

ASW SIMULATION - PAST/PRESENT/FUTURE

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ABSTRACT

Realism in presentation of visual and aural displays is the key to effective antisubmarine warfare (ASW) training. Early ASW trainers were forced to make compromises in realism and to make extensive use of operational equipment to provide adequate training. The generation of ASW trainers currently being procured offers vast improvement in display realism by making use of the explosive growth in computer technology and high-resolution graphics systems. Future trainers promise table-top, part-task trainers to provide instruction at the unit level and operator and team tactics trainers with the realism of the operational equipment without the associated cost. The high cost of operational equipment makes the use of stimulation prohibitively expensive for large tactical team trainers. Team tactics trainers are using simulation of the sonar displays on commercial graphics systems. Commercial graphics systems are also being used in the development of low-cost table-top trainers. Research is contributing to future trainers that will close the gap between the simulator and the stimulation of operational equipment, with look-alike consoles that will provide both the appearance and the features of the operational equipment. This paper not only describes the development of ASW trainers from the earliest concepts, but also presents current research leading to significant advances in the realism of simulated ASW displays.

INTRODUCTION

Anti-submarine warfare (ASW) training encompasses the gamut from individual operator to multi-ship team tactics training. The methods used in generation of the ASW displays for training range from use of tape recordings of actual sonar contacts to generation of the entire tactical situation from mathematical models. The method selected for a given training application depends upon the realism required for training, the interaction between the trainee and the tactical situation, and the limitations imposed by cost and other considerations.

The key to effective ASW training is the presentation to the students of a realistic display of what the student would observe in the real world. In most cases, this requires a display on a cathode ray tube (CRT); however, some sonar sets use electrographic recorders to produce a hard copy. There are three basic methods for generating the information needed to produce the displays necessary for ASW training.

METHODS FOR GENERATING ASW DISPLAYS

ACOUSTIC TAPE RECORDING

Acoustic recordings provide an excellent source of data for generation of high fidelity sonar displays for operator training. The use of acoustic recordings played back through the operational equipment provides a means of training sonar operators in passive acoustic analysis on the job and in the schoolhouse. However, the use of recorded contacts for training is limited to situations where a "canned" scenario is acceptable. In training situations where there is interplay between the target and the trainee (such as tactics training) taped contacts cannot satisfy the training requirement.

One of the drawbacks in the use of acoustic tapes is the limited availability of actual contacts having the features desired for a specific training objective. A large number of examples are required in order that the student will not be familiar with the whole library and thus prone to use sight recognition instead of analysis.

MATHEMATICAL MODELING

Mathematical modeling of the target characteristics, the ocean environment, and the signal processing characteristics of the sonar set is an alternative method for generating ASW displays. This method provides the flexibility required for tactical team training and does not require the use of operational equipment. However, it requires accurate modeling of the signal processing performed in the sonar set, including updating the model each time the sonar set is modified.

STIMULATION

The need for modeling of the sonar set can be eliminated by modeling only the target and ocean characteristics and using this to create an acoustic signal to be used as the input to the operational equipment. This method is particularly applicable to organic training, where the stimulator can be built into the operational equipment.

COMBINATIONS OF METHODS

The three methods described may be combined in various way to provide the display fidelity needed for a particular training application. For example, stimulators often use recordings of ocean noise instead of generating the noise mathematically. A particularly useful combination is the use of a stimulator to generate tape recordings of simulated acoustic contacts.

This generation of synthetic acoustic tapes from mathematical models provides a method for supplying the large number of tapes needed for training and also permits definition of specific training scenarios.

CURRENT TRAINERS

Current trainers use all of the methods described above to provide the training environment. The trainers described below are representative examples of the different applications in ASW training.

SIMULATORS

The earliest generation of trainers that will be described are those developed in the 1960's for operator and team training. These trainers used simulated shipboard equipment with the display contents generated by computer implemented mathematical models.

SURFACE SHIP ATTACK TRAINER, DEVICE 14A2. Device 14A2 duplicates the physical configuration of major operational compartments and equipments of surface ship ASW attack weapons and simulates their functional operation and responses such as target detection, fire control solution, and weapon launching and tracking. Typical training problems include target acquisition, tracking, weapon engagement, firing, and hit evaluation.

In addition to a simulated radar system, fire control system, position keeping system, launcher Captain's control panel, and position indicator, Device 14A2 has several simulated sonar systems which can be used as part of the team training equipment or as stand-alone sonar operator trainers. These sonar operator trainers are the following:

- SQS-23B Sonar Operator Trainer, Device 14A2
- SQS-26CX Sonar Operator Trainer, Device 14E19
- SQQ-23 (PAIR) Sonar Operator Trainer, Device 14E24
- SQS-35 Sonar Operator Trainer, Device 14E23

The SQS-23B Sonar Operator Trainer is a part of Device 14A2. This trainer can be used with the rest of Device 14A2 for ASW team training or used separately as an operator trainer. Devices 14E19, 14E23 and 14E24 are designed to operate in an independent mode for training sonar operators in the detection, acquisition, classification and tracking phases of ASW. In addition to this stand-alone capability, these devices may be operated in a joint mode with Device 14A2.

ASW COORDINATED TACTICS TRAINER, DEVICE 14A6. Device 14A6 simulates 36 individual command centers of various ASW mobile units to provide a synthetic ASW environment within which key ASW personnel can practice collecting and evaluating ASW information, making decisions, and implementing decisions based upon this

information. Eighteen of the command centers are configured to simulate destroyers and submarines. One command center simulates an ASW carrier and one simulates a flag plot. Sixteen command centers are available for use as land-based patrol aircraft, carrier-based ASW aircraft, or ASW helicopters.

STIMULATORS

The more recent trainers use operational equipment stimulated by synthetically generated acoustic signals. The use of stimulation instead of simulation resulted from (1) the difficulty in simulating the characteristics of the early passive sonar signal processors, (2) the development of digital techniques such as slip sampling [1] for generation of acoustic signals, and (3) the improvement in digital computer capability over that available in the early 1960's. The following trainers are examples of systems that use stimulation of operational equipment to provide training.

SQR-17A SONAR OPERATOR TRAINER, DEVICE 14E27. Device 14E27 is part of the 14A2 suite, but the trainer differs from the other operator trainers in the suite in that the SQR-17A is a passive sonar. The 14E27 uses a stimulator to generate acoustic signals for input to an operational SQR-17A.

P-3C, AQA-7 SONAR OPERATOR TRAINER, 14B44. Device 14B44 consists of a Digital Acoustic Signal Generator (DASG) used to stimulate two AQA-7 Acoustic Processors. The 14B44A trainer has 6 training stations for sensor operators, the 14B44B has only two.

S3A WEAPONS SYSTEM TRAINER, DEVICE 2F92A. Device 2F92A is a flight and tactics trainer that uses both simulation and stimulation to train S3A crew members in a realistic ASW training environment. Flight training is performed in a cockpit replica mounted on a motion platform. Tactics training for pilot, copilot, TACCO, and SENSO is performed in a tactics compartment on the equipment floor. The TACCO, SENSO, pseudopilot and pseudocopilot stations provide the tactics functions of the equivalent stations on the S3A. The ASW portion of the trainer uses stimulation of operational equipment to provide realistic displays for training.

S3A TACTICS TRAINER, DEVICE 14B50. Device 14B50 provides comprehensive initial and refresher training for S3A crews to develop increased proficiency in performing the assigned missions of the S3A aircraft. This trainer provides the tactical portion of Device 2F29A.

TAPE-BASED TRAINING SYSTEMS

The primary source of the tape recordings used in training are reproductions of actual acoustic contacts recorded at sea. Synthetic generation of acoustic tapes by computer-controlled stimulators provides acoustic tapes to supplement those available from actual contacts. More important, it allows scenarios to be constructed to fit the training curriculum. The synthetic generation of acoustic tapes has enabled the use of tapes for training

to remain a viable method of training in applications where the use of "canned" scenarios is acceptable. In addition, synthetic acoustic tapes provide a means of providing advanced signature prediction examples based upon intelligence data on new threats.

NAVAL ACOUSTIC SENSOR TRAINING AIDS DEPARTMENT (NASTAD). NASTAD, a department of the Naval Education and Training Support Center, Pacific, is the agency responsible for production and distribution of training tapes. NASTAD collects and maintains a library of acoustic raw data and provides minor support to Naval schools, fleet units and R&D projects as directed. The training materials provided include, in addition to submarine raw acoustic data for classification training, tapes for aural listening, turn-counting, active sonar, DIFAR, and tracking.

DIGITAL ACOUSTIC SENSOR SIMULATOR (DASS). The DASS is a stimulator developed by the Naval Surface Weapons Center (NSWC). It uses a combination of UYS-1 Advanced Signal Processor (ASP) to perform an inverse FFT and a generalpurpose digital computer for problem control and ocean modeling. The DASS uses recorded ocean background noise added to the synthesized target signals. The simulated targets being used are modeled on DASS from real targets that have been detected and recorded by the fleet and have been researched and analyzed by various Navy organizations, including NISC, LANTFAST, and PACFAST (Atlantic and Pacific Forward Area Support Teams) as well as Fleet commands. The Naval Intelligence Support Center (NISC) and Defense Intelligence Agency (DIA) publications are used by the DASS programmer/ analyst in determining relationships, bandwidths, and frequency-line instabilities of the various components. Once research is completed, the various target parameters are converted to DASS command language for target generation. Synthetic tapes produced by the DASS are used in the training systems described below.

DEPLOYABLE ACOUSTIC READINESS TRAINING SYSTEM (DARTS). The DARTS is a training system based upon synthetic tapes used to drive operational equipment. The simulation tape used for DARTS contains (1) acoustic data for simulated multiple RF sonobuoy channels of real-time acoustic contacts, (2) an instructional channel providing the operator in a non-assessment mode with specific direction and guidance, and (3) an assessment voice track providing routine cues from the Tactical Coordinator (TACCO), leaving the operator to perform his duties for the purpose of assessment. The program addresses current and projected VP squadron training needs. It encompasses all phases of passive sonar prosecution and is being expanded to include active sonar. When available and suitable for training, real target recordings and data may be used in creating training material.

SURFACE ASW OPERATIONAL READINESS ASSESSMENT AND TRAINING SYSTEM (ORATS). The ORATS is a shipboard system that is used for training sonar, fire control, and CIC personnel. The system stimulates all current systems including AN/SQR-17 (LAMPS MK-1), AN/SQR-18A, and NTDS.

SUBMARINE OPERATIONAL READINESS ASSESSMENT TRAINING SYSTEM (SORATS). The SORATS is used on-board all SSN and SSBN submarines for individual and team training of sonar and fire control operators.

AVIATION ANTI-SUBMARINE WARFARE BASIC OPERATOR TRAINER (AAWBOT), DEVICE 14D1. Device 14D1 uses a combination of tape recorders and signal synthesizers to train students in rudimentary acoustics, MAD and active sonar principles. The passive acoustic training portion uses the UYS-1 Advanced Signal Processor programmed with P-3C weapon system processing programs. The AAWBOT can train up to 36 students at one time in six training groups. The resulting acoustic displays provide the same quality as video displays in ASW aircraft. Contributing to the relevance of the training is the ability to use the latest operational tapes as well as simulated tapes produced by the DASS. Since the trainer is not dependent on the modeling of ASW targets, students can learn to recognize new signatures as soon as they are available rather than wait for a less realistic computer simulation to be developed. The system can use sensor data recorded from any air, surface or sub-surface acoustic source including sonobuoys, hull mounted arrays, towed arrays and fixed sonar sensors. Present processing options are typical of ASW aircraft capabilities. In addition to high fidelity acoustic training, the AAWBOT provides basic training on four other sensor types: radar, electronic support measures (ESM), dipping sonar and magnetic anomaly detection (MAD). Each is implemented with a complete computer model requiring no external stimulus.

FUTURE TRAINERS

The next generation of trainers will use the improvements in computer capability to implement the basic approaches described above. Mathematical modeling will be improved by (1) a standard target data base and (2) a standard ocean model. This will eliminate the need for development of a new ocean model and target data base for each trainer. In addition, the trainers will take advantage of improvements in computer and high resolution graphics technology to provide greater realism, lower cost, and the ability to update the system capability in a modular fashion.

STANDARD DATA AND MODELS

Standard data and models are being developed to eliminate the need for re-creation of models and data for each trainer and to provide uniform results from similar trainers.

COMMON ACOUSTIC TARGET MODEL DATA BASE (CATMDB). The CATMDB development is a joint effort by Navy activities requiring such data on a continuing basis. This data base, as a common source, is intended to support Navy needs in acoustic target simulation modeling for training device and operational equipment research, development, test, evaluation, and long term testing/training scenario applications. The Naval Training Equipment Center, Naval Underwater System Center-New London Laboratory,

the Naval Surface Weapon Center-White Oak Laboratory, the Naval Air Test Center, and the Naval Intelligence Support Center have been principal participants in the data base content/format development. The CATMDB describes those acoustic intelligence (ACINT) parameters considered to be necessary for developing useful ASW simulator/stimulator targets. All of the parameters described in the data base may not be available for a given target.

STANDARD OCEAN MODEL (SOM). The customary method of acquiring ocean models for trainer applications has been to place the requirement on the trainer contractor, resulting in a new and different model in each trainer. This practice has undesirable consequences for ocean model life cycle costs. It leads to repetitive contractor design, development and integration efforts and results in increased trainer cost to the Navy. Software maintenance of multiple independent ocean models is unnecessarily complicated and costly. Configuration management of multiple models and control over individual model upgrades is complicated and difficult.

More important, the lack of commonality between models in different trainers results in differences in simulation results. In situations where two or more sonar operator trainers have been interconnected to provide team training, disagreement in propagation loss predicted by the different ocean models has resulted in conflicting detection ranges. In addition, the different models produce inconsistent results compared to the detection ranges estimated by the Navy briefing packages of the various ASW prediction systems.

The Naval Training Equipment Center has initiated the development of the SOM in order to avoid the disadvantages of multiple ocean models. This provides a one-time model development, eliminating future duplication of contractor effort and producing a net savings of both development and life cycle support costs [2]. Configuration management is simplified and centralized, resulting in greater control over model evolution and allowing an in-house ocean model baseline and testing capability. Designed and intended for use in all types of ASW training devices, the SOM uses standard Navy models to generate consistent, reproducible results. The SOM will be provided as Government Furnished Information (GFI) to trainer contractors. The first use of this model is currently planned for Device 14A12, Surface ASW Training System.

DEVICES BEING DEVELOPED

The high cost of operational equipment makes the use of stimulation prohibitively expensive for large tactical team trainers. Trainers like the 14A12 Surface Team Tactics Trainer and the 20A66 Multi-Ship Team Trainer are using simulation of the sonar displays on commercial graphics systems.

SURFACE SHIP ASW TRAINING SYSTEM, DEVICE 14A12. Device 14A12 will serve as a replacement for Device 14A2. This new trainer will use a

unique computer architecture based upon distributed processing and local area networking to provide a simulation of any of 14 different ship configurations for ASW single-ship tactical team training. The major computational components are 26 general-purpose consoles that simulate sonar, radar, fire control, EW and CIC units. The six-console sonar room will simulate any of thirteen different sonar systems depending upon the configuration of the ship being represented.

TACTICAL TEAM TRAINING SYSTEM, DEVICE 20A66. Device 20A66 will provide training to battle group commanders and command personnel involved in a multi-unit, multi-threat environment. Like Device 14A6, which it replaces, Device 20A66 will use simulation of the command centers to provide a synthetic ASW environment within which key ASW personnel can practice collecting and evaluating ASW information, and making and implementing decisions based upon this information. The functional characteristics of this trainer are now being developed.

RESEARCH INITIATIVES

The Naval Training Equipment Center is pursuing a research program that will narrow the difference between the ASW display seen by the operator on the job and the ASW display produced by simulation. Look-alike consoles will provide both the appearance and the features of the real hardware, and mathematical models will be developed to provide exact replication of the ASW displays. This will be supported by use of optical storage of digital data for modeling and acoustic signals to reproduce realistic ocean, target and biological noise. Advances in computer technology will make significant advances in realism practical. The result will be trainers that offer better training at a lower cost, a cost that will allow for wide distribution of such training systems to fleet units and reserve components.

ASW SIMULATION RESEARCH FACILITY

The key to the research being performed is the Anti-Submarine Warfare Simulation Research Facility. This facility is the tool necessary for development and evaluation of new ASW training concepts and methods. It provides a means for implementing various ASW stimuli used for training in order to allow users to judge the effectiveness of different techniques.

Hardware available for ASW simulation research consists of a VAX-11/730 digital computer system, a PDP-11/23 computer system, high-resolution graphics display systems, an electrographic recorder, and an AQA-7 Sonar Signal Processor. Expansion planned includes an array processor, instrumentation tape recorders, video and audio equipment, and an acoustic stimulator. The ASW Research Facility is currently being used to generate various ASW displays for evaluation. One of the more important system capabilities is generation of LOFARGRAMS from acoustic tape input, from preprocessed digital data, and from mathematical models of targets and ocean. The system is currently being used for development of display methods for LOFARGRAM training and for development of a standard ocean model for ASW training.

TABLE-TOP TRAINERS

The development of methods for low-cost table-top trainers for Passive Acoustic Analysis (PAA) is dictated by the need for both initial training and continuing refresher training in this volatile skill. The state-of-the-art in computers and graphic systems supports the development of a trainer that produces the high resolution displays of operational equipment, supports a computer-assisted instructional (CAI) system, provides the portability necessary, and meets the low cost prerequisites for wide distribution to multiple fleet units and reserve components.

The need for low-cost table-top trainers for PAA is being addressed by the development of a research gram analysis proficiency trainer for the AN/SQR-18A sonar operator. The trainer is compatible with Computer Aided/Managed Instruction controlled by a microcomputer, and will be portable and capable of operation on board ship. This development includes a graphics display capability using high-resolution raster scan commercial equipment. The display software provides dynamic grams based upon acoustic input data. The acoustic data are processed off-line to provide prestored data to be used in the trainer.

The research effort will extend the present capability to generate linear LOFARGRAMS to other ASW displays, provide synchronized audio output, and investigate improved methods of implementation such as digital/audio videodisc storage.

MATHEMATICAL MODELING

Mathematical modeling of the external environment and the characteristics of the operational equipment is necessary for both simulation of ASW displays and stimulation of operational equipment. Use of models reduces the dependence on the use of GFE in trainers and facilitates full freeplay in conducting the training exercise. Modeling of the external environment (primarily ocean and target characteristics) is necessary for both simulation and stimulation. In addition, simulation of ASW displays using commercial hardware requires mathematical modeling of the signal processing characteristics of the operational equipment.

The purpose of further research in mathematical modeling for ASW training is to (1) improve realism and (2) provide standardization. The long-range goal is to allow simulation to match the realism of acoustic tapes used to drive operational equipment. Immediate goals are the development of a data base of sonar system characteristics and a standard mathematical model for target implementation. The standard target model will use the parameters in the CAMTDB as source data. A significant byproduct of this effort is the capability to predict new threat signatures.

ACOUSTIC TARGET GENERATORS

Acoustic target generators are necessary for stimulation of operational equipment and for the creation of synthetic acoustic tapes. The development of improved methods of stimulation supports existing trainers and the future development of organic/embedded training systems. The addition of a stimulator system to the ASW Simulation Research Facility will support improvements in the mathematical modeling for acoustic target generation and will contribute to development and evaluation of new methods for creating acoustic signatures.

LOOK-ALIKE CONSOLES

The table-top trainer offers a method for training basic techniques like PAA, but these trainers using commercial graphics displays do not provide training in all of the operational features of the actual equipment. The student learns methods, but not the operation of knobs and switches. The present method of teaching the sonar technician to operate the actual equipment is by stimulation of that equipment, a very expensive method that severely limits the number of operator trainers available. The expansion of the table-top trainer to provide many of the features of an operator trainer offers a greater availability of trainers at a fraction of the cost of operational equipment.

The technique for providing a look-alike console is to enclose the table-top trainer described above in a case that looks like the operational equipment. This combination gives the trainee a console that has the features of the operational equipment with the realistic displays provided by the off-line processing of real data. It is estimated that such a trainer can provide 80 percent of the operator training required at less than one one-hundredth the cost of the operational equipment. This type of trainer can provide all of the instructional features supported by the table-top trainer.

INSTRUCTIONAL SYSTEMS

Instructional systems for PAA are being investigated in order to determine appropriate instructional strategies and to evaluate the effectiveness of the different strategies. Previous studies have attempted to identify many of the skills and knowledge required in PAA. However, issues regarding signal monitoring performance such as the perceptual skills and methods required to improve these skills, the enhanced vigilance and attention span required by operators, and new instructional strategies to overcome old deficiencies, have not been resolved.

Software will be developed to allow the comparison of training effectiveness using different instructional strategies and trainer hardware characteristics. An overall training effectiveness evaluation will be based upon variables such as (1) student rate of learning, (2) performance accuracy, (3) transfer of performance, and (4) retention.

SUMMARY AND CONCLUSIONS

This paper has presented an overview of the techniques used in ASW simulation and described some of the existing trainers, the trainers being developed, and the research initiatives being undertaken to improve ASW training. The future generation of trainers should take full advantage of the advances in computer technology and high-resolution display systems. The research initiatives will lead to improved training in both more realistic displays and replication of real-world conditions. More important, the development of table-top trainers will provide a low-cost training capability that can be made available in the schoolhouse and to fleet and reserve units. The result will be more training opportunities for new operators and a chance for experienced operators to refresh and hone their previous skills.

Look-alike consoles will provide the capability to train operators without the use of costly operational equipment. The use of simulated ASW consoles rather than expensive operational equipment will lead to improvement in instructional systems. The simulated console provides feedback about operator response that cannot be obtained from operational equipment. This information, combined with new instructional techniques derived from research, will provide self-paced instruction and automatic student evaluation and record keeping. The result will be better-trained operators who retain their skills.

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