

Circadian Desynchrony

OCHMO-MTB-009

Executive Summary

Circadian desynchrony—involving the disruption of endogenous circadian pacemakers—is associated with issues such as cognitive impairment (e.g., inattention; distraction; slowed reaction time; poor decision making), metabolic disturbance, and sleep disruption. Jet lag and shift work are common examples of circadian desynchrony—where sleep/wake periods occur at inappropriate circadian phases. Several NASA OCHMO technical requirements in volumes 1 & 2 of NASA-STD-3001 provide guidance on mitigating the impact of these disruptions to crewmembers. Additionally, numerous educational and pharmaceutical protocols have been developed as recommended guidelines by NASA medical operations, Fatigue Management Service (FMS), part of Behavioral Health & Performance (BHP) Operations was formed in 2015 to address issues related to circadian desynchrony across different mission phases and are summarized in this brief.



Astronaut Jerry Linenger prepares for his first rest period on Space Shuttle Atlantis [Photo: NASA]



Relevant Technical Requirements

NASA-STD-3001 Volume 1, Rev C

- [V1 3003] In-Mission Preventive Health Care
- [V1 3004] In-Mission Medical Care
- [V1 3016] Post-Mission Health Care
- [V1 4011] In Mission Cognitive State
- [V1 4012] End of Mission Cognitive Assessment & Treatment
- [V1 4014] Completion of Critical Tasks
- [V1 5002] Crewmember Training
- [V1 6001] Shifting Operations & Fatigue Management

NASA-STD-3001 Volume 2, Rev E

- [V2 3006] Human-Centered Task Analysis
- [V2 5007] Cognitive Workload
- [V2 6013] Crew Performance Environmental Zone
- [V2 6017] Atmospheric Control
- [V2 6079] Crew Continuous Noise Limits
- [V2 6082] Annoyance Noise Limits for Crew Sleep
- [V2 6092] Vibration Exposure Limits during Sleep
- [V2 7070] Sleep Accommodation
- [V2 7073] Partial-g Sleeping
- [V2 8001] Volume Allocation
- [V2 8049] Window Light Blocking
- [V2 8055] Physiological Effects of Light (Circadian Entrainment)
- [V2 9057] Hearing Protection Provision

Reference [OCHMO-TB-041 Sleep Accommodation](#)



Overview



What is Circadian Desynchrony?

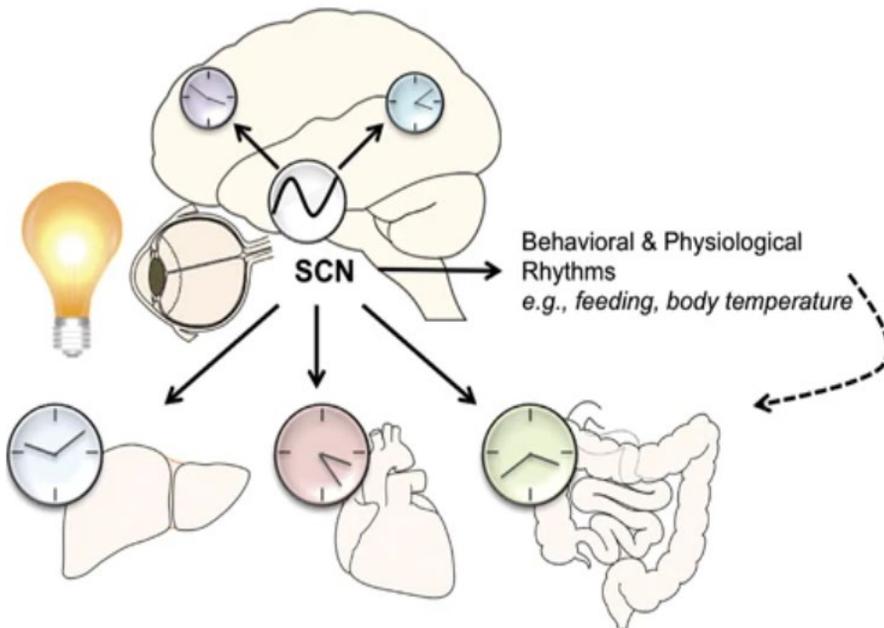
Circadian rhythms, which coordinate a variety of bodily functions (e.g. sleep-wake cycle; hormone release (e.g. melatonin; cortisol); body temperature), follow a roughly 24-hr cycle and are primarily regulated by the suprachiasmatic nucleus (SCN) in the brain—the body’s master clock. When these rhythms are disrupted (e.g. working night shifts or rapidly traveling across time zones), an individual can experience ‘circadian desynchrony.’ Various health and performance issues are linked to these internal disruptions—highlighting the need for guidelines to mitigate their impact.

Spaceflight Considerations:

As crewmembers are exposed to numerous factors increasing their risk for developing ‘circadian desynchrony’ (e.g., altered light-dark cycles; irregular work schedules; confinement)—recommendations and guidelines have been developed to facilitate ‘circadian entrainment’* and adequate sleep during all phases of spaceflight missions.

**The process of coordinating the internal circadian clock to external rhythmic time-cues*

Impacts of light exposure on mood & brain circuits



Night Earth Observation taken by Expedition 25 Crew [Photo: NASA]

Factors Associated with Circadian Desynchrony:¹

- Chronic sleep loss
- Schedule shifts
- Travel across multiple time zones
- Working during biological night
- Altered light cycles

Short-Term Health Impacts Associated with Circadian Desynchrony:²

- Fatigue
- Cognitive impairment
- Impaired performance
- Mood disturbances (e.g., depression, irritability)

Long-Term Health Complications Associated with Circadian Desynchrony:²

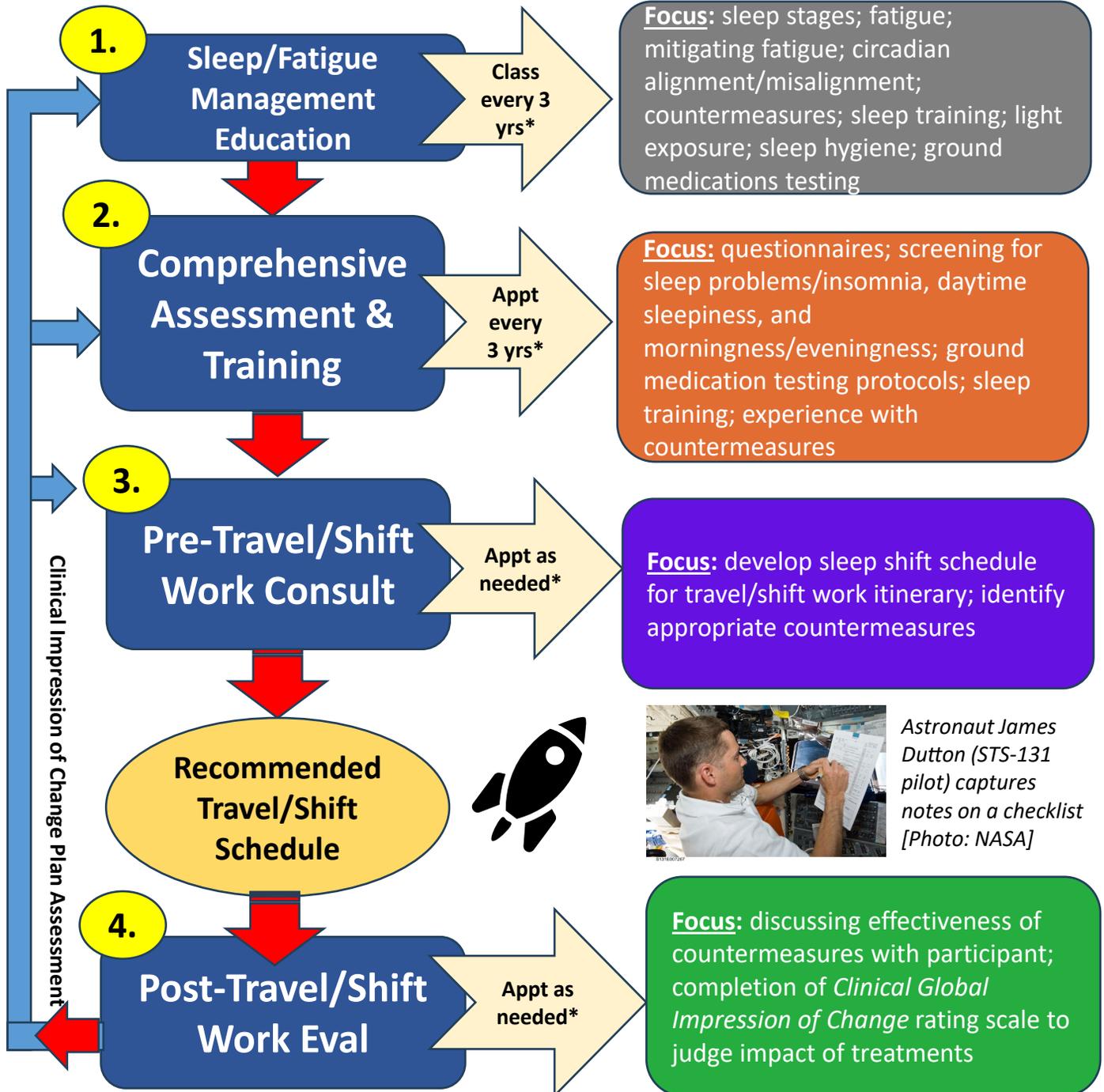
- Cardiovascular disease
- Metabolic disorders
- Neurodegenerative disease
- Digestive problems
- Ulcers
- Various cancers (e.g., breast)

Source: [https://www.nature.com/articles/tp2016262/figures/1]



Countermeasure Implementation Plan

An array of aids have been developed to support crewmembers and operational support staff in **minimizing the impacts of circadian desynchrony** during spaceflight missions, which include:



Astronaut James Dutton (STS-131 pilot) captures notes on a checklist [Photo: NASA]



* or as clinically indicated; consultation appointments with flight surgeon or Fatigue Management Consultation Service (FMCS)



Countermeasures (cont.)



1. Sleep/Fatigue Management Education: Focus Areas

The first step in aiding crewmembers with sleep/circadian/fatigue issues involves 'sleep education'— attendance at a 'sleep class' every 3 years* or as indicated with these topics: overview of sleep, sleep staging, overview of fatigue, mitigating fatigue, circadian alignment/misalignment, countermeasures, and sleep training.

Best Practices for Sleep Hygiene:

- Ensure a Cool/Dark/Quiet Sleep Space (no TV/computers)
- Avoidance of daytime napping (unless indicated on sleep shift schedule)
- No caffeine 6-12 hrs prior to sleep (individual dependent)
- Within 2 hours of sleep, avoid:
 - Vigorous exercise (*light yoga/meditation ok*)
 - Large/spicy meals



Read more about sleep hygiene [here](#)⁹

Best Practices for Timing Light Exposure:

- 1-2 hrs Before Bedtime: Avoidance of bright light/blue enriched light/high Correlated Temperature Light (CCT); Cover windows with blinds; Use of eye masks/sunglasses as needed
- 1-2 hrs before bedtime: avoid use of electronic devices or wear blue blocker glasses or night setting to eliminate/reduce blue light emissions
- 1-2 hrs After Waking: Seek bright light/blue enriched light/high (CCT); Continue light exposure throughout day if fatigued



Read more about light exposure [here](#)¹⁰

Guidelines on NASA Approved Medications:

- **Chronobiologics (for shifting body's internal circadian rhythms):**
 - Melatonin (0.5/1/3/6mg)
 - Circadin (2mg sustained release)
- **Hypnotic (sleep aids):**
 - Melatonin (2+mg)
 - Benzodiazepine Receptor Agonists (e.g. Zaleplon 5/10/15/20mg; half-life 1hr)
- **Alertness (CNS stimulants):**
 - Caffeine (50-600mg) taken every 1-6hrs
 - Modafinil (Provigil) 100-400mg (1 hr before shift)
 - Armodafinil (Nuvigil) 50-150mg) taken on awakening at shift start



To be administered by trained/certified provider [scheduled via FMS]



* or as clinically indicated; consultation appointments with flight surgeon or Fatigue Management Consultation Service (FMCS)



Countermeasures (cont.)

2.

Comprehensive Assessment & Training

After (or during) **Step 1**, a comprehensive history & assessment of participant's sleep & circadian rhythm characteristics are obtained by FMS (*prior to being assigned to a mission*).^{*} Topics include:

Screening for Sleep Problems:

3 General assessments, including:

- **Screening for Sleep Problems Questionnaire:** Covers snoring; breathing problems; sleep-walking/talking
- **Screening for Insomnia Questionnaire:** Covers ability to fall and/or stay asleep, in addition to other aspects of their sleep
- **Daytime Sleepiness Scale:**⁹ Assesses likelihood of dozing off in different circumstances (e.g. sitting/reading; in a car)



Read more about the Epworth Sleepiness Scale [here](#)¹¹

Morningness/Eveningness Assessment:

- An array of questions are asked to assess the participant's preference for performing during morning or evening hours

Read more about the questionnaire [here](#)¹²

Medication Ground Testing Protocols:

- **Questions on Current Med Use/Concerns:** Each med category (chronobiologics; hypnotics; alertness/stimulants) is reviewed
- **Medication Use Protocols Discussed:** including testing procedures with objective sleep measure, vigilance measure, and subjective questionnaires; pre-bedtime/alarm awakening/morning testing cycles



Sample questionnaire [here](#)¹³

Sleep Training Structured Protocol:

- To be administered by trained/certified provider [scheduled via the FMS]

Countermeasure History:

- Experience with use of fatigue management countermeasures (e.g., light restriction/augmentation; noise abatement; medication history; shift schedules; sleep training/relaxation)

^{*} or as clinically indicated; consultation appointments with flight surgeon or Fatigue Management Consultation Service (FMCS)



Countermeasures (cont.)

3.

Pre-Travel/Shift Consultations

Prior to travel/shift work, FMS* will work with participant to complete the **Travel/Shift Consultation: Initial Assessment Form** & then provide a **Recommended Travel/Shift Work Schedule** with countermeasure regimes:

Step 1: Gather information from Travel/Shift Consultation

FMS gathers information on:

- Reason for visit
- Sleep Screening Questionnaires
- Countermeasure History (e.g., use of melatonin)



Step 2: Recommend Travel/Shift Schedule Based on Step 1 data, FMS recommends:

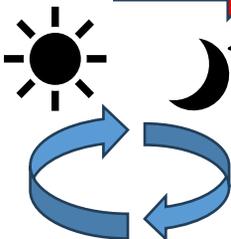
- Travel/Shift Work Schedule
- Countermeasures
- Columbia Jet Lag Scale

Step 3: Prescription Meds Provided (if applicable)



Step 4: Questionnaires Evaluating Countermeasure Effectiveness {Upon Travel Completion}

- Jet Lag Scale Results
- Post Travel/Shift Evaluation
- Use and Effectiveness of Countermeasures



* or as clinically indicated; consultation appointments with flight surgeon or Fatigue Management Consultation Service (FMCS)



Countermeasures (cont.)

4.

Post-Travel/Shift Work Eval

Following travel/shift work,* participant will debrief with FMS to provide feedback:

Completion of Post Travel/Shift Work Evaluation

Focus areas:

- *Pre-travel briefing results*
- *Countermeasures Utilized (e.g. sleep meds)*
- *Positive/Negative Effects Experienced*



Completion of Clinical Global Impression of Change *{administered by FMS post-travel}*

Focus areas:

- **Assess Impacts:** Judge impact of circadian desynchrony treatments [improvement scale: 1 (very much improved) ...7 (very much worse)]
- **Guide for Future:** Capture results in participant's file—use for guiding future countermeasure recommendations



Astronaut Nick Hague of NASA carried by NASA Chief Astronaut Pat Forrester (left) & NASA Flight Surgeon Blake Chamberlain (right) after landing in Soyuz MS-12 in Kazakhstan
[Photo: NASA]

* or as clinically indicated; consultation appointments with flight surgeon or Fatigue Management Consultation Service (FMCS)



Back-Up



View the current versions of NASA-STD-3001 Volume 1 & Volume 2 on the [OCHMO Standards website](#)

Referenced Technical Requirements

NASA-STD-3001 Volume 1 Revision C

[V1 3003] In-Mission Preventive Health Care All programs shall provide training, in-mission capabilities, and resources to monitor physiological and psychosocial well-being and enable delivery of in-mission preventive health care, based on epidemiological evidence-based probabilistic risk assessment (PRA) that takes into account the needs and limitations of each specific design reference mission (DRM), and parameters such as mission duration, expected return time to Earth, mission route and destination, expected radiation profile, concept of operations, and more. The term “in-mission” covers all phases of the mission, from launch, through landing on a planetary body and all surface activities entailed, up to landing back on Earth. In-mission preventive care includes, but is not limited to: (see NASA-STD-3001, Volume 1 Rev C for full standard).

[V1 3004] In-Mission Medical Care All programs shall provide training, in-mission medical capabilities, and resources to diagnose and treat potential medical conditions based on epidemiological evidence-based PRA, clinical practice guidelines and expertise, historical review, mission parameters, and vehicle-derived limitations. These analyses should consider the needs and limitations of each specific DRM and vehicles. The term “in-mission” covers all phases of the mission, from launch, through landing on a planetary body and all surface activities entailed, up to landing back on Earth. In-mission capabilities (including hardware and software), resources (including consumables), and training to enable in-mission medical care, are to include, but are not limited to: (see NASA-STD-3001, Volume 1 Rev C for full standard).

[V1 3016] Post-Mission Health Care Post-mission health care shall be provided to minimize occurrence of deconditioning-related illness or injury, including but not limited to: (see NASA-STD-3001, Volume 1 Rev C for full standard).

[V1 4011] Mission Cognitive State Pre-mission, in-mission, and post-mission crew behavioral health and crewmember cognitive state shall be within clinically accepted values as judged by behavioral health evaluation.

[V1 4012] End of Mission Cognitive Assessment & Treatment End-of-mission assessment and treatment for crewmember cognitive status shall include cognitive assessment, monitoring, and as needed, transitioning the crewmember back to pre-mission values.

[V1 4014] In-Mission Completion of Critical Tasks The planned number of hours for completion of critical tasks and events, workday, and planned sleep period shall have established limits to assure continued crew health and safety.

[V1 5002] Astronaut Training Beginning with the astronaut candidate year, general medical training, including but not limited to, first aid, cardiopulmonary resuscitation (CPR), altitude physiological training, carbon dioxide exposure training, familiarization with medical issues, procedures of space flight, psychological training, and supervised physical conditioning training shall be provided to the astronaut corps.

[V1 6001] Circadian Shifting Operations and Fatigue Management Crew schedule planning and operations shall be provided to include circadian entrainment, work/rest schedule assessment, task loading assessment, countermeasures, and special activities.



View the current versions of NASA-STD-3001 Volume 1 & Volume 2 on the [OCHMO Standards website](#)

Referenced Technical Requirements

NASA-STD-3001 Volume 2 Revision E

[V2 3006] Human-Centered Task Analysis Each human spaceflight program or project shall perform a human-centered task analysis to support systems and operations design.

[V2 5007] Cognitive Workload The system shall provide crew interfaces that result in Bedford Workload Scale ratings of 3 or less for nominal tasks and 6 or less for tasks performed under degraded system conditions.

[V2 6013] Crew Performance Environmental Zone The system shall be capable of reaching atmospheric humidity and temperatures of nominally occupied habitable volumes within the zone provided in Figure 6.2-3—Crew Performance Environmental Zone, during all nominal operations, excluding suited operations, ascent, entry, landing, and post landing.

[V2 6017] Atmospheric Control The system shall allow for local and remote control of atmospheric pressure, humidity, temperature, ventilation, and ppO_2 .

[V2 6079] Crew Sleep Continuous Noise Limits For missions greater than 30 days, SPLs of continuous noise shall be limited to the values given by the NC-40 curve (see Figure 6.6-1—NC Curves, and Table 6.6-3—Octave Band SPL Limits for Continuous Noise, dB re 20 μ Pa) in crew quarters and sleep areas. Hearing protection cannot be used to satisfy this requirement.

[V2 6082] Annoyance Noise Limits for Crew Sleep With the exception of communications and alarms, the system shall limit impulse and intermittent noise levels at the crewmember's head location to 10 dB above background noise levels during crew sleep periods. Hearing protection cannot be used to satisfy this requirement.

[V2 6092] Vibration Exposure Limits during Sleep The system shall limit vibration to the crew such that the acceleration between 1.0 and 80 Hz in each of the X, Y, and Z axes, weighted in accordance with ISO 20283-5, Mechanical Vibration—Measurement of Vibration on Ships; Part 5 - Guidelines for the Measurement, Evaluation and Reporting of Vibration with Regard to Habitability on Passenger and Merchant Ships, Annex A, is less than 0.01 g (0.1 m/s^2) RMS for each two-minute interval during the crew sleep period.

[V2 7070] Sleep Accommodation The system shall provide volume, restraint, accommodations, environmental control (e.g., vibration, lighting, noise, and temperature), and degree of privacy for sleep for each crewmember, to support overall crew health and performance.

[V2 7073] Partial-g Sleeping The system shall provide for horizontal sleep surface areas for partial-g and 1-g environments.

[V2 8001] Volume Allocation The system shall provide the defined habitable volume and layout to physically accommodate crew operations and living.

[V2 8049] Window Light Blocking Each system window shall provide a means to prevent external light from entering the crew compartment, such that the interior light level can be reduced to 2.0 lux at 0.5 m (20 in) from each window.

[V2 8055] Physiological Effects of Light (Circadian Entrainment) The system shall provide the levels of light to support the physiological effects of light in accordance with Table 8.7-2—Physiological Lighting Specifications.

[V2 9057] Hearing Protection Provision Appropriate personal hearing protection shall be provided to the crew during all mission phases for contingency or personal preference.



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