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T AND E GUIDELINES ASW SYSTEMS

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T&E GUIDELINES ASW SYSTEMS

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FOREWORD

This report is an outgrowth of the work of the Defense Science Board Task Force on Test and Evaluation, and the checklists herein have been derived from the study of past major weapon system programs.

The T&E expert in reading this volume will find many precepts which will strike him as being too obvious to be included in checklists of this type. These items are included because examples were found where even the obvious has been neglected, not because of incompetence or lack of personal dedication by the people in charge of the program, but because of financial and temporal pressures which forced competent managers to compromise on their principles. It is hoped that the inclusion of the obvious will prevent repetition of the serious errors which have been made in the past when such political, economic and temporal pressures have forced project managers to depart from the rules of sound engineering practices.

In the long run, taking short cuts during T&E to save time and money will result in significant increases in the overall costs of the programs and in the delay of the delivery of the corresponding weapon systems to the combatant forces.

T&E GUIDELINES FOR ASW SYSTEMS

The checklist items presented here are specifically applicable to ASW testing and evaluation. It is suggested that the user of this volume also refer to the Report of the Defense Science Board on Test and Evaluation which contains general checklist items also applicable to this system T&E program.

In the utilization of checklists on ASW programs, due regard must be given to the fact that ASW encompasses the use of a great many different kinds of systems and subsystems. A partial list follows:

Sensors

- Acoustic, both active and passive
  - Arrays
  - Sonobuoys
  - Sonars
- Electronic
  - Radar
  - ESM
- Magnetic

Platforms

- Surface Ships
- Submarines
- Fixed wing aircraft
- Helicopters

Command and Control Systems

Weapons

- Depth Charges
- Rocket-thrown torpedoes
- Air launched torpedoes
- Ship and submarine launched torpedoes.

Where possible, the particular class of system/subsystem to which the statement or item is applicable has been specified. However, in cases where not specified, reader interpretation is expected. Also, the reader should review other specific weapon checklists as appropriate to the ASW program under consideration (i.e., aircraft, ships, etc.).

The checklist items presented here are organized into time phases of the acquisition process oriented to the DSARC cycle. The checklists cover various aspects of the major activities that should be underway during a given time period. Hence, a checklist might cover the (1) evaluation of work that occurred in the previous phase, (2) conduct of tests planned in in the previous phase and executed in the subject phase, and (3) plans and other preparatory actions for test schedules to be conducted in a subsequent phase. For reasons such as this, items on some subjects, such as development test plans, may appear in more than one phase. In addition, since the Services and the DSARC have flexibility in deciding how rapidly to progress in the validation phase, there may be cases where the Request for Proposals (RFPs), proposal evaluations, source selections, or contract negotiations may occur after the DSARC approves full-scale development instead of before. For this reason, it is recommended that previous checklists in the Validation Phase be reviewed when entering the Full-Scale Engineering Development Phase. The following are the phases used in this report.

CONCEPTUAL PHASE

The checklist items in this phase are for guidance in evaluating T&E activities during the Conceptual Phase of the acquisition of the system. This phase (of research and exploratory development) precedes the first DSARC milestone and is focused on the development of a weapons system concept that offers high prospects of satisfying an identified military need.

Although not called out in DoD Directive 5000.1 specifically, the objectives of this phase should be:

1. To verify that there is a military need for the proposed system.
2. To determine whether or not there is a sound physical basis for a new weapons system.
3. To formulate a concept, based on demonstrated physical phenomena, for satisfying the military need.

4. To determine whether or not the proposed solution is superior to its competitors in terms of potential effectiveness, probability of success, probable cost, impact on the U.S. military posture, and development risks.
5. To analyze the technology outlook and the military needs to determine whether or not it is better to start advanced developments now rather than to wait for future technological improvements.
6. To identify the key risk areas and critical issues that need to be resolved before full-scale development is initiated.

The most important product of this phase is the Development Concept Paper (DCP) or its equivalent. The DCP defines program issues, including special logistics problems, program objectives, program plans, performance parameters, areas of major risk, system alternatives, and acquisition strategy.

VALIDATION PHASE

The checklist items in this phase are for guidance in conducting T&E during the Validation Phase (the time between when the DSARC recommends approval of the DCP for the first time and when the DSARC recommends full-scale engineering development of the system).

While these objectives are not spelled out in the DoD Directive 5000.1, the objectives of the Validation Phase should be to confirm:

1. The need for the selected system in consideration of the threat, system alternatives, special logistics needs, estimates of development costs, preliminary estimates of life cycle costs and potential benefits in context with overall DoD strategy and fiscal guidance.
2. The validity of the operational concept.
3. That development risks have been identified and solutions are in hand.
4. Realism of the plan for full-scale development.

In the pursuit of the above objectives, it is likely that advanced development T&E will be conducted to resolve issues. In some cases, an RFP for full-scale engineering development will be prepared, proposals will be received and evaluated, and contracts negotiated in preparation for seeking DSARC approval for the next phase. Therefore, some checklist items are included to help ensure that this work properly reflects the T&E

interests in this and subsequent phases. For example, the RFP must include adequate guidance to ensure that sufficient resources and time are available so that engineering effort can properly support the initial DT&E with hardware, software, technical data, and training.

The primary emphasis of OSD/T&E activities is with items 3 and 4 above. Special attention should be given to the planning of IOT&E activity as it is incorporated in the engineering development contract as well as the DT&E associated with addressing the critical issues and areas of major risk identified in the DCP.

FULL-SCALE ENGINEERING DEVELOPMENT PHASE

The checklist items contained in this phase are for guidance in conducting T&E during the Full-Scale Engineering Development Phase. This includes the major DT&E and the IOT&E conducted prior to the major production decision. By this time, the system is well-defined and is becoming a unique item and, hence, sound judgment must be applied in using these checklist items.

To enter the Engineering Development Phase, the DSARC will have -

- Confirmed the need in consideration of the threat, alternatives, logistic needs, cost, and benefits.
- Identified development risks.
- Confirmed the realism of the development plan.

Given the above, the primary objectives of the DT&E should be to:

1. Demonstrate that the engineering and design and development process is complete and that the design risks have been minimized (the system is ready for production).
2. Demonstrate that the system will meet design specifications.

The primary objectives of the IOT&E should be to:

3. Assess operational suitability and effectiveness.
4. Validate organizational and employment concepts.
5. Determine training and logistic requirements.

In addition, the validity of the plan for the remainder of the program must be confirmed by the DSARC before substantial production/development will be recommended to the Secretary of Defense.

The level of OSD/T&E activity is highest during this phase. The IOT&E plan must be designed, the tests conducted, and the data analyzed to evaluate the inputs associated with the primary objectives. These tests should not be conducted until the primary objectives of the DT&E have been met. Thus, OSD/T&E activity is required to assess that the DT&E major milestone--the system is ready for production--has been achieved. Close monitoring of the T&E Service activity is required during the latter stages of this phase.

SUBSTANTIAL PRODUCTION/DEPLOYMENT PHASE

The checklist items contained in this phase are for guidance in conducting T&E after the substantial production decision has been made by the DSARC. This includes DT&E and follow-on OT&E to be conducted on the early production items.

To enter the Production/Deployment Phase, the DSARC will have reviewed the program to confirm:

- The need for the system.
- A practical engineering design with adequate consideration of production and logistic problems is complete.
- The realism of the plan.

The primary objective of the DT&E in this phase should be to:

1. Verify that the production system meets specifications.

The primary objectives of the follow-on OT&E should be to:

2. Validate the operational suitability and effectiveness.
3. Optimize organization and doctrine.
4. Validate training and logistic requirements.

At this point, the OSD/T&E activity is similar to that in the previous phase; however, much of the testing is verification that the production system performance is as expected. Hence, most of the items in the previous phase are appropriate to this phase, especially those related to OT&E.

I. CONCEPTUAL PHASE

Activity during the Conceptual Phase is generally concerned with the questions, "How does this system differ from its predecessor?" "What features will make it perform better?" Critical issues will generally relate to these new features.

Advances in ASW acoustic surveillance are being accomplished through the use of lower frequency arrays which use larger and/or an increased number of hydrophones. Important T&E issues involve the physical size of any new array, and tests should demonstrate its ability to fit selected platforms, both new and older ones intended for backfit. Demonstrations should be planned to test their ability to present coherent signals and resolve directional ambiguities. Effect of sea pressure on new components should not degrade the system. New features should not lessen reliability and maintainability. T&E should be planned to show adaptability of new arrays to a spectrum of threat noises, including the future and potentially quieter ones, not just the current and most pressing ones. Plans for measuring the important acoustic parameters should be evaluated. Even at this early state, performance goals should be specified in operational, as well as technical terms.

ASW effectiveness is dependent upon the processing of data at a central control point where the data from many sensors are correlated. An examination of the data handling capabilities of the new system should include security, resistance to jamming, and degree and effectiveness of automation. IOT&E should be planned to show how well the data displays are adapted to expected operator abilities and to the mission requirements.

Conceptual Phase Checklist items are as follows:

1. Use of Prototypes
2. Performance Characteristics
3. Measurements of Mission Effectiveness
4. ASW Evaluation Criteria
5. OT&E Planning

6. Facilities and Instrumentation Requirements
7. Dependency of Production Decision on Testing
8. Evaluation of Interfaces
9. Exploratory Test Results
10. Arrays
11. Effect of Changes in Threat Noise
12. Operational vs. Technical Performance
13. Reliability and Maintainability
14. Data Handling
15. Automated Detection Schemes

1. USE OF PROTOTYPES

If the acoustic sensor or the processor subsystem encompasses new concepts or technologies for detection, localization and tracking of a target, and these concepts/technologies have not been proven, then the advanced development testing program should be structured around the use of a prototype of each approach designed to prove the system concept under realistic operational conditions.

At least one such approach must be demonstrated before proceeding to engineering development. When an implied commitment to production is involved, the technology should be operationally proof tested prior to commencing full-scale development. In a case where this was not followed, a production contract was negotiated for hardware that had never been fully tested, resulting in expensive modifications and schedule delays.

2. PERFORMANCE CHARACTERISTICS

Analytic and empirical studies should be conducted prior to DSARC I to insure that the range of critical performance characteristics has been specified.

Each performance characteristic so specified should be measurable through bench and laboratory testing. The test design and the number of tests should be adequate to provide results with confidence limits compatible with the statements of desired characteristics. For example, if the measurement of the minimum discernible signal of an acoustic sensor system is performed with a device whose error rate is large (as measured by standard deviations) compared to the expected minimum signal, then a large number of tests will be required so that the average minimum discernible signal can be estimated with the confidence so stated. Testing in advanced development should be planned to explore the performance characteristics over a broad range of system inputs so as to provide insight into system performance over the expected range of values and not just at a single point. For example, the effects of sea state, time of year, wind, target type and line spectrum should be investigated.

3. MEASUREMENTS OF MISSION EFFECTIVENESS

During the conceptual phase of the acquisition of a new class of ASW ship, a study effort should be commenced jointly by the CNO and COMOPTEVFOR to establish mission-related measures of effectiveness which may be expressed in numerical fashion and which may later be made the subject of OT&E to determine how closely the new ship system meets the operational need for which it was conceived.

As an example, for a surface ship or submarine whose primary mission is to be ASW, threat-related parameters can be established based on known adversary capabilities; own ship parameters can be set according to the capabilities of present equipment or those demanded of equipment under development; and environmental factors can be entered using results of past and present investigations. Based on such study, a numerical probability of success can be generated in each of the mission areas conceived for the ship, after which acceptable minimum standards can be established as test criteria for operational suitability. Advantages of this process are that it will serve to eliminate bias and subjectivity from the analysis of test results, thereby increasing their credibility, and secondly, it will allow greater use of computer simulation and modeling of the operational scenario with attendant reduction in the amount of live testing.

Analysis and tests of this type were not generally conducted in past ASW platform developments, resulting in the deployment of systems without hard and fast mission success criteria having been established. Over the years expensive backfits and modifications were necessary to bring systems to an adequate state of mission effectiveness.

4. ASW EVALUATION CRITERIA

The test and evaluation plan should include the evaluation criteria to be used for the selection of the final system design.

They should be based on performance factors which are measurable through testing such as probability of detection of submarines as a function of range and attack conditions such as sea state, sound velocity profile, water depth, bottom conditions and ocean area; effect of other shipping and noise sources in area; probability of false alarms under various scenarios such as escort mission, ASW barrier, convoy operation, or operator time on station; probability of localization given a detection, as a function of search time and expended resources (sonobuoys, MAD runs), time late at datum, accuracy of datum, or convergence zone effect. A data collection and evaluation plan should be developed which describes the range of acceptable performance for each factor.

5. OT&E PLANNING

Before DSARC I, the nature of the schedule for the IOT&E plan should be addressed.

The IOT&E plan should include ASW engagements in the environments in which the new system is expected to operate. ASW testing may be addressed in several phases, such as:

(a) One-on-one testing against existing U.S. submarines and available simulators of the assumed threat.

(b) Multiple ASW vehicle testing in a multiple ship environment including multiple submarines and merchant shipping.

(c) Comparative testing (side-by-side if practicable) of the ASW system with existing systems to estimate the increased capability.

6. FACILITIES AND INSTRUMENTATION REQUIREMENTS

Before DSARC I the testing facilities and instrumentation requirements to conduct developmental and operational tests should be identified, along with a tentative schedule of test activities.

The applicability of the test ranges and the adequacy of the facilities and instrumentation should be verified (for example, factors such as location of range relative to submarine operating base, location relative to weapon support facilities, geographical size of range needed for scenario, weather expected at the range at time of test). Due regard should be given to the degree that the range compares to expected operating areas (e.g., AUTEC does not adequately simulate the Mediterranean). Insofar as possible alternative approaches (different ranges, etc.) and instrumentation improvements needed should be specified. If the range and instrumentation factors are found to cast significant doubt on the meaningfulness of the test data the steps necessary to assure meaningful data should be identified and planned.

7. DEPENDENCY OF PRODUCTION DECISION ON TESTING

Allow for sufficient time between the planned end of demonstration testing and major procurement decisions so that there is a flexibility for modification of plans which may be required during the test phases of the program.

In the case of several ASW sensor systems, production decisions and delivery schedules were dictated by previous decisions and schedules regarding platforms. Thus, for these systems, production decisions were made prior to completion of development. In addition, this constraint precluded incorporation of modifications resulting from testing.

8. EVALUATION OF INTERFACES

Whenever two major systems are to be connected, the interface should be carefully evaluated and monitored throughout development.

A relatively minor change in one of the systems could affect the operation of the other. As an example, minor modification to an ASW helicopter has rendered it physically unsuitable, because of increased size, for use on certain ships.

9. EXPLORATORY TEST RESULTS

The use of brassboard or modified existing hardware to "prove" that the concept will work should be seriously scrutinized to ensure that the demonstration and tests are applicable.

Results of tests conducted during exploratory development, which are used to establish the feasibility of the concept or technology, and which most likely have been conducted on brassboard, breadboard, or modified existing hardware should be evaluated with special attention to items such as:

(a) The packaging of the hardware and its location relative to other hardware may significantly affect the performance characteristics so that the suggested proof of feasibility is inconclusive. This is especially true relative to the electronic package on ASW aircraft or remote sensor subsystems such as sonobuoys. As an example, the physical location aboard ships of particular subsystems of an ASW combat system and the manner of their interconnection, is proving to be particularly critical to operational effectiveness.

(b) The environment in which the hardware was tested may preclude the generation of data needed to prove that the approach will be applicable to an operational environment. For example, the effects of multi-layer, convergence zones and casual friendly shipping cannot be evaluated unless the laboratory is situated in such an ocean environment.

(c) The tests must include noise sources representative of those that might be expected in an operational environment. If the sensor performance is sensitive to broad band noise and its internal line structure, any test which uses artificial noise sources and "clean" target signals would not be meaningful. Tape recordings obtained under operational conditions should be used, and should include conditions wherein convergence zone and bottom bounce propagation exist.

10. ARRAYS

Since there is a trend toward lower frequency arrays for tactical as well as surveillance arrays, the size and/or type of hydrophone used in the array field must be critically analyzed.

The proposed array must fit in the intended platform without introducing constraints. It should be capable of backfit into other (older) platforms. If new mounting or towing techniques will be required, they should be included in the test plan. If there are new fabrication techniques required, a demonstration that they will withstand the sea pressure at operating depths should be provided. For example, in the case of towed arrays, longer apertures are being developed, and test thus must be designed to evaluate streaming and recovery techniques and equipment, strumming and other self-noise effects, depth control, and maneuvering constraints imposed on the towing vessel.

11. EFFECT OF CHANGES IN THREAT NOISE

The effectiveness of arrays should be tested using various types of threat noise sources.

An array is generally optimized for response over the relatively narrow frequency range which contains the expected threat noise source. It is important to assess the risk if the threat noise source is replaced by another (or if the characteristics of the threat noise source are changed). As an example, surveillance arrays in broad use have been optimized for particular noise sources. Adequate demonstrations have not always been conducted of their effectiveness under conditions involving changes to the threat noise source.

12. OPERATIONAL VS TECHNICAL PERFORMANCE

Test plans should be formulated to test according to functional as well as design criteria, and should be directed at performance over a wide range of situations rather than single point performance. The measure of system performance based on operational aspects is a more significant criterion for decision making than mere technical performance specifications.

Specification in functional terms is more significant to a decision maker than design specification. As an example, although it is indeed possible to make a prediction of acoustic detection range based on the sonar equation (Figure of Merit), there should be a clear statement of performance in a specified environment, against a specified target class operating in a specified environment.

13. RELIABILITY AND MAINTAINABILITY

Reliability and maintainability goals should be specified early in the program.

Numerical success criteria for primary aspects of reliability and maintenance should be stated. A plan to demonstrate these criteria should be formulated, to include testing under operational conditions with typical operating and maintenance personnel being employed. In specifying these goals, operational failures should be identified separately from technical failures. As an example, if an ASW acoustic processor has 16 channels, and the system will function adequately with fewer than 16 operating, it should be clearly understood in advance whether failure of one channel is counted as a reliability failure.

14. DATA HANDLING

Overall system tests (sensor weapon platform) should be conducted to show achievement of specified "time-late."

In the case of some sonar systems, the data processing will be done at a location remote from the sensor. A demonstration that the volume of data acquired by the sensor can be successfully transmitted to the remote site with acceptable error rate; that it can be made secure from interception; and that it can be made jamming resistent should be planned. In order to minimize "time-late," which is crucial to ASW effectiveness, the system should provide for near real-time operation and automatic relay. Demonstrations should also include the ability of human operators to manage the data as they are received.

15. AUTOMATED DETECTION SCHEMES

If system effectiveness depends on the successful development of automated detection schemes, these schemes must be demonstrated.

Test criteria associated with these demonstrations should be based on detection thresholds and should include acceptable tradeoffs, as a function of threshold levels, between false target rates and failure to detect true targets.

II. VALIDATION PHASE

During the Validation Phase, solutions to the previously noted critical questions and issues of risk are identified. Examination of the T&E plan should be made in preparation for DSARC milestone II, to see if it provides for clear, unambiguous, valid tests to demonstrate that the proposed solutions work. Involvement of the Independent Test Agency should be apparent by this time.

DT&E of subsystems and components will be proceeding, and technical specifications will be the subject of test. An examination should be made to determine that the technical parameters of the proposed sensor or array subsystem are based on an acceptable propagation model and are based ultimately on operational requirements. Assessment of the model can be made from evidence that model predictions conform with experience on existing systems. T&E should be planned to show that the installation afloat will not be unwieldy or unsupportable.

If the proposed data transmission/handling system requires advances in state-of-the-art for components or computer techniques, integrated tests should be scheduled early so that fall-backs can be adopted if the advances are unsuccessful. T&E criteria should include statements of acceptable tradeoff between missed-contact and false-alarm rates, and tests designed for them. Further plans should be made for full-system IOT&E including demonstration of automation, operator alerting features, and measurement of mean "time-late." Target service requirements are identified with respect to numbers of tests required for statistical confidence in results. If the proposed system is part of a program to upgrade a present system, there should be a provision for baseline measurement of the existing system to evaluate improvements achieved.

Validation phase checklist items are as follows:

1. Building-Block Testing
2. Testing Under Various Sea Conditions
3. Authenticating the Human Factors Concepts

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4. Performance Measures
5. User Needs and Participation
6. Software Testing
7. Target Detection Testing
8. Baseline Measurements
9. Uses of Submarine Targets
10. Target Requirements
11. Constraints on the Platform Resulting from Array Configuration
12. Operational Performance

The reader should also review the checklist items in the previous phase since many of them will be applicable during this phase.

1. BUILDING-BLOCK TESTING

The design of the set of tests to demonstrate feasibility prior to DSARC II should be based on a building block concept, with high technical risk items being tested first and with subsequent tests incorporating more of the hardware until the complete system concept has been demonstrated feasible.

For example, if, in the ASW system, the high risk item is the sensitivity of the sonobuoy detector element, then the demonstration of detector performance should be conducted prior to a test of the feasibility that the detector element will meet the more general performance specifications placed upon the sonobuoy subsystem.

2. TESTING UNDER VARIOUS SEA CONDITIONS

Shipboard ASW combat systems must be designed to operate effectively under sea conditions encountered in all seasons in all the world's oceans.

It is unreasonable, however, to conduct tests everywhere to validate this capability. Alternatively, many studies which have been conducted in the past and are still on-going have produced a sufficient body of data on many of the ocean areas of the world to allow accurate prediction of parameters important to undersea warfare. These can and should be used early in the program to develop models for computer simulations to estimate the effectiveness of ASW combat systems contemplated for ships. Adequate at-sea testing should be conducted at such point in the program as practicable to validate the simulations. The simulation technique is particularly useful in comparing alternative suites proposed for a new class of ship, although final evaluation must await the availability of actual hardware.

3. AUTHENTICATING THE HUMAN FACTORS CONCEPTS

At an appropriate time in concept definition or development phase, T&E should authenticate the human factors concepts embodied in the proposed system design, examining questions of safety, comfort, appropriateness of man-machine interfaces, as well as the number and skill levels of the personnel required.

The numbers of personnel required should be validated against both operational and maintenance requirements. Testing early versions in the "human acceptability and compatibility" environment is extremely important. This will also help to validate the manning requirements. As an example, in the development of high-power active sonars, the effects of sound pressure levels on crew comfort should be made the subject of test and evaluation.

4. PERFORMANCE MEASURES

Demonstrations should be designed to measure overall performance, with statistical weighting to compensate for reduced probabilities of success at edge values of condition parameters.

Many development test and evaluation problems have been intensified by the contract form or factors closely tied to the contract. Considerable attention is required to ensure that the contract form and provisions minimize such problems. Improper incentives can warp the proper conduct of the test and evaluation.

In designing contractually required demonstration tests, upon whose outcome may depend large incentive payments, or even program continuation, it is essential to specify broader success criteria than simply target detection or hit or miss in a single given scenario. If this is not done, the entire program may be skewed to meet the requirements of the selected scenario, to the detriment of exploring the entire performance envelope. Such factors as sea state, ocean environment, variety of targets and merchant ship interference may be entered into success or failure of the test.

5. USER NEEDS AND PARTICIPATION

It is imperative that the user participate in all of the T&E phases to ensure that the user needs are represented in the development of the system concept and hardware.

This should facilitate the necessary communication and interaction between the developing and user command which is especially needed during the DT&E and IOT&E phases. User input will be particularly valuable in the areas involving the man-machine interface. For example, the number and skill level of personnel assigned to maintain an ASW helicopter in a new mode of use or different ship platform is critical to the success of the system.

6. SOFTWARE TESTING

Test and evaluation planners should ensure that software products associated with the ASW processor subsystems are tested appropriately during each phase.

Software has often been developed more as an add-on rather than as an integral part of the overall system. Software requirements need the same consideration as hardware requirements in the Validation Phases. Acceptance of the developmental system from the contractor is in large measure based on compliance with hardware specifications, while software acceptance may be based on limited and selected demonstrations by the contractor. This may result in acceptance by the government of a system that has not been tested under full-load, or other operationally significant condition. As an example, usual practices often do not sufficiently provide for testing the final operational software package in OT&E. In one sonar development program, failure to test this package in conjunction with hardware has resulted in schedule delays.

7. TARGET DETECTION TESTING

Tests which are designed to validate the feasibility of a sonobuoy system to detect submarine targets must always be conducted using the full spectrum of signals (generated by the target and the local environmental conditions such as sea state, shipping, etc.) expected in an operational scenario.

Tests should be conducted:

(a) Without the presence of the true target, and data collected which relates the threshold setting of the detection system to the false alarm rate.

(b) With the true target present, to collect data to relate threshold setting to probability of detection of the target.

Data from the above two tests should be used to generate the detection probabilities versus false alarm rates curve which is the main criterion for evaluating the feasibility of the system to detect targets.

8. BASELINE MEASUREMENTS

When the proposed system is a part of a program to upgrade an existing system, the proposed development program should provide for a "baseline" measurement of the existing system by which to evaluate the improvements to be achieved by the proposed system.

As an example, in the case of a new ASW combat system, which was developed to replace an older system, no provision was made for obtaining test data on the predecessor to determine its baseline effectiveness, and thus no comparison could be made as to the relative effectiveness of the successor. Later qualitative judgments were that the new system did not represent an improvement over the old in many respects.

9. USES OF SUBMARINE TARGETS

Test resources should be wisely used.

Since the services of an actual submarine target are difficult to come by, the limited services that are available should be used carefully. How much submarine service time is proposed in the test plan? What level of confidence in the test results will be obtainable, i.e., how many runs to demonstrate passive narrow band, active, etc.? Are the types of submarines used truly representative of the threat? Full recognition should be given the fact that many ASW test objectives can be satisfied without the presence of actual submarines. Others may be accomplished using submarine target simulators. Still others, requiring actual submarines, can be achieved by careful planning involving use of friendly submarines engaged in routine operations, e.g., transit from port-to-port.

10. TARGET REQUIREMENTS

Target requirements should be stated in the initial test concept, and required target development begun concurrently with that of the basic system.

Targets for test of anti-submarine weapons pose special problems. Since homing weapon logic circuitry will probably contain provisions for discrimination between submarine and non-submarine, the adapatation of any submarine simulator for target use will probably be inadequate, in that the weapon will recognize it as a non-submarine and look elsewhere for its true target. It might be desirable to build test weapons with a provision to temporarily deactivate the more sophisticated logic circuitry for certain tests.

11. CONSTRAINTS ON THE PLATFORM RESULTING FROM ARRAY CONFIGURATION

The proposed solutions should result in an array configuration which does not result in burdensome constraints on the platform.

One should ask such questions as: Is the platform restricted in maneuvering? Are power requirements for the system supportable? Do the proposed solutions result in unacceptable environmental conditions, e.g., excessive noise levels in operating/living spaces aboard ship? In the required location of the towed array winch such that it will experience extremes of shock, vibration, salt water exposure, etc.?

12. OPERATIONAL PERFORMANCE

It is desirable that the detection performance be ultimately specified in operational terms, viz., a 50 percent probable detection range against a specified class of target in a specified environment.

Until a full system is available for test, the performance is usually specified in terms of the technical parameters of the system, e.g., directivity index, self noise, etc. The technical parameters of the proposed system must be predicated on an accepted propagation model. There should be evidence that the model predications conform to experience with existing systems, i.e., how good is the model? The degree of uncertainty to go from the technical parameters to the operational capabilities should be identified. This should be minimized and that which is necessary should be recognized.

III. FULL-SCALE ENGINEERING DEVELOPMENT PHASE

Test and evaluation activity during this period involves an examination of test results to see if they demonstrate at an appropriate confidence level that specifications have been attained, and show a reasonable probability that the system considered for production will meet the operational need.

Particular attention in these examinations should be paid to sample sizes and the conditions under which the tests were conducted. In all probability, tests will have been conducted using scarce submarine services, and the quantity of testing and type of target may have been more dictated by target availability than the needs of the test. In some cases, for example, a diesel submarine would not adequately represent a nuclear submarine.

Participation by the independent test agency, OPTEVFOR, is important throughout this phase because in many cases DT&E data can later be added to the body of OT&E data for expansion of the data base and OPTEVFOR can assist in arranging tests of operational validity during DT&E. An adequate IOT&E by OPTEVFOR is a requirement for a decision regarding quantity production of the new system.

Checklist items for Full-Scale Engineering Development are as follows:

1. Concurrent Evaluation Impact on Personnel Skills
2. Target Realism
3. Availability of Aircraft Services
4. Acoustic Propagation Losses
5. Testing of Sonar Domes
6. Effect of Noise Interference
7. Effect of Shipping Interference
8. Demonstration of Operational Suitability
9. Human Factors in Data Processing
10. Tactical Employment Factors
11. Bearing Accuracy

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12. Multi-mode Operation
13. Mutual Interference
14. VDS Test Criteria
15. Controlled Environment
16. Target Noise Level
17. Target Utilization
18. Effect of Fixes on Prior Tests
19. Testing Devices

The reader should also review the checklist items in the previous phases since many of them will be applicable in this phase.

1. CONCURRENT EVALUATION IMPACT ON PERSONNEL SKILLS

Whenever possible the IOT&E should be conducted with operating and maintenance personnel whose skills are considered typical.

Shipboard weapon systems are often put through the process of a concurrent evaluation in the course of their acquisition, wherein sequential DT&E and IOT&E, with some overlap, are conducted. Often, the same operating and maintenance personnel are present and participate in equipment installation and checkout, DT&E and finally IOT&E. In these cases, and particularly if the test program has been long and difficult, a result is that IOT&E is conducted with operating and maintenance personnel whose skills have been peaked through long association with the new equipment. Since they may also have been initially selected for their aptitude, they can in no sense be considered typical. Evaluation of test results must take into account the expertise achieved by these people through long association with the T&E program. This situation occurred in the course of IOT&E of an ASW torpedo system.

2. TARGET REALISM

In the engineering feasibility sea test of sonobuoys, and similar sensors, the targets used (signal generators and conventional subs) should be representative in that they present the full acoustic spectrum associated with main targets for which the system was designed.

The use of signal generators or diesel engine submarines, where the principal targets are nuclear, should be discouraged since noise interference problems will not be fully identified or investigated.

3. AVAILABILITY OF AIRCRAFT SERVICES

ASW systems using airborne processing equipment and sonobuoys require that the schedule of the testing program account for the aircraft availability.

Since the availability of the aircraft may be a driving factor relative to scheduling of DT&E and IOT&E activities, the scheduling of processors and the sonobuoys should be coordinated with that of the aircraft. On one program this aspect caused increased cost and delays in testing.

4. ACOUSTIC PROPAGATION LOSSES

The total propagation losses of an active sonar system should be identified during the early engineering development test program.

Losses occur because of reverberation, spreading, absorption, image interference, surface and bottom interaction, and sound velocity profile which are all related to the depth of the hydrophone. If these losses are unacceptable, major changes could be required in the design of various system components. Fixes late in the program may be very expensive.

5. TESTING OF SONAR DOMES

In the development testing of a sonar designed as a subsystem on a ship, the problem of self-noise resulting from the sonar dome should be fully investigated since if this is found to be excessive, large costs and time delays will result until new dome designs are made available.

Environmental effects on sonar domes should be tested and evaluated before the domes are accepted as part of the sonar system concept. Excessive pitting and salt water corrosion can cause degradation in sound transmission and increases in self-noise which would require frequent off-station maintenance.

6. EFFECT OF NOISE INTERFERENCE

In testing of sonobuoys, noise interference problems should be identified and investigated early.

The design must take into account such noise interference. Generally there are three noise sources that are generated: by the flow of water at the surface level; by strumming of the hydrophone lines; and by other shipping in the general area. Failure to investigate the effects of these on the system could lead to serious shortcomings requiring design changes.

7. EFFECT OF SHIPPING INTERFERENCE

As soon as possible, the effects of merchant shipping interference on the detection and tracking capability of an ASW sensor system should be isolated and its impact on the tactical limitations of the system should be critically analyzed.

Specifically, testing should be devoted to investigation of the merchant shipping signals obscuring submarine generated signals or biasing the bearing information on the submarine because of the manner in which received signals are processed in the tracking circuit. Before the system is operationally tested, this aspect of the system must be fully understood, so that the data collected during IOT&E can be properly understood and evaluated.

8. DEMONSTRATION OF OPERATIONAL SUITABILITY

Before any operational tests for demonstration of operational suitability and effectiveness are conducted, an initial or pilot phase should be conducted with the primary purpose of shaking down the test plan, and briefing or training participants as necessary regarding the instrumentation concept, the data analysis plan, and other test features.

This phase should be conducted early enough that sufficient time is available to make the necessary changes to the IOT&E plan as dictated by the results of the pilot test. As an example, coordination should be established early with activities that will provide submarine target services so that exact requirements for achievement of test objectives can be made known to them and rehearsed if necessary. As a further example, T&E of variable depth sonar may require the towed body to be towed at depths that could be regarded as unsafe for submarines participating in the tests. The test plan should identify such constraints and propose alternative solutions to the problem.

9. HUMAN FACTORS IN DATA PROCESSING

The human factors aspects associated with the operation of the data processing function is especially critical to the performance of an ASW system and should be a primary objective of early operational testing.

During IOT&E, these aspects, which can degrade system performance, must be identified early in the operational tests. Emphasis should be placed on identifying potential human factors problems associated with:

- Being on alert for long periods of time.
- The process required for detection verification and location of a target.
- The process required for tracking the target.
- The overall interactions required, man/machine and man-to-man.

In order to identify these potential human factor problem areas, the all-up weapon system, or a realistic simulator of the platform, processor, and related systems needs to be available.

10. TACTICAL EMPLOYMENT FACTORS

The IOT&E of acoustic sensor systems should be conducted to evaluate tactical plans for employment under varying oceanographic considerations and target source levels.

With each new system, the existing plans should be re-evaluated since the tactical employment factors affect the operational utility and effectiveness of the system. For example, optimum submarine barrier spacing distances may be estimated therefrom.

11. BEARING ACCURACY

In the IOT&E, the bearing accuracy of the acoustic sensor system should be determined as a function of frequency and signal-to-noise ratio.

A controlled set of tests, using realistic targets and target ranges (including convergence zone) and ocean environment should be used to determine the "best" values that can be expected relative to bearing accuracy. These tests should be followed by uncontrolled (but instrumented) testing (obtain a bearing on the target following a detection) when free play is allowed. During these tests, friendly shipping and submarines, etc., should be in the environment. The average length of time required, as well as the mean of the bearing accuracy should be determined in order to assess the bearing accuracy capability.

12. MULTI-MODE OPERATION

The IOT&E of ASW sensors and weapons should be designed and conducted so as to require the system to operate in all of its modes, not just the primary mode.

An overall evaluation of the system requires that the various backup modes be exercised and investigated to determine such factors as the degradation of the system capability using backup modes, in response to countermeasures, because of failures in the primary mode, etc. A measure of the operational utility of the system should include the above aspect. As an example, the ability of a wire-guided ASW torpedo to consummate an attack in case of a broken wire should be assessed. In addition, sufficient testing should be conducted to determine probability of wire breakage and conditions under which this is most likely to occur.

13. MUTUAL INTERFERENCE

In the conduct of the IOT&E of ASW sensors, scenarios should be used which will demonstrate that mutual interference of the sensors does not degrade the detection, localization or tracking capability of the system.

For example, the various sensor deployment concepts should be tested; if more than one ASW system is employed on a platform simultaneously the interaction of one system with the other should be evaluated.

14. VDS TEST CRITERIA

The behavior of towed bodies of variable depth sonar systems should be tested and evaluated under all ship maneuvers and speeds likely to be encountered in combat.

This should include tests of:

- Kiting effect
- Retrieving the towed body
- Gyro stability
- Heading stabilization times after maneuvers
- Streaming depth
- Bearing and distance accuracy while under maneuvers
- Self noise

15. CONTROLLED ENVIRONMENT

It is important that the installation of the system for IOT&E be in an environment controlled with no greater stringency than the intended shipboard installation.

Modern ASW combat systems usually require a controlled environment, i.e., dry air and cooling, for proper and reliable operation.

16. TARGET NOISE LEVEL

Ensure that the range of target noise levels are used in the testing of the system.

Specifications are keyed to mean target noise level, usually specified in a number of decibels at a specified frequency. The true population of target noise levels vary about this mean. How well will the system perform against the quietest? Against the noisiest?

17. TARGET UTILIZATION

Because of limited target service there may be a need to combine DT&E with IOT&E.

Were the tests sufficiently oriented toward operational scenarios to provide realistic data? Was the target "opening" from the sonar or was it "closing" from some unknown range and direction? Was the case of crossing targets properly considered? Have tests been planned without the operator being alerted? Were "live" targets used? Was the target submarine restricted in any way so as to present a less difficult challenge; for instance was the target restricted to a "box" such as that created by instrumentation limits in a range, or limited in its freedom by a continental shelf or an island?

18. EFFECT OF FIXES ON PRIOR TESTS

Be sure that the fix on previous tests have not introduced new problems.

There are usually a series of tests conducted prior to the DSARC III meeting (pre-production, reliability demonstrations). If problems were found (and fixed) in later tests, did they go back and revalidate prior tests? This is necessary to insure that in "fixing" the last problem they didn't do something which would cause prior tests to fail. Be particularly alert to this when dealing with software and interfaces.

19. TESTING DEVICES

The state-of-the-art of testing devices and procedures should be considered when devising the test requirements. T&E may be required on new test facilities.

On one program, the vibration and shock tests of the hoist system (which weighs over 40,000 lbs.) were made at a special facility which apparently "pushed the state-of-the-art." Mechanical problems with the facility caused delays. In addition, there was some doubt as to whether the results were accurate and conclusive and whether this, in turn, caused design redundancy.

IV. SUBSTANTIAL PRODUCTION/DEPLOYMENT PHASE

Follow-on OT&E will be conducted on early production equipment. Depending on the type of system under development FOT&E may be conducted in conjunction with OT&E of the vessel upon which it initially is installed. Considerations of testing realism apply equally during this phase.

Checklist items for Production/Deployment are as follows:

1. Acceptance Testing
2. ASW FOT&E
3. Minimum Discernible Signals
4. Helicopter Support Testing
5. Realism of Test
6. Installation and Testing
7. Hoist Subsystems Tests
8. Towed Bodies and Cable Behavior Tests
9. Self-Noise Tests

The reader should also review the checklist items in the previous phases, especially the last phase, since many of these items will be applicable during this phase.

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1. ACCEPTANCE TESTING

Because of the need to equip ships and submarines on both coasts, acceptance testing of ASW weapons may be carried on at several locations remote from the factory.

In such cases the standards and tolerances for production acceptance test and evaluation (PAT&E) must be uniform and in agreement with factory acceptance standards. Where a portion of the PAT&E uses automatic test equipment (ATE), the same standards and tolerances must be programmed into the ATE.

2. ASW FOT&E

Operational Tests and evaluations of the capability of the system to detect and locate targets must be conducted in the type of ocean conditions expected to be encountered in wartime conditions.

Tests should be planned and conducted in various sea states, in areas of the oceans for which the system will encounter convergence zone conditions and with wartime type ocean traffic including merchant shipping, U.S. warships, and U.S. and allied submarines as well as enemy submarines. It is especially important to ensure that the test crew performing the detection and location function be unaware of when and where the submarine will appear, except for the normal type of alerting available through the various applicable CC&C systems. In fact, operational tests should be conducted when, indeed, the submarine is not present, to determine the false alarm rate of the system.

3. MINIMUM DISCERNIBLE SIGNALS

In testing the operational capability and suitability of acoustic sensor systems, the minimum discernible signal should be determined by using various ocean areas where submarine targets are expected to be encountered.

OT&E should be conducted:

(a) Using a controlled situation (signal generators, adjusted signal-to-noise ratio and known locations of targets);

(b) Using an uncontrolled situation to determine the degradation of operational minimum discernible signals over the above determined optimal value. This situation should simulate true operational conditions (such as uncertainty as to the presence of the target, its location, or what the signal-to-noise ratio is). Further, the human impact on this factor should be allowed to enter the test.

4. HELICOPTER SUPPORT TESTING

Where appropriate tests should be conducted at a realistic operating tempo, helicopter maintenance should be performed by the same number and same technical experience level personnel as planned for normal fleet operations.

Adaptation of helicopters to operate as ASW vehicles based aboard small ships poses special problems relative to supportability. Demonstration of adequacy of manning, spare parts inventory, documentation, and helicopter availability should be major test criteria.

5. REALISM OF TEST

During the testing of ASW systems, care should be taken to insure that the particular type of subs and their exact signatures are not known since this fact will bias the test results.

The crew performing the detection, identification and localization should be given no more information than would be available to operational crew on station at sea.

6. INSTALLATION AND TESTING

A provision should be made which requires the suppliers of complex (e.g., sonar) systems to participate in the installation and testing of their systems.

Improper installation and testing procedures can seriously affect the performance of such systems. If the supplier has no responsibility for installing and testing the system, then he can not be held responsible for failures that could be attributed to improper installation and testing. Moreover, the supplier is probably best qualified to evaluate the effect of any structural design changes required by installation of any new tests required in interfacing his system with other systems.

The result of over a decade of development has been an IVDS electronics system which is regarded as operationally satisfactory, highly reliable, and easy to maintain. However, there are still problems with the hoist subsystem as currently installed in the DE-1052. The nature of these problems is discussed in the next section.

7. HOIST SUBSYSTEMS

The hoist subsystem of a Variable Depth Sonar (VDS) should be tested on the class of ship on which it is to be installed using the same operational configuration.

Major problems have occurred with the hoist subsystems due to water intrusion in the hoist room located below decks. Because of this electrical shorting, corrosion damage, and general deterioration due to inability to maintain the hoist properly has resulted. The problem probably could have been discovered in time to take corrective actions if one of the preproduction models had been installed on an existing ship of the same class.

8. TOWED BODIES AND CABLE BEHAVIOR

Towed body and cable behavior of Variable Depth Sonars should be tested on the class of ship on which it is to be installed, and at speeds and maneuvers likely to be required by operations.

Tests have uncovered a number of problems in the behavior of a towed body. It has been difficult to simulate the configuration of a given class of ship especially with respect to the type of wake "rooster tail" which affects the "kite" angle and retrieval procedures. Whenever possible, the procedures should be developed by installing the VDS on one of the earlier ships of that class.

9. SELF-NOISE TESTS

Early self-noise tests of a VDS should be made on the class of ship on which it is to be installed using the masking devices available on the ship.

The issue here is how soon the self-noise noise configuration of the ship and towed body can be determined and measures taken to minimize noise at various speeds. On one program, a test ship was used which had a different pump jet exhaust system, and a somewhat different Prairie-Masker system, and as a result the self-noise curves were different and the experiments did not reveal a subsequent noise "hump" caused by pure radiated noise emitted by the cable when used on a ship for which it was scheduled. If noise tests had been conducted on early classes of that ship, the remedies and procedures for minimizing noise would have been developed sooner.