

# Occupational Fatigue: Implications for Aviation

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## Abstract

Occupational fatigue has been considered a major contribution to decreases in well-being and performance in a variety of industries.

The objective of the chapter is to review the main issues associated with occupational fatigue and to consider the implications for the globalized aviation industry. Fatigue management in aviation has been associated with rostering practices, countermeasures and the development of international regulations. Recently research has proposed that prescriptive approaches should be replaced with more proactive perspectives, a philosophy that underlies the Fatigue Risk Management System (FRMS).

**Keywords:** fatigue risk management systems, rostering practices, occupational fatigue

## 1 Occupational fatigue: Basic concepts and recommendations

Fatigue has been associated with a variety of occupational domains and industries such as aviation, rail and road transportation, the nuclear industry or healthcare. In order to fully understand the implications of occupational fatigue to aviation, it is necessary to recognize the challenges associated with its study. The first challenge to consider is that despite the relevance for a variety of industries, there is no agreed definition of fatigue. Table 1 presents several definitions and underlying perspectives that can be found in the literature.

Spencer, Robertson and Folkard (2006) present one of the most comprehensive approaches to occupational fatigue management with three separate components being identified. A first component considers the type of job performed, the pace of activity and the provision of breaks as a way to manage fatigue. A second component is associated with duty timing, i.e. the characteristics of the work schedule namely the start time, shift length and the time of day throughout the shift. Finally, the authors propose a cumulative component that relates to the way in which individual duty periods or shifts are put together to form a complete schedule. The level of fatigue associated with a particular shift/schedule depends on the pattern of work immediately preceding it and not the single period considered.

Table1. Examples of the variety of definitions and perspectives of fatigue

A non-specific and subjective feeling of tiredness, physically and/or mentally.	(Loge, 2003, p. 14)
Fatigue is the state of tiredness that is associated with long hours of work prolonged periods without sleep, or the requirement to work at times that are 'out of synch' with the body's biological or circadian rhythms.	(Caldwell and Caldwell, 2003, p. 15)
A physiological state of reduced mental or physical performance capability resulting from sleep loss or extended wakefulness and/or physical activity that can impair a crew member's alertness and ability to safely operate an aircraft or perform safety related duties.	(EASA, NPA 2009-02c; 30 Jan 2009; p. 117)
Fatigue is a term used to refer to a variety of issues	
<ul style="list-style-type: none"> <li>a. Inadequate rest</li> <li>b. Symptoms associated with disturbed or displaced biological rhythms (jet leg in aviation)</li> <li>c. Excessive muscular or physical activity</li> <li>d. Excessive cognitive work</li> </ul>	Hawkins(1987)
Ahsberg (2000) associates fatigue with	
<ul style="list-style-type: none"> <li>a. Bodily changes</li> <li>b. Changes in performance, or</li> <li>c. Perceptual changes</li> </ul>	

Methodological controversies associated with the evaluation of fatigue can also be identified with three main indicators being used: physical indicators (e.g. glycogen, cortisol, body temperature, blood oxygen saturation and cardiovascular activity), psychological indexes (mainly questionnaires) and performance results (e.g. productivity, safety, errors, quality). A variety of options can be found in the literature that involve diversified combinations of these indicators (e.g. Eriksen, Akerstedt & Nilsson, 2006; Roach, Rodgers & Dawson, 2002).

Another methodological issue to be considered is the dimensionality of fatigue. A review of the literature provides support to either a one-dimensional concept while others distinguish between physical and psychological fatigue. Physical (or peripheral) fatigue refers to a reduction in capacity to perform physical work as a function of preceding physical effort. Psychological (or mental) fatigue is inferred from decrements in performance on tasks requiring alertness and the manipulation and retrieval of information stored in memory (Gawron, French & Funke, 2001). Within the multidimensional approaches it is also possible to identify hierarchical notions of fatigue where each first order dimension (i.e. physical and psychological) is then divided into further dimensions (e.g. Checklist Individual Strength (CIS) with Bültmann, de Vries, Beurkens, Bleijenberg, Vercoulen & Kant, 2000 and the Swedish Occupational Fatigue Inventory (SOFI) by Åhsberg (2000) and Åhsberg, Kecklund, Akerstedt & Gamberale, 2000).

Fatigue has traditionally been associated with circadian rhythms and, in particular, with the sleep cycle. Conventionally disturbances to the synchronization process were considered especially in the aviation industry and in transmeridian flights. Synchronization is accomplished through entrainment

by external synchronizers or *zeitgebers* (time givers), which themselves are cyclic, usually with a period of 24 hours. When an individual flies from one time zone to another, his or her body clock and the rhythms it controls must resynchronize to the local geo physical and social *zeitgebers* of the destination time zone. Eastwards flights shorten the day and require a phase advance, while westward flights lengthen the day and require a phase delay. Research also revealed that the circadian system is unable to adjust rapidly to sudden shifts in the timing of its *zeitgebers*. In effect, the system resists changes in its timing and stability and as a consequence, complete resynchronization of the biological timing system can often take up to several days.

Contemporary approaches to fatigue developed these original proposals and recognize that fatigue can be caused by disturbance of circadian rhythms, continuous wakefulness, time zone crossing and cumulative sleep loss.

Symptoms of fatigue and lack of sleep include red eyes, paleness, difficulties in speaking, slurred speech, headaches, lower body temperature, variations in heart rate, lack of muscular tonus, stiffness, cramps, slow response or decreased reaction time, reduced motor coordination (eye-hand coordination) and muscular control, among others.

Fatigue can also lead to micro sleeps, uncontrollable spontaneous episodes of sleep that can last seconds or minutes, involve the disengagement from reality and a failure to respond to outside information.

Behavioural changes associated with fatigue have also been reported in the literature such as irritability or short tempered, mistiming or rough handling, breakdown in mental discipline/faulty processing, decreased attention span, slips in familiar actions.

In Australia, Dawson and Reid (1997) highlighted the impairment associated with fatigue and work schedules by comparing the effect of continuous wakefulness with alcohol consumption. The performance in a variety of cognitive psychomotor tests of a group that was kept awake for 28 hours was compared with another group told to consume alcohol in 30 minutes intervals until they had a mean blood alcohol concentration (BAC) of .10%. The main results of this study are presented in table 2. The authors concluded that performance impairment after 17 hours of sustained wakefulness was equivalent to a BAC of .05%, the legal limit to drive in many European countries. Dawson and Reid (1997) argue that if the impairment resulting from a BAC of .05% is sufficient to ban us from driving, how can it be considered that such impairment may allow us to perform work tasks in an efficient and safe manner. Although Dawson and Reid used laboratory tests, other authors used simulators (e.g., Roach, Dorrian, Fletcher and Dawson, 2001) and others real live driving conditions.

Table2. The effects of continuous wakefulness and alcohol consumption

Progressive Effects of Alcohol			
BAC* (%)	Behavior	Impairment	
0.01–0.029	<i>Average individual appears normal</i>	<i>Subtle effects that can be detected with special tests</i>	
0.03–0.059	<i>Mild euphoria, Sense of well-being, Relaxation, Talkativeness, Decreased inhibition</i>	<i>Alertness, Judgment, Coordination, Concentration</i>	<i>.05 equivalent to 17 hours of sustained wakefulness*</i>
0.06–0.10	<i>Blunted Feelings, Desinhibition, Extroversion, Impaired Sexual Pleasures</i>	<i>Reflexes, Reasoning, Depth Perception, Distance Acuity, Peripheral Vision, Glare Recovery</i>	<i>.10 equivalent 24 hours of sustained wakefulness*</i>
0.11–0.20	<i>Over-Expression, Emotional Swings, Anger or Sadness, Boisterous</i>	<i>Reaction Time, Gross Motor Control, Staggering, Slurred Speech</i>	
0.21–0.29	<i>Stupor, Loss of Understanding, Impaired Sensations</i>	<i>Severe Motor Impairment, Loss of Consciousness, Memory Blackout</i>	
0.30–0.39	<i>Severe Depression, Unconsciousness, Death Possible</i>	<i>Bladder Function, Breathing, Heart Rate</i>	
>0.40	<i>Unconsciousness, Death</i>	<i>Breathing, Heart Rate</i>	

\*BAC - Blood Alcohol Content

Countermeasures to fatigue have also been diversified and include sleep duration and quality (i.e., when to rest, power naps, controlled sleep), diet (i.e., caffeine, tea and energizing drinks), physical exercise, prescription medication, family and lifestyle issues and work schedules.

Additional challenges were also put forward with the new millennium, namely overtime (a growing strategy to control human resources costs), work-rest cycles (i.e. extra time during off days) and early calls (i.e. starting to work before 6.00 am thus jeopardizing the critical period of sleep between 2.00 am and 5.00 am) (e.g. Park, Kim, Chung and Hisanaga, 2001; Rosa, 2001).

## 2 Occupational Fatigue in the Aviation Industry

The previous introduction identified the main challenges associated with occupational fatigue regardless of the industry considered. The globalized nature of the aviation industry forces us to emphasize some additional issues.

A first aspect to be considered is that although the aviation industry involves a variety of operators, the vast majority of research has been conducted on flight duty periods (FDP) and pilots. Nevertheless, it is important to recognize that fatigue issues may be relevant to other occupations within the aviation system. Legal limitations on the flight duty periods are also relevant to cabin crew and shift work is important to ramp and maintenance personnel as well as air traffic controllers (ATCOs).

A second issue to be considered is that it took the industry quite a long time to recognize human fatigue as a central problem in its activities (e.g. Cadwell et al., 2009). In what concerns operational settings, only in 1993 with the Guan-

tanamo Bay accident did fatigue and flight duty times were associated when analyzing an accident.

The uncontrolled collision with terrain by the American International Airways Flight 808 on Guantanamo Bay, Cuba in 1993 is probably the first aviation accident associated with fatigue. According to Rosekind et al. (1994) the main cause of the accident was “the impaired judgment, decision-making, and flying abilities of the captain and flight crew due to the effects of fatigue; the captain's failure to properly assess the conditions for landing and maintaining vigilant situational awareness of the airplane while manoeuvring onto final approach; his failure to prevent the loss of airspeed and avoid a stall while in the steep bank turn; and his failure to execute immediate action to recover from the stall.” (p.v). The report also considered that “the three crew members had been on duty for 18 hours upon their arrival on Guantanamo Bay, which included being awake all night” (p. 56).

In regard to research, the vast majority of studies was conducted on long-haul flights and, in general, analyzes circadian disruptions resulting from long flight duty periods. In 1980 in the USA, the initial concerns with disturbances to the circadian rhythm led to the development of the NASA Ames Fatigue/Jet Lag program (later called fatigue Countermeasures Program, NASA Ames Research Centre, 1997). The program highlighted a potential problem due to fatigue in transmeridian flights and prepared appropriate countermeasures.

Jackson and Earl (2006) argued that initial concerns about fatigue were associated with long haul pilots and that flight duty time legislation was mainly based on the experiences of these pilots. In contrast, the situation of short-haul pilots is less known and maybe the types of fatigue will differ.

Short-haul flights duty periods only started to be considered and implications for fatigue analyzed with the emergence of low cost airlines. Professional associations refer to an airline culture that works the rostering practices to its full legal limits. Jackson and Earl (2006) argued that some airlines “harboured a culture in which pilots are required to work close to the legal maximum of flying hours” (p. 264). The airline responsibility for providing staff with a work schedule that does not require excessive wakefulness and presents the opportunity to obtain sufficient sleep was at the basis of a series of studies conducted by easyJet (e.g., Holmes, Stewart and Jackson, 2008).

Today, the industry recognizes that fatigue has been associated with numerous accidents, incidents and near misses over the years and is a continuing problem facing crews flying aircraft of all sizes (Caldwell and Caldwell, 2003; Caldwell et al., 2009; Petrie and Dawson, 1997). The industry also recognizes that fatigue may influence other human factors issues such as human error or crew resource management.

### 3 Prescriptive and Proactive Approaches to Fatigue

The major challenge the industry faces today regards the philosophy underlying fatigue management systems. Traditionally, the industry relied on a prescriptive approach to fatigue with national and international regulators specifying issues associate with flight times, duty periods and rest.

Table 3 presents the basic concepts of flight duty periods, flight time, window of circadian low and the limitations imposed as proposed in the Notice of Proposed Amendment (NPA) No 2009-02c by EASA (European Aviation Safety Agency).

Table3. Basic concepts for flight duty and rest management

<p><b>Flight Duty Period (FDP)</b> means a period which commences when a crew member is required to report for duty that includes a flight or a series of flights and which finishes when the aircraft finally comes to rest and the engines are shut down or the rotor blades are stopped, at the end of the last flight on which they are a crew member.</p> <p><b>Flight time</b> means the total time from the moment the aircraft first moves from its parking place for the purpose of taking off until the moment it finally comes to rest on the designated parking (for airplanes and touring motor gliders)</p> <p><b>Standby</b> means a defined period of time during which a crew member is required by the operator to be available to receive an assignment for a specific duty without an intervening rest period;</p> <p><b>Window of Circadian Low (WOCL)</b> means the period between 02:00 hours and 05:59 hours.</p> <p><b>Rest period</b> means a continuous and defined period of time, subsequent to and/or prior to duty, during which a crew member is free of all duties.</p> <p style="text-align: right;"><i>(NPA 2009-02c; 30 Jan 2009; p. 25)</i></p> <p><b>Flight times and duty periods</b> The total duty periods to which a crew member is assigned shall not exceed: (1) 60 duty hours in any seven consecutive days; (2) 190 duty hours in any 28 consecutive days.</p> <p>The total flight time of the flights on which an individual crew member is assigned as an operating crew member shall not exceed: (1) 100 flight hours in any 28 consecutive days; (2) 900 flight hours in any 12 consecutive calendar months.</p> <p style="text-align: right;"><i>(NPA 2009-02c; 30 Jan 2009; p. 34-35)</i></p>
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Dawson (2005) considers that the traditional prescriptive approaches (e.g., CAP 371 in the UK; CAO 48 in Australia) may present several risks as they assume that compliance ensures safety, assign no responsibility to an employee, rely on subjective assessment of an internal psychological state, do not address the risk of fatigue and do not provide explicit management strategies for risk mitigation when a compliant individual is fatigued.

Additional limitations to the “one universal rule set” are associated with the quality of sleep on board, crew individual and cultural differences, sector workload (e.g., number of block/duty hours programmed), operational constraints (e.g., delays, aircraft on ground, complex and congested airspace) and risk factors associated with flights are not considered in rostering (e.g. weather, ATC, crew experience) have also been put forward (Dawson & McCullough, 2004).

Today, the industry discusses a variety of concerns associated with fatigue and rest periods namely the maximum daily flight duty period (currently of 11:45 hours) and possible extensions, flight duty in the period 22:00 to 04:59, implications of operations with augmented crews and/or time zone crossings, rest periods and cumulative fatigue, in-flight rest, among others (a detailed

description of these issues can be found in the Meobus report, available online in [www.skybrary.aero/bookshelf/books/799.pdf](http://www.skybrary.aero/bookshelf/books/799.pdf).

The adoption of a Fatigue Risk Management System (FRMS) as proposed in the NPA 2009-02c is central to contemporary approaches to fatigue management or what Dawson (2004) described as proactive approaches to fatigue management.

The FRMS is described as “a scientifically based, data driven flexible approach to fatigue management that forms part of an operator’s management system and involves a continuous process of monitoring and managing fatigue risk” (NPA 2009-02c; 30 Jan 2009; p. 117). Central to fatigue management is a rostering system that takes in account the number of sectors flown, time zone crossing, sleep deprivation and disruption of circadian cycles, night hours, positioning, cumulative duty time for given periods of time, sharing of allocated tasks between crew members, augmented crews, etc. (EASA 2nd Conference on the NPA 2009-02c).

Most recent approaches to the FRMS involve the use of a variety of software such as FAID, DERA, Karolinska, US Airforce SAFE-T. Rostering systems can no longer be analyzed without considering some sort of system for fatigue modelling. FAID, for example, estimates fatigue based on statistical distributions of prior sleep and wake, uses real world data, has specific sleep/wake data derived from some workplace populations but does not predict individual sleep/wake on a specific occasion. The system considers five dimensions indicating the likelihood that a roster will provide an adequate opportunity for sleep: total number of hours worked per week, duration of individual shift, duration of ‘short’ break (work-sleep-work), total hours of ‘night work’ per seven day period, (i.e. total weekly hours worked between 21:00h-09:00h) and the frequency of ‘long break’ (night sleep-day off-night sleep) per seven days ([www.faidsafe.com](http://www.faidsafe.com)). An example of an empirical application in the aviation industry of FAID can be found in easyJet (Holmes, Stewart and Jackson, 2008).

Proactive approaches to fatigue and the use of modelling systems allow the management of large amounts of data in a cost-effective manner, provide software drive recommendations and are empirical based (Stewart, 2006).

#### 4 Future Challenges and Perspectives

Future challenges in regard to fatigue management will be constrained by the national and international regulations and decisions regarding the compulsory adoption of fatigue risk management system and the appointment of a fatigue management steering group (FMSG) as proposed in the EASA’s NPA 2009-02c. Activities will involve, among others, the definition of a “fatigue risk management policy, education and awareness training programs, processes for the

detection, reporting, investigation and management of fatigue risk. Monitoring crew member fatigue, processes for reporting, investigating and recording incidents that may be attributable wholly or partially to fatigue and adjustment mechanisms for the FRMS feedback will be considered" (p. 29). The dominant perspective appears to combine both the presence of legal limitations and the proactive management by airlines as this will allow adjustments to national specificities and activities (i.e. low cost with mainly short-haul flights or major airline with diversified flights).

It should also be expected that these efforts will spread out in the industry and involve other occupational groups such as cabin crew, ground personnel, air traffic controllers and maintenance staff. As with other initiatives (e.g., CRM), it would not be surprising if other industries would follow the general recommendations and legal obligations of the aviation industry (i.e. Crew Resource Management training for medical services or off-shore platforms).

Benefits in terms of performance and safety as well as personnel wellbeing are expected to be empirically sustained thus validating the adoption of fatigue risk management systems.

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