SAFTE-FAST

Circadian Swaps

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Introduction

"Circadian swaps", is a colloquial aviation industry term used to describe a change from an early schedule to a late schedule (or vice versa). Circadian swaps may also be referred to as "circadian switches", "PM-AM swaps", "short/tight turnarounds", or any number of other terms to describe when a crew member switches from an early shift to a late shift or a late shift to an early shift in a short period of time (Hilditch et al. 2023, Herstam 2024). Circadian swaps are not constrained to any one type of operation or industry. "Early" and "late" are relative terms that may describe a number of different schedules based on time. Circadian swaps may occur when a crew member is acclimated to local time or may occur when a crew member is jet lagged or in an unknown state of acclimatization. There is no one clear definition about what constitutes a circadian swap. This makes it difficult to recognize the impact of circadian swaps on fatigue risk.

For the purposes of this white paper, we will use the term "circadian swap" to refer to a quick transition between two different shift work duty periods, defined as patterns of work that require an individual to be awake at a time in the circadian body clock cycle that they would normally be asleep (IATA 2015). Any duty period that extends overnight will impinge on the sleep period. Schedules that quickly transition from overnight operations to daytime operations can be considered a circadian swap. Shift work can also impinge on the normal sleep period through early start (duties that begin before 0659) or late ends (duties that end after 2359) even though the crew member does not work through the night (EASA 2014, Arsintescu et al. 2022). Circadian swaps therefore also include early-to-late transitions, defined as schedules where the crew member has an early start on the first day and a late end on the second day with a quick transition between shifts and late-to-early transitions, defined as schedules where the crew member has a late finish on the first day and an early start on the second day with a quick transition between shifts. For this white paper, quick transitions are defined as 36 hours or less based on guidance from the Federal Aviation Administration (FAA) Part 117.25(c), which states that flight crew members in a new theater who have received 36 consecutive hours of rest have met rest period requirements (FAA 2012).

The purpose of this white paper is to describe what is known about the impact of early-to-late and late-to-early schedule changes, referred to as circadian swaps, on physiological fatigue due to sleep loss or circadian misalignment and psychological fatigue due to workload. This white paper provides examples of how to model fatigue risk related to a circadian swap based on operational specifics and considerations for the limits of modeling fatigue related to circadian swaps.

Definitions

Parameterizing what constitutes a circadian swap in terms of exact hours is relative to the type of operations being conducted. Terms like “early”, “late”, and “quick” describe conditions relative to what is considered the operational norm. These kinds of definitions are called “qualitative” because they describe meaning without the use of numbers. However, definitions that use numbers, called “quantitative definitions” make it much easier to identify areas of risk within a schedule. For the purposes of this white paper, we have imposed the following quantitative definitions, in hours, for key terms:

Quick transition: 36 hours or less between the end of a prior duty and the beginning of the subsequent duty

Early Starts: duties that begin between 0300 and 0700 base time

Late Ends: duties that end between 2300 and 0300 base time

The quantitative definitions listed above are purposely broader than the above references to early starts or late ends defined by EASA Commission Regulation (EU) No 83/2014 or Arsintescu et al. 2022. Broad hourly windows should allow the definitions above to apply to a wider range of operations. These values are also used for SAFTE-FAST default settings for the circadian swap window, early starts, and late ends (described later in this white paper). The definition of quick transitions as less than 36 hours is informed by FAA guidance on flightcrew member rest required to become acclimated (14 CFR 117.3 Definitions, (FAA 2012). SAFTE-FAST default settings for circadian swap parameters are configurable because of the relative nature of swaps. Operators should consider the qualitative definitions for circadian swaps and shift work listed immediately below to determine if the quantitative definitions above need to be adjusted to best reflect their type of operations.

Circadian swap: A quick transition between discordant types of shift work duty hours (i.e., an early-to-late or late-to-early transition)

Shift work: working hours that require an individual to be awake at a time in the circadian body clock cycle that they would normally be asleep

Fatigue Factors Related to Circadian Swaps

Fatigue is jointly defined by the International Air Transport Association (IATA) and the International Civil Aviation Organization (ICAO) as “a physiological state of reduced mental or physical performance capability sleep loss or extended wakefulness, circadian phase, or workload (mental and/or physical activity) that can impair a crew member’s alertness and ability to safely operate an aircraft or perform safety-related duties” (IATA 2015). Fatigued individuals are less alert, have reduced ability to process information, and have slower reaction times than usual. Fatigue can lead to operator errors and procedural violations which can ultimately result in costly damage to people and property (Gaines et al. 2020). In the context of its impact on fatigue, workload is defined by ICAO as “mental and/or physical activity”. Workload includes objective measures such as time on task, or number of duties, but importantly, also incorporates the operator’s psychological perception of effort, frustration or stress in relation to the task (Rubio et al. 2004, Arsintescu et al. 2020, Hilditch et al. 2023). Higher self-reported workload is associated with slower reaction time and higher ratings of fatigue (Arsintescu et al. 2020).

There is limited research that focuses specifically on circadian swaps as a fatigue factor due to the fact that the term itself is vaguely defined and predominately used by industry professionals rather than the research community. However, a recent focus group of United States-based short-haul pilots used thematic coding to identify causes of fatigue based on key terms that pilots mentioned during interviews. The most commonly-identified theme in this study was categorized by the authors as “circadian switches” or, changes in duty start times within a trip, for example switching from an early start time to a late start time (Hilditch et al. 2023). The term “circadian swaps” made up 34% of codes in this theme, followed by inconsistent duty times (25%), and switching time zones (18%) (Hilditch et al. 2023). Workload was also a commonly-reported theme. Pilots reported fatigue related to short turnarounds, length of flights, and operational challenges within the workload category. Inadequate rest opportunities, including rest timing and rest duration, were also frequently identified as fatigue factors.

Circadian swaps may cause fatigue due to a number of reasons. Firstly, a sudden shift in the crew member’s daily routine when they switch between schedules may cause circadian misalignment. Circadian misalignment occurs when your sleep-wake cycle is out of sync with the external environment. Traveling across multiple time zones can cause circadian misalignment as well. Circadian swaps that occur when crew members are not acclimated to the local time will be more fatiguing than circadian swaps that occur when the crew member is acclimated to the local time.

Independently, early starts are associated with higher fatigue and reduced performance at the beginning of the duty period and late finishes are associated with worse performance at the end of the duty period (Gander et al. 2014, Arsintescu et al. 2022). The independent fatigue risk associated with working early or late duties is further exacerbated by rapidly switching between the two types of shifts. Tight turnarounds create a fatigue risk. Transitioning from a late finish to an early start obviously restricts the operator’s opportunity for sleep by impinging on the biological night (Ganesan et al. 2019).

Circadian swaps can also cause fatigue due to sleep loss since circadian misalignment and rapid changes to the schedule can impair sleep quality or restrict sleep opportunities. Swaps may also create psychological stress for crew members. Frustration associated with the schedule change or logistical difficulties complying with the schedule change can increase a crew member’s perceived workload.

The primary causes of fatigue will be circadian misalignment or sleep loss during a circadian swap. However, circadian swaps can create stress and increase workload independently from the fact that early starts, and late finishes impinge on sleep opportunities and disrupt the circadian rhythm. Circadian swaps constitute a short turnaround. Short turnarounds are frequently reported by pilots as a source of workload-related fatigue (Hilditch et al. 2023, Devine et al. 2024, Devine et al. 2025). Time off between shifts during a circadian swap may also feel shorter because tiredness and time of day can influence the operator's perception of time (Kuriyama et al. 2005). Physiological fatigue may also affect crew members' ability to work as a team (Banks et al. 2019), which may leave crew members feeling emotionally exhausted (Klasmeier and Lehmann-Willenbrock 2024). Crew members may also perceive work tasks as requiring more effort if they are physiologically fatigued (Feltman 2016, Marando et al. 2022).

It is important to consider the psychological impact of working a circadian swap on the crew member. However, with as limited research as there is about the physiologically fatiguing effects of circadian swaps on crew members, researchers have an even less clear picture of the impact of circadian swaps on workload. The best approach at this time may be a mixture of sensitivity and caution, wherein the organization is sensitive to the psychological impact of swaps but cautious to include swaps as a workload factor during biomathematical modeling.

Considerations

- The primary cause of fatigue during circadian swaps is due to circadian misalignment and/or sleep loss. Physiological fatigue will impact crew members' perception of workload.

- Flight time limitations (FTL) will affect the frequency and type of circadian swap that crew members may experience. Prescriptive regulations on FTLs differ by region and type of operation. A summary of global prescriptive fatigue management limitations has been compiled by IATA and can be found here: https://ic.iata.org/sites/default/files/iata_sih_document_attachment/IATA%20-%20Global%20Prescriptive%20Fatigue%20Management%20Requirements.pdf

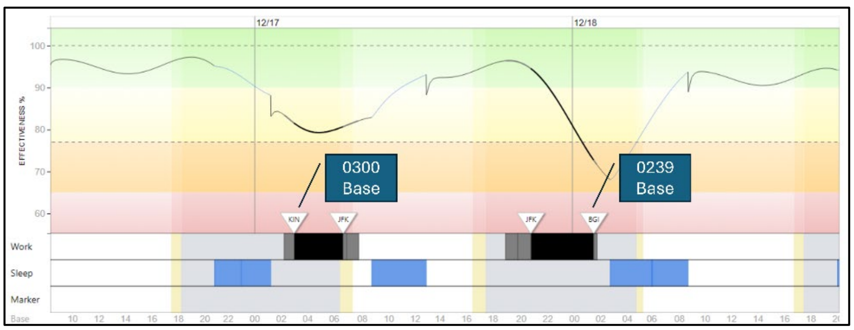
- Be aware that biomathematical models cannot account for individual differences in fatigue or alertness, such as the presence of sleep disorders, use of caffeine or other stimulants, or chronic sleep debt. Models cannot account for individual differences in perception of workload or psychological stress.

Fatigue Risk Related to Circadian Swaps

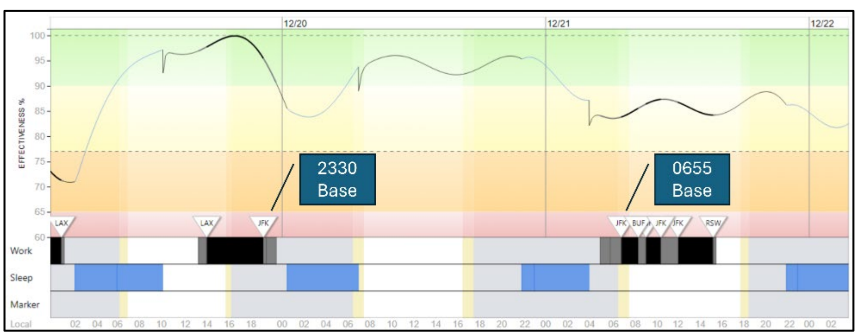
Modeling Circadian Swaps

SAFTE-FAST includes multiple configurable parameters to help users define and identify circadian swaps. SAFTE-FAST defines quick transitions, in hours, using the **Circadian Swap Window** parameter. The default setting for **Circadian Swap Window** is 36 hours. The default setting in SAFTE-FAST for **Early Starts** is between 0300 to 0700 base time and the default setting for **Late Ends** is 2300 to 0300 base time. Users may adjust these parameters according to their operational preferences. Examples of how an early-to-late circadian swap and a late-to-early circadian swap looks like on SAFTE-FAST plots are included below.

Example of an Early-to-Late Circadian Swap

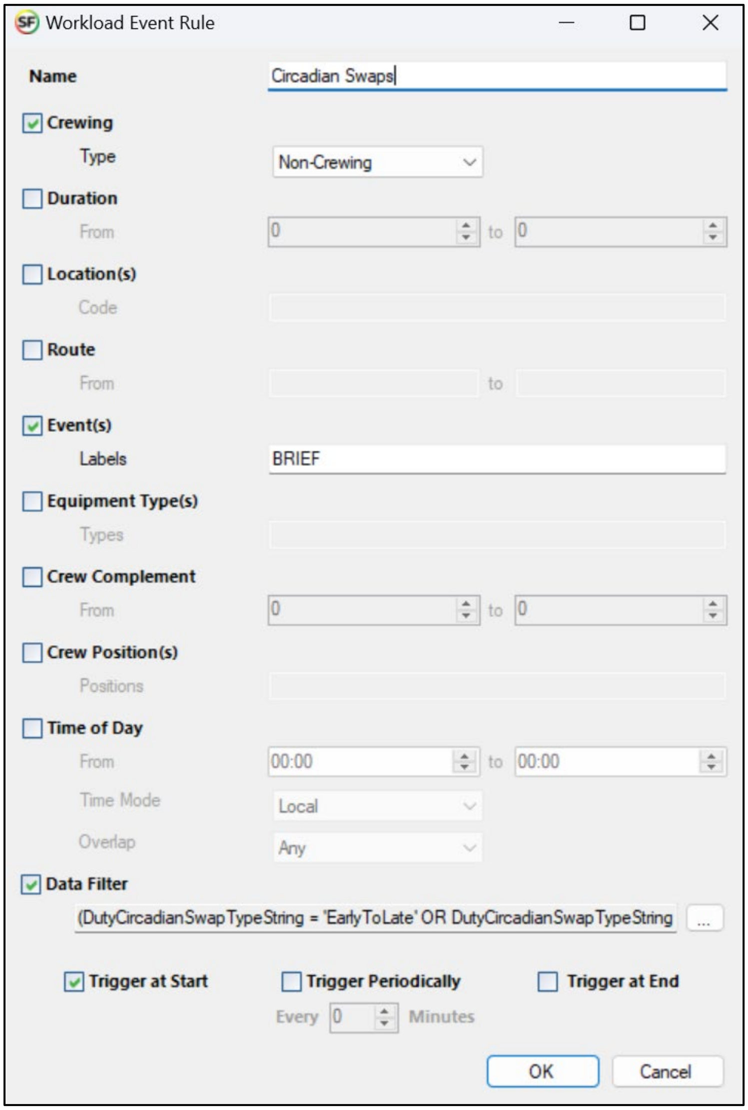


Example of a Late-to-Early Circadian Swap



Circadian Swaps as Workload

Circadian Swaps may also be configured as a workload rule. It is recommended that the BRIEF event be used to trigger the workload effects associated with a circadian swap. This approach ensures that workload is applied to the specific duty period in which the circadian swap occurs. Data filters may be used to capture workload impacts for early-to-late transitions, late-to-early transitions, or both.



Resources

For more information about fatigue estimation using SAFTE-FAST or assistance using SAFTE-FAST to support an investigation, please refer to the SAFTE-FAST user manual, visit https://www.saftefast.com/, or contact Support at support@saftefast.com.

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