



The Scheduling Puzzle: Sleep Science and Driver Fatigue

June 25, 2025

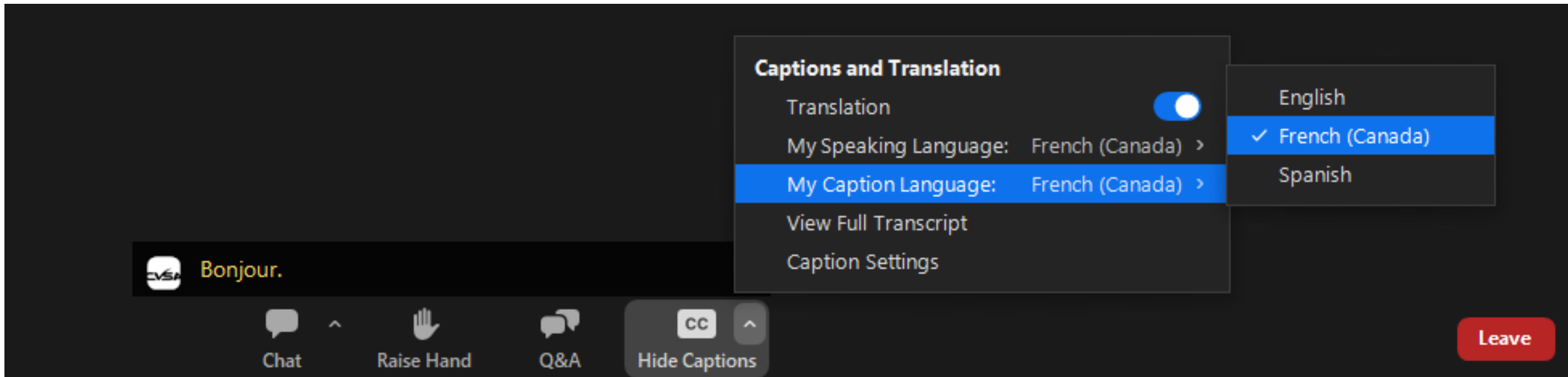
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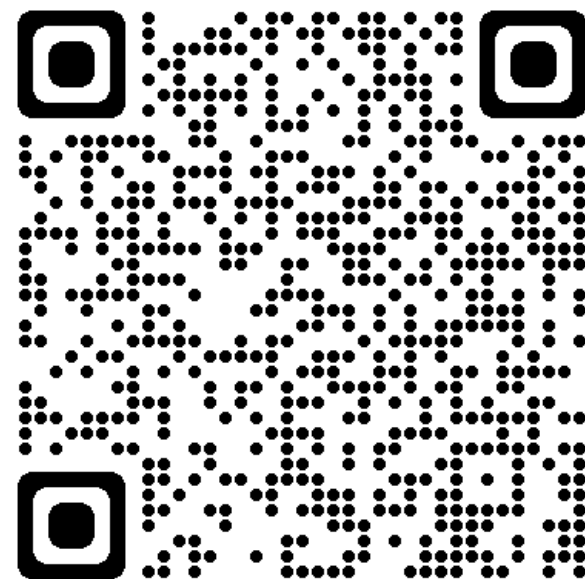
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3. Physiological Factors of Scheduling
4. Six Schedules Resulting in Crashes
5. What Carriers and Drivers Can Do
6. Scheduling Tools
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1. [Implementation Manual](#)
2. [eLearning Platform](#)
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5. [FMP Template](#)

Fatigue Management Program (FMP)



➤ Safety Culture

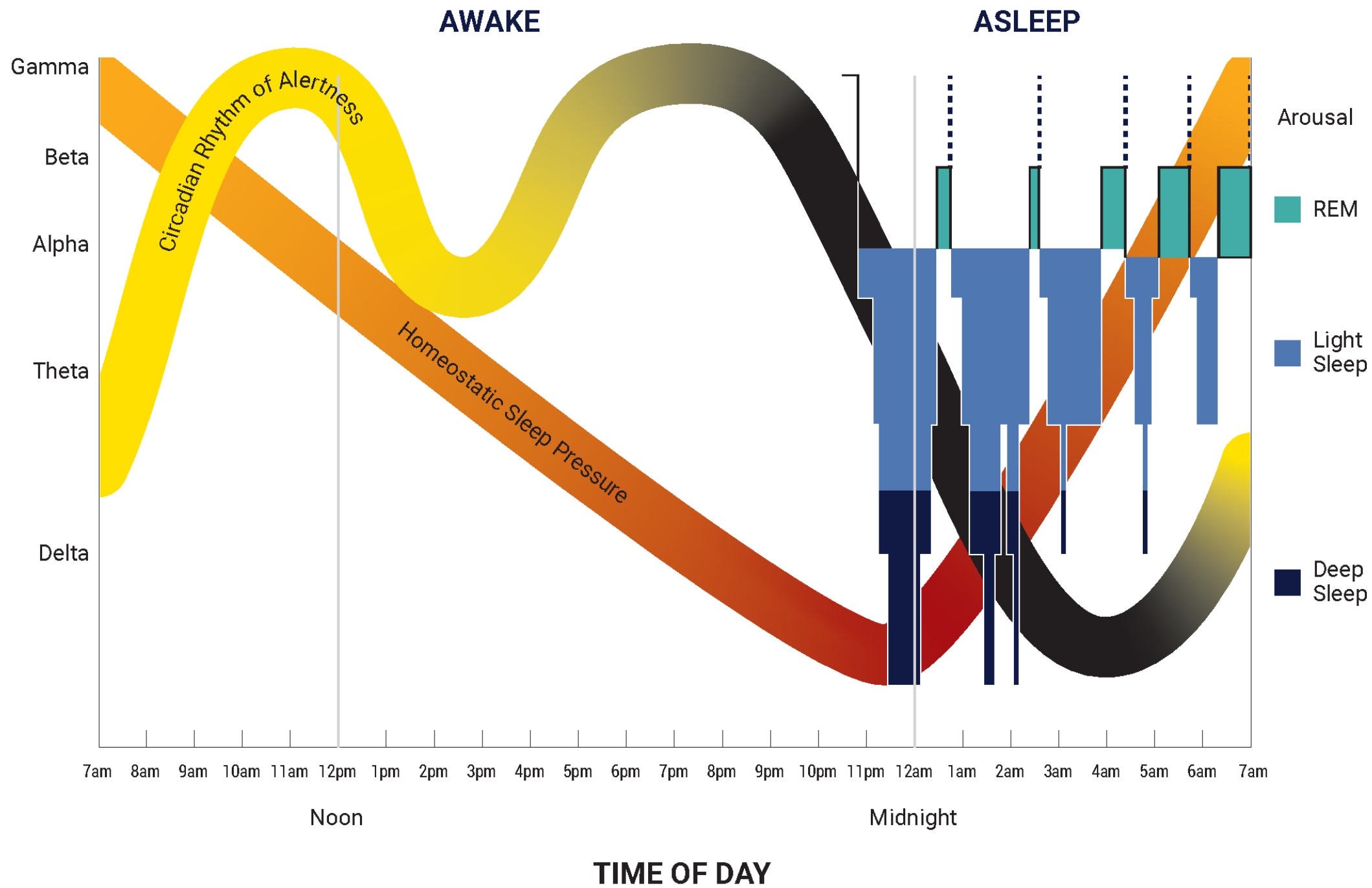
- 1) Education
- 2) Training
- 3) Continuous communications – Including partnerships

➤ Fatigue Risk Management System

- 1) Operations
- 2) Identify risks with processes and controls
 - Predictive, proactive, reactive
 - Sound scheduling & routing, sleep disorders program, fatigue detection technologies
- 3) Risk assessment
- 4) Measures and countermeasures
- 5) Evaluation

Sleep Science to Consider when Scheduling

BRAIN WAVE SPEED



Physiological Factors of Scheduling

- The body's clock promotes daytime alertness and nighttime sleep
- Fatigue significantly increases when driving between midnight and 7 a.m., counteracting natural sleep cycles
- Extensive night driving leads to poorer quality daytime sleep, causing accumulated fatigue and reduced alertness
- Disregarding the body's clock impairs cognitive function, slows reactions, and raises crash risk

Recent Sleep



- Most individuals require 6 to 9 hours of sleep for optimal function
- Insufficient sleep in the last 24 hours is a significant contributor to fatigue
- Scheduling practices that consistently reduce sleep opportunity directly lead to this deprivation, impacting driver alertness

Continuous Hours Awake



- Being awake for more than 16 consecutive hours since the last major sleep period significantly increases fatigue
- This prolonged wakefulness is due to mounting homeostatic sleep pressure, dramatically impairing a driver's ability
- Poorly planned schedules often result in long hauls without adequate breaks, pushing drivers into this dangerous zone and increasing crash risk

Cumulative Sleep Debt



- Accumulated sleep debt must be repaid for optimal function
- More than eight hours of accumulated sleep debt since the last full night of sleep, including disrupted sleep, is a significant fatigue factor
- Schedules that offer inconsistent rest periods or force drivers to constantly "catch up" on sleep contribute to this chronic and dangerous fatigued state

Gradual Schedule Changes



- The body's circadian rhythm adapts slowly to changes in sleep-wake patterns
- When altering work schedules, it's ideal to do so gradually, by no more than 1-2 hours per week
- Drastically changing sleep-wake times overnight can cause significant desynchronization between the internal clock and the external environment
- This desynchronization exacerbates fatigue and impairs performance for several days until the body fully adjusts, highlighting the need for careful schedule transitions

Forward Schedule Changes are Easier



- The body generally adapts more easily to schedules that shift forward (e.g., going to bed and waking up later)
- Shifting forward allows homeostatic sleep pressure to accumulate, making it easier to fall asleep at a later time
- Conversely, shifting schedules backward (going to bed and waking up earlier) fights against existing sleep pressure, making it harder to fall asleep and potentially leading to accumulated sleep debt

Task Monotony or Complexity



- The nature of the driving task significantly influences fatigue levels
- Highly monotonous driving (e.g., long, straight highways) can lead to under-stimulation and boredom, increasing drowsiness
- Overly complex or demanding conditions (e.g., heavy traffic, adverse weather, intricate routes) can increase mental workload and cognitive fatigue
- Both extremes—monotony and complexity—require careful consideration in scheduling and rest planning to mitigate fatigue

Underlying Sleep Disorders



- Undiagnosed or untreated sleep disorders are significant contributors to chronic fatigue, even when sleep opportunities seem adequate
- Conditions like obstructive sleep apnea (OSA), characterized by repeated stops and starts in breathing during sleep, severely disrupt sleep quality
- This disruption leads to excessive daytime sleepiness, regardless of the time spent in bed
- Drivers with unmanaged sleep disorders face a heightened risk of fatigue-related incidents and require proper diagnosis and treatment to ensure road safety

Six Schedules Resulting in Crashes

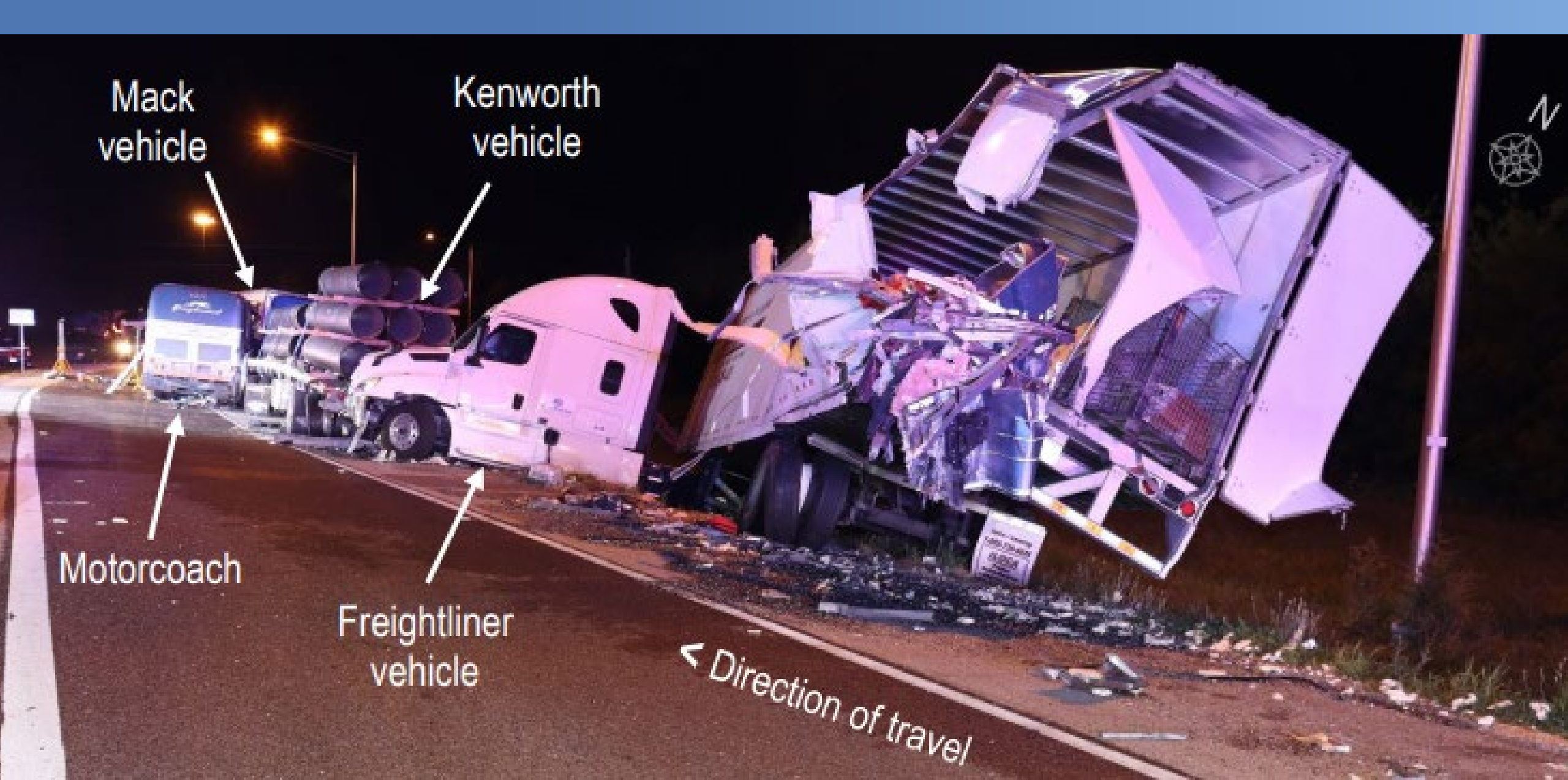
Collision of Motorcoach with Combination Vehicles Parked Along Exit



- At 1:48 a.m. July 12 2023, a motorcoach carrying 21 people veered off Interstate 70 near Highland, Illinois, colliding with three parked combination vehicles
- Three passengers died
- The driver and 11 other passengers sustained injuries of varying severity

Source: NTSB

<https://www.nts.gov/investigations/Pages/HWY23MH015.aspx>



Mack
vehicle

Kenworth
vehicle

Motorcoach

Freightliner
vehicle

← Direction of travel



Schedule

Date	Central Daylight Time																							
	12:00 AM	1:00 AM	2:00 AM	3:00 AM	4:00 AM	5:00 AM	6:00 AM	7:00 AM	8:00 AM	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM	3:00 PM	4:00 PM	5:00 PM	6:00 PM	7:00 PM	8:00 PM	9:00 PM	10:00 PM	11:00 PM
Wednesday, June 14, 2023																								
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Sunday, July 9, 2023																								
Monday, July 10, 2023																								
Tuesday, July 11, 2023																								
Wednesday, July 12, 2023																								

Legend

On-duty

Day off

Schedule



Date	Central Daylight Time																							
	12:00 AM	1:00 AM	2:00 AM	3:00 AM	4:00 AM	5:00 AM	6:00 AM	7:00 AM	8:00 AM	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM	3:00 PM	4:00 PM	5:00 PM	6:00 PM	7:00 PM	8:00 PM	9:00 PM	10:00 PM	11:00 PM
Sunday, July 9, 2023	CPAP use	Off-duty	Off-duty	Off-duty	Off-duty	Off-duty	Off-duty	Off-duty	Off-duty	Off-duty	Off-duty	Off-duty	Off-duty	Off-duty	Off-duty	Off-duty	Off-duty	Off-duty	Off-duty	Off-duty	Off-duty	Off-duty	Off-duty	Off-duty
Monday, July 10, 2023	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use
Tuesday, July 11, 2023	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use
Wednesday, July 12, 2023	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use	CPAP use

Legend



On-duty driving



On-duty not driving



CPAP use



Off-duty



Phone use



Crash

NTSB Probable Cause



- Driver's departure of the motorcoach from the travel lanes onto the shoulder of the exit ramp due to fatigue
- Contributing to the motorcoach driver's fatigue was his irregular work-rest schedule and prolonged time awake
- Driver medical history
 - High blood pressure treated with one prescription medication
 - Diabetes treated with one prescription
 - High cholesterol treated with one prescription medication
 - Diagnosed with obesity
 - Obstructive sleep apnea (OSA) treated with a CPAP device
 - Diagnosed with confusion due to head injury with concussion sustained in a 2018 crash, documented persistent cognitive and behavioral symptoms and was given instructions for additional testing and neurology follow-up that did not occur

Combination Vehicle Rollover, Fire and Interstate 95 Overpass Collapse



- At 6:17 a.m. June 11 2023, a truck-tractor with a tank trailer carrying 8,500 gallons of gasoline crashed while exiting northbound I-95 in Philadelphia, Pennsylvania
- The driver lost control on a curved exit ramp, causing the truck to overturn and strike a concrete barrier
- The resulting fire destroyed the truck, caused the collapse of northbound I-95 lanes and fatally injured the truck driver

Source: NTSB

<https://www.nts.gov/investigations/Pages/HWY23FH014.aspx>



Cottman Avenue exit ramp



Schedule



Date	Eastern Daylight Time																							
	12:00 AM	1:00 AM	2:00 AM	3:00 AM	4:00 AM	5:00 AM	6:00 AM	7:00 AM	8:00 AM	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM	3:00 PM	4:00 PM	5:00 PM	6:00 PM	7:00 PM	8:00 PM	9:00 PM	10:00 PM	11:00 PM
Thursday, June 8, 2023	Phone use			Phone use	Phone use		Phone use	Phone use	Phone use	Phone use	Phone use	Phone use				Phone use			Phone use					
Friday, June 9, 2023									Phone use			Phone use	Phone use	Phone use	Phone use		Phone use							
Saturday, June 10, 2023									Phone use		Phone use		Phone use	Phone use	Phone use	Phone use						Phone use		
Sunday, June 11, 2023	On-duty						Crash																	

Legend



On-duty



Off-duty



Phone use



Crash

NTSB Probable Cause



- Driver's failure to slow the vehicle as he exited the interstate onto the exit ramp well above the posted advisory speed limit due to inattention to the roadway potentially associated with fatigue
- Among the many strategies that a robust fatigue management program can promote, this crash highlights the importance of drivers adopting sleep schedules that do not change substantially between their workdays and their days off
- History of high blood pressure, no medications
- Toxicological testing postmortem detected diphenhydramine, a sedating over-the-counter antihistamine

Box Truck Centerline Crossover Collision with Bus



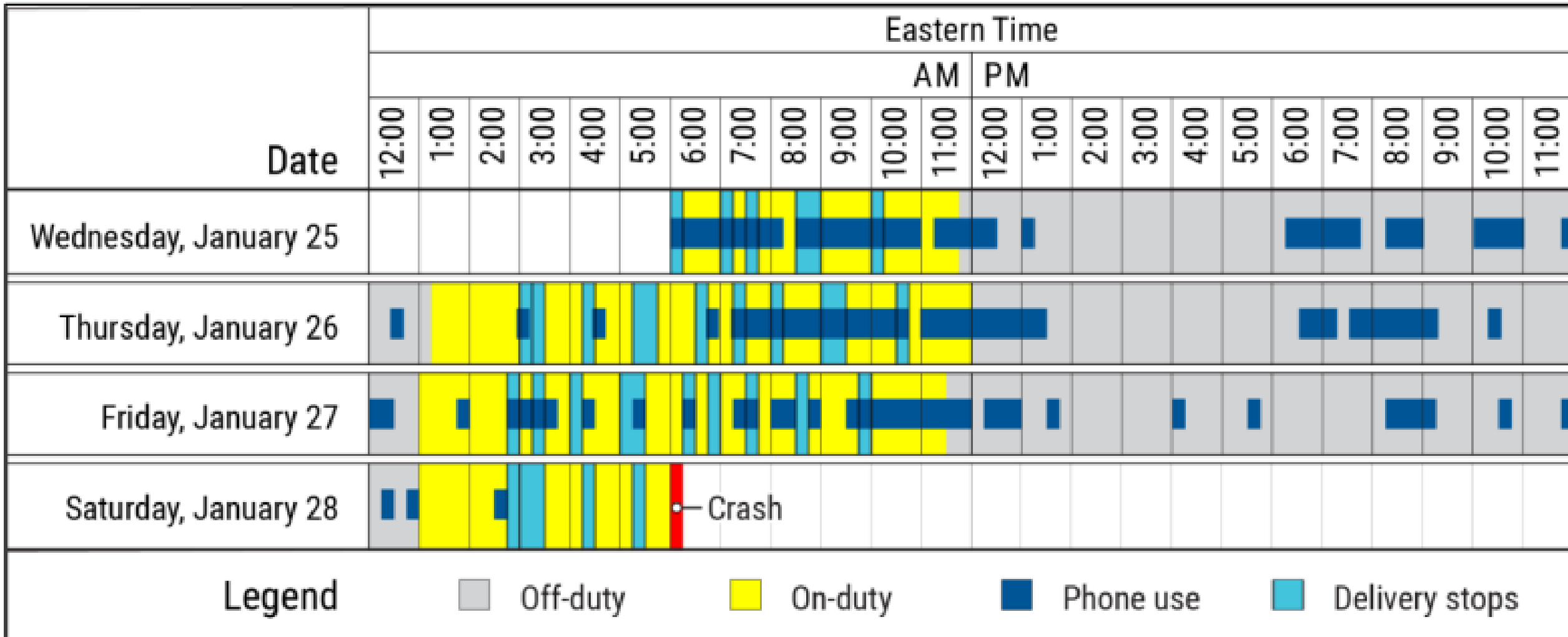
- At 6 a.m. Jan. 28 2023, a bus and a box truck collided head-on on New York State Route 37 in Louisville, New York
- The truck crossed the centerline striking the bus, which was transporting workers to a construction site
- This crash resulted in six fatalities, two serious injuries and five minor injuries among the bus passengers, along with minor injuries to the bus driver and serious injuries to the truck driver

Source: NTSB

<https://www.nts.gov/investigations/Pages/HWY23FH005.aspx>



Schedule



NTSB Probable Cause



- Driver's fatigue due to insufficient sleep and circadian disruption, which lowered his level of alertness to the driving task and resulted in the truck crossing the centerline of the roadway into the opposing lane of travel and colliding with the oncoming bus
- Fatigue caused by limited and fragmented sleep as well as circadian disruption associated with his shift-work schedule
- No medical conditions

Rear-End Collision between Combination Vehicle and Medium-Size Bus



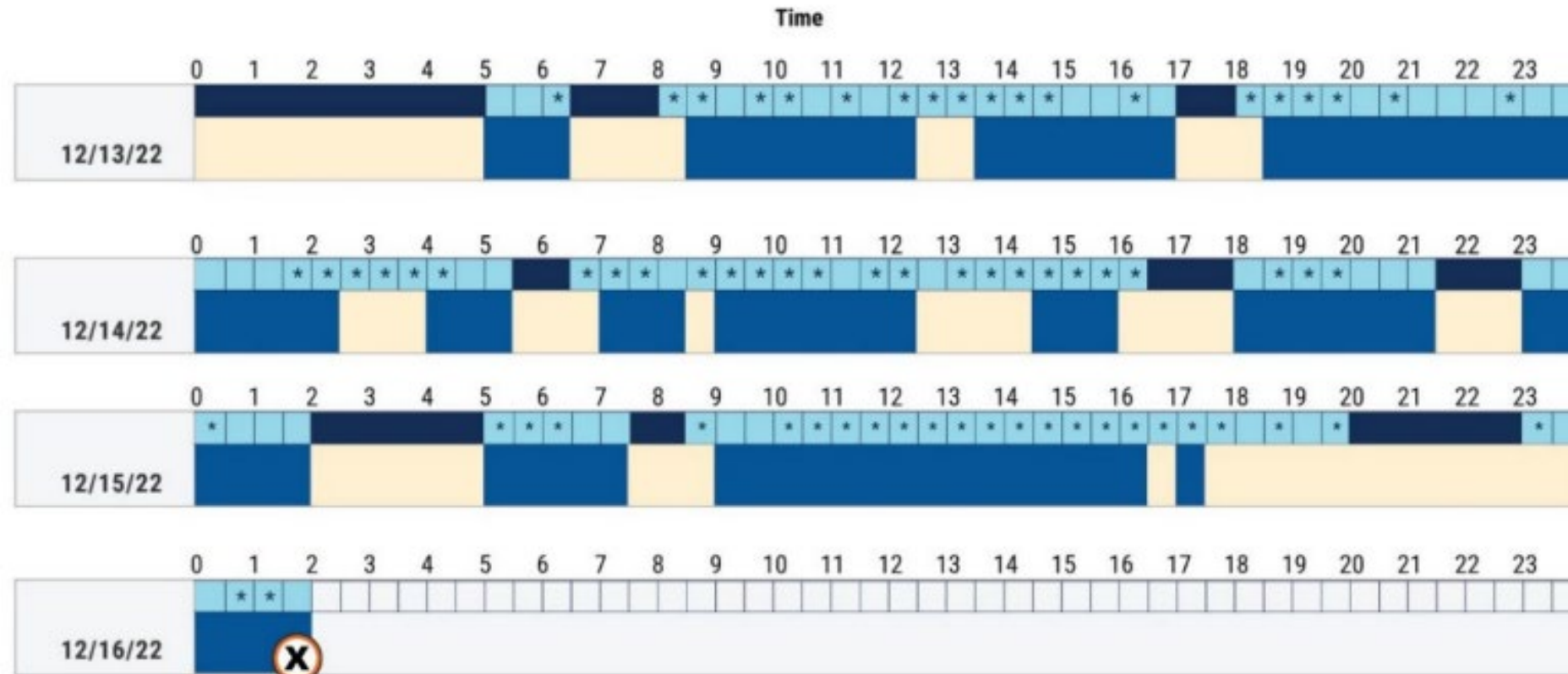
- At 1:36 a.m. Dec. 16 2022, a truck-tractor with a semitrailer crashed into the rear of a slower-moving bus on Interstate 64 near Williamsburg, Virginia
- The truck, traveling between 65 and 70 mph with cruise control, did not brake before impact, while the bus was moving at 20 to 25 mph
- The collision resulted in the deaths of three bus occupants, serious injuries to nine bus occupants and the truck driver, and minor injuries to 11 bus occupants

Source: NTSB

<https://www.nts.gov/investigations/Pages/HWY23MH004.aspx>



Schedule



Key

* = cell activity in period

■ = driver activity

■ = sleeper berth

■ = sleep opportunity

■ = awake

ⓧ = CRASH

NTSB Probable Cause



- Driver's fatigue, due to excessive driving time and limited sleep opportunity, which resulted in his lack of response to the slow-moving bus ahead
- Contributing to the truck driver's fatigue was the motor carrier creation of fictitious driver accounts in the electronic logging device system that enabled drivers to operate their vehicles for hours in excess of federal regulations
- No medical conditions

Multivehicle Collision Involving a Milk Tank Combination Vehicle and Stopped Traffic



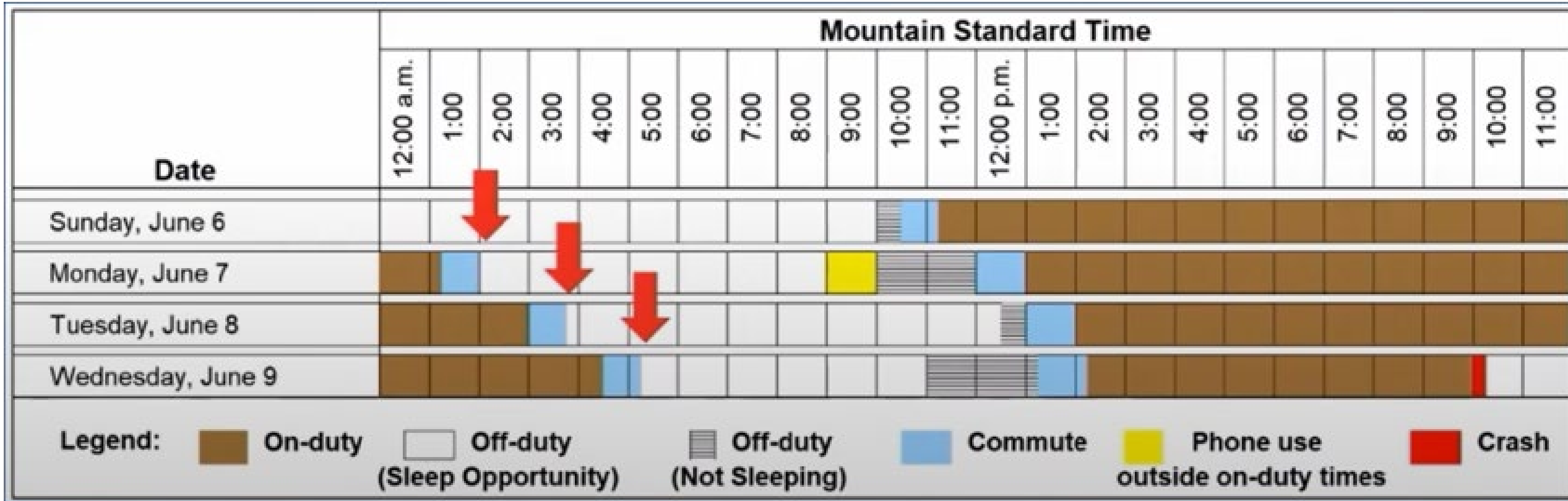
- At 10:07 p.m. June 9 2021, a truck-tractor with a tank trailer crashed into a queue of stopped passenger vehicles on SR-202 in Phoenix, Arizona
- Traveling at 62-64 mph without slowing or steering, the truck initiated a chain-reaction collision involving six other vehicles
- The crash resulted in four fatalities and 11 injuries among passenger vehicle occupants, with the truck-tractor and one car consumed by fire

Source: NTSB

<https://www.nts.gov/investigations/Pages/HWY21MH008.aspx>



Schedule



NTSB Probable Cause



- Driver's failure to respond to the fully conspicuous traffic queue, likely as the result of fatigue
- Contributing to the crash was the motor carrier's
 - Poor oversight of its drivers
 - Lack of fatigue management program
 - Failure to enforce its own policies, such as those regarding on-duty hours
 - All a consequence of its inadequate safety culture
- No medical conditions

Multivehicle Crash in a Queue of Slowed and Stopped Traffic



- At 6:45 a.m. June 12 2020, a truck-tractor with a semitrailer struck the end of a slowed and stopped traffic queue on Interstate 39 near Arlington, Wisconsin, which had formed due to prior collisions.
- This initiated an eight-vehicle crash that resulted in four fatalities and three serious injuries.

Source: NTSB

<https://www.nts.gov/investigations/Pages/HWY20FH006.aspx>

Peterbilt
truck-tractor

Mack truck

Freightliner
truck-tractor

VW sedan

Kia SUV



Schedule



- During the week of the crash, driver's workday began between 1:30 a.m. and 4:00 a.m.
- Workday ended in the late afternoon, about 4:00 p.m. to 4:30 p.m.
- On the Thursday evening before the crash, the driver went to bed at his residence about 8:00 p.m. and woke up about 2:15 a.m.
- The driver's sleep location alternated during the work week, with two nights (Monday, June 8, and Wednesday, June 10) of rest occurring out of state in the truck's sleeper berth
- Because the driver did not survive the crash, limited information was available regarding his activities, sleep opportunity and quality of sleep on the two nights spent in the sleeper berth

NTSB Probable Cause (1 of 2)



- Driver's failure to respond to slow-moving traffic due to fatigue
- Insufficient evidence on medical conditions
 - Cardiac disease
 - Diabetes
 - Gabapentin medication
- According to his wife, the driver had been experiencing ongoing fatigue for which he was scheduled to be evaluated by his doctor the day after the crash

NTSB Probable Cause (2 of 2)



- Contributing to fatigue was his undiagnosed obstructive sleep apnea
 - High BMI (48 kg/m²). The truck driver's BMI corresponds to severe obesity, which alone placed him at high risk of significant OSA
 - Large neck circumference. This factor is even more strongly associated with OSA risk than BMI
 - Men are two to three times more likely to have OSA than nonpostmenopausal women
 - The truck driver was 55 years old. OSA risk in adults increases with age until about the sixth or seventh decade of life
 - The truck driver had high blood pressure and diabetes. OSA is more prevalent among people with those conditions
 - The truck driver smoked which increases OSA risk

What Carriers and Drivers Can Do

Shared Responsibility



- Reducing fatigue in driver schedules is a shared responsibility between management and drivers
 - Management, including planning and dispatch, establishes a driver's work demands and ultimately determines available sleep opportunities through the driving schedule
 - Drivers are responsible for utilizing their available rest time effectively and communicating any fatigue concerns
- An effective fatigue management program requires continuous collaboration to ensure safe and sustainable work practices

Promoting a Safety Culture



- Cultivate a workplace that encourages drivers to value sufficient sleep and actively manage their fatigue for safety
- Drivers must be trained to recognize objective signs of fatigue as a significant physiological risk
- A true safety culture exists when drivers feel comfortable and empowered to communicate when they are tired without fear of repercussions
- If drivers are unwilling to report fatigue, the safety culture is compromised

Schedule Predictability



- Adopt practices that provide drivers with advance information about their schedules
- This allows drivers to effectively plan their work and rest schedules
- Reliable advance information on scheduled appointments is crucial for drivers to plan effective sleep and nap opportunities

Fatigue-Conscious Resource Allocation



- Leverage resources to provide drivers with night-time opportunities to sleep
- Consider travel time to employment location
- Schedule appointments that favor opportunities for naps
- Favor sequences of duty periods that maximize time to recover from sleep debt during restart
- Schedule drivers in line with their natural time of day preferences and promote regularity of schedules or advanced notice to aid driver planning
- Query about fatigue levels when revising assignments

- Encouraging sufficient rest stops during long-haul driving
- Promoting the use of naps to supplement sleep, understanding that any sleep is beneficial, even if night-time sleep is ideal
- Longer naps can lead to deep sleep, but drivers should allow time for recovery from sleep inertia, using strategies like light and noise exposure, physical activity, and smart caffeine use
- Emphasizing the importance of keeping sleep times as stable as possible
- Suggesting considering a nap prior to an evening departure

Driver's Personal Fatigue Management



- Drivers are responsible for obtaining adequate sleep on workdays and during recovery periods to manage fatigue
 - They should follow principles of sleep hygiene and seek treatment for sleep disorders
- While not a substitute for adequate sleep, strategies like breaks, exercise, smart caffeine use, and social interaction can provide short-lived relief from fatigue
 - Drivers should be aware these are temporary measures and not a replacement for proper rest

Scheduling Tools

Scheduling and Routing Tools



- Scheduling and routing tools are valuable assets in managing driver fatigue
- These are decision-support systems, not decision-makers, and are based on bio-mathematical models of fatigue physiology
- They can inform the planning of predictable operations by evaluating fatigue metrics
- Immediate incorporation of mitigations into the scheduling plan and route, reducing the likelihood of unacceptable fatigue levels

Difficult-to-Schedule Operations



- For operations where advance scheduling is challenging, periodic review of actual work schedules using fatigue management tools is crucial
- This helps identify contributing factors to fatigue that might not be apparent during initial planning
- Some tools allow incorporating sleep data collected during operations, further refining the accuracy of fatigue analysis
- This retrospective approach enables management to design customized strategies to mitigate fatigue effectively in day-to-day operations

Sample Tools*



- [Readi/Dispatch by Fatigue Science](#)
- [FAID Quantum Software by InterDynamics](#)
- [CIRCADIAN® Alertness Simulator \(CAS\) by CIRCADIAN®](#)
- [AlertMeter® Fatigue Risk Management System by Predictive Safety](#)

*While neither CVSA nor the NAFMP endorses or recommends any specific product or service, scheduling tools are a key component of a fatigue management program

Questions

Effectiveness of FRMS



How Effective are Fatigue Risk Management Systems (FRMS)? A Review

The primary enablers of, and barriers to, the implementation of FRMS are a set of intra-organizational cultural requisites

One key requisite is the establishment of a shared responsibility framework, without which effective FRMS implementation is not possible

If workers feel they cannot report fatigue, or fatigue-related errors/incidents without punitive actions or stigma, implementation of FRMS are unlikely to yield positive results

Additional questions?



Email additional questions to
Rodolfo.Giacoman@CVSA.org

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Thank you!



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