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Final Report

Principles and Guidelines For Duty and Rest Scheduling in Corporate And Business Aviation

FSF Fatigue Countermeasures Task Force Report

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In This Issue

This month's issue of Flight Safety Digest *presents revised fatigue management recommendations and guidelines, which were developed by the special Flight Safety Foundation (FSF) Fatigue Countermeasures Task Force for corporate and business operations. This final version is based on comments from the aviation community and more recent scientific research.*

The FSF task force, working closely with the U.S. National Aeronautics and Space Administration's (NASA's) Ames Research Center, looked at such issues as circadian physiology, off-duty periods, duty periods and flight time along with education and training issues. The FSF task force, which comprises more than 30 representatives of operators, aircraft and engine manufacturers and training suppliers, relied extensively on research from the Flight Management and Human Factors Division of the NASA-Ames Fatigue Countermeasures Program.

As in similar Foundation-led accident prevention and safety awareness efforts — controlled flight into terrain, wind shear and wake turbulence avoidance — the FSF task force has sought broad industry support and cooperation in developing these strategies.

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Foreword

This issue of *Flight Safety Digest* contains the revised and final version of “Principles and Guidelines for Duty and Rest Scheduling in Corporate and Business Aviation.” This version discusses human fatigue, including the “window of circadian low,” and provides guidance in managing fatigue induced by “back-side-of-the-clock” flights. Other discussions target cumulative duty periods and flight time, and maintenance of operational flexibility.

Note that these are *guidelines and recommendations*. The Foundation task force never intended to determine fixed duty periods and flight times. The information in this document is presented to enable managers and pilots to make sound decisions based on current data.

Pressures, whether levied by employers or self-imposed, to continue their duties while under the influence of fatigue can cause even the most conscientious pilots to exceed reasonable duty limits and thus risk the safety of their aircraft, their passengers and themselves.

Although fatigue is insidious, its effects can be managed successfully. Proper structuring of routines and schedules enables pilots to accomplish their missions and maintain their quality of life, while improving safety.

In 1994, Flight Safety Foundation (FSF) formed the FSF Fatigue Countermeasures Task Force. With the ever-increasing number of segments flown by corporate crews in a single day, with the increased numbers of corporate flight departments flying international routes and with the emergence of corporate aircraft capable of 14-hour flight endurance, the Foundation believed that human fatigue in these operations should be closely reviewed.

The FSF Corporate Advisory Committee asked one of its members, Capt. Pat Andrews, manager, global flight operations, Mobil Business Resources Corp., to chair the Foundation task force.

The task force comprised more than 30 representatives of 21 aviation organizations — corporate flight departments, aircraft manufacturers, service providers, engine manufacturers, training providers and the U.S. National Aeronautics and Space Administration (NASA) Ames Research Center.

As a result of the work by the task force, the draft of “Principles and Guidelines for Duty and Rest Scheduling in Corporate and Business Aviation” was published in the September 1995 *Flight Safety Digest*. This draft supplied the basis for the industry to maintain the operational flexibility often inherent in corporate flight departments, while obviating the need for regulation.

Since the draft was published, the information has been presented at venues around the world and comments have been solicited about the draft from a diverse audience. This final version incorporates information from those comments and additional scientific data.

This document was developed specifically for corporate and business aviation and its content is based on a NASA Technical Memorandum (TM), “Principles and Guidelines for Duty and Rest Scheduling in Commercial Aviation.” Guidelines and recommendations that have been included in this document are based on scientific research (Sections 1.0 and 2.0) and operational practices with empirical effectiveness (Section 3.0). The NASA TM and other scientific information about fatigue can be ordered from:

Fatigue Countermeasures Program
NASA Ames Research Center
MS: 262-4
Moffett Field, CA 94035-1000 U.S.

I believe that the corporate and business aviation industry has developed an effective tool to ensure operational flexibility without compromising safety.

All of us owe a tremendous “Thank You!” to the members of this task force of dedicated volunteers (and to their respective organizations) and to everyone who provided comments and support that contributed to the development of this extraordinary document. Well done!

Stuart S. Matthews.

Stuart Matthews
Chairman, President and CEO
Flight Safety Foundation

Principles and Guidelines for Duty and Rest Scheduling in Corporate and Business Aviation

Flight Safety Foundation Fatigue Countermeasures Task Force

Introduction

Twenty-four-hour Requirements of the Aviation Industry

Corporate and business aviation operational demands require 24-hour-a-day activities, and growth in global long-haul and domestic short-haul operations will continue to increase these demands. Shift work, night work, irregular work schedules, unpredictable work schedules and time-zone changes will continue to be factors that must be considered. These factors pose challenges to human physiology, and because they can result in performance-impairing fatigue, they are a risk to safety. Scientific information, as well as practical experience, about fatigue, human sleep and circadian physiology can maintain and improve aviation safety. This information also can enhance crew performance and alertness during flight operations.

Challenges to Human Physiology

Aviation, operational capabilities and technology have evolved dramatically, while human physiological capabilities have remained unchanged. Flight operations can engender fatigue, sleep deficit and circadian disruption, and these physiological factors can result in decreased performance and alertness during operations. During the past 40 years, scientific knowledge about sleep, circadian rhythms, sleepiness/alertness and the performance decrements associated with these factors has increased significantly. Scientific research has extended its examination of these factors to operational environments, including field and simulator studies. These studies have confirmed the presence in aviators of performance-impairing fatigue resulting from the sleep loss, circadian disruption and workload engendered by current flight and duty practices.

Humans are central in determining duty periods and flight times of pilots in corporate and business aviation. Therefore, human physiological capabilities and limitations are critical factors in maintaining safety and productivity in aviation.

Principles Based on Scientific Knowledge

Although research on fatigue, sleep and circadian physiology, and shiftwork schedules has generated an extensive body of scientific knowledge, the application of this information to the requirements of operational settings is relatively new. Acknowledgment of this scientific information is increasing, and its transfer to operations (e.g., scheduling, regulatory considerations, personal strategies, countermeasures) offers the greatest potential benefit. Current U.S. Federal Aviation Regulations (FARs) and industry scheduling practices rarely acknowledge or incorporate such knowledge. This document outlines scientifically based principles that can be applied to the duty and rest scheduling requirements of the corporate and business aviation industry. This document focuses on guidelines that are supported by scientific data; some successful practices of corporate and business operators are included in Section 4.0.

Shared Responsibility

There is no single absolute or perfect solution to the demands of duty and rest scheduling in aviation. It is critical that safety be acknowledged as a shared responsibility among all industry participants. Each component of the aviation system should be examined for avenues to incorporate scientific information and to apply guidelines and strategies that will maximize performance and alertness during flight operations. Regulatory considerations, scheduling practices, personal strategies and technology design are specific components that could be subject to such an examination. Each of these components is complex and presents unique challenges. Nevertheless, implementation involves many considerations, such as legality, economics and current practice. The intent of this document is that relevant scientific information be considered in regular operational practices.

"Safety" Can Be Difficult to Quantify

Determining what constitutes a "safe" operation is a complex task. Aircraft accidents are such rare occurrences that they may not provide the best outcome variable to estimate safe operations. The aviation industry and the flying public demand a high margin of safety and redundancy. Among modes of transportation, the aviation industry's reputation for safety is well deserved. The challenge will be to maintain and, where possible, to improve safety. Fatigue factors can create a vulnerability for decrements in performance and alertness that can reduce safety. Guidelines to specifically address these factors can help to minimize such vulnerability.

Objectives

The primary objective of this document is to provide empirically derived principles and guidelines for duty and rest scheduling in corporate and business aviation. In the first section, scientifically based principles related to operational issues posed by the aviation industry are outlined. In the second section, the principles are applied to guidelines for duty and rest scheduling in corporate and business aviation, with specifics provided where appropriate and available. In the third section, the importance, availability and content of training programs are discussed. The fourth section provides an overview of other potential corporate and business industry strategies to address these issues and describes potential future directions. The fifth section provides guidelines for cumulative duty periods and flight times. The sixth section acknowledges the importance of maintaining operational flexibility.

1.0 General Principles

1.1 Sleep, Awake Time Off and Recovery Are Primary Considerations

1.1.1 Sleep

Sleep is a vital physiological need. Sleep is necessary to maintain alertness and performance, positive mood and overall health and well-being. Each individual has a basic sleep requirement that provides for optimal levels of performance and physiological alertness during wakefulness. On average, individuals require eight hours of sleep in a 24-hour period. Losing as little as two hours of sleep will result in an acute sleep deficit, which will induce fatigue and degrade subsequent waking performance and alertness. Over days, sleep loss — any amount less than is required — will accrue into a cumulative sleep debt. The physiological need for sleep created by a deficit can be reversed only by sleep. An individual who has obtained required sleep will be better prepared to perform after long hours awake or altered work schedules than one who is operating with a sleep deficit.

1.1.2 Awake time off

Fatigue-related performance decrements are traditionally defined by declines in performance as a function of time spent on a given task. Breaks from continuous performance of a required task, such as monitoring, are important to maintain consistent and appropriate levels of performance. Therefore, awake time off is introduced here to describe time spent awake and free of duty. Thus both awake time off and sleep are needed to ensure optimum levels of performance.

1.1.3 Recovery

Recovery from an acute sleep deficit, cumulative sleep debt, prolonged performance requirement or extended hours of continuous wakefulness is another important consideration. Operational requirements can lead to any of these factors, and it is important that a recovery period be provided to allow recovery sleep and restoration of normal performance and alertness levels. Two nights of an individual's usual sleep requirement typically stabilize the sleep pattern and restore acceptable levels of alertness and performance.

Required sleep and appropriate awake time off promote performance and alertness. These considerations are especially critical when a person is challenged with extended periods of wakefulness (e.g., extended duty periods) and circadian disruption (e.g., altered work schedule). Recovery is important to reduce cumulative effects and to return an individual to usual levels of performance and alertness.

1.2 Frequent Recovery Periods Are Important

Frequent recovery periods reduce cumulative fatigue more effectively than less frequent ones. For example, weekly recovery periods are more likely to relieve acute fatigue than monthly recovery periods. Consequently, guidelines that ensure a minimum number of days off per week are necessary for minimizing cumulative fatigue effects over longer periods of time (e.g., month, year).

1.3 Time-of-Day/Circadian Physiology Affects Sleep and Waking Performance

There is a clock in the human brain, as in other organisms, that regulates 24-hour patterns of body functions. This clock controls not only sleep and wakefulness alternating in parallel with the environmental light/dark cycle, but also the oscillatory nature of most physiological, psychological and behavioral functions. The wide range of body functions controlled by the 24-hour clock includes body temperature, hormone secretion, digestion, physical and mental performance, mood and many others. On a 24-hour basis, these functions fluctuate in a regular pattern with a high level at one time of day and a low level at another time. The circadian (*circa* = around, *dies* = day) pattern of wakefulness and sleep is programmed for wakefulness during the day and sleep at night. The circadian clock repeats this pattern on a daily basis. Certain hours of the 24-hour cycle, that is 0200 to 0600, are identified as a time when the body is programmed to sleep and during which performance is degraded. Time-of-day or circadian effects are important considerations in 24-hour operational requirements because circadian rhythms do not adjust rapidly to change.

For example, an individual working during the night is maintaining wakefulness in direct opposition to physiological programming to be asleep. Physiological, psychological and behavioral functions are set by the circadian system to a low status that cannot be compensated by being awake and active. Conversely, the same individual sleeping during the day is in direct opposition to physiological programming to be awake. The circadian system provides a high level of functioning during the day that counteracts the ability to sleep. Thus, circadian disruption can lead to acute sleep deficits, cumulative sleep loss, decreases in performance and alertness, and various health problems (e.g., gastrointestinal). Therefore, circadian stability is another consideration in duty and rest scheduling.

1.4 Continuous Hours of Wakefulness/Duty Can Affect Alertness and Performance

Extended wakefulness and prolonged periods of continuous performance or vigilance on a task will engender sleepiness and fatigue. Across duty periods, these effects can accumulate further. One way to minimize the accumulation of these effects is to limit the duty period (i.e., continuous hours of wakefulness during operations). Acute effects can be addressed through daily limitations, and cumulative effects can be minimized by weekly limitations. There is more scientific data available to support guidelines for acute limitations than to determine specific cumulative limitations. Nevertheless, cumulative limitations (weekly and beyond) remain an important consideration for minimizing accumulation of fatigue effects.

1.5 Human Physiological Capabilities Extend to Flight Crews

Fatigue has its basis in physiological limits, and performance deficits reflect these physiological limits. Flight crews' human physiology is not different from that of other humans. Therefore, it must be expected that the same fatigue-producing factors affecting performance and alertness in experimental subjects, physicians on call, shift workers, military personnel and others also affect flight crews. It follows that scientific findings relevant to human physiological capabilities and performance deficits from fatigue, sleep loss and circadian physiology extend to flight crews.

1.6 Flight Crews Consist of Individuals

There are considerable individual differences in the magnitude of fatigue effects on performance, physiological alertness and subjective reports of fatigue. These differences extend to the effects of sleep loss, night work and considerations of required sleep and recovery time for an individual. Individual differences can vary as a function of age, sleep requirement, experience, overall health and other factors. Individuals can also vary in their participation in activities that engender fatigue while on duty. In this regard, commuting across long distances immediately prior to starting a duty period is of concern.

1.7 Differences and Variability Preclude an Absolute Solution

The aviation industry represents a diverse range of required work demands and operational environments. Sections 1.5 and 1.6 highlight the diverse situations and individuals that are encompassed by generalized guidelines. This further illustrates that one set of guidelines cannot cover all personnel or operational conditions and that there is no single or absolute solution to these issues.

2.0 Specific Principles, Guidelines and Recommendations

The following are specific principles, guidelines and recommendations to address the 24-hour duty and rest scheduling requirements of the corporate and business aviation industry. These principles and guidelines, based on the general principles introduced in Section 1.0, are intended to provide a consistent margin of safety across corporate and business aviation operations. Therefore, they are intended for application to minimum flight crew complements of two or more.

To provide specific guidelines, it is necessary to define the terms used in the guidelines. Altering these definitions may invalidate the principles upon which the guidelines are based.

An overview of the guidelines and recommendations is provided in Table 1 (page 5). An overview of the guidelines and recommendations for flight operations during the window of circadian low (defined in Section 2.1) is provided in Table 2 (page 6).

2.1 Definition of "Window of Circadian Low"

The window of circadian low is best estimated by the hours between 0200 and 0600 for individuals adapted to a usual day-wake/night-sleep schedule. This estimate is calculated from scientific data on the circadian low of performance, alertness, subjective report (i.e., peak fatigue) and body temperature. For duty periods that cross three or fewer time zones, the window of circadian low is estimated to be 0200 to 0600 home-base/domicile time. For duty periods that cross four or more time zones, the window of circadian low is estimated to be 0200 to 0600 home-base/domicile time for the first 48 hours only. After a crew member remains more than 48 hours away from home-base/domicile, the window of circadian low is estimated to be 0200 to 0600 local time at the point of departure. Recommended guidelines related to the window of circadian low should be applied when any of the following operations occur: landing within the window; flight through both sides of the window; or duty period that starts at 0400 or earlier within the window.

2.2 Off-duty Period

2.2.1 Definition of "off duty"

"Off duty" is a continuous, predefined period of uninterrupted time during which a crew member is free of all duties.

2.2.2 Off-duty period (acute sleep and awake-time-off requirements)

The off-duty period should allow for three components. The first critical component of the off-duty period is an eight-hour sleep opportunity. The general principles clearly describe that an acute sleep deficit and a cumulative sleep debt can degrade performance and alertness. Also, it should be recognized that an appropriate "spin down" time may be required to fall asleep. The second component is awake time off, an opportunity to break from the continuous performance of required tasks. The third component is the other activities necessary during an off-duty period. These other necessary activities can include transportation to and from layover accommodations, hotel check in/out, meals, shower and personal hygiene. Therefore, the off-duty period should be a minimum of 10 hours uninterrupted within any 24-hour period, to include an eight-hour sleep opportunity, awake time off and time for other necessary activities. (In the event of extended duty, see Section 2.3.5; for extended flight time, see Section 2.4.3.)

2.2.3 Off-duty period (following duty during window of circadian low)

It is recommended that following duty during the window of circadian low, the off-duty period should be a minimum of 12 hours uninterrupted within any 24-hour period.

2.2.4 Off-duty period (recovery requirement)

The general principles outline the importance of recovery to minimize the cumulative effects of sleep loss and fatigue. Two consecutive nights of usual sleep is a minimum requirement to stabilize sleep patterns and return waking performance and alertness to usual levels. Two consecutive nights of recovery sleep can provide recovery from sleep loss. Therefore, the standard off-duty period for recovery should be a minimum of 36 continuous hours, to include two consecutive nights of recovery sleep, within a seven-day period (calculated on a seven-day or 168-hour rolling basis). To provide operational flexibility, an alternate off-duty period could be a minimum of 48 continuous hours, to include two consecutive nights of recovery sleep, within a 10-day period.

2.2.5 Off-duty period (following standard flight-duty period during window of circadian low)

Extensive scientific research, including aviation data, demonstrates that maintaining wakefulness during the window of circadian low is associated with higher levels of performance-impairing fatigue than during daytime wakefulness. Duty periods that occur during the window of circadian low will have a higher potential for reduced performance and alertness than those that occur during daytime. Therefore, if three or more duty periods within a seven-day period encroach on all or any portion of the window of circadian low, it is recommended that the standard off-duty period (36 continuous hours within seven days) be extended to 48 hours to ensure recovery.

2.2.6 Off-duty period (following multiple time-zone change)

In general, the longer a flight crew member is away from the home-base/domicile time zone, the more recovery time is needed for readjustment to home-base/domicile time. Therefore, it is recommended that for duty periods that cross four or more time zones, and that involve 48 hours or more in a time zone away from the home-base/domicile time zone, a minimum of 48 hours off duty be allowed on return to home-base/domicile time.

2.3 Duty Period

2.3.1 Definition of "duty"

"Duty" is any task a crew member is required to perform by the operator, including flight time, administrative work, managerial duties, training and deadheading.

Table 1
Flight Safety Foundation Fatigue Countermeasures Task Force Overview of Guidelines and Recommendations for Corporate and Business Aviation

		Off Duty: Per 24-hour Period	Off Duty: Per Week	Off Duty: Other	Duty Period: Per 24-hour Period	Duty Period: Weekly, Monthly, Annually	Flight Time: Per 24-hour Period	Flight Time: Per Week	Flight Time: Monthly, Annually
Two Pilots	Standard	10 hours	Minimum 36 continuous hours, including two consecutive recovery nights, in a seven-day period (calculated on a seven-day or 168-hour rolling basis) … or …	48 continuous hours on return home following duty period across multiple time zones	14 hours	There are not sufficient scientific data to provide specific guidance in this area; nevertheless, maximum cumulative duty periods should be adjusted downward over increasing time frames.	10 hours	There are not sufficient scientific data to provide specific guidance in this area; nevertheless, maximum cumulative flight time should be adjusted downward over increasing time frames.	
Two Pilots	Extended*	12 hours (following extended flight time)	minimum 48 continuous hours in a 10-day period		14 hours		Up to 12 hours (requires that landings, maximum cumulative hours be restricted, with compensatory off-duty time)	Maximum of four cumulative hours of extension	
Three Pilots (Augmented)	Extended*	12 hours 12 hours	*(same as above)*	*(same as above)*	*Reclining seat:* 18 hours *Supine bunk:* 20 hours	*(same as above)*	16 hours** 18 hours**		*(same as above)*

* Extended operations can involve duty/rest cycles longer than 24 hours.

** Each flight crew gets maximum sleep opportunity with minimum four hours total; maxiumum two consecutive duty periods with 18 hours off duty.

Source: Flight Safety Foundation and U.S. National Aeronautics and Space Administration

Table 2
Flight Safety Foundation Fatigue Countermeasures Task Force Overview of Guidelines And Recommendations for Flight Operations During the Window of Circadian Low

The “window of circadian low” is best estimated to be the hours between 0200 and 0600 for individuals adapted to a usual day-wake/night-sleep schedule. Guidelines apply to the following operations within this window of circadian low:

1. Landing
2. Flight through both sides of the window of circadian low
3. Duty period that starts at 0400 or earlier in the window of circadian low

	Off Duty			Duty Period		Flight Time			
	Per 24-hour Period	Per Week	Other	Per 24-hour Period	Weekly, Monthly, Annually	Per 24-hour Period	Per Week	Monthly, Annually	
Two Pilots	12 hours	48 continuous hours in seven-day period following multiple duty periods in circadian low (calcu-ated on a seven-day or 168-hour rolling basis)	48 continuous hours on return home following duty period across multiple time zones	12 hours	There are not sufficient scientific data to provide specific guidance in this area; nevertheless, maximum cumulative duty periods should be adjusted downward over increasing time frames.	10 hours (requires that landings be restricted)	There is not sufficient scientific data to provide specific guidance in this area; nevertheless, maximum cumulative flight time should be adjusted downward over increasing time frames.		**Standard**
	No two-pilot extensions recommended.								
	Off Duty			**Duty Period**		**Flight Time**			**Extended***
Three Pilots (Augmented)	12 hours	*(same as above)*	*(same as above)*	*Reclining seat:* 18 hours	*(same as above)*	16 hours**	*(same as above)*	*(same as above)*	
	12 hours			*Supine bunk:* 20 hours		18 hours**			

* Extended operations can involve duty/rest cycles longer than 24 hours.

** Each flight crew gets maximum sleep opportunity with minimum four hours total; maxiumum two consecutive duty periods with 18 hours off duty.

Source: Flight Safety Foundation and U.S. National Aeronautics and Space Administration

2.3.2 Definition of "duty period"

"Duty period" is a continuous period of time during which tasks are performed for the operator; determined from report time until free from all required tasks.

2.3.3 Duty period

To reduce vulnerability to performance-impairing fatigue from extended hours of continuous wakefulness and prolonged periods of continuous performance requirements, cumulative duty per 24 hours should be limited. It is recommended that this limit not exceed 14 hours within a 24-hour period. The 14-hour duty period can be extended only with augmented flight crew (see Section 2.3.5).

2.3.4 Duty period (during window of circadian low)

It is recommended that this limit not exceed 12 hours within a 24-hour period.

2.3.5 Extended duty period: augmented flight crew

Augmenting the flight crew offers the opportunity for each flight crew member to reduce the time at the controls and allows for sleep during a duty period. Consequently, with additional flight crew and an opportunity for sleep, fatigue would be expected to accumulate more slowly. In such circumstances, duty periods can be increased beyond the recommended limit of 14 hours within each 24-hour period. When an additional flight crew member rotates into the flight deck positions, the duty period can be extended, with specified restrictions. In each circumstance, it is required that each flight crew member be provided one or more on-duty sleep opportunities.

It is acknowledged that an extended duty period with augmented flight crew will usually involve operating during the window of circadian low. Therefore, the following guidelines and recommendations are suggested for all operations.

Any extension of the duty period requires all of the following: a maximum sleep opportunity, with a minimum of four hours total per duty period; a minimum of 12 hours off duty; a maximum of two consecutive extended duty periods; and a minimum of 18 hours off duty following two consecutive extended duty periods. Controlled rest on the flight deck is not a substitute for the sleep opportunities or facilities required for additional flight crew members.

2.3.5.1 Extended duty period (augmented flight crew — four-hour extension)

An 18-hour duty period requires a reclining seat for sleep that is separated and screened from the flight deck and passengers.

2.3.5.2 Extended duty period (augmented flight crew — six-hour extension)

A 20-hour duty period requires an adequate sleep facility (permitting a supine position) that is separated and screened from the flight deck and passengers.

2.3.6 Duty period (cumulative)

A 24-hour cumulative duty-period limit and flight-time limit, a minimum off-duty period per 24 hours and a specified off-duty recovery period per seven days focus specifically on short-term vulnerabilities and considerations. To minimize fatigue that is not compensated by short-term recovery and to reduce excessive accumulation across longer periods of time, cumulative duty-period limitations are recommended. There are not sufficient scientific data to provide specific guidance in this area. Nevertheless, the general principles apply. For example, when determining cumulative duty-period limitations, shorter time frames should be considered. Therefore, in addition to 30-day and yearly cumulative duty-period limitations, a two-week limit should also be set. Also, these cumulative duty-period limitations should be adjusted downward across the longer time period. Rather than just multiplying the two-week cumulative duty-period limitation to calculate the 30-day and yearly amounts, the 30-day amount should be decreased a percentage from the two-week amount. The yearly cumulative duty-period limitation should be decreased a percentage from the 30-day amount. This will further reduce the potential for long-term accumulation of fatigue factors.

2.4 Flight Time

2.4.1 Definition of "flight time"

"Flight time" is the sum of all flight time, calculated from block to block for each flight segment.

2.4.2 Standard flight time

To reduce vulnerability to performance-impairing fatigue from extended hours of continuous wakefulness and prolonged periods of continuous performance requirements, cumulative flight time per 24 hours should be limited. It is recommended that for standard operations, cumulative flight time should not exceed 10 hours within a 24-hour period. Standard operations include multiple flight segments and day or night flying.

2.4.3 Extended flight time (nonaugmented flight crew)

To provide operational flexibility, cumulative flight time can be extended to 12 hours within a 24-hour period to be accompanied by additional restrictions and compensatory off-duty periods. This limit is based on scientific findings from a variety of sources, including aviation data, that demonstrate a significantly increased vulnerability to performance-impairing fatigue after 12 hours that could reduce the safety margin.

2.4.3.1 Extended flight time (nonaugmented flight crew — restrictions and compensatory off-duty periods)

If cumulative flight time is extended to 12 hours, the following restrictions and compensatory off-duty periods should be applied:

Work demand: restricted number of landings. Accident data and performance- and physiology-based fatigue research demonstrate increased vulnerability and risk during critical phases of operation, with the highest level occurring during descent and landing. Each additional landing can increase work demand, further degrade performance and represent a period of increased vulnerability. Because there are not sufficient scientific data to provide specific guidance in this area, the general principles should be applied. If flight time for nonaugmented crew operating during the window of circadian low contains a single, long and continuous block-to-block flight time (e.g., approaching the maximum of 10 hours), then it is recommended that the flight crew perform no other flight duties after landing, such as repositioning flights or short passenger drop-off flights.

Cumulative effects: maximum cumulative hours of extension. Over time, extended flight time can result in cumulative effects of fatigue. To support operational flexibility and still minimize the potential for cumulative effects, it is recommended that flight time can be extended by a cumulative total of four hours within a seven-day period. For example, there could be two two-hour extensions of the standard 10-hour flight time (two hours x 2 = four hours) in a seven-day period. These extensions should not be scheduled on consecutive days.

Recovery: compensatory off-duty period. To promote recovery from the acute fatigue associated with an extended flight time, an additional off-duty period is recommended. The subsequent 10-hour off-duty period should be extended to 12 hours.

2.4.3.2 Extended flight time (nonaugmented flight crew — operating during window of circadian low)

It is recommended that there should be no extensions of flight time for nonaugmented crew operating during the window of circadian low.

2.4.4 Extended flight time (augmented flight crew)

Augmenting the flight crew offers each flight crew member the opportunity to reduce the time at the controls and to acquire sleep during a duty period. With additional flight crew and an opportunity for sleep, fatigue would be expected to accumulate more slowly. In such circumstances, flight time can be increased beyond the recommended limit of 10 hours within each 24-hour period. When an additional flight crew member rotates into the flight deck positions, the flight time can be extended, with specified restrictions. In each circumstance, it is required that each flight crew member must be provided one or more on-duty sleep opportunities.

It is acknowledged that extended flight time with augmented flight crew will usually involve operating during the window of circadian low. Therefore, the following guidelines and recommendations are suggested for all operations.

Any extension requires all of the following: a maximum sleep opportunity, with a minimum of four hours total per duty period; a minimum 12 hours off duty; a maximum of two consecutive extended duty periods; and a minimum of 18 hours off duty following two consecutive extended duty periods. Controlled rest on the flight deck is not a substitute for the sleep opportunities or facilities required for additional flight crew members.

2.4.4.1 Extended flight time (augmented flight crew — six-hour extension)

A 16-hour flight time requires a reclining seat for sleep that is separated and screened from the flight deck and passengers.

2.4.4.2 Extended flight time (augmented flight crew — eight-hour extension)

An 18-hour flight time requires adequate sleep facility (permitting a supine position) that is separated and screened from the flight deck and passengers.

2.4.5 Flight time (cumulative)

A 24-hour cumulative duty-period limit, a flight-time limit, a minimum off-duty period per 24 hours and a specified off-duty recovery period per seven days focus specifically on short-term vulnerabilities and considerations. To minimize fatigue that is not compensated by short-term recovery and to reduce excessive accumulation across longer periods of time, cumulative flight-time limitations are recommended. There are not sufficient scientific data to provide specific guidance in this area. Nevertheless, the general principles apply. For example, when determining cumulative flight-time limitations, shorter time frames should be considered. Therefore, in addition to 30-day and yearly cumulative flight-time limitations, a two-week limit should also be set. Also, these cumulative flight-time limitations should be adjusted downward across the longer time period. Rather than just multiplying the two-week cumulative flight-time limitation to calculate the 30-day and yearly amounts, the 30-day amount should be decreased by a percentage from the two-week amount. The yearly cumulative flight-time limitation should be decreased by a percentage from the 30-day amount. This will further reduce the potential for long-term accumulation of fatigue factors.

2.5 Standby

Flight crew members on standby provide a critical element in operational flexibility and the opportunity to meet unanticipated needs. It is important that flight crew members on standby obtain required sleep prior to a duty period.

2.5.1 Definition of "standby"

A flight crew member on "standby" is required to be available to an operator (away from the airport) for assignment to a flight duty period.

2.5.2 Standby status

Standby status should not be considered duty. Nevertheless, it is important that the flight crew-member have an opportunity to obtain sleep prior to an assigned duty period. Two specific principles should be applied. The flight crew member should be provided a predictable and protected eight-hour sleep opportunity. "Predictable" indicates that the flight crew member should have prior information (24-hour notice is recommended) as to when the eight-hour sleep opportunity can be obtained within the 24-hour standby time. The eight-hour sleep opportunity should not vary by more than three hours on subsequent days to ensure circadian stability. "Protected" means that there should be no interruption by assignment to a duty period. Any approach that satisfies these two principles may be utilized.

2.6 Summary: Guidelines and Recommendations

Table 1 (page 5) provides an overview of the guidelines and recommendations discussed in this document. Table 2 (page 6) provides an overview of the guidelines and recommendations discussed in this document for flight operations during the window of circadian low.

3.0 Education and Training

3.1 Principles

An important first step for the corporate and business aviation industry is to become informed about the extensive scientific knowledge now available regarding fatigue, sleep and circadian physiology as it relates to performance and aviation operations. Training should reflect current scientific information derived from the study of fatigue, sleep loss and circadian disruption and provide information about the physiological mechanisms that underlie fatigue. Training should demonstrate how this information may be applied to improve flight crew sleep, alertness and performance; and training should recommend strategies for alertness management during flight operations.

3.2 NASA-Ames Education and Training Module on Fatigue

Education and training programs on fatigue countermeasures have been implemented successfully within the aviation industry. The NASA-Ames education and training module, "Alertness Management in Flight Operations," is an excellent resource for corporate and business aviation education and training activities. (Information about this module is available by writing the NASA-Ames Fatigue Countermeasures Program at the address provided in the Foreword.) Although this module provides the basis for education and training activities, further materials may be developed to facilitate the implementation of these principles and guidelines and other specific corporate and business aviation issues.

3.3 Dissemination of Information by Training Organizations

Where possible, information on fatigue should be integrated into existing programs, such as pilot enrichment, advanced airmanship, crew resource management courses, manufacturers' programs and others. The format for these courses should be tailored to the specific needs of the corporate operator, aviation organization and training programs. This information should be available to all individuals in the corporate and business aviation industry, including pilots, managers, flight attendants, schedulers and maintenance technicians.

3.4 Other Educational Forums

Other educational forums, such as professional publications, seminars, conferences and manufacturers' and operators' meetings, should be used to disseminate information on fatigue. These forums may be useful in establishing an ongoing interactive dialogue with operators on fatigue issues.

3.5 Quality Assurance

Current scientific literature and research — not opinion, anecdotal experience or casual recommendations — should be the basis for these programs. Support literature should be referenced or made available for additional reading. Instructors should be well informed on fatigue-related topics and should be aware of the current literature and scientific findings. During training, ample time should be made available for questions and answers.

3.6 Practical Application

Information acquired from these education and training programs should be applied daily to corporate and business aviation activities and used to develop strategies that promote individual and organizational performance and alertness in flight operations.

4.0 Other Industry Strategies

4.1 Operational Countermeasures

A variety of other strategies for use during flight operations should be examined and utilized where appropriate. This includes the design and use of technology to promote performance and alertness during operations. Varying work demands or creative uses of flight deck automation could be developed to maintain alertness and performance. Several activities in this area are under way, with some successful applications currently in use. The following are examples of strategies that may be useful to address fatigue in corporate and business aviation operations. These are provided here not as guidelines but to demonstrate the range of options available to manage fatigue in operations.

4.1.1 Break during duty day

For two-pilot crews, when the duty day includes a period of six hours or greater on standby at an en route stop, pilots should obtain maximum rest/sleep opportunity at a local hotel. In such cases, every two hours of hotel rest might be used to extend the duty day by one hour (e.g., four hours rest permits two-hour duty-day extension).

4.1.2 Predeparture quarantine

For crews anticipating maximum-length duty day, predeparture quarantine at a local hotel near the departure airport will help ensure that the duty day is initiated with little or no accumulated sleep debt. In some cases, preparation of the aircraft by a backup crew may afford additional mission flexibility.

4.1.3 Preflight planning

For augmented crews, specific preflight planning of the in-flight duty-rest cycle is important. Priority should be given to the landing crew members, and cabin crew members' needs should be integrated into the plan.

4.1.4 Pre-positioning crews

When operational needs exceed recommended guidelines, relief crews could be pre-positioned at appropriate locations along the route. Pre-positioning should be planned to allow for travel contingencies and should provide opportunity for circadian adaptation and recommended rest prior to commencing duty.

4.2 Scheduling Practices

The scientific information available can be particularly useful in guiding rational and physiologically based scheduling practices. Scheduling is a complex and multi-determined process. Nevertheless, it is possible and essential to include scientific data on human physiology as a factor for consideration. Obviously, priorities need to be established and cost/benefit considerations are necessary. There are examples of successful integration of scientific information on fatigue into schedule construction.

4.3 Controlled Rest on the Flight Deck

Scientific data obtained during flight operations have demonstrated the effectiveness of a planned cockpit rest period to promote performance and alertness in nonaugmented long-haul flight operations. Controlled rest is a single operational strategy and is not an answer to all fatigue engendered by flight operations. Controlled rest is absolutely not intended as a substitute for additional flight crew or appropriate rest facilities, or as support for extended duty. All possible strategies that maintain or improve safety should be considered.

4.4 Other Physiological Stressors Associated with Flight

Besides fatigue, a variety of other physiological stressors are known to affect human performance in flight operations. These other physiological factors include hypoxia, barometric-pressure changes, dehydration, vibration, noise, humidity, temperature changes and "third spacing" associated with blood pooling in lower extremities. [Lack of movement inhibits the return of blood from the legs and feet through the veins toward the heart. The build-up of pressure causes lymphatic and other fluids to be squeezed out of the capillaries, "pooling" in tissues and creating swelling and discomfort.] Managing these other physiological stressors is important to minimize their contribution to, or exacerbation of, fatigue.

4.5 Future Developments

A number of other approaches to manage fatigue in flight operations are in different stages of development. Provocative laboratory studies of several countermeasures are often cited. Nevertheless, validation of their effectiveness and safety in operational settings is still needed prior to widespread implementation. Research continues and may provide further findings on countermeasures relevant to scheduling, personal strategies and technological approaches to manage alertness in aviation operations.

In developing this document, it became clear that a range of issues requires further investigation. Focused research is needed to more clearly define sleep in reclining aircraft seats vs. onboard supine rest facilities; the relationship of minimum blocks of sleep totaling a certain amount and subsequent performance and alertness; the relationship between duty period and flight time; the effectiveness of operational strategies currently used to be applied more broadly as guidelines; and others.

As the corporate and business aviation industry implements education and training programs, information and strategies for managing fatigue will become widespread. Once this core of knowledge and application is established, more specific materials and strategies may be developed to support future corporate and business activities.

Finally, this document's principles and guidelines reflect the current operational demands of corporate and business aviation and the available scientific information. These principles and guidelines are expected to change as the demands of the industry change and as further scientific findings become available.

5.0 Cumulative Duty Periods and Flight Times

Cumulative 24-hour duty-period and flight-time limits, a minimum off-duty period per 24 hours and a specified off-duty recovery period per seven days focus specifically on short-term vulnerabilities and considerations. To minimize fatigue that is not compensated by short-term recovery and to reduce excessive accumulation across longer periods of time, cumulative duty-period and flight-time limitations are recommended. There are not sufficient scientific data to provide specific guidance in this area. Nevertheless, the general principles apply. For example, when determining cumulative duty-period and flight-time limitations, shorter time frames should be considered. Therefore, in addition to 30-day and yearly cumulative duty-period and flight-time limitations, two-week limits should also be set. These cumulative limitations should be adjusted downward across the longer time period. Rather than just multiplying the two-week cumulative limitation to calculate the 30-day and yearly amounts, the 30-day amount should be decreased by a percentage from the two-week amount. The yearly cumulative limitation should be decreased by a percentage from the 30-day amount. This will further reduce the potential for long-term accumulation of fatigue factors.

The cumulative 24-hour duty-period and flight-time limitations are recommended in the guidelines. Table 3 indicates the maximum duty periods and flight times per week if simply determined from the allowable guidelines.

Nevertheless, serious consideration should be given when approaching these maximums. Standard duty periods and flight times that do not involve the window of circadian low present reduced risk of fatigue. Augmented duty periods and flight times will typically involve multiple circadian disruptions in both operations and sleep opportunities. This combination presents a greater risk of fatigue, and this should be a consideration in determining weekly limitations for augmented duty periods and flight times. Again, cumulative duty-period and flight-time limitations should be adjusted downward across the longer time periods. As a general guideline, the current industry standard is 100 cumulative flight hours per month and 1,000 cumulative flight hours per year.

Table 3
Recommended Maximum Duty Period and Flight Time Per Week*

	Duty Period (hours)	Flight Time (hours)
Standard	82	60
Extended	78	60
Augmented: reclining seat	72	64
Augmented: supine bunk	78	70
Window of circadian low	60	50

* In addition to 30-day and yearly cumulative duty-period and flight-time limitations, two-week limits should also be set. Cumulative duty-period and flight-time limitations should be adjusted downward across the longer time periods. As a general guideline, the current industry standard is 100 cumulative flight hours per month and 1,000 cumulative flight hours per year.

Source: Flight Safety Foundation and U.S. National Aeronautics and Space Administration

6.0 Maintaining Operational Flexibility

The on-demand service orientation of corporate and business aviation operations will present occasional challenges to department managers who will be attempting to adhere to policies that protect the critical rest requirements of crew members in these organizations. This section is intended to provide some operational flexibility but does not negate or minimize the critical importance of following established, scientifically derived guidelines for duty/rest scheduling. These principles and guidelines, developed after careful consideration of all currently available scientific data on fatigue-related performance, should be considered a starting point to responsibly address crew fatigue management in the absence of regulation. In exceptional operational circumstances, when a deviation from these guidelines is considered, sound risk-management considerations might include the following elements: agreement among affected crew members, department manager and next level of management (if available) that the deviation does not compromise safe and prudent operations; a detailed written rationale for the deviation; consideration of available alternatives; identified and planned fatigue countermeasure strategies to be undertaken to mitigate the consequences of the deviation; and postevent debriefing. A written policy with an explicit process for addressing potential deviations is recommended.♦

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