BY ORDER OF THE
SECRETARY OF THE AIR FORCE

AIR FORCE MANUAL 99-104

1 AUGUST 1995

Test and Evaluation

ARMAMENT/MUNITIONS TEST PROCESS--DIRECTION AND METHODOLOGY FOR TESTING

NOTICE: This publication is available digitally on the SAF/AAD WWW site at: http://afpubs.hq.af.mil. If you lack access, contact your Publishing Distribution Office (PDO).

OPR: HQ USAF/TE
(Major Dwight L. Harris)

Certified by: HQ USAF/TE
(Lt Gen Howard W. Leaf (Retired))
Pages: 48
Distribution: F

This manual implements AFI 99-103, Air Force Test and Evaluation Process, for Armament/Munitions Test and Evaluation. It provides a methodology for use by program managers, test managers, test engineers, test organization personnel, major command headquarters staff, and others regardless of command level, involved in Armament/Munitions Test and Evaluation. Non-use of the process described in this manual shall be by exception only and requires written approval by the Director, Test and Evaluation, Headquarter United States Air Force (HQ USAF/TE).

Chapter 1

INTRODUCTION

1.1. Introduction. Program offices, operating commands, and test organizations have been directed by the Chief of Staff, Air Force (CSAF), to employ a disciplined test process throughout all phases of an armament/munitions life cycle. This process applies to all testing including developmental, operational, and combined testing. The purpose of this document is to describe a disciplined process, called the Armament/Munitions Test & Evaluation (T&E) Process, and provide guidelines for its application during the systems acquisition process and throughout the life of the system. This document supplements Air Force Instruction (AFI) 99-103, Test and Evaluation, AIR FORCE TEST PROCESS, which directs the use of the process.

1.1.1. Objectives. The objective of the Armament/Munitions T&E Process is to standardize the testing and evaluation process for armament/munitions. Success of the test program is greatly increased with a standardized and structured T&E process based on a scientific approach. The Armament/ Munitions T&E Process is applicable through all phases of the acquisition process; concept exploration/definition through operations and support. This process will provide a T&E audit trail through the acquisition process in addition to early identification of test asset requirements.

1.1.2. Application. This document is intended for program managers, program test managers, test organization personnel, MAJCOM headquarters staffs and others involved in the management of T&E for armament/munitions. Contractors should use this guide to become familiar with the Armament/Munitions T&E Process. Information on conducting armament/ munitions T&E is available from the Single-Face-to-Customer (SFTC) Office, Air Force Development Test Center (AFDTC/ DRC), Eglin Air Force Base (AFB), Florida. Additional information on conducting Operational T&E (OT&E) is available from the Air Force OT&E Center (AFOTEC/XR) at Kirtland AFB, New Mexico. All Air Force development and modification programs are expected to incorporate the principles of this process in their test planning and follow its guidelines to the maximum extent possible.

1.2. Background. The Armament/Munitions T&E Process and the directed implementation of the process is based upon the direction given by the CSAF in a memorandum titled "Air Force Test and Evaluation (T&E) Base Capability - ACTION MEMORANDUM," dated 25 January 1993. The memorandum directed the establish-ment of a center of expertise for armament/munitions and a disciplined T&E process for Air Force weapon systems. AF/TE then directed the development of the generic Air Force Test Process as AFI 99-103 with additional manuals (see **Figure 1.1.**) for Electronic Warfare, Armament/ Munitions, Command/ Control/Communications/Computers/ Intelligence, Airframe-Propulsion-Avionics, and Space. SFTC offices were established to develop and support the early application of the test process in five mission areas (**Table 1.1.**).

1.2.1. Test & Evaluation Process Documentation:

1.2.1.1. Air Force Policy Directive 99-1, Test and Evaluation Process. This policy directive outlines a course of action for conducting T&E activities during the development, production and deployment of Air Force systems. It assigns T&E responsibilities to the implementing command, the operating and supporting commands, and AFOTEC.

1.2.1.2. AFI 99-103, Test Process. This instruction directs implementation of the Air Force Test Process in general terms. Several Air Force documents expand the direction and application of the

Air Force Test Process, to include those specific to the major functional areas illustrated in **Figure 1.1.**.

1.2.1.3. AFM 99-104, Armament/Munitions Test & Evaluation Process. This manual provides guidance and procedures for implementing the Air Force Test Process in testing Armament and Munitions.

Figure 1.1. Air Force Test and Evaluation Process Documentation.

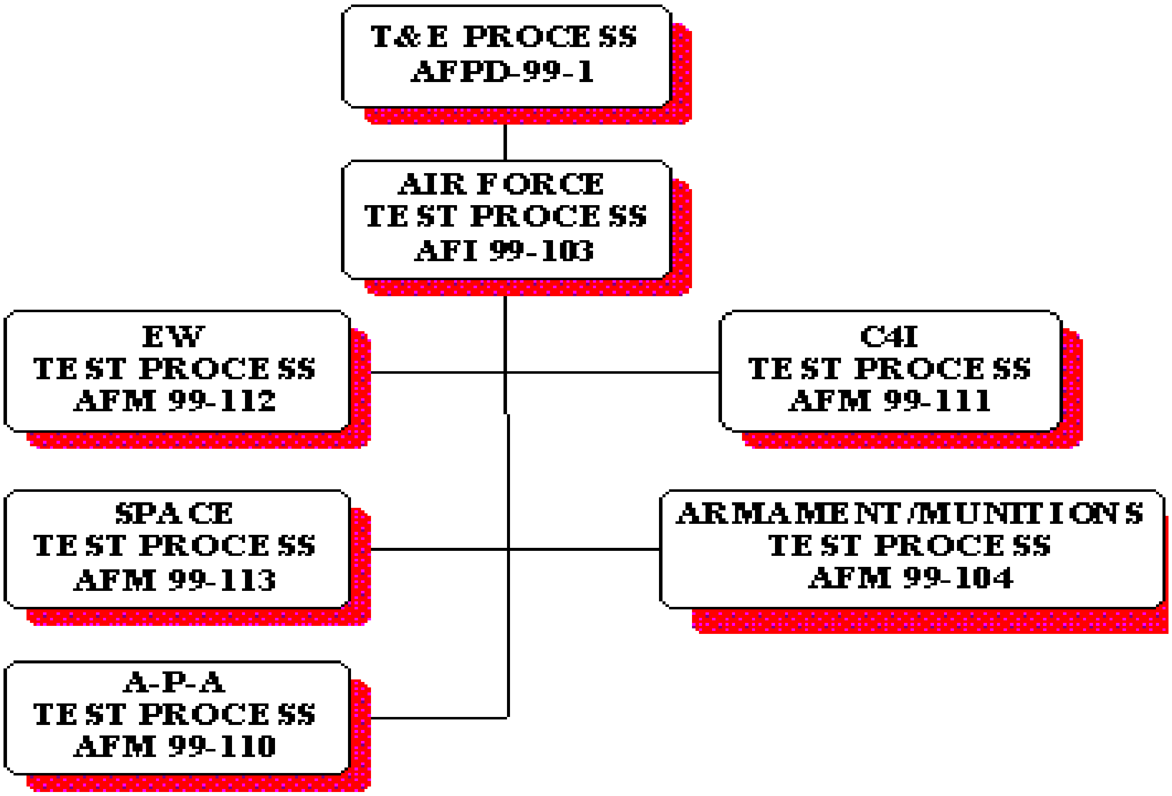


Table 1.1. Single-Face-to-Customer Mission Areas.

NAME	ADDRESS
AIRFRAME/PROPULSION/AVIONICS	AFFTC/CAS Edwards AFB CA 93524-6842
ARMAMENT/MUNITIONS	AFDTC/DR Eglin AFB FL 32542-5495
COMMAND/CONTROL/COMMUNICATIONS/ COMPUTERS AND INTELLIGENCE	AFDTC/DR EGLIN AFB FL 32542-5495
ELECTRONIC WARFARE	AFDTC/DR EGLIN AFB FL 32542-5495
SPACE	SMC/CUC LOS ANGELES AFB, CA 90009-2960

1.3. Scope. This manual covers the armament/munitions mission area. Armament/munitions described in this publication are defined as bombs (guided and unguided), missiles including cruise missiles, guns, ammunition, and directed energy weapons. Each armament/munition subsystem, such as the seeker, guidance unit, fuze, warhead, propulsion, and control sections, must be individually tested to verify subsystem performance prior to integration into and testing of an all-up-round. Armament/munitions also interact with the launch platform. Generally, if the armament/munition is in development or being modified and being certified for carry on a mature platform, the system will be tested via the Armament/Munitions Test and Evaluation Process. If however, the launch platform is in development or undergoing a major modification, integration of inventory armament/munitions is tested via the A-P-A Test and Evaluation Process. Integration of new munitions onto a new platform will be tested using a combination of the Armament/Munitions and A-P-A Test Processes. This manual excludes nuclear bombs and warheads.

1.4. Armament/Munition Test and Evaluation Community. When establishing a test program, all stakeholders need to be involved in the early test planning phase. The stakeholders include the user, the developer (to include the program office test manager), the contractor/sub-contractors, the sustainer, the trainers, and the operational testers. This group forms the nucleus of the Test Planning Working Group (TPWG) which will develop the T&E Master Plan (TEMP). Specifics on TEMP content are contained in AFI 99-101. Other test organizations and facilities which may be involved with the TPWG and can offer advice on specific test issues are discussed in Section C.

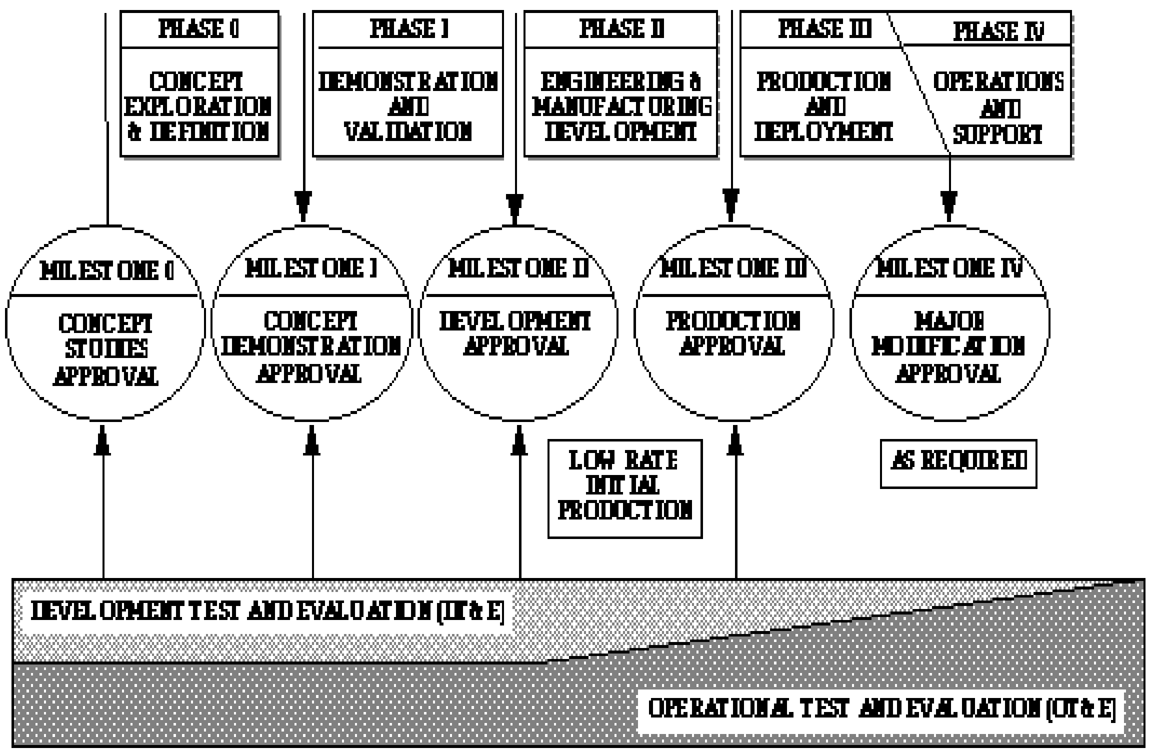
Chapter 2

ARMAMENT/MUNITIONS T&E PROCESS

2.1. Introduction. Testing is conducted during the acquisition cycle to acquire data which are analyzed to evaluate the weapon's current development status and risks associated with the continuation of the development effort. The acquisition cycle is shown in **Figure 2.1.** Testing supports milestone decisions in the acquisition process and is structured to:

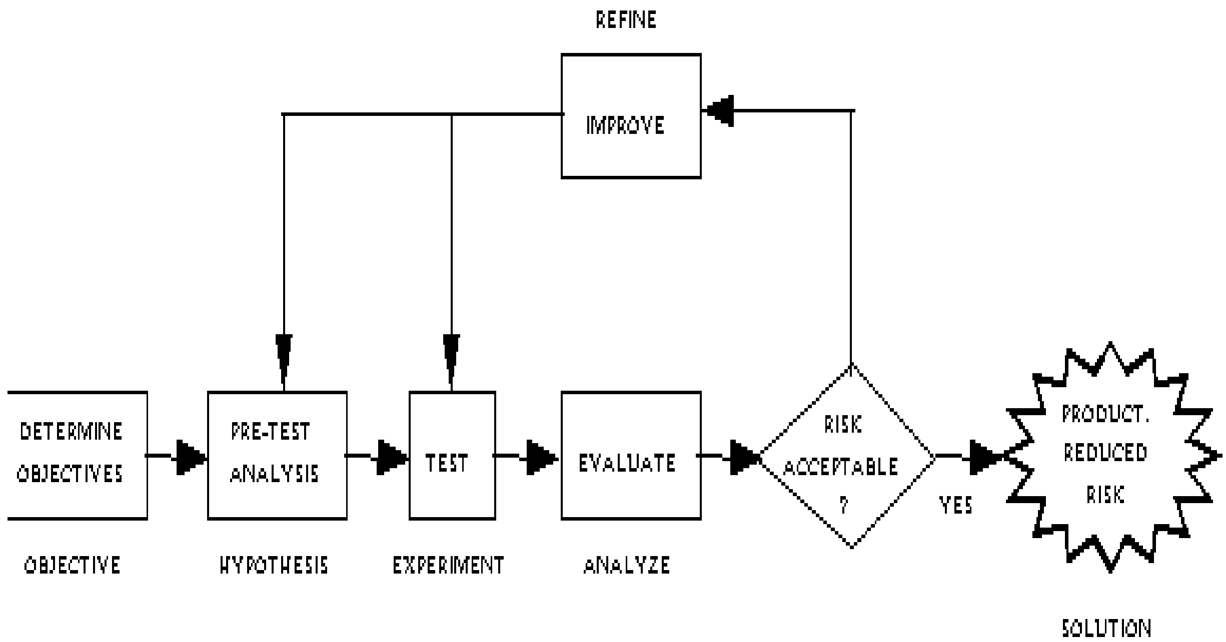
1. Provide essential information for assessment of acquisition risk and for decision making.
2. Verify attainment of technical performance specification and objectives.
3. Verify that systems are operationally effective and suitable for intended use.

Figure 2.1. Testing in the Acquisition Cycle.



2.2. Air Force Test Process. Figure 2.2. depicts the Air Force Test Process. The process applies a structured scientific methodology to formulate a progressive testing program throughout the system acquisition life cycle. The test process begins with studying the test objectives to determine the expected test results, so that measured data can be compared and analyzed against predicted values. Once testing confirms the predicted results, confidence is established to proceed with development of that system. Testing is an iterative process intended to reduce risk, and should be applied to each step of system development.

Figure 2.2. The Air Force Test and Evaluation Process.



2.3. Armament/Munitions Test Process Description. The relationship of the Armament/Munitions T&E process to T&E resources and system maturity is shown in **Figure 2.3.** This relationship will be discussed in the following sections. The first face of the cube is the test process (**Figure 2.4.**). The Armament/Munitions T&E Process utilizes the predict-test-compare philosophy described above, and tailors it to the Armament/Munitions application. Digital System Models (DSMs) predict performance. Differences between the prediction and test results are explained, and the DSM is updated. The Test Process Archive documents decisions relating to resource choices and differences between DSM prediction and actual test results. The following is a brief review of the test process described in AFI 99-103.

- Determine test objectives - What is to be determined?
- Conduct pretest analysis - Predict results.
- Test - Conduct test in appropriate T&E resource facility and collect data.
- Evaluate test data - Compare with prediction.
- Report results - Test reports and/or briefings.

2.3.1. Determine Test Objectives. The first step of the process is to determine the test objectives for the program. Test objectives are statements of system performance with respect to the individual characteristics associated with each subsystem function. For any given test there may be a large set of possible objectives. These objectives are derived from operational requirements defined by the users, which, through analysis, are translated into technical requirements necessary to meet the operational need. Sources for the development of test objectives are:

- Mission Need Statement.
- Operational Requirements Document/Requirements Correlation Matrix
- System Threat Assessment Report.

- Cost and Operational Effectiveness Analysis.
- Concept of Operations.
- Design and Performance Specifications.

Figure 2.3. Test and Evaluation Relationships.

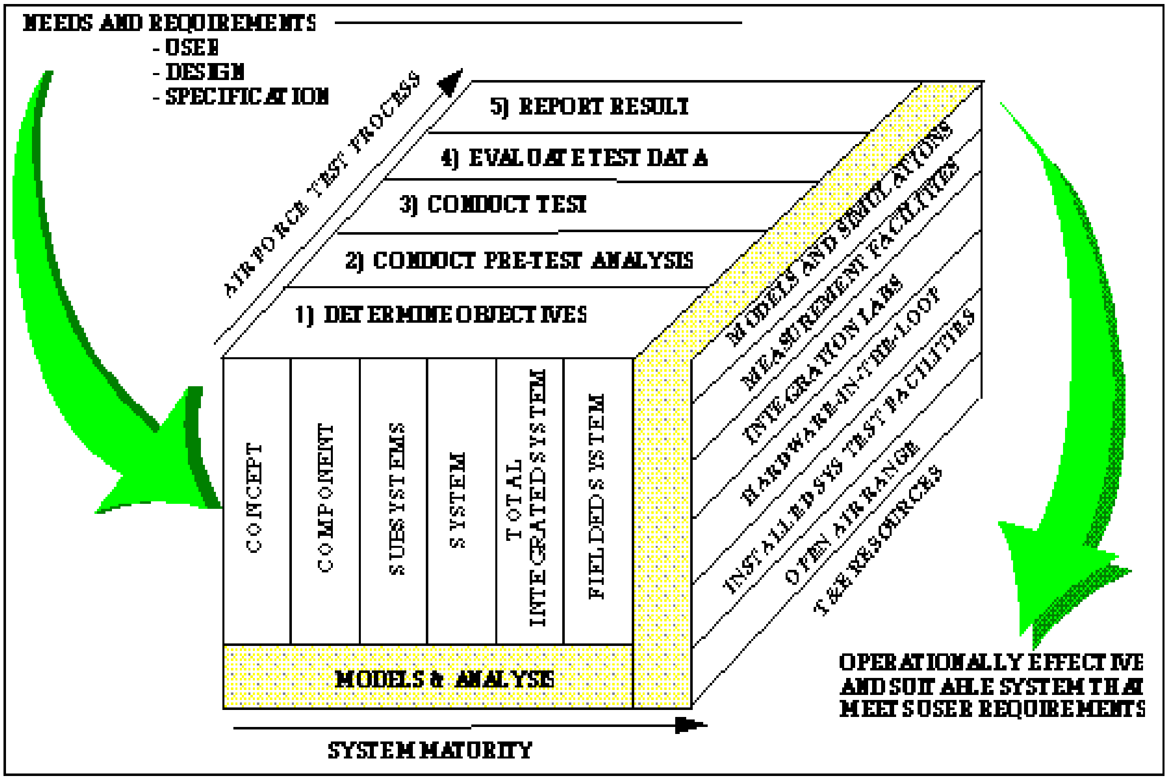
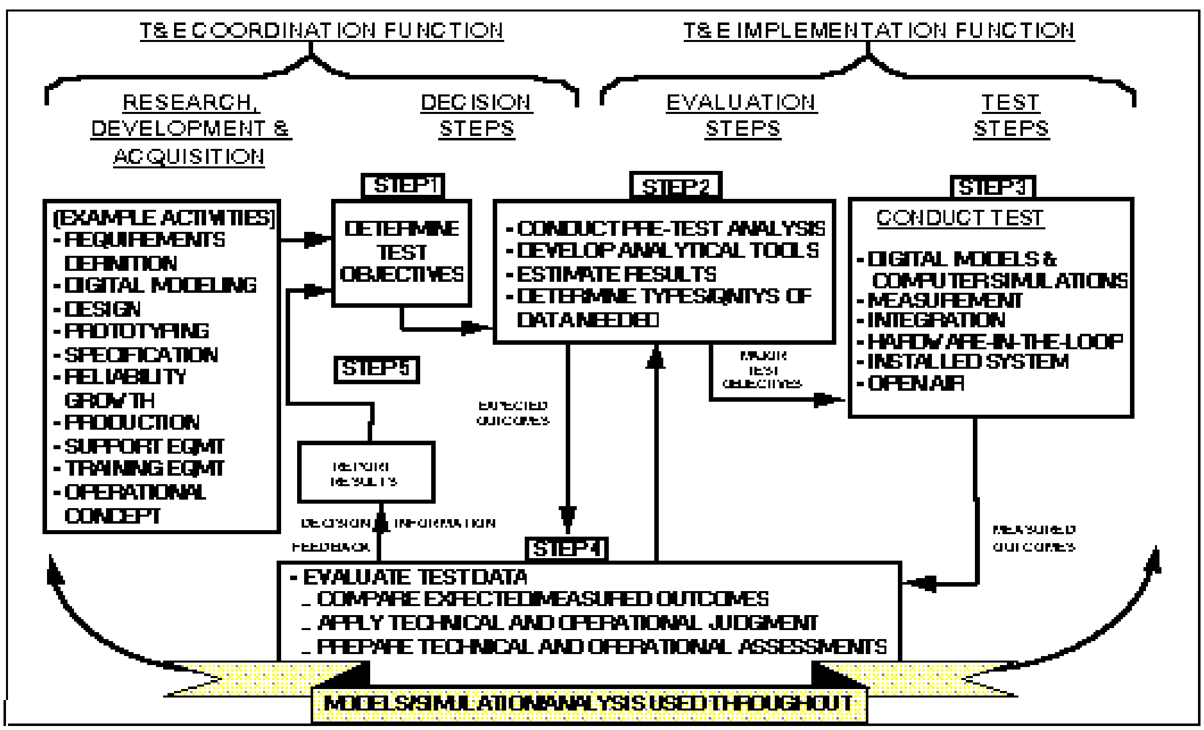


Figure 2.4. Armament/Munition Test and Evaluation.Process.



2.3.1.1. Test Objectives Terminology. To avoid confusion and to convey the proper meaning of test objectives, the following terminology should be used:

- Collect - Testing to collect data with no analysis or evaluation.
- Compare - Testing for the purpose of perceiving likeness and difference in test items.
- Demonstrate - Testing to clearly show or make evident by action or display. Demonstration serves as conclusive evidence of feasibility or possibility without inference to expected behavior or performance.
- Determine - Testing to reveal, recognize, or establish a particular characteristic, trait, or attribute.
- Evaluate - Testing to establish worth (effectiveness, suitability, adequacy, usefulness, capability) of a test item.
- Measure - Testing to make a quantitative determination.
- Verify - Testing to confirm a suspected or partly established contention.

2.3.1.2. Test Objective Practicality. Test objective practicality is determined by at least considering the following topics:

- Achievability - Are sufficient measurement methods, test resources, and instrumentation available?
- Executability - Can the objectives be accomplished within program constraints and limitations?
- Safety - Can the test be performed safely?
- Utility - Do the test objectives clearly and conclusively evaluate the desired feature?
- Cost - Can the customer afford the cost of the objective?
- Schedule - Is sufficient time available to accomplish the objective?
- Environmental Impacts - Can the objectives be accomplished without adverse effects on the environment?

2.3.1.3. Test Objectives Products. The products of this step are a listing of Critical Operational Issues (COIs), Measures of Effectiveness (MOE), and Measures of Performance (MOP). Also formulated during this process are test success criteria and exit criteria.

2.3.1.4. Test Objectives Lessons Learned. A lesson learned from previous programs is that the user sometimes does not adequately define system requirements. When reviewing requirements, testers must ensure the requirements are testable and clearly understood. Ambiguous requirements not identified and corrected early in the acquisition process will cause problems later. The SFTC offices can assist in correcting deficient requirements prior to the Responsible Test Organization's (RTO) designation through early involvement.

2.3.2. Conduct Pre-Test Analysis During Developmental T&E (DT&E). Analyses are performed to determine what and how to test, as well as to predict the outcome of System Performance Parameter (SPP) and Technical Performance Parameter (TPP) values. The type of analysis can range from a paper analysis where correlated predicted results from previous tests are available, to computer simulations using a validated digital model. Assumptions related to the test will be determined and documented. The analysis will help predict the outcome of the test and identify limitations of the test procedures/capabilities. The product of pre-test analysis is a detailed test plan addressing each test objective. The Air Force Material Command (AFMC) Center Directorate of Intelligence will work with the System Program Director and RTO to obtain the most current/detailed threat information and to document requirements for intelligence that will be needed during conduct of the test. The detailed test plan will include as a minimum:

- Definition of each test objective.
- SPPs/TPPs for each test objective.
- Test method/conditions for each SPP/TPP.
- Detailed instructions for each test participant.
- Predicted outcome.
- Test asset requirements.
- Test data products and processing requirements.
- Detailed plan for utilization of test results/data.

2.3.3. Conduct Pre-Test Analysis for Operational Test and Evaluation (OT&E). AFOTEC has developed a new test concept which changes the approach taken during early test planning to develop test requirements and scope the test effort. They have adopted the strategy-to-task process as the guiding structure for T&E strategy development. AFOTEC evaluations should consider a system's ability to perform/support its operational task(s) in the deployment, employment, and sustainment phases. The rule of thumb for initial test concept development is to structure the evaluation at the highest practical level and to ensure that both effectiveness and suitability are addressed. The evaluation should be focused on the system's contribution to accomplishment of its associated task, not on functions, characteristics, or specifications. During the test concept development, the MOEs and MOPs are developed. MOEs are measures of either how well an operational task is accomplished or of how well an operational task element accomplishes an assigned tasking. Documents such as the Operational Requirements Document (ORD), Concept of Operations, and Cost and Operational Effectiveness Analysis provide the necessary reference materials to develop effectiveness issues. MOPs are parameters that address a system's technical characteristics or capability. MOPs can be aggregated to evaluate an MOE that is not directly measurable. For more information concerning OT&E test planning, contact AFOTEC/XRC.

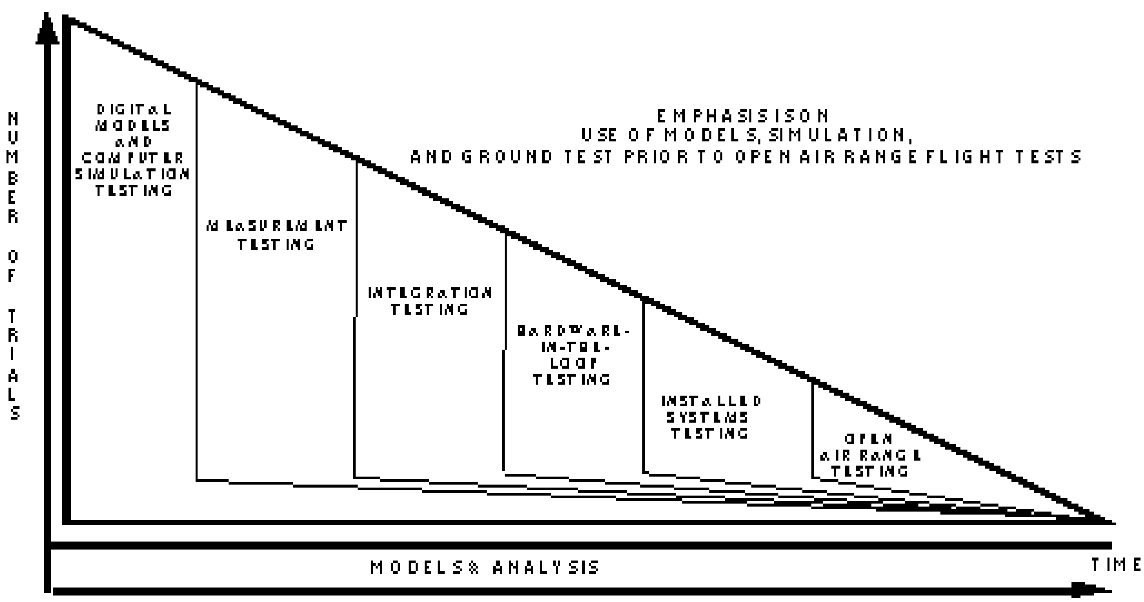
2.3.4. Conduct Test. Tests are conducted utilizing the most appropriate resource categories. The six resource categories are discussed later in this manual. DT&E is conducted to ensure that engineering is complete and that the contractor has met specifications. Testing is conducted based upon a plan which will ensure design problems are solved, the system is compatible and interoperable with the launch platforms, and that the system is ready for OT&E. OT&E is conducted (primarily by AFOTEC) to determine operational effectiveness and suitability under realistic combat conditions. Operational users operate and maintain the system in conditions as close as possible to combat conditions. During the test, the test manager will monitor and report test progress to senior management, resolve problems that arise during testing, and ensure the test plan is fully executed.

2.3.5. Evaluate Test Data. Test data are processed into a form that will allow it to be compared to pre-test predictions, operational requirements, specifications, and other test results. The results are analyzed to determine if predicted results were achieved and operational/technical requirements have been satisfied. If differences between measured and predicted performance are significant, the test manager must determine if one or more of the following occurred; (1) the test design was flawed, (2) the system failed to achieve the required performance, (3) test data collected were corrupted, or (4) the analysis/simulation conducted during pre-test analysis must be improved. Computer models and digital simulations will be updated after discrepancies between predicted values and test results are resolved.

2.3.6. Report Results. Results will be used by program management in support of internal program and milestone decisions by higher management. Results are reported in the form of informal and formal briefings, memoranda, reports, and updates to the TEMP and other milestone decision supporting documentation. System deficiencies identified during this test step, and the following evaluation step, will be documented and processed in accordance with TO 00-35D-54 chapter 2. The Deficiency Reporting (DR) system provides a systematic way to document and validate problems. Then it must be used to investigate, track, and resolve problems.

2.4. Test Resource Categories. The second face of the cube (**Figure 2.3.**) depicts the six T&E resource categories. The following paragraphs define and provide examples of the kinds of tests conducted in each of these categories. A greater number of less expensive ground tests are accomplished to reduce overall test cost as shown in **Figure 2.5.** The more expensive flight tests are kept to a minimum. A more detailed discussion on facilities/capabilities is contained in Section C.

Figure 2.5. Typical Flow of Weapon Testing.



2.4.1. Digital Model and Computer Simulation Testing. This category provides for modeling an armament/munitions system, the host platform, and/or the combat environment and executing the model to simulate a real world event. Computer simulation and analysis are used prior to each phase of testing to help design the test and, after each test, to extrapolate test results to other conditions. In contrast to past practices of accomplishing only design trade-off studies during concept exploration, full implementation of the Air Force Armament/Munitions Test Process requires development of a DSM for each candidate concept. The DSM is a tool that should be developed to help in system design, performing pre-test analysis, and evaluating the results from testing. The DSM should be updated as the system is matured and maintained throughout the life cycle of the system. All digital modeling and simulation must be verified, validated, and accredited. Verification is the process of determining that a model implementation accurately represents the developer's conceptual description and specifications. Validation is the process of determining the degree to which a model is an accurate representation of the real-world from the perspective of the intended uses of the model. Accreditation is the official certification that a model or simulation is acceptable for use for a specific purpose. For more information on the Verification, Validation, and Accreditation (VV&A) process reference DoD Directive 5000.59.

2.4.1.1. DSM Background. DSMs vary significantly in their level of detail (and thus cost). A digital system "description" (i.e., model) of a system under test may be as simple as an aircraft flight path with its associated characteristics (speed, altitude, acceleration) and conditions under which these will change, what they will change to, and their rates of change. Armament/ munitions can be added with varying degrees of detail depending upon system test requirements. DSMs can interact with other models at various levels of detail to predict a system's estimated performance. For example, a DSM for an air-to-air missile can be "flown" through a single engagement with a target aircraft. Many such engagements involving numerous threats and perhaps supporting forces can be combined into a single model to simulate a mission (i.e., a mission level model), and many missions can be simulated in a higher level model to simulate combat action over a time frame (a campaign level model). The DSM will normally be developed by the program office as a system development or modification contract deliverable. It models the proposed system design or brassboard/production hardware. DSMs are developed as part of the system engineering process to support system design, analysis and testing at the engineering, platform, and mission levels, as appropriate. If new components are being developed, an engineering-level DSM is likely to be developed. Platform and mission-level DSMs should be developed by all armament/munitions development and modification programs. The DSM should be maintained by the System Program Office or system manager responsible for Air Force management of the system. If there is no DSM, an alternate way of predicting system pre-test performance must be used. For example, this could be an analog model, equations, or data from similar systems. However, the DSM is a powerful tool. The lack of one will put an extra burden of responsibility on the program manager. Full use of the Armament/Munitions T&E process requires having a DSM. Not having a DSM is more than tailoring, it is severely constraining the ability of the T&E process to work as intended. The DSM generally consists of an interlinked system of algorithms which model the response of the armament/munition to its environment from launch to target intercept/ impact. The DSM addresses the complex interaction of the various facets of the munitions performance, including trajectory analyses, stability/controls/guidance performance, thermal-structures response, and propulsion performance. The DSM and its contributing components must be verified, validated, documented, and configuration controlled throughout the development process. The program office will keep a Test Process Archive. It will be up-to-date and contain adequate data to establish predicted and, in most cases, demonstrated values for SPPs and TPPs. If new test scenarios are developed to respond to changes in defense guidance or changes to the armament/ munition design itself, computer simulations should be used to design new test trials and predict test results. In most cases, computer simulations are adequate to perform a pretest analysis, but retesting to validate key features of the DSM and validate subsequent armament/munition performance will be necessary.

2.4.1.2. DSM Methodology. During concept exploration, actual test data for the complete system are seldom available. The system model is verified and validated by comparing it to a model of a similar system that has demonstrated fidelity. The DSM provides definition of the alternative concepts in sufficient detail to:

- Conduct the conceptual design trade-off studies of the competing alternatives.
- Identify key SPPs for promising candidates and support sensitivity analyses of threat uncertainties.
- Support sensitivity analysis of tradeoffs in performance thresholds and objectives of key SPPs.
- Establish initial SPP and TPP test objectives.

The ability of candidate system concepts to provide the desired mission capability, as stated in the Mission Need Statement (MNS), should be analyzed using DSMs of the system concept. Before engineering prototypes are developed, a more detailed version of the DSM which fully models the complete system should be developed by the contractor in order to make performance predictions. However, if existing hardware components that have already been thoroughly tested are going to be used for part of the system, these components can continue to be modeled for analysis of system design and performance. If the system concept is very complex and a complete engineering prototype is not going to be developed, a real-time version of the DSM should be developed to support evaluation of the prototype components.

2.4.1.3. Types of Computer Simulation. Aside from actual launches/releases, simulation is the only other means to represent a closed-loop operation of the armament/munition. The following types of computer simulations are available.

2.4.1.3.1. Separation and Ballistics Simulation. These simulations are used to investigate armament/munition separation and initial trajectory from launch until the armament/munition has safely cleared the aircraft. They are used in conjunction with launches to define the aircraft/ armament/munition launch envelope. Armament/munition separation, from first movement until clearance of the aircraft, is a critical portion of flight. The aircraft flowfield, in conjunction with launcher operation and armament/munition control, determines the trajectory during separation and thus safe separation without degrading the armament/munition's performance. The major concerns in achieving safe separation are:

- Armament/munition striking the launch aircraft during non-powered separation.
- Armament/munition striking the launch aircraft while powered.
- Armament/munition rocket motor plume impingement on the launch aircraft.

Determination of some level of ballistics accuracy (ballistic coefficients for Operational Flight Programs \{OFPs\}) should be done concurrently with development of the aircraft/ armament/ munition safe-separation launch envelope. AFI 63-104 defines the SEEK EAGLE (SE) process which can provide a continuous process inclusive of Wind Tunnel Testing (WTT) necessary to accomplish safe separation and ballistic accuracy analysis. This process requires a reasonably high fidelity aerodynamic definition of the armament/munition under development and provides the potential for reduced cost and time for armament/munition certification on an operational aircraft. The concept of developing ballistics algorithm coefficients from ground based simulation models serves two purposes: 1) provides a preliminary indication of Circular

Error Probability for the armament/munition/aircraft being integrated, and 2) provides the potential for reduced certification cost and time via the replacement of ballistics flights typically required for ballistics coefficient development.

2.4.1.3.2. Trajectory Simulation. This simulation computes armament/munition forces and moments to define trajectory from launch to target impact/intercept. The simulation incorporates measured data (such as wind tunnel data), armament/munition data, atmospheric data and kinematic equations of motion to predict the armament/munition trajectory. The 6-degree-of-freedom (DOF) digital trajectory simulation provides an excellent representation of armament/munition performance unaffected by detailed guidance and target considerations. When the requirement for many flight simulations over a wide range of launch conditions and other flight parameters exists, a "fast" trajectory simulation is used. It is faster and cheaper, however, some accuracy is sacrificed. A "fast" trajectory simulation is achieved by simplifying detailed trajectory simulation models to obtain the desired run time, while maintaining an acceptable level of simulation accuracy. The "fast" trajectory simulations use fewer degrees of freedom and more simplified assumptions.

2.4.1.3.3. Lethality Simulation. This is an analytical representation of the armament/munition and its interaction with the target. This simulation allows munition effectiveness calculations to be performed and includes fuzing performance, warhead blast/fragmentation effects, target vulnerability/survivability and warhead/ target interactions. To perform this task requires meticulous accumulation of target damage assessment data from combat experience, comprehensive testing, and intelligence sources. Once this data has been collected, it can be transformed into applicable armament/munition effectiveness data with the aid of mathematical modeling and computers. The data may be used to assess the viability of an armament/ munition system, determine the payoff of a new tactic, or provide a realistic estimate of the armament/ munition expenditures required to achieve a desired damage level on a selected target.

2.4.1.3.4. Armament/Munition Response Simulation. An important role for the DSM is to model the response of the armament/munition itself to the environment it experiences from launch to target. The response of the armament/munition to the external environment must be considered, including the effects of aerodynamically induced pressure and heat, rain, dust, radiation, etc. The armament/munition model must also include the effects of structural vibration, control systems performance, seeker system performance, propulsion system performance, etc. The model is generally an integration of subelement algorithms, including structural models of components and subsystems, models of environmental parameters including aerodynamics and weather/dust, and an integration of the subelements to produce an overall system model. Models are used extensively in designing the armament/munition’s subsystems, structure, etc., to achieve necessary performance while ensuring armament/munition integrity throughout its envelope of operation.

2.4.1.4. Simulation Tools.

2.4.1.4.1. Emulation. In the early phases of an acquisition program, the contractor must initiate the design of the armament/munition computer program before the processor is available. The computer program is developed on a computer referred to as an emulator. The emulator is designed to function exactly the same as the armament/munition digital processor and is used as a design and diagnostic tool for debugging software. The emulator can maintain and monitor a baseline armament/munition software configuration.

2.4.1.4.2. Hardware-In-the-Loop (HITL) Simulation. There is a limit to what can be accomplished with analytical simulation. HITL simulation has evolved because of the need to predict armament/munition performance as a function of sophisticated guidance, tracking and signal processing activities. Armament/munition hardware is integrated into the simulation to obtain valid analytical representation of the seeker, guidance, and control subsystem. HITL simulations exercise actual hardware (seeker, sensor, guidance, autopilot, etc.) through stimulation of armament/munition system sensors and simulated forces of motion. HITL analysis allows seeker, guidance, and control software and hardware to be evaluated and validated prior to actual free flight. HITL can include the total armament/munition system or critical subsystems.

2.4.1.4.3. Computational Fluid Dynamics (CFD). CFD is a technology used as a production tool to supplement WTT and enhance the aircraft stores certification process. Specific applications are for safe separation and ballistics accuracy as well as definition of loads on stores.

2.4.1.4.4. Complex Seeker Simulation. The Complex Seeker Simulation is used to quantify Electronic Countermeasures (ECM) performance and predict flight test results, as well as evaluate hardware and software upgrades to air-to-air missiles. This digital simulation accurately represents the missile's tactical software execution by emulating the hardware data processor and reading the actual missile program memory. Missile receiver hardware Inertial Reference Unit, antenna tracking and stabilization, and missile equations of motion are all modeled in Fortran and interact with the tactical software execution. A variety of target radar signatures are available, including glint, Radar Cross Section (RCS) scintillation, and aspect dependent RCS. In addition, a broad range of ECM types are available and can be combined on a single target or distributed across a range of targets. Ground clutter is presented at the proper range and Doppler, and has the correct shape, bandwidth, and angle. The Complex Seeker Simulation has undergone extensive validation, both at the functional (model) level as well as at the performance (probability of guidance) level.

2.4.1.5. Typical Digital Model and Computer Simulation Testing. Table 2.1. shows the typical modeling and simulation tests a new armament/munition would undergo.

2.4.2. Measurement Testing. Examples of measurement data collected are aerodynamic loads/coefficients, target signature, background, clutter characterization, and RCS. Early brassboard or prototype hardware characterization facilitates verification of system models. Prototype hardware may be shipped to measurement facilities in order to measure system parameters such as aerodynamic drag, accuracy, RCS or IR signature. These types of data are needed as inputs to computer simulations. The use of measurement facilities later in the program is much more useful. With systems installed on expected platforms, valid measurements can begin to be taken which can confirm design capabilities, identify design problems, and determine employment options. Measurement facility testing should eventually establish values for TPPs for all mission critical system variables. Specific examples of such testing are measurement of inertial guidance system error and aging and surveillance testing of a rocket motor. Testing inquiries should include developing a plan for direction and guidance in establishing the computational and testing requirements. The concept of developing a reasonably high fidelity aerodynamic simulation model must be stressed to establish structural loads, control actuation and rate requirements, and mission performance acceptability. This can be accomplished where computational driven aerodynamic models complement and add to the data obtained from measurement facilities. **Table 2.2.** shows the measurement tests an armament/ munition would undergo.

Table 2.1. Digital Models and Computer Simulation Testing.

ALL-UP ROUND	3, 4, 5, 6 - DOF Performance - Range - Accuracy - Trajectory - Separation Logistics Support Aging/Surveillance Static/Dynamic Loads	Stability and Control Fit Check Target Signature Cross Section Endgame Lethality Electromagnetic (EM) Compatibility Weapon System Effectiveness
SEEKER/SENSORS	Scene Simulation High Fidelity Simulation Counter-countermeasures	Target/Threat Mode Countermeasures
GUIDANCE & CONTROL	Stability and Control	
AIRFRAME/PROPULSION	Cross Section Models Infrared (IR) Signature	3-D Hydrodynamic Codes Computational Fluid Dynamics
FUZE	Proximity Sensing EM Compatibility	Interoperability
WARHEAD	Lethality Shape Charge Models Warhead Performance Fragmentation Dispersing Pattern	Velocity and Impact Pattern 3-D Hydrodynamic Codes Kinetic Energy Penetration

2.4.3. Integration Laboratory Testing. This testing is performed to evaluate individual armament/ munition components or multiple components and their interaction with each other in a controlled environment. A variety of computer simulations and test equipment are used to generate scenarios and environments to test the component(s) for reliability, safety, and/or functional performance. In some cases, additional real-time digital simulations may be piggybacked on laboratory technology development programs to verify fairly complex concepts that require sensor fusion or involve aircrew displays and operator actions that need to be evaluated with real-time, man-in-the-loop simulations. Test data from on-going technology demonstrations should be correlated with the computer simulation analyses. If additional testing is conducted, computer simulation should be used as appropriate, to conduct pretest analysis to establish desired test conditions and predict expected results. Testing begins in the contractor's System Integration Laboratory (SIL) and other test facilities before any components are shipped for testing in Government facilities. This testing should focus on identifying hardware and software problems, maturing system performance, and evaluating projected reliability and maintainability levels. The DSM and environment simulation should be used to accomplish the pretest analysis and help structure the test trials. A number of tests can be conducted at the contractor's SIL to:

The engineering development will stimulate components of the engineering prototype to evaluate performance and compliance with technical requirements. This testing should repeat the tests conducted during the previous phase to confirm that performance thresholds have been achieved and to correct any identified hardware and software problems. Once the components of the system under test have been tested in the contractor's facilities, they can be shipped to Government test facilities for further testing. The amount of SIL testing needed in the production phase will depend on the number, extent, and complexity of changes to the system. **Table 2.3.** shows the integration laboratory tests a new armament/munition would undergo.

Table 2.2. Measurements Testing.

ALL-UP ROUND	Structural Aerothermal Signatures Environmental Safety	Static/Dynamic Loads Non-Destructive Inspection/Testing EM Compatibility Weight, Balance, Physical Characteristics
SEEKER/SENSORS	Mechanical/Electrical Interfaces Susceptibility to Threats Target Recognition, Acquisition and Track	Countermeasure Effects Clutter/Background Rejection
GUIDANCE & CONTROL	Accuracy Target Recognition, Acquisition and Track	Initial Reference Clutter/ Background Rejection
AIRFRAME/ PROPULSION	Cross Section Models Structural Aerothermal IR Signature	Rocket Motor Burn/Thrust Airbreathing Engine Thrust, Energy Management
FUZE	Proximity Sensing Initiator Performance Target Discrimination Environmental - Shock - Vibration - Drop - Sand/Dust/Humidity/Temperature	Timer Performance EM/ Acoustic Compatibility Impact Penetration Survivability
WARHEAD	Arena Fragment Dispersion Pattern, Velocity, Impact Pattern	Fuze Integration Sympathetic Detonation Non-Destructive Inspection/Testing

Table 2.3. Integration Laboratory Testing.

ALL-UP ROUND	Functional Performance Safety Embedded Software
SEEKER/SENSORS	Target Recognition, Acquisition and Track Functional Performance
GUIDANCE & CONTROL	Software Integration Software/Hardware Interface Functional Performance
AIRFRAME/PROPULSION	Motor Ignition and Burn

FUZE	Electronic Function Mechanical Function Safety
WARHEAD	Warhead/Fuze Integration Functional Performance

2.4.4. Hardware-In-the-Loop Testing. This is ground testing that involves the armament/munition system hardware in a closed-loop mode against high-fidelity target and threat simulations. This testing allows developmental and production systems to be tested under controlled and repeatable test conditions, thus providing a less expensive complement to flight testing. During the Concept Exploration and Development (CE&D) Phase, it is preferable to evaluate the system concept in HITL facilities. However, only a few system concepts will be advanced enough in this phase to have evolved prototype hardware. If prototype hardware is available, HITL facilities should also be used to refine designs, check system performance in operational environments, and work out problems encountered before formal, contractual testing monitored by the government. When contractor SIL testing has been completed, engineering prototype components should be transferred to HITL facilities. Initial testing in Government facilities should be contractor conducted so the contractor is afforded the opportunity to work against a rigorous test environment and mature the system in a non-adversarial manner. The main thrust of HITL testing is to evaluate the performance of the system under test by simulators. Types of HITL activities conducted during demonstration/validation include:

- System trade studies.
- Preflight simulation to verify release conditions and mission profiles.
- Predict in-flight performance.
- Algorithm development, maturation.
- Countermeasure susceptibility.
- Flight test planning.
- Operational MOEs and MOPs.

The production prototype components are usually tested in Government HITL test facilities before the system is installed in a testbed or dedicated test aircraft for OAR testing. This ground testing should focus on confirming that problems identified in earlier testing have been fixed and performance thresholds can be achieved. Because a complete system is available for this testing compared to just critical components available during demonstration/validation testing, this is the first opportunity to conduct integrated system effectiveness tests. Specific tests to be conducted will depend on the functions included in the system. Some examples are:

- Pre-Flight simulations to verify release conditions and mission profiles.
- Flight simulations to assess in-flight performance in adverse weather.
- Flight simulations to assess in-flight performance in the presence of multiple targets and countermeasures.
- Post flight simulation to reproduce field events for analysis and troubleshooting. If an armament/munition system problem is found in a HITL facility and fixed, it can be verified before flight via HITL simulation of the event that caused it.

HITL simulations are used to establish armament/munition systems performance during CE&D, Demonstration/Validation (Dem/Val), and Engineering and Manufacturing Development (E&MD).

HITL test facilities represent a considerable investment which can be applied directly to nondestructive surveillance and shelf life testing during the production and deployment phase. **Table 2.4.** shows the HITL tests an armament/munition would undergo.

Table 2.4. Hardware-in-the-Loop Testing.

ALL-UP ROUND	6-DOF Verification Embedded Software Interoperability With Aircraft	System Performance Verification - Guidance - Lethality - Weapon System Effectiveness
SEEKER/SENSORS	Seeker Integration Countermeasures Counter-Countermeasures Flight Test Focusing Inertial Measurements Prototype Comparison Targeting Endgame	Target Recognition, Acquisition, and Tracking Interoperability With Aircraft Performance Verification Global Positioning System (GPS) Function/Performance 6-DOF Verification Clutter/ Background Rejection
GUIDANCE & CONTROL	Performance Verification 6-DOF Verification Guidance & Control Unit/Inertial Measurement Unit/GPS Interoperability Interoperability With Aircraft	Target Recognition, Acquisition, and Tracking Flight Test Focusing Aero Loads Clutter/ Background Rejection
AIRFRAME/PROPULSION	N/A	
FUZE	N/A	
WARHEAD	N/A	

2.4.5. Installed Systems Testing (IST). IST involves the entire armament/munition and typically its integration with a host platform. Electronic linking of test facilities may be used to provide expanded, more realistic test conditions than those available using a single resource. The armament/munition may or may not be physically installed on the host platform. IST normally provides the first opportunity to evaluate system operation on a armament/munition system platform. This testing is conducted to evaluate the integrated performance of the armament/munition as part of a armament/munition system platform. The purpose of IST is to verify functional (electronic, logical and mechanical) compatibility. By linking HITL and IST facilities, total armament/munition performance, from initialization to fuzing, can be verified in a non-destructive environment prior to flight test. Some examples are:

- IST Facility (ISTF) - Verification of target reference and other targeting data from aircraft to armament/munition. GPS initialization and transfer alignment data from aircraft to armament/munition. Transfer of fire control information to armament/munition prior to launch.
- Linked ISTF and HITL Testing - Armament/munition initialization and launch sequence are accomplished using an aircraft in the ISTF. Information is transferred to the armament/munition over the link. A munitions flight simulation is completed in the HITL facility.

IST continues during the Production and Deployment Phase to evaluate the installed system's interfaces and interoperability with other aircraft systems. The actual configuration of the armament/

munition to be deployed is tested using installed system ground test facilities. These facilities are also used to perform pretest checkout before testing on Open Air Ranges (OARs). This procedure helps in identifying problems, saving flight test hours, and producing more usable test data. **Table 2.5.** shows the IST a new armament/munition would undergo.

Table 2.5. Installed Systems Testing.

ALL-UP ROUND	Aircraft Integration EMI/ EMC/HERO/Rad Haz Transfer Alignment	Target/Retargeting Data Link Performance Pylon/Rack Ejection
SEEKER/SENSORS	Seeker Integration Electronic Counter- Countermeasures (ECCM) Testing	Data Link Transfer EMI/EMC Endgame Targeting Hand-off Antenna Measurement Target Detection/Recognition/Tracking
GUIDANCE & CONTROL	G&C Integration Miss Distance Countermeasure Testing Target/Re-Targeting	Captive Carry Testing Software Algorithms Hardware/ Software Integration Target Recognition, Acquisition, and Tracking
AIRFRAME/PROPULSION	Mechanical/Electrical Fit Checks	
FUZE	EMI/EMC Testing Proximity Function	Arming function
WARHEAD	N/A	

2.4.6. Open Air Range Testing. This testing involves open air test ranges for the purpose of gathering data for evaluating the armament/munition under natural environment operating conditions, for validation of and updating models, and simulations. Testing may be ground or airborne with emphasis on providing an environment of real world phenomena up to and including live armament/munitions against real targets and threats. If advanced technology development programs have already produced brassboard hardware, the laboratories may be conducting flight tests by installing the hardware in airborne testbeds. As was the case with the ground-based technology demonstration testbeds, there may be opportunities to obtain test data from laboratory flight testing to check equipment operation and help verify the computer simulations used in CE&D. Airborne testing is required early in a system's development or modification cycle in order to evaluate its achieved performance. During the Dem/Val phase, this can be accomplished by installing an engineering prototype of components or the proposed armament/munition in a bench configuration, aboard a large-body testbed aircraft or installing components in a pod/missile shape on a fighter aircraft (or on a highly instrumented rocket sled, when precision position and velocity data are of interest). OAR tests are used to:

- Evaluate Human Factors in interfacing with prototype hardware controls and displays.
- Verify that prototype hardware works under actual flight conditions.
- Experiment with alternative employment tactics.

Flight testing during E&MD constitutes the first opportunity to measure selected SPPs and TPPs of the armament/munition in the actual operating environment of its host armament/munition system platform. It provides the means to calibrate the other classes of facilities (i.e., digital simulations, SILs, HITL facilities, IST facilities) and to validate the predictions/ measurements made therein. By so doing, it establishes an acceptable confidence factor for all SPPs and TPPs. Some examples of E&MD OAR testing are:

- Conduct SEEK EAGLE certification tests.
- Verify technical and system performance requirements.
- Conduct live fire tests.
- Verify platform parameters in-flight.
- Collect data on component failure rates for R&M analysis.
- Evaluate software capabilities.

For Initial Operational T&E (IOT&E), OAR testing is indispensable for evaluating operational effectiveness and suitability because it provides the final basis for comparison of previously collected data and a point of departure for additional simulation, analysis and evaluation. OAR testing is required to determine if the production configurations of the armament/munition satisfies user requirements. These tests should confirm whether armament/munition performance requirements established in previous phases have been achieved. During the sustainment phase, open air aging and surveillance testing is accomplished. **Table 2.6.** shows the open air tests a new air-to-surface guided armament/munition would undergo.

Table 2.6. Open Air Testing.

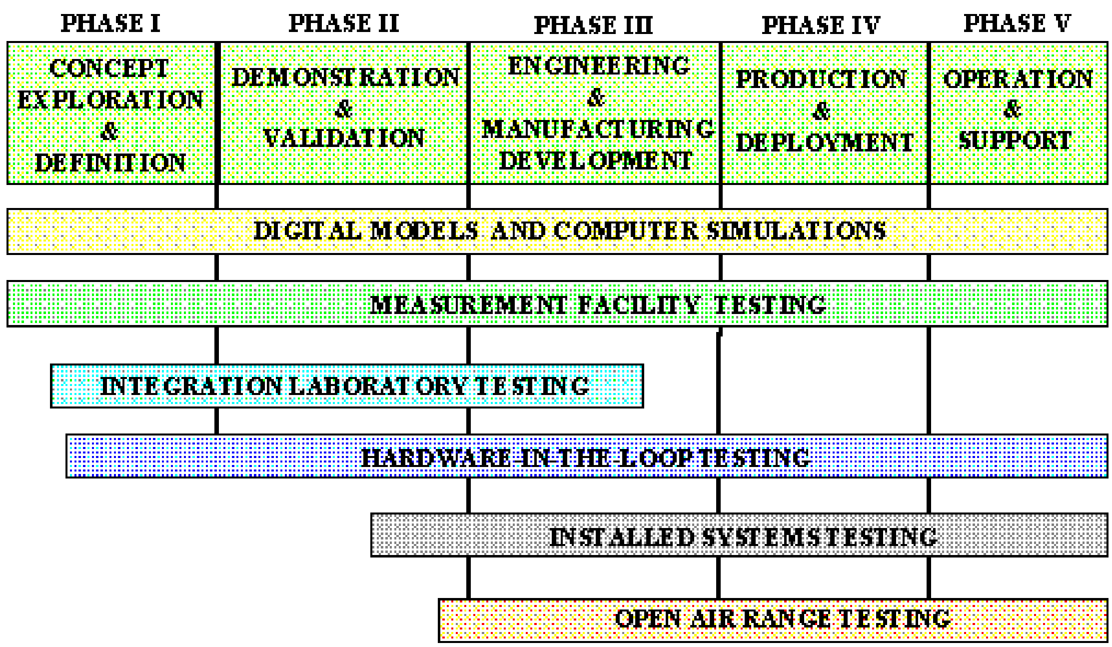
ALL-UP ROUND	Captive Carry One-on-One Flight Test EMI/EMC Compatibility Separation Test Live Launch Many-on-Many Flight Test	Flutter/Loads Jettison Test Weapon System Effectiveness Targeting/Retargeting Data Link Updates ECM/ECCM
SEEKER/SENSORS	Comparative Seeker Evaluation	Clutter/Background Rejection
GUIDANCE & CONTROL	Target Recognition, Acquisition, and Tracking Clutter/ Background Rejection Accuracy	Gain Scheduling Autolock Manual Track
AIRFRAME/PROPULSION	Flight Stability	Motor Ignition and Burn
FUZE	Proximity Sensing Delay Function Warhead Initiation	Impact Functioning Penetration Survivability and Functioning
WARHEAD	Lethality Blast/Fragmentation	Penetration Performance and Effects

2.4.7. T&E Resource Categories in the Acquisition Process. Figure 2.6. shows how the six T&E Resource Categories are used during the life cycle of an armament/munition.

2.5. System Maturity. The third face of the cube (**Figure 2.3.**) illustrates the system maturity concept which must be applied to the test program. Initial testing is carried out on components. Components are then assembled into the various subsystems, which are tested prior to integration into the armament/munition system. This section will discuss the various levels of testing and associate facilities and techniques.

2.5.1. Concept Phase Testing. During the conceptual phase of an armament/munition program, the mission shortfall described in the MNS is evaluated and various solutions to satisfy the deficiency are studied. During the conceptual phase, trade studies would be accomplished using digital models and computer simulation testing to determine the optimum design solution. Once the configuration of the new system is defined, preliminary measurement testing may be accomplished if representative hardware is available.

Figure 2.6. Armament/Munition Life Cycle (Notional).



2.5.2. Component Testing. The basic thrust of component testing is to ensure the components perform within subsystems as designed. Once the initial armament/munition component and subsystem requirement/design has been determined, component testing begins. The test process is applied to prototype components and actual components using various levels of test resources. The test resources chosen for a given component depend on factors such as cost, design risk, integration requirements, maturity of system in which it is embedded, simulation fidelity, and schedule. The facilities used to conduct component testing generally include digital modeling and simulation facilities, measurement facilities, SILs, and some testing in HITL facilities. Generally the first three categories of facilities are owned and operated by contractors/ subcontractors and the testing is done by them with Government oversight and review. Models used during component development are the same models initially used to refine the basic design. Components are generally modeled within subsystem models and represent component performance to the required fidelity. Stand-alone component models are created if the component requirements push the state-of-the-art capabilities or if they must very accurately represent the component. As part of post-test analysis, test results are compared to predicted results from models to ensure components function as designed and meet all requirements. The result of component testing is that the given component is qualified for the next series of tests, which is subsystem development testing.

2.5.3. Subsystem Testing. During the subsystem development phase, the number of new models created begins to taper off, but model sophistication/complexity continues to increase as a system develops. Similarly, test sophistication/complexity has increased from that taking place during component development. Subsystem testing is primarily conducted in SILs and HITLs. These facilities assess how well a given subsystem functions against design requirements and also how well it integrates with other subsystems. Detailed failure modes and effects analysis is typically performed at this time and during system testing using these facilities. This is accomplished by inducing a set of test matrix failures and observing the effect on the subsystem or system. The types of induced failures range from single input/output signals within a component or single component failure to multiple component failures. During subsystem development, integration/interfacing becomes testable to a limited extent. Similar to extrapolating component test results to assess how well they meet user requirements, subsystem testing is the first opportunity to directly assess system integration without excessive extrapolation. Usually subsystem testing is planned and conducted by the contractor with Government involvement. Facilities used are a mixture of Government and contractor owned and operated. Subsystem testing provides an evaluation of an armament/munition's subsystems, such as fuze, warhead, seeker, propulsion, etc. Examples of the types of testing conducted on the various subsystems are:

2.5.3.1. Aerodynamic Testing. The typical aerodynamic test methodologies employed to determine vehicle performance include: static/dynamic stability and control properties, booster and shroud separation characteristics, jet interaction and control effectiveness, inlet performance, aeroheating and surface pressure distribution, and validation of aerodynamic and aerothermal computations. For static stability and control properties, booster and shroud separation characteristics, and jet interaction and control effectiveness test methodologies, the measurement of static force and moments are the critical parameters. The force and moment measurement technique uses a multiple degree-of-freedom static balance. Force and moment data can be obtained either as individual points in the flight envelope (pitch pause) or in a continuous sweep mode.

2.5.3.2. Aerothermodynamics. The aerothermal test methodology is a two-phase approach; 1) define the vehicle's thermal flight environment, and 2) demonstrate material, component, and structural survivability and performance. Aerothermal test results are used for code verification and defining local heat transfer rates around complex geometry such as control surfaces, window apertures, and other protuberances. The test techniques developed for material screening involve placing material samples into specially designed wedges or nosetip holders and inserting the test article into the flow. Test techniques for component and structure performance and survivability make use of the same approach.

2.5.3.3. Weather/Erosion. The weather/erosion test methodology is similar to that of aerothermal in that ground testing starts at the material level and progresses to the component and structural level. Two common test techniques for evaluating and comparing material, component, and structural response are the exposure of the test article to a single impact or multiple impacts.

2.5.3.4. Aero/Electromagnetic. Evaluation of the impact of the aerothermal environment on EM performance is a relatively new field that involves the union of several disciplines: aerodynamics, aerothermal/structures, and advanced diagnostics. Test techniques are available for assessing transmission and possible distortion of EM waves (Radio Frequency (RF) or IR) as they pass through the armament/munition bow shock, flowfield, and EM window. These techniques are essential for assessing performance of seeker, fusing, and communications systems on supersonic/hypersonic munitions. Other test techniques are available to evaluate body and flowfield IR and RF signatures which are essential in validating models/codes for the prediction of flight and mission information.

2.5.3.5. Ordnance Testing. Test engineers working in this broad discipline support the program offices in specialized areas of warhead arena testing for detonation and coupon tests for fragmentation measurement and analysis, fuzing function test for detonating, safe, and arm evaluations, warhead lethality, and safety testing. They are also involved in aerodynamic and thermodynamic environmental analysis and tests.

2.5.3.6. Impact/Lethality. The general objectives of impact/lethality tests are to characterize effects of high speed impacts on materials, components, and structures. Current test programs fall into two classes, assessment of the lethality of kinetic energy armament/munitions requiring impact velocities of less than 7 km/sec, and assessment of hypervelocity impact events, applicable to space-based lethality and orbital-debris encounters, at velocities up to 14 km/sec. For lethality assessment, scaled projectiles and full and subscale targets (including flight hardware) are used. Projectiles which have been successfully launched include standard models such as spheres, long-rods, and slugs as well as complex models such as fragmented projectiles, fluid models, and segmented rods. For assessment of hypervelocity impact effects, targets range from flat plates to full-scale hardware such as satellites. One of the key objectives of both lethality and hypervelocity-impact testing is assessment of make-up and propagation rate of the debris cloud which results from high speed impacts. Measurement techniques developed include soft-catch of debris fragments and use of witness plates to examine damage caused by debris particles.

2.5.3.7. Structures and Materials Testing. The structures and materials test engineers provide mechanical and materials engineering design support for the various munitions programs. Specifically, they are responsible for static and dynamic structural loading, environmental compatibility issues, materials, and processes selection, and nondestructive inspection and materials failure analysis. Finite element analysis methods utilizing state-of-the-art computer programs are available to aid in the mechanical design process and to resolve vibration, structural loading, and wear questions. This discipline also considers the effect of structures and materials on the armament/munitions signature.

2.5.3.8. Propulsion Testing. Propulsion test engineers support the acquisition community throughout a broad spectrum of solid rocket and air-breathing engineering disciplines. Some of these disciplines are propulsion system analyses and assessments, propellants, combustion, plume technology, materials, and design. They are also involved in environmental compatibility and testing, system instrumentation and testing, propellant evaluation, and operational hazard analyses.

2.5.3.9. Guidance and Control Testing. The guidance and control test engineers provide acquisition support in the specialized areas of 6-DOF guidance computer simulations (separation analysis and dynamic inflight simulation), sensitivity performance analyses, and digital signal processing. Analysis and assessment support to program offices also includes design studies and evaluations, sensitivity performance, and support to contractor testing programs.

2.5.3.10. Seekers and Sensors Testing. The seekers and sensors test engineers provide acquisition support in such specialized areas as signal processing, IR, RF/Millimeter Wave (MMW)/ Electro-Optic (EO)/Multispectral sensors, system/component failure analyses, discrimination circuitry, environmental compatibility and testing, and RCS measurement.

2.5.3.11. Ground and Support Equipment Testing. This area involves test engineers who provide program support in disciplines such as packaging and transportation of armament/munition systems, armament/munition container design, MIL-STD-1760 coordination/support, and ground test equipment assessment. Analysis and assessment activities include container design and prototype fabrication, Munitions Material Handling Equipment design and evaluation, computer-aided design support for mechanical and structural design, and maintenance of the container equipment database.

2.5.4. System Testing. During the system testing phase the various subsystems and components come together to form the armament/munition. At each step of assembly the component installation is formally verified and validated against engineering drawings. These are then rigorously tested against functional test procedures for functionality using special test equipment. Once components are linked, the subsystem's functionality is formally tested again, through highly controlled and regulated procedures. During system level testing, the armament/munition is assessed against the user's requirements through both ground and flight testing. System level testing is conducted primarily within the ISTFs and OARs. The focus of the testing is still the performance of the various subsystems. Not until the next phase, the total integrated system testing, is the system tested using fully integrated or mission level tasks. System testing is usually conducted as a team effort by the Government and the contractor. OARs allow testing under a controlled environment in natural climatic conditions. ISTFs and captive testing are used to identify and resolve problems before free-flight testing to assist with mission planning in support of open air testing, and to investigate problems discovered during open-air events. Separation test vehicles are used prior to live launches to demonstrate safe separation. Flight testing begins at the heart of the envelope (altitude and airspeed) and the heart of the individual subsystem's functional design envelope. Along the way, as more confidence is gained, the envelope is expanded. Not all subsystems mature at the same rate and subsystem upgrades occur at different times. Regression testing is often required when these upgrades are performed. Many of the user's performance requirements (range, accuracy, etc.) will be directly tested during system testing. Included in the system test phase is preliminary Technical Order (TO) verification and validation. These documents mature with the system. Maintenance actions should be performed in accordance with draft TOs and recommended corrections or enhancements should be explored/incorporated into the final version. An important step during system testing is the OT&E certification. This occurs when the Program Manager believes the system is ready to transition from DT&E to dedicated OT&E and is confident that the system will pass all required OT&E testing. Details on this process may be found in AFI 99-101 and AFI 99-102.

2.5.5. Total Integrated System Testing. This phase of system development is concerned with the testing of the system in an environment which is as close to the operational environment as practical. The goal of this phase of testing is to deliver an effective and suitable armament/munition system to the user. To accomplish this, realistic suitability testing must be performed, in addition to realistic effectiveness testing. Effectiveness testing relates directly to a system's performance characteristics and to mission accomplishment. Suitability testing relates directly to placing a system in field use with consideration given to availability, reliability, maintainability, logistics supportability, transportability, interoperability, compatibility, training, safety, documentation, and other characteristics supporting the conduct of mission level tasks. Similar to the previous phase of testing, total integrated system testing is conducted on OARs, with some ISTF testing. This usually requires conducting the tests at ranges which closely approximate operational environments. These ranges will include threats and threat surrogates and operationally representative targets.

2.5.6. Fielded System Testing. Normally, follow-on OT&E testing will occur for the life of the program. This testing is again primarily conducted in an open-air environment. If as a result of this testing a deficiency is noted, a major modification may be necessary. The level of testing for the major modification is dependent on the degree/impacts of the modification. All test resource categories may be employed during the modification development effort. The effort usually begins with measurement facilities and ends with OAR testing. Another type of testing conducted on the fielded system is the "shelf life" testing conducted by the depots. This testing is aimed at sensitive components which may degrade overtime. Examples include testing of squibs, solid fuel, warheads, and similar energetic components, as well as seeker, guidance and control, and all-up-found tests.

2.6. Implementation Checklist. How do you know if you have taken the proper actions to implement the T&E Process for your test and evaluation effort? The following checklist is provided to answer this question. If you follow the checklist, a) you will have complied with the direction in this manual, and b) you will have properly set up your T&E to do the test. Then test execution will be done by test plan and/or handbook containing the **how to** procedures. If you get one or more negative checklist answer, you have more work to do.

- Do you have a Predict-Test-Compare Test philosophy?
- Do test requirements flow from user/customer requirements?
- Have you gathered the appropriate source documents? (MNS, ORD, System Threat Assessment Report, etc.)
- Have you gathered or developed the needed program documents? (COI, MOE, MOP, TEMP, etc.)
- Does your T&E effort use a disciplined, scientific process?
- Have you addressed each of the six A/M T&E process steps in your TEMP and test plans, and justified any tailoring done?
- Is the process being applied to answer the COIs and the T&E questions in the TEMP?
- Does your T&E effort emphasize use of modeling and simulation and ground tests prior to costly flight tests?
- Are you working with the Munition SFTC office?
- Do the people on your T&E effort understand the A/M T&E Process?
- Is your contractor on contract to use and support the A/M T&E Process?
- Do your Government T&E agreements require using and supporting the A/M T&E Process?
- Has a DSM been developed and is it being used in the T&E Process?
- Have arrangements been made to maintain the DSM current with the real system?
- Are your modeling and simulation efforts continually updated and do they provide constant feedback for making improvements?
- Do you have a Test Process Archive (TPA) set up?

- Have arrangements been made to keep the TPA on-going and accessible throughout the life cycle of your A/M System?
- Will the T&E effort report results that will be used by decision makers to support system life cycle and maturity decisions?
- If not planning to use the A/M T&E Process, have you obtained a waiver from HQ USAF/TE?

Chapter 3

RELATED TOPICS

3.1. Single-Face-To-Customer Office. The SFTC Office facilitates initial test planning for new programs and major modification/product improvement programs prior to selection of a RTO. The SFTC manages T&E investment planning and maintains the test process.

3.1.1. Initial Test Planning. The SFTC typically provides services during the early phases of new programs and in the early phases of modification/pre-planned product improvement programs. Once initial test planning is completed, the role of the SFTC diminishes to one of test cognizance and support of the RTO, as requested. The transition from SFTC to RTO will take place when the RTO is selected. The SFTC serves as a consultant and works with customers early in the system development cycle to develop a complete understanding of mission and system test requirements and to assist in the use of a disciplined test process and development of test documents. The SFTC uses the test process to provide T&E options, with associated risk, to the customer. The selection of test resources will be made by the Program Manager after considering all available DoD T&E capabilities. The development of the options is an iterative process to ensure that both the SFTC and the customer are in full agreement on the final options provided.

3.1.2. Test and Evaluation Resource Investment Planning. The SFTC offices participate in early development test planning to fully understand program T&E resource requirements. Requirements from test and logistic centers, program offices, operational commands, AFOTEC and any other agency that has test resource requirements are addressed by the SFTC. If the test requirements exceed current or planned T&E capabilities, the SFTCs will advocate those test investments that will meet the test requirements. The SFTC chairs a panel composed of representatives from the acquisition community to validate test resource requirements from all programs, centers, operational commands and AFOTEC. The panel generates a prioritized list of investments and provides that list to the AFMC T&E Operations Panel. This list applies to investments in the AFMC T&E infrastructure which will be of benefit to all test customers, not just the responsibility of the program office; (working through the appropriate SFTC to the proper test center) including funding. Final decisions on T&E resource priorities and their location are made by the T&E Mission Element Board. The SFTC maintains the Munitions section of the Air Force Test Investment Strategic Plan. Acquisition of T&E resources is accomplished by the individual activity or by their acquisition agent. The SFTC chairs the Reliance Air Armament T&E Resource Committee for air-to-surface, air-to-air, and surface-to-air armament/munition systems. This is a tri-service activity aimed at eliminating duplication of service T&E investments. For more information on the test investment process, reference AFI 99-109, Test Resource Planning.

3.1.3. Armament/Munitions Test and Evaluation Process. The SFTC documents and advocates the T&E process. It works to keep T&E capability current with technology and system requirements. The SFTC periodically hosts conferences to expand test process use and facilitate its implementation.

3.2. Aircraft-Stores Certification Program (SEEK EAGLE).

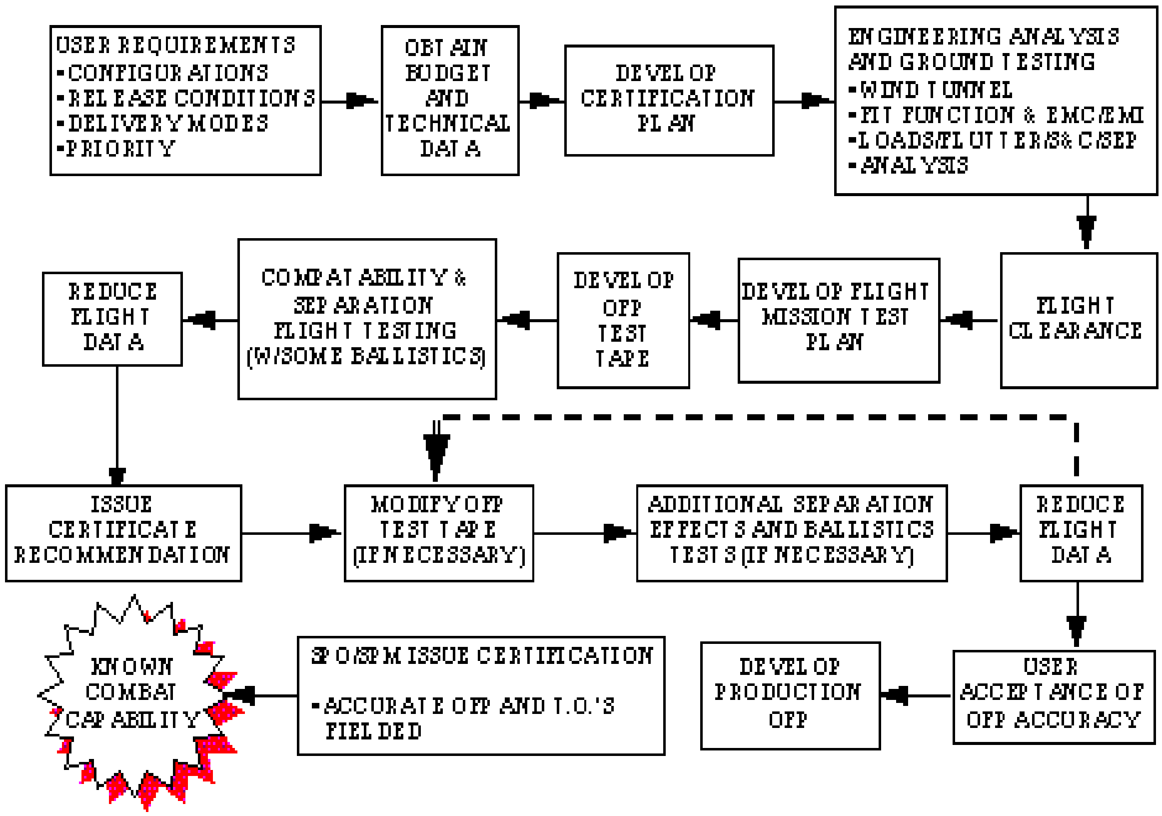
3.2.1. Purpose. The purpose of the Air Force SE program is to certify aircraft-store configurations on production or developmental aircraft (fixed or rotary wing) to meet operational requirements specified by the using command. The program, governed by AFI 63-104, establishes a standard Air Force process for all aircraft-store certification activities. Production or developmental stores include munitions, missiles, bombs, rockets, mines, torpedoes, dispensers, detachable fuel and spray tanks, pods (electronic countermeasures, instrumentation, camera, gun, refueling, thrust augmentation etc.), targets, chaff and flares and suspension equipment (adapters, racks and pylons). Certification provides the using command the capability, including the applicable aircraft TOs and OFPs, to upload, download, safe carriage and separation and verify ballistics accuracy of stores on aircraft. Certification includes development of Combat Weapons Delivery Software, which provides an automated mission planning capability for ballistic and safe escape data, and Combat Stores Loading Software, which provides automated aircraft-stores limitations.

3.2.2. Process. AFI 63-104 defines the SE process and the SE Engineering/Test Capabilities Handbook (August 1992) and identifies the location, primary mission, and major aircraft-store certification test resources available at various government test and analysis facilities. The SE Process (**Figure 3.1.**) includes the engineering analysis, computer simulations, WTTs, ground tests and flight tests to obtain the engineering data needed to update the aircraft TOs and OFP and to verify OFP ballistics accuracy. The SE process begins with a SE Request (SER) submitted by the using command or the Directorate of International Programs (SAF/IAY) for Foreign Military Sales/International programs and ends with the publication of related TOs and user acceptance of the ballistic armament/munition accuracy in the OFPs, as shown in **Figure 3.1.** Program Management Directive 5077 provides direction and funding for certification projects. In developmental or major modification to inventory aircraft-stores, the using command or SAF/IAY submits a SER in parallel with the ORD. Each SER is made into one or more projects designed to include activities required to complete the certification process. Each project is tailored from a standard template by the requirements, performance, schedule, cost and constraints. Offices of Primary Responsibility (OPRs) are identified in AFI 63-104. An OPR is identified with activity duration, start, completion, funding (planned and actual), for each project activity in the SE Management Support System (SEMSS).

3.2.3. SEEK EAGLE and the Systems Acquisition Process. To reduce the time to obtain a fully operational, certified aircraft-store configuration, SE will be integrated with acquisition programs from the beginning. Program offices begin SE planning not later than the Dem/Val phase in both aircraft and store programs. Certification of the baseline aircraft-store configurations defined by the using command in the SER is completed applying Integrated Weapon System Management guidelines. Follow-on certifications are accomplished by the Air Force SE Office (AFSEO) by the completion date specified in the SEMSS.

3.2.4. SEEK EAGLE and Aircraft-Stores Integration. Aircraft-stores integration includes avionics, electrical and mechanical integration or associated modification to the aircraft or store to provide operational interfaces between the aircraft and store. SE does not conduct this integration, nor the development or modification of the aircraft or store to achieve the aircraft-store configurations that are certified under SE. Integration and modification activities are the responsibility of the store and aircraft System Program Offices. The Weapon System Review process and the Weapon Integration Plan (WIP) are established to accomplish seamless armament/munition system management. A WIP is an agreement between the aircraft and store program offices and outlines objectives, procedures, responsible agencies, and resource requirements for integrating an armament/munition onto an aircraft. SE requirements must be defined early in the integration or modification efforts to help define the program, to ensure realistic operational configurations are considered early in the program and to integrate SE to the maximum extent possible, into DT&E and IOT&E. The AFSEO will ensure SE requirements are properly completed and used as a database to meet future aircraft-store certifications.

Figure 3.1. SEEK EAGLE Process.



3.2.5. Production Munitions Requirements, Fore-casting and Budgeting. Inventory armament/munitions requirements are forecasted annually. Many munitions and missiles are out of production. When there is a requirement in a SER for a store that is out of production, the SE program element will plan and budget for it. If there is no SER, it is the responsibility of the aircraft-store program office to plan and budget for the required inventory item.

3.2.6. Flight Clearance (FC). The using commands submit SERs requesting a FC to support a limited duration operational need or an operational flight test. The product is a FC authorization letter/message. Flight clearances should only be requested when mission accomplishment will be impacted, because they are supported at the expense of routine certification efforts.

3.3. Test Resource List. Test facilities and capabilities must accommodate the mix of systems in the various phases of their life cycle as well as the mix in the level of interaction of the systems/subsystems. The functional interrelationships among munitions, EC and aircraft/avionics indicated in **Figure 3.2.** must also be reflected in test facilities and capabilities. **Figure 3.3.** depicts the use of test facilities and capabilities across these three areas. In this figure, test resources are aligned with the six T&E process categories to show which part of the T&E process they primarily support. **Figure 3.4.** shows the location of Armament/Munitions Test Facilities.

Figure 3.2. Test and Evaluation Resource Overlap.

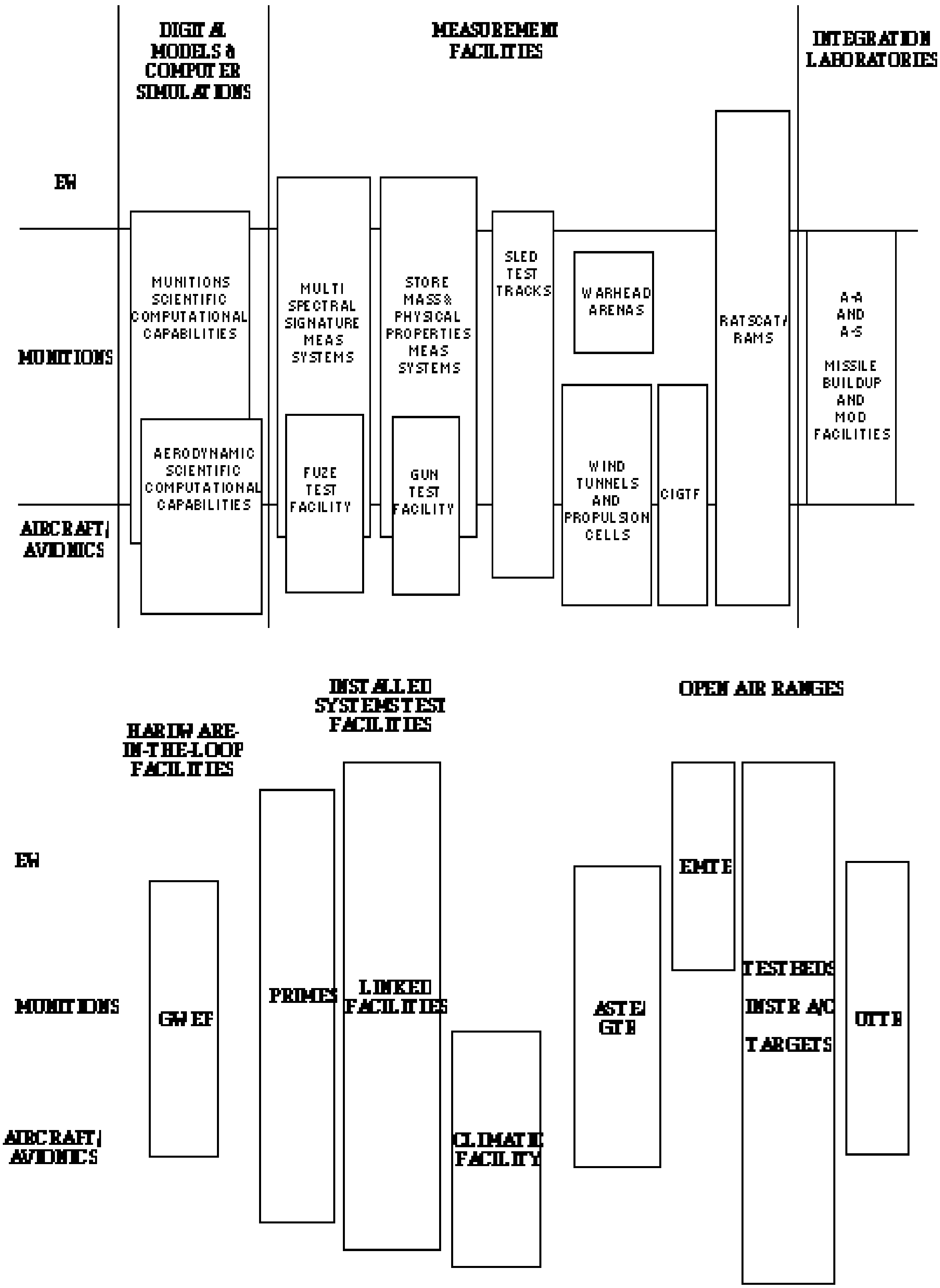


Figure 3.3. Armament/Munition Test and Evaluation Resources.

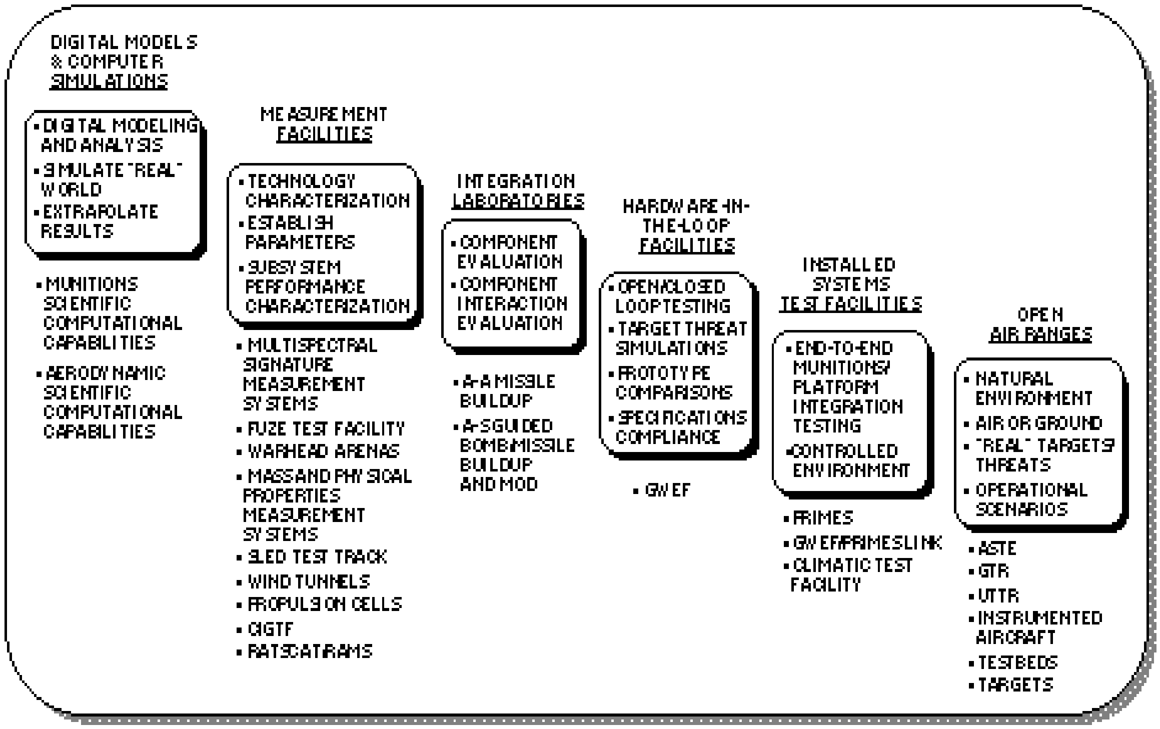
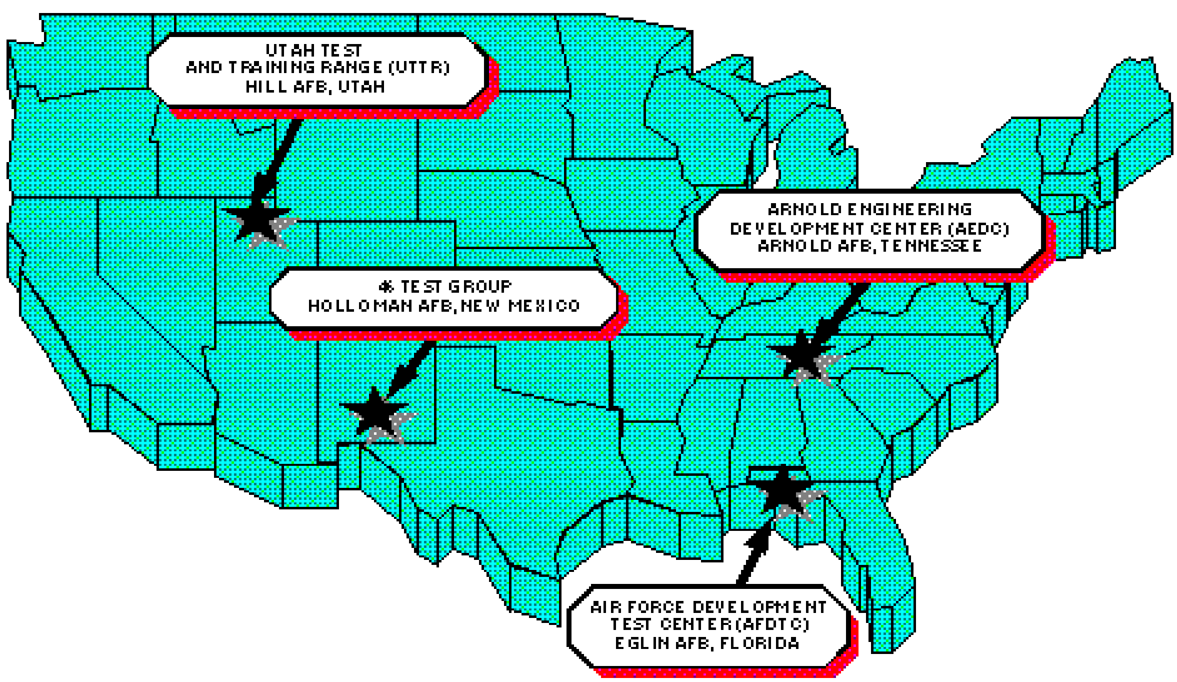


Figure 3.4. Location of Armament/Munition Test Facilities.



3.3.1. Digital Models and Computer Simulation.

3.3.1.1. Munitions Scientific Computational Capabilities. These capabilities are housed in the Freeman Computer Science Center, AFDTC, Eglin AFB, FL and the Central Computer Facility at Arnold AFB, TN. They use computer capabilities for modeling and simulation of armament/ munitions in support of laboratory research, engineering development and test. Modeling and simulation up to and including 6-DOF models and high fidelity seeker models can be accomplished. In addition to the support of development, models and simulations are used to support the safety footprint and other aspects of test planning and analysis including armament/ munition fragmentation and lethality evaluation models. CFD capability is also available to investigate flowfields around munitions and aircraft/munitions configurations.

3.3.1.2. Aerodynamic Scientific Computational Capabilities. For armament/munitions support, this is mainly the CFD to model airflow around armament/munitions as they are carried on aircraft. This is a complementary capability to wind tunnel tests to predict extremely complex configurations. These capabilities are located at the Arnold Engineering Development Center (AEDC), Arnold AFB, TN and AFDTC.

3.3.2. Measurement Facilities.

3.3.2.1. Multispectral Signature Measurement Systems. These systems are a combination of ground and airborne instrumentation systems to collect signature measurements on targets, countermeasures, and backgrounds. The instrumentation covers the EM spectrum from ultraviolet (UV) through IR and the appropriate portions of MMW. Data is collected and presented in the radiometric, spatial, and spectral domains. In addition, missile data (track point and performance) are gathered. Airborne systems are available on various platforms (F-15, UH-1, C-130) for signature measurements in UV, IR and MMW of aerial and surface targets, countermeasures and backgrounds, both day and night, with the capability of evaluating air-to-air, air-to-surface, surface-to-surface, and surface-to-air seeker performance in a captive carry scenario. Ground based systems covering UV, IR and MMW are available for signature measurements of aerial and surface targets, countermeasures and backgrounds. Threat vehicle signature production and assessment using a fleet of over 50 threat combat systems and associated countermeasures are also available. These signatures are processed and stored in the Target and Background Information Library System. Evaluation of surface-to-air, air-to-air seeker, and tower/turntable performance against targets and countermeasures is also provided.

3.3.2.2. Store Mass and Physical Properties Measurement Systems. These systems are used to determine weight, center of gravity, and moments of inertia of armament/munitions and shapes/ stores/pods carried and/or released from aircraft. Measured values are used to determine the weight and balance of the aircraft as well as store loads, flutter, performance, stability and control and separation/post release analysis (e.g., for store ballistics trajectory).

3.3.2.3. Sled Test Tracks. Sled test tracks have the capability to test captive, launch into free flight, and impact test under accurately programmed, closely controlled, and rigorously monitored conditions. Captive testing can be used to study rain erosion, aerothermal or particle impact effects on radomes, sensor windows, fins and other munitions components. Sensor cover removal and skin cutting for submunition deployment can also be evaluated. Launch into free flight can be accomplished using actual aircraft hardware. Armament/munition trajectory, flight control information and inertial sensor performance are examples of the data that can be obtained. Impact tests are conducted with targets suspended above the rails or beyond the end of the rails to assess fuzing system and penetrator performance.

3.3.2.4. Wind Tunnels, Arc Tunnels, and Propulsion Cells. The wind tunnels, arc tunnels, and propulsion cells are located at AEDC, Arnold AFB, TN. These facilities provide a capability to support the design, development and improvement of armament/munitions. The tunnels are equipped with moveable supports on which armament/ munition models are mounted to collect data as if the armament/munition was in free flight. The support is moved to simulate changes in flight maneuvers.

3.3.2.4.1. Wind Tunnels. The wind tunnels are used to investigate:

- Aerodynamic forces when munitions are carried or separated from aircraft and during free flight to the target.
- Aerodynamic performance of inlets for air breathing propulsion of armament/munitions.
- Complex aerodynamic interactions from controls, jets, protuberances, etc.
- Aerothermal environment determination used to assess heat load in supersonic/hypersonic free flight.
- Booster/shround separation effects.
- Optical and RF wave distortion by flowfields surrounding the armament/munition.
- Thermostructural performance in free flight with and without the effects of erosive weather environments.

3.3.2.4.2. Arc Tunnels. The arc tunnels are used primarily to assess thermostructural performance of components and full-up armament/munitions in high-supersonic and hypersonic free flight. Specifically, the arc tunnels are used to:

- Assess material sample thermostructural performance in high-speed heating environments.
- Validate structural integrity of prototype components and armament/munitions under severe aerothermal and dust-erosion conditions.
- Investigate effects of material thermal response and ablation on transmission of RF signals through EM windows on high-speed armament/munitions.

3.3.2.4.3. Propulsion Cells. The propulsion cells are used to test air breathing and rocket propulsion systems performance. Specifically, propulsion cells are used to:

- Assess thermostructural integrity of engine components and full-up prototypes under realistic flight conditions.
- Assess performance in terms of thrust, fuel consumption, pressure loss, etc.
- Identify critical failure mechanisms in a controlled environment which does not put personnel or costly assets at risk.
- Assess performance of the combined engine-airframe assembly for full-up armament/ munitions.

3.3.2.5. Ballistic Ranges. Arnold Engineering Development Center, Arnold AFB TN has several ballistic ranges that support armament/munitions testing. In ballistic ranges, projectiles are fired from either conventional powder guns or two-stage, light-gas guns down a range, usually in a controlled environment, in order to make measurements in free flight or during impact at the end of the flight. Ballistic ranges are used to:

- Assess impact phenomenology to determine armament/munition lethality and effectiveness.
- Evaluate armament/munition static and dynamic stability using subscale models in free flight.
- Investigate effects of the plasma of ionized air surrounding armament/munitions in hypersonic flight or transmission of RF signals to determine interference in seeker, fusing, and communications systems performance.
- Evaluate thermostructural effects of material samples exposed to severe aeroheating, rain, snow, ice, and dust environments.
- Evaluate acceleration effects on component performance.

3.3.2.6. Central Inertial Guidance Test Facility. This facility has the capability to test GPS, inertial systems, and their components (gyroscopes and accelerometers) for armament/munitions. Capabilities include precision rate tables, centrifuges, a combined environmental test chamber (altitude, temperature, humidity, and vibration), dynamic flights, jamming and spoofing, and the full gamut of field testing using vehicles (van), rocket sleds, and aircraft.

3.3.2.7. Radar Target Scatter Facility (RATSCAT)/ RATSCAT Advanced Measurement System (RAMS). RATSCAT is the DoD center of expertise for monostatic and bistatic RCS measurement of aircraft (with and without armament/munitions), spacecraft, unmanned vehicles, and decoys. The RAMS is used for performing RCS measurements on very low observable test articles. For armament/munition applications, these measurements can be on the armament/ munition itself to determine its RCS, or for the armament/munition contribution to the RCS of the carrier aircraft with the armament/munition in its carriage configuration.

3.3.2.8. Gun Test Facilities. These facilities conduct instrumented ground and airborne gun tests. Three test areas within the Eglin complex each have a permanently installed and instrumented GAU-8/A 30-mm gun system and a single-shot 30-mm Mann barrel. Other gun systems can also be mounted for specific tests. Some of the types of tests conducted are gun and ammunition performance, depleted uranium projectile, armor plate penetration, projectile and fuze characterization, target and component vulnerability studies, and terminal ballistic studies. Typical data collected are muzzle velocity, chamber pressure, relative action time, barrel temperature, meteorological conditions, projectile yaw, and dispersion.

3.3.2.9. Arena Test Facility. Arena tests are conducted to characterize the fragmentation pattern of a warhead. Data collected are used to determine warhead lethality against threat targets. Typically, warhead fragment speed, size, and distribution data are collected. The warhead is placed in the center of an "arena" and detonated. Cameras, witness plates, photography, blast gages, fragment collection devices , etc. measure the attributes of the warhead. This raw data are used in models to determine warhead lethality.

3.3.2.10. Fuze Test Facility. The Fuze Test Facility is the primary munitions integration laboratory. This facility is an instrumented laboratory capable of performing research, development, and engineering service tests on fuzes and associated ordnance devices. Simulated environments are provided to determine whether fuzes and associated devices are safe and will function as intended. Some of the capabilities include vibration, shock, jolt/jumble, salt/fog, sand/dust, x-ray, static drop, and failure analysis/teardown.

3.3.3. Integration Laboratories.

3.3.3.1. Air-to-Air Missile Buildup Facility. The Air-to-Air Missile Buildup Facility has two secure vaults dedicated to air-to-air missile test projects; analysts for AIM-7, AIM-120, ASRAAM, AIM-9, and AIM-9X; secure workstations for data reduction; a library of software codes, research references, and intelligence documentation; 3- and 6-DOF simulation capabilities; and a fully automated system test facility for AIM-120 missile preflight and integration.

3.3.3.2. Air-to-Surface Guided Weapon Buildup Facility. The Air-to-Surface Guided Weapon Buildup Facility is used for the assembly, final integration testing, and inspection of guided weapons prior to flight test. The facility integrates fuzes, warheads, actuators, data links, inertial measurement unit/GPS, propulsion, airframes/structures, hardware/software, guidance/control, weapon sensors, and flight termination systems. Buildup and modifications of bombs/missiles, as well as integrated systems tests, are performed at this facility. The test chambers are rated for Category 1 explosives.

3.3.4. Hardware-in-the-Loop Facilities. The Guided Weapons Evaluation Facility (GWEF) is the primary munitions HITL facility. This facility uses a combination of actual armament/munitions hardware components and target background simulators to conduct HITL testing to evaluate armament/munition performance throughout the trajectory from launch to target intercept/impact. T&E of precision guided armament/munitions using IR, RF, laser, MMW, EO, multispectral, and midcourse inertial techniques are conducted. Injection of countermeasures and counter-countermeasure capabilities are also possible. The use of this facility allows much more data to be gathered since testing is ground based, lower cost, and nondestructive as opposed to flight testing. In addition, this capability allows many "what ifs" to be run and therefore focuses the more expensive flight testing on only the most critical areas that require flight test validation.

3.3.5. Installed System Test Facilities.

3.3.5.1. Preflight Integration of Munitions and Electronic Systems (PRIMES). This facility consists of a fighter-sized anechoic chamber and six shielded laboratories providing secure, realistic testing in a controlled RF environment to support one-on-one or many-on-one tests in static or dynamic flight simulation conditions. Bomber sized aircraft can be placed outside PRIMES and linked to the facility. The laboratories include analog and digital equipment to simulate EM flight test environments. Armament/munition guidance commands, auto-pilot functioning, and seeker performance can be monitored during tests. Using PRIMES, many system problems associated with early phases of development can be identified prior to the start of flight testing, and therefore reduce flight test costs and allow the more productive use of available aircraft.

3.3.5.2. Linked Facilities. Total aircraft-avionics-munitions system testing can be conducted using a fiber optic link between the GWEF and the PRIMES. The aircraft can be located in the anechoic chamber in the PRIMES and the armament/munition in the GWEF. The real-time fiber optic link transfers all information normally transmitted from the aircraft to the armament/ munition. This allows closed loop, end-to-end ground test of the total weapon system (aircraft/EC/ munitions) simulating prelaunch, launch and post launch phases of an armament/munition employment.

3.3.5.3. Climatic Facility. This facility has test chambers to conduct tests on armament/ munitions and their components. These chambers can duplicate various conditions including sun, wind, rain, dust, combined conditions or all weather (arctic to jungle-rain, wind, snow), temperature-altitude, and salt. The main chamber can conduct tests on the armament/munitions loaded on launch platforms.

3.3.6. Open Air Ranges.

3.3.6.1. Armament Systems Test Environment (ASTE)/ Gulf Test Range (GTR). The ASTE consists of 724 square miles of varied, multi-environmental land area with 45 test areas, 34 test systems/facilities and 26 multipurpose systems/facilities (instrumentation, data transfer, communication, mission control, targets—fixed, mobile, remote controlled, and scoring) for T&E of armament/munitions. The major test areas are Air-to-Surface Test Ranges, Gun Test Facilities, Electro-optical/MMW Evaluation sites, and Static Warhead Test Arenas (unitary blast/fragmentation, explosively formed projectile, shaped charge). The ASTE also includes special targets ranging from simulated Warsaw Pact A/C shelters and runways to remote controlled tanks; and test facilities that are one-of-a-kind in the world; e.g., the shallow water mine countermeasure testing facility and the HELLFIRE Integration Facility and Test Range. The GTR encompasses 86,500 square miles of the Gulf of Mexico. This area is used for long-range, all-altitude air-to-air (many versus many), long range air-to-surface, surface-to-air/drone target engagements, and long-range anti-ship air-to-surface and surface-to-surface armament/ munitions evaluations. ASTE and GTR are adjacent and provide an extensive land/sea test capability, with a total airspace of 89,062 square miles, that is unique within the Air Force. Further, the tri-service Southeast Test and Training Area can provide over 108,000 square miles of airspace (with varying altitude restrictions). An overland supersonic corridor is 10 nautical miles (NM) from Eglin AFB and 2 over water supersonic areas are in the GTR. A fleet of primarily F-15 and F-16 aircraft with standard programmable digital instrumentation and the capability for unique project modification is available. Other aircraft types are available or can be obtained on loan, if required. Aircraft can be deployed to virtually any location to conduct/support testing. A general instrumentation pod is used on different types of aircraft with minimum aircraft modification. The pod includes an instrumentation recorder, video time inserter, video recorder, time code generator, data acquisition system, data encryptor, and telemetry transmitter. Airborne targets are a mix of subscale and full-scale drones used in conjunction with air-to-air missile tests over the GTR along with the command, control, and tracking system to support the tests. Simultaneous control of up to six drones flying individually or in realistic tactical formations at all altitudes is possible. The system will provide Time, Space, Position Information (TSPI) on four drones, four shooter aircraft, and four air-to-air missiles. Selective flight termination of drones or missiles is included in the system. GTR supports over-the-horizon missions using E-9 aircraft. Approximately 1000 mobile ground targets are available, including actual, simulated, or surrogate vehicles. Remote control of six vehicles simultaneously is possible. Over 1000 fixed targets (bunkers, runways, railroads, vehicles, etc.), are also available. Sea targets are acquired for specific tests with remote control requirements.

3.3.6.2. Electromagnetic Test Environment (EMTE). The collocation of the EMTE with the extensive munitions testing capabilities at AFDTC allows for testing armament/munitions systems in a realistic RF environment. Instrumentation on EMTE supports precision tracking analysis with TSPI sources, multispectral measurements and analysis, and dynamic RCS and target signature measurement. The capability to accomplish extensive integration testing at both the component and system levels is available.

3.3.6.3. Utah Test and Training Range (UTTR). The UTTR encompasses 8,125 sq NM of restricted airspace which can be expanded to 17,000 sq NM through adjacent Military Operating Areas (MOAs) (in an area 207 by 92 NM). Land space is 2,700 sq NM of DoD land and 14,300 sq NM of Bureau of Land Management, State of Utah, and a small amount of privately owned lands underlying the restricted air space and MOAs. This large overland airspace and ground space allow for large safety footprints and long trajectory legs required by Precision Guided Munitions (PGMs), smart munitions (such as off axis High Speed Anti-Radiation Missile launches) and cruise missiles. Major munitions test areas include 12 targets for testing conventional munitions, fuzes, high volume propagation detonations (demonstrated 500,000 pounds), and laser guided armament/munitions; four highly instrumented targets used for testing of PGMs, smart armament/munitions, and home on emitter seeking missiles; two cruise missile impact targets; and five air-to-surface tactical target complexes. All UTTR test areas are capable of munitions tracking, data collection and transfer, telemetry acquisition and recording, communications, mission control, and full data reduction. The four highly instrumented targets are capable of 45 NM armament/munition trajectories, remote command/ control targets and range instrumentation, and armament/munition deliveries using realistic scenarios. The low population density surrounding the range and low density of high value/manned sites within the range safety footprint allows for maximum flexibility in planning test mission trajectories.

3.4. Armament/Munition Effectiveness Testing. Scientifically validated data are required by the Joint Technical Coordinating Group for Munitions Effectiveness (JTCG/ME) to produce Joint Munitions Effectiveness Manuals (JMEMs). The JMEMs are used by operational mission planners to select which armament/munition and how many are required to achieve the required level of damage on a given target. The test program provides the data for these manuals. These data include physical and functional characteristics of the armament/munition. The data are placed in a computer model to assess the viability of a new system or new tactics. Factors that must be fully considered to determine operational effectiveness of an armament/munition include:

- Target Vulnerability. An assessment of how vulnerable a target is to specific armament/munition damage mechanisms.
- Armament/Munition Characteristics. Quantification of damage producing mechanisms and reliability of the armament/munition.
- Delivery Accuracy. A measure of a armament/munition system's ability to place armament/ munitions on a target.

3.4.1. Target Vulnerability. Detailed information about the target is required to understand the effectiveness of an armament/munition. Once this information is known, an analyst can assess the ability of known armament/munition characteristic damage mechanisms to achieve the desired results. A computer model of the target is developed and damage mechanism data, obtained during testing, is applied against the target.

3.4.2. Armament/Munition Characteristics. Knowing the kind of damage a warhead can produce is required to determine the amount of damage required to defeat a specific target. The JTCG/ME has developed standardized testing procedures to facilitate a meaningful evaluation of new armament/ munitions. The following damage mechanism data will be collected:

- Blast.
- Fragmentation.

- Target penetration.
- Combined damage mechanisms.
- Fire.

These data are also used in safe escape analysis to prevent damage to the delivery aircraft from armament/munitions fragmentation.

3.4.3. Delivery Accuracy. Delivery accuracy is a measure of a armament/munition system's ability to place armament/munitions on a target. The JTCG/ME sponsors accuracy tests on instrumented ranges. The data obtained during these tests are used to create and update computer models that generate delivery accuracy estimates.

3.5. Targets. Armament/munition test programs require targets, target signatures, and threat signatures. Targets are often surrogates for real threats and should replicate the threat performance and signature to the maximum extent practical. Some surface targets have a high degree of threat replication and are called "threat simulators." A threat simulator is defined to be a target that matches the threat so well that the same armament/munition system statistical performance will be obtained for the threat and the threat simulator. Other targets, particularly aerial targets, do not have the threat replication of a threat simulator, and are called "targets." These targets require the use of a variety of analytical methods to extrapolate performance from that observed using the substitute target to the performance expected against threats. The extrapolation process depends on the availability of adequate threat intelligence data. The Defense Intelligence Agency (DIA) is responsible for providing these data. The AFMC Center Intelligence Office will work with the System Program Office and the RTO to obtain the most current/detailed threat information and to prepare a DIA Intelligence Production Requirement document (DD-1497) to request threat data required to accomplish the test program.

3.5.1. Joint Service Target Responsibilities. Various types of armament/munitions are developed to engage many types of aerial, surface, and space threats. The Service Acquisition Executives have defined service responsibilities for providing test targets and target data to satisfy test requirements. These responsibilities are shown in **Table 3.1.**

Table 3.1. Targets Points of Contact.

TYPE OF TARGET	RESPONSIBLE SERVICE	POINT OF CONTACT
Full-Scale Fixed Wing Aerial Targets	Air Force	AFDTC/DR SFTC Office Eglin AFB, FL 32543
Subscale Fixed Wing Aerial Target	Navy	Naval Air Warfare Center (NAWC)/Weapons Division Point Mugu, CA 93042
Rotary Wing Aerial Target	Army	PMITTS/TMO Huntsville, AL 35898
Ground Targets	Army	PMITTS/TMO Huntsville, AL 35898
Maritime Targets	Navy	NAWC/Weapons Division Point Mugu, CA 93042

TYPE OF TARGET	RESPONSIBLE SERVICE	POINT OF CONTACT
Space Targets	Ballistic Missile Defense Organization (BMDO)	BMDO Washington, DC 20301

3.5.2. Threat Simulators and Targets. Some surface targets have sufficient threat replication to be designated as threat simulators. A process used to VV&A a threat simulator is available from the SFTC office. The measured signature of a threat substitute is compared to a threat signature which is either measured or calculated using best available DIA intelligence data. Engagement modeling and HITL simulation may be used in threat simulation VV&A. For targets that do not have adequate threat replication to be validated as a threat simulator (this is the case for all aerial targets in the terminal phase of a test), available modeling and simulation techniques, including signature modeling, engagement modeling, HITL simulation, and captive flight testing, must be used to extrapolate test data obtained against the target to predict performance against threats. VV&A of the test resource requires target and threat signature data. The VV&A process must be accomplished during the test program.

3.6. Live Fire Testing. Live fire testing is a statutory requirement for all Category I and II acquisition programs. This requirement has grown directly out of problems the Army experienced with the Bradley Fighting Vehicle. The purpose of live fire testing is to determine if a conventional armament/munition system exhibits battle-resilient survivability (with primary emphasis on, but not limited to, vulnerability) and if an armament/munition or missile exhibits sufficient lethality to inflict the intended damage. Survivability is the capability of the armament/munition to avoid or withstand a man-made hostile environment without suffering an abortive impairment of its ability to accomplish its designated mission. In the case of armament/munitions, most are not designed to, nor intended to, withstand battle damage. Survivability for guided armament/munitions may be interpreted to mean vulnerability to countermeasures. If vulnerability testing is required, the system must be loaded or equipped with all dangerous materials that would normally be included operationally. All critical subsystems which could contribute to the test outcome must also be operating under realistic conditions. Lethality Testing is designed to determine the ability of an armament/munition to cause damage that will cause the loss or a degradation in the ability of the target system to complete its designated mission. For lethality testing, the armament/munition must be production representative. Targets must be representative of the class of systems that includes the threat and be sufficiently realistic to demonstrate the lethal effects the armament/munition is designed to produce. By Milestone I, a decision should be made whether the armament/munition meets the legislative criteria for a covered system. A mature strategy for live-fire testing should be included in the TEMP by Milestone II. The entire Live Fire T&E program, to include testing, evaluation, and reporting, must be completed by Milestone III.

3.7. Joint Munitions Test & Evaluation Program Office (CHICKEN LITTLE). The program office was formed to test and evaluate developmental smart armament/munitions to reduce risk for the Army and Air Force. Test methodologies stress realism to include actual soviet armor, countermeasures, and environment. The Joint Service program has been institutionalized and provides support to smart armament/munitions developers. The program focuses on two areas of smart armament/munitions; warhead effectiveness and seeker/sensor performance. Explosively formed projectiles and shaped charge warheads are tested and effectiveness assessed against threat armored vehicles with and without countermeasures. The program supports the smart armament/munitions development community by developing and providing advanced methodologies for testing warheads and assessing target vulnerabilities. Captive flight tests and signature measurements are conducted to support the development of submunitions that engage and defeat threat ground mobile vehicles. Advanced methodologies are applied to evaluate developmental seeker/sensors to reduce risk and cost. Signatures of threat ground mobile systems are processed and stored in the Target Background Information Library System, a comprehensive interactive source of IR and MMW target and background data.

3.8. Air Force Acquisition Model (AFAM). The AFAM was developed as a vehicle where functional experts in the Air Force Materiel Command (AFMC) provide insight on procedures, best practices, and wisdom used to complete acquisition tasks. AFAM is an automated encyclopedia that depicts the entire acquisition process from cradle-to-grave. In addition, AFAM contains supplement text retrieval system that contains over 65 DoD databases controlled by functional experts. The AFAM Program Office is located at Wright-Patterson AFB, OH, ASC/CXM, DSN 785-0416.

3.9. Software Testing. In many programs the highest risk and most challenging aspect of the system acquisition is the software development effort. This is true whether the software is embedded in a armament/munition system, or a standalone system. However, just as with hardware, the key is to use sound engineering and management principles in the design and test. Since software is such a critical part of our warfighting capability, it is important to discuss a structured approach to it's development together with a list of the common software development problems. This section will discuss the issue of software testing as it relates to the overall munitions test process.

3.9.1. Development Process. The software development process relates directly to the basic scientific process discussed earlier in this document and in AFI 99-103. The steps of the software process are:

- Requirements Analysis.
- Design Specification.
- Testing and Integration.
- Correct Problems.
- Feedback.
- Release of Software.

This process implements the basic building block approach from "components" to "subsystems" to a "system." Following the initial development of the software, it is integrated with the hardware portion of the system and progresses through the various test resource categories and is tested as an integrated system. An important factor is to not break out the armament/munition system into a program focusing on separate hardware engineering and software engineering. Instead, a true systems engineering approach must be adopted. From requirements definition through detailed design, integration and test, software must be looked at as an integral part of the system. Contract structure and contractor oversight must focus on delivery of functional performance through a balanced hardware/software ensemble.

3.9.2. Requirements Analysis. As with hardware the user's requirements must be defined and then a system is designed which will meet those requirements. In the case of software, the requirements definition process can be even more difficult than that of hardware. Many times the customer does not have a firm grasp on the software requirements for the overall system. Analysis of requirements, in addition to the user's needs described in functional and performance terms, must focus on the complete system capability. This includes both the software and the complete environment in which the system is to operate The first step of the software test process is to fully define, as much as possible, the firm requirements on which to base the design. Studies have shown that roughly two-thirds of the errors in software development are a result of the requirements analysis and design specification phases. There are several actions the developer/tester can employ to correct this trend. One action is to have early and continuous user involvement during the entire requirements process. Requirements should be stated so they are understandable by the designer and the developer. One measure of clarity is whether or not the requirement is testable. Tools to use during the requirements definition process include the Computer Aided Software Engineering (CASE) programs. CASE tools can substantially reduce many of the design and development problems in large software projects. Specialized tools available for the requirements analysis phase are user interface prototyping tools, structured analysis tools and information modeling tools. Further information on how the tools can benefit your particular program and provide answers to other software questions are available through the following organizations.

SAF/AQKS

Washington, DC

DSN 227-3108

AF/SCXS

Washington, DC

DSN 223-2699

AFIT/ENG

Wright-Patterson AFB, OH

DSN 785-7913

Air Force Software Technology Support Center

Hill AFB, UT

DSN 458-3207

Another tool to help in the requirements definition effort is the development of early prototypes. Prototyping allows an early opportunity for users and developers to come together to identify promising technical aspects and needed changes while still achievable. Prototyping can take many different forms. It is best to view a prototype as a conceptual or technical test to influence architectures and engineering development. The utility of a prototype is in verifying a concept or set of procedures, assessing design approaches, and testing pieces of a developed system. The prototype, if used properly, can reduce risk, shorten design to implementation cycles, manage requirements, and provide incremental capabilities for fielding the system. Rapid prototyping is an excellent way to ensure a clear understanding of user requirements. As a minimum, there must be agreement with the user on the nature and description of the products with which the user will directly interact. There must also be understanding on the tests and performance thresholds necessary to satisfy user requirements.

3.9.3. Design Specifications. During the design specification phase the software blueprint is developed showing what to build and how to build it. Modules should be identified which can be related back to the customer requirements. During this phase, the tester should be involved to determine the test objectives for each module and to help determine the adequacy of the design process to answer the customer's needs. CASE tools can also be used effectively during this phase of software development. Specific examples of CASE tools in this area are data modeling tools and design specification tools. Considerations during the design specification phase include questions on the ability to grow at a later date. This involves two areas. One is the availability of extra capacity and the second is that the design must be flexible enough to accommodate future growth. Flexibility can be enhanced by the use of modular design, software partitioning and open architectures.

3.9.4. Testing and Integration. Following design specification each module is then coded, tested and debugged to ensure each module performs as originally designed. The tester must make sure that all test requirements identified in the previous phase are fully implemented. The contractor must conduct Formal Qualification Testing (FQT) on the various modules and on the integrated software product. These FQT tests must stress the software at the limits of its specified requirements. Plans for FQT must be documented in the contractor's software development plan and specific tests for each requirement outlined in the contractor's software test descriptions. These two documents are reviewed by knowledgeable software engineers within the program office to ensure adequate testing will take place on the product. The contractor's Software Quality Assurance (SQA) should be heavily involved in the FQT to ensure the test plan and description is followed, and that any discrepancies are accurately recorded. SQA's primary role is to ensure the objectivity of the test. The contractor must document the traceability of requirements which are satisfied by each test case. This traceability is documented in the contractor's software test description.

3.9.5. Correction of Software Faults. Faults found during the testing of software programs can fall into several different categories. These are requirements faults, features faults and functionality faults. Requirements faults are due to the problem discussed earlier of incomplete or ambiguous requirements which are then reflected in software specifications. Requirements are a major source of faults ranging in occurrence from a few percent to over 50% of faults found. These faults typically lead to the next category of faults, the feature faults. Feature faults are comprised of two categories. The easiest one to detect and fix are the missing features faults. Harder to identify and correct are the wrong feature faults. Wrong feature faults tend to result from improper design. One of the easiest ways to avoid these two categories of faults is through the use of techniques discussed earlier for thorough requirements definition and careful initial design. The third category of fault is the functionality fault. Functionality faults are when the program's actual behavior is different than the specified behavior. There are many core reasons for functionality faults. Briefly, these are problems related to structure, data, and coding. These bugs are found by the use of a series of tests such as syntax testing, domain testing, logic testing, and state testing. One of the main questions following the successful fix of any fault is how much of the code must now be tested in regression testing. Regression testing is that repetition testing done to ensure that the software's function is unchanged except that required to correct the fault. Regression testing can be complicated if software modularity is not stressed. If the software is modular in nature, the tester can more easily test only the affected portion of the program. The tester must then ensure that the decision makers are aware of the categories of software faults discovered ranging from minor to critical and that they can be confident that corrections have been implemented successfully.

3.9.6. Feedback/Metrics. It is important that the program office track contractor progress during the design and test of any software product. Meaningful information on progress must be forwarded to the appropriate decision maker so that informed decisions can occur regarding the development effort. Metrics must be utilized which actually give the leadership a true picture of the progress. In the past, metrics such as "lines of code tested" have been used as an indicator. The test organization must be careful in providing metrics such as this, because in many cases this does not accurately depict the true status. Instead, requirements traceability and software error correction metrics may serve to point out potential or real problems the contractor is experiencing. For guidance on software metrics policy and implementation, refer to SAF/AQ Acquisition Policy 93M-017, dated 16 Feb 94.

3.9.7. Release of Software. As stated previously, after the "standalone" software testing, the software is integrated with the hardware and the system then goes through the applicable test resource for a complete test of integrated components, subsystems and the system. During this phase of testing it is very important to remember that software is just as critical to the performance of the overall system as hardware. Problems in function and performance involving software should not be looked at as "just a software fix" but should be looked at from the standpoint of the integrated system. Software development should not be driven by the hardware development effort but instead should be looked at as an equal and very critical part of the process.

HOWARD W. LEAF, Lt General, USAF (Retired)
Director of Test and Evaluation

Attachment 1

GLOSSARY OF REFERENCES, ABBREVIATIONS, AND ACRONYMS

References

AFI 99-101, *Development Test and Evaluation*. Provides guidance and procedures for the DT&E of Air Force systems.

AFI 99-102, *Operational Test and Evaluation*. Provides guidance and procedures for the OT&E of Air Force systems.

AFI 99-103, *Air Force Test and Evaluation Process*. Directs use of and describes the Air Force Test Process.

AFPD 99-1, *Test and Evaluation*. Implements the Air Force Test Process.

Air Force Acquisition Policy Letter 93M-017, *Software Metrics Policy*. Establishes Software Metrics policy.

AFI 63-104, *Aircraft-Stores Certification Program*. Defines the aircraft-stores certification (SEEK EAGLE) process.

SEEK EAGLE Engineering/Test Capabilities Handbook. Identifies the location, primary mission, and major aircraft-store certification resources.

AFI 99-105, *Live Fire*. Defines the Air Force Live Fire test program.

Abbreviations and Acronyms

AFAM—Air Force Acquisition Model

AFB—Air Force Base

AFI—Air Force Instruction

AFMC—Air Force Materiel Command

AFOTEC—Air Force Operational Test and Evaluation Center

AFSEO—Air Force SEEK EAGLE Office

ASTE—Armament Systems Test Environment

CASE—Computer Aided Software Engineering

CE&D—Concept Exploration and Definition

CFD—Computational Fluid Dynamics

COEA—Cost & Operational Effectiveness Analysis

COI—Critical Operational Issue

CONOPS—Concept of Operations

CSAF—Chief of Staff, Air Force

Dem/Val—Demonstration/Validation

DIA—Defense Intelligence Agency

DoD—Department of Defense

DOF—degree-of-freedom

DSM—Digital System Model

DT&E—Developmental Test and Evaluation

EM—ElectromagneticE&MD Engineering and Manufacturing Development

EMTE—ElectromagneticTest Environment

EO—Electro-Optic

FC—Flight Clearance

FCSC—Freeman Computer Science Center

FQT—Formal Qualification Testing

GPS—Global Positioning System

GTR—Gulf Test Range

GWEF—Guided Weapons Evaluation Facility

HITL—Hardware-In-The-Loop

IOT&E —Initial Operational Test and Evaluation

IR—Infrared

IST—Installed Systems Testing

ISTF—Installed Systems Testing Facility

JMEM—Joint Munitions Effectiveness Manual

JTCG/ME—Joint Technical Coordinating Group for Munitions Effectiveness

MMW—Millimeter Wave

MNS—Mission Need Statement

MOA—Military Operating Area

MOE—Measure of Effectiveness

MOP—Measure of Performance

NM—Nautical Miles

OAR—Open Air Range

OFP—Operational Flight Program

OPR—Office of Primary Responsibility

ORD—Operational Requirements Document

OT&E—Operational Test and Evaluation

PGM—Precision Guided Munition

PRIMES—Preflight Integration of Munitions and Electronic Systems

RAMS—RATSCAT Advanced Measurement System

RATSCAT—Radar Target Scatter Facility

RCS—Radar Cross Section

RF—Radio Frequency

RTO—Responsible Test Organization

SE—SEEK EAGLE

SEMSS—SEEK EAGLE Management Support System

SER—SEEK EAGLE Request

SFTC—Single-Face-to-Customer

SIL—System Integration Laboratory

SMM—System Maturity Matrix

SPP—System Performance Parameter

SQA—Software Quality Assurance

T&E—Test and Evaluation

TEMP—Test and Evaluation Master Plan

TO—Technical Order

TPA—Test Process Archive

TPP—Technical Performance Parameter

TPWG—Test Planning Working Group

TSPI—Time, Space, Position Information

UTTR—Utah Test and Training Range

UV—Ultraviolet

V&A—Validation and Accreditation

VV&A—Verification, Validation, and Accreditation

WIP—Weapon Integration Plan

WTT—Wind Tunnel Testing