HSAC RP 15-2

FATIGUE RISK MANAGEMENT SYSTEM (FRMS)

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FATIGUE RISK MANAGEMENT SYSTEM (FRMS)

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Purpose

This Recommended Practice (RP) was developed to describe best practices for eliminating or mitigating the effects of human fatigue during helicopter maintenance activities through a simplified fatigue risk management system (FRMS).

Scope

While not the only means for reducing fatigue in aviation maintenance personnel, this RP provides guidance and recommendations for developing appropriate strategies and procedures to institute appropriate operator-specific human fatigue countermeasures. It describes fundamental concepts of human cognitive fatigue and how it relates to safe performance of duties by aviation maintenance personnel, provides information on conditions that contribute to cognitive fatigue, and provides guidelines and recommended practices on how individuals and aviation maintenance organizations can reduce or mitigate the effects of human fatigue.

Definitions

Circadian Challenge – the difficulty of operating in opposition to an individual's normal circadian rhythms or internal biological clock. This occurs when the internal biological clock and the sleep/wake cycle do not match the local time. For example, the sleep period is occurring at an adverse circadian phase when the body wants to be awake. Engaging in activities that are opposite of this natural biological system represents the circadian challenge (e.g., night work or shift work).

Circadian Rhythm – a daily alteration in a person's behavior and physiology controlled by an internal biological clock located in the brain. Examples of circadian rhythms include body temperature, melatonin levels, cognitive performance, alertness levels, and sleep patterns. The circadian rhythm programs humans to be awake during the day and asleep at night and regulates alertness, performance, and sleepiness leves through though the 24-hour day. This internal rhythm persists independent of periodic changes in external environment based on the time of day and can be modified by rest.

Circadian Synchrony – occurs when a person's internal biological clock matches the local external time cues (e.g., light/dark cycle, social interaction). In other words, sleep opportunities occur when the body wants to sleep and waking activities take place when the body is promoting wakefulness and alertness.

Cognitive Performance – the ability to process thought and engage in conscious intellectual activity, e.g., reaction times, problem solving, vigilant attention, memory, cognitive throughput. Various studies have demonstrated the negative effects of fatigue on cognitive performance.

Fatigue – an adverse physiological state in which there is a decreased capacity to perform cognitive tasks and an increased variability in performance as a function of time on task. Fatigue is also associated with tiredness, weakness, lack of energy, drowsiness, lethargy, depression, and lack of motivation.

Fatigue Risk Management System (FRMS) – a scientifically based, systematic method used to continuously monitor and manage fatigue risks associated with fatigue-related error. The FRMS may be, but is not necessarily required, a fundamental part of an MRO's safety management system (SMS).

Homeostatic Sleep Drive – a fundamental neurobiological process involved in the timing and placement of sleep through a 24-hour (diurnal) day. Sleep is a vital physiological requirement critical to human life. Good sleep is important to health and well-being as is proper nutrition and exercise. The average adult requires 8 hours of good sleep each day.

Safety Management System (SMS) – a coordinated, comprehensive set of processes designed to manage resources for optimal safety achievement. An SMS is a systematic approach to managing safety, including the necessary organizational structures, accountabilities, policies, and procedures representing a management approach to controlling risk.

Sleep Inertia – (also termed sleep drunkenness) refers to a period of impaired performance and reduced vigilance following awakening from the regular sleep episode or nap. This impairment may be severe, last from minutes to hours, and be accompanied by micro-sleep episodes.

Window of Circadian Low (WOCL) – personnel on a regular sleep-wake cycle with sleep at night have town periods of maximum sleepiness known as *windows of circadian lows* (WOCL). The WOCL vary by individual but are generally from 1500 to 1700 and from 0300 to 0500.

Background

Criticality of Fatigue in Aviation Maintenance Operations

On 7 December 2011, about 1630 Pacific standard time, a Eurocopter AS350-B2 helicopter crashed in mountainous terrain about 14 miles east of Las Vegas, Nevada. The pilot and four passengers suffered fatal injuries and the helicopter was destroyed by impact forces and post-impact fire.

The NTSB determined the probable causes of this accident as follows:

> Inadequate maintenance of the helicopter, including (1) the improper reuse of a degraded self-locking nut, (2) the improper or lack of installation of a split pin, and (3) inadequate post-maintenance inspections, which resulted in the in-flight separation of the servo control input rod from the fore/aft servo and rendered the helicopter uncontrollable.
>
> A major contributing factor to the improper or lack of installation of the split pin was the mechanic's fatigue and the lack of clearly delineated maintenance task steps to follow. A contributing to the inadequate post-maintenance inspection was the inspector's fatigue and the lack of clearly delineated inspection steps to follow.

Fatigue is characterized by a general lack of alertness and degradation in mental (cognitive) and physical performance. Fatigue manifests in the aviation maintenance context not only when personnel are sleepy or fall asleep on the job, but more importantly, during task-critical work such as inspection and repair. Reported fatigue-related maintenance events have included procedural errors, selection of wrong components, incorrect installations, errors and omissions, failure to quality control check work, and poor decision-making.

Maintaining optimal alertness and cognitive functioning in aviation maintenance environments is critical for achieving high levels of safety, efficiency, and success. High levels of alertness and performance are necessary to operate complex technology and machinery as well as to make critical task decisions on a sustained basis.

Individuals working erratic schedules experience conflicts between the biological circadian rhythm and environmental time cues and work demands. This physiological conflict can cause a sense of drowsiness (subjective fatigue), mood changes, performance degradation, and physiological upset.

The primary contributor to fatigue is lack of proper sleep. The root cause of fatigue is generally a combination of scheduling and lack of proper rest during sleep opportunities.

Two adverse effects of the circadian conflict between the sleep-wake pattern and the biological rhythm worsen performance levels and sleepiness:

- Trying to sleep when a person's biology is highly energized; and
- Attempting to maintain alertness and perform tasks at a time when a person's biological clock is programming the body to sleep.

Fatigue poses several unique threats related to aviation maintenance operations because maintenance personnel often must work (a) during night hours when people normally sleep so that aircraft are available for periods of typical operation during the day hours, (b) during unpredictable periods following unforeseen malfunctions, and (c) in potentially remote areas where the aircraft may be forced to cease operation due to equipment difficulties. Maintenance tasks are often performed under time pressure to return the aircraft to flight status.

Types of Fatigue

There are three types of fatigue: transient, cumulative, and circadian:

- **Transient fatigue** is acute fatigue brought on by extreme sleep restriction or extended hours awake within one or two days;
- **Cumulative fatigue** is brought on by repeated mild sleep restriction or extended hours awake across a series of days; and
- **Circadian fatigue** referees to the reduced performance during nighttime hours, particularly during WOCL described above.

Effects of Fatigue

Small reductions in sleep over a given time period create the accumulation of sleep loss, which is referred to as ***sleep debt***. The effects of fatigue are predicated upon the degree of the individual's sleep debt, but not specifically limited to that sleep debt. The only way to eliminate cumulative sleep debt is to obtain sleep because it remedies the underlying adverse physiological state brought about by sleep loss.

The effects of fatigue manifest in slightly different ways for each person; however, there are common effects that are associated with tiredness, e.g., weakness, lack of energy, lethargy, depression, lack of motivation, sleepiness, decreased alertness and situational awareness, and poor decision-making skills. Fatigue decreases a person's ability to perform cognitive tasks and increases variability in performance as a function of time on task.

Effects of fatigue may be analogous to cognitive impairment by alcohol or drug intoxication. Moderate fatigue may equate to blood alcohol concentrations of 0.04 g-dL^{-1}; conversely, severe or extreme fatigue may manifest

similar to blood alcohol concentrations of 0.08 all the way to 0.24 g-dL^{-1}, depending upon the severity of the accumulated sleep debt or circadian dysthymia.

Homeostatic Sleep Regulation

The drive for sleep increases over time since the last sleep period and with any cumulative deficit in sleep relative to the average 8-hour day requirement. As a consequence, the sleep drive is at its lowest point in the morning, upon awakening, and as the day progresses, the drive to sleep increases and the ability to sustain attention and engage in cognitive activities decreases. Once sleep begins, this drive gradually decreases until awakening.

The system is homeostatic in the sense that the more a person is deprived of good quality sleep (relative to the nominal 8-hour requirement), the stronger the drive for sleep. The two main fatigue processes—24 hour (circadian) rhythm and sleep regulation—combine to produce dynamic changes in sleep tendency and ability to maintain stable alert performance across a 24-hour period and across days.

Elevated Sleep Drive

For the average person, the daily upswing in alertness produced by the circadian system tends to offset the decrease in alertness produced by depletion of the sleep regulatory process. The result is roughly constant reaction time and lapses during the first 16 hours of the day. After about 16 hours of continuous wakefulness, most adults begin to notice reductions in the speed of performance and in alertness levels. However, a prior history of insufficient sleep quantity and quality can magnify the changes in behavior and alertness.

Consequently, three factors can result in elevated homeostatic sleep drive:

- Increasing time continuously awake;
- Inadequate sleep duration for one or more consecutive days;
- Physiologically disrupted (fragmented) sleep due to medical conditions (e.g., untreated sleep disorder such as obstructive sleep apnea) or environmental factors (e.g., attempting to sleep upright or in an uncomfortable environment).

Circadian Desynchronization

The timing of sleep and wakefulness of most humans, under natural conditions, is consistent with the circadian control of the sleep cycle and all other circadian-controlled rhythms. However, people working in a developed society override their internal biological clock and attempt to sleep at times that are not always consistent with the biological drive to sleep.

For example, when individuals travel rapidly across time zones or work the night shift, the sleep-wake cycle is out of phase with the biological rhythms controlled by the internal biological (circadian) clock. This can adversely affect both alertness while awake and at work, and the ability to achieve restorative sleep. This sort of disruption of circadian synchrony can result in difficulties, such as impaired cognitive function, sleepiness, altered hormonal function, and gastrointestinal complaints.

Sleep Inertia

This sleep-related process causes a temporary degradation in performance immediately after awakening. The degradation or loss of alertness is dependent on depth of sleep at the time of awakening. The degradation dissipates, after awakening, on a time scale ranging from minutes to a few hours. Sleep inertia causes a feeling of drowsiness or lethargy and can be measured as a noticeable change in reaction time and potential for lapses in attention.

The duration and severity of sleep inertia is related to the depth of sleep at the time of awakening. It tends to be greater after short sleep periods of an hour or two, when the need for sleep is not fully satisfied or after sleep when the person is carrying a large sleep debt from prior sleep restrictions.
Sleep inertia manifests itself mostly through sleep interruptions such as being called out in the middle of the night to attend a maintenance issue, especially if the maintenance technician must drive to a stranded aircraft at a remote location.

Recovery Sleep

To reverse the effects of fatigue, humans must receive ***recovery sleep***. The period for recovery sleep may be different for each person because one person's need for required sleep may vary from that of another person. Some people may require eight hours of continuous sleep while others may require more than eight continuous hours.

Sleep Debt

A minimum 8-hour sleep opportunity is the essential element in obtaining restorative sleep, assuming the person actually obtains 8 hours of sleep. Without obtaining the appropriate restorative sleep, a human starts accumulating a sleep debt. Accumulating a sleep debt over several days exposes that the person to a potential fatigue event. The amount of recovery sleep required to repay the sleep debt is related to the total amount of sleep debt. The amount of sleep required to make up a deficit is less than the total number of hours of sleep missed; therefore, it does not take an additional 8 hours of sleep to make up for an 8-hour accumulated sleep debt.

However, since it takes 8 hours of sleep to balance a normal day of wakefulness, it will require more than 8 hours of sleep per recovery day to repay the debt.

In general, if a person has experienced several days of sleep restriction below the nominal requirement of 8 hours per day, full recovery of performance may require several days of 9 hours or more sleep per day. Therefore, it is imperative that aviation maintenance personnel utilize their sleep opportunities to obtain the required rest.

Error Rates

Personnel working regular 24-hours sleep-wake schedules with sufficient time to sleep will experience little change in performance and subjective fatigue during waking hours for one to two hours after awakening to one to two hours before sleep onset. However, in work environments such as aviation maintenance, an increase in error rates and mishap likelihood often occurs early in the afternoon during the 1400 to 1700 WOCL, followed by a much larger increase in fatigue-related risk in the early morning hours between 0200 and 0500 WOCL.

Time on task can also increase fatigue and error rates. After 8 hours of uninterrupted work, opportunities for error increases significantly. Providing short breaks from work, especially if timing of the break is self-selected, can greatly attenuate this effect.

Subjective Fatigue

People are NOT the best evaluators of their own alertness state. Humans can lose awareness of their own fatigue levels. They are often more fatigued than they report. Although individuals report feeling increasing levels of sleepiness and fatigue with the progression of sleep loss, research has shown that these subjective estimates are unreliable.

Environmental conditions can affect subjective estimates. If an individual is in a highly engaged environment involving physical activity or interaction with other individuals, the person's underlying sleepiness may not be noticeable and that person may rate themselves as being more alert than their physiological responses indicate. This creates challenges for detecting and managing alertness and cognitive capability in operational environments because individuals often do not notice the gradual changes in performance until it is too late to take corrective action.

Personnel often report workload as an important component of subjective fatigue. A maintenance technician that performs many tasks during a duty period will report more subjective fatigue than a single task taking the same amount of time. Workload may combine with sleep debt to amplify fatigue.

Emotional Fatigue

Fatigue can affect overall mood and emotional health. Fatigued individuals often show deterioration in mood and have reductions in the amount and quality of communication and social interaction with other individuals and team members. This can have serious consequences for workgroups such as those involved in aviation maintenance that rely on the exchange of information and provide mutual support to avoid errors.

Aviation Maintenance Shift Work Operations

Fatigue is inherent in aviation shift work operations. Many repairs and inspections must be performed overnight to increase the availability of the aircraft during the day when it is most needed. Thus, aviation maintenance personnel are faced with shifted schedules that interfere with normal sleep-wake cycles that permit night-time sleep and daytime work. Shift work has traditionally included only night work and rotating shift schedules, however, the modern definition is more comprehensive. It includes any schedule that can potentially affect both sleep and circadian rhythms. Specifically, any schedule outside the traditional 0700 to 1800 timeframe can be categorized as shift work and such shifts are becoming increasingly common.

Fatigue difficulties are commonly associated with shift work because sleep disturbances and sleepiness are the most commonly reported complaints of shift workers. Although false, it is a not uncommon belief that as the shift worker adapts to their schedule over time and gets used to the non-standard shift, all of their problems associated with shift work are alleviated. However, shift work is not just about sleep; it is a more complex issue.

Shift work is not simply a term used to describe non-standard schedules. It also is associated with the disruption of an individual's underlying physiology. Shift work requires people to override the internal biological clock that programs humans for daytime activity and nighttime sleep. This produces circadian dysrhythmia, a condition in which the biological clock remains synchronized to the local time, driven by exposure to the local pattern of sunlight, but the sleep-wake cycle is out of synchronization with the local time. In other words, the sleep period is occurring at an adverse circadian phase, when the body is programmed to be awake. As a result, one can experience sleep difficulties (e.g., longer than normal times to fall asleep and early termination of sleep) resulting in continuous partial sleep deprivation and chronic sleep loss. The shift worker is further challenged by the fact that their sleep-wake cycle is constantly altered between work days and non-work days due to conflicting time cues from the day-night cycle and a day-oriented society (e.g., keeping the same day schedule as the family on non-work days).

Lastly, a number of common scheduling factors disrupt sleep and circadian rhythms and affect alertness and performance of shift workers in aviation environment. These work schedule factors might include early start times, variable work periods, insufficient recovery time, consecutive work periods, and on-call status, among others.

Managing Fatigue

There are two central elements in managing or mitigating the effects of fatigue. First, the MRO must prepare their work schedules in a manner that accommodates enough time for an appropriate sleep opportunity, even in the face of unscheduled maintenance requests. Secondly, aviation maintenance personnel must take full advantage of each sleep opportunity to ensure they receive adequate sleep and are properly rested before starting a work shift.

Simplified Fatigue Risk Management System (FRMS)

This section presents a simplified fatigue risk management system (FRMS) which would be useful to small MRO conducting helicopter maintenance and repair. This is best accomplished by implementing a combination of prescriptive duty-hour restrictions and performance-based metrics. The FRMS is intended to be part of the overall safety management system (SMS) but may be used by MRO's that do not have an SMS as a standalone safety practice.

There is general agreement that duty time limitations alone are not the best approach in aviation maintenance fatigue risk management because they do not deal with the root problem of fatigue; even an aircraft maintenance technician (AMT) observing duty time limitations may be affected by fatigue if they have not had adequate rest.

Hazard Control Framework

An effective fatigue risk management plan should take a systems approach to minimizing fatigue-related mishaps. The FRMS is based on the five-level error trajectory taxonomy presented in Figure 1.

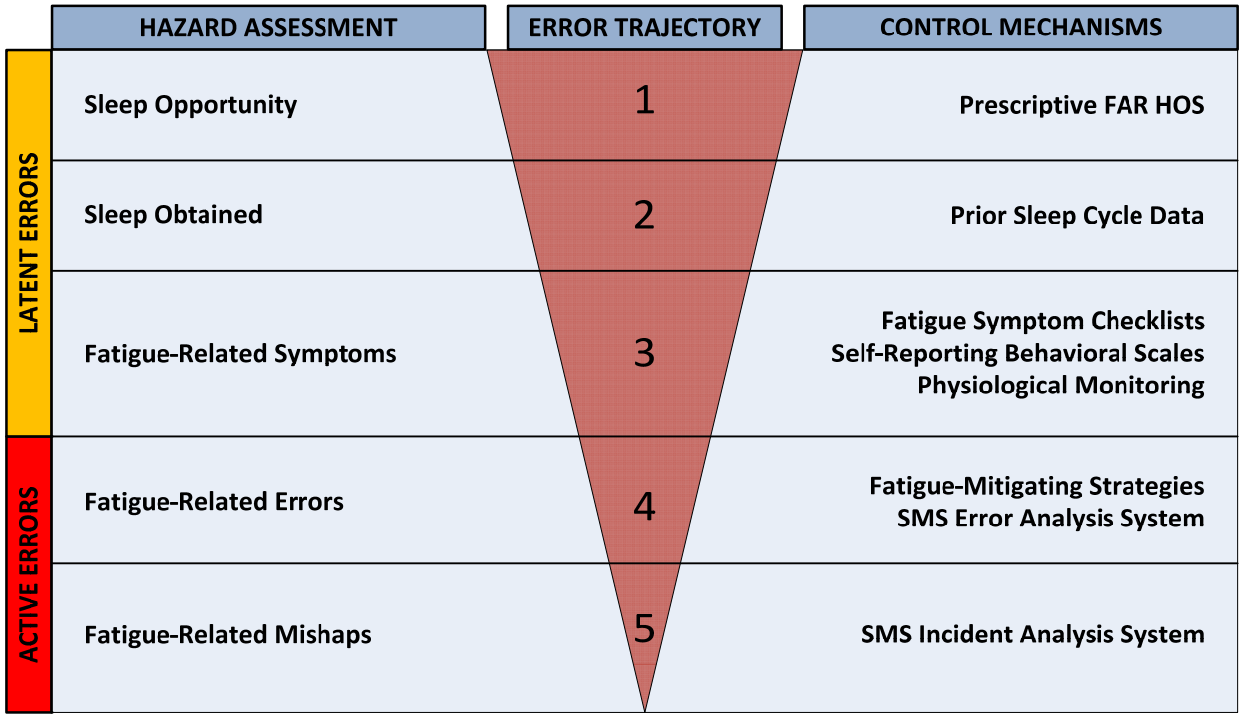


Fig. 1 – Five-Level Error Trajectory

The FRMS incorporates fatigue hazard control mechanisms:

- (Level 1) Sufficient sleep opportunity is provided to personnel;
- (Level 2) Actual sleep is obtained and verified;
- (Level 3) Procedures for monitoring and mitigating fatigue-related symptoms;
- (Level 4) Fatigue-mitigating strategies are implemented to reduce fatigue-related risk; and
- (Level 5) Mishap investigation procedures include fatigue causal factors.

Management Commitment to Fatigue Risk Reduction

To be effective a there must be a clear commitment to the FRMS from the MRO's senior management. This is an overall statement about the management of fatigue hazards. The statement outlines the corporate philosophy of fatigue risk management and clearly identifies the personnel responsible for oversight of the FRMS within the company. FRMS policies and procedures must be communicated to all employees with a clear endorsement by senior management.

An example policy statement is provided below.

1. [Company Name]'s Fatigue Risk Management System (FRMS) policy represents the strongest commitment at the highest level of the company and is signed by the chief corporate executive.

   [Company Name)] is committed to protecting all employees, clients, visitors, and the general public from fatigue-related risk. There will be no compromise in an employee's well-being in anything we do. Implementing measures to minimize fatigue-related risk and create a safe, healthy, and injury-free environment is a leadership responsibility. Continuing support of this effort is the responsibility of everyone.

2. The purpose of the FRMS is to reduce, as far as practicably reasonable, workplace fatigue and its risks, to ensure a safe and error-free work environment for employees, clients, and visitors. The objectives of this policy are to ensure:

   - Employees are fit for work;
   - The company enjoys a safe working environment by minimizing hazards associated with fatigue;
   - The fatigue hazards associated with long work hours and shift work are minimized;
   - Employees have access to assistance through a range of preventative initiatives, including training;
   - Informed decisions are made about work design and workload;
   - On-going risk assessment and hazard monitoring takes place; and
   - Employees unfit for duty as a result of fatigue will be dealt with consistently and fairly in accordance with this policy.

Resources for maintenance, development and implementation, updating and reporting of fatigue in the workplace in relation to the FRMS policy and personnel responsible for it will be through the Human Resources Department (or similar).

Level 1 – Hours of Service (HOS) and Scheduling

The degree of work-related fatigue associated with a given task on a given schedule is linked to the degree a schedule precludes sleep of sufficient quality and duration to ensure employees are fit for work. A schedule produces higher levels of work-related fatigue if it requires an employee to work more often at times when one is socially and biologically predisposed to sleeping.

It is important that schedules provide personnel with sufficient sleep opportunity to ensure they are fit for work. The factors that affect sleep opportunity are the length and timing of shifts, time away from work, long blocks of shifts, and biological limits on recovery.

The simplest method of ensuring personnel are provided with sufficient sleep opportunity within a work schedule is to limit the hours of service (HOS). Work schedules must be assessed for adequate sleep opportunity. Planned work hours are assessed in advance, whereas actual work hours are assessed retrospectively. Recommend imitations on hours of service are provided in the summary of recommended practices section.

Level 2 – Verification of Actual Sleep

The primary physiological determinants of fatigue for a given employee carrying out a given task are the timing and duration of prior sleep and time awake. These factors are the most appropriate criteria for judging whether an AMT is likely to be fit for work. The Level 1 hours of service and scheduling rules outlined in the recommended practices section are effective in predicting how much sleep an employee is likely to obtain in a given break from work. The Level 2 control, however, aims to ensure that the AMT actually obtained sufficient sleep. Admittedly, this is the most difficult part of the FRMS because it relies on honest self-reporting by the individual.

The focus of this level of control is setting minimum and maximum thresholds for sleep and time awake for personnel to ensure that they are fit for aviation maintenance duty. These minimum and maximum thresholds can provide a simple, practical, and easily measurable metric to determine whether a person has obtained sufficient sleep, and by inference, is fit for work.

These thresholds are equivalent to the simple formula used to determine whether a person may be impaired by alcohol consumption, since the effects of fatigue and alcohol are similar.

For example, in counting number of alcoholic drinks they have had over a period of time. While counting sleep and time awake is not a perfect indicator of the level of fatigue for all individuals on all occasions, it can provide a simple measure for determining the relative likelihood that a person is impaired by fatigue.

Individual Fatigue Likelihood Score (IFLS)

To maintain optimum performance, health, and wellbeing, individuals should get between seven and nine hours sleep per 24-hour period as discussed above. In general, performance begins to become impaired after less than five hours sleep over a 24-hour period. Conversely, performance also becomes impaired if sleep consistently falls below six hours per night on an ongoing basis (over the period of a week).

A measure of fitness-for-duty related to fatigue can be calculated using the following table:

CALCULATING INDIVIDUAL FATIGUE LIKELIHOOD SCORE (IFLS)		
Prior Sleep-Wake Factor	**Threshold Value**	**Scoring***
X (sleep in prior 24 hours)	5 Hours	Add 4 points for every hour below threshold.
Y (sleep in prior 48 hours)	12 Hours	Add 2 points for each hour below threshold.
Z (time awake since last sleep)	*Y*	Add 1 point for each hour of wakefulness greater than *Y.*
*Partial hours should be pro-rated or scored proportionally. For example, if scoring calls for 4 points for every hour below the threshold, give 2 points for a half-hour or 1 point for 15 minutes.		

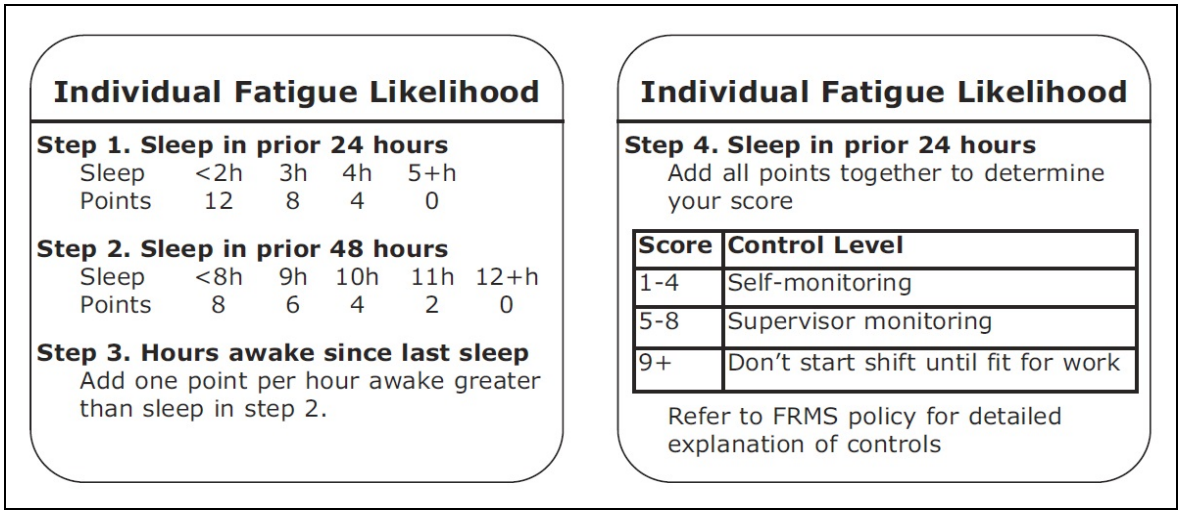
As prior sleep decreases and time awake increases, the likelihood of fatigue-related symptoms, errors, and mishaps also increases. In general, *X* should be greater than 5, *Y* should be greater than 12 and *Z* should be less than *Y*.

Each of the factors (X, Y, and Z) is added to provide an overall score of individual fatigue likelihood.

Personnel who obtain an elevated fatigue likelihood score should inform the appropriate supervisor or manager, and appropriate action should be taken. It is useful to establish a decision tree for personnel and managers that provide clear information about appropriate action at various levels of fatigue. The table below shows an example.

DECISION TREE BASED ON INDIVIDUAL FATIGUE LIKELIHOOD SCORE (IFLS)		
Individual Fatigue Score	**Risk Level**	**Approved Controls**
0	Acceptable	No additional controls necessary except in the presence of higher level indicators of fatigue (symptoms, errors, or incidents).
1-4	Minor	Inform line supervisor and document in daily logbook. Self-monitor for fatigue-related symptoms and apply individual controls such as strategic use of caffeine, task rotation, working in pairs, or additional rest breaks.
5-9	Moderate	Inform management and document a fatigue report. Implement additional fatigue controls such as task reallocation and increased level of peer and supervisory monitoring. All work must be dual inspected. Operational and functional checks must be carried out whenever a critical system has been disturbed. No task-signoff authority
≥ 10	Severe	Call supervisor before driving to work. Document in fatigue report on next work shift. Do not engage in safety-critical tasks (including driving to work), and do not return to work until sufficiently rested as per hours of service (HOS) rules. . May not interact with safety critical systems such as flight controls.

For simplicity, a small pocket card such as that shown in Figure 2 can be provided to each person subject to the FRMS.



Individual Fatigue Likelihood

Step 1. Sleep in prior 24 hours

Sleep	<2h	3h	4h	5+h
Points	12	8	4	0

Step 2. Sleep in prior 48 hours

Sleep	<8h	9h	10h	11h	12+h
Points	8	6	4	2	0

Step 3. Hours awake since last sleep

Add one point per hour awake greater than sleep in step 2.

Individual Fatigue Likelihood

Step 4. Sleep in prior 24 hours

Add all points together to determine your score

Score	Control Level
1-4	Self-monitoring
5-8	Supervisor monitoring
9+	Don't start shift until fit for work

Refer to FRMS policy for detailed explanation of controls

Fig. 2 – Personnel IFLS Card

One way to use the IFLS as a Level 2 control is to apply the minimum sleep and maximum time awake rules as a simple self-assessment tool. Personnel would determine their own risk of fatigue and be required to manage their own fatigue with countermeasures such as sleep planning, strategic napping, caffeine, breaks, task rotation, etc.

When an employee notifies a supervisor or line manager of an elevated fatigue score, the reasons for the score need not to be discussed unless the employee reports such a score more than three times in

90 days. Discussions about the cause of multiple reports should typically involve the employee assistance program in the first instance (where applicable) and can subsequently involve line managers and supervisors where appropriate.

It is imperative that any actions taken with respect to multiple elevated fatigue score reporting be non-punitive unless there is substantial cause. If the actions taken against personnel are punitive, then this destroys any validity of self-reporting and renders the program ineffective. **This cannot be overstated**.

Using IFLS to Improve Work Scheduling Practices

The Level 2 controls are designed to ensure adequate sleep at the individual level. They use relatively objective measures that are intuitively meaningful, observable, and easily recorded at the individual and group levels.

If an MRO emphasizes Level 2 controls that are reliably reported and documented, it can also be used to collect valuable data on fatigue in the organization. The data could be aggregated across an entire organization or even industry to provide the basis of a statistically sound approach to evaluating the amount of sleep and time awake provided by a schedule and forms the basis for evaluating the effectiveness of scheduling factors set out in the summary of recommended practices section.

Untrained Personnel/Contractor Assessment

Personnel and contractors who have not received fatigue management training should be asked to confirm that they have had a minimum of six hours sleep in the preceding 24 hours prior to starting work.

Where personnel have not had six hours of sleep, they should be required to report this to a supervisory or managerial individual. A risk assessment must be conducted to determine the appropriate action. As a general rule, obtaining only five to six hours of sleep should be considered a minor hazard, obtaining four to five should be considered a moderate hazard, and obtaining less than four should be considered a significant hazard.

In general, managers and supervisors should use controls similar to those outlined in the IFLS decision tree. This may include, but is not limited to, task rotation, napping, workload reallocation, sending the person home, provision of transport off site, and requiring the employee get adequate sleep prior to returning to work.

Level 3 – Fatigue Related Symptoms

Level 3 controls are concerned with reducing the likelihood personnel exhibit fatigue-related symptoms and reducing the consequences. There are many reasons that a person may appear to be or act fatigued. If the FRMS is operating effectively, the root cause – insufficient sleep – should be screened out by Level 1 or 2 controls.

The type of work or maintenance task performed may be particularly physically or mentally demanding, which can exacerbate fatigue and lead to fatigue-related symptoms. Environmental factors such as noise, vibration, ambient temperature and lighting, or inclement weather can also affect fatigue. These factors should all be considered in the risk assessment of work tasks so that scheduling parameters can be set for different work tasks where warranted. The appearance of fatigue-related symptoms during certain work periods or tasks can be an indication that the fatigue risk mitigation strategies should be reassessed.

There may be situations where fatigue-related symptoms are not directly linked to work tasks or environmental conditions, and where the person has been provided sufficient opportunity and actually obtained sufficient sleep. Non-work factors are likely the cause. For example, the employee may be experiencing personal stress (e.g., medical illness, newborn baby, financial issues, divorce) that is disturbing sleep.

Personnel who self-report that they get enough sleep and cannot explain their fatigue-related symptoms should undergo screening for a sleep disorder by a competent medical practitioner as soon as possible, particularly if they are performing safety-critical tasks.

Level 3 controls – observing and reporting fatigue-related symptoms – are important in an effective FRMS to determine whether:

- Minimum sleep requirements are appropriate;
- Task-scheduling processes are appropriate;
- Non-work activities are affecting the risk of workplace fatigue; and
- A person has a sleep disorder.

The following table lists typical symptoms of fatigue. If personnel have experienced more than three (3) of the specified symptoms in a 15-minute-period, they are likely to be fatigued and should be considered at an elevated level of fatigue-related risk.

SYMPTOMS OF FATIGUE		
Physical Symptoms	**Mental Symptoms**	**Emotional Symptoms**
• Yawning • Heavy eyelids • Eye-rubbing • Head drooping • Inappropriate or unintentional dozing (micro-sleeps)	• Difficulty concentrating on the current work task • Lapses in attention • Difficulty remembering what they are meant to be doing • Failure to communicate important information to a colleague or team member • Failure to anticipate obvious events or actions • Unintentionally doing the wrong thing (errors of commission) • Unintentionally failing to do the right thing (errors of omission)	• More quiet or withdrawn than normal • Lethargic or lacking in energy • Lacking in motivation to do the task well • Irritable or bad tempered with colleagues, family, or friends

When personnel notice symptoms of fatigue in a coworker, they should point it out to the coworker. If the situation arises again, employees should encourage the coworker to report the fatigue and take the precautions outlined in the Level 2 controls.

Personnel repeatedly exhibiting fatigue-related symptoms should be encouraged to consult a competent medical specialist to determine whether they suffer from a sleep disorder. This is particularly important for personnel with a large body mass index since they are at a greater risk for sleep apnea.

Using Fatigue Symptom Data to Assess Level 1 and 2 Controls

Documenting Level 3 controls can help double-check that Level 1 and 2 controls are appropriate.

For example, if there is a high incidence of fatigue-related symptoms, and personnel say they are complying with the MRO's minimum sleep requirements, the scoring system for sufficient sleep may need to be reviewed.

Fatigue-related symptoms can also flag personnel who breach their responsibility of obtaining appropriate sleep in the time provided. For example, it is unlikely that personnel who choose to engage in social activities rather than sleep will report their inadequate sleep to management. However, if they regularly demonstrate fatigue-related symptoms, they may need to be reminded of their responsibility under the FRMS to arrive at work fit for duty.

Level 3 controls can also flag personnel who experience disturbed sleep quality or quantity beyond their or the MRO's control and who may be impaired by fatigue.

Level 4 – Fatigue-Mitigating Strategies

The main benefit of an FRMS is to provide the MRO and its personnel with an increased level of safety management. The scheduling guidelines set out in the summary of recommended practices should be used for the majority of the MRO's operations. However, there will be occasions when operational demands require extended hours of work. This may result in personnel working through higher levels of fatigue than normal.

In these situations, there are a number of strategies that can be used to mitigate the consequences of increased fatigue. For example, supervisors may rely more heavily on Level 2 and 3 controls. This can help to determine which personnel are most appropriate to complete the additional duties. To prevent fatigue-related errors, supervisors should use Level 4 strategies, such as:

- Napping;
- Supervisor and coworker monitoring;
- Double-check or quality control system;
- Task rotation and reallocation; and
- Additional breaks and strategic use of caffeine.

Napping

As a general rule, those with the highest risk should have the highest priority for napping. In general, the longer the nap, the greater the sleep recovery value. Naps should last at least 20 minutes and no more than two hours to be of maximum benefit. Shorter naps do not produce appreciable or lasting improvements in alertness.

Sleeping more than two hours brings little additional benefit, particularly when that time could be used to provide another person with a napping opportunity. Where controlled napping is allowed, the MRO should detail the circumstances under which it is permitted.

It is important to keep in mind that longer naps are associated with a longer period of sleepiness immediately following waking. This effect is known as ***sleep inertia***. Personnel should be given sufficient time to overcome the effects of sleep inertia before returning to work. Typically, this is at least 10 minutes during the day, and up to 20 minutes in the early hours of the morning, particularly in the early morning WOCL.

Monitoring and Double-Check Systems

Where an employee is at an elevated risk of fatigue-related error, increased monitoring by peers or supervisors for fatigue-related symptoms or impaired task performance can be an effective strategy.

However, this can be a sensitive issue and it is important that the criteria for increased monitoring are clear in advance to minimize misunderstanding.

Increased monitoring can be achieved in a number of ways. It can be as simple and informal as more frequent or regular conversations with the person over the course of the shift. Or it can involve more formal policies or

procedures that call for additional, verified supervisory checks on safety-critical work by the fatigued impaired employee, coworkers, or a line supervisor.

Task Rotation and Reallocation

Monotonous tasks with little variety are particularly susceptible to the effects of fatigue. In many cases, the workload can be made more engaging by varying the tasks during a shift. It is important to understand that the benefits of task rotation do not increase linearly. In general, the number of different tasks undertaken in a given shift should not exceed three or four, or the risk of error due to unfamiliarity with the job at hand may rise. Where task rotation forms part of the control system for fatigue-related risk, the number and types of tasks allocated should be determined in consultation with the personnel to perform the task.

The following types of maintenance tasks are likely to be most susceptible to fatigue-related error:

- Tasks that are monotonous or boring;
- Inspection tasks;
- Familiar tasks and those that can be performed "automatically" at a skill-based level with minimal need for cognitive attention;
- Tasks that rely on prospective memory (memory for intentions);
- Task requiring intense, continuous concentration;
- Task performed in low-light environment such as outside in darkness or internal airframe inspections; or
- Tasks were incorrect performance is not immediately obvious.

When a person shows signs of fatigue, or when a self-assessment tool like the IFLS indicates impairment from fatigue is likely, the MRO should make sure that the person is not given safety-critical tasks. Reallocation acceptable activities might include simple procedural tasks, word or data processing, quality checks, and basic communication. This reduces the risk of a mishap, but does not mitigate the employee's fatigue.

Additional Breaks and Strategic Use of Caffeine

When operational tempo calls for longer hours of work, additional breaks should be provided to employees when fatigue may impair their performance. A break of 10 to 20 minutes may permit improvements in performance on a short-term basis. Personnel assigned to tasks that require sustained attention over prolonged periods of time should take a break at least every two hours. Research shows that performance starts deteriorating after two hours on high-demand tasks. The breaks should be used to engage in strategies to improve alertness, e.g., walk outside to get some fresh air, exercise, have a coffee, etc.) When possible, the breaks should be self-selected by the person performing the task.

Judicious use of caffeine can provide a short-term improvement in alertness when it is used strategically. A typical dose of caffeine (75 to 150 mg) will provide an increase in alertness approximately 20 minutes after ingestion. The stimulating effects will vary in intensity and duration (up to four hours) depending on how often and how much caffeine the body is used to. However, the body can develop a tolerance, meaning the more caffeine the body gets on a daily basis, the less noticeable are the stimulating effects. Note that a typical 8

ounce cup of coffee contains approximately 80-100 mg of caffeine and that there are individual differences in caffeine tolerance as discussed. It is generally accepted that healthy adults can ingest 400 mg of caffeine per 24-hour period without experiencing significant adverse effects.

The best way to think about caffeine is that it has the capacity to "shift" fatigue and alertness to more appropriate times. However, there are significant disadvantages to prolonged regular caffeine use.

Individuals differ enormously in their sensitivity to both the positive and negative effects of caffeine.

High caffeine containing energy drinks or "energy shots" should be used with caution. The popular energy drink Red Bull™ contains 9.625 mg-fl.oz^{-1} or 77 mg of caffeine per 8 fluid ounces. Repeated use of energy drinks or shots over the course of a shift may over caffeinate and produce adverse effects such as jitters, restlessness, increased or irregular heartbeat, anxiety, nausea, sweating, dizziness, or vomiting.

Level 5 – Reporting Protocols and Mishap Investigations

Reporting protocols within the FRMS should be defined on two levels:

1. Reporting fatigue-related risk (insufficient sleep or sleep opportunity, fatigue-related symptoms); and
2. Reporting errors and incidents that are fatigue related.

Reporting Fatigue-Related Risk

Reporting risk is important for FRMS review and evaluation. Collect data on the frequency that personnel are at risk of a fatigue-related error or incident. How often did the work schedule provide insufficient sleep opportunity? How often did personnel report getting insufficient sleep? How often did they report experiencing fatigue-related symptoms?

Personnel may be reluctant to report this level of fatigue-related impairment on formal incident reporting forms, particularly in the early stages of FRMS implementation. The MRO should ensure that personnel are aware of the fatigue reporting policy and that reports submitted to the MRO remain confidential and non-punitive. A special reporting form may be appropriate. The MRO's health, safety, and environmental (HSE) personnel could set up a reporting system and fatigue occurrence database to collect information such as:

- What schedule have you been working for the last week?
- How much sleep did you obtain in the last 24 hours?
- How much sleep did you obtain in the last 48 hours?
- What fatigue-related symptoms have you been experiencing?
- Have you notified a supervisor that you are at risk of making a fatigue-related error?
- Who have you notified that you are at risk of making a fatigue-related error?
- What fatigue-related countermeasures have you used?

Reporting Fatigue-Related Errors and Mishaps

Most MRO have formal requirements to report accidents and incidents as a part of their SMS or HSE policies and procedures. Few, however, systematically examine whether fatigue was a contributing factor.

For an error or mishap to be defined as fatigue related, it must have:

1. Occurred in the presence of fatigue; and
2. Been consistent with fatigue-related error (e.g., caused by employee falling asleep, inattention, delayed reaction time, complacency, etc.)

To define an event as fatigue-related, the first three levels of control (see Fig. 1) must be reviewed:

1. Did the work schedule provide sufficient sleep opportunity for the person (Level 1 control)?
2. Did the person actually obtain sufficient sleep (Level 2 control)?
3. Was the event preceded by the presence of at least three (3) fatigue related-symptoms (Level 3 control?

Examining planned and actual hours of work not only reveals whether changes led to insufficient sleep opportunity, but can help the MRO better understand whether additional work hours were foreseeable and how to better allocate them in the future. Questions about the schedule could also include examining the commute to and from work or to the work site for personnel involved since this can also influence the sleep opportunity.

The second question allows the MRO to collect information on actual sleep obtained by the specific person. How many hours of sleep did the person obtain in the 24 and 48 hours before the event? How long was it since the person had woken up from a sleep or a nap? If the person had not obtained sufficient sleep, why not? Why it was not reported on arrival at work?

Since the reporting process relies heavily on the honesty of personnel, it must be non-punitive. Incidents of insufficient sleep should be considered a learning experience for the MRO and other personnel, rather than as an incident that can affect an person's employment status.

The MRO should also investigate whether the person had been observed falling asleep or struggling to remain alert in the week before the event. This information could be collected either directly from the employee, or from coworkers or supervisors. Similarly, was the person exhibiting any other fatigue-related symptoms directly before the event? Additional questions that could be asked include:

- Did the person take medications or drugs in the week prior to the event?
- Has the person been diagnosed with or show symptoms of a medical problem or sleep disorder that may affect fatigue or alertness?
- Did the person work at another job or have additional responsibilities during the two weeks before the event?

Assessing the information collected with these questions can provide the MRO with a clearer understanding of when fatigue is a contributing factor to an error or mishap.

Reporting non-critical errors also offers an opportunity to analyze the effectiveness of the FRMS. In any organization, there is a greater frequency of errors (near misses) than mishaps (hits).

An organization can determine the root causes of any fatigue-related risk and implement appropriate control strategies before an error becomes a mishap. Root cause analysis of fatigue-related errors and mishaps enable the MRO to devise effective containment and corrective actions as required by the SMS.

Training and Education

All personnel should be trained to understand the purpose of the FRMS and their responsibilities within the system. The person responsible for the FRMS such as the HSE manager should arrange fatigue-related safety training for all personnel. The training program should highlight the risk of fatigue, how it will be managed within the MRO's operations, and how it fits within existing organizational policies and procedures such as the SMS. It is essential that records be kept that include dates, names, subjects covered, and course presenters. The MRO may seek the assistance of human factors specialists in the development of a training program.

All personnel should be provided with an introductory booklet or pamphlet when the MRO implements an FRMS. This publication should also be provided to new personnel as part of the HSE onboarding process and in advance of scheduled training.

The formal FRMS training course must include instructor-led, face-to-face training and a competency-based test to ensure transfer of knowledge. Instructor-led training allows personnel to ask questions about their responsibilities within the FRMS and how it affects the work environment.

The competency-based test ensures that personnel have understood the information and can apply the knowledge and skills to their own work environment.

Summary of Recommended Practices

General

- Aircraft maintenance and repair organizations performing work on helicopters are encouraged to develop risk management systems such as a formal safety management system (SMS) and a fatigue risk management system (FRMS).
- To be effective a there must be a clear commitment to the FRMS from the MRO's senior management. This is an overall statement about the management of fatigue hazards. The statement must outline the corporate philosophy of fatigue risk management and clearly identifies the personnel responsible for oversight of the FRMS within the company. FRMS policies and procedures must be communicated to all employees with a clear endorsement by senior management.
- A training program must be developed to increase personnel's awareness of the problems associated with aviation maintenance shift work and fatigue-related errors and mishaps.

Level 1 Controls (Hours of Service and Scheduling)

- No scheduled shift should exceed 12 hours.
- No shift should be extended beyond a total of 16 hours by overtime.
- A minimum rest period of 11 hours must be allowed between the end of shift and the beginning of the next, and this rest period shall not be compromised by overtime work requirements.
- Scheduled work hours should not exceed 48 hours in any period of seven (7) consecutive days.
- Total work, including overtime, should not exceed 60 hours, or seven (7) consecutive work days, before a period of rest days.
- A period of rest days should include a minimum of two successive rest days continuous with the 11 hours off between shifts (i.e., a minimum of 59 hours off). This limit should not be compromised by overtime work requirements or operational tempo.
- A span of successive night shifts should be limited to six (6) for shifts of up to eight (8) hours long, four (4) for shifts of over 8 to 10 hours long, and two (2) for shifts of greater than 10 hours. These limits should not be exceeded by overtime work requirements or operational tempo.
- A span of nights shifts involving 12 or more hours of work should be immediately followed by a minimum of two (2) successive rest days continuous with the 11 hours off between shifts (i.e., a minimum of 59 hours off), and this should be increased to three (3) successive rest days (i.e., 83 hours off) if the preceding span of night shifts exceeds three (3), or 36 hours of work. These limits should not be compromised by overtime work requirements or operational tempo.
- The finish time of the night shift should not be later than 0800.
- A morning or day shift should not be scheduled to start before 0600 and, wherever possible should be delayed to start between 0700 and 0800.

- A span of successive morning or day shifts that start before 0700 should be limited to four (4), immediately following which there should be a minimum of two (2) successive rest days continuous with the 11 hours off between shifts (i.e. a minimum of 59 hours off). This limit should not be compromised by overtime work requirements or operational tempo.
- Whenever possible, aviation maintenance personnel should be provided their work shift schedules at least 28 days in advance.
- Aviation maintenance personnel should be discouraged from working for other MRO's or other outside work on their rest days as well as exceeding the proposed recommendations on work schedules despite their implementation by their MRO.

Level 2 Controls (Verification of Actual Sleep)

- Aviation maintenance personnel should be required to report for duty adequately rested.
- The MRO should use an Individual Fatigue Likelihood Score (IFLS) or other self-assessment tool to ensure that personnel are getting adequate sleep during sleep opportunities. A simplistic pocket card should be provided to personnel for self-assessment.
- Personnel should be required to report elevated fatigue scores or any fatigue-related impairment to supervision or management. Reporting must be non-punitive in nature.
- Untrained personnel or contractors should confirm that they have had a minimum of six hours sleep in the preceding 24 hours prior to starting work. Where personnel have not had six hours of sleep, a risk assessment must be conducted to determine the appropriate action. As a general rule, obtaining only five to six hours of sleep should be considered a minor hazard, obtaining four to five should be considered a moderate hazard, and obtaining less than four should be considered a significant hazard.

Level 3 Controls (Fatigue Related Symptoms)

- Personnel that have experienced more than three (3) specified fatigue symptoms in a 15-minute period should be considered at an elevated level of fatigue-related risk.
- When personnel notice symptoms of fatigue in a coworker, they should point it out to the coworker. If the situation arises again, employees should encourage the coworker to report the fatigue and take the precautions outlined in the Level 2 controls.
- Personnel repeatedly exhibiting fatigue-related symptoms should be encouraged to consult a competent medical specialist to determine whether they suffer from a sleep disorder
- Fatigue-related symptoms can flag personnel who breach their responsibility of obtaining appropriate sleep in the time provided and reporting fit for work.

Level 4 Controls

- A maximum of four (4) hours work is permitted before a break.
- A minimum break period of 10 minutes plus five (5) minutes for each hour worked since the start of the work period or the last break should be provided.
- Breaks should be self-selected, when appropriate.
- When overtime work or operational tempo require personnel to work extended hours, strategies such as napping, supervisor or coworker monitoring, double-check or quality control monitoring, task rotation and reallocation, additional self-selected breaks, or strategic use of caffeine should be considered.

Level 5 Controls (Reporting Protocols and Mishap Investigations)

- Fatigue-related risk should be formally reported to supervision and management.
- Data on the frequency that personnel are exposed to risk of fatigue-related error or mishap should be collected and analyzed to formulate containment and corrective actions for continuous improvement.
- Personnel must be aware of fatigue-related reporting requirements through formal training.
- Fatigue-related errors and mishaps should be subjected to a root cause analysis to formulate containment and corrective actions for continuous improvement.
- Non-critical errors should be analyzed to assess the effectiveness of the FRMS.

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