

116

Integrating Aircraft Maintenance Technician Fatigue into Safety Management Systems



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Definition of Terms

Aviation Maintenance Technician (AMT)	Aviation Maintenance Technician. For purposes of this document, AMT refers to any technician performing maintenance and repair on an aircraft, component, appliance etc.
Aircraft Maintainers	Broader than AMTs, Aviation Maintainers includes all personnel in the maintenance chain that may affect airworthiness of the aircraft, e.g. AMTs, engineers, maintenance operations control personnel, management/supervision, etc.

Analysis	The conversion of data into information, to identify measures that predict safety related problems to allow risk-management decision-making, by the identification of trends, deficiencies and root causes. This involves the processes of identifying a question or issue to be addressed, modeling the issue, investigating model results, interpreting the results, and possibly making a recommendation. Analysis typically involves using scientific or mathematical methods for evaluation.
Assessment	The process of measuring or judging the value or level of something
Bio-mathematical models	Bio-mathematical models are computer programs used to understand how factors like sleep loss, circadian rhythms, and workload for the average person interact to possibly affect human alertness and performance. All biomathematical models have limitations that need to be understood for their appropriate use.
Circadian Rhythm	The 24-hour physical, mental, and behavioral rhythm generated by our internal biological clock that is synchronized to light-dark cycles and other cues in our environment.
FAA Regional Aviation Safety Inspection Program (RASIP)	Reactive in its approach to aviation safety oversight; and it is intended to provide the FAA with the means to schedule and conduct an intensive surveillance program that addresses the complete air carrier or is targeted to a specific area of emphasis
Fatigue	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 an individual's ability to perform their duties.
Fatigue Risk Management (-n)	FRM, be it a plan, policy, program, or system, is an application of the Safety Management System (SMS) model, through which hazards are identified and risk is managed with a comprehensive approach that extends beyond regulatory compliance. It contains the processes/procedures (i.e., reactive, proactive, and predictive) used for purposes of maximizing personnel alertness. FRM also minimizes fatigue-related performance errors that create safety hazards and risk for the maintainer, team/crew members, the public, and aircraft/equipment.
Lapse of Attention	Long response times to environmental cues resulting from perceptual, processing, or executive failures in the central nervous system. Sleep deprivation amplifies the tendency for lapses to become more frequent and to last for longer periods of time. Lapses of Attention are quantitatively defined as responses

	on the Psychomotor Vigilance Test (PVT) that are longer than half a second.
Psychomotor Vigilance Test (PVT)	A computer-based test of physical reaction time to visual cues to assess alertness.
Rationalization	Organizing something into a logically coherent system or a rationale to make it as efficient as possible.
Safety Assurance	Processes within the SMS that function systematically to ensure the performance and effectiveness of safety risk controls and that the organization meets or exceeds its safety objectives through the collection, analysis, and assessment of information
Safety Management System (SMS)	A formal, top-down, organization-wide approach to managing safety risk and assuring the effectiveness of safety risk controls. It includes systematic procedures, practices, and policies for the management of safety risk
Safety Risk Control	A safety risk control is anything that reduces or mitigates the safety risk of a hazard
Safety Performance Indicator (SPI)	A metric associated with safety, e.g. on-the-job injuries, error events, failure to follow procedure
Safety Risk Management (SRM)	A process within the SMS describing the system; identifying the hazards; and assessing, analyzing, and controlling the risk
Second-set-of-eyes Program	A program that requires a second AMT signature to verify condition and security of certain tasks that have over time proven prone to human error but do not rise to the level of a required inspection item (RII)
Sign of Fatigue	An indicator of fatigue that can be observed by others.
Sleep Debt	The cumulative difference between the sleep an individual needs and actual sleep the individual attains. As the sleep debt grows individuals become progressively less alert and less functional day after day.
Sleepiness	The urge or propensity to fall asleep.
Standardization	The process of implementing and developing technical standards that may be useful in maximizing compatibility, interoperability, safety, repeatability, and quality
Symptom of Fatigue	An indicator of fatigue that is experienced by an individual but is not observable by others
Window of Circadian Low (WOCL)	The period during the circadian cycle associated with reduced alertness and increased sleepiness. Individuals living on a regular 24-hour routine with sleep at night have two periods of maximum sleepiness. One WOCL occurs at night, roughly from 0200-0600, a time when physiological sleepiness is greatest and

	performance capabilities are lowest. The other WOCL is in the afternoon, roughly from 1500-1700, and is less severe than the night time WOCL.
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Chapter 1. AMT Fatigue SMS Background

1-1. Scope

This specification is intended for use by operators in conjunction with their Safety Management System (SMS) incorporating AMT fatigue. It shall apply to AMTs, however strong consideration should be given to Aviation Maintainers, as in Advisory Circular 120-115. Not all aspects will be appropriate to every operator, however the intent is to provide sufficient basis for program design and implementation according to the individual operator's culture, contracts, and operational needs.

1-2. Aircraft Maintenance Technician (AMT) Fatigue Overview

Aviation maintenance fatigue can include several factors: back of the clock operations, condensed scheduling, frequent overtime/shift swapping, and personal choices outside of work. Aside from maintenance personnel duty time limitations referenced below, there are no additional specific regulatory requirements associated with reducing fatigue risk in the AMT population. Therefore, understanding how to detect, identify, assess, and mitigate fatigue risk within an aviation maintenance operation's current SMS is a priority.

Fatigue has been identified as a critical issue in aviation maintenance by the National Transportation Safety Board (NTSB) since 1996. Since 2000, the Federal Aviation Administration (FAA) Civil Aviation Medical Institute (CAMI) in Oklahoma City has conducted research that finds fatigue continues to be a focus area for aviation. One study CAMI has worked on seeks to quantify the extent to which fatigue contributed to events in airline maintenance operations. In this study a total of 8,672 AMTs were studied across 17,786,913 hours worked. **Analysis of the data in the AMT study is incomplete at the time of this Specification issuance** but will study whether duty periods with elevated fatigue risk were associated with an increased risk of events. These results may assist in determining whether AMT fatigue is a potential safety hazard in aviation maintenance operations. It is important that operators identify and address potential risks, including fatigue in aviation programs. A subsequent revision of this Spec may expand on this CAMI study.

1-3. Regulatory Aspects

FAA Federal Aviation Regulations (FAR) 14 CFR Part 5 (Safety Management Systems): Under SMS; operators are responsible to apply SMS principles to address all identified hazards.

Long-standing regulation 14 CFR §121.377 specifies certain limitations related to hours of service that may not prevent certain shift patterns, which can be a fatigue risk factor among maintainers.

Advisory Circular No. 120-115 explains the elements and benefits of Fatigue Risk Management for operators. AC 120-115 specifically identifies fatigue, and the effects of fatigue as a hazard.

1-4. Safety Management System (SMS) Design

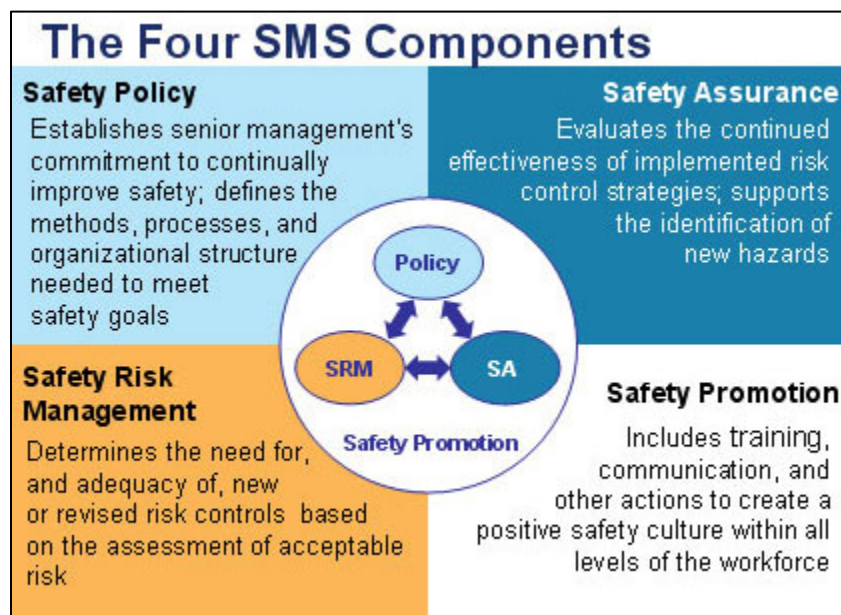
1-4-1. Four SMS Functional Components

Ref: FAA: <https://www.faa.gov/about/initiatives/sms/explained/components/>

SMS is composed of four functional components:

- Safety Policy
- Safety Risk Management
- Safety Promotion
- Safety Assurance

The essential idea of any SMS — be it a product/service provider's SMS or the SMS of the regulator responsible for safety oversight — is to provide for a systematic approach to achieving acceptable levels of safety risk. SMS is comprised of four functional components, including an intangible, but always critical, aspect called safety culture.



Chapter 2. AMT Fatigue “Body of Knowledge”

2-1. FAA Advisory Circular AC 120-115

The FAA published its Advisory Circular entitled [AC 120-115: Maintainer Fatigue Risk Management](#) on December 2, 2016

NOTE: Section 2-1-1 is adapted from Advisory Circular 120-115 and included here for the convenience of the user and continuity of this Specification.

2-1-1. Fatigue Basics

This section summarizes basic concepts of human fatigue including warning signs, impact on performance, and primary as well as secondary factors that can cause fatigue.

FATIGUE BASICS. Complex around-the-clock aviation maintenance operations heighten the challenge of fatigue among AMTs. Event statistics and self-reports from AMTs reveal that employers must be vigilant regarding fatigue. There is evidence that, we can miss signs of our own fatigue and be unaware of the extent to which fatigue has impaired our performance. Understanding the fundamentals of fatigue and how it affects job performance, decision making, and well-being in general will improve the ability to recognize signs of fatigue and manage associated safety risks.

Operational Fatigue is related to factors associated with normal scheduling practices, including but not limited to work or duty time (e.g., shift schedule/duration/quick turn-time, field service trips, irregular operations and other operational requirements).

Non-operational Fatigue is related to factors outside of scheduling practices. Instead, it is typically a result of factors associated with employees’ responsibility to be fit for duty. Examples include employees not allowing for adequate rest prior to reporting for duty due to a second job, family issues, illness, picking up extra shifts, or social decision (e.g., staying up late to watch a sporting event the night before an early morning shift; or an active nightlife).

Signs and Symptoms of Fatigue. Be familiar with the following common signs and symptoms of fatigue that could put individuals, co-workers, and the public at risk (Rosekind et al., 1996) (see Table 1). This is not an exhaustive list, instead this table includes some most common examples of observable indicators of fatigue. Some signs are more noticeable than others, such as yawning, slowed reactions, and limited communication. Less noticeable signs include lack of concentration, forgetfulness, and irritability. Some symptoms of a fatigued individual that may not be visible by others include feeling drowsy, headaches, dizziness, difficulty concentrating, blurred vision, or impaired visual perception.

Physical Signs	Mental Signs	Emotional Signs
• Yawning repeatedly • Heavy eyelids • Eye-rubbing • Nodding off or head drooping • Headaches, nausea, or upset stomach • Slowed reaction time • Slowed or slurred speech • Lack of energy, weakness, or light headedness	• Difficulty concentrating on tasks • Lapses in attention • Failure to communicate important information • Failure to anticipate events or actions • Making mistakes even on well-practiced tasks • Forgetfulness • Difficulty thinking clearly • Poor decision making	• More quiet or withdrawn than normal • Lack of motivation to do the task well • Irritable or grumpy with colleagues, family, or friends • Low morale • Heightened emotional sensitivity

Table 1. Signs of Fatigue

Fatigue and Performance. Fatigue is one of many factors that can have a significant negative impact on performance. Consider this, one study of ground transportation companies found that extended hours of being awake, our mental ability to perform work-related tasks decreases to a level consistent with having a blood alcohol concentration of 0.05 percent. Even longer periods of no sleep, without mitigations, can result in deficits

observed at roughly 0.10 percent blood alcohol concentration. ¹As a point of reference, most U.S. states and countries consider a 0.08 percent or higher blood alcohol concentration a legal level of impairment for driving a motor vehicle of inadequate sleep (i.e., 5 hours of sleep daily). As fatigue levels increase, the level of an individuals' performance decreases without mitigation measures.

Operational data collected by a large U.S. air carrier maintenance organization revealed that, when focusing only on length of workday and not including other factors, compared to an individual working an 8-hour day, individuals working 12-hour days were 2 times more likely to get injured, and individuals working 16 or more hours per days were 4 times more likely to be injured. Field and laboratory studies have concluded that cognitive and psychomotor performance decreases with increasing hours of wakefulness, sleep debt due to insufficient daily sleep, and working at night without mitigation strategies.

Fatigue and Your Brain. Alertness deficits is one of the hallmark signs of fatigue. When deprived of sleep, you may have slower reaction times, and make more errors of omission (lapses of attention) and commission (impulsive errors) (Lim and Dinges. 2008). If deprived of sleep for long enough, you may experience uncontrollable lapses of attention which last half a second or longer. As you become more fatigued these lapses become more frequent and longer. You may also experience uncontrollable sleep attacks that last a second or as long as several minutes. (Dorrian et al., 2005)

Causes of Fatigue. Several factors contribute to fatigue, including the following:

Disrupted Sleep and Sleep Loss. Just like food, water, and air, sleep is a basic biological need that is critical for survival. Sleep is necessary for the mind and body to restore itself; without sleep your performance suffers. You need both enough sleep and good quality sleep. For example, if a barking dog wakes you up multiple times throughout the night, you are unlikely to feel fully rested and restored the next morning. On average, healthy adults need between seven to eight hours of undisturbed sleep.^{2 3} If your daily routine lacks sufficient sleep, without mitigations you will likely experience fatigue symptoms due to sleep debt. Sleep debt happens when the amount of sleep a person gets on a daily basis is less than the sleep that they need. To get rid of the sleep debt it must be repaid by getting

¹ Williamson, A. M., & Feyer, A.-M. (2000). Moderate sleep deprivation produces impairments in cognitive and motor performance equivalent to legally prescribed levels of alcohol intoxication. *Occupational and Environmental Medicine*, 57(10), 649–655. doi: 10.1136/oem.57.10.649

² Hafner, M., Stepanek, M., Taylor, J., Troxel, W., & Van Stolk, C. (2017). Why Sleep Matters-The Economic Costs of Insufficient Sleep: A Cross-Country Comparative Analysis. *Rand Health Quarterly*, 6(4), 11.

³ Barnes, C., & Drake, C. (2015) Prioritizing Sleep Health: Public Health Policy Recommendations. *Perspectives on Psychological Science*, 10(6), 733-737.

one or more days of recovery sleep.⁴ For rapid recovery from sleep debt, you may need more than the suggested 8 hours of sleep per day.⁵

Prolonged Wakefulness – the amount of time since your last restful sleep, (i.e., how long you have been continuously awake).

Circadian Rhythm – your body’s internal clock, which tells your body when to be awake and when to go to sleep. The circadian rhythm is closely aligned with day and night and is sensitive to light exposure. Unlike owls or mice, humans are not nocturnal. This means that our bodies are programmed to be awake during the daytime and sleep at night. The Window of Circadian Low (WOCL) is best estimated by the hours between 2:00 and 6:00 am for individuals adapted to a usual day-wake/night-sleep schedule. In some cases, AMTs may have adjusted to a day sleep/night work schedule thus reducing fatigue risk.⁶

We may also experience, to a lesser degree, a secondary circadian low in the mid- to late afternoon, between 3:00 p.m. and 5:00 p.m., whether we have slept or not. This is sometimes called the siesta dip.⁷

Below are some work-related situations and personal choices that disrupt your body’s internal clock, making it difficult to get adequate sleep without mitigating measures.

- Overtime/back-to-back shifts,
- Early morning and night shifts,
- A rotating schedule,
- Waking up early or getting to bed late due to long commutes to and from work,
- Travel that crosses time zones, and
- Social choices (i.e., staying up late and watching TV; attending gatherings/parties; going out to bars).

⁴ Kitamura, S., Katayose, Y., Nakazaki, K., Motomura, Y., Oba, K., Katsunuma, R., Terasawa, Y., Enomoto, M., Moriguchi, Y., Hida, A., & Mishima, K. (2016). Estimating individual optimal sleep duration and potential sleep debt. *Scientific Reports*, 6, 35812.

⁵ *ibid*

⁶ Dinges, D. F., Graeber, C. R., Rosekind, M. R., Samel, A., & Wegmann, H. M., (1996) *Principles and guidelines for duty and rest scheduling in commercial aviation* (Report No. 110404). Ames, CA: National Aeronautics and Space Administration

⁷ Miltner, M. M., Carskadon, M. A., Czeisler, C. A., Dement, W. C., Dinges, D. F., & Graeber, R. C. (1988). Catastrophes, sleep and public policy: Consensus report. *Sleep*, 11(1), 100-109.

Factors that contribute to Fatigue. The following factors tend to be associated with fatigue, especially if factors occur in combination and do not include mitigations such as acclimation to a work schedule.

Work Schedules. Work schedules that require reporting for duty before 0700, after 1800, and rotating shifts that do not align with the body's natural wake and sleep cycle. Rotating shifts and overtime can result in extended wakefulness (beyond 16 hours), circadian disruption, and sleep debt due to insufficient or poor-quality sleep.⁸

Work Environment. Work environments that put excessive demands on the body may increase fatigue risk. Examples of undesirable work environments may include vibration, loud or continuous noise, excessive physical strain, excessive heat or cold, poor air quality, and poor lighting.

Work Demands. High physical, cognitive, and emotional job demands may increase fatigue.

Crossing time zones. Travel across time zones creates a mismatch between the body's internal clock (natural wake and sleep cycle) and the local time at the destination. This mismatch can result in sleepiness when we want to be awake, and it can make getting to sleep or staying asleep difficult when there is insufficient time for acclimation to the destination local time.

Illness. Medical conditions including allergies, colds, flu, pain, etc., can create a level of discomfort that may keep you from getting adequate quality sleep.

Sleep Disorders. Undiagnosed, untreated, and undertreated sleep disorders, such as sleep apnea, restless leg syndrome, and insomnia can keep you from getting adequate quality sleep. If you experience disrupted sleep, proper medical assessment and care may be necessary.

Personal Factors. Fatigue from sleep debt can result from certain personal factors such as, for example: (1) caring for a new baby, an elderly parent, or a sick family member; (2) having a second job, undertaking household projects or time-intensive hobbies; and (3) socializing with friends and family or simply staying up late watching TV.

Poor Physical fitness. Certain lifestyle choices such as not eating well-balanced meals, not staying hydrated, not exercising regularly, can lead to poor physical fitness which may contribute to poor sleep and fatigue.

Poor sleep hygiene. Sleep hygiene includes all behaviors associated with sleep routine and environment. Generally, the sleeping environment should be quiet, dark, and comfortable.

⁸ Åkerstedt, T. (1998). Shift work and disturbed sleep/wakefulness. *Sleep Medicine Reviews*, 2(2), 117-128.

Poor sleep habits, such as watching TV and using personal electronics in bed, smoking, rigorous exercising, or overeating right before bedtime, can contribute to poor sleep and fatigue.

Medications and other Substances. Substances used too close to bedtime, such as caffeine and alcohol can disrupt sleep and contribute to fatigue. Other medications including sleep aids, medications for colds, allergies (especially antihistamines), and pain (especially medications containing opiates), are associated with sedation effects that can affect your on-the job alertness.

Stress and Anxiety. Stress and anxiety may keep you from falling asleep, even when feeling very tired.

2-2. Evidence of fatigue impact on maintenance operations

Example Airline Operator Insight

A study was conducted that examined incidents in maintenance operations at a 14 CFR Part 121 carrier (de-identified). Data analyzed was collected from maintenance operations at a 14 CFR Part 121 carrier over a span of ~2.5 years. These data indicate how fatigue (focusing on consecutive hours on the job as a proxy for fatigue, without considering other factors) could be a factor in noncompliance rates and injury rates. For purposes of this Spec, it is important to note that “noncompliance” for this operator can mean “errors” that are not necessarily material to mechanical work or immediate safety but are illustrative of the effects of fatigue that can affect task accuracy and ultimately could have safety implications.

Table 2-1 presents statistics including all shift rates, i.e., Company scheduled shifts, employee modified shifts, and shifts resulting from irregular operations for each of the

Year	Total Shifts	1 to 16 hour shifts	17 to 20 hour shifts	21 to 24 hour shifts
2016	468775	93.7%	6.2%	0.1%
2017	484951	93.6%	6.3%	0.1%
2018 (YTD)	363040	93.3%	6.5%	0.2%

three years (2016, 2017 and 2018 to mid-year).

Table 2-1: Shift occurrence statistics corresponding to Figures 2-4 and 2-5.