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DEFENSE SYSTEMS MANAGEMENT SCHOOL

PROGRAM MANAGEMENT COURSE
INDIVIDUAL STUDY PROGRAM

AN ASSESSMENT
OF THE
PRACTICALITY OF A TOTAL SHIP OPEVAL

STUDY PROJECT REPORT
PMC 76-1

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DEFENSE SYSTEMS MANAGEMENT SCHOOL

STUDY TITLE:

AN ASSESSMENT OF THE PRACTICALITY OF A TOTAL SHIP OPEVAL

STUDY PROJECT GOALS:

To identify and analyze the considerations that pertain to the concept of conducting total ship Operational Evaluations (OPEVALs) as part of the ship acquisition process and to document in the study report these considerations and the conclusions that can be drawn for future ship programs.

STUDY REPORT ABSTRACT:

The overall purpose of the study project was to assess the practicality of the total ship OPEVAL for a conventional (production vice R&D) ship program. This report contains an overview of the Navy T&E actions that were taken to implement the policies of DOD Directive 5000.3. A detailed analysis of the ship acquisition T&E process is provided, from which a model is generated to serve as a framework for analyzing the marginal utility of adding a total ship OPEVAL to this process. Three considerations emerge which lead to the conclusion that an OPEVAL would be impractical in all cases (except the R&D case, which was not considered): (1) there are inherent constraints and artificialities in such an exercise; (2) the objectives are already achieved under the existing ship T&E process, and (3) there would be a negligible return on investment.

A recommendation is made that DOD Directive 5000.3 be revised to reflect the conclusions of this report and that two Navy T&E guidance manuals be revised to reflect the conceptualization of the ship acquisition T&E process described in the report. Recommendations are made for several follow-on study projects.

KEY WORDS: "Ship Operational Testing"

MATERIEL EVALUATION SHIPS OPERATIONAL TESTING ACCEPTANCE TESTING

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AN ASSESSMENT OF THE PRACTICALITY

OF A TOTAL SHIP OPEVAL

Study Project Report

Individual Study Program

Defense Systems Management School

Program Management Course

Class 76-1

by

Matthew Thomas Reynolds
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May 1976

Study Project Advisor
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EXECUTIVE SUMMARY

This report describes the results of a study project in which the author investigated the practicality of conducting a total ship Operational Evaluation (OPEVAL) as part of a Navy ship acquisition program. The OPEVAL has become a very useful tool which the Navy has used for the conduct of Initial Operational Test and Evaluation (IOT&E) of its new systems. Since the time that the Office of the Secretary of Defense (OSD) first issued its T&E policies in 1971, there has been a disagreement between OSD and the Navy on whether or not the OPEVAL should be conducted on ships in conventional (i.e. production vice R&D) ship programs. The Navy has taken the position that it should not.

In this study project, the reasons why the Navy has taken this position were investigated. Lessons learned from ship IOT&E programs conducted within the past five years were assessed. Interviews were conducted with T&E managers from current ship acquisition projects and with personnel from the Office of OSD's Deputy Director for Test and Evaluation.

The study project concluded that the conduct of a total ship OPEVAL would be impractical in all cases (except the R&D case, which was not considered). Three considerations are discussed in detail that support this conclusion:

1. The inherent constraints of the test exercise would in themselves introduce uncertainties to and undermine the confidence in the validity of the results;

2. the objectives of an OPEVAL as applied to a ship program are already achieved under the existing Navy ship T&E process; and
3. even assuming that some additional knowledge would be gained from the OPEVAL, it is doubtful that there would be a significant return on investment.

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INTRODUCTION

Purpose of the Study Project

The purpose of this study project was to investigate the practicality of conducting a total ship Operational Evaluation (OPEVAL) as part of a Navy ship acquisition program. For over a decade the OPEVAL has been used by the Navy as a tool for assessing the suitability of new systems prior to their introduction to the Fleet. When Deputy Secretary of Defense David Packard first introduced the new DOD Test and Evaluation (T&E) policies to the Services in 1971 (1:1-2)[1], the OPEVAL was ideally suited as a mechanism for the conduct of Initial Operational Test and Evaluation (IOT&E). During the next two years, as the new DOD directive that would definitize and document the T&E policies was prepared, personnel from the Office of the Secretary of Defense (OSD) and the Navy had many discussions on how these policies would be applied to ships. A specific area of disagreement was the utility of conducting an OPEVAL on a total ship. The issue was not totally resolved. The DOD directive, when finally issued, reflected this by inclusion of the following statement:

> "For all new classes, continuing phases of OT&E on the lead ship will be conducted at sea as early in

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[1]This notation will be used throughout the report for sources of quotations and major references. The first number is the source listed in the References section; the second number, if provided, is the page within that source.

> the acquisition process as possible for specified systems or equipments and, if required, full ship operational evaluation to the degree feasible." (underline added) (2:5)

The specific goals of this study project were to study the reasons why the Navy objected to the concept of a total ship OPEVAL in that 1971-72 time frame, to investigate any new knowledge the Navy has gained since that time from the actual conduct of ship IOT&E programs, and to make recommendations for future ship programs as well as to suggest possible changes to the DOD T&E directive.

Limitations of the Project

As will be explained in Section II, separate policies apply to programs where the lead ship is constructed and tested as an effort, in contrast to the more conventional approach of building the lead ship as a production effort. In the case of the R&D ship, there is a requirement for the conduct of an OPEVAL. While some of the considerations that apply to a conventional ship OPEVAL might be applied here also, this topic was not included in this study project.

Study Project Methodology

While many of the considerations that pertained to this topic during the 1971-1972 time frame are well documented, much has been learned but little written since that time. In investigating what has been learned, it was therefore necessary not only to survey the literature on the subject, but also to conduct interviews with key participants in ship

IOT&E programs that have recently been planned and/or conducted and with personnel from the Office of OSD's Deputy Director for Test and Evaluation. The list of pertinent references as well as personnel interviewed is contained in the References section of this report.

Organization of the Report

The information gathered for this report has been organized around the flow of a typical ship acquisition T&E program, with an emphasis towards highlighting the manner in which this process complies with the spirit and intent of the DOD directive on T&E. Section II provides background information on the development of Navy T&E policies to implement the DOD directive and on the peculiarities of ship acquisition T&E. Section III is a detailed analysis of the ship acquisition T&E process. It describes the key activities that occur during the phases of ship acquisition T&E and presents a model which serves as a framework for considering the marginal utility of adding a total ship OPEVAL to the T&E process. Section IV presents the considerations that emerged from the study project which lead to the conclusion of the impracticality of the total ship OPEVAL. Section V summarizes the conclusions drawn and includes some recommendations for the Navy and OSD to follow based on those conclusions.

SECTION II

OVERVIEW OF THE NAVY T&E POLICIES AND PROCEDURES

Background

Test and Evaluation (T&E) now plays a key role in the weapons acquisition process. When the theoretical benefits did not accrue from the total package procurement concept instituted by Secretary of Defense Robert McNamara in the early 1960's, new approaches were studied and the milestone procurement policy was adopted by Deputy Secretary of Defense David Packard in the early 1970's. (3:1-7) Under this policy, instead of a one-time commitment to an entire research, development and production program, funds and resources are committed incrementally. The acquisition process is thus separated into phases by discrete decision points at which the progress of the program is reviewed and a decision is made on whether or not to proceed. One of the critical inputs to these decisions is the result of T&E, particularly Operational T&E. Operational T&E is defined as T&E conducted by the cognizant Service's designated independent agent in an operational environment for the purposes of assessing military suitability and effectiveness. The Navy's OT&E agent is the Commander, Operational Test and Evaluation Force (OPTEVFOR), who reports directly to the Chief of Naval Operations and is independent of the developing activities (Navy Material Command) and the user activities (the Fleet).

The OPEVAL

The most common and formal vehicle that COMOPTEVFOR uses to perform his function is an Operational Evaluation (OPEVAL). (4:6) An OPEVAL is a project assigned by the Chief of Naval Operations to OPTEVFOR to conduct T&E of a specific system in its projected operational environment for the sake of providing an independent assessment of that system's military effectiveness and suitability. Through the OPEVAL, COMOPTEVFOR assesses whether or not:

(1) The system or equipment functions in an operationally satisfactory manner and performs reliably and effectively in accordance with program objectives in realistic operational conditions.

(2) The system can be effectively operated and maintained by the level of personnel skill anticipated to be available under service conditions.

(3) There is reasonable indication that logistic supportability in a deployed status is feasible.

(4) All test questions germane to a production decision are adequately examined.

Since most Navy systems and equipments are destined to be installed on ships or aircraft, the conduct of an OPEVAL of a new system frequently involves an actual temporary installation of that system in an active fleet ship or aircraft.

In a typical Navy acquisition program, the OPEVAL is the "final exam" of the R&D phase. If it is successful, it will result in a recommendation from OPTEVFOR to the Chief of Naval Operations that the acquisition program proceed from R&D to production and fleet introduction. (This T&E input is only one input - although usually the most critical - to the production approval decision. The final decision will also depend on other factors such as cost, schedule, and military need.) The conduct of an OPEVAL at the end of the R&D phase is a critical Navy mechanism for application of the DOD policy of "try-before-buy." Figure 1 is the schedule of a Navy gun system T&E program which is quite typical and demonstrates the process just described. This system is the MK 75 Gun and MK 92 Fire Control System which will initially be installed on guided missile frigates of the FFG-7 Class and on patrol combatant hydrofoil ships of the PHM-1 Class. A prototype version of this gun system was temporarily installed onboard USS TALBOT (FFG-4) from September 1974 to November 1975. The OPEVAL was successfully conducted from April to June 1975 and CNO subsequently approved the system for production on 8 September 1975.(5:1)

T&E of Ships

From the earliest studies of the "try-before-buy" concept, applying this policy to Naval ships has remained somewhat of an anomaly. The pure application would be to use the lead ship of a class as a prototype for the purpose of conducting an OPEVAL, prior to approving construction of the "follow ships." However, for most programs this is not practical because of the time associated with the design and construction of a ship. Figure 2 is the schedule for construction of the lead ship of the FFG-7

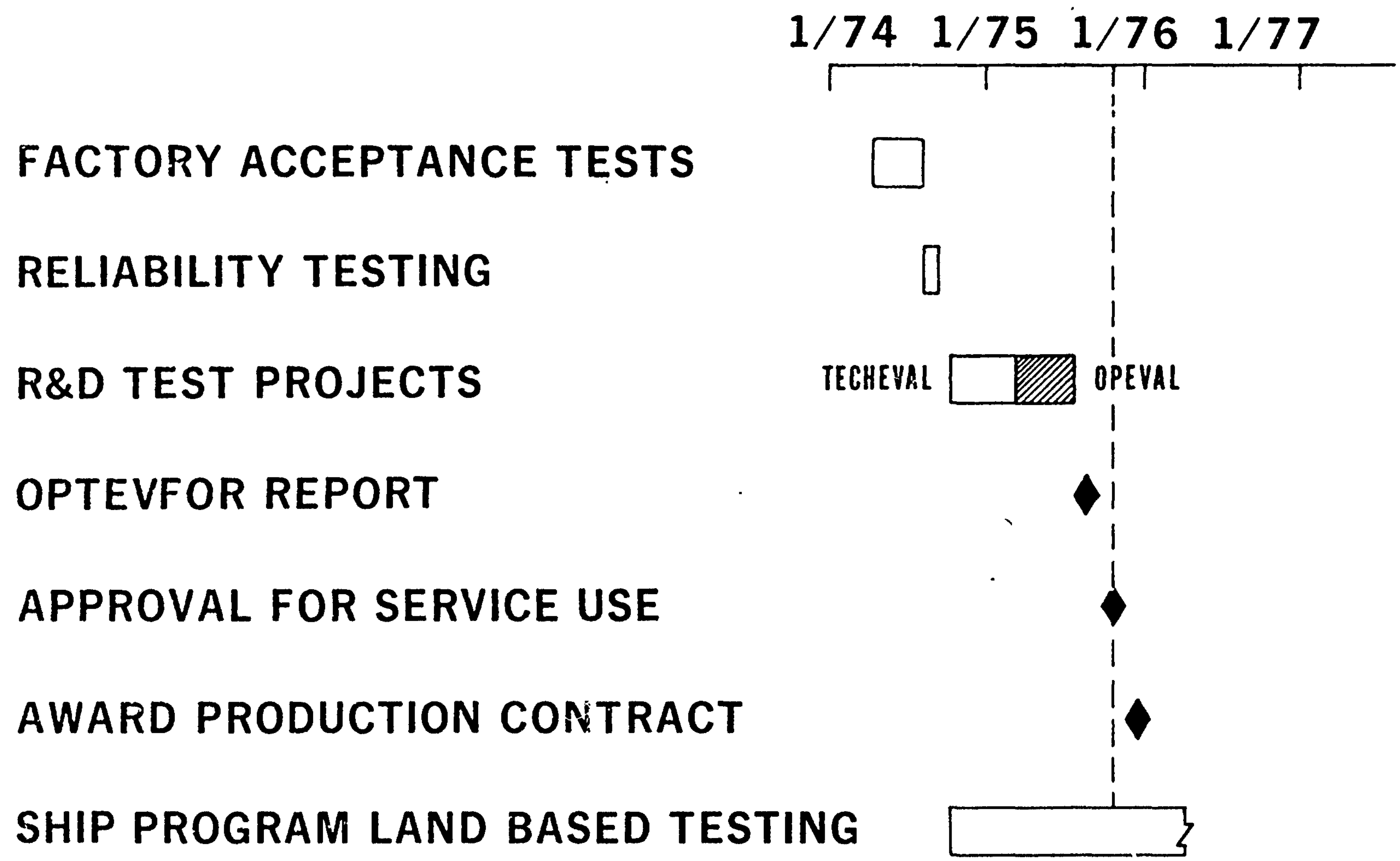

FIGURE 1 TYPICAL NAVY T&E PROGRAM MK 92 FCS/MK 75 GUN SYSTEM

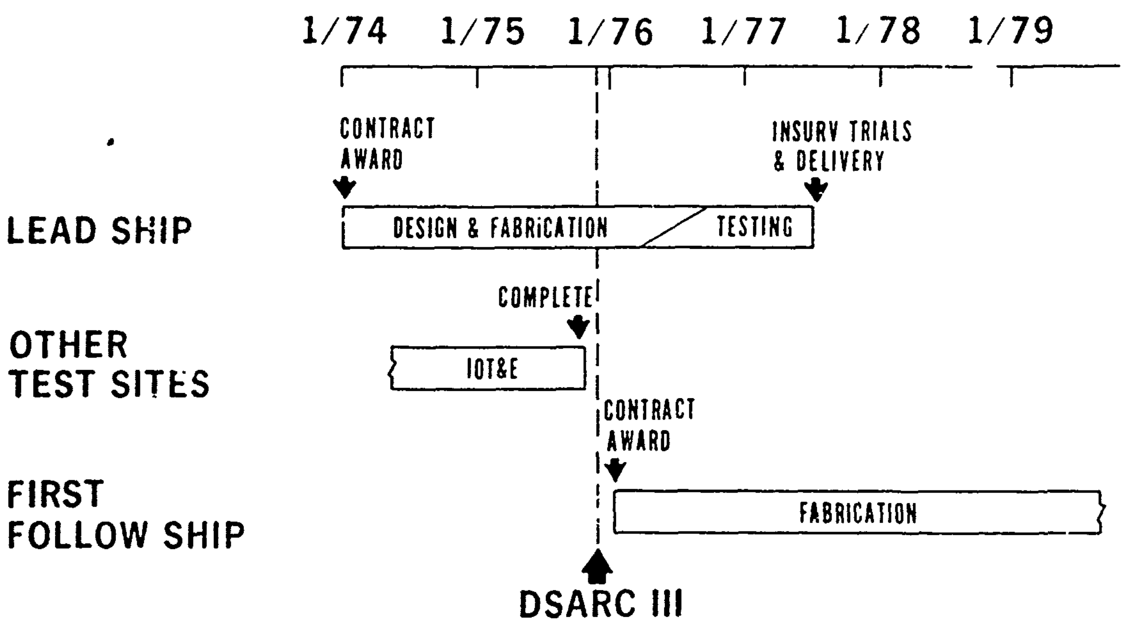

FIGURE 2. TYPICAL CONVENTIONAL SHIP ACQUISITION T&E PROGRAM: FFG-7 CLASS

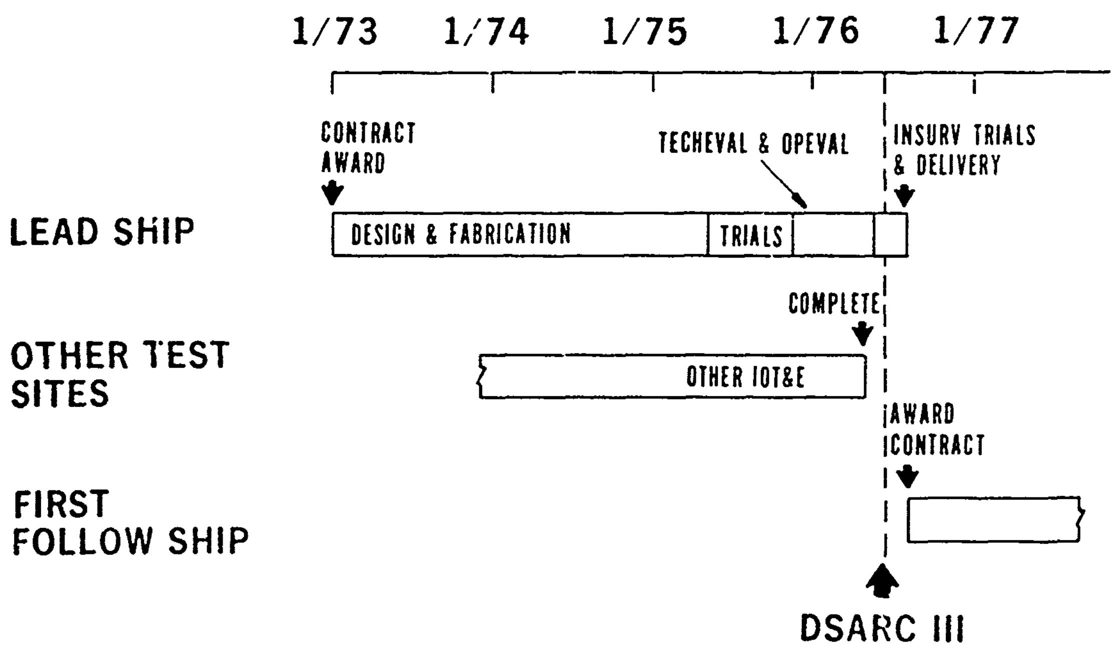

FIGURE 3 TYPICAL R&D SHIP ACQUISITION T&E PROGRAM· PHM 1 CLASS

Class guided missile frigates. The FFG-7 program is typical of a Navy combatant ship program and is the first ship program to be structured to conform to the new DOD milestone procurement process.[2] Note that the lead ship is scheduled for delivery in June 1977. Because of the time required for crew training, qualifications and overall shakedown, the ship would not be ready to conduct an exercise such as an OPEVAL for almost a year. Adding to that the time for the OPEVAL itself, the analyses of the results, and preparation of the report, it would be almost 1977 before any OT&E data from the lead ship would be available for a production decision. Estimating 42 months from time of contract award to delivery of the first follow ship, there would then be a five year delay between delivery of the first ship and delivery of the first follow ship, if the program were structured to use the lead ship as a prototype.

It was agreed between OSD and the Navy that for most ship programs, the spirit and intent of the "try before buy" policy could be achieved without delaying approval for follow-ship production until OT&E could be conducted on the lead ship. The normal combatant ship acquisition usually includes the use of other installations on which sufficient operational T&E data can be generated to provide assurances of the suitability and effectiveness of the overall ship. These installations are (1) the temporary shipboard installations (surrogate platforms) used

[2]SECDEF approved the FFG-7 Class for production on December 11, 1975

for OPEVALs of individual unproven shipboard systems and (2) the land based test sites frequently constructed for the integration of shipboard subsystems prior to installation in a lead ship. (Most major combatant ships have been of a complexity to warrant construction of a land based test site for the combat system, and several of them for the propulsion system.) This procedure for ship acquisition OT&E is documented in DOD Directive 5000.3 on T&E.

There is one notable exception to this rule. When a ship design involves a major technological advance in the hull or propulsion design, the lead ship is designed, constructed, and tested in its entirety as an R&D effort. Such ships must undergo extensive operational testing prior to the commitment to the follow-on production of ships. Testing covers all the extreme conditions to which the ships will be subjected in the Fleet in order to assure that this new platform can perform its designated mission. The two key Navy programs currently following this approach are the patrol combatant hydrofoil ship (PHM) and the Surface Effects Ship (SES). The lead hydrofoil ship, the PHM-1, will undergo a total ship OPEVAL in late Spring of 1976. Unlike the FFG-7 program, the follow-ship production contract will not be awarded until after this OPEVAL and subsequent approval at DSARC III. The structure of the PHM-1 program is depicted in Figure 3, where it can be contrasted to the more conventional schedule of the FFG-7 program in Figure 2.

The Surface Effects Ship program includes planning for a full ship prototype in the 2200 to 3000 ton range, the key purpose of which will be developmental and operational T&E. Unlike PHM-1, which will eventually be deployed as a Fleet unit, the SES prototype will be a test vehicle only, constructed with no intention of actual fleet usage.

SECTION III

THE SHIP ACQUISITION T&E PROCESS

Design and T&E: Two Parallel Processes

The T&E in an acquisition program is tailored to reduce the risks inherent in the design. For a given program, therefore, the T&E process closely parallels the design process. This is a fundamental concept to understand when considering the anomalies associated with T&E for ship acquisition as compared to that for acquisition of other weapons systems. The anomalies are the same ones that are inherent in the overall ship design process itself.

The key anomaly referred to is that from an operational performance perspective the ship is basically only a platform for other systems. For this reason, most of the management concepts, theories and approaches that can be applied to other weapons acquisition programs cannot be given a wholesale application to ship acquisition programs. It is only within the last decade that ships have begun to take on some of the characteristics of unique systems in themselves. This is due largely to the fact that the design and operation of the shipboard systems have become increasingly interdependent with each new ship class in an effort to reduce the response time required to perform its missions.

Program Initiation

The acquisition program for a new weapon system is initiated in response to a clearly defined operational need (e.g., a specific threat) which cannot be satisfied by existing military or commercial hardware. (3:3) (6:5) An Operational Requirement(s) is first written to provide a concise statement of operational needs. A Development Proposal is then prepared which presents alternatives and tradeoffs for achieving the particular capabilities needed to meet the identified operational requirement. If this proposal is approved, development begins. Assuming that the development efforts are successful and the program receives approval to proceed at its program initiation and full-scale development milestones two of the end products will be (1) a prototype for the conduct of DT&E and OT&E and (2) a detail specification for use in the production contract. The T&E requirements are developed in parallel with this design process: operational T&E requirements from the Development Proposal, and, later, production acceptance T&E requirements from the contract specifications.

In contrast to this "top down" direction of the development of design and T&E requirements for other weapon systems, those requirements for a ship are generated more from the "bottom-up," beginning with the early stages of assembly of individual equipments and systems and ending with at-sea exercises of the ship. The ship's suite of systems is a composite of the latest types of systems needed to perform the mission of that particular ship type. Some of these of necessity will still be developmental at the time of their selection. However, an attempt is made to insure that all of them can be subjected to an OPEVAL and be approved for service use by the time they are actually installed during the ship construction period. Thus, for the most part, the design and development of shipboard systems precede that of the ship and are somewhat independent of it. The ship itself is not designed as a unique system.

The timing of when to initiate a new ship acquisition program is usually not related to a specific operational threat, but rather to a need for platforms to replace ships that have reached obsolescence, thereby maintaining or increasing force levels (the notable exception to this being R&D ship programs which are initiated in order to force or capitalize upon technological advancement in the state-of-the-art, such as the current hydrofoil or surface effects ship R&D efforts).

T&E of the Individual Shipboard Systems

A ship, as a platform for different types of systems, is designed to accomplish many missions. A destroyer, for example, has many and varied missions including anti-air warfare, anti-submarine warfare, shore bombardment, search and rescue, blockade and surveillance, and harassment. Each shipboard system plays a role in contributing to the accomplishment of one or more of these missions. As mentioned before, the design and development of individual systems precede and are virtually independent of specific ships. The test of individual systems to meet certain threats is therefore also generally independent of specific ships. A given gun system, for example, will be used on many types of ships from destroyers to replenishment oilers. To perform an OPEVAL of that gun, it will be temporarily installed on one active fleet ship - perhaps a destroyer - for testing in an operational environment. However, the results of the OPEVAL on that one type ship will be sufficient to make a decision for approval to produce that system for all of its prospective platforms. Almost all of the operational risk and uncertainty in the acquisition of that gun are inherent in the system itself. The suitability and effectiveness of the gun with regard to the role it will play on the replenishment oiler can be almost totally demonstrated on the destroyer platform. In other words, the marginal operational risk and uncertainty related to its installation in a specific ship platform and its integration with the other systems on that platform is negligible.

The ship design process, then, as it relates to the particular shipboard systems, consists of integrating the selected systems in some optimum fashion to insure mutual compatibility and to reduce response time in accomplishing the ship's missions, as well as accommodating the physical constraints of the ship as a platform.

The Navy T&E process for a conventional ship acquisition program is based on the fact that the operational risk associated with the ship platfc ..self is minor when compared to that attributable to the individual systems. The Navy has made a major policy comm..ent to demonstrate system operational effectiveness and suitability independent of and prior to permanent installation on specific ship platforms. When a lead ship is constructed, assuming that all of the systems have successfully completed their development and operational T&E, including their own OPEVALs, there is little operational risk that remains and thus minimal operational T&E to be conducted on the lead ship itself. That which does remain to be conducted is not consequential enough to warrant delay of a decision to build "follow ships" until it is completed.

The Navy's commitment is a very conscious one, with far reaching implications for the entire spectrum of T&E policies and procedures. This can be appreciated if one considers the hypothetical possibility that the Navy approach, in contrast, could be to delay the development and operational T&E of the systems until they are installed on the lead ship, and thereby actually use the lead ship itself as a total prototype.

Land Based Test Sites

Land based test sites are another important aspect of ship design and T&E processes which further demonstrate the Navy's commitment to early reduction of development and operational risks prior to ship construction. Many of the shipboard systems - particularly in the combat systems area - have become very operationally interdependent in ships designed during the past ten years. This interdependence has introduced an additional degree of development and operational risk in integrating these systems. The Navy has made a conscious decision, however, not to defer the reduction of this integration risk to shipboard installation. Land based test sites (LBTSs) have been constructed for major combatant ship programs specifically for the design and T&E of system integration prior to shipboard installation. Thus, the Navy commitment to minimize the development and operational risk associated with the ship platform has been preserved. A detailed description of the FFG-7 program's Combat System Land Based Test Site located in Long Island, New York, as well as the DT&E and IOT&E program conducted there, is contained in Appendix A. Therein the extent to which the Navy goes to minimize operational risks and uncertainty prior to ship construction can be seen.

The Ship Construction Period

After integration and testing of the shipboard systems at the land based test site(s), the major design and T&E activity moves to the shipyard. Here, for a time period of three to five years, detailed drawings, construction plans, work orders, and inspection plans are developed and executed as the ship platform is constructed and her systems are installed. During the last year the critical efforts center about the test program as each piece of equipment is lit off, tested, mated with its interfaces, and retested at the next level of integrated operability. A very extensive Integrated Test Package is developed and its tests are conducted to insure that all of the systems are properly installed and functioning within prescribed tolerance levels prior to the at-sea demonstration for the Navy Acceptance Trials. (7:2) (8:27) T&E during this period is neither development nor operational, but is categorized as production acceptance T&E (PAT&E). (4:9)

The Post Delivery Tests and Trials Period

Finally, after Acceptance Trials and delivery to the Navy, the ship undergoes a one year period of post delivery tests, trials, and training exercises prior to deployment. Most of this effort is directed towards individual system certifications and a "shakedown" of the ship and her crew. Towards the end of that time frame, a second set of Navy trials (Final Contract Trials) is conducted by the Board of Inspection and Survey to verify the correction of material deficiencies previously noted and to document any new deficiencies. Those deficiencies that the shipbuilder has responsibility for under contract warrantees are presented to him for correction during a subsequent shipyard availability. A description of the key T&E events for the post delivery period of a surface combatant ship is described in Appendix B.

Model of the Ship T&E Process

Figure 4 is the model of the flow of system/ship T&E phases which emerges from the previous description. Individual systems undergo development T&E and operational T&E independent of and, for the most part, prior to inception of the ship acquisition programs which ultimately use them (first phase). When a ship acquisition program is initiated, and the risks and uncertainties associated with integrating some of these systems warrant it, a land based test site is constructed for further development and operational T&E (second phase). What significant testing remains for the last two phases (ship construction and post delivery) is primarily production acceptance T&E. It has always been a conscious Navy policy to accomplish the necessary DT&E and OT&E as early in this process as possible in order to minimize the necessity for major equipment modifications and time consuming retesting during the construction and post delivery phases where the cost and schedule repercussions would be significant. It is this practice which enabled the Navy to readily comply with the try-before-buy policy. The policy's only significant impact has been in major combatant ship programs in which the decision to construct follow ships of the class (DSARC III) is delayed until the DT&E and OT&E at the combat system land based test site have been successfully completed. The only major testing to be accomplished thereafter is PAT&E to insure that the shipbuilder has fully met the contract

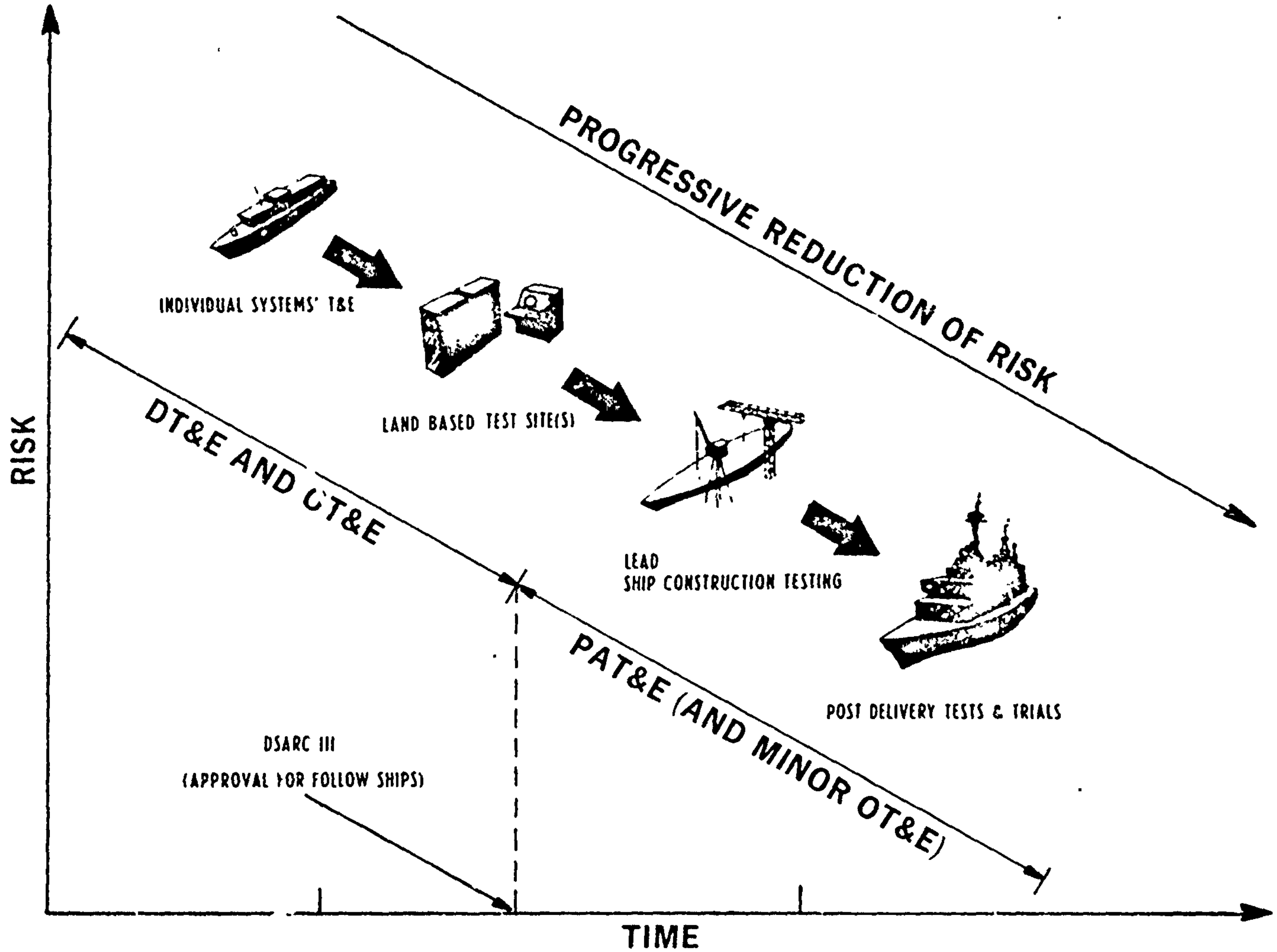

FIGURE 4. MODEL OF THE CONVENTIONAL SHIP ACQUISITION T&E PROCESS

specifications and that the ship is in the proper state of material readiness for at-sea operation.

Although most of the testing on the ship platform itself is PAT&E, the Navy does nevertheless conduct some operational T&E as part of the post delivery T&E phase of the lead ship of a class. However, this OT&E is not critical to the acquisition process in that it is conducted well after the commitment to production of the follow ships has been made. To date, such OT&E projects have been assigned primarily to evaluate some aspects of system integration which hitherto had undergone OT&E in a simulated status only.

SECTION IV

CONSIDERATIONS OF CONDUCTING AN OPEVAL

The desirability of conducting an OPEVAL on a conventional (vice R&D) ship program has been studied for two ships, viz., CGN-38 (formerly DLGN-38) (9) and the FFC-7 (10), but in neither case was it found to be cost effective. Three considerations follow to support the conclusion that, other than in the special case of an R&D ship program, the concept of a total ship OPEVAL would never be practical:

1. The inherent constraints of the test exercise would in themselves introduce uncertainties to and undermine the confidence in the validity of the results;
2. the objectives of an OPEVAL as applied to a ship program are already achieved under the existing Navy ship T&E process; and
3. even assuming that some additional knowledge would be gained, it is doubtful that there would be a significant return on investment.

These three considerations are discussed below.

Constraints

OPEVALs as conceived in DOD Directive 5000.3 and OPNAVINST 3960.10 are highly structured evolutions with conclusions drawn only after the collection of a great amount of data from many replications of combat situations. Variables such as environment and crew training are assiduously controlled so that the result is as clear a reflection of system capability as possible. To undertake this type of analysis on a total system as complex as a combatant ship - to devise, support and conduct valid tests with sufficient replication to overcome statistical anomalies - would be a mammoth undertaking involving the commitment of great amounts of resources in the form of money, time, material, and fleet units. This would require a scenario type exercise similar to a war game or a training battle problem which, by necessity, would be limited to a short period of time. There is considerable uncertainty introduced with this approach. Variables such as crew training, environment, and material readiness that exist at the time will influence the outcome and are likely to yield erroneous conclusions. Although the OPEVAL would seek to simulate a wartime situation as realistically as possible, various artificialities such as safety precautions which preclude live firings would still necessitate careful interpretation of the results.

Furthermore, it would be difficult, if not impossible, to develop valid measures of effectiveness (MOEs) for a total ship OPEVAL. As described previously, combatant ships contain systems which have previously been tested by OPTEVFOR for operational suitability and effectiveness prior to their integration into the total ship system. The concern at the ship system level is with system integration, information flow, transfer between operational modes, reaction time characteristics, and command and control. These factors do not lend themselves to evaluation by combinations of simple MOEs.

A study conducted in 1973 on OT&E of ships expands on this:

> "It may well be that measures of effectiveness no longer are useful in evaluating complex weapon systems operating in an integrated platform environment against an equally complex threat. The ABM debate is a case in point. The Operational Research Society of America ultimately convoked a committee which condemned, in print, the analyses and representations of certain individuals of great personal reputation. [11:1123-1258]. These severe disagreements centered, in part, around the assumption that simple MOEs could, in fact, represent the value of such systems for DOD and Congressional evaluators. The seemingly endless controversies that occurred concerning the methodology for developing the specified MOEs make this assumption questionable." (12:III-13)

Objectives Achieved Elsewhere

The primary purpose of conducting an OPEVAL is usually to provide an assessment of operational suitability and effectiveness as an input to the decision to go into production (DSARC III). However, in some cases an OPEVAL type of project[3] is conducted after the production decision. This would be the situation if an OPEVAL were included in a ship acquisition T&E program, since DSARC III occurs more than two years prior to the time the lead ship could undergo an OPEVAL. In this case the purposes for conducting an OPEVAL are somewhat different. When applied to a ship program, the following

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[3]Throughout this paper, the term "operational evaluation" (OPEVAL) is used in a general sense referring to any OT&E exercise. It does not refer to the more restrictive Navy definition where it is defined as the OT&E exercise occurring at the end of R&D just prior to the major production decision (Chief of Naval Operation's Instruction 3960.10).

six purposes for conducting an OPEVAL are found for the most part to be accommodated elsewhere. The model of a ship acquisition T&E program developed in Section III will be used to demonstrate this.

a. The primary objective of conducting an OPEVAL after production initiation is to demonstrate that the system development has achieved the required operational capabilities. As discussed previously, for a ship this equates largely to the sum of the capabilities of the shipboard systems and is therefore known from the individual systems' T&E. Capabilities which cross major system boundaries can usually be fully demonstrated at the LBTSs. One prominent reason why DDT&E withdrew his consideration of requiring an OPEVAL of FFG-7 was the success in use of the Combat System and Propulsion System LBTSs to demonstrate these operational capabilities and to uncover deficiencies that would otherwise have gone undetected until at-sea operation years later. (13) These two ship program LBTSs were the first ones constructed with a key objective being the conduct of early operational T&E.

One area that cannot be thoroughly demonstrated even with the hardware at the LBTS is how the overall combat capability is affected in selected degraded modes of operation, e.g., when there are electrical or mechanical problems in the interface between weapons systems and the ship or electromagnetic interference problems between radars.

However, the possible permutations and combinations of such degradations are such that a comprehensive study could only be done through the use of model based computer simulation, rather than through actual shipboard demonstration. Within the last several years the Naval Sea Systems Command has developed and utilized a Combatant Capability Assessment Program in this manner during the design of the FFG-7, the CSGN, and the DDG-47 Classes (14).

b. The second purpose is to identify any design deficiencies in order to correct them or learn to adapt to them. The extensive T&E efforts undertaken prior to ship construction have proven to be adequate for this purpose. For a ship program the DT&E and OT&E of the individual systems on surrogate platforms and of the integrated systems in the shipboard configuration at land based test sites will uncover any major technical and operational deficiencies well in advance of the time frame when the ship OPEVAL would be conducted. Also, there is an exhaustive series of tests and trials conducted on each ship during construction and from the time of delivery up to turnover to the Fleet a year later. These include Acceptance Trials and Final Contract Trials by the Navy's Board of Inspection and Survey as well as numerous certifications and qualification trials for the ship's sonar and radars, missile and gun systems, anti-submarine warfare systems, and the propulsion system. (See Appendix B). These, too, uncover any design deficiencies or installation errors.

The imposition of an OPEVAL would not obviate the need to run these exercises separately, since most of them have secondary objectives beyond T&E such as system calibration, contractual acceptance, and crew training. The OPEVAL would therefore be in addition to, and in many areas a duplication of, these trials.

c. The third purpose is to confirm the correction of discrepancies previously noted. This is rather important in a shipboard system acquisition program where the turnover from the Material Command to the Fleet is abrupt. In a ship program, however, the turnover process is gradual. It is a continuing evolution through the eight to ten year course of the acquisition program. During the last year of construction, the ship's crew resides at the shipyard, identifying problems that they see with the ship and trying to get them corrected before they have to take over the ship upon Commissioning. Also, the identification and resolution of material deficiencies is a very high priority with the ship's crew for the year of post-delivery/post-commissioning tests and trials. Any marginal benefits to be gained in this area from a ship OPEVAL are somewhat debatable.

d. The fourth purpose is to develop initial procedures and tactics on how to employ the system. In the case of conventional ships, this is not a significant effort. The missions and roles of the various types of ships are well established in fleet doctrine. In the case of a brand new type of ship, such as a patrol combatant hydrofoil, the development of tactics is a very long evolution beginning with the initial force level studies that originally identified the need for the ship and extending through the first few years of use and participation in major fleet exercises. The contributions to this effort from a one or two month OPEVAL would be negligible.

e. The fifth purpose is to identify key logistics con siderations which should be modified or established to ensure that the fleet can support the product. With the exception of training, logistics support is handled at the equipment/ system level. Each respective system manager develops and refines the logistics support required for his system as well as for its interface with other systems on the ship. The adequacy of this support is later verified by the ship's crew. In addition, these logistics support considerations are continuously refined and validated throughout the acquisition program. For example, in the combat systems area, a Logistics Special Assistance Team comes aboard after delivery as part of the Combat System Ship Qualification Trials of each combatant to verify the adequacy of the logistics support.

In the training area, there is some team training required for the ship which cannot be accomplished within the individual systems' areas. This is accomplished during the usual training evolutions of the ship's post delivery period. Also, each is usually scheduled to participate in a major fleet exercise during the first two years after Commissioning. Any contributions to these training efforts from a ship OPEVAL would of course be beneficial, but in themselves would do little to justify the large expense of the OPEVAL.

f. The sixth purpose is to provide early feedback to assist in the design of future systems. For a ship, this type of feedback must be - and is - a continuous effort throughout the ship's life. It is provided by many means, from the formal Acceptance Trials and Underway Material Inspections to the routine application of the Planned Maintenance Sub-system by the sailors on the ship. The review mechanism of the Fleet Modernization Program is used extensively to document, collect, and sort such feedback information on a continuing basis throughout the ship's life and to prioritize proposed improvements for the allocation of Operation and Maintenance funds. Any feedback from a one-time OPEVAL would provide a negligible addition to this process.

Figure 5 summarizes the coverage of these OPEVAL objectives during the other portions of the ship acquisition T&E program.

	INDIVIDUAL SYSTEMS' T&E	SHIP LBTS	SHIPYARD	POST DELIVERY	DEPLOYMENT
DEMONSTRATE OPERATIONAL CAPABILITIES	✓	✓			
IDENTIFY DESIGN DEFICIENCIES	✓	✓	✓	✓	
CONFIRM CORRECTION OF EARLIER DEFICIENCIES			✓	✓	
DEVELOP INITIAL TACTICS	✓				✓
IDENTIFY KEY LOGISTICS CONSIDERATIONS	✓				
PROVIDE FEEDBACK FOR NEW SYSTEMS	✓	✓	✓	✓	✓

FIGURE 5. COVERAGE OF OPEVAL OBJECTIVES DURING OTHER SHIP T&E PHASES

Doubtful Return on Investment

To conduct an OPEVAL of the CGN-38 has been estimated by COMOPTEVFOR to cost between $3 million and $18 million, depending on what portion of the participating fleet units' operating costs would be charged directly to the OPEVAL. (15) However, little return on this dollar investment can be assured from the conduct of such an OPEVAL. It would provide little feedback which would not otherwise be provided through other T&E and through fleet operations of the ship. The constraints are severe, which would make many of the results inconclusive; additionally there is no proven method of developing valid total ship test criteria.

In considering return on investment, the perishability of any conclusions drawn must also be recognized. The average life of a Navy ship is 30 years. However, usually only the hull and propulsion machinery will serve for that lifetime. Some updating of the auxiliary machinery - either additions or exchanges - typically occurs once in the ship's life. Because of rapid advances in electronics technology and the continually changing threat, the combat system elements are much more short-lived. Recent experience has shown that within the course of ten years, the ship's entire combat system will have been replaced. (12:I-5) Thus, in identifying a time frame over which to amortize the cost of an OPEVAL, it must be realized that any returns from that investment would be netted in less than ten years of operation, which is a shorter time frame than that required for a ship acquisition program.

For there to be a significant return on investment, the results of the OPEVAL should be able to impact the acquisition of the remaining ships in the program. This cannot be done without extending the current acquisition process. In investigating the desirability of conducting an OPEVAL on CGN-38, the Chief of Naval Material reported that by the time such an exercise could be conducted, analyzed, and reported, two of the remaining three ships in the program would already have been delivered to the Navy and the third, with all of her equipments already installed, would be in the final stages of combat system testing. (16) Even on buys of large numbers of ships, an OPEVAL on the completed lead ship occurs too late. For example, on the 30 ship DD-963 program, the earliest that an OPEVAL of the lead ship could be completed is mid-1976. For the program to proceed on schedule, award of the final increment of seven ships had to take place in January 1975, more than a year earlier.

Any extensions of the current acquisition process, on the other hand, would lead to substantially increased shipyard costs that would probably exceed the cost of the OPEVAL itself. The hiring and training of the appropriate numbers of skilled personnel is a mammoth undertaking for a shipyard. Any significant time lag between production of the lead and follow ships would result in severe personnel disruptions. The shipbuilder would be forced to let most of his experienced workers go and rehire others when construction resumed. Much of the "learning curve" of experience would have been lost. Also a significant amount of the equipments for a ship require special fabrication or the use of scarce material. Significant cost savings that are realized by quantity procurement of these items would be lost if a time lag were imposed between lead and follow ships.

In summary, for there to be a payoff from the conduct of a total ship OPEVAL:

(a) it would have to identify significant deficiencies that would not otherwise be uncovered by testing in the rest of the ship acquisition T&E process; and

(b) the value (translated into dollars) of the increased Fleet capability resulting from correcting these deficiencies must exceed (1) the cost of conducting the OPEVAL ($3 million to $18 million for CGN-38, as discussed above) plus (2) the cost of correcting the deficiencies on the lead ship of the class.

SECTION V

SUMMARY

Summary of Conclusions

The conclusions of this study project reinforce the Navy's position in 1972 on the issue of conducting total ship OPEVALs[4]. With much more experience in implementing the new policies on operational T&E and in applying them to ship programs in particular, it would appear conclusive that the conduct of a total ship OPEVAL would be impractical. The difficulty of trying to simulate the combat environment for the ship, and the inherent constraints in any exercise which would attempt to do so, would introduce uncertainty into and undermine the validity of the test results. Most of the measures of ship operational capability can be demonstrated elsewhere. In particular, land based test sites used in ship programs have reached a state of such development and sophistication that they can now satisfactorily be used for the conduct of IOT&E. The FFG-7 program's combat system LBTS, described in Appendix A, is a case in point. Little if any return could be assured for the amount of money invested in an OPEVAL. In most cases, the results of the total ship OPEVAL could not impact the procurement of the

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[4]Although DDT&E has decided not to require an OPEVAL of the two programs studied to date (CGN-38 and FFG-7), he does not consider these decisions as precedents. He will consider requiring a total ship OPEVAL for future ship programs on a case-by-case basis. (13)

remaining ships in the program unless the usual ship acquisition process was significantly extended, resulting in shipbuilding costs of equal magnitude with the OPEVAL itself. In addition, the results would not be valid for the entire life of the ship, since most of its weapons and electronics systems will be replaced within ten years after delivery anyway.

Implications

There are some interesting implications that evolve from the conclusions of this study project, as well as from the report itself. The study project concludes that the conduct of a total ship OPEVAL is impractical in all cases except programs where a lead ship is constructed as an R&D effort involving a major technological advance in the hull or propulsion design. If this conclusion could finally be accepted and the ominous paragraph of DOD Directive 5000.3 imposing conduct of total ship OPEVALs "if required" could be deleted, a major psychological obstacle in the minds of many Navy planners in understanding the ship acquisition T&E process would be removed. Project managers for new ship acquisition programs could be confident that the early planning for their T&E program could be done with a degree of assurance that it meets all of the policy requirements. The threat of being required by OSD to restructure the T&E program, and perhaps the entire acquisition program, to include an OPEVAL would be removed. Ship acquisition project managers have always been accustomed to thinking that the major technical performance hurdles in their program would be accomplished by the time that their land based test site efforts were concluded. Thereafter, except to uncover and correct production discrepancies, their efforts could be focused on the Herculean tasks of keeping shipbuilding cost and schedules on track and providing for a smooth transition of the ship to the Fleet. This perspective is supported by the fact that ship acquisition is funded under a procurement appropriation, vice under an R&D appropriation. But the prospects of possibly having to conduct an OPEVAL on the lead ship a year after delivery has made the project managers feel uncomfortable in thinking this way.

Elimination of the project managers' hesitancy about total ship OPEVALs is not the final solution. Individual project managers have made many innovations to help T&E keep pace with the rapidly advancing technology in the design and integration of shipboard systems. Inactivity, though, on the part of the Navy T&E staff offices in recognizing the possibilities for more widespread application of these innovations has impeded advancement of the ship T&E process. Much still remains to be done. In the words of a noted author and lecturer, we have seen only the "tip of the iceberg" in the potential of T&E as a management tool for ship acquisition programs. (17:27)

This report, itself, is a significant addition to the literature on Navy ship T&E. The description and model of the ship acquisition T&E process presented in SECTION III were culled from a survey of ship T&E program schedules and from interviews with T&E managers of both ship and shipboard system acquisition programs. They incorporate many fundamental precepts of the ship T&E process that are not yet well documented in Navy directives, a fact which is not surprising since T&E was not officially recognized as a key element of ship acquisition program management until early in 1973 with the publication of the first Navy directives on the subject. (18)(19) Two guidance manuals for use by ship project managers in structuring their T&E programs were developed around that time, (20)(21) but have not been updated since then. They reflect the sophistication of thinking that has emerged from the development and conduct of ship T&E programs since early 1973. The lack of a unified description of the ship acquisition T&E process can also be seen if one reviews existing ship programs' Test and Evaluation Master Plans. From these it is apparent that each project manager has a different perception of what the ship T&E process is, how it has evolved, and how it can best be tailored to his program. The conceptual framework of the process presented in this paper, used here for the consideration of adding a total ship OPEVAL to the process, can likewise be used for the purpose of considering other innovations to the T&E process and their implications for the overall ship acquisition process.

Recommendations

In addition to deletion of the paragraph of DOD Directive 5000.3 on total ship OPEVALs and an update of the two Navy guidance manuals on ship acquisition T&E discussed above, three possible topics emerge from this report for further study.

As previously described, total ship OPEVALs are required for R&D ship efforts. The first such OPEVAL, results from which will be used as an input to the DSARC III decision to buy follow ships, is scheduled to commence on PHM-1 within a week of submission of this report. A study project parallel to this one, investigating the utility of that OPEVAL, would be very useful. A model such as that in Section III for a conventional program could be developed to cover the generalized R&D ship case. Quantitative measures of utility, derived from analysis of deficiencies uncovered during the PHM-1 OPEVAL and from the exercise of generating the program model, could hopefully then be used in planning future R&D ship T&E programs. The lack of such measures in planning the PHM-1 T&E program made trade-off analyses difficult. For instance, some equipment development testing that would ordinarily have had to be completed prior to ship construction could have been deferred until and combined with at-sea testing on the PHM-1, since this was a development T&E effort also. But it was difficult to systematically pre-determine what equipment testing could be so deferred without the existence of measures of utility. It was found, for example, that the formal land based testing program being conducted on the foilborne propulsor unit was redundant to and as providing less realistic data than that being routinely collected on the lead ship. The land based test program was subsequently terminated with an associated dollar savings. (22) If a valid model could be developed and utilized to measure the efficiency of such testing, more efficient and less costly T&E programs for such ships could be assured.

A study such as this would be a significant and large undertaking. Throughout Section IV of this report, emphasis was placed on the lack of quantitative factors in conducting - and even in assessing the desirability of conducting - ship T&E. For example, in attempting to develop evaluation criteria for the Surface Effects Ship, the Government Accounting Office's (GAO's) new T&E group found that, because the ship's key performance parameters were too dependent on uncontrollable variables, the criteria could not be definitized. The GAO has since discontinued this effort. A further example of this need for objective forecasting was DDT&E's decision not to require an OPEVAL of either CGN-38 or FFG-7: in both cases the conclusion that an OPEVAL would not be cost effective was by necessity based more on subjective assessment than on a decisive numerical analysis. The DDT&E's staff believes that, while sometime in the future this type of assessment can be made more objectively, the necessary techniques are not available now. (13)

A second possible area for study is a cost benefit analysis of the two FFG-7 land based test sites. There was a consensus among those interviewed during this study project that the test sites paid handsome dividends, but as in the preceding examples, this opinion is rather subjective. Although it was not possible to do so beforehand, an analysis could be performed now using actual cost data as well as estimated values of ne deficiencies uncovered. This would provide useful data for future ship IOT&E programs.

The third and related recommended study would be to investigate the applicability of Bayesian decision statistics in structuring a ship T&E program. Bayesian analyses have been used in developing expected dollar values of alternative test approaches for small equipments and components. They have not, however, been used in large systems on which there would be a very limited production buy (such as the four ship CGN-38 Class program). The possibility of quantifying the value of various tests and alternative test programs for a ship acquisition program has some promising implication for Navy T&E and the entire weapons acquisition process.

APPENDIX A

FFG-7 PROGRAM COMBAT SYSTEM LAND BASED TEST SITE

A combat system LBTS for the FFG-7 acquisition program was constructed at Sperry Systems Test Center in Long Island, New York. The FFG-7 combat system includes radars and sonar for surveillance, detection, acquisition, and tracking of targets. Acquisition and tracking data are stored in the processors. The displays are the man-machine interface with the processors and are used to enter target data and to control engagements of targets. The weapon control processor directs the gun and/or missile launcher in engaging the target. The torpedo control system is presently a simplified stand-alone system.

The need for careful integration follows from the interrelationships among the weapon control processor (which generates the tracking data, and computes ballistics and engageability data), the weapon support processor (which stores and computes the tactical data necessary to control the total ship during engagement), and the displays (by which the crew controls the combat system). In order for the combat system to function, it is necessary that the computer program and the equipment be properly interconnected and integrated. Demonstration of this integration was a prime requirement to support the FFG-7 Class production authorization decision (DSARC III).

The LBTS contained exact replicas of the ship spaces for the four principal compartments in which the combat system is located. These are: (1) the Combat Information Center (CIC), (2) the CIC and Radar Equipment Room, (3) the MK 92 Equipment Room or Forward Radar Compartment, and (4) the STIR Equipment Room or Aft Radar Compartment.

Each compartment was fully outfitted with all of the cabling, air conditioning, water, power, and ancillary equipment that it would have in the actual ship. Live equipment was installed where it was required. Where operational equipment was not required, costs were reduced by using mockups. Equipment foundation, cable laying, and all other systems were installed in accordance with shipyard practice.

In order to provide a complete environment for the combat system and to exercise the combat system interfaces, equipment was installed to terminate or generate every signal in the combat system. It was impractical to install a missile launcher and gun, so these elements were simulated with equipment which have the same interfaces and dynamic responses as the real items. Equipment was provided to simulate those ship motion inputs to the combat system which come from the ship's gyrocompass and Speed Log. The missiles which would be loaded on the missile launcher were also simulated. This allowed the combat system to be operated completely, as if on the ship, to search for, detect, and acquire air targets and to generate and simulate engagements just as in a battle situation. In addition, it was recognized that it would not always be possible to operate the radars and it would not always be possible to operate target aircraft in a manner which would completely exercise the combat system. Sperry, therefore, designed and constructed a radar simulator which provided synthetic targets on the operator's console in the same manner as if they were real targets. (23:147-154)

In March 1975, the Land Based Test Site was formally commissioned and turned over to the Navy for the conduct of the formal IOT&E period. During this period, the combat system was operated exclusively by the Navy crew. The only maintenance performed by Sperry was that necessary to maintain the equipment for the test center or after the Navy crew had determined that the system was inoperable and had identified the subsystem which was at fault. The IOT&E demonstration consisted of the following tests:

(1) Overall combat system reaction times

(2) Acquisition times for various modes of operation

(3) Air surveillance capability of each of the search radars

(4) Operation under simulated tactical conditions, including:

(a) Control of helicopters,

(b) Detection of airborne targets by use of radar,

(c) Tracking and simulated engagements of air and surface targets, and

(d) Casualty mode operation.

A report of this IOT&E period was issued by COMOPTEVFOR (24) and the results were presented to the DSARC in support of its consideration to approve the FFG-7 program for production.

APPENDIX B

SURFACE COMBATANT SHIP POST DELIVERY TESTS AND TRIALS

Key Events and Duration	Purpose
Combat System Ship Qualification Trials (8-10 weeks)	To demonstrate through a series of tests, exercises, and firings that the combat system (gun, missile, radars, and communications) is capable of proper performance and that the crew is capable of maintaining, adjusting, and operating it.
Gun and Missile Structural Test Firings (3 days)	To confirm through live firings that the ship's structure and the weapons hardware has adequate strength, rigidity, tightness, and heat resistance to withstand shock and vibration. Personnel hazards are also checked.
Shock/Blast Tests (5 days)	To determine/verify the ability of the ship and its equipment to withstand external shock blast.
Anti-Submarine Warfare Weapons System Accuracy Test (5 days)	To demonstrate through operability tests and actual weapon firings the accuracy of the ASW system.
Sonar Certification (5 days)	To ensure that the sonar, as installed, satisfies established equipment tolerances and meets specified performance standards.
Ship Electronic System Evaluation Facility Tests (2 days)	To ensure through at-sea tests and calibrations of the communication system antenna patterns that they are installed and operable at their design capability.
TACAN Certification (3 days)	To demonstrate TACAN performance for acceptance certification by FAA.

Helo Certification (5 days)	To test and certify that the helicopter deck is suitable and compatible with the assigned aircraft and meets prescribed safety requirements.
Fleet Operational Readiness and Accuracy Checks (FORACS) (5 days)	To determine the operational range and bearing accuracy of ship's sensors associated with ASW.
IFF Certification (3 days)	To demonstrate and certify proper operation of the Identification Friend-or-Foe system.
Standardization Trials (5 days)	To determine the capabilities of the ship including tactical maneuvering (turning circles, acceleration/deceleration and directional stability and control), fuel economy, and underwater log calibration.
Acoustic Signature (10 days)	To determine a ship's acoustic characteristics (radiated noise, vibration, and structureborne noise) and establish its signature profile.

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