AD-784 397

T AND E GUIDELINES FOR SHIP SYSTEMS

Office of the Director of Defense Research
and Engineering
Washington, D. C.

April 1974

DISTRIBUTED BY:

NTIS
National Technical Information Service
U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road, Springfield Va. 22151

DEPUTY DIRECTOR (TEST AND EVALUATION)

T&E GUIDELINES FOR SHIP SYSTEMS

April 2, 1974

OFFICE OF THE DIRECTOR OF DEFENSE RESEARCH AND ENGINEERING

WASHINGTON, D. C.

LIST OF RELATED REPORTS

REPORT OF THE TASK FORCE ON TEST AND EVALUATION

T&E GUIDELINES FOR AIRCRAFT SYSTEMS

T&E GUIDELINES FOR MISSILE WEAPON SYSTEMS

T&E GUIDELINES FOR GROUND VEHICLE SYSTEMS

T&E GUIDELINES FOR ASW SYSTEMS

T&E GUIDELINES FOR AIRBORNE ECM SYSTEMS

T&E GUIDELINES FOR AIRBORNE GENERAL SURVEILLANCE RADAR SYSTEMS

T&E GUIDELINES FOR COMMAND AND CONTROL SYSTEMS

T&E GUIDELINES FOR COMMON TEST GEAR

CONTENTS

Preceding page blank

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 SHIP SYSTEMS

The checklist items presented here are specifically applicable to ship 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. 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 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 weapon systems acquisition. This phase (often research and exploratory development) precedes the first DSARC milestone and is focused on the development of a weapon system concept that offers high prospects of satisfying an identified military need.

Although not called for 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 demonstrate that there is a sound physical basis for a new weapon system.
3. To formulate a concept, based on demonstrated physical phenomena, for satisfying the military need.
4. To show that 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 need to show that it is better to start advanced development 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 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 weapon 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 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/deployment 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.
- All technical uncertainties have been resolved and operational suitability has been determined by T&E.
- 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

During the Conceptual Phase of an acquisition program for a new ship class, the primary efforts are normally devoted to establishing the need for a program to meet a particular operational requirement in the face of the projected threat. Initial plans are made regarding schedules, costs, risks and issues. Included in this phase are schedules of T&E milestones and such critical issues as are known in this early phase of the program. Where combat system (land based or sea based) testing is to be a part of the program, early configuration planning is essential. Feasibility testing of new hull or propulsion concepts, sufficient to justify proceeding with the program should be conducted.

These and similar matters are usually formulated in the initial DCP and presented to the DSARC as a basis for establishment of the ship acquisition program.

Conceptual Phase checklist items are as follows:

1. Test and Evaluation Plan
2. Test Objectives and Critical Issues
3. OT&E Phasing
4. Test Facilities and Instrumentation Requirements
5. Multiple Approach to Weapon System Development
6. Comparison of New Versus Old System
7. Test Support Facilities
8. Fleet Operating Force Requirements
9. Mission-Related Measures of Effectiveness
10. Ship T&E Management
11. T&E of Large, Integrally-Constructed Systems

Preceding page blank

1. TEST AND EVALUATION PLAN

Prior to DSARC I, sufficient material should be generated to allow for an evaluation of the overall T&E program.

As part of this, a test and evaluation concept for those tests to be conducted prior to DSARC II (to validate the concept and hardware approach to the weapon system) should also be developed. The plan must include statements of:

(a) The critical issues and the overall purpose of the test, such as service approval of weapon subsystem prior to commencement of integrated testing.

(b) The operational requirements, such as desired reliability and maintainability goals.

(c) The major test objectives.

(d) The schedule of test milestones.

(e) The major resources required.

- Test environment, facilities and instrumentation
- Simulated operational environment
- Completed maintenance documentation.

(f) The organizations which will conduct the test program.

(g) The analysis and evaluation approach.

2. TEST OBJECTIVES AND CRITICAL ISSUES

In evaluating the initial test concept, it is important that the test objectives during the time period from DSARC I to DSARC II address the major critical issues, especially technological issues.

As an example, if a shipboard weapon system contemplates use of a new method of target detection or acquisition, this should be evaluated as to feasibility by test during advanced development. Test objectives should be simply stated and given priorities. A plan for the conduct of the test and the data collection, reduction, and analysis must be in sufficient detail so that one can readily evaluate the performance of the system and whether or not the test objectives can be met. The relationship between the identified performance parameters and the expected test results should be established prior to the conduct of the test. Further, the set of objectives for each of the tests should be clearly related to the defined program objective. When this relationship is not clear, amplifying data should be required. The following should be addressed.

- Issues associated with system integration (e.g., placement of radar/radio antennas to avoid RFI problems).
- Issues associated with location of major subsystems on the ship (e.g., sonar domes, gun mounts, weapon launchers).
- Issues associated with combat systems.
- Issues associated with propulsion systems.

3. OT&E PHASING

In evaluating test plans, look favorably on phasing where the OT&E is run in parallel with continued DT&E.

Problems that become apparent in the operational testing can often be evaluated much more quickly and more completely with the instrumented DT&E hardware. This is most attractive where the DT&E is performed with non-expendable hardware, and is particularly applicable to ship systems where the same test installation and crew members are used to perform DT&E and OT&E.

In general, test plans should make provisions for the occurrence of failures, should include time and money necessary for investigating test failures and make provisions for elimination of the cause before another test series. Experience has shown this to be particularly true in software integration testing. As an example, ship C&C integration test sites have frequently been unable to maintain schedule, simply because this factor was not recognized. A percentage of the total tests (sorties, runs, trials, experiments) should be allocated to retesting, over and above the number need if all tests are successful.

4. TEST FACILITIES AND INSTRUMENTATION REQUIREMENTS

Before DSARC I the test 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. Insofar as possible alternative approaches (different ranges, etc.) and instrumentation improvements needed should be specified. Of prime importance are the constraints to be placed on the test because of the range and instrumentation. If 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 before inclusion in the test concept.

Where applicable, instrumentation necessary for T&E of the new ship, such as strain gauges, torque indicators, and position repeaters, should, for economy, be made part of the lead ship design and built into it, rather than added later as an afterthought.

5. MULTIPLE APPROACH TO WEAPON SYSTEM DEVELOPMENT

Whenever possible, the weapon system concept should not be predicated on the successful development of a single hardware or software approach in the various critical subsystems (unless it has been previously demonstrated adequately).

Instead, each should have several potential ways of being achieved. When multiple approaches are possible, critical advanced development activities should proceed with at least two approaches, with T&E being planned for the breadboard hardware resulting from each approach. As an example, in the case of some new ship classes, multiple prototypes have been planned in order to more quickly resolve the uncertainties in the approaches to be taken for weapon system and type of propulsion. Tests to compare the performance of the breadboard items should also be planned. For subsystems for which a single approach is used, tests should be planned which evaluate the breadboard under many degraded modes to investigate the potential limitations of that approach.

6. COMPARISON OF NEW VERSUS OLD SYSTEM

The procedure for examining the relative performance of new or modified systems versus old should be indicated in the T&E plan.

In the interests of updating the technology of systems there has been a tendency to ignore or minimize the operational value of proven systems. Sometimes new or modified systems have yielded relatively minor improvements in effectiveness at considerable additional cost when compared with the proven system. For example, a sonar system intended to provide improved detection capability was found not to be significantly better than its predecessor. Unfortunately, this was not discovered until after a large number had been procured.

7. TEST SUPPORT FACILITIES

The phasing of test support facilities must be carefully planned, with some schedule flexibility to cover late deliveries and other unforeseen problems.

Some systems can't be fully tested without shore test facilities. The long lead times to obtain authorization, appropriations, and to construct facilities can pace a program. For example, many steps and considerable time will be involved in constructing a land based combat systems test site with test instrumentation and equipment checked out and ready to support tests.

8. FLEET OPERATING FORCE REQUIREMENTS

The requirement for fleet operating forces for DT&E or OT&E should be assessed early in the program, and a specific commitment made as to the types of units to be employed.

As the program progresses, the necessary fleet support should be formally included in the fleet employment schedules. To this end

COMOPTEVFOR assistance in the test planning should begin early. Since operational forces for test purposes are always in short supply, vital tests may not be performed in time to have an effect on the program if these actions are not taken.

9. MISSION-RELATED MEASURES OF EFFECTIVENESS

During the Conceptual Phase of the acquisition of a new class of 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 will allow greater use of computer simulation and modeling of the operational scenario with attendant reduction in the amount of live testing.

10. SHIP T&E MANAGEMENT

The management of ship T&E should ensure that test requirements are necessary and consistent relative to system/subsystem aspects and that the necessary testing is coordinated so that test redundancy does not become a problem.

Ship systems are large, complex and comprised of many subsystems, some critical to the primary mission of the ship and all important to the functioning of ship activities.

11. T&E OF LARGE, INTEGRALLY-CONSTRUCTED SYSTEMS

Major subsystems should be proven feasible prior to firm commitment to a detail hull design.

In any situation where a subsystem must be integrally constructed with the ship (i.e., with the ship essentially built around the subsystem) such as large, high-power sonars, phased array radars or complex missile launching systems, T&E planning should be such that sufficient testing of the subsystem will be completed early enough to provide confidence in the continued development and probable ultimate performance and operational suitability prior to firm commitment to a detailed hull design.

II. VALIDATION PHASE

Although ship acquisition programs are of varying complexity and each is somewhat different in time phasing of this part of the cycle, it is possible to state generally some usual characteristics of the Validation Phase. This may involve the execution of one or more preliminary design contracts leading to proposals from which later a single configuration is to be selected. DT&E and possibly some IOT&E on expected major subsystems may be proceeding. Development milestones, including DT&E, will be planned in considerable detail. Where radically new designs in hull or propulsion are involved, test prototypes may be constructed and testing begun. If COMOPTEVFOR participation in test planning was not begun during the Conceptual Phase, it must begin here, both with respect to individual subsystems (weapons, sensors, propulsion, etc.) and to integrated system testing. Cost and schedule of the acquisition are given additional firmness. During this phase sufficient information should be accumulated upon which to base a decision regarding embarkation on full-scale development.

Validation Phase checklist items are as follows:

1. COMOPTEVFOR Participation in DT&E
2. Authentication of Human Factors Concepts
3. Government Commitments
4. Contract Form and Incentives
5. Acquisition Strategy
6. Performance History of Components
7. Effect of Supposedly Minor Modifications
8. End-to-End Study
9. Ocean Parameters for ASW Systems
10. Criteria for Selection Among Competitive Designs
11. Evaluation of Results of Exploratory Testing
12. Prototyping for Technical Risk
13. Prototyping of Competing Systems
14. T&E of Command/Operating Centers

Preceding page blank

15. Software Testing
16. New Hull Forms
17. Effect of Hull and Propulsion on Mission Capabilities
18. Advances in Propulsion
19. Propulsion System in Use in Other Classes
20. IOT&E Shipboard Gun Systems
21. Targets for AAW OT&E
22. Waivers to T&E of Ship Systems
23. Environmental Effects on Sonar Domes
24. Hull/Machinery Testing by Computer Simulation
25. Operational Reliability
26. Inter-shipyard Coordination

The reader should also refer back to the checklist items in the Conceptual Phase since many of these items will also be applicable to the Validation Phase.

1. COMOPTEVFOR PARTICIPATION IN DT&E

It is imperative that COMOPTEVFOR 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.

Initially, COMOPTEVFOR should play an advisor role during the feasibility and engineering testing, and gradually assume more leadership in the conduct of the testing program as it becomes more and more operational. This should facilitate the necessary communication and interaction between the developing and user command--especially needed during the DT&E and IOT&E phases.

2. AUTHENTICATION OF 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.

3. GOVERNMENT COMMITMENTS

GFE items should be accounted for in the T&E program

If there are GFE and other government commitments in the proposed contract, be concerned about the following:

(a) Can the gear with required performance be available when required?

(b) Can government supported facilities provide the assistance required at the time needed? If not, is it reasonable to construct the required facilities (test range, instrumentation, building, etc.)? If not, what alternatives are available?

(c) Avoid contract terms that vaguely commit the government. Don't include, "government support as required" or "test facilities will be made available when needed".

4. CONTRACT FORM AND INCENTIVES

Ensure that development test and evaluation problems are not intensified by the contract form or factors closely tied to the contract.

To minimize these problems, considerable attention is required in the contract wording. 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 a very few points in the performance envelope. 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. For example, a large incentive attached to maximum sustained speed might be self-defeating if habitability and survivability during high sea states are not also designed into the new ship.

The contract should be designed, if possible, so that necessary changes can be quickly made as the development unfolds and appropriate testing activity introduced.

5. ACQUISITION STRATEGY

The acquisition strategy for a ship and its subsystems should allow for a sufficient time between the planned end of demonstration testing and major procurement decisions of government furnished equipment so that there is a flexibility for modification of plans which may be required during the test phases of the program.

The shipbuilding schedule will require the delivery of GFE to the shipbuilder at prescribed times. If the test program for GFE is not planned carefully, the shipbuilding schedule may force procurement decisions on GFE prior to completion of testing.

The acquisition strategy for the system should:

(a) Ensure that sufficient dollars are available not only to conduct the planned T&E but to allow for the additional T&E which is always required due to failures, design changes, etc.

(b) Be evaluated to minimize the so-called T&E gap caused by a lack of hardware. Specifically, a test gap can result if funds are not applied until the results of IOT&E are known because of the required lead time for production planning, production facilities and tool and production hardware.

6. PERFORMANCE HISTORY OF COMPONENTS

Performance histories on non-expendable weapon systems should be maintained.

When developing, testing and evaluating the various subsystems (and systems) of non-expendable weapon systems, each component of the systems should be numbered and a performance history kept which allows an analysis of that component's performance, with respect to reliability, maintainability and availability.

7. EFFECT OF SUPPOSEDLY MINOR MODIFICATIONS

It is important to identify what changes are contemplated, even in the proven systems. Major, and sometimes minor, modifications to systems can sometimes be as troublesome and costly as new system development.

On a number of occasions in the past, minor modifications changed the basic system's physical and operational characteristics enough to cause major interface problems when consolidated with other systems. As an example, certain shipboard radars underwent OT&E and were accepted for service use in the mid-1960s, but were not produced in quantity at that time. Recent modifications which are designed to bring these equipments to 1970's state-of-the-art and production technology should not necessarily be treated as minor modifications and may require further testing to assure operational suitability.

8. END-TO-END STUDY

A complex system needs "end-to-end" study.

Whenever two major systems are required to be operated in conjunction (e.g., a radar, a C&C system, a fire control system and indeed the interaction of a subsystem with the ship itself), test and evaluation plans should provide for tests of the interface(s) and should monitor changes therein. For example, the wake and rooster tail characteristics of a ship are crucial to the streaming, towing, and recovery characteristics of a towed sonar system. T&E of the hoist and towed sonar system should be performed on the class on which the sonar system will be installed or on a ship that has exactly the same wake and rooster tail characteristics. Example: the USS GLOVER (AGDE-1) was <u>not</u> a good test ship for the DE 1052 VDS for checking hoist and towed body behavior even though GLOVER had many characteristics similar to those of the DE 1052. Furthermore, it was not anticipated that major water intrusion would occur in the open hoist room of the DE 1052 class--but this turned out to be a major problem.

The many subsystems which are incorporated in ships dictate that interface testing be conducted to define inputs for configuration control, computer capacity, power and cooling capacity, electrical capability, etc. The totality of the systems definition based on realistic tests which simulate the operational environment to the maximum extent possible must be clearly understood and refined early, particularly in acquisition of our modern complex ships.

9. OCEAN PARAMETERS FOR ASW SYSTEMS

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

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 systems contemplated for ships. Adequate at-sea testing should be conducted at such point in the program as practicable to validate the simulations. The 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.

10. CRITERIA FOR SELECTION AMONG COMPETITIVE DESIGNS

Whenever competitive designs are under consideration, criteria for selection should be specified in advance, with critical issues identified for each design.

Planning should include the evaluation criteria to be used for the selection of the final system design. They should be based largely on performance factors which are measurable through testing. A data collection and evaluation plan should be developed which describes the range of acceptable performance for each factor. This applies particularly to systems for installation aboard ship. For example, the many trade-offs between cost, performance and physical size associated with shipboard weapon systems planned for quantity procurement dictate the need for hard evaluation criteria. Those criteria which are capable of test verification should be addressed in early test planning

11. EVALUATION OF RESULTS OF EXPLORATORY TESTING

Results of tests conducted during exploratory development and which most likely have been conducted on brassboard, breadboard, or modified existing hardware should be carefully evaluated.

Special attention should be given to items such as:

(a) The packaging of the hardware may significantly affect the performance characteristics so that the suggested proof of validation is inconclusive, e.g., mock-ups of operating spaces should be examined to determine the degree to which they duplicate the final installation, differences should be evaluated.

(b) The laboratory-type environment in which the hardware was tested may preclude the generation of data needed to validate that the concept and technology approach will be applicable to an operational environment.

12. PROTOTYPING FOR TECHNICAL RISK

When high technical risk is present, development should be structured around the use of prototypes designed to prove the system concept under realistic operational conditions before proceeding to engineering development.

It is good to take a risk; however, when an implied commitment to production is involved the technology should be operationally proof tested prior to commencing full-scale development. On the other hand, avoid the temptation of thinking that anything is "state-of-the-art" until it is working in the field.

13. PROTOTYPING OF COMPETING SYSTEMS

When a new concept in ship design is being considered for incorporation into the fleet inventory, the weapon/sensor/propulsion system suite which is ultimately chosen should be based in large part on the DT&E and OT&E.

Extensive prototype testing will probably be required to demonstrate the effectiveness of various alternatives. For example, the necessity for evaluating different combat subsystems suites or variations in the propulsion and control subsystems may make it more economical to construct more than one prototype in order to achieve timely test results for the weapon system milestone decisions.

14. T&E OF COMMAND/OPERATING CENTERS

The requirements of effective command and control in an operational fleet environment lead to the need for various information, support, and command centers to be provided aboard ship.

Mock-up, test and re-design iterations will normally be conducted in the laboratory in the process of ship system design. In order to provide a maximum probability of success in this endeavor, it is important to bring OPTEVFOR into the process at an early date, and at some point in the project have an adequate IOT&E with fleet personnel manning the system. Depending on the type of personnel/equipment center involved, it may be possible to integrate this into an existing ship for further IOT&E prior to settling on a final configuration, and this should be done if at all feasible.

Land based test sites constructed for this type of activity should faithfully represent the equipment arrangement anticipated for the new ship class, including such items as cabling, piping, displays, communications circuits, and important structural features. When applicable, full equipment installations including radar antennas, directors and gun/missile launching and handling facilities should be provided. Location of an AAW combat system test site should be such that air targets can be flown against the system.

15. SOFTWARE TESTING

In view of increasing dependence upon computers for ship management and tactical operation, software testing must be exceptionally thorough, and integrated software testing must begin as early as possible.

All computer-managed functions should be tested in conjunction with other combat system equipment either at land-based or at-sea test sites. Data inputs which are not available in actuality should as a minimum be simulated. Testing should include operation in back-up modes, effects of external electronic countermeasures, effects of electromagnetic pulse (EMP). Where a system is designed to include secure data circuits within the ship, T&E should include examination by experienced COMMSEC technicians to discover possible susceptibility to compromise. Extensive testing of the system with whip antennas installed should be conducted to determine nature and extent of EMI/RFI. Testing is also required to determine if corrective actions have solved EMI/RFI problems.

16. NEW HULL FORMS

When a new type of ship involves a radical departure from the conventional hull form, extensive prototype testing prior to further commitment to the new hull form should be required.

This is required since the Froude Scaling Laws, which traditionally allow proceeding directly from model testing to full-size hull with certain knowledge of the latter's performance, will no longer fully apply.

17. EFFECT OF HULL AND PROPULSION ON MISSION CAPABILITIES

The predicted effect of the proven hull and propulsion system design on the performance of the ship's critical systems should be determined.

Proven hull and propulsion system designs can sometimes turn out to be unsatisfactory when the ship is to be used for certain missions and the corresponding critical systems to accomplish the missions are installed. For example, a proven design may have a self-noise configuration that is totally unsatisfactory for ASW missions.

18. ADVANCES IN PROPULSION

Demonstration of the use of new propulsion systems should be conducted prior to making the decision to commit the propulsion system to the ship in question.

Advances in ship propulsion contemplated for new ships may take the form of scaling up systems or portions of systems which have previously seen satisfactory service in smaller size. An example is the controllable reversible-pitch propeller. When such scaling up is contemplated, it is important to conduct adequate testing of the larger model, in a configuration as close as possible to the intended version, prior to making an irrevocable commitment of the program to the design.

19. PROPULSION SYSTEM IN USE IN OTHER CLASSES

When an engine type to be used in the propulsion system of a new ship is already performing satisfactorily in another ship, this is not to be taken as an indication that shortcuts can be taken in propulsion system DT&E, or that no problems will be encountered.

It is possible that redesign will be necessary for some components of the power transmission system (i.e., shafting, gearing, couplings, bearings) before a satisfactory system is developed.

20. IOT&E SHIPBOARD GUN SYSTEMS

Operational tests of shipboard gun systems should simulate the stress, exposure time and other conditions of battle so that the suitability of the weapon can be evaluated in toto.

Tests should include enough rounds fired under these conditions to determine:

- Weapon accuracy during ship maneuvers and under other stress conditions including ability to maintain alignment
- Smoke and toxic gas build-up in gun mount and adjacent spaces and other hazards to the gun crew
- Physical and psychological limitations of gun crew
- Inefficiencies in ammunition handling required of personnel
- An estimate of barrel wear rate, and ease of replacement
- Mean time to failure of critical components
- Suitability of construction and mounting of control equipment
- Susceptibility to spray and water intrusion
- Effects of shock, vibration and temperature
- Adequacy of spare parts provided
- Adequacy of recommended maintenance procedures
- Adequacy of documentation

21. TARGETS FOR AAW IOT&E

Operational test of shipboard AAW weapons demands the use of targets which realistically simulate the present-day threat.

One of the most likely targets is the high-speed, low-altitude anti-ship missile, and a target that realistically simulates this threat may be difficult to obtain. IOT&E planning should provide in any case for adequate targets, and, if necessary, should provide for the development of new targets concurrently with that of the system to be tested.

22. WAIVERS TO T&E OF SHIP SYSTEMS

Waivers to T&E of pre-production models of a system in order to speed up production and delivery should be made only after consideration of all costs and benefits of the waiver, including those not associated with the contract.

A waiver to speed up delivery may simply shift the additional cost of back-fitting or modification of defects that could have been detected by early T&E to another contract or budget classification. Back-fitting via Engineering Change Proposals is extremely expensive. In terms of operational time the net effect of the production speed-up may be minimal.

23. ENVIRONMENTAL EFFECTS ON SONAR DOMES

Environmental effects on sonar domes and their self-noise 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.

24. HULL/MACHINERY TESTING BY COMPUTER SIMULATION

In DT&E of ships, there will be cases where the best means to conduct evaluations of particular hull and machinery capabilities is through dynamic analysis using computer simulation, with later validation of the simulation by actual test.

An example is shock hardness testing. Experience has shown that the concept is not understood by all vendors, and careful selection will be necessary to assure competence. If further training of a selected contractor in the use of this tool will be necessary, the test plan should so provide.

25. OPERATIONAL RELIABILITY

IOT&E should provide valuable data on the operational reliability of ship weapon systems which cannot be obtained through DT&E.

Factors such as operator error failures, and environmentally induced failures should be looked for in the operational tests and investigated to determine if system deficiencies are underlying reasons for the failures. Especially important is the procedure used to evaluate the operational reliability of the system as determined by the relatively small amount of, but significant, data obtained through IOT&E and the larger amounts of data on hardware design reliability collected through DT&E. Further, the maintenance practices should be carefully studied to assess its impact on the observed operational reliability obtained through IOT&E. It may be desirable to require contractor technical personnel during DT&E to use exact maintenance procedures contained in technical manuals to ensure that these procedures, diagrams, and wiring charts are correct and satisfactory.

26. INTER-SHIPYARD COORDINATION

In general, ships are built and tested by more than one shipyard or company. All plans for T&E should be analyzed to ensure that inter-shipyard coordination/cooperation is possible.

Testing procedures designed by shipbuilders do not generally draw upon experience of other yards. Where it is possible to draw on these experiences, the contract, organization, legal and institutional framework of the procurement should encourage such coordination/cooperation. For example, the designer-builder-supplier T&E coordination plan should be requested; the T&E plan should be applicable to all builders; the constraints on interaction of builders should be carefully examined.

III. FULL-SCALE ENGINEERING DEVELOPMENT PHASE

Ideally, contracts for detailed design and later construction of a full-scale prototype or lead ship will be awarded during this phase. During full-scale development, remaining DT&E, and IOT&E of individual combat subsystems will be completed. Additional phases of IOT&E may be performed with pilot or pre-production items of the individual subsystems as necessary to gain approval for service use, if possible, prior to T&E of the integration of the combat system. Integration testing will normally take place at a land-based or sea-based test installation built as nearly as possible to the same configuration of the intended ship installation. It should include software integration, as well as hardware integration testing. (In addition, there may be afloat IOT&E in a prototype ship, although this will not normally be the case.) Sufficient test and evaluation is conducted to reduce risk to the point that a decision regarding quantity production can be made.

Checklist items for this phase are as follows:

1. Initial or Pilot Phase of IOT&E
2. Value of Operational Testing
3. Personnel Performance in Concurrent Evaluations
4. Identify Critical Subsystems
5. Reliability of Critical Systems
6. Consistency in Test Objectives
7. Single Screw Ship
8. Problems Associated with New Hulls
9. Effect on Personnel of Hull/Propulsion Innovations
10. Controlled Environment
11. Reliability/Maintainability: Personnel Interactions

The reader should also refer back to the checklist items in the previous phases since many of these items will be applicable to this phase.

Preceding page blank

1. INITIAL OR PILOT PHASE OF IOT&E

Before any operational tests for demonstration of operational suitability and effectiveness are conducted, an initial or pilot test should be conducted.

The primary purpose of the test is 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 so that sufficient time is available to make the necessary changes to the IOT&E plan as dictated by the results of the pilot test. In the case of ship weapon system testing, the scarcity of test range time and test services dictate the need to conduct such a pilot phase to avoid waste of these valuable services.

2. VALUE OF OPERATIONAL TESTING

Operational tests should be well planned and scheduled.

Operational testing is essential, but it is also expensive and time consuming. To ensure efficient use of submarine, aircraft, ship or range test support units, test concepts should:

(a) Involve organizations with operational experience in establishing measures of effectiveness, so that the outcome of the tests will be accepted as being both technically and operationally significant.

(b) Determine whether the scope of the planned tests will provide sufficient data to justify any change at all in the eyes of potential users.

(c) Compare the scope of proposed tests against checklists of issues frequently raised at major decision milestones, including those contained herein, to assure that the data needed for such decisions will be forthcoming to the extent this is possible from testing alone.

Tests should:

(a) Have specific objectives;

(b) Be instrumented to permit diagnosis of the causes of lack of performance including

- "Random" failures
- Design-induced failures
- Wear out failures
- Operator error failures
- And those as a result of accidental environmantal conditions;

(c) Be scheduled to permit analyses of the methods available to cure each class of failures to corrective actions can be taken;

(d) Never be repeated if failures occurred without a detailed analysis of the failure. Most likely, the failure will not go away.

3. PERSONNEL PERFORMANCE IN CONCURRENT EVALUATIONS

Evaluation of test results must take into account the expertise achieved by T&E personnel through long association with the T&E program.

Weapon systems are often put through the process of a concurrent evalution through the use of sequential DT&E and IOT&E. 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. In particular, new ships normally not only are manned with 100 percent of allowance by rate, but also receive special pre-commissioning training on the subsystems incorporated in the new ship not representative of the average routine personnel replacement. This and other bias in the data which supports the overall results and evaluation thereof must be eliminated if possible, but if not eliminated, then recognized and highlighted in the evaluation of results.

4. IDENTIFY CRITICAL SUBSYSTEMS

In the planning for the IOT&E of a ship system, the critical subsystems with respect to mission performance should be identified.

Adequate measures of effectiveness of these subsystems must be incorproated into the ship IOT&E. The schedule of production and testing should be carefully examined to ensure that time is available for sufficient and necessary subsystem and system testing and that all T&E activities, which are many, are coordinated. Fallback positions should be addressed in the planning process.

5. RELIABILITY OF CRITICAL SYSTEMS

T&E should determine the expected reliability at sea of systems critical to the ship's mobility and primary and major secondary tasks.

Frequent unscheduled maintenance in port severely limits the operational readiness of a ship, and ultimately of its parent unit. Examples of critical systems where crippling reliability problems have occurred are:

- High pressure boilers
- Sonar domes
- Propeller shafts and journal bearings
- Steering mechanisms
- Anchor mechanisms
- Towed body hoists and towed body assemblies
- Reduction gears
- Thrust bearings
- Evaporators
- Oxygen generators

6. CONSISTENCY IN TEST OBJECTIVES

There are various phases of testing of a ship system. One should ensure that the objectives of one phase are not inconsistent with the objectives of the other phases.

If inconsistencies occur, builders and testers could become confused, and test redundancies, delays and ultimately higher program costs will result. It is highly desirable to review all the T&E procedures and acceptance standards prior to the acquisition decision to ensure consistency.

7. SINGLE SCREW SHIPS

T&E of the propulsion systems of ships with a single screw should be especially rigorous to determine failure rates, maintenance and repair alternatives.

A failure in the propulsion system of a single screw ship is especially critical, because the ship has no auxiliary system to bring it to port under its own power.

8. PROBLEMS ASSOCIATED WITH NEW HULLS

Whenever a new hull is incorporated into the ship design, a test and evaluation of this hull should be done prior to the full-scale production and incorporation of the major weapons subsystems.

For example, tests should be conducted to ensure that problems associated with a hull design which takes on board a significant amount of water will not significantly affect the utility of various subsystems on the ship.

9. EFFECT ON PERSONNEL OF HULL/PROPULSION INNOVATIONS

Innovations in hull design and propulsion systems can be expected to cause human factor/habitability problems easily overlooked in the search for technical excellence.

These factors should be evaluated by realistic test in actual operations and results given equal weight with other performance factors. In making the evaluations, it must be realized that the degree of comfort required to live in a ship and operate it effectively exceeds that required to survive aboard for short periods. Thus, a ship with a continuous high noise level from a new type propulsion system, or one with a peculiar motion that induces seasickness in a significant proportion of the crew would be unacceptable as a combat unit, even though technical and operational performance features rendered it otherwise suitable.

10. 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 shipboard weapon and command and control systems usually require a controlled environment, i.e., dry air and cooling, for proper and reliable operation.

11. RELIABILITY/MAINTAINABILITY: PERSONNEL INTERACTIONS

Reliability and maintainability assessments of equipment for installation aboard ships should be designed with due regard for the personality and motivations of the crew members who will operate and maintain the equipment in actual use.

The man should be considered part of the system and his interaction with other parts of the system should be subjected to IOT&E. For example, if an equipment depends for its water tightness on a metal cover secured by twenty screws, and IOT&E reveals a congenital unwillingness on the part of the enlisted technician to repeatedly secure them, then the equipment will have to be redesigned since the man cannot be. It is axiomatic that essential maintenance operations which must be frequently performed, and which at the same time are difficult, awkward or arduous, will be short-circuited or bypassed in some manner by the technician. Widespread failures of shipboard equipment which are reportedly the result of lack of routine care, can often be traced to insufficient regard for this principle in early testing.

IV. SUBSTANTIAL PRODUCTION/DEPLOYMENT PHASE

The period after quantity procurement of ships of the new class commences is the Production/Deployment Phase. It is probable that delivery of the lead ship of the class will occur during this phase, and acceptance trials and, if required, whole-ship OT&E will take place. Results of T&E of the lead ship as it is put through its paces will result in important changes which can be fed back into follow ships. Subsystem OT&E which requires the actual ship must also await this phase.

Checklist items are as follows:

1. Design of Ship FOT&E
2. Operational Testing During Shakedown Period
3. Fleet Operations in FOT&E
4. Ship ASW OT&E Planning
5. Variable Depth Sonar OT&E
6. Ship Self-Noise Tests
7. Effect of Major ECM on Ship Capability
8. Ship System Survivability
9. Interlocks
10. Intra-Ship Communications

The reader should review the previous checklist items since many of them may be applicable to this phase.

1. DESIGN OF SHIP FOT&E

<u>In the testing program of a ship system, it should be recognized that although it may be designated as a special purpose ship, it will in most cases be used in a general purpose role as well.</u>

Thus, the T&E program should address the utility of the ship system in the other roles within its intended general capability. In addition to special mission-related T&E, OT&E to be conducted on the lead ship of a class should be designed to show its ability to perform the routine evolutions that all ships must do regularly during normal fleet operations. The following are examples of recommended objectives in this period:

(a) Investigate and measure replenishment capabilities of the ship, including strikedown of stores. For helicopter replenishment, investigate the effects of helicopter service and maintenance requirements on movement and strikedown of stores.

(b) Examine weapons handling, assembly, loading, and disposal under at-sea conditions, and adequacy of magazine stores to a tactical situation. On aircraft carriers, test to determine whether safe weapon stowage and handling practices, including radiation hazards, can be maintained under conditions of sortie generation at rates expected in tactical operations.

(c) If helicopters are to be operated from the ship, test/examine limitations on courses and speeds in helicopter operations, resulting from superstructure or stack arrangements. Relate these to tactical situations and requirements.

(d) For escort vehicles, including SSN in the escort role, test to ensure that the ship can operate effectively with escorted merchant shipping in terms of communications and data transfer. Test susceptibility to countermeasures.

(e) Test/examine the repairability/maintainability of essential equipment in terms of accessibility, fault location, and fault diagnosis as installed in the ship. Report on adequacy of manuals and diagrams for repair and maintenance under these conditions.

(f) Recognizing that realistic testing in this regard is difficult to schedule because of shortage of services and expense of artificial testing, every effort should be made by T&E planners to incorporate the lead ship as soon as possible into active fleet operations, with experienced observers reporting. Fleet exercises present the most varied opportunities possible short of actual deployment, and consideration should be given to participation by the lead ship in these operations for T&E purposes.

2. OPERATIONAL TESTING DURING SHAKEDOWN PERIOD

The time period for OT&E of a ship can be used more efficiently if full advantage is taken of periods immediately after the ship is delivered to the Navy, i.e., during the shakedown period, final contract trials, and immediately after PSA.

Consideration should be given to extending the shakedown periods for the first ship from each building yard of multiple-yard contracts so that vital operational tests can be conducted. In addition, standard tests (e.g., WSAT, SQT, COT) might be expanded in order to cover any test criteria not otherwise included in the program. Joint planning to include COMOPTEVFOR is necessary to accomplish this effectively.

3. FLEET OPERATIONS IN FOT&E

A great deal of information on the operational effectiveness of a ship can be obtained from standard fleet operations through well designed information collection, processing, and analysis procedures.

Such procedures should be regarded as a necessary adjunct to OT&E and should be utilized by COMOPTEVFOR in assessing the performance of a new ship class, i.e., this kind of data will provide a valuable baseline from which to evaluate new ship classes. The 3M system, Fleet ASW Data Acquisition Program (FADAP), and reports of fleet operational exercises are examples of this kind of data.

4. SHIP ASW OT&E PLANNING

In planning OT&E of shipboard systems, it is important to recognize the difficulty of achieving realism, perhaps more so than in other areas of naval warfare.

This is because fleet operations involve many hours of no contact which may lead to operator boredom and inattention, and many false contacts for every real contact. The need for economical utilization of curtailed operating time and scarce target services thus militates directly against realistic testing.

5. VARIABLE DEPTH SONAR OT&E

The behavior of towed bodies of variable depth sonar systems and towed arrays 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

6. SHIP SELF-NOISE TESTS

The magnetic and acoustic signatures of a ship can be tested accurately only after it is completed.

Furthermore, own ship machinery noise spikes on own sonar can be observed, analyzed, and/or corrected at this time. The settings and power required for effective operation of the degaussing system can be determined at this time. Therefore, these types of testing should be performed as soon as possible after the lead ship is completed so as to permit feedback into follow-on ships.

7. EFFECT OF MAJOR ECM ON SHIP CAPABILITY

The FOT&E of a ship should include tests of the effectiveness of the ship when subjected to major ECM.

This normally cannot be done at land-based test sites: therefore the tests should be performed on the first ship of the class. Tests should not be confined to the effect on equipment, but should consider human factors (stress, mental confusion, COC problems, etc.).

8. SHIP SYSTEM SURVIVABILITY

Operational test and evaluation of modern ships should provide for the assessment of their ability to survive and continue to fight when subjected to battle damage.

This is particularly important today because so much of the ship's combatant capability depends on the functioning of a complex computer network, and because of the lack of semi-automatic and manual modes of operation in some modern weapons. Results of such testing in a land based test site will serve to highlight the need for additional flexibility or degraded modes of operation in the command and control or weapon system. When conducted in a prototype or lead ship, this kind of testing may show that additional redundancy in equipment or cabling is required in the follow ships.

9. INTERLOCKS

Shipboard electronic systems are designed with interlock switches that open electrical circuits for safety reasons when equipment cabinets are opened. OT&E should be able to detect over-design as well as minimum design adequacy of interlock systems.

As an example of over-design, one gun fire control system had interlocks which deactivated unnecessarily the anti-aircraft fire control portion of the system when the surface fire control cabinets were opened for maintenance, and vice versa. Interlock switches should be in a pyramid, with only a few major ones that affect the entire system. Where equipments feed computer input units, dual interlocks should be provided that first open the data lines and second shut down equipment power. Good OT&E can provide timely recommendations for equipment modification.

10. INTRA-SHIP COMMUNICATIONS

In the conduct of lead ship trials and evaluations, particular attention should be given to the operational impact resulting from the absence, by design, of intra-ship communications circuits and stations from important operating locations.

As the most reliable form of intra-ship communications, the sound-powered circuits should be given especially critical examination. Often the addition of a new circuit, or a new station on an existing circuit will be the most effective means of remedying an operational problem that doesn't become evident until the lead ship goes to sea, and one that can be economically incorporated in follow ships.