NSMRL
A SMALL COMMAND WITH A HUGE PRESENCE FOR THE SUBMARINE FORCE

by CAPT J. Christopher Daniel, MC, USN
and Dr. Jerry Lamb

Reprinted with permission from the July 2005 issue of THE SUBMARINE REVIEW, a publication of the Naval Submarine League, PO Box 1146, Annandale VA 22003.

NSMRL
A SMALL COMMAND WITH A HUGE PRESENCE FOR THE SUBMARINE FORCE

by CAPT J. Christopher Daniel, MC, USN
and Dr. Jerry Lamb

*"**To protect the health and enhance the performance of our warfighters through focused submarine, diving and surface research solutions**"* is the mission of the Naval Submarine Medical Research Laboratory, located just a few hundred yards from the waterfront at Submarine Base New London, Groton, CT. One of 10 Navy Medicine Biomedical Research Labs around the world, it has directly supported Naval Submarine Forces since World War II. Yet, like the submariners we support, the majority of our past contributions, as well as our current work, is virtually unknown to those outside of the submarine community. In fact, even on our own base, we are not well known - NSMRL is frequently confused with the Naval Undersea Medical Institute (NUMI). Thus, to educate the broader community, this paper will describe some of the highlights of NSMRL's proud history and discuss some of our current activities.

History

"The medical problems peculiar to submarines arise from unfavorable changes in habitability which may occur, chiefly in combat. The most important of these are excess heat and humidity, the accumulation of carbon dioxide, and the depletion of oxygen from the air under certain conditions. That only 31 patrols in World War II were interrupted or terminated because of these or other deficiencies of habitability speaks well for the progress which was made in the control of these problems. Until these deficiencies have been completely overcome, they will continue to be a limiting factor in submarine operations (Shilling and Kohl, 1947). [1]

What was eventually to become NSMRL started in 1942 as a two-man Medical Research Section of the base dispensary at U.S. Submarine Base, New London, with the mission of providing

"answers to problems in communications, vision, personnel selection, and environmental medicine which resulted from wartime demands on the Submarine Force."[2] The working spaces were "an office, a soundproof testing room, and one large classroom and/or examining room in the south wing of the dispensary, Building 86."[3] LCDR Charles W. Shilling, MC, USN, the submarine medical examiner assigned at the time to the escape training tank (and also responsible for selecting Navy and Coast Guard personnel to be trained by the Naval Submarine School), along with Chief Pharmacist's Mate Ira A. Everley, "a submarine man of long experience,"[4] had initiated research in 1939 on submarine sound problems. They published a series of articles entitled Auditory Acuity among Submarine Personnel in the Naval Medical Bulletin in January, April, July and October of 1942. Some of this initial work led to the development of tests and techniques to select men for sound listening duties on submarines, which appeared as Medical Research Laboratory Report No. 1, The Development of Methods for the Selection of Sound Listening Personnel. Soon, studies on night vision, color vision, and lookout training were begun, and within a year, the initial staff was augmented with a Psychologist-Statistician (William D. Neff, Ph.D.) and a Secretary-Statistician (Mrs. Jessie W. Kohl) from the National Defense Research Committee (NDRC), along with various TAD personnel. In addition, through the assistance of the National Research Council and the NDRC, the lab enjoyed extremely active and productive collaborations with civilian scientists from numerous universities and other institutions.

By the end of World War II, the staff of what had become (in March 1944) the Medical Research Department of the base included 26 officers, 57 enlisted, 11 WAVES and 4 civilians. As a result of demobilization following the war, however, the lab's personnel quickly became predominantly civilian. On 30 June 1946, 7 officers, 24 enlisted and 40 civilians became plank-owners of the new Medical Research Laboratory—a separate activity of the Bureau of Medicine and Surgery, with now-CAPT Charles Shilling, MC, USN, the first Officer-in-Charge. Its mission was three-fold: selection of personnel for training in the Naval Submarine School, instruction of hospital corpsmen and medical officers in Submarine Medicine, and research in medical aspects of submarine and diving including night

and color vision, human engineering, and personnel selection methods.[5] The activity became part of the new Naval Submarine Medical Center in 1964, but since 1974 has functioned as a separate command under its present name, the Naval Submarine Medical Research Laboratory (NSMRL). In 2005, NSMRL remains responsible for screening candidates for the Submarine School and for focused submarine and diving research, while NUMI, established as a separate command in 1973, continues the mission of submarine medical officer and enlisted training.

The laboratory now occupies three buildings on Upper Base, just east of the present Dental Clinic and just west of Rock Lake. It has evolved technologically to include a specially constructed 42,000 cubic foot anechoic soundproof chamber for acoustic discrimination and directional processing work, numerous sound and vision testing booths, a small hyperbaric chamber for instrument testing, and two multi-person man-rated hyperbaric chambers, one of which is capable of high altitude operations to simulate *flying after diving*. This latter chamber was the site of the Genesis 1 experiments conducted in the late 1950s and early 1960s by Drs. George Bond and Robert Workman, who envisioned that men could live and work in habitats on the floor of the ocean. These experiments explored the feasibility of saturation diving, confirmed the suitability of helium-oxygen breathing mixtures, and ultimately resulted in their landmark 1963 study, which reported "that men could live/work in a hyperbaric chamber at 200 feet for two weeks with no untoward consequences. These studies culminated in 1964 in an operational phase, Sea Lab 1, a habitat located 200 ft in the open ocean near Bermuda."[6]

NSMRL's historical accomplishments and contributions to the Submarine Force and to our nation's defense are too voluminous to catalogue here. However, we will highlight a few from earlier decades before discussing our present work. In 1951, NSMRL proved that performance was not affected adversely when men had visual acuity of less than 20/20, leading to a relaxation of the standard to 20/30.[7] Subsequent work in the 70's and 80's resulted in a modification to periscope eye guards to allow the insertion of a refractive correction into the periscope optics.[8] These accomplishments allowed a significant enlargement of the pool of potential

submariners without compromising the submarine mission. In 1960, NSMRL's psychological research aboard USS TRITON as it circumnavigated the globe resulted in the establishment of the mission duration for SSBNs. Between 1977 and 1979, NSMRL "prepared or implemented programs for the diagnosis of 56 common and acute diseases…on several mini and microcomputers ….for use by corpsmen aboard submarines."[9] In addition to the Genesis/SEALAB underwater habitat work, other critical areas in which NSMRL has made a huge operational and scientific impact during its proud history include research: proving that submariners can tolerate and perform well in an atmosphere with elevated carbon dioxide and low oxygen levels, the replacement of *rig for red* viewing in sonar and control rooms with low level white lighting,[10] development of both the International Orange color (air-sea rescue red) for visibility and the Farnsworth Color Lantern Color Vision screening test, studies of nitrogen narcosis, and development of many of the U.S. Navy saturation diving and decompression tables in use today.[11]

Current Challenges

The January 2005 mishap of USS SAN FRANCISCO (SSN 711) reinforced the importance and the impact of NSMRL's efforts in the area of Survival and Escape from Disabled Submarines (DISSUBs). NSMRL is an integral member of COMNAVSUBFOR's Submarine Escape and Rescue Review Group, and is responsible on an ongoing basis for revisions to the Disabled Submarine Survival Guide, the Guard Book. NSMRL's work in this area over the last decade has contributed to the deployment of numerous technological advances in use today, such as Submarine Escape Immersion Equipment (SEIE) suits, PDA-based analytic software to facilitate Senior Survivor time-remaining determinations (SERCIL—Submarine Escape and Rescue Calculator and Information Library), portable gas analyzers and CO_2 scrubbing "Battelle Curtains." In related work, Lab staff is exploring the possibility of escape from depths greater than 600 feet. Additionally, NSMRL is currently evaluating stretcher designs for use on submarines and testing escape and rescue streamers to enhance recognition of DISSUB survivors at sea. In the area of onboard medical treatment, the Lab has recently made

specific recommendations regarding the availability of oxygen dedicated for medical use onboard submarines.

To evaluate DISSUB equipment and procedures, the Lab worked with Submarine Squadron Five to conduct SURVIVEX 03 (March 2003) and SURVIVEX 04 (December 2004) on USS DALLAS and USS SALT LAKE CITY, respectively. These exercises confirmed the ability of the aforementioned CO_2 scrubbing curtains and the use of oxygen release to control the atmosphere during DISSUB conditions. Other DISSUB procedures and equipment were also evaluated, including survival rations and emergency lighting options. As a result of the SURVIVEX research, a new challenge has emerged—to mitigate the increase in ambient temperatures and resultant heat injury risk that occurred in both exercises. This was an unexpected finding—it had been expected instead that a DISSUB would encounter lower temperatures, increasing the risk of hypothermia.

NSMRL's work on submarine survival and escape is simply one facet of its efforts in the area of crew health and safety. The challenges posed by the submarine's unique environment and operating conditions place a premium on having a healthy and fit crew. The submarine atmosphere, for example, must be maintained and evaluated to ensure that it does not pose a potential hazard to the crew. As is well-known, there are automated systems to measure oxygen and CO_2 levels, as well as the concentrations of a few other compounds and elements, but the recycled nature of the atmosphere means that possible contaminants must be monitored on a long-term basis. Even normal items, such as paint, can give off harmful gases. The Submarine Atmosphere Health Assessment Program (SAHAP) addresses these issues. SAHAP has developed wafer-like sensors that measure the level of various possible contaminants during the course of a deployment. On return of the boat, the wafers are removed and analyzed, and the results reported to the boat. Since submarine sailors are continually in a closed environment, limits need to be set well below comparable OSHA standards for shore workplace environments. The Closed Living Space Environmental Concerns Working Group, another Navy-wide organization in which NSMRL plays a key role, determines acceptable limits for these contaminants. The ongoing measurements are supplemented by

analyzing more compounds during sea trials; techniques include utilizing vacuum bottles to draw air samples over a brief time. USS VIRGINIA, lead ship of a new class, will have her atmosphere tested during sea trials this summer to ensure that its new equipment and products pose no unusual problems.

Another unique aspect of the submerged submarine is the absence of sunlight. This can possibly lead to Vitamin D deficiencies during prolonged submergence. NSMRL has studied the effects and potential remedies. The natural solution, liberty in a tropical port, is often not possible; an alternative remedy may be as simple as periodic large doses of Vitamin D.

Another issue, not unique to submarines, is exposure to continuous low-level noise. Noise Induced Hearing Loss (NIHL) is the Veterans Administration's largest bill for service-related disabilities. To improve Sailor self-motivation to practice hearing conservation shipboard, NSMRL is developing a hearing loss simulator for the Office of Naval Research, to be used to demonstrate what the future will sound like to a Sailor who doesn't use hearing protection. It does not simply turn down the level, but shapes the frequencies according to the type of hearing loss that the Sailor has begun to experience. Knowing that you will not be able to understand phone conversations or appreciate music can be a powerful motivation to change behavior.

Early prediction of future hearing loss is also being studied at NSMRL, using Otoacoustic Emissions, minute sounds that the ear produces in response to external sound stimuli. Research conducted on aircraft carrier crewmembers provides early evidence that this technique may be able to indicate future hearing loss. If confirmed, the Navy would be able to provide hearing protection targeted to specific individuals, or to place them in a less hazardous watchstation. This technology could be particularly valuable for the Submariner, who is in a continuous low-level noise environment 24/7 while underway.

In the unforgiving undersea environment, 24/7 operations require a rested and alert crew. Normally, humans have a daily cycle of wakefulness and sleep, the Circadian Rhythm (CR), which is driven by the sun's passage. Submerged Sailors have no daily light clues to stabilize their CR. The current watch cycle of 6 hours on watch and

12 off often leads to a destabilized, free running CR, and the possibility of standing watch at a low point in the sleep/wakefulness cycle. Because the *day* is only 18 hours long, the CR pattern is constantly shifting, causing further loss of alertness—the equivalent of flying eastward through six time zones every 18 hours. NSMRL has been studying how new watch schedules that more closely follow a normal 24-hour day might work. Any potential change must not only help with the CR patterns for increased alertness, but must also accommodate all of the boat's operational requirements. A recent sea trial of an 8/16 schedule was conducted on USS MARYLAND (SSBN 738) with behavioral, physiological, and psychological measurements. While the data are still being analyzed, initial indications suggest that it improved overall alertness. As important perhaps was the crewmembers' reaction; they thought that it was much better—and that it didn't adversely impact their normal routine, operations, or drills.

Since the human element is the most important system on the boat, sailors selected for submarine duty, all volunteers, must meet high standards to be accepted. NSMRL has been evaluating suitability for submarine service since its inception; it is now mandated in the Navy's Medical Manual. Since 1986, NSMRL has been using a self-report psychological test, SUBSCREEN, to assess factors such as claustrophobia, suicidal ideation, depression, etc. Sailors who flag high on one of these factors are referred to the base clinic for psychological evaluation. Based on recommendations from this screening and evaluation, Submarine School command personnel make the decision to retain or release the individual. About 3 percent of the students are taken out of the force, saving both money and time. However, there are still a number of those remaining who are unsuccessful in their Navy career. They attrite for negative causes, are not promoted and don't finish their first enlistment. Using the database of 30,000 former and current Submariners, NSMRL determined that a subset of the SUBSCREEN test could predict which people were more likely to fall into the unsuccessful category. That information is now being used to see if early intervention during Sub School can help prevent this attrition.

The outcome of all the screening and health efforts is to assure that the Submarine Force has capable, high performing crews. NSMRL is also deeply involved with helping Sailors perform more

effectively by working on ways to facilitate the many submarine missions.

With the Global War On Terrorism (GWOT), the submarine mission has once again become focused on Intelligence, Surveillance, and Reconnaissance (ISR), sometimes involving Special Operations Forces (SOF). In fact, Virginia class and the new SSGN, a conversion of former Trident SSBN's, both had insertion of SOF as a primary consideration. NSMRL has been involved with divers and diver functioning since Dr. Bond's original SEALAB work. NSMRL is currently working on diver safety and guidance as well as operational issues.

Waterborne noise is a potential hazard to divers working with tools or nearby active sonar. Based on efforts during the recovery of USS MONITOR turret and USS ARIZONA preservation, NSMRL has developed a portable noise meter for Fleet use. Combined with guidance developed from years of measuring the effects of sound on the diver's physiological state, NSMRL constantly provides the Fleet with timely and accurate parameters for working with underwater tools. The same sonar bioeffects research is being used operationally in two ways. First, it is being used to test safety parameters for divers operating near the newly deployed SURTASS LFA sonar. Second, the inverse of protection is deterrence. NSMRL is the Navy and Coast Guard's lead for determining the potential physiological impacts of proposed diver deterrence systems. The years of developing techniques and conducting research on these factors will pay off in increased Submarine Force Protection. NSMRL's work with submarine SOF operations includes lockout procedures, diver recall, and diver communications as well as improved procedures and equipment.

All submarine missions, including SOF insertion, still call for the types of systems and procedures developed for obtaining and maintaining *situational superiority* at all times. This depends ultimately on command decision-making, a key focus area within Submarine Force Headquarters. NSMRL has studied situational awareness among submarine officers and is now working with Submarine Development Squadron 12 on projects to improve overall naturalistic decision making processes. The way to best display information for this type of decision making may be very different, since it requires rapid integration of multiple inputs to maintain

situational awareness. One example is the problem of coming to periscope depth in a multi-contact environment. NSMRL has addressed this in two ways. One, the Lab has developed, in conjunction with the Naval Undersea Warfare Center Newport Division, a unique signal processing and display technique for collision avoidance. It takes advantage of the human's binaural capability to compare different sounds in each ear. This approach, similar to the *cocktail party* effect that allows you to hear your name when it is mentioned in a noisy room, improves target detection by almost 7 dB, more than doubling the distance at which a contact can be acquired. Secondly, NSMRL and NAVSEA engineers have developed new noise canceling headphones to allow sonar operators to hear acoustic sounds much more clearly.

NSMRL in 2005 and Beyond

"Submarine life consists of a unique combination of environmental stressors. Submarine crews experience prolonged periods of time in a confined space underwater. Since the advent of the nuclear-powered submarine 50 years ago, the near total self-sufficiency of the submarine to create and purify its own atmosphere, distill water, and maintain climate control has increased submerged times far beyond those of its air-breathing diesel counterpart. Crewmembers work in the absence of day-night cues, and under conditions of disrupted sleep-wake cycles, sleep deprivation, varying noise levels, and atmospheric composition and pressure constraints. Most constraining, however, is the lack of habitable space – the person-to-space ratio is one of the highest in any extreme environment (Shobe, et.al., 2005).[12]

In the early years of the 21st century, NSMRL is as engaged in supporting the Submarine Force as it was at its inception. The challenges to submariners noted by CAPT Shilling and Mrs. Kohl in 1947 still pertain. NSMRL continues to excel in operationally relevant work on undersea sound and personnel selection issues; its efforts now include additional areas such as escape and survival, atmospheric monitoring, and crew performance. For these many years of achievements, NSMRL recently received its first Meritorious Unit Commendation, and has been recognized as DOD's First Choice for Undersea Biomedical Research. As leaders of a lean but amazingly dedicated, innovative and productive group of researchers

and support personnel, we have great confidence in Naval Submarine Medical Research Laboratory to continue the proud tradition that is our heritage. As we like to say, NSMRL does not make the Submarine… but it makes the Submarine Better. Pride Runs Deep at NSMRL!■

ENDNOTES

1. C.W. Shilling and J.W. Kohl, History of Submarine Medicine in World War II (Medical Research Laboratory, U.S. Naval Submarine Base New London, Report No. 112), 1947, p. 182.
2. Command Historical Report (OPNAV Report 5750.1), Naval Submarine medical Research Laboratory (NSMRL), 1987, p. 2.
3. Shilling and Kohl, 1947, p. 254.
4. Ibid, p. 253.
5. Command Historical Report, 1987, p. 2-3.
6. NSMRL "Bond" Chamber, from *Hyperbaric Medicine Today* 2001 Calendar, February page.
7. J.K. Herman, "Lab for the Silent Service," *U.S. Navy Medicine*, November 1981, p. 11.
8. Command Historical Report, 1987, p. 4.
9. Herman, 1981, p. 11.
10. Command Historical Report, 1987, p. 4.
11. An excellent summary of some of the lab's more recent accomplishments is Dr. Jerry Lamb and Joe DiRenzo's article, "A Little-Known Lab Makes a Big Impact," *Undersea Warfare*, Winter 2004.
12. K.K. Shobe, P. Benton, M. Bing, L. Crepeau, C. Duplessis, J. Dyche, D. Fothergill, W. Horn, J. Lamb, A. Quatroche and D.E. Watenpaugh, "Environmental, Physiological, and Psychological Challenges of Submarine Life," presented at The Society for Human Performance in Extreme Environments annual meeting, Janaury 2005.