that the operator has already undertaken some preparatory actions. These may include:

- designation of a specific organizational manager(s) with proper authority;
- ensuring that a key person(s) has gained or is gaining adequate knowledge;
- allocation of resources to support FRMS development.

Once initial contact has been established by the operator, the regulator should then provide the operator with a detailed checklist of its regulatory requirements for an FRMS. While necessarily detailed, this checklist should allow the operator flexibility in the way it can meet these requirements. Developing such a detailed checklist takes time and effort but once achieved it provides a key tool for both the operator and the regulator. It will form the basis of the operator’s GAP analysis, required as part of the development of its FRMS implementation plan. For the regulator, it forms the first part of the subsequent audit processes for both approval and oversight purposes. An outline of the checklist items for each of the subsequent regulatory milestones is discussed below.

### **8.2.2 Regulatory Milestone 2 – Review of FRMS plan, policy and documentation**

Based upon the FRMS checklist developed earlier, the regulator can develop a more comprehensive tool that can be used to record where each required component of the FRMS has been documented in the operator’s procedures, the method used by the operator to demonstrate compliance with the required FRMS components, and any regulator comments on the operator’s proposal. Again, development of such a tool (referred to here as the FRMS evaluation form) takes time and effort but is a worthwhile investment given that the resulting document becomes the primary oversight tool. An example of an FRMS evaluation form is provided in Appendix C.

## **Regulatory documentation**

### **1. Review of FRMS plan**

The regulator should review the operator's implementation plan, including the GAP analysis, the operations to which the FRMS is intended to be applied, the key personnel involved and the expected timelines, to allow early detection of any areas needing improvement in the operator's ability to implement an FRMS prior to the State or the operator investing excessive time and effort.

A positive review of the FRMS implementation plan means that the regulator has been provided with evidence that the operator understands what is required.

*Regulatory checklist:*

<b>Checklist for Review of FRMS Implementation Plan</b>
<ul style="list-style-type: none"> <li>• Reflects a commitment to an effective safety reporting culture;</li> <li>• Defines the safety objectives of the FRMS;</li> <li>• Defines roles and responsibilities for all stakeholders in the FRMS, including identifying the accountable executive;</li> <li>• Identifies to what specific operations the implementation plans pertain;</li> <li>• Identifies an overall timeline for seeking final approval.</li> </ul>
<ul style="list-style-type: none"> <li>• Plan for the development of documentation (Chapter 3)               <ul style="list-style-type: none"> <li>– Milestones</li> <li>– Method</li> </ul> </li> </ul>
<ul style="list-style-type: none"> <li>• Plan for the development of FRM processes (Chapter 4)               <ul style="list-style-type: none"> <li>– Milestones</li> <li>– Method</li> </ul> </li> </ul>
<ul style="list-style-type: none"> <li>• Plan for the development of FRMS safety assurance processes (Chapter 5)               <ul style="list-style-type: none"> <li>– Milestones</li> <li>– Method</li> </ul> </li> </ul>
<ul style="list-style-type: none"> <li>• Plan for the development of FRMS training (Chapter 6)               <ul style="list-style-type: none"> <li>– Milestones</li> <li>– Method</li> </ul> </li> </ul>
<ul style="list-style-type: none"> <li>• Plan for the development of FRMS communication procedures and processes (Chapter 6, 6.3)               <ul style="list-style-type: none"> <li>– Milestones</li> <li>– Method</li> </ul> </li> </ul>

### **2. Review of the initial FRMS policy and documentation proposal**

Using the FRMS evaluation form (mentioned above), the regulator should conduct a desktop review of the policy and documentation to determine whether the operator's initial FRMS policy and documentation proposal adequately addresses the regulatory requirements. This will include evaluating:

- policy content;
- the organizational structure;
- the risk-based deviation recording process that will document the extent and reason for significant exceedances of scheduled flight and duty periods, significant reductions of rest periods; and significant numbers of uses of the captain's authority to complete the flight period;

- the proposed fatigue risk assessment process;
- the proposed safety assurance process;
- integration processes with the safety department;
- quality control audit procedures;
- initial training plan and procedures (including fatigue reporting);
- terms of reference for the Fatigue Safety Action Group;
- details of the safety promotion activities; and
- methods for monitoring and managing changes to the FRMS.

The regulator may also wish to conduct some documented interviews of key personnel involved with the development of the implementation plan to check the level of organizational knowledge and commitment to the plan.

A positive review of the FRMS policy and documentation proposal means that the regulator has been provided with evidence that the operator has a commitment to meet these requirements of implementing an FRMS.

*Regulatory checklist:*

<b>Checklist for review of the initial FRMS policy and documentation (Chapter 3)</b>
<ul style="list-style-type: none"> <li>• An FRMS policy is in place.</li> <li>• The FRMS policy reflects organizational commitments regarding fatigue risk management.</li> <li>• The FRMS policy includes a clear statement about the provision of the necessary resources for the implementation of the policy.</li> <li>• FRMS reporting procedures are identified.</li> <li>• There is clear indication of which types of operational behaviours are unacceptable within the context of the FRMS.</li> <li>• The conditions under which disciplinary action would apply are clearly identified in the context of the FRMS.</li> <li>• The policy is communicated, with visible endorsement, throughout the organization.</li> <li>• The accountable executive, who has ultimate responsibility and accountability for the implementation and maintenance of the FRMS and full control of the necessary resources, is identified.</li> </ul>
<ul style="list-style-type: none"> <li>• Delivery of initial documentation including:               <ul style="list-style-type: none"> <li>– FRM processes</li> <li>– FRMS safety assurance processes</li> <li>– FRMS training</li> <li>– FRMS communication procedures and processes</li> </ul> </li> </ul>

### **8.2.3 Regulatory Milestone 3 – Review of initial FRM processes**

Once the plan for the development of the FRMS and the policy and documentation proposal have been positively reviewed, the operator can begin implementing the FRM processes. This incorporates Phases II and III of the operator's implementation process and may take a significant period of time and may require several meetings with the operator.

To achieve the third milestone of the regulatory process, the regulator:

1. reviews the operator's reactive risk assessment process, including the tools used, such as the fatigue hazard log, how the risk matrix was developed and the use of the agreed upon severity and likelihood measures, the methodology for the development of mitigation strategies, fatigue report procedures, any crew surveys, and Fatigue Safety Action Group meeting minutes;
2. reviews the proactive and predictive hazard identification processes, including assessment of agreed fatigue roster metrics, any information from biomathematical modeling, development of FRMS performance indicators and their targets, supporting scientific documentation, Fatigue Safety Action Group meeting minutes, other operational best practices, the fatigue hazard log, and further proposed mitigations to reduce the risk;
3. reviews the results of all the risk assessment processes (reactive, proactive and predictive) and agrees on initial FRMS performance indicators and targets;
4. directly samples some of the records quoted in the risk assessment and assesses the operator's procedures against supplied risk assessments;
5. conducts the final review of the initial training programme and training records (and may possibly attend one of the initial training courses). The regulator will need to review the training proposals for the operator's employees to check that they cover both generic fatigue material and operation-specific FRMS aspects. Training will need to be given in a proportionate manner to the employee groups' involvement in the FRMS. As part of the training programme, all employees who are involved with the fatigue reporting system need to be specifically trained on how the system works, how they use the system information, and at what point an individual would need to be further assessed due to trends in his filed fatigue reports. The regulator may choose to attend a training session rather than just review the training material and/or syllabus.
6. conducts documented interviews with a selection of employees from all the areas involved with the FRMS, and may involve other regulator experts or resources (both internal and external to the State) as part of its review of the information;
7. reviews the outer limits for the proposed FRMS operation and adjusts them accordingly if there is insufficient evidence to support the case;
8. produces an audit report and, where necessary, a list of corrective actions.

If the operator is required by the regulator to make corrective actions, the regulator should agree to an action plan to make these corrections. Once the operator has taken the corrective actions, the regulator will need to go back into the above process at the relevant point and produce an audit closure report.

Where no corrective actions are necessary, or once corrective actions are complete, the regulator may then permit the operator to trial the proposed FRMS operations within the newly agreed outer limits. At this point, the FRMS does not have final approval as the safety assurance processes have not yet been implemented.

*Regulatory checklist:*

General Requirements
<ul style="list-style-type: none"> <li>• Establishment of FSAG               <ul style="list-style-type: none"> <li>– Appointment of FSAG members.</li> <li>– Appointment of a qualified person to manage and oversee the functions of the FSAG.</li> <li>– All FSAG members fulfil the required job functions and responsibilities.</li> </ul> </li> <li>• Establishment of outer limits (maximum values for flight times and/or flight duty period(s) and duty period(s), and minimum values for rest periods).</li> <li>• Maintenance of records of flight time, flight duty periods, duty periods and rest periods.</li> </ul>
Validation of initial FRM processes (Chapter 4)
<ul style="list-style-type: none"> <li>• An effective fatigue reporting system is in place.</li> <li>• The operations covered by each set of FRMS processes are identified (4.2).</li> <li>• Data and information are collected (4.3, 4.4).</li> <li>• Hazards are identified (4.4).</li> <li>• Risk assessments are undertaken and documented (4.5).</li> <li>• Appropriate risk mitigation is undertaken (4.6).</li> <li>• There is a demonstrable information flow between the FRMS and other safety systems (e.g. their SMS through the Safety Action Group meetings or their safety department).</li> </ul>
Validation of initial FRMS promotion processes (Chapter 6)
<ul style="list-style-type: none"> <li>• Training plan implemented (6.2) with personnel involved in FRMS displaying required level of knowledge of sleep and fatigue, and their responsibilities and procedural requirements in relation to the FRMS.</li> <li>• Training records maintained (6.3).</li> <li>• FRMS-related information is disseminated in a timely manner to all necessary stakeholders.</li> </ul>

#### **8.2.4 Regulatory Milestone 4 – Approval of FRMS**

Before final approval of the FRMS can be given, evidence must demonstrate that the FRMS is delivering the required safety outcomes. The operator now needs to validate the safety assurance processes and demonstrate a fully functioning FRMS within the agreed outer limits, which may be outside of the prescriptive limitations. Validation of the safety assurance processes will take time, and this will require the regulator to conduct regular visits, desktop reviews of sample data, analyses of documentation, and interviews of key personnel. All of the components of an FRMS, including the safety assurance processes, need to be functioning in a coordinated way within the operator's overall safety processes. During this trial period, the regulator needs to be closely monitoring all activities.

Importantly, the regulator needs to identify a time limit for the course of this trial period. While adequate time needs to be given to allow the operator to demonstrate that all components of an FRMS (including the safety assurance processes) are functioning, an operator cannot be allowed to operate outside of the prescriptive limits for an indefinite period. Protracted trial periods diminish the value of having an approved FRMS, if an operator can continue using an "FRMS in progress" that is not actively trying to meet approval requirements.

The operator will need to demonstrate that its FRMS safety assurance processes are used to review the FRMS performance indicators against its agreed targets and can identify and undertake any necessary actions. Where trends demonstrate that either the mitigations or the outer limits are not appropriate to achieve the safety performance targets, or where changes affecting the overall FRMS are detected by the safety assurance processes, the failing areas of the FRMS operation(s) are reassessed through the FRM processes.

These processes are documented and form part of the Fatigue Safety Action Group review of the system and are recorded in the minutes. The functioning of the Fatigue Safety Action Group must also demonstrate the identification and management of any new fatigue hazards and its subsequent risk assessment and management. The assurance functions monitor the

effectiveness of the mitigations and suitability of the outer limits of the FRMS. The whole system will also be internally audited to check the procedures are being correctly applied and the effectiveness of risk mitigations and assumptions made. These audits must be documented.

During the course of this trial period, the regulator will have the opportunity to gain confidence in the operator's ability to respond appropriately to the data being collected and should be supplied with evidence that the operator is managing its fatigue risk appropriately. This should include the monitoring of the operator's safety performance after any changes. In some cases, the regulator may have observed the operator lowering flight and duty times that would otherwise be permitted using prescribed limitations using its FRMS processes.

In this final phase prior to approval, the operator will also have demonstrated that it has added effective recurrent training into its training programme. Further, the regulator should ensure that all initial training as identified in the accepted implementation plan has been completed prior to final approval of the FRMS.

Still using the FRMS evaluation form, the regulator should then conduct the final audit of the operator's FRMS. By now, this evaluation form documents the progress made by the operator throughout the approval process. At the final approval audit, the regulator should examine evidence of the operator's FRMS safety assurance functions by reviewing the agreed FRMS performance targets and assessing any trends. It should also check that the system has been subject to internal auditing of the processes. The regulator may choose to audit some of the primary sources of input into the system (for example, fatigue reports). However, the regulator will need to be mindful of the confidential nature of some of the methods of reporting (such as fatigue reports) examining such reports only to confirm the operator's assessment of trends. The integrity of the operator's effective safety reporting system, and the maintenance of reporter confidentiality that is required to support it, should be a priority for the regulator. The regulator should expect the operator to have already documented trends and re-evaluated the fatigue-related risk using the risk assessment functions.

The regulator should also conduct a review of the operator's final documentation and procedures to ensure required corrections or additions have been made. Finally, it should review the final training package, including the recurrent training programme.

Once all the criteria in each of the steps have been met, and all of the FRMS processes are functioning in a cohesive manner with regard to the specific operations to which they have been applied, approval can be given. This means that the operator is no longer on a trial period and may now use the FRMS to adjust flight and duty hours within the approved outer limits **for the particular operations identified**. Any changes to the scope of the FRMS cannot be implemented without regulatory approval for its application to new operations.

The following table provides a checklist of the general requirements for validating the safety assurance processes.

*Regulatory checklist:*

Validation of FRMS safety assurance processes (Chapter 5)
<ul style="list-style-type: none"> <li>• Safety performance indicators are identified and acceptable to the regulator (5.2).</li> <li>• The safety performance of the FRMS is monitored through monitoring of trends in safety performance indicators (5.2, 5.3).</li> <li>• Mitigations and controls are changed where necessary in response to the findings (5.3, 5.4).</li> <li>• There is an existing process for identifying and managing changes that affect the FRMS (5.5).</li> <li>• There is an existing process for continual improvement of the FRMS.</li> </ul>
<ul style="list-style-type: none"> <li>• Review final FRMS documentation, including:               <ul style="list-style-type: none"> <li>– FRM processes</li> <li>– FRMS safety assurance processes</li> <li>– FRMS training (including recurrent training programme)</li> <li>– FRMS communication procedures and processes</li> </ul> </li> </ul>

The final part of the approval process will be for the regulator to set up the ongoing audit requirements and the audit calendar. As part of this, the regulator may require that the operator send monthly updates (or another designated period of time) of trends on all or some of the agreed FRMS performance indicators.

In the same way that normal oversight audit functions are recorded, regulators will need to ensure that where an operator uses an FRMS, it has an adequate record-keeping process. These records will store the outcomes, findings and rectification notifications of the approval process and ongoing oversight.

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## Chapter 9. Oversight of an FRMS

Once approval of an operator's FRMS has been given, it is the State's responsibility to continue monitoring the effectiveness of the FRMS, that it complies with the regulations, and that it demonstrates an acceptable level of performance. Organizational conditions change, and many, such as external pressures on the operator, economic issues, and the overall performance of the operator, may have consequences for the effectiveness of the FRMS. Therefore, after final approval, the oversight of the FRMS forms part of the regulator's periodic surveillance programme of the operator.

### 9.1 REGULATORY PLANNING FUNCTIONS

In order to ensure appropriate levels of oversight, formal audits will need to be planned. Consideration will need to be given to:

- *Establishing an FRMS audit/inspection schedule as part of the oversight programme.*  
The regulator will need to visit the operator at least once a year. Ad hoc visits could also be made and, as part of the oversight, the regulator may also wish to have more frequent documentation sent to it by the operator.
- *Inspectorate resources.*  
Inspectors need to have knowledge of fatigue science (see Chapter 6), experience in regulating FRMS, as well as practical knowledge of the operator.

### 9.2 SPECIAL REQUIREMENTS FOR FRMS OVERSIGHT

In overseeing the operator's FRMS, the regulator will examine evidence of the operator's FRMS safety assurance functions by reviewing the agreed FRMS performance targets and assessing any trends. It will also check that the system has been subject to internal auditing of the processes. The regulator may choose to audit some of the primary sources of input into the system (for example, fatigue reports). It will need to confirm that the operator is documenting trends and, where necessary, is identifying potentially adverse trends and managing them appropriately as part of the risk assessment functions. The regulator will also conduct a review of the operator's documentation and procedures to assess any corrections or additions that have been made post-approval. It will also review the current training package, including all staff training records.

As part of normal oversight, the regulator will conduct interviews with a variety of people involved with the FRMS and monitor changes of key FRMS personnel. Where key personnel have changed, the regulator should seek to ensure the new personnel are included in its list of interviewees. Occasionally, a State inspector might also ask to attend an operator's Fatigue Safety Action Group meeting to gain better insight in its FRMS processes, although the inspector cannot be part of the Fatigue Safety Action Group activities.

The regulator is seeking to ensure that all of the FRMS processes are functioning in a cohesive manner with regard to the specific operations to which they have been applied.

*Regulatory checklist:*

Oversight of an FRMS
<ul style="list-style-type: none"> <li>• FRMS performance indicator and target review</li> <li>• Targeted sampling of records and documentation</li> <li>• Documented interviews</li> <li>• Continuous reporting</li> <li>• Attendance at meetings, training sessions</li> <li>• Evidence of information flow between SMS and FRMS</li> <li>• Fatigue Safety Action Group               <ul style="list-style-type: none"> <li>– Review of hazard log</li> <li>– Review of meeting minutes</li> </ul> </li> <li>• Collection of information from external sources, e.g. scientific reviews, experience gained from oversight of other operators' FRMSs.</li> <li>• Reviewing outer limits</li> <li>• Reviewing flight and duty time limitations identified within the FRMS operations</li> <li>• Assess management of changes, for example,               <ul style="list-style-type: none"> <li>– The operations to which the FRMS applies</li> <li>– Key personnel</li> </ul> </li> </ul>

**9.3 ENFORCEMENT**

Regulators will need to establish a process to be used when deficiencies in an FRMS are identified. Enforcement actions should be commensurate 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.

The three enforcement alternatives in increasing severity are:

- *Operator on notice to improve FRMS processes:*  
Where the State's oversight produces concerns that the operator's FRMS may not meet regulatory requirements, then the operator should first be given an opportunity to improve the specific aspects of its FRMS so that it does meet regulatory requirements. Based on the findings of the audit process, the regulator will need to provide advice to the operator and identify a mutually-agreed corrective action plan.
  - *Regulator-mandated lowering of maximum values (and/or increasing minimum values):*  
Where the State's oversight produces concerns that an element of an operator's FRMS may be ineffective, the State may need to revise an operator's maximum and minimum values. These regulator-set limits should remain in place until the operator can provide evidence that its FRMS processes are effective and the State has regained regulatory confidence in the operator.
  - *Withdrawal of FRMS approval:*  
Where there is a significant safety concern that has not been addressed by the above enforcement alternatives, it is the State's obligation to withdraw the FRMS approval and require the operator to operate within prescriptive flight and duty limitations. While complying with the prescriptive flight and duty limitations, the operator may attempt to improve its FRMS processes and other safety systems and SMS processes, in order to re-establish regulatory confidence and re-apply for FRMS approval. Should the State consider that the operator's FRMS meets its requirements at this point, the State may approve the FRMS on restricted conditions (for example, decreased maximum values for flight and duty periods and minimum values for rest periods) until such time as it is confident of the maturity and effectiveness of the system.
-

## Appendix A. Measuring crew member fatigue

FRM processes (Chapter 4) and FRMS safety assurance processes (Chapter 5) sometimes require the measurement of crew member 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 be sensitive for measuring what they claim to measure (that is, they have been scientifically validated);
- they do not jeopardize crew members’ 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, operators, crew members 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.

### A-1. Crew members’ recall of fatigue

#### A-1.1 Fatigue reporting forms

Fatigue reports allow individual crew members to give vital feedback on fatigue risks where and when they occur in an operation. Crew members are encouraged to do this through an effective reporting system (see ICAO Doc 9859). It is necessary to provide a clear understanding of the 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. Crew members also need to be confident that reports will be acted on, which requires feedback from the Fatigue Safety Action Group, and they need to be assured that the intent of the reporting process is to improve safety, not to attribute blame. A series of fatigue reports on a particular route can be a trigger for further investigation by the Fatigue Safety Action Group.

Fatigue report forms need to be easy to access, complete, and submit. Consideration should be given to making fatigue report forms available for completion electronically, for example, on laptop computers or smart phones (iPod, Blackberry, etc.). The example Fatigue Report Form provided below is adapted from one that has been routinely used in an operator’s FRMS for more than ten years.

When fatigue report forms are first introduced, or other 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 FRMS safety performance indicators may need to be evaluated to decide whether the increase in reporting should trigger further action by the Fatigue Safety Action Group.

### Fatigue Report Form — EXAMPLE

If confidentiality required tick here

Name  Employee No.  Pilot/CCM  (circle)

**WHEN DID IT HAPPEN?**

Local report date  Time of event (local report time)

Duty description (trip pattern)

Sector on which fatigue occurred From  To

Hours from report time to when fatigue occurred  Disrupt? Yes / No

Aircraft type  Number of crew

**WHAT HAPPENED?**

Describe how you felt (or what you observed)

Please circle how you felt

- |   |  |
|---|--|
| 1 Fully alert, wide awake                           | 5 Moderately let down, tired                     |
| 2 Very lively, somewhat responsive, but not at peak |  |
| 3 OK, somewhat fresh                                | 6 Extremely tired, very difficult to concentrate |
| 4 A little tired, less than fresh                   | 7 Completely exhausted                           |

Please mark the line below with an 'X' at the point that indicates how you felt

alert ----- drowsy

**WHY DID IT HAPPEN?**

Fatigue prior to duty?	Yes / No	How long had you been awake when the event happened?	hours	mins
Hotel	Yes / No	How much sleep did you have in the <u>24 hours</u> before the event?	hours	mins
Home	Yes / No	How much sleep did you have in the <u>72 hours</u> before the event?	hours	mins
Duty itself	Yes / No			
In-flight rest	Yes / No			
Disrupt	Yes / No			
Personal	Yes / No	flight deck nap? Yes / No	If yes, when	start end
Other comments				

**WHAT DID YOU DO?**

Actions taken to manage or reduce fatigue (for example, flight deck nap)

**WHAT COULD BE DONE?**

Suggested corrective actions

### A-1.2 Retrospective surveys

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

- demographics (age, flying experience, gender, etc.);
- amount and quality of sleep at home and on trips;
- 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 crew members to be compared across time or with other groups.<sup>1</sup> For example, the Epworth Sleepiness Scale is a validated tool for measuring the impact of sleepiness on daily life. It is widely used clinically to evaluate whether an individual is experiencing excessive sleepiness,<sup>2</sup> and information is available on its distribution in large community samples.<sup>3</sup> Figure A-1 shows the Epworth Sleepiness scale. The crew member 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.

<b>How likely are you to doze off or fall asleep in the following situations, in contrast to feeling just tired?</b>				
This refers to your usual way of life in recent times.		PLEASE TICK ONE BOX ON EACH LINE		
	<i>Would never doze</i>	<i>Slight chance</i>	<i>Moderate chance</i>	<i>High chance</i>
Sitting and reading	0 <input type="checkbox"/>	1 <input type="checkbox"/>	2 <input type="checkbox"/>	3 <input type="checkbox"/>
Watching television	0 <input type="checkbox"/>	1 <input type="checkbox"/>	2 <input type="checkbox"/>	3 <input type="checkbox"/>
Sitting inactive in a public place (e.g. theatre, meeting)	0 <input type="checkbox"/>	1 <input type="checkbox"/>	2 <input type="checkbox"/>	3 <input type="checkbox"/>
As a passenger in a car for an hour without a break	0 <input type="checkbox"/>	1 <input type="checkbox"/>	2 <input type="checkbox"/>	3 <input type="checkbox"/>
Lying down in the afternoon when circumstances permit	0 <input type="checkbox"/>	1 <input type="checkbox"/>	2 <input type="checkbox"/>	3 <input type="checkbox"/>
Sitting and talking to someone	0 <input type="checkbox"/>	1 <input type="checkbox"/>	2 <input type="checkbox"/>	3 <input type="checkbox"/>
Sitting quietly after a lunch <i>without</i> alcohol	0 <input type="checkbox"/>	1 <input type="checkbox"/>	2 <input type="checkbox"/>	3 <input type="checkbox"/>
In a car, while stopped for a few minutes in traffic	0 <input type="checkbox"/>	1 <input type="checkbox"/>	2 <input type="checkbox"/>	3 <input type="checkbox"/>

**Figure A-1 The Epworth Sleepiness Scale**

Retrospective surveys can also be used to track the effectiveness of an FRMS across time (i.e., as an FRMS safety assurance process — see Figure 5-3).

1 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 now.

2 Johns M.W., “Sleepiness in different situations measured by the Epworth Sleepiness Scale,” *Sleep*, 1994, Vol. 17, pp. 703-10.

3 Gander P.H., Marshall N.S., Harris R., Reid P., “The Epworth sleepiness score: Influence of age, ethnicity and socioeconomic deprivation,” *Sleep*, 2005, Vol. 28, pp. 249-53.

### **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 and analysing it.

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 crew members' integrity — inaccurate recall of past events is a common and complex human problem. Concerns about whether some crew members might exaggerate in their responses, 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.

Crew members' 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.

## **A-2. Monitoring crew member fatigue during flight operations**

### **A-2.1 Subjective fatigue and sleepiness ratings**

The following things should be considered when choosing rating scales for monitoring crew member fatigue and sleepiness during flight operations.

1. Is the scale quick and easy to complete?
2. Is it designed to be completed at multiple time points, e.g., across a flight?
3. 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?
4. Is it predictive of objective measures such as performance or motor vehicle crash risk?
5. Has it been used in other aviation operations, and are the data available to compare fatigue levels?

The following two scales meet these criteria.

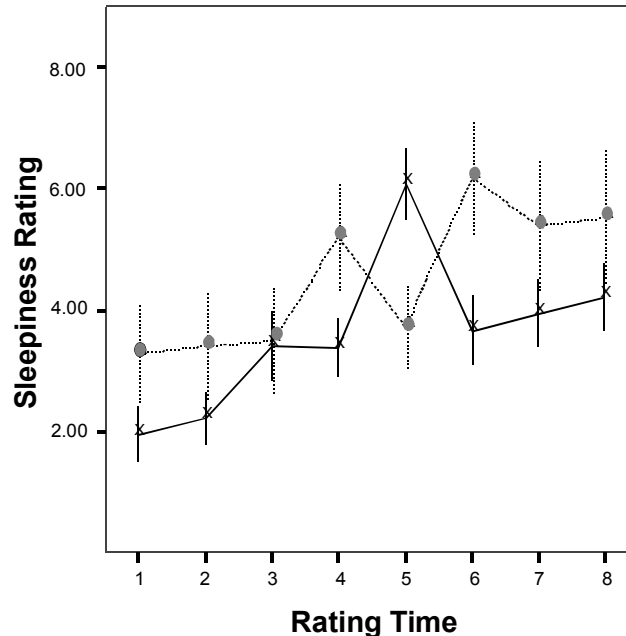
#### ***The Karolinska Sleepiness Scale (KSS)***

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

**Figure A-2 The Karolinska Sleepiness Scale (KSS)**

This scale asks people to rate how sleepy they feel right now.<sup>4</sup> Any of the values from 1 to 9 can be ticked, not only those with a verbal description.

Figure A-3 shows KSS ratings from 25 flight crew members across ultra-long range flights from Singapore to Los Angeles.<sup>5</sup>



**Figure A-3 KSS sleepiness ratings on flights from Singapore to Los Angeles**  
**Solid line: data for the command crew**  
**Dotted line: data for the relief crew**

Each flight had two crews (two captains, two first officers). The command crew (solid line) flew both the take-off and the landing and was allocated the second and fourth in-flight rest periods. The relief crew (dotted line) was allocated the first and third 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 first in-flight rest period;
- rating 4 – after each crew member's first in-flight rest period;
- rating 5 – before each crew member's second in-flight rest period;
- rating 6 – after each crew member's second in-flight rest period;

<sup>4</sup> Åkerstedt, T., Gillberg, M., "Subjective and objective sleepiness in the active individual," *International Journal of Neuroscience*, May 1990, Vol. 52(1-2), pp. 29-37.

Gillberg, M., Kecklund, G., Åkerstedt, T., "Relations between performance and subjective ratings of sleepiness during a night awake," *Sleep*, April 1994, Vol. 17(3), pp. 236-41.

Harna, 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*, 2002, Vol. 11(2), pp. 141-51.

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

Reyner, L.A., Horne, J.A., "Evaluation of 'in-car' countermeasures to sleepiness: cold air and radio," *Sleep*, 1998, Vol. 21(1), pp. 46-50.

<sup>5</sup> Flight Safety Foundation, *Flight Safety Digest*, 2006, Vol. 24, pp. 8-9.

Signal, T.L., van den Berg, M., Travier, N., Gander, P.H., "Phase 3 ultra-long range validation: in-flight polysomnographic sleep and psychomotor performance," Wellington, New Zealand: Massey University, Sleep/Wake Research Centre Report, 2004.

- 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 periods.

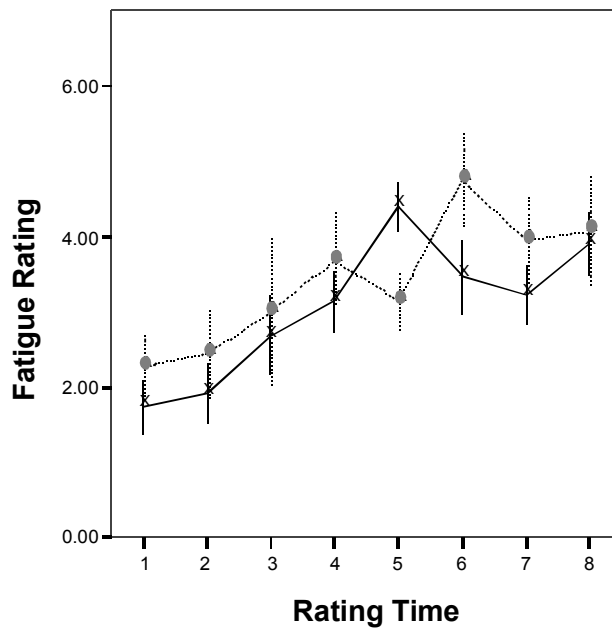
**The Samn-Perelli Crew Status Check**

This scale asks people to rate their level of fatigue right now and is a simplified version of the Samn-Perelli Checklist<sup>6</sup>.

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 A-4 The Samn-Perelli Crew Status Check**

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



**Figure A-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 crew**

<sup>6</sup> Samn, S.W., Perelli, L.P., "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.  
 Samel, A., Wegmann, H.M., Vejvoda, M., Drescher, J., Gundel, A., Manzey, D., Wenzel, J., "Two-crew operations: Stress and fatigue during long-haul night flights," *Aviation, Space, and Environmental Medicine*, August 1997, Vol. 68(8), pp.679-87.  
 Samel, A., Wegmann, H.M., Vejvoda, M., "Aircrew fatigue in long-haul operations." *Accident Analysis and Prevention*, July, 1997, Vol. 29(4) pp. 439-52.



### *Strengths and weaknesses of subjective ratings*

Subjective sleepiness and fatigue ratings are relatively cheap and easy to collect and analyse. Furthermore, how a crew member feels is likely to influence his 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 people have been getting less sleep than they need (sleep restriction) across several consecutive nights.

Concerns about some crew members 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 to 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 Fatigue Safety Action Group can be guided by comparing average (and/or extreme) ratings with data gathered on other operations.

### **A-2.2 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, or short-term memory), not the complex combinations of skills needed by crew members in the course of flight duties. Laboratory tests usually also measure the performance of individuals, not the combined performance of the crew. Nevertheless, some simple performance tests are considered "probes" or indicators of a crew member's capacity to carry out his duties.

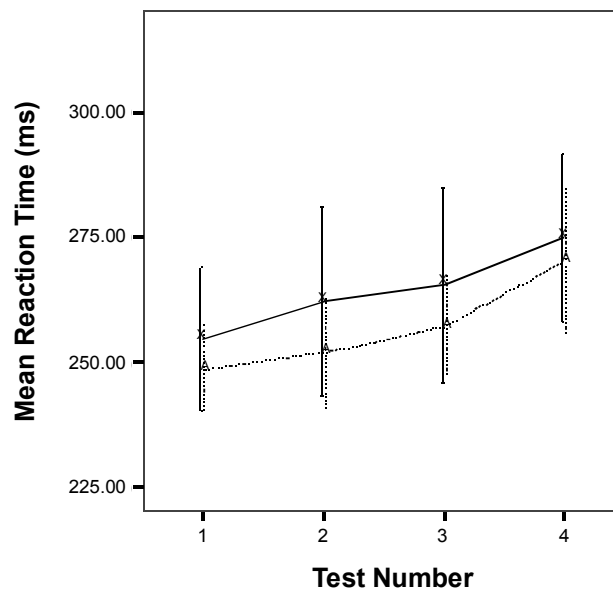
The following things should be considered when choosing performance tests for monitoring crew member fatigue and sleepiness during flight operations.

1. How long does the test last?
2. Can it be completed at multiple time points (for example, a number of times across a flight) without compromising a crew member's ability to meet duty requirements?
3. 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?
4. Is it predictive of more complex tasks, for example, crew performance in the simulator or during an in-flight emergency? (Unfortunately, there is very little research addressing this question at present.)
5. Has it been used in other aviation operations, and are the data available to compare fatigue levels?

One performance test that meets these criteria is the Psychomotor Vigilance Task or PVT<sup>7</sup>. In the most widely used version of the PVT, the test lasts for ten minutes and is carried out on a purpose-built hand-held device. However, some recent studies<sup>8</sup> and large aviation field studies currently in progress are using a five-minute version of the PVT programmed on a Personal Data Assistant (PDA) device.

Figure A-6 shows mean reaction times on the PVT for the same ULR crew members on the same flights as in Figures A-3 and A-5. In this study, the ten-minute version of the test was used. PVT tests were done at the following times:

- test 1 – close to top of climb;
- test 2 – at the start of the second in-flight rest opportunity;
- test 3 – close to top of descent; and
- test 4 – post-flight, before departing the aircraft.



**Figure A-6 Mean reaction time on the PVT task on flights from Singapore to Los Angeles**  
**Solid line: data for the command crew**  
**Dotted line: data for the relief crew**

#### *Strengths and weaknesses of the PVT*

The PVT requires a crew member's constant attention during the test. In the study in Figure A-6, for example, this meant that crew members were required to be out of the operational control loop for a total of 30 minutes during the flight. This is an even greater challenge when crews are not augmented.

<sup>7</sup> Dinges, D.F. and Powell, J.P., "Microcomputer analysis of performance on a portable, simple visual RT task during sustained operations," *Behavior Research Methods, Instruments, and Computing*, 1985, Vol. 17, pp. 652-55.

Balkin, T.J., Bliese, P.D., Belenky, et al, "Comparative utility of instruments for monitoring sleepiness-related performance decrements in the operational environment," *Journal of Sleep Research*, September 2004, Vol. 13(3), pp. 219-27.

<sup>8</sup> Lamond, N., Petrelli, R., Dawson, D., Roach, G.D., *The impact of layover length on the fatigue and recovery of long-haul flight crew*. Proceedings of the Fatigue in Transportation Conference (Session 13c), Seattle, 11-25 September 2005. US Department of Transport.

In the study in Figure in A-6, crew members were asked to complete PVT tests on the flight deck, and there were clearly occasions when their attention was distracted by operational events. This increased the variability of performance on the PVT test across the group and made it more difficult to find statistically significant changes in PVT performance across the flight. Only the post-flight test (Test 4) in Figure A-6 is significantly different from any of the others.

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 crew members know how to operate the testing device.

### A-2.3 Monitoring sleep

Sleep loss is a key contributing factor to fatigue. In addition, crew members need to get recovery sleep to return to their optimum level of waking function. Sleep can be monitored during flight operations 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 crew members to record the following information about each sleep period:

- where they sleep (home, layover hotel, in flight in a crew rest facility or a business class seat, etc.);
- what time they go to bed and get up;
- how much sleep they think they get; and
- how well they think they sleep.

Crew members may also be asked to rate their sleepiness and fatigue before and after planned sleep periods. When sleep is being monitored during flight operations, crew members are also 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 (for example, programmed on a PDA). Different layouts may be required for different parts of a study, for example, pre-trip, during flights, and during layovers.

Figure A-7 shows an example of an in-flight sleep diary designed to be used during ULR flight when crews have multiple in-flight rest periods (courtesy of the Sleep/Wake Research Centre). This example includes Karolinska Sleepiness and Samn-Perelli ratings before and after each sleep period, as well as a sleep quality rating scale for each sleep period.

#### *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, and analysis of diary data has costs associated.

Sleep diaries are known to be less reliable than objective sleep monitoring. One study has compared sleep diaries and objective sleep measures from 21 B-777 flight crew members in a layover hotel and in flight.<sup>9</sup> For in-flight sleep:

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<sup>9</sup> Signal, T.L., Gale, J., and Gander, P.H., "Sleep Measurement in Flight Crew: Comparing Actigraphic and Subjective Estimates of Sleep with Polysomnography," *Aviation Space and Environmental Medicine*, 2005, Vol. 76(11), pp. 1058-63.

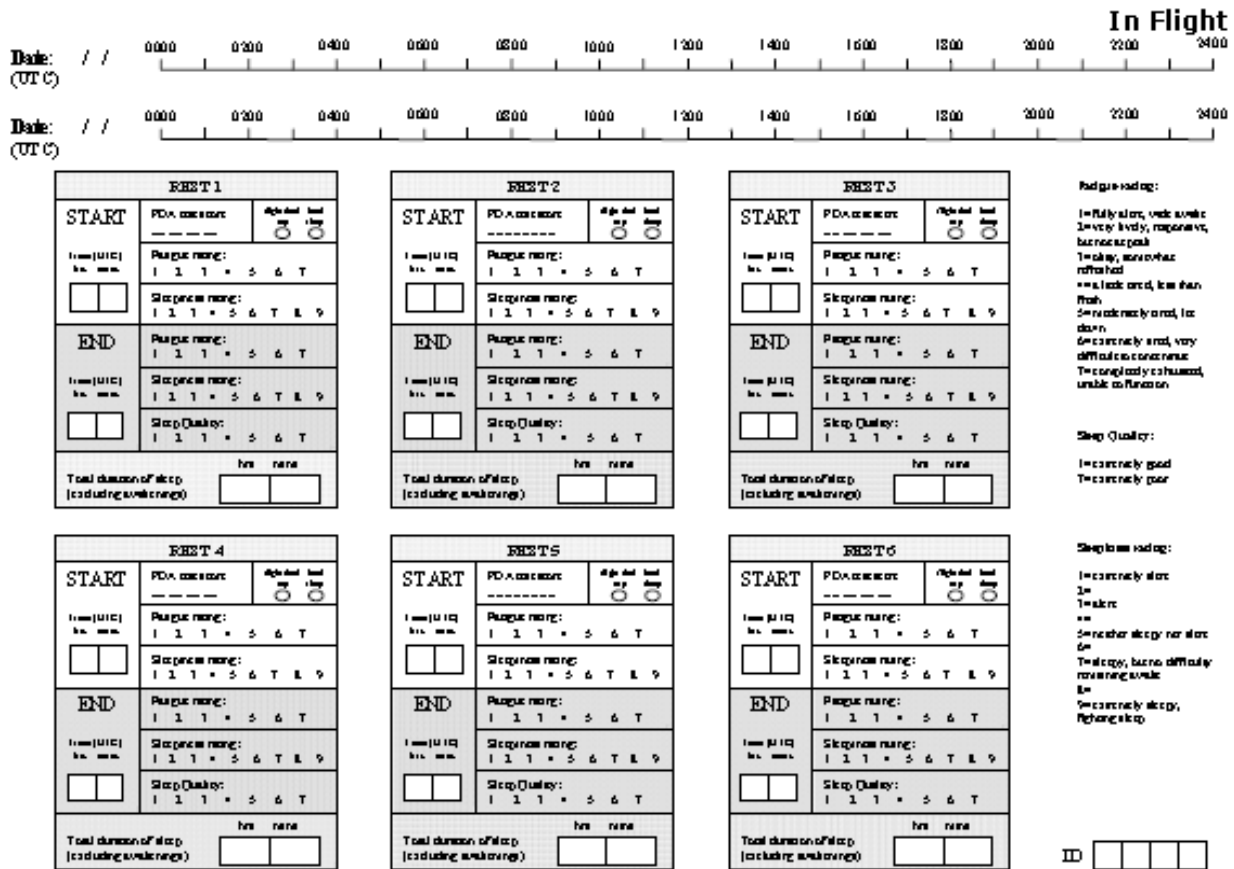


Figure A-7 Example of an in-flight sleep diary for ULR operations

- 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 overestimated 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.

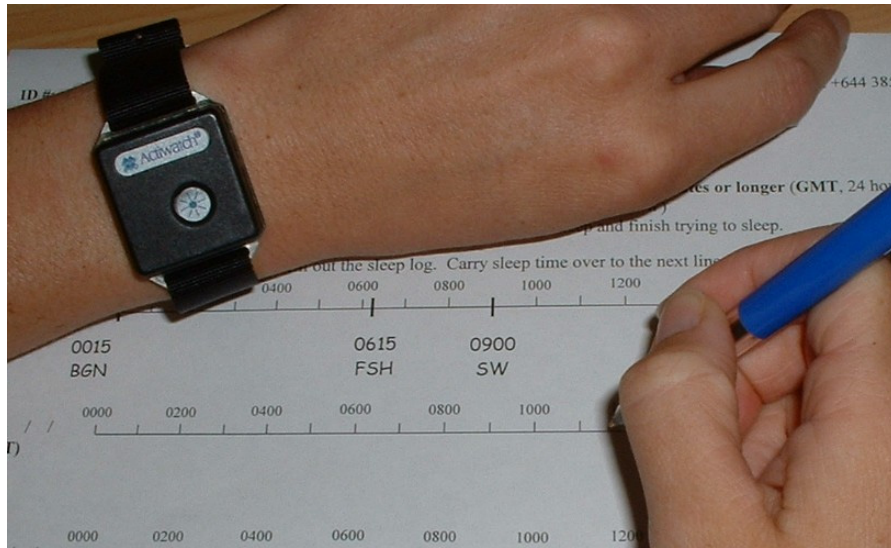
Thus diaries alone may be useful for measuring the sleep duration of groups but *cannot be considered accurate for estimating the sleep duration of any one individual*. In addition, diaries are not generally considered reliable for measuring sleep quality. (However, some very new research suggests that 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 crew members. They are also used to help interpret objective sleep data, as described below.

**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 downloaded to a computer for analysis. Figure A-8 shows an example of an older style actigraph.

There are a number of manufacturers of actigraph devices, and each type comes with custom software that scans through the activity record and decides (based on a validated algorithm) whether the person was asleep or awake in each recorded epoch (for example, every minute). Some devices have light sensors and some also have a regular watch face so that the wearer does not need to wear a normal watch, as well, to keep track of time.



**Figure A-8** An example of an actigraph

Figure A-9 shows an actigraphy record from a crew member before, during and after a Singapore-Los Angeles-Singapore ULR trip. Each vertical gray bar indicates an hour, with 24 hours (from midnight to midnight) plotted across the diagram. Consecutive days are shown down the page. The vertical black bars indicate the level of activity for each minute of the recording (higher bars indicate more movement). Periods with minimal movement (short, scattered black bars) correspond to times when the crew member was asleep.

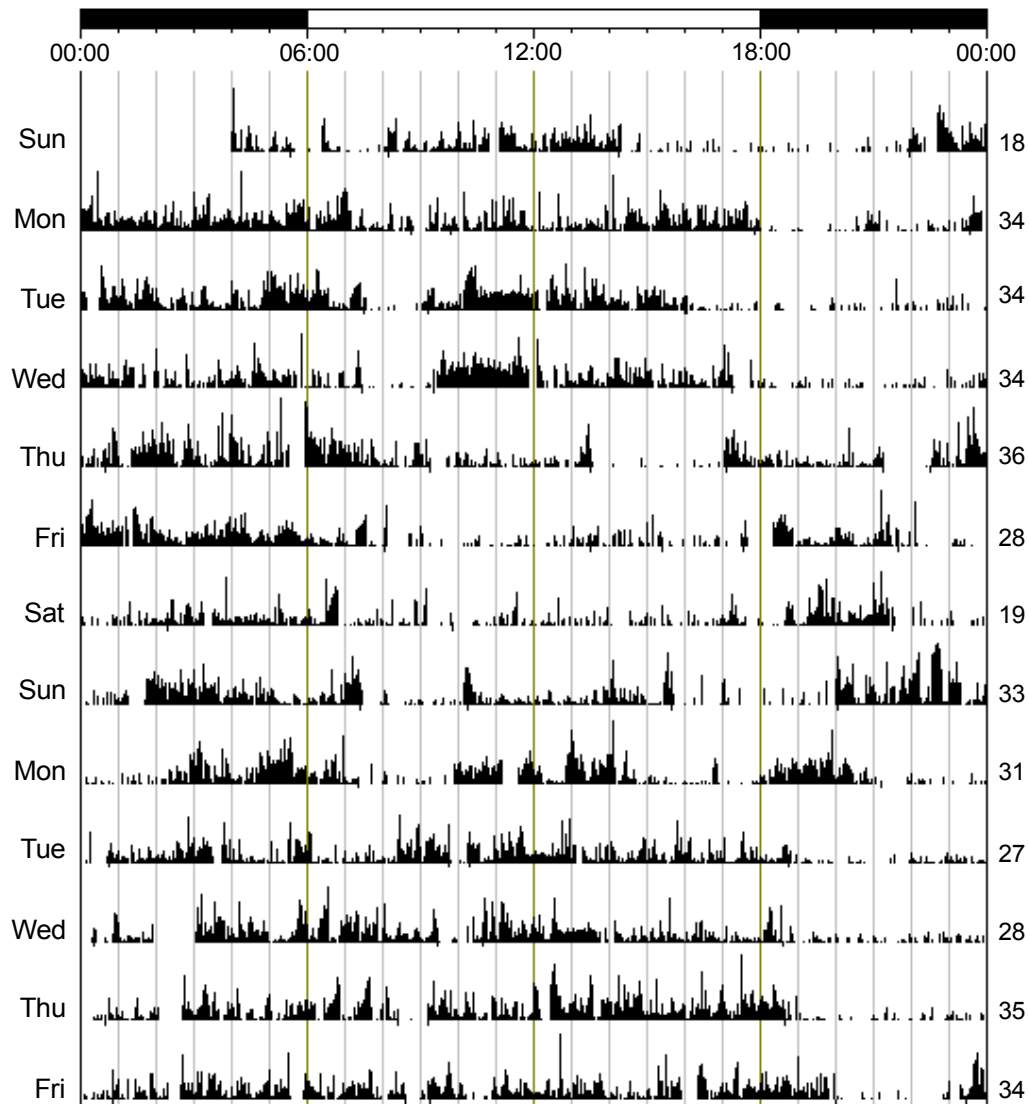
On the first Thursday, the crew member flew as a relief crew member on the SIN-LAX segment, during which he had three in-flight rest opportunities (1 hr 30 mins, 4 hrs, and 2 hrs), but (according to his diary) he went to the crew rest facility only for the second of these. The actigraphy scoring algorithm calculated that he obtained 2hrs 55 mins of sleep during the second rest period, and 1 hr 12 mins of sleep during his third rest period, which he took in a passenger cabin. His sleep diary indicated that he also spent 44 minutes trying to sleep during his first rest period, but the algorithm could not (at that time) score such a short sleep period.

The following Sunday, he flew as a command crew member on the LAX-SIN segment and had two in-flight rest opportunities (3 hrs 15 mins and 5 hrs), both of which he took in the crew rest facility. According to the actigraphy scoring algorithm, he obtained 2 hrs 14 min of sleep in his first rest period, and 4 hrs 3 min in his second rest period.

#### *Strengths and weaknesses of actigraphy*

As Figure A-9 illustrates, actigraphy is very useful for obtaining objective records of the sleep/wake patterns of crew members across multiple days. This is currently the most practical and reliable way to look at whether crew members accumulate a sleep debt across a line of flying, compared to the amount of sleep they average when off duty. Actigraphy can also provide useful information on recovery sleep after a trip.

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.



**Figure A-9 Actigraphy record of a crew member before, during, and after a Singapore-Los Angeles-Singapore ULR trip**

The study described previously<sup>9</sup> also compared actigraphy and polysomnographic sleep recordings from the 21 B-777 flight crew members. For both hotel sleep and bunk sleep:

- average sleep durations calculated from actigraphy were similar to those recorded using polysomnography; but
- for individual crew members, actigraphy could overestimate or underestimate polysomnographic sleep duration by more than an hour. This amount of inaccuracy is particularly problematic for in-flight sleep periods, which tend to be short; and
- comparing actigraphy and polysomnography minute-by-minute, the study concluded that actigraphic estimates of how long crew members took to fall asleep, and of how often they woke up during a sleep period (sleep quality), were not reliably related to polysomnographic measures.

On the positive side, the study demonstrated that actigraphy was not significantly contaminated by in-flight factors such as turbulence or aircraft movement, and that it is reliable for estimating *the average sleep duration of groups of crew members, both in the air and on the ground.*

Actigraphs are currently not inexpensive, although some manufacturers are working on new generation devices that may push costs down. Not all actigraphs on the market have been validated (by comparing their algorithms for estimating sleep quantity and quality with polysomnography), and some have not yet been demonstrated to be robust and reliable for sleep monitoring during flight operations (battery life can be a problem in some devices).

At present, the accepted standard for analysing actigraphy records is to use a sleep diary to identify when a crew member was trying to sleep (as opposed to just sitting still or not wearing the watch). The sections of the record where the crew member was trying to sleep are then analysed for sleep duration and quality. This type of analysis requires a trained person to work 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 analyse. However, the reliability of these new approaches for estimating sleep quantity and quality (compared to polysomnography) remains to be demonstrated.

Some operators may choose to develop the capacity in-house to collect and analyse actigraphy. As part of the FRMS Assurance Processes, an external scientific advisory group could be convened periodically to review the actigraphy analyses and the resulting decisions made by the Flight Safety Action Group.

### **Polysomnography**

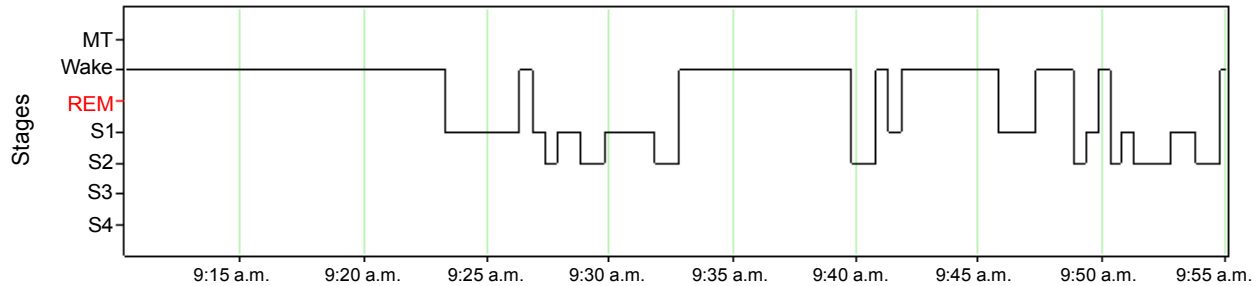
Polysomnography is the accepted gold standard for monitoring sleep and is currently the only method that gives reliable information on the internal structure of sleep and on sleep quality. It involves sticking removable electrodes to the scalp and face and connecting them to a recording device, to measure 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 A-10 shows a flight crew member on the flight deck wearing polysomnography electrodes, which the researcher is connecting to a portable recording device.



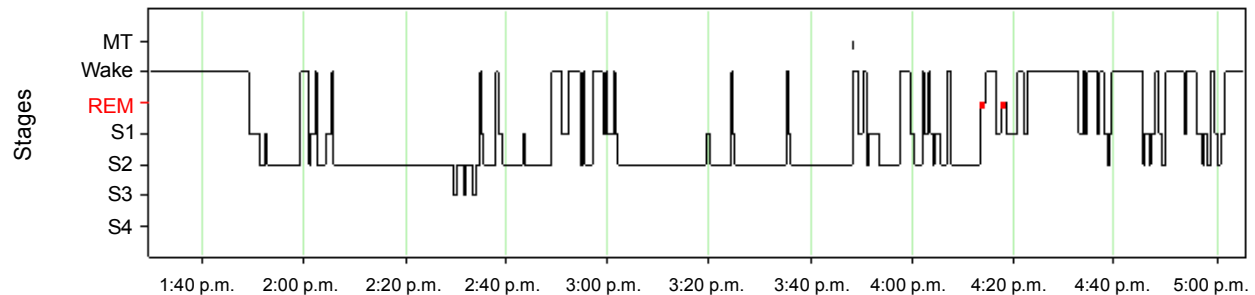
**Figure A-10 Polysomnographic recording in flight**

Figure A-11 shows an analysis of the polysomnography record of the first in-flight sleep period on the SIN-LAX flight for the same crew member whose actigraphy record is shown in Figure A-9 (times in UTC). Figure A-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 A-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 six times across the sleep period. He did not enter deep non-REM sleep (S3 and S4), or Rapid Eye Movement (REM) sleep.



**Figure A-11 Polysomnographic record for the first in-flight rest period on the SIN-LAX flight (same crew member as in Figure A-9)**

Figure A-12 shows the polysomnographic record for the same crew member during his second in-flight rest period on the 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 deep non-REM sleep (S3), 2 minutes in REM sleep, and the rest of the time in light non-REM sleep (S1 and S2).



**Figure A-12 Polysomnographic record for the second in-flight rest period on the SIN-LAX flight (same crew member as in Figure A-9)**

#### *Strengths and weaknesses of polysomnography*

Figures A-11 and A-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 in-flight recordings, the electrical contacts need to be checked periodically (for example, before each in-flight rest



period) to make sure that the signals are still clean. Crew members 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 accompany crew members throughout a trip during which their sleep is recorded using polysomnography. This is costly.

As previously mentioned, the currently accepted standard for analysing polysomnography is to have a trained sleep scoring technician work through the entire recording to decide for each 30 seconds whether the crew member was awake, or in which type of sleep he 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 is 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 A-11 and A-12.

Despite these costs and inconveniences, there have been a number of studies of flight crew sleep that have used polysomnography and these have been very informative. While it is unlikely that any airline would need to develop in-house capacity to record and analyse 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 A-3, A-5, A-6, A-9, A-11, and A-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.

#### A-2.4 Monitoring the circadian body clock cycle

The circadian body clock cycle is a key contributing factor to crew member fatigue, but it is difficult to monitor during flight 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; 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.

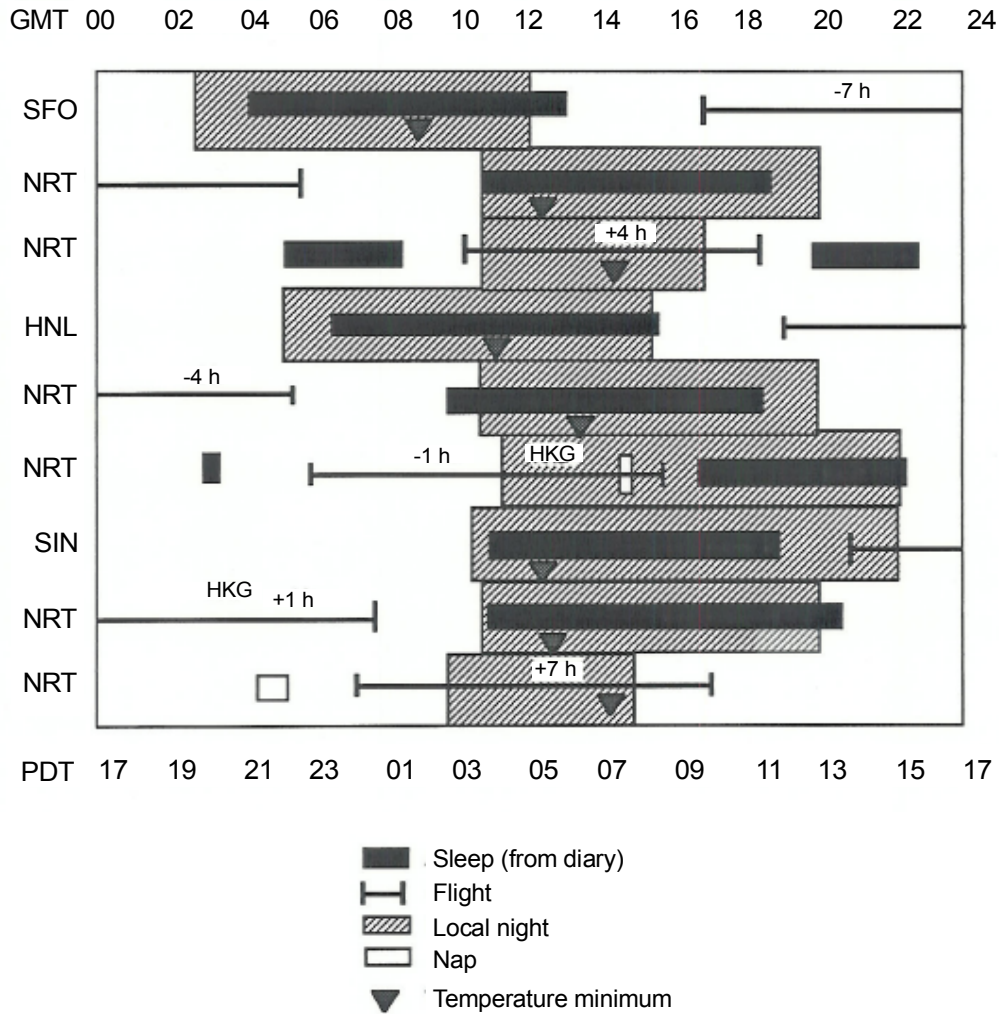
During the 1980s, a number of research teams monitored the circadian body clocks of crew members by tracking the rhythm of core body temperature. Figure A-13 shows the times of the daily temperature minimum of one participating B-747 crew member across an eight-day long-haul trip pattern<sup>10</sup>.

At home in SFO prior to the trip, his temperature minimum (inverted triangle) occurred about five hours into his sleep period (black horizontal bar). During the trip, he repeatedly flew westward then back eastward across multiple time zones, spending around 24 hours in each location. The circadian temperature minimum could not follow this disrupted pattern (it shifted by no more than two hours from one day to the next). Across the trip pattern, it drifted progressively later, so that by the time the crew member arrived back in SFO at the end of the trip, it had drifted about six hours later. Thus, when he got home, the crew member's circadian body clock was six hours out of step with his home time zone and took several days to readapt.

Another interesting feature of this record is that the temperature minimum (when physiological sleep drive is highest), sometimes occurs in flight, for example, on the flight from NRT to HKG. At these times, the crew member is at greatest risk of falling asleep unintentionally on the flight deck. Alternatively, if he has the opportunity for a rest break (which was not the case in this operation), this would represent a very good time to try to get some in-flight sleep.

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<sup>10</sup> Gander, P.H., Gregory, K.B., Miller, D.L., Rosekind, M.R., Connell, L.J., and Graeber, R.C. "Flight crew fatigue V: long-haul air transport operations," *Aviation, Space, and Environmental Medicine*, 1998, Vol. 69, pp. B37-B48



**Figure A-13 Sleep times (diary data) and times of the circadian temperature minimum**

Clearly, Figure A-13 provides valuable information that can be related to the crew member’s sleep, fatigue, mood and performance capacity. However, it has been several decades since this type of monitoring has been undertaken primarily because of the logistics and cost of tracking circadian rhythms during flight operations.

There is ongoing research aimed at developing more robust and less 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 A-13).

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 a crew member is exposed to daylight during his “biological night” (for example, a few hours either side of the temperature minimum in Figure A-13), melatonin secretion will stop. This makes it impossible to track its normal circadian cycle across a trip such as that in Figure A-13. Analysing for hormone levels in body fluids is a highly skilled task that needs to be undertaken by a reputable laboratory.

*Strengths and weaknesses of monitoring the circadian body clock cycle of a crew member during a long-haul trip pattern*

There is remarkably little information available on how the circadian body clock is affected by any kind of flight operations. Where data have been collected, there is evidence of considerable variability between individuals on the same trip patterns. Better information in this area would improve the predictive power of biomathematical models for fatigue hazard identification and might provide insights on how to tailor personal mitigation strategies for crew members 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.

### **A-3. Evaluating the contribution of fatigue to safety events**

There is no simple formula for evaluating the contribution of crew member fatigue to a safety event. For the purposes of the FRMS, the aim is to identify how the effects of fatigue could have been mitigated, in order to reduce the likelihood of similar occurrences in the future. Basic information can be collected for all fatigue reports and safety events, with more in-depth analyses reserved for events where it is more likely that fatigue was an important factor and/or where the outcomes were more severe.

To establish that fatigue was a contributing factor in an event, it has to be shown that:

- the person or crew was in a fatigued state; and
- the person or crew 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 or crew.

In 1997, the Canadian Transportation Safety Board produced guidelines for fatigue analysis. They suggest four initial questions to decide whether or not fatigue was a contributing factor to an event.<sup>11</sup>

1. At what time of day did the occurrence take place?
2. Was the crew member's normal circadian rhythm disrupted?
3. How many hours had the crew member been awake at the time of the occurrence?
4. Does the 72-hour sleep history suggest a sleep debt?

If the answer to any one of these questions indicates a problem, then fatigue should be investigated in greater depth. This requires working through two checklists (adapted from the Canadian Transportation Safety Board guide).

**Checklist 1** is designed to establish whether the person or crew was 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 behaviour expected of a fatigued person or crew.

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<sup>11</sup> Transportation Safety Board of Canada, *A Guide for Investigating for Fatigue*, Transportation Safety Board of Canada, 1997, Gatineau, Quebec.

**Checklist 1 Establishing the fatigued state**

QUESTIONS	BEST CASE RESPONSES	INVESTIGATOR'S NOTES
<b>QUANTITY OF SLEEP</b> <i>(Establish whether or not there was a sleep debt)</i>		
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)	Two credits for each hour of sleep; loss of one credit for each hour awake – should be a positive value	
<b>QUALITY OF SLEEP</b> <i>(Establish whether or not sleep was restorative)</i>		
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	
<b>WORK HISTORY</b> <i>(Establish whether hours worked and type of duty or activities involved had an impact on sleep quantity and quality)</i>		
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 on duty and/or on call and type of duty that do not lead to a cumulative fatigue	
<b>IRREGULAR SCHEDULES</b> <i>(Establish whether the scheduling was problematic with regard to its impact on quantity and quality of sleep)</i>		
Was crew member a shift worker (working through usual sleep times)?	No (The circadian body clocks and sleep of shift workers do not adapt fully)	

QUESTIONS	BEST CASE RESPONSES	INVESTIGATOR'S NOTES
If yes, was it a permanent shift?	Yes – days	<input type="text"/>
If no, was it rotating (vs. irregular) shift work?	Yes – Rotating clockwise, rotation slow (one day for each hour delayed), night shift shorter, and at the end of cycle	<input type="text"/>
How are overtime or double shifts scheduled?	Scheduled when crew members are in the most alert parts of the circadian body clock cycle (late morning, mid evening)	<input type="text"/>
Scheduling of critical safety tasks?	Scheduled when crew members are in the most alert parts of the circadian body clock cycle (late morning, mid evening)	<input type="text"/>
Has crew member had training on personal fatigue mitigation strategies?	Yes	<input type="text"/>
<b>JET LAG</b> <i>(Establish the existence and impact of jet lag on quantity and quality of sleep)</i>		
Number of time zones crossed?	One	<input type="text"/>
If more than one, at what rate were they crossed?	The slower, the better	<input type="text"/>
In which direction was the flight?	Westward	<input type="text"/>

**Checklist 2 Establishing the link between fatigue and the unsafe act(s)/decision(s)**

PERFORMANCE INDICATORS	INVESTIGATOR'S NOTES
<b>Attention</b>	
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	
<b>Memory</b>	
Forgot a task or elements of a task	
Forgot the sequence of task or task elements	
Inaccurately recalled operational events	
<b>Alertness</b>	
Succumbed to uncontrollable sleep in form of microsleep, nap, or long sleep episode	
Displayed automatic behaviour syndrome	
<b>Reaction Time</b>	
Responded slowly to normal, abnormal or emergency stimuli	
Failed to respond altogether to normal, abnormal or emergency stimuli	
<b>Problem-Solving Ability</b>	
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	

PERFORMANCE INDICATORS	INVESTIGATOR'S NOTES
<b>Mood</b>	
Was less conversant than normal	
Did not perform low-demand tasks	
Was irritable	
Distracted by discomfort	
<b>Attitude</b>	
Displayed a willingness to take risks	
Ignored normal checks or procedures	
Displayed a "don't care" attitude	
<b>Physiological Effects</b>	
Exhibited speech effects	
Exhibited reduced manual dexterity – key-punch entry errors, switch selection	

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## Appendix B. Procedures for controlled rest on the flight deck

Controlled rest on the flight deck is an effective fatigue mitigation for flight crews. It should not be used as a scheduling tool. It is not a substitute for proper pre-flight sleep or for normal crew augmentation, but is intended as a response to unexpected fatigue experienced during operations. Some basic principles:

- It should be considered a safety net.
- The Fatigue Safety Action Group should be able to monitor the use of controlled rest on the flight deck to evaluate whether existing mitigation strategies are adequate. Crew reports are encouraged.
- It should only be used on flights of sufficient length that it does not interfere with required operational duties.
- It should only be used during low workload phases of flight (for example, during cruise flight).
- It should not be used as a method for extending crew duty periods.
- Procedures for controlled rest on the flight deck should be published and included in the Operations Manual.

### Recommended procedures for controlled rest on the flight deck

The following recommended procedures are based on a survey of major air carriers. They represent considerable experience in many regions of the globe and include options reflecting variations between different types of operations.

*Note.— This is not intended to be an all-inclusive list, nor are all of these procedures necessarily required. Each operator should work with its regulator to define appropriate procedures.*

#### *Planning*

- One pilot only may take controlled rest at a time in his seat. The harness should be used and the seat positioned to minimize unintentional interference with the controls.
- The autopilot and auto-thrust systems (if available) should be operational.
- Any routine system or operational intervention which would normally require a cross check should be planned to occur outside controlled rest periods.
- Controlled rest on the flight deck may be used at the discretion of the captain to manage both unexpected fatigue and to reduce the risk of fatigue during higher workload periods later in the flight.
- It should be clearly established who will take rest and when it will be taken. If the pilot-in-command requires, the rest may be terminated at any time.
- The pilot-in-command should define criteria for when his rest should be interrupted.
- Hand-over of duties and wake-up arrangements should be reviewed.
- Flight crews should use controlled rest only if they are familiar with the published procedures.

- Some operators involve a third crew member (not necessarily a pilot) to monitor controlled flight deck rest. This may include a planned wake-up call, a visit to be scheduled just after the planned rest period ends, or a third crew member on the flight deck throughout controlled rest.
  - The controlled rest period should be no longer than 40 minutes, to minimize the risk of sleep inertia on awakening.
  - Controlled rest should be used only during the cruise period from the top of climb to 20 minutes before the planned top of descent. This is to minimize the risk of sleep inertia.
  - A short period of time should be allowed for rest preparation. This should include an operational briefing, completion of tasks in progress, and attention to any physiological needs of either crew member.
  - During controlled rest, the non-resting pilot must perform the duties of the pilot flying and the pilot monitoring, be able to exercise control of the aircraft at all times, and maintain situational awareness. The non-resting pilot cannot leave his seat for any reason, including physiological breaks.
  - Aids such as eye shades, neck supports, ear plugs, etc., should be permitted for the resting pilot.
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## Appendix C. Example of an FRMS evaluation form

TO BE COMPLETED AND SIGNED FOR BY THE SAFETY MANAGER OR ACCOUNTABLE EXECUTIVE				
Organization: <input style="width: 95%;" type="text"/>		Approval reference: <input style="width: 95%;" type="text"/>		
Signature: <input style="width: 95%;" type="text"/>		Position: <input style="width: 95%;" type="text"/>		
Print name: <input style="width: 95%;" type="text"/>		Date of signing: <input style="width: 95%;" type="text"/>		
FRMS Manual revision: <input style="width: 95%;" type="text"/>				
FOR AUTHORITY USE ONLY				
Staff name: <input style="width: 95%;" type="text"/>				
Signature: <input style="width: 95%;" type="text"/>		Date of assessment: <input style="width: 95%;" type="text"/>		
0. GENERAL ISSUES AND FRMS IMPLEMENTATION				
<b>FRMS Scope and Implementation</b>				
The Organization should define the scope of the use of FRMS within its operation. In establishing an FRMS a GAP analysis should be carried out and an implementation plan that will address how the organization will transition to a fully functioning and effective FRMS.				
	<b>In place<sup>1</sup></b>	<b>Documented<sup>2</sup> reference:</b>	<b>How is it achieved?<sup>3</sup></b>	<b>Inspector's assessment remarks<sup>4</sup></b>
0.1 In respect of the management system, have the structure, activities and scope of the FRMS operations been defined?	<input style="width: 100%; height: 40px;" type="text"/>	<input style="width: 100%; height: 40px;" type="text"/>	<input style="width: 100%; height: 40px;" type="text"/>	<input style="width: 100%; height: 40px;" type="text"/>
0.2 Does the FRMS correspond to the size, nature and complexity of the operation and the hazards and associated risks inherent with its activities?	<input style="width: 100%; height: 40px;" type="text"/>	<input style="width: 100%; height: 40px;" type="text"/>	<input style="width: 100%; height: 40px;" type="text"/>	<input style="width: 100%; height: 40px;" type="text"/>
0.3 Has a gap analysis been carried out?	<input style="width: 100%; height: 40px;" type="text"/>	<input style="width: 100%; height: 40px;" type="text"/>	<input style="width: 100%; height: 40px;" type="text"/>	<input style="width: 100%; height: 40px;" type="text"/>

1 Yes (Y), No (N) or Partial (P).

2 Where is it documented in your documentation?

3 Provide details that describe or demonstrate your response to the question.

4 This will be completed by the Authority during the assessment process.

	In place <sup>1</sup>	Documented <sup>2</sup> reference:	How is it achieved? <sup>3</sup>	Inspector's assessment remarks <sup>4</sup>
0.4 Is there an FRMS implementation plan that reflects the gap analysis?				

**1. SAFETY POLICY AND OBJECTIVES**

**1.1 Management commitment and responsibility**

The organization should define its FRMS policy which should be in accordance with international and national requirements, and which shall be signed by the accountable executive of the organization. This policy should reflect organizational commitments regarding fatigue risk, including a clear statement about the provision of the necessary human and financial resources for its implementation and be communicated, with visible endorsement, throughout the organization. The FRMS policy should include the fatigue reporting procedures and management commitment to continuous improvement of the FRMS. It must also reflect the shared responsibility for the management of fatigue risks with all the stakeholders.

The policy should be periodically reviewed to ensure it remains relevant and appropriate to the organization and the operations to which FRMS applies.

*(Where the FRMS is integrated within the organization's SMS, these management commitments and responsibilities may be included in the SMS safety policy. If this is done, it must still be possible to demonstrate these responsibilities as clearly referenced to fatigue.)*

	In place <sup>1</sup>	Documented <sup>2</sup> reference:	How is it achieved? <sup>3</sup>	Inspectors assessment remarks <sup>4</sup>
1.1.1 Is there a written FRMS policy clearly stating the safety objectives of the FRMS and endorsed by the accountable executive?  Or are there clear references to fatigue risk management with the SMS policy as endorsed by the accountable executive?				
1.1.2 Were key staff consulted in the development of the FRMS policy/integration of FRMS into the SMS?				
1.1.3 Has the FRMS policy been communicated effectively throughout the organization?				
1.1.4 Does senior management continuously promote and demonstrate its commitment to the continuous improvement of the FRMS?				

	In place <sup>1</sup>	Documented <sup>2</sup> reference:	How is it achieved? <sup>3</sup>	Inspectors assessment remarks <sup>4</sup>
1.1.5 Does the Policy include a commitment: to strive to achieve the highest safety standards; observe all applicable legal requirements, standards and best practice; provide appropriate resources as a primary responsibility of all managers?				
1.1.6 Does the FRMS policy actively encourage fatigue reporting?				
1.1.7 Is the FRMS management system based on the FRMS policy?				
1.1.8 Does the FRMS policy reflect the shared responsibility of the management of fatigue with all stakeholders?				
1.1.9 Does the FRMS policy reflect the need for periodic review?				

**1.2 Accountabilities**

The organization shall identify the accountable executive who, irrespective of other functions, shall have ultimate responsibility and accountability, on behalf of the organization, for the implementation and maintenance of the FRMS. The organization shall also identify the fatigue risk accountabilities of all members of senior management, irrespective of other functions, as well as of employees, with respect to the performance of the FRMS. Responsibilities, accountabilities and authorities shall be documented and communicated throughout the organization and shall include a definition of the levels of management with authority to make decisions regarding fatigue risk tolerability.

*(Where the FRMS is integrated within the organization's SMS, these accountabilities may be included in the SMS documentation. If this is done it must still be possible to demonstrate these accountabilities as clearly referenced to fatigue.)*

	In place <sup>1</sup>	Documented <sup>2</sup> reference:	How is it achieved? <sup>3</sup>	Inspector's assessment remarks <sup>4</sup>
1.2.1 Does the accountable executive have full responsibility and accountability for the FRMS and corporate authority for the organization?				
1.2.2 Does the accountable executive have an awareness of his FRMS roles and responsibilities in respect of the FRMS policy and of fatigue risk management within the safety culture of the organization?				

	In place <sup>1</sup>	Documented <sup>2</sup> reference:	How is it achieved? <sup>3</sup>	Inspector's assessment remarks <sup>4</sup>
1.2.3 Are fatigue risk management accountabilities, authorities and responsibilities defined throughout the organization?				
1.2.4 Are there clearly defined lines of fatigue risk management accountabilities throughout the organization?				
1.2.5 Are all staff aware of, and do they understand, their accountabilities, authorities and responsibilities with regard to fatigue?				

**1.3 Appointment of key safety personnel**

The organization shall identify an FRMS manager to be the responsible individual and focal point for the implementation and maintenance of an effective FRMS. There needs to be a clear mechanism for ongoing involvement of all involved personnel through a functional group responsible for coordinating FRMS activities throughout the organization, which should be defined and documented. (The reference used in this document is to the Fatigue Safety Action Group (FSAG).)

*(Where the FRMS is integrated into the SMS, the FRMS manager would normally report to the safety manager, who would have a direct reporting line to the accountable executive. Where the organization is small but with a functioning SMS, it may not be practical to have a FSAG but to have fatigue as an agenda item on the Safety Action Group meetings.)*

	In place <sup>1</sup>	Documented <sup>2</sup> reference:	How is it achieved? <sup>3</sup>	Inspector's assessment remarks <sup>4</sup>
1.3.1 Has an FRMS manager (or equivalent) been appointed with the appropriate knowledge, skills and experience as defined in the guidance material?				
1.3.2 Is there a direct reporting line between the FRMS manager and the accountable executive? (Or, where integrated with SMS, between the FRMS manager and the safety manager.)				
1.3.3 Does the FRMS manager carry out the functions as detailed in the ICAO guidance material?				

	In place <sup>1</sup>	Documented <sup>2</sup> reference:	How is it achieved? <sup>3</sup>	Inspector's assessment remarks <sup>4</sup>
1.3.4 Has a Fatigue Safety Action Group or equivalent been established that fulfils the functions defined in the guidance material?				
1.3.5 Does the Board monitor the performance and effectiveness of the FRMS as detailed in the guidance material?				
1.3.6 Is the Fatigue Safety Action Group's membership and frequency of meetings defined and minuted?				

**1.4 FRMS documentation**

The organization shall develop and maintain FRMS documentation describing the FRMS policy and objectives, the FRMS requirements, the FRMS processes and procedures, the accountabilities, responsibilities and authorities for processes and procedures, and the FRMS outputs. The organization shall develop and maintain an FRMS manual to communicate its approach to the management of safety throughout the organization or shall incorporate the FRMS documentation into its existing SMS documentation.

	In place <sup>1</sup>	Documented <sup>2</sup> reference:	How is it achieved? <sup>3</sup>	Inspector's assessment remarks <sup>4</sup>
1.4.1 Does the FRMS management manual contain all the elements as detailed in the guidance material?				
1.4.2 Is it regularly reviewed?				
1.4.3 Is there a system for recording scheduled and actual flight times, duty and rest periods with deviations and reasons for any deviations?				
1.4.4 Is there a system for the recording and storage of FRMS outputs, i.e. hazard logs, risk assessments, fatigue reports, safety cases, roster metrics, FSAG minutes?				

**2. FATIGUE RISK MANAGEMENT**

**2.1 Hazard identification**

The organization shall develop and maintain a formal process that ensures that fatigue hazards are identified. This should include the investigation of incidents and accidents to identify potential fatigue hazards. Fatigue hazard identification shall be based on a combination of reactive, proactive and predictive methods of data collection.

	In place <sup>1</sup>	Documented <sup>2</sup> reference:	How is it achieved? <sup>3</sup>	Inspector's assessment remarks <sup>4</sup>
2.1.1 Is there a process for establishing how fatigue hazards are identified and from what sources?				
2.1.2 Is there a confidential fatigue reporting scheme that encourages fatigue-related issues to be reported by staff? (This needs to be open to proactive and predictive as well as reactive information.)				
2.1.3 Is there feedback to the reporter and the rest of the organization?				
2.1.4 Does fatigue hazard identification include reactive, proactive and predictive schemes?				
2.1.5 Have the major fatigue hazards been identified and assessed for the organization and its current activities?				
2.1.6 Do safety investigations throughout the organization include fatigue hazards as possible causal factors?				
2.1.7 Are the fatigue hazards identified from fatigue investigations addressed and communicated to the rest of the organization?				
2.1.8 Are fatigue-related errors, hazards and near misses being reported by staff?				



**2.2 Fatigue safety risk assessment and mitigation process**

The organization shall develop and implement formal risk assessment procedures that determine the probability and potential severity of fatigue-related events and identify those that require mitigation. They shall also develop and implement risk mitigation procedures. The Fatigue Safety Action Group is often used to assess the risks and develop the mitigations.

	In place <sup>1</sup>	Documented <sup>2</sup> reference:	How is it achieved? <sup>3</sup>	Inspector's assessment remarks <sup>4</sup>
2.2.1 Is there a process to assess the risks associated with identified fatigue hazards?				
2.2.2 Is there a criterion (e.g. risk tolerability matrix) that evaluates risk and the tolerable levels of risk an organization is willing to accept? Is the criterion and process appropriate for the operation?				
2.2.3 Are the mitigation actions, including timelines and responsibilities documented?				
2.2.4 Is there a clear process to select the appropriate mitigation actions?				

**3. FATIGUE SAFETY ASSURANCE**

**3.1 Fatigue safety performance monitoring and measurement**

The organization shall develop and maintain the means to verify the fatigue safety performance of the organization and to validate the effectiveness of fatigue risk controls and mitigations. The fatigue safety performance of the organization shall be verified in reference to the fatigue safety performance indicators and fatigue safety performance targets of the FRMS.

*(Where the FRMS is incorporated into the SMS, the fatigue safety performance indicators and fatigue safety performance targets must be clearly identified.)*

	In place <sup>1</sup>	Documented <sup>2</sup> reference:	How is it achieved? <sup>3</sup>	Inspector's assessment remarks <sup>4</sup>
3.1.1 Are fatigue risk mitigations and controls being verified/audited to confirm their effectiveness?				
3.1.2 Are lessons learnt incorporated into the policy and procedures?				

	In place <sup>1</sup>	Documented <sup>2</sup> reference:	How is it achieved? <sup>3</sup>	Inspector's assessment remarks <sup>4</sup>
3.1.3 Have fatigue safety performance indicators been defined and promulgated, and are they being monitored and analysed for trends?				
3.1.4 Is the FRMS audited to assess its effectiveness and that the regulations and standards are being followed? Are these audits documented?				
3.1.5 Are fatigue surveys carried out?				
3.1.6 Are fatigue studies carried out? (where appropriate)				

**3.2 The management of change**

The organization shall develop and maintain a formal process to identify changes within the organization and/or operation which may affect established processes in relation to fatigue risk. These processes need to ensure fatigue safety performance before implementing changes and to eliminate or modify fatigue risk mitigations that are no longer needed or effective due to changes in the operational environment.

	In place <sup>1</sup>	Documented <sup>2</sup> reference:	How is it achieved? <sup>3</sup>	Inspector's assessment remarks <sup>4</sup>
3.2.1 Is there a documented change management process to proactively identify fatigue hazards and to mitigate fatigue risks during organizational and operational changes?				
3.2.2 Are there periodical reviews of the fatigue safety performance after organizational or operational changes to assure assumptions remain valid and the change was effective?				

**3.3 Continuous improvement of the FRMS**

The organization shall develop and maintain a formal process to review the performance of the FRMS, with the aim of continuous improvement of the system and to determine the implications of substandard performance of the FRMS, and eliminate or mitigate such causes.

	In place <sup>1</sup>	Documented <sup>2</sup> reference:	How is it achieved? <sup>3</sup>	Inspector's assessment remarks <sup>4</sup>
3.3.1 Is there a means to monitor the overall performance of the FRMS to allow for continuous improvement to be achieved?				
3.3.2 Is there a means to eliminate and/or modify risk controls that have unintended consequences or are no longer needed?				
3.3.3 Is there evidence of continuous improvement being achieved?				

**4. FRMS PROMOTION**

**4.1 Training and education**

The organization shall develop and maintain a fatigue awareness and countermeasures training programme that ensures that personnel are trained and competent to both perform their FRMS duties and manage fatigue risks in actual operations. The scope of the training shall be appropriate to each individual's involvement in the FRMS.

	In place <sup>1</sup>	Documented <sup>2</sup> reference:	How is it achieved? <sup>3</sup>	Inspectors assessment remarks <sup>4</sup>
4.1.1 Have all staff received training on the organization's FRMS and their roles and responsibilities in respect of the FRMS including the accountable executive, senior management, managers, supervisors and operational staff?				
4.1.2 Is the initial and recurrent training syllabus suitable for the organization's FRMS operations?				
4.1.3 Is the effectiveness of the training measured and documented?				

**4.2 FRMS communication**

The organization shall develop and maintain formal means for FRMS communication that ensures that all personnel are fully aware of the FRMS, conveys fatigue-related safety-critical information, and explains why particular actions are taken and why procedures are introduced or changed.

	<b>In place<sup>1</sup></b>	<b>Documented<sup>2</sup> reference:</b>	<b>How is it achieved?<sup>3</sup></b>	<b>Inspector's assessment remarks<sup>4</sup></b>
4.2.1 Does FRMS communication reach all levels of staff in the organization?				
4.2.2 Does the FRMS communication clearly explain the policies, procedures and responsibilities? Does it complement and enhance the organization's safety culture?				
4.2.3 Is the FRMS information disseminated in suitable communication channels and is it monitored for its effectiveness?				

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