INTEGRATION OF A SHIPBOARD SENSOR TRAINER INTO A COMBAT SYSTEM TEAM TRAINER

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ABSTRACT

The Navy has a longstanding commitment to improving combat readiness by providing sensor operator training aboard surface combatants. The AN/SQQ-89(V)-T() On-Board Trainer (OBT) provides a high-fidelity, front-end stimulation of the AN/SQQ-28 Sonobuoy Signal Processor, the AN/SQR-19 Tactical Towed Array System (TACTAS), and the AN/SQS-53 hull-mounted sonar.

The history of combat system team training has been marked by increases in the fidelity of training, and in the size of the combat team being trained. The Perry Class Pierside Combat System Team Trainer (Device 20B5) uses shipboard stimulation of sensors, communication systems, and fire control systems to provide a highly realistic training environment for all members of the FFG-7 combat team in the Combat Information Center (CIC) and the sonar room.

Integration of existing shipboard sensor training capability into team training systems can be expected to be of growing importance in the next decade. Device 20B5 is currently being modified to use the OBT for training of sonar personnel on Flight III guided missile frigates (FFG-36 through FFG-61). Integration of these trainers, purchased half a decade apart from different vendors by different procuring activities, provides lessons for the specification and system design of embedded trainers and team trainers to provide an open architecture capable of cost-effective growth in an environment of trainers provided by multiple vendors for multiple procuring activities.

INTRODUCTION

World events during the 1980's such as the Falklands War and the war in the Persian Gulf have underscored the need for navies to be truly combat ready or else suffer the consequences. Combat readiness is comprised of many things, such as: having enough quantities of the right types of ships, aircraft, weapons, stores of ordnance, support equipment, and personnel. It also involves maintaining equipment and providing sufficient logistical support. Effective strategy and tactics must also be developed and assimilated by all combat personnel. In this paper we are primarily concerned with the last of these: the need to train and retrain the shipboard combat systems personnel that must go in harm's way.

The threat that must be effectively countered is continually evolving. The general trend has been such that reaction times have had to be reduced, while at the same time larger numbers of coordinated air, surface, and subsurface threats must be dealt with. This has in turn led to more and more integration of combat systems equipment and the coordination of the people who man them, through the use of combat system teams. Combat system teams can only be effective if they achieve a sufficient level of proficiency in such skills as: communication, coordination, and decision making, along with the requisite equipment operator skills. Such proficiency is hard to come by and, once achieved, is easily lost if not practiced sufficiently. This need for continual practice is necessary, not only to maintain the team's cohesion, but to incorporate evolving tactics which strive to meet the continually evolving threat. As many elements of the combat suite as possible must be involved with this training. This has historically been accomplished with shore-based classroom trainers (which allow only a limited opportunity for dynamic team training, plus require that those being trained must be sent away from their warfighting stations) and fleet exercises (which are expensive and due to their complex nature in planning and coordination, cannot be performed frequently). Another approach has been the incorporation of shipboard device-specific trainers, either embedded inside the operational equipment or added on later as a separately connected device. A fourth technique has emerged on the scene: the use of a pierside training system connected to shipboard systems, allowing combat system teams to be trained while manning their stations. We discuss how these last two approaches are being combined into a single shipboard training system.

HISTORICAL BACKGROUND

On-Board Trainers

The U.S. Navy has been using on-board trainers since the early 1970's to provide a shipboard training capability. Table 1 shows the historical evolution of on-board trainers produced by Raytheon Company's Submarine Signal Division leading up to the AN/SQQ-89(V)-T(), and beyond.

The earliest systems were for at-sea sonar training on a single passive subsystem, using a single contact. Later systems incorporated dockside training capability with the addition of simulated background noise from the ocean and ownship. Though not as effective as our own capabilities, Soviet sound quieting technology has produced ever quieter submarines for well over a decade. Major Soviet advances in this area (through their own technological advances plus technology acquired from the West) during the 1980's has led to an increased interest in active sonar for Anti-Submarine Warfare (ASW). This interest is reflected in the use of active as well as passive contacts for recent sonar on-board trainers. Multiple simultaneous simulated contacts have become the norm. As shipboard sensors, displays, controls, and fire control systems have become more fully integrated over

TABLE 1. EVOLUTION OF DS1200 SERIES ON-BOARD TRAINERS

1974	DS1200	Single contact; Active/passive. For AN/BQS-13 Sonar. Development only.
1976	DS1210 AN/BQR-T4	Single contact; Passive; High fidelity. For: AN/BQR-21, AN/BQR-7, AN/BQR-15, and MK-113 Fire Control System. Fleet approved sonar trainer for SSBNs.
1980	DS1210 Modified	Single contact; Passive; High fidelity. For: AN/SQS-26CX, AN/SQR-18. Prototype; Installed on USS Hammond.
1981	DS1213 AN/BQR-T4 Modified	Single contact; Passive; High fidelity. For: AN/BQQ-5 (spherical, hull, and towed array) MK-117 Fire Control System. SSN On-Board Trainer.
1982	DS1240 AN/SQS-T5	Single contact; Passive; High fidelity. For: AN/SQS-53 MK-116 Fire Control System. For: CG-47 class. Dockside trainer with background noise generation and ownship as one contact.
1983	DS1255 MAST	Eight contacts; Active/passive; High fidelity. For: Support of surface ship or submarine training. Shore-based sonar trainer with background noise generation, ownship signature generation, and ability to support two different scenarios at one time.
1985	AN/SQQ-89(V)T()	Multiclass surface ship on-board trainer. Ten contacts; Active/passive; High fidelity. For: AN/SQS-53 series, AN/SQR-19, AN /SQQ-28. Includes background noise generation, ownship signature generation, and ocean simulation.
1986	TSMT-FES	Trident Sonar Maintenance Trainer, shore based. Modular system with 16-contact library. For: AN/BQQ-6 WLR-17 tactical systems. Provides: dual path propagation, background noise generation, ownship course/speed simulation, acoustic bathythermograph and depth/sound speed simulation.
1988	TOBT	Trident On-Board Trainer. 16-contact library; Active/passive. For: Trident SA, HA, TA, AE, and HF arrays. Modular system that provides: special sounds, active emissions signal to all arrays, and multipath.

the years, the use of a sonar on-board trainer has made possible the combined training of ever larger groups of shipboard personnel: sonar operators, sonar subteams, ASW subteams, and even combat system teams.

As technology evolves, making it possible to provide more capabilities in the same size or smaller packages, it is likely that the trend for higher fidelity in the simulation of contacts, background noise, and ocean propagation effects will continue. There will be more interest in including training for under-ice ASW, the use of active sonar tactics, and the coordinated use of air, surface, and subsurface ASW assets.

Pierside Trainers

Ironically, pierside trainers owe their genesis to a trainer developed for a U.S. Army surface-to-air missile, the Nike Hercules. AAI built this trainer, the AN/MPTQ-T1 (T1) in the late 1960's. It was a mobile 5-channel radar simulator used to train the radar operators who fired and controlled the missile in flight. Admiral Kidd was in attendance at a demonstration of this trainer in the early 1970's, and wanted to find out if such a system could be adapted for pierside use. A study was made to evaluate the necessary modifications to the T1. This resulted in two modified T1's being built for the Navy in the mid 1970's. These were used for interim pierside combat systems training for ships carrying the TERRIER and TARTAR missiles, and were designated AN/MPQ-T1(M). Meanwhile, the Navy continued to further define its needs for meeting its growing combat system training needs. This led to the development in the late 1970's for the Mobile Combat System Trainer, Device 20B4.

Four such units were built for the Navy and all are still in use. Device 20B4 is a completely mobile unit, and all equipment is contained in an air-conditioned semitrailer which has an air-cushioned suspension system. The trailer contains the instructor's console, computers, interface equipment, and test equipment. Device 20B4 is capable of interfacing with many types of shipboard radars, enabling Anti-Air Warfare (AAW) and Anti-Surface Warfare (ASUW) training on 187 different surface combatants in the U.S. inventory. There are seven radar channels available for interfacing with up to seven systems on board one or two ships, simultaneously. There are two Device 20B4 units on the east coast, one on the west coast, and one in Hawaii. These units regularly deploy to different sites, bring the training to the fleet.

As an extension of the 20B4 concept, the Navy awarded a contract in the early 1980's for the development of the Pierside Combat Systems Team Trainer, Device 20B5. Like its predecessor Device 20B4, this is a mobile unit housed within a semitrailer. Device 20B5 adds the ability to perform ASW and Electronic Warfare (EW) training (in addition to AAW and ASUW). Unlike Device 20B4, which is designed to interface with several types of shipboard radars regardless of ship class, Device 20B5 is intended to provide combat system team training for a specific class: the Oliver Hazard Perry (FFG-7) class. One or two ships can be trained simultaneously using the same or separate scenarios. Typically, two training exercises can be performed each day once the ship is interfaced and aligned (one to two days' effort). There are four of these units in operation, and like Device 20B4, they make regular deployments up and down each coast to provide training wherever and whenever it is needed.

On-board Trainers Versus Pierside Trainer

Both types of trainers allow training to be accomplished with the ship's own equipment. Thus the team members are trained while they man their normal duty stations, and this training can be scheduled whenever it is convenient to do so. Both types also emphasize stimulation of shipboard systems (usually as close to the equipment's front-end as possible). A simulated environment and threat(s) are then presented to the stimulated equipment for further processing in the normal way. On-board trainers have the advantage of allowing training to be accomplished both at sea as well as at pierside. Pierside trainers, on the other hand, are not as constrained as on-board trainers as far as size and weight are concerned. Therefore, they can provide greater fidelity of simulation/stimulation, more features, and larger capacities (simultaneous threats, contact libraries, ocean libraries, etc.). An on-board trainer must be capable of allowing real sonar contacts to appear and be processed normally when at sea so as not to jeopardize the ship's mission. The simulated contacts are injected "on top of" the real receptions. Pierside trainers must be capable of being quickly disconnected from the ship in case it must get underway on short notice.

TRAINER SYSTEM DESCRIPTIONS

Device 20B5

The Perry Class Pierside Combat System Team Trainer (PCSTT), Device 20B5, provides realistic training on board FFG-7 class frigates for the entire combat team in the Combat Information Center (CIC) and the Sonar Room. Device 20B5 uses front-end stimulation of all the ship's sensors, fire control systems, and navigation and communications equipment to provide a completely realistic environment for the combat team. Instruction is provided by each of three Fleet Training Unit (FTU) detachments (one on the west coast and two on east coast). Each of these units is made up of midgrade and senior grade specialists with extensive sea duty experience in their respective combat team roles. They provide pierside training as their primary role during their FTU tour of duty.

Device 20B5 is mounted in a van, which is parked on the pier near the ship to be trained (figure 1). The equipment in the van includes:

- A computer system that maintains the training environment and provides modeling of the combat environment. The computer system includes operator consoles, moving-head discs, a tape unit, and a line printer.

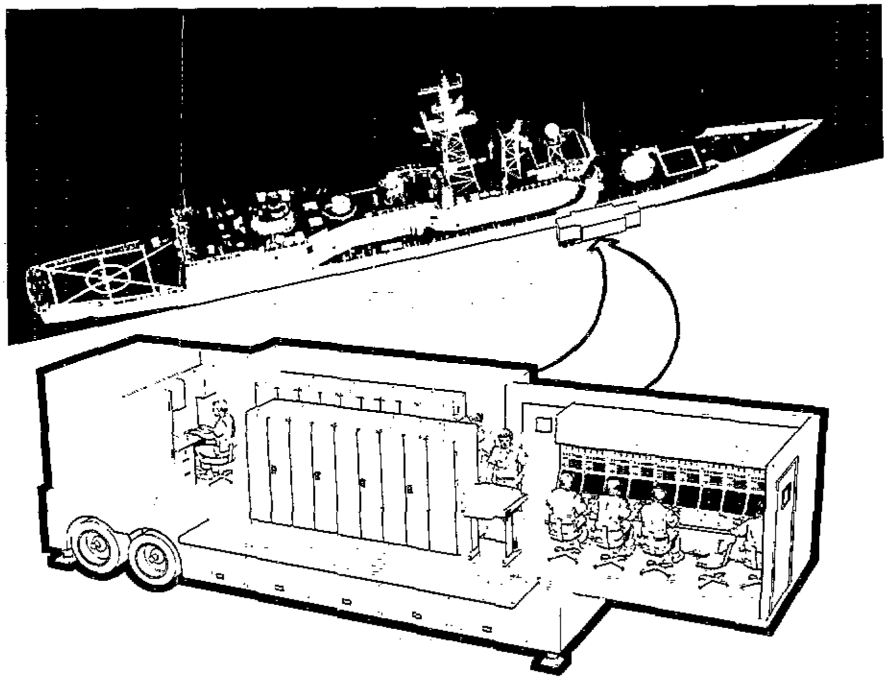


Figure 1. Device 20B5 Physical Configuration

- Five instructor consoles that allow members of the training unit to control the training problem, and to roleplay friendly and hostile platforms. The instructor consoles include communication equipment that stimulates the ship's communications system, allowing the instructors to roleplay radio communications from friendly platforms, to monitor the shipboard communication channels (including the sound-powered circuits), and to communicate with members of the training unit, who are deployed in CIC and Sonar, to serve as over-the-shoulder instructors.

- Simulation hardware that generates signals to inject into the ship's sonar systems: the AN/SQS-56 hull-mounted sonar and the AN/SQR-17 sonobuoy signal processor.

- Fourteen Carry-on Units (CU's) that are carried onto the ship and connected to the ship's equipment to provide the front-end stimulation. Each CU consists of one to three simulation boxes, zero to two power supply boxes, and an interface kit. Each box is rated as a two-man carry. Each CU is named for the system that it stimulates.

- Cables that connect the van to the CU's. A fiber optic cable connects the van to a CU on the ship. The fiber optic cable is 2000 feet long and is less than 0.3 inches in diameter. This small, lightweight cable is a key to the Device 20B5 capability for rapid deployment on and off the ship. The CU to which the fiber optic cable is connected is called the DDL CU, for Digital Data Link. The DDL CU converts the fiber optic signals to electrical signals and drives a daisy chain that connects all the remaining 13 CU's. In case of a CU failure, the input and output cables to the failed CU are disconnected from the CU and connected to each other to drop the failed CU from the daisy chain.

Simulation is used to artificially create the environment external to the ship (threats, media, etc. - see table 2). Stimulation is used to "place" the ship's systems inside this artificially created environment (table 3). The training missions can be under scenario control, or interactive, or both. In each case, control is exercised at the five Problem Control Consoles (PCC's), which accept control inputs and provide CRT displays of responses, status information, and graphic portrayals of the simulated tactical situation. These consoles are directly supported by the Main Computer (figure 2). Data describing the current simulated tactical environment is sent from the Main Computer to the Ownship Computer at a 1 Hz rate. It is here that the ownship weapons simulation is performed. The simulated tactical situation is transformed from an absolute definition to one that is relative to the ownship's position and heading. Control information is generated by the Ownship Computer and sent to the Acoustic Generator in order to synthesize the instantaneous dynamic signature for each simulated acoustic contact. Shipboard equipment specific control information is sent from the Ownship Computer over the fiber optic data link to each CU in turn. The CU's provide the detailed modeling for their respective shipboard equipment.

The simulated tactical situation is modeled as a 3-dimensional gaming area 2,000 nautical miles square, from a depth of up to 25,600 feet (depending on the ocean area selected) to an altitude of 200,000 feet. Up to 100 simulated targets can be active at once; thus, Device 20B5 provides combat system team training in a multi-

TABLE 2. SIMULATED ENVIRONMENT OF DEVICE 20B5

Shipboard Systems

MK-13 Guided Missile Launcher
MK-75 Gun (76 mm)
MK-15 Phalanx Close-In Weapon System (20 mm)
MK-309 Trainable Torpedo Tubes
MK-46 ASW Torpedo
RIM-66 SM-1 (MR) Missile
RGM-84 Harpoon Missile
SRBOC Chaff Launcher
SLQ-25 NIXIE Acoustic Decoy
PRAIRIE/Masker ASW Systems

Media

Ocean Area/Season
Wind
Clouds
Landmass
Sea State
Earth Curvature
Marine Life
Ocean Noise

Sensor Contacts (Friendly and Hostile)

Aircraft (including CAP and LAMPS helicopters)
Missiles (air-to-surface, surface-to-air, surface-to-surface, surface-to-subsurface, and subsurface-to-surface)
Surface Ships (military and commercial)
Submarines (nuclear and diesel powered)
RF Emitters (platform-based, weapon-based, and land-based)

TABLE 3. SHIPBOARD SYSTEMS STIMULATED BY DEVICE 20B5

Radars

AN/SPS-49 2-D Air Search (long-range search)
AN/SPS-55 Surface Search (navigation)
MK-92 Combined Antenna System (CAS) Search and Track
MK-92 Separate Target Illumination Radar (STIR) Track
MK-12 AIMS IFF/SIF

Sonars

AN/SQR-17 Sonobuoy Signal Processor Set
AN/SQS-56 Hull-mounted

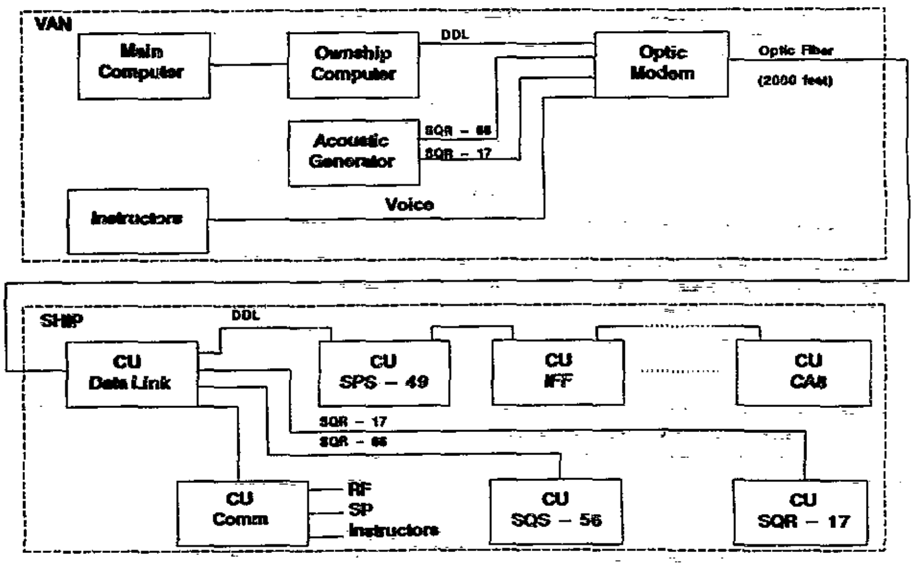
EW

AN/SLQ-32(V)2 Electronic Countermeasures Set

Communications

NTDS Link-14 (AN/UGR-9 Receive Only Telegraph Set)

Figure 2
20B5 Architecture



threat, multi-warfare environment. It has achieved a level of realism not previously attained by any other means except fleet exercises. An added benefit has been the ability to determine whether or not a ship's combat system is combat ready. This accrues since the various systems are being stimulated and must be capable of properly processing and otherwise responding to the signals being injected. Since Device 20B5 is capable of fully exercising the combat system, far beyond the normal day-to-day requirements placed on it (including the Daily System Operational Tests), it provides a good means for equipment readiness assessment.

OBT

The AN/SQQ-89(V)T() On-Board Trainer provides shipboard training, both pierside and at-sea, for the individual operator, the ASW team, and the combat system team of the DD-963, DDG-51, CG-47, and FFG-7 class ships. For the FFG-7, the OBT provides front-end stimulation of the LAMPS MK-III sonobuoy radio receiver, the AN/SQQ-28 sonobuoy signal processor, the AN/SQR-19 TACTAS, and the ship's navigation system to provide a completely realistic ASW environment.

The OBT equipment (figure 3) includes a control panel (unit 1) located in the Sonar Room to allow ship's personnel to perform the instructor exercise control function and the instructor over-the-shoulder function simultaneously. The heart of the OBT is the simulation unit (unit 2) located in the Radar Interface and Communication Equipment Room (RICER), the same compartment in which the Device 20B5 DDL CU is located. The OBT also has an interface to the MK-116 Underwater Fire Control System to allow the OBT to be controlled by the AEGIS Combat Training System (ACTS).

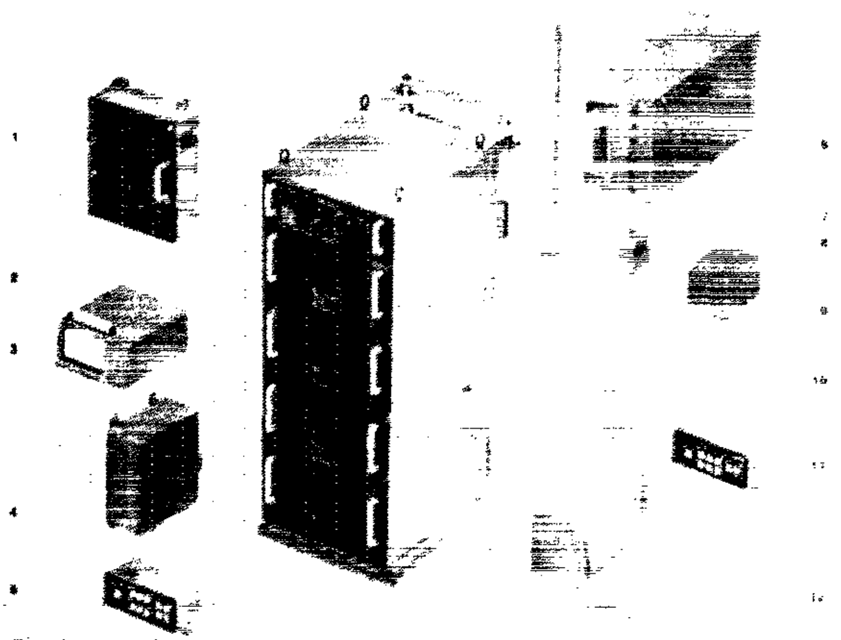


FIGURE 3

AN/ASQQ – 89(V) – T() ON – BOARD TRAINER PHYSICAL CONFIGURATION

1. Trainer Control Console (Unit 1)
2. Signal Generation and Processing Assembly (Unit 2)
3. Printer/Plotter (Unit 3)
4. Injection Assembly (Unit 4)
5. System Status Assembly (Unit 5)
6. RF Transmitter (Unit 6)
7. RF Antenna (Unit 7)
8. Helicopter Interface Assembly (Unit 8)
9. Helicopter Navigation Simulation Assembly (Unit 9)
10. Maintenance Assit. Modules Storage (Unit 10)
11. Remote System Status Assembly (Unit 11)
12. Scenario Input Computer (Unit 12)

INTEGRATING THE OBT WITH DEVICE 20B5

The FFG-7 class incorporates systems not commonly found on other U.S. combatants (e.g, the MK-92 fire control system and the MK-75 gun). As a result of this, there was no "school-house" training available for these systems. Device 20B5 was the solution to this dilemma, by virtue of the fact that training is provided in all weapon systems of the FFG-7 class. Due to this comprehensive scope, Device 20B5 has provided the best team training available. During a pierside training mission, anywhere one looks in CIC or Sonar everything looks real; all displays, indicators, etc. appear as they would during an actual engagement.

The inclusion of the AN/SQQ-89(V) sonar suite (rather than the AN/SQR-17 system) on FFG-36 and subsequent ships of the class presented a problem: Device 20B5 provided no capability for stimulating either the AN/SQQ-28 sonobuoy processing system nor the AN/SQR-19 TACTAS. Thus, on these ships, everything in CIC appears real but only the AN/SQS-56 presentations and responses in Sonar were realistic. By combining the AN/SQQ-89(V)-T() with Device 20B5, these shortcomings were overcome. Now all ships of the class can receive the same level of combat system team training.

The two trainers are combined by having Device 20B5 stimulate the OBT, which in turn stimulates the AN/SQQ-89(V) in the usual way. The Device 20B5 modifications consist of additions to existing hardware and software to use the existing OBT MK-116 interface. These allow Device 20B5 to make effective use of the additional OBT capabilities such as additional sonobuoy types and LAMPS MK III flight crew training. The Device 20B5/OBT interface architecture is shown in figure 4. The Main Computer maintains the training environment with updates at a 1 Hz rate, maintains displays on the PCC's for the instructors, and processes control commands from the PCC's. The Ownship Computer converts the global training environment to the environment seen from ownship, models the sensors of ownship, and communicates sensor and weapon data over the DDL to the CU's. The Ownship Computer and the DDL also run at a 1 Hz rate. The Ownship Computer formats input and output messages for the OBT and transmits them at a 1 Hz rate over the DDL. The current SQR-17 CU is being modified to become the OBT/SQR-17 CU. The OBT/SQR-17 CU functions as a buffer between the Ownship Computer and the OBT, receiving and transmitting Ownship Computer messages at a 1 Hz rate required by the DDL, and receiving and transmitting OBT messages at the 1/4 Hz rate of the OBT. The OBT/SQR-17 CU design must support asynchronous communication since the Ownship Computer and the OBT do not have a common clock. The physical interface between the OBT/SQR-17 CU and the OBT is MIL-STD-1397 NTDS Type A. The OBT/SQR-17 CU will be located in RICER, immediately adjacent to the OBT Simulation Unit.

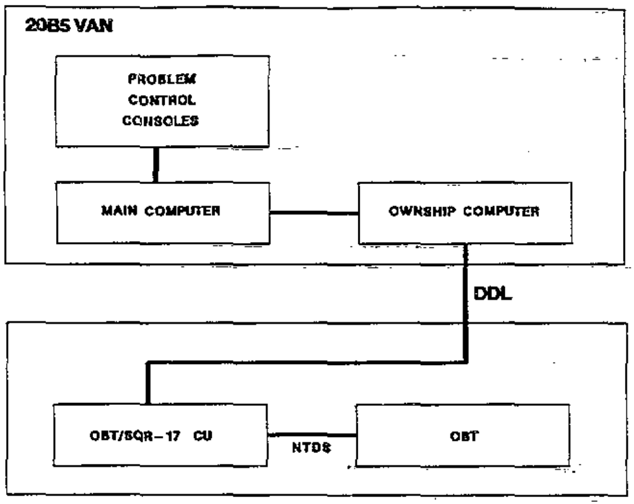


FIGURE 4

OBT/20B5 INTERFACE ARCHITECTURE

CONCLUSIONS

The U.S. Navy is procuring a large number of on-board trainers for several classes of ships. These need to be integrated in order to maximize their payoff in terms of resulting combat readiness. The question is not whether to integrate them, but how can it be accomplished most effectively? Our experience from the Device 20B5 program has provided some lessons learned which should prove helpful for future programs:

- Signal injection points for stimulated shipboard equipment should be specified such that they are easily accessible and as close to the front end as possible.

- A training mode control signal should be included in the design of shipboard equipment such that training signals can be accepted or rejected by a control at a remote location (e.g., Commanding Officer, Training Supervisor, Trainer Device Operator, etc.). Training signals should have the same capabilities for equipment stimulation as do real world signals. Training signals should be allowed in combination with real world signals. The station used for training problem control must be allowed to exercise appropriate control, as well as receive feedback to reflect the accomplishment of training.

- All trainers should be capable of responding to control by another trainer for larger scale training exercises. Provision should be made for the injection of control signals via ports designed into the trainer architecture. When being externally controlled in this fashion, provision must be made to relinquish any controls taken over by the controlling trainer. All future trainers should incorporate this open ended architectural design.

- There should be a review team whose job is to review all interface specifications, identify potential problems (before the installation of new or upgraded equipment is installed), and follow up on their resolution.

The Navy's surface warfare community's current "revolution at Sea" initiative has as its fundamental objective: put maximum ordnance on target. Anything which does not contribute to this objective is counterproductive. Frequent, effective training of the entire combat systems team in all aspects of their warfighting duties is one essential element of achieving this objective. This can best be accomplished by having an installed base of shipboard trainers, pierside trainers, and shore-based trainers which are capable of being used independently or as part of a combined system of interconnected trainers.

ABOUT THE AUTHOR

Dr. Douglas Feiock is a Principal Development Engineer with AAI Corporation, in the Training and Simulation Division. He is currently the Program Manager for 20B5/OBT Interface to add AN/SQQ-89 training capability to Device 20B5. He holds a PhD in Physics from Johns Hopkins University. He was the Senior Design Analyst for the Pierside Combat System Team Trainer, Device 20B5, responsible for the completion of hardware-software integration (HSI) of Device 20B5 acoustics, and for Government in-plant acceptance testing of the development unit. In earlier associations, he was the Manager of Lottery Software for General Instrument Corporation. He is affiliated with the American Physical Society and with Sigma Xi; Scientific Research Society of North America. Dr. Feiock has written over twenty papers/articles on high energy particle physics in international journals and conference proceedings.