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AN ANALYSIS OF WEAPON SYSTEM READINESS
FOR
OPERATIONAL TESTING

by

James B. Mills

March, 1994

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An Analysis of Weapon System Readiness
For
Operational Testing

by

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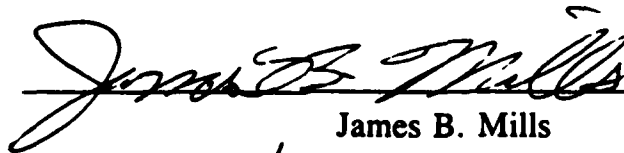
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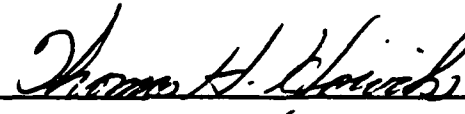
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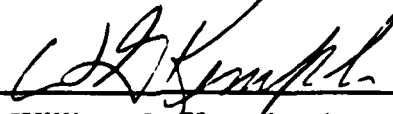
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I. INTRODUCTION

A. PURPOSE

The purpose of this thesis is to analyze Army weapon systems Operational Tests & Evaluations (OT&E) that have been conducted at Fort Hunter-Liggett, California. Many systems have not been fully configured or prepared for operational effectiveness and suitability testing under realistic field conditions. Even though the operational test may be viewed as the culmination of the weapon systems development process, many Program Managers have little experience in this area and as a result, significant problems are encountered during OT&E. This thesis provides an analysis of these problems and the reasons they occurred along with proposed solutions, enhancement observations, and 'lessons learned' that should be useful to Program Managers.

B. BACKGROUND

A major issue that frequently confronts Program Managers and operational test centers is the arrival of a system for testing when they are not fully ready. These readiness issues have resulted in delayed or truncated testing, and unscheduled expenditure of large amounts of money to resolve problems with 'quick fixes'. In the current restrictive budget environment,

these problems can also result in a weapon system's cancellation.

Many of these readiness issues may be quite simple to fix or prevent. The many mistakes that are reported may be due to the inexperience of project team members, since they may experience an operational test only once in several years. Due to rotation of project personnel, much knowledge may be lost and therefore systems may be subject to repeated problems.

C. THESIS OBJECTIVE

The objective of this thesis is to identify the most common problems and enhancements that have affected Army systems undergoing operational testing. This information will point out to members of the Program Manager's Office and the Operational Test Centers the importance of these areas and encourage them to give these areas more emphasis. Ultimately, this information can lead to a smoother, less costly, and more accurate Operational Test & Evaluation process. A 'lessons learned' summary will then be developed into a format that can be useful to Program Managers as a guide or checklist prior to the operational test of their systems.

D. RESEARCH QUESTIONS

The following primary research question will be addressed in this study: What essential tasks should the PM complete to

ensure that his program is ready for Operational Test and Evaluation?

Subsidiary research questions are:

- (1) What are the common problems that Program Managers fail to identify before operational testing?
- (2) What are the common program strategy mistakes that Program Managers make in preparation for operational testing?
- (3) What are the common logistical problems that arise in operational testing?
- (4) How did these failures affect the testing process?
- (5) What can Program Managers do to better prepare their systems for operational testing?

E. SCOPE

The scope of this research is limited to programs that were tested at Fort Hunter-Liggett. These include the ADATS (LOS-F-H) air defense system, Avenger (Pedestal Mounted Stinger) air defense system, OH-58D (AHIP) scout helicopter and the Apache (AH-64) attack helicopter. The intent is to evaluate operational test observations of problems and enhancements, and to develop a set of 'lessons learned' and recommendations from them. The research will also include observations from experienced Fort Hunter-Liggett test personnel.

F. METHODOLOGY

Research for this thesis consisted primarily of a literature review of Operational and Force Development Test

Reports located at the Fort Hunter-Liggett testing facility, General Accounting Office Reports, Congressional Subcommittee Reports, Defense Systems Management College (DSMC) lessons learned, and Department of Defense regulations.

Information was also gathered through interviews with members of the Fort Hunter-Liggett test center. Many of these personnel have experienced numerous operational tests and possess valuable insight and first hand experience with testing problems. These data will be especially useful, since after action reports often have shortcomings. Many times these reports lack detail, or tend to gloss over negative aspects of the event in question.

This thesis will utilize a comparative analysis of significant issues discovered. It will be used to determine relative importance and sources of the problems.

G. THESIS ORGANIZATION

The thesis is divided into five chapters. Chapter II provides a review of the acquisition process and applicable guidelines within the Department of Defense. It also provides a background of the test and evaluation process and its purpose.

Chapter III identifies and discusses problems, enhancements, and 'lessons learned' that have occurred with each weapon system during testing at Fort Hunter-Liggett.

Chapter IV concentrates and categorizes these observations and enhancements into 'lessons learned' for application to future programs.

Chapter V presents conclusions and recommendations, and a 'lessons learned' summary for utilization in future military operational testing.

Many acronyms and abbreviations are used in this thesis. They are defined and discussed in the attached appendices which provide information that should help the reader gain a better understanding of this area of the acquisition process.

II. THE ACQUISITION PROCESS

A. BACKGROUND

The DoD acquisition system defines the process to be used to plan, design, develop, acquire, maintain, and dispose of all equipment, facilities, and services in DoD. The system has been continuously revised to streamline the acquisition process, provide for formal risk analysis, and to reduce or eliminate costly changes later in the production cycle.

In the early 1970's, the Department of Defense test policies became more formalized and placed greater emphasis on test and evaluation (T&E) as a continuing function throughout the acquisition cycle. These policies stressed the use of T&E to reduce acquisition risk and provide early and continuing estimates of the system's operational effectiveness and operational suitability. In order to meet these policy objectives, it is necessary to fully integrate appropriate test activities into the overall development process. [Ref. 1]

The defense system acquisition process underwent revision in 1987 in an attempt to make it less costly, less time consuming, and more responsive to the needs of the operational community. As it is now structured, the defense system life cycle consists of the following five phases:

- (1) Concept Exploration/Definition
- (2) Concept Demonstration/Validation
- (3) Engineering and Manufacturing Development
- (4) Full-Rate Production/Deployment
- (5) Operational Support

These phases are separated by key decision points (milestones) during which a decision authority reviews a program and may terminate it or authorizes it to advance to the next stage in the cycle. T&E results and planned T&E in the future play an important part in this process and are rigorously assessed as part of the milestone review process.

B. THE ACQUISITION PHASES

The following paragraphs describe the five major milestone decision points and five phases of the acquisition process. They provide a basis for understanding the management and progressive decision making associated with program maturation. [Ref. 2]

1. Concept Exploration/Definition Phase

The first phase in the acquisition process is concept exploration/definition. It begins after Milestone 0 grants concept studies approval. This phase starts with an assessment of the current or projected U.S. military capability to perform assigned missions, called a Mission Area

Analysis (MAA). This assessment is conducted before a new acquisition starts. The MAA evaluates threat, friendly capabilities, technological opportunities, doctrine, and new defense interests. The primary objective is to identify deficiencies and determine a more effective means of performing assigned tasks. The MAA may result in recommendations to:

1. Initiate new acquisition programs.
2. Change U.S. and allied concepts and doctrine.
3. Use existing military or commercial systems.
4. Modify or improve an existing system, or
5. Enter into a cooperative research and development program with one or more allied nations.

If the MAA results in a recommendation to initiate a new acquisition program, a mission need statement (MNS) is submitted to the Defense Acquisition Executive (DAE). The MNS is submitted with or before a Program Objectives Memorandum (POM) submission in which funds are requested.

This leads to the Milestone I decision which will mark the start of a new acquisition program if the decision is to enter into the next phase. Milestone I establishes broad goals and thresholds in the areas of program cost, schedule, and operational effectiveness and suitability. These broad guidelines give the Program Manager (PM) flexibility to develop innovative and cost-effective solutions. The

Milestone I decision is made by the Defense Acquisition Executive and is documented in an Acquisition Decision Memorandum (ADM).

2. Concept Demonstration/Validation Phase

The next stage of the process is called the concept demonstration/validation (Dem/Val) phase. During this phase, the following events take place:

1. The feasibility of competing alternatives is demonstrated and the most capable system for fulfilling the mission is selected.
2. Prototype systems are fabricated to support both design development, and testing and evaluation to identify areas of risk.

The program office updates life-cycle costs, sends annual funding input into the Planning, Programming and Budgeting System (PPBS), and prepares documentation during this phase to assist in the Milestone II decision. The Test and Evaluation Master Plan (TEMP) is updated and the Integrated Program Summary (IPS) is prepared. The IPS summarizes the results of the concept demonstration/validation phase, identifies the program alternatives, and establishes explicit goals and thresholds for program cost, schedule, and operational effectiveness and suitability.

3. Engineering and Manufacturing Development Phase

The third stage of the acquisition process is Engineering and Manufacturing Development (EMD). This begins after the Defense Acquisition Executive makes the Milestone II decision and documents it in an ADM granting approval to proceed with the EMD (previously called the full-scale development or FSD) phase. During this phase, the PM completes system development up to the point where an economic decision can be made whether or not to produce the system in quantity. Before this decision can be made in the affirmative, the PM must demonstrate that all technical, operational, and resource requirement thresholds have been met and that adequate resources are available to support production and deployment. This is done through the completion of developmental testing and the conduct of operational testing in a realistic environment with extensive user participation.

In preparation for Milestone III, the IPS and the TEMP are updated to describe any program changes made since Milestone II and to propose goal and threshold revisions, if appropriate. The Milestone III decision is made by the Secretary of Defense and recorded in an ADM. It either terminates the project, requests further testing, or grants approval to proceed with the full-rate production and deployment phase.

4. Production and Deployment Phase

The next phase is production and deployment. During this phase, the PM ensures that systems are produced and deployed according to plans. Operational testing and evaluation, user training, and logistical support are key activities during the production and deployment phase. A formal review is scheduled one to two years after initial deployment of a system to ensure that operational readiness and support objectives are being met. The results of this review are presented for consideration for the Milestone IV decision, which identifies actions and resources needed to ensure that objectives are achieved and maintained.

5. Operational Support Phase

The final stage is the operational support phase. This involves support of the system in the field, as it is monitored for suitability and readiness. It also involves determinations of whether major upgrades are necessary, or if deficiencies warrant consideration of replacement.

C. TEST AND EVALUATION

The purposes of test and evaluation in a defense system's development and acquisition program are to determine the feasibility of conceptual approaches, to minimize design risk, to identify design alternatives, to compare and analyze tradeoffs, and to estimate operational effectiveness and

suitability. As a system undergoes design and development, the emphasis in testing moves gradually from development test and evaluation (DT&E), which is chiefly concerned with the attainment of engineering design goals, to operational test and evaluation (OT&E), which focuses on questions of operational effectiveness, suitability, and supportability.

The integration of T&E requirements has several dimensions which include two broad categories of testing: Government, and contractor. Government tests can be further categorized as user tests, which are broadly operational in emphasis, and builder tests, which focus on achievement of development requirements.

Test and evaluation encompasses the interrelationships of all system elements, including equipment, software, facilities, personnel, and procedural data. Each work breakdown structure (WBS) element must receive appropriate T&E. In most cases (e.g., software) the system element may have unique requirements which constrain the testing approach.

Another T&E dimension to consider is that testing spans the overall acquisition life cycle. It is not simply something that takes place when development is complete. Finally, as T&E requirements are identified for the operation and support functions, the process can also identify the resources and procedures necessary for the test activities themselves.

T&E policy, described in Part 8 of DOD Instruction 5000.2, provides guidelines for planning and conducting test and evaluation. It defines and describes the major categories of DT&E and OT&E, and provides for exceptions such as combining DT&E with OT&E, T&E for special acquisition programs, T&E of computer software, T&E of system alterations, and joint T&E programs. DOD Instruction 5000.2 specifies three general requirements:

- a. Successful accomplishment of T&E objectives will be a key requirement for decisions to commit significant additional resources to a program or to advance it from one acquisition phase to another.
- b. T&E shall begin as early as possible and be conducted throughout the system acquisition process to assess and reduce acquisition risks, and to estimate the operational effectiveness and operational suitability of the system.
- c. The dependence on subjective judgement of system performance will be minimized during testing.

In summary, there is clear policy stating test and evaluation program requirements, with particular emphasis on those programs designated as major weapon systems. Test and evaluation is an integral part of the systems development process. It begins early and extends throughout the acquisition life cycle. The most general objectives of the T&E program are 1) to assess and reduce the risk to the program 2) verify technical specifications and contractual guarantees, and 3) to estimate the operational suitability and effectiveness of the system.

1. Developmental Test And Evaluation

Developmental test and evaluation is conducted throughout the acquisition process to ensure the acquisition and fielding of an effective and supportable system. DT&E includes test and evaluation of components and subsystems at all work breakdown structure (WBS) levels including preplanned product improvement (P3I) changes, hardware/software integration, and related software changes, as well as qualification, live fire, and production acceptance testing. It involves the use of simulations, models, breadboards, brassboards, and testbeds, as well as engineering and manufacturing development models or prototypes of system components or the system itself.

DT&E is normally planned, conducted, and monitored by the developing agency. DT&E is conducted to:

- a. Assist the engineering design and development process.
- b. Verify performance objectives and specifications.
- c. Demonstrate that design risks have been minimized.
- d. Evaluate the compatibility and interoperability with existing or planned equipment/systems.
- e. Provide an assurance that the system/equipment is ready for testing in the operational environment.

DT&E is conducted during the Concept Exploration/Definition (C/E) phase to assist in selecting preferred alternative system concepts, technologies, and designs. During the Concept Demonstration/Validation (D/V) phase, DT&E

identifies and validates the preferred technical approach, including the identification of technical risks and feasible solutions. During the Engineering and Manufacturing Development phase, DT&E demonstrates that engineering is reasonably complete, that all significant design problems are in hand, and that the design meets its required specifications in all areas (such as performance, reliability, and maintainability) within the range of environmental parameters designed for the operational employment of the system. After the Production and Deployment Decision, DT&E is an integral part of the development, validation, and introduction of system changes undertaken to improve the system, to react to new threats, and/ or to reduce life cycle costs.

2. Qualification Testing

As part of DT&E, each developing agency is also responsible for the qualification testing that verifies the design and the manufacturing process and provides a baseline for subsequent acceptance tests. Qualification tests consist of pre-production and production qualification tests.

Pre-production qualification tests are formal contractual tests that ensure design integrity over the specified operational and environmental range. These tests usually use pre-production or prototype hardware fabricated to the proposed production specifications and drawings. Such

tests include the reliability and maintainability demonstration tests required prior to production release.

Production qualification tests are conducted for all production items to ensure the effectiveness of the manufacturing process, equipment, and procedures. All new production items are subjected to first article tests to verify specification compliance and form, fit and function. Production acceptance tests are also conducted on each item or on a sample lot taken at random from each production lot. These tests are repeated when the process or design is changed significantly, and when a second or alternative source is brought on line. Production qualification tests are conducted against the contractual requirements.

3. Operational Test And Evaluation

The primary purpose of operational test and evaluation is to verify that operationally effective and operationally suitable systems are approved for production that meet mission needs and minimum operational performance requirements of the operating forces. [Ref. 3]

For major systems, OT&E is normally planned and conducted by a major OT&E field agency located within the DoD component. This Operational Test Agency (OTA) must be separate and independent from the developing/procuring agency. The OTA is responsible for managing operational testing, reporting test results, and providing its independent

evaluation of the system being tested directly to the Military Service Chief or Defense Agency Director.

The principal objectives of OT&E are to:

- a. Estimate the operational effectiveness and operational suitability of the system.
- b. Identify needed modifications or improvements.
- c. Provide details on tactics, doctrine, organizational, and personnel requirements.
- d. Provide information to uphold and verify the adequacy of various manuals, handbooks, supporting plans, and documentation.

Modeling and simulation can assist in the T&E planning process and can reduce the cost of the conduct of testing. Areas of particular application include scenario development and the timing of test events; the development of objectives, essential elements of analysis, and measures of effectiveness; the identification of variables for control and measurement, and the development of data collection, instrumentation and data analysis plans. Modeling and simulation can be used to predict ahead of time the effects of various assumptions and constraints and evaluate candidate measures of effectiveness to help in formulation of the test design plan.

Simulations are not a substitute for live testing since there are many things that cannot be adequately simulated by computer programs. Examples include the decision process and the proficiency of personnel in the performance of

their functions. Therefore, operational test and evaluation does not include an operational assessment based exclusively on computer modeling or simulation. It also shouldn't be based purely on an analysis of system requirements, engineering proposals, design specifications, or any other information that is contained in the programs documents. [Ref. 4]

Although OT&E is planned and conducted by an independent testing activity, the Program Manager (PM) provides the funding. He must closely coordinate all aspects of test and evaluation with this organization to plan appropriate funding and to ensure that DT&E objectives coincide with OT&E objectives.

OT&E is conducted in an environment that is as operationally realistic as possible. Typical operation and support personnel are used to obtain a valid estimate of the user's capability to operate and maintain the system when deployed under both peacetime and wartime conditions. During operational testing, threat representative forces should be used whenever possible. The items tested must sufficiently represent expected production models to ensure that a valid assessment of the system can be made.

Normally, limited follow-on operational testing (FOT&E) will use the same system and support equipment used in the operational evaluation and will test the fixes to be incorporated in production systems, complete deferred or

incomplete pre-production test and evaluation, and continue tactics development. FOT&E will continue until the objectives specified in the approved TEMP for this phase have been met, regardless of the date of deployment of the production systems.

Other operational testing may include tests of the existing system in a new environment, with a new subsystem, in a new tactical application, or against a new threat. This also includes system upgrades as well as changes made to correct deficiencies identified during previous test and evaluation. [Ref. 5] Examples of this include all hardware and software alterations that materially change system performance (operational effectiveness and suitability) and must therefore be adequately tested and evaluated.

4. Combined Testing

Since DT&E and OT&E take place during the same phases of the acquisition cycle, it may make sense to coordinate developmental and operational testing to use resources more efficiently in obtaining the data necessary to satisfy the common needs of both the developing agency and the operational test agency. This is called combined testing. Development and operational tests can be combined with approval, when significant, clearly identified cost and time benefits will result. Of course, the test objectives of both the developing agency and the operational test agency will have to be

reflected in this combined testing situation. At the conclusion of testing, separate DT and OT reports must be submitted.

D. THE TEST AND EVALUATION MASTER PLAN

A major controlling document for every acquisition program is the Test and Evaluation Master Plan (TEMP), which lays out an overall plan for developmental and operational test and evaluation, designed to verify that the new equipment meets the requirements.

The TEMP documents the overall structure and objectives of the test and evaluation program[Ref. 6]. It provides a framework within which to generate detailed test and evaluation plans and it documents schedule and resource implications associated with the T&E program. The TEMP identifies the necessary DT&E and OT&E activities. It relates program schedule, test management strategy and structure, and required resources to:

- (1) Critical operational issues;
- (2) Critical technical parameters;
- (3) Minimum acceptable performance requirements;
- (4) Evaluation criteria; and
- (5) Milestone decision points.

The TEMP's five part format is detailed in DoD 5000.2-M,
as follows:

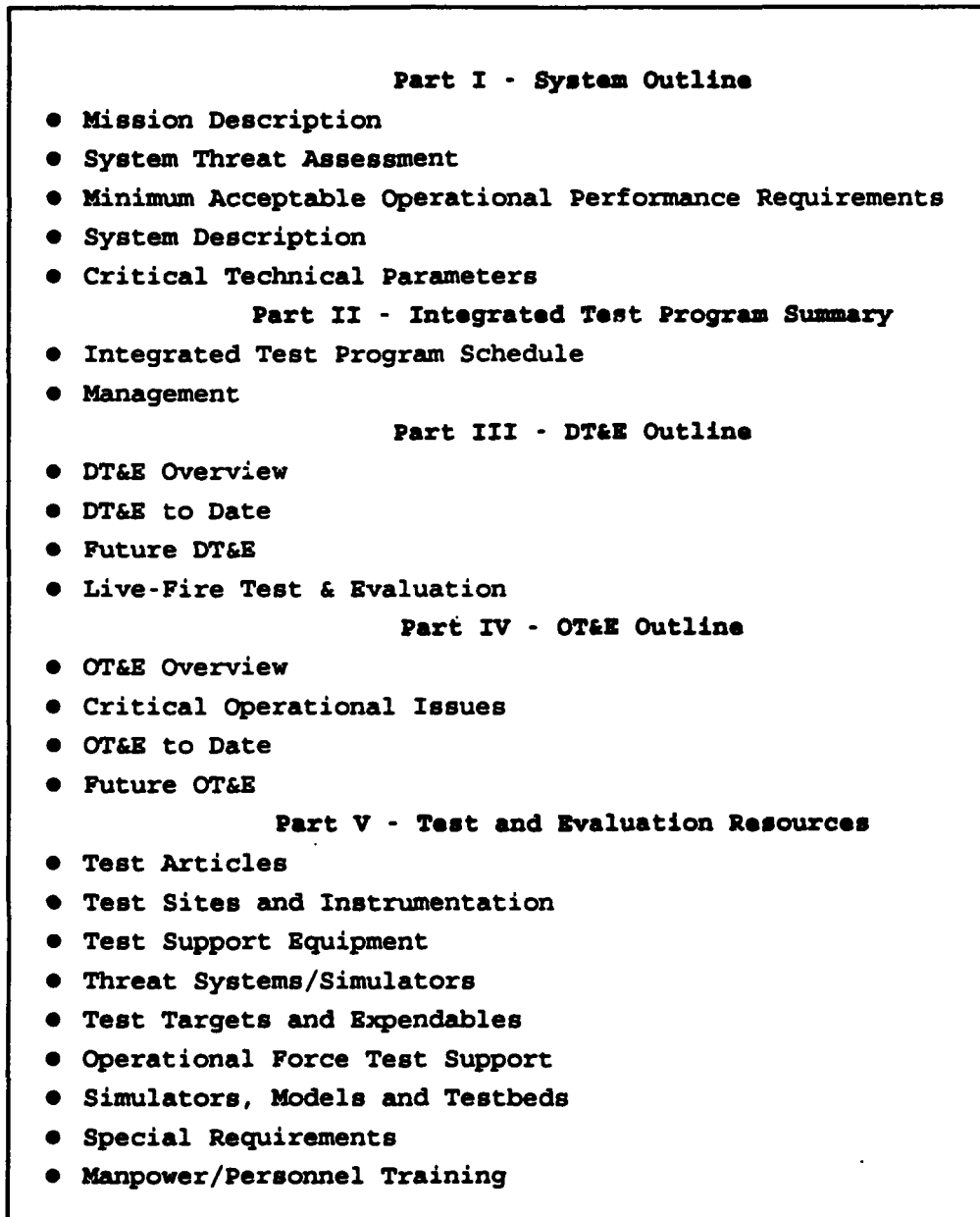


Figure 1

Part I concerns system details including production and delivery information and the operational and technical goals

and thresholds. Part II, program summary, includes a schedule chart that provides an overview of the major acquisition and T&E events. Parts III (DT&E Outline) and IV (OT&E outline) describe in quantitative terms the scope of each major test period. Part V, the Test Resource Summary, identifies special resources required for the test program.

The TEMP is a dynamic document that should be updated at milestones and whenever the program has changed significantly. Its contents should be factual and specific, avoiding generalities, and emphasizing quantifiable and testable requirements, both operational and technical. Although a summary document, it is imperative that pertinent, but integrated, facts and descriptions be included. The contents must describe the amount and type of system testing to be conducted before each milestone, and the resources required. [Ref. 7]

E. TEST RESOURCES

It is important that the necessary test resources be identified early in the acquisition process. These resources include:

- (1) Test Articles. The PM should identify the actual number and timing requirements for all test articles, including key support equipment. Specifically identify when prototype, engineering development, preproduction, or production models will be used.

(2) Test Sites and Instrumentation. Identify the specific test ranges/facilities to be used for each type of testing. Compare the test requirements against the range/facility capabilities and identify any major shortfalls. Also, identify instrumentation that must be acquired specifically to conduct the planned tests.

(3) Test Support Equipment. Identify test support equipment that must be acquired specifically to conduct the test program.

(4) Threat Systems/Simulators. Identify the type, number, availability, and fidelity requirements for all threat systems/simulators. Compare the requirements for all threat systems with available and projected assets and their capabilities. Highlight any major shortfalls. Each threat simulator shall be subjected to validation procedures to establish and document a baseline comparison with its associated threat and to ascertain the extent of the operational and technical performance differences between the two throughout the simulator's life-cycle.

(5) Test Targets and Expendables. Identify the type, number, and availability requirements for all targets, flares, chaff, smoke generators, kill indicators, etc. that will be required for each phase of testing. Identify any major shortfalls.

(6) Operational Force Test Support. For each test and evaluation phase, identify the type and timing of aircraft flying hours, communications station support, on-orbit satellite contacts/coverage, and other critical support required.

(7) Simulations, Models and Testbeds. For each test and evaluation phase, identify the system simulations required, including computer-driven simulation models and hardware/software-in-the-loop testbeds. Identify the resources required to validate and certify their credible usage or application before their use.

(8) Special Requirements. Discuss requirements for any significant non-instrumentation capabilities and resources such as: special data processing/data bases, unique mapping/charting/geodesy products, extreme physical environmental conditions or restricted/special use air/sea/landscapes.

(9) Test and Evaluation Funding Requirements. Estimate, by Fiscal Year and appropriation line number (program element), the funding required to pay direct costs of

planned testing. State, by fiscal year, the funding currently appearing in those lines (program elements). Identify any shortfalls.

(10) Manpower/Personnel Training. Identify manpower/personnel and training requirements and limitations that affect test and evaluation execution.

As system development progresses, the preliminary test resource requirements should be reassessed and refined and TEMP updated to reflect any changed system concepts. Resource shortfalls which introduce significant test limitations should also be discussed, along with an outline of planned corrective action.[Ref. 8]

The PM is responsible for developing the TEMP, including its content and preparation. However, since part IV concerns OT&E, the Operational Test Agency (OTA) is usually responsible for the preparation, content, and coordination of that part of the TEMP. Therefore, the PM must establish early liaison with the operational tester. This assists the OTA with complete integration of operational assessments and OT&E requirements into the TEMP.[Ref. 9]

F. PERSONNEL AND TRAINING

It is DoD policy that manpower, personnel, and training (MPT), as essential elements of integrated logistics support (ILS), be given explicit attention early in the acquisition process. Principal activities required include determination

and specification of requirements based on: previous experience with similar systems, demographic expectations, design trade-offs, and contractor incentives to meet MPT objectives.

1. Personnel

Prior to OT&E, several categories of personnel must be identified, trained and available when the system is ready to test. Billet requirements must be identified and funded for the following personnel categories:

- Installation technicians to design and maintain test support equipment and instrumentation.
- Operations personnel to participate in and support the test as 'enemy' forces, and as typical users manning the tested system.
- Maintenance technicians to maintain the tested equipment (users), and to maintain mockups and simulators that are used in support of the test.
- Supervisors to direct, oversee, support and validate the tests.
- Transportation personnel to test the transportability of the system by land, sea and air.

Each of these categories of personnel may require:

- Training personnel/instructors to conduct support and user training prior to OT&E.
- Training programs of instruction which must be developed for instructor use; and

- Security clearances to allow necessary personnel access to sensitive or classified data which are used in the system itself, or gathered as a result of the testing.

The PM must identify the personnel requirements and skill levels necessary for the system/equipment under all normal conditions of readiness. Operational manning and maintenance manpower requirements at all applicable maintenance levels must be addressed. Manning levels and schedules should be identified by maintenance level for each anticipated field testing site. It is necessary to identify all training courses required for installation, operation and maintenance personnel, together with locations and duration of each course. Special training devices required for such courses at each location should be identified and procured.

2. Training

Training and training support includes the processes, procedures, techniques, training devices and equipment used to train civilian, active duty and reserve military personnel to operate and support a material system. This includes: individual and crew training; new equipment training; initial, formal, and on-the-job training; and logistic support planning for training equipment and training device acquisitions and installations. [Ref. 10]

G. TECHNICAL MANUALS

Technical manuals (TMs) and publications are an integral part of the system /equipment support requirements. They are the prime means of communicating maintenance and operation information to the user. Manual requirements must be planned, progressively monitored and updated to ensure timely completion and delivery for adequate logistics support. Since the quality of TMs affects equipment maintainability, personnel efficiency, safety and readiness, quality in TMs must be a planned objective. [Ref. 11]

Prior to entering into a formal arrangement for a contractor to produce TMs, the Government is responsible for furnishing guidance to the contractor for the development of a Technical Manual Plan (TMP). The contractor has the responsibility of justifying and validating each manual recommended. Additional contractor responsibilities include providing engineering design, maintainability, and maintenance analysis documentation and assistance.

The contractor must develop and implement a validation plan that the Government formally approves. The validation of technical manuals is a continuing effort that the Government is required to verify. This verification refers to the adequacy and accuracy of the manuals.

III. FORT HUNTER-LIGGETT OBSERVATIONS

A. FORT HUNTER-LIGGETT EXPERIMENTATION CENTER

The TEXCOM Experimentation Center (TEC) was established at Fort Hunter-Liggett in 1956. Since that time, it has existed in various sizes and configurations, but always with the same general mission of testing new Army weapon systems. The TEXCOM Experimentation Center's specific mission is to:

a. Plan, conduct, and report on Army user tests and experiments of doctrine, training, organization, and material.

b. Provide advice, assistance, and guidance on test and experimentation to combat developers, training developers, material developers, system managers, material producers, other military services, and private industry.

c. Conduct other tests and experiments as directed by Commander, TEXCOM.

d. Provide high resolution data, other scientifically derived data, and analysis of these data for training, doctrine, organization, and material development decisions.

e. Maintain a highly responsive, trained, combat ready reinforced tank company (M-1 Abrams and M-2 Bradley) for experimentation and testing support.

f. Within TEXCOM, develop instrumentation programs, test and experimentation methodologies and design, develop,

procure, and maintain the instrumentation necessary to generate required data from field experiments.

The TEC facility is composed of instrumented range facilities that permit extensive and detailed computer data collection in support of its mission. TEC is a self reliant organization that is fully capable of supporting most testing requirements. This includes the on site design and manufacturing of training aids and devices which are necessary for successful testing. To facilitate future operational tests, TEC is developing a portable range instrumentation system that will permit testing to be conducted at locations other than Fort Hunter-Ligget.

B. THE APACHE HELICOPTER

1. Background

The earliest system test examined by this thesis is the Apache Advanced Attack Helicopter (AAH) OT II, which occurred from June to August 1981. Operational testing for the Apache, designated the AH-64 Attack Helicopter, was a Follow-on Operational Test & Evaluation (FOT&E). The initial operational test (IOT/OT I) was conducted in 1976. It had compared two candidate systems with their respective baselines, each an AH-1S Cobra, and led to selection of the AH-64 for further development.

The Apache OT II was a comparative baseline, three-phase test conducted at the Test and Evaluation Center (TEC). A typical Army attack helicopter unit provided personnel and resources for both an AH-64 test section and the AH-1S baseline section. The test section consisted of three AH-64s and two Airborne Target and Fire Control Systems equipped AH-1Ss to act as scouts for the AH-64s.

The baseline section consisted of three AH-1Ss and two OH-58 scouts. The AH-1S and AH-64 aircraft were flown in the same operational and threat environment.

The three phases of the test included a training phase, a non-live fire phase, and a live fire phase. Force-on-force and one-on-many engagements, with real time casualty assessment, were conducted during the non-live fire phase. The live fire phase included firing of all AAH weapons. In total, over 400 flight hours were accomplished.

The purpose of the test was to assess the military effectiveness of the AH-64 against the baseline aircraft it was to replace. The OT-II operational test report stated: "the performance of the AH-64 was adequate for combat, superior to the present attack helicopters, night capable, and survivable." There were no operational issues which were considered to preclude the acquisition and development of the system.

DT II was conducted after OT II in June, 1982. The purpose was to fix performance problems and operational

failures which had occurred during the operational test. This primarily involved the Target Acquisition Designation Sight (TADS) which had failed to perform, thus affecting testing of the aircraft weapon systems.

2. Observations

Since there were many new, highly sophisticated systems from eight different PM offices integrated on the AH-64, a separate development test training detachment was formed to prepare for OT II. Preliminary flight training was performed using modified Cobra (AH-1) surrogate aircraft. Eventually, fifteen prototype training devices were developed. Thirteen were for the support of maintenance training, and two were for support of pilot/gunner training.

To support OT II, the Apache PM established a field office at the test area. Included in this office were PMO personnel from the logistics, test and evaluation, and technical divisions. Although controlled by test personnel, these PM representatives were able to improve test continuity and facilitate the flow of spares and repair parts. Controlling spares and parts had the additional benefit of helping to keep PMO personnel informed of what was going on.

Some contractor personnel were permitted at the OT II test site to represent the depot level of maintenance support. These personnel included technical writers whose job had been

to write the AH-64 Technical Manuals (TMs). During the operational tests, the technical writers were able to evaluate recommended TM changes from crew members and support personnel, and update publications on the spot. These updates were then passed back to the users during the test.

During the operational test, the Target Acquisition Designation System (TADS) was undergoing developmental and operational testing at the same time. The development schedule hadn't allowed enough time for qualification testing (a DT&E activity) of the TADS prototype prior to a full field test of the total aircraft system. There also hadn't been time to introduce changes to correct TADS problems discovered in early developmental tests. As a result, the TADS performed poorly and was unreliable during the operational test.

Problems with the weapon systems were experienced from the start of the weapons subtests, and only one trial was successfully completed with no aborts or difficulties. Weapons control failures, aircraft generator failures, random pylon articulation, and dirt inside the 30mm gun's receiver group were all problems that curtailed testing.

These failures included the 2.75" Folding Fin Aerial Rocket (FFAR) engagements which experienced widely dispersed impacts over a 2 kilometer area. This was attributed to problems with the TADS and articulation of the weapons pylon.[Ref. 12] Also, due to the limited firing of

the 30mm gun and the FFAR, only one simulated engagement with the new HELLFIRE missile was accomplished.

The Apache tests also experienced significant test limitations due to ineffective threat weapons simulators. The SA-9 simulator, a air defense missile system, could not be employed quickly, and it constantly overheated. The ZSU-23-4 simulator, a threat air defense gun, wasn't capable of firing on the move. The T-72 tank surrogates couldn't fire on the move either. For these reasons, they did not represent a realistic threat force.

Operational testing for the Apache concluded in August 1981. Results of the operational test showed that the system was superior to the Cobra attack helicopter, night capable, and survivable. At Milestone III, the Apache was approved for production.

C. APACHE ENHANCEMENT OBSERVATIONS AND LESSONS LEARNED

1. Test Schedules

Lesson Learned. Test schedules should be delayed or modified if the system isn't ready for the operational test.

Discussion. The TADS on the Apache hadn't completed DT&E, and it wasn't ready for OT&E. This had a negative affect on the results of all three weapons subsystem tests. The 30mm gun failures were partially attributed to the TADS failure, but that blame may have been misplaced. As recently as Operation

Desert Storm, the Apache continued to experience trouble with the 30mm gun.[Ref. 13] This problem might not have occurred if the PM had delayed testing until the complete system was ready.

2. Technical Manuals

Enhancement Observation. Contractor technical writers were included at the operational test site.

Discussion. Having the technical writers present for OT&E ensured that user input was taken seriously. Problems with the TMs were fixed and the PM improved the quality of his system at the test site.

3. Test Reports

Lesson Learned. Test reports should include user comments and a sufficient discussion of problems found during the test.

Discussion. The Apache test report lacked detail in both of these areas. These comments are very important in enabling non-participants to gain an understanding of the performance of the weapons system.

4. Test Resources

a. Test Articles

Lesson Learned. Operational testing should not be conducted on multiple new systems at the same time.

Discussion. The Apache was composed of multiple new systems integrated together. The failure of any of these systems affected the test data collection on the others. In this test, the TADS was not prepared for the test, and it had a negative affect upon results from the 30mm gun, the rocket system, and the Hellfire missile.

b. Threat Systems/Simulators

Lesson Learned. Threat systems should adequately represent the threat forces.

Discussion. Some limitations were reported with the threat systems due to their inability to react quickly and fire on the move. This gave the Apache helicopters less incentive to mask or fire quickly as they would in a realistic environment. This could have resulted in invalidated test engagements, and overstated the combat effectiveness of the system

5. User Experience Training

Enhancement Observation. Extensive user training was emphasized prior to the operational test.

Discussion. The Apache crews were formed into a separate test training detachment to prepare for OT&E and preliminary flight training was conducted on modified Cobra helicopters. To support this training, the Apache program developed a total of fifteen prototype training devices. Thirteen of these were dedicated to the support of maintenance training. The

operational test report did not cite any OT&E problems that were due to a lack of prior training.

D. THE OH-58D HELICOPTER

1. Background

The Kiowa helicopter is a scout aircraft that has been in the Army inventory for several years. The decision to modify the aircraft from the OH-58C to the OH-58D in the Advanced Helicopter Improvement Program (AHIP) resulted in a major weapon system upgrade. This required Follow-on Operational Testing.

Operational Testing (OT II) for the OH-58D was conducted at Fort Hunter-Liggett from September 1984 to February 1985. The test at Fort Hunter-Liggett immediately followed Developmental Testing which had been conducted Yuma Proving Ground in Arizona.

2. Observations

Although the Operational Test of the OH-58D was considered to be successful, a number of issues were noted as having adversely affected its conduct.[Ref. 14] The first issues involved the pilot and support personnel individual skills instruction which was received at pre-factory training, factory training, and Developmental Testing.

The instruction was judged to be inadequate in the following four areas:

- a. Not all required individual tasks were taught
- b. Combat skills were not taught
- c. Academics during pre-factory training were not reinforced with either flight time or training devices
- d. Not enough flight or hot cockpit time was available for factory training due to the fixed price contract.

Many other factory training problems occurred. These included the lack of procedural trainers. The factory had one actual OH-58D available, and this was used for all pilot and support personnel training. The repeated system start-ups resulted in frequent system failures and caused training delays. All other training was conducted on chalk boards.

Another issue was that this factory training was conducted from two to five months before the test. After training was completed the students were sent back to their home units where they resumed their normal duties. By the time of the test, many had forgotten much of what they had learned.

A positive aspect of the factory training involved user input to improve the technical manuals. The contractor, Bell Helicopter, had technical writers present at the training. They were able to incorporate changes and fix problems on the spot, as they were noted by mechanics and pilots.

Other problems that affected testing included the availability of only two training areas for the first two weeks of crew training prior to the test. This was accompanied by a prohibition from using the system's lasers for the same time period.

Technical restrictions also affected the test schedule. One of these involved a requirement for the issuance of Airworthiness Releases for OH-58C/D pink lights (Night Vision Goggle search lights), which delayed some training. Also, the installation and verification testing of test instrumentation equipment on the aircraft caused further delays. Finally, one day prior to the start of the training program, the parent unit of the test personnel decided to establish the following additional requirements for single pilot NVG flight in the OH-58C: (1) radar altimeters, (2) blue-green level lighting, and (3) selected experienced crews. This created additional delays in training until the appropriate requirements could be met.

Another problem area involved crew qualification to participate in the test. The operational test plan called for OH-58C crews who had gone through a Army Training Evaluation Program (ARTEP) with the AH-1S Cobra attack helicopter before the test. The crews weren't qualified as required when they arrived at the test site. This made additional training necessary.

In October 1984, approximately one month into testing, Headquarters, Department of the Army tasked Fort Hunter-Liggett with an additional system evaluation. This involved a Scout/Gun mix sensitivity experiment. The Test and Evaluation Center delayed testing for several days to develop instrumentation for this unplanned test. They subsequently conducted 18 trials of which only 12 were technically validated. Tactically, none of these additional trials were validated, so the test results were of limited use.

These test delays and additional requirements had an affect upon the test schedule. The trials were originally expected to be conducted two times a day for four days a week. This was accelerated to two to three trials a day, seven days a week. This impacted on staffing support, which was too small for the busier schedule. The aviation support unit was kept extremely busy by this unexpected schedule and suffered from morale problems.

Spare parts supply also had some difficulties due to post DT&E maintenance requirements. DT II had concluded at Yuma, Arizona in August, and the maintenance that resulted had drawn heavily upon the spare parts available for the operational test. The unexpected OT II training and testing schedule further degraded the supply of spare parts. The exact affect of this shortage was not evaluated, but comments in the test report stated that it created a heavier workload for the support personnel.

Weapons simulator problems also occurred. TEC personnel believed that the Air Defense Threat Simulators, which were a contractor responsibility, weren't up to the test requirements. The simulators were supposed to replicate current threat air defense systems that would simulate a realistic operational environment for flight crews. The systems had technical problems as well as crew training and operational difficulties. This resulted in few valid engagements against the OH-58Ds being tested and evaluated.

Operational testing for the OH-58D concluded in February 1985. At the Milestone III decision, the system was approved for fielding.

E. OH-58D ENHANCEMENT OBSERVATIONS AND LESSONS LEARNED

1. Test Schedules

Lesson Learned. OT&E should not be scheduled too closely behind a developmental testing event.

Discussion. The OH-58D went into its operational test one month behind its developmental test at Yuma. The quick transition didn't allow time to correct system problems or to fully recoup the spare parts supply from the post-DT&E maintenance. This caused extra work for the OT&E support personnel, and it could have negatively affected the Reliability, Availability and Maintainability (RAM) data collected during the test.

Lesson Learned. Test requirements should not be added once the schedule has been established, and especially after testing has started.

Discussion. The last minute requirement for a Scout/Gun sensitivity test severely taxed the resources of Fort Hunter-Liggett, and resulted in worn-out crews and support personnel. This extra requirement resulted in the collection of data that were not validated and thus, were of little use. The schedule deviation did have a negative affect upon the test through the long hours and overwork that resulted.

Lesson Learned. User training time should be planned into the beginning of the test schedule.

Discussion. With this system, prior user training was insufficient. This resulted in a need for significant and unexpected retraining at Fort Hunter-Liggett prior to the test. This time was taken from the test schedule, and contributed to the overwork of the support personnel.

2. Technical Manuals

Enhancement Observation. Early efforts were taken to review and correct the TMs.

Discussion. The contractor took advantage of the factory training to have the technical writers and users find and fix TM problems before the operational test. These problems could

have had an adverse affect upon the OT&E RAM data if they hadn't been corrected prior to the tests.

3. Test Reports

Enhancement Observation. A detailed test report can be of great value in determining problems and for developing a programs 'lessons learned'.

Discussion. This thesis found the OH-58D test report to be the most thorough of the four systems examined. It had detailed user comments, and it traced test problems back to their sources. This resulted in a extremely informative test report.

4. Test Resources

a. Test Sites and Instrumentation

Lesson Learned. Sufficient training areas should be made available at the operational test site.

Discussion. Pre-training at Fort Hunter-Ligget was initially hindered by limited training areas and the inability to utilize the laser system on the aircraft. For the OH-58D, pre-training was critical to the success of the weapons system.

b. Test Support Equipment

Lesson Learned. Spare parts supplies should be available to support testing operations.

Discussion. The OH-58D spare parts supply was depleted by post-DT&E maintenance. This could have impacted on the OT&E RAM data and unnecessarily increased program risk.

c. Threat Systems/Simulators

Lesson Learned. Threat simulators should be adequate for the tests.

Discussion. The threat systems in this test did not simulate an effective threat environment. This was due to mechanical and crew training problems on the threat systems. These problems could have invalidated the tests.

d. Operational Force Test Support

Lesson Learned. Coordinate with test support units early on, so that they can voice any concerns.

Discussion. The test support unit had legitimate safety concerns over night flying of the weapon system, but the time to discover a problem is not the day before the test. If the support unit has a full understanding of what is going to occur, they can give their input and make objections early in the process.

Lesson Learned. Sufficient support personnel to meet test requirements should be available.

Discussion. There were insufficient support personnel involved in this test to handle the work load brought on by

the additional training. This shortfall could have negatively affected maintainability data and should be avoided in future test programs.

5. User Experience Training

Lesson Learned. Users should have sufficient technical and tactical training before the tests are scheduled to begin.

Discussion. Even though this system was an upgrade of the OH-58C, significant technical and tactical differences affected the users. They were not qualified as required, and the factory training was insufficient. This resulted in extra on-site training.

Lesson Learned. Testing should follow soon after user training is conducted.

Discussion. With this system, a three to five month lag occurred between training and the tests. The need to conduct retraining used up several days of the available test time.

Lesson Learned. Sufficient simulators should be available for crew and support training prior to the test.

Discussion. Some of the most apparent problems of the OH-58D operational tests involved the lack of simulators or mock-ups for the contractor conducted factory training. This resulted

in extra on-site training and could have had a severe impact on the test results.

F. THE AVENGER AIR DEFENSE SYSTEM

1. Background

The Pedestal Mounted Stinger, now known as the Avenger, is an air defense system consisting of Stinger missiles on a turret mounted on the High Mobility Medium Wheeled Vehicle (HMMWV). The system went through Force Development Testing and Experimentation (FDT&E) at Fort Hunter-Liggett in 1989. The Initial Operational Test & Evaluation followed in 1990.

The purpose of Force Development Testing is to evaluate and develop tactics for the system. An advantage of FDT&E is that it can be used to evaluate a weapon system and iron out 'bugs' prior to operational testing. Another advantage is that it allows the users to gain valuable experience with the system. FDT&E results are not used for the Milestone III decision and give the user an opportunity make mistakes and learn without having the results used against the program.

2. Observations

During Avenger Force Development Testing, exploratory trials were conducted for 11 days. They had been scheduled

for only one week, but the sixth and final Avenger system had not yet arrived from the contractor. Fortunately, the testing schedule was flexible and the extra days were used for additional platoon training. It also permitted Fort Hunter-Liggett (FHL) to improve its data collection procedures for the test.

Only two Avenger firing units were available for user training before the Force Development Test. Three more arrived at FHL in time for the tests, but as noted, the sixth unit didn't arrive until after the scheduled test start date. This meant that the testing unit couldn't conduct realistic, full platoon training until the actual test. During previous training at Fort Bliss, the platoon had only been able to use two available systems with other surrogate vehicles.

When the final Avenger system arrived at Fort Hunter-Liggett, it came directly from the manufacturer. Because it had arrived late, the new sixth system wasn't given an opportunity to go through an extensive mechanical shakedown or 'burn-in' as the previous systems had done. Since this was a Force Development Test, RAM data wasn't recorded to determine if this resulted in any problems. The test report did state that "repair parts were not available" [Ref. 15], so any break-in problems would have been difficult to fix.

Some difficulties with technical manuals were noted during FDT&E. One problem was that the operator manuals were written at a reading grade level of 11.09 years. This

exceeded the Army Training and Doctrine Command (TRADOC) standard of 8.0 years, resulting in comprehension problems for some operators. A similar but less severe problem occurred with the maintenance manuals which were found to be written at a grade level of 9.65 years. Both of these problems were subsequently corrected prior to OT&E.

Another problem was that the Avenger launch signature device was found to be ineffective. Because of this, the firing of Stinger missiles was not discernable by attacking pilots or by other Avenger systems in the test platoon. This resulted in multiple and often unnecessary engagements by the weapon systems.

A related problem was that threat aircraft did not have any type of kill signature. The test report stated that in several instances, this may have caused multiple engagements on one aircraft and none on others.

The small size and compartmentalized terrain of Fort Hunter-Liggett limited testing scenarios and aircraft directions of attack to the valleys. This prevented the Avengers from spreading out laterally. It also enabled the Avenger operators to focus their attention forward down the length of the valley. In a more realistic operational scenario, the Avenger crews would be required to keep 360 degrees of observation.

During Avenger operations, the driver is often expected to dismount the vehicle as an aircraft observer while

the gunner mans the system. During Force Development Testing, the drivers indicated a need for a method to stay in voice contact with the gunner while they were away from the vehicle. As soon as the need was identified, a 50 foot communications cable was provided to the driver/observer in all systems. This remedied a problem which probably would not have been identified until the operational test, when it could have affected system performance.

Finally, during Force Development Testing, an ad hoc cell from the Air Defense Artillery School and the Air Defense Artillery Board was present. This cell was empowered to make changes in system utilization and tactics as they felt necessary. With members of both the school and the board present, many changes were approved and recorded on the spot. This enabled the Avenger Platoon to get immediate feedback to their suggestions and to quickly incorporate the new tactics.

As a result of FDT&E, the Avenger Program Manager was able to incorporate many changes prior to the system's successful IOT&E in 1990. After the production decision was made, the system was fielded in time to be deployed with units participating in Operation Desert Shield and Operation Desert Storm.

G. AVENGER ENHANCEMENT OBSERVATIONS AND LESSONS LEARNED

1. Test Schedules

Lesson Learned. Tests should not be scheduled when the tested system may not be available.

Discussion. The Avenger went to the scheduled tests even though all of the systems had not been delivered by the contractor and the crews hadn't had full platoon training. This could have resulted in RAM problems and tactical difficulties due to a lack of training and experience, and should be avoided in future programs.

2. Technical Manuals

Enhancement Observation. Technical manuals were reviewed and corrected before the operational test.

Discussion. The Force Development Tests were used to screen the TMs and many comprehension problems were discovered and subsequently corrected. If the PM hadn't gone through FDT&E, these problems might not have been discovered until the operational test, when they could have affected the RAM data.

3. Test Reports

Enhancement Observation. Detailed test reports were written.

Discussion. Comments from the Avenger FDT&E were used to make system improvements prior to the system's successful

operational test. Well written test reports can provide the PM with valuable information on his system.

4. Test Resources

a. Test Articles

Lesson Learned. Sufficient test articles should be available for the test.

Discussion. The Avenger only had two of the required six systems available for training prior to FDT&E. At the test site, one of the systems arrived late. This limited platoon training time and it could have adversely affected test results.

b. Test Support Equipment

Lesson Learned. Sufficient test support equipment should be available for the test.

Discussion. The Avenger did not have any spare parts for the conduct of this test. Any maintenance problems due to 'burn-in' on the new systems would have negatively affected the tests. This introduced unnecessary risk into the program and should be avoided in future programs.

c. Threat Systems/Simulators

Lesson Learned. Simulators should be effective.

Discussion. During this test, the simulators on the Avenger and supporting systems were not very visible. This resulted

in unnecessary engagement difficulties which should be avoided in future programs.

d. User Experience Training

Enhancement Observation. Extensive training prior to OT&E gives the user experience and can result in feedback that improves the system.

Discussion. The Avenger system had a dedicated platoon that conducted extensive crew training at Fort Bliss, Texas prior to FDT&E. This resulted in personnel who were knowledgeable of the system prior to the test. During the test, the users were able to make comments and ask for improvements, such as the 50 foot remote communications cable, that enhanced the system's effectiveness. Because this was a Force Development Test, the discovery of problems did not negatively influence the evaluation of the system and it reduced program risk.

Enhancement Observation. Key decision makers and weapons experts were present at user training.

Discussion. An advantage of this early training was that it permitted the presence and participation of a cell of Air Defense experts representing the Air Defense School and Air Defense Board. They were able to obtain direct user input and agree upon changes in utilization and tactics on the spot. This enhanced performance during OT&E.

H. THE ADATS AIR DEFENSE SYSTEM

1. Background

The Air Defense Anti-tank System, also known as the Line-of-Site Forward Heavy (LOS-F-H), is an armored air defense system that was designed to operate at the forward edge of the battlefield. In 1986, Congress approved Army plans to test the system on a compressed time schedule. In the fall of 1987, the LOS-F-H Nondevelopmental Item Candidate Evaluation (NDICE) was conducted at White Sands Missile Range. Four candidates using off-the-shelf technology competed in the NDICE. The ADATS which had been developed by Martin-Marietta, was selected for further development.

The ADATS system went through two iterations of Force Development Testing and Experimentation (FDT&E) in 1988 and in 1989. The purpose of the testing was to develop and evaluate operator, crew, squad and platoon tactics and drills. It was also used to evaluate, modify as necessary, and validate the Test Support Package (TSP) for IOT&E. This included the Threat Support Package.

IOT&E was conducted in two parts, the missile firing phase and the maneuver phase. The test report only describes the maneuver phase conducted by TEC at Fort Hunter-Liggett from March through May 1990. The missile firing phase was conducted at White Sands Missile Range, New Mexico in February 1990.

2. Observations

The ADATS training was conducted by the prime contractor. The stated purpose of the training was "To train soldiers on specific system skills that are required to operate the system in IOT&E". It consisted of 200 hours of instruction conducted over 29 days at Fort Bliss, Texas.

Prior to the start of the tests, the TEXCOM Experimentation Center conducted exploratory trials (pilot tests) from 27 March through 5 April. Fifteen trials, including one night trial, were conducted similar to the record trials. The objectives of the exploratory testing included maturation of the data collection and reduction procedures and resolution of instrumentation problems. It also provided an opportunity for test controllers and players to refine their procedures. In addition, the exploratory testing provided data upon which to decide if procedures, instrumentation, and players were ready for the record trials. [Ref. 16]

Fifty IOT&E trials were conducted from 9 April to 23 May 1990. Each trial was a force-on-force battle which generally lasted one hour. Normally, two trials were conducted each day. Of the fifty trials conducted, three were invalidated due to computer, instrumentation or weather problems.

A number of system manpower problems were discovered and recorded during the test. The first issue was that

drivers complained of poor visibility that degraded their ability to drive the vehicle. Unlike most armored vehicles, the ADATS didn't have a position for a Track Commander (TC) at the top of the vehicle. A vehicle TC normally has a better field of view and can assist the driver. The lack of a TC on the ADATS made maneuvering difficult for the driver whose visibility was partially blocked by the vehicle hull.

Crew members also complained of a variety of physical discomforts inside of the system, and expressed concern over their immediate safety, and long term health hazards. Dust and exhaust seeped into the crew compartment, resulting in headaches, burning eyes, and lung and sinus problems. Poor seating and vibration also resulted in numbness in the extremities and back pain. At times, these problems cause the crew to stop operations in order to exit and ventilate the vehicle.

Cramped conditions within the vehicle caused other problems. The crews had to fit all of their required combat equipment into the vehicle, and this caused difficulty in moving around inside. This problem was aggravated by the presence of test instrumentation which occupied the vehicle bustle rack where some of the field gear would have normally been stored.

Another interior space issue affected the system's maintenance personnel. They had a difficult time replacing the system's power distribution assembly. The job required two

personnel, but there was only room for one man near the assembly. The test report stated that the lack of work space and of easy access to parts resulted in maintainers working longer than would have otherwise been necessary. Of the eleven areas of Reliability, Availability and Maintainability (RAM) data collected, only the Mean Time To Repair at the organizational level met the established requirements.

The maneuver phase of the ADATS IOT&E differed significantly from the FDT&E II which had been conducted at Fort Bliss. Some changes in doctrine, tactics, techniques, and procedures resulted from lessons learned in FDTE II. Other differences occurred because of the different focus of the test, and due to increased player resources which were devoted to the IOT&E.

In the operational test, 14 Apache helicopters were provided as surrogates for Red rotary wing aircraft, compared to the six provided for FDTE II. This continually gave the required availability of six operational aircraft for test support. The remaining aircraft were either in maintenance or available for pilot training. As a result, the number of threat aircraft that the ADATS Platoon faced was substantially increased over the previous force development test. For the operational test, Fort Hunter-Liggett hired a team of ADATS systems manpower evaluators to assess the causality of soldier/squad level errors. For this analysis, errors were confined to those resulting in non-engagement of an aircraft

which the crew should have engaged, and errors during an engagement which resulted in non-intercept of the target. The following table categorizes the errors:

Table 1 **ERROR CAUSE CATEGORY**

Error Category	Frequency	% of Total
Manpower/Personnel/Training	255	43.0
Reliability & Maintainability	226	38.1
Doctrine/Tactics	80	13.5
Human Factors Engineering	19	3.2
Safety/Health Hazards	5	.8
Other	8	1.4
TOTAL	593	100.0

The ADATS operational testing concluded with the last test on 23 May 1990. At Milestone III, the decision was made not to proceed into production. The primary reason, cited by air defense experts, was loss of the ADATS primary mission due to the end of the cold war.

I. ADATS ENHANCEMENT OBSERVATIONS AND LESSONS LEARNED

1. Test Schedules

Lesson Learned. The operational testing schedule should be based upon a system's readiness for the test.

Discussion. The ADATS was scheduled for testing after it had gone through two Force Development Tests which helped to ensure that it was ready for testing. To further ensure its readiness, Fort Hunter-Liggett scheduled time for fifteen exploratory trials to ensure that the procedures, instrumentation and players were ready to start the operational test.

2. Test Reports

Lesson Learned. Test reports should be detailed.

Discussion. The operational test report for the ADATS contained the fewest comments and the least detail of the four reports examined by this thesis. Some operator problems were discussed, but not in detail. This makes it difficult for the Program Manager or other readers to determine problems or possible improvements that could be made.

Enhancement Observations. Information was summarized in easy to understand tables.

Discussion. The ADATS operational test report used simple tables to summarize missile launch and error cause data. This

method made it much easier to understand possible problem areas and their sources. In other reports, the reader is required to search through extensive data in order to find this information.

3. Test Resources

a. Test Sites and Instrumentation

Lesson Learned. Instrumentation should not affect user performance.

Discussion. The ADATS crew members reported problems operating inside of the crew/operator compartment due to the instrumentation. The instrumentation had the affect of slowing movement and reactions inside the vehicle.

b. Test Support Equipment

Enhancement Observation. Adequate test support equipment was provided for the test.

Discussion. For the operational test, sufficient Apache helicopters were provided to allow for continued testing without delays from maintenance or training problems. This resulted in a full threat force being available for all tests.

4. User Experience Training

Enhancement Observation. The user platoon was well trained.

Discussion. The ADATS had a dedicated operational test platoon for over a year prior to the test. This enabled the

crew to receive extensive training in preparation for the test. The ADATS platoon had 200 hours of contractor training and two Force Development Tests at Fort Bliss, Texas and Fort Hunter-Liggett prior to OT&E. This resulted in the users being well prepared for the test.

Enhancement Observation. User training was used to validate test support requirements.

Discussion. The ADATS user training was used to validate the test support package for the tests. This resulted in logistics support that was able to fully support the user and test requirements.

IV. OPERATIONAL TESTING OBSERVATIONS

This thesis has determined that a number of common observations and 'lessons learned' exist in the preparation for and conduct of operational tests by the Program Manager. These lessons involve issues that helped the PM improve his programs readiness for testing, as well as those areas that detracted from weapon system's readiness. A consolidation and categorization of these common observations and 'lessons learned' is presented below:

A. TEST SCHEDULES

Lesson Learned. Test schedules should have some flexibility to allow for delays caused by training, equipment, instrumentation and weather problems.

Discussion. Two out of the four tests reviewed needed additional time for activities other than testing at the beginning of the testing schedule. In one case, the time was gained by cramming the trials into a shorter testing period. This resulted in morale and support problems. In another case, sufficient time had been built into the schedule to allow for a delay, and no significant problems resulted.

Lesson Learned. Unplanned, additional testing requirements should not be added to the test schedule.

Discussion. One of the systems experienced a last minute addition to the testing requirements. This threw the schedule off by several days and resulted in information that was of little use. Once the test schedule is established, additional testing requirements should not be added without increasing the total test time.

Lesson Learned. Test schedules should be established on the basis of system readiness, rather than strictly on milestones.

Discussion. Three out of the four systems went to the operational test before they were physically ready. This caused problems that could have resulted in system cancellation due to poor test results. PMs shouldn't test their system if it is not ready.

Lesson Learned. Sufficient time should be planned in the schedule for system maintenance and recovery after DT&E.

Discussion. One of the four systems reviewed was adversely affected by recovery from DT&E. Developmental testing is designed to stress parts of the weapons system. If OT&E follows too closely, the result may be a system that is in need of maintenance at the start of the test. Even if the system is functional, there may be a shortage of spare parts due to DT&E recovery operations. This will seriously impact

upon RAM data collection. In the worst case, poor RAM data might result in a failure of the operational test.

B. TECHNICAL MANUALS

Enhancement Observation. Contractor technical writers should be brought to the training and testing locations to correct TMs as problems are noted by the users.

Discussion. Two of the four system test reports addressed TM problems. In both cases, these errors were caught and corrected before OT&E. These errors can affect system operation and maintenance support. Research for this thesis indicates that the most practical way to screen and fix TM's is to involve the contractors technical writers early in the users training and testing. This early screening will help to ensure accuracy and clarity. OT&E is the wrong time to discover that the manuals are wrong or unclear, but if they are, having the technical writers present will help ensure that the problems are fixed on the spot.

C. TEST REPORTS

Lesson Learned. Test reports should give a detailed report of what actually happened in the test.

Discussion. Only one of the four test reports gave sufficient details of what took place during the tests. Test reports need to tell why things happened the way they did. The evaluator needs to report more than just events. For tests in which the human factors are involved, the most neglected resource in finding out why things happened the way they did is the test participants themselves. The tester and the PM should not let them go without debriefing them extensively and recording their explanations of why things happened the way they did.[Ref. 17]

D. TEST RESOURCES

1. Test Articles

Lesson Learned. Sufficient test articles should be produced and available well before the operational test is supposed to start.

Discussion. In three of the cases reviewed, the lack of complete test articles caused truncated and ineffective training prior to OT&E. In one case, the users and supporters had minimal hands on experience with the system before the operational test. In another, the testing had to be delayed for almost a week to permit the delivery of all of the required vehicles for testing. In a third, the users didn't have a fully functioning systems due to subsystem integration problems.

Lesson Learned. Systems should go through burn-in prior to the operational test.

Discussion. In one system test, the final weapon system literally arrived off of the truck from the factory. While this did not appear to have affected the test results, it did introduce unnecessary risk into the program. When mean time between failures (MTBF) is to be tested, it is better to test equipment that has already been through its burn-in period.

2. Test Sites and Instrumentation

Lesson Learned. Test sites should be adequate in size, and all special clearances should be obtained.

Discussion. This is especially important when using devices such as laser range finders and certain kinds of communications equipment. These special items frequently require coordination with outside agencies such as the FAA or the Forest Service. A ten day delay was experienced by the OH-58D when the system was prevented from using its laser range finder during scheduled testing.

Lesson Learned. Test instrumentation should not interfere with user operations.

Discussion. In one of the four tests, this was a problem. Instrumentation can be bulky and interfere with movements of the users. Instrumentation should provide the needed data,

but not hinder the users. It should be as unobtrusive as possible to the test participants.

3. Test Support Equipment

Lesson Learned. All necessary support equipment should be available and operable.

Discussion. In two of the four systems examined, the Program Manager had extra support equipment available as back-ups during the test. If the test involves a baseline comparison with another system, or is supported by another system, make sure that appropriate emphasis is also placed on that system's availability. These extra systems assured continuous support and gave the operators extra training systems.

4. Threat Systems/Simulators

Lesson Learned. Threat systems should actually look like the threat systems and not the friendly system they were derived from.

Discussion. This problem occurred in one of the tests reviewed. Poor threat systems can cause confusion among personnel who are trying to identify targets. This confusion can result in fratricide and failures to engage enemy vehicles. These kinds of actions result in data that make the weapon system appear ineffective.

Lesson Learned. Threat system crew members should fully understand the threat tactics they are supposed to use.

Discussion. In some tests, improper tactics resulted in invalidated test results. Training for test support personnel such as threat crew members requires emphasis and verification before the test begins.

Lesson Learned. All weapons effects simulators should be tested and judged to be realistic and effective prior to the tests.

Discussion. There was a problem with simulators in all four system tests. Ineffective kill lights and flash/bang devices result in wasted rounds and unnecessary engagements from the tested weapon systems. In a realistic combat environment, crew members rely visual clues to determine the effectiveness of engagements. These visual clues are just as important in the operational test. A lack of preparation in this area can result in quantatative data that make the weapon system look ineffective.

5. Operational Force Test Support

Lesson Learned. Detailed memorandums of understanding (MOUs) should be executed with all military units providing test support personnel.

Discussion. One of the four tests addressed this as an area of emphasis due to misunderstandings with the test support unit. Fort Hunter-Liggett testers believe that conflict resolution is a normal part of their mission, but testing could be improved if the test support units had a more complete understanding of the requirements and training that they must complete prior to OT&E. Failure to complete this requisite training results in support personnel who are not qualified and must be retrained. This uses up valuable time at the beginning of the test and could possibly endanger the test itself.

Lesson Learned. Support personnel should always be fully informed of the latest requirements and changes.

Discussion. The test support units need to fully understand the requirements of the test so that their questions and objections may be satisfied well in advance. The supporting units often have legitimate questions involving issues such as safety which should not come up just prior to test execution. These last minute conflicts can be reduced with support unit involvement and understanding.

Lesson Learned. Contractor training should be observed and validated.

Discussion. In one of the programs, contractor training was ineffective and incomplete due to a lack of training assets

and funding. The PM needs to be assured that the contractor training is up to an agreed upon standard and that it is completed when these standards have been met. This training needs to include sufficient hands-on training time on a representative system, not just mock-ups. If the PM recognizes that contractor training is insufficient, he needs to plan to correct this shortfall within the testing schedule.

Lesson Learned. OT&E should be restricted to a reasonable duration.

Discussion. Many test support personnel come from other military facilities for the duration of the test. Overly lengthy tests can result in morale problems that may impact on test results. According to Ft. Hunter-Liggett testers, this is especially true when the tests encompass major family oriented holidays. Tests are too important to risk adverse results from tired or apathetic soldiers.

E. USER EXPERIENCE TRAINING

Lesson Learned. The Program Manager should schedule Force Development testing and training prior to IOT&E.

Discussion. Two of the systems reviewed made extensive use of Force Development Tests before IOT&E. This testing resulted in important user familiarization and problem identification

and resolution prior to the Operational Test. While the primary purpose of FDT&E is to verify tactics and crew drills, it also allows users to interact with and learn the system. This helps the users to find problems and make suggestions for system improvements before the operational test, when those problems could negatively affect the systems evaluation.

Lesson Learned. Training should not be conducted too early, since there may not be sufficient production representative systems available to support the training, and users may forget the training.

Discussion. In one system, the training was conducted several months too early. This required extensive retraining that ate into the testing schedule and caused other testing repercussions.

Lesson Learned. Prototypes or detailed mock-ups need to be available for all training conducted before OT&E.

Discussion. Only two of the systems examined had sufficient prototypes to train on before the test. There should be a sufficient number available to accommodate all personnel in training before the operational test.

V. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

Because testing is a major cost and schedule driver, adequate planning is essential long before the start of any testing. Test planning and continuous coordination between the Program Manager, the operational tester and the contractor is essential to the success of the weapon system during OT&E.

DOD decisionmakers rely on the results of operational testing to estimate weapon system performance. But, in the systems this thesis reviewed, problems occurred which may have adversely affected the performance which the production decision would have been based upon. For this reason, the PM needs to ensure that extensive effort has been made in the actual preparation for OT&E.

In the earliest tests examined for this thesis, allowances were made for errors and limited success was acceptable in OT&E. Weaknesses in the weapon systems seemed to be treated as something which could be fixed after the test. Today, these weaknesses would most likely result in cancellation of the program. Program managers need to place greater emphasis in the areas of test schedules, manuals, reports, and training!

B. SPECIFIC CONCLUSIONS

The following specific conclusions were derived from the analysis of these four programs:

1. Test Schedules

This thesis has concluded that pre-established schedules are driving the tests, not system readiness. Instead of testing a system when it is ready, the tendency is to test the system when it is scheduled. The PM's goal is to field an operationally effective weapon system, and this is not always compatible with meeting the schedule. In the four systems examined, Program Managers have generally not ensured that their systems were fully configured and ready for operational testing.

2. Technical Manuals

This thesis concludes that early attention to technical manuals resulted in a more accurate product and led to fewer logistics support problems during OT&E. TMs are an integral part of system/equipment support requirements. They are the prime means of communicating maintenance and operational information to the user. Since the quality of TMs affects equipment maintainability, personnel efficiency, safety and readiness, quality in TMs should always be a planned objective. [Ref. 18] It is imperative that all

system publications and manuals be completed, reviewed and selectively tested prior to the beginning of operational testing.

3. Test Reports

This thesis concludes that operational test reports lack consistency and completeness in their depth of coverage. This weaknesses leads to reports that do not clearly report what happened in the test. The reports are not as useful to decisionmakers or PMs as they could be.

4. Test Resources

This thesis concludes that the majority of the problems which occurred during OT&E are directly related to test resource issues. Part V. of the TEMP details the resources required, however they do not appear to get the attention that they warrant. The GAO stated that "Common weaknesses in the quality of such testing that we have reported include the lack of realism, independence, and test resources in the planning, execution, and evaluation of the tests.[Ref. 19] They cited twenty-seven cases where important test resources were limited or not available for testing.[Ref. 20] In spite of this apparent history of problems, resources still do not get the attention they deserve.

5. User Experience Training

The final conclusion of this thesis is that user experience training and testing before the operational test is extremely valuable to the Program Manager and his system. This training helps to ensure that problems are discovered before the test. It is also the best way for the users to gain realistic experience with the system before they are evaluated. The sooner the user is exposed to the system, the better things will go during OT&E.

C. RECOMMENDATIONS

To improve the operational testing process, this thesis recommends that Program Managers and testers review and address the most common issues that have affected systems that have already gone through testing. The Assistant Program Manager (APM) for testing should address the specific issues of schedules, technical manuals, resources and user training. These are the building blocks of a successful operational test.

The list of 'lessons learned' detailed in this thesis are an important tool which can give the PM an understanding of potential problem areas and how to avoid or overcome them. Program Manager Office personnel and testers should review this list before evaluating system readiness for testing. In

addition they should keep an active list of lessons learned for future Program Managers and test personnel.

To improve the operational testing process, this thesis makes the following specific recommendations:

1. Test Schedules

- Test schedules should have some flexibility to allow for delays caused by training, equipment, instrumentation and weather problems.
- Unplanned, additional testing requirements should not be added to the test schedule.
- Test schedules should be established on the basis of systems readiness, rather than strictly on milestones.
- Sufficient time should be planned in the schedule for system maintenance and recovery after DT&E.

2. Technical Manuals

- Contractor technical writers should be brought to the training and testing locations to correct TM's as problems are noted by the users.

3. Test Reports

- Test reports should give a detailed report of what actually happened in the test.

4. Test Resources

a. Test Articles

- Sufficient test articles should be produced and available well before the operational test is supposed to start.

- Systems should go through burn-in prior to the operational test.

b. Test Sites and Instrumentation

- Test sites should be adequate in size, and all special clearances should be obtained.
- Test instrumentation should not interfere with user operations.

c. Test Support Equipment

- All necessary support equipment should be available and operable.

d. Threat Systems/Simulators

- Threat systems should actually look like the real threat systems and not the friendly system they were derived from.
- Threat system crew members should fully understand the threat tactics they are supposed to use.
- All weapons effects simulators should be tested and judged to be realistic and effective prior to the tests.

e. Operational Force Test Support

- Detailed memorandums of understanding (MOUs) should be executed with all military units providing test support personnel.
- Support personnel should always be fully informed of the latest requirements and changes.
- Contractor training should be observed and validated.
- OT&E should be restricted to a reasonable duration.

5. User Experience Training

- The Program Manager should schedule Force Development testing and training prior to IOT&E.
- Training should not be conducted too early, since there may not be sufficient production representative systems available to support the training, and users may forget the training.
- Prototypes or detailed mock-ups need to be available for all training conducted before OT&E.

APPENDIX A: GLOSSARY OF ACRONYMS AND ABBREVIATIONS

AAH	Advanced Attack Helicopter
AH	Attack Helicopter
ADATS	Air Defense Anti-Tank System
ADM	Acquisition Decision Memorandum
AHIP	Advanced Helicopter Improvement Program
APM	Assistant Program Manager
ARTEP	Army Training Evaluation Program
ASA(RDA)	Assistant Secretary of the Army (Research, Development & Acquisition)
ASARC	Army Systems Acquisition Review Council
DA	Department of the Army
DAB	Defense Acquisition Board
DOD	Department of Defense
DODI	Department of Defense Instruction
DOT&E	Director of Operational Test & Evaluation
DSMC	Defense Systems Management College
DT	Development Test
DT&E	Developmental Test & Evaluation
EMD	Engineering and Manufacturing Development
FDT	Force Development Testing
FDT&E	Force Development Test & Experimentation
FFAR	Folding Fin Aerial Rocket

FHL	Fort Hunter-Ligget
FOT&E	Follow-on Operational Test and Evaluation
GAO	General Accounting Office
ILS	Integrated Logistics Support
IOC	Initial Operational Capability
IOT&E	Initial Operational Test & Evaluation
IPS	Integrated Program Summary
LCC	Life Cycle Cost
MAA	Mission Area Analysis
MNS	Mission Need Statement
MOU	Memorandum of Understanding
MPT	Manpower, Personnel and Training
MTTR	Mean Time To Repair
OH	Observation Helicopter
OPEVAL	Operational Evaluation
ORD	Operational Requirements Document
OTA	Operational Test Agency
OT I	Initial Operational Test
OT&E	Operational Test & Evaluation
PEO	Program Executive Officer
PM	Program Manager/Project Manager/Product Manager
PPBS	Planning, Programming and Budgeting System
P3I	Pre-Planned, Product Improvement
R&D	Research and Development
RAM	Reliability, Availability, and Maintainability
SECDEF	Secretary of Defense

T&E	Test and Evaluation
TADS	Target Acquisition Designation Sight
TADSS	Training Aids, Devices, Simulators and Simulations
TEC	TEXCOM Experimentation Center
TEMP	Test and Evaluation Master Plan
TM	Technical Manual
TMP	Technical Manual Plan
TSP	Test Support Package
WBS	Work Breakdown Structure

APPENDIX B: GLOSSARY OF DEFINITIONS

ACQUISITION - The process consisting of planning, designing, producing, and distributing a weapon system/equipment. Acquisition in this sense includes the conceptual, validation, full scale development, production, and deployment/operational phases of the weapon systems/equipment project. For those weapons systems not being procured by a project manager, it encompasses the entire process from inception of the requirement through the operational phase.

ACQUISITION DECISION MEMORANDUM - A memorandum signed by the milestone decision authority that documents decisions made and the exit criteria established as the result of a milestone decision review or in-process review.

ADVANCED DEVELOPMENT - Includes all projects which have moved into the development of hardware for tests.

ANALYSIS-The qualitative and/or quantified evaluation of information requiring technical knowledge and judgement.

AVAILABILITY - A measure of the degree to which an item is in an operable and committable state at the start of a mission, when the mission is called for at an unknown (random) time.

BRASSBOARD - An experimental device (or group of devices) used to determine feasibility and to determine technical and operational data. It normally will be a model sufficiently

hardened to outside of environments to demonstrate the technical and operational properties of immediate interest. It may resemble the end item, but is not intended for use as the end item.

BREADBOARD - An experimental device (or group of devices) used to determine feasibility and to develop technical data. It normally will be configured only for laboratory use to demonstrate the technical principles of immediate interest. It may not resemble the end item and is not intended for use as the projected end item.

DEVELOPMENT TEST & EVALUATION - That test and evaluation conducted to assist the engineering design and development process and to verify attainment of technical performance specifications and objectives.

EFFECTIVENESS - The performance or output received from an approach or a program. Ideally, it is a quantitative measure which can be used to evaluate the level of performance in relation to some standard, set of criteria, or end objective.

FOLLOW-ON OPERATIONAL TEST AND EVALUATION (FOT&E) - All OT&E after the Production and Deployment Decision.

INITIAL OPERATIONAL TEST AND EVALUATION (IOT&E) - All OT&E prior to the Production and Deployment Decision.

INTEGRATED PROGRAM SUMMARY - A DoD Component document prepared and submitted to the milestone decision authority in support of Milestone I, II, III, and IV reviews. It provides an

independent assessment of a program's status and readiness to proceed into the next phase of the acquisition cycle.

INTEROPERABILITY - The ability of systems, units, or forces to provide services to, and accept services from, other systems, units or forces, and to use the services so exchanged to enable them to operate together effectively.

LIFE CYCLE COST - The total cost to the Government for the development, acquisition, operation and logistic support of a system or set of forces over a defined life span.

LOGISTICS SUPPORT - The supply and maintenance of material essential to proper operation of a system in the force.

LOGISTICS SUPPORTABILITY - The degree to which the planned logistics (including test equipment, spares and repair parts, technical data, support facilities, and training) and manpower meet system availability and wartime usage requirements.

MAJOR SYSTEM ACQUISITION - A system acquisition program designated by the SECDEF to be of such importance and priority as to require special management and attention.

MISSION NEED STATEMENT - A non-system specific statement of operational capability need, prepared IAW the format in DoD 5000.2-M.

OPERABILITY - The design characteristic of the system/equipment that will assure personnel feasibility and optimum utilization of operator personnel.

OPERATIONAL AVAILABILITY (AO) - An index of a weapon system's material readiness, including system software where

applicable, in a mission environment. It is a measure of the probability of an items being in a condition, generally referred to as "up", such that is can perform its intended function, within acceptable limits of degradation, when called upon.

OPERATIONAL EFFECTIVENESS - The capability of the system to perform its intended function effectively over the expected range of operational circumstances, in the expected environment, and in the face of the expected threat, including countermeasures.

OPERATIONAL REQUIREMENT - The basic requirement document for all DoD acquisition programs requiring research and development effort.

OPERATIONAL SUITABILITY - The capability of the system, when operated and maintained by typical military users in the expected numbers and of the expected experience level, to be reliable, maintainable, operationally available, logistically supportable when deployed, compatible, and interoperable.

OPERATIONAL TEST AND EVALUATION - The field test under realistic combat conditions, of any item (or key component of) weapons, equipment, or munitions for the purpose of determining the effectiveness and suitability of the weapons, equipment, or munitions for use in combat by typical military users, and the evaluation of the results of such test.

PREPRODUCTION PROTOTYPE - An article in final form employing standard parts, representative of articles to be produced subsequently in a production line.

PRODUCTION AND DEPLOYMENT DECISION - The Milestone III decision by which the SECDEF reaffirms the mission need, confirms the system as ready for production, approves the system for production, and authorizes the Component to deploy the system to the using activity.

PROGRAM - A plan or scheme of action designed for the accomplishment of a definite objective which is specific as to the time-phasing of the work to be done and the means proposed for its accomplishment, particularly in quantitative terms, with respect to manpower, material, and facilities requirements.

PROGRAM MANAGER - The individual in the DoD who manages a major system acquisition program.

PROGRAM OBJECTIVES MEMORANDUM - A biennial memorandum in prescribed format submitted to SECDEF in April by the DoD components head which recommends the total resource requirements and programs within the parameters of SECDEF's fiscal guidance.

RELIABILITY - The probability that an item will perform its intended functions for a specified period of time under stated conditions.

RELIABILITY, AVAILABILITY, and MAINTAINABILITY (RAM) - Requirement imposed on acquisition systems to ensure they are

operationally ready for use when needed, will successfully perform assigned functions, and can be economically operated and maintained within the scope of logistics concepts and policies.

REQUIRED OPERATIONAL CAPABILITY (ROC) - A brief statement of a specific operational capability which is required in the mid-range period.

SURVIVABILITY - The degree to which a system is able to avoid or withstand a hostile environment without suffering an abortive impairment of its ability to accomplish its designated mission.

TEST CRITERIA - Standards by which test results and outcome are judged.

TEST AND EVALUATION - Process by which a system or components are compared against requirements and specifications through testing. The results are evaluated to assess progress of design, performance, supportability, etc. There are three types of T&E - Developmental (DT&E), Operational (OT&E), and Production Acceptance (PAT&E) - occurring during the Acquisition cycle.

THREAT - The sum of the potential strength, capabilities, and intentions of an enemy which can limit or negate mission accomplishment or reduce force, system, or equipment effectiveness.

TRANSPORTABILITY - The inherent capability of material to be moved by towing, by self-propulsion, or by carrier via railways, highways, waterways, pipelines, ocean, and airways.

VULNERABILITY - The characteristics of a system which causes it to suffer a definite degradation as a result of having been subjected to a certain level of effects in a man-made hostile environment.

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