Modelling the Fatigue Hazards Associated with Workload

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Fatigue and Workload

- Fatigue in aviation can be defined as: “the inability to function at the desired level due to incomplete recovery from the demands of prior work and other waking activities” Gander et al. 2011

- Fatigue can arise from multiple sources:
  - Circadian misalignment
  - Lack of sleep
  - Exhaustion
  - Burnout
  - Stress

Fatigue can be related to workload:

Scheduling factors

Time on task

Mental exertion

Frustration

- Fatigue increases the risk of behavioral errors that create the potential for safety hazards.

Fatigue From an Operational Perspective

"A physiological state of reduced mental or physical performance capability resulting from **sleep loss** or **extended wakefulness**, **circadian phase**, and/or **workload** (mental and/or physical activity) that can impair a person's alertness and ability to safely operate an aircraft or perform safety related duties."

International Air Transport Association (2015)

Long-haul

Medium- or short-haul

Research Questions & Methods

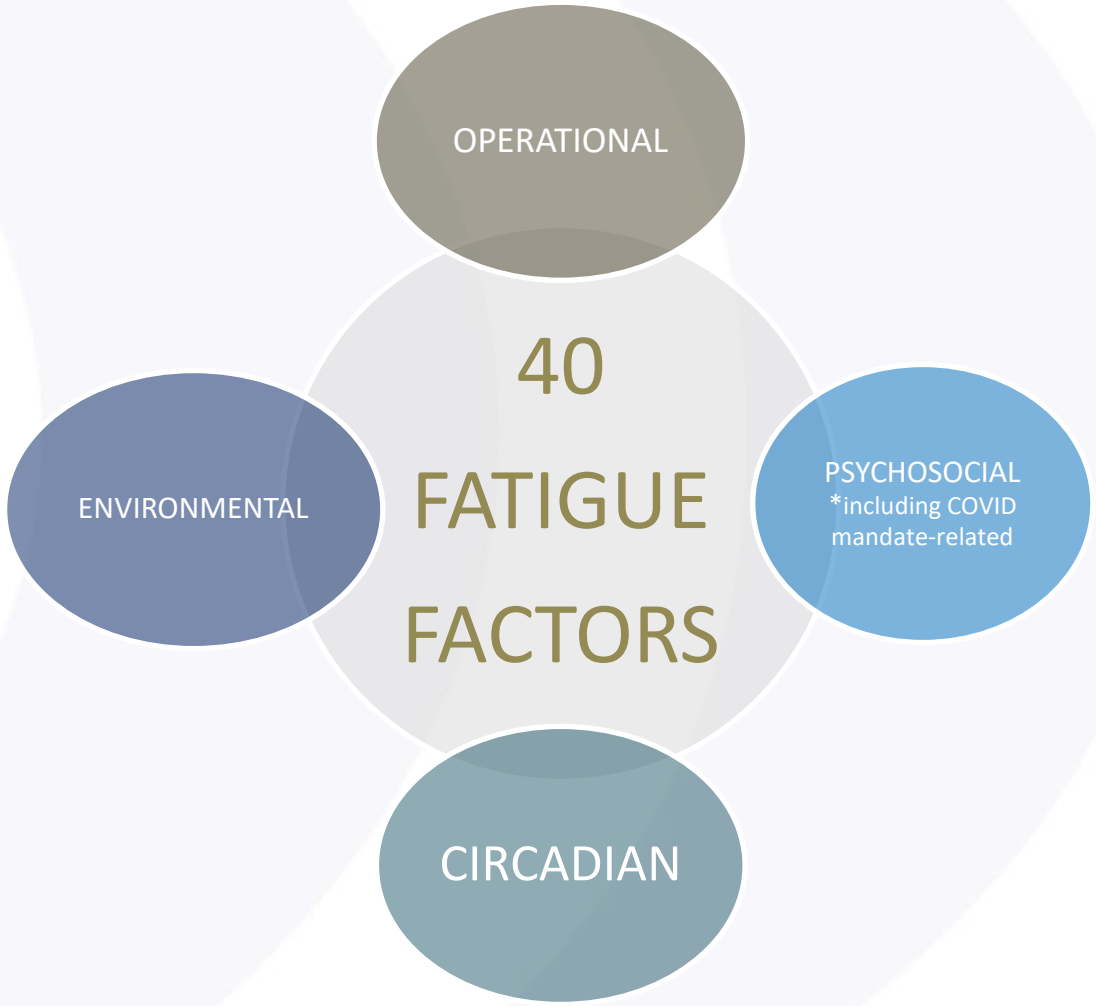
Air France Study

What factors do pilots find most fatiguing?

→ *Better understand fatigue factors in medium-/and short-haul pilots*

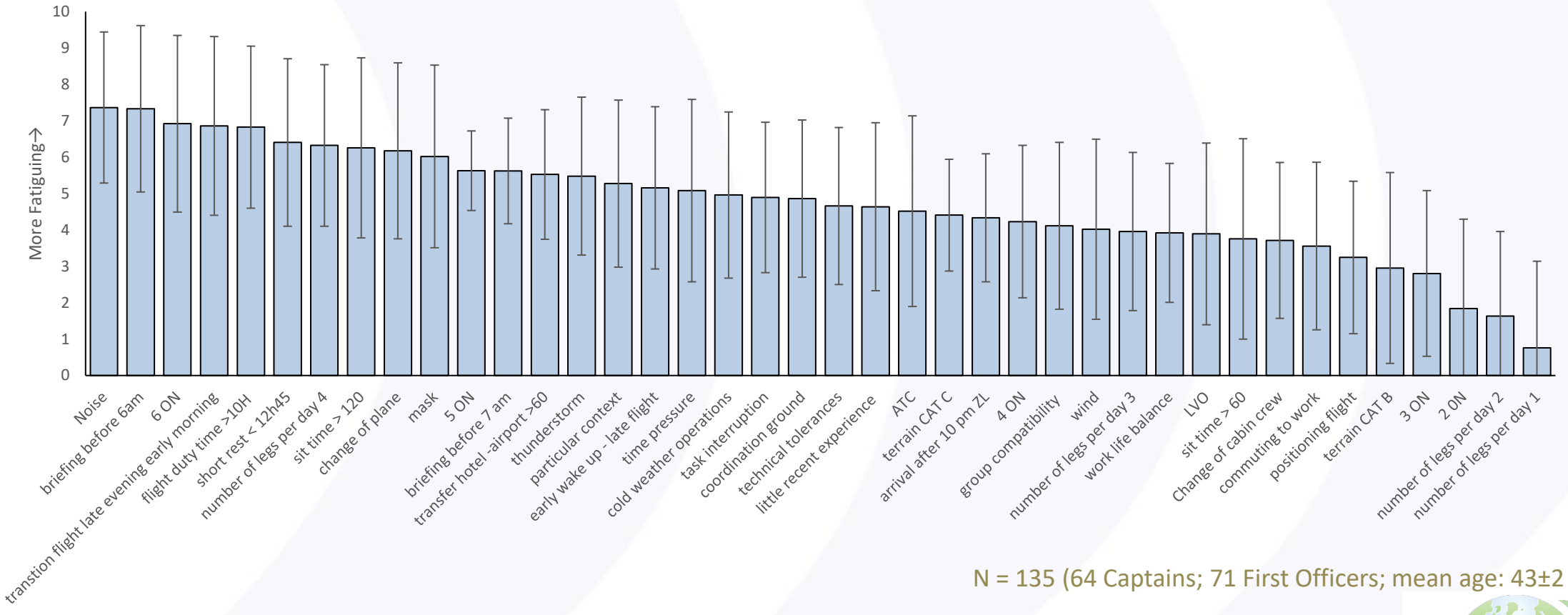
When conducting a survey, we must always remember that individuals may have different understandings of the words used, like “fatigue” and “workload”. It’s always best to ask them to describe the specific situation or condition that they feel causes high fatigue or workload. We can then look for those situations and try to mitigate those conditions.

Domains & Workload Fatigue Factors



Causes of Fatigue in Medium-Haul Operations

Survey Conducted by Air France



N = 135 (64 Captains; 71 First Officers; mean age: 43±2 years)

Causes of Fatigue in Medium Haul Operations

Modelling Workload Factors

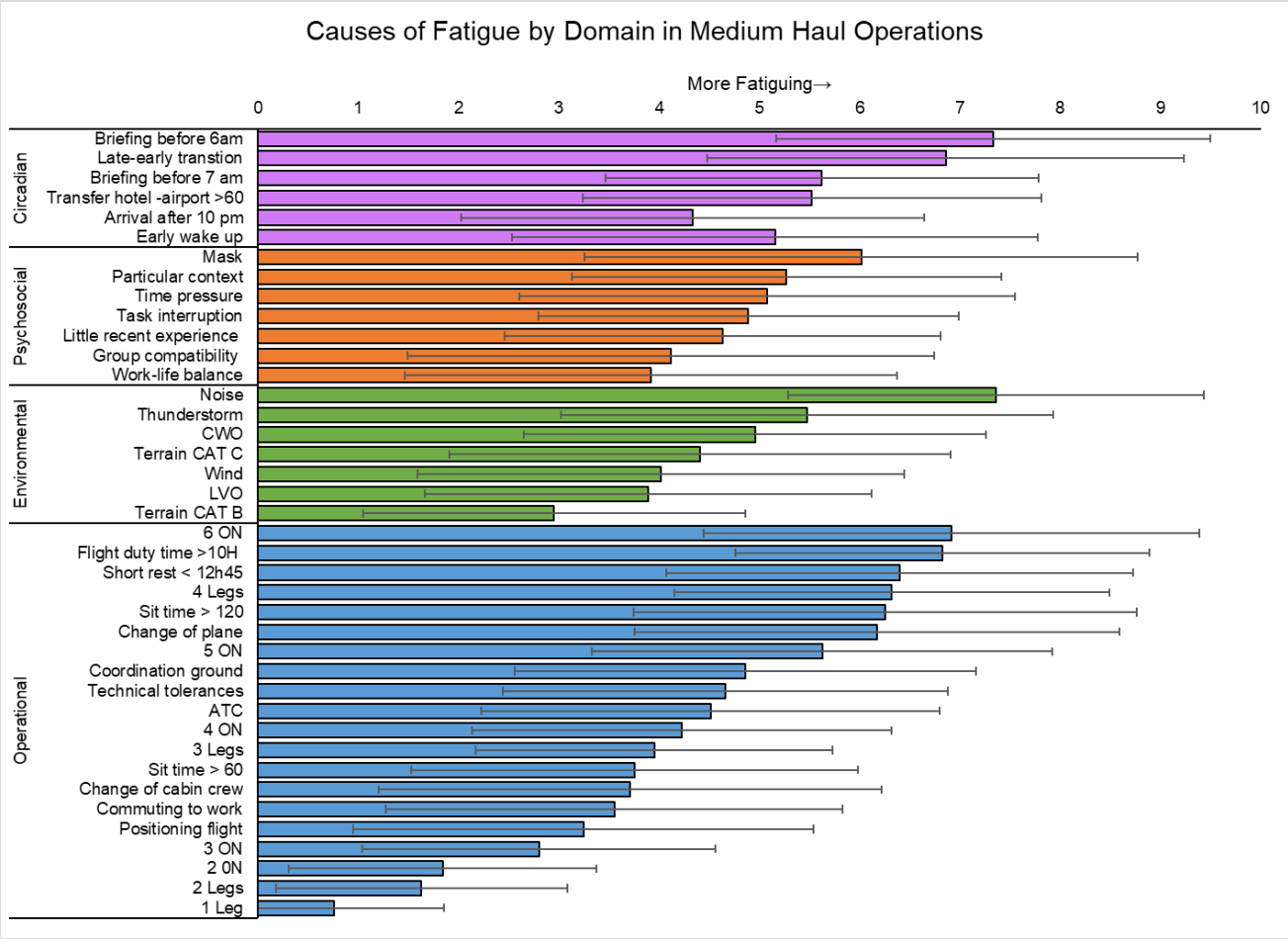
Table 1. Survey Items by Fatigue Domain

Domain	Survey Items	Modeling Status
Demographics	– Age – Habitual sleep duration – Rank (captain or first officer) – Flight hours	N/A
Circadian	1. Arrival after 10 PM 2. Briefing before 6 AM 3. Briefing before 7 AM 4. Early wake up 5. Late-early transition	Can be predictably modeled by SAFTE model circadian process
Operational	6. Air Traffic Control (ATC) 7. Change of cabin crew 8. Change of plane 9. Coordination with ground 10. Commuting to work 11. Consecutive days on (2 ON) 12. Consecutive days on (3 ON) 13. Consecutive days on (4 ON) 14. Consecutive days on (5 ON) 15. Consecutive days on (6 ON) 16. Number of legs per day (1 Leg) 17. Number of legs per day (2 Legs) 18. Number of legs per day (3 Legs) 19. Number of legs per day (4 Legs) 20. Flight duty time > 10 hours 21. Short rest <12 hours 45 minutes 22. Sit time >60 minutes 23. Sit time >120 m 24. Transfer to hotel > 60 minutes 25. Technical tolerances 26. Positioning flight	Can be predictably modeled as workload factors

Table 1. Survey Items by Fatigue Domain

Domain	Survey Items	Modeling Status
Environmental	27. Noise 28. Terrain Category B 29. Terrain Category C	Can be predictably modeled as workload factors
	1. Cold weather operations (CWO) 2. Low visibility operations (LVO)	Can be predictably modeled in some cases (*seasonal)
	3. Thunderstorm 4. Wind	Cannot be predictably modeled
Psychosocial	5. Group compatibility 6. Mask wearing 7. Little recent experience 8. Particular context 9. Task interruption 10. Time pressure 11. Work-life balance	Cannot be predictably modeled

Severity of Modelled Workload Factors



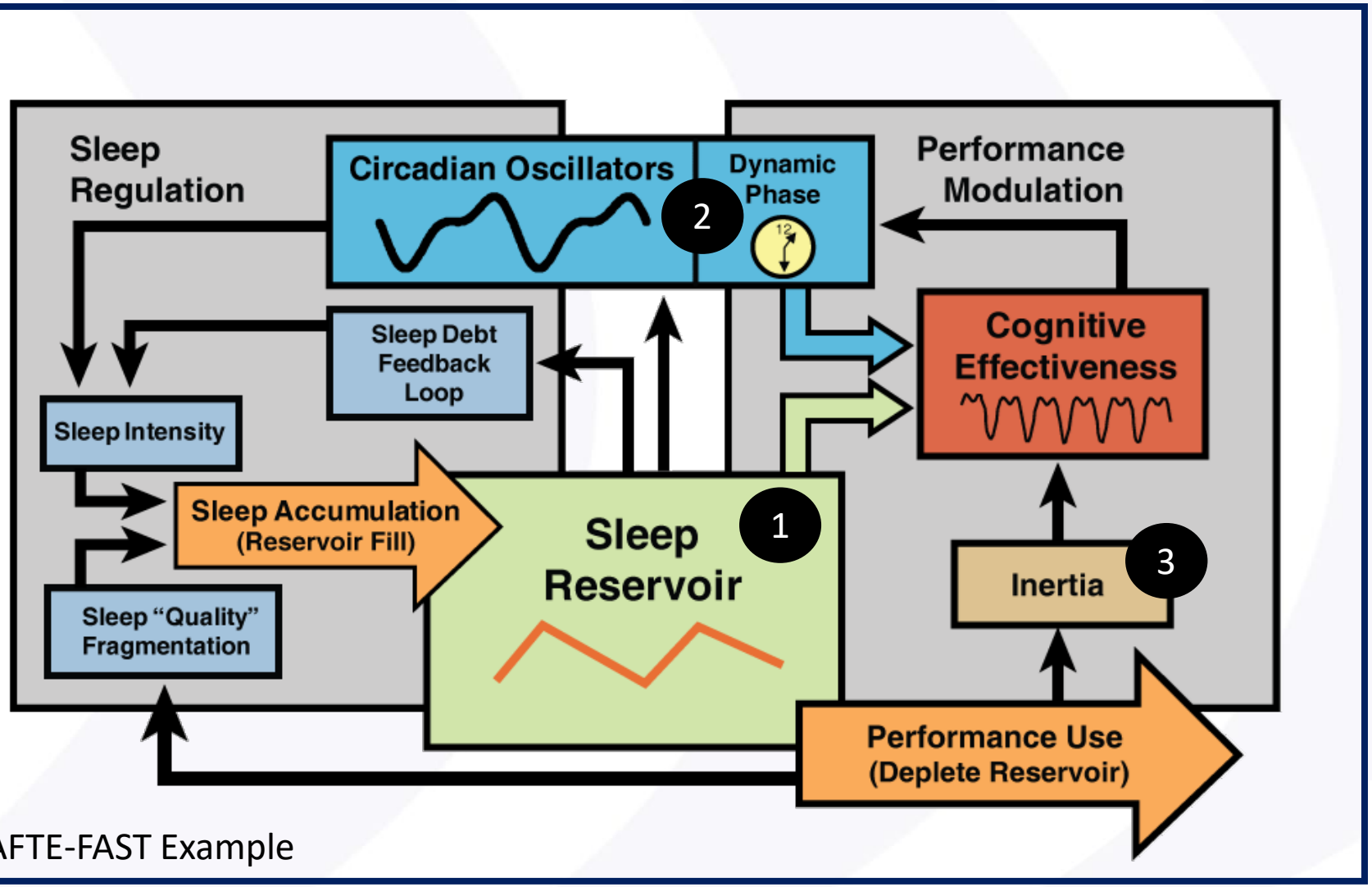
Standard Factors Contributing to Cognitive Fatigue

- Time of Day: between midnight and 0600 hours.
- Recent Sleep: less than eight hours in last 24 hours
- Continuous Hours Awake: 17 or more hours since last major sleep period
- Cumulative Sleep Debt: more than eight hours accumulation over days since last full night of sleep
- Workload and Time on Task: cognitive demands and continuous work time without a break

- Three-process Model:
  - Circadian process
  - Sleep Accumulation
  - Awake Depletion
  - Accumulated sleep debt
- Workload is NOT part of the three-process model

Standard Three-Process Fatigue Modelling Components

No Workload Factor



SAFTE-FAST Example

Two Ways to Incorporate Workload

Approach One

- Add a fourth factor to the three-process model:
- Single fatigue score that reflects the total hazard from all sources.
- Problem is scale:
  - Cognitive fatigue is currently scaled relative to a standard performance test.
  - However, workload is weak factor in test.
  - **Hence, no way to add workload to the cognitive fatigue scale.**
  - **If combined with other factors, hard to isolate the role of workload.**

Approach Two

- Use three-process model to estimate **cognitive capacity.**
- Create a workload model that measures **cognitive demand.**
- Conceptualize the workload hazard as a compound factor:

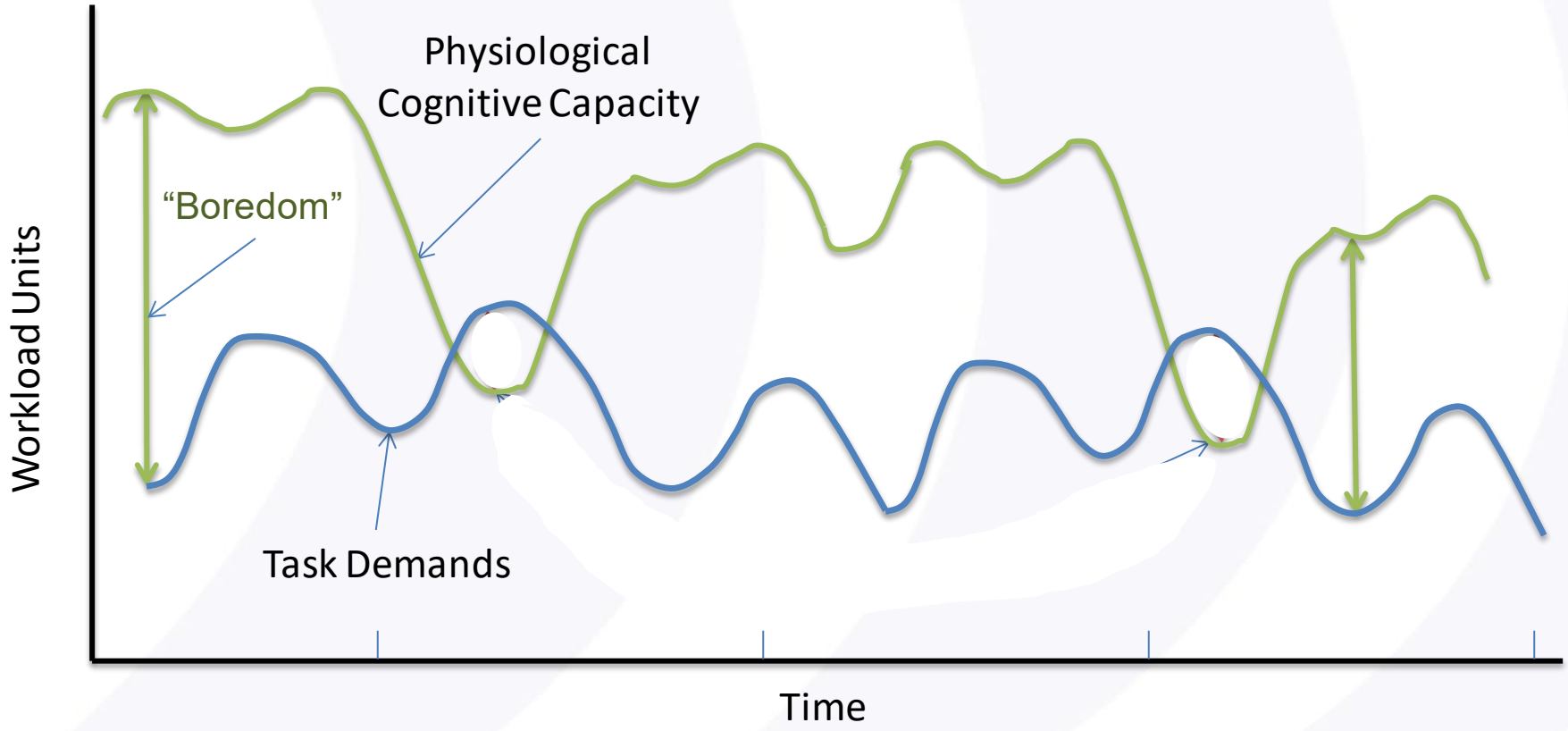
Low Cognitive Capacity (Alertness)

+

High Cognitive Demand (Workload)

Cognitive Capacity and Workload Mismatch

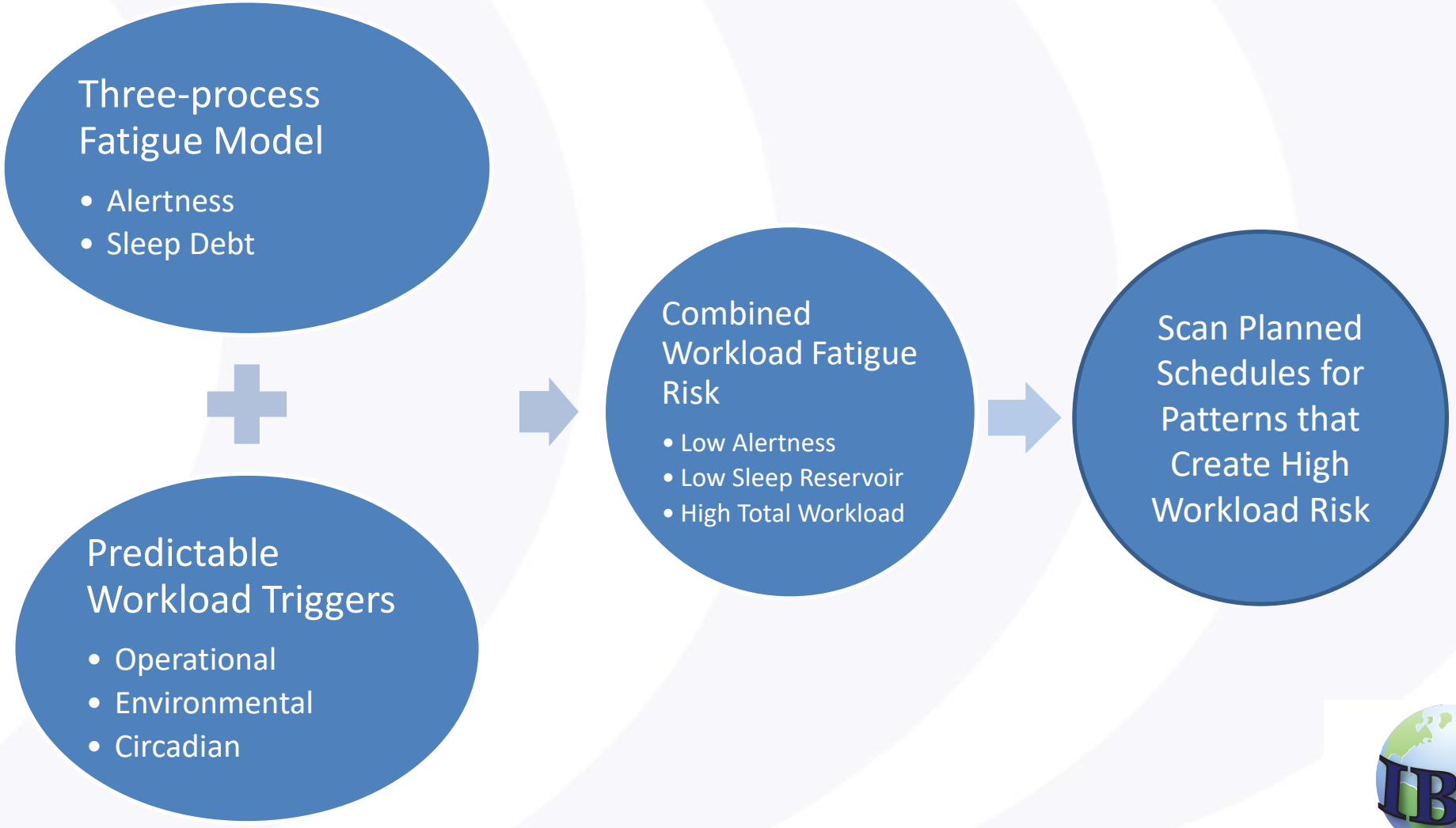
- Fatigue hazard occurs when workload demand exceeds cognitive capacity
- The challenge is automating a process for finding these hazardous situations



Identifying Excessive Workload in Aviation

- Many operations (for example, narrow body fleets) involve many segments per duty and relatively high workload.
- Such workload is common and is generally not a fatigue hazard alone.
- **However, high workload in combination with low cognitive capacity is potentially a fatigue hazard.**
- Modelling software must be designed to identify the conjoint occurrence of low alertness and high workload.
- And the software must identify the scheduling factors that result in this hazardous combination so it can be avoided in the future.

Modelling Components

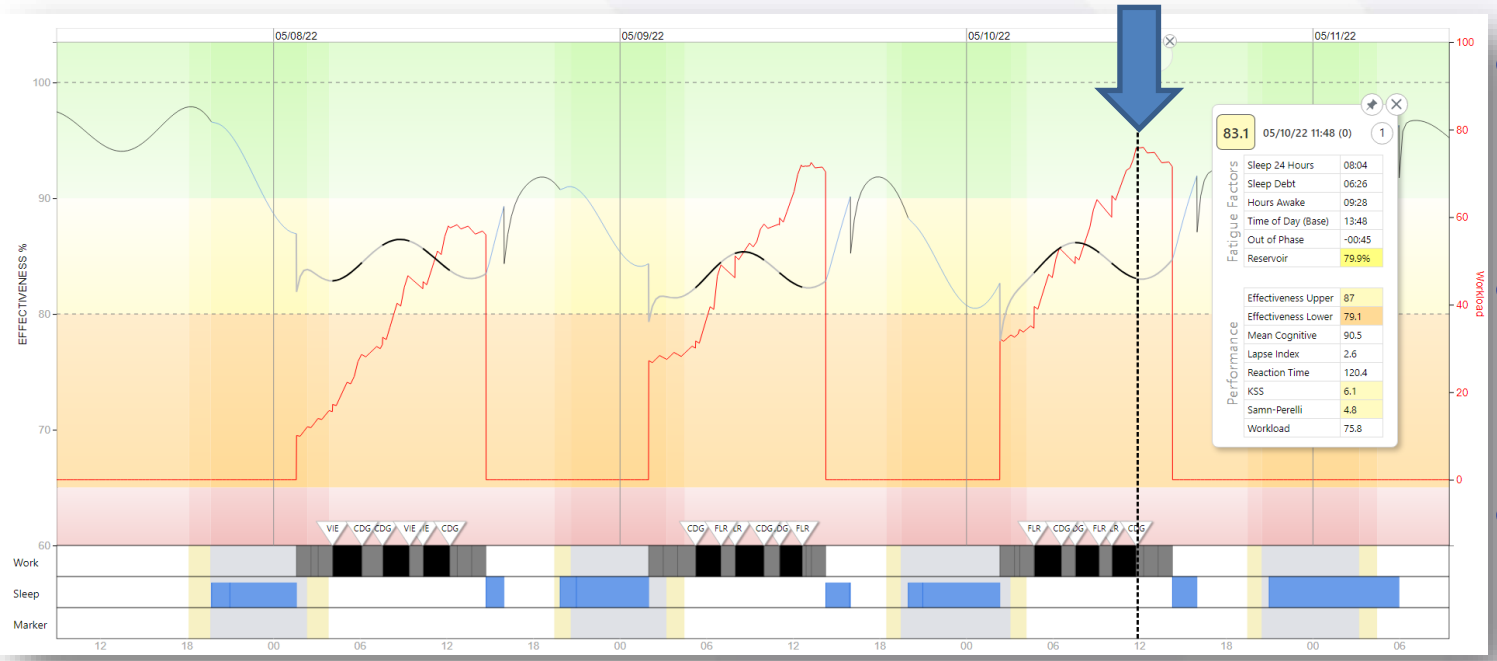


Find Fatigue-Related Patterns Leading to High Combined Risk

- Abstract from biomathematical modelling data knowledge needed to proactively avoid workload related fatiguing patterns in the future.
- Isolate patterns of duties and rest that consistently result in High Workload and Low Sleep Reservoir & Performance Effectiveness.
- Provides the user precise knowledge needed to create rules to prevent the fatigue hazard pattern in the future.

Identified Fatigue Patterns

Sequences of Duties and Rest that Reliably Cause Workload Fatigue Hazard



Combined Fatigue Risk
Workload: 75.8
Effectiveness: 83.1
Sleep Reservoir: 79.9

- Example of an Insights pattern reliably associated with High Workload and Low Effectiveness and Reservoir:
- Two consecutive early starts prior to a third early start (05:43) with three segments.
- Effectiveness progressively declined as workload built across three days.
- This pattern has been associated with repeated fatigue reports confirming the hazard identified by Insights.

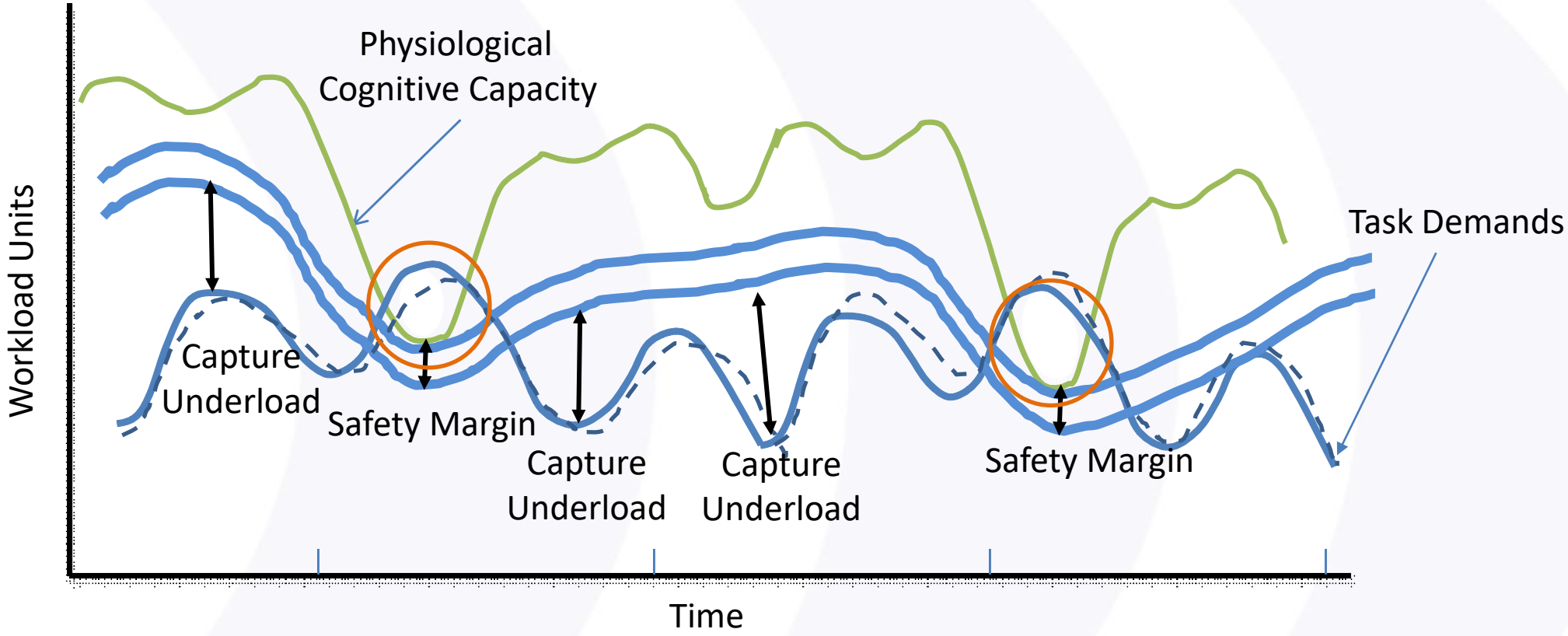
Countermeasures for Workload Fatigue Hazard

- Mitigating schedules with high combined workload fatigue risk.
  - Adjust pairings to increase alertness
  - Rearrange flights to avoid high workload in combination with low alertness
- Protecting alertness as one factor:
  - Ensuring crewmembers make optimal use of time available for sleep.
  - Monitor each other for signs of fatigue
  - Judicious use of caffeine
- Reducing workload as the other factor:
  - Age and experience can help – but may not be sufficient in cases of cognitive fatigue. Fatigue can cause rigid thinking in unusual circumstances
  - Attending to long-term wellbeing – giving crewmembers resources to cope with psychosocial factors that add to perceived workload.
  - Train crewmembers on methods to cope with the consequences of high workload using crew resource management.

Limitations

- Modelling cannot predict certain kinds of workload drivers:
  - Unusual or unexpected weather patterns
  - Equipment malfunctions and unplanned equipment changes
  - Psychosocial factors specific to the crewmembers
- Certain cases of high combined workload fatigue hazard may not be consistently associated with a scheduling pattern, thus hard to avoid in the scheduling process.
- There is uncertainty surrounding how workload factors combine:
  - Do we add them together, so they increase linearly, or do they hit a “breaking point”, so process is nonlinear.
  - Does the workload dissipate over time – how persistent is the effect?
  - Do some factors combine is a super-additive manner – i. e. are synergistic?
    - For example, a difficult weather event combined with ATC language factors might be more fatiguing than a simple sum of the factors.
- Are crewmember’s subjective and retrospective assessment sufficiently precise to predict fatigue consequences? We are relying on crew personal definition of fatigue and workload and their verbal report of the impact on their sense of fatigue. System requires validation against actual fatigue reports.

Cognitive Capacity and Workload Mismatch



- Take credit for the savings associated with higher retention rates due to managed workload.
- Capture and utilize some of the underload to offset the reduced workload at times of overload.

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