BY ORDER OF THE
SECRETARY OF THE AIR FORCE

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1 MAY 1996

Test and Evaluation

SPACE SYSTEMS TEST AND EVALUATION PROCESS
DIRECTION AND METHODOLOGY FOR SPACE SYSTEM TESTING

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This manual implements Air Force Instruction (AFI) 99-103, *Test and Evaluation Process*, for Space Systems Test and Evaluation. It provides a methodology for use by program managers, test engineers, test organization personnel, major command headquarters staffs, and others regardless of command level, involved in Space Systems Test and Evaluation (T&E). This manual directs use of the Space Systems Test and Evaluation Process, describes the process, provides application information, and summarizes resources available. Nonuse of the process described in this manual shall be by exception only and require written approval by the Director, Test and Evaluation, Headquarters United States Air Force (HQ USAF/TE).

SUMMARY OF REVISIONS

Paragraph

Paragraph

OPR: HQ USAF/TEP (Maj Dwight L. Harris)

Certified by: HQ USAF/TEP (Col James E. Brechwald)
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Attachments

Chapter 1

INTRODUCTION

1.1. Overview. The Air Force Space Systems T&E Process is intended to be universal, for use by both Government and contractors in any phase of the Department of Defense (DoD) system acquisition cycle, whether test and evaluation is developmental, operational, or combined. Its use implements a plan-predict-test-compare philosophy and stresses adequate ground testing before launch and on-orbit testing.

1.2. Planning. If you are starting to plan, manage, or conduct a space systems T&E effort, this manual will help you do it in a disciplined, scientific, and cost-effective manner. The Space Systems T&E Process described herein has been developed to help you think through the steps that should be taken to plan and execute a space system test and evaluation effort that meets the needs of the Air Force for mature, usable, operationally effective and suitable space system hardware and software.

1.3. Purpose. The Air Force T&E Process is a scientific approach that supports a plan-predict-test-compare philosophy for testing systems. Discipline in the test process is recognized as a contributor to cost effective system acquisitions that satisfy user needs. A disciplined and well structured test program reduces the risk of acquiring an ineffective system and provides a program manager with timely information required to make prudent decisions during system development. Testing encompasses many levels and methodologies, from component tests in laboratories to full mission demonstrations in a real world environment. Regardless of the type of test,there are six guiding principles to help ensure the system under test fulfills its intended purpose.

1.3.1. Involve the user, developmental tester and operational tester in the initial formation of the Integrated Product Team (IPT) to ensure customer satisfaction and facilitate continuous and timely information exchange.

1.3.1.1. Take the time to ensure all parties (developer, contractor, Operational Test Agency (OTA) and Responsible Test Organization (RTO)) thoroughly understand user requirements and agree on how the system will be tested, scored and evaluated.

1.3.1.2. Write answerable test objectives and stick to them in an orderly and disciplined manner.

1.3.1.3. Use the systems engineering approach, working up from concept, to component, to subassembly, to subsystem and finally to system.

1.3.1.4. Test as early as possible and as often as affordable to find and correct problems during less costly periods of developmental test.

1.3.1.5. Use a concurrent engineering approach to the simultaneous design of the product and its associated manufacturing, test and support processes.

Implementation of the Space Systems T&E Process ensures these principles are systematically adhered to throughout testing.

1.4. Objectives. The five objectives of Space Systems T&E Process implementation are:

1.4.1. To verify that test results are credible and support DoD system acquisition milestone decision making.

1.4.1.1. To provide early identification of space system performance and supportability deficiencies for resolution.

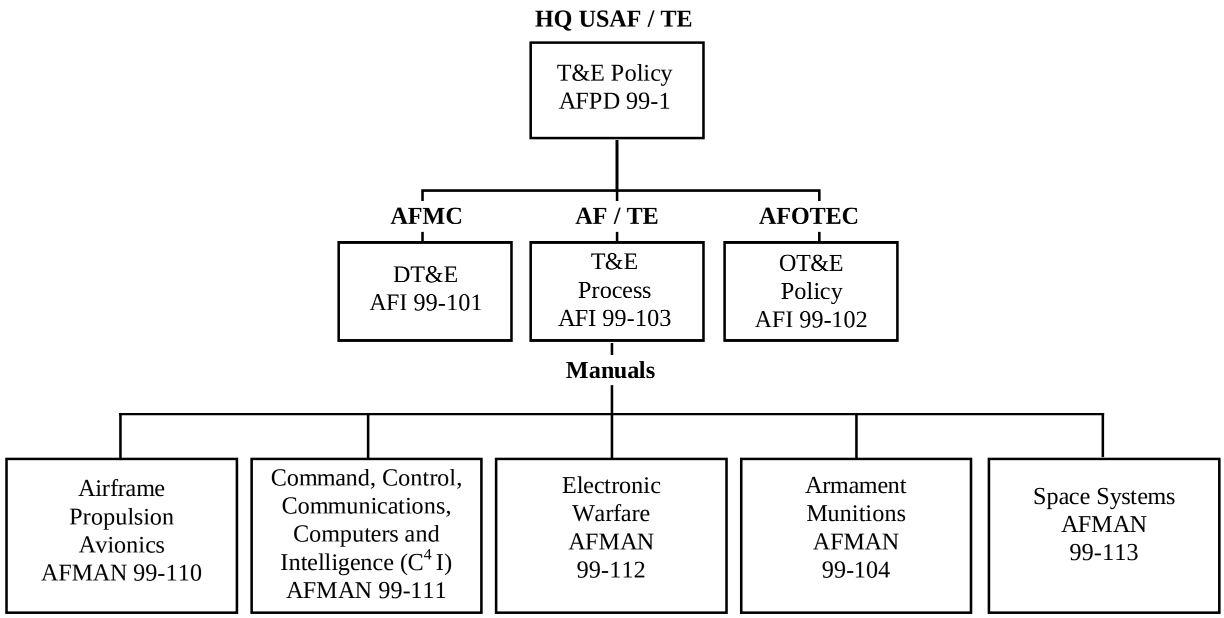
1.4.1.2. To identify and measure performance parameters that are critical to operational effectiveness and suitability through rigorous analysis and evaluation during the evolution of system requirements.

1.4.1.3. To provide early identification and timely acquisition of test assets.

1.4.1.4. To execute test programs that consistently apply the scientific approach to T&E articulated in

AFI 99-103, *Test and Evaluation Process*, describes the Air Force plan-predict-test-compare approach to test and evaluation and its relationship to Department of Defense Directive (DoDD) 5000 series acquisition directives. AFI 99-103 describes a set of guidelines that support the plan-predict-test-compare philosophy for testing systems. By following its guidelines, a test program will be conducted in a disciplined, scientific, and cost-effective manner. AFI 99-103 describes this process on a generic level and is the basis for development of the Space System T&E Process. Figure 1.1 shows the test and evaluation planning documentation set to which AFI 99-103 and Air Force Manual (AFMAN) 99-113 belong.

Figure 1.1. AF Test and Evaluation Planning Support Documentation.



1.5. Need. The need to take a disciplined scientific approach to T&E has been demonstrated many times by costly programs that have experienced preventable catastrophic test anomalies, have come on line too late, have exceeded budget, or have ultimately been unable to meet user needs. In addition, past programs have displayed a pattern of latent deficiencies manifesting themselves too late in the acquisition process, necessitating expensive fixes and retesting.

1.5.1**. Efficient Resource Use.** We need to efficiently use the limited and costly resources that exist to support space system T&E. This means developing test concepts that take advantage of current and emerging Modeling and Simulation (M&S) tools and modern testing techniques to streamline Developmental Test and Evaluation (DT&E) and Operational Test and Evaluation (OT&E). Concurrent engineering practices need to be employed to enable developers to work with testers to provide for more efficient use of resources.

1.5.2. **Risk Management.** We need a process that will help us do a better job of assessing and managing risk. Risk, as used here, means the probability that the product will have latent deficiencies that will not show up until late in the test program, or after the system is fielded. This risk may cause significant 1) disruption of schedule, 2) increase in cost, or 3) degradation of performance even with high contractor concern and close Government supervision. Risks need to be understood and controlled. Once a latent deficiency appears, it is no longer a risk; it is a problem. Test and evaluation activities are an essential means of understanding, addressing and controlling risk. Test activities should focus as early as possible on areas of design with the least performance margin or unproven performance and areas that have the greatest impact on total life cycle cost, such as component reliability.

1.5.3. **User Focus.** The user is the customer. A product that meets user needs is our goal. Customer requirements are the basis for our T&E efforts. We want the end products of Air Force space acquisition and T&E efforts to be operationally effective and suitable systems which satisfy user requirements. Thus, we need a process that focuses T&E activities on the space system product that will be delivered to the user.

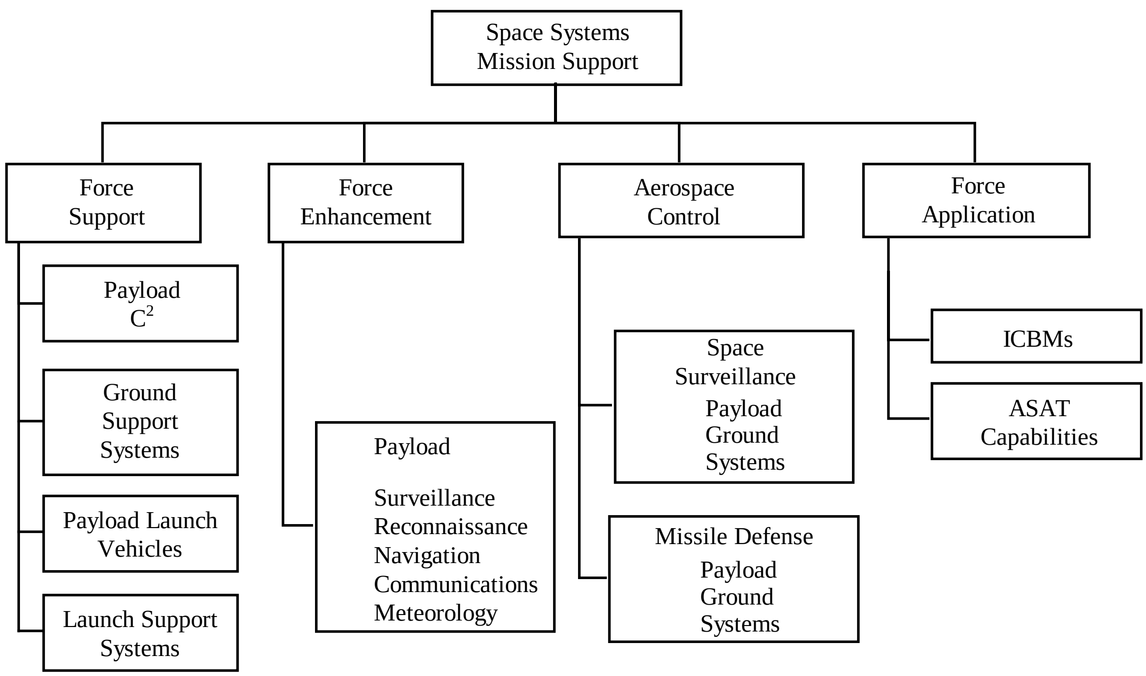
Chapter 2

SPACE SYSTEMS

2.1. Direction. AFI 99-103,Test and Evaluation Process, applies to both developmental and operational testing of space system hardware and software and will be implemented as the test and evaluation process for all space system T&E efforts. It will be used for space components, subassemblies, subsystems, systems and ground, flight and on-orbit test. All space system T&E efforts must use the Space Systems T&E Process described in this manual to plan, execute and report on program test and evaluation activities and to establish and maintain a meaningful record of testing accomplished.

2.2. Space Systems and the Space Mission. Space is a medium in which the Air Force carries out different types of missions in four mission areas: force support, force enhancement, aerospace control, and force application. Space systems are those systems developed and deployed to perform tasks in these four mission areas and specifically associated with the space portion of the aerospace environment. Figure 2.1 shows the types of space systems that support these mission areas. In addition, the Air Force supports experimental and commercial space programs. The T&E process described in this manual applies to all such space systems.

Figure 2.1. Space Systems Support Space Mission Areas.



2.2.1. **Space Systems Overlap.** Since space is a medium, not a mission, many functional aspects of space systems overlap into other areas. In particular, many space systems perform command, control, communications, computers and intelligence (C^4I) functions. Testing of some such systems, for example ground based instrumentation systems without a direct space based system interface like space surveillance radar, should follow the process implementation guidelines provided in AFMAN 99-111, *C^4I Test and Evaluation Process Manual*. Where significant functional overlap occurs, Single Face To Customer (SFTC) offices will coordinate their efforts and determine the appropriate process implementation guidance that applies for specific systems.

2.2.2. **Force Support.** Force support includes systems that contribute to all aspects of on-orbit support for payloads. The Air Force currently maintains this capability through the Air Force Satellite Control Network (AFSCN) and assorted program specific ground control systems or networks. The concept of force support extends to the Eastern Range and Western Range which provide the payload launch support capabilities required to add to and replenish the on-orbit payload force structure.

2.2.3. **Force Enhancement.** Force enhancement includes systems which contribute to combat effectiveness within the areas of surveillance and reconnaissance, navigation, communications and meteorology. In this regard, surveillance refers to the capability as applied from space to earth; surveillance of objects in space is an aspect of aerospace control.

2.2.4. **Aerospace Control.** Aerospace control includes systems which contribute to the areas of ballistic missile defense (BMD) and space surveillance, protection and negation. All elements of the Space Surveillance Network (SSN) and the Space Defense Operations Center (SPADOC) are included in this mission area. BMD space systems are typically still in the technology demonstration stage.

2.2.5. **Force Application.** Force application includes ballistic missile systems which contribute to the areas of ballistic missile offense. Intercontinental Ballistic Missile (ICBM) forces are now under Air Force Space Command purview with the reorganization of U.S. Strategic Command's roles and missions.

Chapter 3

METHODOLOGY

3.1. Applicability. The test and evaluation methodology has applicability at both macro and micro levels in the Air Force. An understanding of this methodology is needed at both levels. The following discussion describes the space test and evaluation process steps at the macro level. The micro level reflects system and acquisition program dependent adaptations of these process steps to specific categories of hardware and software systems.

3.2. Government Test Participation. Government participation in conducting space system T&E is greatest during integrated space system and space flight testing, usually during combined DT&E and Initial Operational Test and Evaluation (IOT&E). There is heavy Government reliance on contractor testing during DT&E at the component and subsystem level during which the Government acts as an observer and monitors progress toward system maturity. Disciplined and well structured programs will also make use of independent Government test organizations at component and subsystem level testing. This independent assessment can be extremely beneficial when directed toward IOT&E.

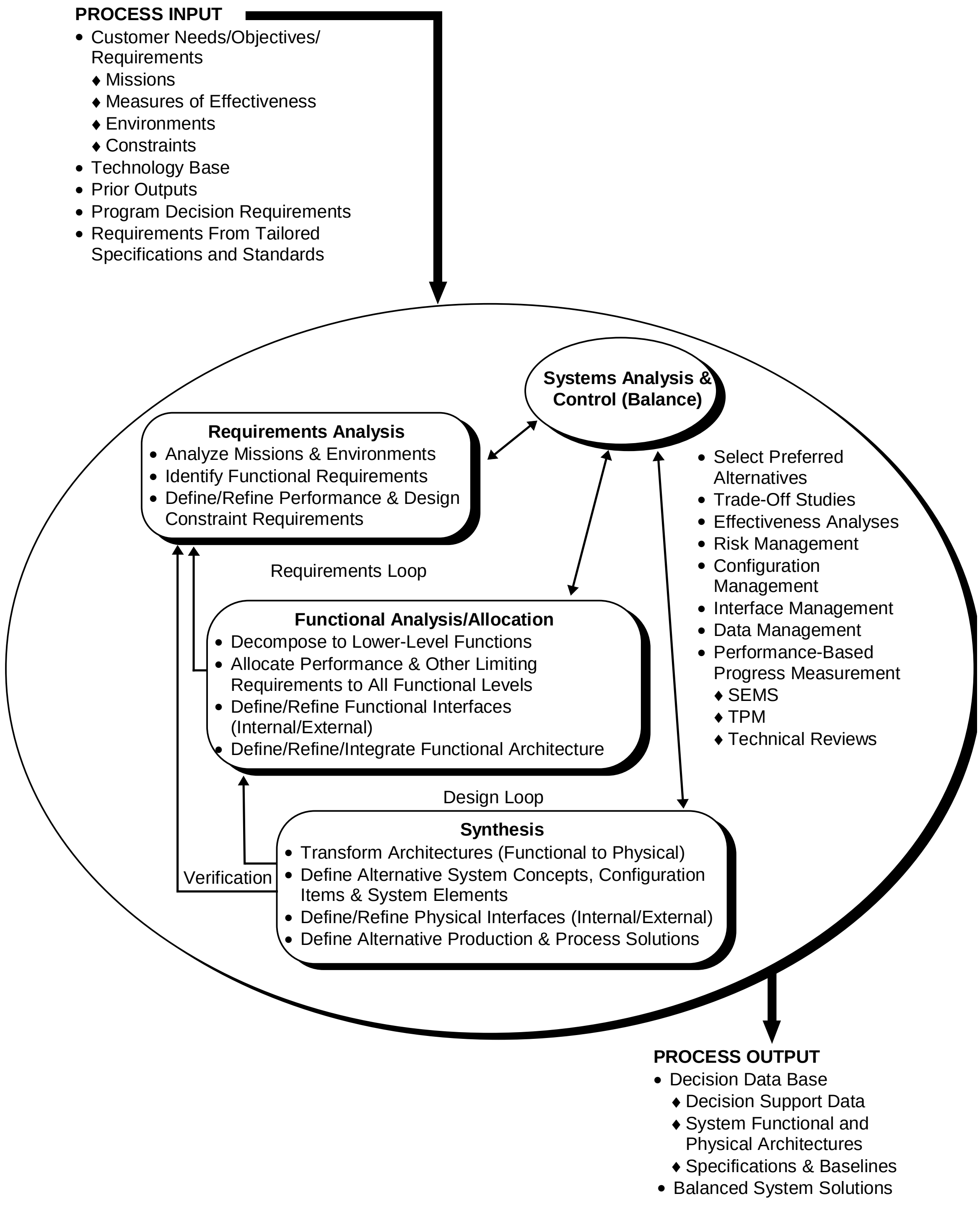
3.3. T&E Support to Experiments. In the case of space system data collection experiments and technology demonstrations [Advanced Technology Demonstrations (ATD) and Advanced Concept Technology Demonstrations (ACTD)] the T&E community provides expertise and necessary facilities to accomplish experiment objectives in the most cost effective manner. This process is an essential discipline for both formally established system acquisition programs and experiments or technology demonstrations.

3.4. T&E Considerations During Development. Early T&E planning activities require significant interaction with the developer, tester, and user. An understanding of the systems engineering process is necessary for the tester to interact effectively with these other members of the IPT. A description of the systems engineering process is included as a prelude to the T&E process discussion.

3.4.1. **Systems Engineering Process.** The Systems Engineering (SE) process defines steps necessary to logically design a system to meet the needs of the operational user. Inputs to the process include Mission Need Statement (MNS), Operational Requirements Document (ORD), technological advancements and output from a previous phase of the acquisition process if the system is well into its life cycle. The SE process is illustrated in figure 3.1 and is comprised of the following steps:

3.4.1.1. **Requirements Analysis.** This is the SE analysis process which creates a performance view of the developing system, wherein operational requirements are translated into system performance requirements. At this point, we are not concerned with specific hardware. Rather we are developing the requirements for the entire system from an operational effectiveness point of view. For example, an operational requirement might be to monitor all foreign launches. What would be the system performance requirement for this operational requirement? Detailed information on this SE analysis process can be found in draft MIL-STD-499B, *Systems Engineering.*

Figure 3.1. The Systems Engineering Process.



3.4.1.2. **Functional Analysis and Allocation**. This part of the SE process provides a functional view of the developing system, wherein the requirements developed above are translated into specific functions that must be accomplished by the system. Continuing with our example, we determine that the best way to monitor all foreign launches would be to deploy a space borne sensor system. Further, we decide the system must detect the target, track the target and report on the target's position. Each of these is a function that must be performed by the sensor system, and in turn, will drive the type of subsystems that must be included in the overall sensor system design. The Requirements Analysis step and the Functional Allocation step taken together form the Requirements Loop of the SE process, an iterative process that may be done several times before the true system performance requirements can be determined and functionally decomposed and allocated.

3.4.1.3. **Synthesis and Design**. In this step of the SE process, we finally begin to allocate functions to specific hardware, making this the architecture view portion of the process. We might allocate the function to detect foreign launches to an infrared sensor, the tracking function to a different wavelength sensor and the reporting function to a communication subsystem. This step coupled with Functional Analysis forms the design loop of the SE process, which is also iterative and may be accomplished numerous times before the system design is finalized.

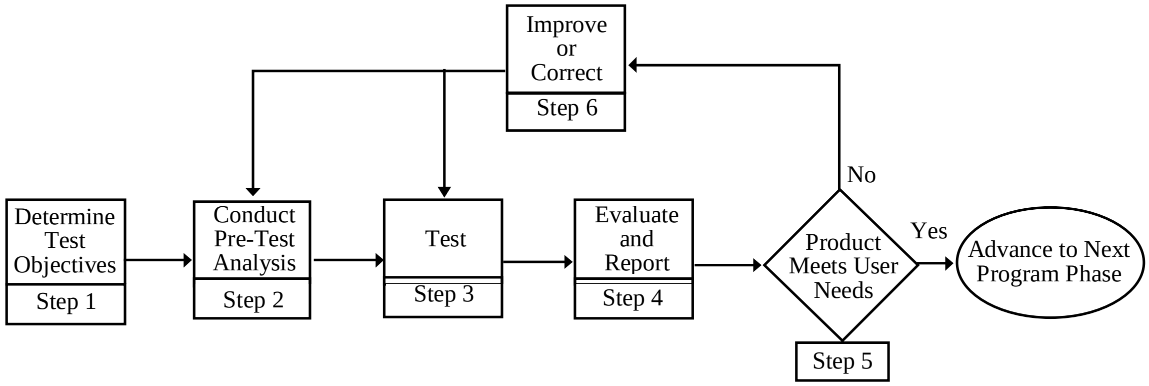
3.4.1.4. **System Analysis and Control (Balance)**. This portion of the SE process feeds each of the steps above and is that portion of the process dedicated to maintaining oversight of all other steps. Here we perform trade studies, maintain configuration control and do what is necessary to control the SE process and ensure it is accomplished rigorously and logically. Information flows in both directions for balance and control with data being fed into all of the analysis and design steps and information flowing back into the system databases developed under this portion of the process.

3.4.1.5. **Verification Loop.** Test and evaluation fits into the overall SE process in the form of the verification loop, in which the architecture arrived at after completion of synthesis and design is compared to the performance requirements. Perhaps the most important thing to remember here is that the overall process and many of its sub-processes are iterative. We continually perform systems engineering in response to changing requirements brought on by changing threats, budgetary constraints, changing national priorities and objectives, etc. T&E can, and will, influence the SE process from beginning to end. One of the most important determinations of the validity of requirements derived during analysis is the ability to test to verify compliance with those requirements. If the requirement cannot be verified by test, accredited simulation, or other acceptable verification method, it should not be accepted as a constraint for the system design. For this reason, both the Developmental and Operational Test Managers should be intimately involved in the SE process from the inception of the system. The T&E process is a very important subset of the overall SE process and whether or not the T&E process can be carried to a successful conclusion for a given system will determine whether or not the SE process should be repeated.

3.4.1.6. **T&E Process Frame of Reference.** Understanding the SE process is important for the tester to effectively communicate with and support other members of the IPT. The Space and Missile Systems Center (SMC) Systems Engineering Office provided the above discussion of the relationship of the SE process to the T&E process and can provide additional assistance to IPTs if needed.

3.5. The Space Systems T&E Process Steps. The Space Systems T&E Process described below is for general guidance and allows for each program to tailor it for individual needs, as appropriate, to cost-effectively implement the overall T&E requirements. Contact the Space and Missile Test SFTC Office for guidance and clarification of specific tailoring requirements. Figure 3.2 illustrates the six step Space Systems T&E Process. Each step has associated questions that should be asked and answered to complete the step. Using the T&E process involves taking actions that answer relevant questions and lead ultimately to producing the information needed by various decision makers.

Figure 3.2. The Space Systems T&E Process.



3.5.1. **Step 1) Determine Test Objectives (PLAN)**. This is an **action** step that requires the attention and involvement of the IPT made up of user, contractor, System Program Office (SPO) Program Manager, SPO personnel, the SFTC, and the Responsible Test Organization (RTO) Test Manager and, when they have been identified, representatives from the other participating developmental and operational test organizations.

3.5.1.1. **General Questions.** At this step the SPO's IPT is resolving such questions as: Are user requirements (or experiment objectives) well defined and understood by the IPT? Are the test objectives based upon well understood mission, task and performance requirements? What are the technical and operational issues that must be resolved? Are the test objectives testable? What high risk areas require special emphasis? Do the test objectives reflect planned system maturity (as defined in the System Maturity Matrix if one is available for your program)? What T&E information is needed by decision makers? Do the test objectives support exit criteria for the acquisition phases of this program?

3.5.1.2. **Specific Questions.** Specific T&E questions that should be answered include: What tests are required at this stage of system maturity to satisfy the information needs of decision makers? What specific measurable test objectives are to be answered? What test methodology best addresses these objectives? What are the test points? What are the predicted outcomes of the tests for the system at the projected levels of system maturity? What analytical tools must be used or developed? What types and quantities of data are needed to evaluate system performance? How long will the necessary test and evaluation activities take and what resources are required ? The what, where, who, how, when, and why of a test as well as its cost and relationship to the integrated test and overall program schedule must be answered and defined.

Note: The concept of integrated product development and the function of the SPO IPT are explained in the Space and Missile System Center Implementation Guide for Integrated Product Development. This document adapts the IPD concept contained in the Air Force Materiel Command (AFMC) Guide On Integrated Product Development, dated 25 May 1993.

3.5.2. **Step 2) Conduct Pre-Test Analysis (PREDICT)**. This is an action step. Pre-test analysis addresses the development and refinement of test concepts and scenarios and selection of the most cost effective and feasible test options available to satisfy test objectives developed in step 1. Feasible options must be technically achievable and affordable and they must recognize and conform to safety, environmental and treaty requirements.

3.5.2.1. **System T&E Performance Questions.** Questions that need to be answered include: How is the system expected to perform? What points have the highest probability of failure? How can performance best be tested? When will the system exceed tolerances?

3.5.2.2. **T&E Resource Questions.** When the test methodology has been determined, alternative test facilities and organizations should be brought into the planning process to identify safety, environmental, cost and schedule issues for individual tests. Information required by supporting organizations for planning and approval purposes must be created and provided in accordance with the requester's planning schedule. Deficiencies in test support capabilities must be referred to the SFTC for Space so that alternative solutions can be identified or new capabilities budgeted for. When all critical test support issues have been resolved, individual support agreements must be developed to document roles and responsibilities of participating organizations and facilities. Funding for support must be provided. Detailed test plans and procedures must be developed and test procedures must be rehearsed by participants.

3.5.2.3. **Detailed Planning Questions.** Additional questions to be answered include: Are individual detailed test plans available that document all relevant roles, responsibilities and actions? Are detailed test procedures developed and adequately rehearsed? Are qualified T&E organizations and appropriate facilities being used to plan and conduct the tests? Will planned tests answer the major test objectives? Will the tests stress the system appropriately? Will the required test data be collected and analyzed? How, when, to whom and by who will test results be reported? Do the test conductor, test manager and local facility safety authority have a documented understanding of their individual roles and responsibilities under all foreseeable conditions.

3.5.3. **Step 3) Test (TEST).** This is the execute step. The test conductor must determine readiness prior to starting this execution step. Checklists must be followed according to the planned schedule of test events. The test conductor should have a thorough understanding of what conditions require stopping or postponing the test. These conditions require prudently frequent monitoring prior to a Go or No Go decision.

3.5.3.1. **Readiness Questions.** Typical questions that must be answered include: Are all participants ready to support? Do required environmental conditions exist? Are all test articles ready to test? Are other test assets such as targets ready to support? Are all supporting instrumentation systems ready and able to support? Are contingency plans available and rehearsed where appropriate? Is the overall scenario and objective understood by all participants? Are all participants in position? Are communications established in accordance with the test procedure? Are any necessary last minute changes to procedures approved by the test manager and understood by all participants? Are pre-test events being monitored and reported as planned?

3.5.3.2. **Test Conduct Preparation.** When the decision is made to begin the test, the test conductor must carefully monitor events and be able to direct participants in the event of contingency or unforeseen developments. The test manager must be able to direct the test conductor as required. The overall test "chain of command" will be established and well understood prior to commencing the test. Rehearsal of all test procedures greatly improves this decision making.

3.5.4. **Step 4) Evaluate and Report (COMPARE)**. This is an action step. The following are some of the questions that require answers: How do measured outcomes compare with predicted values? Did test results fall within the acceptable range of values? Did post test analysis support the comparison of predicted outcomes to test measured outcomes? Have technical and operational judgments been applied to the results? Has the needed information been reported objectively, clearly and concisely to decision makers? Has the necessary system requirements analysis been performed to update and make available a current picture of verification accomplished to date?

3.5.5. **Step 5) Does the Product Meet User Needs?** This is a decision step based on objective information provided to the decision maker by the tester. The decision maker will also receive information and recommendations from the full IPT prior to this decision.

3.5.5.1. **Test Information Supports Decision Making.** The tester provides information that supports development of answers to these questions: Was the test outcome satisfactory? Are test results within acceptable limits? If so, are results sufficient to demonstrate the desired level of maturity and increase confidence in the ability of the system to satisfy user requirements? Is the technical and operational risk identified with the performance measurements of the test at acceptable levels? Will user needs be met with these performance levels? Are exit criteria for the milestone decision satisfied? If yes, proceed forward. If no, the decision maker may direct that the program enter the improve-correct loop. In some cases, a new system falls short of expected results but provides significant operational improvement over the currently fielded system. In this situation, the decision maker may want to field the system while also proceeding with Step 6 to correct the problems.

3.5.6. **Step 6) Improve or Correct**. This is an action step. The following questions must be answered: What must be changed or refined? Who must take corrective action? If the system met or exceeded predicted performance objectives, do these objectives still represent the user's needs? This step includes any actions necessary to improve the space system design, correct a flawed test method, find and fix errors in models and simulations and other prediction methods, or improve/correct the test design to provide the desired information.

3.5.6.1. **Requirement Evolution.** Sometimes the system performs as well or better than predicted. Even then, the improve or correct step may be required to permit adapting the product to respond to changing user needs. Refinement of user requirements recurs throughout the acquisition process as we learn more about the system and as user conditions or requirements change. Responding to these user changes with cost effective changes to the system under test is essential if the end product is to meet user needs and not be obsolete before it is completed. Decision makers need timely information about the system under test that enables them to respond appropriately to indicated changes.

Chapter 4

SPACE SYSTEMS T&E PROCESS

4.1 Satisfying T&E Process Step Objectives. The objective of the test process is to satisfy the user's needs with a cost effective product. Verify that the product meets contractual and operational requirements (i.e. be operationally effective and suitable). This is done through a disciplined application of the plan-predict-test-compare philosophy throughout the entire life-cycle of the space system. Each step is described below in more detail.

4.2. Determine Test Objectives.

4.2.1. **Source Documents.** The first step of the process, shown in figure 3.2, is to determine the test objectives for the system. To accomplish this we refer to these source documents:

- Mission Need Statement (MNS)
- Operational Requirements Document (ORD) /Requirements Correlation Matrix (RCM)
- Concept of Operations (CONOPS)
- System Threat Assessment Report (STAR)
- Cost & Operational Effectiveness Analysis (COEA)
- Design and Performance Specifications
- System Maturity Matrix (SMM)
- Integrated Logistics Support Plan (ILSP)

These documents provide details on user requirements and the threats that may be encountered by the system once it is deployed. (Refer to AFI 10-601, *Mission Needs and Operational Requirements Guidance and Procedures,* for additional information on operational requirement source document development and content.)

4.2.2. **Deriving Test Requirements.** From these source documents, the developer, user, and test organization personnel (developmental and operational) which support the SPO's IPT derive detailed system specifications and determine test requirements for the system. The contractor needs to be advised of test requirements which require consideration during design as well as any specific T&E modeling and simulation (M&S) requirements, test article delivery requirements, or other contractor T&E support not yet fully defined.

4.2.3. **Test Objective Terminology.** The following accepted terminology should be used when stating T&E objectives:

- Evaluate **-** Test to establish overall worth (effectiveness, suitability, operability, supportability, adequacy, usefulness, capability, or the like) of a test item.
- Determine **-** Test to discover certain measurable or observable characteristics of a test item.
- Demonstrate **-** Exhibitions to reveal something qualitative or quantitative that is not otherwise obvious.
- Compare **-** A test for the purpose of perceiving likeness and difference in test items.
- Verify **-** An effort towards the confirmation of a suspected, hypothesized, or partly established contention.
- Collect **-** A test for collecting data.

4.2.4. **Test Program Content.** This first step of the process is also the start of early test planning. The level and amount of planned testing may vary from system to system. Many space systems are one of a kind, indicating a different test program from systems where the production phase produces several of an item or product (Refer to MIL-STD-1540C, *Test Requirements for Launch, Upper Stage, and Space Vehicles,* and DoD-HDBK-343, *Design, Construction, and Testing Requirements for One of a Kind Space Equipment,* for guidance on testing space systems in general and one of a kind space systems in particular). In addition, many space systems are acquired using as incremental acquisition strategy. Operational testing of these systems may require an incremental test strategy to assess and evaluate the system against incremental requirements as stated by the user. Reliability tests/demonstrations (growth, qualification, and acceptance) and maintainability demonstration are contained in Department of Defense Instruction (DoDI) 5000.2, Part 6, Section C, paragraphs 3.g & h. Reliability tests and demonstrations are contained in MIL-STD-785B, tasks 302, 303, and 304; MIL-STD-1543B, tasks 302, 303, and 304; MIL-STD-781D, tasks 202, 301, and 302. Additional guidance on growth testing can be found in MIL-HDBK-189. Maintainability demonstrations can be found in MIL-STD-470B, task 301, and MIL-STD-471A. MIL-STD-471A contains statistical test plans to utilize in maintainability demonstrations.

4.2.4.1. **One of a Kind Systems.** Often, with one of a kind systems, the cost of additional system level testing exceeds the marginal value to be gained by conducting the tests. Additionally, with launch vehicles and spacecraft, the ultimate performance of the system cannot be tested before hand. Verification tests on components and subsystems must be sufficient to give the decision maker a certain expectation of success the one and only time the system is to be used. In view of recent Office of the Secretary of Defense (OSD) directives concerning elimination of Military specifications, increased reliance will be placed on the judgment of the contracting parties, i.e. the Government and the contractor, as to the types and amounts of tests necessary. Contractor qualification testing must be performed adequately. MIL-STD-1540C and DoD-HDBK-343 provides tailoring guidelines and recommended contractual language to address these and other test related contractual and technical considerations.

4.2.4.2. **Software Elements.** Most space system acquisitions have software elements. DoD STD 2167A, *Defense System Software Development*, establishes uniform requirements to be applied throughout the software system life cycle including software T&E during acquisition. Software development has consistently been adversely impacted by the evolution of user requirements during the development phase and minimal early software test planning. Developing and implementing cost effective software solutions to user needs requires early and continuous interaction between the developer and the user. The tester can facilitate this interchange by focusing both user and developer on the translation of user requirements into testable solutions. Adequate DT&E must be done to identify and correct any and all software system deficiencies which decrease operational effectiveness. Software test plans and procedures should be developed early in the acquisition process and not be left until the end of the development contract when adequate resources may not be available.

4.2.5. **Test Support Requirements.** When preliminary test concepts are being developed, it is prudent to identify potential sources of needed test program and process implementation support capabilities. If you have not already done so, this is the time to contact the Space SFTC office and request their assistance. The Space SFTC will be a key member of the initial SPO's IPT and will provide early test planning expertise. The SFTC will recommend an appropriate Responsible Test Organization (RTO). The RTO, when selected by the SPO, will assume test planning responsibilities and the SFTC will continue to act in an advisory capacity in support of the IPT and will help obtain needed test capabilities that are not currently available. (See attachment 2, A2.1 for information on the role of the SFTC for Space in test process implementation.)

4.2.6. **Output from Step 1.**

4.2.6.1. **Documents and Products.** Documents and products that will be developed from this step of the process include:

- Test and Evaluation Master Plan (TEMP)
- Integrated Logistics Support Plan (ILSP) Update if already initiated
- Modeling and Simulation Capability; Digital System Models (DSM), if cost effective, other prediction tools as appropriate
- Test and Evaluation Record (Define Requirements)
- Information required to develop detailed test plans

4.2.6.2. **Focused Test Scenario.** To further define test objectives, a mission scenario with a confidence interval must be specified (e.g. Evaluate the accuracy of a missile against a specified target in a defined set of environmental conditions within specified parameters with an 80% confidence). The definition of acceptable risk varies with the circumstances and is keyed to the ultimate penalty due to a system or component failure. If a system failure means a mission failure or loss of human life, then acceptable risk implies a very high confidence in a very low risk factor. If system failure results in a temporary inconvenience, then medium confidence in a moderate risk factor may be sufficient. T&E resources must be focused to address the most critical areas of system performance risk as determined by the user.

4.2.6.3. **T&E Record Establishment.** There should be a direct cross correlation done between user requirements, derived system requirements, test objectives and the defined test requirements developed to meet these test objectives. This cross correlation is a key permanent element of the T&E Record and should be developed now as a fundamental point of reference for the system requirements analysis process that will be on-going for the life of the program. Software analysis tools, if any, required to produce and maintain the T&E Record should be selected and installed at this time.

Note: Tools that will be helpful during this step are the Air Force Acquisition Model (POC: ASC/CYM, DSN 785-0423), Automated Test Planning System [POC: OUSD(A&T)/DT&E, DSN 225-4608] and DoD 5000.2-M, Part 7, TEMP Preparation.

4.3. Pre-Test Analysis. Once the test objectives have been identified and the initial test planning completed, you need to determine exactly what will be measured for each objective and how it will be measured. The appropriate test methodology must be selected and specific objectives, measures and criteria determined. Test scenarios and support options must be developed and evaluated for feasibility and cost effectiveness. The venue for a test will be largely determined by this evaluation of options.

4.3.1. **Test Definition.** Pre-test analysis is used to predict the results of testing, expressed in terms of events that will occur, and to predict values for system performance and technical performance parameters. The System Maturity Matrix (SMM) should be a primary reference for understanding what the expected capabilities and levels of performance of the system are to be at the time of the test. Pre-test analysis is also used to determine test conditions and sequences. Modeling and simulation are used where appropriate to predict system performance in the test environment.

4.3.2. **System Performance Prediction.** Pre-test analysis can provide early projections of system effectiveness and can reduce testing costs by supplementing actual test data. Analysis techniques are also required to assess those areas where system capabilities cannot be directly observed through testing (such as resistance to and recovery from effects due to nuclear scintillation) or when a test is not affordable. The pre-test analysis should be coordinated with the test effort to ensure that the analysis and tests are mutually supportive. Analysis can identify critical areas for testing and test results can provide parameters needed for further analysis and to validate analysis results. In other words, pre-test analysis is iterative in nature.

4.3.3. **Technical Test Questions.** Questions that should be addressed are: How to design the most cost effective test scenario; How to set up the test environment; How to properly instrument the test articles; How to man and control the test resources; How best to sequence the test events to minimize impact on the environment; And how to predict the outcome values for each of the objectives. By performing this analysis a better understanding of uncertainties can be achieved, resulting in a test program that will find problems and provide the required data for decision makers. Modeling and simulation tools can aid in this effort.

4.3.4. **T&E Support Planning Resource Capability Analysis.** One outcome of the pre-test technical analysis could be the discovery that test resources capable of accomplishing the desired testing are not available. In that case, the Space SFTC office can help identify alternatives or, if no acceptable alternative can be found, assist with developing needs and solutions for input into the Test Investment Planning and Programming (TIPP) process to obtain funding for development of the necessary T&E capability. This can take a significant amount of time and must be addressed as early as possible to avoid impacting your schedule.

4.3.5. **System Design Functional Performance Assessment.** Analytical methodologies are used to assess the performance of as many system functions as possible prior to testing. Individual equipment design parameters are used in the analysis to predict system performance when the equipment is integrated into an operational system. When the analysis shows that the current design will not support the system performance requirements, the equipment parameters can be varied in the analysis to optimize the system design. The information obtained from these pre-test analyses is utilized in changing the system design to meet the system specification requirements. This methodology promotes efficiency in the testing program by identifying equipment that would otherwise cause system failure to meet test performance requirements and would therefore need to be re-tested following a design change. Also, it has been found that for most systems, fewer tests need to be run because some of the system functions have been thoroughly evaluated in the pre-test analysis.

4.3.6. **Pre-Test Analysis Products.** When pre-test analysis is complete, the tester should have all of the specific information needed to conduct the actual test. Detailed test planning is necessary for test conduct to take place in an orderly and efficient manner. Substantial test planning is accomplished in the previous step, Step 1 (figure 3.2), when user requirements are translated into test objectives. In Step 2, pre-test analysis, test methodologies are selected to address the specific areas of performance uncertainty articulated in the test objectives developed in Step 1. Early test emphasis is placed on the areas of uncertainty to identify problems so improvements can be incorporated early and at lower cost. When specific test activities have been identified, conceptualized, and priced, the best options are selected and detailed planning documentation is developed. Safety, security, and environmental documentation also need to be developed and completed before the test step.

4.3.6.1. **Detailed Test Plans and Procedures.** Detailed test plans document the roles and responsibilities of participants as well as the test steps and methods, resources required, sequence and schedule. Supporting test procedures are also developed and rehearsals are conducted as necessary to verify procedures and train test personnel.

4.3.6.1.1. **Contractor Support Definition.** For programs already on contract, refer to the statement of work (SOW), Contract Data Requirements List (CDRL) and Data Item Description (DID), then work with the contractor and Government test organizations (developmental and operational) to understand planned testing and further define specific Government involvement. Contact the SFTC for suggestions and best practices if this area is still being defined on the contract.

4.3.6.1.2. **Test Plan Content.** Different types of system testing have their own individual goals when implementing this step of the test process. Rocket Systems Launch Program (RSLP), which has been developing and testing boosters and reentry vehicles for many years, has developed extensive program specific test guidance. These tests involve multiple participants in the end-game intercept scenario and require coordinated planning and detailed test plans and procedures. A sample list of the minimum contents for such a test plan, as provided by RSLP, illustrates the level of detail needed. The test resource plan (from AFOTEC) or its equivalent details resource requirements.

Detailed Test Plan (DTP) or Test Procedure Content:

1. Specific objectives to be satisfied during test conduct.
2. Success criteria against which test results are to be compared. (e.g., Interface Control Document requirements, mission performance requirements, design loads and environmental constraints.)
3. Test prerequisites and constraints (safety, security, environmental).

4. Test configuration. Includes a detailed description of the test article and its differences from the flight, or operational configuration. In addition, descriptions of each test set-up are required to identify test facilities, personnel, support equipment, instrumentation, test article, and support equipment interconnections.

5. Test methods and test tolerances, as required, to accomplish test set-ups, pre-test checkouts, monitoring during the test event, and post-test checkouts.

6. Special requirements, such as instrumentation to record test critical parameters: Describe sensor types, installations, signal conditioning required, ranges and calibration methods, recording methods, and data reduction requirements.

7. Support documentation references.

8. List of hardware, software, and services required by each agency to support the test.

4.3.6.1.3. **Data Acquisition, Handling, and Analysis Plan.** The primary purpose of a test is to collect the data needed to determine whether test objectives have been met. The management of the data collection effort should leave nothing to chance. Data management includes all the data acquisition, handling, processing and analysis tasks required to fulfill test data requirements. This starts with planning for acquiring and collecting the raw test data, converting it to specified engineering units, processing it, analyzing and validating the data, and finally getting it to the analysts, engineers and any other users on the specified medium and in the desired format on schedule. Tests are conducted to obtain data. If the needed data is not obtained in a usable form, the test is a waste of resources. In cases where a test is a destructive one or one which places the test article beyond affordable means of recovery, and if the system under test is also one of a kind (often the case with space systems), failure to obtain the needed data is devastating. For such situations and when complex or integrated testing is planned, it is recommended that a Data Acquisition, Handling and Analysis Plan (DAHAP) be developed to fully document data requirements and responsibilities in addition to , or as a subset of, the test plan. Government test organizations can provide useful assistance in data collection management.

4.4. Test. The test execution step, as shown in figure 3.2, focuses on test conduct. Tests are conducted in six general categories of T&E resources as described in AFI 99-103. For space systems, these T&E resource categories are described in chapter 6 and major resources are listed in attachment 3 of this manual. Each category has its role in space system testing.

4.4.1. **Readiness.** By the time you reach this step, you will have selected the venue, delegated test responsibilities to participating organizations, and finalized any necessary support agreements and documentation required by supporting test organizations and facilities. Detailed test plans and procedures will have been developed, coordinated and implemented. Rehearsals will have been conducted, both to validate procedures and to familiarize personnel with any unusual or complex aspects of test support requirements.

4.4.2. **Test Execution.** Conducting a space system test that involves only ground testing is quite different from a flight test of a ballistic missile or space launch vehicle or the on-orbit testing of a space system. Each type of test has its own set of associated tasks which will have been assigned in the detailed test plan and described in the detailed test procedures developed in step 2.

4.4.2.1. **Test Observation.** When testing is being conducted by the contractor, Government personnel observing the test must be familiar with the test procedure and expected results. Government observers must understand their role in the test and what to do if procedures are not followed. Government personnel must also know their role in a safety or environmental mishap or a security incident.

4.5. Evaluate and Report Test Results. At the micro level, data from individual tests must be analyzed and results evaluated in terms of individual test objectives. Where differences are found, evaluation must determine if the unsatisfactory differences are due to errors in pre-test analysis, flaws in test design, or failures in achieved system performance. A thorough evaluation of performance must take into account the maturity of the item or system under test and its relation to the developer's planned growth toward maturity. It is essential both to carefully evaluate individual test results and to monitor overall testing progress in order to maintain good management visibility.

4.5.1. **Comparison of Results with Predictions.** Results that exceed expectation must also be analyzed to determine the cause. Evaluation is not complete until all test results have been analyzed, and any differences between predicted and measured values have been resolved. At the micro level, input for this step is data from the prediction methodology (M&S or some other method, if appropriate) and test data. Output is a confirmation of predictions or an explanation of significant differences with recommendations for resolution for the decision maker. In this step digital system models and computer simulations or other predictions should be updated and a record of system performance provided for tracing satisfied objectives back to the original requirements. The appropriate supporting data should be retained for future reference.

4.5.2. **Identification and Reporting of Deficiencies.** System deficiencies identified during the previous Test action step as well as the Evaluate and Report step, will be documented and processed in accordance with AF TO 00-35D-54, section B. The Deficiency Reporting (DR) system provides a systematic way to report, investigate, track, and resolve problems. Test managers should consider providing incentives to contractors to adapt contractor reporting systems as closely as possible to the official AF TO 00-35D-54 system.

4.5.3. **Individual Test Reports.** At the micro level, test reports are developed for and provided to the test customer. That customer could be a small project office, a large system program office, or another Government agency. Test reports vary with the importance and complexity of the specific test. They may be specified as formal published documents, briefings for decision makers, quick look reports for immediate feedback, deficiency reports, or any other form and content required. Formal test reports are usually accompanied by a briefing directly to the decision maker. The report required may be a standard data product or require special development by the producer. The IPT must determine the most cost effective level of detail and formality. Test reports required from contractors are described in the DID specified in the contract.

4.5.4. **Tracking and Reporting Cumulative Test Results.** At the macro level, cumulative test results must also be evaluated and reported for use by various decision makers. For program milestone decisions, the cumulative results of testing to date must be evaluated in terms of system maturity goals established for the system. The tester must be able to provide an objective evaluation of the maturity of the system and support this evaluation by identifying satisfied (and unsatisfied) test objectives, and directly relating these to documented user requirements and the SMM interim values or other bases of predicted results.

Note: The test manager determines if the test demonstrated the objectives, insures test adequacy, and then makes a recommendation to the IPT which in turn makes recommendations to the decision maker. The acceptable risk decision is made by a decision maker with broader management responsibilities based on a number of considerations including satisfactory test accomplishment.

4.6. System Progress Toward Meeting User Needs. When the user, RTO, Government (developmental and operational) test organizations, contractor and SPO work together as active members of a well utilized SPO IPT there should be no surprises at milestone reviews regarding the level of a system's maturity as demonstrated to date by T&E activities. Well defined user requirements will have been addressed by clear test objectives and test results evaluated using well defined evaluation criteria. Individual test results will have been reported to the IPT and the overall test program results should provide a clear picture of system maturity growth toward meeting the user's documented requirements. On-going system requirements analysis is performed to maintain this overall test program visibility.

4.7. Improve - Correct. This is the all important feedback loop where corrective actions must be taken. If testing results are not as predicted, the cause can be the system design, the test method, unexpected environmental factors or flawed predictions. Analyzing test data to determine the cause of performance deviations provides the information needed by decision makers to decide on the next course of action.

4.7.1. **Revalidation of User Requirements.** At this point, it is necessary that unsatisfied requirements be revisited with the user. In many cases, the user may issue requirements that seem reasonable early in development. However, in early DT&E, the user may discover that the last 5 percent of the requirement accounts for 90 percent of the system cost. In this situation, the user may either revalidate the requirement or decide to trim the requirement rather than commit to the increased cost. There is nothing wrong with the test in this instance. It has provided the needed information to the decision maker. If the user revalidates the requirement, the IPT will need to determine what it will take to meet that requirement and whether resources available are sufficient.

4.7.2. **Feedback Maintains Process Integrity.** Consistent and early implementation of the Space Systems T&E Process provides information continuously to decision makers allowing them to focus resources on the areas which most affect successful system development and deployment. As development and testing of the product progress, predictions and measures of performance and effectiveness are verified and improved. Just as system design problems must be corrected by the designer, so must test design and implementation problems be corrected by the tester. Similarly, deficient models and simulations used in the pre-test predictions must be improved. Failure to respond to this feedback information in DT&E can invalidate future testing.

4.7.3. **Proper Timing and Integration of T&E.** Properly planned and implemented testing at appropriate times will provide needed objective information to decision makers to support acquisition milestones. Plan-predict-test-compare- then improve is repeated until the necessary level of system maturity is sufficiently demonstrated to justify proceeding to the next acquisition phase or until available resources are expended. Enough time and resources must be allotted in the high risk areas of a test program to provide for failures and retesting. Studies continue to show the high return on investment from adequate testing that is demonstrated by programs which have closely followed MIL-STD-1540 series recommendations.

4.7.4. **Prioritizing Corrective Actions.** Per AFI 99-101, *Developmental Test and Evaluation*, and TO 00-35D-54, the Program Manager/Single Manager (SM) is required to set priorities on all deficiency reports (DRs) for all Air

Force acquisition programs involving DT&E and OT&E. If the SM cannot correct or resolve all known system deficiencies before OT&E or defers any system capabilities past OT&E, the SM must list, prioritize, and analyze the impact of those deficiencies and capabilities. The SM does not make these determinations in a vacuum. The user and Operational Test Agency (OTA) should also be involved so that community-wide buy in on the relative importance and urgency of the fixes is achieved. The SM must also develop a plan for testing fixes and deferred capabilities after OT&E completion.

4.7.5. **Assuring Sufficient Confidence Levels Prior to High Cost Tests.** There is normally significant concurrence between DT&E and OT&E for what are often one of a kind high cost systems which must be launched or placed into orbit for final testing. Such systems should never be allowed to proceed with launch without very high confidence in system performance predictions. This level of confidence can be gained in part by conducting independent component through subsystem level tests at Government test centers as early as possible in the acquisition process.

Chapter 5

APPLICATION OF THE T&E PROCESS

5.1. DT&E and OT&E. The T&E process should be used for DT&E, OT&E and combined DT&E and OT&E and experimental systems. OT&E can be either an Initial Operational Test and Evaluation (IOT&E), Qualification Operational Test and Evaluation (QOT&E) or Follow-on Operational Test and Evaluation (FOT&E). The two basic but different approaches to developmental and operational testing are defined in DoDI 5000.2, Part 8.
The following comparison between DT&E and IOT&E shows the differences

Table 5.1. Comparison of DT&E and IOT&E Characteristics.

DT&E	IOT&E
MEASUREMENT OF TECHNICAL PERFORMANCE	DETERMINATION OF OPERATIONAL EFFECTIVENESS AND SUITABILITY
TECHNICAL PERSONNEL	OPERATIONAL PERSONNEL
DEV AGENCY RESPONSIBLE	OT&E AGENCY RESPONSIBLE
PROTOTYPE DEVELOPMENT TEST ARTICLE	PRODUCTION OR PRODUCTION REPRESENTATIVE TEST ARTICLE
CONTROLLED ENVIRONMENT	OPERATIONAL ENVIRONMENT
OT&E PREVIEW	DT&E FEEDBACK
CONTRACTOR HEAVILY INVOLVED	CONTRACTOR INVOLVEMENT LIMITED TO OPERATIONAL ROLE

5.1.1. **DoD T&E Directive Implementation.** Title 10, United States Code, is the underlying mandate for the DoD 5000 series of directives. The 5000 series of directives establishes a disciplined management approach to DoD acquisition of systems that satisfy operational user needs. The separation of DT&E and OT&E provides for independent T&E by a designated Operational Test Agency prior to system acceptance by the user.

5.2. Combined DT&E and OT&E. For space systems which are to be launched or deployed into orbit, DT&E and OT&E are often combined out of necessity in a single test. When this is the case, separate test plans are developed and coordinated. Separate data requirements must be satisfied by the same, or combined, test activities and separate analysis of the data and reporting of test results are done by the responsible DT&E and OT&E organizations.

5.3. Test Program Determinants. Specific test process implementation action steps reflect the overall space system test program which is determined by both the **type of system** and the **kind of acquisition** being addressed.

5.3.1. **Space System Types.** Space systems are usually one of these four generic types: (1) **launch vehicle (LV)** used to place payload in orbit and **ballistic missiles**; (2) **payload** (systems placed in orbit); (3) launch range support equipment and resources; or (4) **ground based space support system or weapon system components** of a DoD space based or oriented capability, such as interactive payload command and control (C^2) instrumentation, ballistic missile defense elements or anti satellite weapon system elements. For each of these system types, there is a baseline set of functions to be performed by the system which must be addressed in system design and engineering and in the testing of the system. These four system types each have associated T&E process implementation actions that reflect the test programs normally conducted to verify and validate performance of these baseline functions, as well as any system unique functions, in the intended operating environment.

5.3.2. **Acquisition Variations.** The **kind of system acquisition**, and the **number of systems** to be produced also affect the scope and type of testing to be done to support decision makers and therefore the specific appropriate T&E process implementation actions and their timing.

5.3.2.1. **Acquisition Kinds.** The kind of acquisition refers to the intended use of the product system, either experimental or operational.

5.3.2.1.1. **Experimental Systems. Experimental** systems are normally acquired prior to the start of the formal DoD acquisition process (pre-milestone 0). Experimental systems may be produced by Advanced Technology Development (ATD) programs or Advanced Concept Technology Development (ACTD) programs. Technology Demonstrations are conducted to try out a system concept , collect needed scientific data, or both. Experimental systems may have an intended operational use. That is the case for ACTD programs which are intended to provide the operational community with an advanced technology application product to use and evaluate for operational utility. In most experimental system acquisitions, there are some aspects of the program (C^2 or launch for example) that are not truly experimental and which require the disciplined verification activities found in more formal T&E programs so that the experimental portion of the program can be accomplished in an orderly manner.

5.3.2.1.2. **Operational Systems.** For an operational system product, the acquisition phases and associated milestones which a specific system acquisition must complete are determined directly by whether it is a new system, a new use of an old system, a modification of an existing system requiring R&D effort, or a commercial off the shelf (COTS) enhancement of an existing system or COTS stand-alone capability.

5.3.2.1.3. **System Numbers.** The number of systems to be produced, one of a kind, few of a kind, or many of a kind, is the final factor determining the content of the test program and the specific test process implementation action steps.

5.3.2.1.4. **System Variations.** System acquisitions can vary widely. A wide variability of projects and acquisition programs use the Space Systems T&E Process. Guidelines for applying this process reflect accepted T&E best practices for the four main generic types of space systems.

5.4. T&E Resources. Different types of systems utilize different combinations of facilities and resources to accomplish different kinds of testing. The following diagrams show an overview of the usual resources and capabilities needed for space system T&E support. The Space Systems T&E Process is applied to four system types as shown in figure 5.1. Payload command and control of figure 5.3 applies to all ground based systems that perform system command and control functions for on-orbit space systems. The payload system diagram of figure 5.4 addresses payload T&E. Open air range and range support (figure 5.5) represent the key support elements required for the preflight test and deployment of all launch vehicle systems and payloads.

Figure 5.1. Space System T&E Addresses Four System Types.

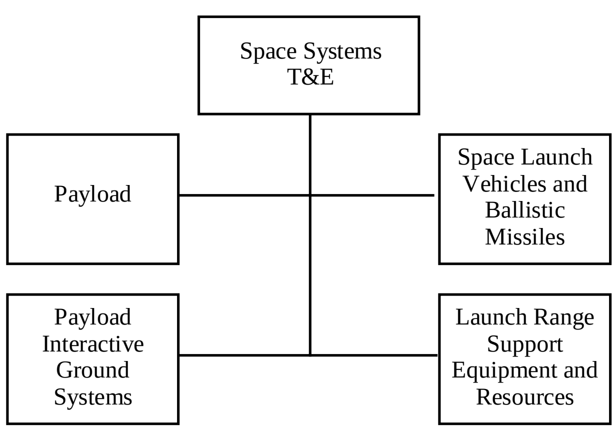


Figure 5.2. Launch and Launch Vehicle Test Elements.

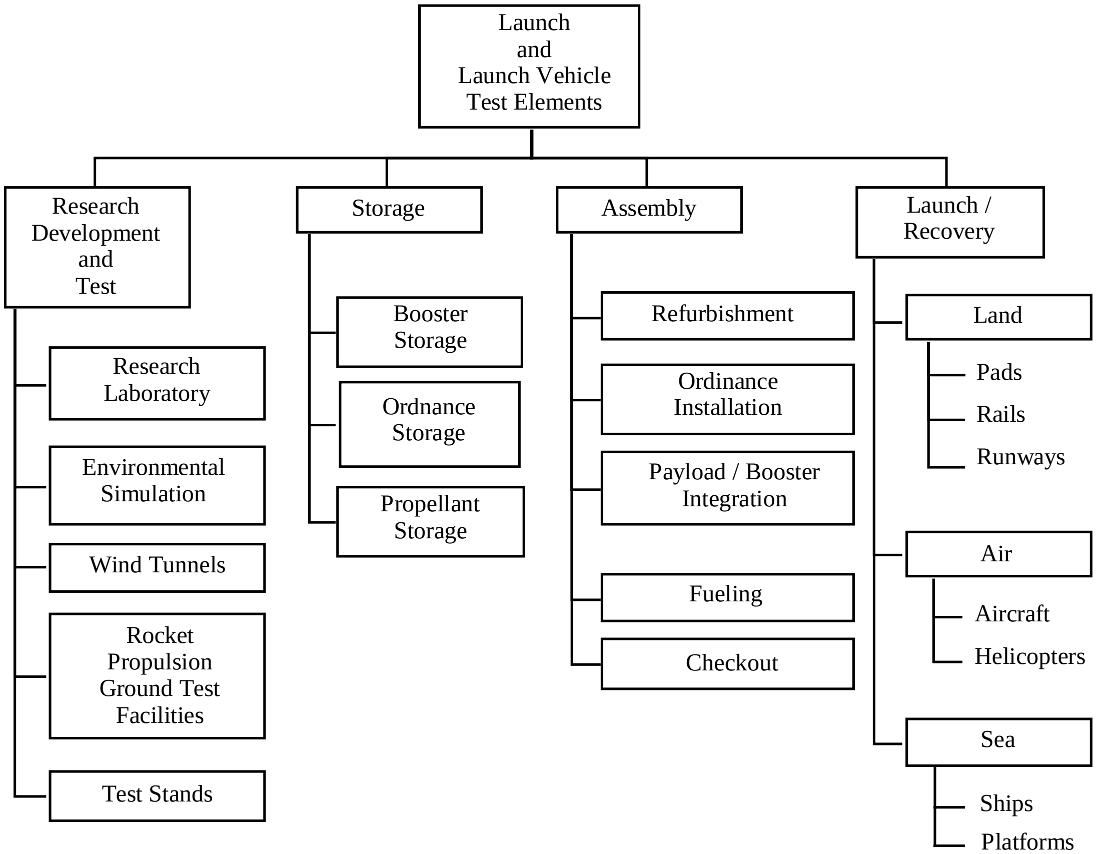


Figure 5.3. Payload Launch and On-Orbit Test Elements.

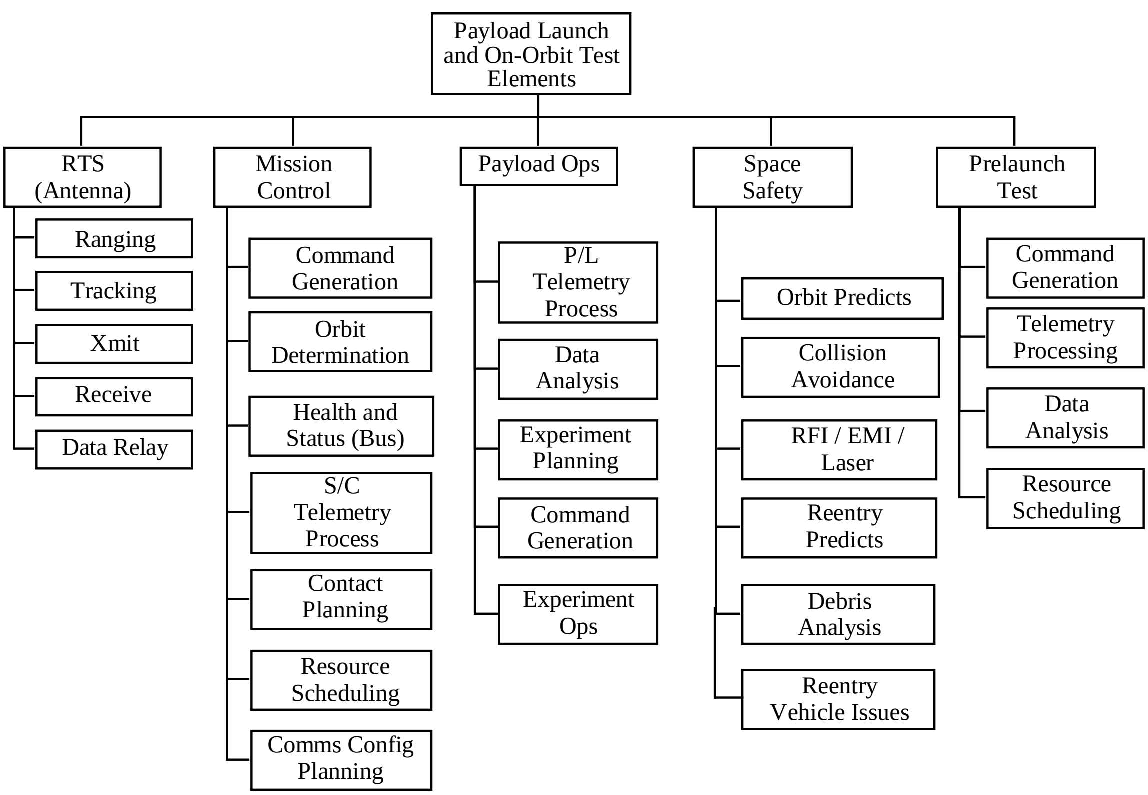


Figure 5.4. Payload System Development Test Elements.

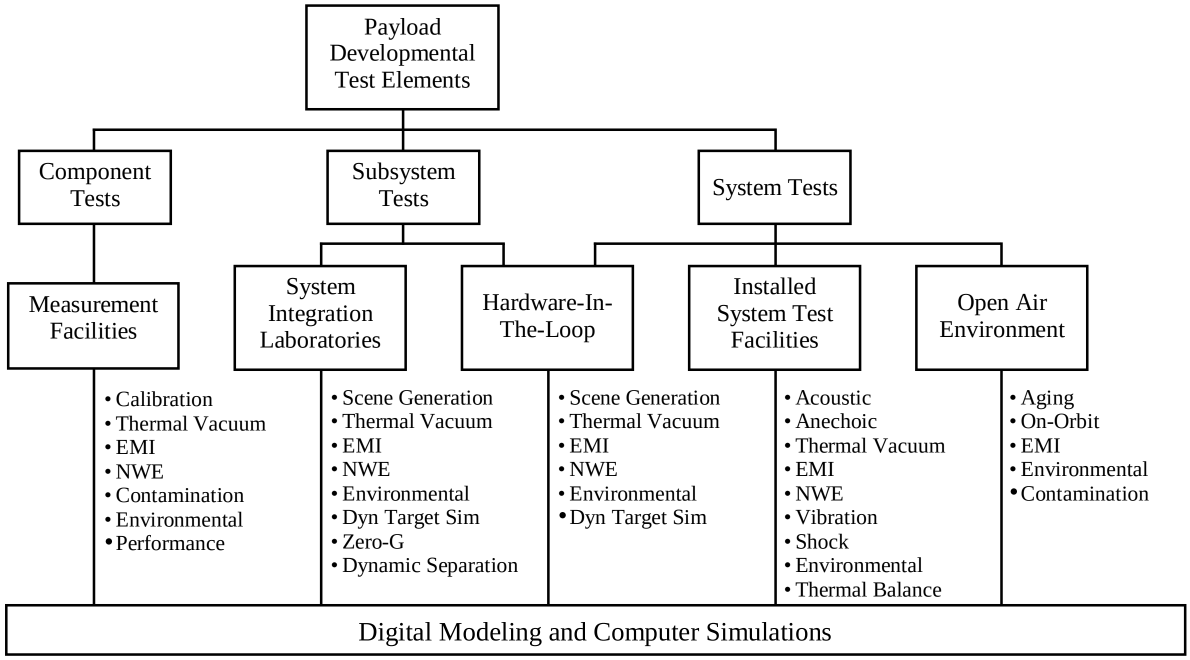
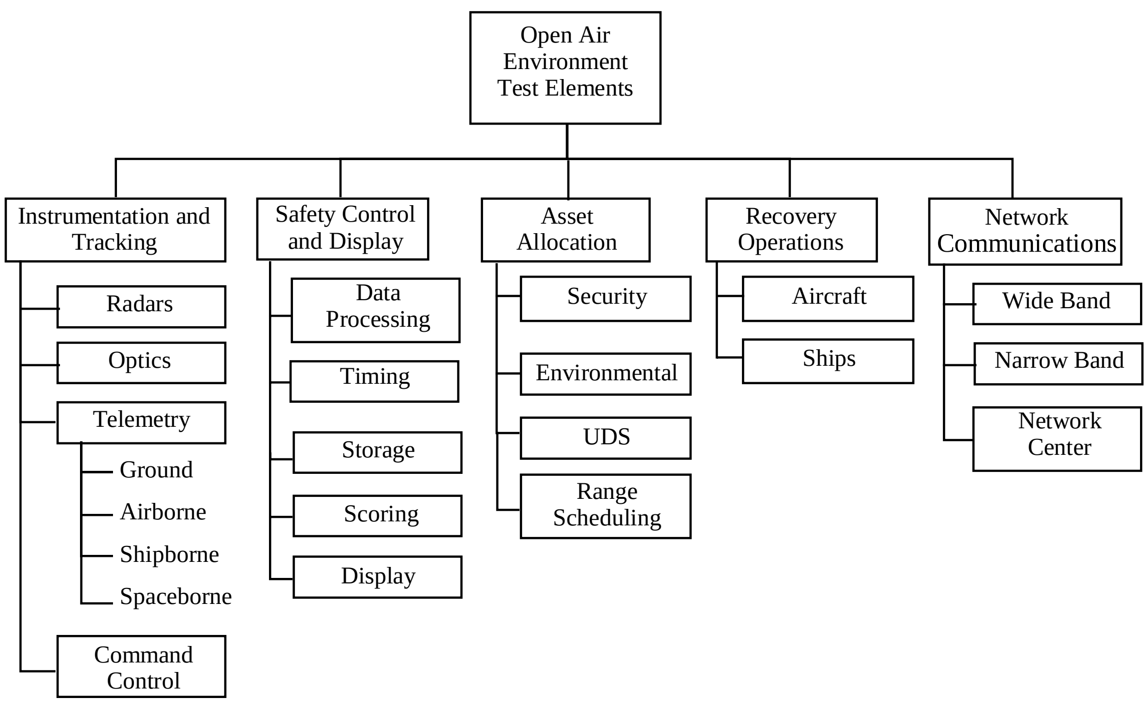


Figure 5.5. Open Air Environment Test Elements.



5.4.1. **Tools for Process Implementation.** There are software applications and supporting analysis capabilities that support test process implementation actions. They include modeling and simulation applications, system requirements analysis (SRA) applications and technical analysis applications. These tools are available from test organizations and test facilities, or from organizations specializing in model and simulation development and certification, to support implementation of the Space Systems T&E Process. These tools are used for the development of test objectives, pre-test analysis, test planning and conduct, evaluation and reporting of test results, and the improve-correct action steps. SRA tools support all of the process steps including decisions regarding system maturity by tracking the satisfaction of evolving user requirements as the test program progresses. A brief discussion of the kinds and uses of these tools follows.

5.4.1.1. **Modeling and Simulation (M&S).** T&E uses modeling and simulation (M&S) to assist in defining critical performance parameters, designing and focusing testing, and evaluating test results. M&S use by testers starts early during concept exploration and continues through OT&E; M&S applications can be used to assist in planning OT&E assessments and to selectively replace certain portions of resource intensive, high cost operational testing. M&S resources are also used to predict test results and to optimize test conditions. Specific Air Force responsibilities, procedures, formats and guidelines for Modeling and Simulation (M&S) are found in AFI 16-1001, *Verification, Validation and Accreditation,* and AFI 16-1002, *Modeling and Simulation Management.*

5.4.1.1.2. **M&S Application.** There is continual improvement in the ability of systems analysts to model and simulate the performance of complex space systems. Examples of current methods include the Test Thoroughness Index (TTI) and the Test Benefit/Cost ratio (TBC). The TTI refers to the thoroughness, in percentage, that components of subsystems and the subsystems themselves are tested prior to a final system test. For example, complete compliance with the applicable testing guidelines and requirements would result in a TTI value of 100. Experience indicates that more thorough testing at lower levels of assembly result in more reliable and successful tests at the higher assembly levels. Rework and retest at high levels of assembly, either for hardware or software, are costly and can largely be avoided through appropriate test planning. This is particularly important with spacecraft since testing sometimes must be accomplished on orbit where repairs are virtually impossible and failure analysis is difficult at best.

5.4.1.1.3. **Cost Effectiveness of M&S.** The cost effectiveness of a test can be quantified with the TBC. The numerator of TBC is the operational cost of a failure times the probability of the failure occurring if a certain test were not performed. The denominator is simply the cost of performing the test. A value of TBC above 1.0 would indicate that the test will most likely provide a cost savings to the program. Test effectiveness analysis is currently relating TTI with TBC to provide a quantitative systems engineering process much as reliability network analysis currently provides for long term system performance.

5.4.1.1.4. **Time-line Modeling.** Another area of importance is that of test time-line projection and statistical modeling of test processing. Large, complex systems such as satellites require different facilities, often remote from each other, for testing the various functions, often including the operating environments, that the system must provide. A probabilistic approach can provide a basis for risk assessment and help identify test schedule problems early in the testing process. Test time-line modeling is useful for calculating test costs.

5.4.1.2. **Systems Requirements Analysis (SRA).** In complex system acquisition programs, which evolve from experimental systems through concept definition and on to the formal acquisition process, the legacy of system requirement verification activities requires careful tracking in order to provide the AFMC Single Manager and other decision makers with a clear picture of the system's progress toward maturity.

5.4.1.2.1. **SRA Elements.** System requirement analysis encompasses three related efforts. These efforts include: (1) the derivation of system requirements from user mission operational requirements; (2) development of the documentation hierarchy that flows user requirements down through the supporting program documentation to verification documentation; and (3) the traceability of verification activities back to their origin in requirements as stated in source documentation. All of these efforts directly support decision making activities.

5.4.1.2.2. **SRA Tools.** The Space and Missile Systems Center (SMC) and Air Force Space Command (AFSPC) are currently establishing a common system requirements analysis (SRA) software tool set for use by all of SMC. SRA traceability tools are intended to add discipline to the creation of source documents, derivation of test objectives, tracking of evolving user and derived system requirements and evaluation of system maturity. Use of these tools will facilitate the identification of system requirements that remain unverified. SMC has identified candidate tools to support these needs. Traceability tools are used by analysts to create a comprehensive relational database capability for analysis of system requirements and system verification progress. They are intended to facilitate continuous management visibility into system maturity growth by tracking the progress of T&E activities and creating a permanent evolving record of requirements verification activities. POC for more information about these tools is the Space SFTC.

5.4.1.2.3. **Other Analytical Tools.** Developing test concepts that are both credible and affordable requires significant analysis of the relationship between system performance requirements, test objectives and test methodologies. Analytical tools are essential for understanding the value of alternative test methodologies and scenarios. Software applications that employ parametric analysis and other proven analytical techniques support the planning of well focused and cost effective tests. Test organizations and centers are continually developing and improving specialized analytical tools that support their unique T&E support disciplines.

5.4.2. **Test Organizations.** The Space SFTC is the initial source of T&E guidance for space system projects and programs and for obtaining space system T&E

support. Attachment 2, AF Space T&E Community, provides information about AF organizations that support space system test and evaluation. The SFTC for Space will assist you in obtaining early planning support and can be called upon at any time to help obtain needed information, expertise or other T&E related assistance.

5.4.2.1 **Air Force Space Command Test Offices.** Within Air Force Space Command (AFSPC), which is the operator, user, or both for many space systems, each of the four space wings (21st, 30th, 45th and 50th) and the 73rd Space Group maintains its own test office which serves as the focal point for OT&E conducted by, or for, the wing. These test offices implement USAF and AFSPC policy, establish its organization programs, conduct and support testing, and exercise other responsibilities. Wing test offices are manned by personnel trained and qualified to perform operational test and evaluation. In addition, each person is a resident expert in the mission area of the wing. A wing test office provides a test manager to act as the single point of contact and on-scene manager for each test program conducted at any wing unit. Wing test offices also ensure compliance with all applicable environmental regulations during T&E conducted by the wing. HQ AFSPC/DOTO, which serves as the AFSPC headquarters level center of test expertise, maintains an up-to-date list of wing test offices.

5.4.2.2. **Test Reports.** Output from test organizations and facilities will be data and information summarized in various test reports. Application of the Space Systems T&E Process is not complete until these reports are provided to various agencies and organizations. The implementing command should use the test results to support recommendations for design and development decisions. The user needs test results to determine if the system's effectiveness and suitability will meet their requirements. Decision makers need the results to determine whether to grant programs approval to proceed through each milestone. Major acquisition milestone decisions are supported by the information contained in formal DT&E, OT&E, IOT&E, QOT&E, and FOT&E reports. Operational assessments provide a comprehensive summary of testing conducted and an evaluation of the results in terms of measured performance as compared to test objectives. Details on these reports can be found in AFI 99-101, *Developmental Test and Evaluation*, and AFI 99-102, *Operational Test and Evaluation.* A number of other test reports are generated during the life of a program. One or more of the following reports is typically required:

- A complete and detailed Technical Report (TR) that summarizes the testing done, presents the results and may analyze the results and give recommendations. The TR is a formal report published a few months after test completion and is typically available to DoD organizations through the Defense Technical Information Center (DTIC).
- A Technical Letter Report (TLR) covers test areas of narrow scope and responds to near term concerns that need to be answered prior to completion of the TR.
- A Preliminary Report of Results (PRR) that is typically a briefing intended to present test results in a timely and concise manner.
- A Quick-look Report that may be an informal fax or phone call of information available at the completion of a test event.

5.4.3. **Test Facilities.** Space systems require the use of both ground test facilities and open air range facilities for DT&E and OT&E. These facilities develop and maintain capabilities used for planning test activities and obtaining the data and test information to prove performance, mitigate risk and demonstrate operational suitability. Make early contact with the Space SFTC to identify existing test facilities and assets that can be used. The SFTC will assist you in locating existing AF, DoD, other Government agency (NASA, Department of Energy (DoE), etc.) or commercial facilities that meet test needs. The Test Investment Planning and Programming (TIPP) process is the vehicle used to develop the T&E Mission Area Plan (MAP) which identifies deficiencies in current capabilities and future requirements. The MAP is developed by AFMC/DOR through inputs by the five mission area SFTC offices.

5.4.3.1. **Test Facility Resource Categories.** Test facility resource categories may include M&S facilities, System Integration Laboratories (SIL), Hardware-In-The-Loop (HITL) facilities, Installed System Test Facilities (ISTF), measurement facilities, and Open Air Range (OAR) launch and on-orbit test support facilities. The last category includes both the open air ranges which support space and missile launch activities and the facilities which support on-orbit test activities. There are multiple facilities within each category. Selecting specific facilities for specific space system T&E efforts requires knowledge of both the capabilities and the limitations of the specific individual resources and the resource category in general. This is discussed in chapter 6 in a generic way, with the most significant resources located at individual Government facilities listed in attachment 3.

5.4.3.2. **Utilization of Government Test Facilities.** Government test facilities must be used to the maximum extent possible. If a non-DoD test facility is needed, the AFMC Single Manager must include the requirement in the request for proposal (RFP) and explain in the TEMP why Government test facilities will not be used. Large programs have had a tendency to delegate space development testing to prime contractors, who formulated their own test process (with Government approval) and developed program-unique test facilities to carry it out. This practice has at times resulted in tests that did not address or adequately demonstrate key performance parameters, and data that could not later be compared with data from Government facilities. Single managers who are considering managing program risk by utilizing contractor in-house testing to provide schedule flexibility, reduce transportation requirements or to achieve other apparent time and resource savings should understand the potential adverse impact of such decisions on test process implementation objectives and proceed with caution.

5.4.3.3. **Government Test Facility Benefits.** The Space Systems T&E Process requires that test scoring criteria reflect operational performance requirements, and that pre-test predictions of system performance provide a means to statistically correlate test results from multiple test facilities. This enhances the integration of DT&E and OT&E, and yields the following additional benefits:

- Increased confidence in test results.
- Increased commonality in data products.
- More standardized data analysis and reporting.
- Reduced costs and shortened test schedules.
- Enhanced credibility in models & simulations.
- Maintenance of Air Force test capabilities.

5.4.4. **T&E Record.** An important part of implementing the Space Systems T&E Process is having a record of all T&E associated with each space system, with the budgets, decisions, and real reasons for the way the T&E was planned and executed.

- It is recognized that during the life cycle of a system, the program will evolve and change. User requirement refinement, technical considerations, schedule requirements, budget realities, facility constraints, and decision maker direction and redirection will impact the T&E of space systems.
- To record this history each space systems T&E effort is highly encouraged to establish and maintain a Test Process Archive (TPA). The TPA is a "permanent" record of information and documents that record all T&E efforts associated with a space system for the life of that system. It consists of the T&E Structure, Test Data Collected, Plans, Evaluations and Results, and Test Process Summaries as described below. This will greatly assist the task of writing the final test report at the conclusion of the project or program.

5.4.4.1. **T&E Structure.** The T&E structure refers to the hierarchy of documentation that supports development and execution of the space system test program. This part of the TPA is typically maintained at the SPO. This hierarchy of documentation includes all top level program management, systems engineering and test program documents; e.g. the MNS, ORD, CONOPS, STAR, PMD, ADM, TEMP, SMM, Threat Validation and Baseline reports, and Prime Item Development Specification (PIDS). In addition it includes the System Requirements Document (SRD), Technical Requirements Document (TRD) and any other non-test documents from which test objectives are derived and which support development of the space system test program. This hierarchy of documentation is used to develop an audit trail linking all test objectives including supporting COIs, MOPs, and MOEs, with documented user requirements. Traceability of test results back to documented user requirements depends on a coherent documentation hierarchy structure. All program documentation must be developed with attention to structure and content to support traceability needs.

5.4.4.2. **Test Data.** Test data includes all data products collected during a test including raw data. The kinds of data and the medium and format vary with the type, acquisition phase and level of maturity of the system under test. Data from contractor testing, Government conducted development test activities, and operational testing all yield different processed data products. The RTO and OTA maintain sufficient data to support reporting requirements and future analysis requirements. Major programs typically review and analyze test results for the life of the program and archive sufficient data to support future operational anomaly evaluations or aging comparisons. Such long term data retention requirements should be addressed as part of the T&E program. At a minimum, all test data will be retained for at least one month after results are reported. After this time period the test manager, with IPT approval, can designate the data to be retained and dispose of data no longer needed. Deficiencies in test data acquisition and processing capabilities must be brought to the attention of the SFTC and if no acceptable alternative can be found, addressed through the test investment strategic planning process.

5.4.4.2.1. **Satisfying Data Requirements.** Planning for the acquisition and handling of data and data products is key. The ability to obtain required data and produce required processed data products is an important consideration in the selection of a test facility or organization. Test data requirements must be clearly specified and understood by all parties in developing contract requirements and test support agreements. It is essential that detailed data requirements be identified clearly in contracts and in requests for test support. Care must be taken to produce only the data needed to satisfy test objectives.

5.4.4.3. **Plans, Evaluation and Results.** This is the record of the T&E information produced and includes the supporting technical detail of program or project test and evaluation program. It includes test program planning documents such as Digital System Model (DSM) information (including DSM definition and interface specification), predicted test results, test concepts, documentation supporting test process decisions, resource identification and selection process documentation, Universal Documentation System (UDS) and Memoranda of Agreement or Memoranda of Understanding (MOA or MOU) for test support, detailed test plans, data acquisition, handling and analysis plans (DAHAPs) and relevant documentation describing the testing conducted and all evaluations and reports produced with a record of distribution. Additional documentation describing how the test reports answer the test objectives questions with results and recommendations and how the results affected program decisions is also included.

5.4.4.4. **Annual Test Process Summary.** An annual Test Process Summary (TPS) will be generated by the SPO which records all DT&E and OT&E testing accomplished, key test process decisions, T&E deficiencies and identified risk areas. This summary will also list all documents added to the TPA during the year. The TPS is a record of testing, decisions, deficiencies, and risk areas which are not covered by the TEMP. Previous program audits have yielded no written record of test decision rationale. The format for the TPS is up to the SPO and can be included in the annual interim "End of Test Phase Report" called for in AFI 99-101, paragraph 7.6.

5.4.4.4.1. **TPA Implementation.** A suggested way to implement the TPA is to create files at the SPO for the TPA Summaries, T&E Structure and the Plans, Evaluations and Results. To address Test Data, you should develop a data management plan which identifies all test products and addresses resource requirements for automated test data tracking and analysis tools.

5.4.5. **System Maturity.** Typically T&E is accomplished as the design of a system matures from the concept level to component level, to sub-system, to system, to integration with other installed systems, and finally to the fielded system. The same basic Space Systems T&E Process steps are applied during each level of system maturity, whether it be contractor testing of components or the operational community performing IOT&E on a production representative system.

5.4.5.1. **Importance of the System Maturity Matrix (SMM).** The SMM, developed by the IPT at the inception of the program, documents the expected levels of system maturity to be achieved over time. Planned T&E reflects these expected maturity levels and test results are scored and evaluated using previously agreed upon and documented criteria to determine whether these predicted levels of maturity are in fact demonstrated by system performance during test.

5.4.5.2. **Specific Test Activities.** The specific space system test and evaluation activities that should be accomplished are described and explained in depth in the Space Vehicle Test training course. This course provides guidance on the application of relevant Military Specifications and Standards as well as overviews of the specific kinds of testing space systems require. This course is offered on an as needed basis to new Space and Missile Systems Center personnel and is recommended for anyone with space system T&E related responsibilities. Requests for the course should be directed to the SFTC for Space.

5.4.6. **System Architecture.** Complexity of T&E varies with system and mission architecture. The system architecture determines the hardware, software and communications design approach and resulting interfaces that will exist internally within the system being developed. The mission architecture determines the interfaces that will exist externally with other systems. (Paragraph C.4.1 describes the systems engineering process steps of synthesis and design that allocates functions to specific hardware or software.)

5.4.6.1. **Architectural Impacts on T&E.** Other interfacing systems may already be operational or their development may be concurrent. Both system and mission architectures also define any human user or operator interfaces and the overall operational concept. The external interfaces and overall operational concept determine system compatibility and interoperability considerations. The internal system architecture also determines the design approach taken for form and fit of components, subassemblies, and assemblies within the integrated system. The limitations placed on weight and volume, the need to create and preserve extreme internal temperatures and levels of cleanliness, or the presence of potentially hazardous materials may restrict the ability to access installed subsystems to perform testing.

5.4.6.2. **Space Environmental Extremes.** The extreme conditions present in the space environment and the high cost associated with placing space systems in orbit require that launch vehicles, spacecraft, missiles, ground systems, command and control systems, and related on-orbit test interfaces be thoroughly tested prior to placing a system in the space environment.

5.4.6.3. **Testing Strategy.** Each type of space system presents a unique set of strategic test and evaluation planning considerations. The ability to test these systems at the component, subassembly, assembly and system level and to test internal and external interfaces must be designed into the system during development to ensure system testability on the ground, during launch, and on-orbit.

5.4.6.3.1. **Consistent Test Process Implementation.** Application of the test process at the component, subassembly, assembly, subsystem and system level and to the integrated system ensures that adequate testing is performed early and on the ground to verify that system compatibility and interoperability objectives will be met. Compatibility and interoperability objectives must be met for on-orbit DT&E and OT&E to be accomplished.

5.4.6.3.2. **Space System Test Standards.** MIL-STD-1540, *Test Requirements For Space Vehicles,* and MIL-HDBK-340, *Application Guidelines for MIL-STD-1540B*, provide guidance for space system component, subassembly, assembly and system level testing. MIL-STD-1540C, *Test Requirements for Launch, Upper Stage,* *and Space Vehicles*, represents the latest revision of MIL-STD-1540 and reflects three major changes: broadened scope to explicitly include test requirements for launch vehicles and upper stages; incorporation of lessons learned from the use of 1540B; and an effort to reduce testing costs where possible.

5.4.7. **T&E Process Supports Diverse Decision Maker Needs.** The way space system T&E is viewed changes with organizational perspective. Congressional and OSD staffers have different interests and objectives. Further, an Air Staff action officer would have different responsibilities and information requirements than a manager in a program office or a test engineer in a responsible test organization. Regardless of a decision maker's point-of-view, the same Space Systems T&E Process is intended to provide the needed data and information from the micro-level of the engineer to the macro-level of Congress.

5.4.8. **Value Added by Implementation of the T&E Process.** In addition to meeting the primary objectives of paragraph 1.4, the Space Systems T&E Process with its extensive use of modeling and simulation provides opportunities for more productive ground, launch and on-orbit testing, better integration of DT&E and OT&E, and better correlation of data produced throughout the life of a system. These, and the benefits described in the paragraphs that follow, allow for constant information feedback for system development and improvement.

5.4.8.1. **High Confidence Prior to Launch.** The Space Systems T&E Process uses a scientific plan-predict-test-compare approach to space system test and evaluation. Rigorous ground testing is typically done before a space system is launched to permit high confidence in launch and on-orbit performance. High cost ground tests are performed only after less costly preliminary testing indicates readiness. Simulations are used to predict ground and flight test results and tests are developed to address the most stressing points in the required performance envelope. Ground tests that address these points are then designed, planned and conducted, differences analyzed, and if appropriate, deficiencies corrected. Once thorough ground testing is successfully completed, launch and on-orbit testing apply the plan-predict-test-compare approach to the deployed system to accomplish those test objectives that require testing in the "open air" or space environment.

5.4.8.2. **Improved Integration of DT&E and OT&E.** The OT&E community is often prohibited from using DT&E results because of contractor involvement. Starting the OT&E program from scratch, besides being expensive, is not in accord with an iterative process based upon prediction and feedback. Integrated DT&E and OT&E, as encouraged by DoDI 5000.2 when cost and schedule savings can be achieved, has always been essential in space system acquisition. The high cost and resulting relatively low number of flight test articles has historically provided no other affordable options. Given that the Space Systems T&E Process provides an audit trail from test criteria back to operational requirements, operational testers can use portions of Government development test data to evaluate initial operational performance and thus concentrate their efforts on verifying performance at the mission and task level. The system TEMP can reflect an integrated T&E strategy in which operational test builds upon development test in such a way as to avoid repetition.

5.4.8.2.1. **Successful Integration Depends on Planning.** If integration of DT&E and OT&E is to be successful, extensive early planning and negotiation must be accomplished to establish database management rules that will compartmentalize DT&E and OT&E data and develop assumptions for database input criteria for failures, test or no test, engineering estimate substitution criteria and other areas that affect the differing objectives of DT&E and OT&E. This prior planning and negotiation lays the necessary groundwork for successful cooperation during the final analysis and evaluation process. For joint DT&E and OT&E efforts the independence and data integrity that use of Government owned test facilities provides is especially important.

5.4.8.2.2. **Examples of Opportunities for Combining DT&E and OT&E Activities.** One example of how operational testers use developmental test data would be a space program in the engineering and manufacturing development phase of the system acquisition cycle. Prior to the start of Initial Operational Test and Evaluation (IOT&E), the Air Force Operational Test and Evaluation Center (AFOTEC) makes an Operational Assessment (OA) summarizing the operational issues addressed in the DT&E. Other examples include combining DT and OT for events that rarely occur, such as launch and orbital insertion, or testing system performance of functions that would be too costly, degrade system performance or reduce the satellite's lifetime such as testing the capability of a satellite repositioning system.

5.4.8.2.2.1. **Aging Surveillance.** The development of an Aging Surveillance (A/S) program also incorporates integrated DT&E and OT&E data. The A/S program analyzes critical performance parameters from tests of aged equipment to determine if those parameters indicate an aging trend. Critical performance parameters that will best indicate age are identified during component design and production. Zero time tests and measurements are taken and are used to anchor subsequent regression analysis performed throughout OT&E. Trends are evaluated against specific criteria to establish an estimate of when equipment will have degraded to the point of affecting system reliability. Aged assets are periodically tested and critical parameters are recorded. Regression analysis is performed on these parameters and the results of the analysis are evaluated to determine if any age degradation is present. If age degradation is indicated, actions are taken to confirm the degradation and logistics actions are taken (replace or modify the component) to preclude any significant reliability or logistic impact on the system due to an ageout condition.

5.4.8.3. **Improved Correlation of Data.** Historically, the correlation between early experimental test articles used in experiments and technology demonstrations and the data collected from these projects to systems entering the acquisition process has been complicated by an absence of comparability due to lack of data calibration and other measurement differences. This can be a huge problem if calibrations are omitted, if data is collected and processed using non-standard hardware and software, and if sites operate in unauthorized modes.

5.4.8.3.1. **Standardization and Discipline Assure Rising Confidence Levels.** The plan-predict-test-compare philosophy encourages use of digital models and simulations and detailed analysis to improve data correlation. Appropriate application of M&S and analysis techniques permit identification and elimination of fixed biases. The use of standardized data acquisition and processing techniques, emphasis on facility calibrations and test modifications that improve correlation all help improve correlation of data. Standardization and increased discipline must be implemented to ensure that test results from laboratory and contractor facilities are complementary. As this is accomplished both the amount of system knowledge and the confidence level associated with that knowledge rise early in the acquisition process and continue to increase with each stage of testing.

5.4.8.4. **Additional Benefits of Implementation.** Value added by implementation of the Space Systems Test and Evaluation Process is manifested in:

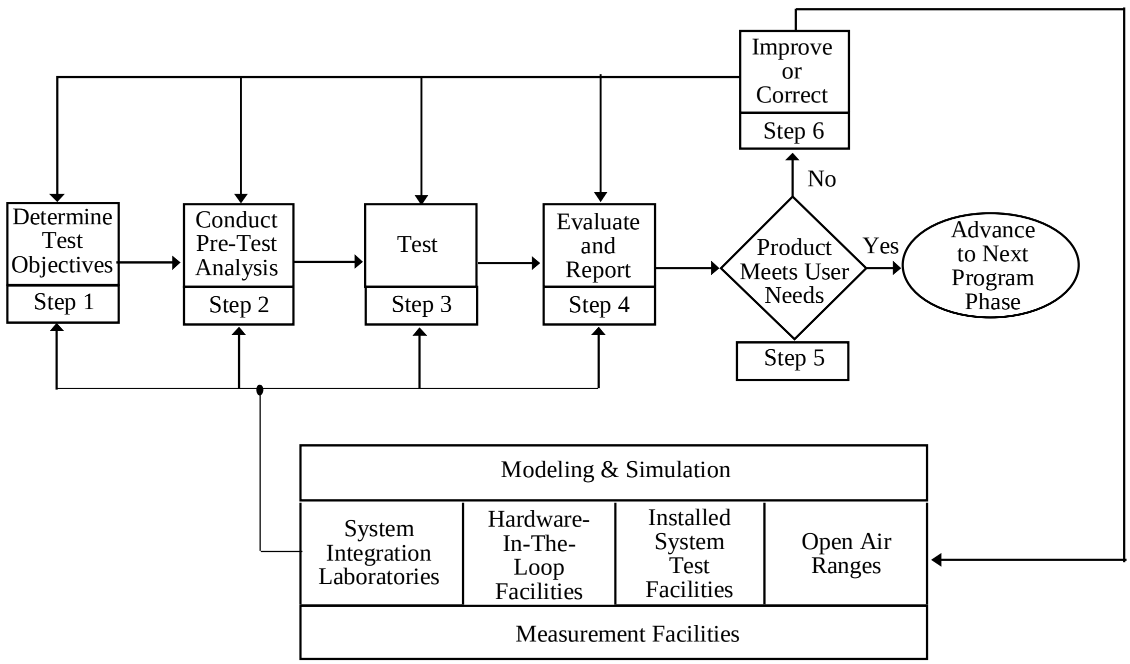
- Early and thorough evaluation of system concepts.
- Early feedback to the design process.
- The creation and evolution of test requirements through rigorous analysis and evaluation.
- The identification of performance parameters that are critical to operational effectiveness.
- Establishment of validated linkages between operational requirements and test criteria.
- Timely and credible test results to support milestone decision making.
- Closer ties among the user, systems engineering, test facilities and testers.
- Early identification of test capability deficiencies and timely acquisition of test assets.

Chapter 6

RESOURCES

6.1. Space Systems T&E Resource Categories. AFI 99-103 describes six general categories of T&E resources. These are M&S, Measurement Facilities, System Integration Laboratories (SILs), Hardware-In-The-Loop (HITL) facilities, Installed System Test Facilities (ISTF), and Open Air Range (OAR) facilities. Proper selection and use of these resources (facilities and organizational capabilities) are important parts of the Space Systems T&E Process. Most major test facilities have resources from more than one category. Figure F.1 shows the test category types and that the space systems T&E process is used for all test category types.

Figure 6.1. Resource Categories Support Space System Test Planning and Execution.



6.2. Modeling and Simulation (M&S). Digital and other models and computer simulations can be used throughout the life cycle of a space system. They support the identification and definition of user needs, the design and development of systems to meet these identified needs, and the development of a cost effective test and evaluation program. They are used throughout the acquisition process in the development and refinement of user requirements, the exploration of design alternatives, the actual engineering of the system and the development of required system manufacturing processes. Step 6 of the T&E Process should provide constant feedback for the development and improvement of M&S tools. Constant feedback is required to accurately represent the system under test.

6.2.1. **Understand M&S Resources.** The models developed and employed for one purpose may have other applications. It is important for the tester to understand the relevant M&S resources that have been created and are available for use in test and evaluation of a space system. In addition, the tester needs to determine what M&S resources need to be developed to support the test program.

6.2.1.1. **M&S Tools.** For the tester, M&S can play an important role in the determination of test objectives and in designing and selecting test scenarios which will yield the required test data. A system model (created and maintained by the developer) can be used in combination with models of the test environment to simulate test activities and predict test results. These models may be sophisticated digital models of a complete system and environment or less sophisticated analytical models that address only a portion of the system or test environment. Modeling and simulation can be a cost effective way of exploring the widest possible range of system and environmental parameters and their interactions. Modeling and simulation provide important tools for applying the T&E process. The following describes the kinds of models and simulation employed in the development, test and evaluation, and operational refinement of space systems.

6.2.1.2. **Engineering Models**. Engineering models support system design and engineering at the component, subassembly, subsystem and system level, as well as the development of manufacturing processes required to produce the system cost effectively. Engineering models may be digital (software) representations of a component, assembly, subsystem or the complete system (Digital System Models fall in this category) or process design or physical scaled or full size mock-ups developed to aid in the design and engineering process. They are used to quantify some or all of the physical characteristics and functions of the system or process.

6.2.1.3. **Test Article Models.** Test article models are models that represent identified significant performance capabilities and characteristics that are relevant to development of test concepts and scenarios. They reflect the level of system maturity demonstrated in contractor testing and other testing to date as well as expected performance capabilities which are to be demonstrated by the test. System test models are used in conjunction with test environment models to predict the performance of a specific test article and to plan cost effective tests.

6.2.1.4. **Test Environment Models.** Test environment models describe the significant parameters of the test environment including the physical environment and the functionally interfacing systems required for the test. Test environment models are used in conjunction with test article models to simulate testing and develop and refine test scenarios.

6.2.1.5. **Mission Models.** Mission models are used to represent the mission environment in which the user or operator is expected to perform an operational role. Mission models are used in building simulations of operational scenarios to identify capability deficiencies and to help develop and refine user requirements for systems. They are also used for developing simulations of responses to various wartime and peacetime mission scenarios.

6.2.1.6. **Mission Simulations.** These simulations permit the interaction of participants in a hypothetical operational mission scenario. The simulation varies in fidelity to the "real world" according to the validity of the models and the variables introduced by the developer of the simulation.

6.2.1.7. **M&S Key to Optimizing Test.** The test process uses M&S to assist in defining critical performance parameters, designing and focusing testing, and expediting system development. These uses all contribute to reduced cost. M&S is not limited to development testing. M&S applications can be used to assist in OT&E assessments and to replace certain portions of resource-rich operational testing. In the T&E process, M&S is used to predict test results, to optimize test design to stress the system under test appropriately, to maximize opportunities to collect needed information, and minimize high cost test activities.

6.2.1.8. **Digital System Models (DSM).** It is unlikely that a space system test program will have the resources or expertise available to develop a digital system model from scratch solely for test purposes. A digital system model that fully represents the test article may or may not be obtainable at an acceptable cost. It is likely that digital engineering models of the physical characteristics of components, assemblies, and subsystems of a space system will be developed and maintained by contractors for their portions of the overall system. These engineering models may be provided to an integration contractor and combined into a comprehensive model of the full system. These engineering models may require significant adaptation to be useful to the tester. The availability and utility of these models can be assured by the terms of the contract provided the tester knows what is needed and when.

6.2.1.9. **Selective DSM Use.** The tester may require development of partial system digital models that represent only key parameters of the system. Some system performance parameters to be considered for modeling are listed as critical system characteristics in the ORD and as critical technical parameters in the TEMP. The tester may also decide to model only some of the parameters of the operational or test environment. Some objectives of modeling a parameter or set of parameters are: safety footprints or limits.

- Defining safety footprints or environmental impact.
- To define test support and facility requirements.
- Test scenario definition and optimization.
- Selection of stressing test points (i.e., successful results would preclude the need for additional heart-of-the-envelope testing).
- Predict test results for each test objective.
- Depending on the complexity of the system and test requirements, the DSM could be as simple as a single number or as complex as a six degrees of freedom interface.

6.2.1.10. **Tailoring.** These modeling objectives must be tailored to the test program and specific DSM requirements identified. The first place to start is the COEA and if a computer simulation is required to meet your modeling needs the SFTC for Space will assist you in contacting the Headquarters Air Force Directorate of Modeling, Simulation and Analysis, AF/XOM. The table below summarizes M&S capabilities and limitations.

Table 6.1. Modeling and Simulation Capabilities and Limitations.

M&S CAPABILITIES AND LIMITATIONS	
What M&S Can Do	Allows a system design to be evaluated before any hardware is built Allows evaluation in environments that could not be simulated in a ground test facility or controlled in an open-air range May provide necessary flexibility, repeatability, and insight into results at lower cost that alternatives
What M&S Cannot Do	Predict absolute performance/effectiveness with high confidence Achieve the necessary degree of fidelity for some kinds of tests Simulate certain complex functions
What Makes M&S Unique	Only way to do T&E without hardware Only way to evaluate operational effectiveness at the mission level

6.3. Measurement Facilities. Measurement facilities measure the physical characteristics of space systems and advanced technology applications. There are a number of government owned measurement facilities available to support space system acquisition efforts (see attachment 3). The table below summarizes measurement facility capabilities and limitations.

Table 6.2. Measurement Facility Capabilities and Limitations.

MEASUREMENT FACILITY CAPABILITIES AND LIMITATIONS	
What They Can Do	Measure parameters which contribute to performance and effectiveness Test certain components/techniques to optimize design Acquire input data for models
What They Cannot Do	Simulate space conditions completely Evaluate fielded performance/effectiveness
What Makes Them Unique	Provides empirical data to characterize process which cannot be emulated accurately

6.4. System Integration Laboratories (SIL). SIL are facilities designed to test the performance and compatibility of components, subsystems and systems when they are integrated with other systems or functions. They are used to evaluate individual hardware and software interactions and, at times, involve the entire system software. A variety of computer simulations and test equipment are used to generate scenarios and environments to test for functional performance, reliability, and safety. SILs are generally system specific and are found in both contractor and Government facilities.

6.4.1. **SIL Uses.** SILs often employ a variety of real-time or near-real-time digital models and computer simulations to generate scenarios and multi-spectral backgrounds. These models are interfaced with brassboard, prototype, or actual production hardware and software of the systems under test. SILs are used primarily as part of the DT&E conducted during the demonstration and validation phase of acquisition and for supporting anomaly resolution activities. The table below summarizes SIL capabilities and limitations.

Table 6.3. System Integration Lab Capabilities and Limitations.

SIL CAPABILITIES AND LIMITATIONS	
What a SIL Can Do	Facilities integration using a building block approach Test static, open-loop performance at specific points in design envelope Provides a "baselined" environment in which hardware and software changes can be tested
What a SIL Cannot Do	Evaluate dynamic performance Evaluate system performance
What Makes It Unique	Test technical performance down to the component level in the controlled environment of a testbed

6.5. Hardware-In-The-Loop (HITL). Space HITL testing is done to provide repeatable measurements and verification of space system effectiveness. HITL testing should be done as early in the development process as possible, even if that means using a "brassboard" configuration. Too often preproduction hardware is developed late in a program, making identification and remedy of problems difficult. The table below summarizes HITL capabilities and limitations.

Table 6.4. Hardware-In-The-Loop Facility Capabilities and Limitations.

HITL CAPABILITIES AND LIMITATIONS	
What a HITL Can Do	Allows closed-loop testing Allows dynamic testing across the system employment envelope Simulates a validated and comprehensive environment Tests systems in an integrated configuration Allows man-in-the-loop interfaces Provides high flexibility, repeatability, and insight into results at medium cost
What a HITL Cannot Do	Test compatibility and interoperability Simulate all space environment aspects with high confidence
What Makes HITL Unique	Provides a way to evaluate system effectiveness prior to launch

6.6. Installed System Test Facility (ISTF). ISTF provide a secure capability to evaluate space systems that are installed on, or integrated with, host platforms. These test facilities consist of specialized environmental chambers, such as thermal-vacuum, anechoic, and wind tunnels, in which measurements are made during operation of the space system. The system under test is subjected to various stimuli and its responses evaluated to provide critical, integrated system performance information. The primary purpose of testing in these facilities is to evaluate integrated systems under controlled conditions that simulate various conditions found in the operational environment. Such testing is done to determine if any problems exist or to determine system reaction to the simulated environments. This ground testing can aid in isolating component, subsystem, or system problems not observable by other means but crucial to system checkout prior to launch. Failure to evaluate installed system performance adequately on the ground typically results in unsatisfactory performance at launch or in space. The table below summarizes ISTF capabilities and limitations.

Table 6.5. Installed System Test Facility Capabilities and Limitations.

ISTF CAPABILITIES AND LIMITATIONS	
What ISTF Can Do	Evaluates system compatibility with the host platform Provides pre-flight checkout capability Tests static performance of the integrated platform at specific points in the envelope
What ISTF Cannot Do	Dynamically test performance in a free-space environment Evaluate closed-loop performance in a free-space environment Evaluate effectiveness
What Makes ISTF Unique	Allows system testing on host platform under controlled conditions

6.7. Open Air Range (OAR). OAR test facilities are used to launch and evaluate space vehicle and spacecraft systems in dynamic environments. Typically these resources are DoD owned and operated test ranges such as the Western Range, CA, and Eastern Range, FL. Open Air Range space and ballistic flight test ranges are instrumented to provide data acquisition during launch. The Air Force Satellite Control Network (AFSCN) provides support for on-orbit operations. Additional on-orbit support capabilities exist at major laboratories and development centers. The primary purpose of open-air testing is to evaluate the system under real-world representative environment and operating conditions. To be credible, open-air range testing is used to validate system operational performance and effectiveness at a high level of confidence. The table below summarizes OAR capabilities and limitations.

Table 6.6. Open Air Range Capabilities and Limitations.

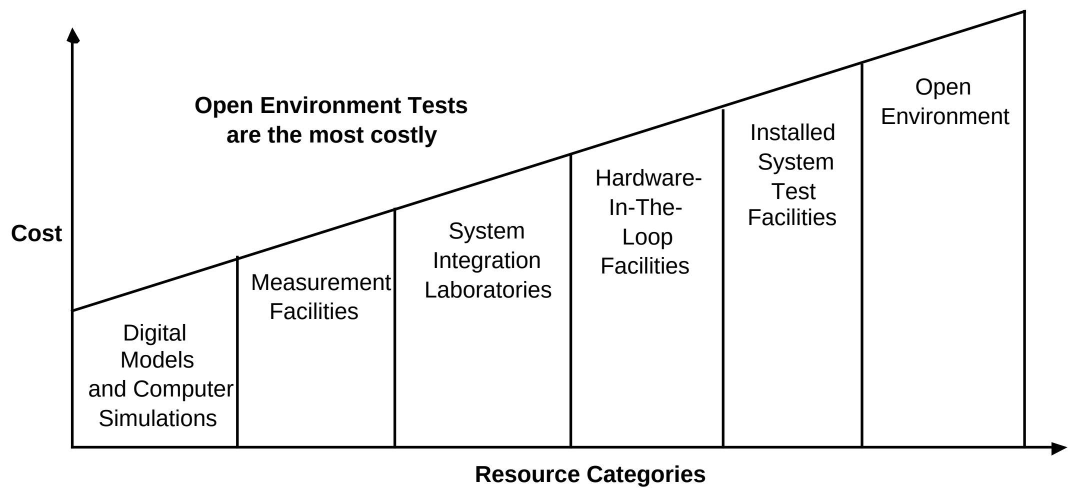
OAR CAPABILITIES AND LIMITATIONS	
What Ranges Can Do	Provides realistic flight environment Allows dynamic closed loop effectiveness testing at specific points in the performance envelope Calibrate/validate digital models
What Ranges Cannot Do	Achieve battlefield threat densities and diversities Provide flexibility, repeatability, or insight into test results Provide high cost-effectiveness
What Makes Ranges Unique	Only facility which provides access to space environment Provides high confidence necessary for production certification

Chapter 7

LIFT CYCLE

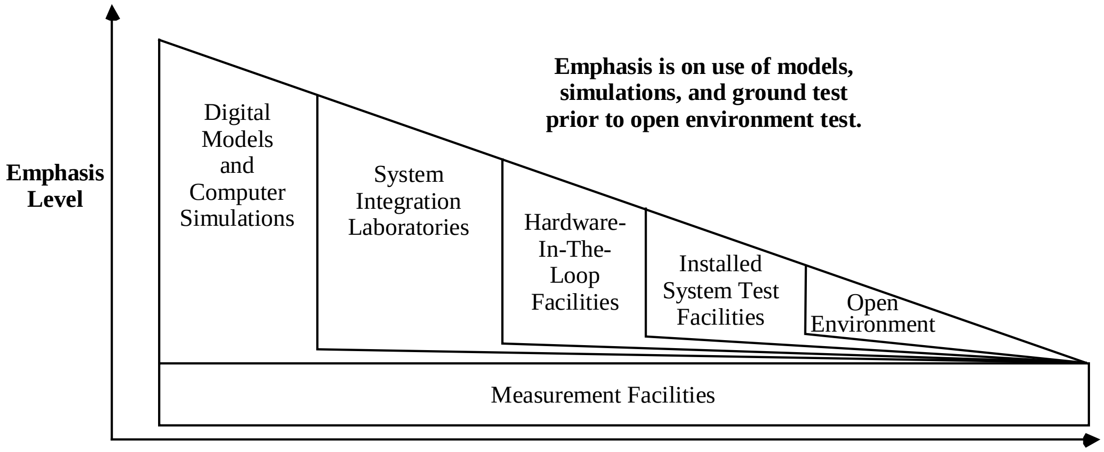
7.1. Space Systems T&E Resource Utilization. In general, the cost per trial or test point becomes more expensive as the testing moves to the right as shown notionally in figure 7.1. Emphasis on the use of models, simulations, and ground testing can reduce overall test costs by enhancing confidence in system performance prior to testing in the open environment, the most expensive type of testing.

Figure 7.1. Relative Cost of T&E Resource Utilization.



7.2. Relative Use. Due to the complexity of space systems and threat interactions, digital computer models and simulations can be used cost effectively to predict system performance under a wide range of progressively more rigorous ground and flight test conditions. Figure 7.2. also notional, shows that M&S and measurement facilities are used throughout the test spectrum. It also shows how the use of each of the different resource categories should decrease as the testing proceeds to the right.

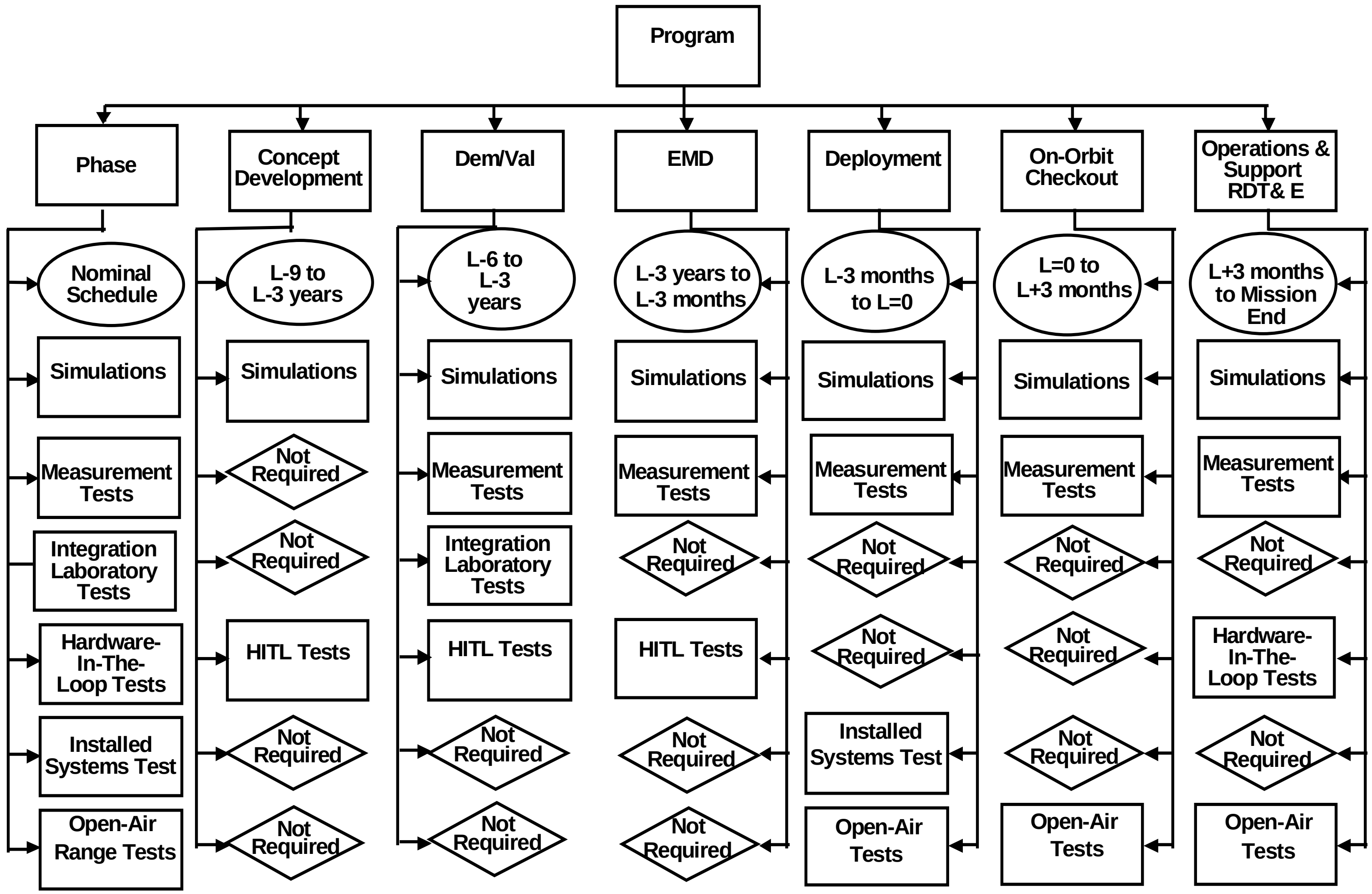
Figure 7.2. Relative Use of T&E Resource Categories.



7.3. Space Systems Life Cycle. Figure 7.3 shows the relationship of the six resource categories as they support the five phases of the acquisition cycle. Each category is used in more than one phase of the acquisition cycle. Regardless of the acquisition phase of the program, the same space systems T&E process (figure 3.2) should be used. Differences will occur in the amount of testing in each of the six categories. Early in the acquisition process, there is a concentration on ground-based controlled testing and testing that allows many repetitions at low cost, as in digital models and computer simulations and Hardware-In-The-Loop. While these resources continue to be used throughout the life cycle, as the system matures, increasingly complex system level and integration testing occurs including open air flight and on-orbit tests. Open air flight and on-orbit testing is required to determine if production and modified configurations of the system satisfy user requirements.

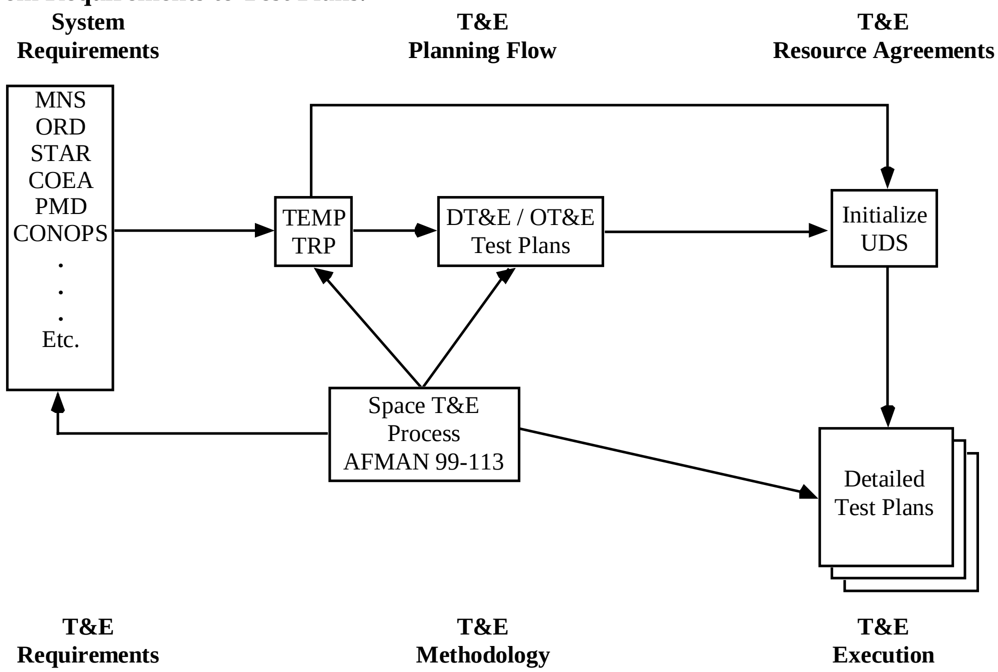
7.4. Resources and Agreements. Rarely will your T&E effort be allocated enough dollars, people, and equipment to do all the testing everyone wants done. You may be severely limited in resources and have to make many tradeoffs in the number of tests, kinds of tests, and test facilities used. Your Test and Evaluation Master Plan (TEMP) and subsequent revisions will document the result of these tradeoffs as your project or program proceeds through its system life cycle. The TEMP will also document how you have tailored and will use the Space Systems T&E Process. Your tailoring should be done to find a good balance between test requirements, available resources, and program risk.

Figure 7.3. Space Systems T&E Life Cycle (Notional).



7.4.1. **Requirements Flow.** As discussed in chapter 4, test plans will evolve from user defined Mission Need Statements (MNS), Operational Requirements Documents (ORD), other source documents and higher headquarters directives such as the Program Management Directive. A typical flow from user's need to tester's plan is shown in figure 7.4.

Figure 7.4. From Requirements to Test Plans.



7.4.1.1 Test requirements and resource requirements evolve and are defined through close coordination between the customer (user), System Program Office (SPO), the Responsible Test Organization (RTO), and other supporting Government test organizations as appropriate. The SPO lays out the T&E road map in the Test and Evaluation Master Plan (TEMP). The RTO and TPWG (which includes Government developmental and operational test organization personnel) assist in identifying and documenting specific test needs. For tests which may have stressing or difficult test support requirements, it is prudent to make early contact with potential test support organizations. This should be done as part of the preliminary test planning effort to explain the proposed test methodology and request assistance in developing test scenarios using available resources. Test facilities and ranges and their resident supporting organizations can provide invaluable expertise and assistance in this area. It is especially important to identify feasibility issues such as support capability deficiencies, environmental, safety or cost issues as early as possible in the planning process as these issues may require a great deal of time, effort and additional money to resolve.

7.4.2. **Universal Documentation System (UDS).** If the test is to be done at a major test range that is a member of the Range Commanders Council (RCC), test support requirements will be formally submitted using the UDS. This system formally documents the user agency test support requirements and the support agency capabilities and commitments to support those requirements. UDS documentation uses a common language and format to provide effective communication between the user and support agency. The UDS process is iterative and evolves over time to address user requirements and range support in increasing levels of detail.

7.4.2.1. **UDS Levels.** The initial Level 1 document for the Range user is the Program Introduction (PI). This should be prepared and submitted as soon as the scope and duration of the test activity is known. (There is a requested lead time of approximately two years if new capabilities are required to support testing. The UDS process can be expedited depending on the nature of support requirements and range resource availability.) The range will respond with a Statement of Capability (SC). When signed, the SC is evidence that the program has been accepted for support. Government resource requirements are developed and refined as these documents are generated. Detailed test plans are then prepared to further specify the tests that will be accomplished. Level 2 UDS documents specify program requirements in the Program Requirements Document (PRD) and the range responds with a Program Support Plan (PSP). Level 3 UDS documents are mission oriented.

The user submits the test Operations Requirements (OR) and the range prepares the Operations Directive (OD) which is the detailed plan for implementation of support functions for the specific test or series of tests. Level 3 UDS documents should correlate directly with individual detailed test plan and test procedure content. The UDS process is accomplished using a standard electronic format (available on disk) which is described in the UDS Handbook and can be obtained from the RCC.

7.4.3. **OT&E TRP.** For OT&E, a Test Resource Plan (TRP) is used as a resource planning and management document. The TRP provides the means for programming all resources to support an OT&E. The Operational Test Authority (OTA) prepares the initial TRP and continues to maintain it following PMD approval. TRPs are updated continuously as programs and test schedules change to reflect the most current status of requirements.

7.4.4. **Formal Agreements.** The above documents are formal agreements between program or project office and the Government organizations that will execute and support the T&E effort. You should ensure the Space Systems T&E Process methodology is being used for the philosophy and development of your TEMP, DT and OT plans, and individual test plans.

7.5. Contracts and Contractors. The test program proposed by the contractor is not a substitute for the Government test program. It is incumbent on the Government to determine the content of the overall space system test program including both contractor testing and Government test and evaluation activities. Contractors must abide by the Space Systems T&E Process as you have tailored it for your project or program. You may need to direct your contractors and suppliers to use certain Government facilities and equipment and produce certain test data and reports. It is vitally important to have your contract say what you want your contractor to do. Ask yourself frequently, "What does the contract say?" Plan early-on to get the contract written or amended to contain the provisions needed to integrate the contractor's effort into the overall T&E effort. What the contractor is to do and what the Government is to do must be unambiguous, on contract, and well documented in your lower level test plans.

7.5.1. **T&E Related Contractual Direction.** Any tasks you want the contractor to accomplish such as participating in test planning working groups (TPWG), modifiying a digital system model , or providing data for a test process archive, must be included in the contract. Any test articles required prior to system delivery must also be identified. If you plan to use a contractor's deficiency reporting system, ensure it is compatible to the government's report system. Also, you should also plan to use Government test facilities and resources when possible. You do not want to have a contractor build and equip facilities that unnecessarily duplicate Government facilities that exist or could be readily modified to meet your needs.

Chapter 8

SELF EVALUATION CHECKLISTS

8.1. Self Evaluation Checklists for Process Application. Affirmative answers to the following questions will tell you if you have properly implemented the Space Systems T&E Process into your test and evaluation effort.

- Do you have a Plan-Predict-Test-Compare test philosophy?
- Does your T&E effort use a disciplined, scientific test process?
- Does your T&E effort emphasize use of models, simulation and ground tests prior to costly flight tests?
- Are you working with the space SFTC Office?
- Do the people on your T&E effort understand the Space Systems T&E Process?
- Is your contractor on contract to use and support the Space Systems T&E Process?
- Do your Government T&E agreements require using and supporting the Space Systems T&E Process?
- Are your M&S efforts continually updated and do they provide constant feedback for system development and improvement?
- 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 space System?
- Do the test requirements flow from user and customer requirements?
- Will the T&E effort report results which will be used by decision makers to support system life cycle and maturity decisions?
- Is your contractor in sync and on contract to support an affirmative answer to the above questions?
- Are M&S resources being updated from information gained through test?

8.2. Process Step Self Evaluation Questions. If the Space System T&E Process has been properly implemented in the system T&E effort, the answers to the following questions will be affirmative.

Determine Objectives

- Have tests been designed to EVALUATE the capability of the test item?
- Are tests included to DETERMINE the characteristics of the test item?
- Will the tests DEMONSTRATE the effectiveness of the test item?
- Will the tests produce results which can be used to COMPARE measured capabilities to the test item requirements?
- Will the tests produce information needed to VERIFY compliance with requirements?
- Are all test objectives directly traceable to the user's requirements?
- Have all of the user's requirements been adequately addressed in the test objectives?
- Has the Space SFTC been contacted for assistance?

Pre-Test Analysis

- Has the pre-test analysis been designed to resolve as many issues as possible prior to testing?
- Has a pre-test prediction been submitted?
- Is coordination being done between pre-test analysis and test groups?
- Is there a procedure in place to exchange analysis and test results?

Test

- Does the test design address all of the test objectives?
- Have the proper test plans been prepared?
- Have adequate test resources been acquired?
- Have adequate plans been made for data collection and reporting?

Evaluate

- Have plans been made for thorough evaluation of the test results?
- Will test results be compared with the established test objectives?
- Do plans exist for updating the DSM and all other computer simulations with parameters determined from the test data?

Acceptable Risk

- Has a procedure been established for implementing improvements if the test results indicate that the test item performance presents too high a risk?

8.3. OT&E Self Evaluation. Have you followed the SAF/AQ Policy Letter, *Certification of Readiness for Dedicated Operational Test and Evaluation*, 17 January 1995.

Chapter 9

SUMMARY

9.1. Manual Summary. This manual institutionalizes the disciplined Space Systems T&E Process, AFMAN 99-113, under AFI 99-103. It describes the methodology you must use when planning and conducting testing for space systems at all levels and in all acquisition phases. If you have questions regarding any aspect of this manual, contact the OPR for this manual, the Space SFTC Office (see attachment 2, section A2.1).They exist to help you apply the Space Systems T&E Process, help you with test planning and in securing test capability deficiency investments, and to help you decide where, how and how much to test.

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

GLOSSARY OF REFERENCES, ABBREVIATIONS, ACRONYMS AND TERMS

References

DoD 3200.11-D, *Major Range and Test Facility Base Summary of Capabilities*
DoD 5000.2-M, *Defense Acquisition Management Documentation and Reports*
DoD Directive 5000.1, *Defense Acquisition*
DoD Handbook 343, *Design, Construction, and Testing Requirements for One of a Kind Space Experiment*
DoD Instruction 5000.2, *Defense Acquisition Management Policies and Procedures*
DoD Standard 2167A, *Defense System Software Development*

AFI 10-601, *Mission Needs and Operational Requirements Guidance and Procedures*
AFI-16-1001, *Verification, Validation, and Accreditation*
AFI 16-1002, *Modeling and Simulation Management*
AFPD 99-1, *Test and Evaluation Process*
AFI 99-101, *Developmental Test and Evaluation*
AFI 99-102, *Operational Test and Evaluation*
AFI 99-103, *Test and Evaluation Process*
AFI 99-109, *Test Resource Planning*

MIL-HDBK-189, *Reliability Growth Management*
MIL-HDBK-340, *Application Guidelines for MIL-STD-1540B*
MIL-STD-470B, *Maintainability Program for Systems and Equipment*
MIL-STD-471A, *Maintainability Verification/Demonstration/Evaluation*
MIL-STD-499B, *Systems Engineering*
MIL-STD-781D, *Reliability Testing for Engineering Development, Qualification, and Production*
MIL-STD-785B, *Reliability Program for Systems and Equipment Development and Production*
MIL-STD-1540, *Test Requirements for Space Vehicles*
MIL-STD-1540B, *Test Requirements for Space Vehicles*
MIL-STD-1540C, *Test Requirements for Launch, Upper Stage, and Space Vehicles*
MIL-STD-1543B, *Reliability Program Requirements for Space and Launch Vehicles*

SAF/AQ Policy Letter, *Templates for Certification of Readiness for Dedicated Operational Test and Evaluation*

TO 00-35D-54, Deficiency Reports

Abbreviations and Acronyms

ACTD	Advanced Concept Technology Demonstration
ADM	Acquisition Decision Memorandum
AEDC	Arnold Engineering Development Center
AFI	Air Force Instruction
AFFTC	Air Force Flight Test Center
AFMAN	Air Force Manual
AFMC	Air Force Materiel Command
AFOTEC	Air Force Operational Test and Evaluation Center
AFPD	Air Force Policy Directive
AFSCN	Air Force Satellite Control Network
AFSPCI	Air Force Space Command Instruction
ASAT	Anti-satellite
ATD	Advanced Technology Demonstration
BMD	Ballistic Missile Defense

Abbreviations and Acronyms

C2	Command and Control
C^{4}I	Command, Control, Communications, Computers and Intelligence
CDRL	Contract Data Requirement List
COEA	Cost and Operational Effectiveness Analysis
COI	Critical Operational Issue
CONOPS	Concept of Operations
COTS	Commercial Off The Shelf
DAHAP	Data Acquisition, Handling and Analysis Plan
DID	Data Item Description
DoD	Department of Defense
DoDD	Department of Defense Directive
DoDI	Department of Defense Instruction
DoE	Department of Energy
DR	Deficiency Report
DSM	Digital System Model
DT	Developmental Test
DT&E	Developmental Test and Evaluation
DTIC	Defense Technical Information Center
DTP	Detailed Test Plan
EMI	Electromagnetic Interference
ER	Eastern Range
FOT&E	Follow-on Operational Test and Evaluation
HITL	Hardware-In-The-Loop
ICBM	Intercontinental Ballistic Missile
ILSP	Integrated Logistics Support Plan
IOC	Initial Operating Capability
IOT&E	Initial Operational Test and Evaluation
IPT	Integrated Product Team
ISTF	Integrated System Test Facility
LOA	Letter of Agreement
LV	Launch Vehicle
M&S	Modeling and Simulation
MAP	Mission Area Plan
MIL-HDBK	Military Handbook
MIL-SPEC	Military Specification
MIL-STD	Military Standard
MNS	Mission Need Statement
MOA	Memorandum of Agreement
Mod	Modification
MOE	Measure of Effectiveness

Abbreviations and Acronyms

MOP	Measure of Performance
MOU	Memorandum of Understanding
OAR	Open Air Range
OD	Operational Directive
OR	Operational Requirements
ORD	Operational Requirements Document
OSD	Office of the Secretary of Defense
OT	Operational Test
OT&E	Operational Test and Evaluation
OTA	Operational Test Agency
PI	Program Introduction
PIDS	Prime Item Development Specification
PMD	Program Management Directive
POC	Point of Contact
PRD	Program Requirements Document
PRR	Preliminary Report Of Results
PSP	Program Support Plan
PTO	Participating Test Organization
QOT&E	Qualification Operational Test and Evaluation
R&D	Research and Development
RCC	Range Commanders Council
RCM	Requirements Correlation Matrix
RFP	Request For Proposal
RSLP	Rocket Systems Launch Program
RTO	Responsible Test Organization
RV	Reentry Vehicle
SC	Statement of Capability
SE	Systems Engineering
SFTC	Single Face To Customer
SIL	System Integration Laboratory
SM	Single Manager
SMC	Space and Missile Systems Center
SMM	System Maturity Matrix
SOW	Statement of Work
SPADOC	Space Defense Operations Center
SPO	System Program Office
SRA	System Requirements Analysis
SSN	Space Surveillance Network
STAR	System Threat Assessment Report
T&E	Test and Evaluation

Abbreviations and Acronyms

TBC	Test Benefit to Cost ratio
TEMP	Test and Evaluation Master Plan
TIPP	Test Investment Planning and Programming
TLR	Technical Letter Report
TO	Technical Order
TPA	Test Process Archive
TPWG	Test Planning Working Group
TR	Technical Report
TRP	Test Resource Plan
TTI	Test Thoroughness Index
UDS	Universal Documentation System
WR	Western Range
WSMR	White Sands Missile Range

Terms

Acoustic--Testing containing, producing, arising from, actuated by, related to, or associated with sound waves.

Aging--A gradual process involving physical change(s) in the properties or characteristics of a material and proceeding in a manner predictable chiefly as a function of time. In addition, the aging process may be accelerated or slowed when the material is also subjected to factors other than time, such as high or low temperature, or ozone. Aging can weaken or destroy specific properties in a material, or conversely, aging can enhance the desired properties, as in curing lumber.

Airborne Telemetry Systems--Airborne telemetry antennas, receivers, and controllers.

Anechoic Chamber--Chamber/room whose boundaries absorb effectively all the sound incident thereon, thereby affording essentially free-field conditions.

ARTS--Automated Remote Tracking Station. System for ranging, tracking, transmitting, receiving, and relaying data.

Asset Allocation--The organization and processes used to determine what range assets are needed for a launch.

Checkout--System testing including pre and post integration.

Climate--The synthesis of the weather; the long-term manifestations of weather, however they may be expressed. The sum of total of the meteorological elements that characterize the average and extreme condition of the atmosphere over a long period of time.

Collect--A test for collecting data.

Command System--Includes the command destruct antennas and transmitters.

Compare--A test for the purpose of perceiving likeness and difference in test items.

Control and Display--Hardware and software used by the range to process, store, and display telemetry, tracking, and command information of space boosters and ballistic missiles before, during, and after launch.

Data Processing--Hardware and software that takes the data produced by the Instrumentation and processes it into a useful form for the range user and Range Safety. Includes telemetry decommutators, bit syncs, radars, optical processors, etc.

Data Storage--Bulk storage devices such as tape recorders, and hard disk drives that store the processed or raw data for analysis later. Includes the record and playback equipment.

Demonstrate--Exhibitions to reveal something qualitative or quantitative that is not otherwise obvious.

Determine--Test to discover certain measurable or observable characteristics of a test item.

Display--Any type of device used to display Instrumentation data to the range user and range safety. Includes CRTs, plotters, printers, etc.

Electromagnetic (EM)--Pertaining to the combined electric and magnetic fields associated with radiation or with movements of charged particles.

Electromagnetic Interference (EMI)--Any EM disturbance that interrupts, obstructs, or otherwise degrades or limits the effective performance of electronics/electrical equipment. It can be induced intentionally or unintentionally/naturally.

Environmental Simulation--Shake, rattle and roll , thermal, etc.

Terms

Environmental--The aggregate of all conditions and influences including physical location and operating characteristics of surrounding equipment and occupants.

Evaluate--Test to establish overall worth (effectiveness, suitability, adequacy, usefulness, capability, or the like) of a test item.

Ground Telemetry Systems--Ground-based telemetry antennas, receivers, and controllers.

Hardware-In-The-Loop (HITL)--Testing that involves system or subsystem hardware in an open- or closed-loop mode against high fidelity targets and threat simulations. It allows testers to test developmental and production systems under controllable, repeatable, non-destructive conditions.

Instrumentation Systems--Hardware and software used by an open air range to receive telemetry, track, and command space boosters and ballistic missiles during launch.

Measurement Labs--Test resources used for exploring and evaluating technologies. Data collected from these resources includes aerodynamic drag, antenna patterns, radar cross sections and infrared and laser signatures.

Mechanical Shock--A test to simulate the effects of a nonperiodic excitation (e.g. a motion of the foundation or an applied force) of a mechanical system that is characterized by suddenness and severity, and usually causes significant relative displacements in the system.

Mission Control--Plans all aspects of the payloads mission (e.g. orbit determination, contact planning, and resource scheduling).

Narrowband--Communications links generally associated with voice and low-speed data.

Network Control--The system used to control the configuration of the range communications system.

Network--Communications systems used to transmit and receive telemetry, tracking, and command data from the transmitter/receiver location to the Control and Display area

Payload Operations--Responsible for payload telemetry processing, data analyses, experiment planning, command generation, and experiment operations.

Payload/Booster Integration--Physical mating and electrical connections.

Planned Recovery--Includes the recovery of reusable launch systems (e.g., Shuttle solid rocket casings, Orbiter landings.)

Prelaunch Test--Integrates final testing of command generation, telemetry processing, data analysis and resource scheduling.

Range Scheduling--The organization responsible for scheduling range assets in accordance with UDS documentation.

Recovery Operations--The organization and procedures used to recover spent or failed launch systems (boosters and payloads).

Refurbishment--Post storage inspections (i.e. ultrasonic testing of booster), refurbishment of site/silo or aircraft, refurbishment of SRM's and orbiter.

Reverberant Chamber--A type of acoustical testing facility in which a specimen is subjected to simultaneous impingement of acoustical energy from many directions. It is characterized by highly reflective walls and may have nonparallel opposing walls or multiple energy sources.

Rocket Propulsion Ground Test Facilities--Test firing stands.

Scoring Systems--Equipment used to determine the accuracy of an event. (e.g. SMILS).

Shipborne telemetry--Shipborne telemetry antennas, receivers, and controllers.

System Integration Laboratory (SIL)--Facilities designed to test the performance and compatibility of components, subsystems, and systems when they are integrated with other systems or functions.

Sled Tests--Applies a set level of acceleration to a system or component to measure the effects on its operation or calibration.

Space Safety--In charge of orbit predictions collision avoidance, RFI/EMI/Laser interference, reentry predicts, and debris analysis.

Space-based telemetry systems--Space-based telemetry antennas, receivers, and controllers.

Technical Letter Report (TLR)--Covers test areas of narrow scope and response to near term concerns that need to be answered prior to completion of the TR.

Technical Report (TR)--Summarizes the testing done, presents the results and may analyze the results and give recommendations. The TR is a formal report published a few months after test completion and is typically available to DoD organizations through DTIC.

Telemetry Systems--Telemetry antennas and receivers and their local control equipment.

Test Process Archive (TPA)--Data and information that documents and records T&E efforts for the life of the system. It consists of the T&E Structure, Test Data collected, Evaluation/Results, and the Test Process Summaries.

Terms

Thermal Chamber--An enclosed, thermal insulted space with equipment and controls to produce a chamber temperature differing from ambient.

Thermal Shock--An environmental test intended to simulate the effect of a sudden, severe change in the temperature of a piece of equipment.

Timing--Equipment used to generate a timing signal for range use.

Tracking Systems--Includes radar antennas, transmitters and receivers and their control equipment. Includes optical systems and their control equipment. Includes GPS systems when used by the range for tracking space boosters and ballistic missiles.

Universal Documentation System (UDS)--Process used to plan the allocation of range assets, to determine the adequacy of range assets, and to request additional assets, if existing assets are not adequate.

Unplanned Recovery--Includes the recovery and damage control of failed launch systems.

Verify--An effort towards the confirmation of a suspected, hypothesized, or partly established contention.

Vibration Test--A test to simulate the effects of random motion of the particles in an elastic body in alternately opposite directions.

Wideband--Communications links generally associated with video, high-speed data, and multiplexed baseband data.

AF SPACE TEST AND EVALUATION COMMUNITY

A2.1. Introduction. The Space Test and Experimentation Program Office was established on 1 July 1992 to act as the Single Face To Customer (SFTC) for space research and development T&E Services. (Reference AFI 99-101, paragraph 2.4.3 regarding the duties of the SFTC Office, and how it supports the test and evaluation functions.) The SFTC is supported by four space and missile test and evaluation organizations: the Rocket Systems Launch Program, the Space Test and Small Launch Vehicle Programs, the Test Integration and Launch Directorate, and the Space Test and Evaluation Directorate.

A2.2. Space Test Single Face To Customer (SFTC) Office, Los Angeles AFB, CA. The purpose of the Space SFTC is to improve the efficiency and cost effectiveness of Space System T&E by assisting customers in the disciplined application of the Space System T&E Process, identifying risks in test options available to the customer, and helping the customer understand the capabilities and test applications of the resources open to them.

A2.2.1. For assistance with the Space System T&E Process, contact the Space SFTC office. They can provide you with the expertise and experience you need to help you efficiently and cost effectively plan, execute, and report on the space or missile system testing your project requires. They are located in Los Angeles, California.

Telephone:	(310) 363-2504	Write:
	DSN 833-2504	SMC/CUC
		160 Skynet Street
Fax:	(310) 363-3773	Suite 1536A
	DSN 833-3773	Los Angeles AFB CA 90245-4683

A2.2.2. AFI 99-103 requires Space Single Managers and program managers to contact the SFTC for T&E planning support. This will be directed: 1) if your Space test program is for a new start that has a Program Management Directive (PMD) and 2) if you are writing or revising a Test and Evaluation Master Plan (TEMP). Working with the SFTC will save you considerable time and effort and help you to get your test planning effort started early and in the right direction. Later, if you assign Responsible Test Organization (RTO) responsibility to a specialized AF test organization, such as one of the four test divisions described below, they will be responsible for detailed test planning. The SFTC will provide support to the RTO as requested to obtain needed test resource capabilities.

A2.3. Responsible Test Organization (RTO). Upon designation of an RTO, test planning responsibility transitions to the RTO. The RTO is the lead organization for designing and conducting all or assigned portions of your test program. The RTO will help prepare and update the TEMP or the test portion of the Program Management Plan and they will plan, program, budget, and manage test support resources for you. During the lifetime of the system, different RTOs may be needed for specific tests. However, there can be only one RTO at a given time. **(*Note*:** In most space system acquisition programs the System Program Office retains responsibility as the RTO and contracts with the development contractor for test planning, conduct, and reporting for test efforts prior to OAR testing.)

A2.4. Participating Test Organization (PTO). A PTO is responsible for the performance of a portion of a program's DT&E or OT&E support. PTOs are selected for their specific knowledge or capability to help the RTO plan, support, or conduct a portion of the overall test program. PTOs plan their assigned portion of specific tests, arrange for logistic support, conduct their portion of the test, and reduce, analyze, and evaluate data associated with their part of the test program, then send a report or data package to the RTO and program manager. **(*Note*:** Since most space system development test planning and conduct prior to OAR tests is accomplished by the development contractor, the RTO should work with the SFTC early in the program before the test portions of the development contract are written to insure that Government capabilities and facilities are used when it is cost effective and efficient to do so**.)**

A2.4.1. Arnold Engineering Development Center (AEDC), Arnold AFB, TN. The Arnold Engineering and Development Center (AEDC) is a participating test organization tasked with providing ground test and evaluation services to the DoD acquisition community. AEDC specifically supports space system testing in its specialized Government test facilities with a wide range of T&E services. These services represent 14 different disciplines including missile propulsion, reentry vehicles, high-velocity projectiles, solid rocket motors, small space thrusters and space environmental simulation. AEDC assistance to the IPT can be provided throughout the life of a space system acquisition or project.

A2.4.1.1. AEDC maintains both measurement and installed system test facilities. AEDC involvement has traditionally been in support of DT&E. However, recent test technique developments and the acquisition of state-of-the-art test facilities and computational tools have made it possible for AEDC to provide assistance to the operational test community in support of space system acquisition efforts. AEDC has begun development of system integration laboratories and hardware in the loop facilities supported by extensive computer systems capable of supporting digital modeling and computer simulation. These new and existing capabilities can be employed to support all 6 steps of the space systems T&E process defined in AFMAN 99-113.

A2.5. Rocket Systems Launch Program. The Rocket Systems Launch Program was chartered in 1972 by the Secretary of Defense as the single DoD agency to provide booster management and support for developmental programs. Since then, as part of the Air Force Ballistic Missile Organization, it has successfully launched over 535 sounding rockets and ballistic missiles.

A2.6. Space Test and Small Launch Vehicle Programs. The Space Test and Small Launch Vehicle Programs is responsible for the Tri-Service Space Test Program (STP) and procurement of Pegasus small launch vehicles. STP was chartered in 1965 by the Secretary of Defense to provide space flight opportunities for advanced DoD research and development (R&D) experiments not authorized to fund their own flights. STP has successfully flown over 300 experiments in its long history, using one of a kind spacecraft and secondary space on the Space Shuttle and various host satellites.

A2.7. Test Integration and Launch Directorate. The Test Integration and Launch Directorate (also known as Detachment 9, Space and Missile Systems Center, at Vandenberg AFB, CA) has integrated and launched Air Force ballistic missiles for more than three decades, including the Thor, Atlas, Minuteman, Small ICBM, Peacekeeper-in-Minuteman Silo, and Peacekeeper Rail Garrison systems. It has been the launch base PTO for integration and launch of Rocket Systems Launch Program experiments for reentry system development and Ballistic Missile Defense Organization (BMDO), formerly Strategic Defense Initiative Organization (SDIO), experiments. As the RTO for the F-15 Anti-Satellite (ASAT) program, it conducted the only successful satellite intercept test in the history of the DoD, and was selected as Advanced Research Projects Agency (ARPA) agent to perform field test management of the new Taurus space booster, the first of which was successfully launched in 1994. The directorate has also successfully managed the reconstruction of the Titan IV solid rocket motor upgrade (SRMU) static firing test complex at Edwards AFB after a catastrophic failure during the SRMU's initial test destroyed it. In addition to supervision of the reconstruction effort, the directorate has directed five successful test firings of the SRMU. The directorate also has experience working with commercial space contractors such as the American Rocket Company.

A2.8. Space Test and Evaluation Directorate. The Space Test and Evaluation Directorate (also known as Detachment 2, Space and Missile Systems Center, at Onizuka AFB, CA) is the DoD focal point for on-orbit space and space related testing. From its inception as the Air Force Satellite Control Facility through its activities as the Consolidated Space Test Center, to the present, it has provided over three decades of 24 hours per day, 365 days per year support to space test mission command and control through a global network of fixed and deployable ground stations. Test missions for DoD, allied, and commercial space systems have relied on its experience in mission planning, space safety assessment, and data analysis and processing.

A2.9. Operational Test Organizations. Each service has a designated Operational Test Agency (OTA) to perform operational test and evaluation on major programs. The OTAs were established by Congress to insure that testing was accomplished under realistic conditions, to user requirements, prior to a production decision. The Air Force Operational Test and Evaluation Center (AFOTEC) is the principal OTA for the Air Force. Some programs are delegated to Major Commands (MAJCOMs) for testing. MAJCOMs maintain individual test organizations to conduct Follow-on Operational Test and Evaluation (FOT&E). Within Air Force Space Command (AFSPC), each of the four space wings (21st, 30th, 45th, and 50th) and the 73 Space Group maintains its own test office which serves as the focal point for all OT&E conducted by, or for, the wing. Wing test offices are manned by test personnel trained and qualified to perform test and evaluation. In addition, each person is a resident expert in the mission area of the wing. Each wing test office implements AFSPC and USAF testing policy, establishes wing test policy, and exercises other responsibilities detailed in AFSPI 99-XX, *Management of Air Force Space Test and Evaluation.* A wing test office provides a test manager to act as the single point of contact and on-scene manager for each test program conducted at any wing unit. Wing test offices also ensure compliance with all applicable environmental regulations during T&E conducted by the wing. HQ AFSPC/DOTO, which serves as the headquarters level center of expertise, maintains an up-to-date list of wing test offices.

A2.9.1. Air Force Operational Test and Evaluation Center (AFOTEC), Kirtland AFB, NM. AFOTEC is a direct reporting unit, independent of acquisition and operational commands, that plans and conducts realistic, objective, and impartial operational test and evaluation (OT&E)* to determine the operational effectiveness and suitability of Air Force systems and their capability to meet mission needs. Results are reported directly to the Air Force Chief of Staff. AFOTEC has primary responsibility for Space Test Process implementation during Initial Operational Test and Evaluation (IOT&E), and Qualification Operational Test and Evaluation (QOT&E). AFOTEC also conducts Follow on Operational Test and Evaluation (FOT&E) when directed by HQ USAF/TE. AFOTEC Space Test Process responsibilities include:

- Assist the user/operating command in the development of reasonable and achievable operational evaluation criteria that are based on valid user requirements.
- Evaluate and report on system operational effectiveness and operational suitability.
- Plan and conduct OT&E in accordance with the Space Test Process.
- Serve as a member of the TPWG.
- Prepare the OT&E section of the TEMP if designated as the OTA.
- Act in an advisory capacity to HQ USAF/TE on all matters affecting the conduct of OT&E and the maintenance of AF test infrastructure.

Note: An OT&E can be either an IOT&E, QOT&E, or FOT&E. OT&E is planned and conducted in accordance with DoDI 5000.2.

A2.9.2. Air Force Space Command (AFSPC), Peterson AFB, CO. Air Force Space Command (AFSPC) is the operator, user or both and the principal MAJCOM OTA for most space and missile systems. HQ AFSPC Division for Operations Training, Testing, Stan/Eval, and Configuration Control (AFSPC/DOT) oversees operational testing of AFSPC systems and the T&E programs of the:

21st Space Wing, Peterson AFB, CO
30th Space Wing, Vandenberg AFB, CA
45th Space Wing, Patrick AFB, FL
50th Space Wing, Falcon AFB, CO
73rd Space Group, Falcon AFB, CO

A2.9.2.1. Each wing or group maintains its own test office that serves as the focal point for all OT&E conducted by, or for, its organization. The test office implements USAF and AFSPC policy, establishes test programs, conducts and supports OT&E, and supports other T&E as required. The test manager from the test office is the single point of contact and on-scene manager for each test program conducted at any unit. The test office is staffed with personnel who are trained and qualified to perform T&E and are resident experts in the mission area of the organization.

SPACE SYSTEMS TEST AND EVALUATION RESOURCES

RESOURCE	MAJOR FACILITIES	SIGNIFICANT FEATURES	GENERAL SUPPORT PROVIDED
Vandenberg AFB (VAFB), CA			
- 30th Space Wing	Space Launch Complexes - Atlas: SLC 3 - Titan: SLC 4 - Delta: SLC 2 - Scout: SLC 5 - Taurus: 576E - Pegasus: Runway - AMROC: ABRES		Space and Ballistic Missile Launch
- Western Range	Instrumented Range - Precision Tracking Radar - Metric Optics - Missile Impact Location System - Telemetry Support Ballistic Launch Complexes - Minuteman (8) - Peacekeeper (2) - Test Pads (2) X-ray Facility Spin Balance Facilities 15,000 Ft. Runway	100,000 Acres (VAFB) West Coast Offshore Operating Area (1000 mi x 200 mi) Western Range - 4000 miles to Kwajalein Atoll	Support (R&D/DT&E/OT&E) Real Time TSPI & Telemetry On-orbit Operations Support Commercial Space Launch Support Communications Recovery Aeronautical Mission Support
- Space and Missile Systems Center (SMC) DET9	Integration Facilities Rail Road Test Loop & Launch Site Computer Data Base Development Facilities		Test Planning Requirements Development System Integration Booster Assembly Payload Integration Ballistic Missile Launch Support

RESOURCE	MAJOR FACILITIES	SIGNIFICANT FEATURES	GENERAL SUPPORT PROVIDED
Patrick AFB (PAFB), FL - CCAFS - Eastern Range - KSC -45th Space Wing	Space Launch Complexes - Titan IV/III - LC 40/41 - Delta II - LC 17 - Atlas II - LC 36 A/B - Shuttle - LC 39 A/B Ballistic Launch Complexes - Trident - Polaris - Poseidon Integration Facilities Instrumented Range - Precision Tracking Radar - Metric Optics - Missile Impact Location System - Telemetry Support - 9000 Ft. Runway	PAFB - 2108 Acres CCAFS - 15804 Acres ER - 1500 miles to Antigua 5000 miles to Ascension	Space and Ballistic Missile Launch Support (R&D/DT&E/OT&E) Real-Time TSPI & Telemetry Commercial Space Launch Support Communications Recovery
Joint Modeling and Simulation System (Wright-Patterson, ASC-XR)	A Software Development Program	N/A	Enables user to create models, configure scenarios, execute simulations, and analyze results
DoD Electromagnetic Compatibility Analysis Center (ECAC) Joint Spectrum Management Center, Annapolis, MD	EMC related databases Measurement Facility with over 2,700 sq. ft. of electromagnetic shielded enclosures	N/A	Promotes electromagnetic compatibility between electromagnetic dependent systems within DoD. Test planning and analysis with an emphasis on M&S.
Det 2, SMC Onizuka AFB, CA	Test Support Complex (1) Agency Data Tape Facility (1) Deployable Test System (4) -Transportable S-Band -S-Band Transportable Ground Station Transportable Vehicle Checkout System	111,000 sq. ft. of technical and administrative area	RDT&E for: - DoD - Allied - Civilian Space & Ground Control Systems

RESOURCE	MAJOR FACILITIES	SIGNIFICANT FEATURES	GENERAL SUPPORT PROVIDED
Edwards AFB (EAFB), CA - Astronautics Lab	R2508 Restricted Airspace	20,000 sq. miles 5440 acres	
- Area 1-120	3 Static Stands 5 firing positions		Liquid Rocket Motor Testing
- Area 1-125	3 Large Rocket Stands 1C 1D 1E		Titan IV SRMU Testing Solid Rocket Motor Testing
NASA Ames Dryden Flight Research Facility	Hangers	KHIT	Aircraft & Helicopter Flight Test
Jet Propulsion Laboratory	Small Rocket/Fuel Test Stand		Small Motor Tests Space Fuels Tests
412th Test Wing	ARIA Tracking & Monitoring Aircraft		Gather telemetry data for missile & satellite programs
Utah Test & Training Range	3 Airfields - Michael Army Airfield - Wendover Field - Hill AFB	1.7 million acres	Flight Tests
Air Force Flight Test Center (AFFTC)	65 square miles of usable landing space with runways up to 7.5 miles long. 19 hangers - 4 on north base ideal for classified programs		

RESOURCE	MAJOR FACILITIES	SIGNIFICANT FEATURES	GENERAL SUPPORT PROVIDED
Edwards AFB (EAFB), CA (Cont.)	Benefield Anechoic Facility DoD's largest anechoic chamber col-located with Air Vehicle Modeling/Simulation (TEMS) and Systems Integration Laboratories - 80' diameter turn table - 40 ton man rated hoist	250' x 265' x 70'	Provides realistic, free space RF environment of both installed and uninstalled, federated and integrated avionics and electronic combat systems
	Electronic Counter Countermeasures Advanced Radar Test Bed Modified C-141 Airborne Laboratory	N/A	Airborne Radar Testing
Phillips Lab	Multiple Test Cells Solid and liquid capability at sea level & altitude (steam ejection plus <u>very limited</u> mech pumping) Shock/vibration table	Various up to 8' diameter (50K thrust)	R&D and limited PQA/A&S
	Electronic Propulsion Lab thermal vacuum chambers	6' x 10' 18' x 30'.	Thermo-vacuum
Air Force Satellite Control Network	<u>Onizuka AFB</u> 5 Mission Control Complexes (MCCs) 3 Test Support Centers (TSCs) <u>Falcon AFB</u> 4 Satellite Operations Center (SOCs) <u>Worldwide Locations</u> 8 Automated Tracking Stations (ARTs)		Space Test Mission Planning Pre-Launch, Launch & Early Orbit Checkout. Command & Control operations for Air Force and DoD Satellite missions, including on-orbit support and space vehicle checkout (health and status)
National Test Facility	Two buildings on Falcon AFB, CO w/computer H/W. Two Cray 2 super computers; two IBM 3090s; DEC VAX cluster; TC2000 parallel processor; numerous high-end workstations.	544,000 sq. ft., over 200,000 w/in steel/welded shield (tempest)	A computer simulation research facility working within BMDO. Performs space and missile defense battle management and threat simulations.

RESOURCE	MAJOR FACILITIES	SIGNIFICANT FEATURES	GENERAL SUPPORT PROVIDED
Cheyenne Mtn AFB, CO - 21st Space Wing	NORAD Command Center US Space and Ops Center; Space Defense Operations Center (SPADOC)	451 Acres	Space Tracking
Air Force Development Test Center (AFDTC) (Eglin AFB, FL)	Climatic Lab large enough for a C-5 Aircraft Seeker Evaluation Instrumentation System Instrumented Range and Central Control Facility Aeroballistic Research Facility 46 Actual and Simulated Threat Systems located at 22 sites	724 sq. miles land 98,000 sq. mile water test range	Environmental Testing Radiometric, spatial and spectral measurements of background and target signatures for the visible through IR and millimeter wave portions of the electromagnetic spectrum. Weapon seeker testing. Air Vehicle Testing Armament R&D Electromagnetic Test
Kwajalein Missile Range (KWR)	Major Range/Test Facility Telemetry Optics Radar (FPQ-19 KREMS) Reentry Vehicle Recovery Met Data Launch Facilities	200 ni mile range around KMR	Support on-site Ballistic Missile R&D programs and strategic offensive development and operational testing and intelligence gathering

RESOURCE	MAJOR FACILITIES	SIGNIFICANT FEATURES	GENERAL SUPPORT PROVIDED
Electronic Proving Ground (Ft. Huachuca, AZ)	Automated Electromagnetic Database Deployment and Analysis Capability Weapon System EM Environment Simulator Spectrum Signature Facility Voice Scoring Facility Voice Interference Analysis System Automatic Data Collection System Communications Test Facility Infrared and Optical Test Facility Image Interpretation Facility Antenna Pattern Measurement Facility System Test Facility	70,000 acres at Ft. Huachuca 23,000 acres at Wilcox Dry Lake 1.3 million acres near Gila Bend	Planning, coordinating, conducting and reporting testing of communications, electronics, and O/EO systems and equipment, and Radiacs and Meteorological systems. Analog and Digital Communications Testing Modulation Transfer Analysis of O/EO Devices Analysis of Airborne Sensors Electronic Warfare, signal intelligence, direction finding, location, or real world sensitivity testing. Vulnerability testing of radar communications and C^3 systems during system and subsystem development.
AMOS, Hawaii (Maui)	Optical Tracking Site		- Optics tracking (Vis, Long Range) of targets and satellites - Sensor Testbed

RESOURCE	MAJOR FACILITIES	SIGNIFICANT FEATURES	GENERAL SUPPORT PROVIDED
Pacific Missile Range Facility, HI - Barking Sands - Kokee Park - Pauiau, Niihau - Makaha Ridge - Port Allen	Fleet training range Radars Telemetry Limited Optics Underwater Tracking Drones VANDAL (TALOS) Met Rockets Rail Launcher Vertical Launcher		Barking Sands Launches T&E Vandenberg Launches

RESOURCE	MAJOR FACILITIES	SIGNIFICANT FEATURES	GENERAL SUPPORT PROVIDED
Newark AFB, OH - Aerospace Guidance and Metrology Center	96 Environmentally Controlled Areas - Classes 1000 to 300,000 51 AF Measurement Standards Laboratories Beryllium Machine Shop Engineering Lab Methods Lab Physical Science Labs Software Labs	205,821 sq. ft. 45,666 sq. ft.	Inertial Guidance and Navigation System Repair Displacement Gyro Repair Support Services for Inertial Guidance. and Nav. Systems AF Metrology and Calibration Program AF Measurement Standards Lab Calibrate and certify standards for AF First article testing, special tests, new procedures AF Metrology R&D Program

RESOURCE	MAJOR FACILITIES	SIGNIFICANT FEATURES	GENERAL SUPPORT PROVIDED
Naval Air Weapons Center, Weapons Division-Pt. Mugu (NAWCWD-PM), CA	Test Range for DT&E and production support which involves air, surface, and undersea activities Mobile Sea Range Capability Extended Area Test System Hardware-In-The-Loop Simulation System Anechoic and Acoustic Facilities EW and Weapon System Support Laboratories Microelectronics Laboratory	- 32,000 sq. mi sea test range - 3 Airways - 11000x200 ft. - 5500x200 ft. - 10000x200 ft. - Sea test range - 200x180 ni miles - SNI - 8x3 ni miles - SCI - 35x17 ni miles	Electronic Warfare Target Systems Aircraft Missiles Major Support for Fleet Users Survivability Eval EO Signature Electromagnetic Compatibility Radar Reflectivity Vulnerability

RESOURCE	MAJOR FACILITIES	SIGNIFICANT FEATURES	GENERAL SUPPORT PROVIDED
Redstone Arsenal, AL	5 Test Stands - Up to 10 million 1b thrust - 2 vertical test bays - Liquid and solid test capability Motor Component Test - Initiators, igniters, gas generators - Flight termination system - Ablative materials 40 foot Drop Test Facility Motor Dissection Capability (<50,000 lb) Warhead/Safety Test Facility Electromagnetic & Nuclear Effects Test Facility Flight Range for Small Motors Vibration Test Facility	20,000 Acres total 580 Acres of static test stands 8 kilometer flight test range	Delta (Castor motor static test) NASA/Marshall SFC static tests SDIO tests (Army)
Wallops Island, VR	Launch Facility - Scout/Probes - 20K Launcher Runway	Small Island off coast of Virginia (1/2 mile x 1 mile)	Vehicle Processing and Launch Telemetry / Radar
Holloman AFB, NM	High Speed Test Track	10 miles of track	Observation and measurement of IR missile warning systems and decoy system performance
Griffiss AFB, NY	Rome Laboratories		Antenna Performance Measurement on Large Air Frames

RESOURCE	MAJOR FACILITIES	SIGNIFICANT FEATURES	GENERAL SUPPORT PROVIDED
Hill AFB, UT - Missile Integration Facility Branch	Strategic Missile Integration Complex - Minuteman AM & B LCCs & LFs - Peacekeeper LF & Equipment Room - G&C Lab Survivability & Vulnerability Complex - EMP Testing - Shock/Vib Testing - Linear Accelerator - Anechoic Chamber - Flash X-ray capability Dissection Facility (Propellant Test Lab)		Component/system level testing for MM & PK weapon systems including software, G&C, ground electronics, and propellants
- Maintenance Branch	Motor Test Stands (2)		Aging & surveillance program support

RESOURCE	MAJOR FACILITIES	SIGNIFICANT FEATURES	GENERAL SUPPORT PROVIDED
Kirtland AFB, NM Sandia National Labs (DoE) Phillips Lab (DoD) Air Force Operational Test and Evaluation Center (AFOTEC)	Sled Track (2 mi) Radiant Heat Facility Drop Towers Vacuum Chambers Wind Tunnels Vibration Facilities Trestle Centrifuge Cable Site	50,000 Acres Tonopah Test Range NV (120 sq. mi.) Kauai (Pacific Missile Range)	Satellite RDT&E RV RDT&E Aircraft Crash Test Models & Simulators Missile Testing Aircraft Testing
412th Test Wing	Big Crow & Little Crow Aircraft EMP Vertical Pulser Horizontal Pulser Aircraft Test Stand Mobile Pulsers		EW Jammers and sensors

RESOURCE	MAJOR FACILITIES	SIGNIFICANT FEATURES	GENERAL SUPPORT PROVIDED
Naval Air Warfare Center, Weapons Division- China Lake (NAWCWD-CL), CA	Skytop Test Facility Solid rocket motor test stands (7) - Horizontal up to 1M lbs thrust - Vertical up to 200K lbs thrust or horizontal up to 300K lbs thrust - High-hazard/High-risk test pads - Tactical-size up to 80K lbs thrust - Performance versus design test capability at normal flight attitude - Combined system test capability Trajectory Measurement System - Optics - Telemetry - Electronic Warfare Range Single test cell Solid or liquid sea-level only	605K Acres Up to 27' diameter	Static testing of solid propulsion systems from small lab scale devices to all-up strategic systems Product Quality Assurance, Aging, and Surveillance

RESOURCE	MAJOR FACILITIES	SIGNIFICANT FEATURES	GENERAL SUPPORT PROVIDED
White Sands Missile Range, NM Army TECOM EBW BED TRADOC NASA Air Force Navy 6585th Test Group	Launchers (6) ARIES SERGEANT BOMARC MINUTEMAN SPRINT VANDAL Payload Facilities (4) 17000 sq. ft. Ordnance Facilities (6) 9000 sq. ft. Radars (21) Telemetry (10) Optics (640) Laser Trackers (2) Interferometers (5) Telescopes (32) GPS TPS (1)	1.875 million acres Full-time restricted air space Northern and western call-up areas increase size to roughly 3.5 million acres. Adding Ft. Bliss and McGregor Range can further expand range boundaries.	TEST LABS Dynamic Climatic Micro biological Chemistry Metallurgy Microwave Warhead Nuclear Effects Facility Software Analysis Facility Ram & Man Print Assessment High Energy Laser Test Fac. High Speed Test Track Aerial Cable Test Fac. Inertial Guidance Test Facility Radar Target Scatter Facility

RESOURCE	MAJOR FACILITIES	SIGNIFICANT FEATURES	GENERAL SUPPORT PROVIDED
White Sands Missile Range, NM (Cont.)	Off Range Launch Corridors 300-350 km 750 km 1400 km High Speed Test Track 100g centrifuge Environmental Test Chamber Gyro and Accelerometer Test Tables		
Marshall Space Flight Center, AL (NASA)	Neutral Buoyancy Simulator X-ray Calibration Facility Wind Tunnel Large-scale Structural Test Facilities Integration Facilities 360 ft. Dynamic Test Tower Engine Test Stands (5)		Develops and tests propulsion engines, stages, and launch vehicle systems
Stennis Space Center, MS	Advanced Solid Rocket Motor Testing Propulsion Test Article Facilities		Booster Propulsion Testing

RESOURCE	MAJOR FACILITIES	SIGNIFICANT FEATURES	GENERAL SUPPORT PROVIDED
Defense Nuclear Agency (DNA)			
- Ft McClelland, AL	Lab environment		Exploratory Concept Development Survivability
- Nevada	Underground Testbed - Horizontal Tunnels		Underground nuclear testing
- WSMR, NM	High explosive testbed		Above ground nuclear effects simulation
- Utah	Thermal testing		

RESOURCE	MAJOR FACILITIES	SIGNIFICANT FEATURES	GENERAL SUPPORT PROVIDED
Arnold Engineering Development Center (AEDC), TN	Wind Tunnels (9)	4,000 acres on a 40,000 acre reservation	Performance, stability and control, store separation, heat transfer, ablation and aeroelastic and loads data for Mach numbers .2 to 10.
			Reentry ablation and erosion testing
	ARC Jet Heaters		Reentry Vehicle Wake testing
	Aeroballistic and Impact Ranges		Model testing - acceleration up to 23,500 ft/sec at simulated altitudes up to 244,000 ft.
	Ramjet Test Cell		
	Rocket Test Cells (5)		Liquid rocket tests up to 1,000K thrust
	Space Chambers		Solid rocket tests up to 300K thrust
			Boost and altitude control engines
			Ultra high altitude testing of small thrusters
			Dynamic target simulation
			Focal plane component and assembly tests - scene generation VIS thru CWIR sensor performance testing.
			Contamination and outgassing, space propulsion; solar, nuclear, and nuclear effects testing
			Space environment, thermal balance, vacuum testing

United States Army Space and Strategic Defense Command (USASSDC), AL	Delco Range now located at Redstone Arsenal	580' long	Reentry Vehicle Wake Physics and Impact Testing
Lawrence Livermore National Laboratory, CA			Nuclear effects testing
Naval Research Lab, Washington, D.C.	Three short ranges Model dia of 19, 40 and 57 mm EMI Room Space Physics Thermal Vacuum Chambers Shock/Vibration Tables	10' to 55' long 8' x 11' 18' x 30'	Impact Range Thermo-vacuum
Goddard Space Flight Center (GSFC), MD	Thermal Vacuum Chamber EMI/EMC Room Shock/Vibration Table		