Development of an Enhanced Underwater Navigation Capability for Military Combat Divers

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Abstract — Military combat divers conduct underwater navigation missions in conditions with extremely poor visibility. Critical to the success of these missions is accurate underwater navigation, as well as staying within closed circuit oxygen rebreather depth limits. Unfortunately, handheld or tactical board mounted compasses, depth gauges, and chronometers can become virtually useless in the zero visibility environment. This has been an ongoing and serious limitation to military combat diving operations.

Naval Surface Warfare Center-Panama City Division (NSWC PCD) is the U.S. Navy's leading laboratory for research, development, testing, evaluation, and technology transition of diving and life support systems, including diver visual display systems. Under a recent joint government development program, NSWC PCD developed a prototype enhanced underwater navigation system for military combat divers. The prototype comprises a micro display, optical lens, electronic compass, depth sensor, microprocessor, associated electronics, and battery integrated into an adjustable position optical display that is mounted to the side of a low volume dive mask. The system provides clear visual display of the diver's compass heading, depth, and swim time regardless of poor visibility conditions.

Divers can turn the system ON/OFF, adjust display brightness, use the stopwatch function, and lock their compass heading using the NAVLOK feature. When the NAVLOK button is pressed, the displayed compass heading is boxed, and a trackball icon appears to assist divers in staying on heading. The system operates on a single 3V lithium ion battery which provides 20 + hours of operation.

Joint service military divers evaluated the prototypes, conducting a series of underwater navigation exercises in both daylight and nighttime conditions. Participants strongly recommended rapid transition of this new underwater navigation tool to military production status.

This paper describes the technical and operational need for such a system by the combat diving community, specifics of the prototype design phases, results of in-water testing by joint service combat divers, and the rapid technology transition plan using a Cooperative Research And Development Agreement (CRADA) for bringing this much needed capability to the joint service military diving community.

Keywords— *head-up display, diving, military, underwater navigation*

I. INTRODUCTION

Military combat divers conduct underwater navigation missions in conditions with extremely poor visibility. Critical to the success of these missions is accurate underwater navigation, as well as staying within closed circuit oxygen rebreather depth limits. Unfortunately, handheld or tactical board (Figure 1) mounted compasses, depth gauges, and chronometers can become virtually useless in the zero visibility environment. As a result, there is an ongoing technical and operational need for an enhanced underwater navigation tool that can address these limitations.

Figure 1. Standard tactical boards used for underwater navigation

The Naval Surface Warfare Center-Panama City Division (NSWC PCD) is the U.S. Navy's leading laboratory for research, development, testing, evaluation, and rapid technology transition of diving and life support systems, including diver visual display systems. Under a recent joint government program, NSWC PCD developed a prototype enhanced visual display underwater navigation system for military combat divers to address this technical and operational need.

II. COMBAT SWIMMER NAVIGATION MASK (CSNM)

A. Prototype Description

Under the first phase of the joint government program, NSWC PCD developed a prototype Combat Swimmer Navigation Mask (CSNM) based on the standard U. S. Navy Rescue Diver mask.

The prototype was designed to provide a clear, visual display of the diver's magnetic compass heading, depth, and swim time regardless of poor visibility conditions. A high resolution, active matrix organic light emitting diode (AMOLED) micro display was used with a fixed position optical lens in the lower right corner of the mask. Electronic compass, depth sensor, microprocessor, associated electronics, battery, and control buttons were built into the left and right side of the mask frame. Additional miniature light emitting diodes (LEDs) were integrated inside the lower left and right side corners of the mask to provide additional navigation cues. (Figure 2).

Figure 2. CSNM Prototype

The display data layout is shown in Figure 3. This includes a digital compass display on top (in degrees), the diver's depth (in feet) in the middle line, and the swim time in the bottom line (minutes:seconds). The lower left side of the screen includes a remaining battery life icon. Over the compass heading are additional navigation icons.

Figure 3. CSNM Display Screen Layout

The diver is able to turn the system on and off, adjust the display brightness levels, track swim time, calibrate the compass, and navigate using the NAVLOK function. When the NAVLOK button is pressed, the selected compass heading is boxed, navigation and alignment icons are displayed, and the LEDs are illuminated. The diver can use the boxed

compass display, alignment icons, and LEDs (which alternately blink when the diver is +/- 5 degrees or more off his selected heading) to assist in underwater navigation. The diver can also turn the NAVLOK function off, and then reset it as often as required.

B. End User Evaluations

Joint service military divers evaluated the CSNM prototype using the U. S. Navy MK 25 (Drager LAR 5) Underwater Breathing Apparatus (UBA) in standard 2-man combat navigation teams (Figure 4).

Figure 4. Combat diver during daytime evaluations

Each team conducted a series of underwater combat navigation exercises performed in daylight and night conditions (Figure 5).

Figure 5. Combat diver during night-time evaluations

At the conclusion of the evaluation each diver was asked a series of questions from a Performance Evaluation Questionnaire (PEQ) in order to gather feedback regarding functional and operational requirements, system design, human factors interoperability, and changes required for continuing development of the enhanced underwater combat navigation capability.

Divers determined that the system should be redesigned as an external module mounted to a low volume dive mask with a flip-down/flip-up display, instead of integrated inside of a dive mask. Additional recommendations were to eliminate the LEDs, and to make the flip-down optical module align directly in front of the eye instead of in the upper, lower, or side position. Also, to reduce cost and eventually make the finished version affordable for dive commands, a low power, low cost micro display should be investigated. From the end users' input, NSWC PCD developed the Combat Diver Navigation Module (CDNM).

III. COMBAT DIVER NAVIGATION MODULE (CDNM)

A. Prototype Description

In the second phase of the joint government program, NSWC PCD developed the prototype Combat Diver Navigation Module (CDNM) based on feedback from joint service divers' evaluation of the previous CSNM system. This prototype was designed to provide the same clear, visual display of the diver's magnetic compass heading, depth, and swim time regardless of poor visibility conditions. The CDNM comprises a lower power passive matrix organic light emitting diode (PMOLED) micro display, plano-convex magnifying lens with red lens filter, upgraded 6-axis electronic compass, depth sensor, microprocessor, associated electronics, and battery integrated into an external housing mounted to the right side of a low volume dive mask with an adjustable position display. The 3-volt lithium battery provides 20+ hours of operation. The diver is able to turn the system on and off, adjust the display brightness levels, track swim time, calibrate the compass, and navigate using the NAVLOK function (Figure 6).

Figure 6. CDNM Prototype

The display layout provides the magnetic compass heading with larger numbers at the top of the display with an alignment mark above the compass reading. The lower right side can display diver depth in either feet or meters, the lower left side displays time in minutes and seconds, and the lower middle section displays the remaining battery life icon. The prototypes

used red lens filters to provide low light red characters (Figure 7) to reduce light signature and preserve operator night vision.

Figure 7. CDNM display screen layout

B. End User Evaluations

Joint service military divers conducted a series of expanded end-user evaluations using the CDNM prototype, U. S. Navy MK-25 (Draeger LAR V), and standard underwater navigation TAC-board in standard 2-man combat navigation teams (Figure 8).

Figure 8. Combat diver during CDNM evaluations

The evaluations comprised a series of underwater combat navigation exercises performed in daylight and night conditions which included performing a dog-leg underwater navigation swim. Each team would take a heading toward a target, submerge, and navigate to the target. Upon reaching the target the divers would reset the NAVLOK on a heading toward a second target, submerge and repeat this exercise. Upon reaching the last target divers would repeat the process during the return leg, switching roles as lead navigator.

Divers conducted the exercises using a standard tactical board for navigation, depth monitoring, and time; and then repeated the exercise using the CDNM prototype for navigation, depth monitoring, and time.

At the conclusion of the evaluations each diver was asked a series of questions from a Performance Evaluation Questionnaire (PEQ), providing feedback regarding final functional and operational requirements, system design, human factors interoperability, and any changes required for final development of a military production version CDNМ.

One hundred percent (100%) of joint service divers participating in the user evaluations rated the CDNМ as Good or Excellent in overall performance.

C. Recommendations

As a result of the successful end user test results, the Naval Sea Systems Command Supervisor of Diving briefed the CDNМ to the Department of Defense (DoD) Military Technical Acceptance Board (MTAB). MTAB representatives from the Navy, Marine Corps, Army, and Air Force

subsequently voted the CDNМ as a *Common Type* diving requirement for the joint military services.

Based on the positive feedback from the end users and the MTAB designation, NSWC PCD proposed a follow-on rapid transition-to-production project that would use a Cooperative Research And Development Agreement (CRADA) to partner with a commercial industry in order to accelerate final development, testing, and production of this much needed capability.

IV. CURRENT STATUS

NSWC PCD has entered into a Cooperative Research And Development Agreement (CRADA) with an industry partner to jointly develop a military production version CDNМ, manufacture initial pre-production units, and conduct end user testing. Anticipated completion is Fall of 2017.