NAVAL
POSTGRADUATE
SCHOOL

Crew Endurance Research
Human Systems Integration Program

The Crew Endurance Team

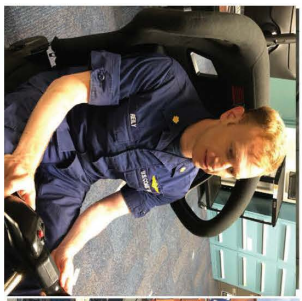
Since 2001, the Crew Endurance Team at the Naval Postgraduate School (NPS) has conducted research into factors that impact the health, performance, and readiness of the warfighter, setting new standards for safety and effectiveness. The NPS Crew Endurance Research Team is part of the Human Systems Integration (HSI) Program located in the NPS Operations Research Department.

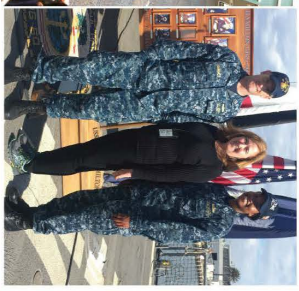
The NPS HSI laboratory is equipped with tools to assess human performance and physiological and psychological states, including various simulators (flight, ship bridge, and use-of-force) and a state-of-the-art wet lab to process biological samples.

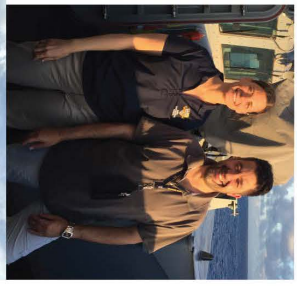
While the HSI Lab is a terrific resource for our research, the most important asset to our research is our access to a wide variety of field settings around the globe. The red pins on the following page indicate some of the locations we have collected data.

As a direct result of our research, the US Navy has implemented circadian-based watchbills, providing USN Sailors with protected sleep opportunities at the same time each day. Going forward, our research will continue to focus on ways to optimize human performance in operational settings for military communities.

The Crew Endurance Team in Action







Research Areas

Optimization of human performance is at the core of our work. We tailor our research to the needs of the communities who request our help. For over 20 years, we have collected data on all branches of the US military with ***35 US Navy ships*** and ***around 6,500 Sailors.*** Recent research topics include:

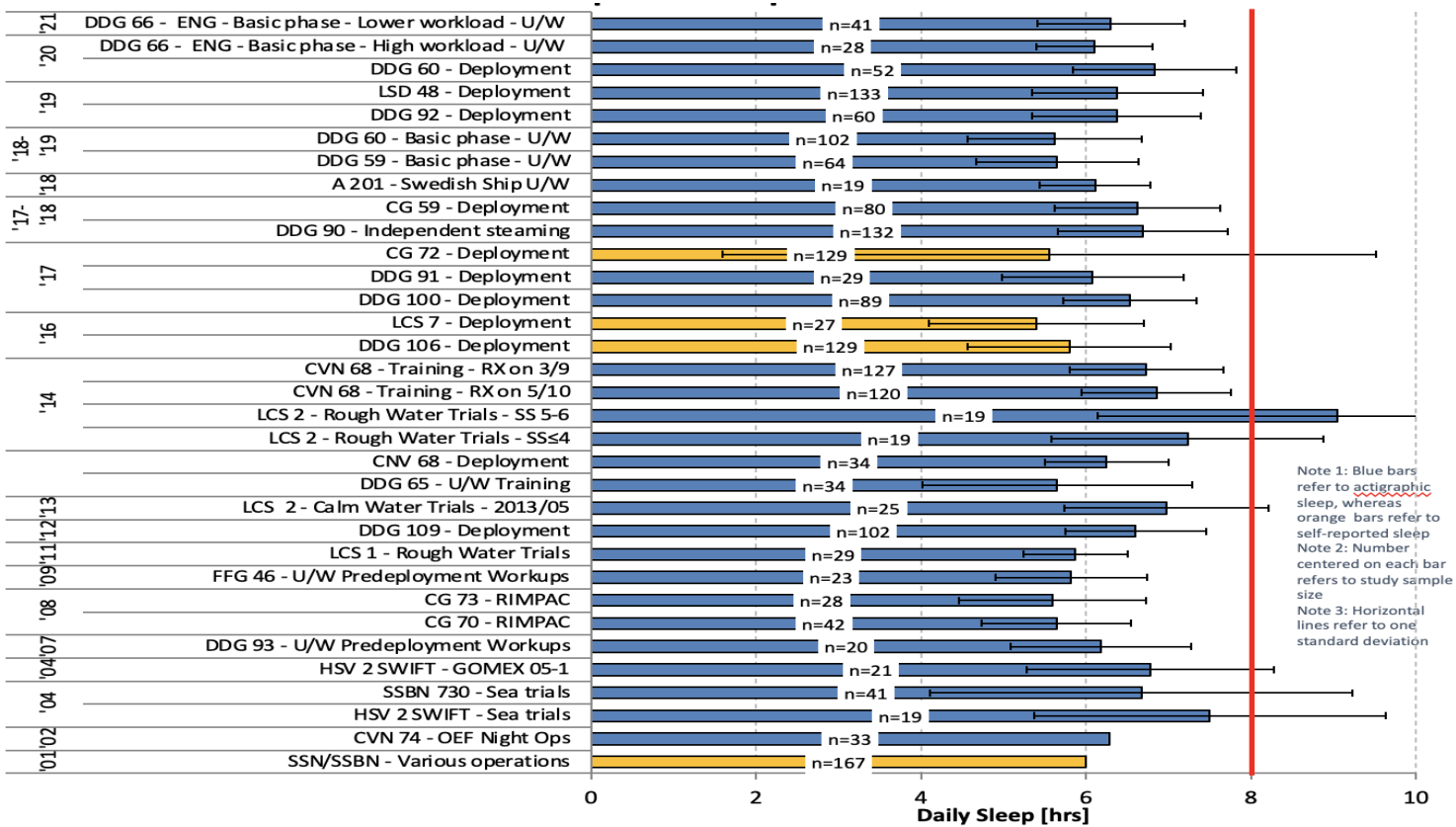
- Circadian-Based Watchbills for 24/7 Operations
- Crew Endurance Training
- Stress Inoculation Training
- HEV Light Management
    - Military Operations in Polar Settings
    - Sleep Inertia Mitigation
    - Transitioning Aviators from Day to Night Flights
- Problematic Video Gaming and Behavioral Health Issues of Military Life
- Long-term Health Consequences from Stress (Telomere Length)
- Improving Shipboard Habitability
- SMART: Risk Assessment Tool

Circadian-Based Watchbills

A "circadian-based watchbill" is a work and rest schedule that conforms to a 24-hour day, allowing individuals to work, eat, and sleep at the same time each day.

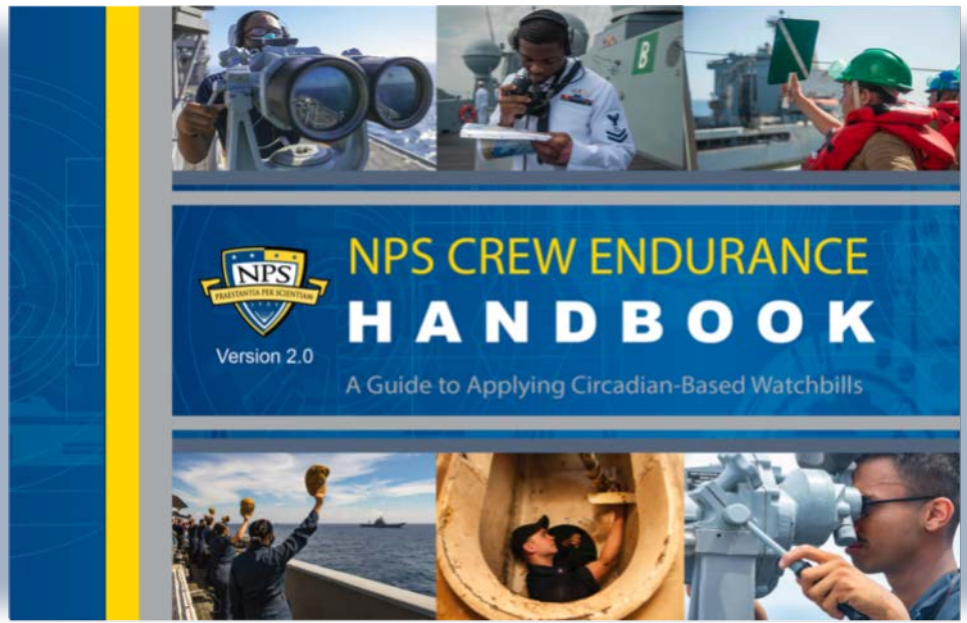
When you combine the hours spent on watch with hours off watch (whether doing other work, eating, or sleeping), a circadian-based system adds up to 24 hours, aligning with the naturally occurring 24-hour rhythm which drives all biological processes, enabling personnel to perform at their best.

Two Decades of Research into Sleep and Fatigue of USN Sailors



Crew Endurance Training

We develop and deliver crew endurance training tailored to the specific needs of various military communities. We provide Crew Endurance Handbooks and a Crew Endurance Website to commands to help them plan their work and rest schedules.



Watchbills: the Good, the Bad, and the Ugly

GOOD CIRCADIAN WATCHBILLS

3 SECTION

4 hrs-on/8 hrs off 8

hrs-on/16 hrs off

4 SECTION

3 hrs-on\9 hrs off

3/3/3/15

6 hrs-on/18 hrs off

5 SECTION

6/5/5/4/4

6/6/4/4/4

Two general principles, borne out of scientific studies, show that:

- **Shorter watches are better than long watches**
- **More watch sections are better than fewer watch sections**

BAD NON-CIRCADIAN WATCHBILLS

3 SECTION

"Five and Dime"
5 hrs-on/10 hrs off

"Classic Submarine Schedule"
6 hrs-on/12 hrs off

4 SECTION

5 hrs-on/15 hrs off

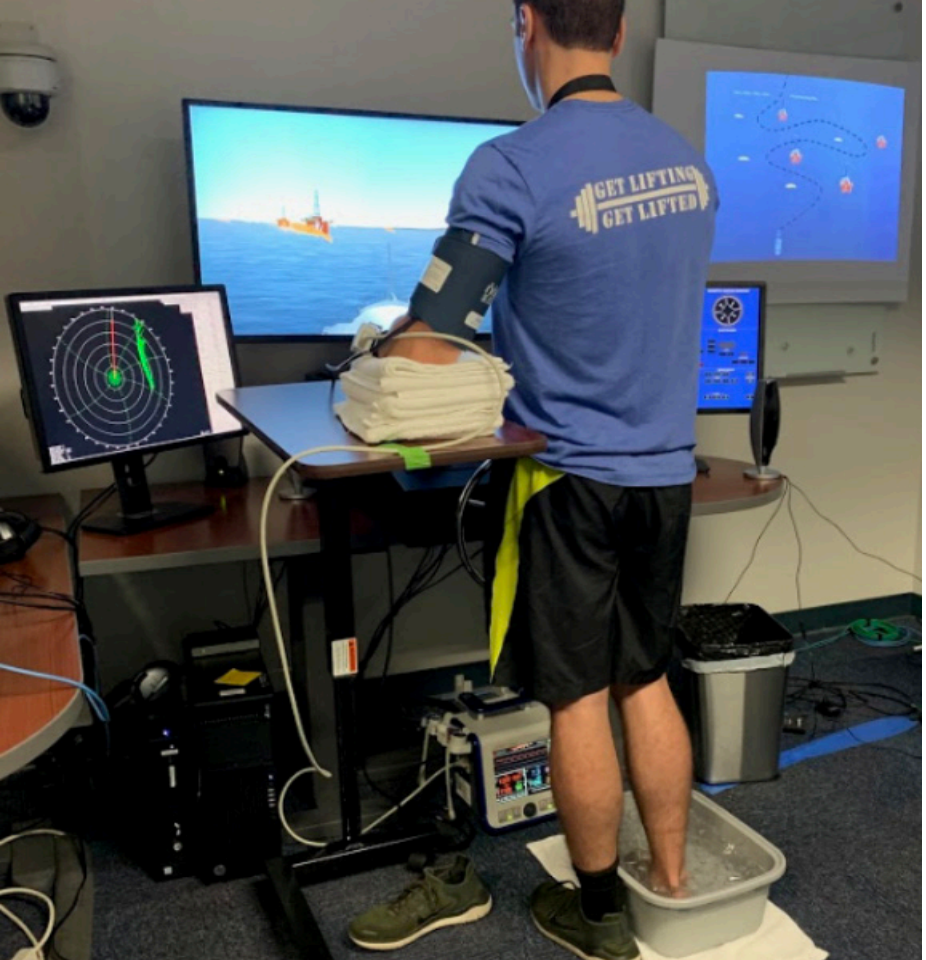
UGLY CIRCADIAN WATCHBILLS

2 SECTION

6 hrs-on/
6 hrs off

7/5/5/7

12 hrs-on/
12 hrs off



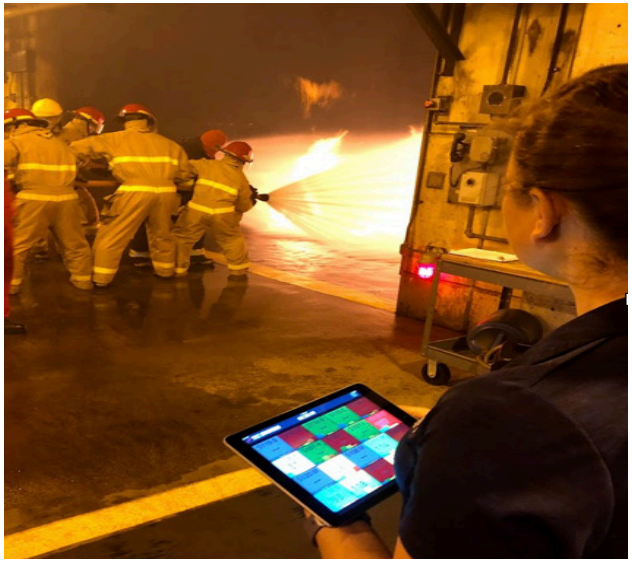
Stress Inoculation Training

The demands of military life – fatiguing daily schedules, prolonged family separations, and dangerous operational settings – can lead to overwhelming levels of stress.

Stress Inoculation Training (SIT) programs teach individuals coping skills to better manage anxiety and stress levels when working in high stress environments.

In the HSI Laboratory

The cold pressor test (foot in ice bucket) can be used to study stress - for example, while operating a ship bridge or flight simulator - and can be used to train individuals to manage their own responses to stress.



Surface Warfare Schools Command (SWSC), Newport, RI

Using simulated settings, individuals are exposed to high levels of stress and taught about their unique stress responses. This training helps them continue performing when they encounter demanding and dangerous operational conditions.

High Energy Visible (HEV) Light Management

Photo: Courtesy of Magnus Wennman

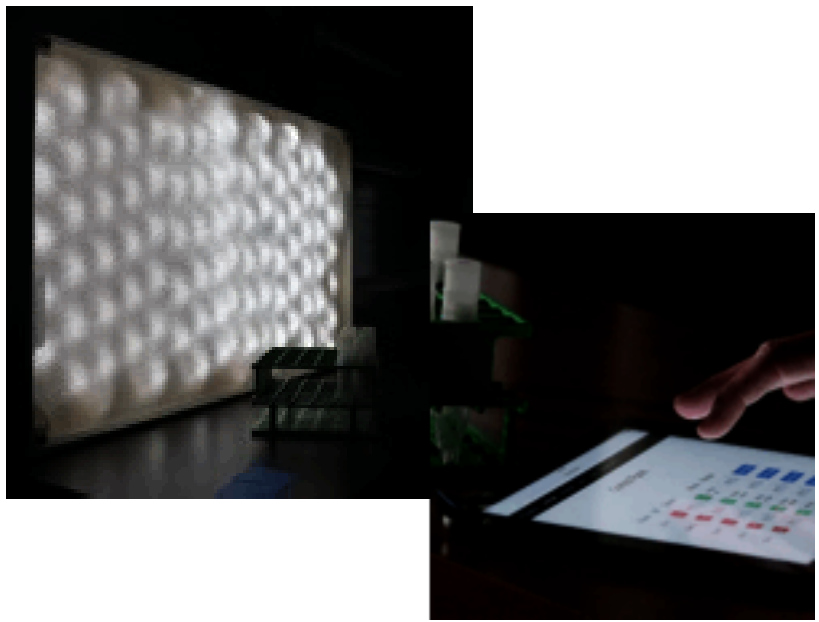
A series of our projects investigates the use of high energy visible (HEV) light to improve sleep and performance.

We explore how to stabilize circadian rhythms so they are better aligned with work schedules, thereby reducing fatigue and increasing alertness.

Findings from these studies are especially important for communities which require night shiftwork, for example, military watchstanders, medical personnel, and first responders.

Shiftwork and Circadian Entrainment Assisted by the Strategic Use of HEV Light

Using a variety of modalities and devices, the Crew Endurance Team strategically administers HEV (blue-enriched white) light to help military shift workers work more effectively while reducing risks. The use of HEV light is often accompanied by improvements in performance and mood.



Military Operations in Polar Regions

Increased access to the polar regions will undoubtedly lead to more military presence and geopolitical conflicts. Naval operations in the polar regions expose the entire crew to new and unexplored environments with regard to sleep and circadian rhythms.

Exposure to heavy sea states, dramatic changes in daylight exposure, and sub-zero temperatures will have a significant effect on human performance. However, certain technologies can potentially help in adjusting to this harsh environment.

Special Challenges When Operating at Extreme Latitudes

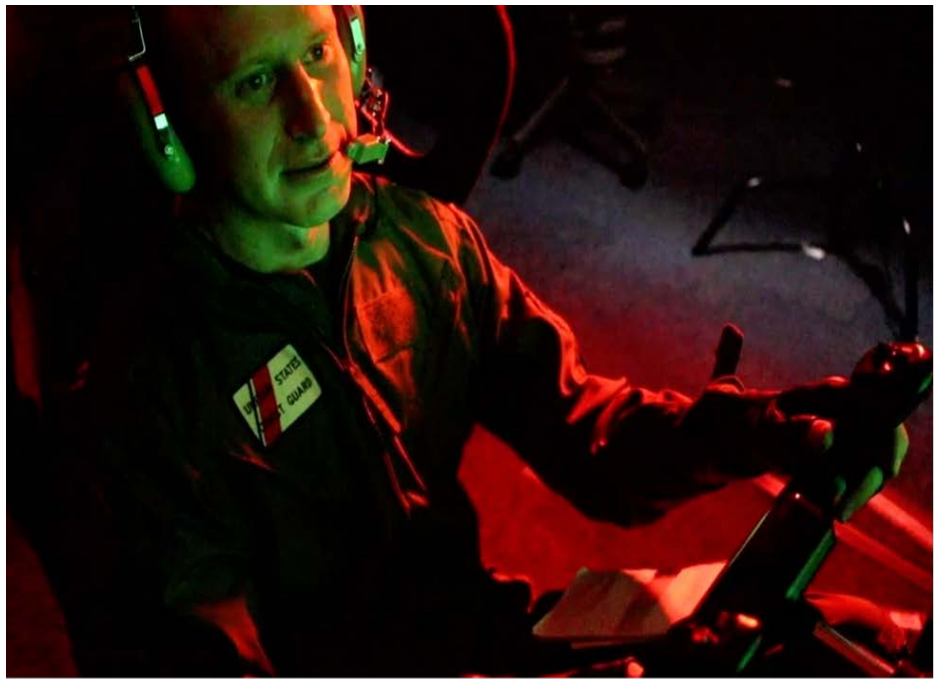
Strategic light management can be beneficial in protecting and stabilizing circadian rhythms for night watchstanders and military members operating at extreme latitudes.

As a direct consequence of these environmental settings, individuals experience long, winter nights with reduced sunlight and sub-zero temperatures and long summer days with continual sunlight exposure. Both these conditions contribute to sleep challenges.

Reducing Risk when Transitioning from Day to Night Flights

A midair collision during a routine nighttime air refueling training mission in the early morning hours of December 6, 2018, resulted in the tragic deaths of six Marine aircrew members and the loss of two US Marine Corps aircraft. Fatigue and the transition from day to night flights was called out as a problem.

The goal of these studies is to explore the limitations and best practices for shifting aviators from day to night operations to mitigate aviator fatigue and facilitate circadian realignment.



Realignment of Circadian Phases

Using the dim light melatonin onset (DLMO) procedure in the laboratory, we measure the circadian rhythm of salivary melatonin to assess an individual's circadian phase. By exposing participants to bright light at their typical bedtime, we can delay the onset of melatonin, thereby shifting their biological "day" and resulting in a phase delay in their circadian rhythm.

These studies were initiated to explore non-pharmacologic methods for shifting aviators from day to night operations. The overall goal is to provide evidence-based recommendations to assist commands when aviators shift from day to night operations. Mitigating aviator fatigue and facilitateing circadian realignment, will enhance safety and reduce risk.

Problematic Video Gaming

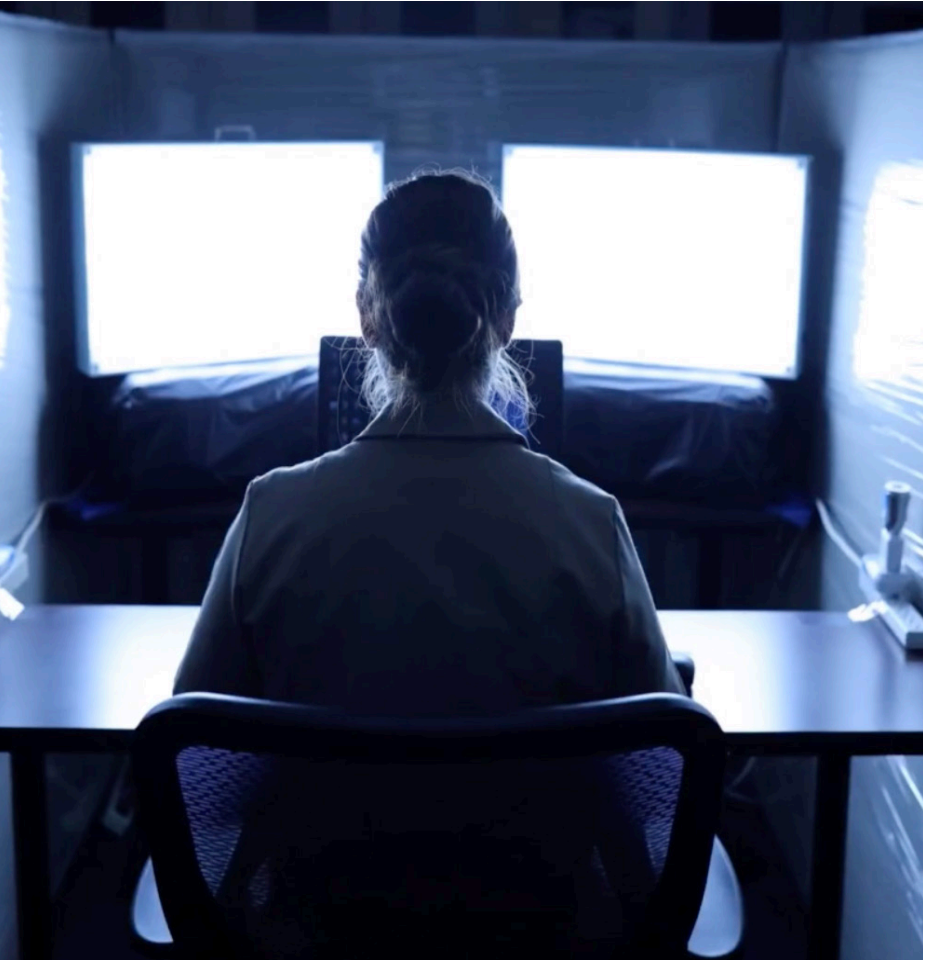
A significant percentage of military service members play video games. However, video gaming can lead to high stress levels, lower psychosocial well-being, higher levels of depression, and more aggressive behavior.

Our project examines video gaming in USN Sailors and US Marines, assessing the prevalence of video gaming, exploring factors associated with this activity, and examining positive and negative effects on service members' well-being.

Behavioral Health and Destructive Behaviors

Life in the military service is often stressful. Military members work in dangerous, at times even hostile, conditions. The decisions they make and the actions they take can have life and death consequences. The buildup over time of this stressful lifestyle can result in negative behavioral health outcomes.

This project examines behavioral health issues and destructive behaviors in military service members to assess the effects of stress on service members' well-being.



Sleep Inertia Mitigation

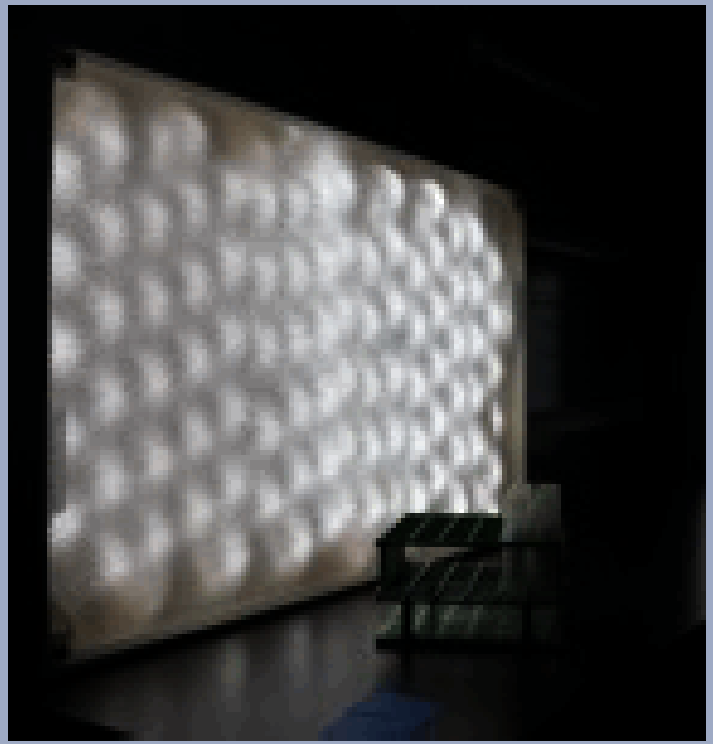
Sleep inertia is that groggy and sluggish feeling of disorientation that one frequently experiences upon awakening and is especially noticeable when awakening from deep stages of sleep.

The condition is of particular concern for the military where unanticipated events may occur at any time of the day or night, requiring personnel to immediately awaken and make critical decisions.

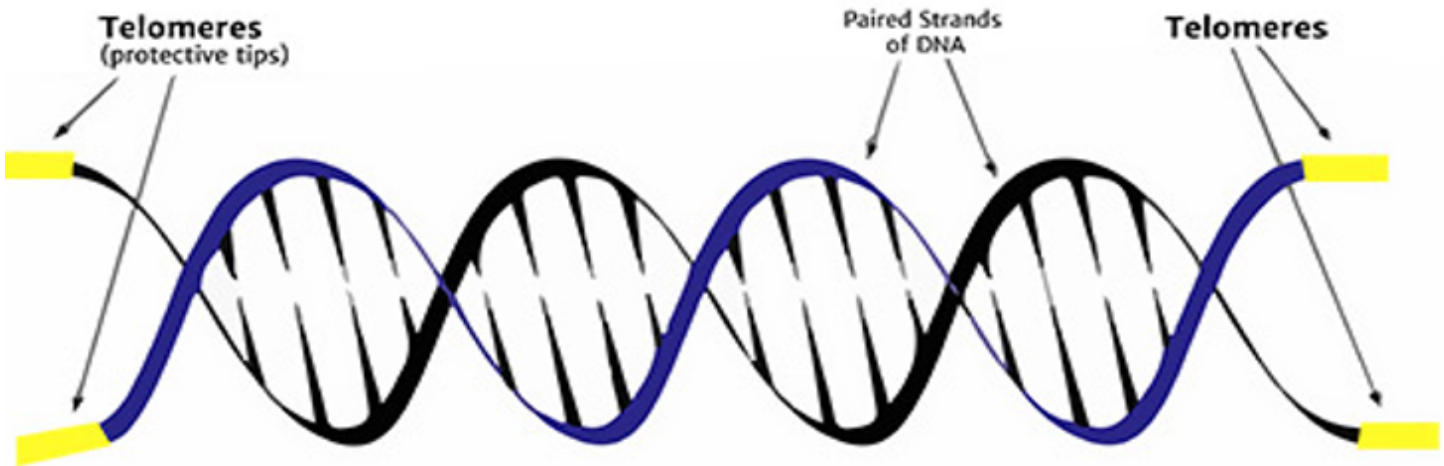
Waking up is hard to do!

In our lab, on-going collaborative efforts with colleagues at NASA-Ames and the University of South Australia are identifying and testing mitigation strategies to reduce sleep inertia when individuals awaken from deep sleep.

We are currently exploring the use of high energy visible (HEV) light and odorants to reduce both the effects and duration of sleep inertia.



Long-term Health Consequences of Military Life using Telomere Length from Salivary DNA



Telomeres are the endcaps of the DNA strands. They are shortened by age, chronic stress, smoking, obesity, lack of exercise, and poor diet.

Objective Measurement of "Wear and Tear" on the Body

Members of the US military are chronically exposed to a multitude of occupational stressors. The effects of these stressors on physical and psychological health accumulate over time and take a toll on long-term health and well-being.

This study assesses the cumulative impact of occupational stressors on well-being through the longitudinal tracking of DNA telomere lengths, a reliable way to quantify physical and psychological 'wear and tear' on the human body. We collect telomeres using salivary DNA from samples taken throughout the two-year study period.

Our working hypothesis is that changes in telomere length over time will be associated with occupational stressors, such as long workdays and rotating shiftwork.

Shipboard Habitability

HEV Light Canvases

Our team is designing and assessing new methods to deliver HEV light to promote alertness and stabilize circadian rhythms in workspaces such as Combat Information Centers. We are also exploring new designs and technologies to improve shipboard habitability.

Berthing

We are installing and assessing new designs and technologies, such as innovative rack curtains for sleeping quarters that limit light exposure and reduce noise.

SMART Risk Assessment Tracking Tool

WATCH STANDER	WATCH/REST RATIO	EXPERIENCE	CREW COHERENCE	EQUIPMENT	IRM
OOD: LT Smith	2	4	4	3	12
JOOD: LTJG Jones	3	2	3	3	10
QMOW: QM1 Door	2	1	2	3	8
Helm: BM3 Anderson	3	4	4	3	12
Lee Helm: BMSN Wray	3	1	1	3	9
Total/Average	13	12	14	15	Avg 10

The Scheduling Management Aid for Risk Tracking (SMART) allows leaders and commands to track and manage risk more effectively – for the entire Ship, by Department, Division or the individual Sailor. Currently, SMART runs in Excel, making it available for immediate use at no additional cost.

The tailorable algorithm behind the SMART dashboard enables visualization of the notional fatigue level of the crew based on prior work and rest history.

The initial efforts of the Crew Endurance Team focused on the sleep patterns and fatigue levels of members of the US Navy: Sailors on aircraft carriers working the night shift, USN Recruits, and members of the Submarine and Surface Warfare communities. While our research initially focused on the US Navy, it soon expanded to other military populations to include the US Army (Army MEDEVAC aircrew in the Arctic and a 4-year longitudinal study of Cadets at West Point), Marine Corps Embassy Security Guards, and members of the US Air Force and US Coast Guard.

Our team relies on the contributions of professional military officers / graduate students at NPS, many from the Human Systems Integration program. This program was the first of its kind in the nation and offers a Masters of Science Degree in Human Systems Integration (in residence), a Masters Degree of Human Systems Integration (via Distance Learning), and a four-course Graduate Certificate in Human Systems Integration.

The Crew Endurance Team is currently partnered with researchers at NASA Ames, the Behaviour-Brain-Body Research Centre at the University of South Australia, and the Sleep and Performance Research Center at Washington State University.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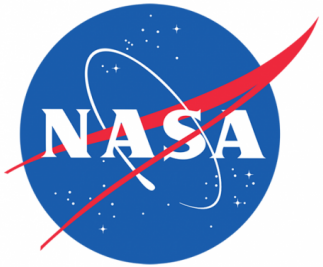
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