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Sleepy Submarines: The Submarine Force's Shift to a Circadian Rhythm

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Executive Summary

Title: Sleepy Submarines: The Submarine Force's Shift to a Circadian Rhythm

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Thesis: Combatting watch fatigue has become a high priority within the submarine force, and shifting to a 24-hour cycle is the first step for many submarine crews. There are many ways to construct a 24-hour cycle with three watch sections to effectively combat the crew fatigue while maintaining the highest crew readiness and effectiveness. This paper will examine potential watch routines and develop a model to maximize the submarine's operational excellence, optimize flexibility, and eliminate crew fatigue.

Discussion: The submarine force and Nuclear Reactors, the governing body for nuclear power plant operations, changed policy and instructions allowing Commanding Officers (COs) to shift their crew from an 18-hour day to a 24-hour day and better align with sailors' circadian rhythms. With a 24-hour day, COs and their command teams have now encountered the problem of how to best construct the crew's watch rotation.

Multiple factors play into the construction of the watch rotation and command teams will have to examine the effects of their watch rotation construction against a performance versus health spectrum with the aim of maximizing the submarine's operational excellence. Many models of potential 24 -watch rotations are examined that can pull out strengths and weaknesses of each model.

Conclusion: While attempting to find a single, best watch rotation for command teams to use, the construction of the watch rotation should be considered unique to each type of underway, tasking, and crew composition. The submarine force tends to use one model to fit all situations, but each command team should continue to evaluate its watch rotation for each situation to maximize the submarine's operational effectiveness. Prior research has linked increased fatigue to a decrease in cognitive abilities, which the lack of a circadian rhythm compounds. Research now needs to expand in developing links between operational effectiveness and the management of the watch rotation to better arm the COs and their command teams to construct the most effective watch rotation for the mission tasking.

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Preface

The submarine force has culturally shifted to a 24-hour day. As different boats have been experimenting different watch rotations and schedules, I wanted to look into the construction of the watch rotation to see if there was a single construction that optimized the operational effectiveness of the boat. As I prepare for my next tour as an XO of a submarine, I was in hopes to find a single answer to apply and share among my shipmates; however, I found a more complex problem in the construction of the watch rotation and its uniqueness to the crew and mission at hand. Hopefully, I will be better prepared and equipped for my next tour and the crew will reap the benefits of it.

I am grateful and want to acknowledge the patience of my family as the research took many hours away from them and also want to acknowledge LtCol Greg Sand for the guidance throughout the year at MCU. Lastly, I genuinely thank my mentor, Dr. Bradford Wineman for the constant guidance, course corrections, encouragement to dig deeper, and patience with my writing abilities.

INTRODUCTION

On the morning of January 17th, 1955, the *USS Nautilus* slipped from the pier and headed into the channel of the Thames River and to sea for the first time. Many watched with enthusiasm and excitement while realizing the importance of the occasion. Prior to *USS Nautilus* submerging in the Atlantic Ocean, her skipper, Commander Eugene P. Wilkinson, delivered the historic message, "Underway on Nuclear Power."

Commander Wilkinson's message was not just a scientific demonstration in a nuclear crazed time, but a glimpse into the future of how the submarine business and culture would be conducted differently now. *USS Nautilus* proceeded to dive off the coast of Connecticut and steam submerged to San Juan, Puerto Rico and would continue to set numerous of records including the first submerged polar cap transit and surfacing at the North Pole. On her first reactor core alone, *USS Nautilus* was able to steam over 62,000 nautical miles a distance no other ship could achieve on a single tank of fuel. A conventional submarine would need approximately two million gallons of fuel to cover this distance. The vastness of the undersea world covers almost three-quarters of the globe, and now the nuclear submarine could cover the domain the fastest and longest. It was the beginning of major procedural, tactical, and cultural changes within the submarine force.

Admiral Rickover, the father of the nuclear Navy, once said, "One very important point concerning the performance records of nuclear submarines should be emphasized. Each new step in performance is aimed toward increasing the nuclear submarine' operational effectiveness and widening the scope of their mission spectrum for America's defense."[1] The conventional powered submarine's dimensions were small when compared to the nuclear submarine developing a culture who prided themselves on very little sleep due to insufficient manpower.

The larger submarine allowed for a larger crew. However, the conventional submarine culture carried over establishing watch cycles on the nuclear submarines similar to those of the undermanned conventional submarines.

The watch cycle is the living heartbeat of a submarine. Crew members develop a repetitive cycle underway, and soon submerged days can become weeks and then months with the type of meal being served as the only means of what day it is to sailors. There have been many different types of watch cycles utilized to rotate sailors in and out of the watches. All these watches have been in an 18-hour cycle, which keep sailors out of their circadian rhythm. The circadian rhythm, a master biological clock that regulates when people have become sleepy and when people have become alert, has been the subject of many studies by industry and academia. By disrupting the circadian rhythm, sailors have been getting less than optimal rest and have been operating less effectively in a complex, technical environment while long-term effects could lead to depression and stressed relationships.[2] Until recently, sailors have simply dealt with the perpetual fatigue that has accompanied the 18-hour cycle. Submariners have almost worn it as a badge of honor. It would not be uncommon to hear sea stories starting with the lack of sleep they have gotten the night or days before. With the lack of sleep or circadian rhythm, sailors could be operating much less than optimal. The drop in effectiveness could lead to an incident such as a collision at sea. Even worse it could lead to a nuclear accident ending the United States Navy's (USN) perfect record to date.

As the submarine force continues to improve crews' quality of life, it has recently revamped policy, which limited crews to an 18-hour cycle, to allow for alignment to a 24-hour cycle and pushing commanders to attempt to maintain the circadian rhythm for their sailors. Combatting watch fatigue has become a high priority within the submarine force, and shifting to

the 24-hour cycle is the first step for many submarine crews. There are many ways to construct a 24-hour cycle with three watch sections to effectively combat the crew fatigue while maintaining the highest crew readiness and effectiveness. This paper will examine potential watch routines and develop a model to maximize the submarine's operational excellence, flexibility, and eliminate crew fatigue.

Describing the submariner's lifestyle helps frame the problem of different watch cycle possibilities aimed to attain the highest operational excellence for a submarine crew. Life in a submarine is more challenging than the daily routine of living aboard a destroyer or cruiser. Living onboard with a nuclear reactor in an enclosed pressure hull with roughly 150-170 men and women, atmosphere control is vital. The atmosphere must be habitable, free of radioactivity and nuclear contamination, air conditioned to cool the heat from the electrical equipment, and purified from all the contaminants like machinery lubricants, cooking oils, and smoke. Toxic gases like hydrogen, a byproduct of charging the batteries, and carbon dioxide, from exhalation, must be stripped from the atmosphere, counteracted, or neutralized. The air also needs to be supplemented with oxygen for prolonged submergence. The submariner exchanges all the hazards of the salty ocean air for hundreds of problems in atmosphere control and its complicated machinery.

These problems, however, existed with the conventional submarines as well, but in much shorter durations. Diesel submarines would only remain submerged for short periods of time and would surface regularly while the crew was only partially asphyxiated. Even in newer generation diesel electric submarines, the problem only lasted twelve to sixteen hours as the diesel electric submarines would have to snorkel and charge their batteries thus ventilating the onboard atmosphere with fresh air. At most, the newer generation submarines would only have

to solve this problem for a day and half. For nuclear submarines a long-term atmospheric environment was paramount in being completely stealthy and free of the surface.

For many years, chemists from the Naval Research Laboratory (NRL) attempted to solve the atmosphere control problem. The development of sodium chlorate candles or oxygen candles allowed for submarines to be able to supplement their oxygen supply. The sodium chlorate would decompose when introduced to heat producing oxygen; however, this technology alone would not be sufficient for a prolonged cruise. The amount of oxygen produced was far less than the amount of candles that would have to be stored in the already tight space. In addition to the sodium chlorate candle, contractors designed the oxygen generator, which uses electrolysis to produce oxygen and hydrogen. The oxygen is stored and dispersed throughout the ship while the dangerous hydrogen is expelled overboard. The oxygen generator was the permanent solution for extended submerged periods. A central monitoring system analyzes air samples throughout the ship, which subsequently directs a myriad of other equipment pieces to manage the atmosphere. Even with all the technology, the atmosphere onboard the submarine, specifically oxygen, is common to around 17-18 percent, which is well below the outside atmosphere of 21 percent. The lower percentage of oxygen leads to crew fatigue that is perpetual and is compounded by the fact that the sailors are not in a circadian rhythm leading to decreased cognitive abilities and degraded performance.

Living in a controlled atmosphere that is absent of sunlight poses other problems for the crew. These psychological aspects of being underway and underwater for months at a time can be related to the crew's physical and mental health, operational effectiveness, and morale. NRL has conducted numerous studies over the last sixty years to help the submariner to better cope

with the effects of the prolonged submerged cruises. Even though the technology exists to remain submerged indefinitely, sailors are still required to operate the technology and the ship.

POLICY

The 18-hour watch rotation has been submarine culture since the 1960s when watches were mandated to only six hours long. This was dictated by Nuclear Reactors, the governing agency for safe operation of Naval Nuclear propulsion, and Admiral Rickover to be the longest amount of time a watchstander could safely operate and monitor a nuclear reactor with respect to operational effectiveness of the watchstander. Naval Reactors assessed that any amount of time after six hours would cause the watchstander to become too weary and tired from working in the harsh environment. An engine room temperature is typically 85 to 90 degrees during operation. The limitation is defined in the overall classified Engineering Department Organizational Manual (EDOM) and Engineering Department Manual (EDM) of Nuclear Reactors. This six hour limitation coupled with the size and manning capabilities of the submarines kept sailors on an eighteen hour day and continuously out of a circadian rhythm.

A standard day or watch cycle is started by first dividing the entire crew into three watch sections due watch keeping and manning purposes. One section will stand watch from 0000 to 0600 while a second section sleeps. The last section who just completed standing watch from 1800 to 2400 is considered “off going,” on duty but not on watch, and has six hours for qualifications, maintenance, training, and administration. The following six hours the section is considered “on coming” and is devoted to personal time and sleeping. There is always someone asleep on a submarine mainly due to the amount of racks, or beds, onboard. Therefore, every 18

hours a new "day" begins for the section. This is the same between the enlisted and the officers of the crew.

The centralized document or instruction for the USN with respect to duties and responsibilities is the Standard Organization and Regulations Manual (SORM), or OPNAVINST 3120.32C series. Interestingly, after research, the SORM does not mandate the amount of time a sailor should or can be on watch. The SORM only prescribes minimum duties and responsibilities of watchstanders.[3] Expanding the search into other regulations and policies, the USN has the following policies, which are medical related policies:

- Navy's Manual of the Medical Department, NAVMED P-117 (2014) – specifying medical conditions which require waivers in USN and United States Marine Corps (USMC).[4]
- Chief of Naval Operations (CNO) Policy Letter Series N453/1U595168 (2001) – CNO directed policy for conducting human health risk assessments to identify lifestyle choices that impact health.[5]
- Personnel Reliability Program (PRP), SECNAVINST 5510.35B – the governing instruction for personnel working with nuclear weapons, which is expansive and focuses more on personnel's physical competence, ability, and mental capability.[6]

None of these, however, give direction in aligning a submarine watchstander's watch cycle with a 24-hour day potentially aligning the watchstanders with their circadian rhythm. The Department of Defense (DOD) does not have a DOD-wide training policy related to sleep; however, the four Services show consistency in each of the Services' initial training pipeline in terms of sleep.[7] The consistency for the servicemembers or trainees was to get seven to eight hours of uninterrupted sleep per night. Each Service did have caveats in this protected sleep for

activities like final graded events or standing watch.[8] The USN's guidance was the most vague in this area using language like "should" instead of "shall." Readers of the guidance interpret "should" as a suggestion and "shall" more along the lines of mandatory.

The USMC offered the best sleep-related instructions in the following Marine Corps Orders (MCOs) and Navy Marine Corps (NAVMAC) instructions:

- Recruit Training, MCO 1510.32F - delineating the "rights" recruits have to eight hours of protected sleep, except for the previously mentioned caveats.[9]
- Interior Guard Manual, MCO 5530.15 – further mentioning the protected amount of sleep and caveats of fire/security details and special night training.[10]
- The Management of Marine Corps Formal Schools and Training Detachments, MCO 1553.2C – allowing for the drop of eight hours to four during the final graded exercise.[11]
- Marine Corps Common Skills (MCCS) Training and Readiness (T&R) Manual, Navy Marine Corps (NAVMC) 3500.18B - listing a technique called maintaining sleep hygiene as a training event teaching trainees defensive sleeping tactics, fatigue countermeasures employment, and aspects of fatigue performance and degradation.[12]

While the aforementioned USMC's guidance was written towards garrison training, the USMC gave commanders their own discretion when on the battlefield. The United States Army's (USA) training policy was consistent with the Marines for soldiers at boot camp. While the USN does not have specific guidance related to sleep Commanding Officers (CO) typically have local instructions giving a command policy aligned with the views of the USMC and USA.[13]

Outside of the overarching documents, there are numerous instructions and/or training manuals on operational stress control informing or guiding services about stressors and the effects of a high stress environment including sleep deprivation. The Department of Navy's (DON), which is applicable to the USMC as well, main training publication is the Combat and Operational Stress Control or NTTP 1-15M/MCRP 6-11C. This training publication is similar to the USA's Combat and Operational Stress Control Manual or FM 6-22.5. This joint training publication is geared towards arming their respective leadership in raising awareness for problems that the combat and operational environment can produce, e.g. degraded sleeping habits, poor sleep discipline, and lack of sleep.[14] The publication gives techniques for leadership to implement in their commands to combat the stressors that are created in a high combat or operational environment.[15] The manual cites and addresses sleep frequently but lacks any definitive language in a sleep requirement to be imposed. The closest language it states is that sleep is an area the command leadership "should" manage.

The USN and USMC have numerous programs that commands can implement or conduct during their deployment preparation phase to educate their servicemembers on physical and mental capacity. An example for the USN is the Operational Stress Control Workshop, which is a week-long workshop geared to the information in the joint publication. This workshop is now required for the submarine force during the deployment preparation phase and strongly recommended in the surface fleet, especially after recent at sea collisions. The workshop, however, mainly focuses on identifying the stressors in the operational environment and how to mitigate the effects of those stressors. It does not place much emphasis or instruction on sleep patterns or different sleep methods or does it review the submarine command's current or

proposed watch cycle to help its leadership identify areas in which it can lower the stressors on the crew during a deployment or day to day operations.

The USMC has a similar program called the Operational Stress Control and Readiness (OSCAR) program.[16] A more intimate program than the USN's Operational Stress Control Workshop, the OSCAR program is geared towards different groups within the program's reach. While teaching ways to identify operational stress and how to mitigate it at the ground combat level, it also extends to the chaplain corps and medics arming them with operational stress geared training to better counsel and treat their Marines.[17] The program even imbeds itself with the unit to provide on the job instruction and mental health evaluations.[18] Another program the USMC utilizes is the forward deployed COSC teams. These teams evaluate and inform the commanders about the most efficient and effective way to utilize their staff while considering the impact of circadian rhythms.[19] This program has not been introduced to the submarine force and could help increase submarine leadership in raising its operational effectiveness of crews as a resident expert in the matter.

The most stringent policy the USN has in effect with respect to sleep requirements and crew rest lies in the aviation community. The NATOPS General Flight Operating Instruction, OPNAVINST 3710.7U[20], requires that naval aviators have uninterrupted sleep prior to a scheduled flight and mandates the amount of sleep required. The other policy is produced by the Navy Medical community for the aviation community. Performance Maintenance During Continuous Flight Operations, NAVMED P-6410, is more geared towards the entire aviation community and not just the naval pilots and flight officers. This policy educates the aviation community on the importance of getting enough rest, circadian rhythm considerations, operational fatigue effects, and medication use and effects.[21] The aviation community has also

created software, like FAST or FlyAwake, that uses fatigue models of sleep deprivation effects to help assess the risks involved in periods of high operational tempo and stress.[22] These sleep requirement policies could lend as a potential framework to future submarine force policies on managing sleep patterns while maintaining good circadian rhythm practices.

On the CNO's required reading list and fundamental books for new recruits and officers, the *Naval Officer's Guide* and *Bluejacket's Manual*, like the SORM, only speak to the duties and responsibilities of watch standing. It fails to address appropriate sleep patterns. This is the same for the book *Watch Officer's Guide*. Sleep techniques and adequate rest could be implied from the proper watch turnover sections, but there is no specific amount or metric that a sailor could determine as adequate.[23]

PERFORMANCE LINK

In 2017, the USN had two untoward incidents in the collisions of the *USS Fitzgerald* and the *USS John S. McCain* and the loss of seventeen sailors. The USN did a comprehensive review of its operational policies, like the ones previously mentioned, to try and determine if there were too many requirements that a sailor could possibly handle. Directed by the CNO and led at the highest levels, the 33-member review team addressed individual training and professional development, unit level training and operational performance, development and certification of deployed operational and mission standards, deployed operational employment and risk management, material readiness of electronic systems, and practical utility of current navigation equipment and combat systems.[24] The Comprehensive Review team found many failures that led up to the collisions, but at least two major failures were related to fatigue and the crew's ability to perform. They found the crews had a degraded watchteam performance

environment and that each of the four bridge teams involved in the mishaps did not work with each other to solve problems as an effective team. They stated, "command leadership on these ships failed in their absolute responsibility to develop and properly balance their watchteams with depth and experience to foster consistent superior performance with multiple testimonies stating fatigue was a factor."[25] The Review team also assessed that the ship's "can-do" culture, and furthermore the entire forward deployed fleet's culture, undermined basic watchstanding and important safety standards. The report summarized how the USN can-do culture has been a trait that has differentiated the USN from its adversaries, but when the can-do culture is top down or when feedback is limited or missed then it becomes a barrier.[26] The report states, "The prevailing belief was that a high pace of operations equates to a high state of proficiency. In part, this belief led to an undervaluing of human performance factors, such as fatigue. When combined with an absence of foundational training and critical assessment, this attitude induced a slow erosion of standards, and organizational drift from the deliberate processes used to manage time, resources, rest and a commitment to safety as a way of operating."[27] This was the first USN-wide review of its operational tempo, safety, and qualification practices in over fifteen years and in which crew fatigue was a major impact.

The report called for all levels of command to evaluate its internal programs and processes and the importance of including these evaluations as part of its day to day operations. It directed the continuous improvement in processes that monitor and account for human factors in individual and team performance, including crew fatigue and operational tempo. Crew fatigue and operational tempo determine mission outcomes regardless of other readiness indicators.[28] Overall, the increasing demand for forces, compressed maintenance cycles, and understanding the human performance elements of operational safety cut across all USN communities.[29]

The five most recent submarine mishaps include the *USS Jacksonville* collision with a trawler while on deployment at night in 2013, the *USS Montpelier* collision with the guided cruiser *USS San Jacinto* while on ascent from periscope depth during a carrier strike group anti-submarine exercise in 2012, the *USS Hartford* collision with the amphibious transport dock *USS New Orleans* during a Strait of Hormuz transit in 2009, the *USS Newport News* collision with a Japanese tanker while submerged in 2007, and the *USS Philadelphia* collision with a Middle Eastern tanker while on the surface at night in 2005. All these incidents occurred while the crew employed an 18-hour watch cycle, and while all the reports indicated that crew fatigue was a potential cause for the mishap, fatigue was not a major impact or root cause in the collision. The reported root causes were all for other reasons ranging from indecision to failure to recognize important indicators on system monitors. What the reports failed to link was the increase likelihood of these failures due to the fatigue of the watchstanders. The fatigue causes a decrease in the sailor's decision making capability as evident in a review of the following studies.

HEALTH LINK

Numerous studies have related operational fatigue with driving under the influence. In one study published in the journal *Nature* in 1997, Australian researchers Drew Dawson and Kathryn Reid hypothesized how the effects of fatigue could relate to the effects of alcohol.[30] In the study, they sleep deprived one group while prescribing another group an amount of alcohol equal to the legal limit. Testing the sleep deprived group's hand eye coordination, they found that after seventeen to twenty hours awake their psychomotor abilities were equal to someone at the legal limit.[31] This was similar to many other studies that linked tiredness and associated psychomotor abilities similar to someone at 0.08 blood alcohol level, the legal limit. Dawson

and Reid conclude, "relatively moderate levels of fatigue impair performance to an extent equivalent to or greater than is currently acceptable for alcohol intoxication."[32]

Another example of linking decreased psychomotor capabilities and fatigue is Lieutenant Colonel Daniel Miller's study at West Point in 2005, which also found that "sleep deprived individuals often do not realize that they are operating with decreased cognitive and physical capacities."[33] This means that our sailors, officers, and even COs could be on the bridge of a national asset with reduced eye-hand coordination, poor planning ability, and negative decision-making ability.

CA Dupplesis' study, "Submarine Watch Schedules: Underway Evaluation" in *Undersea and Hyperbaric Medicine*, concludes that the 18-hour day caused chronic sleep deprivation and circadian desynchronization.[34] The desynchronization can cause a variety of acute and chronic influences on health and performance including increased risks of gastrointestinal illness, coronary artery disease, and depression while reducing memory, alertness, concentrations and vigilance.[35] These problems are compounded by the additional stressors of confined submarine life; however, the submarine force implemented the 18-hour day before the appreciation of maintaining a circadian rhythm had become more widespread.[36] With an 18-hour day, the constant mismatch of the sailor's rotating sleep period and internal clock perpetuates the aforementioned effects during the underway and does not allow for an opportunity for circadian synchronization.

In an attempt to mitigate the effects of crew fatigue that is generated from an 18-hour watch cycle and a lack of a circadian rhythm, the Naval Submarine Medical Research Laboratory (NSMRL), homeported in Groton, Connecticut, studied the effects of sailors working while their body's master clock told the sailor it was time to sleep.[37] NSMRL concluded that the sailor's

fatigue that was created due to the 18-hour cycle could be mitigated by implementing a more circadian rhythm friendly routine. Furthermore, NSMRL concluded that the effects of standing an 8 hour watch on a nuclear reactor was less fatigue generated when compared to maintaining a circadian rhythm.[38] NSMRL has continued studying sailor's sleep patterns using modern devices measuring melatonin, sleep quality level, and activity to continue to match the sailor's endurance level with that of the submarines. At NSMRL's suggestion, the submarine force began experimenting with crews utilizing a 24-hour watch cycle as prototypes starting with the *USS Memphis* in 2006. After years of prototype and testing in May of 2013, the USN authorized submarine commanders to use the 24-hour schedule. Expectations, however, were for submarines to use it "when appropriate," noting it may depend on the mission type. Nuclear Reactors, concurrently, shifted its policy in the EDM and EDOM allowing for sailors to stand a maximum of eight hours of watch while monitoring a nuclear reactor thus effectively ending the 18-hour cycle.

IMPORTANT FACTORS IN WATCH ROTATIONS

The submarine force's guidance has allowed COs to experiment and change their operational strategies focusing on promoting sleep discipline and maintaining a circadian rhythm. COs are ultimately responsible to the ship, and the submarine force's guidance has allowed COs to maintain that responsibility. These operational strategies have not mandated a set amount of sleep hours in a given period like the aviation community, but instead created flexibility for the COs to tailor a crew's sleep pattern in an attempt to increase the ship's operational excellence.[39] The fast attack submarine *USS Scranton* was the first submarine to deploy with the effective policy change in May of 2013. While the crew of the *USS Scranton*

praised the switch to a 24-hour watch cycle and maintaining a circadian rhythm for an entire deployment, the CO expressed concerned with other issues of the transition, particularly logistical problems. The CO implemented a schedule, or rotation, that allowed for a straight, 8-hour rotation, but maintained a structure that allowed for certain parts of the day with everyone awake and able to effectively train.[40]

Since the policy changes from the submarine force and Nuclear Reactors, submarines have tried many different variations of the watch rotations with emphasis on maintaining the circadian rhythm for the crew. As with most cultural changes, many problems can arise when trying to keep the entire crew on its master clock and meet the demanding training requirements of the submarine force and operational commitments. The training program is rigid with concrete requirements and assessment from Nuclear Reactors. Command leadership will have to incorporate at least three hours of classroom training a week minimum for the engineering department and two monthly tests. The forward divisions and the wardroom have less training requirements but have at least two hours a week and a monthly test for each. The training program does not seem like much to manage on paper, but in the confines of the submarine finding a space to hold training is limited to two spaces and possibly a third. The two main spaces are the wardroom and crew's mess, which is primarily a space for meals and operational briefs and commitments. If there is nothing scheduled, then these spaces become the only communal leisure space for relaxation, games, and movies. Command leadership and planners are finding that the 24-hour watch cycle typically lends to an all-hands awake period where every crew member is awake. Creating an all-hands awake period gives command teams the ability to conduct drills and events that require all-hands to participate. The all-hands period maintains the ability to keep sleep periods protected and eliminates the disruptions of a sleep

period for an event. Unlike the traditional 18-hour watch cycle where two thirds of the crew is always awake, the 24-hour watch cycle compresses the amount of training time in the day without disrupting a sailor's sleep cycle. Overscheduling in the all-hands period causes two thirds of the crew to rarely have a communal space to relax.

Logistically, the 24-hour watch cycle presents a new set of challenges for the leadership to handle. Instead of a meal four times a day, on the 18-hour cycle, leadership must decide if three meals a day will suffice or if they will have to supplement with snacks or some other type of nutrition. Sailors have also complained that the 24-hour cycle limits them to the same type of meals during the underway creating a problem for COs to decide if they should rotate the meals or rotate the watch section which would disrupt the crew's circadian rhythm. Everyday items can also be compressed as a submarine has limited amount of showers, heads, and only one washer and dryer. The all-hands awake period and more sleep has created less time for sailors to deconflict these amenities. Another example of over crowdedness and deconfliction is the ship's limited exercise equipment which can directly impact a crew's morale.

Drills are essential for a submarine to conduct in order to remain efficient in fighting the ship during casualties. Most major drill sets are an all-hands event and can last anywhere from four to eight hours depending on the type. Periodicity of drill sets are directly dependent on a ship's mission type, but it is not uncommon for a ship to conduct one to four drill sets a week. The aforementioned problems present commands with complex challenges when constructing a watch cycle while trying to balance operational performance, crew health, and morale.

The construction of a 24-hour watch cycle should not haphazardly be put together by the command team of a CO, executive officer (XO), and chief of the boat (COB). The watch cycle is the heartbeat of a submarine. While the USN's "can-do" attitude will get crews to finish the

job, which the Comprehensive Review concluded could lead to disastrous results, command teams should put further emphasis on the importance of the watch cycle and the battle rhythm of the crew while operating at sea. Putting further emphasis on the watch cycle and elimination of crew fatigue can help eliminate the "can-do" attitude. Each watch cycle should minimize crew fatigue and maintain the sailor's circadian rhythm while trying to maximize its operational effectiveness. The watch cycle must maintain the circadian rhythm of a 24-hour cycle or day. Building a watch cycle therefore becomes an art of balancing performance against health. There will be trade-offs between each type of construction that command teams will have to weigh. Having one solution to the watch rotation will unnecessarily limit the potential efficiency of the cycle.

There are three factors to consider when developing the best watch cycle for an underway: the ability to transition, compatibility with training and drill programs, and crew stability. Crew stability is the ability for a sailor to maintain a rhythm or repeatability of a day which is aimed to decrease the amount of stress generated from disrupting the sailors rhythm. The first factor to consider is the ability to transition. Inevitably in the USN, a submarine will port and conduct maintenance or crew liberty. Any maritime vessel will not stay at sea forever creating transitions in the mode of operation that break a battle rhythm and stress the watchbill. Some major transitions that are common to a submarine are brief stops for personnel (BSP), piloting evolutions, time zone shifts, submerging, and surfacing. Transitions are events that normally require extra watchstanders for longer periods of time stressing the normal watch cycle. When a ship conducts a BSP, the evolution can be an all-hands evolution meaning that every crew member is awake and has a job. At a minimum, the watchbill is supplemented with the extra watchstanders to safely conduct the evolution which could come during the sailor's

"normal" sleep period causing disruption. Typically, transitions such as a BSP are carefully planned out to mitigate these risks and disruptions to the crew; however, the command team usually has little control on rendezvous times and external planning factors. A crew's watch cycle will need to be able to mitigate these disruptions to the point that the crew can maintain its watch cycle and limit the effects of a transition.

The ability to handle transitions is greatly affected by the ship's proficiency and capability. Better performing ships will inherently handle transitions easier. Efficiently handling the transition will decrease the amount of time for accomplishment therefore shortening the length of the disruption. A watch cycle that is modular and flexible with an extended period where the most sailors are available for the extra watch stations will better suit most transitions. Certainly, the scheduling of the command team for the transitions can help mitigate the stressors of transition. When considering selection or creation of a watch cycle, transitions can suggest to a command team that each underway may have a better solution that better balances performance versus health or vice versa.

The second factor to consider is the compatibility with the ship's training and drill plans. The compatibility of the training plans with the watch cycle is critical for a command team to maintain a well-rested, healthy, and proficient crew. The training, maintenance, drill plans are robust and can have more requirements than there are hours in an all-hands awake period. While the training and drill plans are heavily regulated, inspected and crucial to the safe operation of the ship, most drill and training plans are all-hands. The compatibility factor in the watch cycle will develop a time period where all-hands will be awake thus not disrupting a sailor's sleep period. The all-hands awake period will need to be maximized in order to accommodate this factor. Another consideration in this factor is the facilitator of the training and drills. All

training sessions have to be led by someone and drills monitored by a team of crewmembers to ensure the safe and expected outcome of the drills. In the past, it is not uncommon to see a weary eyed sailor leading his third training session of the day to complete the last section. The sailor would have to give his training during his "sleep time" preventing a full rest period that leaders are stressing to protect. The compatibility factor tends to lead command teams to a more modular type watch cycle with shorter watches which will allow for more rotations of training groups; however, this design disrupts the next factor which favors health versus performance.

The third factor to consider is crew stability. A watch cycle has to be long enough to allow for a sailor to settle in and engage his watchstation, but not long enough where operational fatigue will set in. A watch cycle must be stable in a sense that it is repeatable day in and day out. In a sense the less moving parts the better as a battle rhythm can be set and sailors can find their niche. The stability within watch times and relief times allow the sailor to effectively manage their time in the day and properly prepare for the next event. Contrarily, a watch cycle that is constantly moving to accommodate the above scenarios will can lead to lost crew rest, unprepared training sessions, and confusion. Stability tends to lean towards a longer watch period with less watch turnovers. It favors health versus performance when constructing a watch rotation. Having stability in the cycle allows for the crew the opportunity to manage their time and pushes the performance versus health compromise onto their own decisions. Trading stability for flexibility on a watch cycle is also an art to find the right duration of the watch and placement of turnover times. A watch that is too short will cause more frequent watch turnover and changing of personnel potentially degrading the watch performance due to lack of familiarity of the current conditions. The opposite is also true as a watch too long will invite tiredness, inattention, and boredom into the watchstander. Watch turnover can be a vulnerable time for a

submarine as personnel are getting accustomed to the conditions of the ship, conversing with other watch standers, shuffling through orders and watch spaces and generally can be somewhat chaotic. Stability suggests that a command team should construct a watch rotation with the least moving parts and maintain the rotation regardless of the particular tasking within a given underway providing sailors familiarity and routine.

Other scenarios to consider that are not covered within the three factors are special ship conditions. These conditions are less frequent, but have the potential to disrupt a watch cycle and are important to identify early. Planning for future operations is key to include a conversation if the watch cycle is still in the best form to maximize operational effectiveness while minimizing crew fatigue. Command team should revisit the performance versus health balance prior to every underway to ensure the optimal results. There are times when a submarine is transiting from point A to point B and the operational pace is considered slow and unstressful. Contrarily, there are times when a submarine is in a very narrow channel or in high contact density where the crew is under a tense period of operations that require considerable more effort and energy to safely operate. Some of these scenarios can be carefully planned and mitigated, but other events, like a major fire, cannot be planned. Regardless crews will have to be ready and command teams will have to recognize and mitigate these disruptions in the watch cycle.

POTENTIAL WATCH ROTATION CONSTRUCTIONS

A common watch cycle within the submarine force is the 8-8-8 model, see Figure 1, or "Straight Eights." The cycle is constructed into rolling three 8 hour watches by three watch sections or 8 on and 16 off watch. A "protected" sleep time of eight hours, realistically seven hours when you take into account prewatch briefs and tours, is accounted for each watch section.

Typically, Section 1 will be on watch from 0000 to 0800 while Sections 2 and 3 are asleep. Section 2 relieves Section 1 and is on watch from 0800 to 1600. Lastly, Section 3 relieves Section 2 and is on watch from 1600 to 2400 while Section 1 sleeps.

Straight 8s Model												
Section	0000	0200	0400	0600	0800	1000	1200	1400	1600	1800	2000	2200
Harder	Watch				All-Hands Awake				Sleep			
Stingray	Sleep				Watch				Offgoing			
Wahoo	Sleep				All-Hands Awake				Watch			

Figure 1

There are a few advantages to this construction as it has the most stability and simplicity. A battle rhythm can be developed quickly by the crew. A command team that is above average in operational planning can benefit from "Straight Eights" because they would be able to mitigate the effects of the transitions and training plans. The rotation gives the most continuity to watch standers while standing the maximum 8 hour watch. The maximum time off of 16 hours could have the potential of extra rest if a section's training and required work is completed before their sleep period further minimizing the crew's fatigue. However, the disadvantages of "Straight Eights" lies within the all-hands awake section. One section is on watch during the entire all-hands awake period creating the need for either make up training during the evening or introducing complete section watch reliefs. Conducting make up training during the evening limits the presenters to only two sections or disrupts the presenter's cycle. Introducing section watch reliefs would allow the day section to get the training during the all-hands awake period, but will decrease the watchstander's performance. Another disadvantage of this rotation is having two sections asleep during the same time period further lowering the readiness of the ship's response should a special scenario occur.

A potential variant to the "Straight Eights" while maintaining an 8-8-8 rotation is the "Split Eights" rotation, see Figure 2. In "Split Eights," each watch section would stand four hours of watch on the front and back end of their awake period. Therefore, Section 1 would stand watch from 0000 to 0400, then be awake and conducting training, drills, etc. from 0400 to 1200, and stand their final watch from 1200 to 1600. Extrapolating this out for the other two watch sections will create an all-hands awake period from 0800 to 1600. It is similar to the "Straight Eights" model of an all-hands period for training and drills, but this model adds the flexibility of built in watch reliefs during the all-hands awake period. "Split Eights" favors the factors of compatibility and transitions due to its modular design. The variant model staggers the sleep period of the watch sections unlike the first model. By staggering the sleep periods, at any given time more sailors will be awake and available for administration, maintenance, or a casualty response. Another advantage is having a shorter watch as it will keep a fresh set of eyes and tactical acumen in the control centers of the submarine lending to performance. The disadvantage to the added readiness is the removal of the opportunities for sailors to get extra crew rest if needed. Another trade off in "Split Eights" is the amount of watch turnover from section to section introducing twice as many turnovers. Having twice as many turnovers can have competing effects on the crew. The first effect is that it can eliminate the need for a mid watch break or head call due to the much shorter watch gaining continuity in the watch. The competing effect is that amount of turnover in the crew, which usually takes 15 to 30 minutes to conduct, disrupting to the crew's stability and introducing inefficiencies for the command team's scheduling.

Split 8s Model												
Section	0000	0200	0400	0600	0800	1000	1200	1400	1600	1800	2000	2200
Harder	Watch		Offgoing		All-Hands Awake		Watch		Sleep			
Stingray	Sleep		Watch		All-Hands Awake				Watch		Sleep	
Wahoo	Sleep				Watch		All-Hands Awake		Offgoing		Watch	

Figure 2

"Split Eights" would tend to accommodate periods of high contact density and operational pace. During the deployment preparation phase when the requirements and inspections peak in volume, "Split Eights" can give the flexibility and ability to stress the watch rotation to accomplish the mission. The modular design really gives the command teams the ability to move sections around for 16 hours creating opportunity to have the right team in place to perform the task.

The next model available is the 6-6-6-3-3 model, see Figure 3. In Model 3, the watchteams would split the difference between the 8 hour and 4 hour watch durations to the traditional amount of 6 hours. Section 1 would stand watch from 0000 to 0600 while their sleep period would be from 1500 to 2400. Section 2 would stand watch from 0600 to 1200 and again from 1800 to 2100 while sleeping from 2100 to 0600. Section 3 would round out the day by standing watch from 1200 to 1800 and again from 2100 to 2400 while sleeping from 0000 to 0900. The model's construction leaves an all-hands awake period from 0900 to 1500. Immediately noticing contrast in this model with the previous two, the all-hands awake period is only 6 hours while the sleep periods are 9 hours long. The model potentially trades off performance for health. A command team less proficient with operational planning may struggle in this model trying to compact the all-hands requirements into a shorter period. The command team will also have to manage that in Model 3 two watchteams stand 9 hours of watch within a

24-hour period while one section stands only 6 hours of watch. Every sailor will be quick to point that out.

6-6-6-3-3 Model								
Section	0000	0300	0600	0900	1200	1500	1800	2100
Harder	Watch		Offgoing	All-Hands Awake		Sleep		
Stingray	Sleep		Watch		AHW	Offgoing	Watch	Sleep
Wahoo	Sleep			AHW	Watch		Offgoing	Watch

Figure 3

Model 3 adds complexity for the command team. The command team will have to look at extra factors of when, or if it should, rotate the watch sections to even out the total amount of hours standing watch. A rotation that would temporarily disrupt a circadian rhythm creating a jet lag sensation. The 6-6-6-3-3 model trades some of the watch rotations flexibility at the expense of the crew's stability should the command team rotates the watch sections. Rotating the watch sections to gain equality certainly will raise the morale of the crew members. Contrarily, the command team could keep two of the watch section standing the extra watches daily and instead have a good messaging program to keep the crew member's morale high despite standing more watch daily. The model tends to be a fair compromise between the first two models in the length of the watches, the ability to withstand transitions, and crew's stability.

The final model is the 6-6-6-6 model (see Figure 4). Currently, the 6-6-6-6 model, or Model 4, is not achievable due to current submarine manpower regulations, such as the Submarine Military Personnel Manual or SUBMILPERSMAN which delineates the crew size and capacity, but could be a goal for the submarine force to ultimately attain as submarine design evolves with technological advances. Submarine design would have to allow for more berthing and/or less watch standers to fully man a four section watchbill. Model 4 would be a traditional four section rotation of 6 hour watches. Model 4 gives the crew 18 hours off creating the most

stability for the crew and most readiness of the four models as each sleep period is staggered. The main disadvantage of Model 4 is the lack of an all-hands awake period severely limiting the compatibility with the training and drill programs. In the future, as less sailors could be required to operate a more technological advance submarine, Model 4 could be effective in period of low transitions and in areas where all-hands evolutions would be limited like operating on mission.

6-6-6-6 Model								
Section	0000	0300	0600	0900	1200	1500	1800	2100
Harder	Watch		Offgoing		Sleep			Oncoming
Stingray	Sleep	Oncoming	Watch		Offgoing		Sleep	
Wahoo	Sleep			Oncoming	Watch		Offgoing	
Tang	Offgoing		Sleep			Oncoming	Watch	

Figure 4

CONCLUSION

As multiple models were looked at with respect to the model's ability to withstand transitions, compatibility to training and drill plans, and crew's stability, each model has its own advantages and disadvantages. Selecting the correct watch rotation is important for the management of balancing the performance of the ship versus the health of the crew. Submarine operations vary widely and each model has features that can lean more on one side or the other of the equation. Command teams need to look at each underway as a unique opportunity to maximize the effects of the watch rotation for both performance and health. There is value in the variety of watch rotations command teams can construct. For an underway focused on high contact density and operational tempo, "Split Eights" could give commanders the flexibility to accomplish the task; however, for an underway that is geared mostly to transiting, "Split Eights" would have a negative impact on the ship. An underway that is mostly transiting would suggest itself to a more crew friendly, simple model like "Straight Eights" or the 6-6-6-3-3 model.

Commanders will have to maximize the effects of the watch rotation for the particular underway's mission or tasking.

Selecting a wrong model for the mission or task at hand could cause severe disruption while underway especially if it causes the need to shift from one model to another. The Supply Officer and the cooks would certainly agree if shifting from an 8 hour rotation to a 6 hour rotation. The first two models of "Straight Eights" and "Split Eights" offered the best interoperability between the two. A combination of the two watch cycles tends to be the best answer while dissecting the different models as it allowed for the most flexibility at times of a high operational pace and also stability with the longer duration of watches. The ability to go back and forth and the ability of the command team to timely shift between the two models would raise the overall operational effectiveness of the crew and the ability of the submarine to complete its mission. The CO retains the final decision as in any aspect of a ship and it is no different when selection a watch rotation. By mandating a certain watch rotation through policy change, the submarine force would eliminate the CO and the command team's ability to gage the crew's intangible factors; however, the CO and command team should get the support and advice from squadron or the next echelon up. It also provides the opportunity for command teams to optimize the strengths of their crew and provide valuable feedback and best practices for the submarine force to refine its guidance.

As the submarine force continues to experiment with different models and permeations of a 24-hour cycle, command teams should continually assess the feedback from the crew and evaluation results. Command climate surveys are a good tool for assessment as questions can be directly tailored by the command team; however, the survey is less frequent than needed in this case. Measuring crew health can be nebulous for a CO to assess while underway outside

informal conversations and walking around the ship, but indicators can lie within formal metrics. For example, medical reports can show unplanned losses of sailors, suicidal attempts, or depression cases which can be linked to undue stress from fatigue. Another approach could include adding to the current formal inspections from outside agencies like Nuclear Reactors and squadrons in the effectiveness of the watch cycle construction. An outside agency in this capacity provides an outside look into the watch rotation and could potentially see the advantages and disadvantages more clearly. Other metrics can include critiques caused from lack of attention, sleeping on watch, or failing to meet requirements. NSMRL should tailor future studies to measure the effectiveness of different watch cycles that produce optimal results in different scenarios. The results would give scientific data by trained professionals to aid the CO's decision. Tests could include constructing different watch rotations and then deliberately stressing different factors at different points. The results would further produce best practices and awareness with different watch rotations.

Since the history making underway of the *USS Nautilus,* the submarine force has been moving in the direction of maximizing the effectiveness of the crew along while shaking the old paradigms of being a professional mariner who worked regularly while fatigued. A problem unique to submarines when combining the effects of limited space and a controlled atmosphere. As with the DOD, doctrinally, the USN has created new policies and revamped older policies to help match submariners circadian rhythms with their watch rotations. As professional organizations will always carefully calculate their employees effectiveness versus their ability and desire to continue, the USN has placed an ever important and urgent importance on minimizing crew's fatigue levels and ultimately trying to match their daily land internal clocks with their at sea internal clocks.

Command teams have created many models and trials for submarine crews to maximize the operational effectiveness while meeting the rigorous qualification and certification programs and maintain the crew on a 24-hour circadian rhythm. However, the USN should equip COs with guidance and knowledge in how to assess operational effectiveness. Outside studies should be now directed towards the link of a watch cycles and fatigue levels to pinpoint efficiencies. Studies should focus on developing tangible metrics to aid COs in assessing their crew's health. Headquarters can and should establish guidelines to watch construction possibilities while publishing best practices seen around the fleet. The best practices can then be validated by future studies arming command teams with the most information possible when creating a watch rotation. In the interim, COs must weigh the several factors that were examined while selecting between the different models aimed to help construct the best watch rotation for the specific underway and task at hand. The "Straight Eights" and "Split Eights" models seemed to offer the best solution to the most challenges a command team could face. As submarine crews continue to manipulate and trial different models, command teams should continue to weigh the important factors of crew's stability, compatibility with training and drill programs, and ability to withstand transitions at the forefront when deciding on a watch cycle.

Notes

[1] H.B. Harris-Warren, *Dive! The Story of an Atomic Submarine*, (New York: Harper and Brothers, 1965), 57.

[2] C. A. Duplessis, J. C. Miller, L. J. Crepeau, C. M. Osborn, and J. Dyche, "Submarine Watch Schedules: Underway Evaluation of Rotating (Contemporary) and Compressed (Alternative) Schedules," *Undersea & Hyperbaric Medicine* 34, no. 1 (2007): 23, https://search-proquest-com.lomc.idm.oclc.org/docview/204942451?accountid =14746.

[3] Wendy M. Troxel, "Review of Sleep Policies and Programs," *Sleep in the Military: Promoting Healthy Sleep Among U.S. Servicemembers*, (2015): 74, http://www.jstor.org.lomc.idm.oclc.org/stable/10.7249/j.ctt15zc8f8.12.

[4] Headquarters US Navy, *Manual of the Medical Department*, NAVMED P-117 (Washington, DC: Headquarters US Navy, 29 Mar, 2016), 18-11.

[5] Chief of Naval Operations, *Environmental Restoration Program*, Policy Letter Series N453/1U595168, February 12, 2001, 3.

[6] Department of the Navy, *Personnel Reliability Program*, SECNAVINST 5510.35B, 2014, 78.

[7] Troxel, "Review of Sleep Policies and Programs," *Sleep in the Military: Promoting Healthy Sleep Among U.S. Servicemembers*, 75.

[8] Troxel, "Review of Sleep Policies and Programs," *Sleep in the Military: Promoting Healthy Sleep Among U.S. Servicemembers*, 77.

[9] Commandant of the Marine Corps, *Recruit Training*, MCO 1510.32F, December 20, 2012, 5-6.

[10] Commandant of the Marine Corps, *Interior Guard Manual*, MCO 5530.15, October 14, 2008, 2-7.

[11] Commandant of the Marine Corps, *The Management of Marine Corps Formal Schools and Training Detachments*, MCO 1553.2C, September 8, 2016, 4-6.

[12] Headquarters US Marine Corps, *Marine Corps Common Skills (MCCS) Training and Readiness (T&R) Manual*, NAVMC 3500.18B (Washington DC: Headquarters US Marine Corps, May 10, 2012), 1-7.

[13] Troxel, "Review of Sleep Policies and Programs," *Sleep in the Military: Promoting Healthy Sleep Among U.S. Servicemembers*, 80.

[14] Troxel, "Review of Sleep Policies and Programs," *Sleep in the Military: Promoting Healthy Sleep Among U.S. Servicemembers*, 82.

[15] Headquarters US Marine Corps, *Combat and Operational Stress Control*, NTTP 1-15M/MCRP 6-11C (Washington DC: Headquarters US Marine Corps, December 20, 2010), 1-7.

[16] Headquarters US Marine Corps, *Combat and Operational Stress Control*, NTTP 1-15M/MCRP 6-11C, 1-18.

[17] Troxel, "Review of Sleep Policies and Programs," *Sleep in the Military: Promoting Healthy Sleep Among U.S. Servicemembers*, 80.

[18] Headquarters US Marine Corps, *Combat and Operational Stress Control*, NTTP 1-15M/MCRP 6-11C, 3-4.

[19] Troxel, "Review of Sleep Policies and Programs," *Sleep in the Military: Promoting Healthy Sleep Among U.S. Servicemembers*, 80.

[20] Department of the Navy, *NATOPS General Flight Operating Instruction*, OPNAVINST 3710.7U, March 1, 2004, 8-15.

[21] Department of the Navy, *Performance Maintenance During Continuous Flight Operations*, NAVMED P-6410, January 1, 2000, 4-8.

[22] Troxel, "Review of Sleep Policies and Programs," *Sleep in the Military: Promoting Healthy Sleep Among U.S. Servicemembers*, 80.

[23] James, Stavridis, *Watch Officers Guide*, 14th ed, (Annapolis, MD: Naval Institute Press, 2000), 316.

[24] Department of Defense, *Results of the Fleet Comprehensive Review and Investigations into the Collisions Involving USS Fitzgerald and USS John S. McCain*, (Washington, DC: Department of Defense, 2017), 1, https://search-proquest.com.lomc.idm.oclc.org/docview/1958936783?accountid=14746.

[25] Department of Defense, *Results of the Fleet Comprehensive Review and Investigations into the Collisions Involving USS Fitzgerald and USS John S. McCain*, 16.

[26] Department of Defense, *Results of the Fleet Comprehensive Review and Investigations into the Collisions Involving USS Fitzgerald and USS John S. McCain*, 18.

[27] Department of Defense, *Results of the Fleet Comprehensive Review and Investigations into the Collisions Involving USS Fitzgerald and USS John S. McCain*, 18.

[28] Department of Defense, *Results of the Fleet Comprehensive Review and Investigations into the Collisions Involving USS Fitzgerald and USS John S. McCain*, 57.

[29] Department of Defense, *Results of the Fleet Comprehensive Review and Investigations into the Collisions Involving USS Fitzgerald and USS John S. McCain*, 21.

[30] Drew Dawson and Kathryn Reid K. "Fatigue, Alcohol and Performance Impairment," *Nature* 288, (1997): 23.

[31] Drew Dawson and Kathryn Reid K. "Fatigue, Alcohol and Performance Impairment," *Nature*, 23.

[32] Drew Dawson and Kathryn Reid K. "Fatigue, Alcohol and Performance Impairment," *Nature*, 23.

[33] Daniel Miller, "Sleep and Predicted Cognitive Performance of New Cadets during Cadet Basic Training at the United States Military Academy," (master's thesis, Naval Postgraduate School 2005), 2.

[34] C. A. Duplessis, et al, "Submarine Watch Schedules: Underway Evaluation of Rotating (Contemporary) and Compressed (Alternative) Schedules," *Undersea & Hyperbaric Medicine* 34, 23.

[35] C. A. Duplessis, et al, "Submarine Watch Schedules: Underway Evaluation of Rotating (Contemporary) and Compressed (Alternative) Schedules," *Undersea & Hyperbaric Medicine* 34, 23.

[36] C. A. Duplessis, et al, "Submarine Watch Schedules: Underway Evaluation of Rotating (Contemporary) and Compressed (Alternative) Schedules," *Undersea & Hyperbaric Medicine* 34, 22.

[37] Bob Koonce, *Extreme Operational Excellence*, (Chicago: Outskirts Press 2016), 17.

[38] Koonce, *Extreme Operational Excellence*, 19.

[39] Koonce, *Extreme Operational Excellence*, 21.

[40] Troxel, "Review of Sleep Policies and Programs," *Sleep in the Military: Promoting Healthy Sleep Among U.S. Servicemembers*, 80.

Bibliography

Abrashoff, Michael. *It's Your Ship*. New York, NY: Warner Books, 2002.

Armstrong, Benjamin. "Are We Driving the Ship Drunk?" *United States Naval Institute Proceedings* 136, no. 2 (2010): 79-81, https://search-proquest.com.lomc.idm.oclc.org /docview/205987624?accountid=14746.

Blogut, Angela, and Izabella Petre. "Psychobehavioural Implications of the Circadian Rhythm Disorder." *Scientific Research & Education in the Air Force – AFASES*, no. 2 (July 2016): 529–34, doi:10.19062/2247-3173.2016.18.2.6.

Chief of Naval Operations. *Environmental Restoration Program*. Policy Letter Series N453E/1U595168. February 12, 2001.

Commandant of the Marine Corps. *Formal School Management Policy.* MCO 1553.2C. September 8, 2016.

Commandant of the Marine Corps. *Interior Guard Manual*. MCO 5530.15. October 14, 2008.

Commandant of the Marine Corps. *Recruit Training.* MCO 1510.32F. December 20, 2012.

Cordle, John. "A Sea Change in Standing Watch." *United States Naval Institute Proceedings* 139, no. 1 (2015): 34-39, https://search-proquest-com.lomc.idm.oclc.org/docview/1283349256?accountid=14746.

Cordle, John. "Go to 27-Section Duty." *United States Naval Institute Proceedings* 142, no. 8 (2010): 18-21, https://search-proquest.com.lomc.idm.oclc.org/docview/1817050657? accountid=14746.

Cutler, Thomas. *The Bluejacket's Manual*. Annapolis, MD: Naval Institute Press, 2002.

Dawson, D. and K. Reid K. "Fatigue, Alcohol and Performance Impairment." *Nature* 288, (1997): 20-47.

Department of Defense. *Results of the Fleet Comprehensive Review and Investigations into the Collisions Involving USS Fitzgerald and USS John S. McCain*. Washington, DC: Department of Defense, 2017. https://search-proquest.com.lomc.idm.oclc.org/docview/1958936783? accountid=14746.

Department of Navy. *NATOPS General Flight and Operating Instructions.* OPNAVINST 3710.7U, Mar 1, 2004.

Department of Navy. *Performance Maintenance During Continuous Flight Operations*. NAVMED P-6410. January 1, 2000.

Department of Navy. *Personnel Reliability Program*. SECNAVINST 5510.36B, 2014.

Dobbs, Michael J. "How the Twig is Bent: Developing Young Bubbleheads for the Challenges of Command." *United States Naval Institute Proceedings* 133, no. 6 (2007): 28-33. https://search-proquest-com.lomc.idm.oclc.org/docview/205983263?accountid=14746.

Duplessis, C. A., J. C. Miller, L. J. Crepeau, C. M. Osborn, and J. Dyche. "Submarine Watch Schedules: Underway Evaluation of Rotating (Contemporary) and Compressed (Alternative) Schedules." *Undersea & Hyperbaric Medicine* 34, no. 1 (2007): 21-33. https://search-proquest-com.lomc.idm.oclc.org/docview/204942451?accountid=14746.

Fluckey, Eugene. *Thunder Below!* Chicago, IL: University of Illinois Press, 1992.

Frank, A. J. L. Scheer, Wright, Kenneth P. Jr, Richard E. Kronauer, and Charles A. Czeisler. "Plasticity of the Intrinsic Period of the Human Circadian Timing System." *PLoS One* 2, no. 8 (2008). https://search-proquest-.com.lomc.idm.oclc.org/docview/1950156746?accountid =14746.

Gasier, Heath G., Colin R. Young, Erin Gaffney-Stomberg, Douglas C. McAdams, Laura J. Lutz, and James P. McClung. "Cardiometabolic Health in Submariners Returning from a 3-Month Patrol." *Nutrients* 8, no. 2 (2016): 85. https://search-proquest-.com.lomc.idm.oclc.org /docview/2108563390?accountid=14746.

Harris-Warren, H. B. *Dive! The Story of an Atomic Submarine.* New York, NY: Harper and Brothers, 1960.

Headquarters US Marine Corps. *Combat and Operational Stress Control*. NTTP 1-15M/ MCRP 6-11C. Washington DC: Headquarters US Marine Corps, December 20, 2012.

Headquarters US Marine Corps. *Marine Corps Common Skills (MCCS) and Training and Readiness (T&R) Manual*. NAVMC 3500.18. Washington DC: Headquarters US Marine Corps, May 10, 2012.

Headquarters US Navy. *Manual of the Medical Department*. NAVMED P-117. Washington DC: Headquarters US Navy, 29 Mar, 2016.

Jean, Grace V. “Submariners Going ‘Back to Basics.’” *National Defense* 94, (2010): 26–27. https://search-ebscohost.com.lomc.idm.oclc.org/login.aspx?direct=true&db=a9h&AN =47576877&site=ehost-live.

Kawasaki, A., S. Wisniewski, B. Healey, N. Pattyn, D. Kunz, M. Basner, and M. Münch. "Impact of Long-Term Daylight Deprivation on Retinal Light Sensitivity, Circadian Rhythms and Sleep during the Antarctic Winter." *Scientific Reports* (2010): 1-12. https://search-proquest-com.lomc.idm.oclc.org/docview/2127937616?accountid=14746.

Kessler, Michael W. "The Submarine Ethos Runs Deep." *United States Naval Institute*

Proceedings 130, no. 7 (2008): 77-78. https://search-proquest.com.lomc.idm.oclc.org /docview/205976336?accountid=14746.

Koonce, Bob. *Extreme Operational Excellence*. Chicago, IL: Outskirts Press, 2016.

Mack, William P., and Harry A. Seymour. *The Naval Officer's Guide.* Annapolis, MD: U.S. Naval Institute, 1998.

Margel, David, David P. White, and Giora Pillar. "Long-Term Intermittent Exposure to High Ambient CO2 Causes Respiratory Disturbances During Sleep in Submariners." *Chest* 124, no. 5 (2003): 1716–1723. https://search-ebscohost-com.lomc.idm.oclc.org/login.aspx?direct =true&db=a9h&AN=11436637&site=ehost-live.

Marquet, David. *Turn the Ship Around!* New York, NY: Penguin Books, 2012.

Mendenhall, Corwin. *Submarine Diary*. Chapel Hill, NC: Algonquin Books, 1991.

Miller, Daniel. "Sleep and Predicted Cognitive Performance of New Cadets during Cadet Basic Training at the United States Military Academy." Master's thesis, Naval Postgraduate School, 2005.

O'Kane, Richard. *Wahoo*. Novato, CA: Presidio Press, 1987.

Philipps, Dave and Eric Schmitt. "Strains on Crews and Vessels Set the Stage for Navy Crashes." *New York Times*, Aug 28, 2017. https://search-proquest-com.lomc.idm.oclc.org /docview/1932710077?accountid=14746.

Sargent, Cliodhna, Cormac Gebruers, and Jim OMahony. "A Review of the Physiological and Psychological Health and Wellbeing of Naval Service Personnel and the Modalities used for Monitoring." *Military Medical Research*, (2017): 4. https://search-proquest-com.lomc.idm. oclc.org/docview/1865143328?accountid=14746.

Short, Michelle A., "A Systematic Review of the Sleep, Sleepiness, and Performance Implications of Limited Wake Shift Work Schedules." *Scandinavian Journal of Work, Environment & Health* 41, no. 5 (2017): 425-440. https://search-proquest-com.lomc.idm. oclc.org/docview/1716946898?accountid=14746.

Stavridis, James. *Watch Officer's Guide*. Annapolis, MD: U.S. Naval Institute Press, 2000.

Sykora, Charles D. "A Transformation Limited by Legacy Command and Control." *Naval War College Review* 59, no. 1 (2006): 41-62. https://search-proquest-com.lomc.idm.oclc.org /docview/205938858?accountid=14746.

Troxel, Wendy M. "Review of Sleep Policies and Programs." *Sleep in the Military: Promoting Healthy Sleep Among U.S. Servicemembers*, (2015): 67-84, http://www.jstor.org.lomc.idm. oclc.org/stable/10.7249/j.ctt15zc8f8.12.

Trousselard, Marion. "Sleeping Under the Ocean: Despite Total Isolation, Nuclear Submariners Maintain their Sleep and Wake Patterns Throughout their Under Sea Mission." *PLoS One* 10, no. 5 (2015): https://search-proquest-com.lomc.idm.oclc.org/docview/1683578505?accountid=14746.

Wijk, Charles H. van, and Adéle H. Waters. "Positive Psychology made Practical: A Case Study with Naval Specialists." *Military Medicine* 173, no. 5 (2008): 488-92. https://search-proquest-com.lomc.idm.oclc.org/docview/217046655?accountid=14746.